A Geospatial Analysis of Quebec
For Potential Ski Resort Locations

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Introduction

When constructing a ski resort, the choice of location depends on a variety of factors. The geospatial analysis of data allows for the consideration of different factors for each potential site. Similar geospatial studies have been done for ski resort locations such as one by Gabdrakhmanov for Isfahan Province in Iran [1]. In a paper by Cheng [2] the importance of geospatial analysis technology for location selection is emphasized.

The following report details the use of geospatial analysis to assess different factors between 23 hilltop locations in Quebec, Canada. The aim of the analysis is to find the location most suited to the construction of a ski resort and provide four other nearly ideal options. Snowfall is an extremely important factor when deciding the location of a ski resort, as outlined by Beyazit [3]. The factors considered in this analysis when analyzing each location were terrain of the area, precipitation (or snowfall), distance from amenities, distance from protected areas, inhabitants already living in the area and road access to each site. Fang's study of spatial patterns of ski resorts in China [4] showed a lot of similar factors to consider when choosing ski resort locations.

Data

The data used to explore terrain of the areas was a digital elevation model of Quebec [5]. The shuttle radar topography mission (STRM) used two radar antennas on the space shuttle to calculate elevation of each location.

When considering precipitation, the data used was a raster dataset of average precipitation in January of Quebec [6]. Using data during the month of January guaranteed that majority of the precipitation recorded was snowfall. This average was taken for the years 1970-2000 using the SRTM elevation data by WorldClim.

Finding amenities in the area was done using vector point data from Open Street Maps of points of interest (POI) [7]. This data included as amenities may be churches, schools, post offices, car parks, and many other things.

The data used for identifying protected areas in Quebec was vector polygon data taken from protected planet Canada [8]. It provides locations of terrestrial and inland water protected areas, marine protected areas and other effective area based conservation methods. Within Quebec, these areas were located from the Canadian Protected and Conserved Areas database by Environment and Climate Change Canada.

The population data used was a population counts raster dataset provided by NASA [9]. It consists of 2020 data for populations from national censuses and population registers adjusted to the UN world population prospects.

Road network datasets were taken from the National Road Network created by the government of Canada [10]. It is updated annually to reflect current road networks in Canada.

Finally, the 23 hilltop locations used to represent candidate sites for the ski resort were provided with no source information.

Method

In this section, an outline of exactly what methods were used to conduct a geospatial analysis of the data will be provided. Some of the data needed to be processed or converted to be more suitable to the factors being considered.

The first important step was to project all the data into one projection. The one chosen was NAD 1983 CSRS UTM Zone 18N since it seemed appropriate for Quebec. A projection allows the map to reflect the actual earth's surface more closely. Using a projection suitable for the region of study is important because it can limit distortion in said area which may be common in other projections [11].

The next step taken was to buffer each site with a radius of 2.5km. This was important to create an outline of approximately how big the ski resort would be and an accurate representation of what the terrain and precipitation of the location would be. This created a circle of area approximately 20km, which was the given size of each site.

Next, was converting the digital elevation model into slopes of elevation with a percent rise. This was done using a tool to identify the steepness of each pixel compared with those surrounding it and output a percent rise for each slope. Using map algebra it was possible to create a new grid layer of only the values of slope between 10-50%, which were outlined to be ideal for skiing.

Instead of simply creating a layer visually depicting the intersection between the ideal slopes and each site, it seemed like a better decision to create a table of the intersection to provide exact amounts of area covered by appropriate slopes. The raster layer created with map algebra first needed to be converted to a polygon vector layer and then intersection with the buffers was tabulated. This provided a table with an exact percentage of coverage with slopes between 10-50% for each site.

Next, to calculate the total snowfall at each site the precipitation raster dataset was used. The buffers created for each site provided a vector polygon zone to calculate the sum of the raster precipitation cells under. Using the tabular form of this tool, the data of each site was provided in a table alongside the site ID.

