Determining the Optimal Luxury Home Location in Vancouver, BC, Canada

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1 Introduction

Multi Criteria Decision Analysis (MCDA) has become increasingly popular in various environmental and social applications as it allows the decision maker to give attention to all criteria available and to base decision making around the priorities of the available criteria (Kumar et al, 2017). To determine the weights of the surfaces used in the MCDA, the Analytical Hierarchy Process (AHP) is often used as it allows for simple pairwise comparisons of surfaces and has been proven to be an adequate decision support tool in a variety of applications (Ishizaka et al, 2010). AHP is effective at finding the greatest and least priority surfaces and provides the decision maker with information about the analysis without dominating the decisions of the analyst (Ishizaka et al, 2010).

A analysis requiring multiple criteria layers often requires an automated process to iterate through repeated processes. Model Builder and supported Python scripting in ArcGIS allow for complicated tasks to be divided and conquered through the use of iterative, logical and geographical functions. Model builder provides an easy to use graphical interface to run a sequence of tools and processes (ESRI, 2016).

In this study, MCDA, AHP and automation were used to create a suitability surface of optimal luxury home locations in Vancouver, BC, Canada. The final suitability surface created from the analysis was used in combination with proposed luxury home requirements provided in lab to aid in the final site location.

2 Methods

2.1 Study Area and Data

2.1.1 Study Area

The study area for the MCDA encompasses the City of Vancouver. The City of Vancouver is a coastal city located on the mainland of south western British Columbia. Vancouver is the largest city in BC with 631,486 residents, and the Greater Vancouver metropolitan area is the third largest in Canada (City of Vancouver, 2019). A map of the area of interest and surrounding areas is shown in Figure 1.

2.1.2 Data

There were five parameter surfaces created in this study from four input files. The files included a 25 meter resolution DEM of the City of Vancouver, a line file of public streets, a polygon file of 2009 building footprints and a point file of crime incidents from 2019. All files were obtained from the City of Vancouver Open Data Portal and were projected onto the NAD 1983 UTM Zone 10N coordinate system using a Transverse Mercator projection.

2.2 Analysis Methods

2.2.1 Data Pre-Processing

The four input layers; a 25 meter DEM of the city, a public streets file, a 2009 buildings footprint file and a 2019 crime incidents file were loaded into ArcGIS 10.5 software. An attribute query was initially performed on the public streets file to remove arterial roads. This was based on a luxury home requirement of a close proximity to public streets that were not highways. The 2009 buildings footprint raster was then converted to raster format to prepare it for the MCDA.

2.2.2 Surface Derivation

The first derived parameter surface used in the MCDA was a slope surface of the City of Vancouver derived from the DEM and a slope analysis tool. An aspect surface layer was then created from the 25 meter DEM and an aspect analysis tool. Next, a euclidean distance parameter surface was created from the non-arterial public streets derived in 2.1.1. Lastly, a kernel density parameter surface was created from the 2019 crime incidents file. All output parameter surfaces created were set to the same resolution as the original DEM of 25 meters.

2.2.3 Reclassification

The slope, aspect, crime density and non-arterial road distance surfaces were all given a 10 class, equal interval classification to ensure normality between surfaces.

The slope surface was reclassified to have the flattest cells in the tenth class, and the cells with the greatest slope in the first class. This would ensure that the home would be able to be built on a flat, stable site. The aspect surface was then reclassified to prioritize south and south westerly facing cells. This ensured that the site would have ample sunlight for enjoying the Vancouver summers. Next, the non-arterial road distance was reclassified to have the cells of the least distance to a non-arterial road in the tenth class and the cells of the greatest distance in the first class. This method ensured that the site would be accessible to non-arterial roads to be able to travel to and from the site with safety and ease. Finally, the buildings footprint raster was reclassified as binary surface. Cells that contained a building were given a value of 0 and cells that did not were given a value of 10. This approach prioritized non-building cells greatly over building cells but was not intended to completely eliminate building cells when input to the weighted overlay.

2.2.4 Analytical Hierarchy Process (AHP)

An AHP was used to compare the suitability surfaces derived in 2.2.3 pairwise to determine their respective weights. Table 1 shows the consistency matrix ranking the suitability surfaces. The weights derived from this matrix were then input into a weighted overlay along with the suitability layers, producing an integrated suitability surface.

2.2.5 Final Processing and Site Selection

The optimally suitable cells in the integrated suitability surface produced in 2.2.4 were extracted using a conditional expression. The extracted cells were then filtered by majority using a 4x4 kernel. These final optimal locations were converted to a polygon. The integrated optimal polygon surface was then queried to remove cells smaller then 150 meters squared, ensuring an adequate site size.

