Biological Carbon Capture Solutions

for Resilient Natural and Working Lands in North Dakota

2022

The Nature Conservancy

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Acknowledgments

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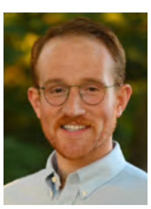

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Natural and working lands, like this cattle grazing land, can offset 31% of North Dakota's carbon emissions and help the state reach its carbon neutrality goals. © Mark Godfrey/TNC

EXECUTIVE SUMMARY

North Dakota's farmers, ranchers, and other resource managers can help sequester an estimated 31% of the state's 2018 carbon emissions by implementing biological carbon capture solutions on their lands. These solutions will also make their operations more resilient to extreme weather events.

As a longtime leading producer in the nation's energy sector, North Dakota is poised to continue that leadership in the growing low-carbon economy. In addition to new innovations in energy and carbon capture technologies, there are biological solutions—the same ones that maintain healthy lands, waters and air—that we can use to sequester carbon across the state.

North Dakota has clear opportunities to make progress toward carbon neutrality.[2] While conversations about innovative low-carbon energy resources and geologic carbon capture continue to develop, North Dakota can make immediate strides using biological carbon capture solutions.

Through biological carbon capture, ranchers and farmers can lead the way in bringing carbon-neutral strategies to scale. Our analysis shows that biological carbon capture solutions can reduce North Dakota's state greenhouse gas emissions by about 27 million metric tons per year—nearly a third of the state's 2018 emissions of approximately 86 million metric tons of CO_2 equivalents.

As described in this report and summarized in Figure ES-1, these solutions can bring a significant carbon benefit to North Dakota through the capacity of working agricultural and other lands.

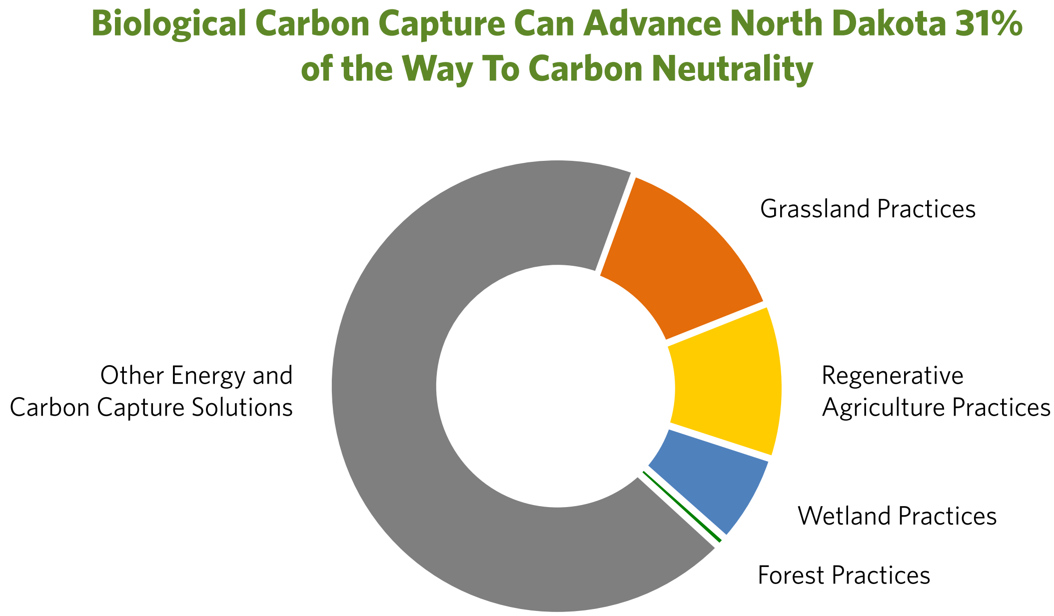


Figure ES-1. Biological carbon capture practices on grasslands, agricultural lands, wetlands and forests can reduce or offset approximately 31% of North Dakota's greenhouse gas emissions, which would complement other energy and carbon capture solutions to reach carbon neutrality.

In addition to sequestering carbon, the biological carbon capture solutions outlined in this report also create opportunities to make North Dakotans more resilient to extreme weather events like flooding and drought. For instance, some of the sustainable agricultural practices described here will reduce soil erosion, increase water infiltration and water retention, and support consistent land productivity.[3]

For biological carbon capture solutions to reach their full potential, protect our communities and reduce the impact of extreme weather events, North Dakota should begin implementing them now. These opportunities require sufficient funding and added capacity to implement successfully due to the upfront investment needed to drive practices at such scale. State policy, agency action, private sector innovation, philanthropic support and individual action will all play a significant role in achieving our carbon potential.

This report is intended to share a high-level picture of the biological carbon capture solutions available in the state of North Dakota. The authors emphasize that the numbers shared are not final but represent our best current estimate of the opportunity. Ongoing research and additional studies in the coming years will certainly be needed to refine these estimates and will need to be considered as they become available.

In addition, although the authors acknowledge the immense impact that carbon markets may have on biological carbon capture solutions in North Dakota, the nation and the globe, access to and impacts of carbon markets are beyond the scope of this work.

North Dakota is poised to continue its leadership in the energy sector while adapting to a carbon-constrained world. © Richard Hamilton Smith.

NORTH DAKOTA'S CARBON LANDSCAPE

North Dakota's carbon landscape is changing. As it works to become carbon-neutral by 2030, North Dakota is poised to cement its role as an American carbon leader within the next decade.

Realizing this potential will require forward-looking innovations and solutions for carbon management. This report focuses on opportunities for scaling an underutilized solution—biological carbon capture—to complement existing efforts such as sustainable energy and carbon capture, utilization and storage.

More than half of North Dakota's 94 million tons of CO_2 emissions (94 million tons are equal to about 86 million metric tons or MMT, which is the unit we use in this report) come from two sources that are core to North Dakota's economy: energy production and agriculture.[4] As a leading energy producer for the nation, the state produces energy ranging from oil and natural gas from the Bakken Formation to electricity derived from wind. North Dakota's plentiful coal reserves support local coal-fired power plants accounting for over half of North Dakota's electricity generation—and surplus electricity generation allows North Dakota to export electricity to surrounding states.[5] North Dakota is also a top-10 ethanol producing state for the United States.[6]

The fossil fuel and agriculture sectors are cornerstones of North Dakota's economy, but they are also carbon intensive. Products like ethanol, coal-powered electricity and fertilizer lead to significant greenhouse gas emissions. While approximately 33% (31.3 Mt or 28.4 MMT CO_2e[i]) of North Dakota's emissions come from the heating and electricity sectors, the agriculture sector also accounts for 22% of emissions (20.6 Mt or 18.7 MMT CO_2e).[7] North Dakota's highest-emitting sectors are depicted in Figure 1.

Despite high current emissions, North Dakota's industries are already adapting in a carbon-constrained world, and the creation of the Clean Sustainable Energy Authority in 2021 demonstrated lawmakers' commitment to invest in the future of sustainable energy. New carbon capture and carbon pipeline[9] technologies are under discussion and development, but exploring additional carbon-related opportunities will be essential to continue supporting local economies and to reach the carbon neutrality goals envisioned by state leaders.[10] The state need not look far for effective carbon management tools: working lands can sequester enough carbon to achieve 31% of net neutrality for North Dakota.

North Dakota's industries are already adapting in a carbon-constrained world.

A Carbon Neutral Vision for 2030

In 2021, Gov. Doug Burgum announced a vision for North Dakota to reach carbon neutrality by 2030. This vision focused on opportunities to maintain North Dakota's economic leadership in the energy and agriculture sectors while exploring opportunities for carbon capture and storage technologies.[11]

The carbon neutrality goal envisioned by Gov. Burgum paves the way for ambitious action that prioritizes innovation over regulation. However, North Dakota will need a combination of state and private efforts to reach this goal and accelerate already widespread innovation and investment in carbon management opportunities across the state. To achieve these carbon goals, North Dakota needs to take decisive action through three key opportunities, as outlined on the following page.

