Farming to Capture Carbon & Address Climate Change Through Building Soil Health

How Well-Managed Grazing & Continuous Living Cover Benefit the Climate, Our Waters, Farmers & Taxpayers Through Improved Soil Health

A Land Stewardship Project White Paper

LAND STEWARDSHIP PROJECT

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Table of Contents

List of Figures and Tables

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Executive Summary

Background

Humans must act to reduce greenhouse gas emissions by at least 25% by 2030 to limit global average temperature increases to less than 2 degrees centigrade.[1] Such a reduction may help us avoid the most catastrophic effects on people, especially the poor and those who live in coastal areas, as well as our life support systems on Earth. Along with reducing fossil fuel emissions, one key way to stabilize atmospheric carbon dioxide levels is by sequestering carbon.

Agriculture is currently a major contributor to emissions that impact the climate — accounting for 9% and 24% of U.S. and Minnesota greenhouse gas emissions, respectively.[2] The good news is that by adopting farming systems that build soil health, agriculture has the potential to sequester significant amounts of carbon and lower greenhouse gas emissions. Many farmers, including farmers in Minnesota, are currently using these practices and showing how this can be done.

Building healthy soil requires the presence of a diversity of plants (and their living roots) on the land via "continuous living cover," also known as CLC. Examples of continuous living cover systems include cover crops planted between the regular corn-soybean growing seasons, four-year crop rotations that include small grains and a perennial legume, prairie strips in row crops, trees integrated into pastures, agroforestry, rotationally-grazed pastures, and the integration of crops with livestock that are distributed out on the land in a grazing system. Managed rotational grazing (MRG) of ruminant livestock significantly enhances soil health and is the most effective system for managing perennial grasslands and utilizing cover crops.

CLC and MRG, along with reduced tillage, can remove some of the excess carbon dioxide from the atmosphere and store it in soils. By building soil's organic carbon, more water can be stored in soil, resulting in less runoff, cleaner water, and more resilient crop fields and pastures.[3]

While many farmers currently use these practices, on average only about 3% of Minnesota cropland is planted to cover crops as continuous living cover in a given year.[4] With the right public investments, there is room for significant improvement in a short period of time.

Conclusions

The Land Stewardship Project (LSP) has gathered farmer experiences and reviewed the literature related to managed rotational grazing and continuous living cover. We have tabulated how these practices contribute to soil carbon capture, improve water quality, and produce other environmental benefits.

We conclude that:

◆ As much as 9% of U.S. greenhouse gas emissions could potentially be offset by shifting 25% of ruminants to well-managed grazing and 25% of cropland to a combination of perennial cover, diverse rotations, and cover crops.[5]

◆ Based on similar adoption rates, we show a scenario that would potentially lower Minnesota crop and livestock net greenhouse gas emissions by 30%, compared to 2016 agricultural emissions totals.

◆ A life cycle assessment study of managed rotational grazing of beef cattle in the Midwest found it produced a net reduction of greenhouse gas emissions. In comparison, a confined feedlot system was a net emitter.[6]

In addition, we found:

◆ Overall, the lack of cover and diversity in the dominant agricultural system leads to declining soil health.[3]

◆ Integrating continuous living cover and managed rotational grazing could help reduce agricultural nitrogen pollution by up to 45% in surface waters, while capturing rainfall and storing more water.[56]

◆ High rates of carbon sequestration have resulted after years of adaptively managed rotational grazing.[5, 10, 11]

◆ A wide spectrum of farmers are interested in improving soil health as demonstrated by attendance at field days and increasing adoption of cover crops. Farmers have seen increases of 3% or more in soil organic matter in five to 20 years by adopting continuous living cover, reduced tillage, and managed rotational grazing.[3]

◆ At least 20% of corn and soybean fields in Minnesota and 26% in the Corn Belt overall can be considered "marginal," with consistently low yields resulting in wasted fertilizer and excess greenhouse emissions.[7]

◆ The interests of farmers and ranchers and those people who seek climate mitigation coincide, because healthy soil helps build agricultural resiliency in the face of climate change, reduces costs of production in the long run, and opens optional markets.

Section I: Introduction to Soil Health & Managed Rotational Grazing

"Livestock are the rock stars of building soil health." **— Justin Morris, soil health expert, NRCS**

Building healthy soil helps farmers reduce operating expenses and their farming systems become more resilient when it comes to weather and market volatility. Livestock on the land in well-managed grazing systems build soil health.

A. Soil Health Building

A system of keeping the soil covered, increasing plant diversity, and keeping living roots in the soil all year-long is a form of "continuous living cover" (CLC). Along with minimizing disturbance from tillage and chemicals and including livestock on the land, CLC helps farmers follow the core principles of soil health (Figure 1). These year-round living plant systems can take many forms, from perennial grasses rotationally-grazed by livestock to annual cover crops grown before and/or after the regular cash crop growing season.

Farmers observe soil health when the soil feels spongy, works easily, or may "smell like coffee." In addition, in a healthy soil a rod can easily be pushed deep, the soil doesn't pond after a moderate rainfall, soil aggregates show up near plant roots, earthworms are visible, and/or corn stalks or other residues break down from year-to-year. The USDA Natural Resources Conservation Service (NRCS) defines soil health as "…the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans."[12]

Producing ruminant livestock — beef cattle, dairy cattle, sheep, goats, or others — on the land offers an economic way for farmers and ranchers to utilize perennial grasslands, small grains, cover crops, and other plants in continuous living cover systems that improve soil health.

B. Managed Rotational Grazing & Soil Health

Simply turning ruminants out onto open pasture or rangelands and allowing them to roam at will creates significant problems. This "continuous grazing" system is easier to manage, but can degrade the land through overgrazing while impairing water quality. When compared to well managed grazing, there is less potential profit per acre for livestock producers utilizing continuous grazing.[13]

On the other hand, livestock are particularly good at building soil health and resilient farming systems when they are raised using what's called "managed rotational grazing" (MRG). When adopted by farmers and ranchers, MRG allows adequate time to rest pastures and grasslands and can be used to graze cover crops. Ruminants ramp up soil health by eating diverse species of plants (cool and warm season grasses, legumes and forbs) and spreading manure in ways that stimulate soil "livestock." The grazing action of ruminants stimulates plant root development.[14]

Managed rotational grazing is a continuum of stocking density, time in paddocks, and rest before re-grazing. Pastures are divided into smaller paddocks, with animals grouped into one paddock at a time while giving grass time to regrow in others. Timing of rotations is based on adaptive management of grass resources, adequate time for recovery of grasses, weather, and management goals. It is also termed "adaptive multi-paddock grazing," and in the 2018 Farm Bill is called "advanced rotational grazing." (See the "Financial Analysis of Grazing Fact Sheet" for more details on this form of grazing.[102])

These well-managed rotational grazing systems regenerate ecological function and increase species mixes of grasses, forbs, and legumes. Pasture yields increase over time after building soil health and thus soil carbon.

Figure 1: The 5 Principles of Soil Health

1) Soil Armor: "Armoring" the soil with growing plants and plant residue doesn't just protect it from erosion, but reduces evaporation rates, moderates soil temperatures, reduces compaction, suppresses weeds and provides a habitat for the soil food web's critters.

2) Minimize Soil Disturbance: Damaging soil disturbance can include: biological disturbance; chemical disturbance, such as over-application of nutrients and pesticides; and physical disturbance, which includes plowing and other forms of tillage.

3) Plant Diversity: Just as biodiversity creates other kinds of healthy ecosystems, a diversity of plants builds a functional soil food web.

4) Continuous Living Plants & Roots: Plants on top and roots underneath 12-months-a-year create a healthy soil ecosystem.

5) Livestock Integration: Animals, plants, and soils have long interacted in a synergistic way to build enough organic matter to make soil self-sustaining. Such integration requires getting livestock out onto the land grazing in a way that nutrients are spread evenly while plants are given balanced periods of disturbance and rest.[106]

"It is not the cow or the sow, but the how, that matters." **— Livestock farmer Bryan Simon**

Renting It Out Right for MRG: A Hilltop View of the Land's Potential

When considering significant changes to the way one farms, there's nothing like a couple acres of convincer, a template for the potential offered up by tapping into the land's ability to build soil health in an economically viable manner utilizing livestock and perennial plants. Mark Erickson points out just such a personal proving ground on a fall day while guiding an old Buick coupe across a pasture in west-central Minnesota's Stevens County.

Beyond a thin line of trees and next to a neighbor's cornfield is a two-acre patch of grass. He explains that fertility-wise, it's probably the best corn ground on the 450 acres of land he farms, but for years he grappled mightily to get it to reach its cropping potential. It was hard to get equipment to that spot and the soil is heavy, making it often too wet to crop. Once it dried up, it was full of ruts. Weeds like cockleburs were a major headache.

