Climate Change Trends and Action Report

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Minnesota Board of Water and Soil Resources
520 Lafayette Road North
St. Paul, MN 55155
651-296-3767
www.bwsr.state.mn.us

This report was developed by Dan Shaw (Native Vegetation Specialist/Landscape Ecologist) and Megan Lennon (State Soil Scientist) of the Minnesota Board of Water and Soil Resources

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BWSR is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audiences. This report is available at http://www.bwsr.state.mn.us/native_vegetation/BWSR_Climate_Change.pdf and available in alternative formats upon request.

How and why does climate change matter to BWSR and what trends have been observed?

The Minnesota Board of Water and Soil Resources (BWSR) mission is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. With extreme weather patterns and disrupted natural cycles, climate change has the potential to decrease the ability of Minnesota landscapes to sustainably provide important environmental and economic benefits. Therefore, BWSR is working to integrate climate change considerations in programs and practices for conservation on private lands that make up approximately 75% of Minnesota's land area through wetland protection, conservation easements (retirement of marginal agricultural lands), and providing soil and water conservation grants. These programs play an important role in climate change prevention by preventing the release of stored carbon and methane in wetlands, sequestering carbon, decreasing nitrous oxide emissions from fertilizer and methane from manure, providing opportunities for biofuel production, and increasing landscape resiliency. Following is a summary of primary program areas with observed climate related trends for each.

Lakeshore restoration in Carver County.

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

The primary goal of the Minnesota Wetland Conservation act is to achieve no net loss in the quantity, quality, and biological diversity of Minnesota's 10.6 million acres of existing wetlands. This is accomplished through avoiding direct or indirect impacts from activities that destroy or diminish wetlands and replacing wetland values where avoidance of such activity is not feasible and prudent. With wetlands holding large amounts of carbon and methane, these actions help protect against climate change. It is estimated that one acre of peatland contains, on average, 750 metric tons of carbon. Total emission of the carbon contained in just 1,000 acres of peatland would increase Minnesota carbon dioxide emissions by almost two percent (Anderson et.al. 2008).

Forested bog in northern Minnesota.

OBSERVED CLIMATE-RELATED TRENDS:

- Precipitation has been falling more frequently in heavy downpours, leading to increased erosion of fields, ravines, streambanks and bluffs. This has led to increasing amounts of sediment accumulation in some wetlands and damage to water control structures and embankments in restored wetlands.
- Large storms and flooding have stress aquatic systems by causing water level fluctuations that favor invasive plant species and interrupt the life cycles of aquatic organisms.

Wetland degraded from altered hydrology.

Approximately half of Minnesota's depressional wetlands (such as marshes and ponds) are considered in poor condition by the Minnesota Pollution Control Agency (PCA, 2012).

- Increased evaporation during hot, dry summers and droughts has caused excessively dry conditions in many wetlands, decreasing wetland services and creating challenges for wetland vegetation establishment for restoration. Climate models predict reductions in water volume, shortening of hydroperiods and less-dynamic vegetation for prairie wetland complexes (Johnson et.al. 2010).

Restored depressional wetland.

Conservation Easements (Reinvest in Minnesota Reserve)

BWSR's RIM program is focused on the acquisition and enhancement of critical habitat in the predominantly agricultural areas of the state by converting marginal crop lands to permanent native vegetative cover. This includes restoring wetlands, establishing riparian buffers, protecting sensitive ground water areas, planting critical winter cover for wildlife, preserving habitat for rare plant and animal species, protecting and restoring native prairie and grasslands, increasing pollinator habitat, and preserving spawning and reproduction areas for fish.

Woodland converted to agriculture.