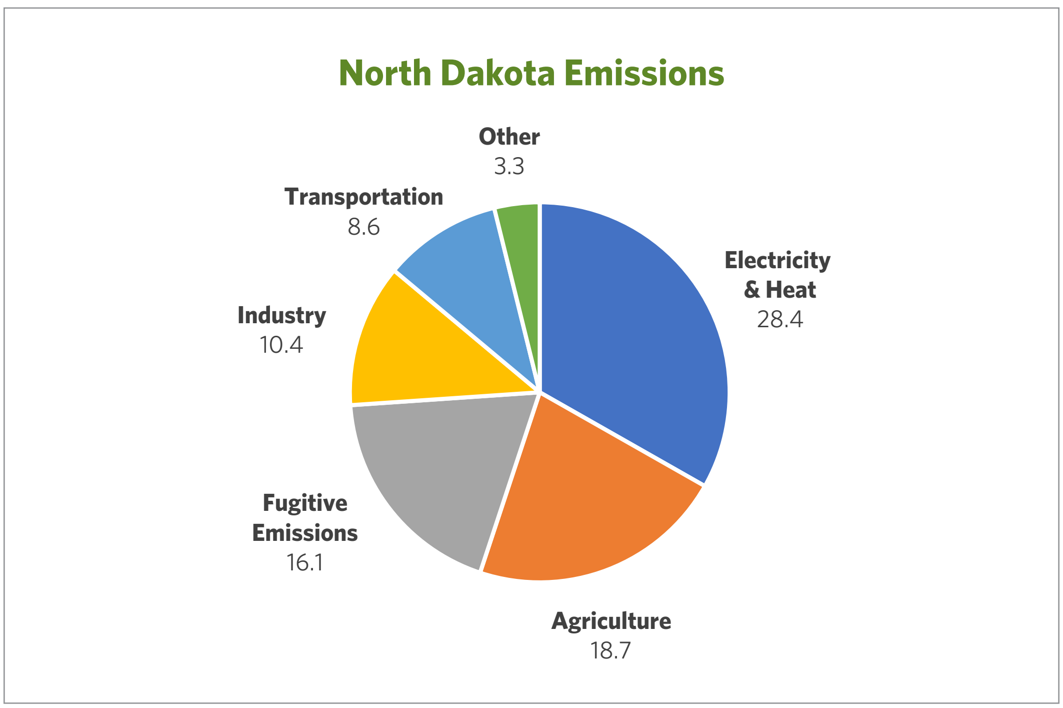


Figure 1. North Dakota emissions sources in million metric tons (MMT) CO_2e, as of 2018.[ii,8]

[i] Mt CO_2e refers to million tons (Mt) of carbon dioxide (CO_2) "equivalents." This unit is used to normalize different types of greenhouse gases compared to the impact of one metric ton of CO_2 in the atmosphere. In this report, million tons (Mt) are differentiated from million metric tons (MMT).

[ii] In this figure, the term 'fugitive emissions' refers to leaks or other non-productive releases of gas. Natural gas flaring is a visible form of fugitive emission, but many other sources—such as gas venting, pipeline leaks and emissions from coal mines—also contribute.

- **Investing in Biological Carbon Capture** will enable decarbonization through biological means, most commonly through photosynthesis. Through biological carbon capture, working lands—including grazing land and crop land—can capture and store carbon in plant biomass and in the soil in a manner that is compatible with economic production. North Dakota farmers and ranchers are critical partners in biological carbon capture, and these land managers may be able to diversify their revenue by taking on biological carbon capture projects.[iii] Current science suggests that biological carbon capture can offset 31% of North Dakota's 2018 emissions.
- **Transitioning to Sustainable Energy** is an important step to reduce the carbon emissions associated with coal, natural gas, fuel oil and transportation fuels. North Dakota lawmakers have already taken an important step by creating the Clean Sustainable Energy Authority and associated fund to invest in all types of cleaner energy, including renewable energy production. The ongoing expansion of renewable energy underscores the importance of responsibly siting these projects in low-impact areas to conserve wildlife habitat.
- **Continuing Innovation on Technological Carbon Capture, Utilization and Storage** is needed to remove carbon directly from the air or directly at emissions sources and store it, reducing total atmospheric accumulation. Although most carbon capture utilization and storage (CCUS) technologies are still being developed and have not been widely deployed, North Dakota's industries are already leading innovative trials. Compared with most geographies, North Dakota has exceptional capacity for underground carbon storage. Although federal and state funding opportunities are increasingly available, technological CCUS solutions tend to be significantly more expensive than their biological counterparts and may face an economic barrier to their widespread adoption. In many cases, there may also be a significant barrier in securing necessary easements for pipelines and other infrastructure that have a footprint on privately owned land.

North Dakota is making strides toward a carbon-neutral future by investing in sustainable energy production and CCUS development. These advances are more effective when paired with other opportunities for carbon sequestration—fueled by biological carbon capture. Biological carbon capture is cost-effective and can be implemented immediately, making it a critical investment to meet the state's 2030 vision. Public and private investment in biological carbon capture will also generate positive externalities for farmers, ranchers, sportsmen and communities around the state: benefits that range from water quality to wildlife habitat to soil health.

Implementing new management practices can help farmers increase nutrients and resilience on their crop lands. © Harlan Persinger

[iii] This report focuses on the opportunity for biological carbon capture and does not explore the reality of financial mechanisms such as carbon markets. Carbon markets, especially for land-based practices, continue to evolve rapidly and deserve further discussion.

Regenerative agricultural practices by farmers and ranchers, like cover cropping and rotational grazing, can store more carbon in the land while improving efficiencies for producers. © Jason Whalen/Fauna Creative

BIOLOGICAL CARBON CAPTURE

Biological carbon capture includes the conservation, restoration and improved land management practices that increase carbon storage or avoid greenhouse gas emissions in landscapes and wetlands across the globe.

Biological carbon capture takes advantage of biological mechanisms through which earth systems process and store carbon and other harmful gases.

For instance, many of the sustainable agricultural practices long used by farmers absorb and store carbon dioxide in productive soils. Biological carbon capture practices like cover cropping, reduced tillage and rotational grazing reduce carbon emissions in an environmentally friendly and economically beneficial manner. These management practices also improve efficiencies for agricultural producers and can even increase yields.

Grasslands—one of North Dakota's richest and most resilient ecological systems—store carbon in native plants and root systems deep in the soil, preventing it from being released into the atmosphere.[12] The effective management of grazing lands is key to maximizing the potential of North Dakota's grasslands. The use of sustainable grazing practices can allow grasslands to thrive and store carbon and other nutrients while also enabling ranchers to thrive and support an important industry.[iv]

[iv] One story of regenerative grazing success is available at https://www.nature.org/en-us/about-us/where-we-work/united-states/north-dakota/stories-in-north-dakota/sustainable-cattle-ranch/

This report estimates the carbon potential of biological carbon capture based on the best currently available data, starting with many of the estimates provided in Fargione et al. (2018).[13] These estimates indicate that biological carbon capture could sequester up to 27 MMT CO_2e/year (or 29.6 Mt), offsetting 31% of North Dakota's 2018 emissions. For comparison, many of the world's largest carbon capture projects are estimated to store about 1 Mt of CO_2e/year, meaning North Dakota's natural and working lands might be able to sequester as much as 30 such facilities, with less technical complication and much lower expense.[14] However, many of the data referenced within this report are regional or national in nature; important ongoing research efforts, such as one led by the North Dakota Natural Resources Trust focused on biological carbon capture in western North Dakota and supported by the North Dakota Outdoor Heritage Fund and the North Dakota Oil and Gas Research Council, will refine estimates of carbon storage potential in the future.

As indicated in Figure 2, the biological carbon capture practices with the highest opportunity for carbon storage in North Dakota include grassland and agriculture strategies. The top three opportunities are:

Biological carbon capture could offset 31% of North Dakota's 2018 emissions.

1. **Avoided Conversion** (8.77 MMT CO_2e/yr potential). Keeping grasslands and wetlands in their natural state instead of converting them to other purposes is an important practice for maintaining the significant carbon stocks currently stored in those ecosystems. Intact, healthy landscapes usually hold large amounts of carbon. Upon conversion, grasslands and wetlands release approximately 60 and 105 metric tonnes of CO_2e per acre, respectively, although these figures vary across geography and soil type (see Appendix B). Conservatively assuming the status quo conversion of about 70,000 acres of grasslands and 20,000 acres of wetlands per year, immense amounts of carbon can be retained on the landscape by avoiding this annual conversion (see Appendix C for additional detail).

