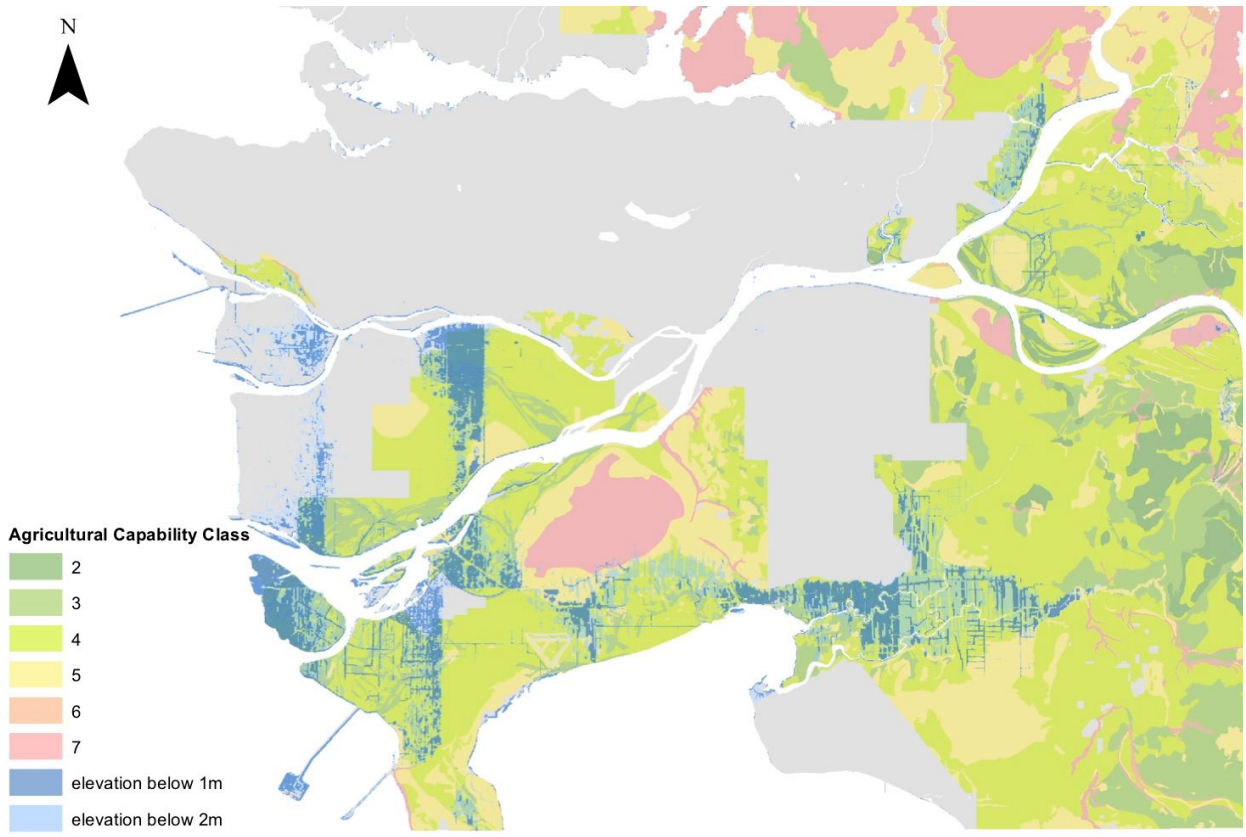

Sea Level Rise and its Impact on Agriculture Production in Metro Vancouver

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Abstract

Agriculture in the Metro Vancouver region makes a significant contribution to British Columbia's economy, making up nearly 30% of the province's gross annual farm receipts. Sea level rise has been posing a more significant threat on the low elevated agricultural land. This project aims to estimate the agricultural area which is under the threat of sea level rise in Metro Vancouver. We have conducted spatial analysis based on 1-meter and 2-meter sea level rise scenarios using ArcGIS software developed by ESRI. In each case, the analysis identified the land area that will be submerged, thus the annual cropland area and the soil capability for agriculture in the identified area. Results show that sea level rise will severely affect Richmond, Delta, Surrey and parts of Port Coquitlam. Within the affected areas, over a quarter of croplands and over 10% of productive soils of Metro Vancouver area are spotted. The future submerged area and croplands are visually presented with the help of maps.

