Chapter 7
Expanding the North American Perspective—Canada

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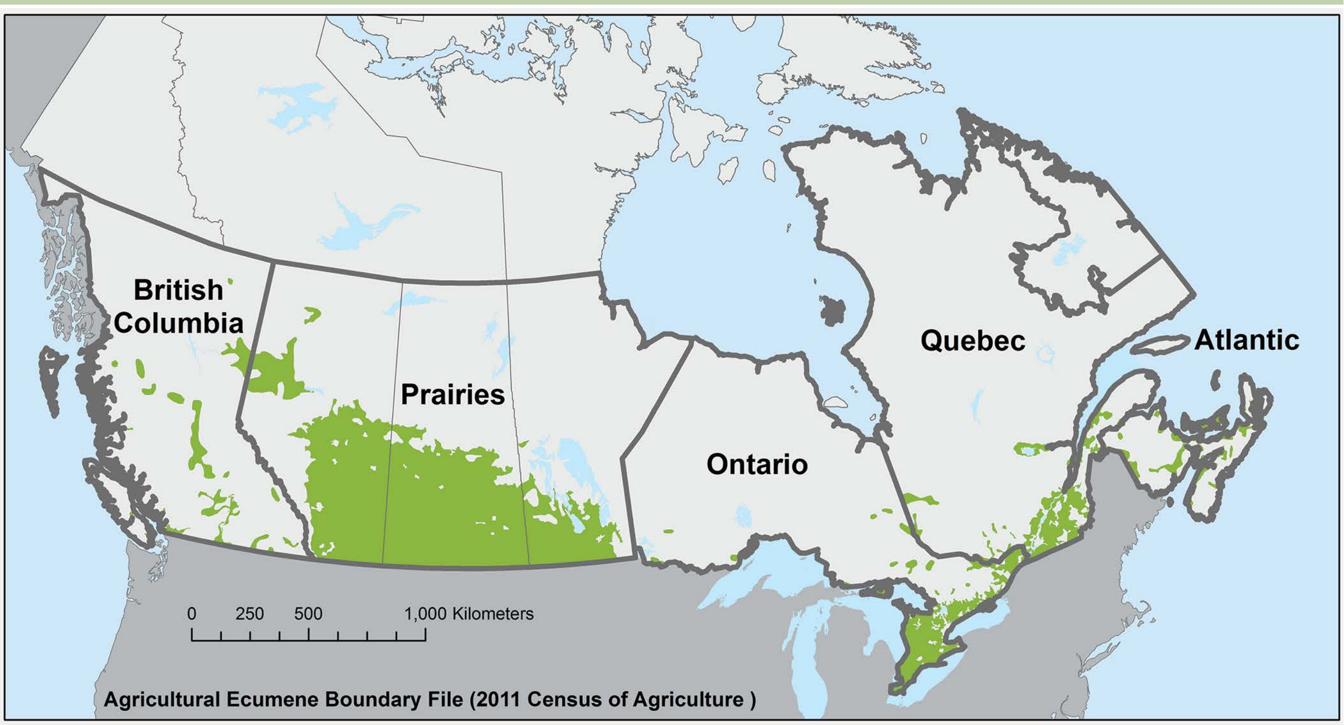
Impacts of Climate Change on Canadian Agriculture

Canada has approximately 65 million hectares (ha) of productive agricultural land (Statistics Canada 2014), with agricultural activity generally limited to southern regions from the Atlantic Ocean to the Pacific Ocean (fig. 7.1). Assessments of climate change in Canada and its impact on Canadian agriculture conclude that most regions of Canada are projected to warm during the next 60 years (Warren and Lemmen 2014). For a high-altitude country like Canada, the warming is expected to be more pronounced than will be the global average. The results will likely be longer frost-free seasons and increased evaporation and plant transpiration. This warming may increase productivity, allow expansion of agriculture into new areas, and provide opportunities for the use of new and potentially more profitable crops (where soil conditions permit). These warmer temperatures could also benefit livestock production in the form of lower feed requirements, increased survival rates of the young, and lower energy costs.

Negative impacts from climate change also are expected, including increased intensity and frequency of droughts and violent storms. As the frequency of droughts increases, crop yields could decrease, particularly in semiarid regions of Canada. New pests and diseases will likely emerge, and more

Figure 7.1. This map of Canada illustrates that most agricultural land is in the southern portion of the country. (Statistics Canada 2012).



severe outbreaks of current ones will occur. Northern and remote communities are likely to see great changes in their environments—some will ease food security concerns, but others could exacerbate already decreasing food stocks and difficulties in delivering supplies into isolated areas.

