Climate Smart Agricultural Recommendations From the Carbon Tracking and Monitoring Workshop, July 2022

Minnesota's Climate Action Framework presents an opportunity for Minnesota Agriculture. These recommendations for Minnesota Community-Based and Farm Organization Leaders result from discussions at the Agricultural Carbon Tracking and Monitoring workshop held in July 2022. With 60 stakeholders, we advanced ideas for a more systematic approach to tracking, monitoring, and goal setting that addressed the need for meaningful reductions in agricultural carbon emissions in the context of environmental co-benefits and social equity. The Workshop Report provides a full description of the discussions.

This synthesis includes Context, Recommendations, and a Workshop Summary.

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Provided by:

- George Boody, SoilCarbon LLC
- Jessica Gutknecht, Associate Professor, Dept. of Soil, Water, and Climate; University of Minnesota
- Green Lands Blue Waters

- With the assistance of the following reviewers:
  Evelyn Reilly, Green Lands Blue Waters
  Aaron Reser, Green Lands Blue Waters
  Erin Meier, Green Lands Blue Waters
  Anna Cates, University of Minnesota
  Brad Heins, University of Minnesota
  Omanjana Goswami, Union of Concerned Scientists

Agricultural Carbon Tracking and Monitoring Workshop

Research Recommendations

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This synthesis includes Context, Recommendations, Background, and a Workshop Summary.

Context

The Ag Carbon Tracking and Monitoring Workshop was an effective convening of diverse stakeholders who contributed thoughtful, well-informed background, promising models, and gaps in policy and programs, as well as recommendations for agricultural carbon sequestration in the context of ecological services, and equity and inclusion. An important shared understanding from participants was that ecological and social systems are at a breaking point, and we must work at a systems level with as much mandated change as possible to reduce emissions and increase sequestration potential. The consequences of inaction are dire. It is important to collectively assert that agricultural climate solutions hold exciting potential, and actions are available and imperative at many scales and via many farm types. These include cropping and livestock systems. A diversity of solutions should be implemented now and into the future.

Participants outlined barriers to immediate action. Feasibility of farmer adoption is one of the most significant, including economic, cultural, technical knowledge, and infrastructure barriers to adoption of climate-smart practices. Pathways to adoption should be prioritized in strategy and measurement protocol development. Small-scale, BIPOC and emerging farmers experience added adoption challenges given the structural inequities of agriculture that present many barriers, including limited land access. The ongoing trend towards consolidation disadvantages smaller farmers.

These challenges also limit the ability of small-scale farmers to participate in and benefit from carbon markets, which are typically designed for large row crop operations. Since new farmers, BIPOC farmers, and small farmers tend to be more likely to implement diversified production systems, perennial crops and other regenerative practices, excluding them by omission or design is contradictory to maximizing climate change mitigation in agriculture.

There is often tension between large-scale incremental change and small-scale transformative change but we need both. Equity and land access must be addressed in any cost-share, incentivization, or payment programs to avoid compounding these existing inequalities. One way to help do this is to include farmers of all types in program design, communicate appropriately, acknowledge and respond to their needs and limitations, and build programs that address adoption barriers. Other challenges lie in the science of carbon itself. Soil carbon measurement is still inexact, and carbon dynamics are characterized by high spatial and temporal variability that makes accurate modeling difficult. The situation is complicated by the importance of nitrous oxide and methane in agriculture's total greenhouse gas emissions impact, especially because nitrous oxide is even more difficult to measure and model than carbon. While we must avoid massively overestimating the impact of given practices, we also must find ways to proceed in the face of uncertainty, since time is critical.

Participants noted the opportunity for adoption of climate-smart practices and systems in the context of soil health improving practices and broader ecological services. Soil health improvement serves both to ramp up soil carbon, avoiding some greenhouse gas emissions (GHG) and potentially sequestering carbon. Such practices provide other ecological services that benefit both farmers and society, such as reduced water quality impacts, and greater wildlife and pollinator habitat. A hopeful area of ag carbon work is the potential to stack climate benefits with social and environmental co-benefits through practices such as perennial cropping systems and local value chain investments. This area is not without its challenges either, such as the complexity of measuring multiple environmental co-benefits or the difficulty of designing programs to support social benefits.

Finally, workshop participants addressed the limitations of carbon markets. Ag carbon sequestration does not negate the need for major reductions in carbon dioxide, methane, or nitrous oxide emissions. Many attendees referenced private sector corporate insetting[1] and other initiatives leading the way on Ag and climate. Yet many remain skeptical of the influence of corporations involved in carbon markets, asking who benefits, how, and why. Carbon markets run the risk of solidifying support for dominant cropping systems that can have significant environmental impacts, especially when built by and for players with significant existing power in agricultural systems and policy.

Instead, workshop participants offer recommendations to build markets and policy to better foster adoption of more diverse farmers and agricultural systems. Workshop participants provided many concrete recommendations, a critical piece in the development of these new markets. Program design should be dynamic, helping to ensure that the focus remains on intended impacts and beneficiaries and are both effective and inclusive. Combined with assessment throughout the adoption and implementation phases, it also ensures that they can be adjusted to avoid unintended negative consequences. State and federal regulation currently lags but should be supported along with current initiatives already moving through the private sector. Government standardization and regulation will ultimately be essential for verifiability and transparency to ensure that farmers have clear options and that companies deliver the promised climate benefits.

[1] Corporate insetting is the financing of projects intended to reduce carbon emissions and support other ecological and social services along the company's value chain.

Recommendations: Tracking and Monitoring for Researchers

There is uncertainty due to measurement difficulties, soil types, management of practices, composition and growth of soil biological communities, and weather perturbations. Challenges also include tackling ecosystem service benefits and changes, investment in and equity for historically underserved communities, and building community among farmers and other people in rural communities.