OBSERVED CLIMATE-RELATED TRENDS:

- Sustained high crop prices and shrinking federal Conservation Reserve Program (CRP) lands have driven a net conversion of permanent vegetative cover to annual row crops. The recent losses in CRP have exceeded gains in all other conservation programs and have led to the loss of sequestered carbon.
- Combinations of flooding and drought, as well as harmful insects and invasive species that are promoted by climate change have been degrading natural wetlands, prairies and forests.
- The composition of northern forests has been shown to be transitioning from coniferous trees to deciduous trees in areas of disturbance (Frelich & Reich 2010). Northern forests are also being invaded by woody species such as common and glossy buckthorn that can change the structure of forests. Green and black ash populations are threatened by emerald ash borer. Black ash swamps cover about one million acres in Minnesota. Flooding in northeast Minnesota has also caused extensive erosion on steep slopes.

Erosion in northern Minnesota from flooding.

Restored buffer along an agricultural ditch.

Soil and Water Conservation Grants

BWSR's soil and water conservation grant programs provide funding to local government units for the implementation of targeted conservation projects and practices in rural and urban landscapes. A wide variety of conservation practices sequester carbon and decrease

nitrous oxide emissions from fertilizer, including: tree planting, grass planting, prairie and wetland restoration, windbreaks/shelterbelts, grassed waterways, contour buffer strips, filter strips, riparian buffers, critical area planting, and cover crops. These practices also increase landscape resiliency and often help protect agricultural fields (protecting productivity) from extreme weather events. Grants also fund nutrient management plans and anaerobic manure digesters that decrease nitrous oxide and methane emissions.

OBSERVED CLIMATE-RELATED TRENDS:

- Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota. BWSR has provided flood relief funding for floods in southeast, northwest and northeast Minnesota in recent years; $42.3 million has been distributed for flood relief through local government units between 2000 and 2012.
- Conservation practices such as grassed waterways, filter strips, vegetated buffers, etc. have helped farmers retain topsoil and agricultural productivity during extreme weather events.
- New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) has shown that the amount of rainfall for given storm frequencies (5-yr., 10-yr. etc.) has risen substantially in many areas of the U.S. in recent decades. The new data indicates that for rainfall events having low probability of occurrence (1-2% chance of occurring in a given year) the amount of predicted rainfall in a 24-hour period has increased by approximately 25%. This rainfall increase could generate approximately one third more runoff volume than estimated using the old data. The previous 100-year 24-hour event that generated approximately six inches of rainfall will now have a probability of occurring two to three times in 100 years (rather than once per 100 years).
- High corn and soybean prices have led to the expansion of agriculture into more marginal lands, releasing carbon stores and increasing the risk of erosion.
- N_2O emissions are projected to increase by 5% between 2005 and 2020, driven largely by increases in emissions from agricultural activities (U.S. Department of State 2007).

Grass waterway eroded from flooding.

What are potential long-term trends and impacts from climate change?

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

Restored wetland with altered hydrology.

LONG-TERM TRENDS AND IMPACTS:

- It is likely that wetland health will decline due to more frequent extreme water fluctuations and periods of drought that will favor invasive species and disrupt the life-cycle of aquatic organisms.
- Wetland acreage may be lost in the prairie region of Minnesota from decreased precipitation and altered hydrology.
- Northern black ash swamps covering about one million acres in Minnesota may significantly change in structure due to emerald ash borer and the loss of black ash trees.

Conservation Easements (Reinvest in Minnesota Reserve)

Invasive buckthorn changing the structure of a forest.

LONG-TERM TRENDS AND IMPACTS:

- State easements with aquatic systems will likely be degraded due to changing hydrology conditions.
- Combinations of flooding, drought, harmful insects, and invasive species will further degrade natural wetlands, prairies and forests.
- With climate change, the National Wildlife Federation concludes that there will be diminished numbers of migratory waterfowl, pheasants, moose, walleyes, northern pike and brook trout, and fish kills will likely become more prevalent (National Wildlife Federation 2013).
- Upland and wetland northern forests could significantly change in structure from the spread of woody invasive species such as common and glossy buckthorn and invasive honeysuckles, invasive insects, and changes in dominant tree species. Some areas may transition from northern coniferous forest to savanna (Frelich & Reich 2010)

Invasive species such as wild parsnip have a competitive advantage with climate change.

Soil and Water Conservation Grants

Large storm events and variable climate may increase erosion and affect agricultural productivity.

