

RESEARCH ARTICLE

The economic value of Canada's National Capital Green Network

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Abstract

The lack of information on the value of ecosystems contributing to human well-being in urban and peri-urban setting is known to contribute to the degradation of natural capital and ecosystem services (ES). The purpose of this study was to determine the economic value of ES in Canada's Capital Region (Ottawa-Gatineau region), so that these values can be integrated in future planning decisions. Using the valuation methods of market pricing, cost replacement, and two benefit transfer approaches (with adjustment and with meta-analysis), the value of 13 ES from five ecosystems (forests, wetlands, croplands, prairies and grasslands, and freshwater systems) was measured. The annual economic value of these 13 ES amounts to an average of 332 million dollars, and to a total economic value of over 5 billion dollars, annualized over 20 years. The largest part of this value is generated by nonmarket ES, indicating that much more emphasis should be put on the management, preservation, and understanding of processes that make up these types of ES. The work generated as part of this study is a first step towards operationalizing the concept of ES in planning. More specifically, these results can be used to raise awareness, but also as a stepping stone to improve ecosystem-wide planning in the Canada's Capital Region.

Introduction

In 2014, 54% of the world's population lived in cities, with this percentage expected to reach 66% by 2050 [1], thus making the management of urban areas one of the top development challenges of the 21st century [1]. The management of urban areas involves many elements, ranging from transportation to health, but also including justice and environmental issues. Urban sprawl is a side effect of the attraction of humans to urban centres, but the extent of the sprawl is a function of land-use controls, municipal fragmentation, housing prices, reliance of municipalities on property taxes to finance public services, and the percentage of public spending on infrastructure and transportation [2]. Although there are many definitions of urban sprawl, common elements of this definition in the North American context include low-

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density developments, reliance on the use of private automobiles, a lack of functional open space, waste of land, segregated land uses, and the presence of a homogeneous population [3–7]. The urban sprawl phenomenon is having impacts on air pollution, especially from transportation, increased traffic congestion, and it is characterized by a wasteful use of resources [4, 8, 9].

Influenced by the works of Ebenezer Howard and the Garden City movement [10, 11], the cities of Ottawa and Gatineau have implemented the Gréber Plan in 1950. The main intentions behind this plan was to control urban growth, improve the beauty of Canada's Capital Region, and put aside land for future institutional and agricultural uses, as well as for recreational use [12]. These lands included a Greenbelt around the City of Ottawa, the Gatineau Park on the Quebec side, and many natural areas within the City of Ottawa and along main waterways. Today, this Green Network is managed by the National Capital Commission (NCC), a federal agency of the Canadian government.

One of the ways to address environmental and well-being issues associated with urban sprawl is through the lens of ecosystem services (ES). ES, as defined by the MEA [13], are functions and ecological processes generated by ecosystems that benefit humans in many aspects of their lives. These benefits can be direct, through the provision of basic goods, but also indirect, through their impact on constituents of well-being, i.e. on security, positive social relations, health, and the freedom of choice.

The concept of ES also enables decision makers, public and private, to reflect on the impact of planning decisions on the quality of life of citizens through the use of new indicators. According to the MEA's [13] classification, there are four categories of ES: regulating, supporting, provisioning and cultural. In an urban and peri-urban context, these classes of services can be represented, for example, by trees and forests that have the ability to capture and store carbon, provide shade, act as habitats for biodiversity, generate timber and non-timber forest products, and have an aesthetic value.

The quality and quantity of ES is especially degraded in urban and peri-urban settings as a result of a failure to recognize their importance and to systematically include them in planning [14–16]. This situation is especially true for ES that have no monetary value in the traditional market. One way to remediate this problem is to determine the economic value of ES and of natural capital, to demonstrate their contribution to human well-being and to enable a true benefit-cost analysis of different planning options. Many cities around the world, like New York and Toronto, have integrated the concept of ES in their land-use plans [17, 18].

The purpose of this study was to determine the economic value of ES and natural capital in the Ottawa-Gatineau region (i.e. Green Network of Canada's Capital Region), so that these values can be integrated in future planning decisions. A technical report was published by Dupras et al. [S1 File], and presented preliminary results for the ES valuation of the Canada's National Capital Green Network. In this article, we deepen the methodological and discussion aspects of the study. To do so, there is a Site description section, a Material and methods section, a Results section, a Discussion section which will focus on the way our results could impact future environmental management and planning decisions in the region, and a Conclusion.

Site description

The Capital of Canada is located in Ottawa, Ontario, but the National Capital Region (NCR) includes cities from both the provinces of Quebec and Ontario. The most important cities of the NCR are Ottawa and Gatineau, which are separated by the Ottawa River, but linked by five inter-provincial bridges and an economy mainly based on federal public services. The NCR also includes 12 cities and municipalities. The population in the metropolitan region of

Ottawa-Gatineau was estimated at 1,329,807 people in 2015 [19]. The region covers an area of 6,767 km² with a population density of 195.6 people per square kilometre [20]. The GDP per capita in the Ottawa-Gatineau metropolitan region was approximately \$48,500 in 2015 [19, 21, 22]. In 2014 the total median income was \$87,060 per household on the Quebec side of the region, and \$102,030 per household on the Ontario side [23].

The NCR is located in a temperate climate zone, with warm summers and cold and snowy winters. It is also located in the Ottawa River watershed which covers an area of 146,334 km² [24].

The creation of the Gatineau Park precedes the Gréber Plan in 1950. The park's appeal for citizens started at the end of the 1800s with recreational activities being carried out in the park and rich individuals building cottages in the hills close to the city [25]. It only gained an official statute in 1938, after the beginning of the Great Depression and the emergence of conflicts between recreational users and resource harvesters. It was created to promote recreational activities and to be used as a conservation area [26]. It is still a prime destination for recreational and cultural activities; more than 2.6 million visits are made to the park annually [27]. The park hosts diverse habitats and has a high level of biodiversity. It contains 50 lakes and hundreds of ponds, mixed, deciduous and coniferous forests, there are also approximately 1,600 floral species, 54 mammals, 232 avian, 17 amphibians, 11 reptiles, more than 50 fish species and many species at risk [28].

The 1950 Gréber Plan recommended the creation of a Greenbelt and the development of a network of urban lands that would be connected to the existing Gatineau Park. The main objectives of the Greenbelt were to contain population growth, up to 500,000 citizens, provide natural areas for the enjoyment of the urban population, and act as a reserve of lands for agriculture and for governmental institutions [12]. The first objective was not achieved, especially because of the low capacity of the inner city. The Greenbelt was originally implemented around the city, but in 2001, twelve local administrations within and outside the greenbelt were merged, with the old City of Ottawa representing only the inner portion. Today, because of the number of people living outside the boundaries of the Greenbelt but working within its limits, transportation is one of the most important challenges to the health of the Greenbelt, in addition to population growth [29].

The creation of the Greenbelt was mainly carried out by the NCC through land purchases and expropriations [12]. Today, the Greenbelt has a spatial extent of approximately 20,600 hectares, composed mainly of natural areas, agricultural lands and forests, but also including roads, an airport, and residential and institutional areas. Recreational and cultural activities are carried out in the Greenbelt, which attracts 3.5 million visitors annually [29]. Conservation of natural areas is also important in the Greenbelt, and the most common habitats are wetlands and significant forests. For example, Mer Bleue is recognized as an internationally significant wetland under the Ramsar convention [29]. There are few old-growth forests in the Greenbelt because of agriculture and urbanization, but the existing ones are very important as seed sources for late succession tree species. There are also many species living in the Greenbelt, including 60 species at risk.

Natural Urban Lands make up for a small proportion of the NCC's Green Network, i.e. 4,500 hectares. These lands are used mainly for recreational and access purposes, but they also provide habitats for species in the form of a heron nesting site, fish spawning habitats and islands that are used by birds as refuges in the urban lands. These lands are also home to more than 70 species at risk.

As part of this study, we consider that the natural capital of the Green Network of the Canada's Capital Region is represented by all lands managed by the NCC, which includes the Greenbelt, the Gatineau Park and natural urban lands. The NCC being one of the largest

owners of natural lands in the area, i.e. more than 55,000 hectares, we decided to focus our study on the lands managed by this entity. Common challenges to the health of Ottawa and Gatineau's natural areas include climate change, encroachment on natural environments, habitat fragmentation and invasive species [28].

Having green spaces within and around cities can increase the resilience of our environments. It can be difficult, however, for city planners to reconcile environmental and development pressures. In Canada, municipalities get funding from the provinces to carry out tasks that are delegated to them. To get additional funding, municipalities have the ability to raise taxes, but a large part of their income comes from property taxes, which can only be raised if houses are built. In this context, cities tend to open up land for housing development, without considering the impact to their natural capital. In addition, it is often politically damaging for municipal governments to raise new taxes or to increase the taxation level of citizens. The case of the NCC's Green Network is singular in the sense that the largest green network in the Ottawa-Gatineau region is not managed by the municipalities, but by an agency of the federal government that is not influenced by the same pressures. It can, however, be indirectly influenced by political pressures, through budget allocation and changes to its mandate. In this case, assessing the economic value of the lands preserved by the NCC, can help to showcase the importance of natural capital to human well-being in the region.

Materials and methods

Many methods exist to determine the economic value of ES, including methods based on market pricing, replacement cost, revealed and stated preferences, as well as benefit transfer.

There is a distinction to be made between the evaluation of stocks of natural resources and of flow of ES. For Jones et al. [30], natural capital encompasses the 'stocks', which represent assets found in the environment, and the processes through which humans perceive benefits, which can be regarded as 'flows' or as transformations or evolutions of the stocks [30: 154]. Whereas the stock value of a wetland would be its replacement cost, the flow of the services provided by wetlands include flood prevention, carbon sequestration and habitat for biodiversity. In this study, we did include the values of the stock of wetlands, as the meta-analysis by He et al. [31] provides the value of the stock of one ha. When it comes to carbon storage, the value of the stock of carbon was taken into account for the service of Global climate regulation for Forests, Wetlands, and Prairies and grasslands. However, the value of the stock of capital was not included in the value of the other ES.

In this study, we used a combination of market pricing method and two benefit transfer methods (i.e. meta-analysis and benefit transfer with adjustment) for the year 2015. The latter are based on the use of secondary data and are frequently used for these types of studies (see Dupras and Alam [9] for a review). This choice of methods was based in part on time and resource constraints, and in part on the purpose of this study, which was to raise awareness on the general importance of ES in the NCC's Green Network.

Our approach follows Troy and Wilson's [32], which starts by choosing the ES to value based on a spatial analysis of the study area (identify land use types). Then, once the goods and ES have been identified by land use types, including whether they are urban, peri-urban or rural, the mode of evaluation of ES is chosen, based on available resources. As a third step, we collected data that enabled us to determine the economic value of ES that had been previously identified. The data collection included research on market prices for provisioning services, spatial data collection on wetlands to carry out the benefit transfer using the meta-analysis method by He et al. [31], a literature review and the creation of a database for services not covered under the market pricing and benefit transfer methods. Using the data collected, we have

determined the value of ES based on the ecosystems present, adapted these values to the land cover, and created maps showing the results.

Spatial analysis

The land cover analysis was performed using Agriculture and Agri-Food Canada's (AAFC) 2014 land cover inventory database [33]. This layer was the most appropriate geographic information system (GIS) database as it included many land use classes (28 categories) and allowed for a consistent coverage of the entire study area at a fine resolution (30 m²). This satellite imagery has a level of precision of 85%. Although the study area was too large to carry out manual correction, which would have increased the accuracy of the GIS analysis, the use of a randomized photo-interpretation approach confirmed the general preciseness of the layer and its suitability for subsequent analysis. This layer was coupled with Statistics Canada's classification of urban and rural areas, to differentiate between these environments. The criteria used to distinguish urban and rural areas is based on demographic characteristics (population size and density) and distance to large agglomerations. For our purposes, an urban area has a population size of at least 1,000 people and a population density of at least 400 people per square kilometre. The land cover analysis was carried out using the ArcGIS software (Esri, Redlands, CA, United States).

Selection of ecosystem services

The selection of ES was based on the most common and standard classifications: the Millennium Ecosystem Assessment classification with its 17 ES divided into four categories, the TEEB with its 22 ES also divided into four categories, and the classification developed by Haines-Young and Potschin [34], the CICES (Common International Classification of Ecosystem Goods and Services), with its nine classes and three themes which excludes the "supporting services categories" and the habitat services/functions. Our selection was also based on our own database. This database was first developed as part of a literature review by Dupras [35] which included studies of ES valuation on forest, wetland and agricultural ecosystems. In the context of this study, the database was supplemented with a literature review of the economic valuation exercises of ES that had been undertaken in Quebec and Ontario [e.g. 9, 18, 36, 37] and with studies on the valuation of aquatic ecosystems. The selected studies from this database are presented in [S1 Table](#). 13 ES were selected for further analysis in the context of the NCC's Green Network. Although the ecosystems under study generate more ES, we limited our analysis to the ES whose value had been estimated previously and to ES for which we could estimate the value using the data available in the allotted time. In order to show the gap between the real contributions of ecosystems to the provision of ES, we use a hollow dot in [Table 1](#) to identify ES provided by ecosystems that were not valued in this study.

