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Managing natural wealth: Research and implementation of ecosystem services in the United States and Canada

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ABSTRACT

The United States and Canada have vast stores of ecological wealth that provide often unseen but critical benefits to the people and economy of each country. The close ties between ecology and the economy make it urgent that action is taken to address the risks of ecosystem degradation, but these close ties also present opportunities to develop new incentives for ecosystem conservation. To highlight the diversity of approaches being implemented in the US and Canada, we describe examples of programs seeking to maintain ecosystem services from wetlands, agricultural lands, forests, and water quality. Corporations are also beginning to account for ecosystem service values. Innovative solutions are being developed mostly within existing government and corporate policies that allow for ecosystem service accounting. To further mainstream ecosystem service values into broader economic decisions, new policies are necessary that not only allow but mandate their inclusion in decisions and reporting.

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1. Introduction

The United States and Canada are both rich in natural capital—with expansive forests, rivers, prairies, lakes, agricultural land, and other ecosystems. Canada contains 25% of the world's wetlands and 20% of the world's freshwater; the two countries are ranked third and fourth in forest cover (Canada has 7.9% of global, US 7.7%) (Alvarez, 2007; Dufour, 2007). Both countries contain large expanses of natural areas, playing a critical role for local, regional, and national economies. With a wide variety of human activities threatening these ecosystems, the impacts will not only be felt by wildlife, but can lead to declines in human health and well-being as well as economies (The President's Council of Advisors on Science and Technology (PCAST), 2011).

While the two countries are roughly equal in land area, the US supports a population approximately 10 times greater (Statistics Canada, 2007; Mackun and Wilson, 2011). In the US, the utilization of market-based ecosystem services has increased over the last half century, including agriculture products, forest products, and freshwater withdrawal. Agriculture has increased at a rate greater than population growth, bringing its own costs and benefits to the ecosystem and humans. Surface and groundwater use has increased 46% (1960–2000). Commercial fish and shellfish landings have increased 90% (1950–2005); however, since 1978, only Alaska has experienced increases, while other regions have declined (The H. John Heinz III Center for Science Economics and the Environment, 2008). In Canada, logging harvest rates have increased substantially since the start of cumulative data collection in 1920, with a 60% increase in harvest rates between 1975 and 1988 (Global Forest Watch, 2000). The extent of agricultural lands only slightly increased between 1921 and 2011, and in recent years there has been a shift from livestock to crops (Statistics Canada, 2011b). But the average annual yield of water has declined between 1971 and 2004 in the regions where populations are concentrated, in Southern Canada (Bemrose et al., 2010). Other critical ecosystem services are less apparent and more challenging to assess, but no less important. These include "natural processes as purification of air and water, regulation of climate and floodwaters, erosion control, pollination, seed dispersal, carbon storage, and renewal of soil fertility" (The H. John Heinz III Center for Science Economics and the Environment, 2008).

In both countries, significant efforts have been made to protect natural resources, whether through public and private networks of protected areas or environmental regulations that limit threats like pollution or habitat conversion. But ecosystems are still at risk, and threats are increasing with rising populations, expanded exploitation of resources, and climate change (Millennium Ecosystem Assessment, 2005b). The links between ecosystem health and economies make action urgent, but also present opportunities to develop new incentives and institutions for ecosystem conservation.

In order to both address these risks and take advantage of the opportunities, the connections between ecosystem health and the benefits that ecosystems provide diverse stakeholders need to be understood. Otherwise decisions and actions – whether by a government, company, or individual – often do not recognize the value of ecosystem services to them and others. "A major part of our 'balance sheet' (representing nature's value) is missing, leading us to use nature's resources wastefully and unsustainably— much as a tenant who does not pay for electricity tends to leave the lights on" (Sustainable Prosperity, 2011). Dollars are a common metric that can be useful in making those values tangible to some audiences, but other quantitative and qualitative measures can be effective or even preferable for other audiences (Cowling et al., 2008).

In this paper, we provide an overview of research, implementation, and industry actions related to ecosystem services in the United States and Canada ("North America" in this paper; Mexico is excluded in this analysis as it is covered in a separate article in this journal). We use a broad definition of ecosystem services, the benefits that nature provides to people (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005b). We do not limit this paper to ecosystem service markets or services that can be valued monetarily.

2. Ecosystem services research

2.1. Research publication trends

Research around ecosystem services began in 1977 with the introduction of the idea as "nature's services" in a paper published in *Science* by Westman (1977). The first publication to use the term "ecosystem services" was written in 1981 by Ehrlich and Ehrlich entitled *Extinction: The causes and consequences of the disappearance of species* (Ehrlich and Ehrlich, 1981). No additional papers were published with the term until 1991. Since then, however, a total of 3770 papers have been published internationally; 1848 (49.0%) of those have had at least one author from United States or Canada.

The publication data used in this paper was collected on August 28, 2012 from the Institute for Scientific Information's (ISI) Web of Science for the analysis of the topic area of "ecosystem services" (papers were included if the term appeared in the title, abstract, or keywords of the paper). The term also had to be in English to be included. ISI Web of Science defines papers as being published in North America if one of the authors on the paper is from the United States or Canada. ISI provides data for a large subset of peer-reviewed journal articles. Different subscription levels are available. The one used in this paper is through University of Maryland, College Park, which includes articles published beginning in 1945. Unlike Google Scholar, it does not include books, book chapters, magazine articles, or other forms of publications. However, ISI does contain the majority of, although not all, peer-reviewed journal articles within the topic area.

While research in this field has increased exponentially, it is unevenly distributed across the different ecosystem services categories, as defined by Millennium Ecosystem Assessment (2005b) (Fig. 1). Within the 3770 published ecosystem service papers, we used the ISI Web of Science to tabulate the number of papers with topic areas for each of these categories, and found that the distribution of categories in the papers with North American authors was similar to the distribution of all ecosystem service literature, with an almost even number of publication between provisioning and regulating services (37% and 38%, respectively) and cultural services accounting for 6%. Most publications within provisioning services were related to food (20% of total North American publications), especially crops (11%) and capture fisheries (8%). Freshwater (6%) and timber (4%) were also represented well. Under regulating services, almost half of the publications included climate regulation (18%), with a more even spread across other services: water purification and waste treatment (8%), natural hazard regulation (6%), pollination (5%), erosion regulation (4%), and pest regulation (4%). Recreation (5%) was included in three-quarters of cultural services publications.