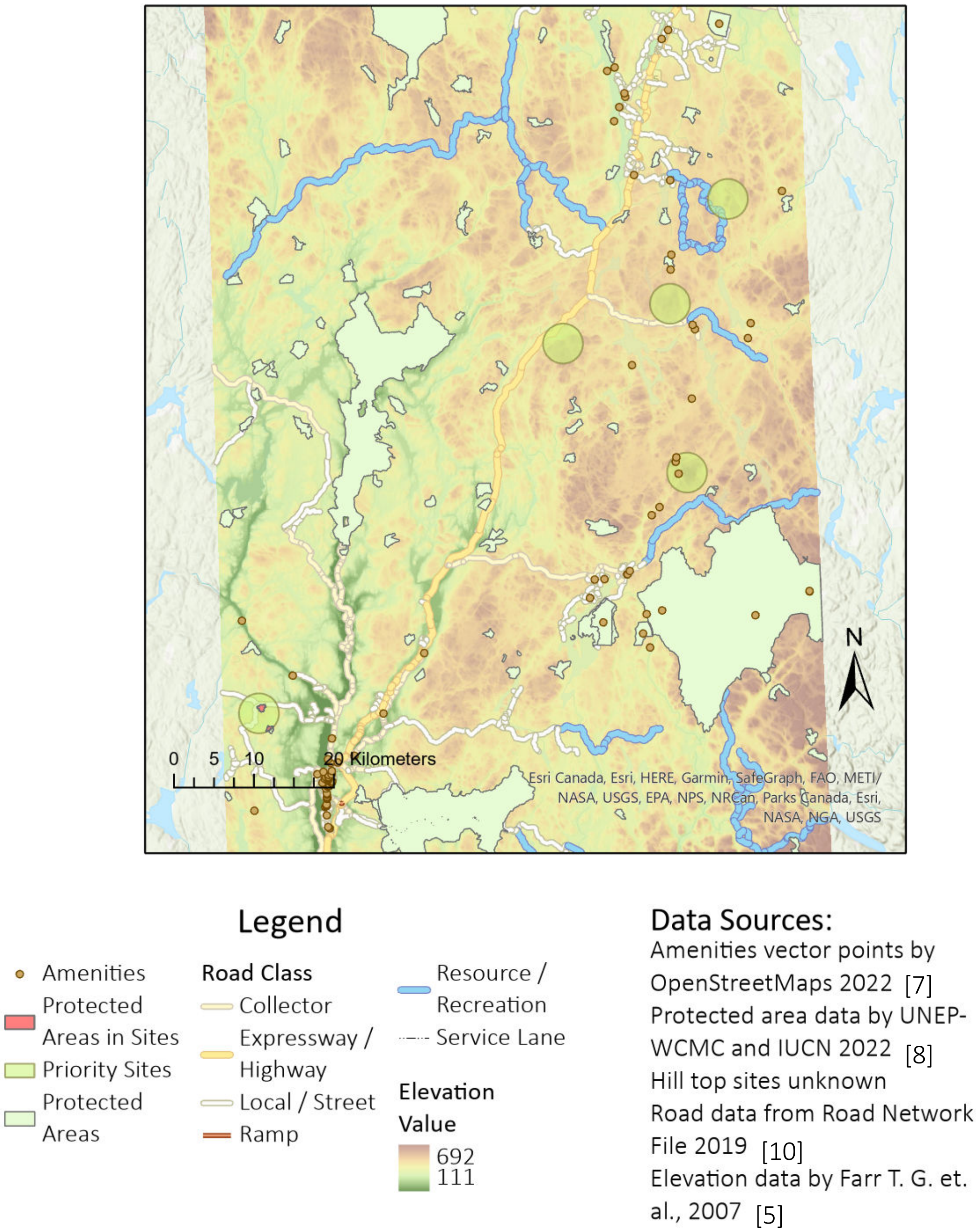
Calculating amenities close to each site required a new buffer be created. This buffer had a 20km radius and was centered around each site (the 2.5km buffer created before). Next was to simply calculate the intersection between amenities and this buffer, done the same as for slopes. This created a table containing the number of amenities within a 20km distance from each site alongside the site ID to identify which one it was for.

Next was finding the proximity or overlap with protected areas. The overlap was calculated by finding the intersection between the protected areas and the site buffers (2.5km radius). The tool used previously for intersections in tabular form was used again. This provided a percentage of area overlap between the two. Finding the distance to the nearest protected area was done using a tool to calculate the Euclidian distance from each site (buffer of 2.5km radius) to protected areas. This allowed the data to be added as a field to the site (buffer) attribute table. This was 0 when there was overlap between the two and otherwise the distance was provided in meters.

