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Natural Climate Solutions for Wisconsin Agriculture:
A ROADMAP TO NET-ZERO AGRICULTURAL EMISSIONS BY 2050

ADVOCACY REPORT
CLEAN WISCONSIN
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Lead Authors:

Katherine (Kata) Young, *Clean Wisconsin*
Dr. Paul Mathewson, *Clean Wisconsin*

Contributing Authors:

Dr. Randy Jackson, *Grassland 2.0*
PJ Connolly, *Savanna Institute*
Dr. Sarah Lloyd, *Grassland 2.0*
Dr. Nicole Tautges, *Michael Fields Agricultural Institute*
Dr. Monika Shea, *Savanna Institute*

Contributors:

Sara Walling, *Clean Wisconsin*
Chelsea Chandler, *Clean Wisconsin*

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

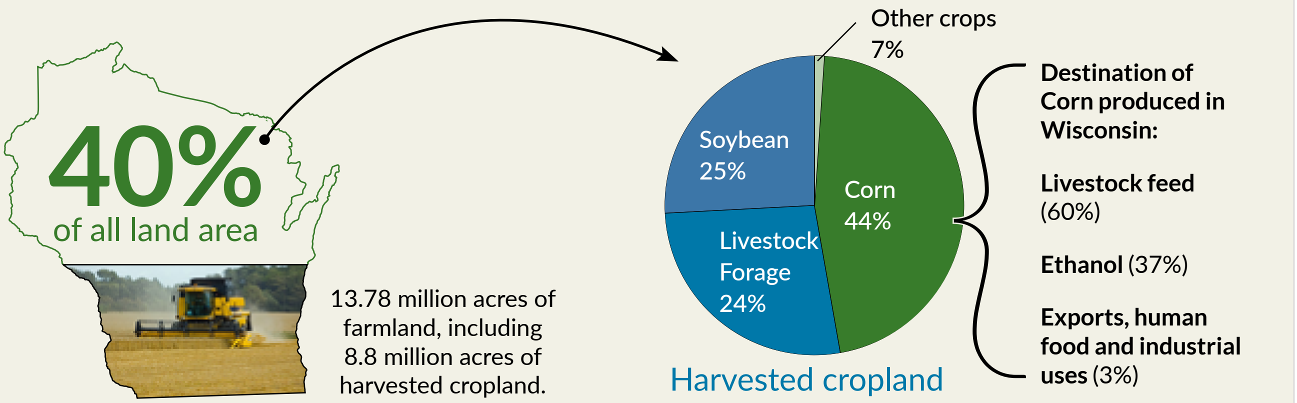
Wisconsin agriculture is a cornerstone of the state economy, generating $116.3 billion annually—14.3% of the total state economy—and supporting 353,900 jobs across on-farm and processing activities (DATCP 2025, Deller & Hadacheck 2024). The agricultural sector contributes $21.2 billion in labor income 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.

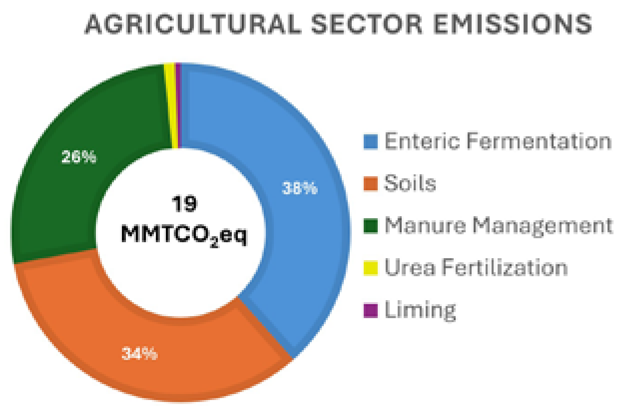


Figure 1. Wisconsin's Agricultural Sector Emissions. *Adapted from* WDNR (2021). Table 11. Agriculture Emissions ($MMTCO_2e$)[2] *In*: 2021 Wisconsin greenhouse gas emissions inventory report. Wisconsin Department of Natural Resources. Madison, Wisconsin. P15.

[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,

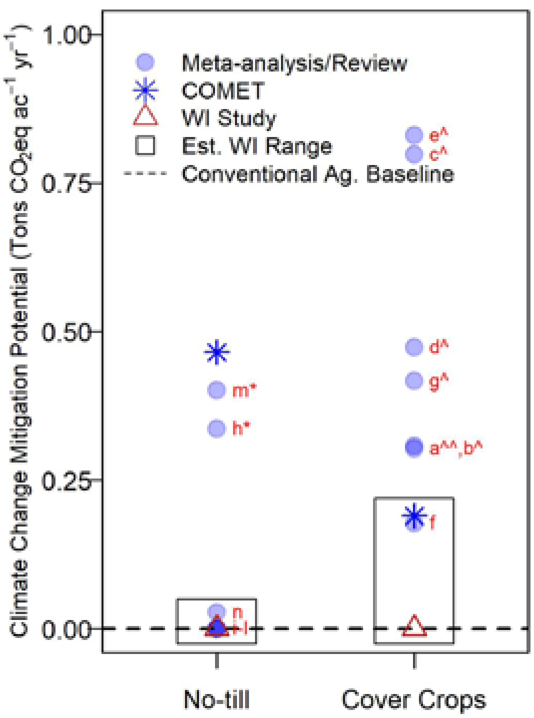


Figure 2. Detailed per-acre GHG mitigation potential of cover crops and no-till, as reported in the literature and existing models.

* 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-l]Liang 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.

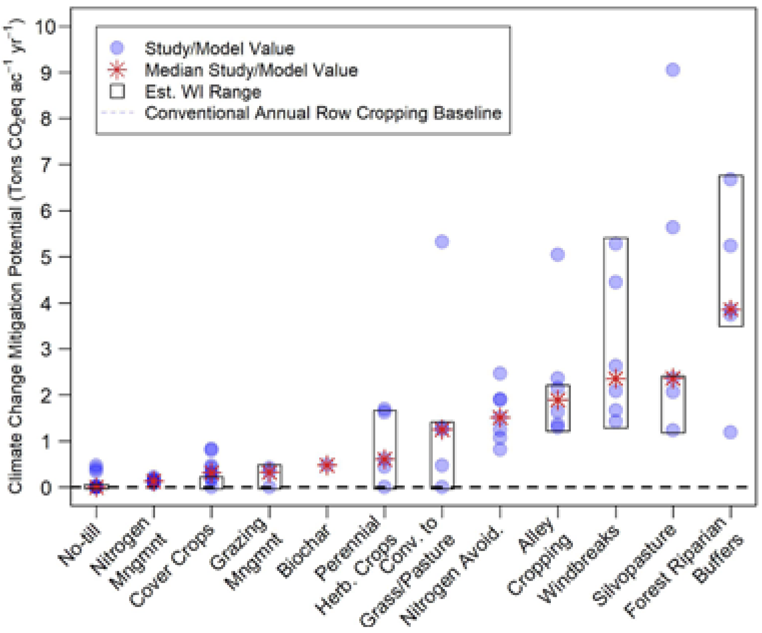


Figure 3. Per-acre GHG mitigation potential of field-based practices, as reported in published literature for no-till and cover crops (left) and the full suite of field-based agriculture practices (right). *Nitrogen Management* values represent the N_2O reduction associated with a 20% reduction in nitrogen 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).

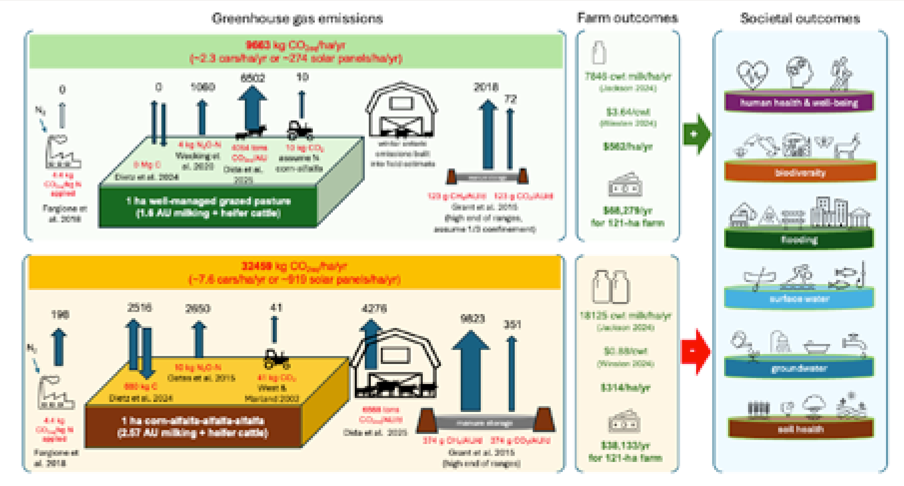


Figure 4. Comparison of GHG emissions, farm production and profit outcomes, and societal outcomes from one hectare (2.47 acres) of land supporting dairy (milk cows + replacement heifers) with either well-managed livestock grazing on perennial pasture or a corn-alfalfa-alfalfa-alfalfa rotation producing 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.

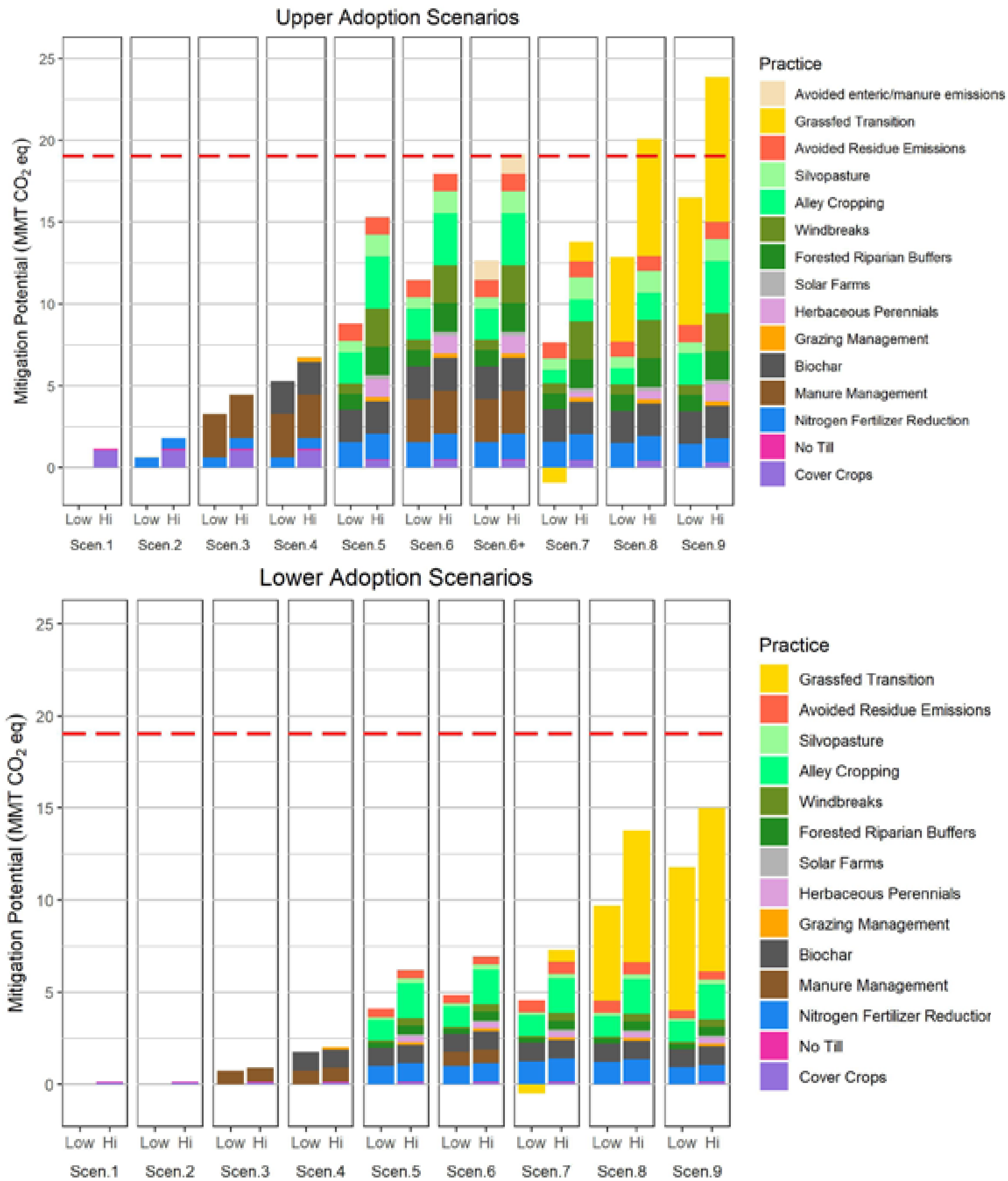


Figure 5. Greenhouse gas mitigation potential under Upper Adoption Rate Scenarios (top) and Lower Adoption Rate Scenarios (bottom). In the *Lower Adoption Rate Scenarios*, estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate Scenarios* uses an 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]

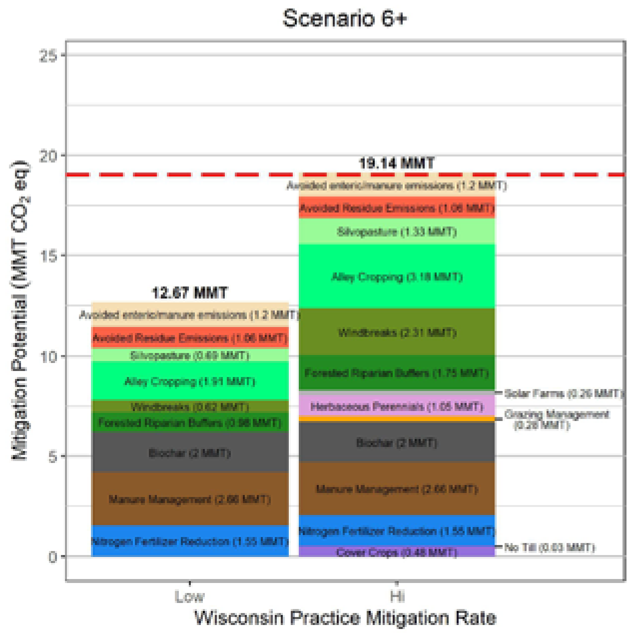
Land-use change[8]	% total ag land	Acres converted to NCS
Annual cropland converted to **solar arrays**	1%	200,000 acres
Annual cropland converted to **perennial row crops**	3-6%	390,000 - 840,000 acres
Existing pasture converted to well-managed **rotational grazing and silvopasture**	9%	1,240,000 acres
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.

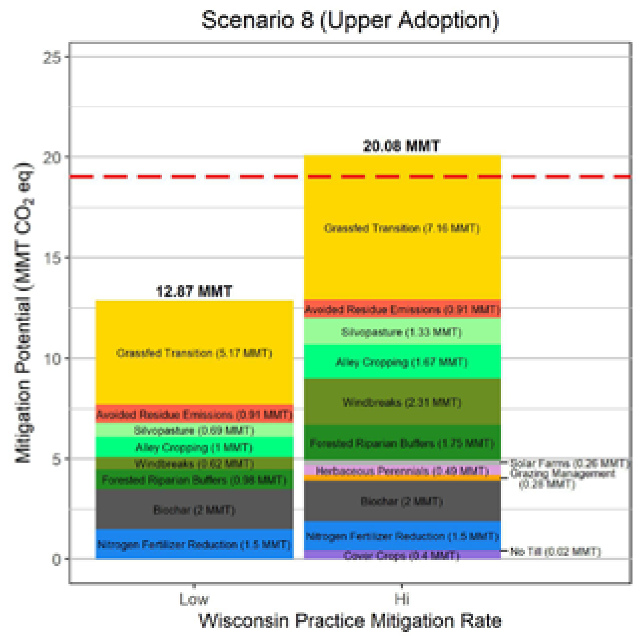
[6] "All land currently being used for dairy production" means all crop acreage used to grow feed for dairy cows. This is defined in more detail in Appendix A: GHG and Scenarios Analyses.

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

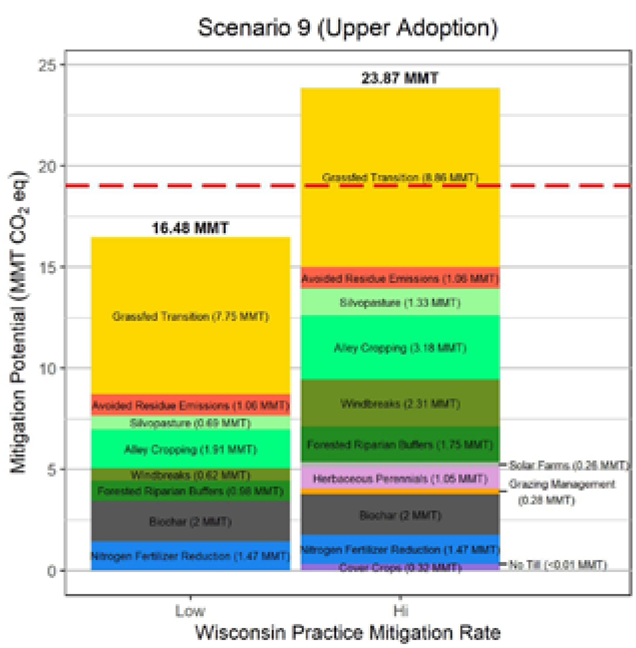
[8] 'Annual cropland' denotes current acreage of corn and soybean not produced for food or livestock feed (3.2 million total acreage as of 2022 USDA Census of Agriculture).



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).

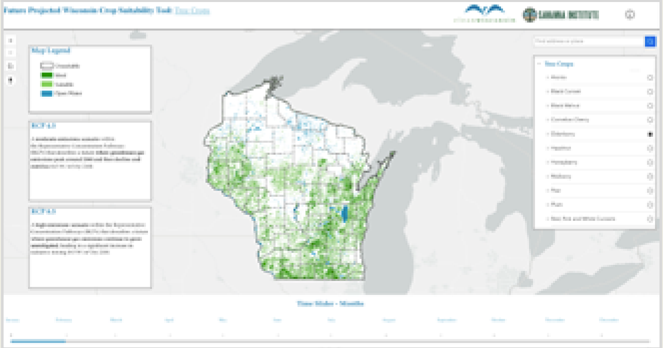
Stable, long-term public funding is necessary to support expansion of technical assistance capacity, development of science-based decision-support tools and to support the facilitation of networks of collaboration across private and public sectors to help guide the agricultural transition towards net-zero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

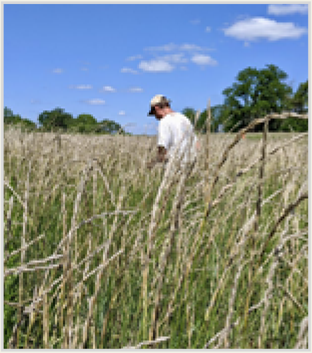
In a rapidly changing climate, farmers, crop insurance providers, technical assistance providers and state agencies need access to science-based tools to (i) better understand the climate risks to our crop commodities into the future, (ii) identify high-value alternative crops that can thrive under future 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

UW-Madison-based *Grassland 2.0* is a collaborative 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).

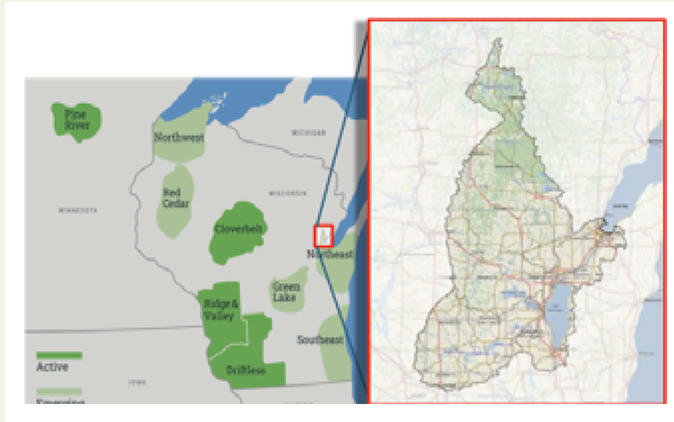


Figure 7. Location of *Grassland 2.0* Learning Hubs in Wisconsin and Minnesota. Dark polygons indicate more mature Learning Hubs, while grey polygons indicate emerging Learning Hubs where local communities are organizing to begin Collaborative Landscape Design process. For this project, we focused in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

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

operations in the rural areas. Over two years, *Grassland 2.0* has engaged with over 60 stakeholders to build 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

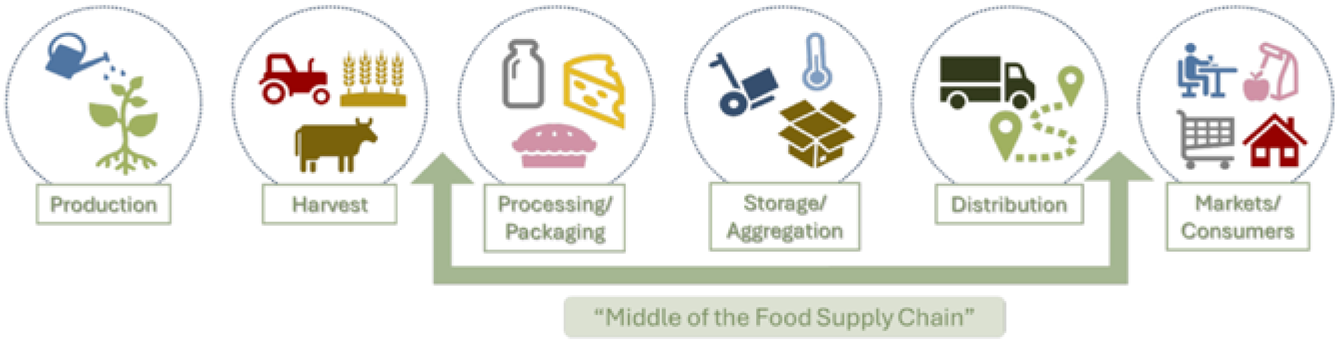


Figure 9: The "missing middle" of perennial supply chains. *From* Wisconsin Resilient Food Systems Infrastructure Program (USDA-RFSI 2025).

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:

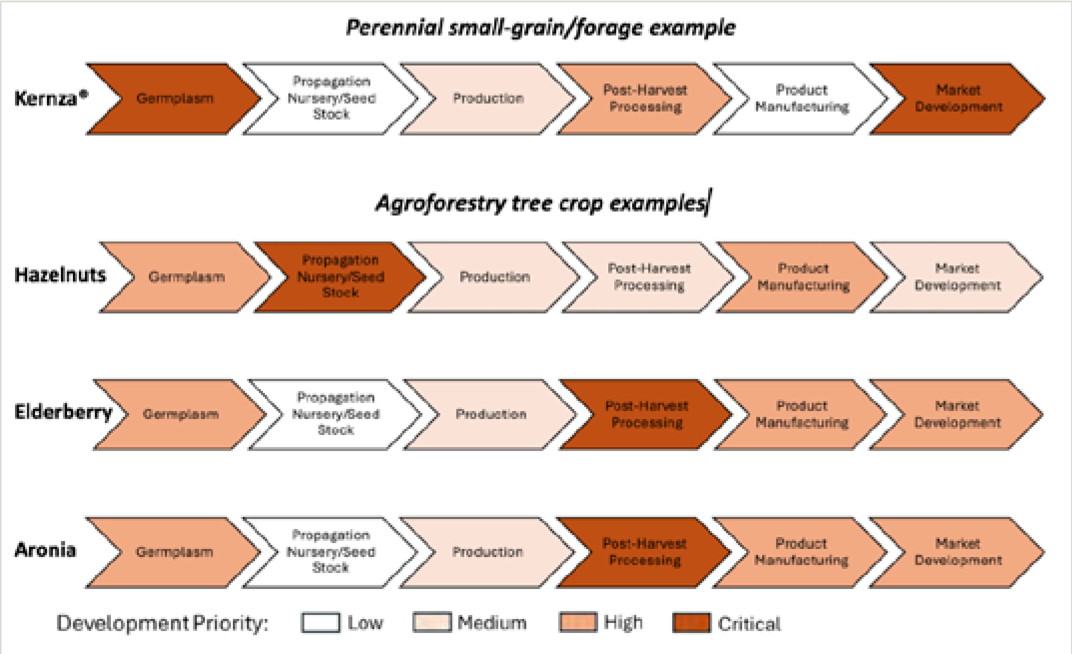


Figure 10. Crop-specific Strategic Development Priorities. *Adapted from:* Fischbach and Mirsky (2024). Development priority levels: Low—not a bottleneck; sufficient activity or success; easily overcome with existing tools or knowledge. *Medium*— bottleneck, but manageable: work is underway, solutions 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
Executive Order, Executive Budget, Legislative	**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
Administrative Rulemaking (DATCP, DNR WEDC); Federal-State Partnerships (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.
Executive Order, Executive Budget, Administrative Rulemaking (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.
Executive Order, Executive Budget, Administrative Rulemaking (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.
Executive Order, Administrative Rulemaking (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
Legislative, Administrative Rulemaking (DATCP)	**Strengthen agricultural practice standards** to align with the land and crop management practices identified in the NCS Roadmap.
Administrative Rulemaking (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.
Administrative Rulemaking (DATCP OCI); Federal-State Partnerships (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.
Administrative Rulemaking (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
Legislative, Administrative Rulemaking (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
Legislative, Administrative Rulemaking (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.

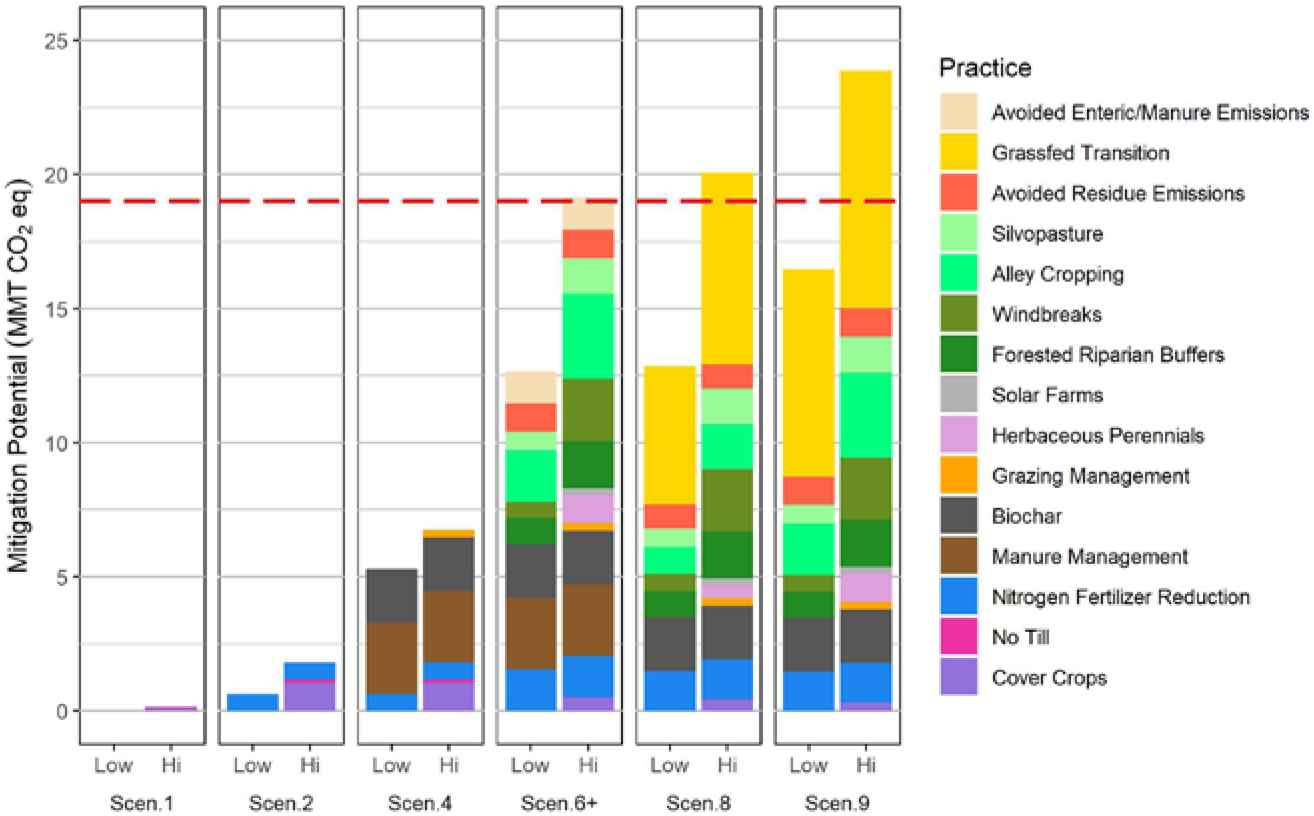


Figure 11. Summary of the primary pathways to achieve net-zero emissions by 2050

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

Notes

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A CLEAN ENVIRONMENT FOR EVERYONE

Case Study:

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

Katherine (Kata) Young and **Paul Mathewson**, *Clean Wisconsin*
Monika Shea, *The Savanna Institute*
Hanan Ali, Cate Wollmuth, and **Imran Ali,** *Clean Wisconsin**

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

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

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

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

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

*2023-2025 Clean Wisconsin research assistants minimum and maximum ranges for ideal productivity, beyond which crop yields are expected to decline. This data is presented for each month of the year to aid users using the Tool (v1.0) to cross-reference average projected suitability and known climate extremes during key months of the year when these extremes can pose significant risks to crop establishment, bud development, fruiting, harvesting, etc.

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

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

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

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

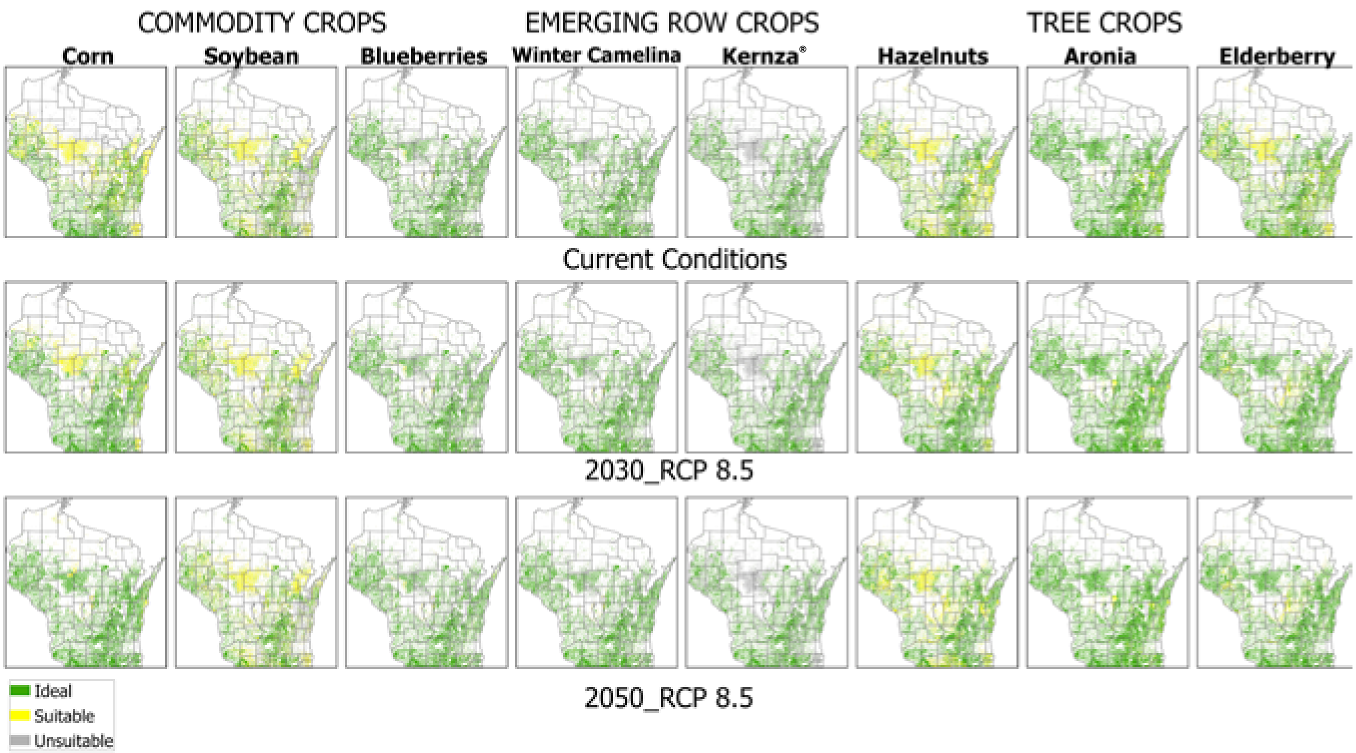


Figure 1. Current and average future crop suitability under high global emissions scenario (RCP8.5).

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

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

Percent of agricultural land shifting suitability.

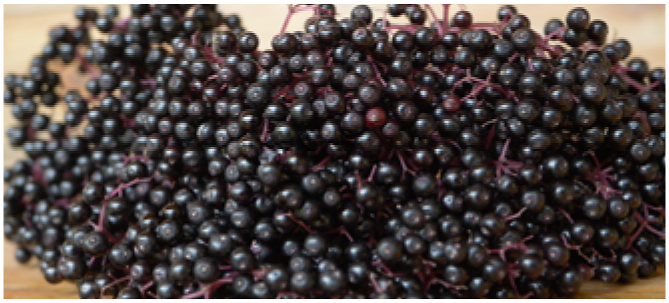
Table 2a. Percent of agricultural land shifting suitability between current and 2030 (RCP8.5) climate conditions for eight selected crops

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

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

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

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



Harvested elderberries, Wisconsin.
Photo credit: Savanna Institute.

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

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

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

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

Wisconsin Hazelnuts.
Photo credit: Clean Wisconsin.

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

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

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

Conclusion

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

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

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

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

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

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

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

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Case Study:

The Wisconsin Kernza® Supply Chain Hub Pilot Project

Katherine (Kata) Young, *Clean Wisconsin*
Nicole Tautges, *Michael Fields Agricultural Institute*

Wisconsin Kernza® Field Day at Michael Fields Agricultural Institute (East Troy). Photo credit: Clean Wisconsin

Grain crops dominate farmland and diets worldwide, but reliance on annual varieties drives soil loss, water pollution, and agricultural greenhouse gas emissions. Kernza®, developed from the perennial intermediate wheatgrass (*Thinopyrum intermedium*), offers Wisconsin farmers an alternative that builds soil health, protects water quality, reduces agricultural greenhouse gas emissions and sequesters carbon long-term with its deep root systems. As demonstrated by the NCS Roadmap, if grown at scale within Wisconsin, Kernza® could play a key role helping our state to achieve net-zero climate goals. At the same time, expanding Kernza® markets and processing capacity can generate new value-chain oopportunities for new, perennial foods and nutrient-dense ingredients, strengthen rural economies. and position Wisconsin as a national leader in perennial grain production.

Despite its promise, Kernza® faces hurdles to widespread adoption, mainly due to high market prices (partly as a result of low supply) and limited market options. Since 2019, early growers of Wisconsin Kernza® have struggled to find a consistent market. Existing regional and national markets, such as *Perennial Promise Growers Cooperative*, *Sustain-A-Grain* and *Patagonia Provisions*, require organic or regenerative organic certified grain to secure grower contracts. New growers often trial new crops in small-scale plots (5- and 10-acres) to decide if they will continue growing to the recommended 30+ acres of pro-

Harvesting Kernza® at Michael Fields Agricultural Institute (East Troy).
Photo credit: Michael Fields Agricultural Institute.

Inspecting Kernza® field development at Four Winds Farm (Fitchburg).
Photo credit: Clean Wisconsin.

duction. For small-scale, new adopters in Wisconsin, field preparation practices to establish new sites for planting Kernza® often disqualifies them from certification, as herbicide applications are often needed to reduce early weed competition to ensure stand success. It can take three years to regain certification, and by then grain yields have reduced and fields grown for food-grade grain must be re-established. There are few regional or national market options for conventionally-grown or transitional Kernza®, leaving small-scale early adopters without a buyer for harvested grain and disincentivizing further cultivation.

At the same time, there is growing interest from local Wisconsin craft breweries, distilleries and bakeries for non-organically certified Kernza®. In 2023, *Lakefront Brewery* (Milwaukee), a champion for supporting local Wisconsin farmers through procurement of locally-grown ingredients, sourced 2,000 lbs of Wisconsin-grown Kernza® for a test run of five beers. At $7.50 per pound of raw grain, Kernza® was significantly more expensive than traditional brewing grains like malted barley, priced at $0.34 per pound. Without a local processor equipped with the specialty equipment necessary to clean and process the small-grains to industry specifications, the brewery then sent the Wisconsin-grown Kernza® to be cleaned in North Dakota, aggregated in Minnesota, and then incurred additional expenses for a grain processor to flake it to industry specifications. This locally grown grain ultimately traveled over 1,000 miles just to end up back in Milwaukee—36 miles from its fields of origin. On top of transportation and additional processing costs, the added transportation emissions negated the climate benefits of the crop, while also reducing profit margins for both growers and end-users alike.