1. Basic and Applied Science on Soil Health and Soil Carbon Dynamics

Topics could include:

- A more detailed understanding of the potentially stacking benefits of clean water, emissions reduction, and climate adaptation from regenerative agriculture.[11,25,2,6]
- An understanding of the variance, limitations, and change in rates over decadal time periods of carbon sequestration rates and totals.[22,24]
- An understanding about how different environmental variables such as local climate, soil type, or soil depth intersect with management to influence carbon sequestration.
- The emissions reduction potential of regenerative agriculture (reduced soil disturbance, CLC and MRG) from a systems perspective, including input costs and fertilizer use efficiencies, regionalized supply chains and life cycle assessment. This includes assessing emissions reduction per product produced and delivered to consumers (food, feed, or bioenergy).
- Methane emissions sources, amounts, and pathways to reduction.[6,27,28]
- AgroVoltaics for grazing, perennial crops, and fruits and vegetables. What is needed to scale up pilot projects such as the WCROC for grazing experiment under solar collectors?
- Developing a select number of soil health metrics that accurately measure change in the short-term and over time in relation to soil carbon persistence from dynamic movement and transformation of carbon inputs via interactions with microbes and the physical soil matrix. Could proxies for flow-based soil carbon persistence be: the percent of year ground cover and aggregate stability for short-term change; and organic matter, topsoil depth, water storage potential, and/or increased microbial processing capacity for longer-term changes (Dynarski et al., Kravchenko et al.)?
- Identifying and tracking benefits of stacking practices, including the soil health/ carbon storage changes from CLC and managed rotational grazing systems that:
    - Cut across farm size, farmer identities, and production systems.
    - Are accurate, cost effective, and easy to use monitoring and tracking strategies.
    - Identify how benefits stack with multiple practices in place.

2. Standardization and transparency in tracking and modeling of Carbon and Co-Benefits

a. *What is needed to ensure standardization and transparency in tracking and modeling by:*

- Building accessible databases with long-term, site-specific GHG emission data?
- Standardizing in ways that recognize the diversity of geology, crop types, farm ownership in Minnesota, and proxy vs farm-scale data?
- Allowing for comparison and verification to help reduce greenwashing?
- Addressing methane and nitrous oxide emissions in addition to carbon?
- Assuring flexibility in the face of uncertainties and evolving science?
- Integrating measurement and prediction-based approaches? Measurement of every single field is not necessary or practical, but a purely prediction-based approach is not adequate either.
- Cleary connecting climate practices with water quality and other environmental co-benefits through data synthesis and modeling by prioritizing measuring changes such as:
    - Soil erosion?

- Surface and groundwater quality?
- Habitat production and increased biodiversity?
- These or other parameters that can be tied to the market and turned into cash payments?

b. *Refine monitoring strategies for maximum accuracy and efficiency by:*

- Utilizing remote monitoring of living cover, soil carbon (by drone with ground penetrating capabilities).
- Simultaneously monitoring "stacked services"/co-benefits even if not all are directly related to GHG mitigation.
- Building long-term MN-specific modeling capability by county, or sub-county level.
- Considering and addressing challenges:
  - Being honest about the limitations of different land uses- where can we realistically reach carbon-neutrality.
  - Developing monitoring and tracking for markets and programs to understand current state of and changes about inclusion and equitable distribution, and affordable and secure access for larger, smaller, women and BIPOC ownership of farms.
  - Evaluating tradeoffs of different monitoring/data systems.
- Measuring environmental benefits from cover crops alongside any emissions reductions or increases from nitrous oxide emissions.
- Estimating costs and time required of farmers, businesses, and/or governments of different tracking system options in ways that make tracking practically and financially accessible to growers and landowners, and that keep the monitoring and reporting burden on the program rather than on farmers.

c) *Evaluate rewards for practices that scale to have the greatest and longest-term effects—e.g., forest and grass-land maintenance and improvement–and be honest about the limitations of different land uses.*

- Identify the most vulnerable lands from production, especially peat soils and former wetlands.
- Determine types and amounts of incentives that might encourage farmers and landowners to:
  - Shift marginal fields to production systems with high levels of conservation, ecosystem services, and potential for GHG reductions.
  - Retain grasslands through managed rotational grazing and "working lands" easements for perennials. For improved grazing, improved or new fencing and watering systems may be needed.
  - Help retire certain marginal fields from production or shift to working land-uses.
  - Convert marginal parcels to forest or other perennial production systems. The main costs are planting and management.
  - Consider whether lower payments for conventional cropping on marginal land would be sufficient to encourage farmers and landowners to shift those lands if market returns were smaller than good fields.
- Evaluate meaningful entry standards for the highest payments and lower payment levels to make sure more people are eligible. Would low bars such as minimal tillage only take up most of the payments and dilute the programs impact?

3. Developing Tools for Comprehensive Tracking and Monitoring Systems for Carbon, Environmental Co-Benefits and Social Equity

a. *Advance True Cost Accounting as a workable tracking and monitoring system(s) by:*

- Developing integrated goals for landscape, management, ecosystem service outcomes, and social equity outcomes related to agricultural GHG net reductions to achieve state goals.

- Identifying near-term methodologies to value, and possibly monetize social outcomes and negative environmental externalities, along with added economic value, from addressing climate change impacts and solutions related to farming and food systems.
- Researching methods, data, and what entities could collect data over the longer-term needed to quantify and value what is harder to accomplish with current understanding.
- Assessing whether community-level food systems, water quality planning, and climate adaptation planning approaches, e.g., Tribal nation's community food systems and food sovereignty plans, are useful.
- Evaluating policies that could help with secure and affordable land access, rather than just changing costs/incentives for people who are already there, by including ownership by emerging, smaller, BIPOC and women farmers.
- Estimating the level of support for small producers through local mills, bakeries, and processors, including mobile abattoirs that would be impactful.
- Identifying approaches that would reward non-operating landowners for leasing land and equipment to emerging farmers.
- Proposing policies that would slow or prevent consolidation.

b. *Identify protocols needed to best apply farm-level LCA, attributional, and consequential LCA methodologies related to soil carbon GHG reduction potentials for different types of farming systems by determining:*
    - The questions, data, system boundaries, and denominators needed to best apply farm-level LCA to soil carbon GHG reduction potentials for different types and sizes of farming systems and related outputs in the context of ecological services.
    - The questions, data, system boundaries, and denominators needed to best support attributional and consequential LCA studies needed to evaluate the impacts or consequences of changing systems at the regional, national, or global level in the contexts of ecosystem co-benefits and social equity.
    - What approaches best account for ecosystem service tradeoffs with GHG reductions.

Research: Background and Case Studies

- **Issues to be Solved**
  1. Agricultural greenhouse gas emissions are ¼ of state's emissions (GHG).
  2. Insufficient data and methods to monitor and track GHG reductions and carbon sequestration.
  3. Agriculture can have expensive and extensive environmental impacts.
  4. Small and medium sized farmers, and women and BIPOC farmers are disadvantaged by subsidies, risk of management systems, and carbon markets in relation to larger commodity farmers.
  5. The markets are developing fast, without sufficient scientific underpinnings or equity in mind.

