7 Tribal Lands

Lead Author

Maureen I. McCarthy, University of Nevada, Reno, and Desert Research Institute

Contributing Authors

Beverly Ramsey, Desert Research Institute and Wa-Hi-La, LLC; John Phillips, First Americans Land-Grant Consortium; Margaret H. Redsteer, University of Washington

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Sasha C. Reed (Science Lead), U.S. Geological Survey; Rachel Melnick (Review Editor), USDA National Institute of Food and Agriculture; Nancy Cavallaro (Federal Liaison), USDA National Institute of Food and Agriculture; Gyami Shrestha (Federal Liaison), U.S. Carbon Cycle Science Program and University Corporation for Atmospheric Research

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KEY FINDINGS

1. Many Indigenous peoples in North America follow traditional agricultural and land-use practices that govern carbon cycling on tribal lands. These practices include no-till farming; moving domesticated animals seasonally in accordance with forage availability; growing legumes and cover crops; raising crops and livestock native to ancestral landscapes; and managing forests sustainably with fire, harvest, and multispecies protection.

2. Scientific data and peer-reviewed publications pertaining to carbon stocks and fluxes on Indigenous (native) lands in North America are virtually nonexistent, which makes establishing accurate baselines for carbon cycle processes problematic. The extent to which traditional practices have been maintained or reintroduced on native lands can serve as a guide for estimating carbon cycle impacts on tribal lands by comparisons with practices on similar non-tribal lands.

3. Fossil fuel and uranium energy resources beneath tribal lands in the United States and Canada are substantial, comprising, in the United States, 30% of coal reserves west of the Mississippi River, 50% of potential uranium reserves, and 20% of known oil and gas reserves, together worth nearly $1.5 trillion. Fossil fuel extraction and uranium mining on native lands have resulted in emissions of carbon dioxide and methane during extraction and fuel burning. Energy resource extraction on tribal lands also has resulted in substantial ecosystem degradation and deforestation, further contributing to carbon emissions.

4. Renewable energy development on tribal lands is increasing but is limited by federal regulations, tribal land tenure, lack of energy transmission infrastructure on reservations, and economic challenges.

5. Colonial practices of relocation, termination, assimilation, and natural resource exploitation on native lands have historically hindered the ability of Indigenous communities to manage or influence land-use and carbon management both on and off tribal lands. These factors combined with contemporary socioeconomic challenges continue to impact Indigenous carbon management decision making.

6. The importance placed on youth education by Indigenous communities creates opportunities for future generations to sustain and pass on traditional knowledge important to managing carbon stocks and fluxes on native lands.

Note: Confidence levels are provided as appropriate for quantitative, but not qualitative, Key Findings and statements.

7.1 Introduction

"Indigenous peoples in North America have a long history of understanding their societies as having an intimate relationship with their physical environments. Their cultures, traditions, and identities are based on the ecosystems and sacred places that shape their world. Their respect for their ancestors and 'Mother Earth' speaks of unique value and knowledge systems different than the value and knowledge systems of the dominant United States settler society. … Some Indigenous people believe that human and nonhuman individuals come from the earth and the ability to reach harmony among individuals is dependent on being a steward of the natural environment by giving back more than what is taken" (Chief et al., 2016).

This chapter discusses how diverse Indigenous peoples in the United States, Canada, and Mexico affect and are affected by carbon cycle processes, and it explores the unique challenges and opportunities these communities have in sustaining traditional practices that are inherently tied to carbon stocks and fluxes on a range of landscapes. Carbon fluxes on tribal lands likely differ from those on analogous non-tribal land types (e.g., non-tribal forested, coastal, aquacultural, grassland, and agricultural lands) due to generations of Indigenous people

following traditional agricultural and land-use practices. These practices, referred to as "traditional knowledge," are rooted in an Indigenous worldview that holds humans responsible for the stewardship of all elements of the living and nonliving world around them. This chapter compares traditional agricultural, land-use, and natural resource stewardship practices with those introduced to North America by European settlers to estimate carbon fluxes on tribal lands relative to similar non-tribal land types.

Intrinsic differences in traditional and historical land-use practices on and off tribal lands can inform understanding of the carbon cycle and are the basis for considering tribal lands as a focused topic in this report. The lack of direct measurements of carbon stocks and fluxes on tribal lands requires that carbon cycle impacts associated with traditional practices be considered in comparison with non-tribal practices on similar land types, as data do not yet exist for creating tribal land carbon budgets. Formidable challenges resulting from the inclusion in this report of geographically and culturally diverse Indigenous peoples across North America are acknowledged. However, outlining opportunities for further exploration of traditional practices and how they could influence the carbon cycle is essential. Both the challenges and opportunities set the stage for identifying research needs that may empower Indigenous communities to expand their influence on decision making, affecting carbon management both on and off of tribal lands. Case studies are used to illustrate how traditional forestry, livestock, and crop production practices can impact carbon stocks and fluxes. Contributions to the carbon cycle from past and ongoing fossil fuel and uranium energy extraction and the role of renewable energy production on tribal lands also are covered.

7.1.1 Indigenous and Eurocentric Worldviews

The worldview of native communities (collectively referred to in this chapter as "Indigenous peoples") from the United States, Canada, and Mexico is ecosystem- and watershed-based, inextricably bound to the land, and thus intimately connected to ecological systems integral to the carbon cycle. Management of carbon stocks and fluxes is encompassed within, and not easily separated from, the overall Indigenous perspectives that holistically link human and ecological health. These perspectives fundamentally differ from the Eurocentric worldview introduced to North American landscapes with the influx and migration of European settlers across the continent. A meaningful (albeit simplified) contrast between Indigenous and Eurocentric worldviews underpins the different approaches tribal and non-tribal communities have toward living on the land, which, in turn, influences how they manage carbon stocks differently on similar land types. Indigenous worldviews are rooted in a communal, spiritual, and cultural sense of place built on a web of connections between humans (living and ancestral) and nature (animals, plants, and minerals). Traditional agrarian practices are based on significant horticultural advancements using grouped planting strategies. One example is the "Three Sisters" agricultural system of mound structures in the eastern United States, where the climate is wetter. Another example involves planting seeds deeply in sand in the arid, rainfed agriculture of the western United States. These practices are native to ancestral landscapes and ecosystems and have integral ties to ceremonial practices and seasonal cycles. In contrast, Eurocentric worldviews are more uniformly applied and were built on the notion of altering the natural world. Agricultural practices introduced to North America by European settlers rely heavily on plowing or tilling fields, which required making significant changes to the land by clearing vegetation, including clearcutting forests, to accommodate planting.

Traditional practices tied to a holistic approach to living in balance with the drivers of air, land, and watershed change are fundamental for Native American tribes in the United States, First Nations Aboriginal peoples in Canada, and Ejido communities in Mexico (Chief et al., 2016; NCAI 2015; Blackburn and Anderson 1993). These communities have ancestral ties to the land that span thousands of years. Many Indigenous communities are agrarian based, with their livelihoods and cultural

identity intimately associated with the health and well-being of the plants, fish, animals, and natural resources of their ancestral homelands (see Figure 7.1, p. 307). Livestock grazing and crop production; seed, nut, and plant gathering; and fishing and wildlife hunting are essential for cultural ceremonies, community wellness, and economic prosperity (AANDC 2013; Assies 2007; Chief et al., 2016; Tiller 1995, 2015).

7.1.2 Carbon Cycling Considerations Unique to Tribal Lands

Carbon cycling among reservoirs in the atmosphere, terrestrial vegetation, soils, freshwater lakes and rivers, ocean areas, and geological sediments is integral to native landscapes. That said, discussions about how Indigenous peoples are affected by carbon cycle processes are different from similar discussions related to non-tribal lands, thus warranting separate consideration due to several key factors:

- Scientific data and peer-reviewed publications pertaining to carbon stocks and fluxes on reservation lands are virtually nonexistent, which makes establishing accurate baselines for carbon cycle processes problematic.
- Traditional knowledge about practices with bearing on carbon stocks on native lands (e.g., intergenerational stories, practices, and observations) often does not conform to mainstream science prescriptions for data gathered and analyzed for technical reports, including this report.
- Indigenous communities throughout North America are culturally distinct, with their own languages, practices, spiritual and cultural systems, governance structure, and deep connections to their lands, hence generalizations across North America may be of limited value.
- Native American communities in the United States and First Nations of Canada (but not Ejidos in Mexico) are recognized as sovereign nations with their own distinct policies, laws, and practices that may impact carbon stocks and fluxes on native lands.
- Native communities are heavily affected by the policies and laws of surrounding national, state, provincial, and local governments, as well as the economic and social drivers of non-tribal landowners and energy and natural resource extraction industries. Land-use decisions by native communities are influenced by high levels of poverty, unemployment, and health challenges.
- Complex Native American land tenure and water rights laws enacted by the U.S. and Canadian governments during the last two centuries have fractionated tribal land ownership, producing checkerboards of land types on reservations. In the United States, some of these lands are held "in trust" by the federal government, while others have been allotted or sold as "fee simple" lands that may be owned by one or many tribal or non-tribal individuals and subject to both tribal and non-tribal laws (Colby et al., 2005; McCool 2002; NCAI 2015; Pevar 2012; Thorson et al., 2006).