2.2. Valuation research

Recent national assessments of ecosystems in the US and Canada have begun to describe the status and trends of ecosystems (The H. John Heinz III Center for Science Economics and the Environment, 2008; Federal Provincial and Territorial Governments of Canada, 2010). Because data only exist for a subset of ecosystems, these assessments were unable to quantify the effects of the delivery of

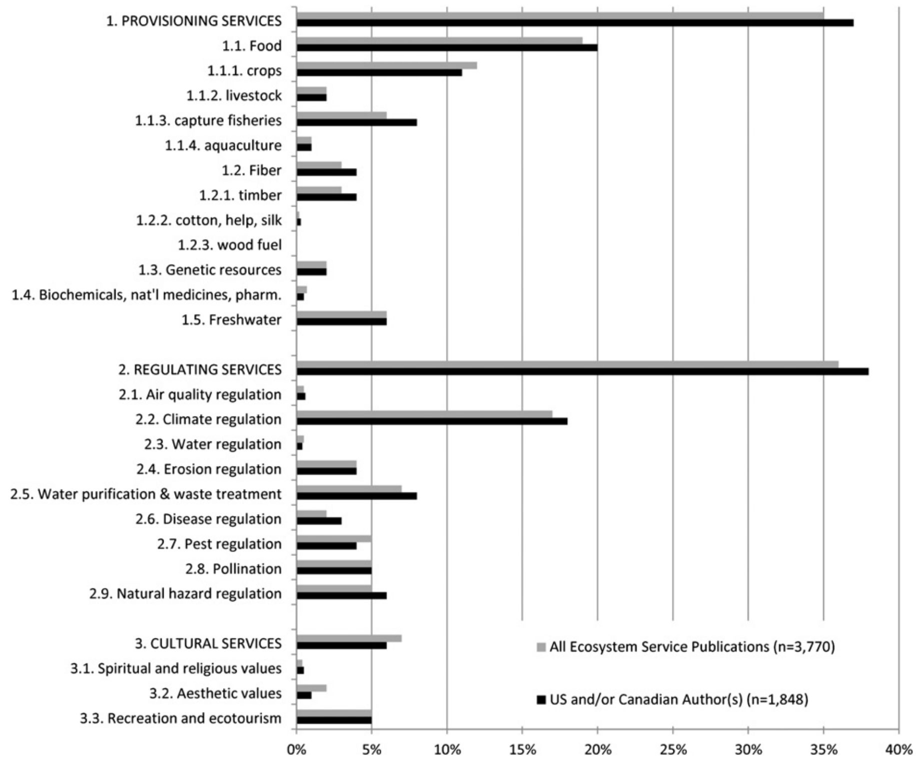

Fig. 1. Distribution of journal publications by type of ecosystem services. Citation search used the list of assessed ecosystem services in Millennium Ecosystem Assessment (2005b). Related terms searched in addition to those listed above: 1.5. "fresh water"; 2.2. "carbon"; 2.5. "water quality"; 2.8. "pollinator"; 2.9. "storm" or "flood"; 3.1. "religion"; 3.2. "scenic"; 3.3 "tourism".

ecosystem services. To begin placing values on the otherwise potentially overlooked values of ecosystem services, rough estimates have been developed through broad analyses. Estimates of "total ecosystem value" can be useful in showing the potential scale of economic values of ecosystem services, but their sensitivity to socio-economic conditions produces extremely large ranges of estimates for individual ecosystem services (The President's Council of Advisors on Science and Technology (PCAST), 2011). It can also be challenging to translate them into actionable policies (Daily et al., 2000). Valuation itself does not necessarily create a direct linkage between ecosystem degradation and policy and action (The President's Council of Advisors on Science and Technology (PCAST), 2011). Below are some examples of valuation analyses in Canada and the US.

The majority of Canada's systemized research agenda has been established by the federal government of Canada. Out of all the provinces and territories within Canada, Ontario has done the most to promote ecosystem services, and their value to the well-being of humans. For example, the Ontario Ministry of Natural Resources commissioned a study estimating the value of ecosystem services in Southern Ontario, finding a total ecosystem service value per year of approximately CAD $85 billion/year (Troy and Bagstad, 2009). Another study showed that non-market ecosystem services of Ontario's Greenbelt, such as climate regulation, flood control, water filtration, erosion control, nutrient cycling and others, offered $2.7 billion to the province each year, an average value of $3571 per hectare annually (Wilson, 2008).

The Canadian boreal forest is the largest ecosystem in Canada, and provides much of Canada's economic income. The boreal forest region provides $14.9 billion in harvested timber, $14.5 billion in mining/oil/gas industry, and $19.5 billion in hydroelectric dams and reservoirs, for a total of $48.9 billion per year. However, if left intact the non-market economic value of its ecosystem services (e.g., clean drinking water, decomposition of waste, carbon sequestration) was estimated at $93.2 billion/year (Anielski and Wilson, 2005). The value of the total current carbon stored in the forests is approximately $3.7 trillion, using Munich *Re*'s carbon value estimates.

A significantly greater amount of research has been done around the value of ecosystem services in the United States than in Canada; however, like Canada, there has been no national, systematic valuation analysis done. Nationwide studies have roughly estimated total ecosystem service values (land and marine) in Canada to be about $5.611 billion and in the US to be approximately $2.084 billion (Sutton and Costanza, 2002). Alternatively estimates are around $6500/ha/yr for the US (Gren and Söderqvist, 1994).

Valuations have been estimated in the US for almost every major ecosystem and service, including coral reefs (Cesar and Beukering, 2004), croplands (Pimentel et al., 1995; Cesar and Beukering, 2004), deserts (Richer, 1995), grasslands (Sala and Paruelo, 1997), coastal wetlands (Farber and Costanza, 1987; Costanza et al., 1989), inland wetlands (Thibodeau and Ostro, 1981), temperate forests (Phillips et al., 2007), tropical forest (Kramer et al., 1992; Kaiser and Roumasset, 2002), open water (Gibbons, 1986), and others. Individual states have also begun to value the services from their natural capital as a means of making more informed decisions. The first was New Jersey in a 2006 study that found the total ecosystem services in New Jersey to be worth $19.4 billion/year (Costanza et al., 2006). Several critical regions have also had valuation studies done on them, including the Puget Sound (Batker et al., 2008) and the Mississippi river deltaic plain (Batker et al., 2010).

