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Open-source based geo-platform to support management of wetlands and biodiversity in Quebec

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ABSTRACT

Wetlands are one of the most productive environments in the world. Despite their importance for water and carbon cycle regulation, wildlife survival and economic value, human activities along with severe climate changes have led to critical loss and degradation of these ecosystems. In Canada, where these lands still occupy a notable percentage of the territory (~14%), efficient strategies and public awareness measures to protect them are required. The Open Government program fosters accessibility to a large amount of data for developing approaches and applications that contribute to this purpose. Web cartographic implementations represent a potential tool for integration and diffusion of diversified information that can support the protection of natural habitats.

In this paper, we present an open-source geo-platform that supports multi-scale management of wetlands and biodiversity in Quebec. This friendly and dynamic prototype allows integration of multisource data, providing, as well, the possibility of geovisualization and correlation analysis of possible stressors impacting these ecosystems. This system proposes useful and easy-to-use functionalities that can facilitate identification of possible habitats in danger. The prototype proposed is flexible and can be adapted to assist other biodiversity studies as well as the practical needs of responsible groups such as planners, conservationists and landscape managers.

1. Introduction

Actual and future trends of human population (UNDESA, 2015), unsustainable urban sprawl and land use practices (UNDESA, 2014) suggest that further loss of wetlands, perturbation of their ecological functions and disappearance of local biodiversity may persist. In Canada, where wetlands cover 14% of the territory and represent 25% of the world's reserves, a notable loss of these unique ecosystems have been recorded (Environment Canada, 2009). Particularly, in Canadian prairies, intensive agriculture practices have rapidly deteriorated and reduced the number of wetlands (Bartzen et al., 2010). In southern Canada, expansion of built-up areas (urban and/or rural) has affected these natural habitats, especially where agglomerations and industrial centres are developed (Canadian Wildlife Service and Environment Canada, 2014). In Quebec, where about 10% of the territory is covered by wetlands (Gouvernement du Québec, 2016), there has been a significant progress in environmental protection and conservation actions (Environment Canada, 2009; Joly et al., 2008). Nevertheless, deterioration of wetlands is still a critical issue.

In the recent years, the Government of Canada has fostered accessibility to a large amount of high-value data useful for developing essential applications that can contribute to basic conservation of wetlands and biodiversity (Government of Canada, 2016a). This large database has rapidly increased due to the advent of new technology that allows fast acquisition of data, at a relatively low cost, compared to traditional in-situ surveys. Satellite imagery, for example, has notably contributed to the mapping, inventory and monitoring of wetlands (e.g., Rebelo et al., 2009; Sun et al., 2016) and habitat change at a global scale (e.g., All and Nelson, 2008; Kim et al., 2014). On the other hand, Geographic Information systems (GIS) allow the integration and analysis of data that can be shared and visualized via Web GIS applications. The Canadian Ducks Unlimited Organization has developed various tools that fulfil these tasks (e.g., Canada Wetland Inventory Progress; Ducks Unlimited Canada, 2016a). Many programs concentrate on the production of interactive maps that provide valuable information on wetlands at local (e.g., Smith Creek Watershed; Ducks Unlimited Canada, 2016b) and regional scale (e.g., Ducks Unlimited Canada, 2014; Ducks Unlimited Canada, 2016c) as well as on related components (Ducks Unlimited Canada, 2008). Some of these implementations are based on commercial applications (e.g., Esri ARCIms) which flexibility for being extended or adapted to particular objectives may be restrained. However, according to the Open Government

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program guidelines (Government of Canada, 2016a), open source geoplatforms are desirable.

Although the existing platforms are very effective in wetland mapping none of them cover the entire province of Quebec. Moreover, to the authors' knowledge, no open-source-based interactive map that integrates wildlife and elements that allow a preliminary evaluation of possible threats to these ecosystems has been produced up to now in the province.

This work presents a preliminary Web GIS prototype for supporting preservation of wetlands and biodiversity in Quebec. This system facilitates combination, interaction and visualization of various datasets that help characterization of wetlands state. The system offers useful functionalities for rapid identification of fragmented habitats and evaluation and/or readjustment of possible zonation areas to protect wildlife. Additionally, data access at different spatial scale is possible thanks to a multiscale functionality.

The remainder of this paper is organized as follows. Section 2 briefly describes the main issues in wetland and biodiversity preservation in Quebec. In Section 3 the available datasets employed and their formats are presented, and the role of some key stressors in the ecosystems functioning of the province is addressed. Sections 4 and 5 characterize the web system architecture, database and components. Section 6 discusses some case examples of useful services the portal offers and future perspectives. Finally, conclusions are presented in Section 7.