Opportunities for managing carbon stocks and fluxes present unique challenges to Indigenous peoples because of external stressors that constrain or complicate a community's ability to sustain traditional practices that affect carbon processes. These include:

- The historical practice by the U.S. and Canadian governments of relocating Indigenous peoples from their expansive ancestral homelands to reservations on "marginal lands" in remote areas, which may or may not be contiguous with their sacred places. Similar disenfranchisement of Ejido communities has occurred in Mexico, where these isolated communities have little or no self-governance (OHCHR 2011; Pevar 2012; Russ 2013).
- Close cultural and economic ties to natural resources, geographic remoteness, and

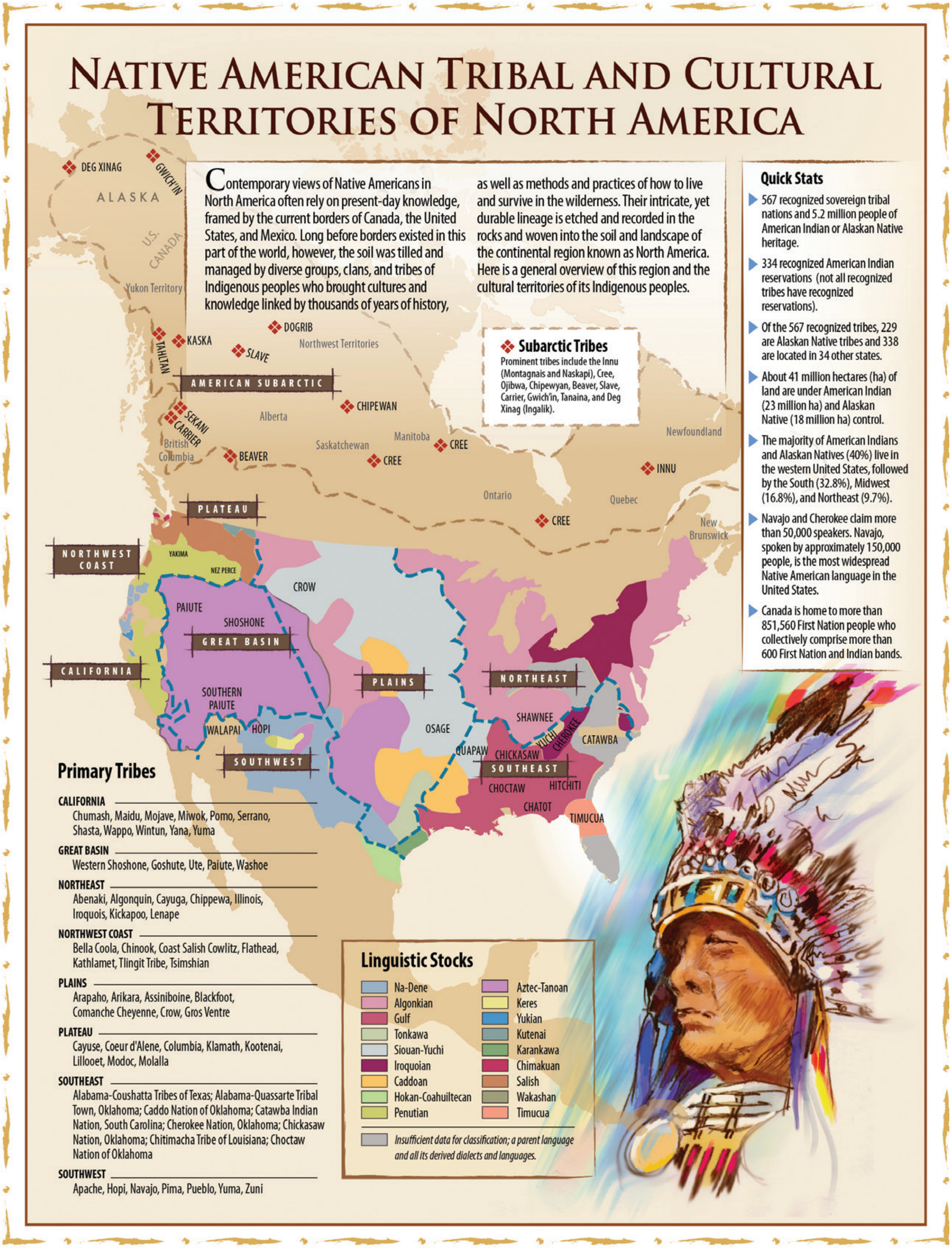

Figure 7.1. Native American Tribal and Cultural Territories of North America. Overview of primary tribes, linguistic stocks, and extent of ancestral homelands. [Figure source: Ron Oden, University of Nevada, Reno. Data sources: NCAI 2015; Prine Pauls 2017; Sturtevant 1991; U.S. Census Briefs 2012; U.S. EIA 2017a.]

economic challenges make Indigenous peoples among the most vulnerable populations to climate change. These include (but are not limited to) tribes being displaced by rising sea levels and thawing tundra and those subjected to increased heatwaves, droughts, and extreme weather events that disrupt the traditional seasonal cycle and affect native fish, plant, animal, and water resources (Bennet et al., 2014; Melillo et al., 2014; Redsteer et al., 2018; Krakoff and Lavallee 2013).

- Colonial practices of relocation, termination, assimilation, and coercive exploitation of native lands have divided Indigenous communities and limited their ability to influence surrounding national and regional government decision making related to land use and carbon cycling (Anderson and Parker 2008; Bronin 2012).
- European settlement mandated that native communities convert traditional agriculture practices to Eurocentric crop and livestock production, which forced changes in landscapes, water supplies, and community health (Reo and Parker 2013; Kimmerer 2003; Thorson et al., 2006).
- Daunting socioeconomic challenges, including high levels of poverty and disease, demand significant time, attention, and resources and can influence land-use decision making by individuals and tribal governments. Native communities are heavily reliant on a wage economy and are subject to different federal policies than other citizens in their respective countries. The poverty rate for Native Americans living on reservations in the United States is 39% (the highest in the country), the joblessness rate is 49%, and the unemployment rate is 19%. Native health, education, and income statistics are likewise lower than those for any other racial group in the United States (NCAI 2015, 2016; GAO 2015; Indigenous Environmental Network 2016; Mills 2016; Regan 2016; Royster 2012; Notzke 1994; Assies 2007; Frantz 1999).

7.2 Historical Context and North American Perspective

Short summaries of Indigenous peoples of North America (United States, Canada, and Mexico) that are relevant to this report are provided in this section. See Appendix 7A: Summary Descriptions of Indigenous Communities in North America, p. 331, for additional details and references.

7.2.1 Governance and Population

Today, federally recognized Native American tribes operate under a government-to-government relationship with the U.S. government. First Nation tribes have similar self-government status within Canada. Mexico has no established system of reservations or formal system of Indigenous community self-government.

According to the 2010 Census, the United States is home to 5.2 million people of American Indian or Alaskan Native heritage. Together, they comprise the 567 federally recognized tribes in 35 U.S. States, 229 of which are in Alaska and the remaining 338 in 34 other states (NCAI 2015; U.S. Census Briefs 2012). About 41 million hectares (ha) are under American Indian or Alaskan Native control, with approximately 5.2 million people identified as American Indian/Alaskan Native (alone or in combination with other races). Approximately 22% of Native Americans live on tribal lands and 78% live in urban or suburban environments, with 19.5% of Native people living in Alaska (Norris et al., 2012).

According to the 2011 National Household Survey, Canada is home to 851,560 First Nation people that collectively comprise more than 600 First Nation and Indian bands. First Nation people make up about one-third of the total population in the Northwest Territories and one-fifth of the population in the Yukon (Statistics Canada 2011). Nearly half of those registered under Canada's Indian Act (49.3% or 316,000) live on reserves or Indian settlements (Statistics Canada 2011).

Indigenous communities in Mexico number 16.9 million people, the largest such community in North

America. Although Mexico does not have a system of reserves or reservations for Indigenous people, the majority (80%) of all people who speak an Indigenous language live in the southern and south-central regions of Mexico (Cultural Survival 1999; Minority Rights Group International 2017).

7.2.2 Land Use: Agriculture and Energy Extraction and Production

United States

Agriculture is an important industry for Native Americans across the United States, providing more than $1.8 billion in raw agricultural products in 2012 from 20.6 million ha of farmland ($700 million from crop sales and $1.1 billion from livestock; USDA 2014). About 80% of tribal agriculture occurs in seven states: Arizona, Oklahoma, New Mexico, Texas, Montana, California, and South Dakota (USDA 2014). Coal, natural gas, and oil reserves present opportunities for an estimated $1 trillion in revenue from mining and energy production across U.S. tribal lands (NCAI 2016), and commercial fisheries, forestry, tourism, energy extraction and generation, and other industries offer other opportunities for economic growth (see Figure 7.2, p. 310). Tribal lands emit a significant amount of carbon today, largely due to a history of federal policies of fossil fuel resource development on Native American reservations. Coal strip mining on Hopi, Navajo, and Crow tribal lands supply coal-fired power plants on and near these reservations, contributing to U.S. carbon emissions (U.S. EIA 2015; Krol 2018).

The National Indian Carbon Coalition (NICC) is one organization explicitly dedicated to engaging Native American communities in carbon management (NICC 2015). NICC is a greenhouse gas (GHG) management service established to encourage Native American community participation in carbon cycle programs with the goal of furthering both land stewardship and economic development on Native American lands. NICC was created as a partnership between the Indian Land Tenure Foundation and the Intertribal Agriculture Council to assist tribes in developing carbon credit programs. With waning U.S. interest in adopting a carbon credit economy, NICC may be less impactful than originally envisioned. However, NICC-sponsored programs represent focused efforts on carbon sequestration; GHG emission reductions; and the promotion of soil health, ecological diversity, and water and air quality in the context of traditional values and economic development. If the United States chooses to pursue a carbon credit economy in the future, programs such as NICC will be invaluable in positioning Native American communities to participate and benefit socially, culturally, and economically.

Land tenure; federal regulations, policies, and laws; and cultural values have made the extraction of fossil energy, uranium, and other mineral resources on tribal lands a socially and economically complex issue. The history of natural resource development on reservation lands, as well as policies such as the Indian Mineral Leasing Act, have led to a dependence on nonrenewable resources and narrowed the economic focus for revenues supporting many tribal governments (Krakoff and Lavallee 2013). As mentioned, Native American communities are among the nation's poorest, with nearly 40% of people on reservations living in poverty (four times the national average) and average annual incomes less than half those of other U.S. citizens (Grogan 2011). Such socioeconomic challenges have been attributed with motivating some tribes to allow extraction of their mineral and fossil fuel resources (Regan 2014). The U.S. Energy Information Administration (EIA) documents the energy profiles for each U.S. state and territory and updates them monthly, including descriptions of energy extraction and use on tribal lands (U.S. EIA 2017a).