Using the final suitability surface and satellite imagery to aid in the decision process, an approximate location of 486,519 mE, 5,457,515 mN in the north western region of the city was chosen as the final optimal luxury home location.

3 Results

The five parameter suitability surfaces created in 2.2 can be seen in Figure 2. The city is relatively flat as shown by the slope surface, and a majority of th south facing slopes are located in the southern regions of the City as shown by the aspect layer. The crime density is highest in the downtown regions and the city shown by the kernel density crime layer, and the buildings are similarly denser in the downtown regions shown by the buildings footprint surface. Finally, the non-arterial road distance surface shows that the entire city has adequate road coverage as most of the layer is classified as suitable.

The AHP output created from the consistency matrix (Table 1) is shown in Table 2. Slope was given the largest weight of 34.48%, followed by aspect at 26.18%, then non-arterial road distances at 17.24%, then buildings at 14.74% and finally crime at 7.37%. This weighting scheme emphasised a flat, ideal lot that would be perfect for development.

The final suitability map is shown in Figure 3. This map details the optimum locations derived from the MCDA. The optimum mansion site selection located in the Point Grey sub district of the City fulfills all criteria. There are other buildings as it is not an empty lot, however due to the density of the City, finding an ideal empty lot is near impossible. The site is located on the coast line providing great view, it is south facing and is on a flat lot. The area is low and crime and accessible from a variety of non-arterial public streets. A large scale map of the approximate location is shown in Figure 4.

4 Discussion

One of the largest impacts on the accuracy of suitably analysis is the resolution of inputs. Due to the 25 meter resolution of the input DEM, other surfaces would have be interpolated to 25 meters to integrate the layers. This resolution is adequate from large scale analysis however when dealing with smaller areas such as housing lots, information can be lost do to interpolation.

MCDA provides the analyst with a framework for solving complex problems. It is important when intergrating spatial data as it captures the objectives of planning and emphasizes layers accordingly (Kumar et al, 2017). Model Builder and Python automation in ArcGIS allow for the MCDA to be feasible on the user end while eliminating repeated tasks to streamline workflow. The model used in section 2.2 to create the final optimal luxury home location surface is shown in Figure 5.

The usage of pairwise comparison through the AHP allows for a simple derivation of weights. AHP has been shown to be effective at assisting the decision making process, especially when there is one dominant criterion (Ishizaka et al, 2011). This is great for the analyst however due to the pairwise comparison process there is still uncertainty and decision maker bias inherent in the process. A weighted approach often introduces new problems , mainly that determining the weights is largely subjective and there is often little to no theoretical foundation supporting them (Malczewski, 2000). Different analysts may weight the same features differently, resulting in a different suitability output.

5 Conclusion

In conclusion, MCDA, AHP and automation through Model Builder have shown to be effective tools to decompose complicated problems into manageable criteria. When determining the location of a luxury home in this study, all surfaces were carefully weighted are reclassified, however due to the uncertainty in weighting, the coarse 25 meter DEM and the numerous other factors that were not considered, the study is quite limited. In order to have a more conclusive final surface, many more criteria must be considered with a variety of different AHP derived weights from various decision makers.

6 References

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7 Figures and Tables

Table 1: Consistency Matrix for the Weights of the Suitability Surfaces

	Slope	Aspect	Crime	Roads	Buildings
Slope	1	2	4	2	2
Aspect	1	1	4	1	2
Crime	1/2	1/4	1	1/2	1/2
Roads	1/2	1	2	1	1
Buildings	1/2	1/2	2	1	1

Table 2: Weights and Consistency Ratio Produced from Consistency Matrix and Suitability Surfaces

