Supporting Local Climate Change Adaptation with the Participatory Geoweb: Findings from Coastal Nova Scotia

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The effects of climate change have been detected in various natural systems in the last century (IPCC, 2014). As a consequence of these changes, governments are seeking to identify adaptive strategies for protecting citizens and vulnerable economic sectors (Adger et al., 2005; Smit & Wandel, 2006). Coastal areas are particularly susceptible to a changing climate as sea level continues to rise and storm surges become more powerful and frequent events. This research introduces the use of the participatory Geoweb as a tool (labelled "AdaptNS") for supporting local climate change adaptation efforts in Shelburne County, Nova Scotia. AdaptNS serves as a visualization tool for displaying high-resolution interactive flood maps of sea level rise and storm surge scenarios between 2000 and 2100. The participatory aspect of this Geoweb tool is integrated as a means for decision-makers, stakeholders, and community members to identify adaptation priorities in response to climate change risks. This interdisciplinary approach was possible through the use of several technologies, including the Arcpy Python library for analysis, and a coupling of the Google Maps API and LAMP bundle for the front-end and back-end tool development. By using feedback from community members, AdaptNS was identified to support local adaptation by providing communities with comprehensive visuals of climate change risks, a platform for identifying adaptation priorities, and a means to communicate local risks to upper levels of government and businesses.

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Dedication

To my parents who guided, supported and encouraged me unconditionally.

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Chapter 1
Introduction

1.1 Overview

The Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) indicates, with a 95 percent certainty, that climatic changes within the last century are primarily caused by human actions (IPCC, 2014a). As a result of these scientific observations, governments are being urgently encouraged to make the necessary changes in present policies for lessening future environmental unbalance, including lowering carbon emissions and seeking clean energy solutions. In addition to mitigating climate change, it is widely accepted that it is also necessary to establish adaptation measures to protect global economies and public safety (Adger et al., 2005; Noble et al., 2014). Adaptation to climate change is defined as any "process, action, or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity" (Smit & Wandel, 2006, p. 282). Commitment by governments to mitigate and adapt is needed to ensure societal well-being and sustainable economies.

Identifying appropriate adaptation strategies is challenging since these are context-specific (IPCC, 2014b). This is due to the fact that, at the global scale, communities are highly heterogeneous geographically, governmentally, economically, culturally and socially; thus, adaptive strategies that are effective in one community may not succeed in another. Although there is no overall consensus on the exact methodologies needed for climate change adaptation, there is consensus in the literature that community-based approaches are promising at capturing local dynamics needed for identifying context appropriate and feasible adaptation goals (Adger, 2006). By engaging with the public and encouraging participation, it is possible to educate them about climate change in a local context, and determine feasible adaptation strategies that reflect their culture and societal norms (Smit & Wandel, 2006; Ebi & Semenza, 2008; Forsyth, 2013). Participatory initiatives are promising in an adaptation context; yet, there continue to be questions about how to integrate the information gathered from these with formal policy-making outside of the individual community (Forsyth, 2013).

Due to their proximity to water bodies, coastal communities are particularly vulnerable to changing climatic conditions as sea level rises and storm surges become more powerful and frequent events (Nicholls et al., 2011). In the Canadian context, the level of impact due to climate change can range in coastal communities as a result of their economic dependence on their natural environment, established governance dynamics[1], and budgeting constraints. Rural, coastal communities in Nova Scotia's South Shore, specifically, face a series of challenges as a result of climate change since they are presently undergoing economic instability, and industries that heavily rely on weather and climate are primary components of their local economies (e.g.: tourism and fisheries; Brown & Patara, 2014). Planning to adapt is more difficult in this scenario since the implementation of required adaptation may not be affordable for these communities (Atwood, 2013). Aside from this, municipalities of the South Shore have reported resource scarcity (e.g.: technical expertise), lack of public knowledge of climate change vulnerabilities, and political disadvantages in comparison to other municipalities in the province (Atwood, 2013; Tipton, 2013; Brown and Patara, 2014).

The Geospatial Web 2.0 (or "Geoweb") is a collection of online mapping platforms and applications that enable users to access and/or contribute geographic information (Haklay et al., 2008, p. 2011). Geoweb technologies have been implemented for a series of applications since their emergence in the mid-2000s ranging from formal (e.g.: forest fire inventories) to recreational purposes (e.g.: geo-tagged photos; Goodchild, 2007; Brennan & Corbett, 2013). Similarly to community-based adaptation, Geoweb tools and their participatory counterparts are also questioned for their formal inclusion within decision-making practices, particularly on when and how should Geoweb tools integrate with these processes (Sieber, 2006; Johnson & Sieber, 2012; Johnson & Sieber, 2013). Nevertheless, the technological capabilities of Geoweb tools have the potential to both strengthen community-based adaptation processes while addressing some of the present issues described by municipalities of the South Shore.

This research was conducted as a follow-up component to previous climate change vulnerability studies that were primarily influenced by in-person interviews in Nova Scotia's Shelburne County—a county in the South Shore. At its core, the purpose of this research is to both develop a Geoweb tool using a community-based framework and evaluate its role and performance as a component of formal adaptation discourse, planning and decision-making. Through exploratory design, the Geoweb tool was developed to integrate scientific climate change data, government-distributed information, and participatory components using a feedback prototype development structure. Citizens and government officials at the study site tested the tool via in-person recruitment and an in-person workshop. This research provides valuable insight to the importance of community-led Geoweb tool development, the role of these tools in local adaptation efforts and processes, and its effectiveness at communicating complex scientific information to non-experts and experts alike.

[1] In this context, "governance dynamics" refer to established institutions (e.g.: non-governmental organizations, government departments) that can facilitate the adaptation process by providing resources, expertise, changes in existing policies, etc.

1.2 Research Purpose and Objectives

1.2.1 Mission Statement

The central purpose of this research is to determine how participatory Geoweb tools support and inform local climate change adaptation in Shelburne County, Nova Scotia.

1.2.2 Objectives

1. Develop a Geoweb tool using a community-based feedback prototype development approach that enables two-way communication with users, where information can be both accessed and contributed by users.
2. Create geographic representations of present vulnerable locations to coastal flooding, as well as climate change scenarios of future vulnerabilities in the 2020s, 2050s, 2080s, and 2100s using high-resolution elevation data, and display these on the Geoweb tool.
3. Conduct in-person data collection and workshops where participants share information digitally through the Geoweb tool of their local knowledge, concerns and adaptation priorities.
4. Allow residents of Shelburne County to evaluate the Geoweb tool and determine its use in local climate change adaptation.
5. Based on user feedback, determine the benefits and constraints of Geoweb technologies as support tools for local climate change adaptation.

1.3 Thesis Outline

In most general terms, this thesis explores the coupling of two distinct research fields: the Geoweb and community-based climate change adaptation (CBA). The methodologies, findings and discussions of this research are separated into two key chapters and a final concluding chapter.

In Chapter 2, the participatory Geoweb is introduced as a subset of a much larger body of literature of recently developed climate change geovisualization tools. It is through a review of present geovisualization tools that it is possible to identify the components and technologies required for developing a Geoweb tool for climate change geovisualization purposes. By learning from present lessons, the Geoweb tool development process is proposed as a community-based feedback prototype approach, where community feedback is sought during development stages and for identifying its role in local adaptation efforts. This proposed methodology is empirically tested in Shelburne County, Nova

Scotia where several Geoweb tools were developed, implemented and evaluated in terms of technological capabilities and its inclusion within CBA processes. This chapter provides insight to the benefits of developing Geoweb tools by engaging the community throughout its development process, how these tools promote the understanding of climate change science among its users, and how vulnerable residents used its participatory capabilities to identify local adaptation priorities.

The purpose of Chapter 3 is to evaluate the Geoweb as a support tool for CBA processes using empirical findings from Shelburne County. As previously mentioned, CBA has been recognized as a valuable method at promoting public participation, education, and deriving adaptation plans that reflect a community's needs and priorities. Although CBA aims to include public opinion in decision-making, it suffers from inability to translate its results to wider geographies and upper levels of government. Through this chapter, the Geoweb is discussed as a means to support present limitations of CBA methodologies and evaluate its overall performance as a CBA-support tool. This chapter provides insight to role of the Geoweb as a valuable tool for supporting local adaptation efforts with climate science, communicating local issues to upper scales, and providing communities with the capabilities to independently conduct CBA efforts in the future.

In Chapter 4, the most significant results outlined in Chapters 2 and 3 are summarized as well as future research directions.

Chapter 2

Building and Identifying the Role of the Participatory Geoweb in Local Climate Change Adaptation using Citizen Feedback

2.1 Introduction

In recent decades, climate change has become a topic of media coverage, political discourse, and extensive research. As a result, climate change as a subject has been highly politicized and criticized by some media outlets, politicians, and members of the general public (Boykoff & Boykoff, 2007). The facts, urgency and importance of climate change, in many cases, have been miscommunicated and misinterpreted in the media creating a social divide between climate change "believers" and "non-believers" (Boykoff & Boykoff, 2007). In addition, many individuals can find it difficult to understand or engage in learning about climate change since it can appear as a "distant or nebulous" issue that may not affect them directly (Preston et al., 2011, p. 178). The lack of public understanding and engagement on climate change pose a significant obstacle that may cause governments to waver on taking decisive action in response to climate change (Klein et al., 2014). Adaptation to climate change is one aspect that requires governments' involvement to minimize climate change risks (Smit & Wandel, 2006). For example, governments can reduce climate change impacts by introducing land-use bylaw changes and new emergency management procedures. Yet, without public awareness of climate science and public support for reducing risks induced by climate change, the process for implementing projects and change in policies by governments is likely to slow, due to a lack of public pressure on decision-makers (Sheppard, 2012; Piccolella, 2013).

Climate change geovisualization tools have emerged as promising efforts to better communicate present and future climate change vulnerabilities to citizens and decision-makers in a local context (Sheppard, 2012). The goals of these tools are to connect broad descriptions of climate change impacts with visuals, as a way to help citizens and governments understand and relate to climate change at the local level. In comparison to traditional static paper maps, geovisualizations enable users to interact with a map through spatially and temporally dynamic 2D and 3D visuals of climate change impacts. In several cases, climate change geovisualizations have proven effective at communicating and disseminating climate change information to those affected, and in integrating scientific and socioeconomic climate change datasets in a unified system (Sheppard et al., 2011; Sheppard, 2012). The interactions between science and socioeconomic factors are often difficult to identify; yet, maps and geovisualizations have shown to comprehensively display how one system influences the other and vice-versa (Preston et al., 2011). In this context, establishing a relationship between climate change impacts with locations that have significant value to a community (whether culturally, economically, or other) can serve as a step towards promoting public discourse, creating a general consensus view, and spurring adaptive action. Despite these benefits of geovisualization, questions remain about their impact and role in more formal settings, such as government decision-making and their long-term uses (Sheppard et al., 2011).

This research introduces the Geospatial Web 2.0 (or "Geoweb"; Haklay et al., 2008) as a means to more formally involve geovisualization tools in climate change adaptation. The Geoweb is a collection of online mapping platforms and applications that enable users to access and/or contribute geographic information (Haklay et al., 2008, p. 2011). The technical characteristics of this collection of tools, including their design versatility, online nature and the inclusion of user content, offer significant potential for Geoweb to act as both a climate change communication platform and as a component in climate change adaptation decision-making. Unlike previous statements suggesting that Geoweb tools can be created easily by non-experts (Leszczynski, 2012), it is hypothesized, that a Geoweb tool must be built by experts while heavily relying on citizen and government input to develop a tool that has value to a community, whether it is to inform the public or support government decisions in regards to climate change.

To determine the benefits and limitations of present geovisualization technologies, several climate change geovisualization tools, including existing Geoweb efforts, are compared in terms of imagery resolution, reliance on climate science and user accessibility. Using these findings and input from local citizens and stakeholders, a new Geoweb tool was developed as a climate change geovisualization tool for coastal Shelburne County, Nova Scotia. This particular location was chosen to launch the Geoweb tool for three reasons: similar Geoweb efforts have not been tested in the Canadian context, municipalities and the province of Nova Scotia have reported interest in climate change adaptation, and other counties in the province are experiencing similar physical and socioeconomic climate change impacts (Fisher, 2011). This research provided insight to the strengths of a community-based prototype approach when developing a Geoweb tool that increases awareness of local climate change impacts and helps communities identify specific adaptation priorities.

2.2 Climate Change Geovisualization Tools

Climate change impacts can introduce vulnerabilities in human populations through various means depending on their geography, demographics, culture, governance structures, etc. (Smit & Wandel, 2006;

Cochran, et al., 2012). Some of these natural impacts, generally, include increases in precipitation and temperature, rising sea levels, forest fires, and the geographic expansion of diseases and invasive species (Fisher, 2011). Due to the context of this research, the following review focuses on geovisualization tools that were created for displaying climate change impacts in coastal environments in North America, including sea level rise and changes in storm surge magnitude. These tools are the following: Sierra Club's Sea Level Rise visualization, Drown Your Town, Firetree.net, Coastal Impacts Visualization Environment (CLIVE), Local Climate Change Visioning Project (LCCVP), Climate Central's Surging Seas, United States Geological Survey (USGS) Coastal Change Hazards Portal (Table 1; Tingle, 2006; Sheppard et al., 2011; Sheppard, 2012; Thaler, 2013; Taber, 2014; Surging Seas, 2014; USGS Coastal Hazards Portal, n.d.). This diverse range of interactive geographic platforms have emerged in recent years for visualizing coastal flood impacts across a landscape and provide insight to the capabilities of present geovisualization efforts. Yet, these tools differ from one another in various aspects giving the opportunity for identifying characteristics that should be implemented or avoided when developing a new geovisualization tool.

Table 1. List of Reviewed Climate Change Geovisualization Tools

Name	Location	Purpose	Visualization Data Source	Resolution	Accessibility
Sierra Club Sea Level Rise	Vancouver, BC	Superimpose a 6m sea level rise on political boundaries	Arbitrary	Coarse	Downloadable
Drown Your Town	Global	Provide Google Earth users with the ability to create their own sea level rise visualizations	Arbitrary	Coarse	Downloadable
Firetree.net	Global	Display global sea level rise impacts by allowing users to select water levels from a drop-down list	Arbitrary	Coarse	Online
CLIVE	Prince Edward Island	Display erosion and sea level rise visuals in various time frames through a video-game interface	Scientific	Detailed	In-Person
LCCVP	Delta, BC	Presents 3D visuals of future sea level rise scenarios with and without implementing adaptive changes	Scientific	Detailed	In-Person
Surging Seas	Coastal US	Enables an interactive scroll-bar representing water levels that can be used to visualize coastal flooding along the two coasts of the United States	Scientific & arbitrary (due to interactive scroll-bar)	Detailed	Online
USGS Coastal Change Hazards Portal	Coastal US	Display coastal vulnerability to extreme storms, shoreline change and sea level rise based on scientific studies along coastal US	Scientific	Detailed	Online

For comparison purposes, the characteristics of these tools are divided into three categories: arbitrary vs. scientific climate change scenarios, coarse vs. detailed imagery results, and offline vs. online nature. Based on these findings, it is possible to recognize benefits and drawbacks of present efforts in offline and online geovisualization tools and how these can be improved upon when developing a geovisualization tool for Shelburne County, Nova Scotia.

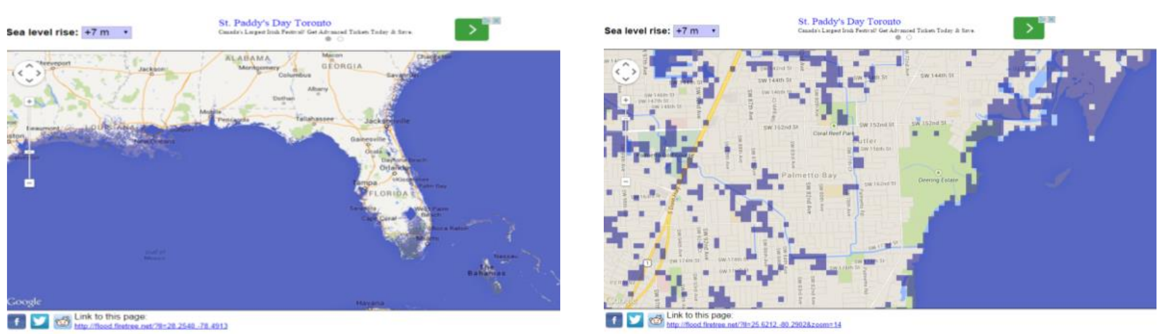
Arbitrary vs. scientific climate change scenarios

For this review, the term "climate change scenario" is employed to signify various present and potential future geographic representations of climate change impacts in a locale. Geovisualization tools display climate change scenarios that have been created using varying data sources that are not necessarily based on formal reports (e.g.: Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report), scientific information or government input. In the coastal flooding context, these climate change scenarios can be created using arbitrary water levels to more scientifically-derived projections. As a result, some geovisualization tools that use arbitrary water levels have led to the over-dramatization of climate change. For example, DrownYourTown is a Google Earth-based initiative that provides users with instructions on how to increase water levels using Google Earth 2D and 3D imagery (Thaler, 2013). Subsequently, individuals have mapped and shared images on social media of cities and towns under hundreds of meters in sea level (Twitter #DrownYourTown, 2014). Although Drown Your Town users are able to engage in learning about sea level changes, these images can detract from the credibility of climate change science and communicate false information to others when taken out of context. Similarly, the Sierra Club initiative mapped Vancouver, BC and surrounding high density areas under a 6m sea level rise. In this case, these images were criticized for their high uncertainty and for the lack of timeframe for when such an event might occur (Sheppard, 2012). Arbitrary scenarios can sensationalize climate change and diminish the public's trust in climate change geovisualizations and studies (Sheppard & Cizek, 2009); thus, these should be avoided in future geovisualization efforts to prevent further climate change misconceptions by the general public.