To overcome these barriers across the supply chain, *Clean Wisconsin*, *Michael Fields Agricultural Institute*, University of Wisconsin-Madison, UW-Extension's *Emerging Crops Program*, and *Rooster Milling* came together with support from the Daybreak Fund and the Platform for Agriculture & Climate Transformation (PACT), to. to make the first concerted effort to address commercialization of Kernza® in Wisconsin and to align stakeholders across the local supply chain. In January 2024, the project secured specialty equipment for *Rooster Milling* in southeastern Wisconsin to adjust their grain cleaning line to optimize Kernza® cleaning and dehulling, thereby increasing access to local cleaning and processing facilities equipped to handle the unique properties of this emerging grain. This became the precipice for the *Wisconsin Kernza® Supply Chain Hub* to connect farmers, processors, and buyers in an effort to streamline operations, identify major challenges faced across the supply chain and to coordinate activities aimed at overcoming these obstacles. So far, ten existing farmers and five research stations—covering 96 acres across 12 counties in Wisconsin—have participated in the project, increasing Wisconsin Kernza® production from 42 acres to over 150 acres in just its first year. By the end of August 2024, 4,000 lbs of Kernza® had been harvested and prepared for processing, enough to produce 100-300 barrels of beer.

Since then, the Wisconsin *Kernza® Supply Chain Hub* has developed resources to build the capacity of Wisconsin Kernza® growers, including post-harvest handling guidelines and resources to guide new growers on the kinds of on-farm equipment necessary to maintain quality in storage and in transport. In collaboration with *The Land Institute*, University of Minnesota's *Forever Green Initiative*, and USDA *Kernza®CAP* project, the *Wisconsin Kernza® Supply Chain Hub* presented at farmer field days and brewer events to raise awareness of Kernza®'s environmental and

Cleaning Wisconsin-grown Kernza® at Rooster Milling (East Troy).
Photo credit: Clean Wisconsin.

Wisconsin-grown Kernza®.
Photo credit: The Land Institute.

culinary benefits. In addition to improving infrastructure, in December 2024, the *Wisconsin Kernza® Supply Chain Hub* brought together over 30 farmers, processors, craft brewers and distillers to facilitate roundtable discussions addressing pricing challenges and to work together to identify the best farm-gate price range that provides fair returns for farmers while being viable for buyers (*see* NCS Toolkit). Wisconsin distillers and brewers shared that this event was the first time in memory where they were in the same room talking about sourcing needs and challenges across the supply chain. Over 400 lbs of Wisconsin Kernza® was processed and distributed to the participating businesses as samples to trial. As a result of these efforts, four new Kernza® beers were released to the public in 2025: *Duesterbeck's Brewing Co.* (Elkhorn) released a Golden Ale at the Walworth County Fair, which sold out. *Karben4 Brewing Co.* (Madison) brewed a *Kernza® Pub Ale*, which sold out. *Hillsboro Brewing Co.* (Hillsboro) released an Amber Lager featuring Wisconsin-grown Kernza®, and prompted them to trial a batch of their nationally-distributed *Fantasy Factory* IPA using Wisconsin-grown Kernza®. This special release was paired with a blind-consumer test, surprising all with the results that the average consumer detected no significant difference between the regular *Fantasy Factory* and the Kernza® *Fantasy Factory*, and if they did they expressed preference for the Kernza® version.

By 2026, Wisconsin-based production is expected to quadruple as first-year fields mature and new growers join the effort. A robust supply chain is critical to meeting this growing demand and ensuring consistent quality and supply to breweries, bakeries, and restaurants.

Looking ahead, *Wisconsin Kernza® Supply Chain Hub* partners are working on securing large-scale steam flaking equipment to enable processing that brewers and distillers, and to process in the volumes required to scale production and to more end-users. Grower technical support continues through information sharing within the network, which was connected in communications via this project, and through a support line maintained by the *Michael Fields Agricultural Institute*. Consumer education efforts initiated through this project are also continued by *Michael Fields*, and we anticipate consumer survey efforts in future years to evaluate gains in consumer awareness and use of Kernza® as a novel food attached to significant environmental benefits. By working collaboratively, Wisconsin aims to lead the way in scaling Kernza® and demonstrating how natural climate solutions can benefit both rural economies and the environment.

Case Study:

Building Collaboration towards Agroecological Transformation:

Scoping a Northeast Wisconsin Learning Hub and Opportunities for Dairy Heifer Grazing

Sarah Lloyd, John Strauser, Clarissa Dietz, Jessica Mehre, Randall D. Jackson
Department of Plant & Agroecosystem Sciences, Grassland 2.0, University of Wisconsin-Madison

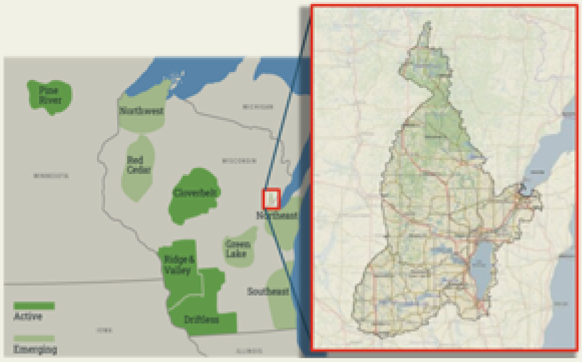

Figure 1. Location of *Grassland 2.0* Learning Hubs in Wisconsin and Minnesota. Dark polygons indicate more mature Learning Hubs, while grey polygons indicate emerging Learning Hubs where local communities are organizing to begin Collaborative Landscape Design process. For this project, we focused in NE Wisconsin, particularly the region west/northwest of Lake Winnebago.

Through the **Collaborative Landscape Design** (CLD) Learning Hub work, *Grassland 2.0* has identified a set of key activities that are necessary for place-based, transformational change:

1) Connecting people,

2) Envisioning novel landscapes,

3) Designing supply chains,

4) Planning enterprises, and

5) Institutionalizing change.

These CLD activities are not entirely sequential, but they do in many ways build off of and are iterative of/with each other. Certainly, the first stage of the formation of a Learning Hub is to begin to build conversations and relationships with key thought and action leaders in the region to understand the interests and issues facing the communities.

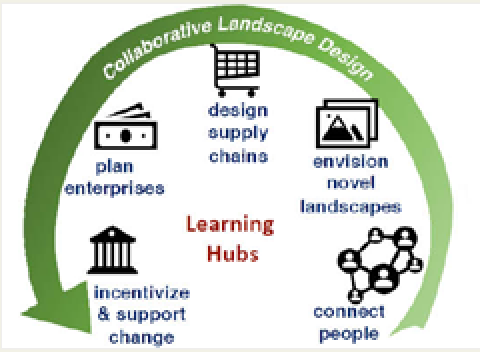

Figure 2. Depiction of Collaborative Landscape Design process situated within Learning Hubs.

Grassland 2.0

Grassland 2.0 is a collaborative project led by UW-Madison and involving farmers, researchers, and public and private sector leaders working to develop pathways for increased farmer profitability, production systems that gain nutrient efficiency while improving water quality, soil health, biodiversity and climate resilience through grassland-based agriculture. *Grassland 2.0* seeks to co-create a vision and action plan to reshape Midwestern agriculture as a perennial, livestock-integrated, grazing-based system in the image of the original native prairies (*Grassland 1.0*).

Grassland 2.0 engages with rural communities interested in managed grazing through regional learning-and-action networks called **Learning Hubs**. To date, there have been three active Learning Hubs and five emerging Hubs in Wisconsin (Figure 1). The *Grassland 2.0* Learning Hub model is a facilitated *Collaborative Landscape Design* (CLD) process bringing together farmers, landowners, community leaders, agency, non-profit, and university partners in a particular place. to build knowledge and action around opportunities and challenges of transforming agricultural systems from current systems that deplete people and the land to those that enrich—economically, ecologically and socially (Figure 2). Participants in these hubs engage in CLD to develop scenarios for change and adaptive planning, and to 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.

Scoping a Northeast Wisconsin Learning Hub

In June 2024, *Grassland 2.0* began efforts in northeastern Wisconsin to assess interest in the formation of a new Learning Hub 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 the past year, *Grassland 2.0* has engaged with over 60 stakeholders to build 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; state-based federal agency representatives (e.g. USDA-NRCS) through interviews, community meetings, farmer roundtable discussions, regional events and field days. The following activities were undertaken to "connect people" and assess the appetite for engaging in other dimensions of CLD:

Key Pilot Project Highlights:

2024

- Collaboration with UW-Oshkosh *Sustainability Institute for Regional Transformations* (SIRT), including work together with WiSyS on a NSF grant proposal, and exploring connections with SIRT's ongoing Harmful Algal Bloom project;
- 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;
- Coordination with UW Extension Dairy Educator in the region regarding opportunities for virtual fencing technologies as a support for transition to grazing systems.
- Conversations with tribal nations in the northeast. Working with the Wisconsin Tribal Conservation Advisory Council (WTCAC)[1] and Great Lakes Intertribal Food Coalition (GLIFC)[2] around some initial scenario development on grass-based beef that is going in the Tribal Elder Food Box Program distributions, which includes distribution of grass-based proteins (beef, chicken, and bison) from both tribal and non-tribal producers;

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 September event support for "GrassStock!", an inaugural celebration of grassland-based systems held in the Basin (Figure 3), where over 20 federal, county and non-profit organizations came together to share information with the public and to celebrate support for grassland-based systems.

Figure 3. GrassStock! event banner. *From* GrassStock!, 2025

[1] WTCAC, a key participant in the Coalition, is a lead in the group on supporting and facilitating producer training and organization to build tribal producer skills and infrastructure to support conservation practices in the tribal food system development.

[2] GLIFC collaborates with UW-Madison on a multi-year USDA grant focused on tribal food sovereignty. Future work in the region should engage with GLIFC and WTCAC as a starting point, to support the work of these organizations.

What have we learned?

Northeastern Wisconsin has a rich mix of people, organizations and initiatives, agencies, and communities active in agriculture and conservation. *Grassland 2.0* brings to the table the ecological, economic, and social opportunities and imperatives around well-managed grazing. The demand and appetite for *Grassland 2.0*'s work with facilitated network building to support relationships between farmers, technical service providers, agency staff, and non-profit organizations is very clear in the four northeastern counties:

> "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

Opportunities for Dairy Heifer Grazing in NE Wisconsin

Building off of Learning Hub development in other parts of the state and Minnesota over the last five years, and insights gained through the place-based work in the Cloverbelt Learning Hub in north-central Wisconsin, *Grassland 2.0* has identified scaling dairy heifer grazing in the region as a win-win-win solution. Heifers represent 24 months of a cow's life and perform well in managed grazing systems. Raising grassfed dairy heifers can[1]:

(i) improve soil health, water quality, and biodiversity,

(ii) provide high value and low-cost forage for ruminants,

(iii) reduce the climate impact and animal stress of shipping heifers long distances.

Animal health and performance is on par if not improved for heifers raised in managed livestock grazing systems, supplying dairy farmers with successful replacements for their milking herd (Kalscheur et al. 2024, Rudstrom et al. 2005[2]). Along with ecological benefits, the reduced input costs of heifer grazing compared to confinement systems can increase dairy farm profit margins.

As part of this pilot work in the northeast, *Grassland 2.0* introduced scaling dairy heifer grazing as a pathway to be explored (Table 1). In this target region, based on USDA figures, there are approximately 23,310 heifers needed each year by the larger dairy herds (500 cows or more). Assuming two acres of well-managed pasture is needed to graze one heifer per year (one acre rotationally grazed during the Wisconsin grazing season and one acre of grass harvested during the growing season and stored for feeding in the winter), transition to putting heifers on grass would impact 46,620 acres. Assuming a 30% "adoption" of heifer grazing by the larger herds in the 4-county area, the impact would reach 13,986 acres.

Table 1. Number of cows and heifers in the target region

	Oconto	Shawano	Winnebago	Outagamie	4-County Area	Heifer demand at 38% replacement rate
1–19 cows	11	58	10	58	137	52
20–49 cows	212	322	135	591	1260	479
50–99 cows	1,447	2,334	615	2,400	6,796	2,582
100–199 cows	2,674	2,269	1,200	2,609	8,752	3,326
200–499 cows	8,147	6,848	3,410	7,818	26,253	9,976
500 or more	10,590	17,313	11,494	21,946	61,343	23,310
Total	23,081	29,174	16,864	35,422	104,541	39,426

NOTE: Estimate on # of cows on 1–19 Shawano and Outagamie because date suppressed by USDA
SOURCE: Wisconsin Table 11, 2022 US Census of Agriculture

1 Lloyd 2025, Dietz et al. 2024, Jackson 2024, Rojas-Downing et al. 2017

2 Ongoing research at the University of Wisconsin-Madison's Marshfield Agricultural Research Station with the USDA Dairy Forage Research Center is assessing the performance of grazed heifers compared to those reared in confinement fed with Total Mixed Ration (TMR) systems, replicating a smaller study showing that when entering a confinement milking herd, heifers raised using rotationally managed grazing methods had higher dry matter intake and milk production in the first lactation.

Where to go from here?

A next step for the northeast would be to lean in on economic and ecological outputs of transition to dairy heifer grazing. The *Grassland 2.0* Smartscape™ and Grazescape™ decision support tools can be deployed by the Learning Hub group to model cropping and production system changes, from for example corn and soy, or corn, soy and alfalfa production in the dairy rotation transitioned to well-managed grazing by the watershed and farm respectively. In other watersheds we have worked in, the models show significant water quality improvements (i.e. reduced N and P runoff, reduced erosion, increased biodiversity supports).

On the economic side, the Learning Hub group can work to imagine how many heifer grazing enterprises and of what size would need to be activated, as well as the types and guidelines for relationships that are necessary between the "sending" farmers and the custom operators to use the grazed and harvested pasture forages from the 13,986 transformed acres. In this same vein, when examining the supply chain dynamics in the region, we can extrapolate how many pounds of milk would be produced when these grazed heifers enter the lactating herds and begin to line up supply to a plant or a product that could pull through ecological data/ecosystem services claims on that milk based on the land use, crop and pasture systems.

In addition to the specific work around dairy heifer grazing, the discussions with the tribes in the region would look at the ecological and economic opportunities and scale and scope around grass-fed meat production (primarily beef) that is part of the current efforts of the Great Lakes Intertribal Food Coalition, distributing indigenous grown, culturally-relevant foods to tribal elders and other community members (i.e. kids, moms).

The challenge more generally in the region is to keep resources coming together, in the light of federal funding cuts and reorganizations, to keep the facilitated network building and collaboration happening and diverse organizations and farmers able to have clear goals that they can come together around and work towards in actions that are relevant for the place.

It is with the development of shared visions for the future ecological and economic contours of the place that actions can be taken, together, to reach those goals.

A closer look at dairy heifer grazing in Wisconsin

Based on *Grassland 2.0* analysis of the University of Minnesota FINBIN farm enterprise numbers (https://finbin.umn.edu/), 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). An operation with 100 heifers over a 180-day grazing season could save $27,180 (Table 2).

Table 2. Value proposition for dairy heifer grazing. *Adapted from*: Lloyd 2025.

Farm transition scenario	Acres and # of heifers in operation* *1 acre/heifer	Profit/Savings from 180-day dairy heifer rearing operation* *1 dairy heifer grazing season, $2.50 head/day	Profit/Savings from 24-month dairy heifer rearing operation* *2 dairy heifer grazing seasons, $2.50 head/day
Dairy farm going out of milking → transition to custom dairy heifer grazing	50	$16,308	$32,616
	100	$27,180	$54,360
	200	$54,360	$108,720
	500	$142,200	$284,400
	1000	$284,400	$568,800
Current cash-grain operator → transition to custom dairy heifer grazing	300	$81,540	$163,080
Current dairy farm → transition from confinement to grazing their own replacement dairy heifers	190	$51,642	$103,284

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

A custom heifer grazier ("custom operator"), 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; at $3.00/head/day, the net return to the custom operator would be $21,708 (Lloyd 2025). Over the 24-month life stage of dairy heifers, the net return to the custom operators (at $2.50 head/day) would be $32,616. Charging a slight up-charge for custom heifer grazing (at $3.00 head/day) would be $43,416. 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.

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APPENDIX A:
Greenhouse Gas Analysis Methods & Adoption Scenario Development

Paul Mathewson, PhD, *Science Program Director*
Clean Wisconsin

PART I. GHG ANALYSIS DETAILS AND METHODS

1. INTENT AND GOALS

This analysis is intended to provide a high-level quantification of the climate change mitigation potential of "conservation practice" implementation in annual systems, the conversion of annual cropland to perennial crops and covers in Wisconsin, drawn from currently available CO2 offset values published in the scientific literature, and greenhouse gas emission reductions from improved fertilizer and manure management. Through this analysis we aim to provide an accessible summary of the climate change mitigation potential for these practices as reported in the most up-to-date scientific literature, highlighting the relative efficacy of different practices, and illustrating what it will take to reach net-zero emissions in the agricultural sector.

This fills a need to explore agricultural NCS practices at a state-level. Published estimates for climate change mitigation potential on agricultural land are currently only available at the global or national level (e.g., Griscom et al. 2017, Fargione et al. 2018, Walton Family Foundation 2022). Nature4Climate's United State NCS Mapper applies the sequestration and emissions factors from a global analysis (Griscom et al. 2017) to individual states to provide a state-level estimate. While this is helpful, a single global/national value may not accurately reflect the specific circumstances in Wisconsin, since the climate change mitigation potential of practices is highly site- and context-specific. Indeed, this important limitation is acknowledged by the Nature4Climate mapper, which encourages "more detailed analysis at the state level for policy and planning purposes."

Similarly, the Carbon Reduction Potential Evaluation (CaRPE) tool provides interactive quantification of some agricultural practices at a state (and county) level. However, this tool is utilizing only a single estimate (the COMET-Farm estimate) of the climate change mitigation potential of the modeled practices. While this model does provide useful information, it has its own important limitations in that it has significant field validation gaps and only models the top 30 cm of the soil, which likely overestimates the soil carbon sequestration potential of several practices.

Given the highly variable nature of the climate change mitigation potential of these practices, it is valuable to have an analysis that can provide a range of mitigation potentials that users can tailor and interpret in the context of their own specific circumstances. This flexibility also allows our modeling approach to be easily adaptable to other states in the region that have different circumstances.

The main goals are to provide a science-based foundation for discussions and decisions about how such practices could or should be encouraged or incentivized in Wisconsin in the context of climate change mitigation by:

1) Clearly demonstrating the challenge of achieving net-zero agriculture by presenting a quantitative analysis;

2) Demonstrating the relative efficacy of different agricultural practices at sequestering carbon or reducing GHG emissions in the agricultural sector;

3) Providing an evidence-based and transparent quantification that anyone can interpret, modify, replicate, and update as new information becomes available. Many existing climate mitigation analyses are inflexible, black box analyses that are difficult to interpret and modify to better reflect a more specific geography.

2. *GENERAL APPROACH*

The baseline agricultural sector emission inventory for this analysis comes from the Wisconsin Department of Natural Resources' 2021 Greenhouse Gas Inventory (Wisconsin Department of Natural Resources 2021), which in turn uses the EPA's state inventory tool (SIT). In this inventory, the agricultural sector module includes emissions largely from the following: enteric methane emissions; manure storage methane and N_2O emissions, and N_2O emissions from fertilizer and manure field applications and plant residues (Figure 1). Carbon emissions from liming fields and urea fertilization, as well as methane and N_2O emissions from agricultural burning are also included with minimal contributions (less than 2% of total sector emissions, combined in Wisconsin).

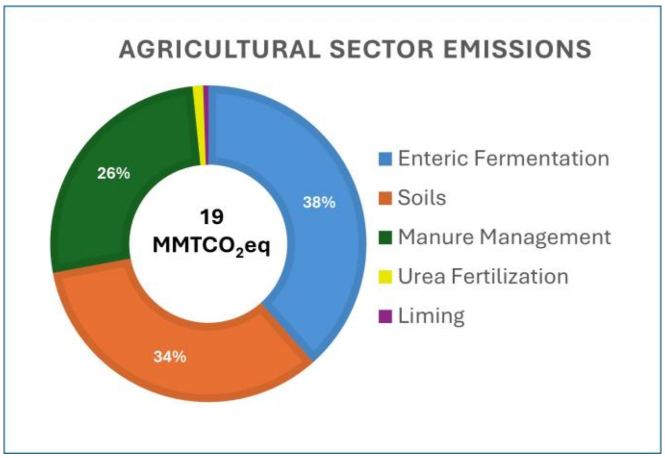

Figure 1. Breakdown of agricultural sector emissions in the Wisconsin Department of Natural Resources' greenhouse gas inventory.

The agricultural sector emissions do not include on-farm fuel and electricity use or carbon flux from the soil. These are included in various other modules of the SIT, which are ultimately synthesized together for the total state inventory.[1] Carbon flux from agricultural soils is considered in a separate Land Use, Land Use Change and Forestry (LULUCF) module. These emissions are calculated in the SIT using a lookup table of values produced using DAYCENT modeling. The agricultural soil carbon flux is reported as the combined flux of land converted to grassland,

[1] The SIT contains 11 modules: agriculture, CO_2 from fossil fuel combustion, coal, electricity combustion, industrial processes; land use, land-use change and forestry; mobile combustion; natural gas and oil; solid waste; stationary combustion; and wastewater.

grassland remaining grassland, cropland remaining cropland, and land converted to cropland. Modifying these values is beyond the scope of this analysis.

However, our goal with this analysis is to examine to what extent climate-smart agricultural practices can reduce or offset the 19 MMT from agricultural sector emissions as defined in this existing inventorying approach, and thus the current soil carbon flux is not relevant. For field management practices like cover crops, no till and conversion from annual row crops to perennial systems that could potentially sequester carbon in soil or biomass, we use existing model estimates and searched published literature for studies that reported sequestration benefits of the practice relative to an annual crop reference system. We then credit the carbon sequestration for newly adopted practices against the current agricultural sector emissions. Practices that continue to lose soil carbon have the same effect in our analysis as a practice that holds soil carbon steady since both practices have zero potential to offset agricultural sector emissions. However, we note that this overlooks the climate mitigation potential of practices that slow or the release of carbon relative to the current annual row cropping system (e.g., Dietz et al. 2024), even if it does not sequester carbon that can offset some agricultural sector emissions.

In our quantification of the potential of agricultural practices to mitigate climate change, we follow the approach used in prior evaluations at global (Griscom et al. 2017) and national scales (Fargione et al. 2018; Drever et al. 2021; Walton Family Foundation Report). Generally, mitigation potential is calculated as:

$$\textit{Mitigation Potential (tons } CO_2eq\ yr^{-1}\textit{)} = \textit{Mitigation Flux x Potential Extent of Practice Adoption}$$

Mitigation flux refers to the rate of climate mitigation per unit (e.g., soil carbon sequestration per hectare or methane reduction per ton of manure produced). Potential extent of practice adoption refers to the total adoption potential (e.g., total acres of cover crop adoption or percent of total manure produced).

We rely on published or previously-used estimates most appropriate to Wisconsin to identify the mitigation flux we use in our calculations, as detailed in the following sections. Climate mitigation fluxes can be highly variable and context-dependent. Thus, to increase confidence in flux values used in our quantification, to the greatest extent possible we rely on values reported in meta-analyses and literature reviews that pool results from multiple studies to report overarching trends across individual studies, thus minimizing the effect of a single study's limitations or bias. Where the meta-analyses provide subsets of results (e.g., specific to certain geography, climate zone or soil type) we use the subset most relevant to Wisconsin. We also supplement these larger meta-analyses with individual studies conducted in Wisconsin (or the Upper Midwest) where available.

To account for the uncertainty in the potential of various practices to mitigate climate change, we provide a range of estimates and a "best estimate" range specific to Wisconsin as detailed in the following sections.

Within the framework of this analysis, practices that do not sequester any carbon and practices that continue to lose carbon are functionally the same since they provide no net sequestration against which to reduce agricultural sector emissions. If an agricultural practice is reported to be a net soil carbon source rather than sink, we assign to it a mitigation flux of 0, rather than assigning a negative flux since the carbon flux from agricultural soils is considered in a separate inventory module, as described above.

3. SCOPE

The following agricultural practices are included in our quantification:

3.1 Cover cropping: cover cropping is the practice of planting crops in between primary harvested crops to keep the ground covered. This practice helps reduce erosion, improve soil health, and suppress weeds. Cover cropping can increase soil carbon by increasing carbon inputs via additional root biomass, microbial carbon transfer, and incorporation of cover crop residue upon termination.

3.2 No-till: tillage is the process of turning up the soil and incorporating any surface residue into the soil to provide a clean surface for planting. No-till refers to the practice of not using plows, discs, cultivators, etc., to invert, turn, or mix the soil; usually involves no-till drill crop establishment implements that minimal-disturbance discs that cut through surface residue to cut a narrow slot in the soil that seeds are dropped into, with press wheels that follow to close the slot. This greatly reduces soil disturbance, reducing erosion, building soil health and improving soil moisture availability. No-till can also increase soil carbon by maintaining soil stability and reducing carbon losses from microbial activity. Finally, no-till reduces the number of tractor passes on a field, reducing fossil fuel usage on the farm.

3.3 Agroforestry practices: agroforestry broadly refers to the deliberate integration of trees and woody shrubs into the agricultural landscape. Agroforestry helps to sequester carbon by increasing soil carbon through the extensive and perennial root systems and soil stability provided by the trees, increased carbon inputs into the soil through leaf litter, and through below- and aboveground carbon sequestration in the woody biomass of the trees.

We are including the following agroforestry practices relevant to Wisconsin in this analysis:

- *Alley cropping* refers to a system of crops planted between rows of trees (Fig. 2). An example relevant to Wisconsin is planting winter wheat between rows of chestnut trees.

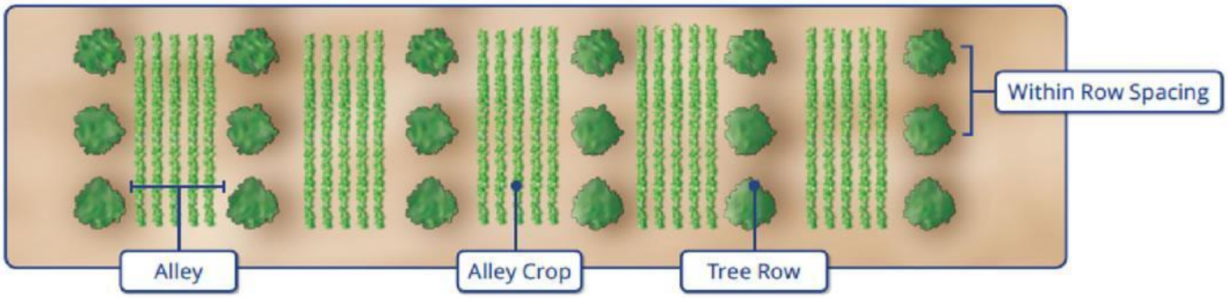

Fig. 2. Alley crop diagram. Source: USDA National Agroforestry Center Illustration https://www.fs.usda.gov/nac/practices/alley-cropping.php

- *Silvopasture* refers to the integration of trees and livestock grazing. This is accomplished by either introducing herbaceous forage into the understories of selectively thinned secondary forest fragments on existing farmland "silvopasture by exclusion"; although removal of trees will introduce additional carbon loss) or planting shade trees and windbreaks on existing, exposed pastures (silvopasture by inclusion). Only the silvopasture by inclusion was included in our analysis.

- *Windbreaks* are linear tree plantings designed to protect cropland, livestock areas, and buildings from damaging winds and snow drifts (Fig. 3).

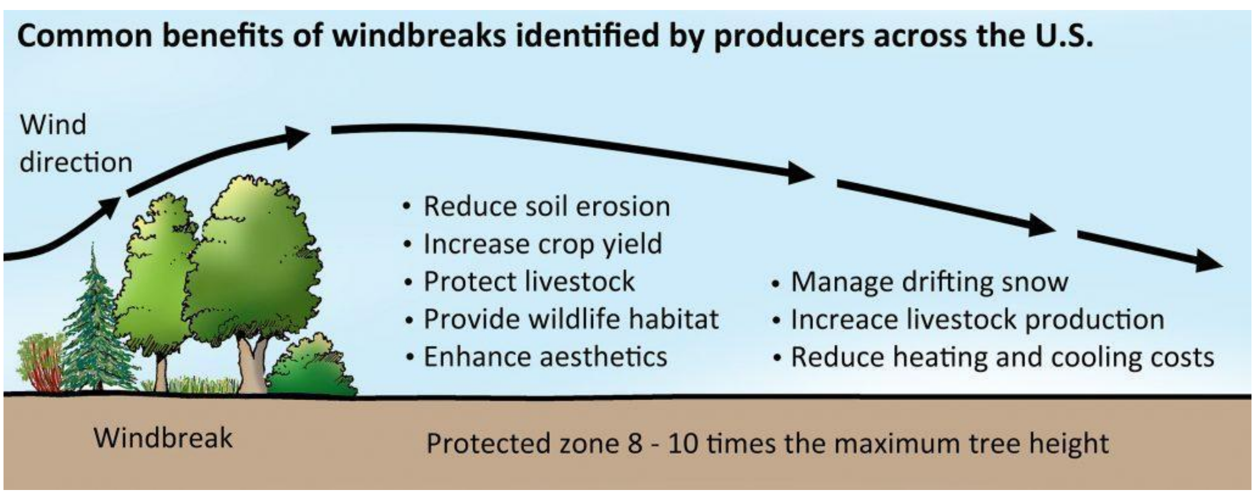

Fig. 3. Windbreak diagram Source: UW Extension: https://woodlandinfo.org/windbreaks/

- *Riparian forest buffers* are strips of trees and other woody vegetation established alongside rivers, streams and lakes (Fig. 4).

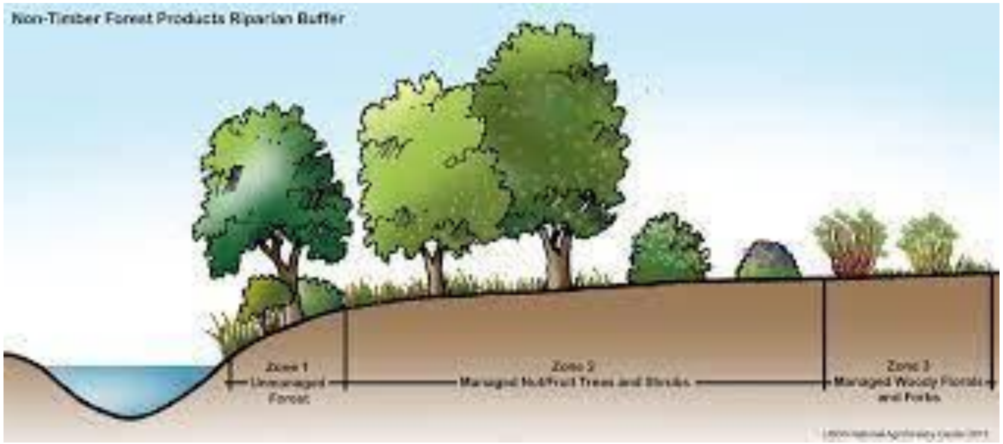

Fig. 4. Riparian buffer diagram Source: USDA forest service: https://www.fs.usda.gov/nac/practices/riparian-forest-buffers.php

3.4 Conversion from annual row crops to perennial herbaceous crops: perennial crops are crops that are planted and then maintained and harvested over multiple growing seasons, over multiple years without (or before) requiring replanting. This includes both woody crops (i.e., agroforestry), which are considered separately in this report, and herbaceous crops (i.e., grasses, legumes, oilseeds, etc.). Herbaceous perennials have multiple end-uses such as human food (e.g., Kernza®), livestock forage (e.g., alfalfa and Kernza®), and bioenergy (e.g., switchgrass). Herbaceous perennial crops provide a greater opportunity to build biomass and thus carbon inputs to the soil compared to annual crops. Perennial fields also have less soil disturbance, reducing carbon loss and promoting the stabilization of carbon in the soil.

3.5 Conversion from annual row crops to grasslands or well-managed, rotationally grazed pastures: Grasslands and well managed, rotationally grazed pastures have the potential to increase soil carbon stocks compared to annual crop fields, similar to herbaceous perennials. Rotationally grazed pastures develop robust root systems that stabilize and increase carbon inputs to the soil, stabilizing reserves of soil carbon for long-term. Grassland and well managed, rotationally grazed pastures can be managed without additional fertilization (e.g., Jackson 2022), leading to a reduction in N_2O emissions compared to annual crops grown with fertilizer input, as discussed below. Similarly, they require little or no diesel fuel to run farm equipment, so reductions in fossil fuel combustion are key climate benefits of these grasslands compared to annual row crops.

Here, we consider two transitions. First, we include the transition of annual row crops to solar farms. Large solar farms in Wisconsin are establishing deep-rooted native grasses under and around the solar panels in their vegetation management plans. As described by Walston et al. (2021), this conversion has the potential to increase soil carbon sequestration from these projects.

Second, we look at the transition from confined milk production to grassfed milk production, which will require an expansion of pastureland in the state. However, the shift from grain-fed ruminant livestock to pasture-fed ruminant livestock has numerous other effects on GHG emissions from a farm. A full discussion of this shift is discussed below in the "*Transition from Confined Dairy Production to Grazed Dairy Production"* section below.

3.6 Improved Grazing Management: Optimizing grazing intensity (i.e., not overgrazing, but not underutilizing forage production either) on existing pastures have the potential to sequester soil carbon by increasing pasture above and belowground biomass production, reducing soil erosion, and improving soil health.

3.7 Biochar soil amendments: Biological charcoal (biochar) incorporation into agricultural fields represents a potential carbon sink. When biomass like agricultural residues or wood biomass leftover from logging operations is burned or left to decompose, much of the previously-fixed carbon is released back into the atmosphere. Creating biochar from these residues through pyrolysis and then incorporating it into agricultural soils stabilizes the carbon and keeps it in the ground for hundreds—and potentially thousands—of years. In addition to sequestering carbon, incorporating biochar into agricultural fields can improve soil health and productivity.

3.8 Nitrogen management: N_2O soil emissions are produced through microbe-mediated nitrification and denitrification processes, and increased emissions are driven primarily by the addition of synthetic N fertilizers and animal manure to fields. The steady increase in atmospheric N_2O concentrations—from approximately 290 ppb in 1940 to 330 ppb in 2017—is linked to the increase in reactive nitrogen in the environment, largely due to the increased use of nitrogen fertilizers in the agricultural sector

(Thompson et al. 2019). N_2O emissions from a field increase with increasing nitrogen inputs to the field (e.g., fertilizer applications), so improved nutrient management will reduce the amount of nitrogen inputs to fields, thus decreasing N_2O emissions. In addition to reducing N_2O emissions from the field, reduced nitrogen fertilizer use will avoid emissions associated with its production, which is energy-intensive and a source of "upstream" greenhouse gas emissions.

Strategies to reduce emissions from agrochemical fertilizer use:

- Reduce/eliminate N fertilizer addition through conversion to perennial systems or less nitrogen-intensive crops
- Practice the 4 Rs: Right time, right place, right form, right rate
- Improved nitrogen use efficiency in crops

3.9 Manure management: Manure management is an important source of methane and N_2O emissions in Wisconsin, accounting for 25% of GHG emissions from the agricultural sector (5 MMT CO_2eq), not including the emissions from the manure when it is spread on the fields.

Methane is produced by the bacterial breakdown of volatile solids in manure under anaerobic conditions. Warm, anaerobic, water-based conditions are most conducive to methane production. N_2O is produced via a combined nitrification denitrification of the N contained in the waste. Ammonia is converted into nitrate in aerobic conditions, followed by nitrate being converted to N_2O in anaerobic conditions. Dry, aerobic systems are more conducive to N_2O emissions. The amounts of volatile solids and nitrogen in the manure depend on cow size, cow digestive physiology, and diet. In our calculations, we used the EPA and DNR quantifications which provide typical nitrogen excretion and volatile solids amounts per animal value for dairy cows in Wisconsin.

The form of manure and storage conditions are the key factors determining emissions. Generally speaking, liquid manure management promotes CH_4 emissions, while solid manure management releases proportionally more N_2O (Fig. 5). Similarly, capping or allowing crust to form on liquid storage ponds will reduce CH_4 emissions but increase

N_2O emissions. Thus, there is some tension between minimizing CH_4 emissions and N_2O emissions since shifting management to minimize one can increase the other.

The manure management practices included in the State Inventory Tool Agricultural Sector are defined by the EPA (2022) as follows:

- Pasture: The manure from pasture and range grazing animals is allowed to lie as is and is not managed.
- Daily spread*:* Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion
- Solid storage: The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
- Deep pit: Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility. Typical storage periods range from 5 to 12 months, after which manure is removed from the pit and transferred to a treatment system or applied to land.
- Liquid slurry: Manure is stored as excreted or with some minimal addition of water to facilitate handling and is stored in either tanks or earthen ponds, usually for periods less than one year.
- Anaerobic lagoon- Uncovered anaerobic lagoons are designed and operated to combine waste stabilization and storage. Lagoon supernatant is usually used to remove manure from the associated confinement facilities to the lagoon. Anaerobic lagoons are designed with varying lengths of storage (up to a year or greater), depending on the climate region, the [volatile solid] loading rate, and other operational factors.
- Anaerobic digestor: Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel (complete mix or plug flow digester) or covered lagoon.