Fossil fuel and uranium energy resources beneath tribal lands are substantial, comprising 30% of the nation's coal reserves west of the Mississippi River, 50% of its potential uranium reserves, and 20% of its known oil and gas reserves, together worth nearly $1.5 trillion (Grogan 2011). Most of these resources are concentrated with a few tribes in the western United States (Grogan 2011; Regan 2014;

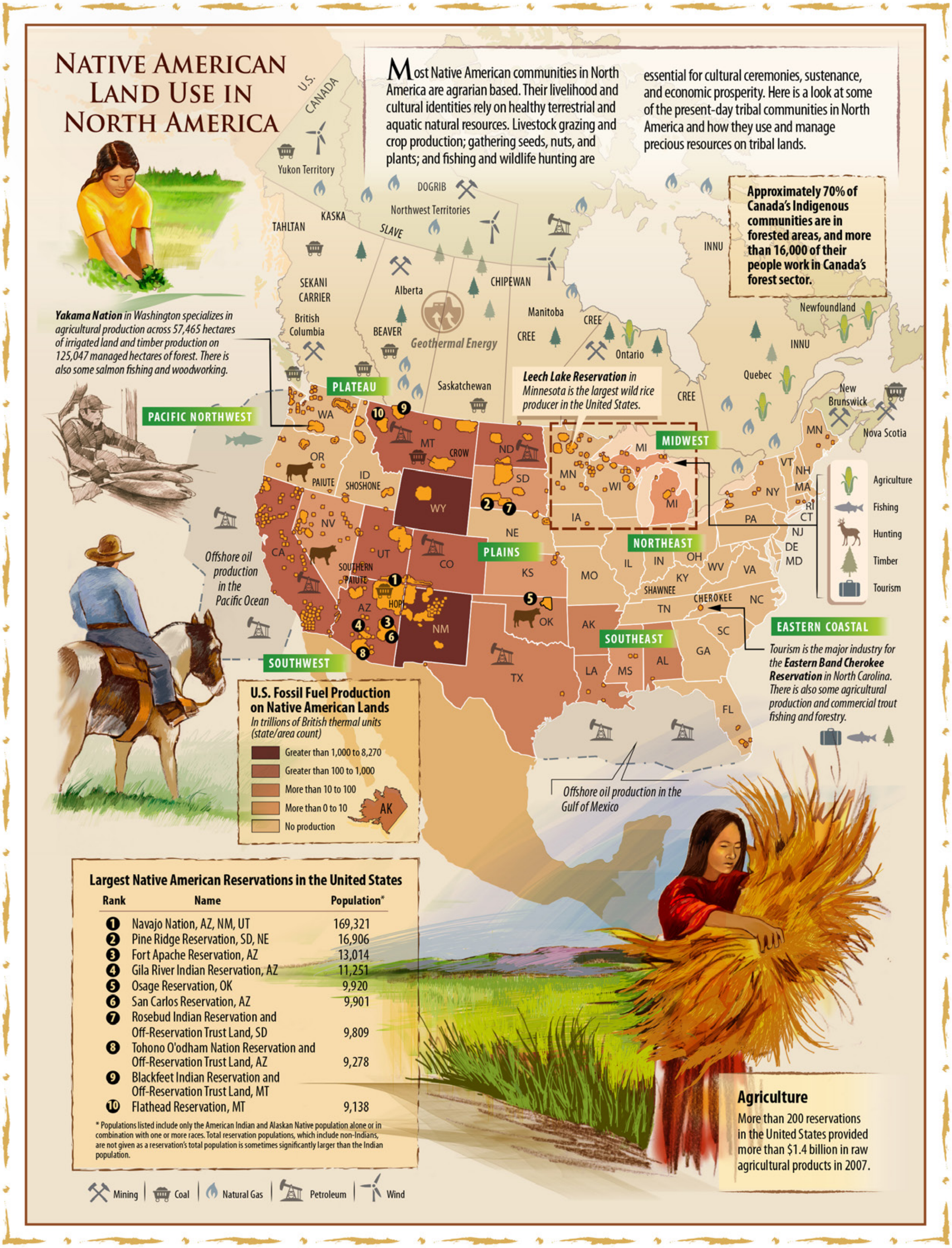

Figure 7.2. Native American Land Use in North America. The size, scale, and location of some Native American reservations in the conterminous United States are shown, along with tribal fossil fuel production, population statistics, dominant industries by region, major socioeconomic drivers, and traditional practices (e.g., agriculture, hunting, and fishing). Coal strip mining on Hopi, Navajo, and Crow tribal lands supply coal-fired power plants on and near these reservations, contributing to U.S. carbon emissions. [Figure source: Ron Oden, University of Nevada, Reno. Data sources: NCAI 2015; Prine Pauls 2017; Sturtevant 1991; U.S. Census Briefs 2012; U.S. EIA 2017a; Natural Resources Canada 2016a.]

Table 7.1. Energy Resources on Tribal Lands in the United States[a]

Tribe	Fossil Fuel and Uranium Resources
Hopi (Arizona)	Coal, oil, and gas
Navajo (Arizona and New Mexico)	Coal, oil, gas, and uranium
Southern Ute (Colorado)	Coal, oil, and gas
Ute Mountain (Colorado)	Coal, oil, gas, and uranium
Blackfeet (Montana)	Coal, oil, and gas
Crow (Montana)	Coal, oil, and gas
Assinboine and Sioux (Montana)	Coal, oil, and gas
Northern Cheyenne (Montana)	Coal and oil
Jicarilla Apache (New Mexico)	Coal, oil, and gas
Three Affiliated Tribes (Fort Berthold, North Dakota)	Coal, oil, and gas
Osage (Oklahoma)	Oil and gas
Uintah and Ouray Ute (Utah)	Coal, oil, gas, and oil shale
Arapaho and Shoshone of Wind River (Wyoming)	Coal, oil, gas, and uranium

Notes

a) Regan 2014

see Table 7.1, this page; see also Ch. 3: Energy Systems, p. 110, for information about non-tribal energy extraction). Conflicts between traditional values and the need for economic development are demonstrated by uranium extraction on Navajo lands, where nearly 30 million tons were removed from over 1,000 mines from 1944 to 1986. Half of these mines are abandoned and awaiting remediation (U.S. EIA 2017b; U.S. EPA 2018; Moore-Nall 2015). Uranium mining provided some short-term benefits from mining income and jobs but resulted in extreme ecological degradation and long-term impacts to water, public health, and soil carbon sequestration (Brugge and Goble 2002; Diep 2010).

Recent discussions have emerged regarding strategies and policy tools that tribal governments could adopt in transitioning to carbon-neutral development and climate action plans (Suagee 2012). These strategies include updating substandard tribal housing and building new homes for the unmet housing need by addressing the lack of inclusion of federally recognized tribes in the U.S. Energy Independence and Security Act of 2007 (Public Law 110–140). Although this law requires housing to conform to an Energy Conservation Code, its application to tribal housing is generally lacking in order to limit the cost of such housing, leaving Native American home occupants with higher energy bills. The Indian Tribal Energy Development and Self-Determination Act provides additional frameworks for developing energy infrastructure (Anderson 2005), but the current legal framework does not adequately address tribal needs (Bronin 2012). The financial dependence of some tribes on fossil fuel extraction is a significant barrier to embracing carbon-neutral practices, especially when tribes are excluded from alternative energy tax credit incentives. For example, 85% of Hopi tribal revenues are from strip mining coal (Krol 2018). Moreover, rigorous studies on land-use impacts to ecosystems on tribal lands would help inform and motivate tribal governments to consider energy alternatives. Other challenges include environmental concerns, such as a lack of rigorous studies on land-use impacts to local ecosystems and the exclusion of tribes from incentives such as tax credits that are available to other entities developing alternative energy projects.

Canada

Indigenous communities in Canada rely heavily on sustenance and production agriculture (i.e., crops and livestock); fishing and hunting; forestry and timber harvesting; coal, oil, and gas extraction; and some alternative energy production (Canada Energy and Mines Ministers' Conference 2016; Merrill and Miro 1996; Natural Resources Canada 2016b). These activities, along with tourism, are the major economic drivers for tribal communities. Typically, Indigenous lands are sparsely populated with few (if any) commercial industries except those associated with gaming.

Forests and forest resources offer economic opportunities for the First Nations in Canada (Natural

Resources Canada 2016a). The Canadian government's Aboriginal Forestry Initiative provides information and support for Aboriginal forestry projects, as well as more than $10 million in funding opportunities across Canada for First Nations, which control more than 3,000 ha of forested land. Approximately 70% of Canada's Indigenous communities are in forested areas, and more than 16,000 Aboriginal people have worked in Canada's forest sector since 2011 for projects across the country (Natural Resources Canada 2016a).

Mining occurs on many First Nation lands, with over 480 mining agreements for more than 300 projects signed between mineral companies and Indigenous groups since 1974. As of December 2015, 380 projects were active (Canada Energy and Mines Ministers' Conference 2016). In the oil sands region of northern Alberta, some Indigenous communities are concerned about the environmental impacts of development, but the oil sands industry also provides economic opportunities for Indigenous-owned businesses that provide goods and services to oil sands companies (Natural Resources Canada 2016b). Fisheries are a traditional and modern source of livelihood for many Aboriginal people, especially in western Canada, where food fishing and commercial fishing are highly important (Notzke 1994).

Mexico

Temperate and tropical forests make up 56.8 million ha or 40.1% of Mexico's land area. Land reforms following the Mexican Revolution of the early 1900s put more than half the country's forested lands in the hands of "Ejidos" (communally owned farming collectives) and Indigenous communities (Bray et al., 2003). The result created community forest enterprises (CFEs), through which local communities own, manage, and harvest their own forest resources including timber. Although not all CFEs are well managed, they have the potential to provide income for poor, rural communities while delivering ecological services and maintaining forest productivity and biodiversity (Bray et al., 2003). The Mexican government initially owned Ejido lands, but a constitutional amendment in 1992 gave the farming collectives formal titles to their own lands (Merrill and Miro 1996).

7.3 Current Understanding of Carbon Stocks and Fluxes

Due to many of the factors previously cited, especially the lack of explicit measurements and data for carbon cycle processes, a quantitative assessment of the carbon stocks and fluxes for Indigenous lands does not presently exist. However, comparisons can be made about carbon cycling between tribal lands and similar, non-tribally managed land types (e.g., rangelands, agricultural lands, and forests). Comparing and contrasting carbon cycling impacts resulting from traditional practices on tribal lands with Eurocentric-based land-use practices on (and off) tribal lands could prove beneficial in developing more effective carbon management programs for both tribal and non-tribal lands. As in all systems, integrating scientific, social, and economic perspectives into strategies to use and protect natural resources and sustain healthy landscapes will be valuable to communities closely tied to the land.

Several case studies are presented throughout the rest of this section to illustrate 1) the role of Indigenous agricultural practices in maintaining or enhancing carbon sequestration on tribal lands, 2) the impacts of European settlement on traditional agriculture, 3) the role of Indigenous forest management approaches for sustaining forest health, and 4) the impact of fossil fuel and uranium extraction on tribal land carbon emissions, as well as the potential for renewable energy production.