Recent extreme events have also begun to increase public awareness and government attention on the importance of ecosystem services. Undoubtedly the most well-known was Hurricane Katrina, a 2005 hurricane with storm surges reaching over 6 m high, placing approximately 80% of New Orleans under water, killing over 1800 people across the Gulf coast, and inflicting over

$100 billion in estimated damages (Grauman et al., 2006). Coastal communities like New Orleans had been left more vulnerable to storm damage as some 4900 km^2 of buffering wetlands have been lost in Louisiana since 1900, depleted by channelized rivers, canals, and other development (Day et al., 2007). There has been widespread acknowledgement that protection of these wetlands could have mitigated some of the impacts of this disaster. As part of a study on the vulnerability of the US Gulf coast (excluding Florida) from future storm damage, large-scale wetlands restoration would be estimated to avert $400 million in annual losses by 2030 ($24 billion total expected annual losses). Despite a high cost/benefit ratio when considering the finances (restoration expected to cost $25 billion over 20 years, non-discounted), the study recognized that the additional co-benefits of wetlands would still make restoration a valuable investment alongside other protective actions in the region (Entergy Corporation and America's WETLAND Foundation, 2010).

3. Implementation

To get beyond ecosystem service analysis to implementation requires connecting valuation with action. This requires connecting science, mapping, and valuation with appropriate policy and regulatory mechanisms within the biological and social context of a project (Daily and Matson, 2008). Research and analysis needs to be driven by stakeholder needs and governance context in order to be useful in successfully implementing potential markets and/or incentives (Cowling et al., 2008).

Policies and methods are evolving that would include ecosystem services in decisions that impact ecosystem health and human well-being. The US has a long history in ''the use of economic instruments to persuade people to take environmental costs into account.... [including] taxes, royalties, access fees or charges, tradable permits, deposit-refund systems, environmental bonds, and liability rules'' (The President's Council of Advisors on Science and Technology (PCAST), 2011). But legal frameworks and cost-benefit analyses for natural resource management in both countries generally do not yet directly account for ecosystem service values (Ruhl et al., 2007). And Canada has even fewer ecosystem market-based instruments or economic incentives compared to other developed countries (Sustainable Prosperity, 2011).

Below is a series of examples of the implementation of programs to maintain ecosystem services, organized by ecosystem: wetlands (through mitigation and payment for ecosystem services (PES)), agricultural lands (payment for ecosystem services (PES)), forests (carbon), and waters (trading programs and watershed protection). There is some overlap between these categories, as not all programs address individual ecosystem services.

3.1. *Wetlands*

Though specific definitions vary across national and state regulations and international treaties, wetlands are ecosystems dominated by water, often transitional between upland and aquatic systems. Not only are they important areas for biodiversity, they also provide a number of services, including flood protection, pollutant filtration, and carbon sequestration (Zedler and Kercher, 2005).

These ecosystems have been in decline—53% of wetlands in the lower 48 US states were lost between 1780s and 1980s, and over 70% have been lost in settled areas of Canada since European colonization (Zedler and Kercher, 2005; Natural Resources Canada, 2009). Threats persist, from increased development to changes in freshwater flow, hydropower, oil extraction, and others.

The value of these ecosystems for people and wildlife comes from their high plant productivity, habitat diversity, and ''their beneficial role in stabilizing hydrologic processes at a watershed scale'' (Brown and Lant, 1999). Due to the values of wetlands and their threatened status, a variety of mechanisms has been developed to protect and restore them.

3.1.1. *Wetlands mitigation*

Protection of wetlands in the United States and Canada largely relies on the mitigation hierarchy to avoid, minimize, or compensate for loss of habitats (Gardner, 2009). Implementation varies by jurisdiction, but often in practice the focus is on the last step in the mitigation hierarchy – compensation for loss – whether monetary or in-kind (Hough and Robertson, 2009). Mitigation programs implicitly create a price for wetlands by requiring mitigation of lost habitat area and (at least in theory) functions, with actual prices determined by availability and price of land as well as cost of offset activities.

In the United States, ''waters of the United States,'' including wetlands, are protected under the Clean Water Act, and its ''no net loss'' requirement has led to mitigation programs to maintain wetland functions and values (*Clean Water Act*, 33 U.S.C. §1344, s. 404). There are three methods of wetlands mitigation available to those permittees required to compensate for wetlands loss: (1) permittee-responsible mitigation, where responsibility lies with permit applicant to meet mitigation requirements, including any required habitat protection or restoration; (2) mitigation banks, where a third party offers mitigation credits for wetland restoration or protection for which they are responsible; and (3) in-lieu fee mitigation, where permittees pay fees to a public agency or nonprofit organization to fund compensation projects (Hough and Robertson, 2009). Permittee-responsible mitigation is responsible for the largest area of compensation wetlands in recent years, but mitigation banks are also increasingly common—representing a third of acreage, with in-lieu fees at 8%. A 2005 review found about 363 banks active in the US, in addition to 75 banks sold-out, and 169 more proposed (Wilkinson and Thompson, 2006). Almost 80% of these banks are for-profit enterprises. Although lacking data as confirmation, larger scale mitigation banks are assumed to be more effective at producing better ecological results, and they do at least make compliance monitoring easier (Hough and Robertson, 2009).

In the US, the annual cost of compensatory mitigation for wetlands is approximately $2.9 billion, representing 77% of federal mitigation costs (Environmental Law Institute, 2007). While wetland mitigation can include establishment, restoration, enhancement, and protection of habitats, regulating agencies prefer restoration to more effectively replace wetland function and area—and annually restoration and enhancement represents 65% of compensation (Wilkinson and Thompson, 2006).