Ecosystem services valuation methods

The analysis of the 13 ES mentioned above was carried out using four methodological approaches. The market pricing method was used to determine the economic value of agricultural products, pollination, and recreational activities and tourism. For all of the other non-market ES, the benefit transfer approach with adjustment, the benefit transfer method with meta-analysis, and the replacement cost method were used. Considering the large number of ecosystems that compose the NCC's Green Network and the quantity of ES that they produced, the use of these methods enabled us to perform the analysis given resource constraints (time, especially), and carry out the main objective of this study. These methods will be discussed in the subsections below.

Table 1. Selection of ES based on ecosystems and data available.

Ecosystem services	Ecosystems / Land uses					
	Urban forest	Rural forest	Wetlands	Cropland	Prairie and grassland	Freshwater
Provisioning services						
Agricultural services				•	•	
Other food	◦	◦	◦			◦
Raw material	◦	◦	◦	◦	◦	◦
Genetic diversity	◦	◦	◦	◦	◦	◦
Regulating services						
Global climate regulation	•	•	•	◦	•	◦
Air quality	•	•	◦	◦	◦	◦
Water provisioning	•	•	•	◦	◦	◦
Waste treatment	•	•	•	◦	◦	•
Erosion control	•	•		•	•	◦
Pollination	•	•	◦	◦	•	◦
Habitat for biodiversity	•	•	•	◦	•	•
Disturbance / natural hazards prevention	•	•	•	◦	◦	◦
Pest management	•	•	◦	◦	◦	◦
Nutrient cycle	•	•	◦	•	•	◦
Cultural services						
Aesthetics (landscape)	◦	◦	◦	•	•	◦
Recreational activities and tourism	•	•	•	•	•	•
Scientific and educational	◦	◦	◦	◦	◦	◦
Spiritual	◦	◦	◦	◦	◦	◦
Heritage and cultural identity	◦	◦	◦	◦	◦	◦

• ES for which we have values; ◦ ES for which we do not have access to values

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In the case where we would have had time to calculate a value that is more specific to our study area, we could have used other methods. Indirect valuation methods include stated and revealed preference approaches. Revealed preference approaches are based on observed behavior [38]. They include the travel cost method, where the value of recreation, for example, is estimated as a function of the distance traveled to a location and of the purchases made on the way to and at the location [39]. They also include the hedonic pricing method, where the aesthetics ecosystem service, for example, can be estimated based on the premium associated to the value of a house that is located in a specific landscape [39]. The stated preference approaches are based on stated behavior, generally gathered as part of a survey, where hypothetical scenarios are presented to individuals. They include contingent valuation and choice experiment methods, where respondents are asked, for example, how much they are willing to pay to preserve an aesthetically pleasing landscape (contingent valuation) or are asked to choose their favorite option of a recreational area, where each scenario is composed of a number of given attributes (choice experiment) [40]. For more information on the methods and suggestions about the most appropriate ones to use in a specific context, we suggest consulting the Ecosystem Services Toolkit [41] or the TESSA [42].

Market pricing method. The market pricing method estimates the values of tradeable ES by looking at their transaction costs. To perform this analysis for agricultural products, we calculated the economic rents for every crop grown in the NCC's Green Network, noting that most of the agricultural lands were located in the Greenbelt. We first had to determine which crops were grown in the area, then we performed research to determine the value of the

economic rent per crop, which is equal to the revenues generated from the sale of the products minus the total costs of producing them. Economic data for crops came from the Financière agricole du Québec [43–47], the Ontario Ministry of Agriculture, Food and Rural Affairs [48, 49], and the Quebec Reference Centre for Agriculture and Agri-food [50–52].

The economic valuation of the pollination service was based on the method described in Winfree et al. [53], where the value of the pollinating service from wild pollinators, in this case, is based on the value of production. As our focus was on wild pollinators, we used the hypothesis from the study by Rands and Whitney [54] which studies the effect of wild field hedges for nesting pollinators and their travel capacity which varies from 125 m to 2 km. As a conservative distance, we chose to consider the distance of 1 km that pollinators can travel towards agricultural lands from nesting sites. By doing so, we estimated the pollinating potential of wild field hedges (forests and prairies and grassland) on the croplands. This was done by measuring the area in a 1 km buffer around the crops dependent on pollination that contains is made of forests and prairie or grassland ($\text{surface}_{\text{FPG}}$). The equation we used is the following:

$$V_{\text{pollination}} = ((P * Y - C) * D * \rho) * \text{surface}_{\text{FPG}} \quad (1)$$

Where $V_{\text{pollination}}$ is the value of the pollination service, P is the price of the crop, Y is the yield, C are the costs of production, D is the crop dependency on insect pollinators, and ρ is the proportion of insect pollinators [53]. In our case, we used the inverse of the values provided by Morse and Calderone [55]; their value reflected the proportion of pollinators that are honey bees. This value, which represent pollinators that are not honey bees, is 0.1 for berries, 0.5 for soybeans and beans, and 0.4 for forage in rural areas. We estimate that this value (ρ) is divided by half in urban areas, considering the quality of the nesting environment [Fetridge et al. 56]. We limited our estimation to crops that have a dependence on pollinators. We used the value of the net benefit ($P*Y-C$) from beans, berries, soybeans, and forage as calculated for the provisioning service, and took into account their surface area and their rates of dependence on pollinators. We used the degree of dependence as reported by Morse and Calderone [55, 57] for berries/strawberries (0.2), soybeans (0.1), and forage (1). For beans, although the degree of dependence was not provided in Morse and Calderone [55], we assumed a degree of dependence of 0.1, as it is a flowering crop.

The value of recreational activities and tourism is estimated based on the value of user fees charged by the NCC for parking, to access the Gatineau Park and to carry out activities like snowshoeing, skiing, and camping. As the general admission to the Park is free, not all activities carried out in the park are covered by user fees; thus the value is likely underestimated.

Replacement cost method. This method is a cost-based approach and estimates the value of an ES, in this case the climate regulation service, based on the cost of the damage that would be induced by its loss. The climate regulation service is evaluated in terms of carbon storage and sequestration, using the value of the social cost of carbon (SCC) as determined by Environment and Climate Change Canada [58]. The SCC is a measure of the expected damage of climate change at a global level resulting from the emission of one additional ton of carbon dioxide (CO_2 ; where 1 ton of C \approx 3.67 tons of CO_2) into the atmosphere over the course of one year. To determine the value of carbon storage and sequestration, a discount rate of 3% was used in the present value calculation, as recommended by Environment and Climate Change Canada [58]. To obtain the value of carbon storage annually, we calculated the present value of carbon stocks over 50 years. To estimate the value of the carbon stored and sequestered by specific features of ecosystems, we relied on estimates from the literature. These specific studies are mentioned in the Results section.

Benefit transfer with adjustment. The benefit transfer valuation method uses the results of economic valuations of ES from other sites and transfers the economic values onto the target site. The transfer is performed only when the economic valuation of the transfer site comes from primary data and if the initial site has a similar biophysical environment (e.g. climate) and similar socio-economic characteristics, as represented by the GDP per capita.

To perform this benefit transfer, we created a database that included land classes found in the NCC's Green Network and the ES they produce. We started from a database that was created for the purpose of the Greater Montreal Greenbelt analysis [36], and then included studies gathered from an extensive analysis of the scientific literature using recent and representative studies of the NCC's Green Network. This analysis was undertaken using existing databases such as the Environmental Valuation Reference Inventory (www.evri.ca) and the Ecosystem Services Valuation Database [59], but also by performing research in specialized search engines (e.g. EconLit, Francis, Scopus).

The database that was built contains 149 monetary estimates, all of which came from 78 different studies published between 1990 and 2016 in peer-reviewed journals. The database includes monetary estimates for ES for the five ecosystems under study (forests and woodlands, wetlands, prairies and pastures, croplands, and freshwater). This database is different from a database that can be used for a meta-analysis, because of the number of estimates that is available per ES and per ecosystem, and because of the subsequent use of the monetary estimates. Monetary estimates from this database are adjusted and then directly used to perform benefit transfers. When the values were in a currency other than Canadian dollars, we performed a first adjustment using Purchasing Power Parity (OECD), then we adjusted all values in Canadian dollars using the consumer price index (Bank of Canada).

The level of accuracy of this methodology is based on the level of similarity between the transfer and the target sites. This is why we used two characteristics to limit the number of studies that can be used to undertake the benefit transfer. We first used an ecological criterion, to ensure all transfer sites came from temperate ecosystems and have similarities to the NCC's Green Network. The second criterion was based on socio-economic characteristics and ensured that transfer sites were found in regions and countries that have comparable socio-economic and demographic conditions to the target site. This second criterion is especially important given that the value of ES is related to their contribution to communities' well-being. Based on these criteria, the studies selected as transfer sites mainly came from North America and Western Europe (United States, Canada, Italy, France, Finland, Sweden, Austria, United Kingdom, Ireland).

The last step of this economic valuation method was to perform an adjustment to transform values in Canadian dollars of 2015. The first step was to convert the values in Canadian dollars using purchasing power parity conversion tables (OECD stats), a method more precise than simply using exchange rates, because it takes into account the purchasing power of each currency. Then, the values in Canadian dollars were transferred into 2015 dollars using the proper inflation rates. All of the values used as part of the benefit transfer are described in detail in [S1 Table](#), with the country where the valuation took place, the methodology, the value in \$2015 CAD/ha/yr and the ecosystem service(s) studied.

Benefit transfer with meta-analysis. The meta-analysis is a statistical method that uses information from a large number of independent studies to infer a value onto a target site, based on characteristics of the system under study. This approach differs from the benefit transfer method with adjustment mainly because, in the latter, the monetary value from one or more primary studies is directly transferred to a target site, with an adjustment for currency and year. In the case of the benefit transfer with meta-analysis, the monetary values from primary studies are not directly transferred onto a target site. Rather, the model transfers the

explanatory factors related to significant socio-economic and environmental characteristics that are associated to the value of an ecosystem. This method reduces transfer errors, thus making it more precise and rigorous than other benefit transfer methods. Despite this increase in precision, a meta-analysis is more complex to undertake and the availability of models is low, because existing models are few and/or privately owned.

The meta-analysis model used as part of this study was developed by He et al. [31] and allowed us to estimate the value of three ES (disturbance prevention, waste treatment and habitat for biodiversity) generated by wetlands. In the initial model, the value of commercial products generated by wetlands is also estimated, but this ES doesn’t apply in the context of this study, because there are no commercial activities in wetlands in this area. This specific model cannot be used to estimate the value of ES provided by ecosystems other than wetlands, because the coefficients that represent explanatory variables are defined using a database of studies about wetlands. The explanatory variables and their associated coefficients used as part of this meta-analysis are presented in Table 2. Eq (2) was used to calculate values of the ES. The values of the constant \hat{a} and of the coefficients \hat{b}_{var} had been estimated by the meta-analysis [31].

$$\hat{Y}_j = \exp(\hat{a}) * \exp(\hat{b}_{serv}X_{servj}) * \exp(\hat{b}_wX_{wj}) * \exp(\hat{b}_{geo}X_{geoj}) * \exp(\hat{b}_{eco}X_{ecoj}) * \exp(\hat{b}_{type}X_{typej}) \tag{2}$$

In the equation, j refers to each wetland that was assessed. The dependent variable (\hat{Y}) is represented by the value of the natural logarithm of the stock of natural capital of 1 ha of wetland.

In order to include site-specific information about the NCC’s Green Network in the statistical model, we performed a documentary and a spatial analysis. The documentary analysis

Table 2. Description of explanatory variables for the meta-analysis (adapted from He et al. [31]).