	Weight (%)
Slope	34.48
Aspect	26.18
Crime	7.37
Roads	17.24
Buildings	14.74

Consistency Ratio	0.06400882

Figure 1: Study Area Map of the City of Vancouver and Surrounding Areas

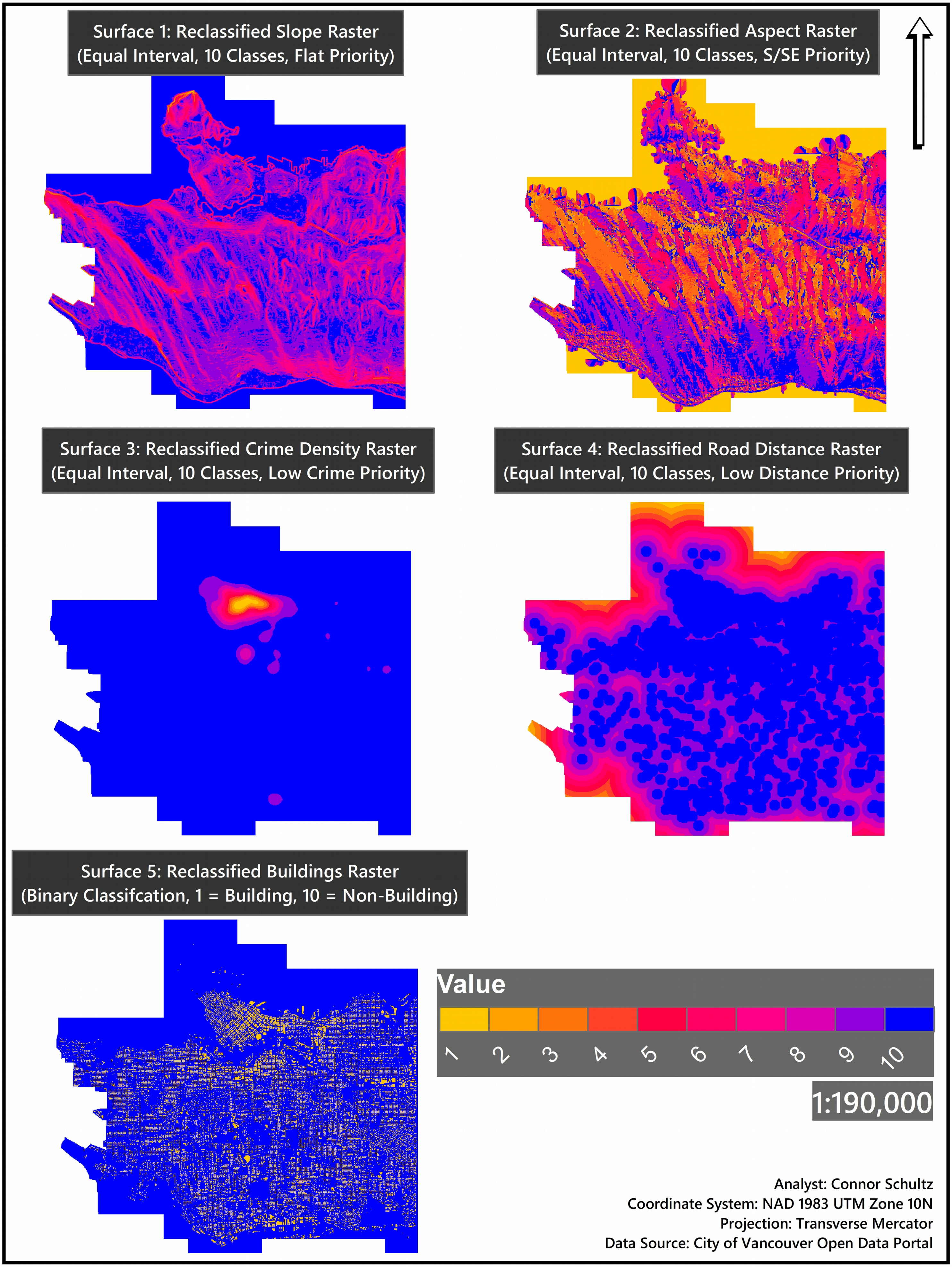

Figure 2: Suitability Surfaces used to Produce Optimal Luxury Home Location Surface