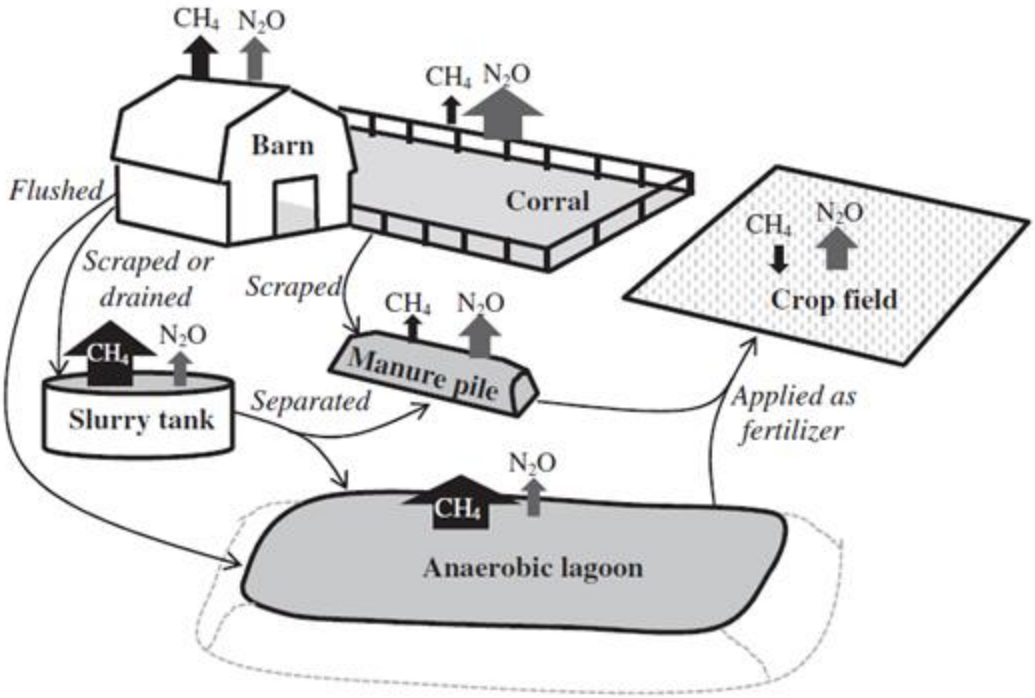

Figure 5. Relative CH_4 and N_2O emissions on dairies (source: Owen & Silver 2014). Thicker arrows represent greater emissions.

The majority of greenhouse gas emissions from manure management (i.e., not including emissions once manure is landspread) are methane emissions. GHG emissions from manure management have increased 3-fold since 1990, driven by increases in methane emissions (Fig. 6). This increase is responsible for half of the agricultural sector's emissions increase since 2005. While milk production per cow has also increased, the manure management GHG emissions per unit of milk has increased by 50% from 1990 (0.2 Mg CO_2eq per Mg milk produced) to 2018 (0.31 Mg CO_2eq per Mg milk[2]). This is largely driven by the shift away from daily spread and solid storage on smaller farms (methane conversion factor of <5%) to anaerobic lagoons and deep pits at larger farms, which create conditions that promote methane conversion (methane conversion factors of 24-68%; Figure 7).

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[2] Using manure emissions from WDNR GHG inventory agricultural module and milk production data from: https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/

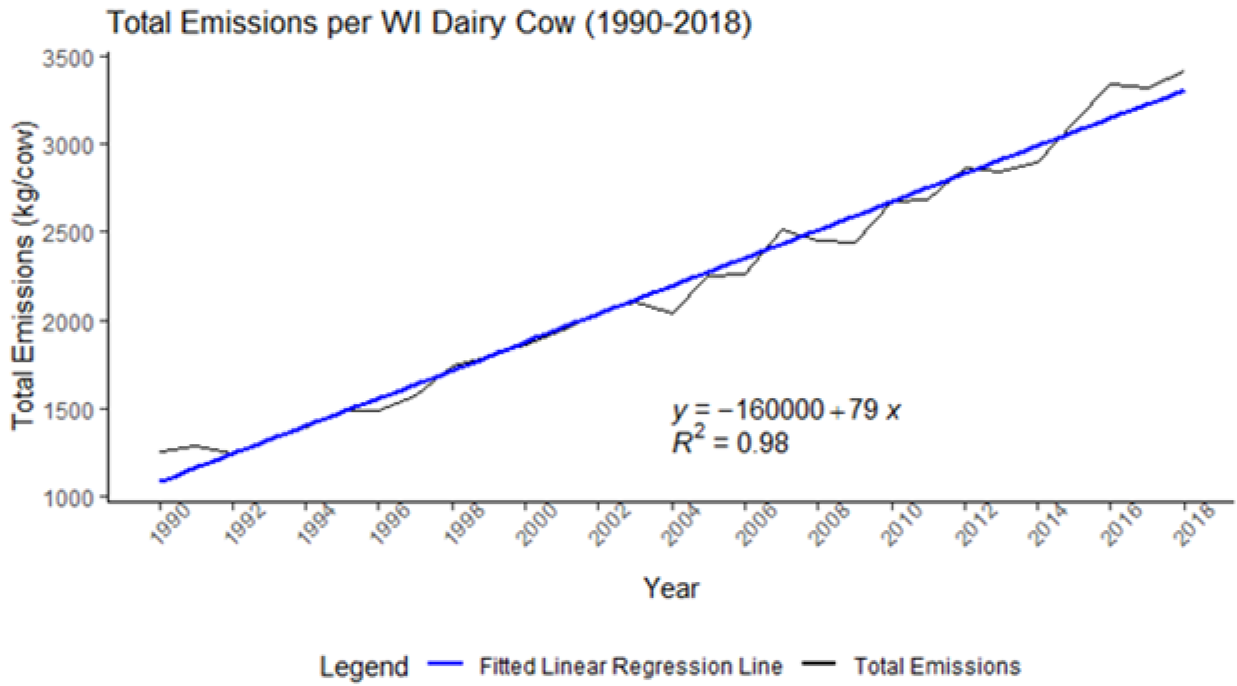

Figure 6. Manure management GHG emissions per dairy cow in Wisconsin over time, reflecting shift towards anaerobic lagoon between 1990-2018. Data from the Wisconsin DNR GHG Inventory.

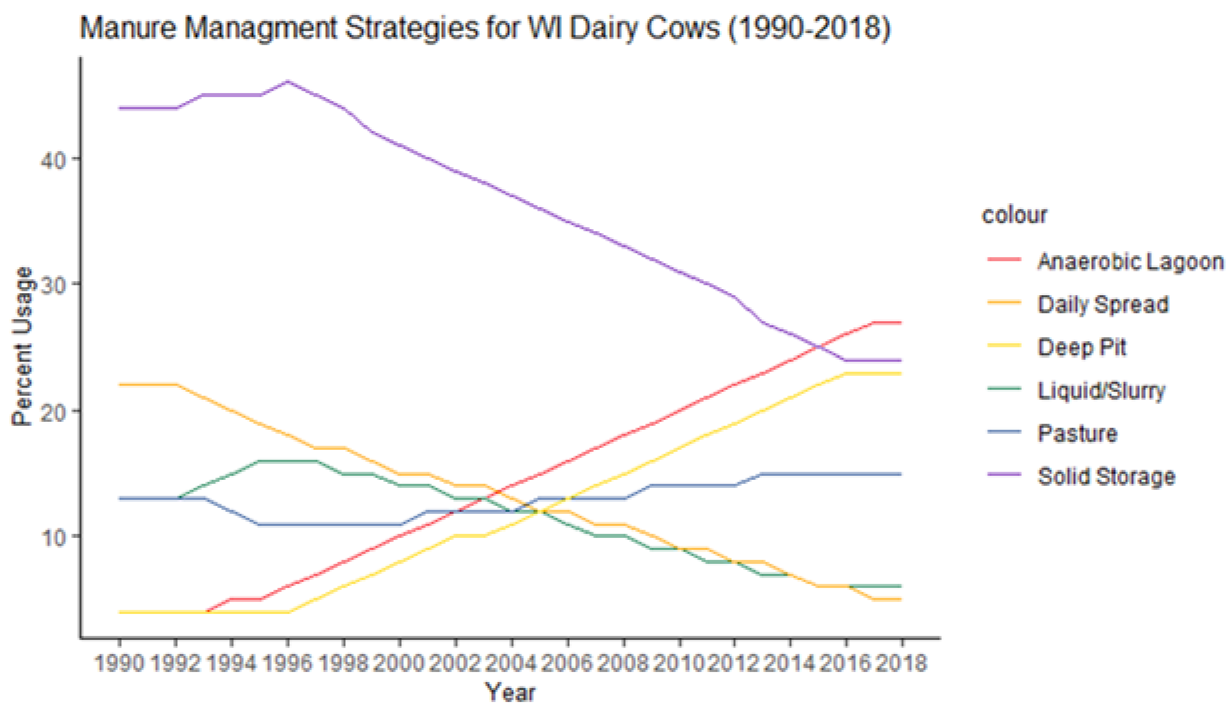

Figure 7. Percent of dairy cow manure managed by various practices in Wisconsin over time, as estimated by the EPA in the State Inventory Tool.

As a result of this shift in manure management, the state weighted methane conversion factor (i.e., the sum of the proportion of manure in the state managed by a practice multiplied by that practice's methane conversion factor) has increased 3-fold from 7% in 1990 to 23% in 2018 (Fig. 8). As discussed above, methane accounts for the majority of GHG emissions from manure management resulting in the direct relationship between MCF increase and total emissions increase.

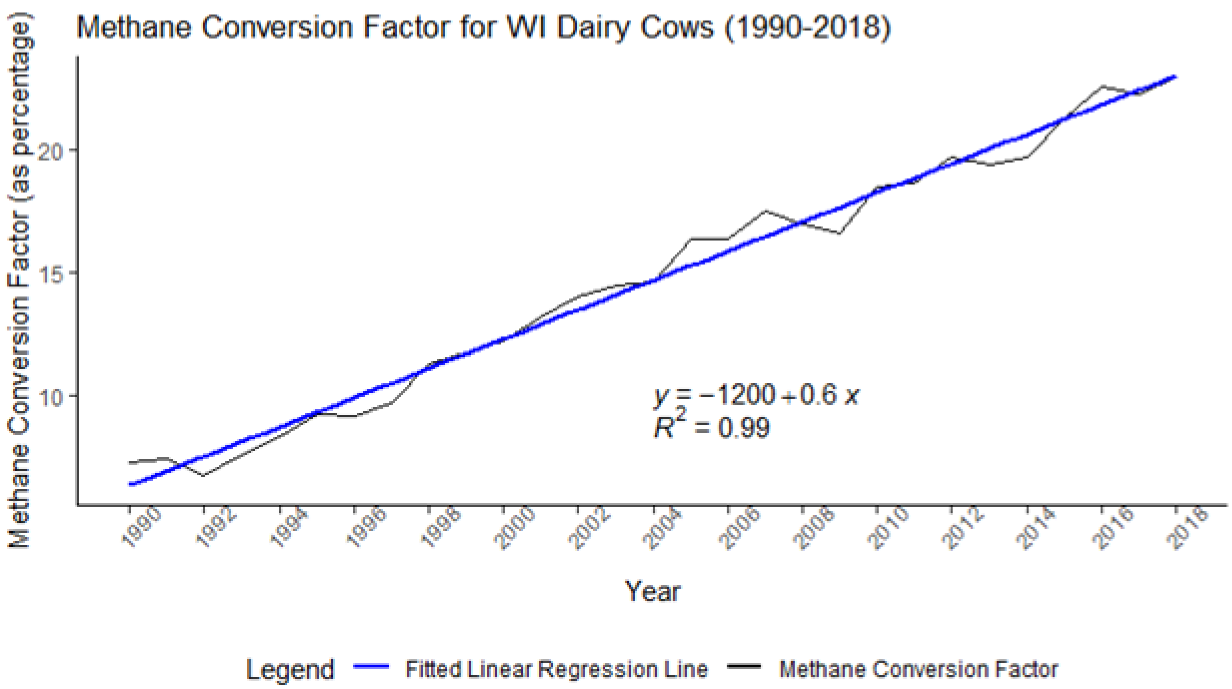

Figure 8. Increase in overall state-weighted methane conversion factor for dairy cow manure management in Wisconsin, as estimated by the EPA in the State Inventory Tool.

Strategies to reduce emissions from manure management include:

- Reducing storage time through increased daily spread or pasturing.
- Composting to increase solid manure management in aerobic conditions to reduce methane production

- Solid-liquid separation moves volatile solids into dry, aerobic storage conditions, reducing methane production. Mechanical separation can separate 45% of the solids from the manure.[3]
- Covering liquid storage allows for the capture and destruction of methane through flaring.
- Anaerobic digesters capture and destroy or use methane.

The scope of this analysis does not include the following:

- Potential feed additives to reduce enteric emissions. Enteric emissions represent a significant amount of GHG emissions from the agricultural sector in WI. There is considerable interest in developing feed additives/supplements to reduce these emissions, and some are promising, such as 3-NOP with meta-analyses indicating over 30% reductions in enteric emissions (Dijkstra et al. 2018; Kebreab et al. 2023). However, studies to date are short-term (up to several months), and the long-term efficacy of supplements in reducing enteric emissions are highly uncertain. Indeed, some of the longer-term studies indicate that emissions begin to return to baseline levels as the rumen microbial community adjusts to the supplement (Melgar et al. 2020, 2021; Schilde et al. 2021).

- Electricity/fuel usage on the farm itself, as this is not included in the agricultural sector of WDNR GHG inventory we are using as our baseline.

- Soil carbon flux beyond the sequestration potential of a conversion from an annual system to perennial systems that we credit towards offsetting agricultural sector emissions as discussed above.
- Potential societal diet changes to reduce demand for animal products
- Land-use conversion to/from agricultural land

Note that while we do not consider these as primary options, we do briefly explore what reduction in milk demand or enteric emissions from the dairy industry would be needed to close

[3]https://learningstore.extension.wisc.edu/products/solid-liquid-separation-of-manure-and-effects-on-greenhouse-gas-and-ammonia-emissions-p1844

the gap between our most optimistic NCS adoption scenario and reaching net-zero in the agricultural sector.

4. LIMITATIONS

This is a first-of-its-kind, high-level analysis exploring the challenge of net-zero agriculture in Wisconsin, establishing a foundation from which future analyses can build and improve. In particular, the agricultural module in the SIT is incomplete and this analysis is effect only looking at the potential to offset current livestock, fertilizer, and crop residue emissions. Future analyses should develop a more comprehensive baseline inventory of agricultural emissions that adds fuel and electricity consumption and existing soil carbon flux to the existing components of the EPA SIT agricultural module.

It is important to note that the true, realized climate mitigation result of practice implementation on a given farm can be highly variable. For example, soil carbon sequestration of a given practice is dependent on a number of factors including the specifics of how the practice is implemented (e.g., species used, timing and duration of implementation), cropping system, prior field management, local climate, and field soil characteristics. This means that even within a given farm, the climate change mitigation potential of implementing a given practice can vary substantially from field to field.

Thus, these estimates are best interpreted as high-level estimates of the relative climate change mitigation potential for Wisconsin agriculture, rather than precise, absolute predictions of what will happen in Wisconsin if these practices are implemented.

5. GREENHOUSE GAS MITIGATION POTENTIAL RATE SELECTION

5.1 General Comments on Soil Carbon Sequestration

First a general note with respect to soil carbon sequestration applicable to all practices that rely at least in part on soil carbon sequestration. Long-term research from the University of Wisconsin's Arlington Research Station has raised concerns that existing estimates may be overestimating the soil carbon sequestration potential of agricultural practices (Deitz et al. 2024, and citations therein). This work has identified some important shortcomings of many of the existing analyses that could be causing overestimates of the soil carbon sequestration.

First, rather than using long-term monitoring following the implementation of a practice on a field to evaluate carbon stock change due to the practice, many studies compare concurrent soil carbon stocks in fields with a practice implemented on it to stocks in reference fields without the practice implemented and assume that stocks in reference fields remain constant. Thus, in this "space-for-time" substitute approach, any increase in carbon stocks in the managed field compared to the reference fields are considered to reflect soil carbon sequestration. However, if reference fields are losing carbon rather than remaining constant, the interpretation of any observed increased carbon in the managed fields relative to the reference field is quite different. At a minimum it would reduce any carbon sequestration benefit from the management practices but the relative increase may only represent slower loss or maintenance of carbon, rather than carbon accrual that could offset emissions elsewhere. To overcome the "space-for-time" limitation, long-term monitoring from fields with practices implemented on them are needed to evaluate whether soil carbon is actually increasing.

Second, many studies only measure soil carbon in the top 15 or 30 cm of the soil profile. However, gains in the surface soil may be partially or even fully offset by losses deeper in the soil profile. In the case of a partial offset, the climate benefit of a practice only evaluated in the surface soil will be overestimated. In the case of a full offset, the practice will not be providing any net soil carbon increase. To overcome this limitation, sampling to deeper depths (e.g., at least 60 cm; Raffeld et al. 2023) is needed.

Finally, changes in soil bulk density that often accompany management changes are not always accounted for. A change in bulk density will change the mass of soil sampled at a given depth. For example, if adopting no-till increases soil bulk density, the mass of soil from 0-30 cm at the start of adoption will be more than that of the same profile after years of no-till adoption. However, if this bulk density change is not accounted for, the change in soil carbon stock will be overestimated.[4] To overcome this limitation of fixed depth sampling, using an equivalent soil mass approach is recommended (Raffert et al. 2024).

Indeed, comprehensive data (long-term monitoring up to 90 cm soil depth) from Arlington Research station convincingly demonstrate these limitations. The comprehensive dataset shows that the reference fields, fields with cover crops and no till practices implemented, and semi-perennial fields (corn-alfalfa rotations) have all lost soil carbon over the past 30 years, while rotationally-grazed pasture and restored prairie have maintained their soil carbon (Dietz et al. 2024). However, using incomplete methodologies ("space-for-time" substitution, shallow sampling, fixed depth sampling) on this dataset resulted in overestimations of soil carbon increases, including the reference fields, cover cropped fields, and semi-perennial fields maintaining carbon and the pasture and prairie fields gaining carbon (Dietz et al. 2024).

Given these findings and the prevalence of these limitations in the studies underlying existing estimate of the soil carbon sequestration potential of these practices, we set the lower soil carbon sequestration potential for all field-management practices to zero.

However, we also note that another long-term study from Michigan that overcomes the common limitations highlighted by Dietz et al. (2024) found that soil carbon was maintained in conventional agricultural fields and that some conservation practices have resulted in a soil carbon gains over 25 years (Córdova et al. 2025). This illustrates the site- and management-specific nature of soil carbon sequestration dynamics, and the potential of some practices to result in carbon sequestration not observed at the Arlington Research Station.

It is also important to note some temporal aspects of soil carbon sequestration in agricultural fields. First, any carbon gains are only in place as long as the practice is maintained. If the practice is discontinued, any stored carbon is likely to be released back into the atmosphere. This underscores the importance of irreversible reductions like reduced livestock emissions and fertilizer use reductions. Second, the soil carbon sequestration rates will slow and then stop as the soil reaches carbon saturation. For this analysis, we are relying on Fargione et al. (2018) assumptions that time

[4] Similarly, if a practice reduces soil bulk density, failing to account for the change will underestimate the change in soil carbon stock.

to saturation for these practices is greater than 50 years. However, to the extent that saturation times are significantly lower, our analysis results should be considered optimistic.

5.2 No-till soil carbon sequestration flux

We identified eight potential soil carbon sequestration rates for adoption of no-till ranging from 0-0.80 Mg CO_2 ac^{-1} yr^{-1} (Table A.1).

Early interest in no-till as a mechanism for increasing soil carbon was based on the following pieces of evidence: 1) the well-understood relationship between conversion to cropland, which is cultivated by plowing, and large soil organic carbon (SOC) losses; 2) research showing that no-till increases and stabilizes soil aggregates, protecting carbon from microbial decomposition; and 3) empirical studies documenting more carbon in soils that had been converted to no-till (Ogle et al. 2019).

However, early studies only looked at the top 30 cm of soil which have the most gains in SOC because no till leaves organic material on top of the soil and doesn't redistribute SOC deeper into the soil. However, subsequent studies analyzing deeper into the soil profile found that carbon gains at the top from no-till are offset by reduced carbon deeper in the soil (e.g., Luo et al. 2010, Powlson et al. 2014, Haddaway et al. 2018).

Furthermore, studies often fail to correct for increased soil bulk density in no-till soils, leading to overestimates of carbon sequestration under no-till (Powlson et al. 2014) and there is evidence that no-till can increase N_2O emissions (e.g., Six et al. 2004, Guenet et al. 2021) offsetting any carbon storage benefit.

Specific to cool moist climates like Wisconsin, specifically, there is less certainty for any overall SOC gains from no-till, particularly in silty/loamy/clayey soils (Ogle et al. 2019). One of the mechanisms by which no-till can increase SOC is through protection of SOC by reducing disturbance and increasing aggregate stability. However, in colder climates, there are limits to the protection no-till can provide due to disturbance from freeze-thaw cycles.

Taken collectively, the early promise of no-till to mitigate climate change through carbon sequestration is greatly undermined. Indeed, a recent review concluded that no-till should be best viewed as a means of adapting to climate change through improved soil health rather than as a tool to mitigate climate change through carbon sequestration (Ogle et al. 2019). Indeed, two quantifications of natural climate solution potential globally (Griscom et al. 2017) and in the United States (Fargione et al. 2018) chose not to include no-till as a mechanism with sufficient confidence in its efficacy.

The most robust Wisconsin-specific information is available from the long-term soil studies at the Arlington Agricultural Research Station, where long-term studies have not found no-till to sequester atmospheric carbon (Sanford et al. 2012; Rui et al. 2022, Dietz et al. 2024).

For these reasons, we use a value of 0.03 Mg CO_2eq ac^{-1} yr^{-1} as the upper end of the best estimate range for no-till climate mitigation in Wisconsin. This is the estimate for Eastern Canada used by Drever et al. (2021) and reflects the limited certainty that no-till will actually result in carbon accrual but still acknowledging that some studies do indeed find a soil carbon benefit.

5.3 Cover crop soil carbon sequestration flux

We identified nine potential soil carbon sequestration rates for adoption of cover crops ranging from 0.18-1.09 Mg CO_2 ac^{-1} yr^{-1} (Table A.2). The sequestration rate from Poeplau and Don (2015) of 0.47 Mg CO_2 ac^{-1} yr^{-1} is frequently used in prior quantifications of NCS potential on agricultural land at national or global scales. However, Poeplau & Don's value is based on a collection of global studies, and the current understanding of cover crop carbon sequestration in Wisconsin suggests that the potential sequestration is lower than a global estimate.

The effectiveness of cover crops in sequestering carbon is highly dependent on local conditions and specific implementation (e.g., leguminous vs. non-leguminous species; timing of planting). For example, Blanco-Canqui (2022) found that cover crops only increased carbon stocks in 1/3 of comparison studies in the United States. One of the most important factors determining the soil carbon sequestration potential of cover crop adoption is the amount of biomass produced by the cover crop (McClelland et al. 2021; Blanco-Canqui 2022; Wooliver & Jagadamma 2023, Joshi et al. 2023). In cooler, higher latitude fields, cover crops that are planted following harvest of the primary cash crop do not have many growing degree days to accumulate much biomass and develop extensive root structure, limiting the sequestration potential of cover crops in such environments. Indeed, McClelland et al. (2021) found that the 95% confidence interval of soil carbon sequestration in temperate, cool agroecological zones (which encompasses Wisconsin) include no increase in soil carbon, and Jian et al. (2020) found a negative relationship between SOC gains from cover cropping and both latitude and mean annual temperature.

Specific to Wisconsin, long-term studies from the Arlington Agricultural Research Station had found that cover cropped fields were not sequestering carbon over the past 30 years when the full soil profile is considered (Sanford et al. 2012, Cates & Jackson 2018; Cates et al. 2018, 2019; Rui et al. 2022, Dietz et al. 2024). As with no-till practices, as more research explores the soil carbon effects of cover crops at depth, there is increasing awareness that any gains in the surface soil can be offset by losses in deeper soils (McClelland et al 2021, Dietz et al. 2024).

For these reasons, we use the value of 0.18 Mg CO_2eq ac^{-1} yr^{-1} from Blanco-Canqui (2022) as the upper end of our best estimate range for cover crop climate mitigation in Wisconsin. This is on the lower end of reported sequestration values (which, as described above, we could expect for Wisconsin if there is any sequestration), is specific to the United States with good representation from the midwestern United States, and is within the range of estimates from the COMET-Planner model.

5.4 Conversion of Annual Row Crop to Perennial Herbaceous Crops

The soil carbon benefit from meta-analyses analyzing the conversion from annual crops to perennial herbaceous crops are summarized in Table A.3. These potentials are derived nearly entirely from bioenergy grasses (switchgrass, *Miscanthus*) and alfalfa. An additional meta-analysis evaluated soil carbon changes in fields following a conversion to perennial crops[5] (largely bioenergy crops and forage crops) but did not report the rate of change, but rather a percent difference (Siddique et al. 2023). Consistent with the analyses in Table A.3, they found perennialization increased soil carbon, reporting an increase of 17-23% in the top 30 cm soil (Siddique et al. 2023).

We are unaware of any literature reviews or meta-analyses of the potential for Kernza® to increase soil carbon stocks compared to annual crops. However, van der Pol et al. (2022) sampled three sites in Kansas that had been converted from annual grains to Kernza® between 5 and17 years prior and found that the fields accrued SOC at a rate of 0.61 Mg CO_2eq ac^{-1} yr^{-1} across 0-100 cm

[5] Note that this analysis is not strictly related to herbaceous perennials since ~20% of the studies included in the analysis included woody perennials (e.g., poplar, willow).

soil depth compared to annual crop fields. This is consistent with some of the longer-term studies of other perennial herbaceous crops summarized in Table A.3.

Specific to Wisconsin, as noted above, long-term research at the Arlington Research Station found semi-perennialization (alfalfa and corn rotation) was found to continue to lose carbon (although at a slower rate) compared to a continuous corn rotation while full perennialization in the form of a grass-based pasture or prairie maintained carbon (i.e., neither gained or lost carbon).

For the upper end of our best estimate range for the conversion of annual crops to perennial herbaceous crops, we use 1.26 Mg CO_2eq ac^{-1} yr^{-1}, which is the average of the available meta-analyses.

5.5 Conversion of Annual Row Crop to Grassland or Well-managed Rotationally-Grazed Pasture

In the most comprehensive meta-analysis we are aware of, Conant et al. (2017) found that conversion from cropland to grassland increased soil carbon by 1.30 Mg CO_2eq ac^{-1} yr^{-1}. This dataset included 93 studies with a global scope, but a strong bias toward temperate North America, and had a mean sample depth of 44.5 cm.

Fargione et al. (2018) use a sequestration flux of 1.78 Mg CO_2eq ac^{-1} yr^{-1} for restoring cropland to grassland in the United States, and this average value is representative of estimates for Wisconsin specifically (see Figure S19 in Fargione et al. 2018).

Kaempf et al. (2016) found that the average sequestration rate in temperate grassland following conversion from cropland was 1.07 Mg CO_2eq ac^{-1} yr^{-1}

Specific to Wisconsin, Becker et al. (2022) compared soil carbon in paired pastures and row crops in central and southern Wisconsin. They report that pastures had significantly more surface (0-15 cm) carbon than row crop counterparts and that soil carbon increased with pasture age at a rate of 0.49 Mg CO_2eq ac^{-1} yr^{-1}. Although this increase in soil carbon with pasture age does not directly reflect a conversion from agricultural fields, we assume that soil carbon accumulation rates in row crop agriculture are likely close to zero, if not negative and thus this value represents a conservative potential increase in soil carbon that could be seen under a conversion to pasture.

At the long-term Arlington Research Station, Rui et al. (2022) found that after 29 years pasture fields had 18-29% more soil carbon in the top 30 cm than any of the annual crop fields and conclude that grazed perennial grasslands have the potential to accumulate soil carbon in Wisconsin's grassland soils. However, Sanford et al. (2022) and Dietz et al. (2024) report that soil carbon gains in the top 30 cm can be offset by losses deeper in the soil profile, resulting in pasture maintaining its original carbon (i.e, not losing or sequestering carbon).

Finally, in Michigan, Stanley et al (2018) found that adaptive multi-paddock grazed pastures sequestered carbon at a rate of 5.34 Mg CO_2eq ac^{-1} yr^{-1} in the top 30 cm of soil.

We note that, as with other practices to increase soil carbon, the potential of grasslands and pastures to sequester carbon is site- and context-specific. Soil type and initial conditions, as well as local environmental conditions will strongly influence the amount of carbon storage. Management also plays an important role; for example, intensity and type of grazing and incorporation of legumes have been shown to affect soil carbon storage rates (e.g., Oates and Jackson 2014, Conant et al. 2017).

We use the 1.30 Mg CO_2eq ac^{-1} yr^{-1} from Conant et al. (2017) as the upper end of our best estimate range as it reflects the most statistical power coming from 93 different studies, and lies in between more recently-published individual field data points in the Upper Midwest.

<u>5.6 Improved Grazing Management</u>

Meta-analyses have found that rotational grazing increases soil carbon compared to continuous grazing (Byrnes et al. 2018) or that lighter grazing increases soil carbon sequestration in pastures (McSherry & Ritchie 2013; Zhou et al. 2017).

Fargione et al. (2018) used a national value of 0.07 Mg CO_2eq ac^{-1} yr^{-1} in soil carbon sequestration due to grazing optimization from a dataset compiled by Henderson et al. (2015). However, this dataset reports no expected sequestration in WI (see Fig. S17 in Fargione et al. 2018).

A synthesis by Conant et al. (2017) reports a global potential of 0.42 Mg CO_2eq ac^{-1} yr^{-1} for improved grazing. Similarly, a review from Smith et al. (2008) reports a global potential in humid climates of 0.32 Mg CO_2eq ac^{-1} yr^{-1} from improved grazing practices.

As with other practices, the soil carbon sequestration potential for optimized grazing intensity will vary by specific implementation: geography, soil characteristics, baseline soil carbon stocks, and historic pasture management (Godde et al. 2020). Based on these values we use a range of 0-0.42 Mg CO_2eq ac^{-1} yr^{-1} for improved grazing management.

5.7 Agroforestry carbon sequestration fluxes

The carbon sequestration of a given practice is highly dependent on the specific implementation, including species, age, tree density, agroecological conditions and soil conditions (Feliciano et al. 2018). In general, there are fewer studies of agroforestry carbon impacts in cool, temperate areas than there are for other practices like no-till or carbon, and none from Wisconsin that we are aware of. Most agroforestry carbon sequestration studies are from tropical areas, limiting their applicability to Wisconsin, so to the extent that reviews and meta-analyses break down their results by agroecological zone we extracted values most relevant to Wisconsin.

We also note that the relatively small number of studies examining the carbon dynamics of transitioning from annual systems to agroforestry systems leaves the possibility that further study will find less potential, along the lines of how increased study of cover crops and no-till practices found reduced potential after initial optimism. However, most of the reported sequestration potential from agroforestry systems comes from tree biomass, which is significantly less uncertain than soil carbon sequestration. Additional study may find less optimistic soil carbon gains from agroforestry systems, but there will always be some sequestration from the biomass carbon accumulation.

5.7.1 Agroforestry carbon sequestration fluxes: alley cropping

Studies presenting alley cropping carbon sequestration fluxes are summarized in Table A.4. Reported fluxes ranged from 1.30 to 5.06 Mg CO_2eq ac^{-1} yr^{-1}. As an upper estimate we use 2.19 Mg CO_2eq ac^{1} yr^{-1}, from Fargione et al. (2018), and which is also similar to the global value from Feliciano et al, and all temperate, cool studies from Cardinael et al. (2018). For a lower estimate we use 1.30 Mg CO_2eq ac^{-1} yr^{-1}, from Drever et al. (2021), the lowest reported value.

5.7.2 Agroforestry carbon sequestration fluxes: windbreaks

There are limited reported carbon sequestration fluxes from windbreaks (Table A.5). For our best estimate range we use this full range of all reported values (1.42 to 5.26 Mg CO_2eq ac^{-1} yr^{-1}) as no individual reported values stood out as being more robust or applicable to Wisconsin than others.

5.7.2 Agroforestry carbon sequestration fluxes: Silvopasture

Carbon sequestration fluxes from silvopasture are summarized in Table A.6. As an upper estimate we use 2.36 Mg CO_2eq ac^{-1} yr^{-1}, from Feliciano et al.'s (2018) North American value, which is also similar to Cardinael et al.'s (2018) cool/temperate North American values. For a lower estimate we use 1.23 Mg CO_2eq ac^{-1} yr^{-1}, from Drever et al. (2021), the lowest reported value.

5.7.3 Agroforestry carbon sequestration fluxes: Riparian Buffers

Carbon sequestration fluxes from riparian buffers are summarized in Table A.7. As an upper estimate we use 6.68 Mg CO2eq ac^{-1} yr^{-1}, from COMET Planner estimates in Wisconsin, which is the highest reported value. For a lower estimate we use 3.74 Mg CO_2eq ac^{-1} yr^{-1}, from Drever et al. (2021) the lowest reported value other than Kim et al., (2016), which only included a single study site.

5.8 Nitrogen Fertilizer Use Changes Due to Conversion from Annual Row Crops

We also accounted for changes in nitrogen fertilizer use due to conversion from corn or soybeans to the NCS practices discussed here. The precise changes will depend on the local soil conditions and the particulars of the species being established, but Table 1 summarizes the general changes in fertilizer use that we assumed in our calculations.

Table 1. Nitrogen fertilizer changes as a result of annual row crop conversion.			
Conversion	**Prior N fertilizer application rate (pounds per acre) for corn/soy**[1]	**NCS N fertilizer application rate (pounds per acre)**	**Notes**
Corn/soy to perennial herbaceous crop	180/5	60	Based on 80 pounds per acre for switchgrass, miscanthus, Kernza and 5 pounds per acre for alfalfa (Laboski & Peters 2012, Pennington 2012, Tautges et al. 2023)
Corn/soy to pasture	180/5	0	Assuming pasture fertilized only by manure deposits from grazing cows (E.g., Jackson 2022)
Corn/soy to forested riparian buffer	180/5	0	Assume no fertilizer applied to forested buffer
Corn/soy to windbreak	180/5	0	Assume no fertilizer applied to windbreaks
Corn/soy to alley crop	180/5	50	Based on 50-100 pounds per acre for poplar; 20-100 for nut trees, including chestnut and hazelnut; 50 pounds per acre for fruit trees; and 30 pounds per acre for berries (Braun n.d., McDonald n.d.,University of Georgia n.d., McLaughlin et al. 1987, Cheng 2010, Laboski & Peters 2012, Lizotte & Mandujano 2015, Buchman et al. 2020, Lowenstein & Crain 2025,)
[1] Based on Laboski & Peters 2012			

5.9 Biochar Soil Amendments

The climate mitigation potential of biochar amendments follows IPCC methodology and is calculated from Woolf et al. (2021) as:

$$Mitigation\ potential = Mass\ biochar\ \times organic\ carbon\ content\ of\ biochar \times fraction\ biochar\ carbon\ remaining\ after\ 100\ years$$

Fargione et al. (2018) and Drever et al. (2021) used agricultural residues as biochar feedstock in their analyses; however, the NRCS does not recommend using agricultural residues as a feedstock since leaving it place provides important soil protection and soil health benefits. Thus, we use woody biomass from forestry residue that can be economically and sustainably removed (i.e., leaving residues important for ecological services in place). Springer et al. (2017) estimate that Wisconsin sustainably produces between 1 and 2 million dry tons of forestry residue annually. Assuming that one ton of woody biomass feedstock produces 0.42 tons of biochar (Woolf et al. 2010), this represents an annual potential of 420,000-840,000 tons of biochar. Biochar can be applied to the plow layer at a rate of 50 tons per hectare per 100 years (Woolf et al. 2010). Given the amount of cropland in the state, this annual supply of biochar corresponds to 278-555 years of applications, meaning that we have more than enough agricultural land to be incorporating this biochar through at least 2050.

To calculate the greenhouse gas mitigation potential of this annual biochar application, we assumed an organic carbon content of the biochar of 76% and that 85% of the carbon remains after 100 years (Woolf et al. 2021). This results in 1-2 MMT CO_2eq of biochar greenhouse gas mitigation potential on agricultural lands.

We note that our sole focus on persistence-derived carbon sequestration from binding the carbon up in the biochar may under- or overestimate net total lifecycle greenhouse gas balances from biochar applications. This sequestration is typically the largest impact on net GHG balances (Woolf et al. 2021), but future analyses could include other GHG impacts for a more complete analysis. For example, on the one hand, there are transportation and production emissions associated with biochar. On the other hand, biochar applications can also reduce soil N_2O emissions and reduce nitrogen fertilizer needs by improving soil fertility. Production emissions can also be minimized through co-production of bioenergy or the use of renewable energy sources (Woolf et al. 2021). Lacking a standardized methodology for a full lifecycle analysis, we are following the methodology of prior analysis from Fargione et al (2018) and Drever et al. (2021) and include only the persistence-derived carbon sequestration.

5.10 Nitrogen Fertilizer Management

The climate change mitigation potential from improved nitrogen management is calculated as the avoided GHG emissions associated with nitrogen fertilizer production and the reduction in soil N_2O emissions from nitrogen inputs to fields.

Fargione et al. (2018) provide upstream emissions associated with each type of nitrogen fertilizer (e.g., anhydrous ammonia, urea, etc.). Based on current use of each type in the U.S., they provided an overall estimate of 4.41 g CO_{2eq} per gram of N fertilizer in the United States, which is what we use in this report. This is consistent with other estimates of 3.9 g CO_2eq per g N fertilizer from Carmago et al. (2013), an estimate of 4.05 g CO_2eq per g N fertilizer in Canada from Dyer et al. (2017), and a global range of 3.2-6.6 g CO_2eq per g N fertilizer from Bellarby et al. (2008).

N_2O emission quantification is done using emissions factors, which relate N_2O emissions to total N-input. Emissions factors represent the percent of total N input that is subsequently emitted as N_2O; for example, an emissions factor of 1% indicates that 1% of all the N applied to a field will be emitted to the atmosphere as N_2O.