In Canada, wetland protection has increased since the country signed on to the Ramsar Convention on Wetlands in 1981. The national government and six provinces have wetland mitigation measures, with a number of provinces having developed programs with the goal of "no net loss" of wetlands and/or wetland function through laws or policies—while other provinces have stricter "no loss" requirements. Even so, standardized approaches to mitigation are not available throughout Canada, since natural resource protection outside of federal lands is largely the responsibility of the provinces (Rubec and Hanson, 2009). Obtaining offsets through third parties or mitigation banks is rare in Canada, although there are examples of consolidated compensation projects like Nova Scotia's

Department of Transportation's banking program for new highway construction (Sustainable Prosperity, 2011).

Do these programs actually meet the goal of no net loss of wetlands and their ecosystem functions and services? In the US in the 1990s, over 70% of banks achieved no net loss in wetland area. But due to offset ratios below guidelines and other implementation challenges, there was a net loss in wetlands in banks (Brown and Lant, 1999). As of 2001, 61% of wetland mitigation banks in the US used acreage to define credits (Environmental Law Institute, 2002). Even when there is no net loss of area, studies have questioned whether wetlands constructed or restored as offsets can maintain the lost function (let alone economic value) of the original wetland (e.g., Magee et al., 1999; Salzman, 2005). Climate change poses additional challenges, as changes in flow and hydrology, increased temperatures, and land use changes further threaten the viability of wetlands and their ability to provide services (Erwin, 2009).

Whether or not mitigation programs achieve no net loss of wetland area or function, off-site compensation can shift who receives the ecosystem service benefits. Wetland offsets are moved to a bank or other off-site project to maintain ecological value at lower cost. While regulations and policies usually require the offset to be nearby or within a watershed, changes in local benefits provided by wetlands are not accounted for and their allocation can shift between communities. This is especially true for local services like pollution filtration and flood protection (King and Herbert, 1997). Because development tends to be focused in or near urban areas and habitat restoration is cheaper on rural lands, the restoration benefits tend to move away from urban areas where more people would benefit (Ruhl and Salzman, 2006).

3.1.2. *Wetland payment for ecosystem service (PES) programs*

There are a variety of private and public programs to protect and restore wetland habitats through more direct payment for ecosystem services programs, often within agricultural landscapes. A few examples are described below.

In California and Oregon, the "Walking Wetlands" program has sought to both improve wetland habitat for waterfowl and support sustainable agriculture through a partnership of diverse agencies, universities, nonprofit organizations, and farmers. This program began in Tule Lake National Wildlife Refuge, where a unique refuge system mandate required management objectives to protect important declining waterfowl habitat, while sustaining commercial agriculture (Integrated Land Management Working Group (Tule Lake National Wildlife Refuge; Calif.), 2000). The Walking Wetlands program began in 1997 on leased agricultural lands within the refuge, and involves the rotation of wetlands and crops. Fields are flooded for two to three years before being drained and planted with crops again. The results of including wetlands in the rotations have not only been improved wildlife habitat value during flooded periods, but also benefits to the farmers including improved soil health and crop yields, and increased weed and pest control (Coatney, 2007). In the region, wetland rotations have increased crop yields up to 25% and reduced the need for soil fumigants, with farmers seeing cost savings of up to $494 per hectare (Cole and Mauser, 2006). In 2005, the program was expanded to private lands outside the refuge, where there have been challenges including costs associated with flooding if levees are required, and the loss of income when farmland is in wetland rotation. To offset these challenges, the program is compensating farmers with farmland to use within the refuge (Cole and Mauser, 2006).

The Nature Conservancy has implemented a similar program in Washington State called "Farming for Wildlife." Starting in 2006, they have worked with farmers in the Skagit Delta to experiment with integrating wetland rotations on several properties to determine if they could develop an economically and ecologically improved model for providing migratory shorebird habitat on agricultural lands. With results from initial pilot studies from 2006 to 2009 indicating that wetland rotations attracted diverse bird species while potentially improving soil health for farmers, there is interest from stakeholders to expand. Ongoing research is determining if an increase in crop gains can result from flooding, as those gains would need to exceed the cost of maintaining the wetland. Initial analysis shows that this could potentially be done with a 15% increase in crop yields (The Nature Conservancy, 2011).

A voluntary federal program in the US that has resulted in significant wetlands restoration is the Wetlands Reserve Program (WRP). Initially funded through the 1990 Farm Bill, it operates similarly to PES programs by offering guidance and incentives for private landowners to restore wetlands in agricultural landscapes. There are currently more than 931,000 ha enrolled in the program (U.S. Department of Agriculture Natural Resources Conservation Service, 2011). Analysis in the Mississippi River Valley, where more than 275,000 ha were enrolled in the WRP program in 2005 (King et al., 2006), found that the "social value surpasses the public expenditure or social cost of wetlands restoration in only 1 year" (Jenkins et al., 2010).

In Canada, PES programs are also used to conserve wetlands. In Saskatchewan, Assiniboine Watershed Stewardship Association, Ducks Unlimited Canada, and the Saskatchewan Watershed Authority have developed an innovative program with landowners that uses reverse auctions to incentivize the restoration of wetlands on agricultural lands. It sets up landowners as sellers to set the value that restoration is worth to them through bids that are then evaluated with an environmental benefits index (Hill et al., 2011). Restoration activities began in 2009, with a goal of restoring 56,000 ha of wetlands over 20 years (Sustainable Prosperity, 2011).

All of these PES programs to protect and restore wetlands are contingent on payments and/or benefits from conservation funding mechanisms being at least equal to the value landowners get from the next best land allocation, which is often crop or livestock production. A Canadian study also found that farmers were more interested in agricultural benefits like erosion control than wildlife habitat (Yu and Belcher, 2011). This suggests that not only do PES programs need to develop methods for determining appropriate payments and incentives, but they will likely be more effective if they are aimed at providing multiple services, in addition to protecting biodiversity.