Category	Variable	Coefficient	Summary Description
Wetlands’ Ecosystem Services (serv)	Biodiversity Habitat	1.584	The wetland holds a particular biodiversity and natural habitat
	Waste Treatment	0.893	The wetland removes pollutants and filtrates water
	Disturbance Prevention	1.485	The wetland provides its management role of flood control and retention
Type of Wetland (w)	Commercial Activities	1.899	The wetland allows commercial activities that are either commercial fishing, hunting or ducks breeding
	Manmade	2.505	The wetland is not natural (i.e. built by man)
	Isolate	-0.856	The wetland is isolated
Geographic Characteristics (geo)	Complex	0.868	The wetland is complex
	Agriculture	-0.019	The percentage (%) of the territory in agriculture area within a radius of 10 km around the wetland
	Urban	0.007	The percentage (%) of the territory in urban area within a radius of 10 km around the wetland
Socio-economic Characteristics (eco)	In wetlands’ size	-0.560	Logarithm of the size of wetlands in hectares
	In GDP per capita	1.291	Logarithm of GDP per capita in PPP 2003 USD
Type of Value (type)	Marginal	1.484	Economic value of wetland was determined for a marginal change.
	Median	3.004	The economic value of wetland reported in the primary study is a median
	Stated preferences	1.087	The study is either based on contingent valuation or choice experiment methods
Constant (\hat{a})		-3.668	

Adapted from Dupras et al. [S1 File]

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involved going through land classifications [33] and reports [26, 29] to verify wetland uses and obtain the GDP per capita of people living in the Ottawa-Gatineau region [20–22]. Using this information, we identified values corresponding to categories of ES provided by wetlands and associated them to wetland types and to socio-economic characteristics. The method used to conduct the spatial analysis, an essential step towards identifying values for the categories of geographical characteristics, was based on the methodology developed by He et al. [31]. Using ArcGIS's software, we divided the NCR into sub-regions of 50 km², and then measured the total size of wetlands and the percentage of agricultural and urban lands surrounding each individual wetland.

Results

Spatial analysis

The NCC's Green Network, composed of the Greenbelt, the Gatineau Park and Urban Lands, represent more than 55,000 hectares and about 11% of the total National Capital Region's spatial area. The most important land uses in the NCC's Green Network are forests (72%) and agricultural lands which include pastures/forages and fallow land (10%), followed by urbanized areas (8%) and combined freshwater systems and wetlands (10%). The description of the land cover analysis is presented in Fig 1 and Table 3. When compared to the entire NCR's land cover, forests in the NCC's Green Network are overrepresented (72% vs 49%), and urban and agricultural lands are underrepresented. These differences can be explained by the mandate of the NCC in managing those lands for conservation, recreation and improvement of federal lands.

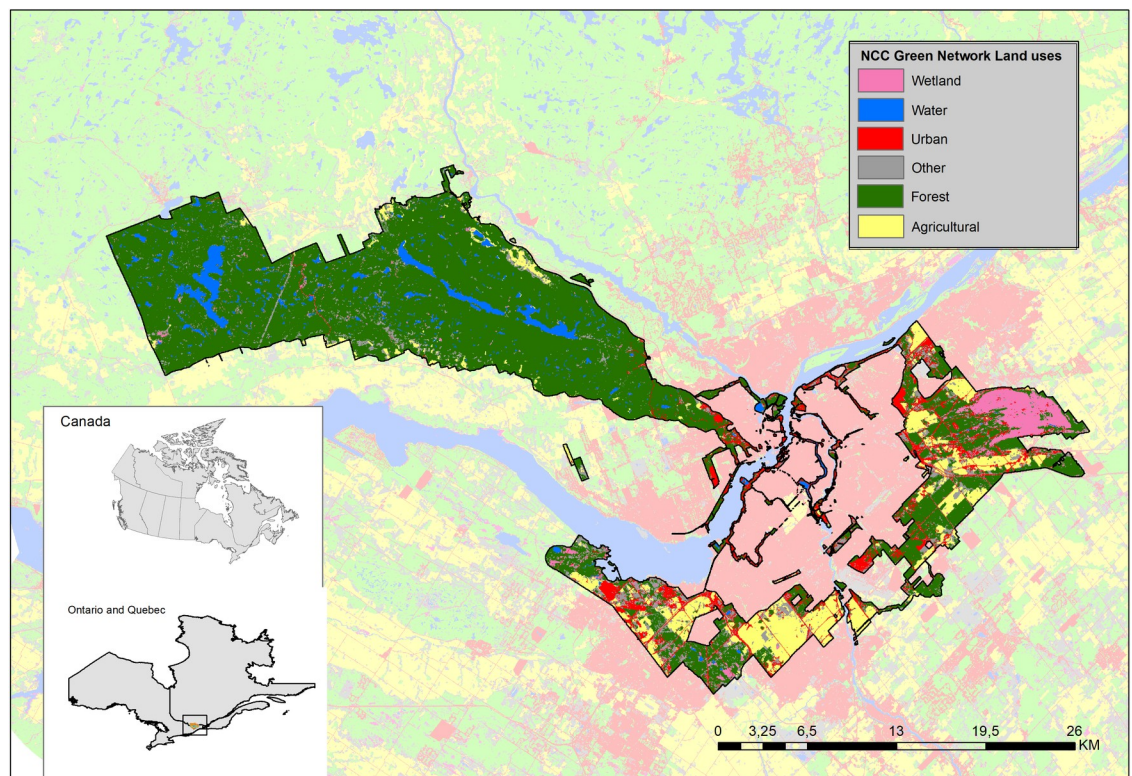


Fig 1. Land use cover of the Canada's National Capital Green Network. (adapted from: Dupras et al. [S1 File]).

<https://doi.org/10.1371/journal.pone.0245045.g001>

Table 3. Land use cover, ecosystem services and valuation of the NCC's Green Network and of the National Capital Region.

ES	Area (ha)	Method of valuation	Benefit transfer with Adjustment		
			Nb of Values	Sources	Methods
Urban Forests	1552				
Global climate regulation		RC			
Air quality		BTA	1	[60]	i-Tree
Water provisioning		BTA	3	[61, 62]	RC, MP
Waste treatment		BTA	1	[62]	RC
Erosion control		BTA	3	[62, 64]	RC, AC, HP
Pollination		MP			
Habitat for biodiversity		BTA	3	[65–67]	CV
Disturbance prevention		BTA	2	[62]	AC
Pest management		BTA	1	[9]	BT
Recreation		MP			
Rural forests	38128				
Global climate regulation		RC			
Air quality		BTA	1	[68]	AC
Water provisioning		BTA	5	[61, 62, 69, 71]	RC, MP
Waste treatment		BTA	4	[63, 70, 71]	RC, MP
Erosion control		BTA	6	[62, 69–71]	RC, OC, HP
Pollination		MP			
Habitat for biodiversity		BTA	14	[65–67, 72–77]	CE, CV, PF, DC
Pest management		BTA	2	[9, 71]	BT, RC
Nutrient cycling		BTA	3	[70, 71]	MP, RC
Recreation		MP			
Wetlands	2453				
Global climate regulation		RC			
Water provisioning		BTA	2	[78, 79]	RC
Waste treatment		BTM			
Habitat for biodiversity		BTM			
Disturbance prevention		BTM			
Recreation		MP			
Croplands	3306				
Food production		MP			
Erosion control		BTA	3	[80, 81]	AC, RC
Nutrient cycling		BTA	1	[9]	BT
Aesthetics		BTA	5	[82–86]	CE, CV, HP
Recreation		BTA	1	[9]	MP
Prairie and grasslands	2320				
Agricultural products		MP			
Global climate regulation		RC			
Erosion control		BTA	3	[80, 81]	AC, RC
Pollination		MP			
Habitat for biodiversity		BTA	1	[9]	BT
Pest management		BTA	1	[9]	BT
Nutrient cycling		BTA	1	[81]	RC
Aesthetics		BTA	5	[82–86]	CE, CV, HP
Recreation		MP			

(Continued)

Table 3. (Continued)

ES	Area (ha)	Method of valuation	Benefit transfer with Adjustment		
			Nb of Values	Sources	Methods
Freshwater	1643				
Habitat for biodiversity		BTA	1	[87]	CR
Waste treatment		BTA	1	[87]	CR
Aesthetics		BTA	1	[87]	CR
Recreation		MP			

AC (Avoided cost), BT (Benefit transfer), CE (Choice experiment), CV (Contingent valuation), CR (Contingent ranking), DC (Damage cost), HP (Hedonic pricing), MP (Market price), OC (Opportunity cost); RC (Replacement cost).

<https://doi.org/10.1371/journal.pone.0245045.t003>

Ecosystem services valuation

The results of the economic valuation of ES are presented by the type of ecosystem, i.e. forest, wetlands, croplands, grasslands and freshwater systems.

Forests and woodlands. ES provided by forests and woodlands vary based on their location, whether they are in an urban, rural or peri-urban setting, and based on their composition, i.e. whether the forest is composed mainly of broadleaves, conifers or is mixed. Based on the spatial analysis, 4% of the forest cover is known to be located in urban area and 96% in rural area. In terms of forest composition, 57% is mixed, 40% is composed mainly of broadleaves, and 3% has a majority of conifers. Forests and woodlands provide 11 ES in the NCC's Green Network.

The ES of global climate regulation was calculated using the replacement cost method and decomposed into carbon sequestration and storage. Carbon sequestration, which represents the annual flow of carbon stored in forests and woodlands, was calculated using the value of the SCC estimated by Environment and Climate Change Canada (ECCC) at \$43/tonne of CO₂eq [58], and the average value of recorded carbon sequestration rates by ECCC between 1990 and 2013 [82]. This flow corresponds to 1.93 tCO₂/ha/year and the economic value of carbon sequestration is valued at \$83/ha/year.

Carbon storage, or the stock of carbon stored in forests and woodlands, was evaluated using data from a long-term study undertaken by Kurz and Apps [88]. As part of their analysis, they evaluated carbon fluxes in the Canadian forest sector over a 70-year period and estimated that the stock of carbon stored in cool temperate forests was equal to 220 tonnes of carbon per hectare or 807 tonnes of CO₂eq per hectare. Over the forested surface, it means that nearly 9 million tonnes of carbon are stored in the NCC's Green Network.

To obtain this value annually, we calculated the present value of carbon stocks over 50 years, at a 3% discount rate. Using these parameters, the annual value for carbon storage was evaluated at \$158/ha/year. Overall, the economic value for climate regulation is \$241/ha/year.

Air quality was calculated using the benefit transfer method, more specifically using Hirabayashi's [60] I-tree software, which has the ability to differentiate between urban and rural effects of trees on air quality. The multipliers used in the analysis are provided in Table 4. The resulting value for the ES of air quality is \$10/ha/year for rural forests and \$554/ha/year for urban forests.

Pollination was calculated using the market price method as described in the methodology. The value of this service is estimated at \$10/ha/year for rural forests and at \$14/ha/year for urban forests in the NCC's Green Network. While calculating the value of the pollinating service, we took into account the quality of the nesting environment for wild pollinators, as it is

Table 4. Multipliers derived from the United States' total values.

Pollutant	Removal Multiplier (kg/ha/yr)		Value Multiplier (\$/ha/yr)	
	Urban	Rural	Urban	Rural
CO	1.27	1.00	1.7	0.02
NO ₂	7.00	5.45	3.1	0.04
O ₃	54.04	54.93	154.1	2.6
PM ₁₀	15.34	18.51	97.3	2.1
PM _{2,5}	2.76	2.66	297.4	4.9
SO ₂	3.44	3.47	0.5	0.01
Total			554.1	9.7

Source: Adapted from Nowak et al. [89] and Hirabayashi [60]; Adapted from Dupras et al. [S1 File]

<https://doi.org/10.1371/journal.pone.0245045.t004>

preferable to take into account the quality of the nesting environment, as well as the quality of the agricultural environment [90]. This meant dividing the value of ρ by half for urban crops, according to insights about the quality of urban environments for wild pollinators [56]. The values were obtained by using the sum of the value of pollination for crops grown in rural areas (from Eq 1), divided by the total area in the 1 km buffer around crops that can be considered as nesting habitats for wild pollinators and then multiplied by the share of rural forests in the 1 km buffer (Eq 3). We then did the same for urban forests, rural and urban prairies and grasslands.

$$\text{Pollination ES} = (V_{\text{pollination}} \text{ Rural Total} / \text{Area}_{\text{Rural buffer}}) * (\text{Area}_{\text{rural forests buffer}} / \text{Area}_{\text{forest buffer}}) \quad (3)$$

The economic value associated to recreational activities and tourism was estimated based on results from the NCC's 2014–2015 Annual Report [91] which showed that the NCC collected \$2.7 million in user fees, which is equivalent to \$75/ha/year when the \$2.7 million value is divided over the Gatineau Park's entire spatial area (36,161 ha). These user fees correspond to annual passes used to access the park during the winter to perform cross-country skiing and snowshoeing, to camping fees and to parking fees within specific areas of the park. When we compare this value to a report by Environics [27], which showed that Gatineau park visitors (77% of residents and 23% of non-residents) spent \$184 million in the region as part of their travel to the Gatineau Park in food, sport supply and other purchases such as gas, the \$2.7 million in user fees seems quite low. As a result, the value of \$75/ha/year is most likely insufficient to represent the real value of the recreational potential of the Gatineau Park. It is nevertheless the only value that we can directly tie to activities performed in the Park.

The remaining seven ES for forests and woodlands are evaluated based on the benefit transfer method and are described below. The primary studies which were used to perform the benefit transfer with adjustment are provided in S1 Table.