There are two approaches to calculating N_2O emissions factors: bottom-up and top-down. Bottom-up approaches divide emissions between direct emissions (i.e., directly from the cropland) and indirect emissions (N_2O emissions from ecosystems downstream/downwind of agricultural land which receive reactive nitrogen from leaching, run-off or atmospheric redeposition), using different emissions factors for direct and indirect emissions. Top-down approaches relate changes in total measured atmospheric N_2O concentrations to changes in N-inputs, accounting for changes in industrial emissions and emissions from non-agricultural land (Smith et al. 2017).

There is some broad convergence between top-down and bottom-up estimates at a global scale (Del Grosso et al. 2008, Smith et al. 2012). However, some regional analyses have found that bottom-up approaches underestimate N_2O emissions compared to top-down approaches, potentially due to hidden "hot-spots" of N_2O emissions within a landscape and errors in the indirect emissions factors, which are relatively understudied (Griffis et al. 2013, Turner et al. 2015). For example, a study in southern Minnesota found that measured N_2O emissions from streams are up to 9 times greater than commonly used indirect emissions factors, resulting in the bottom-up approach underestimating N_2O emissions by 40%. (Turner et al. 2015). Specifically, zero-order streams (e.g., headwaters, drainage ditches) enriched with reactive nitrogen from runoff and leaching from agricultural land are N_2O emission hotspots that can double agricultural emissions when appropriately accounted for.

Direct soil emission factors are the most studied and estimates relevant to Wisconsin are summarized in Table A.8. Top-down emissions factors reported in the literature range from 2-5% (Table A.9).

We follow the EPA's Greenhouse Gas Emissions and Sinks methodology[6] for quantifying greenhouse emissions from synthetic fertilizer applications in Wisconsin. This is the methodology used by the WDNR in its Greenhouse Gas Inventory, which is the baseline we use for this Roadmap. The emissions factors used in this approach are summarized in Table A.10.

Overall, this approach results in a total emissions factor of 1.2 kg N_2O-N per kg N synthetic fertilizer. This is lower than top-down emissions factors, such as the 2.3% from Thompson et al. 2019, which was used in the NCS potential calculations for the United States used by Fargione et al. (2017). This is also lower than emission factors from the 2019 IPCC revisions (summarized in Table A.10), which would result in 1.84% for wet climates. Thus, this should be considered a conservative potential for the climate mitigation potential of synthetic N fertilizer management. This is particularly true when considering the non-linear relationship between N_2O emissions and nitrogen fertilizer application rates (e.g. Hoben et al. 2010). Reductions at the higher end of the rate scale will have disproportionately high reductions in N_2O emissions that aren't reflected in the SIT methodology.

The total mitigation potential for reductions in nitrogen applications to fields is calculated as:

$$\begin{gathered} N\ Fert.\ Management\ Potential = \\ (ProductionEmissions_{Fert,\ current} + N_2OEmissions_{Fert,\ current}) \\ -\ (ProductionEmissions_{Fert,red} + N_2OEmissions_{Fert,red}) \end{gathered}$$

where $Fert,_{current}$ is for current nitrogen application and $Fert,_{red}$ is reduced nitrogen fertilizer application.

5.11 Manure Management

The general equations for quantifying the GHG emission from manure management are:

$$\begin{gathered} Methane\ emissions = total\ volatile\ solids\ in\ manure\ x\ methane\ conversion\ factor \\ N_2O\ emissions = total\ nitrogen\ in\ manure\ x\ N_2O\ emission\ factor \end{gathered}$$

[6] https://www.epa.gov/ghgemissions/methodology-report-inventory-us-greenhouse-gas-emissions-and-sinks-state-1990-2021

The methane conversion factor and N_2O-N emission factor depend on climate and manure form and management system (Table A.11).

We follow the EPA's Greenhouse Gas Emissions and Sinks methodology[7] for quantifying greenhouse emissions from manure management in Wisconsin. This is the methodology used by the WDNR in its Greenhouse Gas Inventory, which is the baseline we use for this Roadmap.

To calculate 2018 methane emissions, the EPA calculated a Wisconsin-specific methane conversion factor of 23% for dairy cows. This is based on apportioning total statewide manure management among six practices: pasture, daily spread, solid storage, liquid slurry, deep pit, anaerobic lagoon, and anaerobic digesters. Based on the percentage of manure volatile solids handled by each practice and that practice's MCF, an overall state-weighed MCF of 23% is calculated (Table A.12).

For direct N_2O emissions, total nitrogen excretion is apportioned between liquid systems (anaerobic lagoons and liquid/slurry) and solid storage and other systems (in WI, solid storage and deep pit). The total nitrogen in liquid systems is multiplied by a liquid systems emissions factor of 0.1%. The total nitrogen in solid systems is multiplied by an emissions factor of 2%.

Direct N_2O emissions for pastured cows are calculated by multiplying the N excreted by pastured cows by an emissions factor of 2%.

Direct emissions from landspreading of managed systems and daily spread is calculated by multiplying the total N excreted that is managed or daily spread, less the amount volatilized (assumed to be 20%), and multiplied by an emissions factor of 1.25%.

Indirect N_2O emissions from volatilization are calculated by multiplying total N excretion by the amount volatilized (20%) and a volatilization emissions factor of 1%.

Indirect N_2O emissions from runoff and leaching is calculated by multiplying total unvolatilized N excretion, by the amount of N assumed to leach (30%) and an emissions factor of 0.75%.

[7]https://www.epa.gov/ghgemissions/methodology-report-inventory-us-greenhouse-gas-emissions-and-sinks-state-1990-2021

Quantifying the methane mitigation potential of manure management practices to reduce emissions involves shifting the proportion of total state manure managed in each of the seven classes according to adoption scenarios and calculating a new state-weighted MCF.

To reduce GHG emissions, we developed scenarios of increased manure management via the following: solid manure management, increased use of anaerobic digesters, and covering lagoons coupled with flaring captured methane.

Based on these shifted proportions of manure handled by the different practices, a new state-weighted MCF is calculated, which in turn is used to calculate methane emissions under that scenario. The total climate mitigation potential of manure management adjustments is calculated as the difference in emissions from BAU manure handling and the emissions from the manure management scenario.

The climate benefits of reduced methane emissions via increased management of solid manure management in aerobic conditions will be somewhat offset by increased N_2O emissions, which are accounted for in our calculations, as described above. However, the methane emissions decrease more than N_2O emissions increase, resulting in a net climate benefit through improved manure management.

5.12 Transition from Confined Dairy Production to Grazed Dairy Production

Transitioning from confined milk production to grassfed milk production has numerous clearly established health and nutrition, economic (Dartt et al. 1999; Wiedenfeld et al. 2022; Winsten 2024), and ecological benefits when grazed livestock are managed well (Franzluebbers et al. 2012; Rotz et al. 2020, Jackson 2024). Ecological benefits include little to no soil loss (Vadas et al. 2015); little phosphorus loss to surface waters via runoff (Young et al. 2023); low nitrate loss to groundwaters via leaching (Jackson 2020); improved water interception, infiltration, and storage reducing flooding (Basche & DeLonge 2019; Bendorf et al. 2021); little use of anti-biotics reducing resistance risks, little use of pesticides reducing human health risks (Gerken et al. 2024) and impacts on pollinators and birds, better air quality reducing human health impacts (Hill et al. 2019), improved habitat for biodiversity (Temple 1999, Lyons et al. 2000, Undersander et al. 2000). Many of these outcomes are likely to improve agriculture's resilience in the face of climate change, making this a climate-smart practice. However, the focus of this analysis is solely on the greenhouse gas emissions consequences of this transition.

Numerous studies have reported the carbon intensity of either confined dairy production or grazed dairy production in Wisconsin or the upper Midwest. Unfortunately, there is no standardized approach for calculating the carbon intensity of milk production. As a result, different analyses use different models, assumptions, and system boundaries making comparison across studies intractable.

Thus, we are limited to using studies that used the same approach to compare the grazed and confined systems. We identified five such studies that calculate the carbon intensity of confined and grazed milk production in Wisconsin. None of these studies modeled 100% grassfed milk production. All grazed systems modeled in these analyses supplemented grass with grain (up to 60% of grazing season dry matter intake from pasture) and assumed a confined system diet in the non-grazing months.

Overall, two of the five analyses found that grazed systems have comparable or lower cradle-to-farm gate milk production carbon intensities as confined systems (Reinemann & Cabrera 2013, CIAS 2019), two analyses found grazed systems had comparable to slightly higher carbon intensities (Dutreuil et al. 2014, Aguirre-Villegas et al. 2017), and one study found increased grazing had substantially higher carbon intensity (Aguirre-Villegas et al. 2022). A summary of these analyses can be found in the appendix (Tables A.13-A.18).

This lack of consensus is consistent with global analyses that find that carbon intensity was associated more with specific management practices on a given farm than by general system type (Wattiaux et al. 2019). Generally, grazed systems have higher enteric emissions due to the lower digestibility of grass and lower milk production rates per cow, while confined systems have more machinery and chemical inputs and higher manure storage emissions, particularly when using liquid manure storage. Except for Dutreuil et al. (2014), none of these analyses consider the potential for soil carbon storage in the pastures of grazed systems.

Rotz et al. (2020) modeled the cradle-to-farm gate carbon intensity of different dairy production systems in Pennsylvania finding that 100% grassfed dairy production was the most carbon intensive system (1.46 kg CO_2eq per kg fat and protein corrected milk; FPCM), followed by confinement (1.28 kg CO_2eq per kg FPCM) and grazed with grain (1.15 kg CO_2eq per kg FPCM). This is the most relevant analysis we are aware of comparing the confined to 100% grassfed dairy production in the United States. Although this comparison does not reflect potential soil carbon sequestration following the conversion of cropland to pasture, the paper notes that the soil carbon sequestration potential of converting cropland to pasture could reduce the grassfed system's milk carbon intensity below that of a confined system.

It is important to note that most studies assess carbon intensity of dairy agroecosystems on a per unit milk basis, which always favors approaches that produce more milk. This productivist framing assumes milk is scarce and pushes us away from absolute reductions in greenhouse gas emissions and other environmental pollution rather than relative reductions, which could result in overall higher emissions.

We identified four transition scenarios: 1) maintain milk production constant, but shift 25% of total production to grassfed; 2) maintain milk production constant but shift 47%[8] of total production to grassfed; 3) maintain milk cow herd size constant and shift it all to grassfed; 4) limit milk production to what can be produced by grassfed cows on the land currently being used by dairy production.

For each transition scenario, we calculated the difference in cradle-to-farm gate greenhouse gas emissions for milk production under the current confined system paradigm (assuming 1.28 kg CO_2eq per kg FPCM for all milk production) and the transition scenario (assuming 1.28 kg CO_2eq per kg FPCM for any milk production that remains in confined systems and 1.46 kg CO_2eq per kg FPCM for any milk production that is shifted to 100% grassfed).

We converted milk production to FPCM milk production using ratios for grassfed and confined systems reported by Ranathunga & Wattiaux (2017) from national data.

The cradle-to-farm gate emissions include emissions from sources not included within the EPA State Inventory Tool agricultural module, such as electricity and on-farm fuel combustion. Approximately 10-20% of cradle-to-farm gate life cycle analysis emissions are from such sources for both confined and grazed systems (Reinemann & Cabrera 2013, O'Brien et al. 2014,

[8] 47% was chosen rather than 50% as it is the amount of production that can be shifted to grassfed on the 1.6 million acres of non-livestock feed corn and soy available after the lower end of our NCS practice adoption.

Cabrera & Dutreuil 2014, Aguirre-Villegas et al. 2017, CIAS 2019, Aguirre-Villegas et al. 2022; see Tables A13-A18). Thus, we assumed that 85% of the emissions difference is appropriately included within the scope of our analysis focused on the agriculture module. This is consistent with our treatment of other practices with GHG emission consequences outside of the agricultural module such as not including the effects of no-till on farm fuel use.

To account for soil carbon sequestration associated with the conversion of row crop fields to pasture to accommodate the transition to grassfed milk production, we use a potential sequestration range of 0 to 1.30 Mg CO_2eq ac^{-1} yr^{-1} as discussed above, for any annual row crops converted to pasture.

For corn/soy cropland converted to pasture that is not currently used for milk production, we also account for avoided nitrogen fertilizer applications (assuming 180 pounds per acre corn and 5 pounds per acre soybean) and crop residue emissions, as calculated in the SIT agricultural module.

Total reduction in greenhouse gas emissions for the transition to grazing scenarios is calculated as:

Total Reduction in GHG emissions = [area converted from annual crop to pasture x soil carbon sequestration rate] + [(current milk production carbon emissions – pasture transition scenario milk carbon emissions) x 0.85] + avoided GHG emissions from nitrogen fertilizer and crop residues on row crop conversion not currently used for dairy production.

The relevant variables and assumptions used in these calculations are summarized in Table 2.

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Table 2. Relevant variables and assumptions used in the transition to grazing scenarios.		
Variable	**Value**	**Source**
Current land used for dairy production in WI	796,592 ha	Jackson 2024
Current row crop land used for dairy production in WI	345,655 ha	Jackson 2024
Current milk production in WI	14.4 billion kg milk per year	Jackson 2024
Current herd size	1,270,000 milk cows	Jackson 2024
Milk yield per unit land area in confined system	18,125 kg milk per ha per year	Jackson 2024
Milk yield per animal in confined system	11,369 kg milk per milk cow per year	Jackson 2024
Milk yield per unit land area in 100% grazed system	7,846 kg milk per ha per year	Jackson 2024
Milk yield per animal in 100% grazed system	6,641 kg milk per milk cow per year	Jackson 2024
Milk carbon intensity in confined system	1.28 kg CO2eq per kg FPCM	Rotz et al. 2020
Milk carbon intensity in 100% grazed system	1.46 kg CO2eq per kg FPCM	Rotz et al. 2020
Ratio of confined milk production to FPCM	0.964	Ranathunga & Wattiaux 2017
Ratio of confined milk production to FPCM	0.953	Ranathunga & Wattiaux 2017

PART II. Natural Climate Solution Practice Adoption Scenario Development and Statewide Mitigation Potentials

1. *SCENARIO OVERVIEW*

For each practice, we have defined two adoption scenarios, an aggressive upper estimate of adoption and a more conservative adoption scenario. The scenarios are built progressively as follows (and summarized in Table 3 and Table A.19).

We began by modeling a set of scenarios with practices that can be adopted within the current dominant paradigm of intensive annual row cropping and confinement dairy production. Within this set of scenarios, we first looked at the GHG mitigation potential of only cover crops and no-till adoption. Next, we added reduced nitrogen fertilizer use and improved manure management. Finally, we added biochar soil amendments.

In our second set of scenarios, we looked at the GHG mitigation potential of a transition from annual row crops to perennial systems and the introduction of trees in existing pasture. First, we looked at the conversion to perennial crops and agroforestry systems, while assuming cover crops +no-till + nitrogen management + biochar amendments scenario on the remaining annual cropland. Next, we looked at improved manure management on top of the conversion to perennial systems. Finally, we explore various scenarios of transitions to 100% grassfed milk production.

Table 3. Summary of NCS adoption scenarios. CC = Cover crop adoption; NT = no till adoption. See Table A.19 for more specific inputs into each scenario.

Working within current dominant system of annual row crops and confined dairy production			
Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
CC + NT	(Scenario 1) + N Fertilizer Management	(Scenario 2) + Manure Management	(Scenario 4) + Biochar + Improved Grazing
Transition to Perennial Agriculture (excluding transition to grassfed milk production)			
Scenario 5	**Scenario 6**	**Scenario 6+**	
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	
Transition to grassfed milk production			
Scenario 7	**Scenario 8**	**Scenario 9**	
(Scenario 5) + Maintain current milk production but shift 25-50% of 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 land currently supporting dairy production	

2. *SUMMARY OF FIELD-BASED PRACTICE MITIGATION POTENTIAL*

The per-acre greenhouse gas mitigation potential of the field-based practices are summarized in Figures 9a,b. These potentials are multiplied across the area of adoption defined in the scenarios below to arrive at a total mitigation potential for the practice. The range of potential values we used for our upper and lower estimates for a given practice are outlined in the rectangles in Figures 9a,b. The justification for these ranges is detailed in Part I of this Appendix.

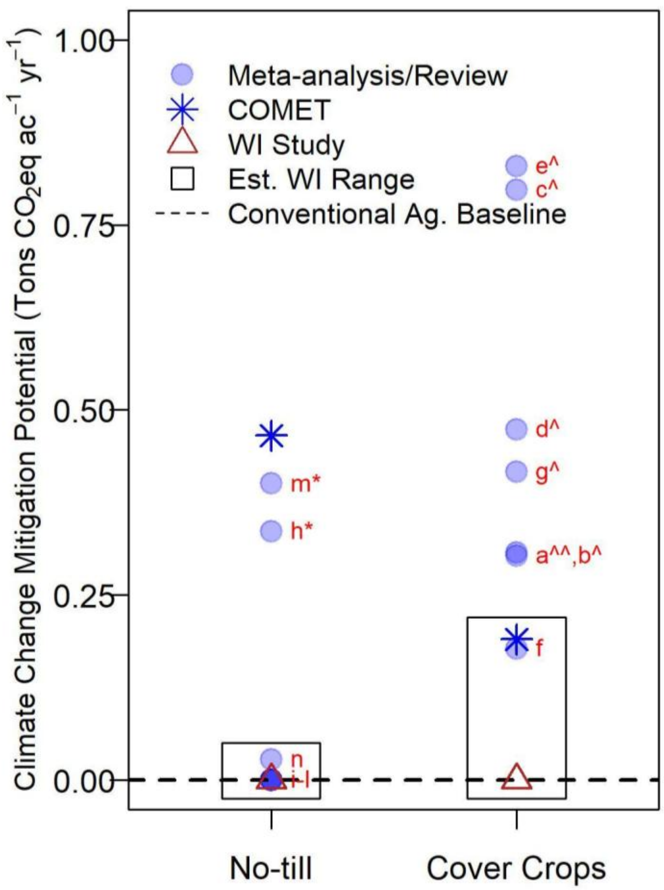

Figure 9a. Details of per-acre soil carbon sequestration of no-till and cover crops. In the no-till studies, *indicate studies that report sequestration only in the surface 30 cm of soil. The Wisconsin study site refers to findings from the Arlington Field Station (Dietz et al. 2024). In the cover crop studies, ^indicate global studies and ^^indicate 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-l]Liang et al., Meurer et al., Haddaway et al, Luo et al.; [m]Ogle et al.; [n]Drever et al.

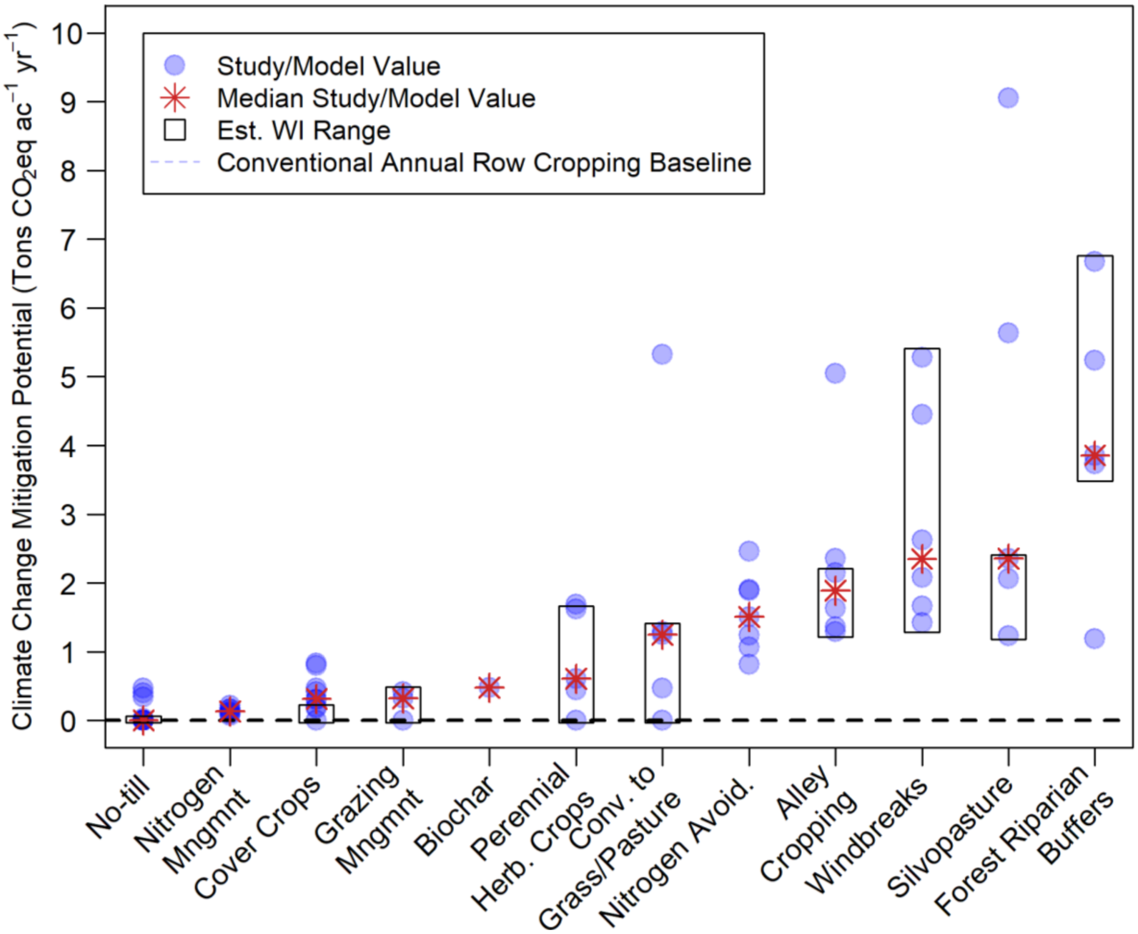

Figure 9b. Per-acre GHG mitigation potential of field-based practices, as reported in published literature for no-till and cover crops (left) and the full suite of field-based agriculture practices (right). *Nitrogen Management* values represent the N_2O reduction associated with a 20% reduction in nitrogen 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 boxes indicate the best estimates for Wisconsin that were used in our analysis. See Part I of this appendix for rationale behind the selected range of values.

3. *SCENARIOS WORKING WITHIN CURRENT DOMINANT ANNUAL ROW CROPPING PARADIGM*

3.1 *Scenario 1: Cover crop and no-till adoption only*

For the lower end of future adoption of cover crop and no-till, we extrapolate from trends in adoption in the USDA's Census of Agriculture from 2012-2022 (with 2012 being the first year that acreage of these practices is reported).

If these linear trends were to continue to 2050, 20% of non-forage cropland will have cover crops and 65% of non-forage cropland will have no-till adoption (Figure 10).

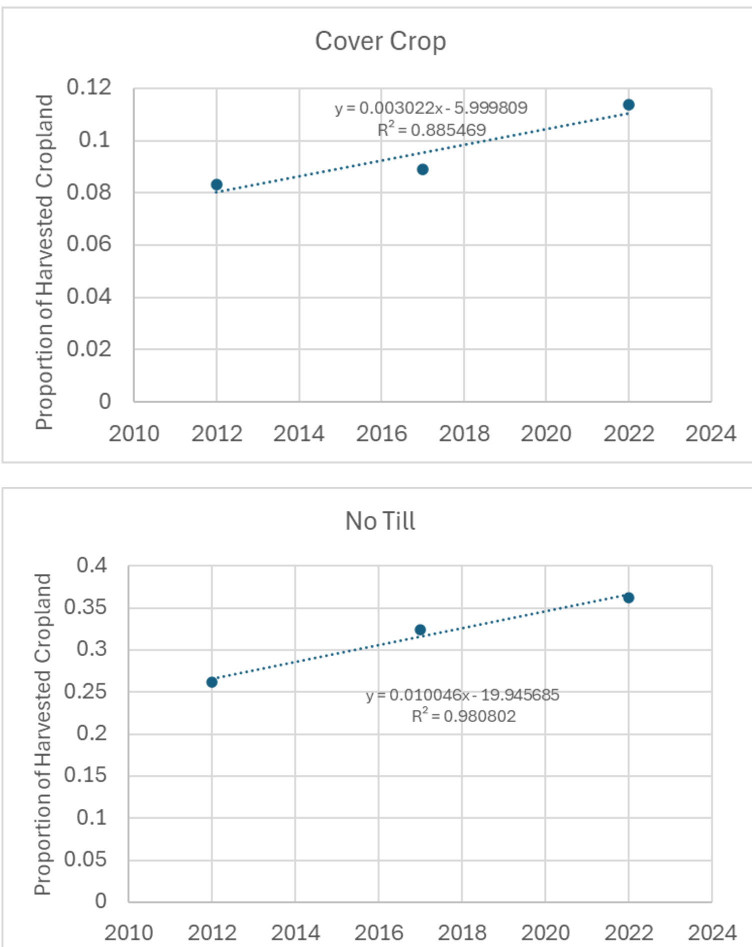

Figure 10. Linear trends in cover crop (top) and no-till (bottom) adoption on harvested cropland in Wisconsin as reported in the USDA Census of Agriculture between 2012 and 2022. Adoption is presented as a proportion of all harvested cropland in Wisconsin.

For the upper end of CC + NT adoption, we assume that all of the non-harvested cropland has cover crop and no-till adopted. This is unlikely to occur, and assumes that sequestration benefits from the two practices are additive when combined which may not be the case. However, this scenario is used to illustrate the maximum soil carbon sequestration potential of CC + NT in the state.

Under the lower adoption scenario, cover crops and no-till can offset up to 1% of current agricultural sector emissions; under 100% adoption, these practices can offset up to 6% of emissions (Fig. 11).

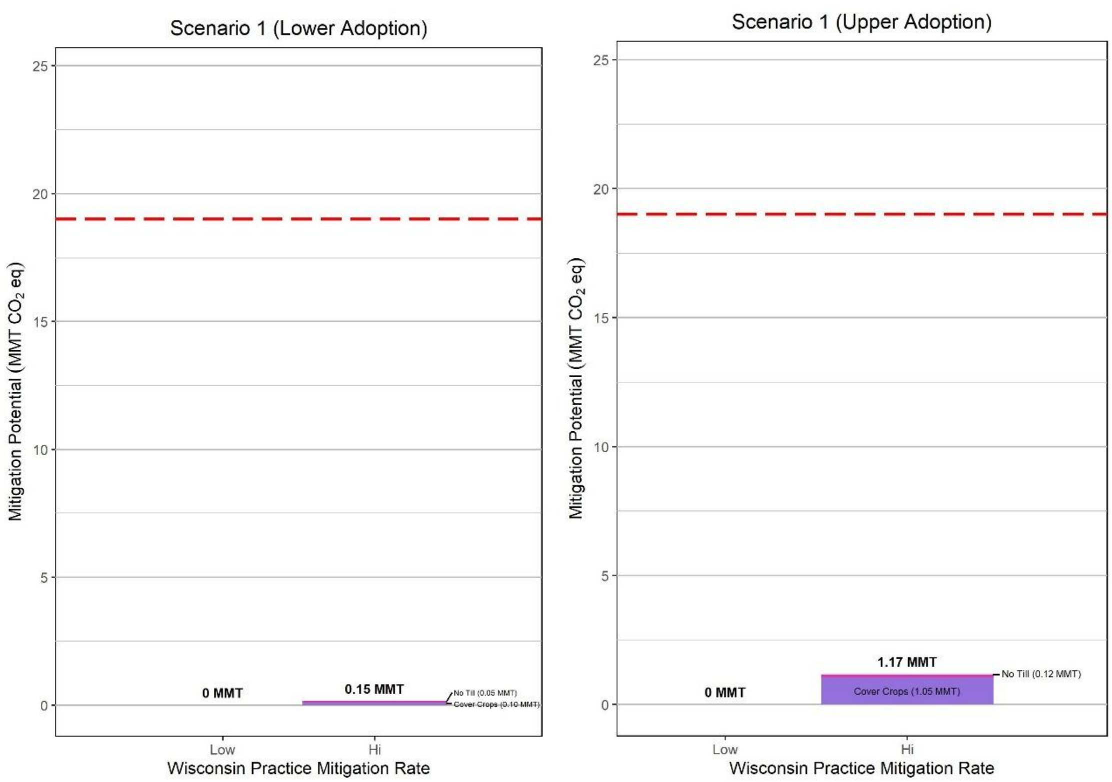

Figure 11. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 1. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

As explained in the methods, we are using lower per-acre soil carbon sequestration rate than other studies and analyses. However, even if we assume higher soil carbon sequestration rates, CC + NT alone is insufficient to offset agricultural sector greenhouse gas emissions. For example, we ran a scenario that assumed no-till can sequester 0.40 Mg CO_2eq $ac^{-1}yr^{-1}$ (from Ogle et al. 2019 values for loamy soils in cool, humid climates and similar to COMET planner estimates) and cover crops sequester 0.49 Mg CO_2eq $ha^{-1}yr^{-1}$ (from the commonly-used Poeplau & Don 2015). In this scenario, cover crops and no-till applied to all available harvested cropland not currently using these practices will sequester enough carbon to offset 23% of agricultural sector emissions.

3.2. Scenario 2: Cover Crop + No Till + Nitrogen Management

For the lower end of nitrogen management, we assume that nitrogen fertilizer use in Wisconsin stabilizes at 2016 levels, the level used by the WDNR inventory we use as a baseline in this analysis. Nitrogen use fluctuates year to year, but has shown a generally increasing trend since 1990 (Fig. 12). Thus, a lower end scenario of not increasing nitrogen fertilizer use is a minimal step towards climate-smart agriculture in Wisconsin by avoiding increased GHG emissions from its use by 2050.

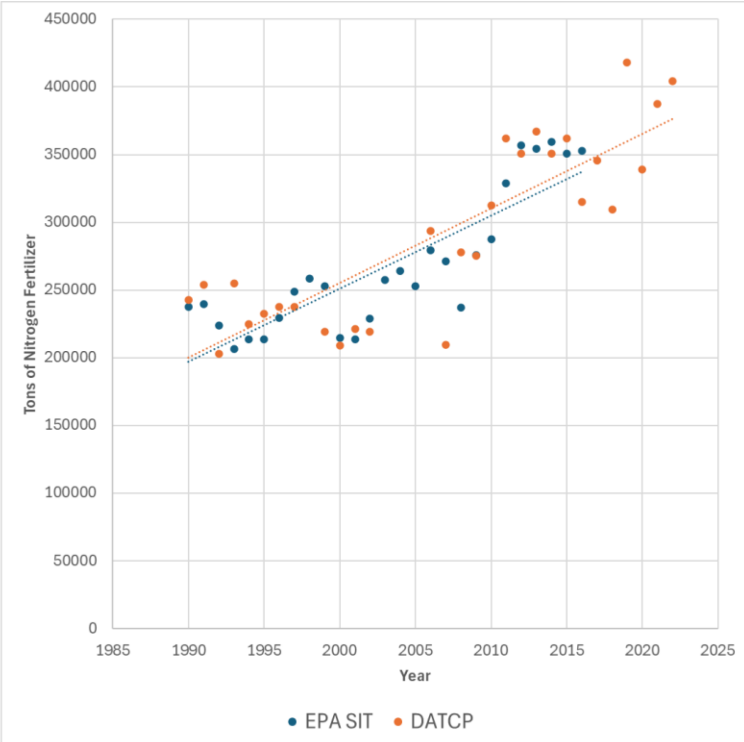

Figure 12. Trends in nitrogen fertilizer use in Wisconsin from two data sources. The EPA state inventory (SIT) tool provides annual estimates of nitrogen fertilizer use in Wisconsin. The DATCP data are annual total nitrogen fertilizer sales in the state. However, not all sales indicate use in the state. Although the DATCP data includes residential use, the vast majority of the use is agricultural.

For the upper end of nitrogen management, we assume a 20% reduction in nitrogen fertilizer use through the four "right" principles for nutrient use: right source, right rate, right time, and right place. Prior analyses in the United States and Canada estimate that these principles can reduce nitrogen fertilizer use by 17 to 22% (Fargione et al. 2018, Drever et al. 2021).

Under the lower adoption rates, CC+NT+Nitrogen Fertilizer management can offset up to 1% of current agricultural sector emissions; under upper adoption rates, these practices can offset up to 9% of emissions (Fig. 13).

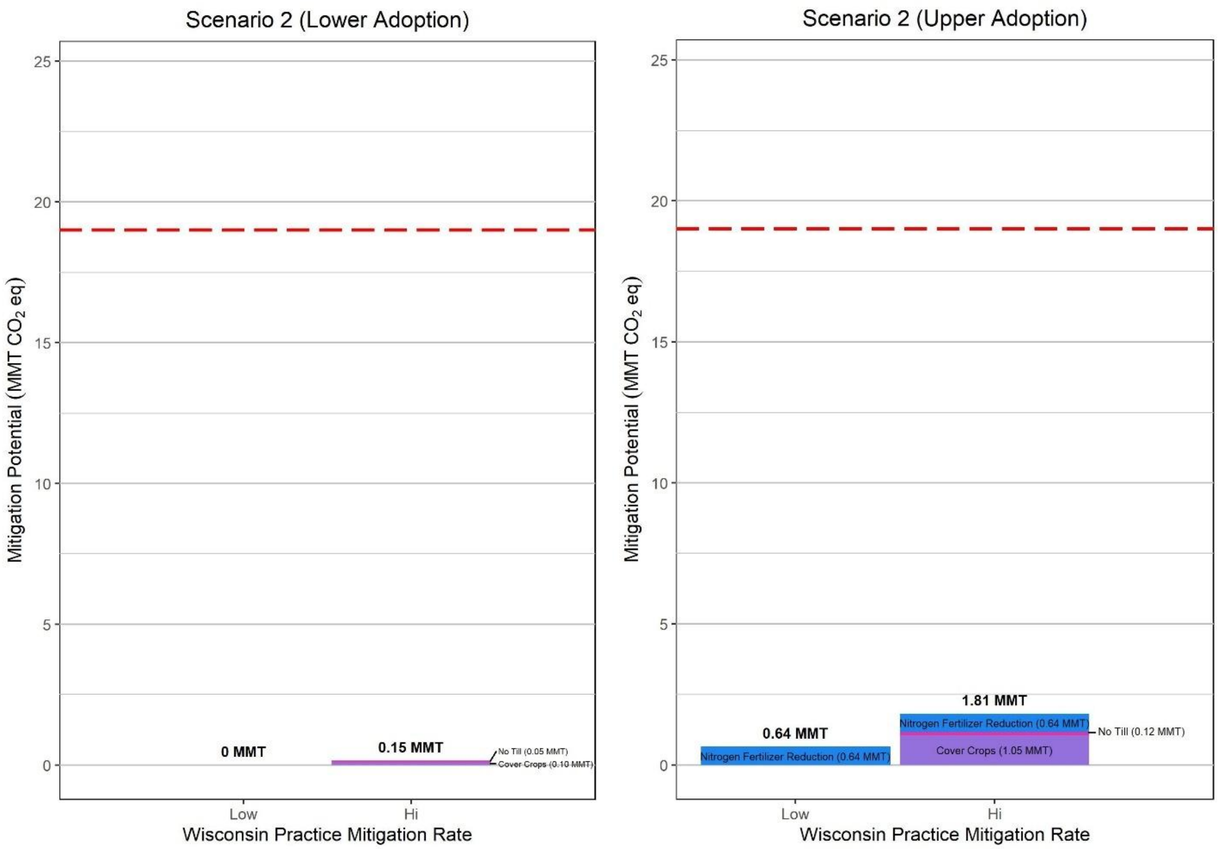

Figure 13. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 2**.** In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

3.3. Scenario 3: Cover crop + no-till + nitrogen management + manure management

We developed three dairy cow manure management scenarios that could reduce greenhouse gas emissions (Table 4). We focus only on dairy cows because dairy emissions account for 96% of the state's total livestock manure storage emissions, and 75% of emissions from livestock manure applied to soils in the state. We note that additional manure management greenhouse gas reductions could be seen by addressing manure in other types of livestock in the state.

First, we assumed that all manure currently managed with anaerobic lagoons is first processed with solid-liquid separation. The amount of volatile solids that are removed :depends on the type of separation system used, but here we assume 40% removal (Aguirre-Villegas et al. 2019). To model this within the EPA SIT framework, we re-assign 40% of the volatile solids currently assigned to anaerobic lagoons to solid storage.

For our second manure scenario, we assumed that all manure currently managed with anaerobic lagoons is covered and flared. To model the GHG emission reductions from covering and flaring, we use data from Wrightman and Woodbury (2017), who investigated the GHG emission reductions of these systems in New York state, which has a relatively similar climate to Wisconsin. They found that covered lagoons had a methane conversion factor (MCF) of 0.61 and that flares had an annual efficiency of 81% (i.e., 19% of methane generated is still released. The CO_2 created by the flaring is considered neutral in these calculations since it represents the same carbon that the cow ate (Wrightman, pers. comm.). Thus, we assume that covered and flared lagoons had an effective methane conversion factor of 0.12 (0.61 MCF of covered lagoon x 19% of methane not destroyed by flaring), a significant improvement on the assumed MCF of 0.67 for uncovered lagoons.

For our third scenario, we assumed that all farms with more than 1,000 milk cows used anaerobic digesters to handle manure, and that the remaining anaerobic lagoons on smaller farms were covered and flared. Anaerobic lagoons are a costly investment, so we only applied them to larger farms. Milk herd size breakpoints in USDA Census of Agriculture estimates are 500, 1,000, and 2,500 head. Applying digesters to farms between 500 and 1,000 head is likely too economically burdensome, while only applying them to farms with more than 2,500 head underestimates the climate mitigation potential of digesters in a scenario designed to be as optimistic as possible.