7.3.1 Role of Indigenous Agricultural Practices in Maintaining or Enhancing Carbon Sequestration

Carbon can be stored above and below ground in vegetation (live or dead) and in soils on tribal lands such as agricultural lands, rangelands, aquacultural systems, and forests (Zomer et al., 2017; Baker et al., 2007). Compared to surrounding non-Indigenous lands, agricultural (crop and livestock) practices on

tribal lands tend to be significantly less intensive, with extensive reliance on free-range grazing, dryland farming, and no-till cropping especially in arid regions (Ingram 2015; Teasdale et al., 2007; Wall and Masayesva 2004; Kimmerer 2003). Because these traditional practices are less disruptive to native ecosystems, they tend to conserve carbon stocks on the landscape (Baker et al., 2007; West and Post 2002). However, compared to agriculture on non-tribal lands, traditional practices also may reduce economic output from crop production, cattle-carrying capacity on rangelands, and timber harvests (Drinkwater et al., 1998; Gabriel et al., 2006). Therefore, carbon inventories on native lands reflect a balance between sustaining traditional practices and the adoption of more intensive Eurocentric agricultural practices to increase trade and income.

The colonial-driven transformation of human and natural systems that pushed Native American communities to marginal areas and forced tribes onto restrictive reservations with limited options for food and safety (Lynn et al., 2013; Reo and Parker 2013), coupled with the introduction and adoption of Eurocentric agriculture, crops, and land-use practices, has (in many cases) led to desertification, soil degradation, erosion, and deforestation on tribal lands. These impacts, in turn, may have reduced the carbon-carrying capacity of the soils and vegetation (Redsteer et al., 2010; Baker et al., 2007; Kane 2015; Schahzenski 2009). Alfalfa, an introduced perennial crop with a deep root structure, is a dominant production crop and economic driver for many tribes in the arid southwestern United States (USDA 2014; U.S. Census Briefs 2012). Continuous alfalfa planting has been shown to contribute to the accumulation of soil organic carbon and total nitrogen under certain temperature and precipitation conditions (Chang et al., 2012). Overall, tribal and non-tribal carbon fluxes for multiple types of agriculture are probably close to net neutral in areas where both traditional and introduced agricultural practices are in use (see Ch. 5: Agriculture, p. 229). An exception is the continued use of slash-and-burn practices by some communities in Mexico (Bray et al., 2003; Deininger and Minten 1999).

Case Studies Utilizing Traditional Farming Practices for Carbon Sequestration

"For millennia, from Mexico to Montana, women have mounded up the earth and laid these three seeds (corn, beans, and squash) in the ground, all in the same square foot of soil. When the colonists on the Massachusetts shore first saw Indigenous gardens, they inferred that the savages did not know how to farm. To their minds, a garden meant straight rows of single species, not a three-dimensional sprawl of abundance. And yet they ate their fill and asked for more, and more again" (Kimmerer 2003).

Carbon sequestration projects on agricultural lands can be realized through improved management of fertilizer applications, erosion mitigation, return to no-till or reduced-tillage farming methods (depending on location), restoration of riparian areas, grazing management plans, good livestock waste management, and other measures (Zomer et al., 2017; West and Post 2002; Baker et al., 2007; see Ch. 5: Agriculture, p. 229, and Ch. 12: Soils, p. 469, for more information on no-till agricultural impacts on carbon sequestration). In southwestern Oklahoma, NICC worked with the Comanche Nation to establish a new agriculture leasing management system across 40,000 ha of allotments and tribal-owned land. Actions that could prove to be carbon sequestration measures on this reservation include a return to no-till farming, establishment of shelterbelts to prevent wind erosion, and rotational grazing management plans (NICC 2015).

On rangelands, overgrazing, soil erosion, wildfires, offroad driving, and conversion of rangeland to farmland can release carbon into the atmosphere, but carbon also can be sequestered through sustainable land management practices. On the Santa Ana Pueblo reservation in New Mexico, NICC worked with tribal members to improve land management for carbon sequestration across 4,000 ha. Provisions included increasing vegetation cover to prevent soil erosion, decreasing the density of woody species

to prevent wildfires, minimizing offroad driving, and developing and implementing livestock grazing plans (NICC 2015). On prairie lands, the Inter-Tribal Buffalo Council is a collaborative among 58 tribes in 19 states dedicated to restoring bison to Indigenous communities to promote Native American culture and spiritual practices, ecological restoration, and economic development. Bison have a smaller ecological impact on prairie lands than cattle, and their reintroduction by Indigenous communities in the Great Plains (albeit on a small scale compared to cattle ranching) is contributing to prairie restoration (Kohl et al., 2013).

There are data from across all of North America on traditional (Indigenous) agricultural practices going back several thousand years. Both oral tradition and written accounts dating from the 1500s show evidence of agricultural practices that are now being examined as a meaningful contribution to "carbon farming" or carbon sequestration via agricultural practices. These practices include no-till seeding, use of organic mulches (wood wastes and straw), use of composts (nonconsumed plant parts and animal wastes), moving domestic animals among areas based on season and forage availability, use of legumes (nitrogen-fixing plants), and complex cropping such as planting corn in perennial fields of clover or vetch (Baker et al., 2007; Drinkwater et al., 1998; Gabriel et al., 2006).

It has long been known that soil organic matter contains one of the planet's largest carbon sinks (see Ch. 12: Soils, p. 469; Zomer et al., 2017; Kane 2015; Marriott and Wander 2006; Teasdale et al., 2007). Various organizations, including Nourishing Systems in Oregon, are working to refine traditional methods of composting and soil carbon enrichment (Goode 2017). This approach, inspired by the Buffalo Dance tradition of the Northern Plains Tribes, is designed to mimic the soil nutrient cycling resulting from buffalo roaming on tallgrass prairie lands. Sunflower stalks, which are porous and recalcitrant (rich in lignin and therefore slowly degrading), are used as the base layer in the trenches between row crops and perennials (see Figure 7.3, p. 315). Less recalcitrant cellulosic wastes such as straw are placed on top of the sunflower stalks. As the final layers, wastes or the nonedible portions from crops are added as compost. These filled trenches are covered and used as walkways as the soils are enriched slowly by the decay of the organic matter, and the soil ecological assemblage of microorganisms, insects, and worms cycle the carbon and nutrients within the soil subecosystem (Goode 2017; Schahzenski and Hill 2009; West and Post 2002). A key to soil carbon sequestration may be a switch of the mechanisms that move soils away from bacterial dominance toward fungal dominance (Johnson 2017). At least in some systems, this change in soil community can result in increased soil fertility and water storage capacity, plant water-use efficiency, and soil nutrient availability to plants. The process also reduces plowing and tillage costs, fertilizer and pesticide applications, and water (both surface and groundwater) pollution (Johnson 2017).

"In Indigenous agriculture, the practice is to modify the plants to fit the land. As a result, there are many varieties of corn domesticated by our ancestors, all adapted to grow in many different places. Modern agriculture, with its big engines and fossil fuels, took the opposite approach: modify the land to fit the plants, which are frighteningly similar clones" (Kimmerer 2003).

The Pueblo Farming Project (Bocinsky and Varien 2017; Ermigiotti et al., 2018) has documented the drought resiliency of traditional Hopi farming practices, including the development of drought-tolerant Hopi corn varieties and dryland (non-irrigated) farming. An ongoing collaboration between the Hopi tribe and the Crow Canyon Archaeological Center in Cortez, Colorado, the Pueblo Farming Project has planted, tended, and harvested experimental gardens in southwestern Colorado every summer since 2008 to investigate the viability of growing Hopi maize outside of the Hopi mesas in northern Arizona. Traditional Hopi farmers grow their corn using entirely manual cultivation practices: a digging stick, a gourd of water, and seed corn selected to meet the subsistence and ritual needs of the Hopi community (Wall

(a)

(b)

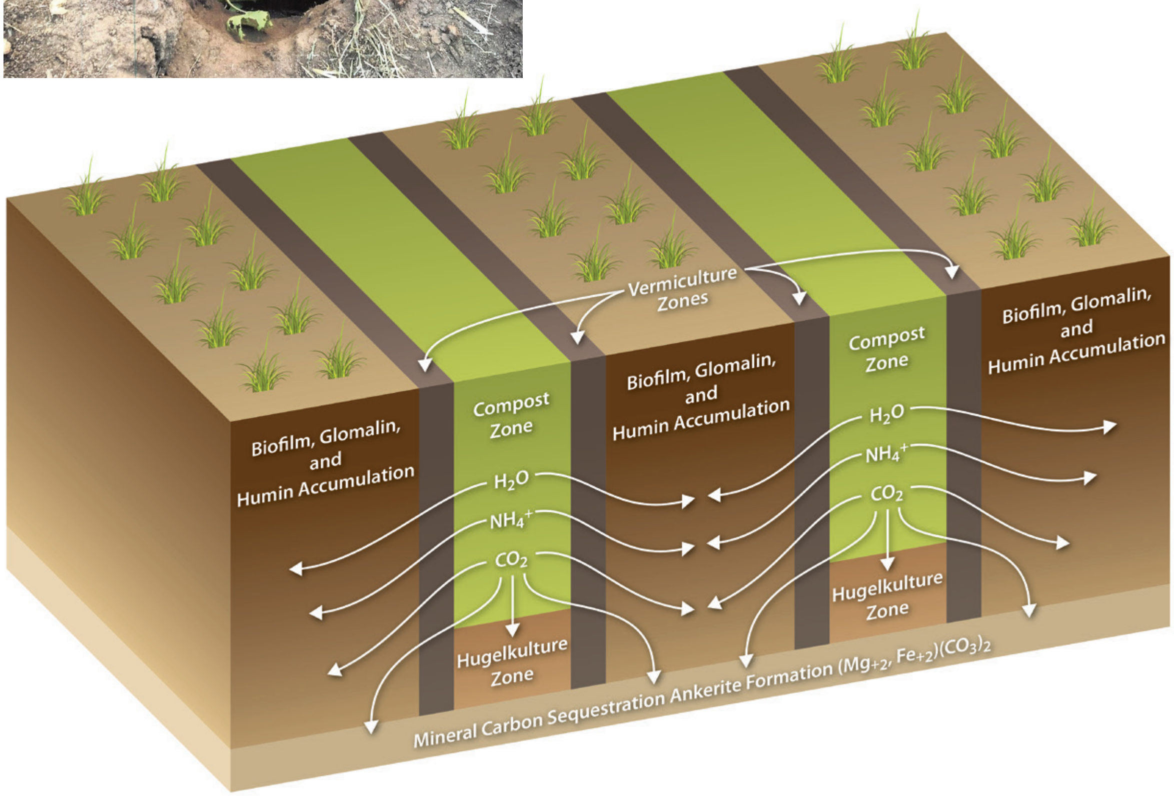

Figure 7.3. Traditional Composting and Soil Carbon Enrichment. (a) Trenched complex compost for soil carbon accumulation in soil organic matter (SOM). **(b)** SOM development using trench composting. Key: H_2O, water; NH_4^+, ammonium; CO_2, carbon dioxide. [Figure source: Scott Goode, Desert Research Institute.]

and Masayesva 2004). With no tilling or tractors and minimal water inputs, Hopi corn farming maximizes moisture, nutrient, and carbon storage in the sandy soils of the Hopi mesas. As Hopi oral history attests and archaeologists have documented, traditional Hopi corn farming has sustained the Hopi community and their ancestors for millennia (Bocinsky and Varien 2017; Coltrain and Janetski 2013; Cooper et al., 2016; Matson 2016).