Agroforestry Across Canada

In Canada, agroforestry provides ecosystem goods and services that support integrated management of farmland and rural spaces (De Baets et al. 2007). Ecosystem services derived from agroforestry practices typically include pollination services from wild pollinators; suppression of crop pests and diseases; nutrient cycling; carbon (C) sequestration; water purification,

Box 7.1. Agroforestry in Canada and Its Link to the United States

Many ecological regions of North America span the Canada/United States border, providing commonality in landscapes, climate, soils, wildlife, land management, and farming systems, including agroforestry. As such, Canada and the United States have a longstanding history of collaboration on agroforestry and formalized decades of collaboration through a Memorandum of Understanding (MOU) between Agriculture and Agri-Food Canada (AAFC) and the U.S. Department of Agriculture (USDA) in 2012. The MOU commits AAFC and the USDA to work together to accelerate the application of temperate agroforestry systems in agricultural landscapes, including research and science, outreach, education materials, and science tools for climate change mitigation that support the Global Research Alliance on Agricultural Greenhouse Gases.

USDA and AAFC jointly sponsored the Great Plains Windbreak Renovation and Innovation Conference in July 2012 at the International Peace Garden (Manitoba-North Dakota border). The event brought together scientists, natural resource professionals, and landowners to discuss renovating windbreaks, some of which were first established to slow soil erosion during the Dust Bowl era. They also discussed ways to design multifunctional windbreaks. Approximately 82 participants from 11 States and 3 Provinces attended the conference in person, and 35 joined remotely.

Presenters and participants at the Great Plains Windbreak Renovation and Innovation Conference in 2012. Photo courtesy of Agriculture and Agri-Food Canada.

cycling, and retention; and soil conservation and regulation of soil organic matter (Thiessen Martens et al. 2013). The ecosystem services of trees in tree-based intercropping (also known as alley cropping) have been the focus of several studies in Ontario and Quebec. Beneficial effects identified in these studies include increased soil organic C; greater C sequestration (Oelbermann and Voroney 2011, Peichl et al. 2006, Thevathasan and Gordon 2004); reduced leaching of water contaminants, including nitrate and *Escherichia coli* (Bergeron et al. 2011, Dougherty et al. 2009, Thevathasan and Gordon 2004); reduced nitrous oxide (N_2O) emissions (Beaudette et al. 2010); enhancement, diversification, and stabilization of arbuscular mycorrhizal fungi populations (Bainard et al. 2012, Chifflot et al. 2009, Lacombe et al. 2009); and augmentation of earthworm, bird, and insect populations (Thevathasan and Gordon 2004).

Many Canadian citizens are concerned about potential negative ecological impacts of agricultural production, and thus the role of agroforestry in Canada's agricultural landscapes has largely been linked to lessening environmental impacts of modern agriculture while balancing productivity and environmental stewardship. Adaptation and mitigation to climate change impacts are emerging concerns, and key environmental benefits sought to address these concerns include C sequestration and greenhouse gas (GHG) reductions, soil conservation, nutrient management, and water-quality protection (Van Rees 2008). Capitalizing on multiple services is a primary objective. For instance, riparian buffer zones with poplar trees can be used for water-quality protection while producing biomass that could then serve as a biofeedstock source, ultimately reducing GHG emissions (Fortier et al. 2010a).

Because the climate, soil, landforms, and resource management systems vary among Canada's five broad agricultural regions—Atlantic, Quebec, Ontario, Prairies, and British Columbia—agroforestry solutions will need to be region specific. For instance, a common agroforestry practice such as shelterbelts (table 7.1; Statistics Canada 2006) has been implemented across Canada, but the design characteristics, such as single rows versus multiple rows of trees and tree species selection, may vary from farm to farm and region to region based on agroecological conditions. The remaining paragraphs in this section summarize agroforestry trends and opportunities in each region.

Atlantic

In Canada's Atlantic region, comprising the Provinces of New Brunswick, Newfoundland and Labrador, Nova Scotia, and Prince Edward Island, a large percentage of the land area is forested and government owned. Many agricultural producers have woodlots that generate significant income through the sale of wood as a source of fuel and pulp fiber. The purposeful integration of trees and shrubs into the agricultural landscape through the adoption of agroforestry practices has been less prevalent than farm woodlots. The interest in agroforestry, however, has grown in the region during the past 10 years.