2. **Grassland Restoration** (7.37 MMT CO_2e/yr potential). Grassland restoration enables additional carbon storage in soil and plant biomass when land previously converted for other uses is returned to a perennial grassland

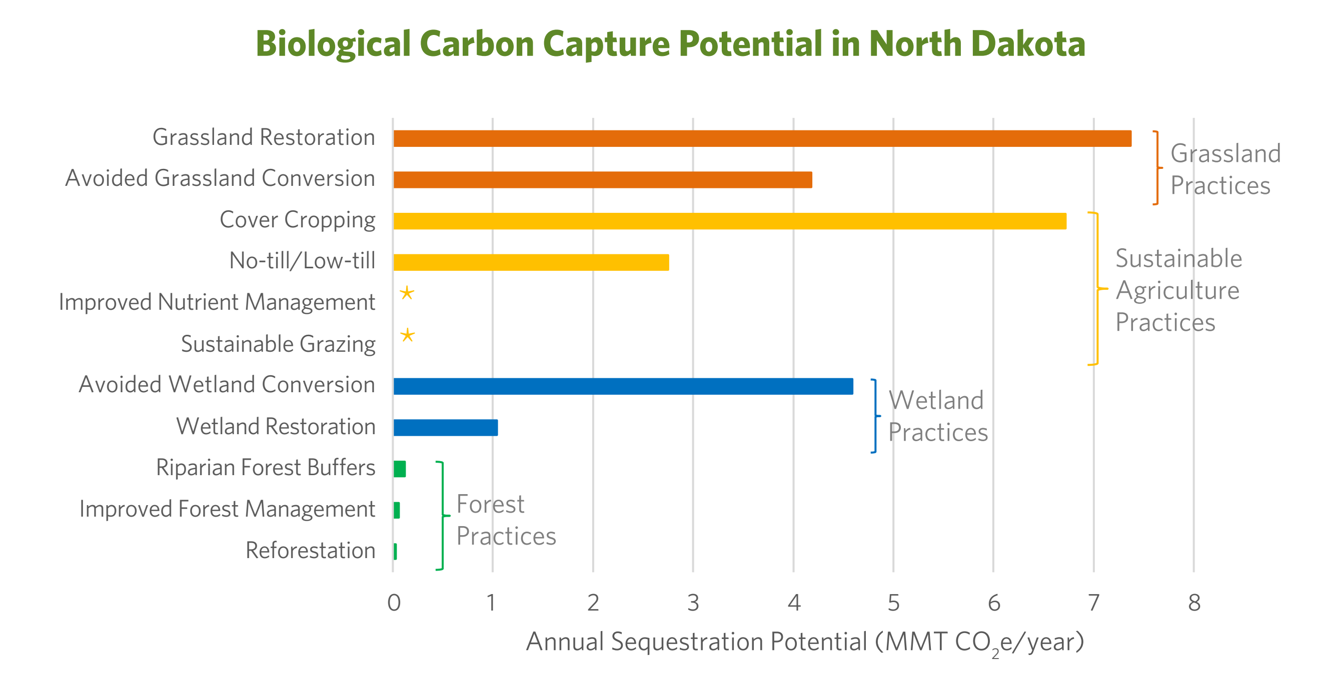


Figure 2. Biological carbon capture offers 27 million metric tonnes CO_2e/year carbon potential in North Dakota, with the largest opportunities in grassland and agricultural landscapes.
**This figure excludes the opportunity for emissions reduction via improved nutrient management and sustainable grazing, which are not quantified in this report.*

state.[15] This potential assumes that approximately three million acres of the total 22 million acres of converted grasslands are candidates for restoration efforts (see Appendix C for additional detail).[16]

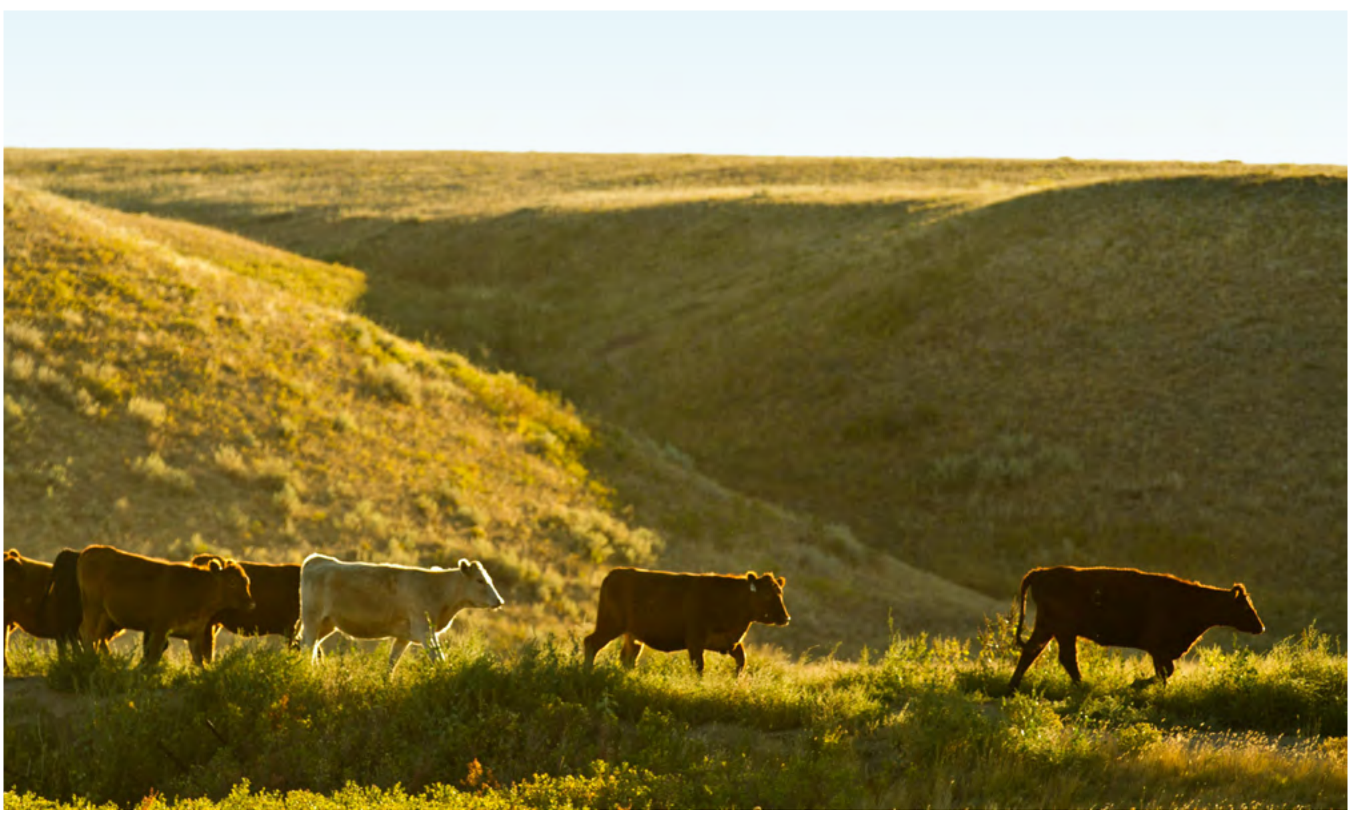
3. **Cover Cropping** (6.72 MMT CO_2e/yr potential). Cover cropping provides "additional soil carbon sequestration gained by growing a cover crop in the fallow season between main crops" and is mainly considered where it can supplement major row crops like corn and soybeans.[17] Despite the relatively low sequestration rate per area of cover crops implemented, the large area of row crop land on which cover crops could be deployed (over 14 million acres; see Appendix C for additional detail) drives this large opportunity.

It is important to note that although some agricultural practices, like no-till and improved nutrient management, appear to have less potential for carbon sequestration, this is because they are already in use by a significant share of North Dakota farmers.

Biological Carbon Capture Activity in North Dakota

Many North Dakota farmers and ranchers are championing biological carbon capture by way of sustainable agriculture. Reducing tillage, reducing nutrient runoff and implementing sustainable grazing practices allows these land managers to keep carbon in the ground, make their lands more productive and support the state's long-term carbon goals.

