A GIS-based model of ecosystem services for the Northeast Swale in Saskatoon, Saskatchewan

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ABSTRACT

Protecting natural places on urban fringes requires tools that are dynamic, easy to update, and support analysis. A Web GIS system was produced to develop an ecosystem services-based framework for the Northeast Swale, a natural protected area in Saskatoon, Saskatchewan. Data were integrated in a user-friendly Web GIS system to identify ecosystem services and their values. The building of the tool and its connection with the spatial data of the ecosystem are discussed.

1. Introduction

The Northeast Swale (hereafter the Swale) is a natural protected area in the northeast of the city of Saskatoon, Saskatchewan. The Swale provides important ecological, environmental, and cultural benefits (City of Saskatoon, 2018), but is under increasing pressure from the cumulative impacts of human activity and urban land use. Disturbances in this area have caused a decrease in species diversity and an increase of invasive species. The planning and future development of adjacent residential neighborhoods is an enduring threat, that will shrink and further impact the Swale (Gersher, 2015)

The overall goal of this project is to develop and apply an ecosystem services-based regional strategic environmental assessment (RSEA) framework to evaluate baselines and assess potential risks of future conservation and development scenarios for the Swale. Ecosystem services (ES) are the benefits that society obtains from healthy and functioning ecosystems (ChapinIII, 2013), including food provision, flood control, and cultural benefits (D.S.Ojima, 2013). To make informed decisions about the protection of ES, City planners, conservation authorities and land developers need baseline information about ES, the importance of those services, and an understanding of how different choices about land development affect ES. The evaluation of ES is thus essential to assessing, planning for, and understanding the impacts of lade use decisions (Kenneth J. Bagstad, 2012). A major challenge, however, is that current land use planning processes, particularly urban land use plans, rarely integrate futures-based strategic assessments of 'what if' scenarios.

GIS is increasingly used to support the evaluation of ES, as it can emphasize the

spatial relationships between land use and human activities (R.S.de Groot, 2010). GIS also helps to present the complexity of current and future land use scenarios that urban areas are facing (Philip Stessens, 2017). In previous studies (Austin Troy, 2006), GIS technology has also been linked as a tool to value ES, using a transfer method with spatial analysis. With the development of Internet technology, Web GIS has been widely used. Compared with traditional GIS, Web GIS allows multiple users to access maps and supporting data, and to effectively manage resources, which can increase the flexibility and reliability of GIS applications for ES valuations and assessments (Su Tianyun, 2008).

In this paper we develop a Web GIS platform to visualize existing ES provided by the Swale, and to identify future conservation and development pressures. The sections that follow describe the development of the Web GIS tool to connect spatial information with ES. The online maps developed integrate important features, such as disturbed areas, rare species observation locations, and cultural heritage sites. Landscape scanning shows changes in the Swale landscape over half a century. Three scenarios, baseline, no growth, and fully development, are then shown to depict possible future pressures to ES services in the Swale under different levels of development and conservation.

The results from this work will serve as input to a participatory Web-based survey of city residents, using a choice experiment design, to assess future scenarios and derive ES values. In this paper, we focus on the Web GIS platform.

2. Study Area, Data and Methods

2.1 Study area

The study area for this project is in the northeast region of the City of Saskatoon, Saskatchewan (Figure 1). The Swale is a 26-kilometer-long corridor that links native prairie uplands and a series of wetlands. The Swale is home to hundreds of species, including federally-identified species of concern. The Swale is also subject to the cumulative stress of a growing city, including residential development, storm water drainage, and an approved commuter parkway.
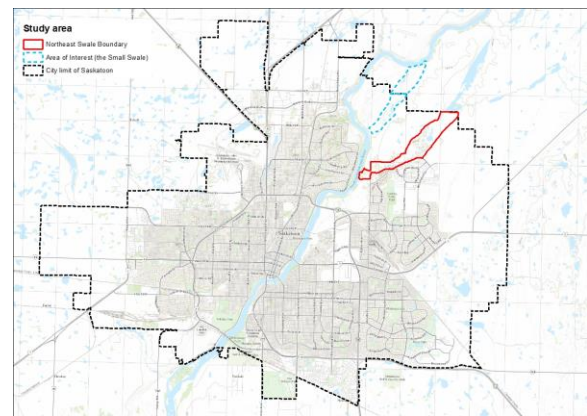

Figure 1. Study area.