Geovisualization tools whose goals are to inform decision-makers or become a part of the decision-making process display scientifically-derived climate change scenarios. For example, the USGS Coastal Change Hazards Portal displays areas that are vulnerable to extreme storms and sea level rise. This particular tool's goal is to provide decision-makers with the necessary information for understanding climate change impacts at the local level and use this information to improve planning strategies and emergency management. Other tools have taken visualizing a step further and introduced both scenarios of vulnerability and potential adaptation solutions that are based on the IPCC reports. The LCCVP tool displayed climate change impacts in Delta, BC that were based on the low to high emission scenarios provided by the IPCC (Sheppard et al., 2011). Using these, they were able to create 3D geovisualizations of the city with and without the realization of adaptive projects (e.g.: building a sea wall, re-locating coastal property, changing building codes). When the community was shown the tool, they reported a change in perspective where they now felt that planning for climate change was essential, both personally and municipally, to lessen their climate change vulnerability (Sheppard et al., 2011). Although there continue to be questions about the long-term impacts of climate change geovisualization tools in decision-making processes, it is evident that the use of scientifically reliable sources strengthens the tool by informing the public and decision-makers with information that can raise awareness and help plan for climate change futures.

Coarse vs. detailed imagery results

Climate change geovisualization tools have to consider geographic scale due to significant issues with coarse imagery resolution. At the global or regional scale, it is possible to use coarse datasets to have a general understanding of which areas, generally, are more affected than others. Firetree.net, for instance, uses open data provided by NASA to visualize sea level rise at multiple water level intervals (Figure 1a). By superimposing the sea level rise scenarios on satellite imagery, it is possible to compare which countries and which regions within countries are low-lying and consequently more susceptible to rising sea level. Nevertheless, at the local level, the sea level rise scenarios appear coarse, overgeneralize impacts and may give users a false impression of places that are and are not vulnerable to climate change impacts (Figure 1b).



(a) Small scale visualization (b) Large scale visualization

Figure 1. 7m Sea Level Rise in Florida Using Firetree.net (Tingle, 2006)

To address these accuracy issues, some tools (e.g.: CLIVE & Surging Seas) have used high-resolution topography imagery to generate sea level rise scenarios (Webster et al., 2011; Cooper et al., 2013). Light Detection and Ranging (LiDAR) is a "high-resolution state-of-the-art" data form that can be used to create detailed models of the earth's terrain (Cooper et al., 2013, p. 746). These models can then be used to create many types of detailed 2D and 3D products related to coastal flooding, including sea level rise and storm surge scenarios (e.g.: 1 meter resolution; Sheppard & Cizek, 2009; Webster et al., 2011; Cooper et al., 2013). This data is costly to acquire; yet, other data types cannot be provide the same high-resolution topography products (Eid et al., 2004; Næsset, 2009; Hummel et al., 2011). Due to the high realism of LiDAR-derived climate change scenarios, researchers have reported emotional responses from citizens upon seeing these images, as well as an increase in understanding the urgency of proactive adaptation (Sheppard et al., 2011; Taber, 2014). LiDAR-based sea level rise scenarios are also beneficial at localizing specific problem areas at the local level, including vulnerable public and private infrastructure. Surging Seas and CLIVE have both been able to show in detail which properties and infrastructure are at risk of present and future coastal flooding. With the use of LiDAR data, these tools help citizens make the connection between broad descriptions of climate change and tangible, locally-relevant impacts and risks. Despite the benefits of high-resolution visuals, Sheppard and Cizek (2009, p.2108) warn of the ethical issues surrounding high-resolution climate change scenarios since modelling results of potential futures cannot be presently validated and "it can become harder to remain aware of the limitations or uncertainties of the underlying data". As a suggestion, they promote transparency along with geovisualization tool in terms of metadata and documentation on assumptions and level accuracy of the displayed climate change scenarios. In this manner, the tool can be assessed by external experts who can confirm its appropriateness as an information source for decision and policy makers.

Offline vs. online platform

In broadest terms, geovisualization tools can be divided into two categories in terms of user accessibility: offline and online environments. Here, any type of platform that does not need Internet access is considered to be an offline geovisualization tool (see Table 1). Although effective at displaying comprehensive 2D & 3D visuals and in educating the public on climate change risks, these tools suffer from limited audiences. To interact with these offline geovisualization tools, citizens, stakeholders and government officials must attend an in-person workshop with researchers who guide users on how to use the tool and explore its content. This is the case for both the LCCVP and CLIVE tools, where citizens depend on researchers for organizing and executing an in-person workshop to use the tool. Thus, it can be said, that these tools help workshop attendees learn about local climate change impacts, but the same is not done for those who did not attend. The lack of engagement in climate change education of broader audience is an issue for two reasons. First, citizens need to become aware of their own local climate change risks to become less vulnerable (e.g.: public acceptance of proposed protective infrastructure) and to have a political voice for influencing climate change decision-making (e.g.: prioritizing adaptation action where citizens most need it; Noble et al., 2014). Second, the United Nations Framework Convention on Climate Change (UNFCCC) urges that awareness is needed at the local level, but also in upper levels of government (UNFCCC, 2007). By informing national or provincial levels of local impacts, it is possible to promote the inclusion of local needs in policy changes and decision-making for creating more integrated climate change-related goals at all government levels. In response to the need for the promotion of public and government climate change awareness, research suggests that there is an opportunity for technological innovation and "knowledge-sharing and learning platforms" (Noble et al., 2014, p. 845).

Online geovisualization tools, such as Geoweb tools, can address the audience issue of offline tools while still providing capabilities for visualizing climate change impacts. Geoweb tools provide a two-way communication platform where users can both access and/or contribute geographic information (Haklay et al., 2008). This new type of online user-contributed geographic information is labelled "Volunteered Geographic Information" (VGI; Goodchild, 2007, p. 212). Since its emergence in the mid-2000s, there has been widespread use and creation of Geoweb tools and VGI by non-expert users (Goodchild, 2007; Goodchild, 2009; Leszczynski, 2012; Feick & Roche, 2012). Geoweb tools can empower non-experts with a data collection framework, and an alternate approach to tasks that were traditionally completed by professional geographers and cartographers (e.g.: displaying geo-tagged photos on a map; Goodchild, 2007; Goodchild, 2009; Elwood, Goodchild & Sui, 2012). As a platform for communicating climate change to citizens, Geoweb tools, such as Surging Seas and USGS Coastal Change Hazards Portal, have been developed to display coastal flooding scenarios using high-resolution imagery (USGS Coastal Hazards Portal, n.d.). Surging Seas goes a step further and presents climate change scenarios with socioeconomic datasets, including population, income, ethnicity and property value (Surging Seas, 2014). These examples show that Geoweb tools are capable of communicating information to the masses online, and that it presently has the technological capacity to display both scientific and socioeconomic factors in comprehensive ways. Yet, these present Geoweb efforts for climate change visualization have not integrated its participatory or VGI component and how this data could aid in climate change adaptation discourse, planning and prioritizing action.

Learning from the lessons of present geovisualization tools, this research introduces a participatory Geoweb tool designed for coastal Shelburne County, Nova Scotia to increase public understanding of climate risks and encourage climate change adaptation planning at the municipal scale. This particular Geoweb platform integrates scientifically-derived coastal flooding scenarios and citizen-contributed places of concern. It is through this tool that it becomes possible to explore how participatory Geoweb tools integrate the beneficial technical characteristics of present geovisualization tools in its design, and how these types of tools can promote adaptation discourse and decision-making in the Canadian context.

2.3 Case Study Methodology and Results

2.3.1 Study Site

Location and Demographics

Shelburne County is located in southern Nova Scotia and is divided into five municipalities: District of Shelburne, Town of Shelburne, Town of Lockeport, District of Barrington, and Town of Clark's Harbour (Figure 2). In totality, the county has a population of 14,495 people that accounts for about 1.6% of the total population in Nova Scotia (NSCC, 2015a; NSCC, 2015b). Shelburne County is large in size with an area of 2,464.65 km^2 and its residents live in small dispersed communities primarily along the coast (Statistics Canada 2006a; CBCL Ltd., 2009). Within the past years, Shelburne County has experienced a 6.7% decline in population between 2006 and 2011, and changes in the median age from 42.8 years in 2006 to 47.2 years due to outmigration of youths (Statistics Canada, 2006b & 2011; Brown, 2014). In relation to Internet access, the Province of Nova Scotia since 2007 has helped connect 99% of Nova Scotians with access to high speed Internet (MacDonald, 2014). This initiative provides the basic technological infrastructure needed to execute a Geoweb project in this region.

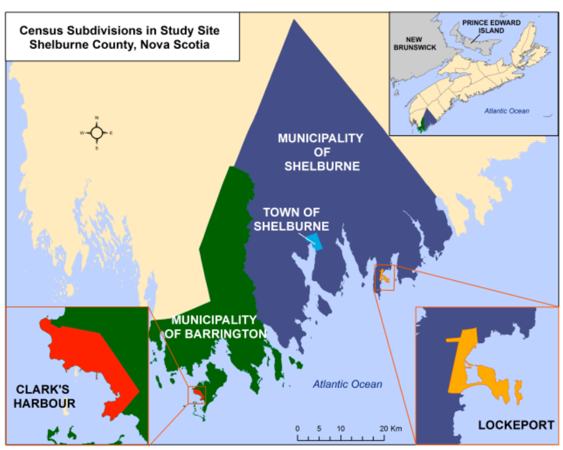


Figure 2. Municipalities in Shelburne County, Nova Scotia

Economic Structure

Similar to other rural counties in the Atlantic Provinces, one of Shelburne County's main economic drivers is the fisheries industry (NSCC, 2015c, NSCC, 2015d, NSCC, 2015e). In addition to its role in the county's economy, fishing also plays a role in the cultural identity of residents in this region, particularly lobster fishing (Province of Nova Scotia Lobster Festival, 2015). In relation to climate change, fishermen have reported changes in abundance of certain species, varying migration patterns, changes in species habitat (e.g.: lobster grounds are receding), as well as extensive damage from storms on fishing infrastructure (e.g.: fishing wharves; Brown, 2014).

Another secondary, but also a significant economic driver, is the tourism industry. Similar to the fisheries industry, tourism is both weather and climate-dependent since poor weather can lead to fewer visitors (Brown & Patara, 2014). Stakeholders in the tourism sector have reported negative climate change impacts, such as an increase in property damage costs due to poor weather, and a growing negative perception of coastal property buyers (Brown & Patara, 2014). Climate change can potentially bring more tourism to Shelburne County through longer summer seasons; nevertheless, this region is vulnerable to climate change impacts as these are negatively affecting and are expected to continue affecting the financial stability of businesses in main economic industries in the future.

Local Climate Change Initiatives

Within the last few years, several municipal and academic climate change initiatives have been taking place in Shelburne County and surrounding counties. As of late 2013, all municipalities completed and submitted climate change action plans (MCCAP) to the Province of Nova Scotia. This particular document was requested by the province as a means to encourage municipalities to plan sustainably and to later provide them with funding to realize those plans (Fisher, 2011). The MCCAP documents included information on each municipality's observed and potential climate change vulnerabilities, adaptation strategies for addressing these vulnerabilities, and mitigation plans. Many municipalities across Shelburne County reported concern over present and future coastal flooding impacts on public and private infrastructure (Atwood, 2013; Tipton, 2013; MCCAP Shelburne, 2014). The same was not expressed for other climate change impacts such as erosion and forest fires. Many of these reports used tabular references provided by the province of future changes in sea level and storm surge events (Richards & Daigle, 2011). Yet, high-resolution maps of such coastal flooding scenarios were not present in the MCCAP documents suggesting a gap in present information sources. The unavailability of flood maps in the region was later confirmed by A. Robinson (personal communication, April 18, 2014) from the

Province of Nova Scotia's Geomatics Centre, and E. Tipton (personal communication, October 2, 2014), municipal coordinator and engineer in Shelburne County. The lack of detailed maps and concern of coastal flooding impacts gave this research guidance to the types of information that could be visualized using the Geoweb tools. This need was further ensured by the municipality's interest in improving communications with other levels of government and the public, particularly for consultation on future development, raising awareness of natural hazards-related services, and encouraging citizen science projects (Tipton, 2013).

Somewhat parallel to municipal initiatives, climate change researchers had also been actively involved across the county. Their efforts particularly focused on identifying climate change vulnerabilities through in-person interviews (Brown & Patara, 2014). These interviews were mainly focused on stakeholders in the tourism and fisheries industries and were ultimately successful at identifying issues in governance structures, and learning from people's personal experiences with climate change and/or natural hazards and their impacts on businesses. This established researcher-community relationship aided in connecting this research to citizens, stakeholders and government actors across the county.

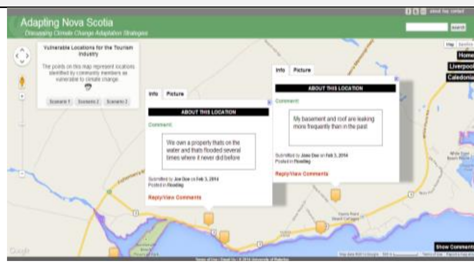
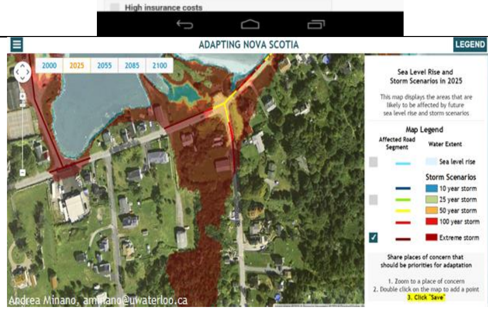
2.3.2 Geoweb Tool Design and Development

Prototype Development

To create a Geoweb tool for Shelburne County, a prototype development approach was used. In software development, prototyping refers to the creation of many versions of software, normally incomplete, that allows developers to test different components of the final product with clients throughout all stages of development (Schach, 2010). This development approach served three purposes in this research: to test technological aspects of each Geoweb tool and ensure proper functionality throughout, to enable community feedback during stages of tool development, and to continuously learn from active research and municipal findings in relation to climate change. Specifically, the community feedback helped to identify technical faults of the Geoweb tool (e.g.: errors in data collection, design flaws), and to also determine how the Geoweb tool could address present challenges in the climate change adaptation decision-making process (e.g.: information gaps, public involvement in governance).

Overall, three Geoweb prototypes were created for this research: VGI-Based Geoweb, Mobile Geoweb, and Science-VGI Based Geoweb (Table 2). Each of these has distinct objectives; yet, they all have the same tool structure: Google Maps Application Programming Interface (API) in the front-end user interface, and LAMP (Linux, Apache Server, MySQL Databases, and PHP computer programming language) bundle in the back-end developer interface (Appendix A). Geoweb tools can be created by using a series of technologies that vary in terms of technological capabilities, features and price (e.g.: Leaflet, ArcGIS Online, CartoDB; GIS Stack Exchange, 2011). However, Google Maps API/LAMP structure was chosen since previous examples showed that the combination of these technologies allowed the creation of a participatory Geoweb tool (Beaudreau et al., 2012), related documentation and technical support on these technologies is widely available, and their technological nature provides developers with flexibility when customizing Geoweb tools and administrating user-contributed data (e.g.: creating online database structures for storing user-contributed data).

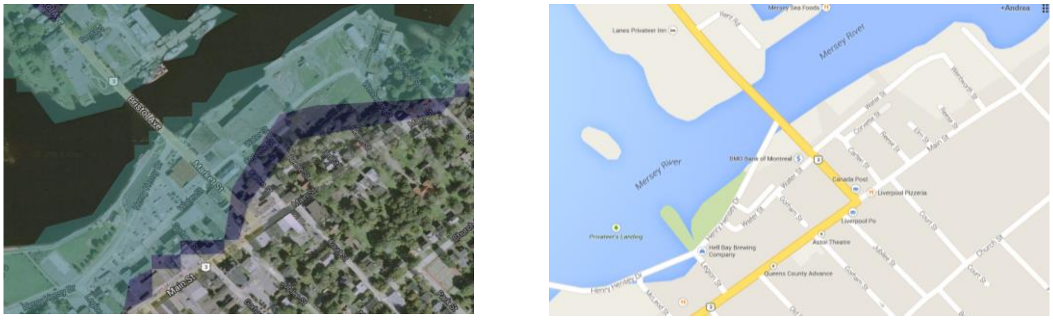
Table 2. Geoweb Prototypes and Characteristics

Prototype Name	User Interface	Characteristics	Medium	Tested with Citizens?
VGI-Based Geoweb		Provided users with the ability to share online comments and VGI in relation to their own climate change observations	PC	No
Mobile Geoweb		Form-based mobile Geoweb tool where participants were asked to locate places where they had seen flooding and erosion. This was followed with additional questions on types of related damage (e.g.: public infrastructure)	Nexus 7 Tablet	Yes. 25 participants
Science-VGI Based Geoweb (“AdaptNS”)		Integrates precise LiDAR-derived sea level rise and changes in storm surge events and VGI in the form of citizen concerns and citizen science	Nexus 7 Tablet and PC	Yes. 11 participants

VGI-Based Geoweb

The first prototype served to answer significant technology-related questions about the combined use of Google Maps API and LAMP bundle for creating a participatory Geoweb tool. This particular prototype primarily focused enabling users to contribute VGI by thematically tagging comments and images on the tool. Using this prototype, users can categorize their VGI contribution as erosion or flood observation and attach comments or images to them. The combination of the Google Maps API and LAMP bundle proved useful at managing and permanently storing user-contributed information in a centralized online database system. This database stored VGI for later analysis while also populating the tool with saved VGI content. Through this first prototype, it was determined that the chosen Geoweb tool technological structure provided sufficient capabilities for enabling user participation and permanent storage of user-contributed content.