3.2. *Agricultural lands*

Crop and rangelands provide people with critical sources of food, fiber, and fuel. These lands are unique in "both supplying and demanding other ecosystem services" (Swinton et al., 2007). These managed lands depend on a variety of ecosystem services to be productive, including water provision, fertile soils, and pollination. And in addition to agricultural products, they supply services like aesthetics, recreation, carbon sequestration, and biodiversity habitats. On the negative side, agriculture lands can be affected by pests and disease, and can also contribute to water pollution, nuisance odors, and biodiversity loss (Swinton et al., 2007). Various agricultural practices can affect the delivery of ecosystem services and support of biodiversity on these lands (Dale and Polasky, 2007; Sustainable Prosperity, 2011).

Agricultural lands in the US and Canada are significant land uses and support major sectors of the economy. In the US, 38% of land area is in farms (2007), the second largest sector in the economy with net farm income of $101 billion (2011) (U.S.

Department of Agriculture, 2012). In 2011, there are $208.3 billion in cash receipts for crops, dominated by corn, soybeans, and wheat, while there were $166.0 billion in cash receipts from livestock: cattle and hog meat, poultry and dairy (U.S. Department of Agriculture Economic Research Service, 2012).

According to the 2011 Census of Agriculture in Canada, farms covered 7.2% of the country's land area and net farm income was $2.96 billion in 2010 (Statistics Canada, 2011b, 2011a). This total agricultural area has remained relatively constant since the 1950s, dominated by oilseed and grain farms (35.7% of gross receipts in 2011) and beef farms (14.3% of gross receipts in 2011). There has been a recent shift towards cropland due to a number of factors, including residual effects of US regulations on cattle import due to bovine spongiform encephalopathy (BSE) and strong crop prices (Statistics Canada, 2011b).

3.2.1. Agricultural payment for ecosystem service (PES) programs

While many of the wetlands ecosystem service programs are focused on agricultural lands, other PES systems are designed primarily to maintain the ecosystem services that agricultural lands themselves provide.

In Canada, most of these programs provide incentives to reduce the loss of biodiversity on agricultural lands, either through PES schemes or by removing incentives for detrimental activities (Statistics Canada, 2011b). In addition to some provincial programs, Agriculture and Agri-Food Canada has funded pilot projects to test various approaches to enhance ecosystem services from farmlands. One pilot was in Prince Edward Island where agriculture is shifting from family farms to industrial production, with concerns about "impacts of agriculture on environmental health, erosion form large fields, degradation of stream habitat, impacts of agricultural pesticides, impacts on human health, nitrate concentrations in groundwater reserves" (Roy et al., 2011). The project included annual payments to improve management practices, and insurance that removed uncertainty. There is the potential for the agriculture producer to begin seeing enough environmental benefits that the new management practices would be profitable (in addition to providing broader benefits to communities and the environment), in theory reducing the need for payments and insurance (Statistics Canada, 2011b).

The US Department of Agriculture (USDA) has a number of conservation programs to protect environmentally sensitive areas as well as soil, water, and other ecosystem resources. In 2007, approximately 4% of farmland was in a form of conservation status (U.S. Department of Agriculture National Agriculture Statistic Service, 2008). In addition to the Wetlands Reserve Program (WRP) described in Section 3.1.2, the Conservation Reserve Program (CRP) is the other primary federal program for agricultural conservation. Initially established in the 1980s as a land retirement program, CRP was designed to both meet environmental goals and increase crop prices by reducing production. Farmers are paid by the program to maintain plant cover and ecosystem health. While payments are not tied to ecosystem service values, USDA's Farm Service Agency estimates the resulting benefits improved nitrogen and phosphorus pollution, soil erosion, and carbon sequestration (Ferris and Siikamäki, 2009).

A US example of a PES scheme outside of the WRP or CRP is the Florida Ranchlands Environmental Services Project (FRESP), a partnership between World Wildlife Fund (WWF), state agencies, researchers, and ranchers. The project has the goal of showing that ranchlands near Lake Okeechobee in Florida can be managed to provide ecosystem services at a lower cost than investing in new infrastructure (Cremer, 2009). As the northern Everglades were drained and filled beginning in the 1940s, settlement and agriculture production spread through south-central Florida, with hydrologic flow in the region largely managed through canals and ditches. Increased development and altered hydrologic regimes have led to increased flow fluctuation and nutrient runoff into water bodies like Lake Okeechobee. To supplement increased engineered infrastructure investment, the FRESP project has been designed for state agencies to pay cattle ranchers for managing their lands to increase water storage and reduce nutrient loading. While the ranches in the region include large areas of natural cover that provide services like water retention as well as biodiversity benefits like wildlife corridors, economic pressures could force landowners to convert to more intensive agriculture or development. An initial study by WWF determined that state agencies could pay for ecosystem services, at a lower cost than would be required to obtain the same results through investment in infrastructure (Bohlen et al., 2009). In 2005, FRESP began as a pilot program to test the effectiveness of this strategy in providing the ecosystem services at lower costs, as well as to design a full program for implementation. As is seen in other PES programs, the largest challenges were related to transaction costs in implementation, specifically related to monitoring of services provided, negotiating and executing contracts, and dealing with regulatory challenges (Bohlen et al., 2009; Bullock et al., 2011).

3.3. Forests

Forests provide a wide variety of services to people—from timber to clean water to recreation. Programs that provide payments for forest ecosystem services are focused on carbon sequestration to regulate climate change, watershed protection (described in Section 3.4.2), and biodiversity.

In 2007, a conservative estimate for the total payments for these services in the US was almost $1.9 billion. Payments for bundled services and biodiversity represented the bulk of these payments ($1.4 billion and $500 million, respectively), with voluntary carbon offsets accounting for less than $2 million. Private sources paid for $1.5 billion, with government programs like the Conservation Reserve Program supplying $366 million (Mercer et al., 2011).

In Canada, while there is growing interest in market-based forest protection, government programs are primarily focused on reducing forest biodiversity loss, with some tax programs rewarding benefits provided by forests or removing incentives for economic activity that degrades forests (Sustainable Prosperity, 2011).

Markets for carbon sequestration are some of the most well-known payments for ecosystem service programs, despite currently representing a small percentage of forest ecosystem service investments in the US and Canada. Their growth will depend on future climate legislation (Mercer et al., 2011). These markets are described in Section 3.3.1 in more detail.