Project Description

Project Description

This project provides 5 maps depicting the affected area and agricultural loss in our study area, Metro Vancouver, under one-meter and two-meter sea level rise scenarios. These scenarios are set based on the Intergovernmental Panel on Climate Change (IPCC)'s Climate Change 2013 Report which states that 1m and 2m of sea level rise will be reached in 2100 and 2200 given a high greenhouse gas concentration (IPCC, 2013, p. 1140-1141). To provide an overview of the impact of sea level rise, the areas with an elevation of 1m and 2m and all cropland area in Metro Vancouver are highlighted in Map 1 and Map 2. Cropland that will be submerged in the two scenarios is shown in Map 3 to display to total impact in agricultural production. The agricultural capacity of all land in Metro Vancouver are also included in Map 4 and Map 5 to illustrate the proportion of land with a high agricultural capability which will be lost.

Spatial analysis was conducted in a mathematical context to provide interpretational statistics on the projected impact. Using Statistics command, we read the total area of affected land, the total area of affected cropland in Metro Vancouver and calculated the loss percentage. Percentage loss of agricultural arable land in Metro Vancouver is also computed to demonstrate the extent of the negative impact on grain production in the region.

Methodology

Acquire

Digital Elevation Model (DEM) data with a solution of 25m was acquired from Open Data Canada to depicted the submerged area in 1m and 2m sea level rise. As a recent estimation on future sea level rise is accurate to 0.1m, our initial goal was to find DEM data with a resolution of 1m. However, only 1m DEM data for the City of Vancouver could be found online, and the high resolution for the data for the rest of the region is not available at the moment. The limitation of this data will be addressed later. To investigate the impact on agricultural production, we acquired British Columbia's land use and agricultural capacity data from Data BC.

Parse and Filter

Geodatabase was created after downloading data. We renamed the original data and organized our data by storing data inconsistent paths and removing the original data layer after clipping and intersection. All data/layers were clipped to our project boundary polygon, which is created using the New Feature class function to represent our project area of interest.

Mine

The DEM data represents the relief of the surface. In its attribute table, a specific elevation level in meter is given for each raster grid. Since our project focus only on the area impacted by 1m and 2m sea level rise, we reclassified the raster data into 3 classes: 0-1m, 1-2m, and all value above and converted it to polygons. To extract cropland polygon out of land use data, we first used select by attribute to get selected set of croplands then exported the set of data to a new layer for further data processing.

For agricultural capacity data, we noticed that in the attribute table, land areas with the same level of soil capacity are given an attribute of either "X" or "OX" to differentiate between organic and inorganic classes. To combine these classes with the same agricultural capability level for further analysis, we added a new field in the attribute table and assigned lands with each capability level with consistent attribute value (e.g. land polygons of Class O1 or 1 are assigned with an attribute value of 1 in the new field).

We intersected below groups of layers to conduct spatial analysis and to visualize the impact of sea level rise on agricultural production: 1) Cropland layer and

dem1m/dem2m layer; 2) High Capacity layer and dem1m/dem2m layer. To conduct mathematical analysis and discern the pattern, we also calculated the total areas of polygons of interest, e.g. total affected cropland. These statistics and its implication will be addressed in the discussion and results section.

Represent

All layers are projected to NAD 1983 UTM Zone 10N coordinate system by using the Project tool. For Map 1, we symbolized the reclassified DEM data to give an overview of projected sea level rise. In Map 2 and Map 3, submerged area, total and affected cropland areas are displayed. In Map 4 and Map 5, the agricultural capacity of land in the affected area and the overall capacity of all land in Metro Vancouver.