7.3.2 Impacts of European Settlement on Traditional Agriculture

For tribal communities that have adopted Eurocentric crop and livestock agricultural practices, carbon fluxes likely are comparable to fluxes from adjacent, non-tribal lands, including carbon losses due to soil erosion and desiccation. Before the 1860s, Navajo Nation families lived on a subsistence mix of farming, hunting and gathering, and herding livestock. This subsistence mix required families to range widely over a vast area of traditional Navajo lands (Fanale 1982). Families moved their livestock around core grazing areas shared by networks of interrelated, extended families; during droughts they used other kinship ties to gain access to more distant locations where conditions were better. This land-use regime helped families distribute their livestock over the range as conditions warranted (Redsteer et al., 2010). After the reservation was established in 1868, land-use pressure from non-Native American settlers cut them off from the wettest areas that were best for hunting, gathering, and summer grazing. Navajo families were forced to depend more heavily on farming and especially stock raising within the more arid to semi-arid sections of their homeland (Redsteer et al., 2010). By the early 20th century, both tribal and federal government officials along with other observers were warning about desertification of Navajo ranges (Kelley and Whiteley 1989; White 1983). Stock-reduction programs of the 1930s created further restrictions by establishing grazing districts and requiring each Navajo family to have a permit for raising livestock within a particular district, not to exceed a certain number (White 1983; Young 1961). Erosion has continued to be a problem, though range managers now recognize that climate, landscape conditions, and other hydrological processes also cause regional soil erosion even without additional grazing pressures (Redsteer et al., 2010; White 1983). Currently, the early 20th century grazing policies remain in place, and further revisions to grazing are being proposed as prolonged drought conditions from 1994 to 2018 and increasing aridity continue to degrade rangeland viability, water supplies, and general living conditions (Redsteer et al., 2018).

7.3.3 Role of Indigenous Forest Management Approaches for Sustaining Forest Health

Carbon fluxes between the biosphere and atmosphere may result in net carbon sinks (via carbon sequestration) in areas engaged in sustainable forest management and timber harvesting (see Ch. 9: Forests, p. 365). Numerous Indigenous communities throughout North America have sustainably managed forestlands, which may serve as carbon sinks in both tribal and non-tribal areas. Indigenous forestry practices in some cases have resulted in large and diverse stands of timber (Trosper 2007) that could be evaluated for their carbon storage impacts.

Case Studies of Sustainable Forest Management in the United States, Canada, and Mexico

United States. A renewed focus on traditional values, environmental stewardship, public health, and food sovereignty has led many Native American communities to adopt (or re-adopt) sustainable forest management practices rooted in their traditions and cultures. Exemplifying this renewed focus are the Confederated Salish and Kootenai Tribes (CSKT) of the Flathead Reservation in Montana, who have implemented an ecosystem-based forest management plan (Chaney 2013; CSKT 2000) that uses ecological, cultural, social, and economic principles to maintain and restore the ecological diversity and integrity of forests on the Flathead Reservation. Fire was integral to how the Salish, Kootenai, and Pend d'Oreille tribes managed the forests that provided them with sustenance and livelihood.

The CSKT have reintroduced traditional practices including the use of fire to manage their forests. These practices are enhancing forest ecosystem health and diversity and have reduced the impact of catastrophic wildfires that occurred on neighboring non-tribal federal lands (CSKT 2000). Carbon stocks are affected by the distribution and health of both trees and culturally important understory plants. Although fire can release large amounts of carbon and carbon stocks and fluxes have not been explicitly measured on the Flathead Reservation, the reintroduction of these traditional practices is resulting in more sustainable and healthy forests that are more diverse and fire-resistant.

Prior to European contact, the Salish, Kootenai, and Pend d'Oreille tribes of northwestern Montana (who were subsequently relocated to the Flathead Reservation) derived most of their sustenance from the surrounding forested lands, including culturally significant tree species (e.g., whitebark pine) and understory vegetation (e.g., huckleberries and medicinal plants; CSKT 2000). They used fire to actively manage forests for at least 7,000 years, according to oral tradition. These "Indian-lit fires" were usually set in the cooler days of spring, early summer, and fall when burning conditions were less hazardous; the fires were typically lower in intensity than lightening fires, which usually ignite in the hotter summer season. Using both fire and active harvesting, the tribes managed the forests holistically to balance stand density, understory vegetation health, and animal habitats to support hunting. The fire-exclusion policy introduced by the U.S. government in 1910, as well as the introduction of clearcut logging and cattle grazing, changed the biodiversity and health of these forests. During the last century, many tree stands have grown denser with many trees stressed from lack of water and insect and disease outbreaks. Although carbon stocks may have increased in these forests during this time, the forests are much more susceptible to catastrophic wildfires, as was evident in the summer of 2017 when over 405,000 ha were burned by wildfires in Montana (USDA 2017). Such burns, of course, result in large losses of carbon to the atmosphere.

Carbon sequestration projects involving forested land can also take the form of afforestation projects (i.e., planting trees on land that was previously unforested) or reforestation projects (i.e., planting trees in places where trees were removed). The Nez Perce Tribe of Idaho began an afforestation and reforestation project for carbon sequestration during the 1990s, planting trees on a 160-ha plot of previously unforested land. The tribe has since expanded its efforts to include 33 different afforestation and reforestation projects (including fire rehabilitation projects) covering approximately 1,379 ha (NICC 2015).

Canada. Canadian forest management programs include initiatives to build capacity and allocate revenues from resources shared among First Nations (AANDC 2012). With the emergence of carbon markets as an option for addressing climate change, First Nations formed the First Nations Carbon Collaborative, which is dedicated to building capacity among Indigenous communities to access and benefit from emerging carbon markets (IISD 2010, 2011). A goal of these programs is to address the economic challenges facing these communities by developing revenue-generating activities associated with carbon sequestration through sustainable forest management, restoration, and protection; biomass tree farming; and protection of boreal forest peatlands or "muskegs." The challenges identified by First Nations to engaging effectively in carbon markets are not unlike those faced by Indigenous communities in the United States and Mexico.

Mexico. Ejidos in Mexico are based on traditional Native American land-tenure systems that allow individuals to farm communally owned lands (Bray et al., 2003). An in-depth study analyzing the role of poverty, Ejido land tenure, and governmental policies in stimulating deforestation in Mexico revealed that poverty and government policies to hold maize prices above the world average increased deforestation (Deininger and Minten 1999). In contrast, Ejido communal land-tenure arrangements did not directly affect deforestation rates, and, within the Ejidos, Indigenous communities were associated with lower deforestation rates. Although several

factors likely contribute to this finding, evidence indicates that the sociocultural safety net provided by this traditional system of land use promotes natural resource management practices that overcome the "tragedy of the commons," which leads to land deforestation to increase cash crop production. In recognition of the benefits of dramatically reducing deforestation in Mexico and other developing countries, the World Bank and United Nations initiated two projects: the Forests and Climate Change Project (World Bank 2018) and REDD+, or the Reducing Emissions from Deforestation and Forest Degradation project (United Nations 2016). In May 2016, the World Bank reported that through job creation and other support to Ejidos and Indigenous communities, these programs have led to the conversion of 1.8 million ha of forestland to sustainable management, thus reducing Mexico's deforestation rates (World Bank 2018; United Nations 2016).

7.3.4 Impact of Energy Extraction and Production on Tribal Land Carbon Emissions

Within tribal lands, net carbon fluxes are estimated to be positive, with more carbon released to the atmosphere than is taken up in areas dominated by land leased for coal, oil, and gas extraction (primarily in the northern central United States and Canada). This is due to the carbon dioxide and methane (CH_4) released during extraction processes and the accompanying tree removal on forested lands. Fossil fuel extraction and uranium mining on tribal lands (described in the subsequent case studies) have resulted in significant ecosystem degradation and carbon emissions (Brugge et al., 2006). For tribal lands heavily vested in fossil fuel exploitation and use, carbon fluxes to the atmosphere may equal or even exceed those on similar non-tribal lands. Renewable energy generation on tribal lands primarily results from leasing lands or community-owned hydroelectric, geothermal, solar, wind, and biomass production facilities (U.S. DOE 2015).

Case Studies in Fossil Fuel and Uranium Extraction

The United States is a significant carbon emitter, and many of its fossil fuel resources are on tribal lands, where energy development is big business (Indigenous Environmental Network 2016; Mills 2016; Regan 2016). Fossil fuel and uranium extraction have provided economic gain for some tribes, but at the cost of significant environmental degradation, loss of cultural resources, and adverse health effects (Brugge 2006). Most of the low-sulfur coal mined in the United States is on tribal lands in the Southwest and Great Plains (Pendley and Kolstad 1980; NCAI 2015; U.S. EIA 2017a). The Osage tribe in Oklahoma and Crow Nation in Montana are pursuing coalbed CH_4 projects, while the Three Affiliated Tribes of the Fort Berthold reservation in North Dakota are entering the oil refinery business. The Southern Ute and Ute Mountain tribes in Colorado have developed their own oil business exploration and development companies and also have embraced coalbed CH_4 development. The Fort Mojave tribe along the lower Colorado River in Arizona and California is leasing its land to a California-based energy company, Calpine Corporation, to build a natural gas electrical generating plant. Easements allowing the building of electrical transmission lines throughout Indigenous lands are being negotiated, often without adequate input from grassroots tribal members.