"And when I planted that into grass, it went from the worst spot on the farm, the biggest headache, to the best," recalls Erickson. By grazing beef cattle on that two-acre patch, he calculates it went from a $300 suck on the farm's finances, to a $500 benefit.

On a day in late September, beef producer Mark Erickson moved cattle on land he rents in west-central Minnesota. He is shown here moving portable interior fencing to open a new paddock on rented land. "I think it's important to talk about what the future of the land is, and what the value of it is to children and grandchildren," he says. (*LSP Photo*)

This and other experiences with grass farming won Erickson over, but since he rents the 450 acres of what makes up Boss Ridge Ranch from four different landowners, he doesn't have the final say on how the land is managed. He regularly talks to the landowners about how when a certain farming practice improves soil health, everything follows, from improved resiliency of the land to guaranteeing Erickson and his family can remain economically viable enough to steward those acres long into the future.

"I think it's important to talk about what the future of the land is, and what the value of it is to children and grandchildren, and how you can make a system that will fit something other than just be all big farms," says Erickson. "Is there a value to that, is there a value to returning the soil to the organic matter standards it used to be?"

One day, he took his landlords on a tour of the land he rents from them, and asked them to imagine it all planted to grass. They liked the idea, and Mark hasn't raised row crops on those acres since. He has built up a cow-calf herd of Scottish Highlands crossed with Black Angus. Erickson has as many as 320 animals grazing on 450 acres and finishes cattle on grass, direct marketing the beef as well as selling through the Thousand Hills Cattle Company.

Erickson has built his organic matter levels from around 3 percent to, in some cases, 6 percent, and that's paid off in more productive paddocks and better water infiltration. On a recent fall day when neighboring farmers were idled from corn harvest by heavy rains, the grazier was able to drive his coupe out into his pastures to move cattle without getting stuck.

"The infiltration here is mind-boggling," says Erickson. "We got four inches of rain in July and normally that would have drowned out whatever crop I had out there. After that rain, there was not a drop of water in any bottom ground here."[15]

Section II: The Land Stewardship Project's Vision for Building Soil Health

We can build soil health and support family farmers by empowering them to shift marginal row cropland to working lands perennial systems, incorporating continuous living cover in remaining row croplands, and using managed rotational grazing with ruminants.

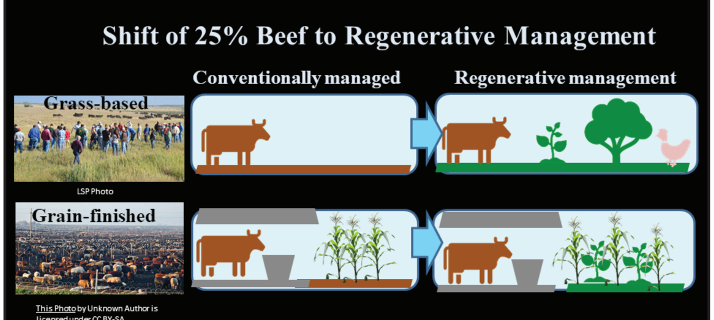
A shift of 25% of cropland and pastures to continuous living cover by 2030 in a way that integrates managed rotational grazing is depicted in Figure 2.

This could include shifting:

- 20% of Minnesota's marginal cropland (26% in the Upper Midwest) to perennial systems, which could reduce greenhouse gas emissions and sequester carbon.[16, 17]
- 25% of existing pasture and grassland acres on private, state, and federally owned grasslands from continuous grazing to MRG in the Upper Midwest.[16, 17]
- Summer annual row crops to include cover crops on at least 25% of the best row cropland.[18, 19]
- More production to grass-finished beef and pasture-based dairy farms.

Twenty percent of corn and soybean acres in Minnesota, and on average 26% of acres in the Upper Midwest, are marginal (they consistently produce low yields of corn or soybeans, no matter what the weather circumstances or how much fertility is added). This results in hundreds of millions of dollars in lost fertilizer costs, with corresponding annual greenhouse gas emissions of 6.8 million metric tons across the Midwest.[7] Assisting farmers in shifting these marginal acres to perennial-based working land systems or longer crop rotations with perennials would benefit them financially and build soil health.

Figure 2: Shifting beef systems by 25% to regenerative management with managed rotational grazing (MRG) and feed from continuous living cover (CLC)



(Adapted from DeLonge. 2017. *Reintegrating Land and Livestock*, Union of Concerned Scientists, citation 16)

There are multiple continuous living cover options for marginal and good row cropland, shown in Figure 3. Agroforestry, longer rotations, and prairie strips are options for including perennials. Adding cover crops in row crops also adds continuous living cover. Re-integrating livestock in existing operations or establishing new grazing farms are also possibilities.

For example, 25% of the marginal parcels planted to corn and soybeans in Minnesota's Chippewa River watershed are large enough at 40 acres to make contract grazing on fields converted to pastures a more viable option.[20] Contract grazing of cover crops and pastures is one way for these acres to be utilized when landowners do not have livestock of their own.

Preserving the beauty of rural landscapes that are managed with diverse farming and ranching systems well-suited to the particulars of the ecology, topography, geology, and human history of a region is vital. Vibrant economies with living wage jobs, community-based food enterprises, and other businesses are needed to attract young people to rural communities.

Achieving these outcomes requires conditions that enable more small- and medium-sized farmers or ranchers, including women, people of color, veterans, and Indian tribal members, to raise crops and livestock on the land in diverse farming systems. Pasture-based dairying, grazing heifers, and grass-finished beef could make economic use of more living cover.

Figure 3: Options to farm with continuous living cover

More stewards achieve greater stewardship — Wes Jackson and Wendell Berry call this the "eyes-to-acres-ratio," such that management is "adapted to local ecosystems, topographies, soils, economies, problems, and needs." We need more, not fewer, small- to medium-sized farmers.[21]

Carbon's Crisis Management Potential

Tom Cotter, along with his wife Alma, farms near the Cedar River outside of Austin, Minn. He integrates summer annual crops such as corn and soybeans, cover crops, and livestock production via managed rotational grazing to build organic matter in his fields. Sometimes he integrates all those practices in one field during the same growing season. "How many farmers can say they get three acres out of one acre? Every acre I have, I'm double-dipping—getting multiple enterprises. This is a way to deal with an economic storm," Cotter said at a field day in July 2019.

The increased organic matter from incorporating continuous living cover through cover crops and managed rotational grazing reduces the need for chemical inputs, while breaking up weed cycles. One field in 2019 was planted to a cocktail cover crop mix of sorghum-sudangrass, brassicas, peas, rye grass, sunflowers, vetch, clover, millet, and oats. He hayed it early in the season, and planned to divide the 20-acre field into eight paddocks to graze it during late summer. He planned to plant winter rye in the fall and harvest that in 2020 for seed, followed by a legume in preparation for organic corn in 2021. Using covers and grazing improves the farm's ability to manage precipitation, all while increasing fertility and sequestering carbon. "Capturing water, capturing carbon — I know if I get those two things, I will get a pretty good crop," said Cotter.[103]

Tom Cotter described the role soil health practices like cover-cropping and managed rotational grazing play in keeping his farm economically and environmentally resilient. Shown here is a soybean field where an annual cover crop from the previous winter is serving as a mulch between the rows. "Capturing water, capturing carbon — I know if I get those two things, I will get a pretty good crop," said Cotter. (*LSP Photo*).

Section III: Managed Rotational Grazing Coupled with Continuous Living Cover at Scale May Sequester Enough Atmospheric CO_2 to Meet Emission Reduction Goals for Agriculture

25% adoption of managed rotational grazing and continuous living cover in croplands could potentially reduce:

◆ U.S. greenhouse gas emissions by 9% ◆

◆ Minnesota's crop & livestock greenhouse gas emissions by 30% ◆

Now is the time to find ways to empower farmers to adopt the best soil health improving innovations that fit their management systems and goals, build soil, and also sequester carbon in the soil.

Agricultural systems, including those coupled with managed rotational grazing, can play a critical role in addressing climate change. That was an assessment of those gathered at a 2017 international conference in Paris, attended by the Land Stewardship Project. The conference included scientists and farmers, as well as government officials and leaders from the Global South and Organization for Cooperation and Economic Development countries.

Attendees concluded that we know enough to be able to say that improved soil health can make a significant contribution to reducing atmospheric greenhouse gas emissions and sequestering carbon, while providing greater food security for the future. There was agreement that soil health is improved in agricultural systems by integrating continuous living cover through cover crops, perennials, and agroforestry, while enhancing management of ruminant livestock on the land with managed rotational grazing, composting of manure, and restoration of degraded lands. Reduced tillage of cropland is also a key component of this strategy.[22]

Farmers have the ability to increase organic carbon levels in their soils. (*LSP Photo*)

A. Farmers increase soil organic matter with continuous living cover systems & MRG.

Innovative farmers in Minnesota, the Midwest, the U.S. and around the world are showing that they can put in place systems to adapt to extreme weather that's already being caused by climate change. These systems can also help farmers who want to step off the technological treadmill that continually increases farmers' cost of production when using high-priced inputs.