2.2 Data

Five categories of data were employed: (1) the study area delineation, (2) development and conservation (land use polygons, road construction current and future), neighborhood areas, trails, and target management areas, (3) ecological environments (rare species observation locations, habitat area, wetland area, and vegetation-type polygons), (4) cultural heritage (historical highlights data were gathered, such as the pinned rock, Moose Woods Batoche Trail), and (5) alternative scenarios of land uses. Shapefile features are shared with the Meewasin Valley Authority (MVA) - – a conservation agency created under the provincial Meewasin Valley Authority Act for the management of lands in the South Saskatchewan River Valley, including Saskatoon's Northeast Swale.

Aerial photographs showing changes in the landscape were provided by the University of Saskatchewan Library, the National Air Photo Library, and Natural Resources Canada. Photographs from year 1956 and

year 1977 were processed. Landsat satellite level-2 imagery was downloaded from the USGS website and was used to represent the landscape in 1988, 1998, 2008, and 2018. Airborne Lidar imagery was collected from the City of Saskatoon to analyze surface features.

2.3 Methods

A Web GIS was developed to present a baseline Swale map. Geospatial data were gathered and uploaded into the Web GIS server so users can view them in a Web browser or other electronic device with Internet access. Web GIS is a data management tool that allows users to choose specific targets and easily turn data layers on and off (Ningning Kong, 2014). Web GIS supports multiple data sources such as HTML and JavaScript so that designers meet client and user requirements (Yu Nakayama, 2017).

Figure 2 illustrates the Web GIS model. Shapefiles were input into ArcMap for spatial analysis. Maps were generated with selected styles, saved as .mxd files, stored in a Microsoft SQL Server, then published using ArcGIS API for JavaScript.

Aerial photographs of Saskatoon taken in different years were mosaiced and georeferenced. We used the City of Saskatoon road map as the reference for mosaic image registration; this also provided the basis for all map scales. Photographs

were processed in Esri ArcGIS software. Aerial photographs from 1960 and 1972 were geo-referenced for use in the online map. Airborne Lidar imagery was collected for 2017 with 67 tiles covering the Swale region. Data for full feature cloud points and bare earth points were explored.

The 67 tiles covering the Swale region were assembled in a mosaic with 1 m spatial resolution and 0.05 m vertical accuracy in Esri ArcGIS software to generate the raster layers of the digital elevation model (DEM) and the digital terrain model (DTM). The DEM was from the bare earth point clouds, and the DTM was from the full feature point clouds. Then the imagery was put into the ArcScene to show the different elevations of the surface features.
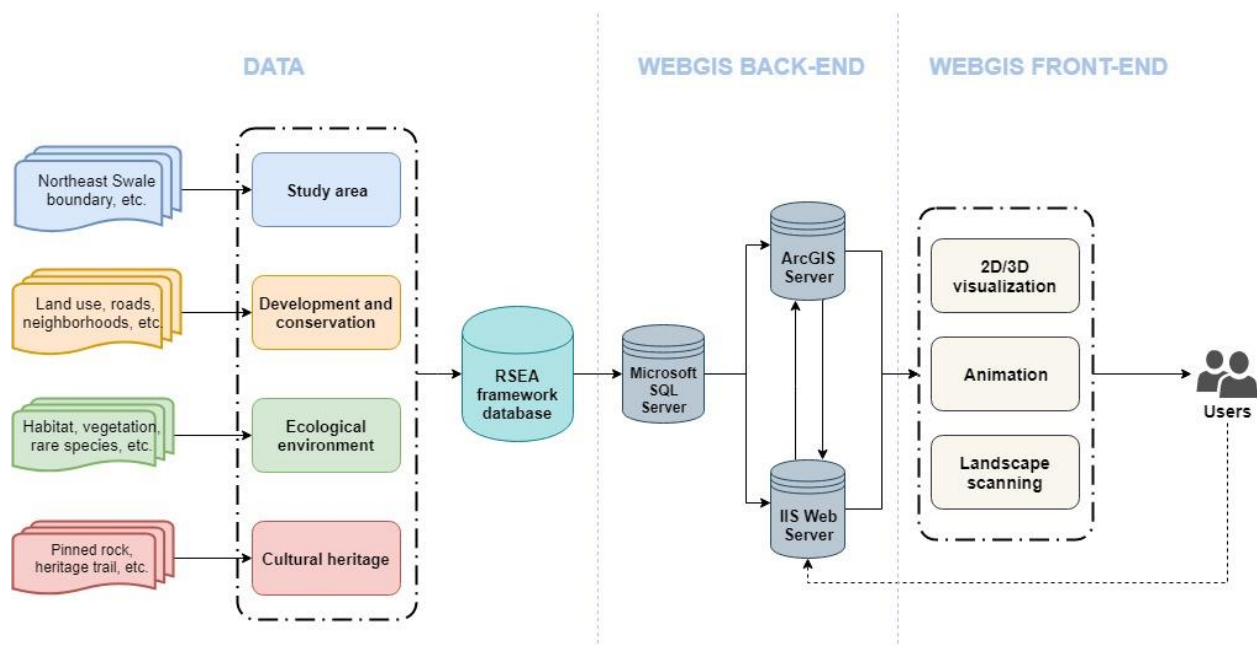