Minnesota's Next Generation Energy Act set goals for greenhouse gas emission (GHG) reductions across all sectors of the economy. While Minnesota has accomplished significant reductions from the energy sector, emissions from livestock and cropping agriculture increased by 17% through 2020.[2]

The Minnesota Climate Action Framework calls on the state to "Identify opportunities for farmers and landowners to participate in ecosystem services markets (e.g., for carbon removal, flood protection, and water quality) that incentivize best management practices for climate mitigation and adaptation." Climate-smart agricultural conservation practices are not being adopted fast enough by farmers or providing large enough cuts in emissions to achieve the goals required to avoid dramatic consequences of climate change (see IPCC February 2022 Working Group II report).

Increasing continuous living cover (CLC) in the form of perennial production systems and managed rotational grazing builds soil health, boosts resilience to climate impacts, and sequesters carbon in the soil—providing potential climate solutions that also generate environmental and social co-benefits. No-till combined with cover crops, longer rotations with small grains, and other nutrient/manure management practices can also be climate-smart. These systems could reduce agricultural emissions and future production costs for farmers, as well as help meet Minnesota's goals for nitrogen reduction and habitat improvement.

Carbon markets, broader ecosystem service markets, and publicly funded incentives that pay farmers to implement carbon-sequestering practices could help farmers increase adoption of these practices, but additional data on effectiveness would help prioritize where to invest time and money. The lack of research on carbon and GHG emission reductions attributable to climate smart practices has hampered efforts to promote the most effective practices. Goals and baselines are needed to inform what should be tracked to determine progress or the lack thereof.

If goals and metrics are clear, these initiatives offer high potential to advance agricultural systems in a way that holistically serves the environment and the people living and working on it. However, the agricultural sector has historically underserved Black, Indigenous, and People of Color (BIPOC), women, immigrants, and beginning farmers. Therefore, including the diverse perspectives of "emerging" farmers is essential as we consider sustainability goals and tracking methods to ensure equity and inclusion in climate change solutions.

Goals should be set for avoiding emissions so that agriculture might achieve net emission reductions of 30% in five to six years and deeper reductions over longer horizons. Related goals should be formulated to advance equitable participation by small- and medium-sized farming and agricultural enterprises, including those led by underserved and

[2] MPCA https://public.tableau.com/app/profile/mpca.data.services/viz/GHGemissioninventory/GHGsummarystory

under-represented farmers. A framework of metrics and methods must be developed to track the achievement of goals.

- **Opportunities**
  1. Soil-health based systems more widely on the land offer the potential to avoid some emissions, sequester carbon in soils, and supply other environmental co-benefits but more localized research is needed.
  2. Research on soil carbon and sequestration is ramping up but more is needed for Minnesota soils, weather conditions and management strategies.
  3. Consumers increasingly want to know more about their food, including ecological and social footprints.
  4. Dietary changes, reduced food waste, soil health-based agricultural systems, and other agricultural practices can avoid significant GHG emissions.

The MPCA through its _Greenhouse Gas Reduction from Agricultural BMPs_ is a worthy start to develop predictive GHG metrics for Minnesota farming systems. There is a need and the opportunity to add estimates from systems with complex living cover on working farmland such as:

- Multiple species cover crops in combination with no-till,
- Extended rotations and cover crops with grazing,
- Well- managed rotational grazing,
- Silvo- pasture,
- Grazing of any kind, and
- Vegetable and fruit production with CLC.

Millions of Tons/Year

MPCA's report was based on a review of peer-reviewed and a small amount of "gray" literature (certain agency reports), so this lack of inclusion could have stemmed from a lack of value assigned to these systems from the scientific community, any entity that funds scientific research, and/or the MPCA.

Scenarios for Minnesota Agriculture -- Opportunities and Gaps to research
Two approaches to understanding the application of MPCA data to Minnesota agriculture are noted below. Additionally, Project Drawdown data and estimates for global solutions that include agriculture and temperate climate rates are discussed. Further analysis with process modeling might confirm or change these estimates.

Regenerative Ag is not a silver bullet—A Scenario from Jungers and Gutknecht

Based on the MPCA report and other sources, Gutknecht and Jungers (2021) identified sequestration rates from 0.1 st C/ac/yr for CLC and reduced tillage systems up to 0.34 st C/ac/yr for perennial systems They analyzed the potential impact of different land management options. Their analysis found that regenerative agriculture, using no-till, cover crops, and perennial forages could lower net ag GHG emissions (See Figure 1), but is not a silver bullet.

Gaps needing research cited by the authors:

- A more detailed understanding of the potentially stacking benefits of clean water, emissions reduction, and climate adaptation from regenerative agriculture.[11,25,2,6]
- An understanding of the variance, limitations, and change in rates over decadal time periods of carbon sequestration rates and totals.[22,24]
- An understanding about how different environmental variables such as local climate, soil type, or soil depth intersect with management to influence carbon sequestration.