As an exploratory approach, this Geoweb prototype was used to visualize coastal flood impacts. This aspect was particularly tested since displaying large datasets on Geoweb tools can detriment the speed of the user-interface when zooming and panning content. As a result of this testing phase, it was evident that the Geoweb tool was able to handle large datasets without compromising user experience. Nevertheless, the datasets used for creating these coastal flood scenarios have a 20 m resolution and generalized impacts, particularly at the local scale (Figure 3a). This suggested the need for higher resolution imagery that could be used to create precise scenarios. In addition to these findings, significant cartographic errors in the default Google Maps basemap were noted. These cartographic errors spatially misrepresented the geography of the region (e.g. coastline boundary; Figure 3b). Climate change geovisualization literature suggests that false representations of geography can lead to a decrease user credibility of climate change scenarios (Sheppard and Cizek, 2009). For this reason, later prototype efforts solely use satellite imagery basemaps. Finally, the overall user interface of the prototype could be improved upon to ensure design consistency (e.g.: font type and size, interface colour combinations) and “high-quality professional graphics” for encouraging users to trust the prototype and its content (Skarlatidou et al., 2013, p. 1673).



(a) Coarse Scenario Imagery (b) Cartographic Errors in Roadmap Basemap

Figure 3. Errors in VGI-Based Geoweb Tool

Mobile Geoweb

The second Geoweb prototype was primarily designed to engage randomly-selected citizens of Shelburne County in sharing VGI. To allow researchers to test the tool at various locations across Shelburne County, this Geoweb prototype could be accessed using mobile devices. This tool was accessible online using Android tablets and it provided citizens with a series of climate change-related questions. The tool first asked users to place an observation related to a natural phenomenon followed by a series of questions related to damages caused by this impact and to identify any responsive action for addressing this impact (Figure 4).

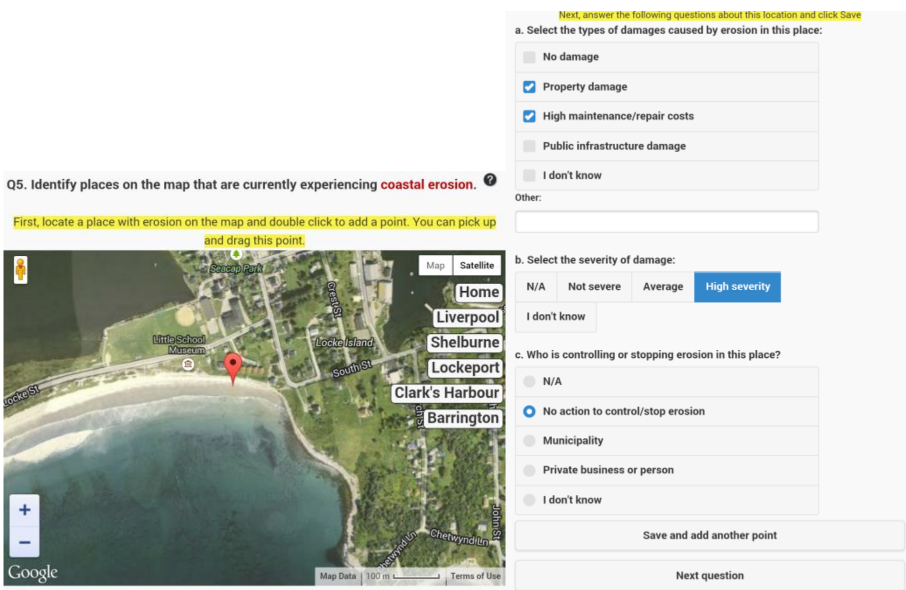


Figure 4. Mobile Geoweb User Interface

Using the results from 25 participants, it was possible to understand whether Shelburne County residents were inclined to engage with a participatory Geoweb tool, whether the user-contributed content they produced had significant accuracy issues, and if there were design issues with the prototype. Without testing the Geoweb tool with participants, it not possible to know whether the technology would be accepted or rejected by them. During the testing phase of this prototype, some participants preferred to use paper maps instead of the Geoweb tool and others mentioned that they had not previously used a tablet in the past. Yet, the majority of participants completed the questionnaire using the mobile tool. This suggested that the participatory Geoweb tool does have potential to be accepted by a large majority of Shelburne residents; yet, there are citizen groups who may not be inclined to use this technology. In terms of accuracy of VGI, participant responses were confirmed by in-person site visits, multiple independent participants sharing the same information, and cross-referencing with observations found in the MCCAP documents (Figure 5a & b). Although in some cases, the VGI had some precision errors, participant observations were generally accurate. This finding suggested that participants can express their personal observations through this prototype; thus, encouraging the inclusion of VGI as a feature in future Geoweb prototypes.

(a) Reported Flood (Blue) and Erosion (Yellow) VGI

(b) Photograph of Flood Event

Figure 5. Reported Flood Event on Dock Street, Town of Shelburne. The photograph provided in the Town of Shelburne's MCCAP document confirms flooding events identified using the Geoweb tool (2013)

Through this Geoweb-citizen interaction, faults in the mobile design and Geoweb approach were identified. When recruiting participants, some citizens were not interested in using the tool since it took approximately 10 minutes to complete all the questions. This finding suggested that the third prototype should allow users to choose the length of time when interacting with the tool.

Science-VGI Based Geoweb

Several factors actively shaped the design of the third and final prototype (labelled "AdaptNS"): technological lessons learned in the first prototype stage, citizen feedback gathered in the second prototype stage, findings from external research and the MCCAP documents, and informal online feedback of a municipal engineer/development coordinator from Shelburne and other active researchers in the region. The Adapting Nova Scotia or AdaptNS tool was designed as a platform that incorporates scientifically-derived coastal flooding scenarios and participatory components. The decision to display coastal flooding scenarios, in terms of present and future sea level rise and storm surge extents, was a result of the high interest of municipalities in these phenomena (Tipton, 2013; Atwood, 2013; MCCAP Shelburne, 2014), negative economic impacts as a result of flooding in local businesses (Brown & Patara, 2014), and the recent purchase of LiDAR data by municipalities of 9 sites across the county.

In terms of coastal flooding scenarios, LiDAR data allows for precise geographic representation of areas that are vulnerable to sea level rise and storm surge impacts (Nicholls et al., 2011; Fisher, 2011; Cooper et al., 2013). Using the LiDAR data and existing projections of local measures of sea level rise and storm surge changes provided by the Province of Nova Scotia, 29 climate change scenarios were created for each of the 9 LiDAR sites (Figure 6).

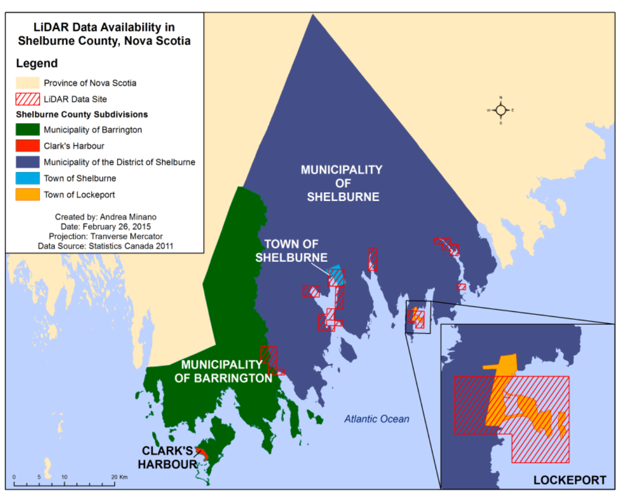


Figure 6. LiDAR Data Availability Sites in Shelburne County, Nova Scotia

By applying similar methods as those presented by Webster et al. (2011), high-resolution sea level rise and various storm surge scenarios were generated for the years 2000, 2025, 2055, 2085 and 2100 (Table 3; Appendix B). This approach was taken to provide municipalities with information that could be used in short-term and long-term adaptation decision making, as well as to communicate and raise awareness to all citizens of local climate change impacts.

Table 3. List of Sea Level Rise and Storm Surge Scenarios Displayed on AdaptNS. Where white represents the available scenarios in AdaptNS.

Climate Change Scenario	**Water Level (meters CD)**				
	2000	2025	2055	2085	2100
Sea Level Rise		x	x	x	x
10-Year Storm Return	x	x	x	x	x
25-Year Storm Return	x	x	x	x	x
50-Year Storm Return	x	x	x	x	x
100-Year Storm Return	x	x	x	x	x
Extreme Storm Event		x	x	x	x

In AdaptNS, two forms of VGI collection were implemented: flood and erosion observations (citizen science), and citizen concern mapping. Similar to the second prototype, users were also provided with the capability to report flood and erosion observations (Figure 7). Some municipalities had addressed the need of citizen science projects in relation to climate change impacts (Tipton, 2013), but they had no present method to address this need. Particularly, citizen science projects were proposed by municipalities as a means to improve methods of monitoring climate change impacts and “improve understanding” of such impacts (Tipton, 2013, p. 26).

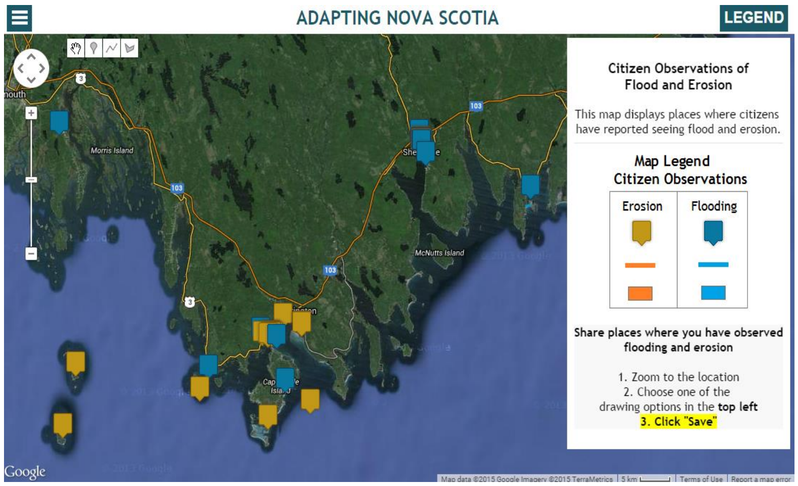


Figure 7. Citizen Flood/Erosion Observations in AdaptNS

To promote climate change adaptation planning, VGI sharing in the form of concern mapping was implemented as a feature of AdaptNS. This feature was designed for citizens to share concerns when seeing the coastal flooding scenarios (Figure 8). It was conceptualized that specific sites could be highlighted when concern data were aggregated; thus, these concern areas could potentially become adaptation priorities.

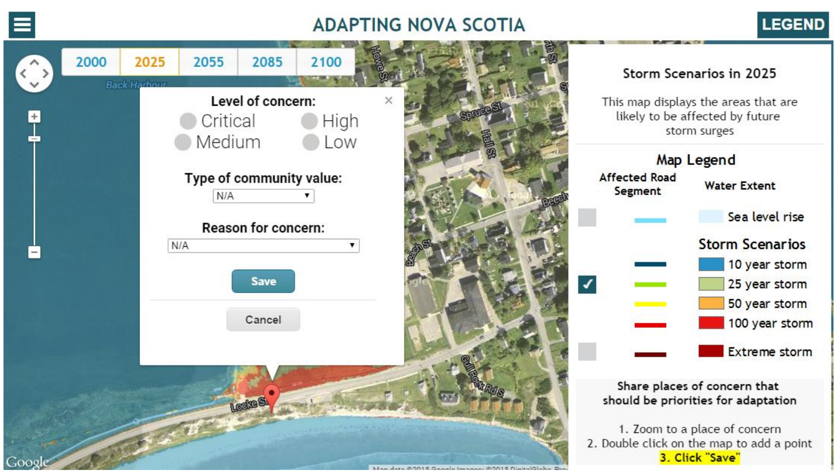


Figure 8. Concern Mapping with AdaptNS

AdaptNS was subjected to evaluation during an in-person workshop with residents of the Town of Lockeport, Nova Scotia (see Figure 2). The Town of Lockeport was chosen to test the tool since it is vulnerable to coastal flooding being situated on an island, and LiDAR data was available at this site for building climate change scenarios. This workshop did not focus on the citizen science component of AdaptNS since this aspect had already been tested in the second prototype stage, but rather, it focused on the concern mapping component. By introducing AdaptNS to 11 residents during a workshop, it was possible to evaluate its ability to communicate climate science to citizens and in understanding how it can formally be used in climate change adaptation discourse and planning at the municipal scale.

2.3.3 Workshop Results

The feedback workshop's structure had 3 general phases: introduction to the study and tool, allowing participants to try the tool, and in-person feedback (Appendix C). First, participants were given an overview of key terminology definitions (e.g.: adaptation), a description of current municipal climate change initiatives and an overview of geovisualization tools. This was followed by an overview of the capabilities of AdaptNS, including its context, scenarios and concern mapping capabilities; however, this introduction was not a live demonstration of the tool. Participants were then asked to browse the tool and contribute their concerns online. Though participants had been discussing while engaging with the tool, time was allocated for a formal group discussion which was then followed by a written feedback form that was completed by the individual participant. The citizen feedback and opinions gathered from the in-person workshop can be grouped into three categories: user experience, climate change understanding, and adaptation planning. For evaluation purposes, participants were asked to use a ranking system between 1 and 5 where 5 generally represented positive feedback, in addition to other methods for evaluation (e.g.: written comments; Appendix D).

User Experience

During the workshop, participants interacted with AdaptNS using Android tablets and a laptop for two hours. Their feedback on user experience was grouped into two categories: observed and reported technological challenges with the tool, and digital literacy. In terms of technological difficulty, 90% of participants ranked the tool 4 or above, where 5 represented that the tool was "very easy" to use. Participants thought the zooming, panning, and making their concerns known through AdaptNS were particularly easy-to-use features. When asked how this technology was different than paper maps, they reported that AdaptNS centralizes information storage, enables multiple user access, and is user-friendly. Many of the technical difficulties users found were related to the small size of the tablet screens (e.g.: small text, screen lock up), which suggests that this medium is perhaps inappropriate for sharing climate change scenarios and related information.

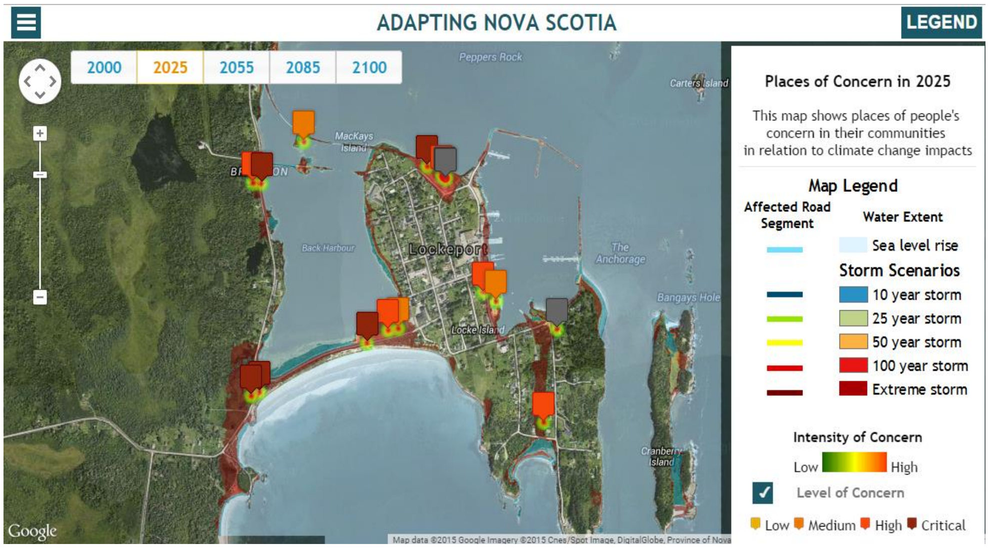
Although most participants had no issues navigating the tool, one participant felt that he/she “not being computer savvy didn’t help”. Yet, approximately 50% of them warned that a pitfall of the tool was that not everyone in the community can use computers or has Internet access. Similar to the results from the second Geoweb prototype, this again indicated that some citizen groups in the region may not be inclined to use or be intimidated by the Geoweb tool. Overall, however, 90% of participants ranked the tool 4 or above, where 5 represented that they would “absolutely” access the tool after the workshop. This suggests that participants had a positive experience using the tool since they would like to access it again in the future.