Table of dataset

Table 1
List of data we used in the project

Data	Source	Uses	Data model	Attribute	Modification
dem92g	Open Data Canada	To determine the area affected	raster	Value(elevation)	Reclassify, convert to vector data
Land use	Data BC	To locate the farmland	vector	Landuse_type	Clip to project boundary, selected by attribute: "annual cropland"
BC_Ag_Cap_Mapping	Data BC, last modified in 2018	To determine agricultural capability of specific area	vector	Agricultural capability class and subclass	Add attributes to combine capability classes, clip to project boundary
Project boundary	Created by New Feature Class Command	To clip geospatial of interest	vector	N/A	N/A

Discussion and Results

Based on our maps and following spatial analysis, we are able to identify and examine the potential loss of valuable agricultural land. The damage is going to happen by direct loss of current cropland and losing the land's capacity to perform agricultural activities.

Submerging Cropland

The lowlands of Richmond, Delta, Surrey and riverside of Port Coquitlam will be greatly affected by sea level rise indicated in Map 1. Much of the area below 1 meter are located in the middle part of Richmond, parts of Sea Island, Westham Island, Northern Delta and South-western Surrey. These regions also contain high yielding and agriculturally valuable land in the Lower Mainland, Map 2 shows the overlay between cropland area and potential sea level rise elevation. A substantial area of the annual croplands are located (croplands cluster around the blue submerging zone). In the area below 2 meters, over 30% are the annual croplands. Table 3 suggests a high share of cropland within 1-meter to a 2-meter elevation in Metro Vancouver.

Table 2
Total area affected by 1m and 2m sea level rise

Total area of Metro Vancouver	2882.7 km^2
Area below 1-meter elevation	59.8 km^2
Area below 2-meter elevation	122.3 km^2

Table 3
Percentage of cropland affected in 1m and 2m elevation under 1m and 2m sea level rise

Percentage of Cropland in Area below 1-meter elevation	28.6%
Percentage of Cropland in Area below 2-meter elevation	30.3%

Also, the percentage of cropland affected compared to unaffected cropland are the following: **12.1% loss** of total cropland within Metro Vancouver with 1m sea level rise; **26.2% loss** with 2m sea level rise. By the time sea level rises up to 2m, a quarter of current cropland within Metro Vancouver will be underwater. (Table 4)

Table 4
Percentage of Metro Vancouver's cropland affected under 1m and 2m sea level rise

	The cropland loss (km^2)	Percentage of Total Cropland affected (%)
1m Sea level rise	17.1	**12.1**
2m Sea level rise	37.1	**26.2**

*Total Cropland Area 141.8 km^2

Loss in Land with High Soil Capability

To analyze the impact of sea level rise on land with high agricultural capability, we calculated the total area of land with Class 2,3,4 of soil capability (land with Class 1 capability is not in the range of our project). 5.2% and 11.% loss in agriculturally capable land will occur in 1m and 2m sea level rises in Metro Vancouver respectively.

Table 5
Percentage of agriculturally capable zone affected under 1m and 2m sea level rise

	Affected Agriculturally Capable Zone (km^2)	Percentage of Agricultural capable land loss (%)
1m Sea level rise	39.7	**5.2**
2m Sea level rise	84.5	**11.1**

*Total area of Class 2,3,4 within Metro Vancouver: 764.3 km^2

Although 5% and 11% is not a significant percentage, it it strategically important to protect these area from sea level rise to ensure local food security. Besides the sea level rise, saltwater intrusion is also weakening the soil capacity of the coastal area, leading to further erosion of agricultural capable land.