To model this, we need to appropriately shift manure currently managed on large farms from existing manure management systems into anaerobic digesters. However, the EPA SIT used by the WDNR in its GHG inventorying does not break down manure management by farm size, and thus this required making some assumptions subject to error.

To illustrate, the EPA SIT assumes that 24% of all dairy cow manure in Wisconsin is handled in anaerobic lagoons. Aguirre-Villegas and Larson (2017), the only source reporting manure management by farm size in Wisconsin that we are aware of, report that 80% of dairy farms with over 1000 animal units (more than 700 cows) use liquid manure management, which creates a conflict when attempting to apportion manure in this scenario.

According to the USDA Census of Agriculture, 36% of dairy cows in Wisconsin are on farms with 1,000 or more animals. If 80% of this manure is handled by anaerobic lagoons per the estimate from Aguirre-Villegas and Larson, this would mean that at a minimum 29% of manure in the state would be managed by lagoons. This already exceeds the dairy cow manure assigned to lagoons in the EPA SIT, before even accounting for any use of lagoons by smaller farms.

To overcome this discrepancy, we made the following assumption to work within the framework of the SIT. We assumed that 95% of the dairy cow volatile solids assigned to anaerobic lagoons and 100% of the volatile solids assigned to anaerobic digesters comes from farms with 1,000 head. Further, we assumed that the remainder of volatile solids from farms with over 1,000 head are currently assigned to deep pit management in the SIT (i.e. large farms only use digesters, lagoons, and deep pits for manure management).

Table 4. Summary of manure management scenarios that could reduce greenhouse gas emissions, along with avoided emissions.

Manure Management System	Percent of dairy cow volatile solids managed			
	Current	Manure Management Scenario 1: Solid Liquid Separation	Manure Management Scenario 2: Cover and Flare	Manure management Scenario 3: Anaerobic Digester Adoption and Flaring
Anaerobic Digester	5.9%	5.9%	5.9%	36.2%
Anaerobic Lagoon	23.7%	14.2%	0.0%	0.0%
Daily Spread	5.4%	5.4%	5.4%	5.4%
Deep Pit	22.7%	22.7%	22.7%	14.9%
Liquid/Slurry	3.2%	3.2%	3.2%	3.2%
Pasture	14.9%	14.9%	14.9%	14.9%
Solid Storage	24.2%	33.6%	24.2%	24.2%
Cover and Flare	-	0.0%	23.7%	1.2%
State-Weighted MCF	23.02	16.82	9.89	6.20
Reduced Emissions ($MMTCO_2eq$)		0.75	1.86	2.66
% Manure Management Emissions Reduced		15%	37%	53%
% Ag Sector Emissions Reduced		4%	9%	13%

There are some important limitations of this manure management analysis that can hopefully be addressed in future efforts. These limitations include:

- This analysis would be improved with a better understanding of manure management strategies in the state, broken down by farm size.
- This analysis does not include the effect of management shift on heifer manure, which is calculated separately from milk cow manure in the SIT. If farms manage milk cow and heifer manure concurrently with the same systems, this should be reflected in the emissions inventory. Currently, the EPA SIT assumes that all heifer manure in Wisconsin is managed as a dry lot, to which an MCF of 1% is applied, providing no room for improvement from a climate perspective.
- This analysis does not include the potential benefit of solid liquid separation on the back end of digesters. The MCF for anaerobic digesters includes both leakage and emissions from the storage of digestate. We are not aware of any MCF estimates that include SLS of the digestate. However, the benefit of this practice has been quantified in a different modeling framework (Aguirre-Villegas et al. 2019).

- This analysis does not include any changes in N_2O emissions due to the digestion process in anaerobic digesters. This is not currently included in IPCC recommended methods.
- This analysis does not include the climate benefits of electricity generated from anaerobic digesters displacing fossil fuel-generated electricity. On-farm electricity use is considered in a different module of the EPA SIT.
- The EPA SIT used by the WDNR in its GHG inventorying uses the 100-year methane global warming potential (GWP) of 25 rather than the 20-year GWP of 84. To maintain consistency with the WDNR inventory, which we are using for our baseline emissions, we also use the 100-year GWP. However, using the 20-year GWP would both increase the baseline agricultural sector emissions but also magnify the climate benefit of improved manure management.

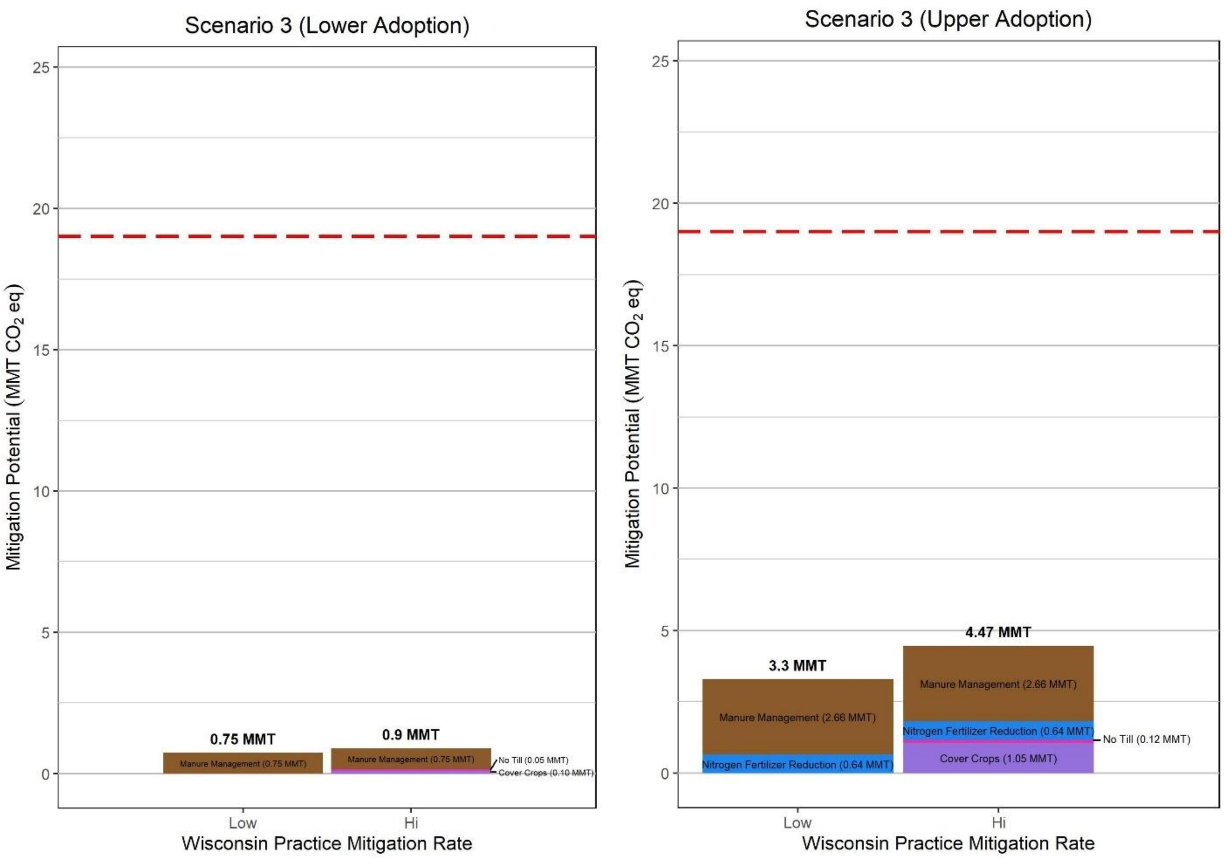

Figure 14. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 3. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

3.4. *Scenario 4: Cover crop + no-till + nitrogen management + biochar + manure management + biochar amendment + grazing management*

This scenario represents the greatest possible GHG offsets from adoption of practices within the current dominant paradigm of annual row crops and confined milk production.

For the lower and upper potentials of the biochar amendment scenarios, we use the lower and upper estimate of logging residue woody biomass available as biochar feedstock, respectively (see methods). We assume that 60% of current pasture in Wisconsin could benefit from improved grazing management (grazing intensity and grazing frequency). For our lower adoption scenario, we assume that 50% of this pasture improves its grazing management. For our upper adoption scenario, we assume that 100% of this pastureland improves its grazing management.

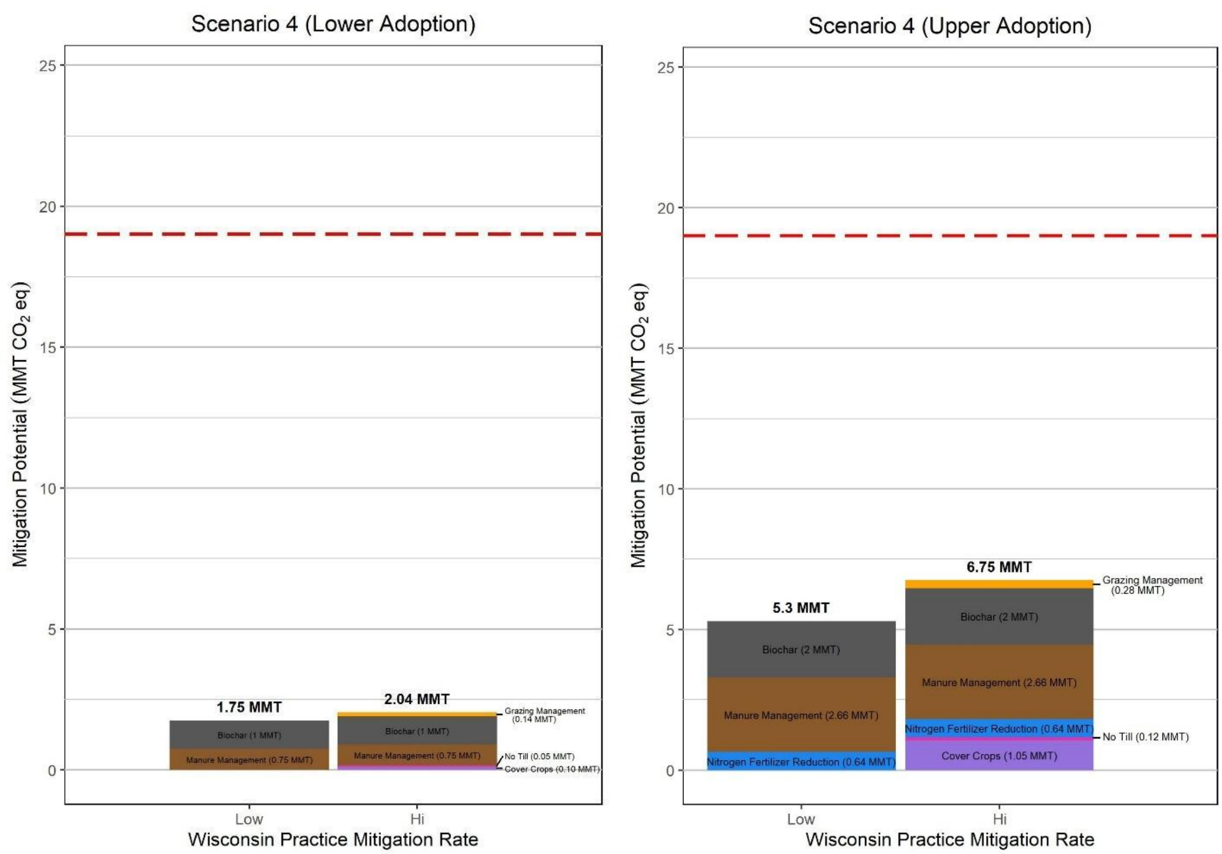

Figure 15. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 4**.** In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

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4. *SCENARIOS INCORPORATING TRANSITION TO PERENNIAL SYSTEMS*

In the following scenarios we model the conversion of annual row crops to herbaceous perennial crops, agroforestry, pastures and solar farms, as well as the introduction of trees into existing pasture for silvopasturing.

4.1 Potential Scope of Row Crop Conversion

The scope of the implementation in this round of scenarios is to avoid impacting any annual crop land needed for livestock feeding in the state. Of all corn grain grown in

Wisconsin, 37% goes to ethanol production, amounting to 1.12 million acres. Another 25% of corn grain is either surplus or exported (Jackson 2024; estimates based on Iowa data). This provides another 743,000 acres of corn not used to feed livestock in the state. Furthermore, 65% of soybeans in Wisconsin are exported (CoolBean 2024), amounting to 1.4 million acres.

All this land provides 3.2 million acres of current soy or corn production that is not used for food or feeding livestock in the state.

The one exception is that when modeling conversion to pasture needed to support a transition from confined to grassfed dairy production, we do take into account the cropland currently used to feed confined cows (see methods).

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. A digitization of state land cover in the mid-1800s from these records was obtained from the Wisconsin Department of Natural Resources (WDNR 2025). Of all the current cropland, approximately 20% had historically been prairie with no trees. Thus, total cropland-to-agroforestry conversion could not exceed 7 million acres. Of all the current pasture, 14% had historically been prairie with no trees. Thus, total pasture-to-silvopasture conversion cannot exceed 963,000 acres

4.2. Scenario 5: Annual Agricultural soils + Perennial system conversion

4.2.1 Conversion of annual crops to grassland in the form of solar farms

Utility-scale solar farms (defined here as greater than 100 MW capacity) in Wisconsin are being developed on former agricultural land and are maintained with perennial vegetation grassland (e.g., side-oats grama, upland bent, little bluestem) underneath and around the panels. Wisconsin needs approximately 200,000 acres of utility scale solar farms to reach carbon-free electricity production targets. For a conservative adoption scenario we assume that half of this target is achieved; for a more aggressive adoption scenario, we assume that the full target is achieved.

4.2.2. Riparian forest buffer establishment

NRCS Standard 391 suggests maximizing widths and lengths of buffers to maximize environmental benefits. It lists a minimum width of 35 feet for sediment and organic matter control, carbon storage and wildlife habitat. It recommends expanding width to 50 feet to reduce nutrient, pesticide, and pathogen runoff and to improve edge habitat. Finally, it recommends 100-foot width for interior forest bird habitat and 165 feet for large mammals.

Using the Wiscland data set (30-meter resolution) we calculated the amount of non-forage agricultural land within 30 m (98 feet) and 60 m (197 feet) of perennial water bodies and primary streams. This amounts to 142,645 and 261,350 acres, respectively for potential conversion to riparian buffer.

For the lower end of our full NCS scenario we assume that half of this area within 30 m is converted, to approximate 50-foot forest buffer widths. For the upper end we assume conversion of all current non-forage agricultural land within 60m to riparian forest buffer.

4.2.3 Windbreak Establishment

For the lower end we follow the approach of Fargione et al. (2018) to calculate the windbreak opportunity area as being 5% of wind-erosion prone acres in the state, which amounts to 77,000 acres (0.88% of current cropland). For the upper end, we assume that benefits of windbreaks go beyond erosion control to include increased crop production and homestead sheltering. Following Ballesteros-Possu et al. (2017), we assume windbreaks are established on 5% of cropland, with 5% being identified as the threshold for economic advantage of windbreaks.

4.2.4 Silvopasture Adoption

For a lower end, we assume that 10% of existing pasture can be converted to silvopasture, following Udawatta & Jose (2010), as done by Fargionne et al. (2018). For the upper end we assume introduction of trees onto 50% of all current pasture land occurring in historically forested or savanna land.

4.2.5 Conversion of annual crops to herbaceous perennial crops (e.g., Kernza®, alfalfa, switchgrass)

For a lower estimate, we assume that conversion to perennial herbaceous crops will reach the current acreage of an established non-corn or soy crop. The two most prominent non-corn or soy field crops are wheat (240,000 acres) and oats (65,000 acres). We thus assume a lower end of conversion to perennial herbaceous crops to 240,000 acres.

Assuming the upper end conversion for solar farms, riparian buffers and windbreaks, as well as the lower end conversion to perennial herbaceous crops and alley crops, there are still 1.2 million acres of non-feed corn and soy that could be converted. For the upper end of perennial herbaceous crops and alley crops, we apportion the remaining 1.2 million acres equally between the two practices.

4.2.6 Alley crop establishment

For a lower end, we assume that 10% of cropland is converted to alley crops, following Fargione et al. (2018) and Drever et al. (2021). Assuming the upper end conversion for solar farms, riparian buffers and windbreaks, as well as the lower end conversion to perennial herbaceous crops and alley crops, there are still 1.2 million acres of non-feed corn and soy that could be converted. For the upper end of perennial herbaceous crops and alley crops, we apportion the remaining 1.2 million acres equally between the two practices.

This conversion contemplates establishing strips of tree crops (e.g., fruit or nut trees, trees desired for wood) within larger crop fields of annual or perennial herbaceous crops.

Table 5. 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. See Table A.19 for more specific inputs into each scenario

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 rest of 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 needed for 100% carbon free electricity generation in state	200,000	Acreage needed for full implementation of utility scale solar needed 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 rest of 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 crop: 1.8m – 2.7m No-till: 160k – 1m	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 (at 0.2 tons per acre)			

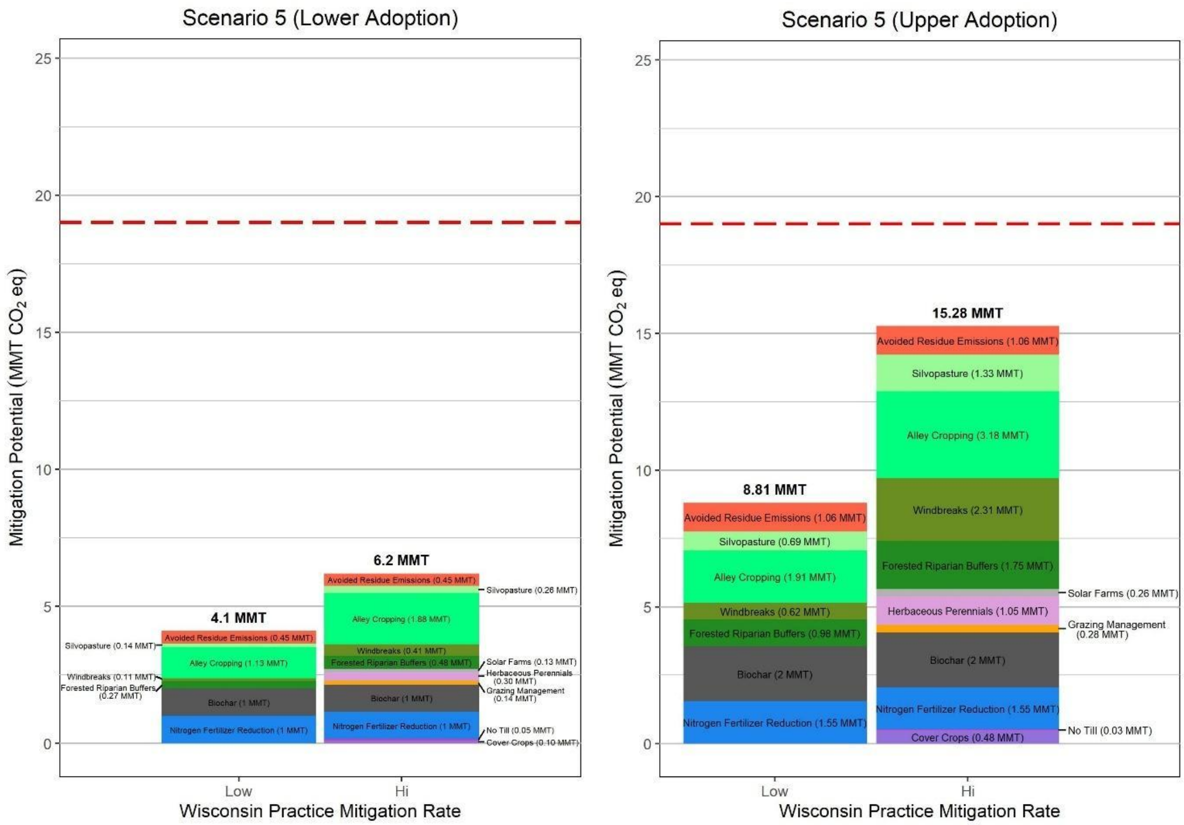

Figure 16. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 5. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

4.2.7 Scenario 6: Annual Agricultural soils + Perennial system conversion + Manure Management

In Scenario 6 we add manure management to Scenario 5, using increased use of solid liquid separation for the lower adoption scenario and replacing anaerobic lagoons with anaerobic digesters on large farms, while covering and flaring the remaining anaerobic lagoons as the upper adoption scenario.

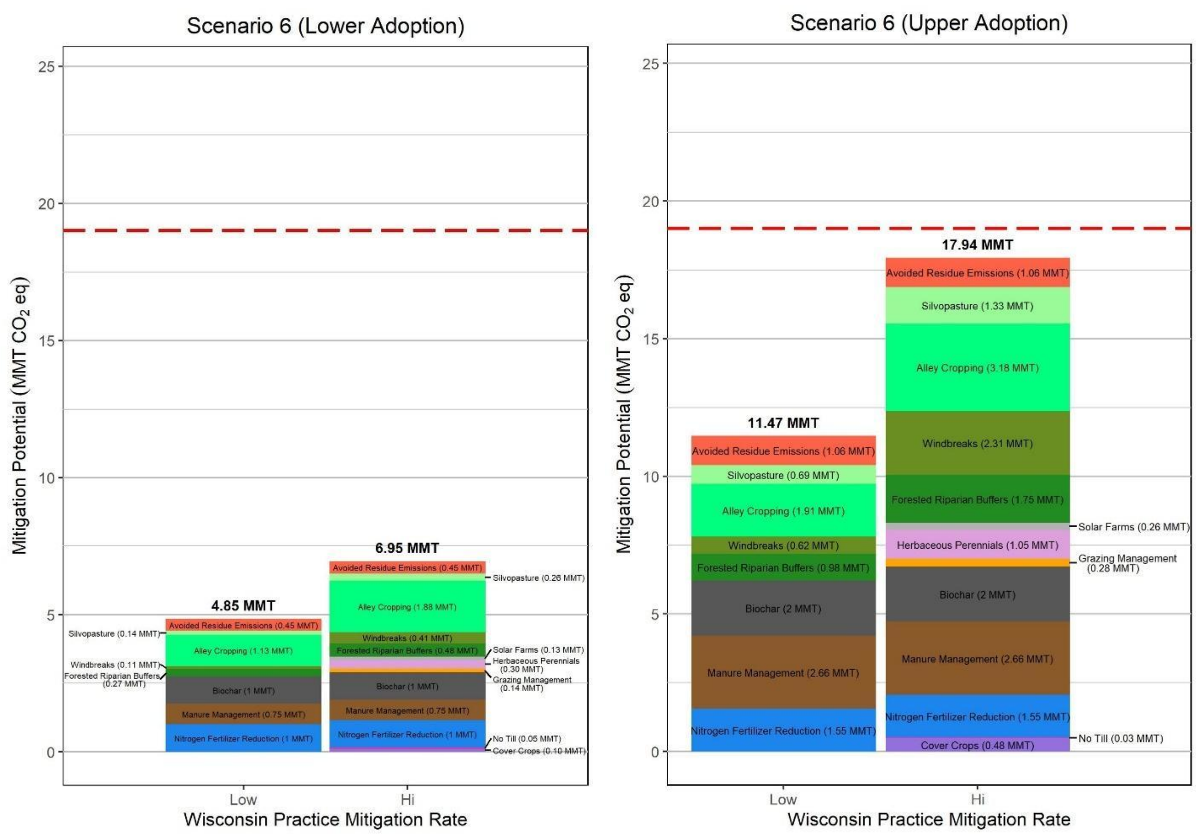

Figure 17. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 6. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

5. *SCENARIOS INCLUDING TRANSITION TO GRASSFED MILK PRODUCTION*

Our first grassfed transition scenario assumed that milk production in the state remained constant, but 25% (lower adoption) to 47% (upper adoption[9]) of the milk production was shifted to 100% grassfed. There is a net increase in cradle-to-farm gate GHG emissions for the milk production when shifting from shifting 25-47% of milk production from confined to

[9] 47% was chosen rather than 50% as it is the amount of production that can be shifted to grassfed on the 1.6 million acres of non-livestock feed corn and soy available after the lower end of our NCS practice adoption.

grassfed (Table 6). However, this is more than offset by potential soil carbon sequestration in land converted to pasture and by avoided nitrogen fertilizer emissions and crop residue emissions on land not currently used for dairy production that is converted to pasture. Assuming no soil carbon storage there is a slight decrease (0.07-0.13 MMT CO_2eq) in GHG emissions associated with this shift; assuming our upper end of soil carbon sequestration, shifting 25% of milk production to grassfed will reduce agricultural sector GHG emissions by 1.18 MMT CO_2eq and shifting 47% of milk production to grassfed will reduce agricultural sector GHG emissions by 2.22 MMT CO_2eq.

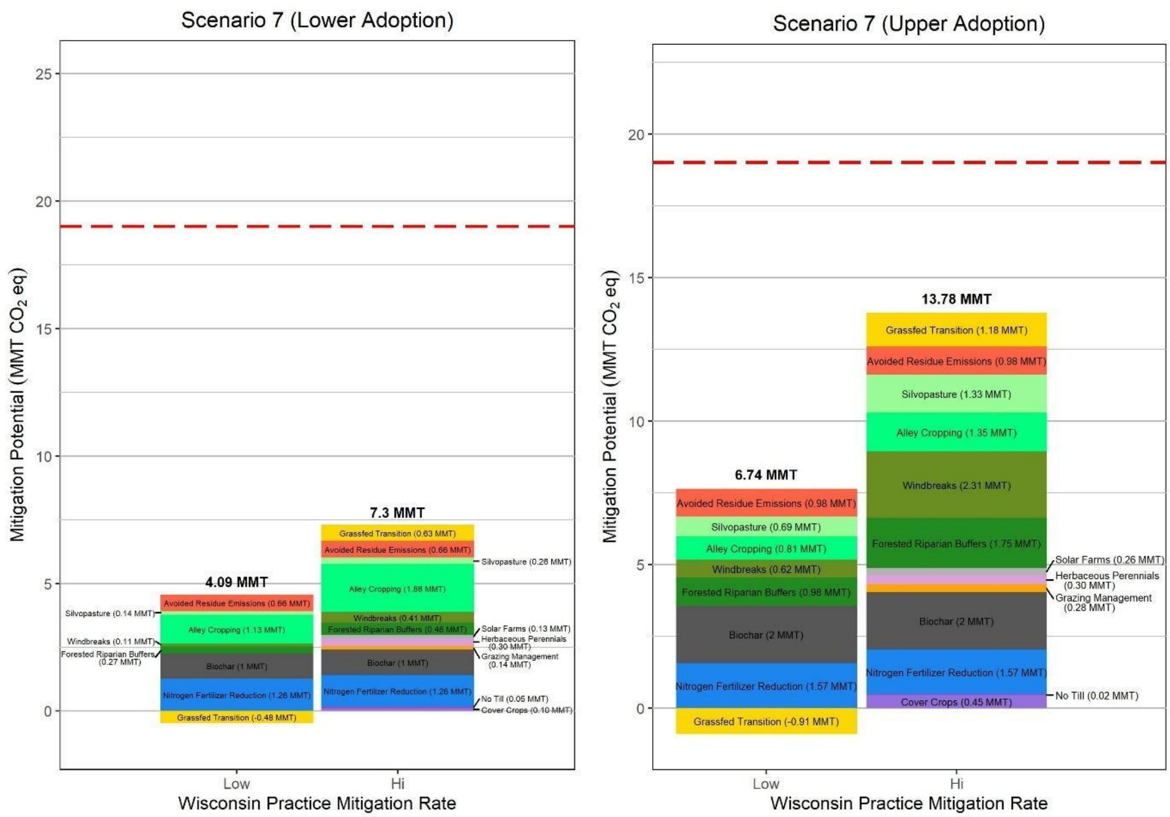

Figure 18. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 7. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

Our second grassfed transition scenario assumed that milk production in the state was limited to milk produced by grassfed cows while maintaining the current milk-cow herd size. The current herd size of 1.27 million milk cows would produce ~8.43 billion kg of milk (a 42% reduction from current production levels). This results in a 5.17 MMT CO_2eq reduction in GHG emissions. This also leads to the conversion of 1.5 million acres of corn and soybean fields to pasture, providing 0 to 2.0 MMT CO_2eq of soil carbon sequestration, as well as 0.59 MMT of avoided GHG emissions from nitrogen fertilizer applications and crop residues on corn/soy land converted to pasture not currently used for dairy production.

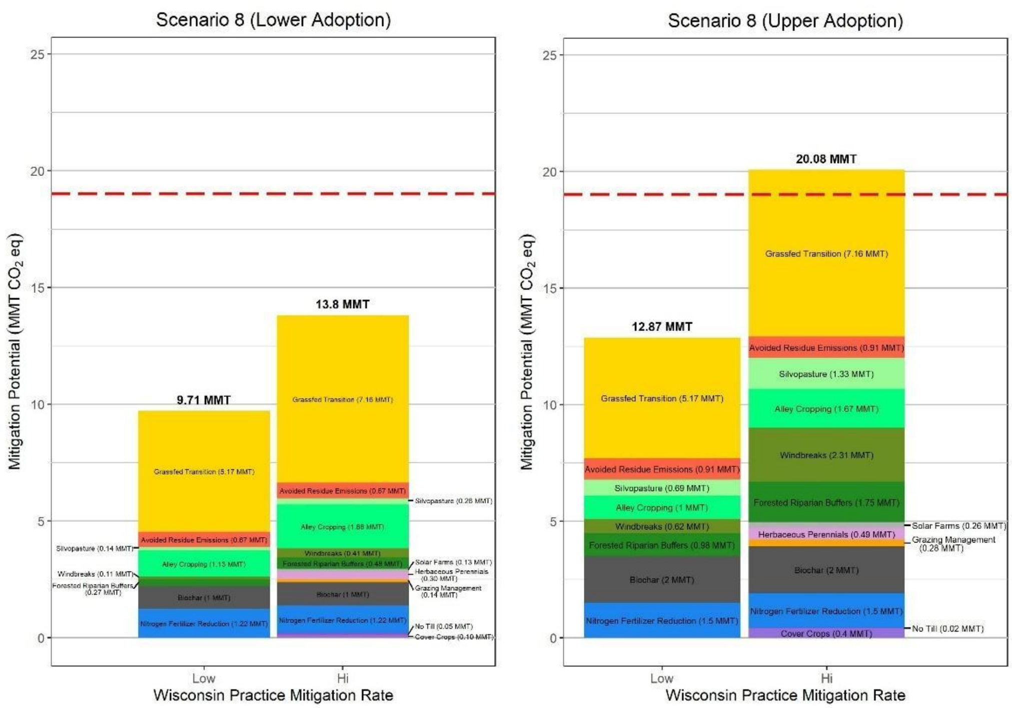

Figure 19. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 8. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

Our final grassfed transition scenario assumed all milk production was limited to milk produced by grassfed cows on the land area currently used for dairy production. The land currently used for dairy production can support 940,000 grassfed milk cows, producing 6.25 billion kg of milk (a 57% reduction from current production levels). This results in a 7.75 MMT CO_2eq reduction in GHG emissions. This also leads to the conversion of 854,000 acres of corn and soybean fields to pasture, providing 0 to 1.0 MMT CO_2eq of soil carbon sequestration.

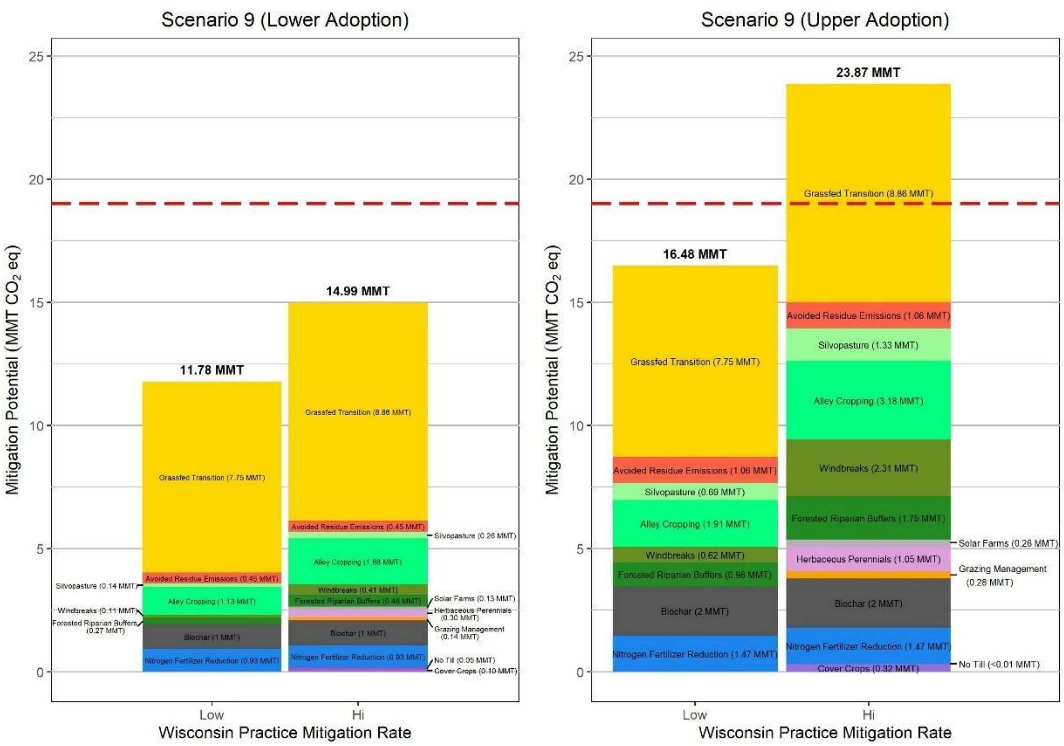

Figure 20. Greenhouse gas mitigation potential under Lower Adoption Rate (left) and Upper Adoption Rate (right) for Scenario 9. In the *Lower Adoption Rate,* estimates assume more conservative increases in practice adoption on Wisconsin farms. The *Upper Adoption Rate* uses an optimal upper estimate 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. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

When incorporating the shift of 47% of milk production to grassfed (Scenario 7) or moving the current milk cow herd to grassfed (Scenario 8) into the existing perennial transition scenario (scenario 5), we reduced the acres of adoption of alley cropping and transition to perennial herbaceous crops to accommodate the land needed for pasture conversion. Conversion to alley crops and perennial herbaceous had the lowest GHG mitigation potential of the conversions we included in this analysis.

Finally, for all scenarios that include a transition to grassfed dairy production, we do not also include improved manure management in the remaining confinement dairies. Thus, additional greenhouse gas reductions could be achieved in these scenarios by improving manure management in the remaining confinement dairies.

Table 6. Changes in milk production, land use, and greenhouse gas emissions under alternative transition-to-grassfed dairy scenarios.

	Shift 25% of milk production to grassfed	**Shift 47% of milk production to grassfed**	**Maintain current herd size**	**Maintain current landbase**
Milk production (Mg/yr)	14,438,230	14,438,230	8,434,070	6,250,061
Change in milk cows (head)	+226,035	+343,668	0	-328,832
Change in milk production (%)	0	0	-42%	-57%
Total corn/soy converted to pasture (acres)	857,873	1,612,799	1,541,317	853,768
Existing dairy corn/soy converted to pasture (acres)	213,443	401,271	853,768	853,768
Other non-feed corn/soy converted to pasture (acres)	644,430	1,211,528	687,549	0
Reduction in cradle-to-farm gate milk production emissions allocated to the agricultural module (MMT CO_2eq per year)[1]	-0.48	-0.91	5.17	7.75
Soil carbon sequestration potential from corn/soy converted to pasture (MMT CO_2eq/yr)	0-1.11	0-2.09	0-2.0	0-1.11
Estimated avoided N fertilizer GHG emissions from non-feed corn/soy converted to pasture (MMT CO_2eq/yr)2	0.34	0.64	0.36	0
Estimated avoided corn/soy residue emissions from non-feed corn/soy converted to pasture (MMT CO_2eq/yr)2	0.21	0.40	0.23	0
Total Ag Sector GHG Offset (MMT CO_2eq/yr)	**0.07-1.18**	**0.13-2.22**	**5.76-7.76**	**7.75-8.86**

[1] Assuming 1.28 kg CO_2eq per kg FPCM produced in confinement and 1.46 kg CO_2eq per kg FPCM produced by 100% grassfed cows (see methods)

[2] Avoided emissions from fields currently used for dairy production already included in the cradle-to-farm gate carbon intensity calculations.

6. *CLOSING THE GAP WHILE MINIMIZING MILK PRODUCTION REDUCTIONS*

In the above scenarios, the only ones that fully offset current agricultural sector emissions are those that involve significant reductions in milk production (Scenarios 8 and 9). Our most optimistic scenario without milk production reductions offsets 94% of greenhouse gas emissions in the agricultural sector (Scenario 6; Fig 9b). To close this gap, we consider two pathways. First, we look at reducing enteric emissions from dairy production through dietary supplements. As noted in the methods, the long-term effectiveness of dietary supplements in reducing enteric emissions is understudied, leading to questions about the longevity of the observed reductions (see methods for more details). However, recent meta-analyses of short-term trials of supplementing diets with 3-NOP report enteric emissions reductions of over 30% (e.g., Kebreab et al. 2023). Using this level of reduction is recommended in the recent USDA "blue book" of GHG accounting (Hanson et al. 2024).