Planting riparian forest buffers is one of the main agroforestry practices being used in this region, especially to address issues of soil erosion and contamination of watercourses by sediments, nutrients, and pesticides from intensive potato production. Each Atlantic Province has some form of environmental legislation that can affect the choice of agroforestry system that the Province adopts, particularly the use of riparian forest buffers (ADI Limited 2007). Multirow riparian forest buffers with willow (*Salix* spp.) as the primary species are being looked at for their potential to effectively buffer adjacent waterways and also to provide harvestable biomass and C sequestration (fig. 7.2). Although forest farming has only recently been introduced in the region, the potential for diversifying products and income under climate change is significant, given the number of agricultural producers that have woodlots.

Figure 7.2. Willow riparian forest buffer on Prince Edward Island. (Photo courtesy of Agriculture and Agri-Food Canada).

Table 7.1. Shelterbelt adoption in Canada's agricultural regions.

Agricultural region	Total farms reporting	Number of farms reporting shelterbelts	Percentage of farms reporting shelterbelts
Atlantic	8,829	2,525	29
Quebec	30,675	5,994	20
Ontario	57,211	19,044	33
Prairies	112,814	52,365	46
British Columbia	19,844	4,794	24
Canada	229,373	84,722	37

Source: Statistics Canada (2006).

Quebec

Notwithstanding maple syrup production by woodlot landowners, which is a well-established industry in the Quebec and Atlantic regions, agroforestry has not been traditionally practiced in Quebec. Because of growing social pressure for sustainable management of the Province's natural resources, combined with the economic and environmental challenges that the agricultural and forestry sectors face, however, agroforestry is attracting greater attention and popularity (De Baets et al. 2007).

Planting shelterbelts is the most widespread agroforestry practice in Quebec, with approximately 400 kilometers being planted annually since the mid-1980s to protect crops, soil, livestock, buildings, and roads from the wind (De Baets et al. 2007). In the early 2000s, windbreaks began to be planted to reduce odors from intensive livestock operations. Though not as widely adopted as windbreaks, riparian forest buffers have been receiving increased attention from environmental and agricultural stakeholders (Fortier et al. 2010b).

Maintenance of a network of trees distributed throughout modified landscapes, such as those of southern Quebec, where cultivated fields form a significant component, is an option for facilitating climate change adaptation (Auzel et al. 2012).

Since 2004, provincial and Federal funding agencies have supported research on tree-based intercropping (fig. 7.3) in Quebec (Hesselink and Thevathasan 2012). Current research in Quebec and Ontario is attempting to quantify the capacity of this practice to mitigate the impact of agricultural GHGs. Several years of field trials indicate that widespread adoption of tree-based intercropping could improve current agricultural systems and also provide various social, economic, and ecosystem services to rural communities and to society as a whole. If applied on a large scale, tree-based intercropping systems could substantially reduce agricultural GHG emissions and increase atmospheric C sequestration in soils and woody biomass.

Figure 7.3. Young alley cropping system in southern Quebec. (Photo courtesy of David Rivest).

Ontario

Tree-based intercropping systems have been widely researched in relation to their ecosystem services (fig. 7.4).

Figure 7.4. Tree-based intercropping research site at Guelph, Ontario. (Photo courtesy of Naresh Thevathasan, the University of Guelph).

The major areas of research include C sequestration, N_2O reduction potentials, nutrient leaching reduction and improved water quality, enhancement of bird diversity and earthworm activity, and woody biomass production for bioenergy. It is possible for these systems to make a considerable contribution to climate change mitigation. Thevathasan and Gordon's (2004) research determined that, because of reduced fertilizer use and more efficient nitrogen-cycling, tree-based intercropping systems could contribute to the reduction of N_2O emissions from agricultural fields by about 0.7 kilograms per hectare (ha) per year (1.5 pounds per acre per year).

The ecobiological processes and the combined tree and crop yields provide tangible benefits that show tree-based intercropping has increased capacity over conventional agricultural systems in terms of long-term overall productivity (Thevathasan et al. 2004). Dyack et al. (1999) determined that the low adoption rate of tree-based intercropping systems is partially due to current tax policies that do not take into consideration the numerous intangible, societal-level benefits associated with agroforestry systems. Adoption of these systems is also hindered by initial establishment costs and also by the income loss resulting from the removal of cropland from production. An economic analysis (Toor et al. 2012) found that tree-based intercropping systems in central Canada were less profitable than annual cropping systems due to reduced area for annual crops and low revenue from trees, especially when trees were slow-growing timber species such as red oak (*Quercus rubra* L.).