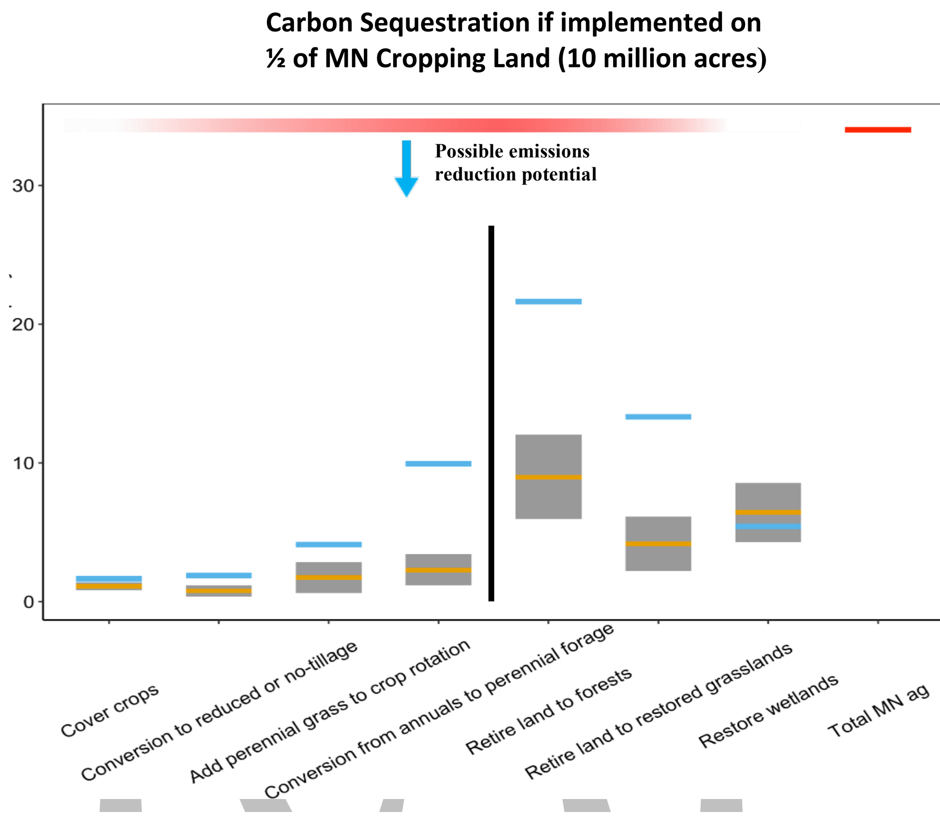

Figure 1. C sequestration and emissions reduction potential scaled to 1/2 of MN cropland. Yellow lines = average C sequestration based on literature review. Gray areas are the range, within 95% confidence, of the average. Blue lines represent the sequestration + emissions reduction potential across the cropping system life cycle. The red line represents the 13-year average MN total emissions from agriculture. (Copied from Jungers and Gutknecht 2021 and used with permission).

- The emissions reduction potential of regenerative agriculture from a systems perspective, including input costs and fertilizer use efficiencies, regionalized supply chains and life cycle assessment. This includes assessing emissions reduction per product produced and delivered to consumers (food, feed, or bioenergy).
- Methane emissions sources, amounts, and pathways to reduction.[6,27,28]

Setting Advanced CLC and MRG Farming Goals, Estimated Net GHG Reductions and Ecological Outcomes, and Valuing Public Costs and Benefits – A Scenario from Boody

Literature from the U.S. has quantified lower and higher estimates of emissions reduction for soil health-based solutions compared to the MPCA report.

Boody (in publication by MISA) addressed these opportunities by setting hypothetical goals for land use change. Continuing conservation from existing state and federal program acreage was enlarged by adding cover crops plus no-till on 25% of corn and soybean on good fields, and shifting 100% of marginal corn-soybean parcels to longer rotations, set-aside, or added cover crops with no-till and grazing. Acreage for existing grassland parcels was shifted to include 25% more using managed rotational grazing. Along with acreage already in these practices in 2017, the new combined acreage totaled 7.5 million acres over six years. Rates for carbon sequestration and avoided emissions from MPCA were considered to be for average management. About 60% of newly shifted parcels were assumed to use advanced management, as outlined in Figure 2, using rates in published studies from .0.27 to 1.61 st/ac/yr for carbon sequestration before being adjusted for longevity. Net GHG reductions also included avoided emissions. Economic costs and the social values of GHG reductions and co-benefits related to water quality were estimated. Details can be found in Table 1 in the Appendix.

Figure 2 shows estimates for net GHG reduction from those changed acres that might help achieve state goals for greenhouse gas reduction from agriculture sector by 30% over six years. This would be the equivalent of 2.2 million cars or about 11 million st CO_{2e} yr-1 for that period. The required state of Minnesota continuing and additional public investment in farmer incentives was estimated to be about \$330 million over six years. Federal program cost-share and farmer investments would be additional. Program development, farmer engagement, community building, research, and market development investments were estimated to cost another \$120 million over six years. However, public benefits totaled about \$450 million over six years for the social values of net GHG reductions, and reduced soil erosion and nitrogen loss to water. This could offset Minnesota's public investment costs (see Table 1 in the Appendix).

Based on interviews with farmers using these practices and literature, research gaps cited included:

- Expanding funding for whole systems research on ICGR ecosystem services, including climate change mitigation over time (Dynarski et al 2020, Robertson et al. 2008 , Russelle et al. 2007).

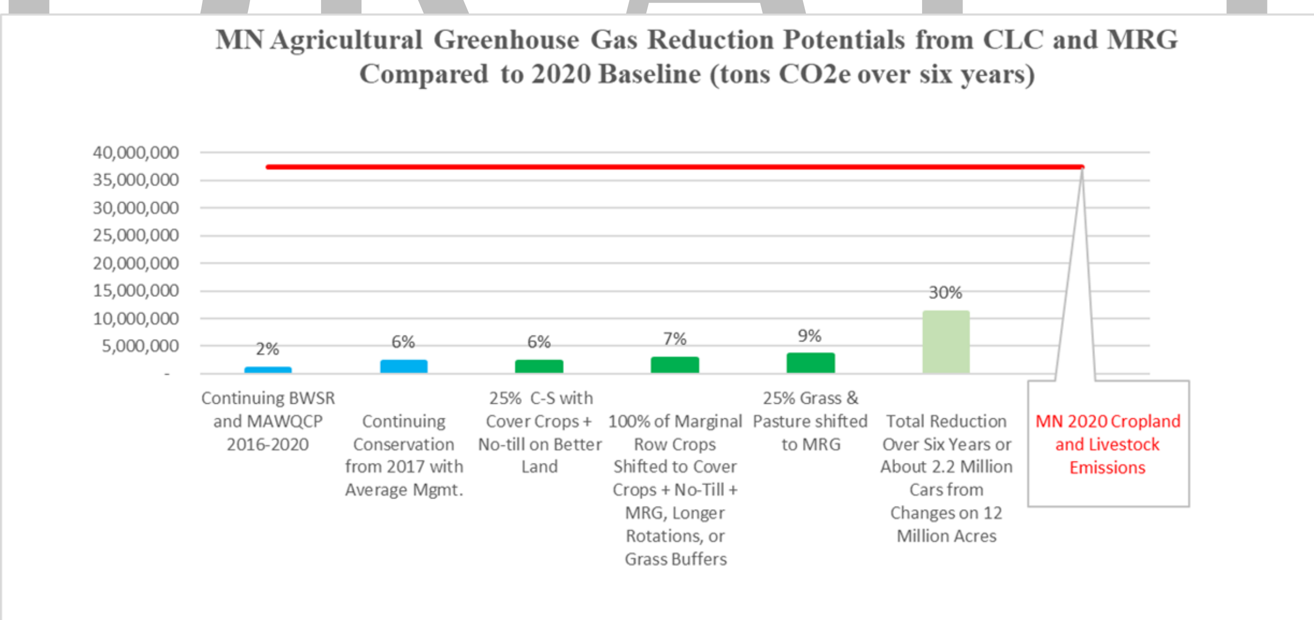

Figure 2. C sequestration and avoided emissions reduction potentials scaled to 7.5 million acres of crop and grasslands over six years. Blue boxes show estimates for emissions reductions for continuing conservation with average management. Dark Green boxes show estimates for emissions reductions for CLC or MRG, 60% with advanced management. Light greenbox is the total reduction potential over six years. The red line represents the 2022 average MN total emissions from agriculture. (Copied from Boody, in press, with permission).