North Dakota is internationally recognized as a leader in soil health practices. Soil health experts from as far away as South Africa and Australia have toured some of the state's innovative farms.[19] These practices vary, of course, but they have huge implications when they are used over large land areas. North Dakota holds 13.5 million acres of grazing land, and in 2018, a majority of North Dakota ranchers who responded to a statewide survey said they were already implementing some degree of sustainable grazing practices like rotational or management-intensive grazing.[20,21]



Ranchers and farmers are already making strides toward greater biological carbon capture on their lands, but continued expansion of these practices will require additional public support. © Kenton Rowe

BIOLOGICAL CARBON CAPTURE PRACTICES

In this report, we identify 11 biological carbon capture practices—which we have divided into grassland, sustainable agriculture, wetland, and forest practices—that can contribute to carbon capture in North Dakota.

Grassland Practices

Grassland Restoration enables additional carbon storage in soil and plant biomass when land formerly converted for other uses is returned to its original grassland state.[44] Grassland restoration is the single biological carbon practice with highest potential in North Dakota. Sustainable grazing contributes significantly to this practice.

> **If North Dakota restored 3.11 million acres of degraded grasslands and marginal croplands, that action would sequester 7.37 MMT of CO_2 annually. Grassland restoration would help sequester other greenhouse gases as well (amount not calculated here).**

Avoided Grassland Conversion maintains the significant carbon stocks available in healthy grasslands by protecting them against degradation. The majority of grassland carbon is stored below ground, and above-ground harvest of grass (biomass) can reduce the overall stock of carbon available.

> **If North Dakota prevented the conversion of 70,000 acres of grassland each year, that action would prevent the release of 4.18 MMT CO_2 annually. This is equivalent to the emissions of one coal-fired power plant.**

Sustainable Agriculture Practices

Cover Cropping involves growing additional crop(s) during the fallow season in order to retain cover year-round. This practice can enable more carbon sequestration by extending the season for photosynthesis and reducing greenhouse gases released from the soil and is mainly considered where it can supplement major row crops like corn and soy.[43]

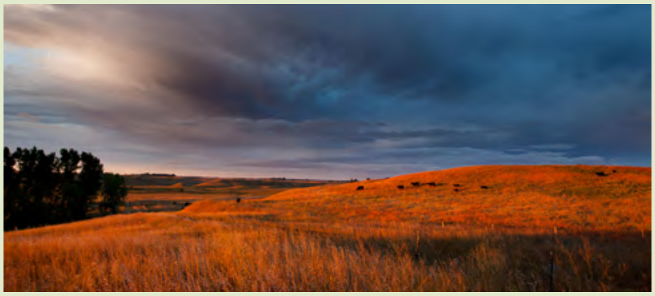
> **If North Dakota used cover crops on all row crop fields, that action would sequester an additional 6.72 MMT CO_2 annually. Cover crops would help sequester other greenhouse gases as well (amount not calculated here).**

No-Till/Low-Till practices, also referred to as reduced tillage, reduce aeration of the soil. Since aeration of upper levels of the soil ordinarily accounts for greater decomposition rates and the release of greenhouse gases, reduced aeration can result in slower decomposition and thus greater carbon (and other nutrient) stocks throughout the soil. Reduced tillage practices vary significantly across different soil types and measurement practices.[47]

> **If North Dakota reduced tillage on all row crop fields, that action would sequester 2.75 MMT CO_2e annually.**

Improved Nutrient Management reduces emissions of nitrous oxide (N_2O), a greenhouse gas, that result from the reaction of nitrogen-based fertilizers. Reduced nutrient application rates, the transition from anhydrous ammonia to urea, improved timing of fertilizer application, or variable fertilizer application within the field can all reduce the total base of nitrogen available for potential release to the atmosphere.[46]

The total carbon potential for improved nutrient management has not been quantified in this report due to lack of data.



Sustainable grazing and other grassland management practices can help North Dakota's prairies capture more carbon. © Richard Hamilton Smith

Farmers who plant cover crops see an improvement in the health of their soil, which results in an overall improvement to their yields and financial performance. © Jason Whalen/Fauna Creative

Sustainable Grazing uses improved management techniques to increase the uptake of atmospheric carbon in grazing lands. Global studies have established the importance of grasslands in storing carbon,[95] and recent studies indicate that managed grazing can lead to greater plant productivity and an increase in carbon stored in the ground beneath grasslands.[96, 97] A new study led by the North Dakota Natural Resources Trust will begin a field test in early 2023 to address the need for data specific to the grasslands of this region.

The total carbon potential for sustainable grazing has not been identified in this report due to the potential for double-counting carbon storage on grasslands, since sustainable grazing practices could overlap with avoided grassland conversion and grassland restoration locations and practices. However, many North Dakota ranchers are already implementing sustainable grazing methods, and it is a crucial part of a comprehensive carbon capture approach.

Wetland Practices

Avoided Wetland Conversion reduces the loss of carbon naturally stored in plant biomass, soil organic matter and other sediment buildup by protecting grasslands from being drained or converted.[42]

> **If North Dakota prevented the conversion of 20,000 acres of wetlands each year, that would prevent the release of 4.59 MMT CO_2 annually. In addition, preventing this conversion would help sequester other greenhouse gases as well (amount not calculated here).**

Wetland Restoration enables carbon lost from biomass, soil carbon and sediment to be rebuilt. It is most common where wetlands have been drained or altered for agricultural activity and where the soil has been degraded. Wetland restoration offers a host of other benefits as well, including community and reduced flood risk, water retention and biodiversity enhancement.[51]

> **If North Dakota restored 280,000 acres of degraded wetlands, that action would sequester 1.04 MMT CO_2e annually.**

Forest Practices

Riparian Forest Buffers protect land adjacent to streams, lakes or other bodies of water by filtering runoff, reducing erosion and creating habitat through the restoration of tree coverage. They offer adaptation benefits by protecting nearby land from floods, and carbon sequestration benefits by increasing carbon storage in plant biomass and soil carbon through increased vegetation and vegetative diversity.[50]

> **If North Dakota implemented 30,000 acres of riparian buffers, that action would sequester 0.12 MMT CO_2e annually.**

Improved Forest Management acknowledges the importance of active forest management and includes practices such as extended rotation, increased stocking, thinning and multi-age management. These practices increase the amount of biomass in a forest by enabling longer growth, greater diversity and greater resilience—in addition to helping increase the amount of carbon stored in harvested forest products. In particular, older trees and the inclusion of multiple age cohorts within a single stand can store more carbon per acre. Forests that have older trees and greater species diversity have greater resilience and reduced susceptibility to disturbances. This resiliency enables better carbon management due to improved overall health—as well as by enabling greater tree density due to differential tree size.[45]

> **If North Dakota used improved management practices on 80,000 acres of forest, that practice would sequester an additional 0.06 MMT CO_2e annually.**

Reforestation offers "carbon sequestration in above- and below-ground biomass and soils by converting non-forest to forest in areas where forests are the native cover type."[48] Here, it includes the potential for carbon sequestration through tree-planting in all historically forested areas, including degraded, converted, agricultural and urban lands. In particular, some studies refer to urban reforestation—additional carbon stored in above- and below-ground biomass in urban settings—or alley cropping, which stores carbon "by planting wide rows of trees with a companion crop grown in the alley-ways between the rows" and is assumed to be feasible on no more than 10% of row cropland.[49]

> **If North Dakota reforested 40,000 acres of historically forested land, that action would sequester 0.03 MMT CO_2e annually.**

"With practices already in use such as cover cropping, rotational grazing and no-till, North Dakota farmers are already capturing more carbon and putting it to beneficial use."