The Prairies

Canada's Prairies region comprises the Provinces of Alberta, Manitoba, and Saskatchewan. Widespread agricultural settlement occurred rapidly after the railroads were built in the early 1880s. Agroforestry activities in this region began soon afterward. Many settlers acutely felt the need for shelter on the wide-open, windy, treeless southern plains, but the need was less in the more wooded northern and eastern portions of the Prairies region.

In 1886, the Federal Government adopted the Experimental Farm Stations Act; it was through this program that tree nurseries were developed to produce tree and shrub seedlings (Van Rees 2008). Early agricultural settlers, while adamant about clearing land for agricultural practices, were also cognizant of the important roles that trees play in sustaining farm systems, and they appreciated the products and services that could be derived from trees. Multirow farm shelterbelts surrounding yards and single-row field shelterbelts became the predominant tree culture practiced on the prairie landscape (Edwards 1939).

Federal programming supported the planting of shelterbelts on the prairies since 1901 (fig. 7.5), including the provision of seedlings through the Federal tree nursery at Indian Head, Saskatchewan, and, from 1935 to 1959, special support for establishing field shelterbelts for erosion control under the Prairie Farm Rehabilitation Act (Amichev et al. 2014). Throughout the period from 1901 to 2013, more than 630 million seedlings were provided for protecting farmyards and fields and were used for other environmental plantings through the Prairie Shelterbelt Program, enough seedlings to potentially sequester more than 218 megatonnes of carbon dioxide (CO_2) during the lifetime of the trees (Kort and Turnock 1999).

As a result of the *Saskatchewan's State of the Environment Report 1997* (Saskatchewan Environment and Resource Management 1997), which highlighted the need to support research and development in emerging value-added sectors in agriculture, the Province of Saskatchewan created the Agri-Food Innovation Fund (AFIF). Developing sustainable agroforestry economic diversification opportunities for farmers was one of the five priority areas of AFIF, with much of the emphasis on poplar-afforestation and small woodlots, with research and demonstration directed toward efforts that could supplement traditional forest products and harvest (Van Rees 2008).

Figure 7.5. Farmyard and field shelterbelts near Francis, Saskatchewan, established with seedlings provided through the Prairie Shelterbelt Program. (Photo courtesy of Agriculture and Agri-Food Canada).

Land tenure in the Prairies region continues to evolve toward larger specialized farms with more corporate ownership of farming operations on rented land. The predominance of large-scale agriculture and the introduction of precision farming technology have led to a noticeable reduction in habitat on marginal lands adjacent to agricultural fields. Although improved land management techniques, such as zero tillage, can help mitigate the negative impact of the loss of shelterbelts, the positive functionality of agroforestry systems cannot be adequately replaced by monoculture farming practices (Schroeder et al. 2011). The domestic market provides opportunities for more specialized, often smaller, farm enterprises, such as organic farms and market gardens. Corporate farms may be less interested in tree planting or other environmental practices that are not seen as profit-generating activities, and farming on rented land may also present obstacles to long-term conservation practices with trees. Public concern about environmental issues, however, may encourage corporate farms to make sound environmental management of the landscape an essential part of their core business.

British Columbia

Agroforestry applications within British Columbia have evolved from efforts to integrate resource practices on public lands to, more recently, a means of economic diversification and as an approach to environmental stewardship.

Shelterbelts were reported on less than 25 percent of the farms in the Province (Statistics Canada 2006). The low percentage of adoption may be reflective of generally naturally treed landscapes of many agricultural areas of British Columbia and a need for more shelterbelt design, demonstration, assessment, and management for a variety of agricultural production systems. In British Columbia, producers rank economic efficiency and effectiveness as the most important criteria for decisionmaking, followed by adoptability, adaptability, flexibility, and independent benefits (Dobb 2013).

Various natural and land management elements—including success in using sheep grazing for silvicultural purposes since 1984, economic diversification efforts in coastal woodlots starting in the mid-1990s, and the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemic in the British Columbia interior—converged, creating awareness of agroforestry's potential usefulness in British Columbia. This awareness has given rise to organized research, pilot projects, and demonstration initiatives, as illustrated in figure 7.6.

Figure 7.6. Silvopasture pilot site, southern interior of British Columbia. (Photo courtesy of British Columbia Ministry of Agriculture).