Figure 2. Web-GIS model.

3. Results

The Web GIS system can be accessed at https://gis1test.usask.ca/swale/. The user interface is shown in Figure 3.
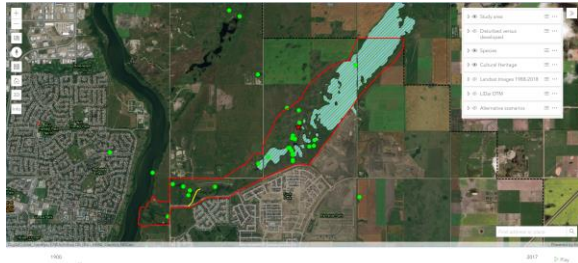

Figure 3. Northeast Swale online map interface.

The website is designed in a user-friendly way. A drop down menu can be found on the top right corner of the web page, where functionalities are grouped in 7 categories, namely study area, distributed versus developed, species, culture heritage, Landsat images 1988-2018, lidar DTM and alternative scenarios. Layers under each category can be turned on or off.

3D viewer option allows users to see landscape changes in elevation. Common GIS functionalities such as zoom, compass, default map view is also available through the quick buttons located on the top-left corner. Furthermore, changes in rare species from year 1900 to 2017 can also be accessed on the bottom of the web page; the changes during all those years can automatically be played in a forward time-order image sequence.

3.1 Ecological environment

The Swale is covered by native vegetation and rare plant species, thanks to the efforts of conservation management. It holds over 200 plant varieties, 100 species of birds, and other species such as hares, foxes, coyotes, and deer (Watchers, 2018). Rare species have been observed all over the Swale, mostly around wetlands. A higher accumulation of rare species is found in the Swale than in other areas of Saskatoon (Figure 4).
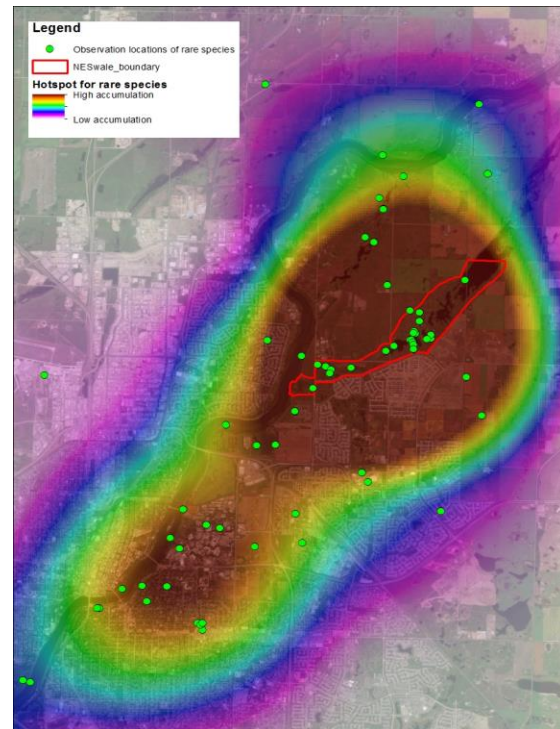

Figure 4. Hotspot map for rare species locations.