- Developing a select number of soil health metrics that accurately measure change in the short-term and over time in relation to soil carbon persistence from dynamic movement and transformation of carbon inputs via interactions with microbes and the physical soil matrix (Dynarski et al. 2020 and Kravchenko et al. 2019).
- Researching healthy soil microbiome and gut microbiome relationships from ICGR systems (Atwood et al. 2019, Benbrook et al.2018, Daley et al 2010).
- Testing virtual fence in Minnesota and Upper Midwest row crops and grasslands at farm- and landscape-scales (Campbell et al. 2019).

Project Drawdown Scenario on Global Solutions

For the global agriculture sector (including related land management), Project Drawdown's Table of Solutions (See Appendix Table 2) showed that soil health-based solutions such as regenerative annual cropping and managed grazing have similar or more potential than conservation agriculture, improved cattle feed, and nutrient management. They named changing diets and reducing food waste as having the third and fourth largest potential global reduction across all economic sectors. Table 2 shows agricultural/food reductions on a global basis from Project Drawdown's Table of Solutions. Several solutions highlighted in green are applicable for Minnesota's food and agriculture systems that have both avoided emission and soil carbon sequestration potential. Rates for temperate zone sequestration and emissions are shown for comparison to the previous two scenarios.

Accounting for Carbon, Ecological Co-Benefits and Social Equity through LCA and True Cost Accounting

Both the technical and the social metrics, the interplay between them, need to be considered to implement a systematized approach.

- Social capital includes relationships and social networks, as well as the social norms and values that shape behavior.
- Natural capital includes the air, water, soil, geology, ecosystems, and creatures that provide us with the building blocks of all other forms of capital.

Negative (and sometimes positive) impacts of production on natural and social capital are typically not included in the direct cost of a product. Tallaksen discussed implications of these discrepancies for the agricultural carbon market, as well as the opportunities to reduce emissions from row crop and confined livestock systems[3] Methods of tracking impacts and progress toward goals include True Cost Accounting (an emerging body of research and applications to understand more about the scale and nature of these external impacts) and Life Cycle Assessment (a framework for considering the impact of a production system). Both frameworks have advantages and disadvantages. Scientific consensus is lacking on aspects of the systems and data is missing for aspects of the systems that would allow full quantification or assessment in these frameworks. Understanding system effects necessarily involves examining trade-offs, e.g., maximizing, or balancing row crop production with soil carbon sequestration and water quality impacts. Unintended consequences need to be anticipated, if possible.

Millions of Short Tons CO2e/Year

True Cost Accounting

The public costs of the current system, such as flooding and water quality impairments, are not internalized into dominant farming or food systems. Farmers or landowners generally do not receive a market benefit for lessening those public costs, which constitutes a type of market failure (Tegtmeier and Duffy, 2004).

[3] Tallaksen, Joel. May 24, 2022. The opportunities and challenges of the agricultural carbon market. *Steven's County Times.*

However, True Cost Accounting (TCA), by considering natural, social, human, and produced capitals involved in food and agriculture systems, provides a construct to value or measure both private benefits and public well-being (El-Hage Scialabba et al. 2021) of improvements and continuing practices. Impacts on equity and inclusion and overall human wellbeing could be evaluated. Organic, grass-fed, humane, and fair-trade markets have paid for more of the true costs/benefits, enabling farmers to make investments in CLC and MRG. But true cost approaches of paying for cover crops or other changes suggested in the workshop should be more holistically evaluated.

Research to support policy instruments is also occurring through the Economics of Ecosystems and Biodiversity for Agriculture & Food (TEEBAgriFood 2018). This initiative focuses on the holistic evaluation of agriculture and food systems along value chains. When possible, the most significant externalities related to ecosystems and communities are valued and may lessen the value of assets or development.

A Genuine Progress Indicator was developed and tracked for Maryland and other states (McGuire et al. 2012) This initiative has revealed possibilities for more environmentally and socially minded policymaking that accounts for human well-being and environmental impacts as well as Gross Domestic Product. A proposal for a GPI indicator was introduced in the Minnesota Legislature.

Research on gaps for TCA implementation could include ways to:
- Set integrated goals for social equity, landscape-level living cover, and other metrics related to these issues.
- Identify near-term methodologies to value and possibly monetize social outcomes, negative environmental externalities, production, and added economic value from addressing climate change impacts and solutions related to farming and food systems.
- Invest in developing longer-term methods to identify and value what is harder to accomplish with current understanding.

<u>Life Cycle Assessment (Adapted from a Joel Tallaksen 2022 communication)</u>

In Life Cycle Assessment (LCA) terms, examining how changes impact one farm is typically done differently than examining changes to the entire agricultural sector. A single-farm LCA could disregard the impacts that the change in production will have on the wider world. Broader supply chain impacts from changing systems could be examined with attributional LCA methodology. However, when addressing policy there could be sector-wide changes that affect the system as a whole. This is examined with consequential LCA methodology, which typically includes the impacts or consequences of changing a system at the regional, national, or global level.

Based on the focus of this workshop, some changes are not likely to have sector wide impacts -- things like the addition of non-harvested cover crops or no-till farming. These may have some limited outside impacts on fossil fuel, seed use and other farm inputs, but are mostly internal to farms. LCA as often practiced is relevant for such analyses.

Some of the more dramatic farm changes being discussed for the region would very likely have impacts that require a broader analysis. If, for example, soybeans were shifted to be grown under a system with more rotational crops, adding other crops may reduce the amount of soybeans produced. System-wide impacts of a reduced amount of soybeans on the market should be considered. The assumptions would likely be that either people/the market responds by using less soybeans or those soybeans are produced in other new locations such as the Amazon basin. Both assumptions have policy and environmental impacts associated with them.

A more politically sensitive example is the production of meat. If policy promoted more pasture-based beef production systems in Minnesota that reduced the state's overall amount of beef being produced, we might assume that people will either eat less beef or that the beef will be produced in other locations where it may have different impacts.