— North Dakota Gov. Doug Burgum[18]

Even forward-looking producers can't optimize biological carbon capture practices alone; support from the state government, educational and technical advisors and other partners is critical. North Dakota is already making progress to this end. In 2021, the North Dakota Legislative Assembly designated funds for a soil health cost-share assistance program that would enhance soil health statewide.[22] North Dakota Game and Fish recently partnered with conservation, agriculture and federal partners to launch the Meadowlark Initiative to restore and sustain grasslands, and other collaborative efforts are targeting grassland restoration across the state.[23] The USDA Conservation Reserve Program (CRP) offers opportunities to improve environmental health—many of which can contribute to carbon storage. NDSU Extension provides trainings on soil health systems and management initiatives and research.[24]

Non-governmental partners also play a significant role in supporting biological carbon capture projects, and state support through outlets like the North Dakota Outdoor Heritage Fund (OHF) are crucial to the success of North Dakota's carbon neutrality goals. Since 2017, Ducks Unlimited Cover Crop and Livestock Integration Project (CCLIP) has been awarded cost-share grants from the OHF to implement soil health improvements, water quality benefits and habitat conservation practices in 37 counties in North Dakota.[25] Audubon Dakota also received an OHF grant to restore 18,000 acres of marginal cropland back to grass.[26,27] In addition to storing carbon, land management and sustainable grazing can be a key tool for ensuring North Dakota landscapes are more resilient to drought. Sustainable grazing benefits not only livestock production, but also wildlife habitat and outdoor recreation.[28] To help ranchers advance these outcomes, some grazing coalitions offer trainings to promote soil health and a whole farm systems approach while maintaining a balance of productivity and profitability.[29]

While some producers are adopting many biological carbon capture practices, there is still potential for expansion. In order to be scaled up to a meaningful level, biological carbon capture requires support from a wide range of stakeholders. Individuals must take the initiative to build awareness and acceptance of new practices and demonstrate that they work so that they can become more widely implemented. Nonprofit and philanthropic efforts will likely need to help bridge the gap to scalable, financially viable implementation—which will be implemented by private-sector businesses. Finally, more policy support is needed to incentivize and scale solutions to achieve our full potential, and public–private partnerships may be a key tool to develop the right programs.

Implementing biological carbon capture solutions on grasslands and wetlands will help North Dakota reach its carbon neutrality goals while providing habitat for the state's iconic wildlife, like this Western Meadowlark. © Lauryn Wachs/TNC

Increased severity and duration of extreme weather events, like droughts and flooding, will put additional strain on working lands. Practices that increase biological carbon capture will also make agriculture more resilient to extreme weather. © Harlen Persinger

NATURE-BASED ADAPTATION

Nature-Based Adaptation

In addition to reducing carbon emissions, the state should also enable residents to cope with the types of droughts, water shortages and other weather-related events that have caused damage in recent years. The good news is that the biological solutions in this report can help drive this resiliency.

Nature-based adaptation is the use of nature-based strategies to facilitate adaptation in natural systems for both people and other species that rely on those systems.

Droughts and weather-related events like flooding threaten farmers, ranchers and other land managers. Weather changes over the next century will likely include overall drier weather with severe drought conditions, with frequent intense rain and flooding when precipitation does occur.[30] As evidenced in 2021, severe droughts can increase feed costs by up to 50%, causing many ranchers to sell off part of their herd.[31] Droughts are estimated to cost the state nearly 400 jobs every year.[32] With more erratic weather and warming winters, crop pests will increase[33] and diseases like fusarium head blight (impacting grains like wheat, barley and durum) can cause $1 billion worth of crop loss per year.[34]

Droughts also impact the resilience of shared infrastructure. For instance, the 2000–2006 drought caused low water levels that cut hydropower production and drove a damaging fire season.[35] Wildfires, extreme heat and droughts decrease access to outdoor recreation including hunting, hiking and fishing.[36] Projections for future summer boating seasons suggest that low water levels could prevent the use of many boat ramps.[37] Warming winters could also limit winter recreation activities—and diminished recreation activity can lead to fewer tourism dollars.

These weather-related changes impact individual livelihoods and the larger economy. Luckily, North Dakota land managers are already opting to increase resilience to these kinds of changes, and helping to maintain its tourism industry, agricultural production and other economic drivers.

Nature-based adaptation strategies are critical when it comes to North Dakota's response to these weather events and for making sure biological carbon capture can persist through weather-related changes. Nature-based adaptation reflects many of the practices required for community and ecosystems to continue thriving in the face of increasingly severe weather impacts.

In North Dakota, some of the most critical nature-based adaptation practices are solutions to address wind erosion and other natural risks. These practices mimic or restore nature's potential to reduce flooding and erosion through planning, zoning and built projects. For instance, cover crops and wind breaks can reduce soil erosion on crop land during the off-season; notably, these solutions will also enhance carbon sequestration potential.

Similarly, nature-based solutions can help address the impacts of flooding. Flash floods in 2002 caused over $2 million in rural infrastructure damage[38] and more recent flood events have led to major negative economic impacts.[39,40] Water diversions like beaver dam analogs and other efforts to restore floodplains can help to slow down water and hold it on the landscape, thereby reducing flood damage. At the same time, climate-forward planning can introduce elements like flood-friendly culverts to minimize damage.

As extreme weather increases, North Dakotans will experience greater threats to our livelihoods, communities and ways of life. Solutions to achieve carbon neutrality and reduce the impact of extreme weather events exist, and now it is up to us to find the strategies that will work best for North Dakota.

Wetlands, like this prairie pothole at Davis Ranch in Sheridan County, play a significant role in North Dakota's potential for expanding biological carbon capture. They also help with water storage during extreme weather events and provide excellent habitat for wildlife, which in turn supports a booming tourism economy. © Layne Kennedy

North Dakota's rich grasslands are the foundation of its robust ranching economy, and improved management, restoration efforts, and keeping grasslands from being converted to other uses will help this crucial economic driver thrive. © Richard Hamilton Smith

NEXT STEPS

To become a carbon-neutral state by 2030, North Dakota will need to take a comprehensive approach that exemplifies all-of-the-above planning. Biological carbon capture and nature-based adaptation will be important cornerstones of that approach. These solutions can also help us become more resilient to changing weather patterns, which threaten our economy and way of life.

The potential of biological carbon capture will not be realized without strategic prioritization. North Dakota's working lands require proactive planning and investment to continue storing carbon and building natural resiliency. Our working lands can be a powerful tool as we explore forward-looking solutions for carbon management.

Natural and working land solutions to North Dakota's carbon management will require cooperation from a diverse set of supporters. State agencies, local governments, non-governmental organizations and resource managers like farmers and ranchers all have a role to play. Public–private partnerships may be a crucial strategy for supporting on-the-ground practices.

State-led programs (like the existing Soil Health Cover Crop Grant Program funded in 2021 by the North Dakota Legislative Assembly) and state funding distributed through partners—such as several existing projects funded by the Outdoor Heritage Fund—can support natural and working land solutions as well.

Furthermore, continued research on the regional variation of carbon sequestration on agricultural lands will help refine standardized measurement protocols as biological carbon capture solutions are deployed around the state.

Key strategies for expanding biological carbon capture in North Dakota could range from the coordinated expansion of soil health implementation programs and additional grassland protection to the provision of financial mechanisms to support private implementation of agricultural best management practices.

Further action and funding from the North Dakota Legislative Assembly can help new and existing programs reach more private landowners.

Federal policy developments may also provide an opportunity for expanding biological carbon capture solutions. For instance, as Congress begins to draft the next Farm Bill, advocacy to prioritize these solutions could support the agricultural transition and ensure adequate investment to help North Dakotan producers who are experimenting with and implementing new farming and ranching practices.

Through additional investments in technical assistance and implementation, North Dakota's agricultural producers will begin to see real improvements in the productivity of their working lands. © Harlan Persinger

APPENDIX A. Practices and Data Summary

Eleven biological carbon capture practices are relevant to North Dakota. These are depicted in Figure A1, while an overview of the opportunity for these practices is provided in Table A1. The practices are further defined below.