For example, Gabe and Shelley Brown and son Paul increased soil organic matter on their 5,000 acres of crop and rangeland from an average of 2% to 6% over a span of 20 years. They farm in a northern temperate area of North Dakota that receives low rainfall amounts (approximately 18 inches annually). The Browns increased water infiltration from 1.5 inches an hour to 8 inches an hour, while eliminating use of synthetic fertilizer and reducing herbicide use. The carrying capacity of cattle on their 5,000-acre operation increased from 65 cow-calf pairs to 350 pairs (plus yearlings and grass-finished cattle).[23]

B. Soil carbon monitoring shows the potential for high rates of soil carbon accumulation under managed rotational grazing.

Soil carbon accumulation rates were found as high as 3.6 short tons per acre, per year (st C/ac/yr) in a study by Machmuller et al. on land shifted from cropping to fertilized pastures and managed with managed rotational grazing (MRG).[24] Stanley et al. measured soil carbon increases of 1.6 st C/ac/yr over four years with managed rotational grazing that utilized high stocking densities.[3] Teague et al. measured a 45% increase in soil organic matter from MRG (which he and others describe as adaptive multi-paddock grazing) compared to heavy continuous grazing on nine Texas ranches located in tallgrass rangelands.[9] (See box on page 11 for explanation of calculations.)

Estimates of the amount of carbon that can be stored in soil using a variety of grazing systems still vary widely.[25] A review of 50 grazing studies found increases from improved grassland management of 0.13 st C/ac/yr.[10] This was similar to the previous review by Conant et al. Project Drawdown estimates a rate of 0.28 st C/ac/yr for well-managed grazing.[27] These estimates of grazing's ability to sequester carbon are lower than those measured by several researchers who specifically study MRG.

Stepping Up the Soil Health Game in Minnesota

Southeastern Minnesota farmer Rory Beyer was troubled by the erosion he saw on his family's land in 2008. In all, 17 inches of rain was dumped on the area in under 24 hours. "So, there was massive washing of soil," he recalls.

Beyer decided he needed to find a better way to keep his fields covered year-round to protect the land, or he wouldn't have any topsoil left to plant crops in. About seven years ago, he started growing cover crops before and after his regular corn growing season. Beyer also uses managed rotational grazing of perennial pastures and cover crops to produce milk and beef.

It has paid off: a recent six-inch rainstorm caused devastating erosion in his neighborhood, but Beyer's soil remained in place. It isn't just the soil's surface that has benefited from his use of continuous living cover. All those living roots have helped build soil organic matter. In one of Beyer's fields, organic matter increased from 1.7 percent to 4.4 percent in approximately seven years.[2]

Rory Beyer (left) **has used continuous living cover to build soil health and protect the land's surface.** (*LSP Photo*)

Richard Teague reasons that low measurements or modeling estimates result from the following (see Figure 4):[28]

◆ Studies often sample the more typical heavy continuous grazing systems, not MRG.

◆ Studies may have employed a rigid rotational grazing system that moves cows on a calendar schedule, instead of adapting to grass conditions in a way that builds healthy pastures.

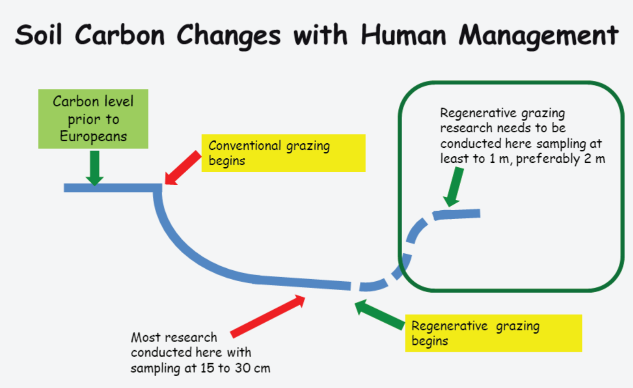
◆ Small plot-based studies may not provide the management flexibility that an actual ranch or farm operation would have to respond to varying conditions.

◆ Rotational grazing studies may have looked at conversion early in the cycle without considering time for management to build soil health in a way that creates well-functioning pasture or range agroecosystems.

◆ Light continuous grazing performs similarly to MRG in some studies, so that comparisons won't necessarily yield changes.

◆ Measurements have often been taken only in the top layers of soil.

Figure 4: Conceptual changes in grazing management related to soil carbon sampling



(From Richard Teague, 2017, citation 28)

C. Modeling shows high potential for net greenhouse gas reduction via MRG and continuous living cover systems.

- A team of researchers from the USDA, Iowa State University, Texas A & M University, Ohio State University, and Michigan State University, among other institutions, collected years of peer-reviewed research and compared the relative contributions of greenhouse gas emissions from dominant and continuous living cover-based systems.

Estimates included emissions from the production systems used to grow grain for feed, as well as soil erosion. Notably, simply halving the number of ruminants netted very small reductions in emissions because soil erosion, fertilizer use, and cropping practices have a much greater impact than ruminant livestock numbers.[4]

One scenario shifted: (a) 25% of ruminant livestock to managed rotational grazing and (b) 25% of crop production to conservation cropping systems with more continuous living cover. This scenario resulted in an annual net reduction (related greenhouse gas emissions minus carbon sequestration) equivalent to all of 2016 U.S. agriculture greenhouse gas emissions for methane and nitrous oxides.[7] A carbon sequestration rate of 1.35 st C/ac/yr, found in field studies, was used to calculate sequestration from MRG and conservation cropping systems. Under this scenario, soil erosion was reduced by 50%, reducing CO_2 losses to the atmosphere.

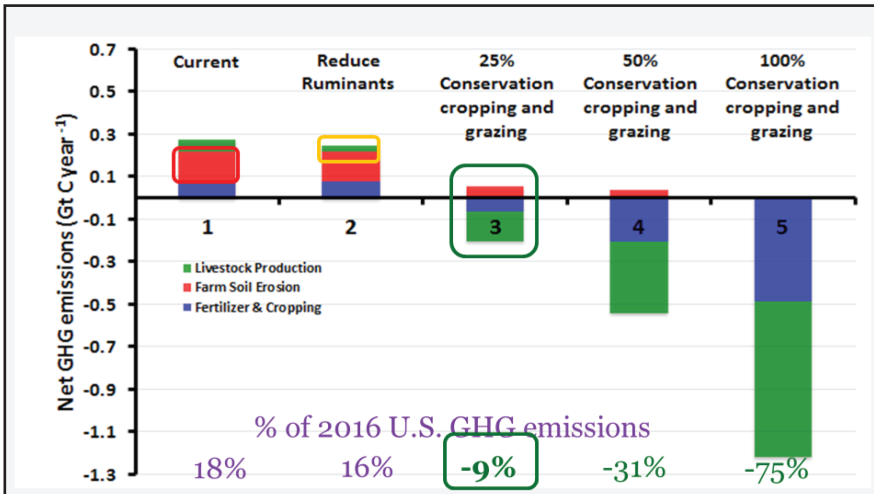
- Higher protein in grass from improved pasture management under MRG has been estimated to reduce enteric methane emissions by 30%.[29] Wang et al. in that life cycle assessment concluded that "…cow-calf farms converting from heavy continuous grazing to [managed rotational grazing] or light continuous grazing in the (Southern Great Plains) region are likely net carbon sinks."[29] Similar estimates have been made for Midwestern systems.[30]

- Managed rotational grazing in a silvopasture setting (with trees) could, according to Project Drawdown, increase sequestration to 2.2 st C/ac/yr.[31] Adding compost or biochar may further increase carbon sequestration rates in grazing systems.[32]

- Fifteen NRCS practices for continuous living cover and reduced tillage were applied to 70% of cropland and three prescribed grazing practices on 25% of pasture and rangeland by Chambers et al.[17] By 2050, the carbon sequestration estimated to a depth of eight inches was projected to lead to a net reduction of approximately 4% of 2013 U.S. greenhouse gas emissions (or about half of agricultural emissions). Rates of atmospheric benefits for cover crops were up to 0.1 st C/ac/yr and for prescribed grazing were up to 0.2 st C/ac/yr.