LONG-TERM TRENDS AND IMPACTS:

- Water quality in streams, rivers, wetlands, and lakes will likely degrade and/or be more challenging to restore, due to runoff from heavy rainfall, particularly in agricultural lands that are prone to erosion.
- Increase in requests for assistance to repair and replace structures installed to manage water and improve habitat.

- Soil productivity and crop yields will decrease due to increased soil erosion and loss of organic content.

Climate change may lead to the transition from coniferous trees to deciduous trees in northern forests.

What has BWSR already done?

Over the years BWSR has played a significant role in decreasing greenhouse gas emissions by protecting wetlands, retiring marginal agricultural land and through soil and water conservation grants. The following information summarizes benefits from BWSR programs.

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

The Minnesota Wetland Conservation Act has been in place since 1991 and has significantly reduced the loss of wetland acres. Wetlands contain significant amounts of carbon and methane that can be released to the atmosphere with wetland losses. Approximately 16,000 acres of wetland have been restored to replace wetland losses though wetland banking and on-site mitigation since the start of wetland conservation act, capturing approximately **35,000 – 111,000 metric tons of carbon dioxide** per year (assuming .6-1.9 MT of C seqestered per ac./yr., Anderson et al, 2008).

Wetlands in Washington County.

Conservation Easements (Reinvest in Minnesota)

- 230,000 acres of marginal farm land has been restored (or prevented CRP conversion to agriculture) over the last 26 years, leading to the sequester of approximately (**316,500 – 781,000 metric tons of carbon dioxide per year** (assuming easements in 75% grassland and 25% non peatland wetlands and sequestering .3-.6 MT C per ac./yr in prairie and .6-1.9 MT C per ac./yr. in wetlands) (Anderson et.al.2008). **Cumulative CO^2 sequestration over 26 years has been approximately 8.2 million MT CO^2 – 20.3 million MT CO^2.**

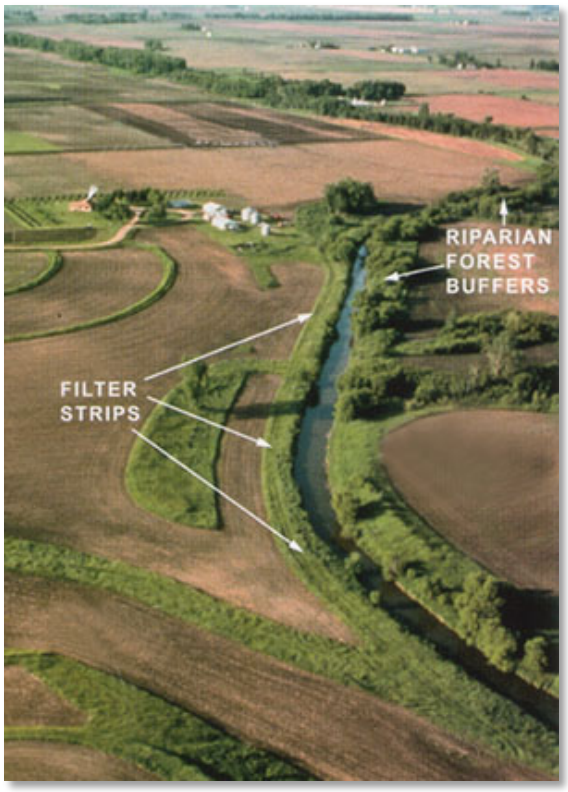
The equivalent of approximately **66,790 metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from fertilization and release of nitrous oxide (assuming 44% of agriculture in fertilized corn and the equivalent of .66 mT of CO^2 emitted per ac./yr. for anhydrous ammonia use) (Pearson et.al. 2010). Approximately **14,170 additional metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from fertilizer production for retired lands (assuming 44% of agriculture in fertilized corn and .14 mT of CO^2 to produce fertilizer for one acre, EPA 2013).

- Approximately **9,200 metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from burning of fossil fuels for farming marginal agricultural fields that are restored to native vegetation (assuming .04 mT of CO^2 to cultivate, plant and harvest, EPA 2013).

