Identifying Uninhabitable Regions in South Island, New Zealand

Group 3

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Abstract

The following report is the spatial analysis study which is aimed at identifying the main uninhabitable areas in South Island of New Zealand. This project is based on finding these areas based on 4 criteria which is a combination of topography (elevation and slope), road proximity, and forest density to generate a map which would show where these uninhabitable areas are concentrated. As a part of spatial analysis, Multi Criteria Evaluation (MCE) and masking was used to generate this final map. The findings do reveal that approximately 74 percent of the South Island is uninhabitable because of the widely present steep slopes, dense vegetation and inaccessible areas by road.

However, the study has its limitations with missing data while identifying some infrastructure, information lost with low resolution data and not enough information about some conservation zones. These challenges have inhibited the generation of an accurate map that has a lot of future implications with better and improved data sources and high-resolution imaging.

Introduction

With the rise of the economy, there is also a growing demand for land and other resources to build infrastructure. Building infrastructure not only has a positive impact of increasing land value, rising profits but also negative effects like soil erosion, drastic changes in weather and more. This project aims to provide insights for construction agents and policy makers investing time and money in improving infrastructure around the South Island.

By combining spatial analysis, data preprocessing and extensive literature review, the project aims at generating a map that would plot these uninhabitable regions of South Island. Along with addressing drastic changes in land, the study does align with current developments in the geospatial, conservation and construction industries.

The outcome of the project is expected to provide key insights and solutions for industries, local communities, and the country's policymakers to be aware of the harm occurring to these areas, and to plan infrastructure in a more practical manner.

Data

This is an overview of the datasets utilized for this project. Most of the datasets came from open sources which are recognized by the government of New Zealand. These datasets were gathered in 2024, and it is divided according to the criteria selected for generating the map:

- Topography (Elevation and Slope)
- Road Proximity
- Forest Density

1. Topography:

Topography or terrain would be assessed by 2 criteria, elevation and slope. These criteria have been selected based on the fact they are the 2 most important features of topography which can affect areas to be habitable.

Elevation:

An elevation above 1500 meters is defined as unsuitable for habitation as this altitude can contribute negatively to a lot of physiological factors. With an increase in elevation, there is a reduction in the level of oxygen, resulting in hypoxia. This can also cause further health issues relating to shortness of breath and impaired cognitive function (Barry, 2002).

This altitude also makes it difficult to have vegetative cover in the region and keeping resources like water and pipelines at these temperatures is not ideal which overall gives elevation a reason of why a place would uninhabitable (Bigham, 2016).

Because of the above reasons, we have considered any elevation of 1500m and higher to be regions which are uninhabitable.

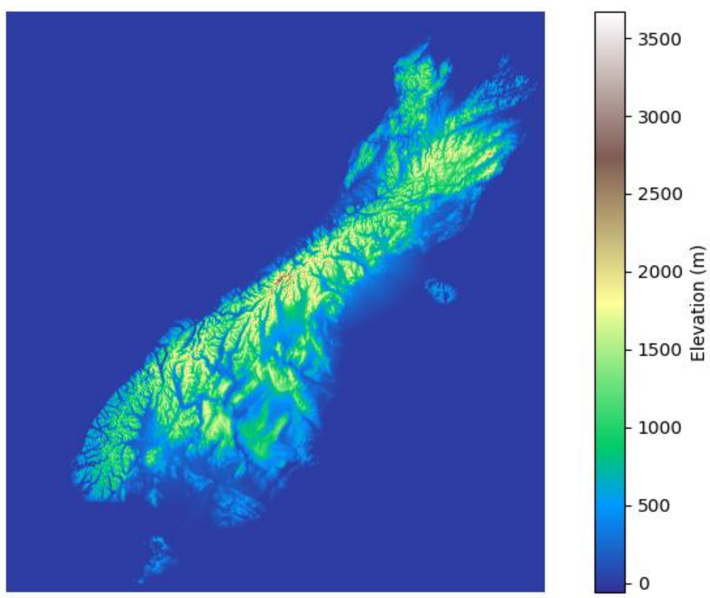

Figure 1: Elevation of South Island

Slope:

Along with elevation, another important criterion while evaluating terrain data would be to investigate the slope of such elevation. Building infrastructure at different slope heights would be to take advantage of the scenic view around the area, and to make use of the natural drainage system which reduces the risks of floods. A slope of up to 26 degrees is ideally flat and would usually have the normal expenses of building on flat terrain (CC Architects, 2024). However, while building at a slope greater than this, slope stability analysis must be further carried out to find the Factor of Safety (FoS) to build at such a slope. This procedure, though time-consuming, is also expensive, which makes this an impractical way of spending council resources. Hence, we have defined the criteria to choose slopes above 27 degrees as uninhabitable and habitable as the latter (New Zealand Geotechnical Society (NZGS), 2023).