3.2 Development and conservation

The Swale is a protected habitat surrounded by agricultural and urban land use. The area adjacent to the Swale has been disturbed, potentially by factors that influence the balance between ecosystem and social activities. The MVA has conducted targeted conservation grazing and prescribed burning to control invasive plant species, as shown in Figure 5. Such actions maintain and improve the ecosystem balance.
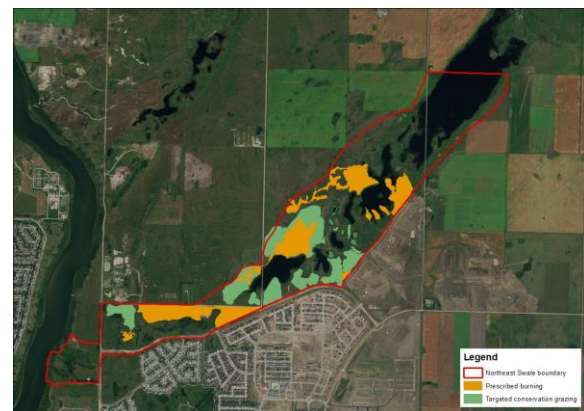

Figure 5. Map of prescribed burning and targeted conservation grazing in the Swale.

3.3 Cultural heritage

Figure 6 shows important historical sites in the Swale that should be protected. Such sites have high educational value to Saskatoon citizens.

Figure 6. Cultural heritage sites in the Swale.

A 3D animation tour along the Moose Woods Batoche trail tells the story of this historical site and rare species in the Swale (https://gis1test.usask.ca/swale/trail/).

3.4 Alternative scenarios

This category shows three scenarios of the Swale's "future", which will be used in a choice experiment survey to gather resident's values of ES and impacts to ES.

Figure 7 represents the current development level around the Swale. Urban infrastructure (roads, residential) development potentially or directly affects this area. Three major roads go through the Swale. The North Commuter Parkway passes across the Swale and cuts the small southwest edge of the swale off from the main Swale. Range Road 3050 cuts through the middle of the Swale. Trails are currently only in the southwest of the Swale, providing limited public access. Existing neighborhoods around the Swale are Silverspring and Evergreen, which are fully developed. Aspen Ridge is currently under development. A greenway was built to separate the ecological area and residential area, which includes an ecological buffer, trail zone and transition zone. The greenway

supports active transportation, stormwater management and conservation of sensitive areas (Gersher, 2015). Among these three communities, only Aspen Ridge has a greenway.
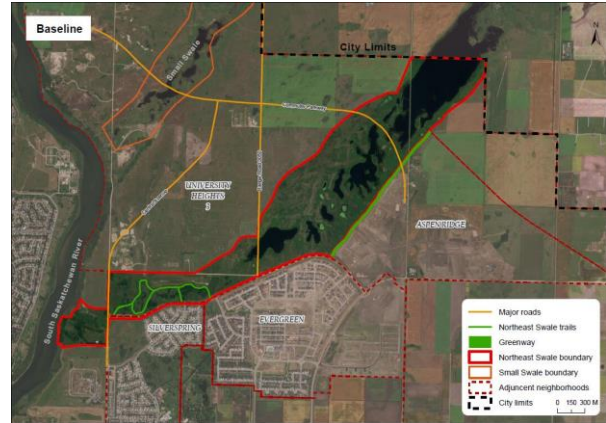

Figure 7. Baseline shows the existed development around the Swale.

Compared with the "baseline" condition, a "no growth" scenario only adds future planned roads. As shown in Figure 8, the northern part of the Saskatoon Freeway (dark red line) is a planned future highway.
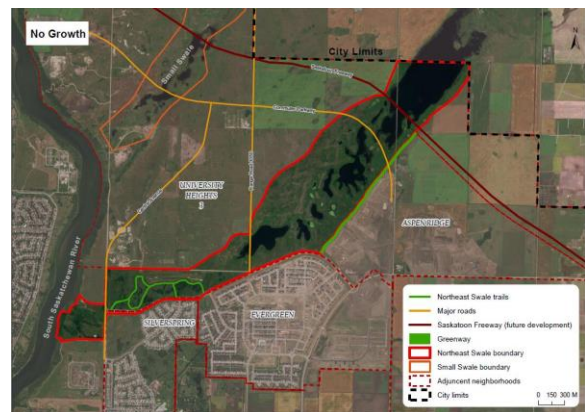

Figure 8 shows a provincial highway is in the future construction plan.