- Globally, regenerative cropping and grazing systems that build soil health, along with restoring degraded lands, could potentially reduce 2015 global greenhouse gas emissions by 8%, according to Paustian et al.[32]

Figure 5: Net emissions with farming involving continuous living cover and managed rotational grazing



(Adapted from Teague et al. 2016, citation 5; U.S. EPA data added, citation 8)

D. Production for livestock and direct human food in continuous living cover cropping systems reduces greenhouse gas emissions and improves soil health.

Carbon sequestration rates for cover crops were found to be 0.54 st C/ac/yr by Olson et al. with no-till, and estimated by the Sustainable Agriculture Research and Education Program to be as high as 1 st C/ac/yr.[34, 35] Composting manure as a fertilizer for crop rotations in organic systems can result in carbon sequestration rates of up to 1 st C/ac/yr[36] and cut energy use by 20%.[37] Project Drawdown estimates 0.28 st C/ac/yr sequestration and 0.10 short tons per acre per year of avoided greenhouse gas emissions for cover crops and reduced tillage systems in temperate/boreal humid areas.[38]

In one life cycle assessment, keeping cows outdoors in Pennsylvania lowered total greenhouse gas emissions by 10% compared to a full confinement operation. When fields were converted to grass from grain crops, sequestration went from zero to 1.7 st C/ac/yr. Production per cow was much lower, but total milk protein and fat were similar.[33] Methane digesters are sometimes used in large CAFOs, but do not change soil health practices on fields. They are hard to manage and expensive to install.[108]

E. Expanding grazing under solar collectors captures solar energy twice.

Dairy cattle are grazing underneath solar collectors at the University of Minnesota's West Central Research and Outreach Center.[39] The collectors are mounted on 8-foot pylons to allow for the cattle to move around underneath. This system not only produces solar electricity without displacing working farmland, but provides shade for the cattle (see page 11). Sheep also graze pollinator-friendly prairie habitat under solar collectors here and in other countries.[40] Such systems provide great opportunities for providing multiple eco-services while reducing a livestock farm's carbon footprint.

F. A life cycle assessment shows net greenhouse gas reductions from managed rotational grazing of beef.

A life cycle assessment (LCA), is a common approach to GHG emissions accounting. Stanley et al. used on-farm data from Michigan State University's AgBioResearch Lake City Center. They utilized MRG (which they term adaptive multi-paddock grazing) with high stocking density and longer pasture rest periods to evaluate greenhouse gas emissions compared with feedlot finishing. Emissions estimates included assessments of the contribution of enteric methane, feed production, mineral supplement manufacture, soil erosion, manure handling, on-farm energy use, and transportation. The carbon sink potential from sequestration was evaluated. A four-year sequestration rate of 1.6 st C/ac/yr from the MRG fields was measured.[5] By contrast, Pelletier et al. used a rate of 0.05 st C/ac/yr for MRG in their LCA study.[41]

Greenhouse gas emissions per hundredweight (CW) of meat production were higher for MRG (see left side of Figure 6). However, when soil carbon sequestration potential was considered, there was a net reduction of emissions due to the increase in soil carbon (see right side of Figure 6). On-farm gas measurements of methane reduced the enteric methane footprint of grazing by 19% compared to the Intergovernmental Panel on Climate Change default method.

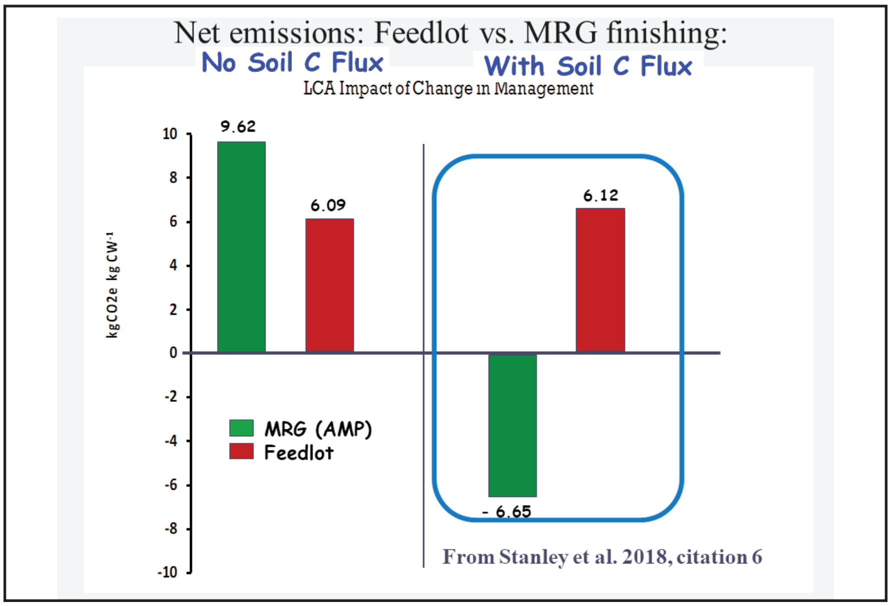


Figure 6: A life cycle analysis comparing feedlot beef with grass-finishing in a managed rotational grazing system with higher stocking densities (also known as "adaptive multi-paddock grazing" or AMP) at Michigan State University shows how grass-fed cattle can be a net greenhouse gas sink due to the carbon sequestration potential.

G. Include managed rotational grazing in Minnesota's Next Generation Energy Strategies.

Agriculture in Minnesota is estimated to contribute 26% of Minnesota's greenhouse gas emissions — the third largest contributor.[8] The Minnesota Board of Water and Soil Resources estimates greenhouse gas emission reductions of 330,000 short tons of CO_{2e} per year on 500,000 acres of land that was exposed to conservation practices. That report listed ways to include more living cover on the land in the form of perennials, winter annual cover crops, conservation crop rotations, and reduced tillage, but makes no mention of MRG.[42] The Minnesota Agricultural Water Quality Certification Program has enrolled a similar number of acres in conservation practices.[43]

The Center for Climate Strategies in 2015 used average rates for Minnesota at 0.23 st C/ac for the first five years after converting to grazing. Subsequent years (10-20) were estimated at only 0.08 st C/ac. They then assumed that only 20% of those acres would stay in grazing permanently.[44] A similar approach was used for cover crops.

COMET-Farm, used by NRCS and other agencies to estimate carbon sequestration, adjusts rates for prescribed grazing and other practices depending on field parameters such as data from available studies, field soil type, local weather, stocking rates, grazing and rest periods, and start and end dates, according to Ryan Anderson at Nori. COMET-Farm Planner (pre-2019) carbon sequestration rates for utilizing grazing were listed conservatively at 0.08 st C/ac/yr for the humid/moist areas and less for dry/semiarid areas.[9]

In 2019, the Minnesota Pollution Control Agency (MPCA) published *Greenhouse Gas Reduction Potential of Agricultural Best Management Practices.* It defines rates for carbon sequestration and avoided greenhouse gas emissions from converting corn-soybean crops to: longer rotations, grasslands, utilizing winter cover crops, and other practices such as moving to no-till.[45]

Their rates assume carbon storage for up to 20 years. However, one ton of carbon sequestration must remain in storage for 52 years to offset one ton of CO_{2e} fossil fuel emissions. Thus rates are lowered by 60%, unless longer-term storage in permanent grasslands is assumed. The analysis does not include rates for carbon sequestration or avoided emissions for grazing, due to uncertainty.

When considering agriculture's potential to sequester carbon, the Land Stewardship Project recommends inclusion of MRG in continuous grassland and CLC systems that involve, for example, utilizing multi-species cover crops with no-till. A tiered approach is shown in Table 1

Nancy Matsumoto interviewed Stanley and wrote: "Many of these studies have prioritized efficiency — high-energy feed, smaller land footprint — as a way of reducing greenhouse gas emissions. The larger the animal and the shorter its life, the lower its footprint." But Stanley added, "We're learning that there are other dimensions: soil health, carbon, and landscape health. Separating them is doing us a disservice." [45]

in Appendix A, and is compared to MPCA's rates. Scenarios include acreages of marginal row crop fields (20% of Minnesota corn and soybean acreage) shifted to perennial crops, some with MRG. Cover crop adoption on 25% of the remaining higher quality corn and soybean fields is included, along with estimates for other conservation practices.

LSP's spreadsheet-based analysis (Table 2 in Appendix A) is used to calculate potential reductions in net agricultural greenhouse gas emissions compared to the baseline of 2016. Agricultural emissions, not including forests, increased from 2005 to 2016; therefore, 2016 is used as the baseline.

Table 2 includes scenarios for sequestration/avoided emissions using acreage for cover crops, conservation tillage, pastureland, and land in corn and soybeans from the 2017 U.S. Agricultural Census.[46, 47] Total grassland estimates for Minnesota are from the 2010 National Resources Inventory.[48] Estimates for land enrolled in the Conservation Reserve Program are from the Minnesota Department of Natural Resources.[49]

Reductions in net greenhouse gas emissions resulting from a shift from corn and soybeans or from continuous grazing to managed rotational grazing are shown in Figure 7, which is drawn from Tables 1 and 2.