Significant opportunity exists in the implementation of silvopastoral systems and riparian forest buffers to address concerns related to water quality and also to provide additional economic opportunities other than those based on forestry products. Development of agroforestry in British Columbia is driven by partnerships among producers and industry associations; First Nations; academic institutions; nongovernmental organizations; and municipal, provincial, and Federal Government agencies (Dobb 2013).

Overview of Existing Policies and Programs

"Climate change is perhaps the greatest environmental policy challenge of the 21st century" (Gleeson et al. 2009). Effective policies supporting agroforestry land-use systems in Canada can provide the framework for landowners and land managers who may become active agents of change through their own personal undertakings and examples. At present, few specific policies exist at any level of government that govern agroforestry practice and adoption. Policies and programs that do exist are not coordinated across provincial jurisdiction and generally are limited in the time they are available. More likely, agroforestry practices will be influenced by other agricultural policies affecting land use or, in some instances, forest management regulation changes.

To obtain successful adoption rates and well-maintained agroforestry systems across Canada, policy measures and/or tax incentives and cost-share programs will likely be required at Federal and/or provincial levels of government.

Federal

To date, the only Federal organization that has a national agroforestry mandate is Agriculture and Agri-Food Canada (AAFC). Activities in support of agroforestry and tree planting in the agricultural landscape have existed at the Federal level of government since 1901. Activities in research, development, and tree distribution have continually evolved during the past century based on environmental and economic drivers and to meet the needs of the changing agricultural sector. Additional regional and national strategies for agroforestry, with the goal of improving the competitive position of the agricultural sector by incorporating agroforestry systems for the sustainable management of the agricultural land base, have also evolved over time (Van Rees 2008).

Federal-provincial cost-share agreements integrate environmental actions across levels of government and focus programs on helping producers reduce environmental risks and improving benefits. The current agricultural framework agreement, Growing Forward 2, continues to encourage agricultural producers to adopt management practices that benefit the environment and sustain the natural systems that provide ecosystem goods and services. For example, in Saskatchewan, eligible landowners can receive funding through the Farm Stewardship Program at a rate of $1,200 Canadian dollars (CAD) ($904 U.S. dollars [USD]) per mile to a maximum payment of $5,000 CAD ($3,769 USD) (Government of Saskatchewan, 2016). Table 7.2 lists the number and funding of projects involving agroforestry practices under the Agricultural Policy Framework.

Table 7.2. Agroforestry-related projects by Province funded under the Agricultural Policy Framework.

Province	Number of projects	Funding (Canadian dollars, thousands)
Alberta	98	250
British Columbia	29	207
Manitoba	73	139
New Brunswick	10	21
Newfoundland	0	0
Nova Scotia	5	6
Ontario	336	586
Prince Edward Island	3	7
Quebec	1,081	1,086
Saskatchewan	64	100
Totals	**1,729**	**2,399**

Source: Agriculture and Agri-Food Canada program data.

As illustrated, support and promotion at the provincial level can have a significant effect on the uptake of program initiatives by producers in a region. Projects in Alberta, Manitoba, and Saskatchewan, although lower than those in Ontario and Quebec, do not take into account most of the tree-planting activities that would have occurred under the Prairie Shelterbelt Program, which provided trees, on average, to 5,000 or more landowners annually.

Agricultural Greenhouse Gases Program

The Canadian Government, through AAFC, has initiated and promoted a national network of agroforestry practitioners in research and development through the Agricultural Greenhouse Gases Program (AGGP). This proposal-based program is part of GHG mitigation initiatives undertaken in countries that are members of the Global Research Alliance and ran from September 1, 2010, to March 31, 2016. The AGGP supports projects that will create technologies, practices, and processes that can be adopted by farmers to mitigate greenhouse gas (GHG) emissions.

Within the priority area of agroforestry, six projects within the Agricultural Greenhouse Gases Program (table 7.3) were funded at a level of $4.85 million CAD. These projects address knowledge gaps and increase capacity in two main theme areas: (1) understanding C sequestration on agricultural land through agroforestry systems and (2) adoption and efficacy of agroforestry practices. Areas of study in the first theme encompass the understanding of C dynamics in agroforestry practices, including aboveground and belowground C pools and fluxes; quantifying the potential for agroforestry practices to store C on agricultural land; and developing methodology for the measurement, monitoring, and verification of C in agroforestry systems, all providing a basis for a national inventory of C in agroforestry systems in Canada. Areas of study under the second theme include assessments of how agroforestry practices interact with or affect agricultural practices, the quantification of co-benefits, and C sequestration from agroforestry systems. The six projects are also examining existing policies and developing policy tools that encourage sustainable and effective GHG mitigation practices, and conducting life-cycle assessments and economic analyses to assess the sustainability and performance of agroforestry systems for GHG mitigation.