To achieve a 100% offset in GHG emissions from the agricultural sector, it would take a 24% reduction in enteric emissions added to Scenario 6. This is not out of the realm of possibility, although longer-term studies would be needed to evaluate the long-term efficacy of 3-NOP diet supplement on enteric emissions reductions. Another area showing promise for permanent reductions is breeding for lower methane emissions. There is evidence that enteric reductions up to 24% from selective breeding are possible by 2050 (Bell et al. 2010; de Haas et al. 2021) which would also be enough to close the gap to net-zero from Scenario 6.

Second, we look at what level of milk production reduction would be needed in addition to Scenario 6 to reach 100% GHG emissions offset in the agricultural sector. Reduced manure and enteric emissions alone from a 10% reduction in milk production added to Scenario 6 would reach 100% GHG emissions offset.

An estimated 22% of dairy products in the United States are thrown away (Campbell and Feldpausch 2022). Working to reduce this food waste by just half would provide the production reduction needed to reach net-zero GHG emissions in the agricultural sector from reduced manure and enteric emissions alone.

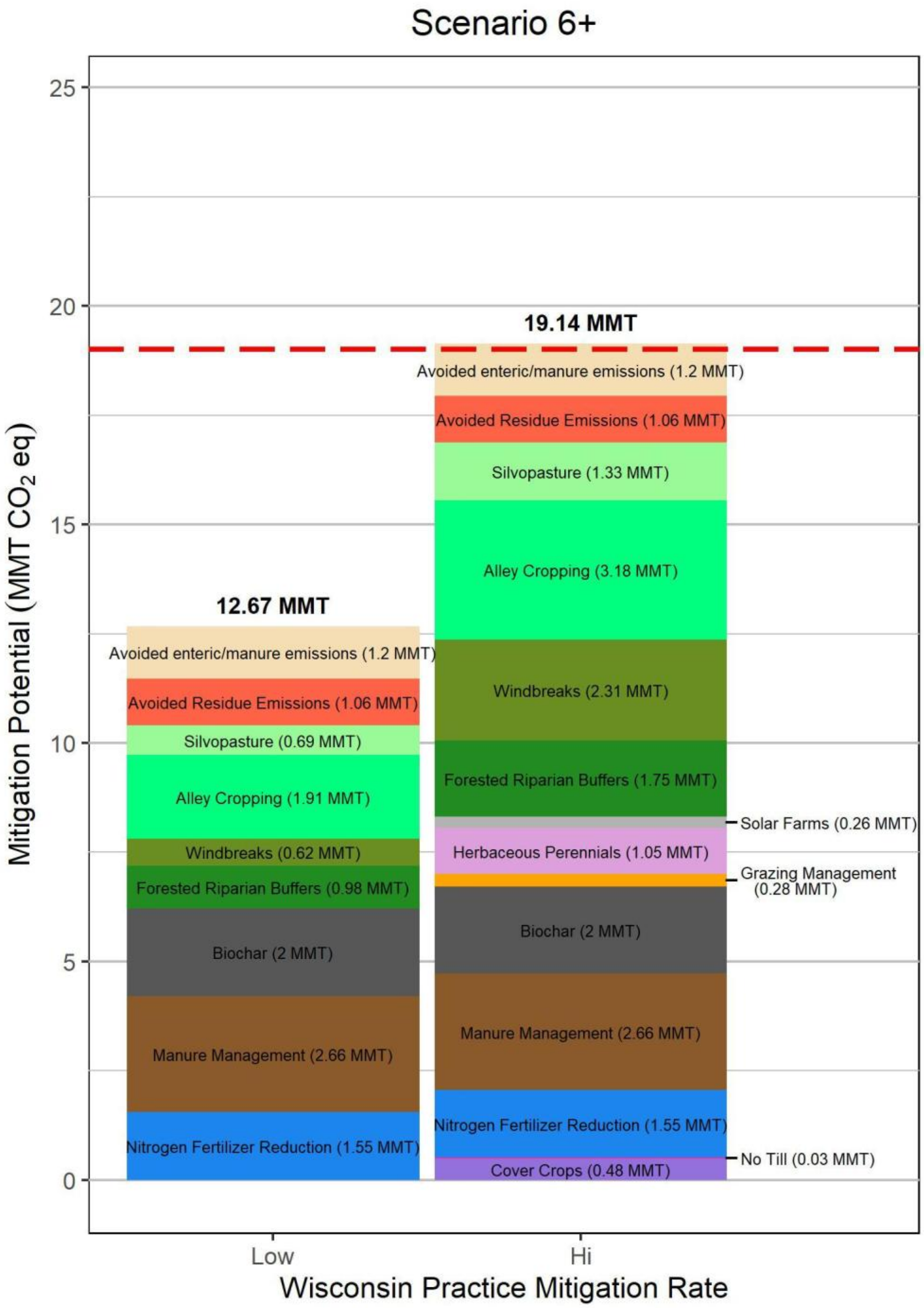

Figure 21. Greenhouse gas mitigation potential under Scenario 6+, where we add to Scenario 6 the avoided manure and enteric emissions reductions from a 10% reduction in milk production in Wisconsin. The horizontal dashed red line indicates the total agricultural sector emissions in the 2021 WDNR GHG Inventory. Each scenario includes an upper (*hi*) and lower (*low*) range of mitigation potential estimates for Wisconsin for each agricultural practice in Wisconsin, as described in the methods, above.

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clean wisconsin

Table A.1 Summary of soil carbon sequestration potential of adopting no-till as reported in published reviews and meta-analyses. If climate was found to be a significant modifying factor in sequestration potential, appropriate values for WI are provided. Uncertainty presented in terms of standard error.

Study	**SOC Potential (Mg C $ac^{-1}yr^{-1}$)**	**CO_2Eq Potential (Mg CO_2eq $ac^{-1}yr^{-1}$)**	**Scope**	**Depth Measured**
Virto et al. 2012	0.09 (0.02)	0.34 (0.09)	Global, Euro and NA Focus	30cm
Liang et al. 2019	Insignificant[1]	--	Eastern Canada, Wet and Cool Climate	60cm
Meurer et al. 2018	Insignificant	--	Global, Boreo-temperate regions	150cm
Ogle et al 2019	0.11 (0.06)	0.40 (0.22)	Global Cool, Moist, and Loamy, Silty, and Clayey soils[2]	30cm
Haddayway et al. 2017	Insignificant	--	Global, Boreo-temperate regions	150cm
Luo et al. 2010	Insignificant	--	Global	60cm, with data down to 140cm
Drever et al. 2021	0.01-0.06	0.03-0.21	Canadian provinces	Not reported
COMET-Planner	0.11(Red Till[a])/ 0.14(Int Till[b])	0.41(Red Till[3]) / 0.52(Int Till[4])	Averaged across WI counties	30cm

[1] - Study covers Eastern and Western Canada; reported Eastern Canada results due to proximity of Eastern Canada to Wisconsin
[2] - Note that the confidence intervals for this estimate include 0.
[3] - Reduced Till: increased carbon sequestered by switching from reduced tillage to no tillage.
[4] - Intensive Till: increased carbon sequestered by switching from intensive tillage to no tillage.

Table A.2. Summary of potential soil organic carbon (SOC) gains from implementation of cover crops as reported in published reviews and meta-analyses of field-based experimental measurements. If climate was found to be a significant modifying factor in sequestration potential, appropriate values for WI are provided in footnote. Uncertainty presented in terms of standard error. We have also included estimates for Wisconsin based on COMET-Planner's process-based modeling of carbon cycling informed by land management, soil properties, and climate conditions.

Study	**SOC Potential (Mg C $ac^{-1}yr^{-1}$)**	**CO_2eq Potential (Mg CO_2eq $ac^{-1}yr^{-1}$)**	**Scope**
McClelland et al. 2021[a]	0.09 (0.004)	0.31 (0.01)	Global, temperate-cool fields
Abdalla et al. 2019	0.22 (0.03)	0.80 (0.13)	Global
Poeplau & Don 2015	0.13 (0.02)	0.47 (0.06)	Global, temperate-biased
Joshi et al. 2023[b]	0.30 (0.03)	1.09 (0.12)	Global, temperate
King & Blesh 2018	0.09 (N/A)	0.31 (N/A)	Global
Jian et al 2020[c]	0.23 (N/A)	0.83 (N/A)	Global
Blanco-Canqui 2022	0.05 (N/A)[e]	0.18 (N/A)	United States
COMET-Planner	0.07 (legumes)/0.04 (non-legumes)	0.25 (legumes)/0.13 (non-legumes)	Average across all WI counties[d]

[a]If subsetting this data to temperate-cool zone, which encompasses WI, SOC potential is 0.08 (±0.01) Mg C ac^{-1} yr^{-1} or 0.30 Mg CO_2eq ac^{-1} yr^{-1} (not statistically significant from no cover crops).
[b]If subsetting to the 27 comparisons looking at 0-60 cm soil depth, the SOC potential is 0.11 (0.05) Mg C ac^{-1} yr^{-1}
[c] This study did find a negative correlation between SOC and latitude, and SOC and annual temperature
[c] For studies that found an increase, the average increase was 0.17 Mg C ac^{-1} yr^{-1}
[d] When looking at south central and southwestern counties specifically, estimated impact of cover crops is larger: 0.34 Mg CO_2e ac^{-1} yr^{-1} for legume cover crops and 0.18 Mg CO_2eq ac^{-1} yr^{-1} for non-legume cover crops

Table A.3. Alley cropping carbon sequestration rates reported in published studies, as well as COMET Planner estimates for Wisconsin

Source	Carbon Sequestration rate (Mg CO_2eq $ac^{-1}yr^{-1}$)	Location of Data	Species Used	Conversion	Tree Density	Stand Age
Feliciano et al	2.36 (1.78 biomass; 0.58 SOC)	Biomass: global value from tropical/arid areas in Africa, Latin America and Asia. SOC: from 3 US/Canada studies	SOC: poplar and Norway Spruce No species details on biomass	Cropland to "agrisilviculture", which includes parkland, intercropping, and taungya	No density info for most studies; mix of "dense"/"sparse" when reported	Biomass: 6-50 years SOC: 6-30 years
Fargione et al.	2.15 (biomass + SOC)	Average of 6 values in published lit: 1 global review, southern France, temperate Europe, 3 Quebec/Ontario, southeastern China	Norway spruce, poplar, red oak, black cherry, white ash, walnut, orchards	Cropland to alley cropping	No density information	Not reported
Drever et al.	1.29 (1.04 biomass; 0.25 SOC)	From literature review of 8 North American studies	Hybrid poplar or "hardwood species"	Cropland to alley cropping	Standardized to 111 trees per ha	Not reported
Cardinael et al.	1.36 (1.09 biomass*; 0.28 SOC)	SOC: based on 16 studies in North America; Biomass: based on 7 studies in North America	No species information presented	Cropland to alley cropping	SOC: based on mean density of 231 trees per ha; Biomass based on mean density of 111 trees per ha	12-100, with most in the 20-40 year range
Udawatta & Jose	5.05 (biomass + SOC)	From 8 study locations in North America: GA, MO, FL, Quebec, Ontario	Mimosa/sorghum/wheat, poplar, spruce, oak, "tree-based conventional systems; pecan	Cropland to alley cropping	Not reported	1-47; average 17
COMET-Planner	1.63			Replacing 20% cropland with hardwood		NA

*If using data from all temperature/cool zones (9 studies), biomass increases to 2.08 Mg CO_2eq $ac^{-1}yr^{-1}$ with density of 271 trees per ha

Table A.4. Windbreak carbon sequestration rates reported in published studies, as well as COMET Planner estimates for Wisconsin						
Source	**Carbon Sequestration rate (Mg CO_2eq $ac^{-1}yr^{-1}$)**	**Location of Data**	**Species Used**	**Conversion**	**Tree Density**	**Stand Age**
Feliciano et al	1.66 (biomass)	Biomass: 1 North American Study	Shelterbelt with Scots pine in prairie	Grassland to boundary planting	Not reported	40 Years
Fargione et al.	5.28 (biomass + SOC)	Average of 4 values in published lit: 3 US studies (Plains states); 1 Canadian study; 1 Chinese study	Green ash, red cedar, caragana, Siberian elm, red mulberry, cotton wood, red cedar-scotch pine, poplar, white spruce	Cropland to windbreak	Not reported	Not reported
Cardinael et al.	2.63 (1.63 biomass; 1.0 SOC)	Biomass: 12 North American studies in temperate/cool climates. SOC: 6 North American studies	Not reported	Cropland to hedgerow	Biomass: 816 trees/ha SOC:546 trees/ha	12-100, with most in the 20-40 year range
Kim et al.	2.08 (1.63 biomass; 0.45 SOC)	2 studies (US, Canada)	Red cedar, Scotch pine	grassland to shelterbelt	Not reported	Not reported
Udawatta & Jose	1.43 (biomass + SOC)	One North American study	Hybrid poplar and white spruce	Cropland to windbreak	40 trees/ha	35
COMET-Planner	2.97-5.94			Replacing strip of cropland with conifer/hardwood		NA

Table A.5. Silvopasture carbon sequestration rates reported in published studies

Source	Carbon Sequestration rate (Mg CO_2eq ac^{-1}yr^{-1})	Location of Data	Species Used	Conversion	Tree Density	Stand Age
Feliciano et al	2.36 (1.78 biomass; 0.58 SOC)	Biomass: 1 US study; SOC 3 US/Canada studies	douglas fir/ryegrass/clover; poplar on grassland	Grassland to silvopasture	Not reported	Biomass; 11 years SOC: 11-18 years
Drever et al.	1.23 (0.94 biomass; 0.30 SOC)	Determined from review of 5 studies from North America	Deciduous trees	Biomass and carbon accumulation following the introduction of trees into existing pasture	Not reported	Not reported
Cardinael et al.	2.06 (1.57 biomass*; 0.28 SOC)	Biomass: 1 NA cool/temperate study; SOC: 6 temperate/cool studies (5 Europe, 1 South America)	Not reported	Grassland to silvopasture	Biomass: 283 trees/ha SOC:546 trees/ha	12-100, with most in the 20-40 year range
Kim et al.	5.64 (2.67 biomass; 2.97 SOC)	13 global studies (1 US study, majority from India)		Grassland to silvopasture	Not reported	5-11 years, when reported
Udawatta & Jose	9.06 (biomass + SOC)	4 US study locations (OR, FL)	Douglas fir/ryegrass/clover; pine/bahia grass	Grassland to silvopasture	Not reported	Not reported

*All cool/temperate regions: 6 studies with average tree density of 312 trees: total biomass 3.4 Mg CO_2eq ac^{-1}yr^{-1}

Table A.6. Riparian Buffer carbon sequestration rates reported in published studies, as well as COMET Planner estimates for Wisconsin

Source	Carbon Sequestration rate (Mg CO_2eq $ac^{-1}yr^{-1}$)	Location of Data	Species Used	Conversion	Tree Density	Stand Age
Feliciano et al	5.24 (5.54 biomass; -0.30 SOC)	Biomass: 1 Canadian study; SOC: global; largely tropical	Biomass: poplar /green ash on prairie SOC: largely eucalyptus/acacia	Biomass: grasslands to woodlots; SOC: Cropland/fallow to woodlot	Biomass: "dense" trees	SOC: Mostly 4-5 years, but one 31 and one 50; Biomass: 40 years
Drever et al.	Biomass: 0.11*stand age (year) +0.30; SOC: 1.33 (Corresponds to 2.68 for a 10 year stand, 3.74 for a 20 year stand)	Biomass: Determined from review of 3 biomass stock studies from North America; SOC: average from 4 studies of SOC accumulation following forest cover restoration in North America	Deciduous trees	Reflective of growth potential in productive riparian sites of southern Ontario	Not reported	Not reported
Kim et al.	1.19 (all biomass)	1 US (IA) location (series of 3 studies)	Poplar/switchgrass	Cropland to riparian buffer	Not reported	Not reported
Udawatta & Jose	3.86 (biomass + SOC)	11 study locations in: IA, NY, SC, Ontario, WA	Poplar/switchgrass, mixed hardwoods in natural riparian systems	Cropland/grassland to riparian buffer	Not reported	Biomass 1-250 years; SOC: 2-60 years
COMET-Planner	5.94-7.42			Replace strip of cropland/grassland with mixed hardwoods		NA

Table A.7. Summary of soil carbon sequestration potential of conversion from annual crops to perennial herbaceous crops as reported in published reviews and meta-analyses.

Source	Soil carbon sequestration (Mg CO_2eq ac^{-1}yr^{-1})	Perennial Crop	Geographic Scope	Soil Depth Sampled
Ledo et al. 2020	0.40	Switchgrass and *Miscanthus*	Global temperate regions, at least 10 years since conversion	50-100 cm
King & Blesh 2018	0.61	Mostly alfalfa, but some legume/grass mixtures	Global, but heavy North America bias (63% of sites included); median time since conversion is 14 years.	20 cm
Angostini et al. 2015	1.69-2.79	Switchgrass, *Miscanthus*	Not reported; generally short-term (<6 years) studies	150 cm
Qin et al. 2016	1.62 (*Miscanthus);* 1.90 (switchgrass)	Switchgrass, *Miscanthus*	Global; North America and Europe bias	100 cm

Table A.8. Summary of direct N_2O emissions factor (N_2O-N emissions from nitrogen fertilizer as a percentage of total N-input) or equations describing N_2O-N emissions as a function of N-input calculated from bottom-up approaches.					
Source	**Global**	**US**	**US Corn**	**US North Central Region**	**Notes**
IPCC 2019	1% (0.2-1.8%)				Synthetic N fertilizer in wet climate: 1.6% (1.3-1.7%)
Grace et al. 2011				1.75%	
Griffis et al. 2013				1.3%	
Hoben et al. 2010				[4.36 + 0.025 N]xN (0.56-0.93% for 50-200 kg N input/ha)	Michigan experimental plots; eqn provides g N_2O-N per ha and requires kg N input per ha.
Shcherbak et al. 2014	[6.49 + 0.0187N]xN (0.74-1.02% for 50-200 kg N input /ha)				Global meta-analysis; this eqn is for upland grain crops; requires kg N input per ha and outputs g N_2O-N per ha.
Gerber et al. 2016	0.77%	0.83%	0.92%		Global meta-analysis; See Table S12 for overall model calculations for different levels of N_2O emissions per N added with 95% CIs.

Table A.9. Summary of top-down estimates of N_2O emissions factors for nitrogen fertilizer reported in published literature

Source	EF	Scope
Mosier et al. 1998	5.5%	Global
Prather et al. 2001	2.6-5.5%	Global
Crutzen et al. 2008	3-5%	Global
Davidson 2009	2.5% for fertilizer N and 2% for manure N.	Global
Griffis et al. 2017	5.3%	US Corn Belt
Thompson et al. 2019	2.3 (±0.6)%	Global

Table A.10. Comparison of N_2O emissions factors from nitrogen fertilizer in the US Environmental Protection Agency's state inventory tool (used in the Wisconsin Department of Natural Resources Greenhouse Gas Inventory report) and factors from the most recent Intergovernmental Panel on Climate Change report		
Parameter	**EPA SIT/WDNR GHG Inventory**	**IPCC 2019 for wet cool climates**
Direct EF (%)	1	1.6
Synthetic N volatilized (%)	10	11
Synthetic N leach/runoff (%)	30	24
Indirect EF (%)	1	1
Leach/Runoff EF (%)	0.75	1.1
Total EF (kg N_2O-N/kg N fert)	1.20	1.86

Table A.11. Methane conversion factors and N_2O emissions factors for various manure management practices from the IPCC and EPA

Manure Management Practice	Methane Conversion Factor (%)	N_2O Emission Factor (%)
Pasture	0.5	0[a]
Daily Spread	0.1 (cool moist climate)-0.5 (temperate moist climate)	0[a]
Solid Storage	2 (cool moist climate)-4 (temperate moist climate)	1
Deep Pit	24.1[b]	0.2
Liquid/Slurry	24.1[b]	0.5
Anaerobic Lagoon	67.5 (uncovered)[b]	0 (uncovered) - 0.0.5 (covered)
Anaerobic Digester	2.9[c] (1-10)[d]	0.06

[a] N_2O emissions associated with pasture-deposited manure and daily spread are accounted for under emissions from managed soils. For the purposes of manure management emissions category, N_2O emissions are considered zero

[b] Calculated for Wisconsin's climate by the EPA using the van't Hoff-Arrehenius equation recommended by the IPCC.

[c] EPA estimate for anaerobic digester systems in Wisconsin

[d] Range of EFs from IPCC.

Table A.12. Estimated percent of manure handled by different practices in 2018 by the EPA, along with each practice's methane conversion factor (MCF). The overall state weighted MCF is calculated by summing the product of each practice's proportion of manure handled by its MCF.		
Manure Management Strategy	**Percent of Manure Handled in WI**	**Methane Conversion Factor (%)**
Pasture	14.9	1
Daily Spread	5.4	0.1
Solid Storage	24.2	2
Liquid/Slurry	3.2	24.1
Deep Pit	22.7	24.1
Anaerobic Lagoon	23.7	67.5
Anaerobic Digester	5.9	2.9

Table A.13. Carbon intensity of grazed vs confined milk production in Wisconsin from Reinemann & Cabrera 2013.		
Greenhouse gas emissions (kg CO_2eq per kg FPCM)	**Grazed**	**Confined**
Enteric emissions	0.37-0.44	0.39
Manure	0.12-0.15	0.18
On-farm energy use	0.04-0.05	0.06
Crops and feeds on-farm	0.03-0.07	0.1
Crops and feeds off-farm, other off-farm inputs	0.03-0.04	0.04
Total	**0.6-0.75**	**0.77**

Table A.14. Carbon intensity of grazed vs confined milk production in Wisconsin from Cabrera & Dutreuil 2014.		
Greenhouse gas emissions (kg CO_2eq per kg FPCM)	**Grazed**	**Confined**
Enteric + barn CH_4	0.34-0.49	0.3
Manure storage	0	0.09
On farm fuel combustion	0.019-0.028	0.023
Feed production (includes emissions from field applied manure)	0.13-0.14	0.08
Secondary sources (manufacture of fuel, machinery, fertilizers, pesticides, etc.)	0.04-0.06	0.1
Total	**0.48-0.7**	**0.58**

Table A.15. Carbon intensity of grazed vs confined milk production in Wisconsin from Dutreuil et al. 2014.		
GHG Emissions (kg CO_2eq per kg ECM)	**Grazed**	**Confined**
Enteric + barn CH_4	0.45-0.68	0.45
Manure storage	0-0.05	0.132
On farm fuel combustion	0.02-0.04	0.035
Feed production	0.12-0.18	0.114
Secondary sources	0.08-0.16	0.149
Net biogenic (includes soil carbon sequestration)	(0.28)-(0.31)	(0.3)
Total, not including biogenic	**0.76-1.01**	**0.88**

Table A.16. Carbon intensity of grazed vs confined milk production in Wisconsin from Aguirre-Villegas et al. 2017		
GHG Emissions (kg CO_2eq per kg FPCM)	**Grazed**	**Confined**
Enteric CH_4	0.47-0.51	0.49
Manure (barn + storage)	0.08-0.09	0.1
On farm energy use	0.18-0.19	0.14
Crop production (incl. land application of manure)	0.06-0.08	0.08
Off-farm emissions	0.05-0.05	0.06
Total	**0.85-0.92**	**0.87**

Table A.17. Carbon intensity of grazed vs confined milk production in Wisconsin from CIAS 2019		
GHG Emissions (kg CO_2eq per kg FPCM)	**Grazed**	**Confined**
Enteric CH_4	0.47-0.51	0.48
Manure (barn + storage)	0.08-0.09	0.23
On farm energy use	0.18-0.2	0.139
Crop production	0.06-0.07	0.078
Off-farm emissions	0.06	0.064
Total	**0.85-0.93**	**0.991**

Table A.18. Carbon intensity of grazed vs confined milk production in Wisconsin from Aguirre-Villegas et al. 2022		
GHG Emissions (kg CO_2eq per kg FPCM)	**Grazed (organic)**	**Confined**
Enteric CH_4	0.66	0.49
Manure CH_4+N_2O	0.23	0.24
Energy	0.17	0.12
Soils N_2O	0.16	0.09
Inputs	0.05	0.04
Total	**1.27**	**0.98**

ROADBLOCKS TO THE ROADMAP:
Barriers to Adoption of Natural Climate Solutions in Wisconsin

Katherine (Kata) Young, *Natural Climate Solutions Manager*
Clean Wisconsin

Introduction

To achieve any of the three identified pathways to net-zero by 2050 in Wisconsin agriculture, widespread adoption of natural climate solutions will be needed. This process will require changes to policies and programs that currently incentivize practices that have negative environmental outcomes. It will require changes to production systems, supply chains, markets and economic structures. To navigate these broad changes and transitions and begin to put into place the systems to support them, we first must understand what the current barriers to widespread adoption of natural climate solutions actually are.

The complexity of agri-food system dynamics in Wisconsin makes it important to understand them from a system-wide perspective. Agri-food systems dynamics shape and influence federal- and state-level agriculture policies and programs. Understanding agri-food system dynamics and the barriers found throughout the system can help identify and design high impact leverage pathways to support adoption of climate-resilient food systems (The Climate Farmers and ReImagined Futures 2024).

In this report, we introduce concepts crucial to understanding systemic barriers in agri-food systems. We then contextualize these systems-level dynamics within Wisconsin, summarizing the key barriers to adoption of perennial systems. Our analysis focuses on barriers to adoption of perennial systems because they have the highest potential for significantly reducing agricultural emissions in Wisconsin *and* will require the greatest land-use change within each of the three pathways to net-zero. Our analysis is informed by the experiences Wisconsin farmers, processors and end-users shared with us during our three two-year pilot projects, which focused on a particular perennial crop (in this case, the dual-use intermediate wheatgrass known as Kernza®) cropping system (agroforestry) or dairy production system (grazed dairy heifers). Our analysis is further informed by discussions with state and regional thought leaders active in the perennial agriculture sector and by published literature and systems-change strategies currently at play within the wider regenerative food system movement—regionally, nationally and globally.

Background: *Systemic Barriers in the Agri-food System*

Understanding agri-food system dynamics can help identify and design high impact leverage pathways to support adoption of climate-resilient food systems

- The Climate Farmers and ReImagined Futures, 2024.

Systemic barriers are *the socio-political contexts, policies and programs embedded within the dominant agriculture production system that incentivize certain practices and pathways to reinforce the* *dominant system, drive norms of accepted practice, and create barriers to opportunities that exist outside dominant norms*.

A plethora of research on global, U.S./national, and regional agri-food systems contextualizes systemic barriers of agri-food systems[1]. Agri-food systems are *highly complex networks* that include all inputs and outputs tied to agricultural and food production and consumption, and shaped within larger economic, social and environmental contexts.

They encompass ***on-farm* production practices, harvest and post-harvest handling** of food and non-food agricultural products (including on-farm aggregation, sorting, pre-cleaning, quality control and storage); ***off-farm* post-harvest handling** (including transport, commercial-scale cleaning, sorting and aggregation, value-added processing, quality control and storage), **marketing and distribution** (including value-added product development, market entry, wholesale and retail distribution, consumer behavior, and disposal); **and the enabling environment** (including policies, infrastructure, and other factors that influence the entire agri-food system, such as regulations, insurance and finance, market access, and research & development).

Each interconnected component of the system is connected via feedback loops and impacted by external drivers, either directly (positively) or indirectly (negatively) correlated **(Figure 1).**

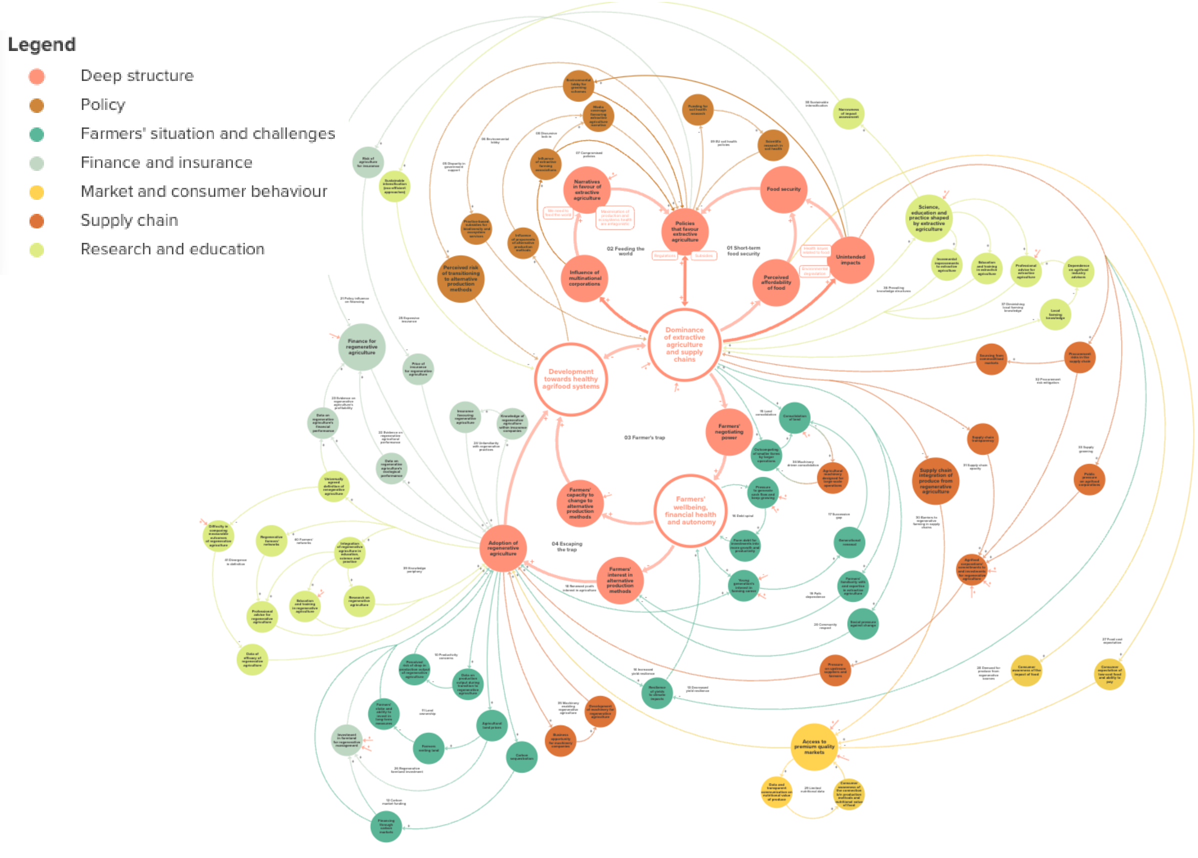

Figure 1: The complexity of agri-food systems, as conceptualized by The Climate Farmers and ReImagined Futures (2024).

[1] *See:* (Global) Swinnen and Barrett 2025; The Climate Farmers and ReImagined Futures 2024; IFPRI 2022; Hebinck et al. 2021; IFPRI 2020; IPES-Food 2016; Allen and Prosperi 2016; Hodbod and Eakin 2015; Ericksen et al. 2012; Ericksen 2008; (U.S./National) National Academies 2015; Nesheim et al. 2015; Reganold et al. 2011; Heller and Keoleian 2003; and (Regional) Magliocca et al. 2025; Wald et al. 2025; Miller 2021; Duerfeldt 2014; Jordan and Warner 2013, among many others.

Systemic frameworks of the food system recognize the importance of social norms in the economy, political environment and broader culture as enabling and constraining factors for farmers and other actors in the food system:

- **Economic structures**— shaped by consumer demand for low-cost food, export-oriented trade policy, subsidies and risk management programs—create incentives for large-scale and capital intensive operations, driving agricultural market consolidation that favors larger firms and limits opportunities for smaller farmers and agricultural and food system businesses.
- **Agricultural policies** are shaped by political, economic and agricultural industry interests, cultural norms, environmental pressures, and consumer demand, driving what agricultural practices are prioritized for public investment in the form of research and development, subsidies, tax incentives, insurance and risk management, and other policy mechanisms.
- **Cultural norms** in rural communities, shaped by public policy and the economy, drive beliefs about 'what good farming looks like', how farms should operate and what is possible, and are socially reinforced within and between farm families and rural communities (*See* Bruce et al. 2025 and Leitschuh 2022).

The difficulty these three systemic forces create for farmers is widely recognized. The current agricultural landscape presents farmers with a complex web of economic, social and environmental challenges that inform their decision-making and ability to adopt alternative agricultural practices, particularly perennial cropping and grazing systems. Federal and state agricultural policies and programs reinforce dominant production practices and guide decision-making at the farm-level that can result in negative societal and environmental outcomes. Social pressures from family or neighbors, rising production costs, limited cost-share opportunities, fluctuating market prices, low profit margins and weak bargaining power against industry consolidation and monopoly, and market competition trap farmers in spirals of debt, undermining their financial stability (The Climate Farmers and ReImagined Futures 2024). A path of dependency or "systemic lock-in", particularly in the dairy industry, makes it exceptionally challenging to break out of the dominant system due to reinforcing feedback loops between science, practice, market monopolies, policy and investments (Lowe et al. 2023).

While the broader systems-level dynamics cannot be ignored, a comprehensive agri-food system analysis falls outside the scope of this project. In our Wisconsin-based analysis, we adapt the USDA food-system framework (Figure 2) to include larger agri-food system components (e.g. the enabling environment) to examine the key barriers along the value chain of perennial crops and systems in Wisconsin. This framework provides a tangible understanding of existing barriers and the levers of opportunity to remove those barriers and scale perennial adoption across the landscape.

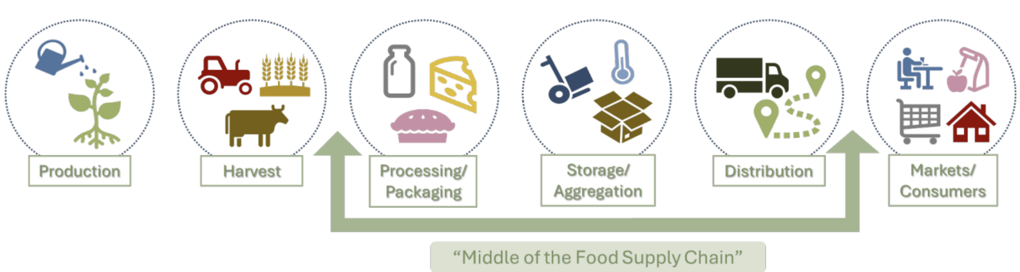

Figure 2: *From* Wisconsin Resilient Food Systems Infrastructure Program (USDA-RFSI 2025).

Foreground: *Key Barriers to Adoption of NCS Practices in Wisconsin*

Increasingly, rural communities in Wisconsin contend with biodiversity loss, soil erosion, and contaminated surface and groundwater largely as a result of intensive agricultural practices (e.g. seasonal tilling, monocropping and herbicide applications, heavy use of fertilizers and pesticides and concentrated animal farming operations)– particularly from grains, oilseeds and manure management (Deller and Hadachek 2022). Rural communities also suffer economically; small farms continue to exit the industry at alarming rates as competition from large-scale, consolidated farming operations overwhelms small- and medium-sized farms' ability to compete– particularly in the dairy industry (Hadachek and Deller 2025, Deller and Hadachek 2024). The average corn/soybean grower in Wisconsin nets a financial loss each year: **-**$140/acre (corn) and **-**$162.50/acre (soy) (Deitmann 2024), relying heavily on government subsidies and subsidized crop insurance. Supply chain concentration enables large-scale processors and aggregators to push down prices for farmers; **less than 16% of every food dollar goes to the farmer** (USDA-ERS 2025c). Equitable access to fresh, healthy, local foods in urban, rural and Tribal communities continues to be a challenge (Pettygrove 2016). Intensive agricultural consolidation, exurban development and food insecurity have stressed the fabric of rural communities.

The existing system isn't sustainable.

Components of agri-food systems:

On-farm **production practices, harvest and post-harvest handling**
Agricultural systems, practices and inputs, harvesting, equipment and infrastructure, aggregation, cleaning, sorting, quality control, storage, waste and disposal, etc.
Off-farm **post-harvest handling, marketing and distribution**
Transport, cleaning, sorting and aggregation, value-added processing, quality control and storage, value-added product development, marketing, wholesale and retail distribution, consumer behavior, waste and disposal, etc.
The enabling environment Factors that influence the entire agri-food system:
Economic structures, capital & finance, policies, regulations, insurance and risk management, social norms, technology and infrastructure, market access, public agricultural research & development, etc.

In the following section (**Tables 1-3**), we summarize the primary barriers to adoption of perennial agri-food systems in Wisconsin and as informed by three two-year pilot projects focused on perennial agricultural systems: **agroforestry**, **managed grazing** and **perennial row crops** (in this case, the dual-use intermediate wheatgrass known as Kernza®). The barriers highlighted in the summary tables reflect common challenges across system types and are viewed to be actionable– they can be tangibly addressed in our state to scale adoption of natural climate solutions. Because agri-food systems are complex and systemic barriers exist at various scales simultaneously, several barriers intentionally appear within multiple tables. Other systemic barriers are intentionally withheld from the table to simplify interpretation and to highlight actionable levers within the state.