3.3.1. Forest carbon

Trees help regulate global climate change by sequestering carbon from the atmosphere in their trunks and branches as they grow and through storage of carbon in organic soil matter. Carbon sequestration is a unique ecosystem service in the sense that it provides global benefits, so emissions offsets do not need to be local. This has helped lead to markets forming to allow individuals and businesses to offset their carbon footprint. These include investments in forestry-related activities such as reforestation, improved forest management, and avoided deforestation, as well as alternative energy and energy-efficiency programs. These markets either consist of "over-the-counter" transactions, often investments in larger forestry projects managed by land trusts, or organized markets like the Chicago Climate Exchange (CCX), a voluntary but legally binding market active from 2003 to 2009. Exchanges like CCX include private sector sellers of credits, and allow for the aggregate of offset activities by smaller landowners (Mercer et al., 2011).

Though there are no federal programs in the US or Canada, state, provincial, and regional programs have developed to reduce greenhouse gas emissions, and most allow forestry offsets. For example, in Alberta's Greenhouse Gas Offset System, large industries can meet mandatory carbon limits through direct reductions in emissions, by paying a tax per ton of carbon emitted, or by buying offsets, which currently include afforestation projects (Anderson et al., 2010). The California Climate Action Registry (CAR) is a voluntary program established in 2000 to facilitate the reporting of direct and indirect emissions, so that reductions could be tracked and recognized in case of future mandatory reductions (Franco et al., 2008). In 2006, California passed the Global Warming Solutions Act (AB 32) that was the first US policy mandating greenhouse gas reductions across the economy. With the goal of reducing greenhouse gas emissions to 1990 levels by 2020, it includes certifiable carbon credits for forests (Ramseur, 2007; Daniels, 2010).

Regional climate programs within and between US and Canada are also including forest offsets. The Western Climate Initiative is made up of 7 US states and 4 Canadian provinces that have committed to reducing greenhouse gas emissions to 15% below 2005 levels by 2020. The Initiative is in the planning stages, but will include provisions for forest offsets (Golden et al., 2011; Mercer et al., 2011). On the east coast, in 2009, 10 US states from Maryland to Maine launched the Regional Greenhouse Gas Initiative (RGGI), a cap and trade program designed to reduce carbon dioxide emissions from electricity generators, which includes offsets through protecting and managing forests. In its first 3 years, $912 million in CO2 allowances were bought by power plants, and analysis found the program added $1.6 billion in net present value (NPV) in benefits to the 10 state region (Hibbard et al., 2011). But as political interest in controlling carbon waned, some politicians have questioned the value of the program to their states, and the governor of New Jersey withdrew his state from the program in Wald (2011).

To address the challenges of accounting for forestry offsets, most markets and programs have standardized guidelines. Projects need to be real, verifiable, and permanent, and cannot include actions that would have happened anyway (additionality) or merely shift activities like deforestation elsewhere (leakage) (Fahey et al., 2009). These forest offset projects also must be managed to reduce the risk that the carbon will be rereleased into the atmosphere due to disturbances like storms and fire, human activities on the property, and even shifts in climate that affect tree health (Galik and Jackson, 2009).

Carbon sequestration is still only a small part of investment in forest ecosystem services, but also represents a small part of carbon offset investments. Across all the voluntary markets, investment in forestry activities represented only 6.5% of the 111 million tCO_2e carbon offsets traded in the US in 2009 (Hamilton et al., 2010). In the US, since 2002, forestry offset payments were made to landowners in only 16 states.

3.4. Waters

Maintaining water quality in inland and coastal waters is critical for human, ecosystem, and economic health. Both the US and Canada have used traditional command-and-control regulations to limit pollution flowing from point sources. As pollution control equipment costs increase and nonpoint source pollution pose a challenge to regulators, innovative solutions are needed.

3.4.1. Water quality trading programs

Similar to cap-and-trade for carbon and other air pollutants, water quality trading programs have been designed to find cost-effective ways to reach water quality goals. After a cap is set for pollution emissions or ambient pollutant concentrations in a region, those who reduce their pollutants below thresholds can sell credits to others who cannot meet restrictions. Successful implementation of a trading program requires not only a strong conceptual design, but also "community agreement, legislative backing, credit and cost certainty, simplified delivery and verification, written instruments, and legal liability protection" (O'Grady, 2011). Water quality trading faces more than challenges than air quality trading because the location of watershed reductions is critical to success.

Tradable pollution rights have been used in the US since the 1980s. A 2005 review looked at US programs that fell into four categories of water quality trading: "on-going offset/trading programs [$n=19$], one-time offset agreements [$n=8$], state and regional trading policies [$n=6$], and other projects and recent proposals that involve trading [$n=31$]" (Morgan and Wolverton, 2005). The review found that the most common programs were between point and nonpoint source pollution, with point sources often liable for nonpoint source reductions. While market structures varied, almost all programs were focused on one pollutant, and 22 of 27 ongoing or one-time programs traded nutrients like phosphorus or nitrogen. Usually, a total maximum daily load (TMDL) or watershed limit has been used as the cap for trading (Morgan and Wolverton, 2005).

An example of a regional trading program that includes both point and nonpoint source pollution is in the Chesapeake Bay. Important ecologically and economically, the bay is the largest estuary in the US, with a watershed reaching into six states. Despite extensive restoration efforts, excess nutrients running off agricultural fields and roads and from effluent of waste water treatment plants have resulted in a dead zone forming each summer as oxygen is depleted from its waters. Nutrient trading was first discussed in the late 1990s when guidelines were first established (Chesapeake Bay Program Nutrient Trading Negotiation Team, 2001). Individual state trading programs were established in Maryland, Pennsylvania, Virginia, and West Virginia. Although they use similar frameworks to reduce nitrogen, phosphorus, and sediments, most trades have occurred within states. With new restrictions on ambient pollutant levels in the bay (TMDL) implemented in 2010, there is movement towards Bay-wide trading (Jones et al., 2010; Branosky et al., 2011).