Climate Change Understanding

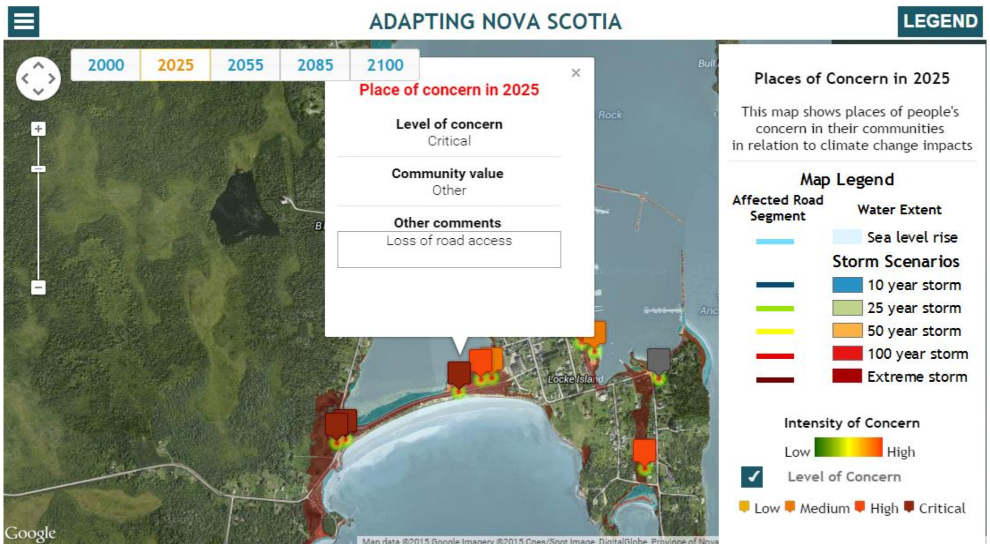
In relation to the tool’s communication capabilities for enhancing citizen understanding of climate change impacts, all participants reported 4 or above, where 5 represented “it enhanced my learning greatly”. When asked to give one example of how the tool enhanced a participant’s understanding of climate change, participants stated that “visual tool very powerful and showed areas of vulnerability that I did not think of before” and that AdaptNS made them “more aware of vulnerable areas”. Another said “The visual helped me see possible impact overtime and storm intensity”. Similar responses were shared by other participants who stated that the visuals improved their understanding of local climate change impacts. While others felt that the tool could “educate the general population of Lockeport and area”. These findings provided insight to the educational capacity of AdaptNS as a means to disseminate climate science in understandable and locally-specific ways to the public and vulnerable citizens facing climate change risks. In terms of improving AdaptNS’ educational capacity, participants suggested that the symbology used for displaying the scenarios could be improved (e.g.: colour coding).

Adaptation Planning

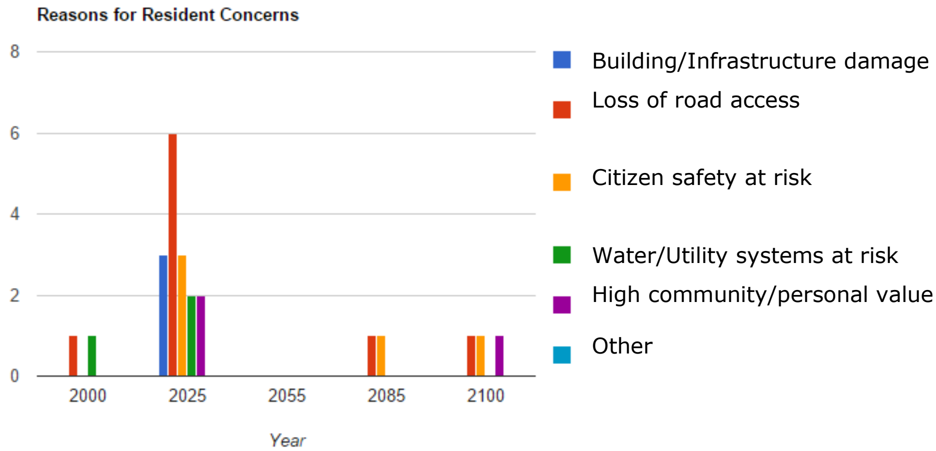
In addition to educating participants on climate change risks, the tool also promoted discourse on the need for adaptation planning by the municipality, and the ways in which the community needs to adapt to climate change. By interacting with the tool, participants were able to identify specific areas of concern and the need for ongoing adaptation planning efforts. Using participants’ VGI contributions, it was possible to highlight clusters of concern in relation to coastal flood impacts (Figure 9a).



(a) Clusters of Citizen Concern



(b) VGI Showing Citizen Concern of Loss of Road Access to Lockeport



(c) Summary of Reasons for Citizen Concern by Year

Figure 9. Citizen Concerns in the Town of Lockeport

Two main clusters of citizen concern were the following: participants' "critical" concern over loss of road access to Lockeport (Figure 9b & 9c), as well as power loss due to flooding of their town's substation located on the north of the island (see Figure 9a). Lockeport has a single road access to the island. In the event of an extreme storm event, loss of road access and power loss would detriment the safety of Lockeport residents, particularly since these storm events sometimes occur in the winter months and several retirement homes can be found on the island (Atwood, 2013). In response to these issues, participants suggested that evacuation planning is needed in case of emergency situations as well as the immediate need for a 2nd road access off the island. AdaptNS also guided participants to reflect on the need of future adaptation efforts, particularly in using the tool to guide future workshops and discussions and to promote continuous public education and climate risk awareness to residents in Lockeport and surrounding areas. Overall, AdaptNS "brought [climate change] home", and with the inclusion of VGI capabilities, it allowed Lockeport residents to identify tangible adaptation goals and priorities based on the presented climate change scenarios.

2.3.4 Summary of Prototype Results

The findings from the three presented Geoweb prototypes are summarized in Table 4. As a collective, they served to guide developer decisions when creating a Geoweb tool and to determine its purpose.

Table 4. Summary of Findings from Prototype Testing Phases

Prototype #1 VGI-Based Geoweb	**Prototype #2** Mobile Geoweb	**Prototype #3** Science-VGI Based Geoweb ("AdaptNS")
• Google Maps/LAMP stack Geoweb structure can manage and permanently store VGI in a centralized online database system. • Large datasets can be displayed on the Geoweb tool without compromising user experience (e.g.: speed when panning and zooming content). • Design flaw: Significant cartographic errors in default roadmap basemap, leading to the use of satellite imagery basemap in future prototypes. • Design flaw: 20m resolution for geographically representing coastal flood impacts is too coarse and overgeneralizes at-risk areas. • Design flaw: Improve overall tool interface design to ensure viewers perceive the content as trustworthy.	• Some participants preferred to use paper maps instead of the Android tablets to complete the questionnaire, suggesting that some citizen groups may not be inclined to use Geoweb technology. • Although there were some precision errors in the collected VGI, participant observations were generally accurate. • Design flaw: Some participants did not want to engage with Prototype #2 since the questionnaire took approx. 10 minutes to complete, suggesting that future efforts should allow users to choose the length of time when interacting with the tool.	• 90% of workshop participants ranked 4 or above, where 5 represented the tool was "very easy" to use. • Participants recognized the benefit of the Geoweb tool over paper maps suggesting that the Geoweb tool centralizes information storage, enables multiple user access and is user-friendly. • Participants found the tablet screens too small, suggesting that this size of device is inappropriate to use in future efforts. • Although only 1 participant expressed having difficulty interacting with AdaptNS, 50% of participants warned that not everyone in the community can use computers or has Internet access. • Participants expressed interest in accessing the tool after the workshop. • All participants ranked 4 or above, where 5 represented "it enhanced my learning greatly". • Participants showed interest in sharing the tool to increase climate change awareness to residents of Lockeport and surrounding area. • Using the participatory component of AdaptNS, workshop participants were able to specify areas of concern and report their level of concern (critical vs. low concern). • Participants were able to use the identified areas of concern to determine adaptation needs and priorities (e.g.: second access road). • Participants suggested that the tool can be used in future workshops and planning activities

2.4 Discussion

Reflecting upon the lessons learned by testing the three Geoweb prototypes, and how these results compare with other geovisualization tools, this section discusses the benefits and constraints of the Geoweb as a climate change geovisualization tool and its role in adaptation planning.

2.4.1 Benefits

Technology

When comparing geovisualization tools in section 2.2, these were compared using the following categories: Arbitrary vs. scientific climate change scenarios, coarse vs. detailed imagery results, offline vs. online. Through this comparison, it was concluded that to avoid communicating false climate change risks to the public and promote their use in adaptation decision-making, geovisualization tools should provide scientific and detailed information. Meanwhile, it was also concluded that although offline geovisualization tools offered an educational experience to those who attended in-person workshops, they do not disseminate this information to the masses. This prevents larger audiences from becoming aware of their own vulnerability and risks to climate change, recognizing the importance for addressing those risks, as well as having a political voice in adaptation decision-making.

In terms of technological capabilities, AdaptNS incorporates beneficial capabilities of other geovisualization tools by displaying high-resolution scientifically-derived climate change scenarios in an online environment. Yet, the tool goes beyond present features of geovisualization tools and also provides a participatory component. AdaptNS' technical capabilities are largely a result of the chosen tool structure: the combination of Google Maps API and LAMP stack. The combination of these two technologies provided AdaptNS with the foundation to become a geovisualization tool for coastal Nova Scotia. Specifically, the Google Maps API provides developers with flexibility to customize the user interface as needed, and to display large quantities of data without compromising user experience. AdaptNS uses the latter as an advantage by displaying scientifically-derived coastal flooding scenarios at the regional scale without slowing-down the speed of map interactions (e.g.: zooming and panning). These visuals are high-resolution (1m resolution) and provide a detailed geographic representation of vulnerable areas across Shelburne County that are vulnerable to coastal flooding events. Its online nature enables AdaptNS to be accessible online and to widely disseminate climate science to vulnerable residents and surrounding areas for raising climate change awareness and the need to adapt.

Understanding, Discourse, Planning and Decision-Making

The importance of the two-way communication abilities of a Geoweb tool is emphasized when creating a tool for promoting climate risk understanding, and formalizing its use in adaptation planning. Similar to other climate change geovisualization tools (e.g.: LCCVP; Sheppard et al., 2011), participants showed an increase understanding of climate change risks in their community using AdaptNS. This enabled them to educate themselves on climate change impacts at the local level, and to promote discussions on how to address these impacts and minimize risks. Similar to other geovisualization studies, citizens had an enhanced understanding of climate change risks by using this Geoweb tool. Nevertheless, by enabling the use of VGI, Geoweb tools can also help define adaptation priorities. Participants in the in-person workshop were able to share their concerns using the online map and define specific adaptation priorities (e.g.: 2nd road access and substation issues) based on their increase understanding of climate change risks. This participatory aspect of the Geoweb tool quantifies public opinion into geographic clusters of concern, and promotes accountability of public opinion by displaying this information online. Though the Municipality of Lockeport had previously addressed the causeway as a concern (Atwood, 2013), the tool allowed residents to improve their understanding of coastal flood impacts on the causeway overtime and the urgency to minimize the current risks resulting from road inaccessibility, such as public safety.

Although more research is required to confirm the Geoweb's role in long-term decision-making and planning, the tool provides a means for promoting responsive action to lessen climate change risks at the municipal scale. Based on citizen feedback, it is evident that the tool increases public understanding of climate change impacts, quantifies public opinions into specific climate change concern areas, and has potential to have a future role in climate change discourse and municipal adaptation planning due to its online nature.

Expert and Non-Expert Development Strategy

It was advantageous to involve the community at multiple stages when designing, developing and requesting feedback on the Geoweb tool. This is to not be confused with statements in Geoweb literature that suggest that non-experts can build Geoweb tools without expert involvement (Lescynszki, 2012). Rather, in this case, the "experts" were the researchers who were needed to process the LiDAR data and create coastal flooding scenarios, cartographically display all datasets comprehensively online, build the Geoweb tool, etc. But the community's involvement was essential for the success of this project since they supplied researchers with LiDAR data, and also to define the purpose and role of the tool in adaptation planning and public education of climate risks. The prototype approach helped to test smaller components of the Geoweb tool throughout the development process to understand any technological difficulties experienced by citizens, and to define the types of information that municipalities needed for moving to the next stages of adaptation planning. Both sources of expertise and knowledge served significant role in designing and developing a tool that has value to residents in Shelburne County, and potential for its use by communities in the long-term.

2.4.2 Constraints

Although the Geoweb approach is beneficial, there are some constraints that were identified including: availability of LiDAR data, legal and ethical considerations, and digital divide. These issues have been identified in other Geoweb efforts and/or climate change geovisualization efforts and do not necessarily apply to only Geoweb approaches (Sheppard & Cizek, 2009; Elwood, Goodchild & Sui, 2012).

LiDAR Data Availability

This research shows that despite open data efforts by the Canadian government (Open Government Home Page, 2015), there continue to be limitations when openly accessing LiDAR data. In addition to this, smaller Canadian municipalities find it difficult to afford the acquisition of LiDAR data due to its high costs. The climate change scenarios displayed on AdaptNS were only possible to create due to an established relationship with municipalities and their recent decision to purchase LiDAR data. Even so, there is only LiDAR data availability in parts of Shelburne County's coastline (see Figure 6). Not only does the lack of data availability prevent the creation of climate change Geoweb tool or geovisualization projects, but also it limits the level of understanding of climate change impacts by municipalities. This lack of data influences a lack of awareness of climate change impacts and inability to inform proactive adaptation (Noble et al., 2014).

Legal and Ethical Considerations

Legal issues are particularly predominant in the Geoweb approach since anyone can see which specific properties are vulnerable to climate change if the scenarios are created using high-resolution imagery. In the case of AdaptNS, the tool was password protected at the time of the in-person workshop to allow residents to review the tool and determine whether they would want it publicly online. Prior to the workshop, the legal aspect was seen as an issue since some property owners may be impacted by AdaptNS due to their property becoming less valuable or less appealing for future buyers. One participant from the workshop also experienced the same concern and warned that "property values may be impacted based on the tool (negatively)". To make matters more complex, scenarios cannot be validated at the time of creation, there are a series of potential futures as outlined by the IPCC emissions scenarios, and there are assumptions associated to each scenario displayed on geovisualization tools (Sheppard & Cizek, 2009; Richards & Daigle, 2011). Yet, legal considerations are at the forefront of Geoweb tools since the scenarios are provided online and anyone can access the information (Surging Seas, 2014; USGS Coastal Hazards Portal, n.d.; CalAdapt, 2015). To prevent liability issues, the Geoweb tool should have legal disclaimers outlining its terms, conditions and user restrictions (e.g.: legal matters and insurance purposes), online documentation on how the scenarios were created and levels of uncertainty and assumptions. A visual strategy to tackle the legal problem can include the restriction of the zoom level of the interactive map and a replacement of the satellite imagery basemap to one that does not display specific vulnerable property locations or property boundaries. This set of solutions can also address ethical issues of AdaptNS since climate change futures are modelled with a set of assumptions and do not represent exact futures. Thus, it can be considered inappropriate to display these visuals at a scale where individual homes are highlighted as vulnerable rather than focusing on more general affected areas within a town or community. These broader vulnerable areas within communities can continue to be informative for establishing local adaptive measures by municipalities, such as protective infrastructure in certain neighborhoods and zoning by-laws for restricting future building construction in a particular area. There is no doubt that AdaptNS is an effective communicator and participatory tool for adaptation purposes; yet, precautions must be taken to avoid legal and ethical issues associated with high-resolution visuals.

Digital divide (or "Tech-Savviness")

Varying levels of digital literacy in non-expert users is a prominent reality in empirical studies involving Geoweb tools (Ricker et al., 2013; Stevens et al., 2014). The same constraint was observed in testing AdaptNS when participants reported concern that some members of the community could not use the tool due a lack of Internet access or be intimidated by the technology. Evidence of this was seen during the second prototype testing phases, where some participants chose to use paper maps instead of the Android tablet to complete the questionnaire. Though, this finding is counterbalanced by participant recommendations to enable commenting capabilities when identifying sites of concern rather than having drop down menus, suggesting that AdaptNS can have more user-intensive capabilities in the future.

Although the tool is online and can disseminate climate change risks to a wider audience than offline geovisualization groups, there continue to be citizen groups that may not be inclined to use this technology. This gap can be potentially minimized by encouraging users to provide feedback for informing development decisions (e.g.: what was easy/not easy to use), as well as by providing a demo of the tool online or in-person and instructions on how to use its features (Sheppard, 2012).

2.5 Conclusions

The rise of the Geoweb since the mid-2000s has motivated researchers to reflect on its implications within traditional academic and professional environments (Elwood, Goodchild & Sui, 2012; Johnson & Sieber, 2012; Johnson & Sieber, 2013). This research introduced the use of the participatory Geoweb tool as a climate change geovisualization tool for Nova Scotia, Canada. By reviewing present geovisualization tools, it was possible to note that these tools have a strong visual impact on spectators and have the ability to inform vulnerable citizens of local climate change risks. Yet, there are still questions regarding how to more formally involve these tools in present climate change-related decision-making and planning (Sheppard et al., 2011). This research responded to that gap by introducing a participatory Geoweb tool (labelled "AdaptNS") that was developed and evaluated with the input of local residents of Shelburne County, Nova Scotia.

To develop AdaptNS, this research employed a community-based feedback prototype approach which allowed Shelburne County residents to test and communicate feedback on their experience throughout the development process. As a developer, the user feedback is valuable for identifying the purpose of the Geoweb tool that is being developed, for determining design flaws and for addressing those in future prototypes. In this case, the heavy reliance on the end-user (or community residents) is reflected in developer decisions to create a tool that displays coastal flood impacts since these were deemed important for the community due to the proximity of industry-related and cultural heritage sites to the ocean. The community input also proved necessary for providing researchers with LiDAR data needed for accomplishing this research, and to identify that present flood maps were unavailable in this region. By understanding present community limitations, it was possible to respond to those needs with research support. As a result, AdaptNS displays coastal flooding scenarios of present and future climate change-induced impacts that fill present information gaps for communities in Shelburne County.

The benefits of the community-based feedback prototype approach also translated to the acceptance of these tools by residents of a community in Shelburne County. Through a workshop with researchers, residents of the Town of Lockeport, Nova Scotia were able to interact with AdaptNS and provide feedback on its user friendliness, its overall capacity for communicating climate science to the public, and its role in climate change adaptation. 90% of participants stated that AdaptNS was easy or very easy to use, suggesting that Geoweb tools are capable of providing large amounts of information and still be perceived as being user friendly due to their multiple geographic and temporal capabilities. Similar to other geovisualization tools, AdaptNS was also perceived as being capable of delivering local climate change risks in an understandable manner and for enabling users to learn about climate change. During the workshop, Lockeport residents were able to define climate change risks and the urgency to start adapting to minimize those risks. AdaptNS was capable of quantifying this public concern and determine that losing road access of the causeway during a storm surge event is of “critical” concern for Lockeport residents and that this risk should be an adaptation priority. In terms of its long-term role in adaptation, AdaptNS was perceived by participants to have potential uses in raising awareness of climate change risks to the public, as well as in future adaptation discussions and for supporting municipal adaptation planning due to its online nature. Though to ensure the benefits of this tool, it is also necessary to consider the legal and ethical dimensions of it by limiting the zoom level of the visualization and the inability to display specific vulnerable properties affected by coastal flood impacts.