Provincial

In Quebec, in 2011, the provincial Department of Agriculture, Fisheries and Food of Quebec (MAPAQ; Ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec) launched a pilot program on the multifunctionality of agriculture, specifically targeting agroforestry and tree-based intercropping systems as production systems for which the implementation of such systems may qualify for a subsidy. This pilot program ended in March 2015. Some other Quebec departments have also considered the various functions of agroforestry. For many years the Quebec Ministry of Natural Resources (Ministère des Ressources Naturelles du Québec) has provided trees for windbreaks and riparian forest buffers in collaboration with MAPAQ. Various timber-oriented agroforestry projects have also been funded through a regional forest development program, now titled the Regional and Forestry Development Program (Programme de développement régional et forestier) (Government of Quebec 2013). The Quebec Ministry of Transportation (Ministère des Transports du Québec) implements windbreaks in rural areas to reduce snow-control costs. In a perspective of regional development, the Quebec government’s Ministry of Municipal Affairs, Regions and Land Occupancy (Ministère des Affaires municipales et de l’Occupation du territoire) also supported experimental agroforestry development projects, notably tree-based intercropping systems

Table 7.3. The six agroforestry projects funded under the Agricultural Greenhouse Gases Program.

Lead institution	Title	Primary objective
Government of British Columbia	Evaluating silvopasture systems for economic and environmental performance and greenhouse gas mitigation potential	Examine how the practice of combining forestry with forage and livestock production in the southern interior of British Columbia will support greater biological and economic diversity and benefit the environment.
University of Alberta	Quantifying carbon sequestration and greenhouse gas emissions in planted shelterbelts, natural hedgerows and silvopastoral systems in different soil-climatic zones in Alberta	Quantify the value of shelterbelts, natural hedgerows, and silvopastoral systems for facilitating carbon storage and reducing greenhouse gas emissions.
University of Saskatchewan	Shelterbelts as an agroforestry management practice for the mitigation of GHGs	Determine how effective shelterbelts and other agroforestry plantings are in sequestering carbon and how they can better function as carbon sinks.
Upper Assiniboine River Conservation District	Demonstration and investigation into agroforestry based livestock systems adoption	Evaluate various beneficial management practices on the farm to see if they can be easily adopted by the farming community.
University of Guelph	Tree-based intercropping: An agroforestry land-use for greenhouse gas mitigation in Canadian agricultural systems	Assess how tree-based intercropping can mitigate greenhouse gas emissions and enhance carbon sequestration in tree biomass and agricultural soils.
Eastern Townships Forest Trust	Effects of hybrid poplar agroforestry systems on carbon sequestration in agricultural landscapes of Eastern Canada	Determine the potential for riparian and upland agroforestry buffers to sequester carbon in agricultural landscapes in Eastern Quebec.

Source: Agriculture and Agri-Food Canada program data.

in the Gaspe Peninsula. Moreover, some municipalities are exploring agroforestry approaches as a means to increase the value of abandoned land, to enhance green corridor acceptance among farmers, and to offset C emissions from urban areas.

In British Columbia, the Agroforestry Industry Development Initiative (AIDI) supported the development and adoption of agroforestry practices by improving market connections, expanding partnerships, improving awareness, and establishing demonstrations. Funding for AIDI was provided by AAFC through the Canadian Agricultural Adaptation Program from 2010 to 2013 and was delivered by the Investment Agriculture Foundation of British Columbia.

Alternative Land-Use Services

Financial incentives have become popular for protecting the environment in Canada (Lantz et al. 2012). Alternative Land-Use Services (ALUS) are community-developed, farmer-delivered programs that provide incentives to farmers and ranchers for the conservation and protection of environmental assets on privately owned land (ALUS 2016, Keystone Agricultural Producers 2011). Most of the current programs rely on grants through nongovernment funding agencies (Campbell 2014).