What is the impact of making either of these assumptions? What is the social impact of suggesting that people eat less meat? This is a good example of the intersection of large-scale economics, environment, and social issues.

To avoid dealing with these consequential considerations on top of the already complex existing mix of carbon and other environmental impacts, many LCA researchers avoid them by only looking at farm level issues.

Appendix I Additional Background Material

Additional background material, in bullet form, was drawn from workshop discussions during the first three sessions. This is organized by Knowns, as well as Unknowns and Gaps. Please see the Report for more detail and in-depth discussions.

A. Knowns

1. Carbon Fundamentals and Measurement Difficulties.
    a. Long term implementation is key because SOC in an agriculture system may only temporarily store C.
    b. Ag soil carbon sequestration does not negate the need to reduce GHG emissions.
    c. Direct measuring is harder and more expensive, but most accurate. There is a trade-off between labor time and data quality.
    d. For environmental co-benefits, prioritize measuring: Soil erosion, water quality, habitat production and increased biodiversity, parameters that can be tied to the market and turned into cash payments, and things that can be certified for producers to increase the value of products.

2. BIPOC, women, beginning, and small farmers are a part of the solution.
    a. They face multiple barriers: land access, finances, racial profiling in lending, student loans, belonging and being seen as a part of the space, access to information, lack of infrastructure for local and specialty products.
    b. Land access and scale differences lead to unfair rewards and opportunities.
    c. Payments alone are not enough to achieve equity without secure and affordable land access.

3. Theme: Conflict between scaling and equity.
    a. The urgency of action creates tension between working with largest landowners (typically incremental changes in corn-soy systems) vs. addressing the full range of opportunities for change including small, transformative, and diversified farms.
    b. We won't create diversity and equity without focusing on smaller producers AND cannot make the biggest difference without larger producers; it must be both/and.
    c. We need both broad in-the-system change and structural change for carbon neutrality.
    d. TNC was working with a lot of smaller farmers when developing ambitious climate goals, but shifted to larger farmers to get most impact.
    e. Programs and transformative visions need to have entry points for different farmers and views, and be designed to both capture scale and support groups that need help.
    f. Not all relevant and willing groups are involved.
        i. Some landowners would be willing to do something about climate change; they may need funding but are open to tree planting and more.
        ii. Only 2% of people in rural areas are farmers; only 6% are related to ag professions - they are a meaningful group that wants clean air and water.
        iii. We are not leveraging consumers enough to educate them on how they could help shape public policy.
    g. Find ways to accelerate on-farm implementation and state policymaking.

4. Businesses.
    a. Programs need to have strong standards, supported over time - there is concern about weak and short-term standards; some are very low bars, like minimal tillage.
    b. Could have a focus on practices/GHG sources with high per acre GHG-avoidance rate.
    c. Programs should include a temporal component to account for carbon residence time.
    d. There needs to be support farmers during a 3–5-year transition period.

B. Unknowns and Gaps

1. Carbon Fundamentals.
    a. The rate of accumulation may slow after ~10 years.
    b. There is uncertainty still about amount of C sequestered and residence time.
    c. In addition to best practices on ag lands, some land will need to be converted back to prairie, forest, wetlands, or well-managed working grasslands to maximize sequestration.
    d. Some research is finding more carbon stabilization and persistence in diverse farming systems resulting from micropore formation and soil aggregation under suitable conditions.

2. Scientific and Measurement Difficulties.
    a. There are fundamental gaps in carbon measuring and quantification capabilities.
    b. The high variability across fields and farms makes modeling and estimating field-level GHG changes of management very difficult.
    c. Gathering data on small diverse farms is harder than on large homogenous farms.
    d. Using national/regional averages is easy but inaccurate.
    e. Measuring nitrous oxide emissions is difficult (significant impact, but highly variable).
    f. Currently, general or relative comparisons of practice impacts are more reasonable than trying to pinpoint actual quantities.
    g. Remote sensing and other innovative technologies might be helpful.
    h. Do we know where all the peat soils in Minnesota are?
    i. Address methane and nitrous oxide emission in addition to carbon.

3. Environmental Co-benefits.
    a. Practices that support soil health and C sequestration tend to have many other benefits, including improved soil health (water holding capacity, stability, erosion and nutrient loss reduction, and resiliency to large rain events and drought), water quality, and bird and pollinator habitat, as well as on-farm benefits such as birds for insect control.

4. Equity.
    a. How do we decide which land is converted back to wetland, prairie, or forest?
    b. How do we define what social benefits are? Who gets to define them?
    c. How can we target BIPOC farmers with these programs?
    d. How can we integrate small to midsize farms that are doing scalable low emission, high C sequestration practices into conversation/marketplace/strategy?
    e. How can we ensure fairness to farmers who have already implemented practices with environmental and social co-benefits, and still incentivize new implementation?

5. Markets.
    a. How could we create a market for social benefits, like environmental benefits?
    b. How do we get more corporations on board? This is already happening slowly.
    c. Can we encourage consumers valuing these products by educating them about true externalities of food production and ecosystem service benefits of regenerative practices?

6. Adoption.
    a. Who carries the burden of data collection, proving impact, risk? Who owns data?

   b. What is the transition point for wide-spread adoption – like technology adoption in commodity agriculture?
   c. Are there ways other than payments that farms can benefit from changing practices?
      i. How are soil health improvements valued in financial risk management?
   d. Can we make tracking accessible to farmers and keep the burden of data collection off them?
   e. Can greater transparency and trust about data use and ownership be provided?

7. Engagement and communication.
   a. What are the key messages to communicate about regenerative and sustainable agriculture? What are the methods?
   b. How can we ensure that people are informed about these programs, especially BIPOC and other emerging farmers?
   c. What is needed to have robust engagement of all relevant groups, including non-farmer rural individuals and communities, landowners, consumers, people who have been historically excluded?

Appendix II The Ag Carbon Monitoring and Tracking Workshop

The agricultural climate solutions workshop held in the fall of 2020 provided the impetus for developing a proposal to pursue Ag Carbon Tracking and Monitoring. By holding a workshop with a variety of stakeholders we sought to advance ideas for a more systematic approach that encompassed social equity and carbon emission reduction from agriculture.

After funding by IonE, a Core Team guided the development of the workshop by refining its purpose, determining the focal areas, and planning for post-workshop synthesis. Organizers engaged nine people affiliated with BIPOC-led organizations and agencies in conversations about the project. We heard that while this effort could be useful to them, it was not necessarily closely aligned with their work. We received helpful feedback on drafts that was subsequently incorporated into planning and invite materials for April 2022 distribution.