Habitat for biodiversity is part of the ES with the highest value per hectare for forests and woodlands. The value of this ES has been estimated using three monetary estimates for urban forests [65–67], resulting in a mean value of \$2,684/ha/year, and using fourteen estimates for rural forests [65–67, 72–77], for a mean value of \$2,185/ha/year.

The service of disturbance prevention, or flood control, is estimated only for urban forests, because of its impact on the stormwater control and retention. In Morri et al. [62], this service is calculated based on the cost of a water reservoir. Using two monetary estimates [62], this service has a mean value of \$5,030/ha/year, making it the ES with the highest value per hectare for forests and woodlands.

Water provisioning was estimated using three values for urban forests [61, 62] and four values for rural forests [61, 62, 69, 71], which rendered a mean value per hectare of, respectively, \$339/ha/year and \$839/ha/year.

The ES of nutrient cycling has been calculated only for rural forests, using three monetary estimates [70, 71], and has an estimated value of \$319/ha/year. The values from the benefit transfer come from studies that have used the market pricing method [70] and the replacement cost method [71].

Waste treatment refers to the capacity of forests and woodlands to prevent and reduce the proportion of nutrients and pollutants from going directly into rivers and to their ability to filter, store and transform pollutants. This ES is estimated at \$140/ha/year for urban forests [62], and at \$318/ha/year for rural forests [63, 70, 71].

Erosion control has an estimated value of \$211/ha/year for urban forests [62–64] and of \$137/ha/year for rural forests [62, 69–71], and pest management was estimated at \$45/ha/year for urban forests [9] and at \$30/ha/year for rural forests [9, 71].

Table 5 presents each monetary estimate per ES for urban and rural forests. This table also includes minimum, maximum and mean values, as well as the standard deviation for ES that

Table 5. Value of ES provided by forests and woodlands of the NCC's Green Network (\$CAD 2015).

Ecosystem Services	Nb. of \$ estimates	Total area (ha)	Min. value (\$/ha/y)	Max. value (\$/ha/y)	Mean (\$/ha/y)	Std. dev. (\$/ha/y)	Method	Total value (\$'000/y)
Urban Forests	15	1552	6797	14,312	9328			14,484.8
Global Climate Regulation	1		-	-	241	nd	RC	374.0
Air Quality	1		-	-	554	nd	BT	859.8
Water Provisioning	3		203	609	339	234	BT	526.1
Waste Treatment	1		-	-	140	nd	BT	217.3
Erosion Control	3		111	396	211	161	BT	327.5
Pollination	1	1582 ^a	-	-	14	nd	MP	22.1
Biodiversity Habitat	3		444	7160	2684	3876	BT	4,165.6
Disturbance Prevention	2		4975	5085	5030	78	BT	7,806.6
Pest Management	1		-	-	45	nd	BT	69.8
Nutrient Cycling	-		-	-	-	-	-	-
Recreation	1		-	-	75	nd	MP	116.4
Rural Forests	36	38,128	498	16,971	4161			158,529.1
Global Climate Regulation	1		-	-	241	nd	RC	9188.9
Air Quality	1		-	-	10	nd	BT	381.3
Water Provisioning	5		123	3053	839	1252	BT	31,989.4
Waste Treatment	4		26	806	318	344	BT	12,124.7
Erosion Control	6		1	536	137	202	BT	5,223.5
Pollination	1	16,501	-	-	10	nd	MP	165.0
Biodiversity Habitat	14		0.1	11,349	2185	3673	BT	83,309.7
Disturbance Prevention	-		-	-	-	-	-	-
Pest Management	2		14	45	29	22	BT	1124.8
Nutrient Cycling	3		0.1	848	319	462	BT	12,162.8
Recreation	1		-	-	75	nd	MP	2859.6

^a: The area of urban forests is larger than the total as it includes some forests that are classified as "Rural" in our database. Std. dev.: Standard deviation; BT: Benefit Transfer; MP: Market Price; RC: Replacement Cost; Adapted from Dupras et al. [S1 File]

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have been estimated using the benefit transfer method and at least two monetary estimates. As indicated in the table, when using mean values for urban and rural forests, the total value for forest ecosystems is equal to \$173.0 million per year. When taking into account the forest cover, the most important ES in terms of economic value are habitat for biodiversity, water provisioning, and nutrient cycling.

Wetlands. Wetlands represent 4.5% of the NCC's Green Network landscape. Most wetlands are relatively small, except the Mer Bleue bog, which is a 3,500-hectare conservation area.

The meta-analysis approach was used to determine the value of three ES: habitat for biodiversity, waste treatment and disturbance prevention. Different criteria were included as part of this statistical method, namely wetland size and type (man-made, isolate, complex), GDP per capita, and land cover composition around the wetlands (e.g. % agriculture, % urbanized areas). After performing the analysis for each wetland in the study area, we found a value of \$21,461/ha/year for habitat for biodiversity, \$15,893/ha/year for waste treatment, and \$20,766/ha/year for disturbance prevention. As mentioned, no value was found for market services, because there are no commercial activities carried out in wetlands in the study area.

As a way of comparison, we found a number of studies that have used other methods to estimate the value of wetlands. For urban wetlands, the service of habitat was estimated by Kosz [92] in Austria at a value of \$149,161/ha/year to \$338,960/ha/year using contingent valuation. For rural wetlands, the value ranges from \$22/ha/year [93] to \$4,251/ha/year [94] when using contingent valuation methods. For the service of waste treatment, urban wetlands have an estimated value of \$0.3/ha/year [79] to \$19,713/ha/year [95], using the avoided costs method. Rural wetlands have an estimated value that ranges from \$1,697/ha/year [79] to \$6,282/ha/year [96] using the replacement cost method. Finally, the disturbance prevention service has been estimated, for both rural and urban wetlands, at a value ranging from \$77/ha/year [97] using the market price method to \$5,967/ha/year [98] using the avoided costs method. The high values obtained with the meta-analysis, when compared to the results from the studies mentioned above, are largely explained by two environmental factors: the scarcity of wetlands, as it increases the relative importance of the ES provided, and their geographic location, especially with regards to the proximity to agricultural and urban lands which affects the importance of the ES provided. These values are also explained by socio-economic factors, namely demographics and the relative wealth of the population, as these factors influence the value of the ES.

As carbon sinks, wetlands provide global climate regulation services. Using the values of carbon stocks found in peat bogs across representative regions in the province of Quebec [99], an average stock of 1,468 tonnes of carbon per hectare was found for the NCC's Green Network wetlands. An economic value for carbon storage of \$1,057/ha/year was found using the value of the SCC (\$43/tonne of CO₂), a 50-year annualization period, and a 3% discount rate.

The carbon sequestration value was estimated based on the Mer Bleue wetland sequestration rate of 0.7 tC/ha/year [100], and rendered an economic value of \$111/ha/year. By combining these two values, the global climate regulation service is estimated at \$1,168/ha/year.

The value of recreational services of \$75/ha/year was estimated based on the Gattineau Park analysis. The use of this value is based on the fact that accessible wetlands and their surrounding areas in the NCC Green Network are mainly used for birdwatching, biking, hiking, snowshoeing and cross-country skiing. Shirley's Bay, in the Ottawa Greenbelt, is the only place where ice fishing is allowed. These are activities that some people pay to access in the Gattineau Park. It is also difficult to estimate the value of the recreational service in wetland areas specifically, due to the limited number of studies and the fact that all of the activities in the Greenbelt, where the largest wetlands are located, are free. In addition, most studies that evaluate the

Table 6. Value of ES provided by wetlands of the NCC's Green Network (\$CAD 2015).

Ecosystem Services	Nb. of \$ estimates	Total area (ha)	Min. value (\$/ha/y)	Max. value (\$/ha/y)	Mean (\$/ha/y)	Std. dev. (\$/ha/y)	Method	Total value (\$'000/y)
Urban and Rural Wetlands	7	2453	59,371	59,417	59,394			145,693.5
Global Climate Regulation	1		-	-	1168	nd	RC	2865.1
Water Provisioning	2		8	54	31	32	BT	76.0
Waste Treatment	1		-	-	15,893	nd	BT	38,985.5
Biodiversity Habitat	1		-	-	21,461	nd	BT	52,643.8
Disturbance Prevention	1		-	-	20,766	nd	BT	50,939.0
Recreation	1		-	-	75	nd	MP	184.0

Std. dev.: Standard deviation; BT: Benefit Transfer; MP: Market Price; RC: Replacement Cost; *Adapted from Dupras et al. [S1 File]*

<https://doi.org/10.1371/journal.pone.0245045.t006>

recreational service of wetland include fishing and hunting as part of their activities. In this case, it would be inappropriate to compare our value to these, as hunting and fishing are generally not allowed in the study area.

The last service to be estimated is water provisioning. Its value of \$31/ha/year was determined based on two monetary estimates from the benefit transfer database [78, 79].

The combined value of all six services provided by wetlands is equal to \$59,394/ha/year and a total value of \$145.7 million/year (Table 6).

Croplands. Croplands represent 10% of the NCC's Green Network land cover, and the main agricultural crops grown in the Greenbelt are soy, corn and barley.

The value of the agricultural production service was evaluated using the market pricing method. The net benefit was calculated for barley, oat, wheat, corn, soy, dry beans, strawberries, and other cereals, and rendered a mean value of \$919/ha/year or \$3 million per year.

The value of recreational activities was estimated based on a study by Dupras and Alam [9], where the income from agro-tourism of 66 agro-businesses in the Greater Montreal area was estimated at \$94/ha/year.

The other non-market ES were estimated using the benefit transfer with adjustment method. Using the benefit transfer database, a value of \$112/ha/year was identified for erosion control [80, 81], of \$184/ha/year for nutrient cycling [9], and of \$76/ha/year for landscape aesthetics [82–86].

The total mean value of all these ES is equals \$4.59 million per year, with an average of \$1,389/ha/year (Table 7).

Table 7. Value of ES provided by croplands of the NCC's Green Network (\$CAD 2015).

Ecosystem Services	Nb. of \$ estimates	Total area (ha)	Min. value (\$/ha/y)	Max. value (\$/ha/y)	Mean (\$/ha/y)	Std. dev. (\$/ha/y)	Method	Total value (\$'000/y)
Croplands (Annual Crops)	11	3306	1279	1581	1389			4592.0
Food Production	1		-	-	919	nd	MP	3038.2
Erosion Control	3		61	193	109	73	BT	360.3
Nutrient Cycling	1		-	-	184	nd	BT	608.3
Aesthetics	5		21	191	83	76	BT	274.4
Recreation	1		-	-	94	nd	BT	310.8

Std. dev.: Standard deviation; BT: Benefit Transfer; MP: Market Price; *Adapted from Dupras et al. [S1 File]*

<https://doi.org/10.1371/journal.pone.0245045.t007>

Prairies, pastures and grasslands. Prairies, pastures and grasslands are represented by pasture and forage lands, and by fallow lands.

In addition to the value of agricultural products in the form of forages, which have a value of \$116/ha/year [52], these ecosystems provide many ES that are incremental to those provided by croplands, because of the positive effects of non-intensive land use.

As opposed to croplands, a value was calculated for the climate regulation services provided by grasslands, pasture and forage crops. Smith et al. [101] estimated that these ecosystems contain on average 105 tonnes of carbon per hectare. The value of carbon storage, annualized over 50 years, with a discount rate of 3% and the value of the SCC (\$43/tonne of CO₂) is equal to \$76/ha/year. The value of carbon sequestration, using a sequestration rate of 2.17 tonnes of C/ha, is equal to \$342/ha/year. The total value for climate regulation is then of \$418/ha/year.

Recreational services have been estimated at \$75/ha/year, based on the results obtained for the Gatineau Park. The pollination service value was calculated for urban and rural prairies and grasslands, using the same methodology as the one used for forests and woodlands. However, due to the very small land area from this land use present in buffers around agricultural areas, the value we obtained was too small to report. Few studies estimate the value of the recreational service for prairies and grasslands, as a result we will use the reported value from Costanza et al.'s [102], based on the study by Boxall [103], as a comparison for recreation (\$4/ha/year).

The remaining five ES estimated for prairies, pastures and grasslands were evaluated using the benefit transfer database. The calculated mean value are \$109/ha/year for erosion control [80, 81], \$2,467/ha/year for biodiversity habitat [9], \$45/ha/year for pest management [9], \$147/ha/year for nutrient cycling [81], and \$76/ha/year for landscape aesthetics [82–86].

The total mean value for all nine estimated service is \$8.0 million per year, or \$3,460/ha/year (Table 8).

Freshwater. Freshwater systems represent 5% of the NCC's Green Network in the form of lakes, streams and of two rivers. Despite the importance of freshwater systems in the world, few studies have been produced on ES, aside for cultural services. This limited the analysis of freshwater ES to four ES. The service of recreational activities and tourism was evaluated based on the analysis conducted for the Gatineau Park, for a value of \$75/ha/year. This value only takes into account the recreational visits to freshwater ecosystems in areas actively managed by the NCC. It does not take into account the fish harvested as part of fishing activities.