An example of a US trading program focused solely on point sources is Connecticut's program to reduce nitrogen pollution in Long Island Sound. Like the Chesapeake Bay, excess nutrient pollution leads to a seasonal dead zone in the western portion of the sound, but the source of those nutrients is primarily waste water effluent. In 1998, New York, Connecticut, and federal agencies established a goal of 58.5% reduction from point and nonpoint sources within 15 years, establishing the Long Island Sound TMDL. In 2001, Connecticut established the Nitrogen Credit Exchange Program, the first of its kind in the country (Vandevort, 2005). Annual discharge limits were determined for each of 79 municipal wastewater treatment plants. Plants with effluent above their limits must purchase credits, while plants with discharge below their limit can sell credits, with the state setting the price for credits (Morgan and Wolverton, 2005; Vandevort, 2005). It was projected that the trading program could reduce the cost of required pollution abatement by 33% (Jones et al., 2010). In 2009, with all of the wastewater treatment plants cooperating in the program, 43 plants needed to purchase credits, at a total value of $2.3 million on the Nitrogen Credit Exchange, and 35 plants sold credits, at a total value of $3.3 million (one facility did not need to buy or sell any) (Connecticut Department of Energy and Environmental Protection, 2011).

Although ecosystem markets are rare in Canada, trading systems for reducing pollution are included in the Canadian Environmental Protection Act (CEPA). It gives Environment Canada the authority to using trading programs to manage toxics, nutrients, fuels, air and water pollutants, and federal activities (CEPA, 1999, section 326). They are not as common as in the US, but there are several water pollution trading schemes established in Canada (Sustainable Prosperity, 2011).

For example, to reduce phosphorus leaching in the watershed of Ontario's South Nation Conservation Area, a water quality trading market was established by the provincial Ministry of the Environment. Point source dischargers cannot increase phosphorus effluent above a cap, and to meet the restriction can either reduce effluent through removal technology or buy credits from rural landowners and farmers who reduce their nonpoint source pollution through better land management. Trading is brokered by a community watershed association (O'Grady, 2011; Sustainable Prosperity, 2011). The program includes 15 municipalities and 2 industrial dairy wastewater treatment plants, and after some initial challenges, has succeeded in complying with federal effluent restrictions (Selman et al., 2009).

3.4.2. *Watershed protection*

Certain regions of the United States have chosen to protect their watersheds as a means of reducing capital costs of building filtration systems. For example, New York City, with a population of 9 million, receives 90% of its water supply from the Catskills/Delaware watershed. This water has a filtration waiver, which allowed the state to spend $1.5 billion on watershed protection instead of $6 billion with $300 million annual operating costs over 10 years (Postel and Thompson, 2005). Other cities in the US have chosen to also protect their watershed instead of investing in the construction and maintenance of filtration plants. Boston, Massachusetts (population of 2.3 million) avoided $180 million (gross) in costs; Seattle, Washington (population 1.3 million) avoided $150–200 million (gross) in costs; Portland, Oregon has spent $920,000 annually to protect its watershed while saving $200 million in capital costs. Other cities include Portland (Maine), Syracuse (New York), and Auburn (Maine) (Postel and Thompson, 2005).

To facilitate watershed protection by other landowners, some US regions have developed payment for ecosystem service (PES) and other market-based mechanisms. For example, in Santa Fe, New Mexico, the municipal watershed plan includes PES as a strategy for improving land management, with a focus on avoiding damages from catastrophic forest fires. They estimate that restored forest conditions can be maintained at an annual cost of $200,000, compared to $22 million in cost from a fire (based on 2800 ha forest fire with 1 in 5 likelihood each year) (Santa Fe Watershed Association, 2009).

4. Industry

Whether a local US or Canadian company or multi-national firm, corporations rely on ecosystem services to maintain their bottom line, including by providing raw materials, protecting facilities from natural disasters, and regulating regional or global climate. At the same time, corporate activities are major drivers of ecological change, which not only impacts natural systems but also effects the services those ecosystems provide to people—and industry itself. Often companies do not recognize the role that ecosystems play in maintaining their bottom line or how their actions impact the broader benefits that those ecosystems provide. While these ecological interactions are rarely captured in environmental performance indicators (Waage et al., 2008), they are also missing from but could inform financial measures (TEEB, 2010).

Millennium Ecosystem Assessment (MA), 2005b was a milestone in highlighting the connection between ecosystem health and the economy. By finding that two-thirds of ecosystem services are being degraded or unsustainably used at a global scale, the MA helped to make global environmental change relevant to companies, especially related to water scarcity, climate change, habitat change, biodiversity loss and invasive species, overexploitation of oceans, and nutrient overloading. It showed how companies were faced with potential increased costs and risk as resources become more scarce, changing business frameworks from customer expectations to regulations, as well as business opportunities like new ecosystem markets (Millennium Ecosystem Assessment (MA), 2005a).

More recently, ecosystem decline was one of the ten global sustainability megatrends that the accounting firm KPMG identified as having the greatest impact on companies, noting "Business is both heavily involved in causing this damage and likely to be increasingly affected by the consequences" (KPMG, 2012). Ecosystems and their services were related to other megatrends on the KPMG list, including energy and fuel, material resource scarcity, water scarcity, food security, and deforestation.

Companies that do not account for how they both depend on and impact ecosystems will likely have unforeseen risks as well as missed opportunities (TEEB, 2010). There is a need for action to protect resources they depend on, but also to be ready for increasing expectations from regulators, shareholders, customers, or financers. Companies can also take advantage of opportunities to "consider risk mitigation, differentiate among competitors, realize new revenue streams through ecosystem services protection, access capital and new markets, [and] save on costs" (Waage et al., 2008).

While companies are often motivated by self-interest to invest in maintaining services that matter to them directly, many recognize that their activities can positively and/or negatively influence ecosystem health and how those ecosystems benefit the public. While less directly tied to their bottom line, there are indirect connections, including through a company's license to operate in a landscape, brand reputation, or community relations. By including these externalities that might otherwise be ignored unless regulated, it can also help address "the economic invisibility of nature's flows into the economy [that] is a significant contributor to the degradation of ecosystems and the loss of biodiversity" (TEEB, 2010).

While some companies are beginning to account for ecosystem services to preempt tighter future regulations, currently these corporate efforts to account for ecosystem services are largely voluntary and not driven by government actions. Many of the companies who are entering this space are major global brands; below are examples of activities by US-based companies.