An extensive list of background references for each of the four workshop focal areas and overall workshop topics covered by catalyst presenters was assembled and provided to invitees. Five catalyst presenters were identified and recruited to make presentations.

The invitee list grew to about 140 people known to be interested in these issues, including about 30% farmers (row-crops, livestock, fruits and vegetables and grazers), as well as researchers, Minnesota agency leaders and scientists, nonprofit staff, and the corporate sector employees. An effort was made to invite at least 25% BIPOC individuals.

A total of about 60 people registered and were asked to rank interest in focal areas upon registration.
They were then assigned into focal area groups of up to eight or so people based on their preferences and achieving a balance among focal areas. Moderators and note-takers were pre-identified and provided guidance.

The Workshop Report provides a full description of the discussions.

Workshop Core Team
- Jessica Gutknecht and Zachary Buell: Department of Soil Water and Climate, U of M
- George Boody: Soil Carbon LLC
- Peter Ciborowski: Retired from Minnesota Pollution Control Agency and Minnesota state government.
- Colin Cureton: Department of Agronomy and Plant Genetics, U of M

- Joel Tallaksen: West Central Research and Outreach Center, U of M
- Jennifer Schmitt and Kimberly Long: Institute on the Environment, U of M
- With assistance from Erin Meier, Aaron Reser and Evelyn Reilly: Green Lands Blue Waters

This project was supported by a joint award for an Impact Goal Grant from the Agricultural Climate Solutions workshop, which was supported by the University of Minnesota's Institute on the Environment and the McKnight Foundation.

Workshop Synthesis Reviewers

Appendix III Resources

	A	B	C	D	E	F	G	H	I	J	M	R	S	T	U	V
1	**Table 1: Scenario -- Ramping Up Acreage in CLC With Public Investments and Related Public Benefits Repeated**															
2					*MPCA/EQB Rate Scenario*			*High Carbon Rate Scenario with 60% advanced implementation*								
3					*Emissions With Average Management*			*Emissions With Advanced Management for CLC and MRG Goals*								
4	**CLC and MRG scenarios based on corn and soybean acres and grassland acres in 2017**	**MN 2016 total ag emissions (b)**	**2017 or later conservation Acres**	**Acreage goals for increased CLC and MRG**	CO2e sequestered (e)	CO2e avoided emissions (e)	**Net GHG compared to corn and soybeans for 2017 or later conservation acres**	CO2e sequestered (f)	CO2e avoided emissions (g)	**Net GHG compared to corn and soybeans for 2017 or later conservation acres and goals for CLC and MRG with advanced management**	**State of Minnesota share of public investments to meet acreage goals per biennium (2 yrs) with 50% from the state**	**Public value of potential net GHG reduction based on social cost of carbon (i)**	Soil erosion reductions from CLC or MRG compared to corn-soybeans (j)	**Public and private savings at \$5/ton (k)**	Nitrogen loss reductions from CLC or MRG compared to corn/soy in lbs/acre (l)	**Social cost of nitrogen reductions for NO3- water and based on fertilizer use at \$1.14/lb (m)**
5	Units	U.S tons CO2eq /yr	Acres	Acres	U.S tons CO2eq/yr/ac	U.S tons CO2eq/yr/ac	U.S tons CO2eq/yr	U.S tons CO2eq/yr/ac	U.S tons CO2eq/yr/ac	U.S tons CO2eq/yr	**\$/biennium**	**\$/biennium**	Tons/ biennium	**\$/biennium**	Lbs/ biennium	**\$/biennium**
6	Corn and soybean acres in Minnesota (a)			**15,933,013**												
7	**Percent marginal corn and soybean acres (a)**			**20%**												
8	**Goals: Land use change and acres in advanced management**			**25%**						**60%**						
9	**Social cost of pollution parameters**			-								**\$30.21**		***\$5.00***		***\$1.14***
10	Corn soybean acres include cover crop and no till on 25% of good land		579,147	3,186,603	-0.35	0.00	(198,537)	-0.80	-0.10	(2,359,167)	\$27,808,419	\$23,756,813	(751,295)	\$3,756,473	(3,154,737)	\$3,609,019
11	Longer crop rotation on 50% of marginal corn or soybean fields		1,091,337	1,593,301	-0.32	-0.17	(542,231)	-0.40	-0.10	(1,336,121)	\$2,071,292	\$13,454,734	(1,297,691)	\$6,488,454	(2,358,086)	\$2,697,650
12	Conservation cover set-aside for water quality, habitat or other programs on 25% of marginal row crop land		579,147	796,651	-0.78	-0.83	(932,647)	-0.78	-0.83	(2,215,557)	\$28,546,648	\$22,310,659	(2,037,204)	\$10,186,019	(2,497,500)	\$2,857,140
13	Managed rotational grazing on 25% of marginal corn soybean fields with cover crops and no-till		520,100	796,651	-0.43	0.00	(221,244)	-1.19	0.21	(828,459)	\$19,650,716	\$8,342,581	(648,845)	\$3,244,227	(788,684)	\$902,255
14	Managed rotational grazing on 25% of 1,073,788 acres of pastures+ 25% of 2.6 million acres of grasslands +25% of 1,058,955 of MN CREP acres (c)		268,447	1,183,186	-0.92	0.06	(230,028)	-5.92	1.86	(3,519,899)	\$29,185,249	\$35,445,386	(1,055,587)	\$5,277,936	(7,394,911)	\$8,459,778
15	MAWQCP acres 2016- 2020 (d)		734,000			-0.66	(485,321)			(485,321)		\$4,887,180				
16	BWSR conservation acres in 2019 (d)		500,000			-0.66	(330,600)			(330,600)		\$3,329,142				
17	**Totals**		4,272,178	7,556,391							**\$107,262,323**	**\$103,310,203**	**(5,790,622)**	**\$ 28,953,115**	**(16,193,917)**	**\$18,525,843**
18	*MN 2020 cropland and livestock emissions and scenario reductions*	*37,327,790*	-				**(2,940,608)**			**(11,075,124)**						
19	**% reduction**						-8%			-30%						
20	**Equivalent cars off the road at 4.6 Mt per vehicle yr**									2,184,787						
21	**Total public benefits (includes the public benefits from reductions of GHG, soil erosion, and nitrogen to water**											**\$ 150,789,161**				

22 *Footnotes*

23 a. Assuming 20% of 15,933,013 acres of corn and soybean from 2017 Census of Agriculture (USDA NASS 2017a)are marginal economically and environmentally for row crop production with substantial negative externalities based on Basso et al. (2019).