Table 8. Value of ES provided by prairies, pastures and grasslands of the NCC's Green Network (\$CAD 2015).

Ecosystem Services	Nb. of \$ estimates	Total area (ha)	Min. value (\$/ha/y)	Max. value (\$/ha/y)	Mean (\$/ha/y)	Std. dev. (\$/ha/y)	Method	Total value (\$'000/y)
Pastures and Grasslands	13	2320	3350	3652	3460			8027.2
Agricultural Products	1		-	-	116	nd	MP	269.1
Global Climate Regulation	-		-	-	418	-	RC	969.8
Erosion Control	3		61	193	109	73	BT	252.9
Biodiversity Habitat	1		-	-	2467	nd	BT	5723.4
Pest Management	1		-	-	45	nd	BT	104.4
Nutrient Cycling	1		-	-	147	nd	BT	341.0
Aesthetics	5		21	191	83	76	BT	176.3
Recreation	1		-	-	75	nd	MP	174.0

Std. dev.: Standard deviation; BT: Benefit Transfer; MP: Market Price; RC: Replacement Cost; Adapted from Dupras et al. [S1 File]

<https://doi.org/10.1371/journal.pone.0245045.t008>

Table 9. Value of ES provided by freshwater systems of the NCC's Green Network (\$CAD 2015).

Ecosystem Services	Nb. of \$ estimates	Total area (ha)	Min. value (\$/ha/y)	Max. value (\$/ha/y)	Mean (\$/ha/y)	Std. dev. (\$/ha/y)	Method	Total value (\$'000/y)
Aquatic Systems	4	1643	137	137	137			225.1
Biodiversity Habitat	1		-	-	10	nd	BT	16.4
Waste Treatment	1		-	-	48	nd	BT	78.9
Aesthetics	1		-	-	4	nd	BT	6.6
Recreation	1		-	-	75	nd	MP	123.2

Std. dev.: Standard deviation; BT: Benefit Transfer; MP: Market Price; *Adapted from Dupras et al. [S1 File]*

<https://doi.org/10.1371/journal.pone.0245045.t009>

The estimated value for biodiversity habitat, waste treatment and aesthetics was adapted from a study by Poder et al. [87] on the willingness to pay for the Blue Network of the Greater Montreal area, where a stated preference method was used. The value of the WTP from the initial study, expressed in dollars per household, was multiplied by the number of households in the Ottawa-Gatineau Metropolitan region, and then this value was divided by the number of hectares of freshwater systems in the region. The details of this adaptation is provided in S2 Table. The annual present value was then calculated using a 20-year actualization period and a 3% discount rate. The values obtained were \$10/ha/year for biodiversity habitat, \$48/ha/year for waste treatment, and \$4/ha/year for aesthetics. These values were chosen because of the proximity of the study area to the Green Network. A number of other studies performed on freshwater ES focus on the issue of eutrophication, the costs of improving water quality [104–108] and the impact of invasive species on property prices [109–111]. Although these issues are present in the Green Network, the aim of our exercise was not to investigate the resolution of a specific environmental issue.

The total value for freshwater systems is \$225,091 per year or \$137/ha/year (Table 9).

Total economic value. The total mean economic values per ES and per ecosystem are presented in Table 10. In dollars per hectare, wetlands are the ecosystems with the highest

Table 10. Total annual values per hectare for ES of the NCC's Green Network (\$CAD 2015/ha/year).

Ecosystem Services	Urban Forests	Rural Forests	Wetlands	Croplands	Prairies, grasslands	Freshwater Systems
Agricultural Products	-		-	919	116	-
Global Climate Regulation	241	241	1,168	-	418	-
Air Quality	554	10	-	-	-	-
Water Provisioning	339	839	31	-	-	-
Waste Treatment	140	318	15,893	-	-	48
Erosion Control	211	137	-	109	109	-
Pollination	14	10				
Biodiversity Habitat	2,684	2,185	21,461	-	2,467	10
Disturbance Prevention	5,030	-	20,766	-	-	-
Pest Management	45	29	-	-	45	-
Nutrient Cycling	-	319	-	184	147	-
Aesthetics	-	-	-	83	83	4
Recreation	75	75	75	94	75	75
TOTAL	9,333	4,163	59,394	1,389	3,460	137
Number of ha	1,552	38,128	2,453	3,306	2,320	1,643

Adapted from Dupras et al. [S1 File]

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Table 11. Total annual values (\$ '000 CAD 2015) for ES of the NCC's Green Network.

Ecosystem Services	Urban Forests	Rural Forests	Wetlands	Croplands	Prairies, grasslands	Freshwater Systems	Total
Agricultural Products	-		-	3038.2	269.1	-	3,307.3
Global Climate Regulation	374.0	9,188.9	2,865.1	-	969.8	-	13,397.7
Air Quality	859.8	381.3	-	-	-	-	1,241.1
Water Provisioning	526.1	31,989.4	76.0	-	-	-	32,591.5
Waste Treatment	217.3	12,124.7	38,985.5	-	-	78.9	51,406.4
Erosion Control	327.5	5,223.5	-	360.4	252.9	-	6,164.3
Pollination	22.1	165.0	-	-	-	-	187.1
Biodiversity Habitat	4,165.6	83,309.7	52,643.8	-	5,723.4	16.4	145,859.0
Disturbance Prevention	7,806.6	-	50,939.0	-	-	-	58,745.6
Pest Management	69.8	1,124.8	-	-	104.4	-	1,299.0
Nutrient Cycling	-	12,162.8	-	608.3	341.0	-	13,112.1
Aesthetics	-	-	-	274.4	192.6	6.6	473.6
Recreation	116.4	2,859.6	184.0	310.8	174	123.2	3,768.0
TOTAL	14,485.2	158,529.1	145,693.5	4592.0	8027.2	225.1	331,552.7

Adapted from Dupras et al. [S1 File]

<https://doi.org/10.1371/journal.pone.0245045.t011>

economic value, followed by urban and rural forests. When taking into account land cover (number of ha) associated with each ecosystem as shown in Table 11, rural forests are the ecosystem with the highest economic value. When looking at individual ES, recreation has the highest value (\$154 million) followed by biodiversity habitat (\$146 million), which is provided by five out of six ecosystems studied. Fig 2 provides a spatial representation of the natural capital value in \$/ha/year.

The total mean economic value for the entire NCC's Green Network is \$332 million per year, with a minimum of \$187 million per year and a maximum of \$829 million per year (Table 12). The minimum and maximum values come from benefit transfer estimates, where at least two monetary values were used. The largest variation between minimum and maximum values comes from the rural forest ecosystem, especially from the biodiversity habitat ES, where the standard deviation has a value of \$3,673/ha/year and values ranging from \$0.1/ha/year to \$11,349/ha/year.

Aside from ES values calculated for forests and woodlands ecosystems and the pollination service for prairies and grasslands, values were not differentiated between urban and rural environments, mainly because of data availability. In the case of wetlands, distance to urban areas was taken into consideration in the meta-analysis to define the value, but wetlands were not explicitly labelled as urban or rural in the tables. This is because of the nature of the benefit transfer with meta-analysis which takes into consideration the characteristics of ecosystems in the value estimation. Another reason for not explicitly labelling ecosystems other than forests as urban or rural is the fact that most areas were considered peri-urban. It is especially true in the case of the Greenbelt, because it is enclosed between urban environments. This is also the case for the southern portion of the Gatineau Park.

Discussion

Currently, the NCC's Green Network has an estimated value of 332 million dollars per year, which represents a mean value of \$6,014/ha/year, for a total economic value of more than \$5 billion annualized over 20 years. This value represents the contribution of ES provided by forests and woodlands, wetlands, agricultural areas, prairies, grasslands, and pastures, and by

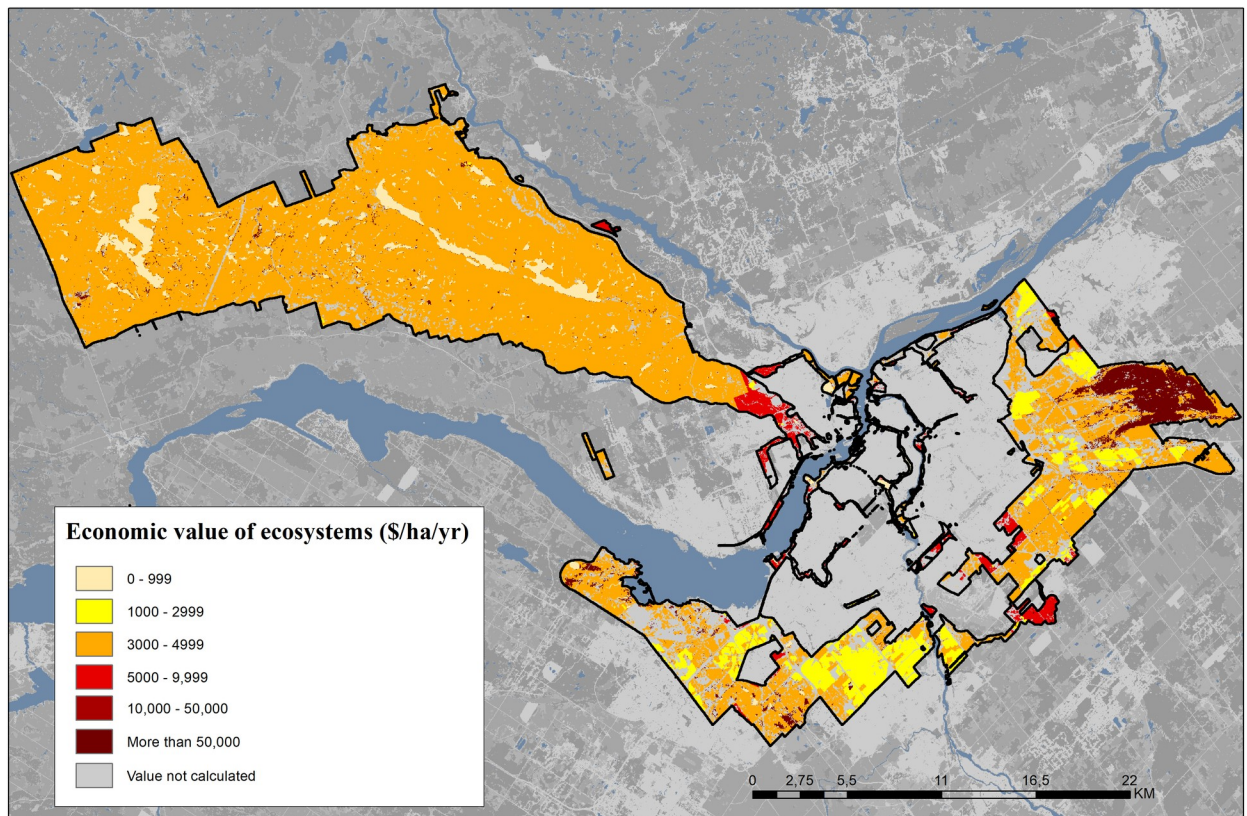


Fig 2. ES value of Canada's National Capital Green Network (values expressed in \$CAD 2015 /ha/year). (adapted from: Dupras et al. [S1 File]).

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freshwater systems. The most important part of this value is represented by nonmarket ES, mainly regulating services, such as biodiversity habitat, waste treatment, disturbance prevention, and global climate regulation.

The aim of this study was in part to explore the value of a suite of regulating services, since in many studies, these services are often left aside because of their difficult association with economic indicators. The interest of exploring the regulating services is all the more relevant as they largely explain the variations in the total economic value for the different ecosystems (Table 10). 76% of the total economic value per ha in the NCC's Green Network is captured by the wetlands, because of their particularly important contribution to habitat biodiversity,

Table 12. Total minimum, mean, and maximum annual values (\$M CAD 2015) for the studied ecosystems.