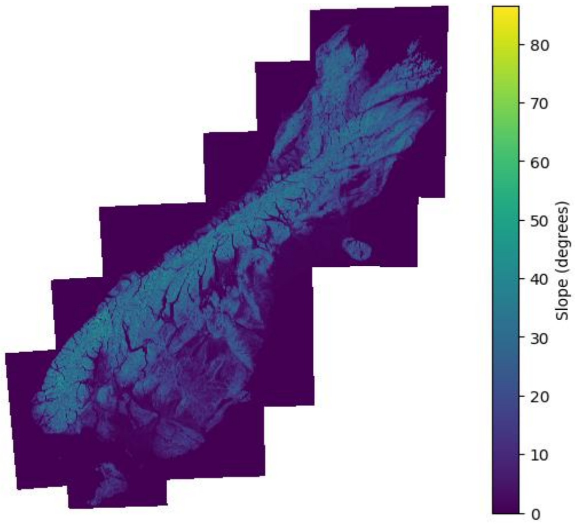

Figure 2: Slope across South Island

2. Road Network:

   Finding road networks is important to understand the proximity to accessible areas across the island. With road proximity analysis, we can assess the distance away from the nearest road, predict how isolated the area would be.

   For this, we have used Road Section Geometry dataset in combination with Shuttle Radar Topography Mission (SRTM) data (Land Information New Zeland, 2024). The road network is an indication of settlement patterns and a way of viewing the distribution of infrastructure across places with high-density road coverage which normally suggests high population, while the lightly connected areas may reflect uninhabitable or remote regions. The integration of road geometry with environmental factors such as elevation and slope provide an insight into the challenges and determines regions with poor accessibility that might lack development in most regions. Furthermore, data on road networks can also be applied in the planning response to emergencies based on how effectively it could be possible to access most recent amnesty. Having better analysis and visualization of the road network in the South Island helps in guiding infrastructure development and land use policies in areas of complex topography.

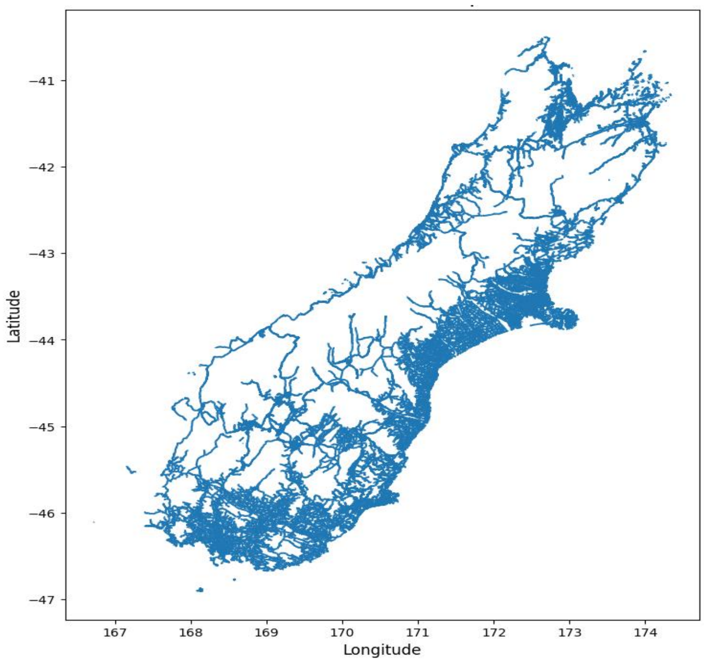

Figure 3: Road Network across South Island

3. Forest Cover:

   Building a map that highlights forest density of the island is an important condition for our analysis so that we can identify dense vegetation which are possible challenges for habitation. Establishing forest density as a criterion for uninhabitability estimate regions which are at risk of soil erosion and should be preserved.

   While trying to identify these uninhabitable area, we used the MODIS land Cover data from MODIS/006/ MCD12Q1/2020_01_01 as per the year 2020 (Google Earth Engine Data Catalog, 2024) to figure out forest areas, which can be accessed via GEE, in mapping the forest cover at South Island New Zealand. This land cover dataset offers a yearly global classification at 500 meters resolution and provides information on the patterns of land-used, including forest density and possible conservation. This information becomes very important in determining the areas that can't be settled on and insufficient of natural conditions, poor accessibility, and natural hazards like wildfires as well. Other than this dataset, combining the information of other geospatial data will be utilized for plotting a detailed representation of forest cover across the island to enable more detail in land use, vegetation distribution, and environmental conditions.