This research shows the importance of community involvement throughout the development of Geoweb tools for not only evaluating the final product, but also as a means for developers to make informed decisions for creating and designing Geoweb tools that address community needs and for establishing a more formal role of geovisualization tools in local climate change adaptation discourse and planning. Having been the first of its kind in Canada, there is potential to expand present participatory Geoweb tool capabilities for providing valuable information to communities across Atlantic Canada and for encouraging the need of proactive adaptation planning at the local scale.

Chapter 3

Evaluating the Performance of Geospatial Web Technologies as Support Tools for Community-Based Climate Change Adaptation

3.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) identified that in addition to lowering carbon dioxide emissions at the global scale, there is significant need for climate change adaptation (Noble et al., 2014). This decision is based on evidence that the "warming of the climate system is unequivocal" and challenging societies across the globe in terms of public safety, economic stability, resource availability, among others (Adger et al., 2005; Van Aalst et al., 2008; IPCC, 2014a, p. 40). Adaptation to climate change can be any "process, action, or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity" (Smit & Wandel, 2006, p. 282). Adaptation can come in the form of collective changes to land use by-laws and building codes, to more individual efforts such as farmers changing their agricultural practices (Osbahr et al., 2010). In recent years, the IPCC has suggested that adaptation to climate change should not be a stand-alone process but it should rather integrate with other existing interests and needs, such as presently proposed infrastructure plans (Noble et al., 2014). Yet, identifying appropriate adaptation goals is not a simple task since adaptation is context-specific (IPCC, 2014b). This is primarily a result of varying levels of vulnerability to climate change by populations according to their geographic location, socioeconomic status, present governance structure, culture, gender, etc. (Mirza, 2003; Haddad, 2005; Artur & Hilhorst, 2012). To add to the challenges of specifying needed adaptation goals, there are also concerns surrounding the ways that adaptation should be approached by governments.

Generally, adaptation approaches can be grouped into two categories: top-down and bottom-up. Top-down adaptation is based on the premise of downscaling global climate change models to individuals regions followed by identifying adaptation strategies (Van Aalst et al., 2008). Although beneficial at identifying physical climate change impacts (e.g.: precipitation increase), there was a growing dissatisfaction with this approach since it referenced climate change scenarios created from limited environmental variables, and it overlooked important social factors needed for "effective" adaptation (Smit et al., 2000; Van Aalst et al., 2008; Forsyth, 2013; Field et al., 2014). Bottom-up adaptation or Community-Based Adaptation (CBA) emerged to address issues with top-down adaptation. Its goal is to “allow local people to determine the objectives and means of adaptation practices” (Boyd et al., 2009; Forsyth, 2013, p. 439). This approach focuses on local economic and cultural dynamics and present governance structures to understand how societies have historically dealt with climate-related issues, and how present systems could be adjusted to reduce climate change risks (Smit & Wandel, 2006). CBA uses community “knowledge and networks to undertake locally appropriate activities that increase resilience and reduce vulnerability” (Forsyth, 2013, p. 440) and aims to represent vulnerable and marginalized populations (Huq & Reid, 2007). Despite present efforts, CBA has several shortcomings including its isolated nature, lack of incorporation of climate science, and its inability to make local findings relevant to adaptation efforts in upper and wider governance and political scales (Ayers & Huq, 2009; Forsyth, 2013; Dodman & Mitlin, 2013). These issues are important to address since adaptation to climate change must consider citizen needs and multi-level governance interactions to streamline adaptation efforts across scales and to connect adaptation plans to existing societal needs (Klein et al., 2014).

This research introduces the use of Geospatial Web Technologies (or “Geoweb”; Haklay et al., 2008, p. 2011) as a means to determine how these technologies perform as CBA-support tools. The Geoweb is a collection of Internet-based mapping platforms and applications that enable users to access and/or contribute geographic information (Haklay et al., 2008, p. 2011). In terms of climate change, Geoweb tools and other geographic tools have previously been used to display climate change vulnerability scenarios and guide adaptation discourse (Sheppard et al., 2011; Taber, 2014; Surging Seas, 2014; Coastal Flood Exposure Mapper, n.d.). Yet, thus far, the Geoweb has not been discussed in terms of how it supports the CBA process. Here, a Geoweb tool created for a coastal region in Nova Scotia, Canada is presented as a means to explain how the Geoweb responds to present CBA challenges with empirical evidence, and how it performs as a CBA-support tool. The tool presented in this research (labelled “AdaptNS”) displays scientifically-derived climate change scenarios, enables online citizen participation and was evaluated by members of a vulnerable community. Ultimately more research on the Geoweb as a CBA-support tool is needed; yet present empirical evidence gathered from this case study suggest the role of the Geoweb as a valuable tool for supporting local adaptation efforts with external knowledge, communicating local issues to upper scales, and enabling communities to independently conduct CBA efforts in the future.

3.2 Community-Based Adaptation: Overview and Challenges

3.2.1 Climate Change Adaptation and Community-Based Efforts

Since the global agreement that adaptation to climate change must be conducted in addition to climate change mitigation, there have been debates about how to conduct adaptation (top-down vs. bottom-up) and the benefits and limitations of each approach (Van Aalst et al., 2008; Dodman & Mitlin, 2013). In short, both top-down and bottom-up adaptations provide significant benefits to the adaptation process, and each is guilty of having shortcomings or lack of inclusion of important factors. As top-down adaptation lacks the inclusion of social factors in its analysis, community-based approaches focus too much on the local scale, overlook climate science and its role or relationships with broader scales (Ayers & Huq, 2009; Dodman & Mitlin, 2013). Nevertheless, more and more, it has become evident the interconnectedness between governance scales (citizens, stakeholders, and governments) is needed to identify climate change vulnerabilities, managing and addressing these risks, increasing adaptive capacity, and identifying feasible and socially-accepted adaptation strategies (Smit & Wandel, 2006). Multi-scale governance in climate change adaptation, for instance, can ensure that local adaptation needs are facilitated and not restricted by policies or interests at regional and national scales (Klein et al., 2014). As a result, there is a need to increase the interactions between local needs to upper and wider scales, but to also encourage interactions from external entities (e.g.: non-governmental organizations, businesses, and upper levels of government) in local adaptation efforts (Noble et al., 2014).

In the broader scheme of adaptation efforts, CBA's primary role is to encourage the representation of local perspectives and needs in adaptation decision-making. It is based on the "premise that local communities have the skills, experience, local knowledge and networks to undertake locally appropriate activities that increase resilience and reduce vulnerability to a range of factors including climate change" (Dodman & Miltin, 2013, p. 640-641). Despite its context-specific nature, there is a series of general sequential phases to accomplish CBA in practice (Figure 10; Ebi & Semenza, 2008). In short, Ebi & Semenza (2008) propose that CBA entails the interaction between stakeholders, community members and government officers to identify present vulnerabilities, adaptation constraints, and community interests. For example, CBA practitioners can include mapping initiatives to allow communities to geographically identify important assets for the community (e.g.: economic, cultural) that should be protected against climate change risks. By promoting discussions between various governance actors, adaptation action can reflect existing local needs and be conscious of its feasibility in terms of locally-available resources and financial support.

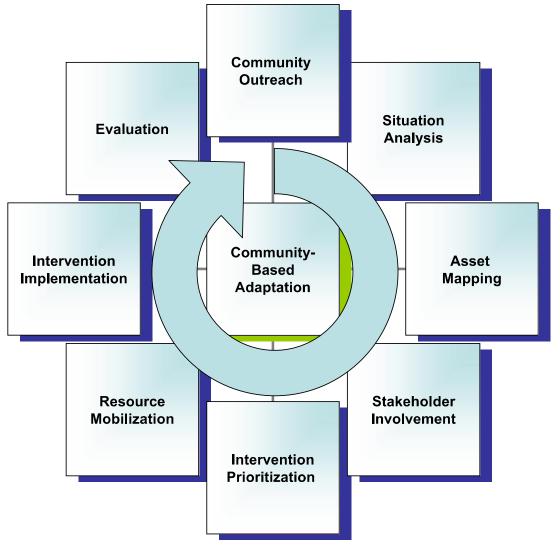


Figure 10. Community-Based Adaptation Framework (Ebi & Semenza, 2008)

The applications of CBA can greatly differ from one another in overall purposes as it can range from addressing health concerns due to climate change to increasing resilience to droughts (Lasage et al., 2008; Ebi & Semenza, 2008). CBA, in practice, has been successful at "addressing issues of capacity building, gender equity and participatory approaches" (Rossing et al. 2012, p. 13). Many of these initiatives have encouraged and engaged marginalized groups in adaptation discussions (Forsyth, 2013), who are also often experiencing more severe vulnerabilities to climate change than others citizen groups in their communities (Adger et al., 2004). Yet, the benefits that arise from the reliance on the local level and community knowledge are juxtaposed with CBA's isolated nature, lack replicability, and its inability in promoting the use of local findings at wider and upper scales (e.g.: surrounding communities and national policies; Forsyth, 2013).

In the literature, the challenges of overcoming CBA's isolated local nature are described as "scalability" issues (Ayers and Huq, 2009; Rossing et al., 2012; Forsyth, 2013). Scalability has been used as an umbrella term for describing CBA's inability to be a replicable process, lack of translating local results to wider and upper scales, and the overreliance on local knowledge and resources (Forsyth, 2013; Dodman & Mitlin, 2013). In terms of addressing CBA scalability challenges, it is possible for CBA to learn from top-down adaptation by more closely integrating the use of downscaled climate science in its analysis, while still encouraging the transferability of local knowledge of climate risks and locally-identified adaptation needs to wider and upper scales. Specifically, this research focuses on identifying how Geoweb technologies support CBA by addressing its present scalability challenges and how these technologies perform overall as CBA-support tools. To do so, two CBA scalability challenges are described, upscaling and downscaling (Forsyth, 2013), followed by a discussion on how the Geoweb responds to scalability. Lastly, present Geoweb constraints are described including suggestions on how to overcome present challenges.

3.2.2 CBA Scalability Challenges

Upscalability

Forsyth (2013, p. 441) defines upscaling as "the challenges of making CBA relevant to risks and policies wider than the scale of communities". This is directed at the issue that CBA provides an educational opportunity for communities to learn about climate change and increase their resilience through discussions among each other; however, the lessons learned from the CBA process often remains within an individual community or a subset of communities. The lack of making CBA relevant to upper and/or wider scales prevents the results to be used by other communities experiencing similar climate change vulnerabilities, or communicating these results to external entities who could facilitate the adaptation process and streamline local findings with "wider development processes" and policies (UNFCCC, 2007; Rossing et al., 2012, p. 3; Noble et al., 2014). The inability to translate CBA results from the local level to wider and upper scales is based on the premise that a community underwent the CBA process. Nevertheless, CBA continues to be a rarity rather than a standard at the global scale (Rossing et al., 2012). Forsyth (2013) suggests upscaling CBA can be accomplished by identifying ways to ensure continuous social learning and risk identification through methodologies that are "replicable" and inclusive of multiple types of information sources (governments, stakeholders, citizens, marginalized groups, etc.; Ayers & Huq, 2009). Essentially, this implies that CBA should not only benefit a subset of communities, but instead, it should be a method that can be replicated by communities at large (Rossing et al., 2012). While Dodman and Mitlin (2013, p. 643) suggest that CBA has to be reinvented as "an open-ended, ongoing and political struggle for development and well-being". Oftentimes CBA is initiated by research efforts; yet, due to its benefits for the communities involved in research studies, it is now encouraged that this method should have a larger and ongoing outreach. The Geoweb can address two upscalability challenges: the need for communicating CBA results to wider and higher scales, and the need for a replicable CBA methodology. Geoweb tools, on one end, are online and can store user-contributed content (Goodchild, 2007). In the CBA context, these tools can serve as a platform for users to contribute CBA-related information to others, whether those are community members in other communities or upper scales of government. Geoweb tools can also serve as a platform created for the use of several communities at multiple geographic scales while still providing individual communities with locally-relevant climate change information (Surging Seas, 2014). This platform can be replicated for various regional contexts as well as a tool for initiating community-led climate change adaptation discussions.

Downscalability

Downscaling can be defined in various ways (Forsyth, 2013). In this case, the lack of downscaling is referred to the overreliance of CBA on local people, local knowledge and locally available resources to adapt, while overlooking external knowledge, forces and powers (e.g.: national interests and climate science; Forsyth, 2013; Dodman & Miltin, 2013). This is a misconception of the power of CBA since there are significant external forces that can be detrimental to local adaptation efforts such as broader economic interests, national policy restrictions, and financial needs that require assistance of external entities (e.g.: upper levels of government and non-governmental organizations; Noble et al., 2014). Smit and Wandel (2006) further this claim when describing Community-Based Vulnerability Assessments (CVBA) suggesting that community-based efforts should integrate multiple sources of expertise and knowledge, which are sometimes found inside and outside of the individual community, for determining vulnerabilities and appropriate and feasible adaptations. Overall the message in these statements is to encourage the connectedness between upper and lower levels of government and citizens, such as the provision of external sources of expertise or information resources to lower scale, and avoiding the sole reliance on the local scale. An example of how external organizations have provided communities with locally-relevant climate change information, that was previously not known by communities, has emerged from research teams that create climate change visualization tools (e.g.: 3D sea level rise visualizations; Sheppard et al., 2011; Watson, 2014). Although effective at communicating local climate change vulnerabilities to the public, communities are often only able to use these tools during in-person workshops held by a group of researchers (Sheppard et al., 2011; Sheppard, 2012). This issue becomes an aspect where Geoweb tools could enrich community understanding of climate change by displaying downscaled climate change visuals that they did not have access to previously; yet, these online tools can be re-used by communities after research is complete.

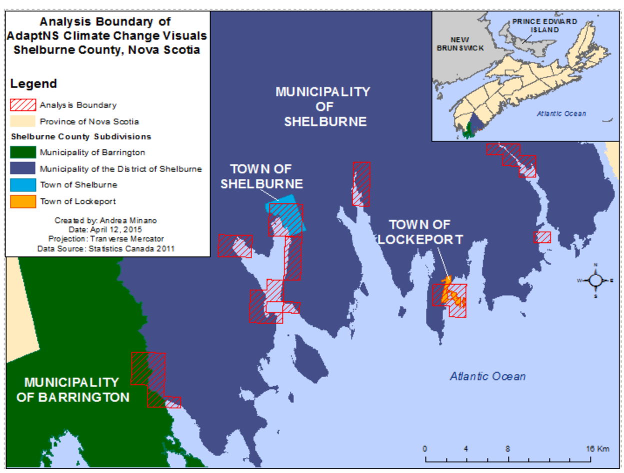
3.3 The Geoweb for Climate Change Adaptation

Geospatial data and maps are commonly used in climate change studies as these play an important role in identifying vulnerabilities created by various stressors at multiple geographic scales (O'Brien et al., 2004;

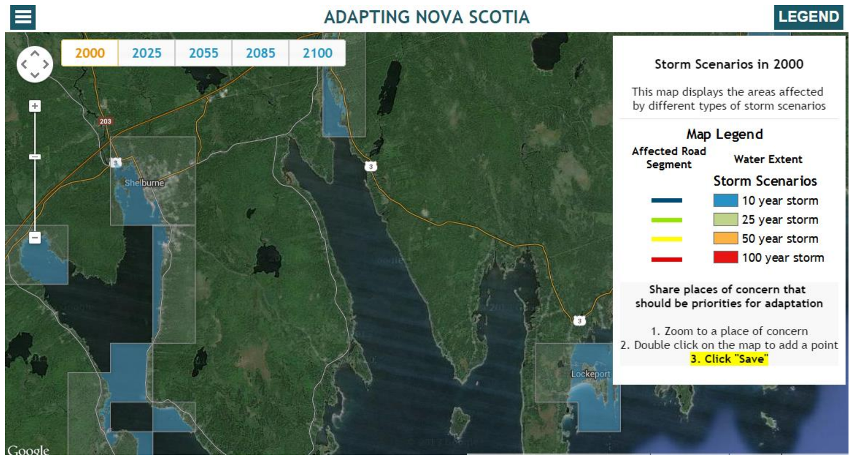
Preston et al., 2011). The information portrayed in maps serves to communicate the "vulnerability of place" in relation to climate change impacts in communities, regions, and at the global scale (Cutter, 1996; Adger & Kelly, 1999; Preston et al., 2011, p. 178). In the climate change context, Geoweb tools act as an extension of more traditional mapping initiatives (e.g.: paper maps) since these tools can be designed to show multiple geographic scales and time periods in a single interactive platform. Since its emergence in the mid-2000s, Geoweb tool capabilities have improved significantly where they now are able to incorporate large datasets (e.g.: regional and global climate change impacts; Surging Seas, 2014), citizen participation (e.g.: comments, pictures; Ricker, Johnson & Sieber, 2013), and display many climate change scenarios (e.g.: scientific modelling results; USGS Coastal Change Hazards Portal, n.d.). These recent technological capabilities of Geoweb tools are incorporated in AdaptNS—a CBA-support tool for a southern region of Nova Scotia, Canada. AdaptNS displays detailed climate change visuals at multiple geographic scales. The tool also incorporates a participatory component where, through the tool, users can report places of concern that should be priorities for adaptation at the local scale.