Soil and Water Conservation Grants

- Approximately **28,000 -56,000 metric tons of carbon dioxide per year** have been sequestered through soil and water conservation grants (assuming 23,265 acres of grassland planted sequestering ,.6-1.9 MT C per ac./yr., and 6,424 acres of trees and shrubs planted sequestering .1-.2 MT C per ac./yr.) (Anderson et.al.2008).

- The equivalent of approximately **8620 metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from fertilization and release of nitrous oxide (assuming 29,689 acres, 44% of agriculture in fertilized corn and the equivalent of .66 mT of CO^2 emitted per ac./yr. anhydrous ammonia use)(Pearson et.al. 2010). Approximately **1830 metric tons of additional carbon dioxide per year** will be prevented from entering the atmosphere from fertilizer production (assuming 29,689 acres, 44% of agriculture in fertilized corn and .14 mT of CO^2 to produce fertilizer for one acre)(EPA 2013).
- Approximately **520 metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from burning of fossil fuels for farming land areas in conservation practices (assuming 29,689 acres, .04 mT of CO2 to cultivate, plant and harvest)(EPA 2013).
- The equivalent of approximately **17,320 metric tons of carbon dioxide per year** will be prevented from entering the atmosphere from nitrous oxide release from lands with nutrient management plans (assuming 180,723 acres, 44% of agriculture in fertilized corn, a 33% reduction in nitrogen fertilizer use with nutrient management plans, and the equivalent of .66 mT of CO2 emitted per ac./yr.)(Pearson et.al. 2010, EPA 2013).



Examples of soil and water conservation projects.

How have BWSR's actions benefited Minnesotans and created jobs?

These conservation programs have many benefits to Minnesotans. In addition to mitigating climate change through carbon sequestration and decreased petroleum and fertilizer use, important environmental services such as hunting, fishing, bird watching, boating and swimming are provided. Conservation projects also support jobs to those involved in restoration planning and design, native seed production, construction, native seeding, vegetation management and regulatory and conservation program administration. In addition, the United States Fish and Wildlife Service's "National Survey of Fishing, Hunting and Wildlife Associated Recreation" finds that hunters, fishers, and wildlife watchers spent over $3.9 billion (2006) on their activities in Minnesota.

What is BWSR doing now to mitigate further climate change?

Wetland Protection (Wetland Conservation Act)

- Continued protection of Minnesota Wetlands through administration of the Wetland Conservation Act, preventing the release of stored carbon and methane.
- Restoration of high quality, diverse, and resilient wetlands to replace wetland losses. Evidence suggests more carbon is sequestered by a richer mix of native species (such mixed forests) and communities are more stable over time. BWSR has developed technical resources to help practitioners restore diverse and resilient landscapes.
- Restoration of forested wetlands (particularly white cedar and tamarack swamps) through planting and hydrology restoration in northern Minnesota.
- Investigating methods to restore wetlands that are more resilient to landscape stressors with improved site assessment, installation and maintenance techniques.

Conservation Easements (Reinvest in Minnesota)

- BWSR is securing easements on approximately 5,000 - 8,000 acres per year.
- Re-enrollment of CRP into conservation programs preventing loss of landscapes where carbon sequestration has been occurring for many years.
- Sequestering and protecting stored carbon by promoting restoration of high functioning and sustainable conservation prairies and wetlands in key corridors and complexes informed by the Minnesota Prairie Conservation Plan and other key plans.
- Protecting stored carbon by preserving natural shoreline forest lands around shallow wild rice production lakes via permanent riparian easements in

Lakeshore buffer in Washington County.

northern Minnesota forest region.

- Sequestering carbon by converting floodplain lands from crop production to permanent native flood plain forest cover in areas that have been frequently flooded.
- There is a greater focus on restoring habitat complexes and corridors to buffer and increase the resilience of native plant communities. These areas also provide key areas of refugia for pollinators and many other wildlife species.
- BWSR is focusing on the restoration of high quality pollinator habitat to support declining pollinator populations. Pollinators play a key role in supporting landscape resiliency by pollinating about 30% of crops and 70% of native plants that in turn provide many landscape functions.