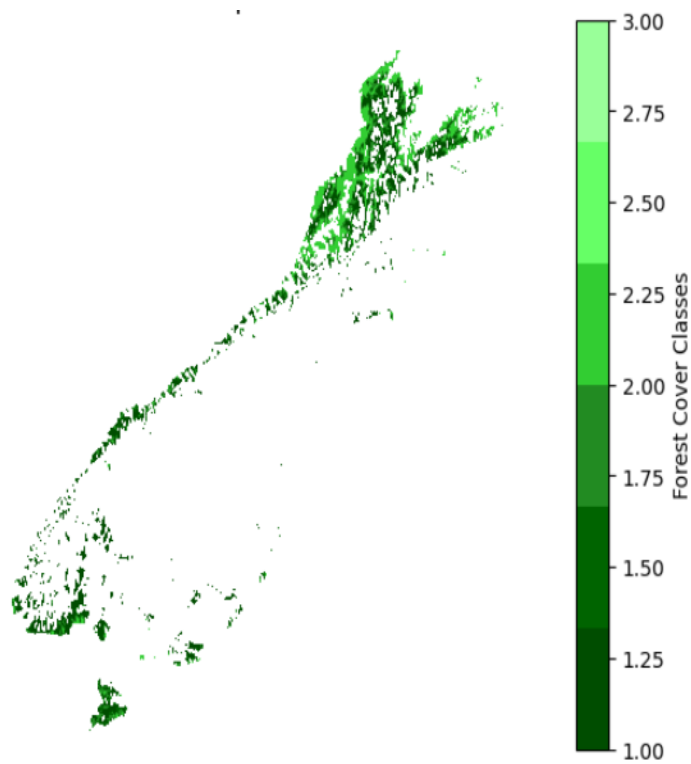

Figure 4: Forest Cover across South Island

To process the Road network data, we directly used SRTM Road Section Geometry dataset (Land Information New Zeland, 2024) and reprojected it to align with coordinate reference system (CRS) EPSG:2193. It provides the road network data within South Island of New Zealand by providing linear geometry data.

We used Google Earth Engine (GEE) to process the above Elevation, Slope and Forest datasets. SRTM Digital Elevation Model (DEM) dataset was used to derive both Elevation and Slope (Google Earth Engine Data Catalog, 2024) while MODIS the Land Cover dataset was utilized for Forest cover. Since there are 2 datasets, we created 2 separate code blocks for each dataset (DEM and MODIS) and processed them as mentioned below.

As the first step we needed to define the South Island region by creating a bounding box geometry and then loading datasets and masked datasets to focus on the South Island region, excluding areas outside this boundary. As the next step, we reprojected the clipped dataset into the coordinate reference system (CRS) EPSG:2193 so as to match with the New Zealand's local grid system. At this point the slope was calculated from the reprojected DEM data and for the forest cover, data was extracted from MODIS land cover data by selecting the relevant classification band and clipping it to the South Island.

As the final step, we exported the reprojected and processed Elevation, Slop and Forest cover data as Geo TIFF files for further geospatial analysis.

Methods

Geographic Information System based Multicriteria Evaluation (MCE) is a very effective method to make decisions with spatial data. This method involves multiple factors and makes complex decisions. In this method we assign weights to the criteria. The collected data then underwent thorough calculations using assigned weights to calculate score (ESRI, (n.d.)). This method is applicable to multiple fields urban planning, environmental science and engineering.

Criteria	Rank	Weight
Road	1	50 %
Forest Coverage	2	30 %
Elevation	3	10 %
Slope	3	10 %

Table 1: Evaluation Criteria

Roads are given the highest priority because they play a critical role in mobility, transportation, accessibility and economic development. Road helps us to connect through for essential services like markets, healthcare centers, educational institutes. Well-connected roads across the area can enhance jobs, business opportunities and trade which support economic growth. The weight assigned to road network criteria is 50%. Without roads there is no habitability possible in today's day and age. In MCE conditions we have checked if there is presence of road in area. The absence of road in the area gives it a higher uninhabitability score for the point.

Forest is the second most important factor we have considered for evaluating uninhabitability score, because living near dense forest areas can be challenging for habitation. Dense forest lack of connectivity, water supply and electricity. It also brings environmental challenges like wildfire, landslides and these natural hazards. Forest coverage was given 30% weight in MCE calculations. Forest density greater than 2 according to Google Earth Engine data we extracted as is not a habitable area due to high forest density.