Climate Change Visioning

AdaptNS is a Geoweb tool that displays coastal flooding scenarios of present realities and future climate change-induced impacts for 9 locations across Shelburne County—a regional municipality in southern Nova Scotia, Canada (Figure 11a).



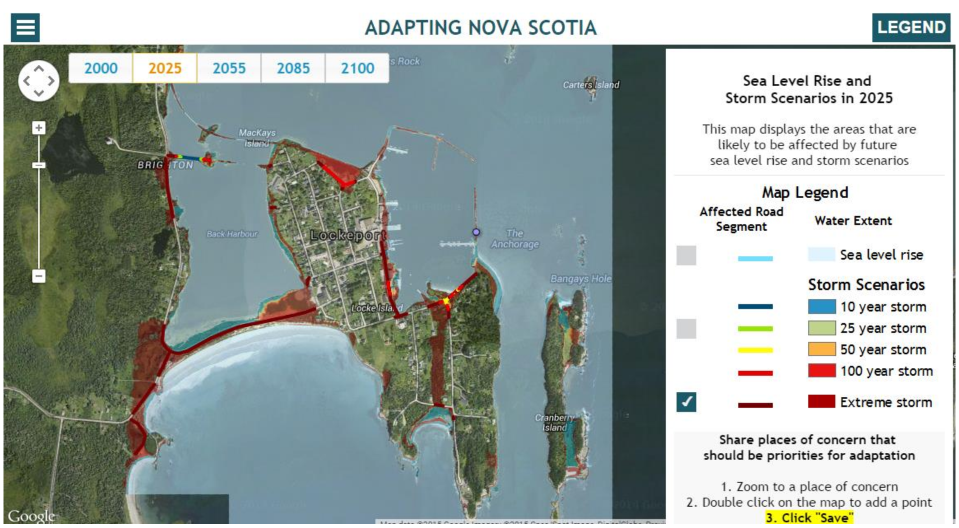
(a) Map of Analysis Boundary of AdaptNS Climate Change Visuals



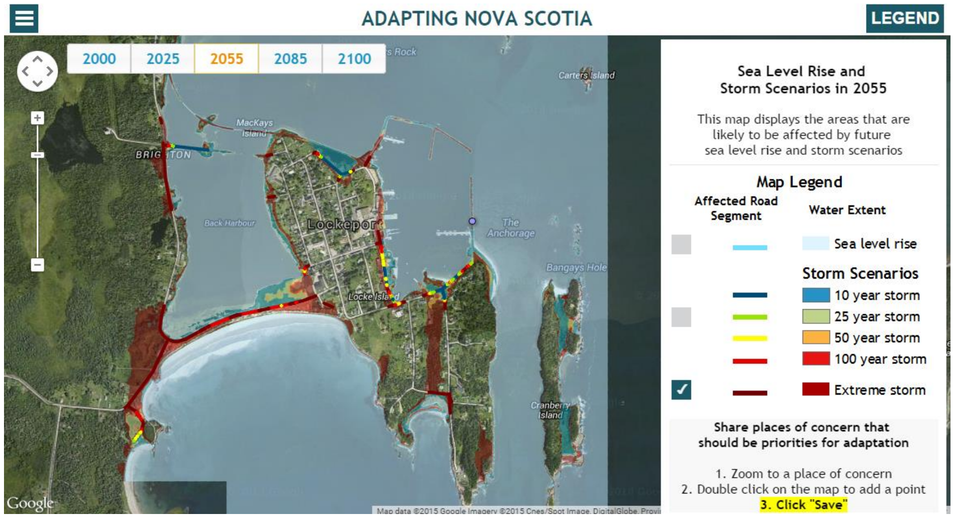
(b) Boundary of Climate Change Visuals as seen on AdaptNS

Figure 11. Boundary of AdaptNS Climate Change Visuals

By working closely with municipalities, it was identified that coastal flood impacts were a climate change concern due the proximity of industry-related infrastructure and cultural heritage sites to the shoreline (Tipton, 2013; Atwood, 2013; MCCAP Shelburne, 2014). Specifically, the climate change scenarios represent impacts of coastal flooding as a result of sea level rise and many types of storm surge events from the year 2000 to 2100. The visual representation of these coastal flood impacts overtime was largely based on existing scientifically-based estimates of present and future water levels in this region of Nova Scotia (Richards & Daigle, 2011; Appendix B). AdaptNS displays coastal flood impacts at multiple geographic scales and temporal scales (Figures 12a & b).



(a) Coastal Flood Impacts in 2025



(b) Coastal Flood Impacts in 2055

Figure 12. Temporal Aspects of AdaptNS

The scenarios were also paired with road block data related to each climate change scenario and public buildings across the region (see Figures 12a & b). By displaying affected roads, it was possible to provide a glimpse of potential emergency scenarios that could result in the inaccessibility to specific neighborhoods in case of storm surge events. Public buildings were also included to display the vulnerability to coastal flooding of potentially valuable locations to communities (e.g.: heritage sites and emergency-response locations).

Participation and Engagement

AdaptNS was designed to allow its users to share places of concern, through the tool, that were also perceived as adaptation priorities (Figure 13). It was conceptualized that through the tool, it would be possible to support CBA by providing community members with a platform where they can share their concerns and identify specific climate change risks that should be prioritized in the adaptation process.

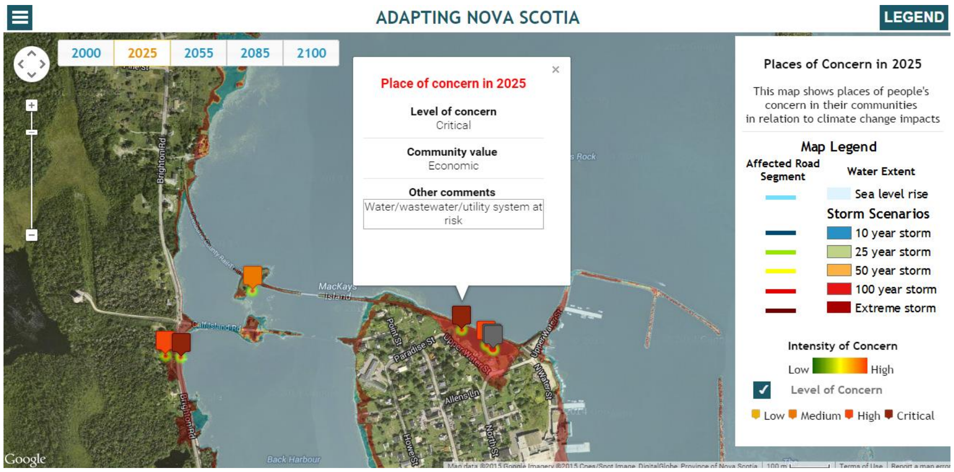


Figure 13. AdaptNS Displaying Citizen Concerns in Response to Coastal Flooding Changes

Of the 9 communities where visuals were provided, only 1 community was subjected to evaluating the tool and identifying its benefits and drawbacks in local adaptation efforts. Eleven residents of the Town of Lockeport, Nova Scotia were able to use the tool during a research-led two-hour workshop that allowed them to interact with AdaptNS by using Android tablets, a laptop computer and a projector screen. Lockeport was chosen as the site to launch AdaptNS since it is an island community and vulnerable to coastal flood impacts (Atwood, 2013). During the workshop, participants engaged with the tool and identified specific areas of concern (Figure 14), and discussed among each other strategies to address these climate change risks. Primarily, participants reported concerns over the loss of their main access road to the island during a storm surge event.

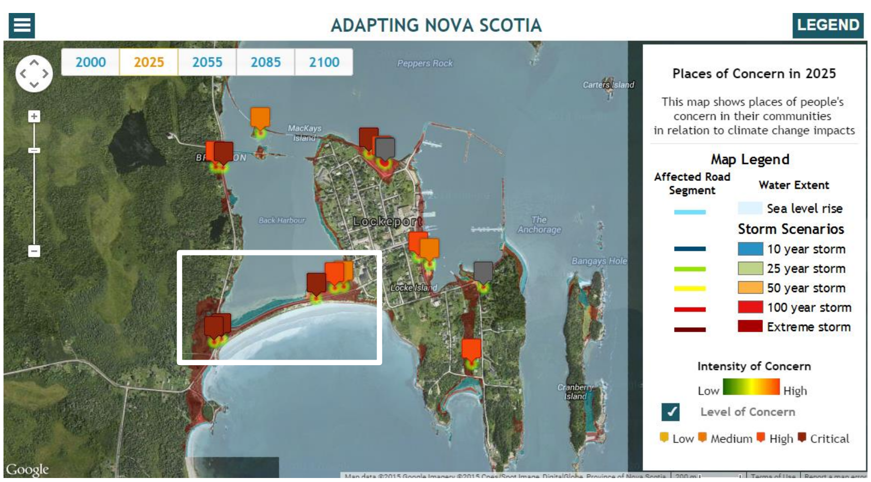


Figure 14. Places of Concern as Identified by Residents of the Town of Lockeport, Nova Scotia. The main access road (also labelled "causeway") is highlighted in white.

Using the findings of this workshop and participant feedback, AdaptNS is evaluated as a CBA-support tool by focusing on its benefits as well as its present constraints.

3.4 Benefits

AdaptNS supports the CBA process by addressing its scalability challenges, both in terms of upscalability and downscalability.

3.4.1 Upscalability

Based on the feedback supplied by citizens who tested and evaluated the tool, there are two central CBA upscalability issues that are addressed by AdaptNS. First, the tool serves as an information source for replicating adaptation discussions at wider scales by Lockeport residents who did not attend the workshop as well as residents in the surrounding area. Second, the tool was perceived by citizens as a source to communicate local adaptation concerns to external entities outside of the individual community.

Adaptation Discourse at Wider Scales

AdaptNS was created as a platform that displays coastal flooding impacts for 9 communities across a southern region in Nova Scotia, Canada; yet, it was only tested and evaluated by 11 citizens of 1 of the selected vulnerable communities. Those who attended the in-person workshop were able to visualize how sea level rise and changes in storm surge events can impact public and privately-owned infrastructure across their town, and share their concerns by using the tool. Although this particular town is vulnerable to coastal flooding impacts, the discussions largely focused on proactive adaptation planning. During the evaluation stage, participants reported that AdaptNS was "extraordinarily valuable!" and that it can be used to "educate general population of Lockeport and area for the need for adaptation and change" and for "helping others understand the [climate change] issue and need for planning". Statements such as these signify the importance of AdaptNS as an education tool to residents within the town boundaries or workshop attendees, and also to those outside of these environments. Although AdaptNS was only evaluated by 11 citizens of 1 community, workshop attendees identified its role in climate change awareness and in promoting ongoing adaptation discourse among town residents who did not attend the workshop and citizens who reside in Shelburne County. In terms of upscaling, AdaptNS provides a re-usable education platform that is accessible to citizens across the region for promoting citizen climate change understanding of local climate change risks and the importance to embrace adaptation and change.

Communication with Higher Scales

As a secondary response to upscalability issues, citizens also perceived AdaptNS to be a means to communicate the importance of adaptation planning to upper levels of government and businesses. Specifically, participants suggested the tool is "very valuable to municipalities and residents" and that it promotes "planning for individuals at all levels of government/business". These statements are further complemented with a participant suggesting that AdaptNS is a "great tool when trying to access funding for projects from governments". Essentially, the tool was perceived to be beneficial to municipalities and residents, and also as a motivator to promote adaptation planning and engagement by all levels of government and businesses. This is particularly a benefit for guiding implementation of adaptation projects at the local level, such as protective infrastructure plans, that will require the assistance of external entities whether it is business consultants or additional funds from upper levels of government. Further research is needed to examine AdaptNS' long-term role in communicating local concerns to the mentioned external entities; yet, there is evidence that this particular community is willing to use the tool for communicating local climate change concerns to upper levels of government and businesses.

3.4.2 Downscalability

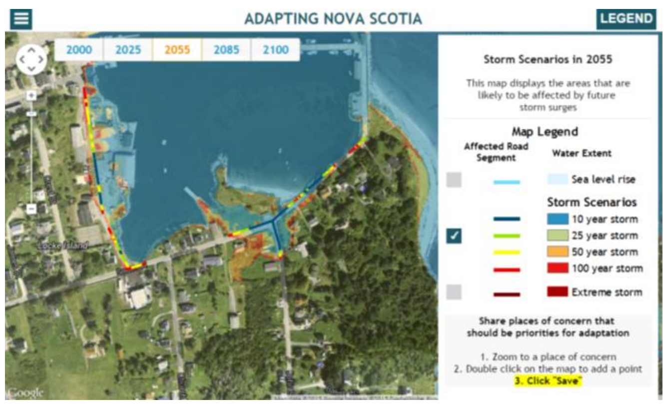
The CBA downscalabilty aspect that is primarily supported by AdaptNS is its ability to provide communities with readily available and comprehensive climate change information that they did not have access to previously or the resources and expertise at the local level to acquire it. The benefit of having readily available climate change information influenced workshop participants to use climate science for identifying adaptation priorities, and for promoting future community-led adaptation workshops.

Involvement of External Expertise

In the initial phases of this research, it was identified that communities had been provided by the Province of Nova Scotia with quantitative climate change-related information (Figure 15a). The information provided, however, was not sufficient for communities to have a thorough understanding of local climate change risks. By working with the community, it was also determined that municipalities had invested heavily on high-resolution datasets for 9 locations across Shelburne County that were needed for creating detailed coastal flood maps but did not have the expertise or resources (e.g.: software) at the local level to browse the data and analyze it accordingly. As a result of this lack of expertise, this research focused on using the acquired high-resolution datasets for creating climate change scenarios that could be valuable and informative for the community. These results were then displayed on AdaptNS (Figure 15b).

Return Period	Residual	Level 2000	Level 2025	Level 2055	Level 2085	Level 2100
10-Year	0.71 ± 0.20	3.01 ± 0.20	3.16 ± 0.23	3.44 ± 0.35	3.84 ± 0.56	4.07 ± 0.68
25-Year	0.81 ± 0.20	3.11 ± 0.20	3.26 ± 0.23	3.54 ± 0.35	3.94 ± 0.56	4.17 ± 0.68
50-Year	0.88 ± 0.20	3.18 ± 0.20	3.33 ± 0.23	3.61 ± 0.35	4.01 ± 0.56	4.24 ± 0.68
100-Year	0.95 ± 0.20	3.25 ± 0.20	3.40 ± 0.23	3.68 ± 0.35	4.08 ± 0.56	4.31 ± 0.68

(a) Climate Change-Related Information Resources Prior to Research Involvement (Richards & Daigle, 2011)



(b) Climate Change-Related Information Resources After Research Involvement

Figure 15. Differences in Climate Change-Related Information Before and After Research Involvement

AdaptNS was created with the purpose to provide communities with the information that they were currently lacking in understandable and usable means. The community itself noted this as a benefit of AdaptNS, where they stated that the tool is “easy to access current information” for “municipal planning, emergency planning”. In terms of long-term planning, participants also stated that the tool provided “…a timetable, specific areas of concern”. Essentially, AdaptNS, in this case, connects the expertise found within researchers to derive climate change scenarios and display these comprehensively online for citizen use. By providing the Town of Lockeport with locally-relevant information in usable and comprehensive ways, they were able to determine how this information can guide adaptation planning at the local scale. This research provides empirical evidence of the importance for the interaction of various sources of knowledge and expertise as stated by Smit and Wandel (2006) for guiding local adaptation efforts. Similar to the inclusion of citizen views on adaptation governance at all scales, community-based adaptation must recognize the need of external support, whether it comes from researchers, non-governmental organizations, businesses, or upper levels of government.

Inclusion of Climate Science in CBA

As a result of the research-community relationship, AdaptNS ensured the inclusion of climate science in CBA discussions and prioritization. This is a particularly beneficial aspect of the Geoweb as a CBA-support tool since there is a present need to better "integrate climate science into CBA while maintaining a community-driven process" (Ayers & Huq, 2009, p. 2). In this case, AdaptNS guided participants to reflect on adaptation needs and priorities by displaying climate science through geographic and locally-relevant visuals. To add to this benefit, the tool's multiple geographic nature, is also capable of providing 9 communities across a region with locally-relevant scientific climate change information in accessible means for guiding each community's discussion on local adaptation needs.

Ongoing Local Adaptation Discourse

The involvement of external expertise also provided communities with a tool that can be used in future community-led workshops. Using AdaptNS, participants were able to identify one main subject of concern: road accessibility to the Lockeport. This issue emerges from the fact that this is the only road access to the Town of Lockeport, and it also vulnerable to being inaccessible during storm surge events resulting in public safety issues. One participant noted "that there are immediate things to be done/put in place and long term goals such as a 2nd access off the island should be planned now" while municipal reports state that another viable option is to elevate causeway (Atwood, 2013). The community had previously acknowledged issues with the causeway due to flooding in the event of storms (Atwood, 2013); yet, the tool helped them understand that the present flood risks affecting the causeway can worsen overtime. The benefits of AdaptNS were also seen as not only defining climate change-induced problems, but also as being "a necessary planning tool for municipal units". The causeway issues and proposed adaptation solutions to address it gathered from the research-led workshop can be used in future planning activities hosted by municipalities to discuss in depth which specific option is needed and how such options could be accomplished (e.g.: financial burden, permit requirements, involvement of the provincial government, etc.). Rather than having a lengthier process for understanding communities' culture and societal values by non-resident researchers, the communities themselves can use Geoweb tools for guiding their own public consultations and adaptation discussions which can be complemented by external resources when needed.