Soil and Water Conservation Grants

- Protecting soil carbon and decreasing nitrous oxide emissions from fertilizer by promoting cover crops and conservation tillage through a soil health initiative.
- Focus on multipurpose drainage management to provide multiple environmental benefits including the management of more frequent large storm events. These types of practices minimize pollutants and water fluctuations into natural ecosystems, maintaining their resilience.
- BWSR is using major watersheds as the scale for monitoring and assessing water quality and for developing water management and TMDL implementation plans. This new approach involves four steps: 1)monitoring and gathering data, 2)assessing data, 3)setting targets and goals, and 4) implementing permits, projects and policies.
- New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) is being incorporated into water plans to ensure that new infrastructure and stormwater systems plan for increased frequency of large storms.
- The Minnesota Ag Water Quality Certification Program is a voluntary program currently under development that is designed to accelerate adoption of on-farm conservation practices that protect soils and restore water quality in Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices will be certified and in turn assured that their operation meets the state's water quality goals and standards for a 10-year period.

Grant/Information Links:

Wetland Protection (Administration of the Minnesota Wetland Conservation Act): http://www.bwsr.state.mn.us/cs/index.html
Conservation Easements (Reinvest in Minnesota): http://www.bwsr.state.mn.us/easements/index.html; http://www.bwsr.state.mn.us/grants/RIM_services.html
Soil and Water Conservation Grants: http://www.bwsr.state.mn.us/cleanwaterfund/index.html; http://www.bwsr.state.mn.us/cs/index.html; http://www.bwsr.state.mn.us/cs/index.html; http://www.bwsr.state.mn.us/cs/index.html
Disaster Recovery Assistance: http://www.bwsr.state.mn.us/grants/DRAP.html

What is BWSR doing now to adapt to climate change?

The following are key strategies being used by BWSR to adapt to climate change and other landscape stressors. Many of these strategies focus on methods to increase the resiliency of landscapes. Appendix C provides additional information about restoring resilient, functional landscapes.

BWSR relies on strong partnerships to achieve successful conservation projects.

Wetland Restoration and Protection

- Carbon Sequestration
- Restoring Native Vegetation for Landscape Resiliency
- Cooperative Weed Management Areas
- Soil Health Initiative
- Multipurpose Drainage Management
- Northern Forest Management
- Disaster Response

The RIM and the RIM-WRP wetland restoration partnership, as well as WCA implementation, help restore and maintain water retention, runoff reduction, wildlife habitat, and water quality in Minnesota through wetland restoration and protection. This, in turn, enhances adaptation to climate change. Specifically, the ecosystem services provided by wetlands protect against intense storm events and periods of drought. RIM-WRP restores tens of wetlands per year, many of which are quite large. Associated upland buffers provide substantial native vegetation areas, with all of the interconnected benefits for landscape resiliency.

Carbon Sequestration

The primary purpose of RIM-WRP, Native Buffers, and other BWSR programs is to reduce soil erosion, restore native landscapes, improve water quality and improve wildlife habitat. Carbon sequestration is a secondary benefit of many of these conservation implementation activities. The increase of soil organic carbon in Minnesota landscapes provides many ecosystem services that enhance our adaptability to a changing climatic regime. Landscape management practices such as planting trees in urban and rural landscapes, forest thinning and prescribed burning can increase the landscapes ability to sequester carbon. Soils rich in organic carbon are better able to:

- Tolerate drought conditions
- Increase infiltration rates and reduce surface runoff
- Store water on the landscape (for every 1% increase in soil organic matter, the soil can hold an additional 16,500 gallons of water per acre to a depth of 1 foot).

Emergent plants provide many ecological benefits.