2. Overview of the situation of wetlands in Quebec

Quebec, the second most populated province of Canada (NRCAN, 2016a; 8,263,600 people in 2015; André, 2015), possesses a great diversity of wetlands that serve as habitat to a large variety of species either permanently or temporarily, being bogs the most common in the province (85%; Pellerin and Moulin, 2013). As other Canadian provinces, Quebec has been undergoing a notable urban and consumption transformation (Asselin, 2011; Simmons and Bourne, 2013). Provincial statistics indicate continuous population growth (Institut de la statistique du Québec, 2014), which may be accompanied with expansion of infrastructure and public services at the cost of wetlands loss. In the region of Montreal, around 85% of wetlands were destroyed by 2015 and devastation may continue (Gerbet, 2015). In the Eastern Townships, where 2.1% of the territory is occupied by wetlands that host a rich fauna (e.g., Palm Warbler, Rusty Blackbird, Goldeneye, Yellow Perch, Smallmouth bass, Walleye) the situation is not much different (Canards Illimités Canada, 2007a). Urban expansion, artificialization of riverbanks, water treatment stations and other man-made constructions are the main stressors in this region and other ones. Comprised between the regions of Mauricie, Lanaudière, Montérégie and Centre-du-Quebec, the lake Saint-Pierre, one of the richest biospheres in the world, shelter extensive wetlands and waterfowl that are critically disturbed by various sources (e.g., navigation practices, input of pollutants, water level manipulation; Canards Illimités Canada, 2007b; MDDELCC et al., 2013).

In the high-latitude coastal regions of Quebec, conditions are favourable for the formation of salty marshes and optimal nesting of coastal birds (e.g., herons, roseate tern, herring gull) (Barbour and Billings, 1988). Nevertheless, drastic climate changes at these northern locations are predicted to produce critical impact on ecosystems (Canards Illimités Canada, 2009). The spillage of hydrocarbon-based products from commercial navigation is another critical and constant threat to coastal habitats. To illustrate the gravity of this risk we can name the case of 2015, when 14 oil spills occurred in the north of Quebec (MDDECC, 2016). Moreover, large hydroelectric projects have also influenced a number of wetlands at these locations (e.g., Outardes and Manicouagan rivers; Canards Illimités Canada, 2009). One specific example of this situation is the bogs notably perturbed by La Grande River installation, which requires important deviations of the natural river to supply 97% of the energy employed in Quebec (MERN, 2012).

Table 1
Data and corresponding sources employed.

	Data	Source data type	Transferred data type
1	Wetland inventory	Shapefile	WMS
2	Wildlife	Shapefile	Geojson
3	Provinces of Canada	Shapefile	Geojson
4	Regions of Quebec	Shapefile	Geojson
5	MRC of Quebec	Shapefile	Geojson
6	Fire	KMZ	Geojson
7	Invasive species (Hemlock looper)	Shapefile	Geojson
8	Power lines	Shapefile	Geojson
9	Highways	Shapefile	Geojson
10	Population	CSV	Json
11	Pollution sources	CSV	Geojson
12	Drought	Shapefile	Geojson
13	Water quality	Kmz	Geojson
14	Water quantity	Kmz	Geojson
15	BaseMap1	Raster	WMS
16	BaseMap2	Raster	WMS

Governmental and non-governmental institutions make continuous efforts to protect and conserve these valuable lands and biota by exploiting new technologies but also considering legal aspects to achieve conservation purposes (e.g., LégisQuébec, 2016). Many territories have already implemented urban plans that include regulations for preservation of these and other natural areas (e.g., Longueuil Direction de l'aménagement et de l'urbanisme, 2014; Ville de Gatineau, 2016).

3. Data selection and formats

Table 1 summarizes the available data used in this project. Wetlands polygons are one of the main geospatial components of the map. Five main types of wetlands (bog, marsh, swamp, shallow water, non-classified), derived from satellite imagery and photography are included (Ducks Unlimited Canada, 2016d). Specific wetland biodiversity data was not available; however, we include a fauna habitat layer to facilitate the identification of species within wetlands polygons. This dataset was established from wildlife inventories and other thematic information (MFFP, 2016a).

Because decisions about conservation, territorial and land use planning are taken at various political divisions (Fig. 1), three main levels of administrative divisions were integrated in a multiscale database (Section 4.2). Efficient preservation of natural habitats also requires identification of stressors in order to develop or improve management strategies. Many representative stressors were recognized to affect wetlands and biodiversity in Quebec (Fig. 1). Below we present the stressors that are part of the geoportal. They were chosen on the basis of their availability and pertinence to the project.

In Quebec metropolitan areas, two of the main pressures on these ecosystems are the notable urbanization and industrialisation (e.g., Queste, 2011). Information about population related to these processes at regional and MRC (Municipalité régionale de comté) levels are considered for analysis (St-Amour et al., 2015). Manufacturing, production and processing sites produce detrimental substances that can affect quality and quantity of water, air and soil. Mining activities, for example, uses large volumes of water for petroleum, minerals and gas exploitation (Ptacek et al., 2013), endangering availability of this essential resource and possibly altering hydraulic functions of wetlands. A layer containing multiple pollution sources (e.g., Chemical, Paper, Oil industries, Power Plants and others), as well as water quantity and quality data produced by the Open Government Program are incorporated in the geoportal. Highways and roads can transport sediments, chemicals and other polluting elements coming from industry, agriculture and urban areas into these ecosystems. Moreover, because noise pollution from road traffic can also influence birds' behaviour (Parris and Schneider, 2008), they are significant stressors of wetlands