Although nuclear energy production is carbon neutral, the human cost of nuclear fuels extraction has been high. The legacy of uranium mining and milling has resulted in considerable environmental and human health issues in Indigenous populations in the western United States, including the Navajo, Hopi, Southern Ute, Ute Mountain, Zuni, Laguna, Acoma, Eastern Shoshone, Northern Arapaho, and Spokane tribes. These legacy impacts are integral to the life cycle costs of nuclear energy production and should be included in assessments of nuclear energy's role in the carbon cycle. The largest open-pit uranium mine was located at Laguna Pueblo, New Mexico. Thousands of abandoned mining sites are

as yet unreclaimed, with 75% of unreclaimed mining sites occurring on tribal land (Moore-Nall 2015). Additional uranium milling locations are now "Superfund sites" (sites outlined in the U.S. Comprehensive Environmental Response, Compensation and Liability Act of 1980) on Navajo and Spokane tribal lands. Ecological destruction due to uranium mining and milling on tribal lands reduces the carbon-carrying capacity of these lands and impacts the ability of Indigenous communities to maintain traditional and sustainable land-use practices. The lack of compensation for human health impacts and continuing environmental problems resulting from uranium production led to the uranium mining ban on Navajo lands in the Diné Natural Resources Protection Act of 2005 (LaDuke 2005).

Case Studies in Renewable Energy Production

Renewable energy development on tribal lands is increasing (Jones 2014; Royster 2012) but is still limited by federal regulations, tribal land tenure, lack of energy transmission infrastructure on reservations, and economic challenges. Recent examples include a proposed solar facility on Hopi land near Flagstaff, Arizona, that would supply the town with electricity; two adjacent Navajo Nation solar projects near Kayenta, Arizona; and a Jemez Pueblo solar project in New Mexico (U.S. EIA 2017a). If these projects prove to be economically viable, increased interest and development of renewable energy resources on tribal lands may offset fossil fuel energy exploitation and consumption. One novel approach is the Tulalip Tribe's involvement in the Qualco anaerobic digester, which has been in operation since 2008. It utilizes animal waste, trap grease, and other pollutants (thus keeping them out of landfills and drains and preventing illegal dumping) and burns CH_4 to create renewable energy. This process helps clean the air and water, helps farmers keep their dairies operating, protects salmon streams, and provides environmentally friendly compost (Qualco Energy 2018).

7.4 Indicators, Trends, and Feedbacks

Ecological indicators, trends, and feedbacks for carbon cycle processes have not been monitored on tribal lands. As previously discussed, tribal communities that have adopted Eurocentric agricultural and land-use practices, such as raising cattle and growing irrigated crops, likely have land with carbon stocks and fluxes similar to those in neighboring non-tribal lands. In some cases, these stocks and fluxes could result in larger net carbon emissions to the atmosphere on tribal lands where reservation population pressures or adverse climatic conditions have increased land-use stresses. However, for other Indigenous lands, carbon stocks and fluxes may differ considerably from surrounding non-tribal areas because of more traditional and culturally distinct agricultural, forestry, and land-use practices. These practices include dryland farming, no-till seeding, in-ground soil composting, sustainable forest practices, and grazing management of open-range herds of bison and certain varieties of sheep.

Fossil fuel (e.g., oil, gas, and coal) extraction and uranium mining on tribal lands have produced significant ecological disturbances that affect carbon stocks and fluxes. Moreover, the carbon cycle impacts of fossil fuel extraction on tribal lands may exceed the impacts in non-tribal areas with active fossil energy economies when the accompanying ecological impacts are not addressed. In some cases, such as the abandoned uranium mines on Navajo Nation lands, the impacts of these disturbances were substantially greater compared to surrounding areas (Moore-Nall 2015).

Increased awareness of the value of Indigenous worldviews and traditional knowledge in sustaining landscapes that can effectively sequester carbon in soils and vegetation offers policymakers and resource managers insight into new approaches to carbon cycle management. Trends affecting carbon cycle processes in the future include 1) the cessation of uranium mining and decreases in fossil fuel extraction; 2) increasing on-reservation development and use of renewable energy; and

3) agricultural production adaptations increasingly based on traditional knowledge, which could include, but are not limited to, increasing reliance on traditional drought-resistant crops and agricultural practices and the local production of native foods.

7.5 Societal Drivers, Impacts, and Carbon Management

As previously described, carbon cycle issues are integral to natural resource and land management decision making by Indigenous communities across North America. Generational values rooted in deep connections to the Earth form the basis for many of these communities. Eurocentric agricultural practices and fossil fuel energy extraction challenge these values, especially when they promise opportunities for job creation and revenue generation for tribal communities facing extreme poverty, unemployment, and public health challenges. Inherent conflicts between traditional values and the need to improve community livelihoods underlie the societal drivers for land and natural resource management decisions that affect carbon management.

Current carbon cycle programs aiming to improve both land stewardship and economic development on tribal lands are constrained because of funding, education, governmental policies on agriculture pricing, and natural resource management, as well as limited federal government participation in global carbon markets. Indigenous communities share substantial socioeconomic challenges that make successful implementation of future carbon management programs dependent on revenue generation through sustainable management.

Drivers that can both positively and negatively affect carbon stocks and fluxes include:

- Increased population growth, increasing demand for water, and stresses from land use and limited natural resources in both tribal and surrounding non-tribal communities.
- Economic incentives for tribes to engage in fossil fuel extraction projects.
- Community stresses from high levels of poverty, unemployment, and public health issues.
- Strong cultural commitment to ecological stewardship among tribal members.
- Growing reliance on sustainable traditional agricultural and forestry practices and local native food production.
- Increased implementation of renewable energy projects on tribal lands for both local energy use and economic development.

7.6 Synthesis, Knowledge Gaps, and Outlook

As previously discussed, carbon inventories on native lands across North America are affected by the balance between the use of traditional practices and the economic drivers for more intensive agriculture and natural and energy resource exploitation. The extent to which traditional practices have been maintained or reintroduced serves as a guide for estimating carbon cycle impacts on tribal lands through comparisons to carbon cycle impacts on similar non-tribal land types.

Quantitative understanding of carbon stocks and fluxes on tribal lands is notably poor, with limited direct monitoring or modeling of carbon cycling. Nevertheless, carbon cycle issues are increasingly integral to natural resource and land management decision making, and they may be informed by further research involving partnerships to understand how traditional land-use practices alter the carbon cycle. Traditional Indigenous peoples' practices may offer new opportunities for carbon management. Further, because of the spatial extent of tribal lands and their potential to affect carbon cycling at large scales, an improved understanding of the carbon cycle on tribal lands would advance quantification of the continental carbon cycle. Many North American Indigenous communities maintain traditional practices that inherently affect carbon stocks and fluxes. These practices include sustainable management of forests, agriculture, and natural resources.

High levels of poverty and unemployment have encouraged some tribes with fossil fuel and mineral resources to engage in ecologically destructive extraction practices as a means to improve livelihoods. However, further development of renewable energy programs on tribal lands is providing new opportunities to improve reservation economies, community health, and carbon cycle sustainability.

7.6.1 Seven Generations Youth Education

Understanding the importance placed on youth education by Indigenous communities is critical to fostering and sustaining traditional practices of community and ecological sustainability that affect carbon management on tribal lands now and in the future. Tribal education is closely aligned with tribal core values and traditional concepts of sustainability and thus carbon cycle management (Tippeconnic III and Tippeconnic Fox 2012; Kimmerer 2002). In particular, youth are widely revered as representing the future vitality of tribal nations and tribal lands. This thinking is consistent with the core tribal value of sustainability, which often is articulated as planning for Seven Generations, that is, that the tribe's human, social, and natural capital must be sustained with a time horizon comparable to seven human life spans (Brookshire and Kaza 2013). Therefore, youth education, development, and leadership are near-universal tribal priorities, with tribal education being framed by traditional and cultural values and by deep connections to ancestral homelands (Cajete 1999). Tribal education is considered a journey and life pathway that is neither defined nor constrained by western notions of a segmented and stepwise educational pipeline. This approach has several practical implications. Tribal colleges and universities (TCUs) were created, in large part, to provide a culturally relevant educational pathway that is congruent with core tribal values, traditions, and commitments to sustainability (Benham and Stein 2003). TCUs often serve as the research and science centers for tribal nations, conducting primary research on tribal issues, maintaining repositories of cultural and natural assets, and facilitating long-term tribal planning on issues such as climate change and sustainability, economic development, and health and wellness. TCUs exemplify the Seven Generations approach by providing youth with the foundation, support, and pathway to become productive members of their tribal nation, thereby ensuring that the tribe and tribal lands will thrive into the future.

7.6.2 Knowledge Gaps and Ways Forward

Significant knowledge gaps remain in assessing the unique impacts of tribal land and resource management on carbon stocks and fluxes. Closing these gaps would benefit from the combined insight of native wisdom and western science about forest health, crop cultivation, livestock grazing, water management, ecosystem protection, and community health and well-being. These knowledge gaps should be discussed within the larger context and with a focus on ways to empower Indigenous communities and support their engagement in matters within their decision domains and spheres of influence that affect the carbon cycle. Research could usefully be directed at the unique circumstances and needs of Indigenous communities. Particular research needs include:

- Quantifying the impacts of traditional practices on carbon stocks and fluxes, including the use of fire on the landscape, co-cropping of synergistic plants, and cultivation of plants with high moisture retention and temperature tolerance.
- Evaluating potential changes in carbon fluxes from site-specific applications of carbon capture and sequestration efforts and developing quantification methods for projects involving soil enrichment and renewable energy.
- Evaluating opportunities for deploying innovative technologies and practices that potentially can affect carbon fluxes at the community level (e.g., renewable energy, energy-efficient substitutions, local sourcing, carbon-based purchasing policies, and carbon markets).

Actions that may contribute to future carbon storage and reduce carbon emissions on tribal lands include:

- Developing community-based programs that address carbon sequestration in the context of enhanced access to nutritional foods.
- Promoting intergovernmental coordination and cooperation among partners to preserve and protect the public trust, as well as the use of special relationships such as fiduciary obligations and consultation requirements and principles of free, prior, and informed consent (United Nations 2008).
- Advancing collaborative efforts to increase awareness and combine western science and traditional knowledge, including facilitation of access to and sharing of data, information, and expertise.
- Implementing place-based monitoring and systems for recording and reporting environmental observations to establish baselines and provide a history of changes in temperature, humidity, precipitation, phenology, and species compositions.
- Increasing knowledge sharing about traditional agricultural practices that minimize carbon emissions and enhance carbon storage.
- Engaging in outreach education about alternative, efficient, and economical energy production on tribal lands.
- Implementing programs that enable tribes to quantify and realize the economic benefits associated with sustainable forest management, reforestation, boreal forest protection, and sustainable agriculture.
- Building capacity among tribal youth to support and inform the next generation of decision makers.