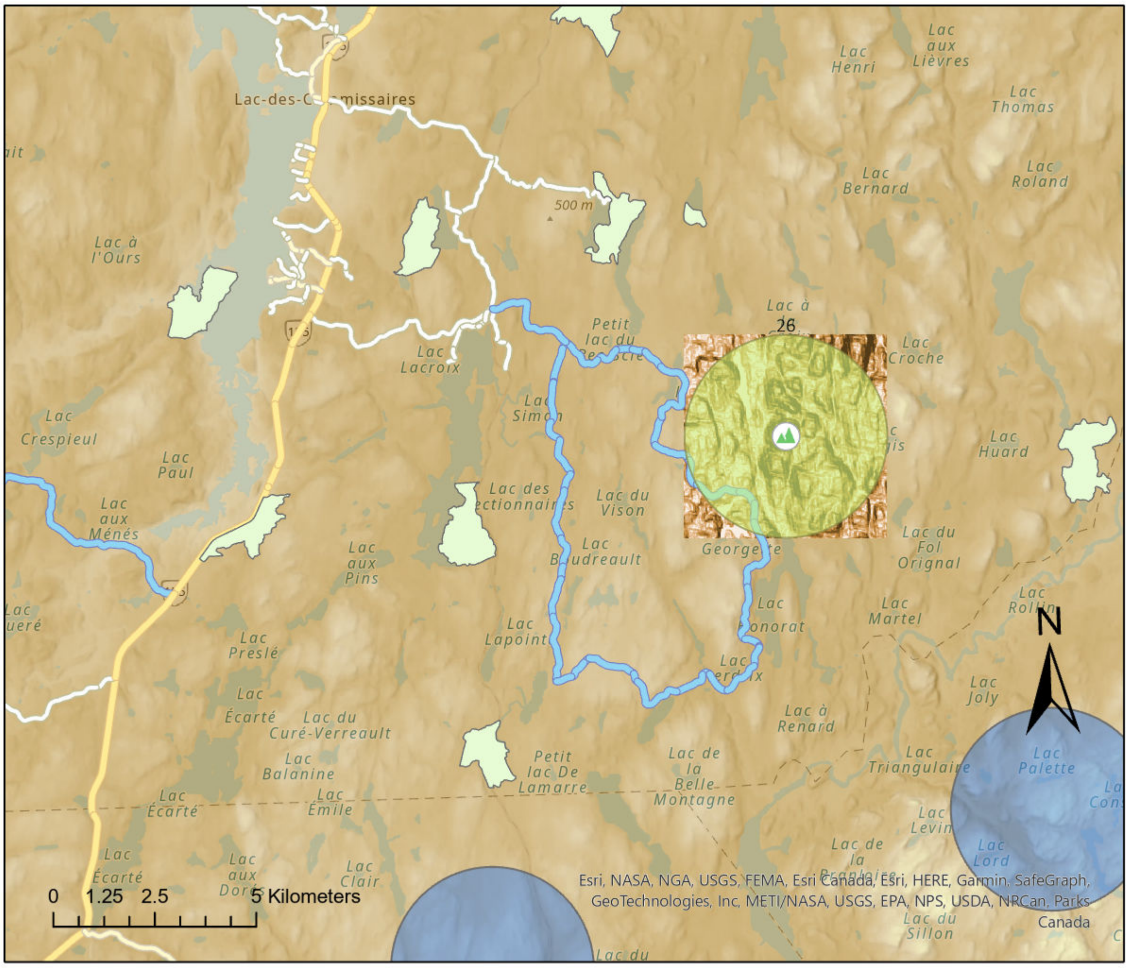
The inhabitants of each site were one of the easiest things to calculate since there were none for any site. This was visually clear from the maps however to be sure of it the tool used for intersection previously was used. This tool calculated the sum of the cells of population under each buffer around the given hilltops. It turned out to be 0 for every site, as expected.

Lastly, to assess the road accessibility of each site was similar to the distance from protected areas. The distance from each site (2.5km radius buffer) to the nearest road was calculated in meters. This data was added as a field to the site attribute table. When there was an overlap between the road and the site this was found to be 0.

Result



Map of the Area Showing 5 Priority Sites
Figure 1



Legend

Hill Top
Recommended Site
Other Sites
Protected Areas

Roads

Road Class

Collector
Expressway / Highway
Local / Street
Ramp
Resource / Recreation
Service Lane

Slope At Site

Value

0.001 - 2.424
2.425 - 4.242
4.243 - 5.757
5.758 - 7.271
7.272 - 9.089
9.09 - 10.907
10.908 - 13.028
13.029 - 15.755
15.756 - 19.39
19.391 - 25.45
25.451 - 77.259

Elevation

Value

692
111

Data Sources:

Hill tops from unknown source

Protected area data by UNEP-WCMC and IUCN 2022 [8]

Road data from Road Network File 2019 [10]

Elevation data by Farr T.G. et. al., 2007 [5]

Map of the Area Showing Best Site

Figure 2

Table 1:

Site Number (ID)	Total Snowfall (mm)	Distance to Road (m)	Percent. Of slopes (%)	Percent of prot. areas or distance from	Number of amenities	Inhabitants at Site
8	2077	5580.57	49.07	100%	0	0
9	2090	0	58.77	5.56%	15	0
11	2271	9920.13	39.01	1047.25 m	0	0
13	2124	0	44.80	9.28%	18	0
14	2054	682.71	52.12	0.35%	9	0
17	2135	445.43	40.25	13.50%	4	0
21	2036	936.39	34.81	2216.82 m	0	0
22	2267	451.98	45.20	1.32%	17	0
26	2268	0	48.21	3050.06 m	19	0
27	2102	5749.16	51.80	3347.03 m	0	0
30	2143	2545.76	50.80	0.23%	2	0
37	2012	13307.65	49.09	15.15%	0	0
38	2537	5652.77	59.31	1540.11 m	12	0
41	2535	44.73	44.65	1949.42 m	15	0
44	2350	0	45.71	4294.81 m	9	0
48	2264	3631.11	64.14	3209.78 m	3	0
57	2499	1149.10	55.42	818.86 m	26	0
63	2546	2108.16	70.80	23.20%	28	0
66	2042	1796.75	58.30	3276.32 m	4	0
78	2382	3052.90	51.82	210.60 m	21	0
86	2302	863.49	49.10	13.46%	29	0
89	2633	0	63.85	72.16%	32	0
91	2057	0	58.82	4.96%	56	0

The results of this study showed the variety of sites available for building. In Table 1 the snowfall is consistently above 2000mm for the month of January for every site. The distance to roads has a bigger variation between each site. The maximum distance recorded is up to 13,307 meters from a site although the minimum goes down to 0.

The percentage of slope ideal for skiing, with a percent rise of 10-50%, is around an average of 50% for a lot of the sites, although it goes up to 70% with a low of 39%. Protected areas seem to cover some sites almost entirely and for more than half the sites at least somewhat. The distance from each site has a maximum of around 4294 meters.

The amenities within 20km of each site is generally above 0, although it is at 0 for some of the sites. The inhabitants within the sites are consistently at 0.

The small-scale map, Figure 1, provided illustrates the five sites chosen as priority sites for this skiing resort. The best site can be seen in more detail in the large-scale map, Figure 2, provided. The site IDs of the priority sites were 41, 44, 57, 91 and the best site chosen was 26. Figure 2 also shows the slopes at the site, not perfectly fit to the circle since the data pixels had corners. The elevation model in both figures is represented with a stretch symbology as it seemed to be the only representation visually appealing to the map.

Discussion

The sites chosen as priority sites were based on the data illustrated in Table 1. Since the precipitation does not vary by much, this was not considered as the most important factor in choosing a site. There was effort to prioritize all other factors, but emphasis was put on road access of the location and the distance from protected areas. A lack of overlap with protected areas seemed like the most important factor to consider, since it would not be ideal to have a ski resort close to protected areas, which are important conservation and minimizing biodiversity risk [8].

Out of all the options available the best site (site 26) seemed to maximize all ideal factors. With easy road access, development costs would be minimized. The precipitation and slopes at the site maintained around the average of all the sites. The number of amenities in the area were high enough to be considered beneficial for a ski resort. Perhaps the most important factor was this locations distance from protected areas, the second highest of all the locations.

The lack of variation in some of the data for sites provided a clear strength in this analysis. It gave factors to focus more on, such as distance to protected areas, roads and amenities, and ones to focus less on, such as precipitation or slope percentage.

A weakness in this approach would be the inability to quantifiably consider each factor equally. If it were possible to create a measure in percentage of how much each factor was prioritized this may allow for a more equal consideration of each factor.

Another weakness in this analysis was a lack of consideration for climate change affecting future climate conditions of the region. Without this consideration, the location is likely to have drastic changes in the near future which prevent it from being ideal [12]. It could have been improved by using data making predictions for the coming changes to the climate of Quebec, which could have been taken as a factor in choice of location.

A couple of errors may have been introduced during the analysis. When using a projection there is some degree of error to consider. While the projection was suited for Quebec, it still may provide some skewed data. In a perhaps comically titled piece, ‘Maps are liars’, Starkey outlines how no map representing the earth as a projection to a planar surface can accurately represent the real conditions of the earth [13]. Another error that may have occurred would have been from the processing of raw data to different forms (such as the conversion of raster to vector data). This may cause minor differences in results.

Conclusion

The results of this analysis were five ideal locations for the construction of a ski resort in the province of Quebec in Canada. Since the most ideal location selected managed to fulfill all the outlined factors, the analysis could be deemed successful overall. A geospatial analysis is perhaps the best way to decide location for a ski resort site, or any construction. It provides the ability to consider many factors, visually see large spaces, and process raw data available to reflect real life situations.

Word count: 2174

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