24 b. Minnesota agricultural greenhouse gas emissions from MPCA (Claflin et al. 2023).

25 c. Pasture acreage and rate of rotational grazing from 2017 Census of Agriculture (USDA NASS 2017c); overall pastureland from USDA NRCS n.d); and MN CREP acres from USDA FSA (2017).

26 d. Acres for MAWQCP (Redlin 2021) and BSWR (CWF 2020); \$ investments for MAWQCP (MDA 2019); \$ investments for BWSR programs from CWF (2020); MN EQIP 2019 cost-share spending (USDA NRCS MN 2019).

27 e. Rates for sequestration and avoided emissions from Ciborowski (2019) CO2e for 100,000 ac divided by 100,000 acres to estimate CO2e sequestration or avoided emissions per ac]; except pasture from Center for Climate Strategies (2016). The MPCA assumed a 20-year storage reducing potential rates to 40% of full values for permanent storage that would avoid a full ton of emissions from fossil fuels. Greenhouse gas reduction rates from BWSR Climate Change report (Shaw and Rhees 2019) applied to BWSR and MAWQCP acreages.

28 f. Olson et al. (2014) for cover crops; Project Drawdown (2018b) for longer rotations; Stanley et al. (2018) for MRG sequestration; and Ciborowski (2019) for set-aside. MPCA reductions of rates to 40% are used for cover crops and long-term rotations.

29 g. Rates are from Project Drawdown (2018c, 2018b) for avoided emissions from cover crops and longer rotations, respectively; Rountree et al. (2016) for MRG greenhouse gas emissions/acre for MRG cattle; Ciborowski (2019) for set-aside. MPCA reductions to 40% are used for advanced carbon mgmt. for cover crops and long-term rotations, reduction to 40% for MRG on marginal row crop land and no reduction for MRG on continuing pasture/grasslands. Avoided emissions for grazing are multiplied by 2.5 to account additional cows needed for higher stocking rates. However, it is assumed that 1/2 the cattle on pastureland are not additional, so do not contribute new emissions above the baseline and 1/2 are additional cattle needed to achieve higher stocking densities in multi-paddock MRG systems that lead to greater sequestration and increased GHG emissions per acre.

30 h. Total cost-share rates from MN NRCS EQIP FY 2021. Fencing costs of \$76/ac for an 80 acre field based on NRCS fencing calculator updated to 2021 EQIP rates for fencing of \$0.95 per foot for a 4-strand electrified perimeter fence plus \$42/ac for a prescribed grazing plan, interior fence at \$10/ac and watering systems of \$20/ac (USDA NRCS MN 2021a).

31 i. Social cost of carbon from MN PUC (IPI 2019).

32 j. Average water erosion rates and wind erosion rates from 2017 NRI (USDA NRI 2017b) modified by percentage reductions on LCC 1 and 2, LCC 3 or LCC 4 for corn-soybeans, corn-soybeans with cover crops, or longer rotations from C10 APSIM model (Jaradat and Starr shared data 2016); Reductions for conversion to grass are from Miller 2018 for prairie strips; Reductions for MRG compared to conventional grazing from USDA NRCS -WI 2018 modified for CG by comparison rates with continuous grazing from Pilon et al, 2017.

33 k. Cost per ton of erosion from Lazarus and Keller (2018b).

34 l. Nitrogen reductions from Lazarus and Keller (2018b) modified by percentage reductions on LCC 1,2 and LCC 3 or LCC 4 from corn and soybean, with cover crops, longer rotations from C10 APSIM model; Reductions for MRG compared to conventional grazing from C10 APSIM model (Jaradat and Starr shared data 2016).

35 m. Social cost of nitrogen for nitrate-nitrogen to water and ammonia air emissions are from Keeler et al. (2016).

Table 2: Project Drawdown Solutions for Food, Agriculture, and Related Land Use or Land Sinks Relevant in Minnesota

(CO2 Equivalent Reduced / Sequestered (2020–2050) from Sources by Two Reduction Scenarios)

Solution (Workshop focus in Green)	2˚ C Scenario (GT)	1.5˚ C Scenario (GT)	Rank by 93 sources *
Plant-Rich Diets	78.33	103.11	3
Reduced Food Waste	88.5	102.2	4
Silvopasture	26.58	42.31	11
Peatland Protection and Rewetting	25.4	40.27	12
Tree Plantations (on Degraded Land)	22.04	35.09	13
Perennial Staple Crops	16.34	32.87	14
Temperate Forest Restoration	19.42	27.85	16
Tree Intercropping	15.03	24.4	17
Regenerative Annual Cropping	15.12	23.21	18
Managed Grazing	13.72	20.92	21
Abandoned Farmland Restoration	12.48	20.32	22
Improved Cattle Feed	4.42	15.05	28
Indigenous Peoples' Forest Tenure	8.69	12.51	32
Nutrient Management	2.77	11.48	34
Forest Protection	5.55	8.83	46
Conservation Agriculture	12.81	8.08	47
Perennial Biomass Production	4	7.04	50
Improved Manure Management	3.34	6.09	51
Farm Irrigation Efficiency	1.13	2.07	72
Sustainable Intensification for Smallholders	1.36	0.68	84

Compiled by George Boody from the Project Drawdown webpages

Key:
- Rank is based on 93 society-wide actions.
- Rows highlighted in green are practices that both sequester carbon and/or reduce ag emissions, according to Project Drawdown.
- NA = Not Applicable as no per acre rates given

I. Link to Background Documents Google Folders

Environmental Co-Benefits
Implementation
- Adaptable Minnesota Policies or Programs
- Carbon Markets
- COMET-Farm Model
- Ecosystem Service Markets
- Life Cycle Assessment
- True Cost Accounting

Minnesota Agricultural Emissions
- Hypothetical Ag Land Use Goals
- MN Climate Reports
- US Climate Assessment

Social Co-Benefits
Tracking GHG Reduction Potential
- C Storage in Soils Through Dynamic Persistence
- Cover Crops, Longer Rotations, Perennials
- Diet, Food Waste and Climate Change
- Managed Rotational Grazing
- Nutrient and Manure Management
- Project Drawdown Food and Ag Global Climate Solutions

II. Citations

To be added