Although farmers are improving soil health, carbon sequestration from current conservation practices is insufficient to help meet state goals.

Two scenarios using higher carbon sequestration rates already described in this section for managed rotational grazing, cover crops with no-till, and longer rotations[50] are compared to 2016 baseline agricultural emissions and current practices.

Shifts toward CLC, including MRG, on 25% of acres might achieve a 30% reduction in emissions from agriculture.

Such changes would contribute significantly to meeting the 2025 milestone, albeit perhaps in 2030 or later, for the Minnesota Next Generation Energy Act. Minnesota is currently falling behind schedule in meeting the 2025 milestone, despite advances in the energy sector.

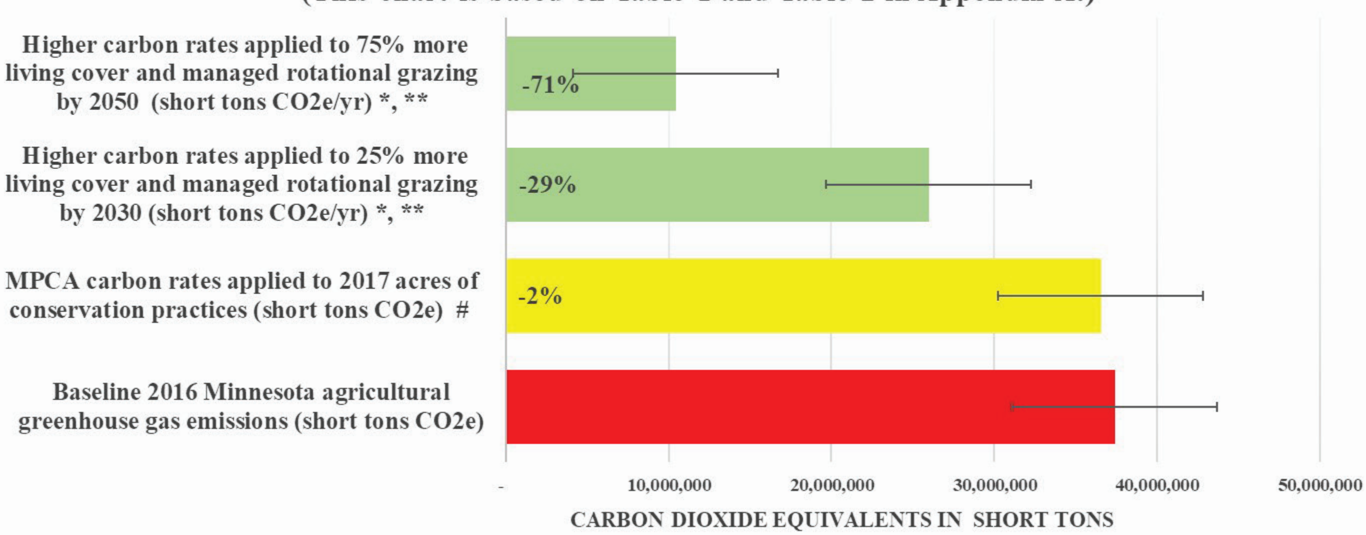
Minnesota's Next Generation Energy Act set a goal of 80% reduction in emissions by 2050. Figure 7 indicates that an 80% reduction in the agriculture sector's emissions would likely require widespread adoption of CLC and MRG systems, as well as other reductions from the sector.

LSP recommends that the Minnesota Pollution Control Agency include a second tier for higher carbon sequestration potential from continuous living cover and managed rotational grazing. We suggest convening a panel and identifying people who use and research the best managed rotational grazing and continuous living cover systems to help the agency set those rates. Further analysis with process models will be useful.

Meeting state goals will necessitate encouraging and assisting farmers to adopt the most effective soil health improving systems and keeping continuous living cover and/or managed rotational grazing in place for decades.

Figure 7: Current and potential Minnesota agricultural greenhouse gas emission and carbon sequestration scenarios for 2017, 2030 and 2050 compared to baseline.

(This chart is based on Table 1 and Table 2 in Appendix A.)



WCROC Dairy Grazing Research Involving Cover Crops & Solar Panels

Dairy scientist Brad Heins leads a team of staff and students who conduct research with the 120 certified organic dairy cattle at the University of Minnesota's West Central Research and Outreach Center (WCROC) in Morris. WCROC seeks to provide practical, innovative solutions for those looking to raise organic dairy herds on pasture. Research is conducted on forage quality, crossbreeding to find the most profitable mix on pasture, and other aspects of production. The genetic composition of the herd is 40 percent Holstein, and 60 percent crossbreds consisting of Jersey, Swedish Red, Montbéliarde, and Normande, among others. Addressing inbreeding is a growing concern in the U.S. dairy herd.

Solar shading for dairy cows is being researched to determine how cows and grass perform under solar collectors. Heins is showing it is possible to capture solar energy from collectors and grass at the same time.

In addition, a type of intermediate wheatgrass called Kernza is being studied as a good fit for potential grazing. "If we go out and clip Kernza by hand, it can improve the yields," Heins says. "Our thought was maybe we could sort of mimic that clipping with livestock and get some benefits there, as well."

As a perennial crop, Kernza can grow two to three years without any sort of tillage. That makes Kernza a potential cover crop that will hold valuable soil in place all winter long. Breeding programs through the University of Minnesota's Forever Green Initiative and the Kansas-based Land Institute have been able to increase Kernza's grain yield by 5-10 percent per year — that's an astoundingly quick pace given the use of traditional plant breeding methods.

"We've been looking at it from a 'dual-use' type system, where we can graze it, get some forage off the land for livestock, and also harvest the Kernza for grain, and maybe get some straw off the land," Heins says.[52, 53, 54]

Calculations in Climate Change and Soil Carbon

The metric system is generally used in calculating climate change scenarios. A metric ton (Mt) weighs 1,000 kilograms or 2,204.6 pounds. A gigaton (Gt) is a billion metric tons. A hectare (ha) is 2.47 acres. Carbon dioxide (CO_2) is the primary greenhouse gas. All other greenhouse gases are converted to carbon dioxide equivalents ($CO_{2\,e}$). A molecule of CO_2 contains 27.29% carbon (C). One part per million of CO_2 in the atmosphere contains 2.126 Gt of carbon.

A common metric for rate of soil carbon sequestration is metric ton of carbon per hectare, per year, or Mt C/ha/yr.

In this paper, metric units are converted to short tons of carbon per acre, per yr (st C/ac/yr): 1 Mt C/ha/yr = 0.45 st C/ac/yr.

Section IV: Managed Rotational Grazing Benefits Water Quality, Stores Water in Soil, Expands Wildlife Habitat, & Provides Support for Pollinators

"If we want soils to be more resilient to events like drought and intense rainfall, we need to regenerate organic matter. We need to take a long view and take care of our soils, making poorer soils into better soils and keeping good soils good." **— soil scientist Jerry Hatfield**

The Minnesota River Sediment Reduction Strategy called for reducing sediment loads by 50% by 2030, along with reducing the two-year annual peak water flow rates by 25% by 2030.[55] An MPCA study found that a 20% shift from row crops to perennials and cover crops, along with improved water holding capacity beyond those acres, could achieve a 40% to 60% reduction of total suspended solids in the Minnesota River Basin.[56] This is consistent with other studies.[57, 58]

The effects of integrating cover crops into row crop systems are also included in the Minnesota, Iowa, and Illinois nutrient reduction strategies.[59, 60, 61] Grazing is specifically identified as a positive land use practice in the Iowa strategy. When it comes to water quality, progress toward milestones has been slow in each state.