Indigenous communities are continuing to create opportunities to locally develop more diverse, distributed, and sustainable sources of energy, food, and income, which is strengthening ecological and community resilience and enhancing sustainable carbon management.

SUPPORTING EVIDENCE

KEY FINDING 1

Many Indigenous peoples in North America follow traditional agricultural and land-use practices that govern carbon cycling on tribal lands. These practices include no-till farming; moving domesticated animals seasonally in accordance with forage availability; growing legumes and cover crops; raising crops and livestock native to ancestral landscapes; and managing forests sustainably with fire, harvest, and multispecies protection.

Description of evidence base

Key Finding 1 is supported by studies and detailed reports about Indigenous tribes (e.g., AANDC 2013; Assies 2007; Chief et al., 2016; NCAI 2015; Tiller 1995) and agricultural crop and grazing and forestry practices (Zomer et al., 2017; Baker et al., 2007; Redsteer et al., 2010; Drinkwater et al., 1998; Gabriel et al., 2006; CSKT 2000; Bennet et al., 2014).

Major uncertainties

Uncertainties result from the limited number of reports in the literature documenting the extent to which traditional practices on native lands have impacted carbon cycle processes.

KEY FINDING 2

Scientific data and peer-reviewed publications pertaining to carbon stocks and fluxes on Indigenous (native) lands in North America are virtually nonexistent, which makes establishing accurate baselines for carbon cycle processes problematic. The extent to which traditional practices have been maintained or reintroduced on native lands can serve as a guide for estimating carbon cycle impacts on tribal lands by comparisons with practices on similar non-tribal lands.

Description of evidence base

Key Finding 2 is supported by findings presented in the *First State of the Carbon Cycle Report* (CCSP 2007) and resources on carbon programs in the United States (NICC 2015), deforestation in Mexico (Deininger and Minten 1999), and the First Nations Carbon Collaborative in Canada (IISD 2010, 2011).

Major uncertainties

Uncertainties result from a lack of in-depth studies and technical reports documenting carbon stocks and fluxes on tribal lands throughout North America.

KEY FINDING 3

Fossil fuel and uranium energy resources beneath tribal lands in the United States and Canada are substantial, comprising, in the United States, 30% of coal reserves west of the Mississippi River, 50% of potential uranium reserves, and 20% of known oil and gas reserves, together worth nearly $1.5 trillion. Fossil fuel extraction and uranium mining on native lands have resulted in emissions of carbon dioxide and methane during extraction and fuel burning. Energy resource extraction on tribal lands also has resulted in substantial ecosystem degradation and deforestation, further contributing to carbon emissions.

Description of evidence base

Key Finding 3 is supported by resources on fossil fuel and uranium extraction on tribal lands (Indigenous Environmental Network 2016; Mills 2016; Regan 2014, 2016; U.S. EIA 2017a, 2017b; Grogan 2011; U.S. EPA 2018; Moore-Nall 2015) and on ecological degradation from energy extraction (Brugge and Goble 2002; Diep 2010).

Major uncertainties

Uncertainties result from the lack of carbon emissions monitoring during energy extraction on tribal lands. Although energy extraction and use on Native American and First Nation lands are fairly well documented, carbon emission and consumption measurements are scarce, and studies of the adverse effects of tribal fossil fuel economies are limited.

KEY FINDING 4

Renewable energy development on tribal lands is increasing but is limited by federal regulations, tribal land tenure, lack of energy transmission infrastructure on reservations, and economic challenges.

Description of evidence base

Key Finding 4 is supported by reports on the opportunities and challenges for renewable energy production on tribal lands in the United States (Saugee 2012; Anderson 2005; Bronin 2012; U.S EIA 2017a, 2017b; Jones 2014; Royster 2012; Canada Energy and Mines Ministers' Conference 2016; Natural Resources Canada 2016a; Notzke 1994].

Major uncertainties

Uncertainties result from a limited number of case studies of areas where renewable energy sources have been developed and operated on tribal lands for extended periods of time.

KEY FINDING 5

Colonial practices of relocation, termination, assimilation, and natural resource exploitation on native lands have historically hindered the ability of Indigenous communities to manage or influence land-use and carbon management both on and off tribal lands. These factors combined with contemporary socioeconomic challenges continue to impact Indigenous carbon management decision making.

Description of evidence base

Key Finding 5 is supported by reports on climate vulnerability of Indigenous peoples (Bennet et al., 2014; Melillo et al., 2014) and the impacts of European settlement on tribal communities (NCAI 2015; GAO 2015; Indigenous Environmental Network 2016; Mills 2016; Regan 2016; Royster 2012; Statistics Canada 2011; Cultural Survival 1999; Minority Rights Group International 2017).

Major uncertainties

Uncertainties result from the limited number and duration of carbon cycle education programs implemented in North America and globally.

KEY FINDING 6

The importance placed on youth education by Indigenous communities creates opportunities for future generations to sustain and pass on traditional knowledge important to managing carbon stocks and fluxes on native lands.

Description of evidence base

Key Finding 6 is supported by reports on the tribal community youth education programs in the United States (Tippeconnic III and Tippeconnic Fox 2012; Kimmerer 2002; Cajete 1999; Brookshire and Kaza 2013).

Major uncertainties

Uncertainties result from the limited number of comprehensive studies on the role youth education plays in sustaining traditional practices for different Indigenous groups in Mexico and Canada, as well as uncertainty in the magnitude to which those practices could affect the carbon cycle.

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Appendix 7A
Summary Descriptions of Indigenous Communities in North America

7A.1 Location and Populations

According to the 2010 Census, the United States is home to 5.2 million people of American Indian or Alaskan Native heritage. Together, they comprise the 567 federally recognized tribes, 229 of which are in Alaska and the remaining 338 in 34 other states (NCAI 2015; U.S. Census Briefs 2012). About 41 million hectares (ha) are under American Indian or Alaskan Native control, with approximately 5.2 million people identified as American Indian/ Alaskan Native (alone or in combination with other races). Approximately 22% of Native Americans live on tribal lands and 78% live in urban or suburban environments, with 19.5% of Native people living in Alaska (Norris et al., 2012).

Most American Indians and Alaskan Natives live in the western United States (40.7%), followed by the South (32.8%), Midwest (16.8%), and Northeast (9.7%; Norris et al., 2012). States with the highest populations of Native Americans living on or near tribal reservations are Oklahoma (471,738), California (281,374), and Arizona (234,891; BIA 2013). The largest reservation in the United States is the Navajo Nation Reservation of Arizona, New Mexico, and Utah (about 7 million ha), with a population of 169,321. The second most populated reservation is Pine Ridge Reservation in South Dakota and Nebraska, with 16,906 Native Americans (Norris et al., 2012).

According to the 2011 National Household Survey, Canada is home to 851,560 First Nation people that collectively comprise more than 600 First Nation and Indian bands. Of these, most live in Ontario and the western provinces. For example, about 23.6% of Canada's First Nation people live in Ontario (201,100), 18.2% in British Columbia (155,020), and 13.7% in Alberta (116,670; Statistics Canada 2011). First Nation people make up about one-third of the total population in the Northwest Territories and one-fifth of the population in the Yukon. Of the 851,560 people who self-identify as First Nations, 637,660 are officially registered under Canada's Indian Act. Nearly half of those registered (49.3%, or 316,000) live on reserves or Indian settlements (Statistics Canada 2011).

Mexico's Indigenous community consists of 16.9 million people, the largest such community in North America. These people represent 15.1% of the national population and together speak 68 Indigenous languages and 364 dialects (Del Val et al., 2016). Although Mexico does not have a system of reserves or reservations for Indigenous people, the majority (80%) of all people who speak an Indigenous language live in the southern and south-central regions of Mexico (Cultural Survival 1999; Minority Rights Group International 2017). About 18.1% of Mexico's Indigenous people live in the state of Oaxaca, followed by Veracruz (13.5%), Chiapas (13%), Puebla (9.42%), Yucatán (8.2%), Hidalgo (5.7%), state of Mexico (5.6%), Guerrero (5.2%), San Luis Potosí (3.2%), and Michoacán (2.9%; (Cultural Survival 1999).

7A.2 Summary Descriptions by Geographical Region

7A.2.1 Native Americans in the United States

Alaskan Native

Alaska is home to only one federally designated reservation, and most Alaskan Natives are associated with village or regional "corporations" (created by the 1971 federal Alaska Native Claims Settlement Act). Many of the native communities

reside in coastal areas where commercial fishing and tourism are two major sources of income (Tiller 1995). Some of these communities face imminent relocation due to rising sea levels (Melillo et al., 2014).

Pacific Northwest

The Yakama Nation specializes in agricultural production across 57,500 ha of irrigated land and in forestry on 125,000 managed ha of timber. Fisheries along the Columbia River are primarily for subsistence and ceremonial use, and tourism supports other members of the tribe (Tiller 1995). Along the coast, the Quinault Indian Nation uses its reservation's resources primarily for fisheries, timber harvesting, and tourism related to trout and salmon fishing (Tiller 1995).

Southwest

The southwestern United States is home to some of the country's largest reservations, including the Navajo Nation (6,566,000 ha in Arizona, New Mexico, and Utah); Hopi (632,000 ha surrounded by the Navajo Nation in Arizona); and Tohono O'odham (1.1 million ha straddling the U.S.-Mexico border). Major industries and land uses on these reservations include mining of coal, oil, and natural gas and tourism in parks, monuments, and recreation areas (Tiller 1995). For other southwestern reservations, main industries and land uses are production agriculture and livestock (Gila River Indian Community in Arizona and Walker River Paiute Tribe in Nevada), fisheries (Pyramid Lake Paiute Tribe in Nevada), and mineral mining (Uintah and Ouray Reservation in Utah; Tiller 1995).

Intermountain West

The large Blackfeet, Flathead, and Crow reservations in Montana contain rich farmland; extensive livestock grazing areas; commercial timberland; and coal, oil, and natural gas resources that, along with tourism, support the local economies. Land leases for energy extraction, hydroelectric power generation, and timber harvesting provide significant revenue streams for the tribes (Tiller 1995).