Discussion

According to the spatial analysis, we suggest that the agriculture production in the lower mainland will be notably impacted by sea level rise. At present, agriculture in Metro Vancouver is well established with over $789 million in gross annual farm receipts in 2010 (27% of the BC farm total) on only 1.5% of the province's agricultural land. The region's farmers supply over 130 different farm commodities including a wide array of fruits, vegetables, dairy, poultry and other livestock products (MetroVancouver, 2019). However, a 1m sea level which is projected to happen in 2100 will affect these farmland, people who make a living out of them and crush one of the important pillars of the province's economy. As a matter of fact, in Delta, where it is composed of rich lowland, agriculture is a major contributor to the local economy given "the total gross farm receipts of almost $170 million in 2010" (City of Delta, 2019). Even though Delta is home to only 3.3% of farms and 6.4% of the total agricultural land base in the Lower Mainland, its farms earned 11.5% of the area's gross farm revenues and a relatively high proportion of BC's total gross farm receipts (City of Delta, 2019). Also, about 50% of the province's potato acres, 50% of the greenhouse

vegetable area and 25% of the field vegetable acres are located here (City of Delta, 2019). Delta is located at the river mouth of the Fraser River receiving continuous supply of sediments from the upper stream. The favourable condition of the environment has contributed to the success of its agricultural economy. However, much of the land in Delta is low-lying and under the threat of sea level rise. It is important to aware of the threats to the economy in the future The entire economy of Delta is shaped by agriculture, so the land loss is not simply a problem of agricultural output but also an issue of loss in job opportunities, houses and communities. Richmond also has a significant portion of land dedicated to agriculture as Agricultural Land Reserve occupies 39% of the whole city (City of Richmond, 2019). There are 211 farmers and its revenue accounts $48.6 million (City of Richmond, 2019). Furthermore, Richmond contributes to BC's berries industry by large. Dedicating 858 ha of land towards the cranberry field, the city produces about 33% of cranberries produced in BC (City of Richmond, 2019). Thus, losing these land signifies an impact for both local communities and and the whole province. Also, the livelihood of local residents will be destroyed and provincial food security will be undermined.

To figure out the solution to mitigate the seemingly inevitable sea level rise, we need to understand the mechanism behind sea level rise. As long as we emit greenhouse gas into the atmosphere, the energy budget of the earth will be positive; more longwave radiation will return to the earth and heat the planet. Consequently, the thermal expansion caused by warming of the ocean, and melting glaciers and ice sheet lead to the global mean sea level rise. The rise will be continuous unless the glacial period or global dimming takes place for the next time. Furthermore, there is a time lag between the action of cause (emission) and the effect; Therefore, our priority is to minimize our emission of greenhouse gas as much as possible.

Even though there is uncertainty in the projection of the sea level scenario after 21st century, a 2m rise could happen with a medium GHG concentration level of 500-700 ppm CO_2 (IPCC, 2013). Under other extreme events, such as flood and storm surge, the water level is expected to be even higher. Results from our analysis show that 2m rise will be fatal since Metro Vancouver would lose a quarter of current annual croplands among which 11.1% is land with high soil capacity. Displacement of people and economic loss will be inevitable and will stir society in negative ways, which may eventually lead to social disorder. Even though it is hard to determine when the 2m mean sea level rise and extreme events will happen, it is vital to estimate the severity of these potential events and prepare ourselves in light of the estimated impact shown in our project. Inaction and indifference attitude is present as both cities' websites had no mention of the potential loss of their land due to sea level rise. We hope this project could raise the awareness by visualizing the foreseen situation.

Sea level rise is anthropogenically caused and humans will be those who suffers too. It depends on today's us to have brighter future or not when it comes to sea level rise because of oceans response time lag. In this analysis, we looked at sea level rise by elevation and not chronologically, as a result, we were able to assess the impact through a much larger time frame. Sea level rise will inevitably take place from what we are doing today and the same thing applies to climate change where today's emitted CO_2 will circulate the earth's system for 500 years to continually increase the temperature of Earth. Most of the research does not dare to estimate more than 100 years to the future but, maybe thinking through and planning according to natural system is important.