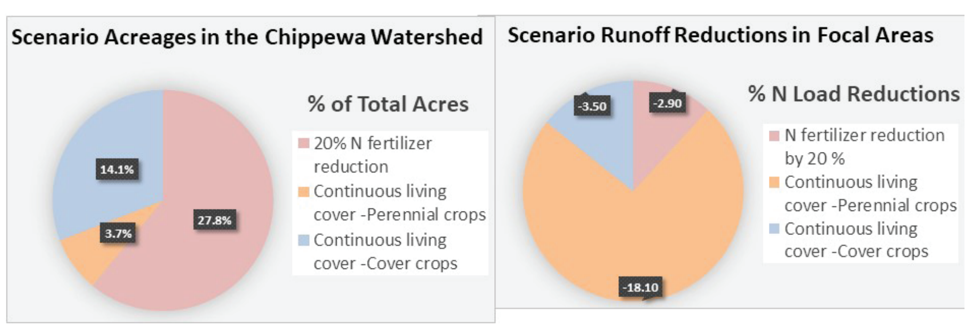
In *Beyond The Status Quo: 2015 EQB Water Policy Report*, the Minnesota Environmental Quality Board (EQB) included a goal to "Increase and Maintain Living Cover Across Watersheds." Perennial plant systems such as hay and pasture grass, cover crops, native grassland species, wetlands, forests, and reduced tillage were identified as options for increasing living cover across watersheds. Enhancing markets for grass-fed meat and dairy, along with developing markets for bioenergy from perennial crops, was one of three "Systems Change" strategies the EQB identified to achieve the goal.[62]

Monitoring & Modeling

- A monitoring analysis conducted by the Chippewa River Watershed Project and LSP for the Chippewa 10% Project (C10) predicted that a 10% increase in working lands perennials (an increase of 105,000 acres, which would total 34% of the Chippewa River watershed) might meet Minnesota state water quality standards for total suspended solids with a better economic return.[63] RESPEC adapted the MPCA's Hydrologic Simulation Program FORTRAN model to include C10 scenarios. A 3.7% shift from corn and soybeans to perennials on part of the marginal cropland might meet standards for phosphorous and achieve a third of the reduction needed for total suspended sediments, along with reducing stream nitrogen loads.[44, 64] Figure 8 shows the results of modeling that compared scenarios for reduced nitrogen fertilizer, increased perennials, and more cover crops.

- The Board of Water and Soil Resources subsequently conducted a study for the Minnesota Legislature on the use of continuous living cover on marginal land to meet water quality goals. It estimated the impacts of continuous living cover on six smaller watersheds across Minnesota. Managed rotational grazing involving grass-fed

Figure 8: Chippewa 10% Project modeling comparing reductions from shifting corn and soybean acres to perennials, cover crops, or reduced nitrogen fertilizer



From: GIS analysis by LSP; ecosystem services output coefficients from Agricultural Production Systems Simulator model run by Agricultural Research Service; and Hydrologic Simulation Program FORTRAN (HSPF) modeling by RESPEC, from citation 57.

beef, cow-calf, and contract grazing of dairy heifers was included in the modeling and economic analysis. MRG was one of the techniques that required less public support for successful establishment and implementation, according to the modeling.[65]

- A Texas study compared shifting to MRG from continuous grazing. Modeling, based on field studies, predicted a 47% reduction of surface water flow in a rangeland watershed, as well as a 5% increase in infiltration and a 29.5% decrease in streamflow.[66]

Managed rotational grazing can also reduce fecal coliform in streams compared to continuous grazing.[67] Based on this monitoring study, the Environmental Protection Agency included MRG as an approved implementation practice to address fecal coliform impairment in southeastern Minnesota.[68]

Existing state water quality programs could more fully address MRG:

- The Minnesota Agricultural Water Quality Certification Program acknowledges the benefits of building soil health on farmland. There is an opportunity through this program to promote managed rotational grazing of perennials to meet greenhouse gas reduction goals.[69]
- The water quality programs of the Minnesota Board of Water and Soil Resources should ask watershed planners to evaluate MRG as a viable option for managing perennials on a working lands basis.[52]

MRG, if planned and implemented with conservation goals in mind, can benefit wildlife habitat.[70] The Minnesota Prairie Plan calls for the support of more pasture and grazing land to buffer and manage native prairies.[71] Farmers and researchers have found increased pollinator and grassland songbird habitat on land that is exposed to managed rotational grazing.[104]

Rotating in a New Generation: Building Soil Biology Can Make Room for Perenniality, Profits & People

When Kaleb Anderson was growing up on his family's farm in southeastern Minnesota's Goodhue County, he made a vow that someday cattle would be removed from the land. Over the years, the steep hills that make up the Anderson operation suffered greatly as cattle overgrazed pastures, creating gullies and washouts.

But on a recent fall day, as he recalled this promise, Anderson laughed at the irony of his wish to ban bovines. To one side of the farmstead, an eight-acre field of sorghum and other cover crops extended above his head. He had just turned a herd of beef cows, with calves at their side, out into the field, and they were busy mowing it down. On the other side of the farmstead was a hillside pasture that was lush with the growth of perennial grasses, despite being grazed regularly. "I realize now it wasn't the cattle I didn't like, it was the management," said Anderson. Now he breaks up bigger pastures into smaller paddocks, plants cover crops, and utilizes crop rotations. This is building the kind of soil health that this land hasn't seen since before Anderson's grandfather got a good deal on a rundown farm in 1945.

Kaleb Anderson in a cover-cropped field he recently turned cattle out into. "I have no interest in just sustaining this farm," he says. "I want to regenerate it." (*LSP Photo*)

It turns out managing livestock in a way that the landscape benefits has provided Kaleb an opening into agriculture as well. On this fall day, the Anderson farm was one stop on a Land Stewardship Project Soil Builders' Network field tour that was showcasing how building biology not only protects and improves the soil, but injects a little human resiliency into communities by providing an entry for beginning farmers wishing to return to the land.

During his stop on the tour, Anderson showed how he is using a combination of cover cropping and rotational grazing to build soil organic matter. Organic matter drives soil's water-retention capacity, structure and fertility. Anderson made it clear he feels it also drives his farm's profitability. "I believe that there's a direct relationship between farm profitability and your available soil organic matter," he said. "It's an investment in the soil that will pay me dividends every year."[105]

Section V: Economic Barriers to Adoption of Managed Rotational Grazing/Continuous Living Cover & Emerging Policy Opportunities

To address climate change, simply implementing more conservation practice-by-practice — what we've done for the past 50 years — won't be adequate. We need research into how to include MRG and CLC in climate change and soil health proposals, along with added technical and financial assistance for innovative farmers, and payments for ecosystem services.

Given the tough economic environment farmers face today, it is important to relieve some of the risk involved with shifting out of the dominant system of raising annual row crops for feed and continuously grazing pastures. Managed rotational grazing as part of a strategy for integrating crops and livestock requires capital investment, new skills, and knowledge.

While MRG/CLC can reduce ecological and financial risk, conservation and financial risk management programs and markets are less robust for integrated crop and livestock systems, and farmers know that. In order to effectively support beginning and small- to medium-sized farmers, public payments should be higher for initial increments of production or environmental services, declining for additional increments, and total payments should be capped. In addition to needs identified in this paper, there are several areas of opportunity to advance CLC and MRG.

A. Research to advance climate friendly farming systems

Research needs to include an examination of the performance of different livestock breeds on a pasture-based diet, as well as measurements of soil carbon and methane emissions with improved diets, grazing under solar collectors, and developing (through the Forever Green Initiative at the University of Minnesota) new cultivars for forage and continuous living cover systems. Effective strategies to develop new markets for CLC should be included in research. Integrating farmer/rancher knowledge, experience and experimentation with MRG and CLC systems will advance research faster.

B. Green New Deal, Carbon Fee and Dividend focused on climate change

The Green New Deal "calls on the federal government to wean the United States from fossil fuels and curb planet-warming greenhouse gas emissions across the economy. It also aims to guarantee new high-paying jobs in clean energy industries."[72] Achieving these outcomes requires conditions that enable more small- and medium-sized farmers or ranchers, including beginning farmers, women, people of color, veterans, and Indian tribal members, to raise crops and livestock on the land in diverse farming systems.

A "carbon fee and dividend" has been proposed in bipartisan legislation introduced in 2019 and advocated by Citizens' Climate Lobby. The proposal says: "To account for the cost of burning fossil fuels, we propose an initial fee of $15/metric ton on the CO2 equivalent emissions of fossil fuels, escalating by $10/metric ton each year, imposed upstream — as near as feasible to the mine, well, or port of entry." This could have the effect of creating a level playing field for energy sources. " …100% of the net fees from the carbon fee are held in a Carbon Fees Trust fund and returned directly to households as a monthly dividend," according to the proposal.[73] MRG and CLC, in conjunction with reduced tillage, need to be understood as ways to help reduce agricultural greenhouse gas emissions. However, waiving fees for fossil fuel-based emissions produced by agriculture, or incentives that disadvantage MRG and CLC, would further retard adoption of soil health building systems.

A different strategy being followed in Australia is a system for carbon payments that involves measurement and a market that pays for certain conservation practices.[74] Eligible carbon payments for crop and livestock systems include:

- Controlling herd movements.
- Providing feed supplements that reduce enteric emissions.
- Culling inefficient cows.
- Changing the timing, intensity, stocking rate, and duration of grazing to maximize pasture land quality.
- Converting from agricultural cropping to grazed pasture.[75]
- Other practices and systems.