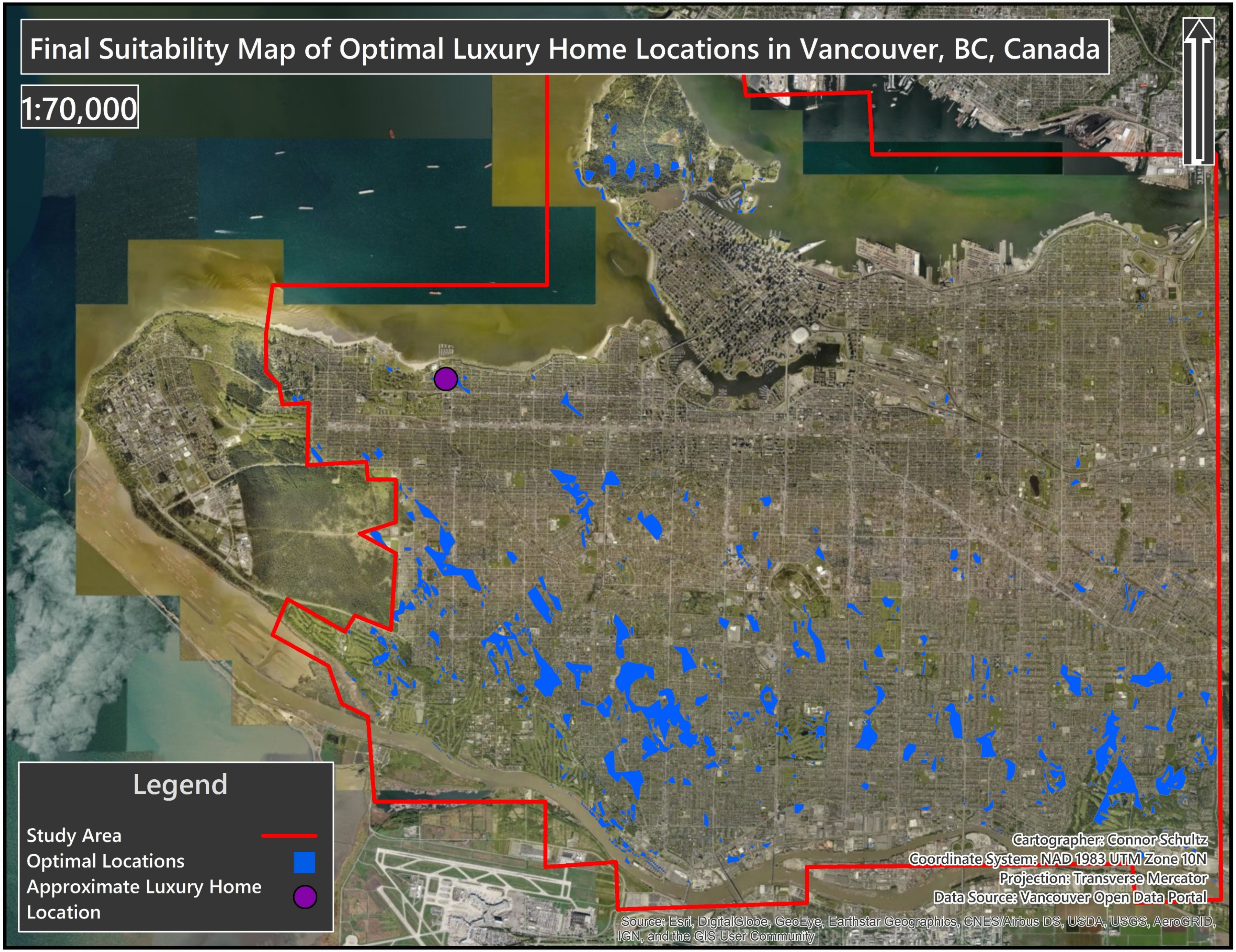

Figure 3: Map of Final Optimal Luxury Home Locations in Vancouver BC

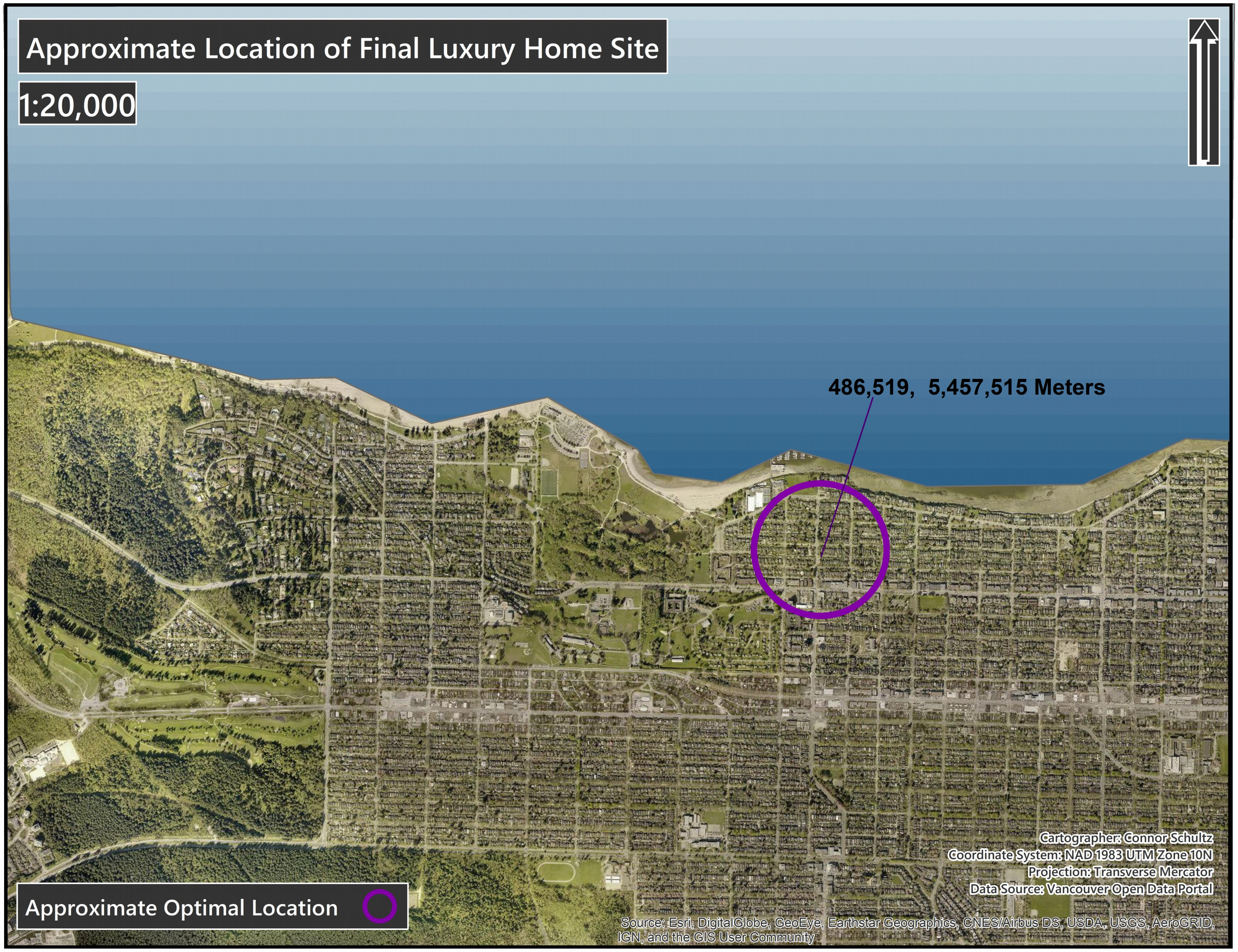

