Highlights

The *Second State of the Carbon Cycle Report* (SOCCR2) provides a current state-of-the-science assessment of the carbon cycle in North America (i.e., the United States, Canada, and Mexico) and its connection to climate and society (see Box 1, What Is SOCCR2?, this page). Information from the report is relevant to climate and carbon research as well as to management practices in North America and around the world. This general overview provides abbreviated highlights of some of the many significant findings from the 19 chapters in SOCCR2.

Carbon Dynamics in North America and the United States in a Global Context

Land ecosystems and the ocean play a major role in the removal and sequestration of carbon dioxide (CO_2) from the atmosphere. From 2007 to 2016, these reservoirs annually removed and stored an average of about 5.4 billion metric tons of carbon that otherwise would have remained in the atmosphere—about half the amount emitted during that period. About 11% to 13% of global ecosystem carbon removal can be attributed to North American ecosystems. Whether the land and ocean will continue to absorb similar amounts of carbon in future years is unclear, since changes in climate, human activities, and ecosystem responses may alter future long-term removals of carbon from the atmosphere. Although North America contributed substantially to global atmospheric carbon emissions over the past decade, its total carbon emissions due to fossil fuel use (referred to in this document as "fossil fuel emissions") decreased by about 23 million metric tons of carbon per year. Meanwhile, global emissions continued to increase, thus reducing the relative contribution of North America to total fossil fuel emissions from 24% in 2004 to less than 17% in 2013.

In addition to reducing the use of fossil fuels, mitigation and management activities in North

Box 1. What Is SOCCR2?

Authored by more than 200 scientists from the United States, Canada, and Mexico, the *Second State of the Carbon Cycle Report* (SOCCR2) provides an up-to-date assessment of scientific knowledge of the North American carbon cycle. This comprehensive report addresses North American carbon fluxes, sources, and sinks across atmospheric, aquatic, and terrestrial systems, as well as relevant perspectives from scientific observations and modeling, decision support, carbon management, and social sciences. The report presents Key Findings and actionable information on the observed status and trends within the North American carbon cycle, as influenced by natural and human-induced factors. These findings are based on multidisciplinary research that includes experimental, observational, and modeling studies from the last decade. Intended for a diverse audience that includes scientists, decision makers in the public and private sectors, and communities across the United States, North America, and the world, SOCCR2 provides information to inform mitigation and adaptation policies and management decisions related to the carbon cycle and climate change. It also will help support improved coordination for pertinent research, monitoring, and management activities necessary to respond to global change. SOCCR2 informs policies but does not prescribe or recommend them.

America and around the world include afforestation and reduced deforestation, restoration of coastal[1] and terrestrial wetlands, and improved land-management practices in forests, grasslands, and croplands. These activities can maintain or increase ecosystem carbon sinks (i.e., carbon storage or removal) while decreasing the sources or emissions of carbon to the atmosphere. However, Arctic warming and disturbances such as pest outbreaks, wildfires, and destruction of wetlands may disrupt and decrease carbon removal, thereby releasing previously removed carbon back to the atmosphere (see Box 2, Why Is the Carbon Cycle Important?, this page).

Fossil Fuels and Economic Impacts

Over the past decade, fossil fuel emissions continued to be by far the largest North American carbon source. The United States is currently responsible for about 80% to 85% of fossil fuel emissions from North America. The financial crisis around 2008 contributed to a reduction in North American fossil fuel emissions as economic and industrial growth slowed. Yet, as the economy has recovered, increased energy efficiency and economic structural changes have enabled economic growth while continuing the trend of lowering CO_2 emissions. Over the last decade, North America has reduced its CO_2 emissions from fossil fuels by about 1% per year, as the result of various market, technology, and policy drivers.

A Changing Landscape

At the global level, land-use change due to social, demographic, and economic trends is projected to contribute between 11 and 110 billion metric tons of carbon to the atmosphere by 2050. However, the trend in the United States is the opposite: current assessments suggest that better forest management practices, as well as reforestation and other improvements in ecosystem and resource management, are helping the nation decrease its carbon emissions.

[1] Coasts and coastal ecosystems in SOCCR2 include mangroves, tidal marshes, and seagrass meadows.

Box 2. Why Is the Carbon Cycle Important?

The carbon cycle encompasses the flow, storage, and transformation of carbon compounds that are central to life and to the production of food, fiber, and energy. Carbon also helps regulate Earth's climate, including temperature, weather events, and more. This report assesses the complex, interconnected ecological and societal aspects of the carbon cycle, illustrating the importance of the carbon cycle to ecosystems, regions, and communities and projecting possible future changes to the carbon cycle and impacts on humans and ecosystems, while also presenting relevant issues for decision makers.