California has both emissions controls and a soil health-building program.[71]

The American Carbon Registry (ACR) protocols include livestock management and grazing land, but they have not been implemented. Eligible ACR protocols include reducing fossil fuel usage, enteric methane emissions, nitrogen fertilizer use, and manure methane emissions, as well as increasing carbon sequestration in soils associated with grazing land management.[76] The ACR allows credits to be generated from adding compost to grazing lands and provides credits for the avoided conversion of grassland to crops. Rates are based on COMET-Farm values for carbon sequestration.

Private markets for ecosystem services — such as INDIGO Ag — expect to pay \$15 to \$20 per ton of CO_{2e} at the expected sequestration rate of 2 to 3 tons CO_{2e}/acre for grain production.[77] An Ecosystem Services Market Consortium (ESMC) is being formed by 11 private-sector companies and nonprofits.[78] It is not yet clear what the measurement tools will be, how continuous living cover is treated, or if managed rotational grazing will be one of the Consortium's recognized systems. On the other hand, Nori is building a marketplace that is transparent with predicted rates based on COMET-Farm.[79]

C. Existing conservation and other risk management programs should be enhanced to prioritize soil health-building

Multiple federal and Minnesota conservation programs could be enhanced via more technical assistance and cost-share support for managed rotational grazing technology such as improved fencing, watering, and shade systems. These programs could also support integrating into row cropping systems summer annual crops and other continuous living covers.

Although managed rotational grazing can help improve profitability by lowering costs, it is tough for farmers to make the transition when farm gate prices are so low. A South Dakota survey found that ranchers not using MRG may not perceive benefits for increased stocking rates.[80] In a 2014 modeling study, a risk-neutral beef producer would have needed a market or insurance premium of \$22.92-\$79.84 per animal, or \$32.43-\$132.96 an acre, to justify switching from rotational or continuous grazing to "mob grazing" (mob grazing is a MRG system that utilizes high stocking densities).[81]

"The biggest limitation to date is the general lack of understanding of the requirements and complexity of grass-based systems. These (MRG dairy) systems are not cow-focused but grass-focused and require a different skill set. Over time, farmers and the farm extension services have focused on the cow, and whole systems and support have been developed around them. This includes the commercial support systems like farm advisory, feed, machinery and genetics companies. For successful growth of this segment, the knowledge base needs to be re-established at both the farm and advisory level," writes Peter van Elzakker in *Progressive Dairy*.[82]

Under normal weather conditions, cover crops have a net per-acre return of roughly \$18 and \$10 on corn and soybean fields, respectively, by the fifth year. Grazing cover crops brings immediate benefits — averaging \$40 per acre, per year, from reduced fertilizer and chemical use, plus the forage value produced by the cover crop.[84]

Complicating the picture for farmers is that much land is rented. About 50% of Iowa's cropland is rented out by landowners; it can be as high as 80% in some areas of the country. Landowners have often pressed their renters for top rates on one-year rentals.[86] This can limit investment in long-term soil building methods such as cover cropping.

The Land Stewardship Project has learned through conversations that neither landowners nor the operators they rent to necessarily understand the value of managed rotational grazing or cover cropping for soil building. Both may be concerned about lack of infrastructure and who will finance it. They may also be worried about liability.

It's good news that some landowners are beginning to shift their thinking and engage their renters in a different conversation that includes discussions about soil building and sometimes managed rotational grazing (for an example, see Mark Erickson's story on page 3). Robust organizing through individual visits, peer learning networks, conservation agencies, workshops, and media outreach is needed to engage farmers and landowners about soil health. The Land Stewardship Project's *Conservation Leases Toolkit* provides helpful resources for landowners who want soil health to play a major part in how their land is managed.[107]

D. Market changes needed

Concentrated markets mean farmers face higher costs for their inputs and lower prices for their goods. In the 1980s, 37 cents out of every dollar went back to the farmer. In 2017, farmers took home less than 15 cents on every dollar.[87] The technological treadmill of input use binds farmers to expensive technology, and they experience increasing costs of production as a result.

Dollars leave rural communities in the form of excessive profits for multinational agribusiness corporations.

A dairy farmer wrote in response to an LSP survey that in 1979 he received \$17 per hundredweight of milk and in 2018 it was \$15, while land went from \$500 per acre to \$5,000 per acre. He asked: "What other occupation pays less now than 39 years ago?"

This "…economic reality forces farmers to survive on volume, creating a system where only the largest farms can make a living." Government payments for commodities make up an increasing percentage of total income and are costly to taxpayers.[88]

Mega-sized confined livestock operations overproduce and push out smaller-scale producers. Nationwide, 64,000 dairy farms with fewer than 200 cows have stopped doing business since 2000, while factory farms with more than 1,000 cows increased 109%, and those with over 2,000 cows increased by 268%.[89] There are a growing number of mega-factory farms — organic and conventional — that house 10,000 or more cows.

However, Maine developed a program that protects smaller-scale producers by paying more for the first increment of milk production.[90] The National Farmers Organization and Wisconsin and Minnesota Farmers Unions have proposals based on that concept.

Support for small- and medium-sized dairy producers was provided through the 2018 Farm Bill's Dairy Margin Coverage Program and the Minnesota Dairy Assistance, Investment, and Relief Initiative (DAIRI), as well as the Agri Livestock Investment Grant programs. However, USDA and Minnesota state-level programs require deeper structural changes to more fully support smaller-scale producers.

Additional issues include:

- Meatpacking is concentrated at unprecedented levels. "Four companies, two of which are foreign-owned, now slaughter 52 percent of all meat consumed in the U.S."[59]
- The importation of grass-fed beef as a "Product of the USA" is taking market share from grass-fed production in the U.S. — 75% to 80% of grass-fed meat sold in the U.S. is now imported from Australia, New Zealand, and South America, according to Allen Williams.[91] This is a drastic change that occurred since Country of Origin Labeling (COOL) was eliminated in the U.S. This has climate change ramifications — a study found the natural capital costs of Brazilian beef to be highest, due to land conversion.[92] The American Grass-fed Association and other certifiers have asked the USDA to stop the mislabeling of imported beef as a U.S. product.
- Since grass-fed products command a high premium in the marketplace, there is a temptation on the part of large industry players to circumvent the regenerative benefits of animals grazing on pastures by feeding grass pellets in confinement.[93, 94, 95]
- Strict enforcement of the Packers and Stockyards Act is needed.

As a result of public investment in the Forever Green Initiative by the federal government, foundations, the state of Minnesota, and private companies, Kernza's practical potential to produce grain, forage, and ecosystem services in corn country is emerging. *(LSP Photo)*

E. Pay for multiple ecosystem services, including carbon sequestration, within a true cost accounting framework

The passage of an amendment to the Minnesota Constitution in 2008 that directs tax money toward paying for improved water quality and wildlife habitat, along with arts and culture activities, indicates people's willingness to pay for public conservation benefits. However, progress towards greatly improved water quality is slow and we need new approaches.[96] The public costs of the current system, such as flooding and water quality impairments, are not internalized into dominant farming systems. Farmers or landowners generally do not receive a market benefit for lessening those public costs, which constitutes a type of market failure.[56]

Organic, grass-fed, humane, and fair-trade markets have paid for more of the true costs, enabling farmers to make investments in CLC and MRG, as well as organic systems. True cost approaches need to be applied broadly.

Research to support policy instruments is occurring through an initiative called, "The Economics of Ecosystems and Biodiversity for Agriculture & Food (TEEBAgriFood)." 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 also valued.[97]

In the U.S., a concrete application of a true cost accounting system that monetizes negative externalities and public benefits is the Genuine Progress Indicator. It has been developed and tracked for Maryland and other states.[98] A proposal to advance such a system was introduced in the Minnesota Legislature.[99]

A "Payments for Ecosystem Services" program based on true costs could account for net gains or reductions of greenhouse gas emissions from baseline conditions. Public payments for carbon emission or sequestration should be developed in ways that benefit small- and medium-sized farmers, as well as communities and the landscape.

Payments for commodity crops spur farms to grow bigger as production increases, input costs rise, and market prices waiver.[61] Shifts in commodity crop payments to a system of supply management may be necessary.

Another policy option is a state-based soil health program. Several states have developed state soil health programs, task forces, or other efforts to incentivize soil health building systems.[100] The Izaak Walton League of America has documented states that have soil health programs or are considering them.[101] The Soil Health Institute has documented many academic, state agency, and legislative soil health initiatives on its website: http://bit.ly/SHIcatalog.