Great Plains

Some of the largest reservations in this region are in the Dakotas (e.g., Standing Rock, Cheyenne River, and Pine Ridge), where major industries and sources of tribal income include agriculture, oil and natural gas mining, forestry, and tourism (Tiller 1995).

Midwest

Most tribal reservations in the Midwest are in Michigan, Wisconsin, and Minnesota where timber harvesting, agriculture, big game hunting, fisheries, and tourism are major industries. In Wisconsin, the economy of the Menominee Indian Tribe revolves around sustainable forestry practices, with 95% of tribal lands forested after more than 100 years in the forestry industry (Tiller 1995). The Leech Lake Band of Ojibwa in Minnesota is the largest wild rice producer in the United States, with 4,000 ha of wild rice fields (Tiller 1995).

East Coast

Tribal reservations in the eastern United States are generally much smaller than those in the West because of European settlement, assimilation, and forced relocation. The Cherokee are the largest tribe in the United States, and their ancestral territory spanned over eight southeastern states. Most of the Cherokee Nation was forced to relocate to Oklahoma under an 1835 treaty. The Eastern Band of the Cherokee, who resisted removal during the 1800s, maintain a reservation in western North Carolina where tourism is a major industry and some commercial revenues are produced from small-scale farms and ranches. Tribes in the Northeast, such as the Allegany Reservation in New York, rely on agriculture, livestock, and some commercial forestry (Tiller 1995).

7A.2.2 First Nations of Canada

Eastern Canada: Quebec, Ontario, Newfoundland, and Labrador

In Canada's eastern woodlands region, First Nation tribes traditionally consisted of small groups (fewer than 400 people) who migrated in search of food, subsisting via hunting and trapping of migratory

animals. In fertile regions of southeastern Canada, the Iroquoian First Nations founded permanent communities where they farmed food crops, including corn, beans, and squash (AANDC 2013). Today, forestry provides opportunities for Indigenous people. In Newfoundland, Labrador, Quebec, and the Yukon, modern treaties have resulted in the transfer of more than 6 million ha to First Nation people. In Ontario, a 2014 to 2015 forest tenure modernization project provided funding to support sustainable forest licenses for Indigenous communities (Natural Resources Canada 2016a).

Central Canada: Alberta, Saskatchewan, and Manitoba

On the plains, First Nation people traditionally lived as migratory groups of hunters who followed the buffalo herds (AANDC 2013). Today, geothermal energy produced on the Peguis First Nation and Fisher River Cree Nation Reserve in Manitoba heats reserve homes, and First Nation people are trained and certified in geothermal trades (Paul 2015). On the remote Opaskwayak Cree First Nation reserve, where fresh produce is expensive, community members are experimenting with a method for indoor farming called "vertical farming" (CTV News 2016).

Western Canada: British Columbia

Along the Pacific Coast, First Nation people traditionally settled in permanent villages and subsisted on food resources from the ocean such as salmon, shellfish, sea lions, otters, whales, and seaweed. Red cedar from forests along the coast was used to build homes (AANDC 2013). Today, fisheries are an important industry for First Nations located in western Canada, where salmon, halibut, herring, and other fish are caught and processed in canneries (Notzke 1994). Forestry is also an important industry in this region. The First Nations Forestry Council of British Columbia works to support First Nation forestry activities through training programs, business support, policy development, mountain pine beetle action plans, ecosystem stewardship planning, and more (B.C. First Nations Forestry Council 2015). In central British Columbia, a liquid natural gas pipeline called Pacific Northwest LNG is under development. For environmental reasons, some First Nation groups oppose the pipeline while others support it for the economic benefits it will bring their First Nation communities (Jang 2016).

The Far North: Yukon and Northwest Territories

First Nation people of northwestern Canada traditionally hunted for game animals such as caribou across large territories (AANDC 2013). Today, the Yukon and Northwest territories are used for renewable and nonrenewable energy projects such as crude oil, natural gas, thermal electrical facilities, hydroelectric plants, and wind energy projects. Several pipelines carry crude oil and natural gas through the region (Canada National Energy Board 2011). Some First Nation people oppose energy development projects. For example, in the Yukon Territory, members of the Vuntut Gwitchin First Nation live along the migration route of the Porcupine caribou herd and rely on resources provided by the herd for food, clothing, and crafts. Their traditional way of life is being threatened by oil and gas companies that want to develop the Arctic National Wildlife Refuge (Vuntut Gwitchin First Nation, N.D.).

7A.2.3 Indigenous Communities in Mexico

Oaxaca and Guerrero

In the La Mixteca region of Mexico, which covers portions of the states of Oaxaca, Puebla, and Guerrero, centuries of destructive land-use practices have converted forest into desert. Here, Mixteca Indian farmers are reviving pre-Hispanic farming practices to restore and farm the land. Actions taken by these farmers include terracing hillsides, plowing with oxen, and farming via a technique called "milpa," where corn, squash, and beans grow together and increase soil nutrients (Malkin 2008).

Yucatán Peninsula and Quintana Roo

In Quintana Roo, forest resources provide a major source of income for the Mayan people, who make up about 25% of the population (Bray et al., 1993). Traditionally, the Maya used the forest for nontimber products such as palms for roof thatching,

fruits and herbs for food and medicine, and deer and peccary for meat. In the 1970s, the Maya and members of local Ejidos (communally farmed lands) began to harvest trees for railroad ties. In the 1980s, a forestry pilot program helped members of the Ejidos learn timber marketing strategies and sustainable management techniques. The Ejidos of central Quintana Roo occupy more than 400,000 ha of forest, much of which is permanent forest reserve (Bray et al., 1993).

Sierra Madre Occidental (Jalisco, Nayarit, Zacatecas, and Durango)

In the Sierra Madre Occidental Mountains, Huichol people live as subsistence farmers, using slash-and-burn practices to convert forest into agricultural land. They produce mostly maize, but also beans, squash, and sometimes livestock. Some Huichol are cattle ranchers, and others sell lumber. The quality of Huichol land is harmed by the slash-and-burn farming, and cattle grazing further damaged soil quality (Cultural Survival 1992).

Central Highlands, Sierra Norte de Puebla, and the Gulf Coast

The Nahua, speakers of the Nahuatl language, live near what was once the center of the Aztec empire. Most Nahua farm, growing maize, beans, chili peppers, squash, camotes, onions, tomatoes, and other cash crops such as sugarcane and coffee. Most families supplement farming with other sources of income (Sandstrom 2008).

7A.3 Land Tenure and Water Rights

U.S. reservation lands not "allotted" to individual tribal members under laws enacted in the late 1800s and early 1900s are held "in trust" by the U.S. government, meaning that the federal government must manage the lands and resources in a manner most beneficial to tribes (NCAI 2016). While tribal governments have the authority to manage their land base, the complexities of overlapping jurisdictions and land-use customs can delay crucial resource management decisions. For this reason, tribally owned lands may face greater obstacles to achieving sustainable resource management than public or private lands (Anderson and Parker 2008; Russ and Stratman 2013).

Land-tenure issues create challenges for tribal communities managing natural resources on reservation lands. Some reservations consist entirely of trust land, but, as a result of the General Allotment Act of 1887, many reservations also include other types of land, such as land owned by individual Indian families or land owned by non-Indigenous people who acquired the land from tribal families (Frantz 1999). The resulting checkerboard pattern of land ownership on many reservations is problematic for farming, ranching, and other activities—including developing and implementing carbon management plans—that require access to or management of large land tracts (Indian Land Tenure Foundation 2016). On trust lands, approval by the U.S. Secretary of the Interior is required for most land-use decisions, complicating tribes' ability, for example, to sell, lease, or develop their lands (Indian Land Tenure Foundation 2016).

In addition to land-tenure issues, Native American tribes in the United States have historically faced challenges in obtaining water for their reservations (Colby et al., 2005; McCool 2002; Thorson et al., 2006). In arid regions of the West, early settlers began a tradition of removing water from rivers via dams, diversions, and canals for agriculture, mining, and other purposes. Native American reservations downstream from western civilizations had no guarantee of sufficient water delivery during much of the 1800s. A 1908 Supreme Court decision known as the Winters Doctrine set the priority use date for water rights on tribal reservations as the same date that each reservation was established regardless of whether the tribe was using water for irrigation or other purposes at that time (Frantz 1999). The Winters Doctrine means that, today, tribes hold some of the most senior (highest-priority) water rights (referred to as "paper water") on river systems in the West. However, gaining access to actual water allocations ("wet water") can still be a long and arduous process for tribes that involves legal settlements

or adjudication agreements with federal and state governments.

On Canadian First Nation reserves, land is held in trust by the crown for use by specific bands. A "First Nation band" (or First Nation) is a recognized self-governing Indigenous community under the Indian Act of 1876 (Canada Indian Act 1985). The Canadian government may assign individual Indians the right to use land via certificates of possession (CP), but they do not have full legal ownership. Land not assigned by CP to an individual is held as community property of the band. Although bands may not sell reserve land, they may lease it to non-Indigenous people for uses such as natural resource development, farming, ranching, recreation, or rights-of-way for transportation or transmission (McCue 2011). Canadian First Nation tribes face land-tenure challenges similar to those confronting many Native Americans in the United States. Land-use opportunities may be limited by a reserve's location (e.g., areas with limited economic opportunities) or resource scarcity. Governmental regulations on access to fish, timber, mineral, subsurface, and other resources may restrict band members' efforts to develop land. In addition, reserve lands often are intersected by government rights-of-way for power lines, railroads, and highways, dividing useable spaces and making land use more difficult (Hanson 2009).

Water rights laws differ by province across Canada and consist of either prior allocation, public authority, riparian rights, or civil code. In addition, Indigenous and Canadian water rights laws co-exist. Prior to colonization, Indigenous cultures governed water use via their own customs and practices. The Constitution Act of 1982 protects any Indigenous rights (including water) not taken away from First Nations by 1982 (Canada Program on Water Governance 2010).

Unlike the United States and Canada, Mexico does not have a system of federal reserves or reservations. Rather than setting aside land and resources for Indigenous people, the Mexican government historically focused on cultural integration via assimilation (Minority Rights Group International 2017). Today, Mexico's constitution guarantees Indigenous people the right to self-determination, including the right to autonomy, education, infrastructure, and freedom from discrimination (Aban 2015). Each state has its own constitution, and some states have established legislation that limits the rights recognized by the national constitution (OHCHR 2011). Rights of Indigenous people vary from state to state; in Chiapas, Michoacán, and Oaxaca, Indigenous people have formed autonomous Indigenous governments (Minority Rights Group International 2017).