Figure 4: Map of Approximate Final Location

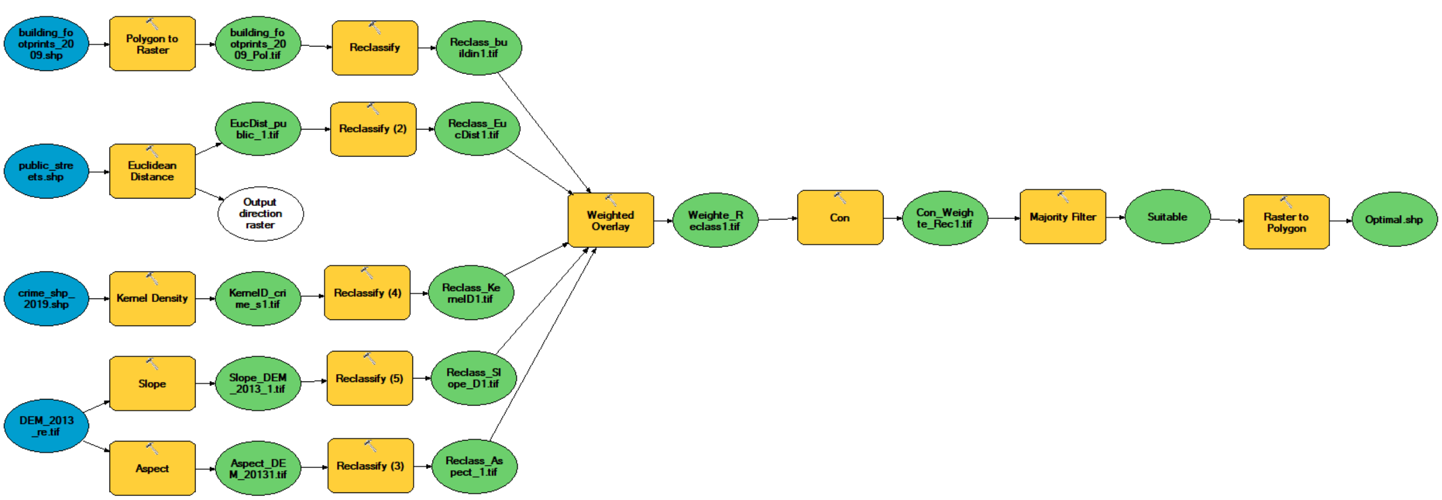

Figure 5: Model used to Create Suitability Surfaces and Final Optimal Luxury Home Location Layer