The goals of ALUS programs are to empower landowners in conservation, to increase the supply of environmental goods and services, and to improve land management by reducing soil erosion, improving water quality, improving and increasing wildlife habitat, and reducing the impacts of climate change (Government of PEI 2012). The current impact of ALUS programs has been minimal regarding agroforestry; approximately 243 ha (600 acres [ac]) have been planted in trees and shrubs across Canada, with most planted in Ontario. Many of these seedlings are provided by the Ontario Ministry of Natural Resources and Forestry's 50 Million Tree Program. With goals of sequestering C and of enhancing and diversifying southern Ontario's landscape to increase adaptive capacity and resiliency regarding climate change, the program substantially decreases costs of large-scale tree planting to increase the total number of trees planted (Forests Ontario 2016) In the Province of Prince Edward Island, 251 ha (620 ac) of tree planting within the 15-meter (49-foot) regulated buffer zone have been established and expanded buffer zones (beyond 15 meters [49 feet]) have been created on 553 ha (1,366 ac) (ALUS 2012) with payments of $185 CAD ($139 USD)/ha/year (Lantz et al. 2012).

Ecosystem Goods and Services

The value that ecosystem goods and services produced from establishing agroforestry practices is significantly higher for the public than the costs they engender for farmers (EcoRessources Consultants 2011). Some of the most important benefits relate to C sequestration. Kulshreshtha and Kort (2009) estimated that the benefits of tree seedlings distributed through the Prairie Shelterbelt Program for the period from 1981 to 2001 was $73 million CAD ($47 million USD) for C sequestration. Some indications suggest that the demand for ecosystem goods and services from rural lands is growing as incomes rise and values change in Canadian society, but the supply side does not seem to be responding (Fox 2008).

Current discussions of alternative approaches to facilitating the provision of ecosystem goods and services have not made a distinction between taxpayer-funded programs and beneficiary-funded market programs (Fox 2008). To develop programs and policies that recognize and support the contributions that landowners make through agroforestry, a greater understanding of the benefits of ecosystem goods and services will be needed (Kulshreshtha and Kort 2009).

Needs for Agroforestry in Canada

Although each Canadian Province has its own unique preference to different agroforestry systems adapted for local conditions, the challenges/constraints and potential impacts are similar across the Provinces (Thevathasan et al. 2012). Key research needs across the Provinces include understanding of the evolution of agroforestry practices in light of changing socioeconomic and environmental conditions; evaluation of the ecosystem goods and services provided by different types of agroforestry systems; accounting for potential impacts (both benefits and concerns) of agroforestry systems at the landscape level; and understanding how agroforestry can best be included in management of water quality and GHG mitigation in agricultural watersheds, and in emerging taxation and credit schemes. To address these needs, continued studies and analyses of the economics, risks, and life-cycle components of agroforestry systems currently found on the Canadian landscape will be required. The formation of a national agroforestry network would provide a means for efficiently addressing these many issues and building the scientific information needed at both the regional and national levels (Van Rees 2008).

Adaptability of Species Used in Agroforestry

Having woody plant material that is adapted to the future climate conditions in Canada will be critical to the success of agroforestry as a climate change tool (Johnston et al. 2009, Silim 2004). Tree species currently used and potentially available for use in Canada are vulnerable to erratic and extreme weather events and also to climate-induced fluctuations in insects and pathogens (Allen et al. 2010, Fuhrer 2003). It is essential to understand the vulnerability of tree species under predicted climate change to determine reasonable options for adaptation of agroforestry plant materials.

The Agriculture Canada Balsam Poplar (AgCanBaP) program is focused on developing adaptable balsam poplar (*Populus balsamifera* L.) materials. Occurring across a wide range of North America, balsam poplar is both highly variable and capable of a broad range of adaptive physiological responses to a changing climate (Keller et al. 2011). With its natural range in Canada extending from coast to coast, balsam poplar is one of the most widely distributed poplars in Canada. Researchers at AAFC who have advanced genetic improvement on a number of species have also now assembled a balsam poplar collection. The AgCanBaP collection consists of material from throughout North America that provides germplasm for future climate change, breeding, and genomic studies (fig. 7.7). This collection is currently being screened to identify fast-growing selections that have greater C sequestration and biomass yields (Soolanayakanahally 2010).

GHG Accounting and Inventory

Significant potential exists for agroforestry to contribute to Canada's GHG mitigation goals. Canada has an estimated 57 million ha (141 million ac) of agricultural land that have slight to significant degrees of agricultural crop production limitations. If 5 percent of this land area were converted to agroforestry, the potential for an annual C sink of 47 to 76 megatonnes of CO_2 (up to 30 percent of the emission reductions for Canada) would exist (Van Rees 2008).