Ecosystems	Minimum value	Mean value	Maximum value
Urban Forests	10.6	14.5	22.2
Rural Forests	19.1	158.5	647.1
Wetlands	145.6	145.7	145.7
Croplands	4.2	4.6	5.2
Prairies, pastures, grasslands	7.8	8.0	8.5
Freshwater Systems	0.2	0.2	0.2
TOTAL	187.5	331.6	829.0

Adapted from Dupras et al. [S1 File]; \$M: '000 000

<https://doi.org/10.1371/journal.pone.0245045.t012>

disturbance prevention, waste treatment and global climate regulation. This result is not surprising since the great importance of the wetland's ecological functions is already demonstrated in the scientific literature [102, 112, 113]. The variation of the total economic value between ecosystems can be explained along a rural-urban gradient. Indeed, at the NCC's Green Network scale, rural forests have a total annual value more than 10 times greater than that of urban forests (Table 11). However, as the area of urban forests is relatively small compared to the vast area of rural forests, the total annual value per hectare of urban forests is more than twice that of rural forests (Table 10). This disparity was also highlighted in the study of Nikodinoska et al. [114] in which only 1% of the economic value was generated by green urban areas of Uppsala (Sweden); when considering the size of different land uses, the average economic value of green urban areas was the highest (53%). These results support the importance of urban ecosystems for the population as they provide an important contribution in terms of regulating and cultural ES. Thus, ES hotspots tended to be located in urban settings where a higher population density led to a stronger demand for ES (see also [115]). Urban-related pressures like air pollution also increase the need for ES, although this can lead to local mismatches between ES supply and demand [116, 117]. Indeed, these results should not obscure the fact that most of the total economic value is provided by the rural ecosystems (Table 11) and that a conservation effort must be made on these ecosystems to promote sustainability. A better understanding of the processes that make up nonmarket and rural ecosystems is important to make more informed decisions on their management and preservation.

The integration of knowledge about the value of ES in decision-making for planning is a relevant and evolving area of study [118–122]. Although there are still few real-world examples of the use of ES knowledge in public planning and decisions [123–125], a few trends seem to emerge relative to their use based on current examples from the literature. The first approach is based on ecosystem-wide planning used to resolve specific issues. Examples of this planning approach is the one adopted by the city of New York to protect its water supply [17, 126], and the one adopted for the management of nitrogen in the Chesapeake Bay in the United States [118]. Another approach is through regional and strategic planning (e.g. [115]), where ecosystems are managed regardless of jurisdictional limits. This includes the planning approach adopted by the United States Forest Service as part of its 2012 Planning Rule, where it is required to plan forest management activities at the ecosystem level. The region of Tampere, in Finland, has also included this approach in its strategic plan towards 2040. The spatial valuation of ES by Tammi et al. [115] provided input into the regional planning strategy by performing an analysis of ecosystems along a urban-rural gradient, but without consideration for inner jurisdictional boundaries. Their results were used by decision makers to plan for ES hotspots. This information also interested local groups within and outside of the Tampere region.

Tools that are not solely based on land use planning also exist to enable the maximization and protection of ES supply. Payments for Ecosystem Services (PES) are such an example. The implementation of PES vary across the world, but they are programs where landowners are compensated (in money or in-kind) for the provision of ES when they carry out agreed upon land use management practices. These programs exist in developing and industrialized countries alike, although PES programs implemented in latter countries tend to focus on agricultural lands [127, 128].

Despite these examples of the use of ES knowledge into policies, plans or tools, the use of ES in decision-making is currently limited by the amount of knowledge available. For example, there are few sets of longitudinal data on ES supply, which limits the tracking of services over a longer period [118, 119]. Other limits include the type of policies and the legislative framework in place in a region, the interest of planners and decision makers, as well as social and political will [115, 119, 122].

In addition, to ensure the provision of ES, planners and decision makers need to understand that the quality and stability of ES are related to land uses, to the capacity of species to interact with one another, and to move across the landscape [129, 130]. As a result, the NCC should facilitate the creation of corridors to increase connectivity within the Green Network and with surrounding natural environments, through land acquisition or partnerships with public and/or private owners [131]. The results of this study can be used to raise awareness on the value of ES, but this new knowledge that is available to decision makers of the region can be taken further. These results can be used as a stepping stone to improve ecosystem-wide planning in the Ottawa-Gatineau region, especially since the report was received with great interest by the NCC, media [132–134], and the community within the immediate Ottawa-Gatineau region, but also within the larger national capital region of Canada.

These results should nevertheless be considered in light of methodological limitations inherent to the approach chosen in this study, especially with regard to the spatial analysis and the economic valuation. Data availability was a limiting factor in both the spatial analysis and the economic valuation. Although tests were made to detect errors in the GIS layer, the chosen source only had an 85% precision. Data availability also impacted the economic valuation, especially when using the benefit transfer approach. Even though care was taken to avoid transfer bias, the results are not as robust as a study based exclusively on primary data. Additionally, the benefit transfer analysis was dependent on published literature, for which the coverage of ecosystems and ES is unequal. This unequal attention affects the accuracy of some monetary estimates. For example, there were more studies on forests and wetlands than on freshwater and agricultural lands. Finally, our analysis was not exhaustive with regard to the valuation of the stock of natural capital, where only the values for Wetlands ES included the stock of natural capital and the values for the service of Global climate regulation included the value of the stock of carbon. This suggests that our estimate of the value of the NCC's Green Network is an underestimation.

Nonetheless, since the objective of the study was not to establish a precise value that would be used to put in place a program or market, but rather to increase the awareness of a number of stakeholders, citizens and decision makers about the real contribution of ecosystems to their well-being, the choice of data and methodology is valid.

Conclusion

Since the implementation of the first Canadian Greenbelt in Ottawa in 1950, there has been an evolution in the design of greenbelts globally. Instead of surrounding a city to prevent growth, the focus is on building corridors for biodiversity, so that species can move within the landscape and people can enjoy cultural services within cities. The final design of the Golden Horseshoe in Toronto and of the proposed Montreal greenbelt and its associated natural infrastructure network are based on this approach.

Initially, the Plan Gréber of 1950 included provisions to connect the Greenbelt and the Gatineau Park through urban lands. The appeal of connected structures is the ability to improve the production of ES. In the case of the NCC's Green Network, there is an opportunity to connect these landscapes, but it will require discussions between the NCC and municipalities for the purchase and protection of lands. As mentioned in the introduction, an important challenge to the integrity of the green network is encroachment, especially since the green network does not have a formally protected status.

The lack of information on the value of natural habitats to human well-being in urban and peri-urban setting does lead to the degradation of natural capital. With the monetary values elicited as part of this study, managers at the NCC will be able to showcase the contribution of

natural landscapes to reduce the cost of grey infrastructure and to improve the quality of life of citizens.

Supporting information

S1 Table. List of studies used as part of the ES valuation with benefit transfer (Values in \$2015 CAD).

(DOCX)

S2 Table. Conversion of the WTP values from Poder et al. [87] to values for the NCC Green Network.

(DOCX)

S1 File. Dupras et al. 2016. natural capital. The Economic Value of the National Capital Commission's Green Network. Dupras J, L'Ecuyer-Sauvageau C, Auclair J, He J, Poder T. Natural Capital. The Economic Value of the National Capital Commission's Green Network. David Suzuki Foundation & National Capital Commission. 2016. 51 pages. (PDF)

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References

1. United Nations (UN). 2014 revision of the World Urbanization Prospects. United Nations Department of Economic and Social Affairs. New York: 2014 July 10. [Cited on 2017 July 7]. Available from: <http://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html>
2. Pendall R. Do land-use controls cause sprawl? *Environ Plan B Plan Des.* 1999; 26(4):555–71.
3. Ewing R. Is Los Angeles-Style Sprawl Desirable? *J Am Plan Assoc.* 1997; 63(1):107–26.
4. The Sierra Club. The dark side of the American Dream: the costs and consequences of suburban sprawl. San Francisco, CA: The Sierra Club; 1998. Accessible from: <https://vault.sierraclub.org/sprawl/report98/report.asp>
5. PTCEC. Report of the Pennsylvania 21st Century Environment Commission. The national literacy survey. Harrisburg, PA; 1998.
6. U.S. Department of Housing and Urban Development. The State of the Cities 1999. 1999

7. Johnson MP. Environmental impacts of urban sprawl: A survey of the literature and proposed research agenda. *Environ Plan A*. 2001; 33(4):717–35.
8. Orfield M. Metropolitcs: A regional agenda for community and stability. *Forum Soc Econ* [Internet]. 1999 Mar; 28(2):33–49. Available from: <http://dx.doi.org/10.1007/BF02833982>
9. Dupras J, Alam M. Urban Sprawl and Ecosystem Services: A Half Century Perspective in the Montreal Area (Quebec, Canada). *J Environ Policy Plan* [Internet]. 2014; 17(2):180–200. Available from: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84924246571&partnerID=tZOTx3y1>
10. Howard, E. *Tomorrow: a Peaceful Path to Real Reform*. Swan Sonnenschein, London. (2nd edition 1945, entitled *Garden Cities of Tomorrow*. Faber, London.). 1898. 198 pages.
11. Taylor J, Paine C, FitzGibbon J. From greenbelt to greenways: four Canadian case studies. *Landsc Urban Plan*. 1995; 33(1–3):47–64.
12. Gordon, D., Scott, R. Ottawa's Greenbelt Evolves from Urban Separator to Key Ecological Planning Component. In: Amati, M. editor. *Urban Green Belts in the Twenty-first Century*. Ashgate; 2008. pp. 129–147.
13. Millenium Ecosystem Assessment (MEA). *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press; 2005. 155 pages.
14. Breuste J., Haase D., and Elmqvist T. Urban Landscapes and Ecosystem Services. In: Wratten S., Sandhu H., Cullen R., and Costanza R., editors. *Ecosystem Services in Agricultural and Urban Landscapes*. Wiley-Blackwell; 2013. pp. 83–104.
15. Sandhu H., Wratten S. Ecosystem Services in Farmland and Cities. In: Wratten S., Sandhu H., Cullen R., Costanza R., editors. *Ecosystem Services in Agricultural and Urban Landscapes*. Wiley-Blackwell; 2013. pp.1–15.
16. Mace GM, Hails RS, Cryle P, Harlow J, Clarke SJ. Towards a risk register for natural capital. *J Appl Ecol*. 2015; 52(3):641–53. <https://doi.org/10.1111/1365-2664.12431> PMID: 27563153
17. Chichilnisky G, Heal G. Economic returns from the biosphere. *Nature* [Internet]. 1998 Feb 12; 391:629. Available from: <http://dx.doi.org/10.1038/35481>
18. Wilson SJ. Ontario's wealth Canada's future: Appreciating the Value of the Greenbelt's Eco-Services. David Suzuki Foundation. Vancouver B.C., Canada; 2008. 62 pages.
19. Statistics Canada. Table 051–0056 - Estimates of population by census metropolitan area, sex and age group for July 1, based on the Standard Geographical Classification (SGC) 2011, annual (persons), CANSIM (database). 2016 February 12. [Cited on 2017 July 3].
20. Statistics Canada. Focus on Geography Series, 2016 Census. Statistics Canada Catalogue no. 98-404-X2016001. Ottawa, Ontario. Data products, 2016 Census. 2017. Available from: <http://www12.statcan.gc.ca/census-recensement/2016/as-sa/fogs-spg/Facts-CMA-Eng.cfm?TOPIC=1&LANG=Eng&GK=CMA&GC=505>
21. Arcand, A., McIntyre, J., Sutherland, G., Wiebe, R. Metropolitan Outlook 1: Economic Insights into 13 Canadian Metropolitan Economies: Autumn 2014. The Conference Board of Canada, October 17 2014. 2014. 78 pages.
22. Bagnall, J. October 20, 2014 [Cited on 2016 October 14]. Ottawa-Gatineau economy is ready to rebound: study. *Ottawa Citizen*. Available from: <https://ottawacitizen.com/news/local-news/worst-may-be-over-for-regions-economy/>
23. Statistics Canada. Table 111–0009 - Family characteristics, summary, annual (number unless otherwise noted), CANSIM (database). 2016 July 12. [Cited on 2017 July 2].
24. Ministère du Développement durable de l'Environnement et de la Lutte contre les changements climatiques. Summary Profile of the Rivière des Outaouais Watershed [Internet]. Bibliothèque et Archives nationales du Québec. Québec, Qc; 2015. 57 p. Available from: <http://www.environnement.gouv.qc.ca/eau/bassinversant/bassins/outaouais/portrait-sommaire-en.pdf>
25. National Capital Commission (NCC). Prior plans for the Capital. [online]. [Cited on 2017 July 3]. Available from: <http://capital2067.ca/legacy/prior-plans-for-the-capital/>
26. National Capital Commission and Del Degan Massé (NCC). Gatineau Park Master Plan. 2005. 129 pages. Available from: <https://ncc-website-2.s3.amazonaws.com/documents/Gatineau-Park-Master-Plan.pdf?mtime=20180830104351>
27. Environics Research. Gatineau Park Visitor and Economic Impact Study Final Report. Report Presented to the National Capital Commission. 2017. 56 pages. Available from: http://publications.gc.ca/collections/collection_2017/ccn-ncc/W93-38-2017-eng.pdf
28. Del Degan Massé. Gatineau Park Ecosystem Conservation Plan. Report presented to the National Capital Commission; 2010. 178 pages.