APPENDICES

A. Tables on Carbon Sequestration & Minnesota Agriculture

(Two tables which were referred to in Section III are shown in this appendix)

Table 1: MN Agricultural Greenhouse Gas Reduction Potential by 2030 Under Different Scenarios if Continuous Living Cover and Managed Rotational Grazing Were Adopted More Widely

		MPCA/EQB Rate Scenario			High Carbon Rate Scenario		
CLC &MRG Scenarios	**Acreage for increased CLC & MRG**	**CO2e sequestered (short tons/ acre/yr.)^**	**GHG emissions (short tons/ acre/yr.)^**	**Net GHG reductions compared to corn & soybeans (short tons/ yr.)**	**CO2e sequestered (short tons/ acre/yr.)◆**	**CO2e sequestered (short tons/acre/ yr.)* ***	**GHG emissions (short tons/ yr.)**
Corn-soybean acres include cover crop and no-till on 25% of good land	3,186,603	- 0.20	- 0.00	(652,425)	- 0.80	- 0.10	(2,872,783)
Longer crop rotation on 50% of marginal corn or soybean fields*	1,593,301	- 0.32	- 0.17	(791,632)	- 0.40	- 0.10	(795,395)
Set-aside for filter strips, habitat or other programs on 30% of marginal row crop land* #	796,651	- 0.78	- 0.84	(1,293,848)	- 0.78	- 0.84	(1,293,848)
Managed rotational grazing on 25% of marginal corn-soybean fields with cover crops and no-till*	796,651	- 0.38	0.06	(417,680)	- 0.59	- 0.04	(1,140,456)
Managed rotational grazing on 25% of 1,073,788 acres of pastures plus 25% of 2.6 million acres of grasslands +	1,183,186	- 1.68	0.06	(1,920,628)	- 5.92	0.74	(6,124,988)
Total				**(5,076,213)**			**(12,227,471)**
MN 2016 cropland and livestock emissions ++				(37,387,382)			37,387,382
% reduction				**14%**			**33%**

Footnotes

*Assuming 20% of 15,933,013 acres of corn and soybeans from 2017 Ag Census are marginal economically and environmentally for row crop production with substantial negative externalities, citation 46

+ Pasture acreage from 2017 Census of Agriculture, citation 46; overall pastureland from 2010 NRI, citation 48; CRP acres from DNR, citation 49

Highest cost to the public and removes land from production of food or energy crops

^ All From Ciborowski, citation 45; except pasture from Center for Climate Strategies 2016, citation 44; the MPCA assumes 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

◆ Olson et al., citation 34 for cover crops; Project Drawdown citation 50 for longer rotations; Stanley et al., citation for 6 for MRG sequestration; Ciborowski, citation 45 for set-aside; MPCA reductions of rates to 40% are used for cover crops and long-term rotations

* * Rates are from Project Drawdown, citation 38 for cover crop avoided emissions and citation 50 for long rotation; Rowntree et al., citation 30 for MRG greenhouse gas emissions/acre for MRG cattle; Ciborowski, citation 45 for set-aside; MPCA reductions to 40% are used for higher carbon 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; it is assumed that half the cattle on pastureland are not additional, so do not contribute new emissions above the baseline and half are additional cattle needed to achieve higher stocking densities in multi-paddock MRG systems that lead to greater sequestration and increase emissions per acre, according to Rowntree et al., citation 30

+ + Minnesota agricultural greenhouse gas emissions from MPCA, citation 9.

Table 2: Current and Potential Minnesota Agricultural Greenhouse Gas Emissions by 2030 and 2050 with Three Scenarios Compared to Baseline 2016 and 2017 Acres in Conservation

Agricultural System-Shift from corn/soybean acres to:	2017 Conservation Acres	Baseline 2016 Minnesota agricultural greenhouse gas emissions (short tons CO2e)	MPCA carbon rates applied to 2017 acres of conservation practices (short tons CO2e/yr) #	Higher carbon rates applied to 25% more living cover and managed rotational grazing by 2030 (short tons CO2e/yr) *, **	Higher carbon rates applied to 75% more living cover and managed rotational grazing by 2050 (short tons CO2e/yr) *, **
Cover crops without no-till	579,147		(115,829)	(115,829)	(115,829)
No-till without cover crops	1,091,337		(260,633)	(260,633)	(260,633)
Cover crops with no-till	579,147			(2,428,712)	(7,286,135)
Managed rotational grazing +	520,100		(101,420)	(6,280,017)	(16,949,668)
Perennial in rotation estimate	350,000		(173,898)	(794,642)	(794,642)
BWSR conservation practices	500,000		(330,000)	(330,000)	(330,000)
Buffers or grasslands				(1,293,848)	(1,293,848)
MN Ag Water Quality Certification/NRCS ++	450,696		(297,459)	(297,459)	(297,459)
Sub-total of net reduced emissions			*(1,279,239)*	*(11,801,141)*	*(27,328,216)*
Total ag emissions		37,387,382	***36,484,606***	**25,962,703**	**10,435,628**
Percent reduction from baseline			**-2%**	**-29%**	**-71%**

Footnotes

For current practices assume net zero sequestration on land due to effects of erosion on fields without no-till, CLC or MRG--Teague et al, citation 5.

* Assuming 20% of 15,933,013 corn and soybean acres in 2017 from 2017 Ag Census, citation 46; are marginal economically and environmentally for row crop production with substantial negative externalities based on Basso et al., citation 6

+ Pasture acreage from 2017 Census of Agriculture, citation 46; overall pastureland from 2010 NRI, citation 48; CRP acres from DNR, citation 49

++ Minnesota Agricultural Water Quality Certification Program from Minnesota Department of Agriculture, citation 43

** 20% of additional CLC and MRG acres are assumed to sequester at MPCA rates from Table 1 and 70% at higher tier carbon sequestration rates from Table 1 for these scenarios

B. People & Groups with Expertise in Managed Rotational Grazing & Continuous Living Cover

The following are people or groups with research and practical experience in using and tracking the carbon sequestration potential of managed rotational grazing systems and continuous living cover. The Land Stewardship Project recommends they be invited to participate in a workshop to set high carbon rates for managed rotational grazing and continuous living cover systems.

• **Farmers** who use continuous living cover and managed rotational grazing with multiple paddocks: Kaleb Anderson, Dawn and Grant Breitkreutz, Tom Cotter, Mark Erickson, Jennifer and Mike Rupprecht, Bryan Simon, Kent Solberg, and Jim Wulf.

• **Organizations** that host education on managed rotational grazing and continuous living cover include the Land Stewardship Project, Practical Farmers of Iowa, New England Organic Farming Association, Sustainable Farming Association of Minnesota, Wallace Center's Pasture Project, and Minnesota Cattlemen's chapters.

• **Researchers and federal agency invitees** should include Steven Apfelbaum (Center for Humans and Nature, research on high stocking density, multi-paddock managed rotational grazing systems), Anna Cates (Board of Water and Soil Resources/University of Minnesota Soil Health Specialist), Adam Chambers (Natural Resources Conservation Service-Colorado researcher modeling greenhouse gas emission reductions from agriculture), Peter Ciborowski (Minnesota Pollution Control Agency lead on assigning greenhouse gas reduction estimates for agriculture practices), Richard Conant (Colorado State University-Natural Resource Ecology), Troy Daniell (Natural Resources Conservation Service State Conservationist-Minnesota), Marcia DeLonge (Union of Concerned Scientists-USA scientist working on soil health and climate change), Jeff Duchene (Natural Resources Conservation Service Grazing Specialist-Minnesota), Alan Franzluebbers (USDA Agricultural Research Service managed rotational grazing researcher), Jerry Hatfield (USDA Agricultural Research Service, Director of the National Center for Agriculture and Environment), Elaine Ingham (Soil microbiology consultant), Laura Jackson (University of Northern Iowa prairie research), Randy Jackson (University of Wisconsin-Madison Director of Pasture Grazing 2.0), Matt Liebman (Iowa State University researcher on continuous living cover systems), Kristin Nichols (consultant), Keith Paustian (Colorado State University climate and natural resources researcher), Phil Robertson (Michigan State University Kellogg Field Biological Station researcher on continuous living cover and managed rotational grazing), Jason Rowntree (Michigan State University Lake City Research Station researcher using managed rotational grazing with multiple paddocks and high stocking density in adaptive multi-paddock grazing systems), Alan Rotz (USDA Agricultural Research Service researcher on dairy grazing systems), Whendee Silver (University of California-Berkeley researcher on compost and use in rangeland grazing), Lance Smith (Natural Resources Conservation Service Grazing Specialist for Minnesota), Paige Stanley (University of California-Berkeley graduate student working on adaptive multi-paddock grazing who led a study in Michigan), Richard Teague (Texas A & M researcher on adaptive multi-paddock grazing), Sharon Weyers (USDA Agricultural Research Service soil scientist working with farmers using cover crops and managed rotational grazing), Tong Wang (South Dakota State University economist working with farmers and researchers on cover crops and adaptive multi-paddock grazing), and Allen Williams (consultant with the Pasture Project working on adaptive multi-paddock grazing).

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