Restoring Native Vegetation for Landscape Resiliency

The strategic use of native vegetation can play an important role in restoring resilient landscapes. The following are some key strategies:

1) Restoring natural systems that provide multiple landscape benefits

2) Buffering and decreasing fragmentation of intact plant communities and creating genetic corridors
3) Restoring plant communities that fit site conditions
4) Promoting vegetation sources that fit current and expected project site conditions (in some cases this may mean selecting sources from south of projects rather than north of projects).
5) Promoting individual species for projects that can handle expected conditions (such as prairie species for drought, and rhizomatous emergent plants for fluctuating water levels) and provide ecological functions.
6) Promoting species diversity to increase resiliency and promote habitat for a wide range of wildlife species including pollinators.
7) Use of deep rooted plants in stormwater systems to promote infiltration and groundwater recharge.
8) Managing invasive species across geographic and ownership boundaries to minimize their competitive advantage.
9) Conducting outreach (BWSR What's Working Page) on successful strategies for installing and managing native vegetation.
10) Studying how our landscapes and plant species adapt in the future
11) Adapting our approaches based on what we learn

Cooperative Weed Management Areas (CWMAs)

Cooperative Weed Management groups are local organizations that provide a mechanism for sharing invasive species management expertise and resources across jurisdictional boundaries in order to achieve widespread invasive species prevention and control in a broader geographic region.

BWSR has helped start up and/or support 23 CWMAs in Minnesota covering 33 counties in recent years. These cooperative groups help to control invasive species and noxious weeds on public and private lands, which in turn helps improve native vegetation areas, including species diversity, which improves climate adaptation. These efforts help make conservation lands more resilient and sustainable.

The rapidly expanding invasive plant wild parsnip has been a focus of several CWMAs.

Soil Health Initiative

BWSR is coordinating with the USDA-NRCS, other agencies and local government units to develop and accelerate a Soil Health Initiative, including connection with multipurpose drainage management, nutrient management and soil erosion reduction. Through information and education sharing, momentum is growing for this initiative. These efforts address several aspects of landscape resiliency and sustainability, including erosion reduction, soil water holding capacity, runoff reduction, nutrient management, and agricultural productivity.

Cover crops planted to stabilize soils and improve soil health.

Basic Principles of Soil Health

1) Keep the soil covered as much as possible
2) Disturb the soil as little as possible
3) Keep plants growing throughout the year to feed the soil
4) Diversify as much as possible using crop rotation and cover crops

Soil Health Management BMPs

1) Conservation Crop Rotation
2) Cover Crops
3) No Till
4) Mulch Till
5) Mulching
6) Nutrient Management
7) Pest Management

No till farming helps maintain soil structure and organic content.

These practices improve soil characteristics that allow soils to adapt to a changing climate including drought, intense storm events, and increased soil temperatures.

- Increase soil organic matter (SOM)
- Reduce sheet, rill and wind erosion
- Conserves soil moisture
- Improves water holding capacity of soil
- Increases soil moisture for plants
- Moderate soil temperatures

Multipurpose Drainage Management

BWSR promotes and supports implementation of traditional and new conservation practices, including conservation drainage and drainage water management practices. These practices help reduce runoff and nutrient loss, avoid runoff concentration, protect areas where runoff concentrates, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding. New for FY 2013 in the CWF Conservation Drainage Management Program is cost-share for targeted drainage water management in tiled agricultural land and for development of multipurpose drainage management plans for public drainage systems. Multipurpose drainage practices help make working lands, as well as artificial and natural drainage systems, more resilient to extreme weather events.

A variety of conservation practices can be used to improve water quality in agricultural areas.

Northern Forest Management

BWSR is working through partnerships to protect the integrity of northern forests. Two recent efforts include the protection of wild rice lakes and surrounding forest through the Reinvest in Minnesota Program, and an effort to protect and restore while cedar wetlands that are becoming much less common.

Coniferous forest in Itasca County.

Disaster Response

Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota. Between 2000 and 2012 BWSR has provided $42.3 million for flooding in southeast, northeast and northwest Minnesota with a focus on rebuilding infrastructure that will be resilient to future storms.

Flooding in southeast Minnesota.

Riverbank eroded following heavy rains.

Where are we going with future efforts?