Ocean Acidification

Ocean acidification, or the decrease in seawater pH due to increased oceanic CO_2 absorption, can adversely affect many marine populations and ecosystem processes, including organisms that people rely on for food and ecosystem services that sustain economies and cultures throughout North America. Acidification is occurring faster in circumpolar regions and some coastal areas than in the open ocean. For example, over the past decade, Arctic and Pacific Northwest coastal waters have experienced longer, more frequent periods of lower pH, putting livelihoods reliant on these areas at increased risk. Maintaining and expanding existing ocean observing programs, as well as continuing coordinated work with stakeholders, will be critical to ensure a healthier ocean, resilient communities, and strong economies.

Arctic Changes

The environment of high-latitude regions, such as the Arctic, is changing at a faster pace than the rest of North America. For example, Arctic surface air

temperatures are rising about 2.5 times faster than the global average. This increase can destabilize permafrost soils (i.e., soil that remains permanently frozen at some depth) and surrounding landscapes, which exist throughout the Arctic and store almost twice the amount of carbon currently contained in the atmosphere. Warming temperatures can release this stored carbon into the atmosphere. In addition, accelerated warming increases the frequency and intensity of fires, which also release large amounts of carbon stored in Arctic permafrost, surface soils, and vegetation.

Carbon in Crops

Most carbon in croplands is stored in the soil and is sensitive to increasing temperatures, land-use changes, and agricultural development and practices, all of which can result in the loss of carbon from the soil to the atmosphere. Soil carbon stocks can be increased or stabilized by incorporating practices that 1) keep the land covered with plants, especially deep-rooted perennials and cover crops, 2) protect the soil from erosion (e.g., by decreasing tillage), and 3) improve nutrient management. Additionally, optimizing nitrogen fertilizer management to sustain crop yields and reduce nitrogen losses to air and water can help reduce greenhouse gas (GHG) emissions and increase food availability for growing populations.

Indigenous Communities

North American non-Indigenous, fossil fuel–based societies can benefit from understanding how Indigenous communities manage carbon in day-to-day living. These communities offer potentially valuable lessons on how to address emissions reduction and carbon capture through people-focused approaches that couple technological and ecological systems with their traditional practices of agrarian-based infrastructure and tribal community values. While quantitative analysis of these practices is only beginning, many Indigenous communities across the United States, Canada, and Mexico are managing carbon stocks and fluxes to reduce GHG emissions through sustainable management of forests, agriculture, and natural resources.

Box 3. How Can SOCCR2 Inform Decision Making?

The information in the *Second State of the Carbon Cycle Report* (SOCCR2) reflects the current peer-reviewed, scientific consensus of the multidisciplinary carbon cycle research community. This decadal assessment responds to the needs of multiple stakeholder groups that rely on the science it encompasses to manage ecosystem services and prioritize actions for reducing carbon emissions, as these groups aim to mitigate the effects of climate change on their communities and environments. Stakeholders in governments and institutions at the federal, provincial, state, and local levels, as well as carbon registries, utilities, and corporations, can use SOCCR2 information to better inform management strategies and options for transportation systems, critical infrastructure, land and ecosystem management, and other decisions that are sensitive to carbon cycle changes.

Cities and Carbon

Urban areas in North America are the primary source of anthropogenic carbon emissions. Emissions from the urban built environment are directly shaped by societal factors, including regulations and policies governing land use, technologies such as transportation, and indirect factors such as demands for goods and services produced outside city boundaries. Such societal drivers can lock in dependence on fossil fuels in the absence of major technological, institutional, and behavioral change. In urban areas many pivotal decisions and policies are made that shape carbon fluxes and mitigation (see Box 3, How Can SOCCR2 Inform Decision Making?, this page).

Knowledge Gaps and Science Informing Investments in the Future

Future research will facilitate improvements in knowledge, practices, and technologies for managing carbon emissions, removing carbon from the atmosphere, and accumulating and storing it in Earth systems over the long term. Expansions in monitoring, advanced syntheses of available observations, improvements in assessment tools and models, and extension of existing modeling capabilities can help provide more reliable measurements and future estimates of carbon stocks and flows at the local, regional, and global level. Co-benefits, such as improvements in air quality, crop productivity, energy efficiency, economic savings to taxpayers, and enhanced quality of life, often result from reduction in carbon emissions. Research identifying and responding to such opportunities—as well as addressing needs for research in carbon management and emissions mitigation across decision-making stakeholders, sectors, and governance at multiple levels—is an investment in the sustainable well-being of Earth, society, and future generations.

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Recommended Citation

Shrestha, G., N. Cavallaro, L. Lorenzoni, A. Seadler, Z. Zhu, N. P. Gurwick, E. Larson, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, and P. Romero-Lankao, 2018: Highlights. In *Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report* [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1-4, https://doi.org/10.7930/SOCCR2.2018.Highlights.