In Figure 9, future potential neighborhoods and trails are added. On the north of the Swale, University Heights 3 will be developed, resulting in the Swale being surround by residential area. Also, in the full development scenario, the density of trails increases (i.e. access), which provides more education and recreation area, but may also bring additional disturbances to the natural landscape.
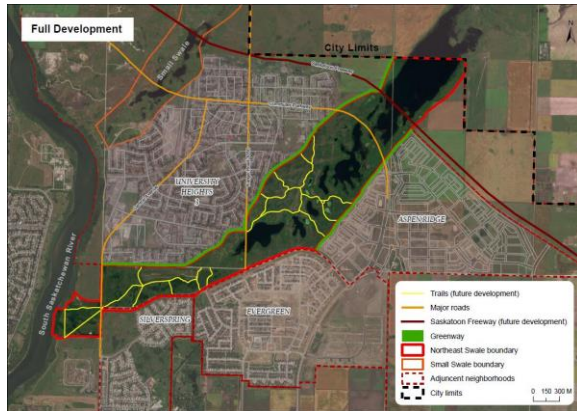
Figure 9. Full development shows the potential future for the Swale.

Urban development stress, including increased access, invasives, and storm water runoff/management, may adversely affect the ecological environment of the Swale and how residents value the Swale's ES.

3.5 Other information

The online map scanning function allows for comparison of 1988, 1998, 2008, and 2018 (Figure 10). Urbanization can be observed throughout these years. In 1988, the land south of the Swale was covered by native grassland. Now, it is residential. In the future, when the neighborhood north of the Swale is developed, the Swale will become a grassland "oasis" surrounded by urban areas.
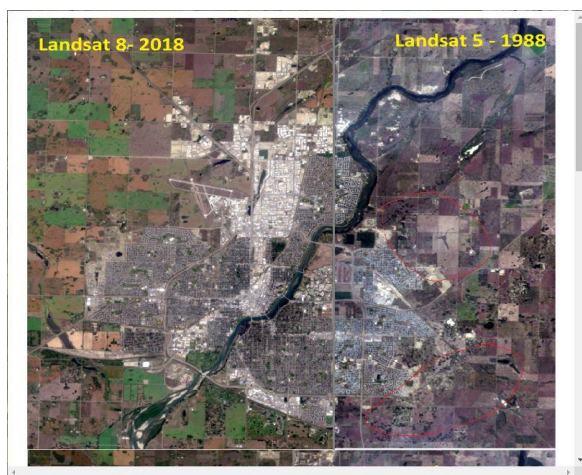

Figure 10. Online map scanning function shows difference of landscape around the Swale in 1988 and 2018.

4. Conclusion

The Northeast Swale has significant ecological and historical value for Saskatoon. This Web GIS platform provides non-technical users access to technical maps. By visiting the website on a laptop or a mobile device, users can easily review ES features around the Swale and customize the maps to discover their interests. Public users can also learn about existing, emerging, and future development pressures and potential. The visualization of ES and potential threats can raise people's awareness, which could further influence their willingness to become involved in public issues, influence the way they use natural areas, and their willingness to financially support their conservation. For professionals (e.g. city planners), land developers, and government, the platform provides a common and transparent baseline to explore, plan for, and value ES in land use zonation, permitting and decision making.

Although conservation management is being conducted, the Swale continues to face pressures from adjacent urban development. Citizen education and informed management are needed to maintain a balance between human activity and a healthy ecosystem. This means that the values placed on ES have a significant role to play. If, for example, the ecological buffer around the Swale increases, wildlife in the Swale could be less affected by human activity; however, the required revenue (i.e. residential property tax base) for developing and maintaining such a buffer zone may increase. Similarly, more trails would provide greater public access to the Swale, which is good for education and recreational benefit; however, increased access may result in adverse effects to some ecosystem services (e.g. habitat), or a decrease in the value placed on other ES (e.g. natural view-scape).

The next stage of our work will involve a survey of residents adjacent to the Swale, to

assess ES derived from the swale, their willingness to pay to protect those services, and how the ES values may change under the different scenarios of conservation and development pressures. The results will be of value to targeting education programs, informing land use zoning, and establishing funding programs to ensure ES protection.

Acknowledgements

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