Wetland Protection (Wetland Conservation Act)

Sedge meadow wetland in Clay County.

- Continued protection of Minnesota Wetlands preventing release of carbon and methane.
- Targeted restoration of wetlands in habitat complexes and corridors to promote resiliency to landscape stressors and to provide refugia for wildlife species.
- Focus on restoring forested plant communities and deep marshes that may have higher rates of carbon sequestration (Adamus 2008).
- Focus on restoring wetlands that will have high levels of carbon sequestration.
- Ensuring that the planning and design of replacement wetlands will be more resilient to the effects of climate change.
- Encourage greater public outreach and participation in wetland protection.
- Investigate methods to restore natural hydrology and diversity to forested wetlands.

Conservation Easements (Reinvest in Minnesota)

Restored wetland with diverse wet meadow planting.

- Targeted protection and restoration of key habitat complexes and corridors to maximize habitat and plant community benefits.
- Continue efforts to increase carbon sequestration in all parts of Minnesota by converting marginal lands from agricultural production to permanent native vegetative species. As part of this effort, promoting land use and land cover changes that will most effectively sequester carbon.
- Promoting management practices that promote carbon sequestration such as forest management (lengthening time between harvests, selective thinning for increased stocking rates and planting fast growing species) and grassland management such as prescribed burning and prescribed haying and grazing that increases carbon storage of prairies.
- Use of carbon markets as part of conservation easements. Management of easements to maximize carbon sequestration.
- Increased use of native prairie species for bioenergy production

- Focus on controlling woody invasive species that are starting to invade northern forests.

Soil and Water Conservation Grants

- Multi-functional (carbon sequestration, biofuels, pollinator habitat, food production) plantings in agricultural areas.
- Targeted and reduced use of nitrogen fertilizer to decrease nitrous oxide release.
- Increases use of no-till farming, cover crops and perennial vegetation in agricultural areas to store carbon, promote soil health, and decrease heat absorption from tilled ground.
- Increased incentives and new standards that encourage carbon sequestration and greenhouse gas emission reductions.
- Promote innovative urban stormwater BMPs.
- Increased focus on tree planting in urban and previously forested rural areas to sequester carbon, improve air quality, reduce stormwater runoff, decrease the heat island affect in urban areas, control erosion, promote biodiversity and stabilize watersheds.
- Development of new tools to estimate the amount of carbon stored and greenhouse gas emissions reduced by agriculture BMPs.
- Further development of carbon and environmental benefit markets.
- Increased perennial cover and biofuel production in agricultural areas.
- Increased local food production.

Native prairie holds potential as a source of biofuel production.

Appendix A: Summary of Recent Climate Reports

NOAA Atlas 14 – New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) show that the amount of rainfall for given frequencies has risen substantially.

Minnesota Environment and Energy Report Card (2012) – shows that lakes are thawing sooner.

Minnesota Sea Grant – Since 1980 surface water temperatures on Lake Superior in summer has warmed twice as much as the air above it. Over the winter, the area of the lake covered by ice is decreasing by about .5% per year. Ice cover in Lake Superior has decreased from 23% to 12% over the last century.

National Climate Assessment and Advisory Committee – Concludes that by the middle of the century, the average temperature of the Midwest Region will increase by approximately 3.8 degrees Fahrenheit, relative to the average for 1979 to 2000. If the current high emissions trend scenario is followed, the increase will be approximately 4.9 degrees Fahrenheit.

Working Group 1 Contributions to the IPCC Fifth Assessment Report "Climate Change 2013: The Physical Science Basis Summary for Policymakers" - At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.

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Appendix C: Strategies for Restoring Resilient, Functional Landscapes

The following information summarizes strategies for restoring landscapes that are resilient to climate change and other stressors and will provide important landscape functions and services into the future. These strategies borrow from the disciplines of conservation, ecological restoration, landscape ecology, and sustainable farming and are key methods for developing landscapes that are resilient to climate change.