4.1. *Corporate ecosystem services*

Early companies that explored the corporate relevance of ecosystem services were often reacting to easily discerned connections to their reliance on ecosystems. For example, the Coca Cola Company focused on a key resource for its products: freshwater. Even before the MA was published, it was clear that freshwater resources were getting scarcer in many places in the world. The company recognized that "proactive management contributes to their profitability and competitiveness in the market and avoids risks" (Gerbens-Leenes and Hoekstra, 2008). The company not only looked for water use efficiencies in their factories, but also invested in watershed conservation projects, in sustainable agriculture to reduce water usage by other product ingredients, and in greenhouse gas reductions to limit climate change threats on freshwater ecosystems (Diamond, 2009; World Wildlife Fund and The Coca Cola Company, 2012). To assess the total water consumed directly or indirectly to produce a product, the company worked with partners to calculate product water footprints. Analysis showed that a 0.5 L bottle of Coca Cola produced in Netherlands consumed 0.4 L directly as an ingredient, and an additional 7.4 L were consumed in supply chain, mostly in agricultural ingredients. Now the company is working to assess whether their footprint is sustainable (The Coca Cola Company and The Nature Conservancy, 2010).

As more companies began to recognize the need to account for ecosystem services, the challenge became how to recognize, measure, and report changes in their values, and then how to tie that to business strategies and decisions. Several complimentary frameworks have been developed to help companies approach this process. The Corporate Ecosystem Services Review (Hanson et al., 2012) helps businesses review potential risks and opportunities related to ecosystem services, and the Corporate Ecosystem Valuation (CEV) framework (World Business Council for Sustainable Development, 2011) guides companies on how to do quantitative assessments of those risks and opportunities. A number of companies have been testing these frameworks, including five tests in the US. The mining company Lafarge looked to improve land management at a reclamation site in Michigan by accounting for erosion regulation, water purification, and recreation/ecotourism. Syngenta built evidence for farmers to invest in native bee habitats by assessing pollination services at farms in Michigan. Cook Composites assessed building a wetland to provide flood control and water treatment currently offered by their storm water management system at a site in Houston. The Houston By-Product Synergy (BPS) Project did an ecological life cycle assessment to connect ‘‘undervalued or waste materials from one country with the needs of another.’’ Weyerhaeuser assessed the value of ecosystem services produced under various forest management scenarios to identify new income streams. Corporate motivations and benefits from these tests included cost savings, improving broader societal benefits tied to reputation and license to operate, and new solutions to business needs (World Business Council for Sustainable Development, 2011).

A more comprehensive corporate ecosystem services effort is the 5-year (2011–2015) collaboration between The Nature Conservancy and The Dow Chemical Company and its Foundation. It has the goal of developing methods for companies to recognize, value and incorporate biodiversity and ecosystem services into business goals, decisions and strategies. At three pilot sites (Freeport, Texas; Santa Vitoria, Brazil; and a third to be determined), the collaboration team is testing methods to embed ecosystem values in a range of corporate decisions at the site-level, and then will use the results to influence decisions at broader scales within the corporation and develop replicable methods and tools that can be used by other companies. At the Texas pilot, analysis is focused on developing evidence and decision-support methods related to freshwater supply, coastal natural hazard mitigation, and reforestation for air pollution mitigation (The Nature Conservancy and The Dow Chemical Company, 2012).

Most of these efforts are in the experimentation or exploration phase to find how businesses can mitigate risks and find opportunities by valuing and investing in maintaining ecosystem services. Reporting on results, both ecological and financial, will help determine how business strategies can be more effectively designed to benefit both ecosystems and businesses.

5. Conclusion

There is a growing recognition across governments and sectors in the US and Canada that ecosystem services are a critical component of economies and human well-being. Experience and bodies of evidence are being built to enable diverse decisions to account for these connections. To do this, not only is it important to understand the value of ecosystem services, but also how that information can inform how actions can affect their delivery.

We’ve highlighted a number of examples of innovative ecosystem services programs in the US and Canada, many of which adapted existing policies and regulations to include ecosystem service values. Companies are beginning to act as well, but tools and methods are still being developed to tie ecosystem service values to business. Many of these examples are focused on ecosystem services that can be traded in a market or whose value can be estimated. They are innovative precisely because they are able to, at least conceptually if not financially, link beneficiaries to actions that maintain the services they rely on. At the same time, this potentially has limited these programs to focus on ecosystems and services that are easier to measure or have more obvious beneficiaries, with other societal and ecosystem values left out if they are not inadvertently captured.

Of the examples we describe in the US and Canada, wetlands mitigation programs may be the most advanced in terms of markets established for ecosystem service protection and restoration. However, there are still implementation challenges. Even if new wetlands can restore the full function or economic value of the originals, there is the question of whether that value still reaches the original beneficiaries. Water quality trading programs are creating incentives to reduce nutrient pollutants, though they can be hard to design and monitor, especially if regulating non-point sources, and where actions are taken in the watershed matters here as well. With the global benefits of regulating climate, forest carbon markets do not have the same location challenges of the other two ecosystem markets described, but it will likely require national climate legislation to grow these markets to a substantial scale in the US or Canada.

Many of the PES schemes are still in the ‘‘proof-of-concept’’ stage, with initial or annual payments from the government or other parties needed to instigate changes in behavior and land management practices. Conceptually, each program would need the combination of these payments and the benefits from the ecosystem services to at least equal the next best land use or practice by the land owner or manager. Once initial capital investments are made and/or benefits are seen, the need for payments in these programs could be diminished or eliminated. Some of the watershed protection examples were established to avoid the cost of new water treatment infrastructure (e.g., New York City). In these cases, the ecosystem service benefits of a protected watershed were recognized upfront.

These examples all represent innovative ways to incentivize conservation activities. To further mainstream the use of ecosystem service values, new government and corporate policies would be needed to not just allow for the accounting of ecosystem services but to facilitate the use of their values and include them systematically in economic decisions. These concepts can also be applied beyond land and resource management, in broader government and corporate investment decisions that impact ecosystems. By building on the evidence and tools from past efforts, new solutions can be designed to maintain the critical ecological resources that sustain both the US and Canada.

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