Based on the ability of the AdaptNS to supply CBA with downscaled climate change scenarios, it can be proposed that this Geoweb tool becomes a method that encapsulates beneficial informational sources of top-down and bottom-up adaptation (Figure 16). Particularly, this is proposed since AdaptNS displays downscaled climate change models to communities which is a beneficial information source of top-down adaptation; yet, it also provides a platform for in-person and online citizen engagement at the local level for identifying feasible adaptation strategies that reflect local needs which is a benefit of bottom-up adaptation.

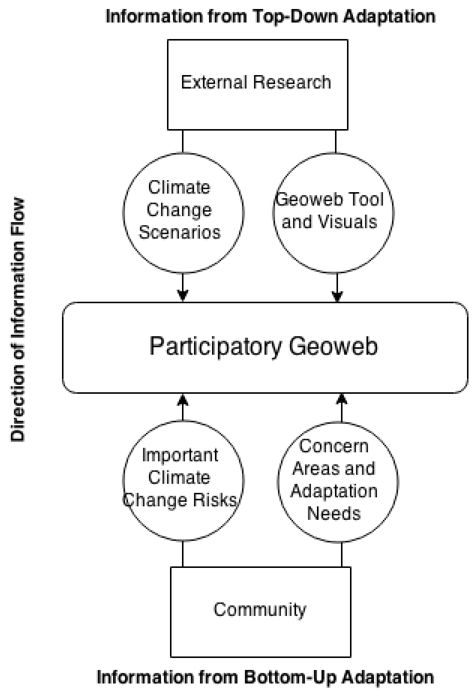


Figure 16. Information Integration of Top-Down and Bottom-up Climate Change Adaptation with AdaptNS

3.5 Present Constraints

Although the Geoweb provides scalability support to CBA, there are present constraints to AdaptNS as a CBA-support tool: audience, uncertainty management, and its long-term maintenance. These constraints are also paired with potential solutions in future Geoweb projects.

3.5.1 Audience

Although Internet infrastructure is available to 99% of Nova Scotians (MacDonald, 2014), members of the general public may not purchase this service in their homes or have a personal computer or digital device. These present facts not only affect the number of users who can access Geoweb tools online, but it could skew results gathered online by favoring those who have access to Internet technologies and computers.

In the case of AdaptNS, participants warned that some members of the community did not have Internet access or are not particularly comfortable using computer technology. CBA emerged from initiatives that encouraged the expansion of democracy to the vulnerable and marginalized sectors in populations (Forsyth, 2013). In many cases, these marginalized sectors may be those who may not have the income to purchase Internet packages in their homes or reside in locations where Internet infrastructure is unavailable. As mentioned by Adger et al. (2004), these marginalized sectors are also often those who are most vulnerable to climate change and who would benefit from workshops that can enhance their resilience by raising awareness of institutions that can aid in times of crisis, emergency plans, etc. As a result, it is proposed that Geoweb platforms are used in two ways. First, Geoweb tools can be used during in-person workshops or public consultation events, as it was in this research, to increase the public's understanding of climate change and encourage adaptation discussions. Through an in-person workshop, many people can attend the event, including marginalized groups and those who are uncomfortable with technology, and still be given the educational opportunity to learn about climate change by displaying the Geoweb results on a projector screen. Second, the results gathered online can be used in conjunction to results gathered during in-person events and discussions or other public engagement avenues (e.g.: paper maps) for prioritizing or identifying adaptation plans. To ensure that all participation resources are jointly stored, if necessary, it is possible for a municipal employee to individually transfer information gathered through paper maps to the Geoweb tool after a public consultation workshop is complete. Although there are some accessibility limitations to Geoweb tools, the platform can be used during in-person events in conjunction with other public engagement avenues to avoid excluding some citizen groups from adaptation discussions.

3.5.2 Uncertainty Management

Preston et al. (2011) warn that maps have the power to create false perceptions on decision-makers due to concluding "prematurely" that all information is now available without critically analyzing the source and context of the map. AdaptNS has the potential to create false perceptions that all climate change related information is now know when this is not presently the case since it only display coastal flood impacts and ignores other climate change risks (e.g.: in-land flooding). This information limitation also relates to the fact that maps are limited to representing information geographically and visually which can oftentimes not include other climate change-related information (e.g.: current policies, stakeholders in charge of specific infrastructure) that may be difficult or not possible to geographically display on a map. As a result, AdaptNS should be presented with a context that highlights the importance to relate the visual information shown in the tool with policies, documents, municipal knowledge, open discussions, etc. that are needed for establishing adaptive measures. To add to the potential misconception that all information is now available, maps and Geoweb tools have limitations in how to manage uncertainty. For example, changes in sea level are represented with numerical values that have a margin of error (e.g.: 3 meters ± 0.5 m; Richards & Daigle, 2011). This margin of error is often challenging to display comprehensively on an online map; thus, encouraging present tools, including AdaptNS, to display future sea level rise with a harsh boundary dividing vulnerable areas and non-vulnerable areas (Tingle, 2006; Surging Seas, 2014; CalAdapt, 2015). These types of maps can provide a false sense of reality to viewers if they are not aware of how these maps are created, including assumptions when modelling future scenarios (Sheppard and Cizek, 2009). This problem is further emphasized in Geoweb tools since citizens who are exposed to these maps are not all experts in climate change science or have understanding of assumptions in climate change modelling.

In response to uncertainties when mapping future climate change and engaging the public, it is essential to provide thorough context to the Geoweb tool in comprehensive ways, including documentation on data source and modelling procedures to prevent the misuse of maps, particularly by stakeholders and decision-makers (Sheppard & Cizek, 2009). Online documentation was considered a necessity for AdaptNS in terms of reporting the analytical processes used for generating the climate change scenarios and its data sources. Using transparent methods of documentation in sources of uncertainty in the climate change futures and modelling, it is possible for the public and stakeholders to be critical of Geoweb tools and in determining its acceptance and use in adaptation decision-making and public consultation. Yet, it is also evident that future work with AdaptNS will also require improvements in terms of visual representation of error margins and the inclusion of other climate change risks.

3.5.3 Long-Term Maintenance

A challenge that was identified during latter stages of research was the long-term maintenance of AdaptNS. This was not previously of concern since there were questions about whether the community would accept or reject the use of AdaptNS and whether it would have value once research was complete. However, there are currently questions about who is responsible for hosting the tool online and who is responsible for developing these tools in the future.

Through this research, it was evident that AdaptNS can provide communities across a region with climate change information. Not only this, but the tool's acceptance by Lockeport residents highly benefited from existing adaptation efforts by both the municipal and provincial governments in Nova Scotia. Thus, it can be suggested that future Geoweb tool development should emerge from higher scales, whether it is provincial or regional scales. This is specifically to avoid the need for individual communities to create their own Geoweb tools when the technology itself can display information at the regional scale. This regional development strategy has been adopted by both CalAdapt (2015) and Surging Seas (2014) by providing the state of California and the United States' east and west coasts, respectively, with regional climate change-related geographic visuals. Also, as seen in this research, communities have limited funds for acquiring data (which resulted in the creation of scenarios for only 9 sites across the County), and they do not always have the technology or expertise to generate their own climate change scenarios or visualization tools. Part of this issue can be addressed by researchers, as seen here; however, upper scales of government or wider scale initiatives are needed for supporting lack of local resources and expertise and connecting local issues to wider scale governance. To add to these challenges, climate change scenarios are not fixed realities; thus, more accurate and up-to-date modelling results will continue to emerge overtime (Richards & Daigle, 2011; James et al., 2014). For example, AdaptNS can ensure its longevity by providing an interactive slide bar for raising and lowering water levels (e.g.: 30 cm intervals), as it has been done by Surging Seas (2014), instead of fixed scenarios. This suggestion reflects one participant's comments where they wanted to "see the changes inch by inch year by year" in a future Geoweb product. Yet, to maintain its realistic aspect, the interactive scenarios can be paired with current numerical information of present and expected water levels in the future. In this manner, the scenarios themselves do not need to be frequently updated, which can be a long and time consuming process, particularly at a time when there is uncertainty about who is in charge of reproducing the displayed climate change scenarios on AdaptNS as new information emerges.

3.6 Conclusions

Approaches to climate change adaptation have shortcomings whether the chosen strategy reflects top-down (government to community) or bottom-up (community to government) methodologies. Nevertheless, each adaptation approach has utility and benefits. Where top-down adaptation is capable of providing communities with downscaled climate change models, bottom-up adaptation gathers public opinions that should be taken into consideration when defining locally-necessary adaptation goals and priorities (Van Aalst et al., 2008; Forsyth, 2013; Noble et al., 2014). Yet, as top-down adaptation struggles with the inclusion of public opinion, bottom-up or CBA approaches are isolated in nature (Rossing et al., 2012). The issues arising from CBA's isolated nature are generally labelled "scalability" constraints by scholars.

This research introduced the use of the Geoweb in CBA processes and evaluated its performance as a CBA-support tool using empirical evidence. Specifically, this research focused on evaluating how the Geoweb supports CBA by addressing its present scalability challenges, while still providing descriptions of present constraints of this technology as a CBA-support tool. To conduct this evaluation, a Geoweb tool, labelled "AdaptNS", was developed for displaying coastal flood risks as a result of climate change for a southern region of Nova Scotia, and for providing a platform where citizens can share places of concern that should be adaptation priorities. Using feedback from residents of one vulnerable community, it was identified that AdaptNS addressed several scalability issues of CBA. First, citizens perceived that AdaptNS had a role in ongoing efforts to promote climate change awareness of local residents as well as others across the region. Second, participants stated their interest in using AdaptNS to communicate local concerns of climate change risks to upper government scales and businesses. Third, the CBA process benefited from a research-community relationship where researchers were able to provide the community with accessible and ready-to-use climate change visuals that they did not previously have or could attain due to a lack of local resources and expertise. This relationship helped to promote the inclusion of climate science in CBA as well as potential for ongoing local adaptation discourse through future community-led workshops.

Despite the benefits, there are also some constraints in relation to AdaptNS as a CBA-support tool. Although AdaptNS has the ability to widely disseminate climate change risks to the public, some citizen groups in Nova Scotia may not be inclined to use the technology if they do not have Internet access at home or a computer. Yet, it is possible for this tool to be used in conjunction to other public engagement avenues or during events for informing citizens of climate risks in person. A more profound present constraint is its ability to only display one climate change risk as well as difficulties in visually expressing error margins that are an integral part of climate change modelling. Currently, thorough documentation is needed to describe all conducted procedures to attain climate change visuals, to maintain transparency and allow decision-makers to be critical of the visuals. Future efforts in this field would be beneficial for identifying means for improving the visualization of error margins in climate changes scenarios. Finally, long-term maintenance is now seen as a challenge since the community would like to use the tool in the future and there is no present established maintenance system or manager. It is suggested that these types of tools should be created and maintained by regional or provincial governments to provide climate change-related information to many communities, but to also ensure its long-term maintenance and information update as new climate change research emerges.

Overall, the Geoweb tool positively served as a means to support CBA by encouraging citizens to define adaptation needs using locally-relevant climate science visuals, and to provide them with tools that are re-usable in the long-term for their own needs and for communicating local concerns to wider and upper scales. Communities should in return be aware that the tool encourages the start of adaptation discussions but requires further assistance to establish adaptive measures from governance systems as well as the inclusion of other non-geographic information sources.

Chapter 4

Concluding Remarks and Future Research

4.1 Summary of Conclusions

This research introduced the participatory Geoweb as a support tool for local climate change adaptation in coastal Shelburne County, Nova Scotia. Here, findings from the presented two chapters are summarized.

In Chapter 2, the participatory Geoweb was introduced as a subset of a much larger body of literature of recently developed climate change geovisualization tools. It was identified that although geovisualization tools communicate local climate risks to its viewers, they presently have challenges in formalizing their role in adaptation planning and decision-making. To address this gap, a participatory Geoweb tool (labelled "AdaptNS") was created as a means to complement present benefits of geovisualization tools and promote the use of these technologies in local adaptation efforts. Similar to other geovisualization tools, AdaptNS provided its users with comprehensive visuals of climate change risks at the local scale. Yet, its participatory component allowed users to specify adaptation priorities for lessening local climate change risks. It was identified that AdaptNS raises awareness of climate change risks to vulnerable citizens, communicates the urgency for communities to adapt, quantifies public opinion and was perceived to have potential uses in long-term municipal adaptation planning due to its online nature. Much of its success for promoting its use in formal adaptation planning is based upon the premise that AdaptNS not only incorporated community feedback to evaluate a finalized product, but to also incorporate community feedback and needs throughout its development stages and in the identification of its purpose.

In Chapter 3, AdaptNS was evaluated as a support tool for CBA processes using feedback from residents of one community in Shelburne County: the Town of Lockeport, Nova Scotia. By reviewing present benefits and constraints of CBA, it was identified that most of these issues emerged from CBA's isolated nature in practice. The term "scalability" has been used by academics as an umbrella term for describing issues arising from CBA's isolated nature. Despite the challenges, CBA is commended for its capability of including local needs in adaptation identification and in providing learning opportunities for those involved in the CBA process. Thus, AdaptNS was introduced in this case as a means to provide existing CBA benefits, but to also support CBA drawbacks by addressing its lack of scalability. AdaptNS proved valuable to Lockeport residents for promoting ongoing adaptation discussions among residents in the region, for using the tool to communicate local concerns to upper levels of government and businesses, and for referencing climate science information in adaptation discussions that they did not have access to before this research.

Despite some shortcomings of the participatory Geoweb, of which many can be addressed in future efforts, these tools serve to support and enrich present community-based climate change adaptation efforts and have the potential to be included in future adaptation efforts as well.

4.2 Future Research

Though this research provided insight to the Geoweb as a CBA-support tool, future research is needed in this field. Future research directions are summarized into three categories: online release, long-term impacts, and increase emphasis on user-contributed content.

Online Release and Implications

In this research, Geoweb tools were delivered to participants in controlled environments (e.g.: in-person workshop). Future research should aim at evaluating AdaptNS and similar tools as online tools. Particularly, this refers to the evaluation of how online users are able to understand the contents presented on the Geoweb tool and how online users provide VGI. Specifically in terms of participation, it is possible for users in online environments to misuse AdaptNS and provide faulty and non-credible information. As a result, there are also questions on how to ensure credibility of online-contributed VGI.VGI credibility has been a subject of concern by scholars (Flanagin and Metzger, 2008) as well as the challenges of its adoption by governments (Johnson & Sieber, 2013). Potential research in VGI credibility can argue that to ensure its credibility, there must be Geoweb tool design aspects that minimize the potential for error of VGI and require users to contribute information using their personal identity (e.g.: forcing users to create a profile prior to contributing information, using Facebook profiles as a means to ensure that VGI is not contributed anonymously, etc.).

Empirical Evidence of Long-Term Impacts

Future research should also evaluate the long-term use of AdaptNS and similar tools in adaptation efforts. Thus far, it is understood that residents of Lockeport are willing to use AdaptNS for future workshops and sharing concerns with upper levels of government. Yet, it is important to also determine whether the tool is used for these purposes in reality and in the long-term. Perhaps future researchers can re-visit communities in the South Shore and interview them about how they have been using AdaptNS and how the tool has supported, in actuality, climate change education and adaptation. This research evaluation can also include the assessment of how AdaptNS is maintained in the long-term, whether it is maintained by a business, government entity, or through open-source and open data collaborations (e.g.: GitHub), and whether the selected approach has been sufficient for providing technical long-term support. This would then address Rossing et al.'s (2012, p. 6) concern that CBA-support tools should be well-documented to promote "well-informed…continued innovation" of tools. This is an aspect that the Geoweb is also beneficial since other, unrelated researchers can access these tools online and evaluate them in the future. Other related analysis could relate to the use of AdaptNS by upper levels of government to better understand local vulnerabilities and priorities for providing external resources and financial aid to enable local adaptation. This upper-lower government interaction can be examined to determine how Geoweb tools facilitate adaptation through upper and lower government interactions (e.g.: provision of financial aid), and how local level concerns influence upper level decisions.

Increase Emphasis on User-Contributed Content and Implications

Finally, future Geoweb research could involve a more thorough use of user-contributed online content, such as online discussion boards. This is to emphasize Geoweb tools' knowledge-sharing capabilities by enabling communities to report proposed adaptation plans to the public and receiving online feedback. Meanwhile, by having more user-contributed content capabilities, Geoweb tools can also function as a means to share success adaptation stories to other communities online. This is to better understand how CBA-support tools enable knowledge-sharing at the local level (Rossing et al., 2012), and whether communities are able to learn from one another's successful adaptation strategies or adaptation knowledge and advice.

Appendix A
AdaptNS Technological Structure

The Adapting Nova Scotia tool (labelled "AdaptNS") was created by using a defined technological structure involving the Google Maps Application Programming Interface (API) and LAMP stack (Linux-based, Apache web server, MySQL databases, and PHP programming language). A similar technological structure was previously used and tested by Beaudreau et al. (2012) who indicated that the Google Maps API and WAMP bundle (Windows-based, Apache web server, MySQL databases, and PHP computer programming language) can be integrated to create a participatory Geoweb tool. The WAMP and LAMP stacks are application server platforms that are equivalent to each other and their only significant difference is that the web server is hosted in either on a Windows or Linux machine, respectively (UCCI, n.d.).

To better understand how these two technologies interact and what each provides, it is essential to first describe the differences between the client and the server. Kurose and Ross (2012, p. 10) define the "client" as "desktop and mobile PCS, smartphones, and so on" and "servers" and "more powerful machines that store and distribute Web pages, stream video, relay e-mail, and so on". In this regard, the client is the computer or mobile device being used to access AdaptNS, while the LAMP's Apache Server hosts and distributes AdaptNS online (Figure 17).