1) ***Strategic Site Selection -*** Work with project partners to identify the functions that are most beneficial for an individual landscape and where projects should be located to best provide those functions. It many cases this involves restoring habitat complexes or buffering key water resources or plant communities to restore natural, nutrient cycling and plant and animal populations. Site projects in locations where ecological stressors such as un-natural water fluctuations, decreasing water tables, or invasive species will not significantly detract from key functions into the future.

2) ***Designing for Multiple Functions*** - Be strategic in the selection of primary and secondary goals. Be hydrology selective in making certain functions a priority, but remember that multiple functions including wildlife habitat, plant diversity, food production, stormwater treatment, soil quality and nutrient cycling can often be accomplished at once.

3) ***Making Landscape Connections*** - Establish strong connections through landscapes. Create habitat and genetic dispersal corridors and decrease landscape fragmentation. Or, create a network of conservation practices in agricultural areas. Pulling together small parts plays a key role in restoring landscape resiliency and providing refugia for pollinators and other at-risk species.

4) **Matching Plant Communities to the Site -** Match your targeted vegetation to the native plant community that best fits the topography, soils, hydrology, and climate conditions (including the potential future climate) of your site. Also restore natural hydrologic regimes to aquatic and wetland systems. Historic plant community information can be used as a guide for decision making. Determine the kinds of native wildlife that live in the area or migrate through, and include native plants natural to the site that will provide food and shelter for many animal species.

5) ***Restoring and Maintaining Diversity*** - Plant diversity (and structural diversity of plant communities)supports wildlife species and increases resiliency by helping plant communities and agricultural systems to continue functioning as intact systems during climate variation. Filling niches with native species also prevents the establishment of invasive species. Restoring natural disturbances such as prescribed fire, grazing and water fluctuations plays a key role in maintaining diversity. In addition to plant species diversity protect genetic diversity of individual plant species by using site appropriate sources that can adapt to future conditions.

6) ***Working with Ecological Adaptation*** - Natural plant communities have the ability to adapt. They develop a natural dynamic though genetic adaptation, succession and natural colonization. Incorporate these processes into projects to complement restoration efforts, provide desired ecological functions, and buffer the community during future changes in climate and associated disturbance. Assisted migration may be needed in some ecosystems to help maintain plant community integrity.

7) ***Providing Habitat for Pollinators and other Beneficial Insects*** - Pollinators and other insects play an essential role in supporting ecosystems by pollinating around 70% of flowering plants and providing food sources for a wide range of wildlife species. Support insect populations by minimizing pesticide use, buffering natural areas and diverse plantings from pesticide exposure, restoring habitat complexes and wide natural corridors, increasing plant diversity, and restoring clean water sources.

8) ***Effective Water Management, Treatment and Use*** - A variety of practices including perennial crops, conservation tillage, conservation drainage, cover crops, buffer strips, infiltration basins, raingardens and wetland restoration help manage water resources. Incorporate these practices in urban and rural landscapes to reduce runoff, recharge groundwater, maintain agricultural productivity, improve water quality, and reduce flooding. Promote the wise use of water resources and the use of catchment systems to help ensure adequate supplies into the future.

9) ***Preserving and Restoring Soil Health*** - Soils that have good soil structure, organic content and microorganism populations translate into healthy and productive ecological and cultural landscapes. Soil health can be restored through planting cover crops, no-till farming, and establishing perennial vegetation.

10) ***Managing Invasive Species Across Boundaries*** - Invasive species are effective at dispersal, giving them an advantage in adapting to climate change. Plan to work in partnerships and manage invasive species across ownership boundaries to restore resilient landscapes.

11) ***Practicing Adaptive Management*** - Adjust management practices based on monitoring efforts and experience with successes and failures to improve the long-term effectiveness of management practices and resiliency of plant communities. Practices such as prescribed burning, water level management and prescribed grazing may replicate natural disturbances and promote diversity and resiliency.

12) ***Learning from Project Experience*** - Information about project successes and innovative practices is valuable. What practices provide the most benefits in our landscapes? What common activities are not worth the cost or, worse, make a problem worse? BWSR's "What's Working" information summarizes real-world outcomes.