29. National Capital Commission (NCC). Canada's Capital Greenbelt Master Plan [Internet]. Ottawa, ON; 2013. 196 pages. Available from: http://www.ncc-ccn.gc.ca/sites/default/files/pubs/gbmp-en_jan2014.pdf
30. Jones L, Norton L, Austin Z, Browne AL, Donovan D, Emmett BA, et al. Stocks and flows of natural and human-derived capital in ecosystem services. *Land use policy*. 2016; 52:151–62.
31. He J, Moffette F, Fournier R, Revéret JP, Théau J, Dupras J, et al. Meta-analysis for the transfer of economic benefits of ecosystem services provided by wetlands within two watersheds in Quebec, Canada. *Wetl Ecol Manag*. 2015; 23:707–25.
32. Troy A, Wilson MA. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. *Ecol Econ*. 2006; 60(2):435–49.
33. Agriculture and Agri-Food Canada. Land cover inventory database. Temporal coverage 2014. Available from: <https://open.canada.ca/data/en/dataset/ae61f47e-8bcb-47c1-b438-8081601fa8fe>
34. Haines-Young R., Potschin M. England's terrestrial ecosystem services and the rationale for an ecosystem approach. Full technical report to Defra. Defra Project Code NR0107. 2008. 89 pages. Available from: https://www.nottingham.ac.uk/cem/pdf/NR107_FTR_080108.pdf
35. Dupras J. Évaluation économique des services écosystémiques dans la région de Montréal: analyse spatiale et préférences exprimées. Université de Montréal; 2014. Available from: <https://papyrus.bib.umontreal.ca/xmlui/handle/1866/11333>
36. Dupras J, Alam M, Revéret J-P. Economic value of Greater Montreal's non-market ecosystem services in a land use management and planning perspective. *Can Geogr / Le Géographe Can* [Internet]. 2015; 59(1):93–106. Available from: <http://onlinelibrary.wiley.com.ezproxy.lanacs.ac.uk/doi/10.1111/cag.12138/abstract%5Cnhttp://onlinelibrary.wiley.com.ezproxy.lanacs.ac.uk/store/10.1111/cag.12138/asset/cag12138.pdf?v=1&t=i95eb7fo&s=8fd8964c7ffa1f577e130eb5a0c708acb7b6a9a>
37. Dupras J, Laurent-Lucchetti J, Revéret JP, DaSilva L. Using contingent valuation and choice experiment to value the impacts of agri-environmental practices on landscapes aesthetics. *Landsc Res* [Internet]. 2017; 6397(June):1–17. Available from: <http://doi.org/10.1080/01426397.2017.1332172>
38. Whitehead JC, Pattanayak SK, Van Houtven GL, Gelso BR. Combining revealed and stated preference data to estimate the nonmarket value of ecological services: An assessment of the state of the science. *J Econ Surv*. 2008; 22(5):872–908.
39. Boardman AE, Greenberg DH, Vining AR, Weimer DL. Cost-benefit analysis: concepts and practice. 4th ed. Boston: Pearson Education Inc.; 2011.
40. Bateman I.J., Carson R.T., Day B., Hanemann M., Hanley N., Hett T., et al. Economic Valuation with Stated Preference Techniques—A Manual. Cheltenham: Edward Elgar Publishing, Inc.; 2002.
41. Value of Nature to Canadians Study Taskforce. Completing and Using Ecosystem Service Assessment for Decision-Making: An Interdisciplinary Toolkit for Managers and Analysts. Ottawa, ON; 2017. Available from: <https://biodivcanada.chm-cbd.net/documents/ecosystem-services-toolkit>
42. Toolkit for Ecosystem Service Site-Based Assessment (TESSA). Available from: <http://tessa.tools/>
43. La Financière Agricole Québec (FADQ). Avoine Janvier à Décembre 2013, Coût de production, Revenu stabilisé et compensation d'assurance stabilisation. Direction principale du développement des programmes en assurance. Lévis; 2015 February 12. 3 pages.
44. La Financière Agricole Québec (FADQ). Blé d'alimentation humaine Janvier à Décembre 2013, Coût de production, Revenu stabilisé et compensation d'assurance stabilisation. Direction principale du développement des programmes en assurance. Lévis; 2015 February 12. 3 pages.
45. La Financière Agricole Québec (FADQ). Maïs Janvier à Décembre 2013, Coût de production, Revenu stabilisé et compensation d'assurance stabilisation. Direction principale du développement des programmes en assurance. Lévis; 2015 February 12. 3 pages.
46. La Financière Agricole Québec (FADQ). Orge Janvier à Décembre 2013, Coût de production, Revenu stabilisé et compensation d'assurance stabilisation. Direction principale du développement des programmes en assurance. Lévis; 2015 February 12. 3 pages.
47. La Financière Agricole Québec (FADQ). Soya Janvier à Décembre 2013, Coût de production, Revenu stabilisé et compensation d'assurance stabilisation. Direction principale du développement des programmes en assurance. Lévis; 2015 February 12. 3 pages.
48. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2014 Grain and Oilseeds (in Metric units), from Area, Yield, Production and Farm Value of Specified Field Crops, Ontario, 2012–2017 (Imperial and Metric Units). [Cited on 2017 June 19]. Available from: http://www.omafra.gov.on.ca/english/stats/crops/estimate_new.htm
49. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2016 Field Crop Budgets, Business Analysis and Cost of Production Program and OMAFRA Field Crops Unit. © Queen's Printer for Ontario: Toronto; 2015. ISSN 0838-5657X, 20 pages.

50. Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ). Haricots secs de couleur, Budget, AGDEX 142/821a, Septembre 2011. *Références économiques*. 2011. 5 pages.
51. Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ). Fraises d'été standard (en rang nattés), Budget, AGDEX 232/821, Février 2014. *Références économiques*. 2014. 10 pages.
52. Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ). Foin de luzerne et de mil sans plante-abri, Budget, AGDEX 121/821, Octobre 2014. *Références économiques*. 2014. 6 pages.
53. Winfree R, Gross BJ, Kremen C. Valuing pollination services to agriculture. *Ecol Econ* [Internet]. 2011; 71(1):80–8. Available from: <http://dx.doi.org/10.1016/j.ecolecon.2011.08.00184>.
54. Rands SA, Whitney HM. Field margins, foraging distances and their impacts on nesting pollinator success. *PLoS One*. 2011; 6(10):e25971. <https://doi.org/10.1371/journal.pone.0025971> PMID: 21991390
55. Morse RA, Calderone NW. The value of honey bees as pollinators of US crops in 2000. *Bee Cult* [Internet]. 2000; 128(March 2000):1–15. Available from: <http://www.beeculture.com/content/pollinationreprint07.pdf%5Cnpapers2://publication/uuid/480F22F5-2367-4853-AD20-88441298BE0B85>.
56. Fetridge ED, Ascher JS, Langellotto GA. The bee fauna of residential gardens in a suburb of New York City (Hymenoptera: Apoidea). *Ann Entomol Soc Am*. 2008; 101(6):1067–77.
57. Agriculture and Agri-Food Canada (AAC). Statistical Overview of the Canadian Honey and Bee Industry and the Economic Contribution of Honey Bee Pollination. 2017; Available from: https://www.agr.gc.ca/resources/prod/doc/pdf/honey_2016-eng.pdf
58. Environment and Climate Change Canada. Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates. 2016. 44 pages.
59. Van der Ploeg, S. and de Groot, R.S. The TEEB Valuation Database—a searchable database of 1310 estimates of monetary values of ecosystem services. Wageningen, The Netherlands, Foundation for Sustainable Development. 2010.
60. Hirabayashi S. i-Tree Canopy Air Pollutant Removal and Monetary Value Model Descriptions. 2014.
61. Hein L. Economic benefits generated by protected areas: The case of the Hoge Veluwe Forest, the Netherlands. *Ecol Soc*. 2011; 16(2).
62. Morri E, Pruscini F, Scolozzi R, Santolini R. A forest ecosystem services evaluation at the river basin scale: Supply and demand between coastal areas and upstream lands (Italy). *Ecol Indic* [Internet]. 2014; 37(PART A):210–9. Available from: <http://dx.doi.org/10.1016/j.ecolind.2013.08.016>
63. Croitoru L. How much are Mediterranean forests worth? *For Policy Econ*. 2007; 9(5):536–545. <https://doi.org/10.1016/j.forpol.2006.04.001>
64. Yoo J, Simonit S, Connors JP, Kinzig AP, Perrings C. The valuation of off-site ecosystem service flows: Deforestation, erosion and the amenity value of lakes in Prescott, Arizona. *Ecol Econ* [Internet]. 2014; 97:74–83. Available from: <http://dx.doi.org/10.1016/j.ecolecon.2013.11.001>
65. Kniivilä M, Ovaskainen V, Saastamoinen O. Costs and benefits of forest conservation: regional and local comparisons in Eastern Finland. *J For Econ* [Internet]. 2002; 8(2):131–50. Available from: <http://www.sciencedirect.com/science/article/pii/S1104689904700094>
66. Loomis J, and Ekstrand E. Alternative approaches for incorporating respondent uncertainty when estimating willingness to pay: the case of the Mexican spotted owl. *Ecol Econ*. 1998; 27(1): 29–41. [https://doi.org/10.1016/S0921-8009\(97\)00126-2](https://doi.org/10.1016/S0921-8009(97)00126-2)
67. Siikamäki J, and Layton DF. Potential Cost-Effectiveness of Incentive Payment Programs for the Protection of Non-Industrial Private Forests. *Land Econ*. 2007; 83(4): 539–560. Available from: <https://www.jstor.org/stable/27647793>
68. Remme RP, Edens B, Schröter M, Hein L. Monetary accounting of ecosystem services: A test case for Limburg province, the Netherlands. *Ecol Econ* [Internet]. 2015; 112:116–28. Available from: <http://dx.doi.org/10.1016/j.ecolecon.2015.02.015>
69. Häyhä T, Franzese PP, Paletto A, Fath BD. Assessing, valuing, and mapping ecosystem services in Alpine forests. *Ecosyst Serv* [Internet]. 2015; 14:12–23. Available from: <http://dx.doi.org/10.1016/j.ecoser.2015.03.001>
70. Ninan KN, Inoue M. Valuing forest ecosystem services: Case study of a forest reserve in Japan. *Ecosyst Serv* [Internet]. 2013; 5:78–87. Available from: <http://dx.doi.org/10.1016/j.ecoser.2013.02.006>
71. Xue D, Tisdell C. Valuing ecological functions of biodiversity in Changbaishan Mountain Biosphere Reserve in Northeast China. *Biodivers Conserv*. 2001; 10(3):467–81. <https://doi.org/10.1023/A:1016630825913>
72. Garrod GD, and Willis KG. The non-use benefits of enhancing forest biodiversity: A contingent ranking study. *Ecol Econ*. 1997; 21(1):45–61. [https://doi.org/10.1016/S0921-8009\(96\)00092-4](https://doi.org/10.1016/S0921-8009(96)00092-4)