In the case of the Lower Mainland, we elucidate the agricultural loss. Delta and Richmond need to prepare for the future; collaborating with the provincial government, national government and various civil society, they need to strategize their action and promote public awareness. Overall, planning, preparing, observing and making new knowledge are all in need to combat global sea level rise; however, it is also a wicked problem which agreement between countries are often is difficult to reach. Nonetheless, conducting the spatial analysis all around the world similar to what we have done can elucidate their future loss and will be a valuable tool to prepare ourselves.

Error and Uncertainty

The area of analysis in this project is based on DEM data showing the Metro Vancouver Area. It determines the areas affected by sea level rise when we filter out cells with an elevation below 2 meters, hence this is crucial to the precision of the results in the following analysis. As the value of a cell is based on the average elevation within the cell area, a 25-meter resolution may limit the accuracy of results by ignoring the elevation fluctuations in each cell. The reason for using this DEM data is because there are no other DEMs showing Metro Vancouver with higher resolution available to us. DEMs with higher resolutions such as 10-meter can bring a better picture and distinguish areas in the threat from those in the 25-meter resolution.

Data incompleteness has also affected the results of the analysis. The actual croplands affected by sea level rise might be underestimated since only annual croplands are analyzed in the analysis. There are some other land use types of cropland such as perennial cropland and cultivated agricultural land which are excluded so that sea level rise is expected to affect more areas of croplands than the areas shown in the figures. Also, the agricultural capability data only represents the soil and climate conditions of the areas but

not all the areas covered in the capability layer are croplands. Farming activities which are under the potential effects of sea level rise might be overestimated. Meanwhile, we did not include the soil subclasses in the agricultural capability data according to Data BC, we might not be able to indicate the exact class name of the soil. Nevertheless, Map 4 and Map 5 serves to show the general types of soil and areas of productive soil affected.

In addition, we are less confident in predicting the actual croplands affected by sea level rise in a longer time frame. As mentioned in the IPCC's *Climate Change 2013: The Physical Science Basis* report, a 2-meter sea level rise will be reached in two centuries under a high concentration of greenhouse gases. In a lower concentration scenario, it will take more than 500 years to reach that (IPCC, 2013). Uncertainty arises when predicting the annual croplands and soil affected in such a long time when the number of croplands is constantly changing in the area. For example, there are 30477 hectares of land are actively farmed in 2011. As the Metro Vancouver federation promotes METRO 2040 VISION by increasing the amount of actively farmed land, the number of active farmland as well as the potential croplands affected by sea level rise are expected to rise in the area. Data should be updated constantly in order to make better predictions.

Future Research and Recommendation

This research has been limited in scope due to the constraints in terms of the resolution of digital elevation data, this project will benefit from data of higher resolution to reduce the uncertainties in results and better indicate the areas within the area of 2-meter sea level rise.

Beyond the threat of sea level rise, storm surges and king tides also pose threats to coastal regions. If their effects come together areas higher than 2 meters will be definitely affected as well. Another step to change the analysis process would have been to set up buffers around the affected croplands. In the analysis, we only indicate croplands below 2 meters but it would be informative to indicate croplands around those affected croplands. This would reflect farming activities, above the elevation of 2 meters, that should be aware of the threats of storm surges and extremely high tides.

Furthermore, the inclusion of other types of farmland land use such as dairy farms can help to determine the overall farming activities being affected by sea level rise, and it is useful to estimate the numbers of livestock in threat. The analysis can also include the region's Agricultural Land Reserve (ALR) data to inspect the threats of sea level rise to potential farmland. Data shows only half of the ALR was farmed in 2011 so with this data much more area is being screened to provide a better picture. If more data related to farm production activities such as road network are present, we will be able to estimate the

economic impact of sea level rise in the farming sector. Research can also be done on whether the agricultural capability of land, especially coastal soil, will change due to sea level rise and climate change.

The project visualizes the areas of farming productivity and potential farming which are under the danger of submergence when sea level rises. It can be useful in the processes of city planning and environmental assessment, to show the agriculture production needed to be protected or relocated in the future. We hope the analysis can spark more discussions on how to protect our valuable farmland in the future.

Appendices

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