Information on GHG accounting from agroforestry practices is not fully developed, however, and, therefore, is not currently reported in the National Inventory Report (NIR) on GHG sources and sinks in Canada. As the Canadian government's submission to the United Nations Framework Convention on Climate Change, NIR provides an annual report on GHG accounting across sectors, including agriculture and land use, land-use change, and forestry. Impacts of changes in woody biomass in the agricultural landscape is characterized under "perennial woody crops" in the NIR and includes land-use

Figure 7.7. Natural range of balsam poplar (*Populus balsamifera* L.) and geographic locations of 65 provenances (indicated by green dots) and common garden locations (indicated by red stars) in the AgCanBaP program (Soolanayakanahally et al. 2013). (Map created by Chris Stefner, Agriculture and Agri-Food Canada).

activities such as vineyards, fruit orchards, and Christmas trees reported under the Canadian Agricultural Census on a 5-year basis. Current estimates of sequestration from perennial woody crops account for the removal of only 10 gigagrams of carbon dioxide equivalent (CO_2eq) (Environment Canada 2014). Compared with sequestration from practices such as reduced fallow or tillage, woody biomass seems to have an insignificant effect on total C removals. This seeming insignificance is an accounting byproduct resulting from the lack of inventory of agroforestry practices in Canada and the lack of activity-specific data on the GHG impacts of agroforestry practices. The Agricultural Greenhouse Gases Program is addressing both deficiencies.

Emerging Opportunities

In an increasingly complex commodities mix, it is beneficial that various economic diversification strategies be available to Canadian landowners through agroforestry systems (Gordon et al. 2008). Bioenergy from short-rotation willow and/or poplar has considerable potential for the future because economic inputs in some woody bioenergy systems are substantially less than those involved in grain-based systems used for ethanol production. Agroforestry, as stated by Gordon et al. (2008), offers long-term rural landscape sustainability and provides economic resilience through income diversification.

It has been suggested that payments in a C market or a grant/subsidy program for ecological services are necessary to encourage adoption of agroforestry practices (EcoRessources Consultants 2011, Thiessen Martens et al. 2013). It is anticipated that as C markets emerge, agroforestry plantings will generate C offsets and provide revenue for landowners. The Government of Alberta has created the Climate Change and Emissions Management Fund to establish or participate in funding for initiatives that reduce emissions of GHGs or improve Alberta's ability to adapt to climate change and has placed a value of $15 CAD ($11 USD)/tonne CO_2eq (IETA 2015). British Columbia has also developed a C market with offset prices being paid in the range of $9 to $19 CAD ($7 to $14 USD)/tonne CO_2eq (IETA 2015).

Key Findings

- As Canadian agriculture likely expands into new areas under changing weather and climate conditions, agroforestry can be an important component in enhancing food security, particularly in northern and First Nation communities.
- Agroforestry can play a critical adaptation role in existing agricultural areas as these lands experience more extreme and variable weather events, increased pest infestations, and other climate-related stressors.
- Agroforestry systems can have a significant effect in mitigating GHG emissions from Canadian agricultural activity if agroforestry implementation is increased.
- Climate, soils, and agricultural systems vary considerably across the broad farming and ranching areas in Canada, requiring agroforestry solutions to be region specific.

Key Information Needs

- Better understanding of GHG dynamics across Canadian agroforestry systems and regions.
- A national inventory to track land currently in agroforestry to feed into Canadian GHG inventory assessments.
- Development of a Canadian agroforestry network to help build the scientific information and support needed at both regional and national levels.
- Coordinated land-use policy between levels of government that addresses both short-term economic pressures of the landowner (private risk) and longer term public benefit.

Box 7.2. Enhancing Food Security in Northern Canada With Agroforestry

Food insecurity is one challenge that First Nations people residing in northern Canada face. Warming temperatures are already creating many other challenges for these communities, especially for those in the more remote subarctic and arctic regions of northern Canada. These warming temperatures, however, also provide an opportunity to build food security through local agricultural production. Work by Barbeau et al. (2015) demonstrates that with the selection of appropriate plant materials, potatoes and bush beans could be grown successfully and used as a source of local, fresh, and nutritious foods. They also found that yields could be significantly enhanced by growing the crops in alleys between rows of willows. By capitalizing on this windbreak function and with the resiliency and potential other uses of and services from willow (i.e., biodiversity including pollinator habitat, C sequestration, soil conservation, and biofeedstock), agroforestry can be more specifically designed to better meet the needs of the people in these regions.

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