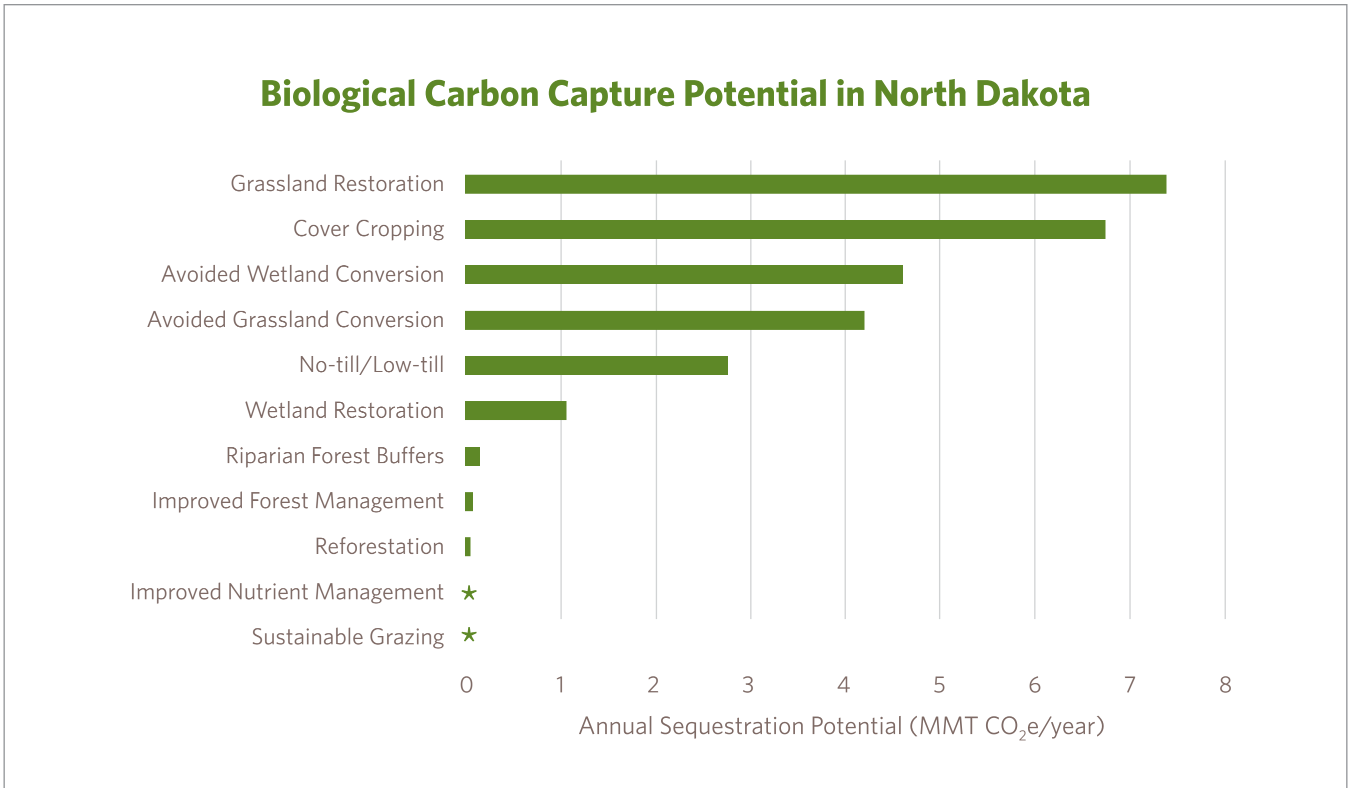


Figure A1. Biological carbon capture offers almost 27 million metric tonnes CO_2e/year carbon potential in North Dakota, with the largest opportunities in grassland and agricultural landscapes.
**This figure excludes the opportunity for emissions reduction via improved nutrient management and sustainable grazing, which are not quantified in this report.*

Table A1. Summary of North Dakota's 11 biological carbon capture practices and the magnitude of their respective sequestration rates, area of relevance and total carbon storage potential.

Practice	Sequestration Rate	Potential Extent	Total Annual Sequestration Potential (MMT/year)*
Avoided Grassland Conversion	60.54 Mt CO_2e/acre	0.07 mil acres/yr	4.18
Avoided Wetland Conversion	254.77 Mt CO_2e/acre	0.02 mil acres/yr	4.59
Cover Cropping	0.47 Mt CO_2e/acre/yr	14.30 mil acres	6.72
Grassland Restoration	2.37 Mt CO_2e/acre/yr	3.11 mil acres	7.37
Improved Forest Management	0.81 Mt CO_2e/acre/yr	0.08 mil acres	0.06
Improved Nutrient Management	0.17 Mt CO_2e/acre/yr	**	**
No-Till / Low-Till	0.33 Mt CO_2e/acre/yr	8.47 mil acres	2.75
Reforestation	0.80 Mt CO_2e/acre/yr	0.04 mil acres	0.03
Riparian Forest Buffers	4.00 Mt CO_2e/acre/yr	0.03 mil acres	0.12
Sustainable Grazing	**	**	**
Wetland Restoration	3.70 Mt CO_2e/acre/yr	0.28 mil acres	1.04
Total**			26.87

* Mt = metric tonnes CO_2 equivalents; MMT = million metric tonnes CO_2 equivalents
** Excluding carbon potential for improved nutrient management and sustainable grazing due to lack of available data

Many farmers are already making use of precision agriculture technology to improve their nutrient management and therefore reduce emissions. © Isaac Shaw

APPENDIX B. Sequestration Potential of Biological Carbon Capture Practices

The sequestration potential of biological carbon capture practices calculated here result from an upper Great Plains analysis across Minnesota, North Dakota and South Dakota. High, medium and low sequestration rates are calculated to demonstrate the potential range of rates that may occur across the landscape; however, unless noted otherwise, medium sequestration rate values were assumed for biological carbon capture potential calculations throughout this report.

The sequestration rates noted throughout Appendix B reflect the best available understanding of North Dakotan biological carbon capture practices. These rates will likely be refined as the science is improved.

Avoided Conversion

Avoided conversion practices are separated from the others, because the emissions avoided by preventing land conversion are a one-time benefit that can be measured as the carbon not lost from the landscape.

Avoided Grassland Conversion

Storage Capacity: 60.54 Mt CO_2e/acre

Methods: The Climate Action Reserve Tool was used to calculate the total emissions per acre over a 50-year period and down to a soil depth of 20 cm.[52] Following standard practice and including the baseline emissions from soil carbon (including below-ground biomass), baseline N_2O, and project methane emissions from enteric fermentation from beef cattle grazing yielded an average storage rate of 55.55 CO_2e. The baseline scenario refers to the case where the site would have been converted to row crop agriculture, while the project scenario reflects a site protected from conversion.

The Climate Action Reserve Tool's Baseline Emission Factor tables, modeled for each Major Land Resource Area (MLRA)[53] across the United States using the DAYCENT mechanistic model, were used to identify the MLRAs for Minnesota, North Dakota and South Dakota. Soil carbon emissions were then averaged across the three modeled soil textures (fine, medium, coarse) for each MLRA. The model results were used for grasslands that have existed as grasslands for at least 30 years, assuming many of the sites we will be interested in working on are remnants. The same process was conducted for the N_2O emissions for each MLRA in the region. Finally, soil carbon and N_2O emissions were added together to provide the total baseline emissions.

The project scenario assumed that all sites would be grazed with beef cattle. Emissions related to enteric fermentation were subtracted from baseline emissions. The Climate Action Reserve's table for grazing values yielded 0.2521 kg CH_4/head/day as the enteric fermentation emission factor for cattle. A stocking rate of 0.607 beef cattle/acre/ month was assumed—rounded up from stocking recommendations from South Dakota and North Dakota.[54] A season- long grazing practice of 2.56 months (May 15–Sept 15) every year was also assumed. These inputs resulted in 1.558 beef cattle/acre for the 2.56 months and 0.3938 kgCH_4/acre/yr or 19.64 kgCH_4/acre per 50 years.

The Climate Action Reserve's Global Warming Potential values of 25 for methane and 298 for N_2O were assumed. Final average CO_2e storage rates were calculated of 65.53, 55.55 and 43.31 Mt/acre for high, medium and low sequestration based on MLRAs represented across the three states. We assume the rate for North Dakota to be an average of the high and medium rates per the map in Figure A2.