Table 1. Summary of key barriers to adoption of NCS practices in Wisconsin: *Farm-operation level*

Systemic Barriers		Description
Establishment and transition costs	Land tenure	• **Rising agricultural land prices** (USDA-NASS 2023, Hadachek and Deller 2025) drive up land rental costs, limiting renters' ability to buy land (USDA-ERS 2025a); **lack of long-term lease opportunities** limit land access and opportunities for adopting perennial crops and grazing systems, and may eliminate eligibility for conservation programs (Lowe et al. 2023, Sawadgo et al. 2020). • If recent trends continue, 515,200 acres (3%) of Wisconsin farmland will be **converted to non-agricultural use** by 2040 as low-density residential, commercial, industrial or moderate-high density residential areas (American Farmland Trust 2022). **Development pressures** and rising land values near urban areas **can abruptly end land access** to tenant farmers, especially for those **farmers marginalized by race, gender or orientation** (Lowe et al. 2023). • **Declining farm numbers**— down by 25% since 2007 and by 50% for dairy farms— and an **aging farmer population**— 34.3% of Wisconsin farmers are aged 60 and older (USDA-NASS, 2024b) underscore the need to **protect existing farmland**, support farm transition planning to the **next generation** of Wisconsin farmers, and **reduce land tenure risks** for all farmers (Hadachek and Deller 2025, Lowe et al. 2023).
	Information, Knowledge and Local communities of practice	• 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. • **Agroeconomic analyses** and **enterprise budget models/tools** are needed to quantify the potential of emerging perennial crops for rural economic development in Wisconsin. • 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 their location and **on-farm profitability comparisons–** to ensure transition planning for perennial enterprises thrive both economically and ecologically (Bennell et al. 2021). • **Field-based training, peer-to-peer knowledge exchanges, demonstration and research farms** are essential for learning new or complex management practices and building support networks (Lowe et al. 2023, NRCS 2023a, Savanna Institute 2023). • **Access to extension** services, strong **farmer-to-farmer network**s, and perceived **environmental benefits** are **key enablers of adoption** (Fudge et al. 2025, Bogado et al. 2024, Lowe et al. 2023) • High demand for **field-based training, peer-to-peer knowledge exchanges, demonstration and research programs** for agroforestry, rotational grazing and perennial grains in Wisconsin (NRCS 2023b, Savanna Institute 2023), but availability is constrained by **funding.**

	Availability of commerciall y viable seed or seedling cultivars	● **Public agricultural research & development** for emerging crops and systems suitable to Wisconsin's changing climate is **significantly underfunded**, resulting in slow emergence of **regionally-adapted perennial crop cultivars** that are both climate resilient and commercially viable. ● **Weak and missing infrastructure**—such as regional propagation centers, seed cleaning infrastructure, commercial tree crop nurseries, seed banks and commercial-scale distribution networks—**compounds delay** in distribution of commercially-viable perennial cultivars and **limits access** for farmers (Midwest Hazelnuts 2025, Savanna Institute 2025). ● Overcoming these challenges will require **targeted investment in regionally-adapted seed and propagation centers**, expanded public agricultural research and development breeding efforts, and better **collaboration between research institutions, agricultural economic areas (AEAs), rural economic development offices and workforce development**.
	Access to capital and financing	● Producers manage a **multiplicity of business relationships and agreements** to produce and market their products, including lenders, government agencies, suppliers, insurance and incentive programs (Bennell et al. 2021). ● Perennial crops and production systems typically have longer **establishment periods** before they yield marketable returns, require **seasonal labor** skilled in perennial system management, and often require **new or modified on-farm equipment and infrastructure**, which are often incompatible with conventional machinery. ● **High costs** of skilled labor, materials for installation, specialized harvesting equipment (e.g. commercial-scale nut and berry harvesters, stripper headers, etc.), post-harvest equipment (e.g. dehuskers, dryers, aerators, ProBoxes, etc.), and on-farm infrastructure (e.g. mobile water lines, electric fencing, season extenders like refrigeration and freezers, food-grade dry storage) **creates financial barriers**, especially for small and mid-sized farms. ● **Traditional agriculture lenders** often rely on established underwriting criteria and collateral models for annual operating loans which differ from cash flow needs and extended returns of perennial crops and systems (e.g. reduced production costs, lower input needs and environmental resilience) (TIFS 2025a); the **misalignment** of traditional lending structures creates barriers for farmers (e.g. cash flow deficits or high interest loans) pursuing transition to perennial crops or grazing systems (World Economic Forum 2024). ● **Publicly subsidized programs** like the NRCS Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) can help with transition costs, but they receive far more applications than can be funded—only 36% of EQIP and 34% of CSP applications from Wisconsin were approved between fiscal years 2018 and 2022; recent and proposed changes to federal budget allocations further limit resource support for farmers, resulting in **misalignment** between need, demand and available assistance (NSAC 2023).

		● **Strict verification requirements** of carbon and ecosystem services markets may be an added obstruction for those seeking an additional revenue stream from the emerging offset market (Bennell et al. 2021).
Risk management	Technical assistance capacity	● **Technical Assistance Providers (TAPs)** play a **crucial role in reducing risk** for producers by assisting them with planning, design, establishment and management practices aimed at improving soil health, water quality, and overall environmental sustainability. ● **Federal budget cuts** to technical assistance services and NRCS programs, like EQIP and CSP, and **insufficient state budget allocations** for Land and Water Conservation Districts (LWCDs), UW Extension programs, and nonprofit organizations reduces state technical capacity (WI Land & Water 2023). ● Remaining TAPs are **oversubscribed and underfunded**, with limited capacity to develop technical knowledge in emerging perennial crops and practices like agroforestry. ● **Expanded technical assistance is needed** to adequately support farmers adopting practices that help to achieve net-zero goals in Wisconsin.
	Subsidies, crop insurance eligibility and disaster payments	● Existing **subsidies** provide financial incentives for intensive systems such as mono-cropping and concentrated animal farming operations. ● Between 1995-20240, Wisconsin farmers received **$13. billion in subsidies**. Of this amount, $7.9 billion (approximately **61%**) were allocated to **commodity programs**, which support crops like corn, soybeans, and dairy. In contrast, conservation programs, such as the Conservation Reserve Program, received about $1.1 billion (approximately 8%) of the total subsidies during the same period (Environmental Working Group 2025). ● **Federal crop insurance** heavily favors major commodity crops and, offering subsidies up to 80%; in contrast, emerging or perennial crops and systems often receive minimal federal support with subsidies as low as 0–20%, leaving small grains, perennial crops and systems with **minimal** and often **expensive coverage** (NSAC 2023, USDA-ERS 2025b; Agroforestry Partners 2024, Asprooth et al. 2024, O'Neill & Kerska 2021, USDA-FSA 2019)**:** ○ The **Whole Farm Revenue Protection** program (WFRP), designed to insure diversified farming operations, faces low adoption rates due to short coverage term, high premium rates, state availability, filing deadlines, complex record-keeping requirements, limited participation of insurance providers. ○ USDA-Risk Management Agency's **Good Farming Practices** rules are restrictive and often prohibit innovative practices that could enhance sustainability and resilience (e.g. interseeding cover crops or integrating trees into pastures, essential components of agroforestry and rotational grazing systems). ○ USDA-Farm Service Agency (FSA)'s **Tree Assistance Program (TAP)** covers eligible trees, shrubs and vines including commercial nursery fruit and nut trees, however adjusted gross income (AGI) and

		indemnity payments place limitations on scale of operations and unlikely to be effective in recovering capital investments and lost production. ○ USDA-FSA **Noninsured Crop Disaster Assistance Program (NAP)** provides risk assistance to producers for non-insurable crops, but with high premiums inaccessible to many producers. ● **Traditional crop insurance** relies on long-term data, such as yield history and risk assessment models, but for newly installed, perennial grains or tree crops that may not produce a marketable yield for 5-8 years after establishment, **restrictive rules discourage adoption of practices that help mitigate flood and wind damage risks** and may have higher tolerance to drought conditions than annual crops. ● **Risks to diversified cropping systems** from climatic variability and pests are **not adequately addressed** by **federal risk mitigation insurance models** leaving many farmers **transitioning to natural climate solutions** without sufficient coverage (Agroforestry Partners 2024, USDA-RMA 2024, Environmental and Energy Study Institute 2022). ● Policy reforms are needed to **expand insurance options** at **affordable premiums,** simplify program access, develop risk models for perennial and diversified cropping systems, and provide **pre-disaster mitigation incentives** for natural climate solutions.
Market access	Business support and marketing	● Supply chain concentration enables large-scale processors and aggregators to push down prices for farmers; **less than 16% of every food dollar goes to the average farmer** (USDA-ERS 2025c). ● Exiting commodity production requires farmers to navigate **new or emerging markets** and market uncertainties, develop new products or supply existing product lines, **optimize operations** and **financial performance** and **to market their products**, either individually or cooperatively. ● **Despite some premiums** for grass-fed products and reduced processing, and transportation and marketing costs achieved by working with co-ops, producers at times still **struggle to cover production costs** (Grassland 2.0 2025). ● **Consumers are often unaware of the nutritional and/or potential health benefits of perennial crops and products**. For example, aronia (*Aronia spp.*) and elderberry (*Sambucus spp.*) are native Wisconsin berries with powerful antioxidant and anti-inflammatory properties (Sharma et al. 2025, Sidor and Gramza-Michalowska 2015)– well-suited to agroforestry systems– but their market presence is inferior to the now ubiquitous “superfood” açai (*Euterpe oleracea*) from Brazil. Kernza only recently received nutritional analysis (Craine and DeHaan 2024), which has the largest market pull for consumers second to price. Marketing has amplified the health benefits of açai and led to its success in U.S. food markets, highlighting a market opportunity for WI aronia and elderberry growers and food businesses to leverage.

		• Farmers need **access to entrepreneurial tools, marketing and business development support** for informed decision-making and effective marketing strategies, to **ensure returns on investment** and commercial viability.
	Equitable and reliable market pathway	• Farmers need a clear, reliable **market pathway** and committed farmgate buyers at **fair, equitable prices.** • Small- or medium-sized processors and intermediary buyers for perennial crops often lack the **capital and infrastructure** to purchase, aggregate and store farmgate products until economies of scale can be achieved for further processing. • Without subsidies to reduce costs of production and on-farm storage infrastructure, and a committed buyer at the farmgate, farmers **risk** spoiled field harvests and milk waste, lost income and debt. • In absence of commercial buyers to purchase at larger volumes, farmers will adjust their scale of production proportionally to costs of labor and market their products locally (e.g. farmers markets or CSA programs). While direct local markets and economies are key to thriving communities and should continue to be supported, **scaling natural climate solutions** to the level needed to achieve net-zero will require diversifying scales of production and processing, so as to expand market options for perennial crops beyond niche small-scale markets. • **Supply and demand** for grassfed milk and meat remain poorly aligned, resulting in **periodic surpluses and shortages** that create **instability for producers and markets**. • **Value chain infrastructure** like storage and **market development** is needed to secure reliable commercial farmgate buyers, ensure farmers earn a **profitable return on investment**, and to **strengthen supply chains** of perennial crops and systems.
	Availability or access to off-farm cleaning and processing facilities	• Emerging crops may require **specialized cleaning or processing lines** (e.g. dehusking, steam-flaking, etc.) that existing local or regional infrastructure may not have or be economically viable to operate at **smaller scales** of processing (MFAI 2025, Savanna Institute 2025). • In the **absence of local processing options**, farmers are forced to ship or transport raw products over long distances, **increasing costs and carbon emissions**, and **removing economic opportunities from local communities** (MFAI 2025). • Organic Valley has a *100% Grass-Fed* line of fluid milk but with just one truck route in the state, producers may have **limited access** unless enough dairy producers in their area are raising grass-fed livestock; smaller family-run farms often direct market grassfed milk or dairy to consumers from their farms or farmers markets (Grassland 2.0 2025, Organic Valley 2025a, Organic Valley 2025b). • Since 2020 there has been an increase in USDA-certified mobile slaughter units in Wisconsin; however, there are currently **(17) mobile meat processors located in (15) counties** (DATCP 2024b), leaving 16 counties with

		significant agricultural focus (AEAs) and livestock graziers without sufficient access to processors certified to process grass-fed meats. ● Investing in **mobile processing** and **geographically-clustered infrastructure** located where producers are can **unlock local markets** for emerging crops, **keep value in local communities**, **reduce overhead costs** that can reduce price to consumer, and **reduce carbon emissions** in transport."

Table 2. Summary of key barriers to adoption of NCS practices in Wisconsin: "*The Missing Middle" of Perennial Food Supply Chains*

Systemic Barriers		Description
Off-farm post-harvest handling & processing	Limited processing and distribution infrastructure for perennial crops	● While **existing state assets provide a foundation** for perennial crops and grassfed milk or meat processing (e.g., cranberry, grapes, apples, cherries and strawberry processing centers; Northland College/UW-Madison Extension nut processing infrastructure; Artisan Grain Collaborative's network of small-grain processors, Organic Valley grassfed dairy, and grass-fed beef cooperatives, etc.), they are limited across the state, reducing access for producers of perennial products (Grassland 2.0 2025, MFAI 2025, Savanna Institute 2025). ● **Underdeveloped processing** (e.g. cleaning, drying, milling, juicing, packaging), **storage** (e.g. food-safe dry storage, refrigeration, freezers) **and distribution infrastructure** (e.g. dedicated transport) for specialty small grains, nuts, berries, and grassfed milk and meat products in Wisconsin **limits entry to critical markets** and **stalls value-chain development** (Grassland 2.0 2025, MFAI 2025, Savanna Institute 2025). ● Significant **infrastructure gaps constrain access** and reduce adoption of perennial practices across Wisconsin's agricultural landscape (MFAI 2025, Savanna Institute 2025)..
	High operating costs for small- and mid-tier processors	● Emerging perennial crops and grassfed products often require **specialized equipment** and **infrastructure,** such as dehusking and cracking equipment for nuts; steam-flaking and color-sorting for small-grains; de-stemmers, juice presses and sterilizing equipment for berries; food-safe dry storage such as ProBoxes, refrigeration and freezers, and refrigerated transport vehicles (Grassland 2.0 2025, MFAI 2025, Savanna Institute 2025).. ● **High equipment costs** put this technology out of reach for small- and medium-scale processors without early-stage processing grants or cost-share support (Grassland 2.0 2025, MFAI 2025, Savanna Institute 2025). ● **Small- and medium-scale processors** cannot match prices set by large facilities operating at 45,000+ lbs, as their **operating costs exceed their processing capacity**, increasing costs to producer and end-user (MFAI 2025)**.**
Markets	Market access	● Outside of commodity systems, markets for nuts, small berries and perennial grains are **underdeveloped** with high entry costs for existing certified-organic and regenerative organically certified (ROC) markets, including certifications, and burdensome verification processes (Bennell et al. 2021).

		• **Absence of consistent grading standards** and **product specifications** for emerging perennial crops (e.g., hazelnuts, elderberries, aronia, Kernza®) disrupts supply chain efficiency, complicates processing, product development, distribution, and logistics planning, and creates uncertainty for buyers, limiting market access (Savanna Institute 2025). • **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.
	Marketing and distribution	• Processing of emerging, perennial crops and products requires post-harvest handlers and food-product businesses to navigate **new or emerging markets** and market uncertainties, develop new products or serve as intermediaries to supply existing product lines, **optimize operations** and **financial performance** and **to market their products** through wholesale or retail distribution, either individually or cooperatively (Savanna Institute 2025, MFAI 2025, Ecotone Analytics et al. 2023). • Food-related entrepreneurs need **access to entrepreneurial tools, marketing and business development support** for informed decision-making and effective marketing strategies, to ensure returns on investment and commercial viability (MFAI 2025, Ecotone Analytics et al. 2023). • **Low consumer awareness** of **nutrient-dense foods** grown in Wisconsin (such as hazelnuts, aronia, elderberry and Kernza®) is a result of under-resourced marketing and an untapped potential (Savanna Institute 2025, MFAI 2025). • **Warehouse infrastructure**, **distribution assets** and **traceability technology** are all currently lacking for perennial product development and urgently needed.
Capital & Finance	Enabling investments	• Many farmers and small businesses **lack the financial resources to meet costly match obligations**, effectively excluding them from critical infrastructure grants needed to build local processing facilities, storage, and distribution networks. • **High barriers to matching funds** slows the development of essential supply chain infrastructure that could create rural jobs tied to emerging perennial crops and grazing systems (Savanna Institute 2025). • While federal programs such as the USDA-Resilient Food Systems Infrastructure Grant ($41 million for food supply chain resilience) and the USDA-Specialty Crop Block Grants (SCBG) ($1.3 million for new and emerging crops) have supported physical infrastructure– particularly

		for tree crops such as chestnuts and berry development– these **federal grant programs are highly competitive** and **overly subscribed**, leaving small and medium-sized food-businesses with few financially viable options to fund early-stage processing (DATCP 2023). ● **Complexity and time demands of grant applications** deter smaller actors from pursuing funding, limiting the diversity and reach of perennial value chain investments (MFAI 2025, Savanna Institute 2025). ● **Lack of early-stage processing subsidies** for capital-intensive investments or **dedicated capital pools** for perennial agriculture infrastructure **delays value chain development**, **hinders grower adoption** by creating uncertainty around market access and long-term viability, and **stalls job creation** in **rural areas** where these facilities could serve as **economic anchors** (MFAI 2025, Savanna Institute 2025). ● Grant **restrictions on soft-cost spending, such as value chain coordination** (e.g. project management, post-harvest technical assistance, relationship and network building, and information-sharing channels) **limits impact** (Savanna Institute 2025, Food Systems Leadership Network, n.d.) ● **Enabling investments are needed** to support processing and storage infrastructure, and supply chain and traceability technology (RFSI 2025, World Economic Forum 2024, Bennell et al. 2021). Without more accessible and flexible funding mechanisms, rural communities struggle to develop the processing capacity and skilled workforce necessary to scale perennial agriculture and drive broader economic growth.

Table 3. Summary of key barriers to adoption of NCS practices in Wisconsin: *State-level enabling conditions*

Systemic Barriers		Description
Research, development and extension	Public agriculture research and development of perennial crops and grassfed livestock	● Emerging crops may require further **crop breeding** to select for improved genetics under **differing climate and soil conditions** that are aligned with production/post-harvest processing needs and consumer tastes, or development of new **propagation** techniques to rapidly expand nursery stock and increase access for farmers (see *Wisconsin Emerging Crops Strategic Plan*, Fischbach and Mirsky 2024). ● **Nutritional analysis** for many perennial crops suitable to Wisconsin is lacking, though such data is a foundational step for advancing emerging crops into mainstream markets and public food systems to **guide public research and breeding investments,** strengthen **market adoption** and consumer confidence, and **advance public health and climate goals**. ● **Applied agro-economic analyses** are urgently needed to develop or refine average yield, production cost, market value, and potential return-on-investment for emerging crops and dairy heifer grazing to help inform farmer adoption decisions and to quantify total economic value potential for the state.
	Technical assistance and extension services	● **Technical Assistance Providers (TAPs)** implement federal, state and local agriculture and conservation programs through state NRCS offices, Land and Water Conservation Departments (LWCDs), university and extension programs (e.g. UW-Extension, UW-Madison's Grassland 2.0, Food Finance Institute, etc.), and civic sector intermediaries (e.g. Savanna Institute, Michael Fields Agricultural Institute, Grassworks Inc., etc.). ● **TAPs** provide **critical training, demonstration, and technical support** for natural climate solutions like agroforestry and rotational grazing; for example: ○ **The Grassland 2.0 Academy** have shown early success in **training-the-trainers** (i.e. LWCD and USDA-NRCS TAPs) in rotational grazing, generating over 130 graduates and 90 new grazing plans in just 2 years. ○ In 2024, **USDA-NRCS partnered with the Savanna Institute** to launch a $1.4 million agroforestry demonstration network to create a support system focused on **peer-to-peer education**, **demonstration**, and **on-farm research** in the state **in response to the high demand** for agroforestry technical services in Wisconsin (NRCS

		2023b; Savanna Institute 2023). • **Demand for assistance far exceeds supply** due to insufficient state budgetary allocations– and subsequent staffing shortages– and recent federal funding cuts to USDA programs, limiting the capacity to support producers and meet statewide conservation and climate goals (WI Land & Water 2025). • **Without consistent state investment** in technical assistance and training programs, these efforts remain **vulnerable to shifting federal priorities** and **short-duration philanthropic grant cycles**. • **Stable state investmen**t is essential to **maintain and expand technical assistance capacity** to help farmers boost productivity, enhance soil and water quality, and achieve long-term ecological and economic resilience(WI Land & Water 2025).
Policies & Programs	Agricultural programs and incentives	• While much **progress to advance water quality and soil health** has been made in Wisconsin through state programs like Soil & Water Resource Management (SWRM) grant program, the Conservation Reserve Enhancement Program (CREP) and the Nitrogen Optimization Pilot Program (NOPP), among others, agricultural policies and state program incentives in Wisconsin **fail to target the practices most effective at reducing GHG emissions for the long-term.** • Public funding for improved agricultural practices are **underfunded and oversubscribed, often duplicating practice incentives and reducing funding for more impactful climate solutions**. • Strategic program and capital coordination is needed to direct financial and human resources into transitioning existing systems for climate resiliency, with expanded **priority, eligibility and funding** for natural climate solutions practices and systems, **simplified application processes and metrics**, **realistic timelines** for perennial establishment and transition. • *See* APPENDIX D_NCS Policy Recommendations
	Risk management, Insurance and	• The USDA-Risk Management Agency has discretion over crop insurance policy offerings, coverage, and administration. **Federal crop insurance** heavily favors major commodity crops,

	Pre-disaster risk mitigation	leaving high-value perennial crops and systems with **minimal and expensive coverage**, complex requirements, and restrictive rules that discourage adoption of sustainable practices like agroforestry and rotational grazing (NSAC 2025, USDA-ERS 2025b; Agroforestry Partners 2024, Asprooth et al. 2024, O'Neill & Kerska 2021, USDA-FSA 2019). ● Commercial insurance rates and forms are not filed within the Wisconsin's Office of the Commissioner of Insurance, so there is **limited state oversigh**t in the types of **multi-state agricultural insurance policies** farmers can choose from. ● The Division of Wisconsin Emergency Management (WEM) provides mitigation, preparedness, response and recovery resources and planning services to municipalities, counties, regional planning commissions, federally-recognized Tribal Nations and non-profit organizations; according to the National Institute of Building Sciences (Multi-Hazard Mitigation Council 2019), **for every $1 spent on mitigation saves an average of $6 in future reduced losses.** ● **Pre-disaster mitigation** in Wisconsin is advanced through WEM's 2021 State Hazard Mitigation Plan, including funding through the Pre-Disaster Flood Resilience grant program. ● Currently there are **no explicit incentives in place** within the pre-disaster program stream for the adoption of agricultural practices that reduce flooding or wind damage risks and contribute meaningfully to climate risk mitigation. ● Policy reforms are needed to **expand insurance options** and **pre-disaster mitigation incentives**, simplify program access, and develop risk models that better support natural climate solutions.
	Rural agro-economic development	● **Rural economic development** programs offered through the Wisconsin Economic Development Corporation (WEDC) have provided crucial training, resources and support for rural communities including entrepreneurship and rural industry, housing, placemaking, broadband, leadership and organizational development, in partnership with USDA-Rural Development, regional economic development directors (REDD), UW-Extension Community Economic Development, UW System for Business and Entrepreneurship, and early-stage venture funds and fund managers. ● **Agricultural economic development** has largely been within the purview of DATCP, with WEDC food-based services focused on cooperative development or export-oriented trade; **growing interest** within the WEDC-**Office for Rural Prosperity** to expand further into **sustainable agriculture**. ● As of 2025, there are 51 **Agricultural Economic Areas (AEAs)** across 31 counties with significant agricultural focus in Wisconsin (DATCP 2025a).

		● **Business capitalization grants** are needed to help rural, perennial agriculture entrepreneurs, cooperatives and established small- and medium-sized businesses invest in **equipment, storage, processing and distribution infrastructure** to help bring perennial crops and grass-fed products from farm gate to retail and consumers (Ecotone Analytics et al. 2023). ● Producers, processors, and buyers often operate independently, lacking a centralized system to coordinate efforts or share information; **value-chain coordination** is needed. ● Limited funding in existing DATCP grants for **essential "soft costs" like facilitation, post-harvest technical assistance, and value chain engagement**, which hampers supply-chain collaboration and economic network development needed for sustainable growth. ● The **long-term sustainability of agriculture** in Wisconsin requires **strategic investments** in **value chains** and **market development** to support grower adoption of perennial systems, infrastructure, and growth of rural workforces and economies.
	Labor and Workforce development	● Wisconsin faces a persistent **workforce shortage**—averaging 93,000 openings monthly since 2021 (Boyce and Deller 2025, Deller and Hadachek 2022). ● In **rural areas** an aging workforce, **mismatched skills** compared to job requirements, challenges such as unreliable transportation, limited childcare and housing constraints disproportionately affect women and lower-income populations contribute to this shortfall (Boyce and Deller 2025). ● **Immigration policies impede consistent labor supply** across all agricultural sectors. ● Lack of skilled workforce in rural areas is **amplified in sectors like perennial agriculture with less infrastructure and training services available**. ● **Workforce Development** generally emphasizes automation, efficiency, robotics, and other broadly applicable agricultural technologies tailored to **commodity crops and confined animal dairy operations** (DWD 2024), but there's a **lack of programming** for management, harvest and post-harvest handling, quality control, specialized processing, product manufacturing or distribution logistics tailored to the needs of perennial crops and products such as nuts, small berries, small grains and grassfed dairy.
	State coordination	● The 2021 Wisconsin Department of Natural Resource (DNR)'s **Greenhouse Gas Inventory** utilizes outdated greenhouse gas emissions data.

		● Governor's Task Force on Climate Change and Office of Sustainability and Clean Energy (OSCE)'s **Priority Climate Action Plan** (OSCE 2022) authorized DATCP to pay farmers for increasing soil carbon through: ○ Producer-Led Watershed Protection Program (PWPP) grants ○ Commercial Nitrogen Optimization Pilot Program (NOPP) ○ Crop insurance premium rebates for planting cover crops ○ Nutrient management farmer education ● Our analyses indicate that **these initiatives alone are insufficient** to reduce Wisconsin's agricultural emissions by 2050. ● While modest inter-agency collaboration exists (e.g. DATCP and WEDC on Beginning, Minority, and Underserved Farmer Assistance Program), WI state agencies and department programs remain **highly siloed**, **missing key opportunities** to streamline and direct targeted, high-impact public investments into natural climate solutions via rural, agro-economic development (DATCP, WEDC), water/conservation protections (DNR), and pre-disaster mitigation programs (WEM).
Capital and finance	Enabling investments	● **Market mechanisms**—*such as product premiums, cost savings, and payments for ecosystem services*: ○ Product premiums exist in Wisconsin for grass-fed meat, poultry and dairy, organic and regenerative-organic certified (ROC) crops, but not guaranteed; timing of the financial benefit may not align to support the immediate transition stage (e.g. agroforestry tree crops)(RFSI 2025). ○ Payments for ecosystem services are **under-developed or not well-established**: ■ V**oluntary Carbon Markets (VCMs)** and **Compliance Carbon Markets (CCMs)** are becoming easier for smaller landowners to participate but are still relatively nascent outside of large landholdings (PDP 2025, UW Extension-Forestry 2025, Gathering Waters 2022). ■ **Biodiversity market**s have been around for decades–particularly for wetlands– but not particularly well-known nor utilized (Sarsfield 2025, Madsen 2024). ■ **Biochar markets** (CDR.FYI 2025) are in their infancy, and not yet available in Wisconsin. ● **Public funding**—*grants, loans, bonds and cost-share programs*: ○ **Misaligned** with the practices that will significantly reduce GHG emissions *and* provide economic gains. ○ Those that include eligibility for new/next generation farmers or perennial crops and grazing systems are **underfunded and oversubscribed**[2]: ■ Beginning, Minority, and Underserved Farmer Assistance:

[2] All FY24 funding/allocation summaries that follow provided by WEDC 2024.

- **No state funding or incentives available**[3]
- Buy Local, Buy Wisconsin Grant Program
  - **$200k funded 5 projects**
- Farm to School and Institutions
  - 26% of 31 applications selected, **$250k funded 8 projects**[4]
- Grow Wisconsin Dairy Processor Grants
  - 42% of 36 applications selected, **$400k funded 15 projects**
- Meat Processor Infrastructure Grant Program
  - 54% of 70 applications selected, **$1.8m funded 38 projects**
- Organic Certification Cost-Share Program
  - 99% of 498 applications received a rebate; **$490k was distributed to 30% of Wisconsin's 1,656 certified organic operations.**
- USDA-Specialty Crop Block Grant
  - No data on % of total applications selected; **$1.2m funded 16 projects**

- Places burden on public tax dollars and is susceptible to changes in the political environment.

- With the **prime interest rate at around 7.5%**, most farmers, new agribusinesses, and small businesses **cannot afford the loans and bonds** available to them:
  - The **Economic Development Conduit Bond Issue Program** was established through Wisconsin State Statute §234.65 *to provide Wisconsin businesses financing that will create and retain jobs in the state of Wisconsin, and promote economic development in both rural and urban communities.*
    - Eligibility includes facilities for the production, packaging, processing, or distribution of raw agricultural commodities.
    - **In fiscal year 2024, no bonds were issued** (WEDC 2024)**.**

  - The **Wisconsin Development Reserve Fund (WDRF) Agribusiness Program** was established through Wisconsin State Statute §234 to provide *loan guarantees to farmers, other agribusinesses and small businesses,* with **variable rate loans not to exceed the prime rate plus 2.75%**.
    - Up to $34.8 million in guarantee authority is available for all WDRF programs, including agribusiness.
    - **In fiscal year 2024, no applications were received nor guarantee payments were processed** (WEDC 2024)**.**

- **Corporate financing**—*industry partnerships that provide premiums or incentives for producers in their supply chain*:

- **Private capital**— *leveraged through direct and indirect investment through funds from investors, institutions, insurance companies and philanthropic organizations:*

[3] FY24, five workshops/outreach events funded by USDA 2501 Grant, and The Wisconsin Beginning Farmer Resource Guide (WEDC, DATCP) funded by USDA-Farm Service Agency (WEDC 2024).

[4] FY24, funded by USDA Specialty Crop Block Grant ($100k) and USDA Farm to School Grant ($400k); Farm to School Program Administration: $90.6k (WEDC 2024).

		● **Public-private investments**– *Nascent.* ○ Wisconsin Investment Fund (est. 2023) leverages *public and private dollars to increase investment in WI 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.** ○ Green Innovation Fund (est. 2023) leverages *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**. ○ Strategic Investment Fund (est. 2024) supports 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 2 projects** (WDEC 2024)**.**

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LEVERS OF OPPORTUNITY:
Scaling Adoption of Natural Climate Solutions in Wisconsin to achieve net-zero goals

Katherine (Kata) Young, *Natural Climate Solutions Manager*
Clean Wisconsin

In this report, we further discuss **rural economic development** and **blended capital and finance** mechanisms to help scale adoption to the level needed to achieve any one of the three pathways to net-zero.

I. Rural Economic Development

Natural climate solutions can help Wisconsin save **$902 million to $3.3 billion annually** in avoided climate damages[1]. Diversification into perennial systems like agroforestry, perennial row crops and grassfed dairy protects water quality, regenerates soil health, mitigates climate risks, reduces statewide greenhouse-gas reductions *and* produces high-value crops and products—providing both ecological and economic value. Perennial agriculture can strengthen Wisconsin's rural communities and economy while advancing net-zero goals.

Food processing activities in Wisconsin contribute $107 billion annually to industrial sales[2], mostly in the form of raw conventionally-grown commodities and cheese (DATCP 2025b). Consumer demand for regenerative agricultural[3] products is at an all-time high, with nearly 75% of U.S. consumers expecting companies to source ingredients sustainably (ADM 2023). U.S. revenue from regenerative agriculture–sourced products is projected to soar from $8.7 billion in 2022 to $32.3 billion by 2032 (ADM 2023). The agricultural food industry is responding to rising consumer demand (Table 1):

Table 1. 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).	

[1] Deller & Hadacheck 2022, Multi-Hazard Mitigation Council 2019.
[2] 'Industrial sales' refers to the business-to-business (B2B) process of selling raw agricultural products, equipment, and/or services to other companies that use them in their own manufacturing or production.
[3] "Regenerative agriculture describes farming and grazing practices that, among other benefits, address climate change by rebuilding soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle" (ADM 2023).

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, highlighting 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).
Tyson Foods	Created the Local Grain Services (LGS) Sustain Program in 2023, a pay-per-practice program that offers producers financial incentives per acre of practice implemented and technical assistance to adopt a closed-set of practices: cover crops, reduced tillage, nutrient management, edge-of-field and un-specified "innovative practices" (Tyson Foods 2025).	Sources livestock from independent Wisconsin farmers, primarily hogs and cattle. In 2021, Tyson Foods closed its prepared food facility in Jefferson (Hauer 2021).
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.	

These corporate initiatives, and many more like them, employ market mechanisms and provide economic incentives for farmers in rural communities to adopt improved agricultural practices, including perennial systems like managed grazing and agroforestry.

Within Wisconsin, larger companies—both family-owned and cooperative—also provide Wisconsin producers with economic incentives for improved agricultural practices. **Meister**

Cheese (Muscoda, WI) offers premium prices for farms that have pasture in their production system as part of their CowsFirst™ program and leverages this program in their contracts with national retail and foodservice companies, including **Chipotle** (Meister Cheese n.d.)**.** Wisconsin's flagship cooperative, **Organic Valley** (La Farge, WI), features a *100% Grass-fed* milk line (Grassmilk®) and requires pasture-based systems for all its standard organic dairy products (Organic Valley 2025a, 2025b).

To advance rural economic 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 or further developing public-private partnerships that support 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 large-scale corporate incentives *alone* will not achieve net-zero goals in Wisconsin**. Small- and medium-sized farms often face significant barriers to market entry, and have fewer options and weak bargaining power in the face of the agricultural industry's consolidated market power (see APPENDIX B: Barriers to Adoption of NCS in Wisconsin). Further, large-scale production favors simplified production systems, which have a negative ecological impact–even if those systems are perennial. Wisconsin needs a diversity of equitable market opportunities to meet the diverse needs of farmers of all scales and to ensure biodiversity is well protected in pursuit of climate goals.

Strategic investment into local and regional perennial value chains can unlock new economic opportunities for rural communities while advancing state net-zero commitments.

High-protein crops like hazelnuts, chestnuts and Kernza®, nutraceuticals like elderberries and aronia, and grassfed dairy offer nutrient-dense, high-value agricultural products that consumers are increasingly demanding. Development of value chain infrastructure presents an opportunity to unlock local, regional, national and international markets through production, processing, product development and branding of climate-resilient food and beverages—both raw and value-added—not yet available on the market (Ecotone Analytics et al. 2023, Global Alliance for the Future of Food 2022).

Regional value chain hubs also provide local and regional farmers with direct-market access to Wisconsin businesses like breweries, distilleries and bakeries. Development of strategically-located tree crop propagation centers, commercial tree crop nurseries, specialized processing and distribution facilities, product manufacturing—when paired with business development support—can stimulate rural job creation in agricultural industries including specialized food processing, product development, logistics and distribution systems. These value-chain hubs keeps food dollars circulating in local communities, which in turn supports other local businesses[4]. Examples of replicable, scalable value-chain hub models already exist in Wisconsin **(Table 2)**:

[4] Wisconsin Food Hub Cooperative 2025.

Table 2. 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. 2013). 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)[5]	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.

Scaling and replicating these and other similar value chain development models across Wisconsin's Agricultural Economic Areas (AEAs) provides the foundation to advance

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

commercialization of emerging perennial crops, provides market access and supports greater adoption of perennial agriculture. Without enabling investments into early-stage supply chain infrastructure, high-value perennial crops risk remaining economically marginal and the natural climate solutions Wisconsin must scale to achieve net-zero emissions in our agricultural sector by 2050 risk remaining fringe practices. By leveraging proven models and aligning rural economic development with ecological outcomes, Wisconsin can support a diversity of emerging market pathways to spur adoption of natural climate solutions and advance net-zero goals.

Value chain development priorities for NCS 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 1** illustrates differing levels of development priority across crops and crop types:

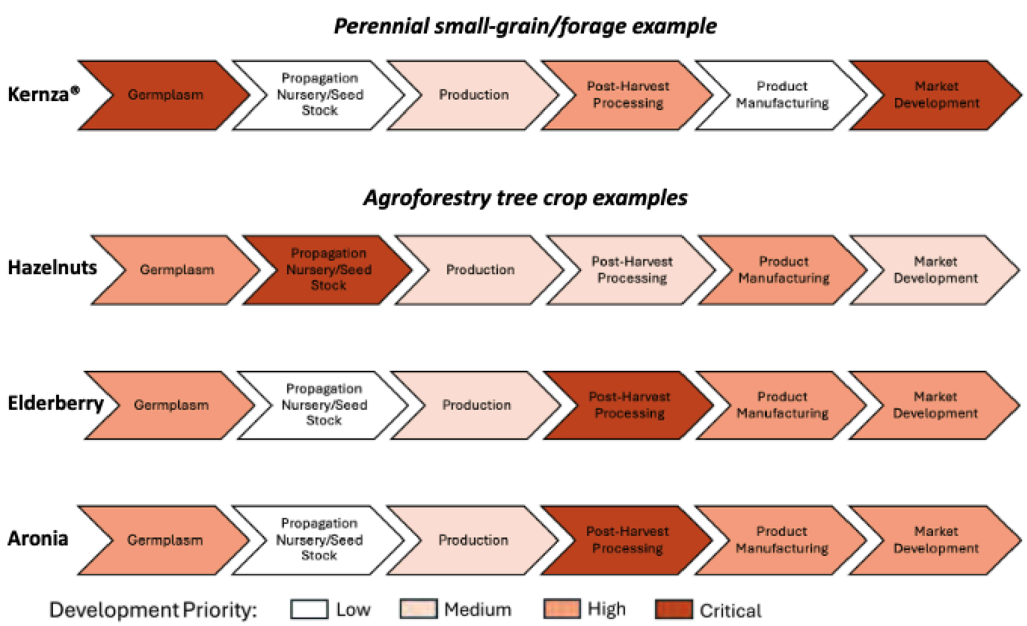

Figure 1. Crop-specific Strategic Development Priorities. *Adapted from:* Fischbach and Mirsky (2024). Development priority levels: *Low* - not a bottleneck; sufficient activity or success; easily overcome with existing tools or knowledge. *Medium* - bottleneck, but manageable: work is underway, solutions 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.