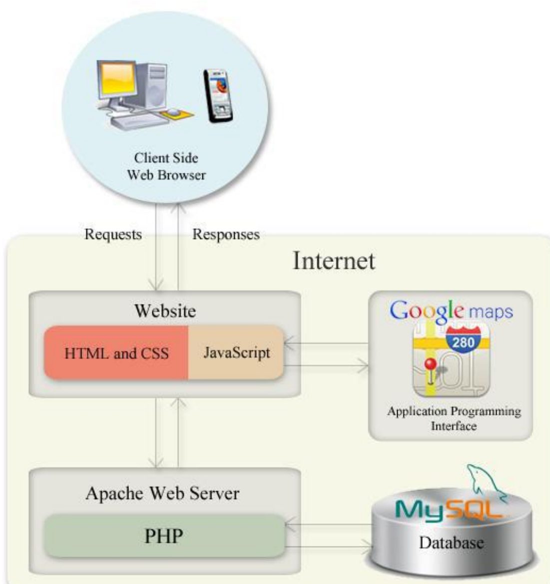


Figure 17. AdaptNS Technological Structure (adapted from Beaudreau et al., 2012)

The client and the server must interact with each other to enable AdaptNS' technological capabilities (e.g.: enable the acquisition and storage of user-generated content). Generally, this interaction involves the client sending requests to the server via the Geoweb tool, and the server sending responses to those requests back to the client. It is within this interaction that the Google Maps API and remaining technologies become relevant in the development process. The Google Maps API, in conjunction with HTML5, CSS3, and JavaScript, are used to create AdaptNS's user interface, such as its map capabilities, legend, toolbar, display climate change scenarios, etc., that is accessed by the client. To allow the storage and retrieval of user-generated content, the MySQL database works in conjunction with the Apache Server and the PHP programming language. An example to better illustrate this client-server interaction is seen when users access user-generated content. Essentially, the client (Android tablet) accesses the Geoweb tool (that is enabled by Google Maps API) and requests to see all of the places of concern. Upon detecting the client's request, the Apache web server replies to the client (via PHP computer programming language) by sending all of the existing user-generated places of concern stored in the MySQL database. With the omission of any of these technological platforms, AdaptNS would not have been possible to create. Each of these has use, purpose and value in terms of providing AdaptNS with its technological capabilities.

Appendix B
Methodologies for Creating Climate Change Scenarios

Two sources of data were needed to create the coastal flood scenarios displayed on AdaptNS: numerical data on present and future water levels, and digital elevation models (DEM).

First, numerical data of present and future water levels was acquired from a report that Nova Scotia's provincial government suggested municipalities to use for creating geographic representations of coastal flood impacts (MCCAP Assistant, 2012). This report was written by Richards and Daigle (2011), and provided water levels for a series of locations across the province of Nova Scotia. The closest location to Shelburne County that was part of the Richards and Daigle (2011) report was Liverpool, Nova Scotia. As a result, the values of Liverpool, Nova Scotia were selected for creating coastal flood scenarios for Shelburne County. The water levels provided by Richards and Daigle (2011) included those for sea level rise (SLR), extreme total sea level (ETSL) in the case of a storm surge event, and plausible upper bound water levels (PUBWL) in the case of an "extreme" storm surge event. Richards and Daigle (2011) described an "extreme" storm as the highest recorded storm surge by existing tide gauge records. The provided water levels account for crustal subsidence that is presently occurring in Nova Scotia, they assume high tide, and do not account for wave height in the event of a storm surge. These estimates are based on the A2 IPCC scenario (Fourth Assessment Report) and the water levels are based on Chart Datum (meters CD; Table 5; Richards & Daigle, 2011, p. 11). In terms of the 2025, 2055, and 2085 water levels, Richards and Daigle (2011, p. 8) indicate that each of these estimates represents a range of years, where 2025 represents 2011-2040, 2055 represents 2041-2070 and 2085 represents 2071-2100.

Table 5. Water Levels in Liverpool, Nova Scotia Between 2000 and 2100 (Meters CD; adapted from Richads & Daigle, 2011)

Climate Change Scenario	Water Level (meters CD)				
	2000	2025	2055	2085	2100
Total Sea Level Rise	-	0.15 (± 0.03)	0.43 (± 0.15)	0.83 (± 0.36)	1.06 (± 0.48)
10-Year Storm Return Level	3.01 (± 0.20)	3.16 (± 0.23)	3.44 (± 0.35)	3.84 (± 0.56)	4.07 (± 0.68)
25-Year Storm Return Level	3.11 (± 0.20)	3.26 (± 0.23)	3.54 (± 0.35)	3.94 (± 0.56)	4.17 (± 0.68)
50-Year Storm Return Level	3.18 (± 0.20)	3.33 (± 0.23)	3.61 (± 0.35)	4.01 (± 0.56)	4.24 (± 0.68)
100-Year Storm Return Level	3.25 (± 0.20)	3.40 (± 0.23)	3.68 (± 0.35)	4.08 (± 0.56)	4.31 (± 0.68)
Extreme Storm Event	-	-	-	-	5.47

Richards and Daigle (2011, p. 24) also provided information on present Higher High Water at Large Tide (HHWLT) in Liverpool (2.30 meters CD) which is "calculated over a 19 year cycle and represents the average of the highest annual high water". Therefore, to calculate the total sea level at high water tide on a particular year, the provided SLR values are added to HHWLT. A similar procedure was done to calculate the extreme storm event for 2100, where HHWLT (2.30 m CD) was added to the maximum sea level rise + error (1.54 m CD) and maximum storm surge to date (1.63 m CD) resulting in 5.47 m CD (see Table 5).

Thus, total sea level at high water on a specific year is calculated by:

Total Sea Level at high water tide = HHWLT + SLR

And extreme storm surge event on a specific year is calculated by:

Extreme storm = HHWLT + SLR + Upper-Bound Error Margin + Maximum Recorded Storm Surge

Using these equations and the provided water levels by Richards and Daigle (2011), the water levels for each scenario and year are calculated and shown in Table 6.

Table 6. Updated Water Levels in Liverpool, Nova Scotia Between 2000 and 2100 (Meters CD; adapted and based on Richads & Daigle, 2011)

Climate Change Scenario	**Water Level (meters CD)**				
	2000	2025	2055	2085	2100
Total Sea Level at High Tide	-	2.45	2.73	3.13	3.36
10-Year Storm Return Level	3.01 (± 0.20)	3.16 (± 0.23)	3.44 (± 0.35)	3.84 (± 0.56)	4.07 (± 0.68)
25-Year Storm Return Level	3.11 (± 0.20)	3.26 (± 0.23)	3.54 (± 0.35)	3.94 (± 0.56)	4.17 (± 0.68)
50-Year Storm Return Level	3.18 (± 0.20)	3.33 (± 0.23)	3.61 (± 0.35)	4.01 (± 0.56)	4.24 (± 0.68)
100-Year Storm Return Level	3.25 (± 0.20)	3.40 (± 0.23)	3.68 (± 0.35)	4.08 (± 0.56)	4.31 (± 0.68)
Extreme Storm Event	-	4.11	4.51	5.12	5.47

The second component needed for creating the coastal flood scenarios displayed on AdaptNS was the availability of DEMs for Shelburne County. Fortunately, municipalities in Shelburne County recently purchased LiDAR data which is needed for creating DEMs. LiDAR data was acquired for 9 sites in Shelburne County: Birchtown, Clyde River, Gunning Cove, Jordan Falls, Town of Lockeport, Louis Head, Sandy Point, Sable River, and Town of Shelburne (see Figure 6). Leading Edge Geomatics, a company that specializes on LiDAR data, collected and processed the LiDAR data to DEMs, and these datasets were later provided by the University of Saint Mary for this research (M. Christian, personal communication, November 7, 2014; B. Kidman, personal communication, April 30, 2015). The DEMs represent topographic height at a 1m resolution and are based on meters above Vertical Datum (CGVD28), unlike the values provided by Richards and Daigle where the water levels are based on Chart Datum (CD). As a result, the water levels in meters CD must be converted to meters CGVD28 (Richards & Daigle, 2011). The difference between these two reference points in Liverpool is 1.125m (CD_CGDV28_Diff; D. McCarthy, personal communication, August 7, 2014). Similar to the methodologies presented by Webster et al., (2011, p. 104) also for the Nova Scotia context, the CD_CGDV28_Diff was subtracted from the water level heights for calibration (Table 7). In the case of 10 year, 25 year, 50 year, and 100 year storm events, the error margin was not considered for this conversion.

Table 7. Water Levels in Liverpool, Nova Scotia Between 2000 and 2100 (Meters CGVD28; based on Richads & Daigle, 2011)

Climate Change Scenario	**Water Level (meters CGVD28)**				
	2000	2025	2055	2085	2100
Total Sea Level at High Tide	-	1.325	1.605	2.005	2.235
10-Year Storm Return Level	1.885	2.035	2.315	2.715	2.945
25-Year Storm Return Level	1.985	2.135	2.415	2.815	3.045
50-Year Storm Return Level	2.055	2.205	2.485	2.885	3.115
100-Year Storm Return Level	2.125	2.275	2.555	2.955	3.185
Extreme Storm Event	-	2.985	3.385	3.995	4.345

Using the values in Table 6 and the DEMs for each of the 9 sites, the coastal flood scenarios were possible to create. A model that uses Esri's Arcpy functions was created to identify vulnerable and non-vulnerable locations to coastal flood impact by using the DEMs and water levels as inputs (Figure 18). This model essentially identifies pixels that are below and above the water level of a specific year and scenario and classifies them as vulnerable and non-vulnerable. The model also ensures that the vulnerable pixels are connected to the ocean to ensure results only display coastal flood impacts. The output results reflect an even rise of water and do not account for wind direction in the case of a storm surge event.

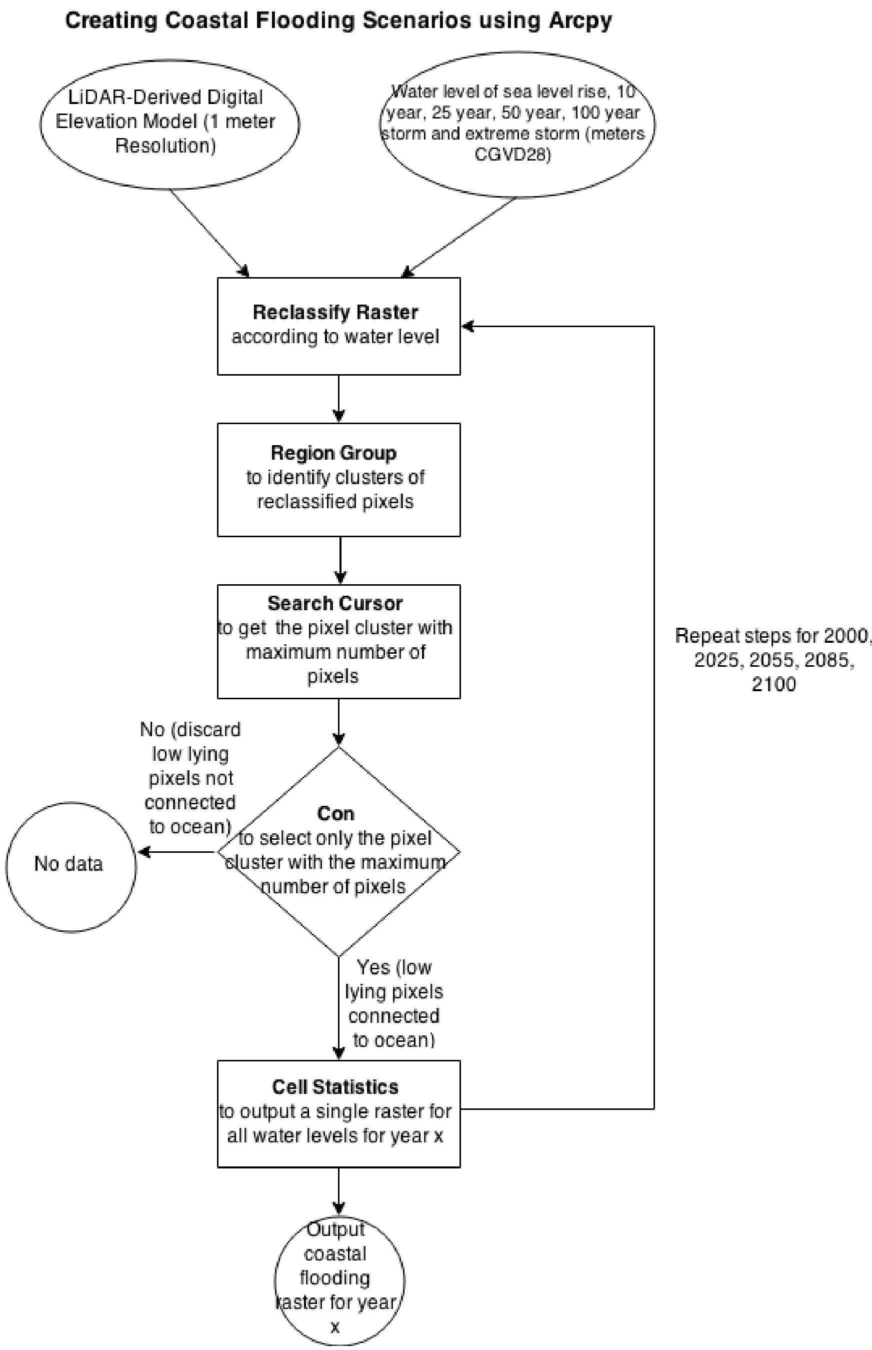


Figure 18. Workflow Diagram of ArcPy Functions Used for Creating Coastal Flood Scenarios

Appendix C
Select Slides from Workshop Presentation

Agenda

5:30 – 6:00pm	Introduction to study Pre-tool survey Introduction to tool
6:00 – 6:45pm	Supper Demo / try out tool
6:45 – 7:30pm	Group discussion Post-tool survey & feedback Concluding remarks

Vulnerability

- Beach / coastal erosion
- Flooding
- Weather extremes

Vulnerable infrastructure, Lockeport, NS

Locke Street West during storm surge Feb 2013

Locke Street West during Hurricane Bill 2009

Locke Street, Lockeport, NS
Source: Lockeport MCCAP (Atwood, 2013)

Adaptation

- Response to climate change that takes action to minimize damage or exploit beneficial opportunities

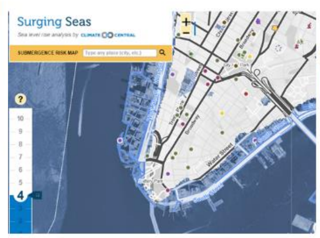
- Adaptation planning
  - Adaptation action (relocation of infrastructure)
  - Policy development (zoning by-laws)

Sand Dunes at Crescent Beach, Lockeport, NS
Source: Lockeport.ns.ca, 2013

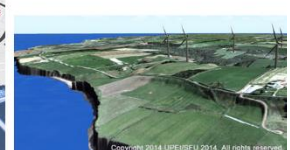
Climate Change Visualization Tools

- What is a climate change visualization tool?

Surging Seas – U.S. Initiative



CLIVE – Canadian Initiative



Municipal Climate Change Action Plan

- By December 2013, the Town of Lockeport and other municipalities in Nova Scotia submitted MCCAPs to the province → **funding for projects**

- Lockeport's MCCAP
  - Listed vulnerable locations on the island
  - Adaptation initiatives and plans
- At the time of writing, some information was not available

AdaptNS Characteristics

- Focuses on coastal flooding impacts in 2000, 2025, 2055, 2085 and 2100
  - 2025: Short-term impact scenarios (2011 – 2040)
  - 2055: Long-term impact scenarios (2041 – 2070)

AdaptNS Characteristics

- User interactions and commenting
  - What concerns you in relation to these maps?

What to look for

- Share **at least 2 places** that are of concern to you
  - If you have a tablet, do so on the tablet
  - If you have a paper map, draw it. Please, add your drawings to the tablet once you get a chance

- Think about valuable places in Lockeport and what is important to you

About the Maps

2025 – Short-term scenario – (2011 to 2040)

2055 – Long-term scenario – (2041 to 2070)

First Impressions

- What were your first impressions?

- What stood out to you?

Post-tool Survey
(5 minutes)

Tool Feedback Survey
(5 minutes)

Appendix D
Workshop Participant Feedback Form

<u>Feedback Survey</u>

1. **Circle one type of value in your community that is most important to you?**

Economic Cultural/Heritage Ecological Future Value Other: ________

2. **How aware were you of climate change impacts in your community before coming to this workshop?**

Using a scale of 1 to 5 (where **1 is "not aware",** and **5 is "very aware"**)

1 2 3 4 5

3. **If this tool was available online (through a public website), would you access it outside of this workshop?**

Using a scale of 1 to 5 (where **1 is "Not at all",** and **5 is "Absolutely"**)

1 2 3 4 5

4. **In your opinion, what is the most important thing that you learned during this workshop?**

____

____

5. **How easy was it to use the tool?**

a. Using a scale of 1 to 5 (where **1 is "Not easy at all",** and **5 is "Very easy"**)

1 2 3 4 5

b. Give 1 example of what was easy and what was not easy to use:

Easy to Use	Not Easy to Use

6. **How has this workshop enhanced your understanding on climate change impacts and adaptation?**

a. Using a scale of 1 to 5 (where **1 is "it did not enhance my learning",** and **5 is "it enhanced my learning greatly"**)

1 2 3 4 5

b. Give one example of **how** this workshop enhanced your understanding of climate change

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7. **How do you see this tool being used by people (e.g.: municipality, citizens, etc.)?**

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8. **What are the advantages/disadvantages to using this type of online technology over paper maps?**

Advantage of Online Maps	Disadvantage of Online Maps

9. Is there information that is missing in the current map products that you would like to see in the future?

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