This result is conservative compared with Ahlering et al. (2016)'s findings that the grasslands of North Dakota's Missouri Coteau region release 51.6 short tons CO_2e/ha, or over 200 MMT CO_2e/acre. However, that study focuses on a region that contains only one type of soil and includes non-CO_2 greenhouse gases, while the analysis used in this paper does not.[54]

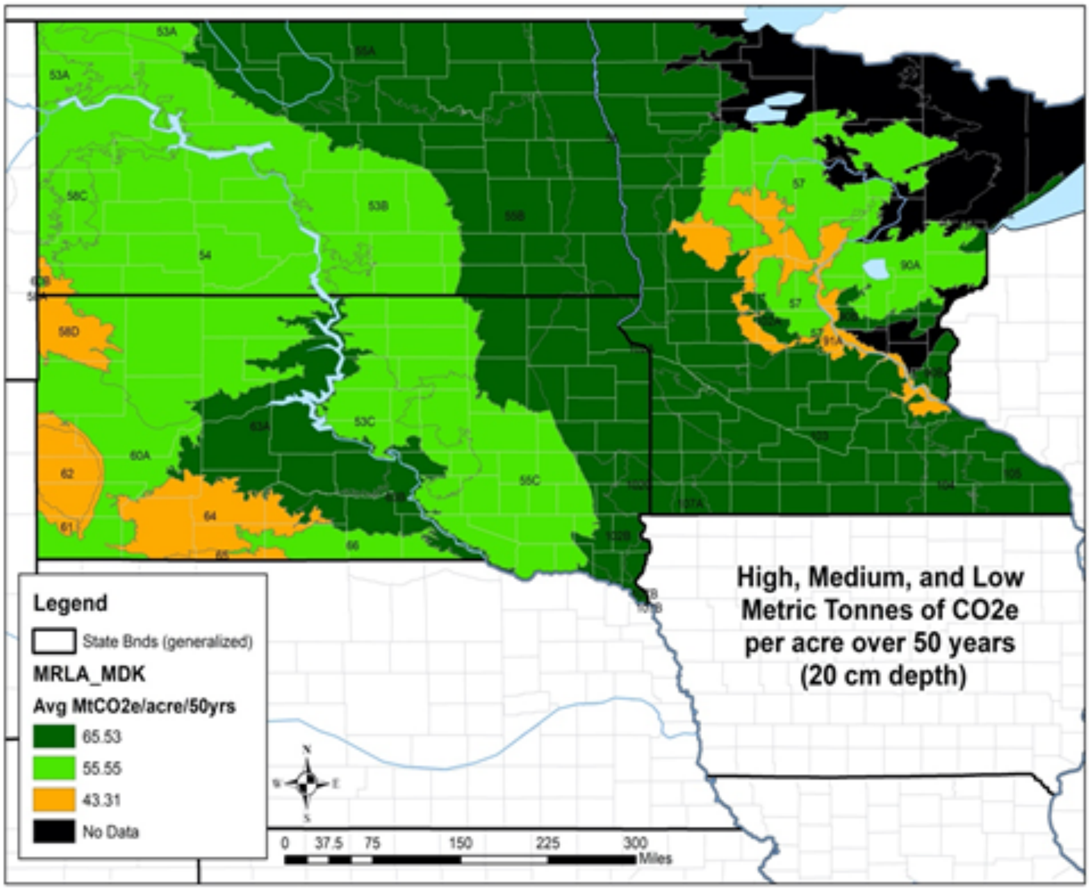


Figure A2. High, medium and low grassland carbon dioxide equivalent storage rates per acre over 50 years.

Avoided Wetland Conversion

Storage Capacity: 105 Mt CO_2e/acre

Methods: Avoided conversion mitigation benefits for non-peat wetlands were estimated using values from the literature. The estimated carbon stock was taken to be between 33 and 258 Mt C/acre for wetlands; Midwest carbon stocks are reported as ranging from 75 to 200 Mg C/ha, while Minnesota values are shown to span 227–258 Mt C/acre.[55,56] Mg/ha were converted to Mt/acre by multiplying by 2.47 (acres per hectare) and 3.67 (CO_2e/C), respectively. Midwest wetland soils are assumed to have lost 30–50% organic matter following drainage and agriculture.[57]

High storage value: A maximum storage value was derived by multiplying 258 Mt C/acre * 50% avoided loss of soil carbon * 3.67 to convert carbon to CO_2e. (473 Mt CO_2e/acre)

Medium storage value: The medium value was taken as the midpoint between the high and low values identified. (255 Mt CO_2e/acre)

Low storage value: A low storage value was estimated by taking a low-end estimate for wetland carbon stocks of 81 Mg C/ha * 30% avoided loss of soil carbon * 3.67 CO_2e/C * 1 ha/2.47 acres. (36 Mt CO_2e/acre)

All Other Biological Carbon Capture Practices

Eight additional practices are explored here. These represent practices that are available on the land, which offer annual carbon sequestration benefits once implemented. Some of these are combined in the summary provided in Table A1 and throughout this report.

Cover Cropping

Sequestration Rate: 0.47 Mt CO_2e/acre/year

Methods: A range of values for carbon sequestration through cover cropping were obtained from agency reports, online tools and published literature.

High sequestration rate: A sequestration rate was adopted from the Minnesota Board of Water and Soil Resources, as derived from Anderson et al.[58,59] (0.6 Mt CO_2e/acre/year)

Medium sequestration rate: The U.S. State Carbon Mapper tool was used to calculate annual sequestration rates for cover cropping (based on Fargione et al. 2018).[60] This straightforward calculation involved dividing the millions of Mt CO_2e per year benefit by millions of acres available for the practice. This was calculated at the state level with equivalent results for Minnesota, North Dakota and South Dakota. (0.47 Mt CO_2e/acre/year)

Low sequestration rate: The sequestration rate from Biardeau et al. (2016) was adopted as a low-end estimate.[61] (0.4 Mt CO_2e/acre/year)

Grassland Restoration

Sequestration Rate: 2.37 Mt CO_2e/acre/year

Methods: The U.S. State Carbon Mapper tool—based on Fargione et al. 2018—was used to calculate annual sequestration rates for grassland restoration in Minnesota, North Dakota and South Dakota.[62] This straightforward calculation involved dividing the millions of Mt CO_2e per year benefit by millions of acres available for the practice. The sequestration rate is highest for Minnesota (2.53 Mt/acre/year) and lowest for South Dakota (2.06 Mt/acre/year), with North Dakota falling in between (2.37 Mt/acre/year).

Improved Forest Management

Sequestration Rate: 0.81 Mt CO_2e/acre/year

Methods: We used the Forest Vegetation Simulator model for a temperate-southern boreal forest with extended rotation, projecting 50–70 years beyond economic rotation age.[63] The same were assessed for multi-aged mixed-wood management based on results from White and Manolis (2011).[64]

For aspen forests, extended rotation is approximately 20 years beyond a normal rotation (usually 40 years). Multi-age values represent the difference in CO_2e uptake rates for the first 100 years of simulation. Additional CO_2e uptake was calculated based on the increase in carbon gained using multi-aged management above baseline values in business-as-usual forest management. Extended rotation yielded an approximate sequestration rate of 0.75 Mt CO_2e/acre/year and multi-age management a rate of 0.81 Mt CO_2e/acre/year, but we chose the more ambitious rate of 0.81 Mt CO_2e/acre/year given its applicability to the North Dakota landscape.

To determine total carbon stored for a given number of years above baseline sequestration rate, additional storage capacity is added to the baseline value. For example, a calculation for extended rotation is provided below.

ER = extended rotation rate

ER = Cy,t1 − Cy,t2 total years where Cy,t1 = Carbon at year 120 and Cy,t2 = Carbon at year 61ER = Cy,t1 − Cy,t2 total years where Cy,t1 = Carbon at year 120 and Cy,t2 = Carbon at year 61

ER = (195-120)/50 = 1.51 MtCO_2e/acre/yr

Extended rotation of 40 years: Total C at age 110 = 120 (C age 60) + (1.51 *40 years) = 180.4 Additional C = 40 MtCO_2e/acre

Improved (Precision) Nutrient Management

Sequestration Rate: 0.17 Mt CO_2e/acre/year

Methods: A range of values was obtained from published literature and online tools.

High sequestration rate: Rate was adopted from Biardeau et al.[65] (0.2 Mt CO_2e/acre/year)

Medium sequestration rate: The medium value was taken as the midpoint between the high and low values identified from the literature. (0.17 Mt CO_2e/acre/year)

Low sequestration rate: Figures from the U.S. State Carbon Mapper tool (based on Fargione et al. 2018) were used to calculate annual sequestration rates for the Improved Nutrient Management practice.[66] This assumes impacts accrue from avoided N_2O emissions achieved through more efficient use of nitrogen fertilizers and avoided upstream emissions from fertilizer manufacture. The U.S. State Carbon Mapper considered four improved management practices: 1) reduced whole-field application rate, 2) switching from anhydrous ammonia to urea, 3) improved timing of fertilizer application, and 4) variable application rate within field.