Multiple stages of value-chain development must advance simultaneously and in coordination. For instance, early integration of market development and commercialization with germplasm and propagation is critical to ensure breeding efforts align with consumer demand as well as production, processing and manufacturing needs. Key market activities may also include the sale of seed and nursery stock, investment in harvest and handling infrastructure for new crops, and product development to deliver consumer-ready products (*see* Wisconsin Emerging Crops Strategic Plan (2024) for more crop-specific information). Paired with the *Future Projected Wisconsin Crop Suitability* tool, this information can be used to identify priority crops for development, where those crops are projected to thrive under future climate conditions, and where investment into value-chain development is needed to advance rural economic development goals across the state.

II. Blended finance mechanisms and Public-private partnerships

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 (RFSI), 2025.

Building robust perennial value chains requires coordinated investment all along the value chain. *Enabling investments* can be made anywhere across the value chain and are crucial to support the transition to perennial agriculture practices (RFSI 2025, TIFS 2025). These may include investment into practice transition and establishment, biological inputs (e.g. biochar processing and development), data collection and analysis, measurement and monitoring tools, supply-chain and processing infrastructure, food brands, policy and advocacy efforts, and more. **Figure 2** provides a simplified illustration of the investment opportunities along the value chain:

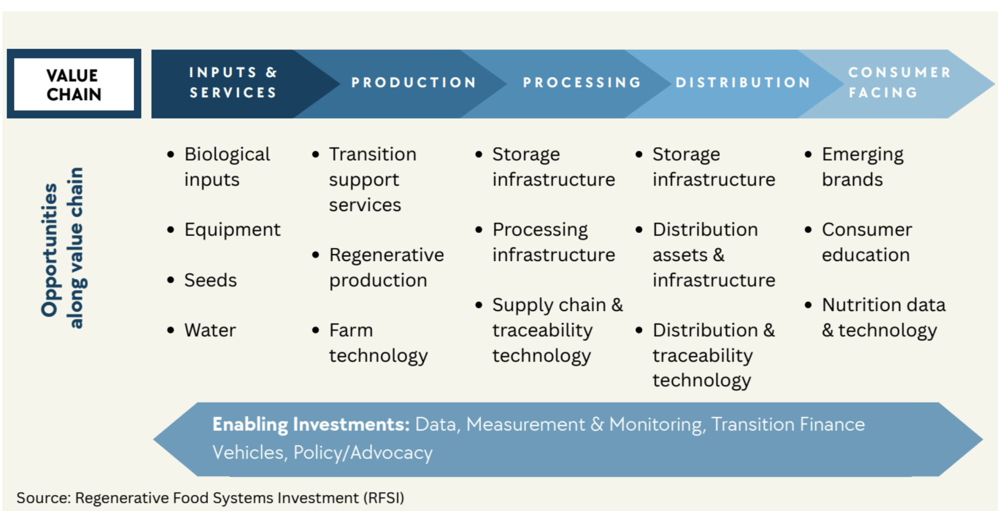

Figure 2. Enabling investments across the value chain. *From* Regenerative Food Systems Investment (RFSI) 2025.

Currently there are four primary sources of capital that fund improved agricultural practices: markets, public funding, corporate financing and private capital.

Market mechanisms (e.g. market premiums or reduced costs as a result of improved practices, and payment-for-ecosystem-services) are still under-developed and often unreliable.

For example, premiums are not guaranteed or the timing of the financial benefit may not align to support the immediate transition– such as in the case of agroforestry tree crops (RFSI 2025). Voluntary carbon markets (VCMs) and Compliance Carbon Markets (CCMs) are becoming easier for smaller landowners to participate (PDP 2025, UW Extension-Forestry 2025, Gathering Waters 2022) but are still relatively nascent outside of large landholdings. Biodiversity markets have been around for decades–particularly for wetlands– but not particularly well-known nor utilized (Sarsfield 2025, Madsen 2024). Biochar markets (CDR.fyi 2025) are in their infancy, and not yet available in Wisconsin.

Public funding (e.g. government subsidies, grants, loans, incentive programs, bonds, etc.) places an extraordinary burden on public tax dollars and is susceptible to changes in the political environment– as we've seen in 2025 with budget cuts to U.S. federal programs.

Corporate financing has the potential to make a significant impact as a result of the scale of corporate supply chains (RFSI 2025). However, mistrust of corporate intentions based on historical farmer experiences, barriers to market entry for small- and medium-sized farm enterprises, and replications of historical incentive models that reward large-scale, simplified agricultural production models are significant challenges to the stand-alone efficacy of this funding mechanism.

Private capital (e.g. direct/indirect financing from banks and lending institutions, insurance companies, investors, asset owners/managers and philanthropic organizations) fills the gaps of conventional public-corporate-market financing structures and is rapidly changing in response to emerging opportunities for financial and impact returns (RFSI 2025, USFRA 2021).

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. However, these primary financing mechanisms remain largely siloed, resulting in capital flows that are slow, fragmented, diluted and uncoordinated—ultimately not reaching the food producers making on-the-ground impact at the speed and scale needed to affect food system transformation (TIFS 2025a, World Economic Forum 2024). This underscores the need and opportunity for policy mechanisms—such as incentives, blended finance structures, and public–private partnerships—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.

Leverage blended finance mechanisms and public-private partnerships:

Blended finance combines different types of capital (e.g., equity, loans, grants, donations) through coordinated public–private partnerships. By pooling resources from multiple sources, it aligns public and private interests while expanding investment opportunities. In the context of perennial agriculture, blended finance can help bridge the gap between producers' needs (longer timelines, delayed returns, multiple co-benefits, and higher uncertainty) and traditional investors' expectations (predictable, annual returns) (RFSI 2025; World Economic Forum 2024, Bennell et al., 2021). These approaches offer additional advantages: integrating technical assistance into investment packages, funding infrastructure alongside operations, lowering interest rates for farmers, structuring loans to match multi-year transitions, and reducing public tax burdens.

Public-private partnerships (PPPs) can combine technical assistance (e.g. public/university partners and civic sector organizations), outcome-based payments (state procurement or pay-for-success), and "patient" capital (e.g. long-term investment capital; flexible, long-horizon funding; growth-oriented investment and early-stage or "catalytic" funding, such as low-interest loans, loan guarantees, and revolving funds) to align private incentives with public environmental outcomes. Wisconsin can develop and leverage a coordinated capital strategy that blends public, philanthropic, and private funds to de-risk investments, pool capital at scale, and deliver shared public benefits (i.e. water quality, soil health, climate stabilization) while enabling private returns and commercial viability of natural climate solutions.

Blended finance and PPP models have been used in other states to mobilize far more private capital than public dollars alone and to translate environmental outcomes into financeable revenue streams—mechanisms Wisconsin can adapt to accelerate perennial systems and the processing/supply-chain needed to scale them (Table 3):

Table 3. Examples of existing public-private partnerships for blended financing

State/Initiative	Description	Reference
Maryland Conservation Finance Act (SB348)	Authorizes novel procurement and contracting approaches that allow agencies to purchase verified environmental outcomes (e.g. soil carbon, water quality) and structure public–private deals to attract private capital to nature-based projects. Creates procurement pathways and legal frameworks to monetize outcomes.	Maryland General Assembly (2022)
Connecticut Connecticut Green Bank	Uses modest public seed capital to leverage multiple times more private capital through loans, loan guarantees, and co-financing. Broadens remit to environmental infrastructure and markets (including agriculture-adjacent outcomes). Converts public dollars into market-rate financing and catalytic credit enhancements.	Connecticut Green Bank (n.d.)
California California Climate Investments	Channels carbon market cap-and-trade revenues into competitive grants and incentive programs for	California Air Resources Board (n.d.)

	sustainable agriculture, processing, and infrastructure. Demonstrates how a large public revenue stream can attract complementary private investment and scale supply chains.	
Minnesota University of Minnesota's Forever Green Initiative	Public research institutions (e.g. University of MN, The Land Institute) plus private sector actors (e.g. Cargill, General Mills, Perennial Promise Growers Cooperative, etc.) partner to advance crop development, demonstration farms, commercialization and early-market aggregation, reducing technical and market risks to attract private buyers and processors. Reduces technical and market risk, enabling private buyers and processors to invest.	University of Minnesota (n.d.)

Farmers should be offered a **flexible portfolio of financial and non-financial support and services** tailored to their context—including favorable loans and insurance policies that reflect the reduced risk exposure for financial actors, and upfront payments or guarantees to reduce early adoption risks—alongside technical assistance, data services, and access to equipment and inputs (World Economic Forum 2024). A central financing strategy for scaling and sustaining regenerative practices is to capture the **full value of the ecosystem services** they provide—from healthier soils, carbon storage, and lower greenhouse gas emissions to reduced water use, improved water quality, greater resilience, and enhanced biodiversity (World Economic Forum 2024). **All who gain from natural climate solutions should contribute to financing its adoption**, including supply chain partners, financial institutions, insurers, and governments. Because farmers need sustained financial and technical support in the early years before environmental outcomes materialize, capital must be pooled from both public and private sources, using tools such as catalytic, concessional, and long-term investments (World Economic Forum 2024).

In Wisconsin, there are nascent opportunities for leveraging PPPs and blended capital to advance natural climate solutions—especially for rural economic development:

- In 2023, the Wisconsin Investment Fund was established *to leverage public and private dollars to increase investment in WI 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.**

- Also in 2023, the state's first Green Innovation Fund was established 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**.

- In 2024, the Strategic Investment Fund was established 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 2 projects** (WDEC 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 1-3** to achieve net-zero emissions in Wisconsin agriculture. Partnerships with public and civic sector organizations providing technical assistance services—such as USDA-NRCS, UW Extension, UW-Madison's Grassland 2.0, the Savanna Institute, Michael Fields Agricultural Institute, and others—can reduce transition, establishment and production risk and ensure knowledge transfer of best practices. This in turn builds private investor confidence for purchase commitments and investments into value-chain infrastructure. Targeted blended capital products, including loan guarantees, subordinated debt, and matching grants, can further lower financing costs for small- and mid-scale processors and shared-ownership models. Together, these strategies can direct funding to scale adoption of natural climate solutions, generating significant ecological, economic, and climate benefits along the way.

Attract impact investors to Wisconsin:

There are additional private investment mechanisms that Wisconsin can leverage to attract new investors into the state– funding mechanisms that are rapidly changing in response to market and environmental signals[6]. Private equity and venture capital—such as "bridge" capital funds, rural business investment companies, community development venture capital, etc.—are positioned to make equity investments in small businesses or rural communities with strong growth potential and can be targeted to support economic development of perennial agriculture systems and value chains in underinvested communities (USFRA 2021).[7] Creating and marketing attractive impact investment portfolios is the first step to attracting impact investors to Wisconsin. These additional funders can help refill existing funds (e.g. Green Innovation Fund) or develop new blended capital pools to target Wisconsin's agricultural transition to a net-zero economy (Table 4).

Table 4. Examples of impact investors financing emerging agriculture transitions in the Midwest (TIFS 2025b, USFRA 2021).

Capital & Networks	Capital Activators & Supply Chain	Impact Investment Managers
Funders for Regenerative Agriculture	TIFS - Transformational Investing in Food Systems	Iroquois Valley Farmland REIT
Perennial Fund	Proofing Station	Farmland LP
Builders Vision	Traction Capital	MAD! Capital
MRAF- Midwest Regenerative Agriculture Fund	Propagate	Potlikker Capital
Compeer Financial	DiversiFund	Trillium Asset Management

[6] *See* USFRA 2021 for detailed summaries on *Transformative Finance* mechanisms (pp. 52-87).

[7] There are many resources to guide public- and private-sectors on best practices for investing in agricultural climate solutions, including investment standards and disclosures (*see* TCFD 2021a, TCFD 2021b, Negra et al. 2019, TCFD 2017, SASB 2015) and frameworks (*see* Global Alliance for the Future of Food 2022, Ceres 2021, Ascui & Cojoianu 2019, Fenichel et al. 2016). These can inform the state's process for attracting, regulating and monitoring private investment commitments to natural climate solutions for Wisconsin agriculture.

Dirt Partners	Blue Highway Growth Capital	Impact Assets
Fractal	2SF - Second Story Farms	Regenerative Agriculture Foundation

Coordinate Capital to Scale Perennial Agriculture and Natural Climate Solutions

Wisconsin can catalyze the deployment of finance into enabling investments across the value-chain to accelerate the transition to natural climate solutions and a net-zero agricultural economy. 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 re-design 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 (Global Alliance for the Future of Food 2022).

- **Unlock co-benefits**: Coordinated investment in perennial agriculture delivers multiple returns—climate mitigation, soil health, water quality, and rural economic resilience (RFSI 2025, Bennell et al. 2021, Ceres 2021, TCFD 2021a, TCFD 2021b, Ascui & Cojoianu 2019, Negra et al. 2019, TCFD 2017, Fenichel et al. 2016, SASB 2015). Prioritize investment packages for agricultural systems that deliver ecosystem services, climate mitigation and adaptation, and long-term economic resilience.

- **Leverage partnerships to support adoption at scale**: Farmers require financing mechanisms that reflect multi-year transitions and evolving risk profiles, rather than short-term repayment expectations. Pair public resources with private capital to lower risk, extend timelines, and enable long-term adoption of perennial systems (RFSI 2025, TIFS 2025, Global Alliance for the Future of Food 2022).

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Policy recommendations to achieve net-zero emissions by 2050 in Wisconsin agricultural sector

Clean Wisconsin and partners have developed a set of cross-cutting policy and program recommendations to support Wisconsin's agriculture industry to achieve net-zero emissions by 2050. Our recommendations are informed by existing federal and state policies and programs, and findings from our two-year pilot projects barriers to expansion of agroforestry, perennial row crops (e.g. the dual-use, intermediate wheatgrass known as Kernza®), and well-managed rotational grazing in Wisconsin. Each policy seeks to remove at least one key barrier to adoption of these Wisconsin agricultural climate solutions, though most support multiple climate solutions.

Below is a summary of each of the **Wisconsin agricultural climate solutions** to achieve net-zero emissions by 2050, the **Policy Pathways** to achieve these goals, and the names/abbreviations of **State and Federal Agency Designations**:

Wisconsin agricultural climate solutions to achieve Net-Zero emissions by 2050

🌱 **Cover Crops & No-till** on 100% of annual row crops	🌳 **Agroforestry** on 2.1-3.2 million acres converted from annual cropland (non-food or livestock feed)
💧 **Nitrogen optimization** (20% reduction of application) on all annual row crops	🌾 **Perennial row crops** on 240,000 to 840,000 acres converted from annual cropland (non-food or livestock feed)
🌋 **Anaerobic digestors** on 100% of livestock facilities with herds >1000 head of dairy cows	🐄 **Managed grazing** on 671,000 acres (existing pasture) to 1.2 million acres (existing *plus* expanded pasture)
🌑 **Biochar soil amendments** applied annually to 100% of cropland	🌞 **Agrivoltaics** on 200,000 acres of grassland converted from annual cropland

Policy Pathways

STATE	🏛️ **Legislative**	*The Wisconsin State Legislature drafts, debates, passes laws; Sent to governor for approval/veto.*
	✍️ **Executive Order**	*The Governor issues executive orders to direct state agencies or respond to emergencies.*
	💲 **Executive Budget**	*The biennial state budget allocates funding and shapes priorities for state programs and services.*
	🏢 **Administrative Rulemaking**	*State agencies (e.g. DATCP, DNR, etc.) develop rules and regulations to implement statutes/laws passed by Legislature, with public input and legislative oversight.*
FEDERAL	⚖️ **Federal-State Partnerships**	*State agencies (e.g. DATCP, DNR, etc.) implement federal programs (e.g. EQIP, CRP) in coordination with federal agencies (e.g. USDA, EPA, etc.).*

State and Federal Agency Designations

Abbreviation	Full Name
State Agencies	
DATCP	Department of Agriculture, Trade & Consumer Protection
DFI	Department of Financial Institutions
DMA-WEM	Dept. of Military Affairs- Div. of Wisconsin Emergency Management
DNR	Department of Natural Resources
DOR	Department of Revenue
DPI	Department of Public Instruction (K-12)
DWD	Department of Workforce Development
LWCD	Wisconsin Land & Water Conservation Departments
OCI	Office of the Commissioner of Insurance
UW-Ext	University of Wisconsin-Extension
WDOA	Department of Administration
WEDC	Wisconsin Economic Development Corporation
WHEDA	Wisconsin Housing and Economic Development Authority
WTCAC	Wisconsin Tribal Conservation Advisory Council
Federal Agencies	
AMS	USDA – Agricultural Marketing Service
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FSA	USDA – Farm Service Agency
NRCS	USDA – Natural Resources Conservation Service
RMA	USDA – Risk Management Agency

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LEVER OF OPPORTUNITY			
Impact Potential	Policy Pathway	POLICY RECOMMENDATION	Near-, Medium- or Long-term Strategy
State collaborations		*Key program components*	Barriers to Adoption Addressed

WRD	USDA – Wisconsin Rural Development State Office
USDA	United States Department of Agriculture

EXPAND TECHNICAL ASSISTANCE CAPACITY			
HIGH	✍️ 💲 🏛️ 🏢 **DATCP, UW**	**Expand technical assistance programs** to build statewide technical capacity for and adoption of the land and crop management practices outlined in the NCS Roadmap.	NEAR
In collaboration with: 🏢 **DNR, DWDUW, WEDC, WTCSB** 🧑‍🌾 **LWCDs, UW-Ext, NGOs** ⚖️ **NRCS, WTCAC**		*Key priorities:* I. Create a **certification program** for **technical assistance providers** on best management practices. II. Create **train-the-trainers** technical assistance **modules** and **enhance technical guidelines** for each of the agricultural climate solutions identified**.** III. **Expand technical support within DNR's** Wisconsin Forest Landowner Grant Program (WFLGP) and Urban Forestry Grant Program IV. **Provide full and continuous funding for Land and Water County Conservation Departments (LWCDs) including supplemental funding to counties** that support a full-time conservation agronomist. V. **Provide full and continuous funding** for **UW-Extension** programs that support adoption of natural climate solutions, such as the Emerging Crops Program, Community Development and others. VI. Develop a **Workforce Development Initiative** specific to perennial crop production and value chain development to fill labor and skill gaps, including training in digital ag tools, post-harvest technology, and specialized equipment operations suitable for perennial cropping systems and grazing operations. VII. **Offer grants or low-interest loans** to support training program participants, farmers transitioning to perennials, and entrepreneurs entering the value chain, with tailored support for women, BIPOC farmers, veterans, and rural youth who may face additional barriers to entry. VIII. Advance the technical capacity of the next generation of Wisconsin farmers through development of **new curriculum, applied research, faculty positions, equipment, and career services,** IX. **Expand 4-H and FFA programming curriculum** to include the crop and land management practices identified in the NCS Roadmap.	Technical capacity Risk Management

ADVANCE RURAL ECONOMIC DEVELOPMENT of NATURAL CLIMATE SOLUTIONS			
HIGH	✍️ 💲 🏛️ 🏢 **WEDC**	**Create** an **Agriculture Innovation & Development Program** within the Office of Rural Prosperity, to support rural economic development of natural climate solutions, including supply chain infrastructure for emerging crops and agrivoltaic installation.	NEAR
	In collaboration with: 🏢**DATCP, DFI, DOR, UW-Ext, WHEDA** ⚖️**WRD, WTCAC**	*Key program components:* I. Pilot a **Developing Markets Program** modeled after Minnesota's Developing Markets Program: A. **Business planning,** rural economic development **grants,** supply chain **infrastructure cost-share program** and **low interest, graduated loans** targeted to support developing new or expanded revenue streams, enterprises, supply chains and markets for perennial agriculture systems, including: 1. Commercial tree crop nurseries and rapid propagation centers 2. Equipment development tailored for small- and medium-scale perennial cropping systems 3. On-farm specialized equipment >$10K 4. Shared-use on-farm equipment including specialized harvesting or post-harvest handling equipment <$10K 5. Shared-use specialty processing equipment and infrastructure, and mobile processing equipment. 6. Shared-use distribution infrastructure and traceability technologies 7. Business support tools for product and market development B. Create a **Tribal-to-non-Tribal market and supply chain development program** in consultation and collaboration with the Wisconsin Tribal Conservation Advisory Council (WTCAC)**.** II. Offer tax rebates, credits, cost-share and low-interest loans for **agrivoltaic installation.** III. Create an **Applied R&D** funding pool to develop NCS technologies such as **precision agriculture equipment** for small- and medium-sized farms, **biochar pyrolysis** units and small-scale **anaerobic digesters**. IV. Prioritize **Agricultural Economic Areas (AEAs), wellhead protection zones** and rural communities with **high populations of farmers aged >60** and/or stagnant or declining **agricultural economies** to spur rural economic development opportunities and next-generation land transfer. V. Fund through public-private partnerships and impact investment through the Wisconsin Green Innovation Fund	Establishment costs Risk management Commercialization

HIGH	$ 🏢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, administered by DATCP in collaboration with DNR.	NEAR
In collaboration with: 🏢 **DNR, WEDC** 🧑‍🌾 **LWCDs, UW-Ext** ⚖️ **WRD**		*Key program components:* I. **Wisconsin Train-the-Trainers program** to expand technical capacity of program administrators and implementers, in collaboration with WEDC, LWCDs and UW-Extension. II. **Provide annual ecosystem service and risk-sharing payments** (up to 5 years) to landowners that transition low-yielding and/or highly erodible annual row crop fields to natural climate solutions III. Prioritize areas most sensitive to groundwater or surface water impacts IV. Add-on payments to producers who supply nutrient management plan implementation documentation, conduct GHG assessments and demonstrate **GHG emission reductions** over the 5 year cost-share period.	Technical capacity Establishment costs Risk management
MEDIUM	🏛 🏢DOR	Create a **Sales Tax Incentive for WI brewing and distilling companies** to source **locally-grown products**	MEDIUM
In collaboration with: 🏢**DATCP**		*Key program components:* I. Model after **Michigan** and **New York**'s state tax programs II. Provide **tiered**, increased **tax benefits** for perennial crops and products.	Commercialization

IMPROVE ALIGNMENT of STATE POLICIES & PROGRAMS			
HIGH	✍️ ***and/or*** 🏛️ 🏢 **DATCP**	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, and **strengthen agricultural practice standards** to align with the land and crop management practices identified in the NCS Roadmap.	LONG
In collaboration with: 🏢 **DNR, DOA, WEDC, OCI,**		*Key program components:* I. **Prioritize GHG mitigation potential** in funding decisions for state cost-share programs. II. **Codify agricultural practice standards** to align with the land and crop management practices identified in the NCS Roadmap **III.** Extend maximum length of grant projects to align with **establishment timeframes for perennial systems**. **IV.** Explore and expand **agricultural technological solutions that support NCS practices**, including precision agriculture, anaerobic digester and biochar pyrolysis development and utilization **V.** Strengthen **permits, licensing, and oversight for manure system storage, anaerobic digesters and biochar pyrolysis** to ensure full compliance with state soil and water quality standards. VI. Expand and disseminate **data collection** of water quality, soil health metrics and yield to receive cost-share benefits.	Establishment costs Risk management Commercialization
HIGH	✍️ 💲 🏛️ 🏢 **DOA**	**Improve coordination among local governments and state agencies** to align state planning and development with targets identified within the NCS Roadmap.	LONG
In collaboration with: 🏢 **DATCP, DFI, DNR, DOR, DWD, OCI, UW, WHEDA, WEDC** 🧑‍🌾 **LWCDs, RDC, UW-Ext, NGOs, WICCI** ⚖️ **AMS, FSA, NRCS, WRD**		*Key priorities:* I. **Incorporate NCS Roadmap targets and recommendations** into the state [Priority Climate Action Plan (Wisconsin Emissions Reduction Roadmap)] II. Require and support **county comprehensive climate action plan development statewide** by 2030 and use them to prioritize and target resources III. **Improve coordination of municipal, county and statewide action plans** to mobilize the technical assistance, cost-share programs, and infrastructure necessary to advance agricultural emissions targets IV. Create structures to **facilitate collaboration between state agencies and departments** on crossover program areas, for example DATCP and DNR of administration of agroforestry incentive programs. V. Improve state **information technology** systems to streamline information sharing between agencies and departments.	Risk management

HIGH	✍ and/or 🏛 DATCP	Review and amend **DATCP grant and financial support programs** to **include climate benefits criteria** when making award decisions.	NEAR
In collaboration with: DNR, DOA		*Key programs:* I. §93.59 Producer-led Watershed Protection Grants and Administrative Code ATCP 52 A. Producer-led Watershed Protection Grant Program (PLWPG) II. §93.46(1)(d) Agricultural diversification, §93.46(2)(b), and §93.46(2)(c) III. Soil and Water Resource Management Grant Program (SWRM) IV. §93.48 Buy Local Grant Program A. Buy Local, Buy Wisconsin (BLBW) Grants V. §93.485 Tribal Elder Community Food Box Program VI. §93.49(3)(a) Farm to School Grant Programs VII. §93.68 Grants for meat processing facilities A. Meat and Poultry Supply Chain Resiliency Grants B. Meat Processor Infrastructure Grants C. Meat Talent Development VIII. §93.40 Dairy Promotion A. Dairy Processor Grants IX. §93.44 Commodity Promotion A. Something Special from Wisconsin Program X. §93.42 Center for international agribusiness marketing and §93.425 Agricultural Exports Program A. International Markets Access Grants	Establishment costs Technical capacity Risk management Commercialization
HIGH	✍ $ and/or 🏛 DMA-WEM	**Amend the** Wisconsin's Pre-Disaster Flood Resilience Grant Program to include critical stormwater control measures, including agroforestry and other eligible natural climate solutions, in partnership with FEMA.	NEAR
In collaboration with: FEMA DATCP, DNR, OCI WTCAC LWCDs,UW-Ext		*Key additions:* I. **Assessment grants** to support DATCP, DNR, County Offices of Emergency Management, LWCDs, Tribal Nations and UW-Ext coordination to generate, gather and map information on agricultural vulnerabilities to climate change impacts, and identification of agricultural resilience priorities on a watershed, catchment, or stream reach scale. II. **Implementation grants** to provide public-private funding for installation of (i) agricultural climate solutions and/or (ii) flooding, drought and GHG mitigation/adaptation strategies, in vulnerable agricultural areas of priority.	Risk Management

HIGH	✍️ $ *and/or* 🏛️ 🏢 **DNR**	Review and amend the relevant **DNR grant and financial support programs** to **incorporate agroforestry systems and potential climate benefits as a key factor** when evaluating participation and financial assistance applications and making award decisions, and to expand funding to align with establishment costs and timelines of perennial crops/systems:	NEAR
In collaboration with: 🏢 **DOA, DOR**		I. §283.84 Trading of water pollution credits and Water Quality Trading Program II. §26.42 Forestry diversification, §26.38 Forest grant program and Forestry Plantation Planting and Design Guidelines to include **agroforestry systems** (e.g. understory forest farming), **managed grazing** for understory rejuvenation and invasive species removal, and **biochar** applications as "most likely to provide high forest productivity benefits to the economy of the state"(per §26.35 Forest productivity) III. **Expand DNR use of biochar** in state-owned forests, plant nurseries, agricultural parcels and in urban forestry street tree installations to improve water holding capacity, filter runoff, and carbon sequestration.	Establishment costs Risk Management Commercialization
HIGH	✍️ *and* 🏛️ 🏢 **DATCP**	**Amend DATCP's Soil and Water Conservation cost-share program eligibility to incorporate potential climate benefits as a key factor** when evaluating financial assistance applications and making award decisions.	MEDIUM
In collaboration with: 🏢 **DNR, DOA**		*Key amendments:* I. Align with the management practices identified in the NCS Roadmap. II. To qualify for **manure storage system cost-share dollars or loan**, storage systems must include solid-liquid separation, covering and flaring and/or anaerobic digestion.	Risk Management
HIGH	🏢 **DATCP**	**Create an agricultural certification program,** modeled after Ohio's Agricultural Certification Initiative program:	NEAR
In collaboration with: 🧑‍🌾 **LWCDs and UW-Ext**		*Key program components:* I. Recognizes farms that **meet and exceed state soil and water management requirements** II. Provides **training for technical assistance providers** about implementation of emerging technologies and climate-smart cropping practices and systems that reduce nutrient inputs and losses and increase soil carbon storage III. **Includes verification, certification and continuing education requirements** for state-administered agricultural incentive program participation.	Risk Management

MEDIUM	⚖️ **AMS, FSA, NRCS** 🏢**DATCP**	Review and amend the following **state-administered federal grant and financial support programs** to **include climate benefit potential as a key factor** when evaluating program participation and financial assistance applications and making award decisions:	MEDIUM
In collaboration with: 🏢**DNR, DOA**		I. [Conservation Reserve Enhancement Program (CREP)] II. [Environmental Quality Incentive Program (EQIP)] III. [Specialty Crop Block Grants Program (SCBGP)] IV. [Organic Certification Cost Share Program (OCCSCP)] A. Prioritize funding for emerging tree crops, perennial grains and oils, and winter annual oil crops B. Prioritize certification rebates for organic and regenerative organic perennial agriculture practices and systems V. **Partner with NRCS State Technical Advisory Committee to evaluate and adjust practice payment rates** under enhancement codes 311, 379, 381 and #E3280 to better align with actual practice implementation costs and timelines for perennial crops/systems.	Establishment costs Risk Management
MEDIUM	✍️***and/or*** 🏛️ 🏢**OCI**	**Amend Wisconsin Statute** [§625.11 Insurance Rate Standards] and [§625.12(1-4) Rating Methods] to include definitions for contributions to environmental degradation and climate-related risks and damages.	MEDIUM
In collaboration with: 🏢**DNR**		*Include science-based evidence for:* I. Past and prospective **degradation of water, soil and greenhouse gas (GHG) emissions and associated remediation** expenses; II. **Climate change** catastrophe, hazards and contingencies; and III. The definition of "riskiness" of the class of business to include **contributions to environmental degradation and/or GHG emissions and subsequent climate impact risks, catastrophes, hazards and contingencies.**	Risk Management
MEDIUM	✍️ 💲 ***and/or*** 🏛️ 🏢**DATCP**	Establish a **NextGen Farming Program** to support new farmers across the state, with tailored support for women, BIPOC farmers, veterans, and others who may face additional barriers to equitable land access	MEDIUM
In collaboration with: 🏢**DWD, UW-Ext, WEDC**		*Key program components:* I. Expand the **Wisconsin Workforce Development Apprenticeship program** to include a **NextGen Sustainable Farmer Program** in partnership with UW-Extension and WEDC, to help smooth inter-generational land transition, reduce high opportunity costs of accessing, leasing, and/or purchasing suitable agricultural land and infrastructure, and to develop sustainable business plans that benefit Wisconsin agriculture.	Establishment Costs Risk Management

		II. **Pair NextGen Farmer mentees with** experienced sustainable farming mentors, perennial agriculture technical advisors, producer-led group members, agricultural enterprise business advisors, and value-chain development advisors III. Provide comprehensive, hands-on training under approved Farmer Educators IV. Paid apprenticeship for NextGen farmers interested in taking on farm management V. **Compensate Mentors** for their time and resources required through stipends, tax credits, and/or cost-sharing opportunities	
MEDIUM	**DATCP, WEDC**	Create a **Program Resource Website** for **soon-to-retire and NextGen aspiring farmers** to track available county, state, federal and public-private financial and technical resources to guide land transitions and improve access.	MEDIUM
In coordination with: **LWCDs, UW-Ext**		*Key resources include:* I. Relevant WEDC and DATCP programs II. Land and agricultural practice transition guidance III. Land tenure opportunities, by county IV. Local, state, federal and private cost-share opportunities V. State tax incentive programs, and VI. Low-interest, graduated loans/mortgages offerings VII. Technical assistance resources	Establishment costs Risk management
MEDIUM	**DATCP**	**Amend** [§96.02 of the Agricultural Marketing Act] to include perennial agricultural commodities and products, dairy waste reduction, agrivoltaics and biochar production.	LONG
In coordination with: **DNR, DOR, WHEDA**		*Key amendments include:* I. **State-recognized certifications** for verified Wisconsin agricultural climate solutions and green infrastructure practices II. Provide **sales tax exemptions or rebates** for Wisconsin-grown perennial agriculture products. III. **Align administrative rulemaking and agency coordination** to build production, processing and local/regional marketing, certification and consumer education programs.	Risk management Commercialization

LEVERAGE BLENDED CAPITAL to FINANCE TRANSITION COSTS			
HIGH	🏢DATCP, WEDC	**Provide farmers with a flexible portfolio of financial and non-financial support and services** from which they can select the support they need based on their specific context.	NEAR
In coordination with: 🏢 DOR, WHEDA ⚖️WRD 🧑‍🌾 LWCDs, UW-Ext, NGOs		*Key priorities include:* I. Include favorable loans and insurance policies that reflect the reduced risk exposure for financial actors II. Provide upfront payments or guarantees to defray economic risks encountered during early stage of practice adoption III. Include technical assistance services, data services, and access to equipment and inputs in service offerings.	Establishment costs Technical assistance Risk management
HIGH	🏢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 (CPGs), impact investors, and others.	NEAR
In coordination with: 🏢 DOR, WHEDA ⚖️WRD 🧑‍🌾 LWCDs, UW-Ext, NGOs		*Key priorities include:* I. **Cost-share technical assistance and production transitions** to the land and crop management practices identified in the NCS Roadmap to advance adoption of natural climate solutions, corporate sustainability and community impact goals. II. Partner with technical assistance providers within LWCDs, UW-Ext and NGOs.	Establishment costs Technical assistance Risk management Commercialization
HIGH	✍️ 💲 🏛️ 🏢WEDC, DOA	**Attract private impact investments and augment with public funding the** [Wisconsin Green Innovation Fund] to launch and leverage blended finance mechanisms for advancing natural climate solutions in Wisconsin	MEDIUM
In coordination with: 🏢DATCP, DFI, DNR, DOR, OCI, UW and WHEDA		*Key components include:* I. **Develop a Regenerative Agriculture Innovation Fund** within the Green Innovation Fund II. **Allocate the projected cost of agricultural climate-related damages to Wisconsin** to program funding. III. Provide **sustainability-linked loans, with tiered increases in low-interest loans repayments** as farmers meet environmental benchmarks.	Establishment costs Risk Management Commercialization

		IV. Provide **cost-share and tax credits** for natural climate solutions implementation and rural industry development V. Create an ***Advancing Wisconsin Agriculture* applied R&D fund** to support scientific excellence in Wisconsin through public-civic partnerships between state agencies and Wisconsin non-profit science-based and community development based organizations. A. Provide **pooled capital grants** to fund projects that directly benefit Wisconsin's agricultural sector including development of precision agriculture technologies for small- and medium-sized farms, biochar pyrolysis units, anaerobic digesters, perennial crop breeding/propagation, etc. VI. Pilot a tax-exempt **Wisconsin Agriculture Climate Solutions Green Bond Pilot Program,** including both state-issued bonds and municipal bonds**,** modeled after CT Green Bond framework and tailored to Wisconsin's agricultural sector context A. **Utility or stormwater authority** assigned as the "outcome payer," where utilities benefit (permit compliance) and where **water-quality trading** or consent-decree drivers exist. B. Capitalize with a **surcharge on agricultural utility bills,** proceeds from sales of emissions allowances, **federal competitive and non-competitive grants,** the sale of **tax-exempt Bonds and Notes**, and private investment sources.	
HIGH	🏢 **OCI, DATCP, DNR**	**Pilot** two 5-year **Insuring Resiliency of Rural Infrastructure** and **Insuring Agricultural Resiliency pilot projects** in partnership with private agricultural insurance providers to demonstrate how agricultural climate solutions reduce impacts of flooding, drought and storm damage on insurance claims.	NEAR
In collaboration with: ⚖️**RMA, FEMA**		*Key program components:* I. **Insuring Resiliency of Rural Infrastructure pilot project** A. **Provide tiered insurance premiums for agricultural enterprises**, with premium rates adjusted proportionally based on agricultural practices and associated greenhouse gas (GHG) emissions and reduction potentials. II. **Insuring Agricultural Resiliency pilot project** A. **Insurance premium discount program** similar to the function of the **Cover Crops Rebate Program** B. **Provide tiered insurance premiums for agricultural enterprises**, with premium rates adjusted proportionally based on carbon intensity levels, associated greenhouse gas (GHG) emissions and reduction potentials.	Establishment costs Risk Management

MEDIUM	DOR	**Create tax incentives for long-term leases and/or sale of agricultural land** for perennial agricultural production and to support NextGen farming transition.	MEDIUM
In collaboration with: DATCP, WHEDA		*Key program components:* I. Tax incentives for landowners to long-term lease agricultural land for perennial agriculture production (five-, ten- and twenty-year renewable leases) II. Tax incentives for landowners to sell agricultural land to NextGen farmers for perennial agricultural production III. **Tiered**, **low-interest graduated farm loans and mortgage payments** to align with economics of establishing a new farming operation, and enhance rural rejuvenation**:** A. **I**ncreased monthly payments proportionally to the increase in perennial yield profits, B. Ten-, twenty-, and thirty-year loans and mortgage terms to help NextGen farmers secure long-term land tenure	Establishment costs Risk Management