73. Knowler DJ, MacGregor BW, Bradford MJ, & Peterman RM. Valuing freshwater salmon habitat on the west coast of Canada. *J Environ Manage*. 2003; 69:261–273. <https://doi.org/10.1016/j.jenvman.2003.09.001> PMID: 14580727
74. Ovando P, Oviedo JL, Campos P. Measuring total social income of a stone pine afforestation in Huelva (Spain). *Land use policy*. 2016; 50:479–89. <https://doi.org/10.1016/j.landusepol.2015.10.015>
75. Roesch-McNally GE, Rabotyagov SS. Paying for Forest Ecosystem Services: Voluntary Versus Mandatory Payments. *Environ Manage*. 2016; 57(3):585–600. <https://doi.org/10.1007/s00267-015-0641-7> PMID: 26661136
76. Scarpa R, Chilton SM, Hutchinson WG, Buongiorno J. Valuing the recreational benefits from the creation of nature reserves in Irish forests. *Ecol Econ*. 2000; 33(2):237–50. [https://doi.org/10.1016/S0921-8009\(99\)00143-3](https://doi.org/10.1016/S0921-8009(99)00143-3)
77. Walsh RG, Loomis J, Gillman RA. Valuing Option, Existence, and Bequest Demands for Wilderness. *Land Econ*. 1984; 60:14–29. Available from: <https://www.jstor.org/stable/3146089?seq=1>
78. Folke C. The Societal Value of Wetland Life-Support. In: Folke C., Kåberger T. (eds) *Linking the Natural Environment and the Economy: Essays from the Eco-Eco Group*. Ecology, Economy & Environment, vol 1. Springer, Dordrecht; 1991. pp. 141–171. PMID: 1881219
79. Farber S. Welfare loss of wetlands disintegration: A Louisiana study. *Cont Econ Pol*. 1996; 14(1): 92–106. <https://doi.org/10.1111/j.1465-7287.1996.tb00606.x>
80. Fox G, Dickson EJ. The Economics of Erosion and Sediment Control in Southwestern Ontario. Vol. 38, *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*. 1990. p. 23–44. <https://doi.org/10.1111/j.1744-7976.1990.tb03447.x>
81. Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, McNair M, et al. Environmental and Economic Costs of Soil Erosion and Conservation Benefits. *Science* (80-). 1995; 267(5201):1117–23. <https://doi.org/10.1126/science.267.5201.1117> PMID: 17789193
82. Dupras J, Revéret J-P, He J. L'évaluation économique des biens et services écosystémiques dans un contexte de changements. *Ouranos*. 2013; 218.
83. Alvarez-Farizo B, Hanley N, Wright RE, Macmillan D. Estimating the benefits of agri-environmental policy: Econometric Issues in Open-ended Contingent Valuation Studies. *J Environ Plan Manag*. 1999; 42(1):23–43.
84. Bastian CT, McLeod DM, Germino MJ, Reiners WA, Blasko BJ. Environmental amenities and agricultural land values: A hedonic model using geographic information systems data. *Ecol Econ*. 2002; 40(3):337–49.
85. Bowker JM, Didychuk DD. Estimation of the Nonmarket Benefits of Agricultural Land Retention in Eastern Canada. *Agric Resour Econ Rev*. 1994; 23(2):218–25.
86. Sandhu HS, Wratten SD, Cullen R, Case B. The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecol Econ*. 2008; 64(4):835–848. <https://doi.org/10.1016/j.ecolecon.2007.05.007>
87. Poder T, Dupras J, Fetue Ndefo F, He J. La valeur économique de la Ceinture et trame bleue du Grand Montréal. Montréal; 2015.
88. Kurz WA, Apps MJ. A 70-year retrospective analysis of carbon fluxes in the Canadian Forest Sector. *Ecol Appl*. 1999; 9(2):526–47.
89. Nowak DJ, Crane DE, Stevens JC. Air pollution removal by urban trees and shrubs in the United States. *Urban For Urban Green*. 2006; 4(3–4):115–23.
90. Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, et al. Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. *Ecol Lett*. 2007; 10(4):299–314. <https://doi.org/10.1111/j.1461-0248.2007.01018.x> PMID: 17355569
91. National Capital Commission. 2014–2015 Annual Report. Catalogue number: W91E-PDF. 94 pages.
92. Kosz M. Valuing riverside wetlands: the case of the “Donau-Auen” national park. *Ecol Econ*. 1996; 16(2): 109–127. [https://doi.org/10.1016/0921-8009\(95\)00058-5](https://doi.org/10.1016/0921-8009(95)00058-5)
93. Meyerhoff J and Dehnhardt A. The European Water Framework Directive and economic valuation of wetlands: The restoration of flood-plains along the River Elbe. *Eur Environ*. 2007; 17(1): 18–36. <https://doi.org/10.1002/eet.439>
94. Pate J, Loomis J. The effect of distance on willingness to pay values: A case study of wetlands and salmon in California. *Ecol Econ*. 1997; 20(3):199–207. [https://doi.org/10.1016/S0921-8009\(96\)00080-8](https://doi.org/10.1016/S0921-8009(96)00080-8)

95. Breaux A, Farber S, Day J. Using Natural Coastal Wetlands Systems for Wastewater Treatment: An Economic Benefit Analysis. *J Environ Manage.* 1995; 44: 285–291. <https://doi.org/10.1006/jema.1995.0046>
96. Jenkins WA, Murray BC, Kramer RA, Faulkner SP. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecol Econ.* 2010; 69:1051–1061. <https://doi.org/10.1016/j.ecolecon.2009.11.022>
97. Byström O. The replacement value of wetlands in Sweden. *Environ Res Econ.* 2000; 16(4): 347–362. <https://doi.org/10.1023/A:1008316619355>
98. Dunderdale JAL, Morris J. The Benefit: Cost Analysis of River Maintenance. *J Inst Water Environ Manag.* 1997; 11:423–430. <https://doi.org/10.1111/j.1747-6593.1997.tb01375.x>
99. Garneau M, Van Bellen S. Synthèse de la valeur et la répartition du stock de carbone terrestre au Québec. 2016.
100. Lafleur PM, Roulet NT, Admiral SW. Annual cycle of CO₂ exchange at a bog peatland. *J Geophys Res Atmos.* 2001; 106(D3):3071–81.
101. Smith WN, Desjardins RL, Grant B. Estimated changes in soil carbon associated with agricultural practices in Canada. *Can J Soil Sci.* 2001; 81:221–7.
102. Costanza R, D'Arge R, De Groot R, Farber S, Grasso M, Hannon B, et al. The value of the world's ecosystem services and natural capital. *Nature.* 1997; 387(6630):253–60. 59.
103. Boxall PC. The Economic Value of Lottery-Rationed Recreational Hunting. *Can J Agri Econ.* 1995; 43:119–131.
104. Dodds WK, Bouska WW, Eitzmann JL, Pilger TJ, Pitts KL, Riley AJ, et al. Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. *Environ Sci Technol* [Internet]. 2009; 43(1):12–9. Available from: <https://doi.org/10.1021/es801217q> PMID: 19209578
105. Pretty JN, Mason CF, Nedwell DB, Hine RE, Leaf S, Dils R. Environmental costs of freshwater eutrophication in England and Wales. *Environ Sci Technol.* 2003; 37(2):201–8. <https://doi.org/10.1021/es020793k> PMID: 12564888
106. Van Houtven G, Mansfield C, Phaneuf DJ, von Haefen R, Milstead B, Kenney MA, et al. Combining expert elicitation and stated preference methods to value ecosystem services from improved lake water quality. *Ecol Econ.* 2014; 99:40–52. <https://doi.org/10.1016/j.ecolecon.2013.12.018>
107. Mueller H, Hamilton DP, Doole GJ. Evaluating services and damage costs of degradation of a major lake ecosystem. *Ecosyst Serv* [Internet]. 2015;1–11. Available from: <http://dx.doi.org/10.1016/j.ecoser.2016.02.037>
108. Nelson NM, Loomis JB, Jakus PM, Kealy MJ, von Stackelburg N, Ostermiller J. Linking ecological data and economics to estimate the total economic value of improving water quality by reducing nutrients. *Ecol Econ* [Internet]. 2015; 118:1–9. Available from: <http://dx.doi.org/10.1016/j.ecolecon.2015.06.013>
109. Zhang C, Boyle KJ. The effect of an aquatic invasive species (Eurasian watermilfoil) on lakefront property values. *Ecol Econ* [Internet]. 2010; 70(2):394–404. Available from: <http://dx.doi.org/10.1016/j.ecolecon.2010.09.011>
110. Olden JD, Tamayo M. Incentivizing the public to support invasive species management: Eurasian milfoil reduces lakefront property values. *PLoS One.* 2014; 9(10):15–20. <https://doi.org/10.1371/journal.pone.0110458> PMID: 25333619
111. Tuttle CM, Heintzelman MD. A loon on every lake: A hedonic analysis of lake water quality in the Adirondacks. *Resour Energy Econ* [Internet]. 2015; 39:1–15. Available from: <http://dx.doi.org/10.1016/j.reseneeco.2014.11.001>
112. Zedler JB, Kercher S. Wetland Resources: Status, Trends, Ecosystem Services, and Restorability. *Annu Rev Environ Resour.* 2005; 30(1):39–74.
113. He J, Dupras J, Poder TG. The value of wetlands in Quebec: a comparison between contingent valuation and choice experiment. *J Environ Econ Policy* [Internet]. 2017; 6(1):51–78. Available from: <https://www.tandfonline.com/doi/full/10.1080/21606544.2016.1199976>
114. Nikodinoska N, Paletto A, Pastorella F, Granvik M, Franzese PP. Assessing, valuing and mapping ecosystem services at city level: The case of Uppsala (Sweden). *Ecol Modell* [Internet]. 2018; 368:411–24. Available from: <http://dx.doi.org/10.1016/j.ecolmodel.2017.10.013>
115. Tammi I, Mustajärvi K, Rasinmäki J. Integrating spatial valuation of ecosystem services into regional planning and development. *Ecosyst Serv* [Internet]. 2017; 26 Part B(August):329–44. Available from: <http://dx.doi.org/10.1016/j.ecoser.2016.11.008>
116. Baró F, Gómez-Baggethun E, Haase D. Ecosystem service bundles along the urban-rural gradient: Insights for landscape planning and management. *Ecosyst Serv.* 2017; 24:147–59.

117. Kroll F, Müller F, Haase D, Fohrer N. Rural-urban gradient analysis of ecosystem services supply and demand dynamics. *Land use policy* [Internet]. 2012; 29(3):521–35. Available from: <http://dx.doi.org/10.1016/j.landusepol.2011.07.008>
118. Compton JE, Harrison JA, Dennis RL, Greaver TL, Hill BH, Jordan SJ, et al. Ecosystem services altered by human changes in the nitrogen cycle: A new perspective for US decision making. *Ecol Lett*. 2011; 14(8):804–15. <https://doi.org/10.1111/j.1461-0248.2011.01631.x> PMID: 21624028
119. Maes J, Egoh B, Willemens L, Liqueste C, Vihervaara P, Schägner JP, et al. Mapping ecosystem services for policy support and decision making in the European Union. *Ecosyst Serv*. 2012; 1(1):31–9.
120. Albert C, Aronson J, Fürst C, Opdam P. Integrating ecosystem services in landscape planning: requirements, approaches, and impacts. *Landsc Ecol*. 2014; 29(8):1277–85.
121. Martinez-Harms MJ, Bryan BA, Balvanera P, Law EA, Rhodes JR, Possingham HP, et al. Making decisions for managing ecosystem services. *Biol Conserv* [Internet]. 2015; 184:229–38. Available from: <http://dx.doi.org/10.1016/j.biocon.2015.01.024>
122. Hansen R, Frantzeskaki N, McPhearson T, Rall E, Kabisch N, Kaczorowska A, et al. The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosyst Serv* [Internet]. 2015; 12:228–46. Available from: <http://dx.doi.org/10.1016/j.ecoser.2014.11.013>
123. Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, et al. Ecosystem services in decision making: Time to deliver. *Front Ecol Environ*. 2009; 7(1):21–8.
124. Laurans Y, Rankovic A, Billé R, Pirard R, Mermet L. Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. *J Environ Manage* [Internet]. 2013; 119:208–19. Available from: <https://doi.org/10.1016/j.jenvman.2013.01.008> PMID: 23500023
125. Guerry AD, Polasky S, Lubchenco J, Chaplin-Kramer R, Daily GC, Griffin R, et al. Natural capital and ecosystem services informing decisions: From promise to practice. *Proc Natl Acad Sci* [Internet]. 2015; 112(24):7348–55. Available from: <http://www.pnas.org/lookup/doi/10.1073/pnas.1503751112> PMID: 26082539
126. Brunette, V. Programmes incitatifs dans les bassins versants qui approvisionnent New York en eau potable. Colloque en agroenvironnement Le respect de l'environnement : tout simplement essentiel! 2008. Drummondville. 9 pages.
127. Sattler C, Matzdorf B. PES in a nutshell: From definitions and origins to PES in practice—Approaches, design process and innovative aspects. *Ecosyst Serv*. 2013; 6:2–11.
128. Schomers S, Matzdorf B. Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosyst Serv*. 2013; 6:16–30.
129. Mitchell MGE, Bennett EM, Gonzalez A. Linking Landscape Connectivity and Ecosystem Service Provision: Current Knowledge and Research Gaps. *Ecosystems* [Internet]. 2013; 16(5):894–908. Available from: <http://dx.doi.org/10.1007/s10021-013-9647-2>
130. Dupras J, Patry C, Tittler R, Gonzalez A, Alam M, Messier C. Management of vegetation under electric distribution lines will affect the supply of multiple ecosystem services. *Land use policy* [Internet]. 2016; 51:66–75. Available from: <http://dx.doi.org/10.1016/j.landusepol.2015.11.005>
131. Dupras J, Drouin C, André P, Gonzalez A. Towards the Establishment of a Green Infrastructure in the Region of Montreal (Quebec, Canada). *Plan Pract Res*. 2015; 30(4):355–75.
132. Butler D. NCC green spaces provide \$332M in annual economic value: study. *Ottawa Citizen* [online]. December 6, 2016. [Cited 2017 July 3] [Last accessed 2020 April 2]. Available from: <http://ottawacitizen.com/news/local-news/ncc-green-spaces-provide-332m-in-annual-economic-value-study>
133. Butler D. NCC green spaces provide \$332M in annual economic value: study. *Ottawa Sun* [online]. December 6, 2016. [Cited 2017 July 3] [Last accessed 2020 April 2]. Available from: <http://www.ottawasun.com/2016/12/06/ncc-green-spaces-provide-332m-in-annual-economic-value-study>
134. Sabourin B. Un cowboy dans le labo, Le Droit. [online]. 2017 January 27. [Cited on 2017 July 3]. Available from: <https://www.ledroit.com/actualites/petite-nation/un-cowboy-dans-le-labo-0565ea8eee91bd53664db2b5fd9fd3ca>