The low sequestration rate figure was calculated using numbers for South Dakota, dividing millions of Mt CO_2e per year benefit (2.41 million Mt CO_2e total) by millions of acres of cropland (19 million acres according to the USDA for SD). (0.13 Mt CO_2e/acre/year)

No-Till / Low-Till (Reduced Till)

Sequestration Rate: 0.33 Mt CO_2e/acre/year

Methods: Numbers were adopted from Biardeau et al. (2016) for high and low levels and a value for medium levels was calculated between the two endpoints.[67]

High sequestration rate: Numbers for no-till were used, which considers additional carbon stored over that stored by conventional agriculture practices. (0.45 Mt CO_2e/acre/year)

Medium sequestration rate: The medium value was taken as the midpoint between the high and low values identified from the literature. (0.33 Mt CO_2e/acre/year)

Low sequestration rate: Numbers for reduced tillage were used, which considers additional carbon stored over the amount stored by conventional agriculture practices. (0.2 Mt CO_2e/acre/year)

Reforestation

Sequestration Rate: 0.80 Mt CO_2e/acre/year

Methods: Values were derived from the FIA plot database for forests between 50 and 100 years old in Minnesota, North Dakota and South Dakota accessed through the EVALIDator tool and GTR343.[68,69] GTR343 provides regional carbon estimates for forest type group for the continental United States. Data were accessed directly through EVALIDator, as the regional estimates indicated significantly higher rates for North and South Dakota than individual state data. Low sample size for North Dakota and South Dakota data resulted in many cover types being poorly represented.

For Minnesota's Northern Temperate-Southern Boreal Forests, the reforestation estimates for high, medium and low, respectively, are as follows: red pine-white pine, oak-hickory and spruce-fir. Aspen-birch also fits in the medium category. Within North and South Dakota, the estimates for high, medium and low, respectively, are as follows: oak-hickory (SD) forest on timberland (ND) and ponderosa pine (SD). Accordingly, we use the sequestration rate of 0.80 Mt CO_2e/acre/year for North Dakota.

Riparian Forest Buffers

Sequestration Rate: 4.00 Mt CO_2e/acre/year

Methods: A range of values for riparian forest buffers was obtained from agency reports, online tools and published literature.

High sequestration rate: A sequestration rate was adopted from the Minnesota Board of Water and Soil Resources as derived from Anderson et al. (2008).[70] (5.5 Mt CO_2e/acre/year)

Medium sequestration rate: The medium value was taken as the midpoint between the high and low values identified from the literature. (4.00 Mt CO_2e /acre/year)

Low sequestration rate: The sequestration rate from Biardeau et al. (2016) was adopted.[71]
(2.50 Mt CO_2e/acre/year)

Wetland Restoration

Sequestration Rate: 3.70 Mt CO_2e/acre/year

Methods: Restoration is assumed to be implemented on land now in a drained, farmed condition. Values were derived from the scientific literature, agency reports and tools, converting to standard units of Mt CO_2e/acre as required.

High sequestration rate: The high value was obtained directly from BWSR (2009) (as derived from Anderson et al. 2008), which is consistent with Euliss et al. 2006 (originally presented as 305 g C/m^2).[72,73,74] (4.5 Mt CO_2e/acre/year)

Medium sequestration rate: The medium value was taken as the midpoint between the high and low values identified from the literature. (3.70 Mt CO_2e/acre/year)

Low sequestration rate: The low value was adopted from Lennon (2008) (originally presented as 195 g/m^2).
(2.9 Mt CO_2e/acre/year)[75]

APPENDIX C. Area Available for Biological Carbon Capture Implementation in North Dakota

To calculate the total opportunity for biological carbon capture, the extent or land area available for practice implementation must be estimated. We used the best currently available data, while acknowledging that more refinement will be required. For example, different data sources and scales are used for different practices due to inconsistencies in measured and reported values in different geographies. Despite this shortcoming, we feel it is important to begin the conversation on biological carbon capture despite data imperfections. This report assumes a 50-year permanence requirement for avoided conversion practices.

Avoided grassland conversion

Using the WWF Plowprint tool,[76] we calculate average annual habitat loss from 2015 to 2019 as 281,000 acres per year. Plowprint also reports that about 25% of intact habitat is composed of grassland, so we estimate one-quarter of the acreage (about 70,000 acres) of grassland is lost annually. This estimate is conservatively calculated based on recent trends; for instance, expanding the time horizon to a 2010–2019 window results in annual loss estimates of 440,000 acres in North Dakota. Our estimate is consistent with findings from Lark et al., who find that 51,000–61,000 acres of grassland are lost per year in North Dakota.[77]

Avoided wetland conversion

Lark et al. (2015) estimate that 18,385 acres of wetlands are lost annually in North Dakota.[78] This estimate is consistent with other findings that 12,000–16,000 acres are lost annually within the Prairie Pothole region.[79] For comparison, Dahl et al. estimate that 2.5 million acres of wetlands remained in North Dakota in the 1980s[80] and the National Wetland Inventory estimates 2.65 million acres of non-lake wetlands in North Dakota today.[81]

Cover cropping

We follow the methodology of Fargione et al. to assume that cover cropping is applicable on land used to grow five major field crops—16.25 million acres.[82] The latest available Natural Resources Conservation Service data indicate that cover cropping has already been introduced as a conservation practice on 1.951 million acres.[83] Therefore, we assume that new cover cropping practices could be viable on remaining row crop land, or 14.3 million acres.

Grassland restoration

We use the WWF Plowprint tool to estimate the area available for grassland restoration. We start with the total 2019 Plowprint (or habitat already converted) and multiply by the percentage of the Plowprint at low or moderate risk.[84,85]

Improved Forest Management

We assume that 10% of forested land in North Dakota—quantified by the U.S. Forest Service[86]—is under management and eligible for improved management. This is consistent with data for South Dakota that can more easily be confirmed.[87]

Improved Nutrient Management

Area is not reported for the improved nutrient management practice. As there are insufficient data available to estimate the current extent of practices, it is not possible to estimate the opportunity for additional nutrient management to be implemented. With better data, carbon estimates for this practice can be refined.

No- and low-till

We use the most recent USDA National Agricultural Statistics Service data to estimate the current extent of these practices.[88] The consistency of publicly available USDA figures make them ideal for this type of analysis; however, it is important to acknowledge the variance that may occur based on accuracy of reporting. In the future, it would be ideal to use a remote sensing technology such as OpTIS to measure real implementation of soil health practices; at the time of this report, OpTIS data were not available for the full extent of the state.

Using USDA data, we assume that acres reported as no-till and conservation tillage have come close to maximizing the benefits of reduced tillage practices, while acres still utilizing conventional tillage can still realize substantial benefits through reduced tillage. USDA QuickStats indicate that about 7.8 million acres are already under improved tillage practices, so we assume the remainder of the 16.25 million acres of cropland in North Dakota[89] still present opportunities for no-till or conservation tillage implementation.

Reforestation

We follow the methodology of The Nature Conservancy and American Forests from the Reforestation Hub tool. We estimate the opportunity for reforestation as the total land area listed on reforestation less the acres isolated in the riparian forest buffer pathway.[90]

Riparian Forest Buffers

We follow the methodology of The Nature Conservancy and American Forests from the Reforestation Hub tool. We estimate the opportunity for riparian forest buffers as the sum of acreage available for floodplain reforestation and streamside buffers listed on the Reforestation Hub.[91]

Sustainable Grazing

Area is not reported for the sustainable grazing practice. As there are insufficient data available to estimate the current extent of practices, it is not possible to estimate the opportunity for expanded implementation of these practices. With better data, carbon estimates for this practice can be refined.

Wetland restoration

Because wetland restoration has the potential to introduce conflict over different land-use priorities (especially on marginal agricultural lands), we create a conservative estimate by extrapolating current rates of wetland restoration. Dahl (2006) estimates 7,000 acres per year are restored in North Dakota.[92] Using a 40-year time horizon—the time period over which restored wetlands see increased rates of carbon sequestration[93]—we estimate that 280,000 acres of restored wetland could be in flux.

For comparison, a ceiling for wetland restoration might be estimated from the EPA Potentially Restorable Wetlands on Agricultural Lands database, which indicates that there are 1.6 million acres of high potential restorable wetlands in North Dakota.[94] Although such a ceiling could be used to estimate total biological carbon capture potential, in this analysis we choose not to use it due to the political and social constraints we see to achieving such magnitude of wetland restoration on agricultural lands.

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Improving farmers' ability to access cover crop inputs will increase the prevalence of this important biological carbon capture solution.
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