Elevation and slope are considered as the third ranked criteria for MCE. Higher elevation makes it difficult to access essential services. At highly elevated places it lacks oxygen levels which affects human health. As elevation beyond 1500 meters is unsuitable, we used this condition in MCE.

Steep slopes are very dangerous and difficult to build houses on. Making construction is very expensive in such areas. Steep slopes are not suitable for farming due to water runoff and soil erosion. Because of these reasons make slope areas unsuitable for living. For MCE we have used a threshold up to 27 degrees of slope.

The data we collected was in raster as well as vector form. For this project, elevation, slope, forest coverage data was in raster form and road network data was in vector form. As data from Google Earth Engine i.e. elevation, slope, forest coverage data has some additional portions, to mask data i.e. to get exact clipped data for South Island of New Zealand, which was used for masking. We used land area data in form of shape file from Stats New Zealand to get data representing costal line and land boundaries of New Zealand. We masked our original raster data using this boundary data and get exact boundary for New Zealand South Island and stored the new raster files i.e. clipped version of original data and used those to calculate MCE score.

For calculating uninhabitability scores, road network which is in vector format is rasterized and used along with clipped elevation, slope and forest data. Each criterion is then checked and classified as binary values. Then the criteria are then combined according to assigned weights for each criterion. Which eventually calculated uninhabitability score from range 0 (habitable region) to 1 (extremely uninhabitable region).

This score is then visualized on a continuous color scale. The output is plotted in the form of a heatmap using matplotlib. Areas with red color highlights are highly uninhabitable areas whereas areas with green color are habitable ones.

Results and Discussion

After Multi Criteria Evaluation (MCE). The output generated was shown in the graph depicted below:

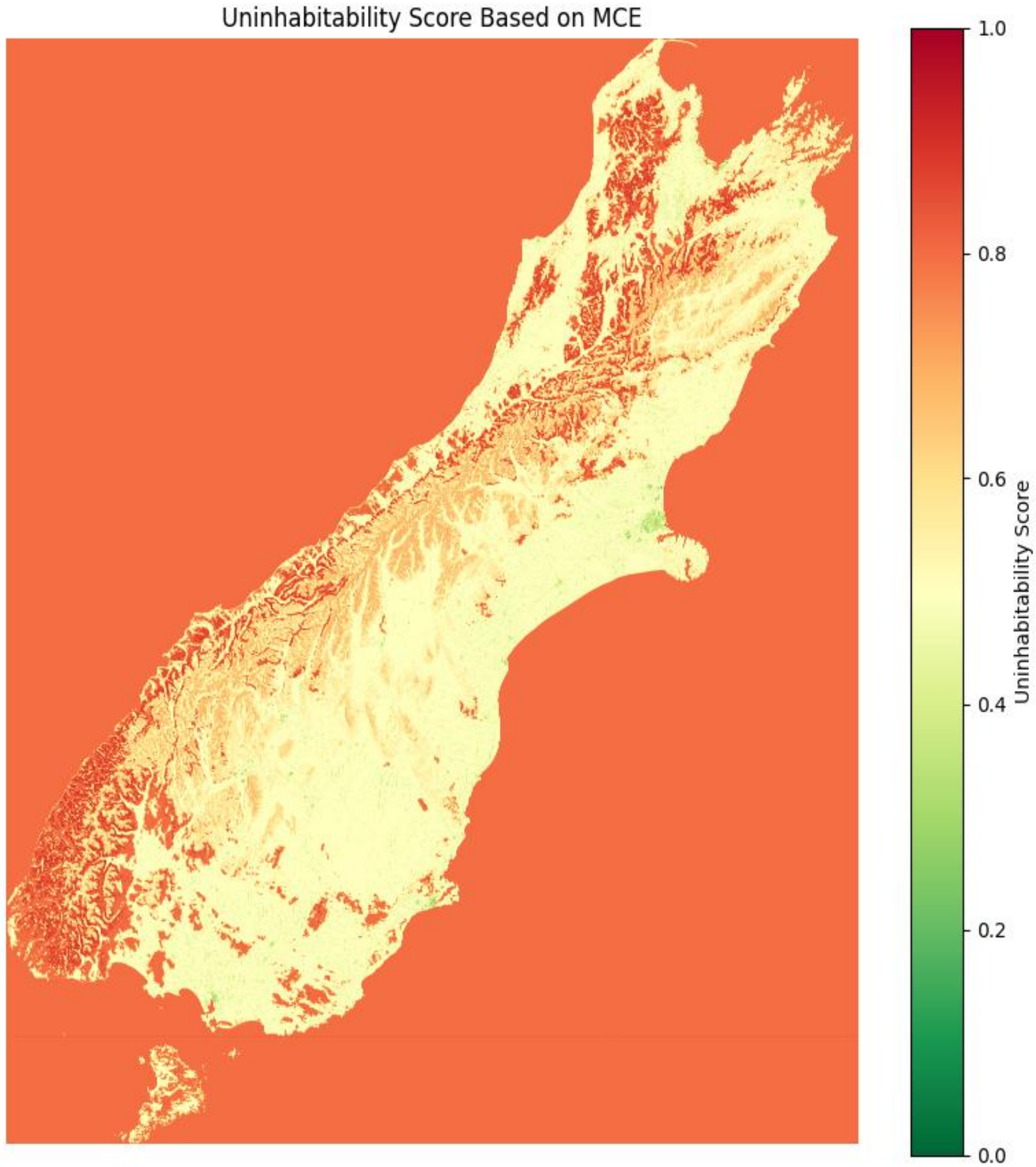

Figure 5: Uninhabitability Map of South Island

We calculated total percentage of uninhabitable areas in South Island, New Zealand. A total of 74.14 % of the area in South Island is uninhabitable. Which justifies similar results as that of (Khan, 2023). Nearly 80% of New Zealand land is uninhabitable. We considered an uninhabitable score of 0.8 as a threshold above which all scores were counted. Using the total score count and uninhabitable score count we calculated the total percentage of uninhabitable areas.

The concentration of uninhabitable regions across the South Island does align with the tourist attractions of the country as well. The main tourist attractions of South Island are Abel Tasman (Tasman), Mount Cook (Aoraki/Mount Cook National Park), Arthur's Pass National Park, Fiordland National Park and Westland Tai Poutini National Park. These areas are seen as severely uninhabitable areas on the map, primarily because these areas are on the extreme of the criterion, which results in the orange/red areas on the map and hence the areas where they are concentrated are considered as uninhabitable regions (Must Do New Zealand, n.d.).

Along with the final uninhabitability map, we also have considered the population across regions to validate our findings. From the map above, we have collected information about 4 parts of South Island each, based on uninhabitability. The heatmaps below provide a better understanding of how the populations are concentrated in each region. There is a clear contrast between both maps.

In Figure 6, we have identified 4 main hotspots across South Island where there is high uninhabitability present. In such conditions, estimation would be that the population is less. The heatmap below shows the concentrations are ideally located across the region where there is slight habitability possible in these regions. The findings also align with the population density of this place. The borders across Westland show a higher unsuitability score compared to the other regions, which shows how the population density is also less compared to them.

In Figure 7, we have found the 4 hotspots where habitability score would be high. These green hotspots align with the popular cities of the South Island which are Nelson, Christchurch, Dunedin and Invercargill. These green hotspots in the map align with the higher population density across the 4 regions. The flatter terrain for Christchurch depicts why it is the most populated city of the South Island.

Place	Population
Westland	8,940
Buller	9,670
Tasman	57,807
Southland	103,900

Place	Population
Nelson City	55,600
Invercargill	57,900
Dunedin	134,600
Christchurch	396,200

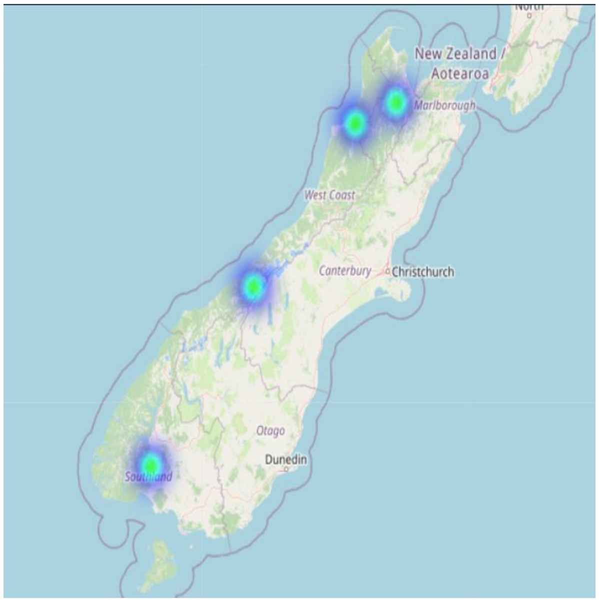

Figure 6: Population Density of Uninhabitable regions

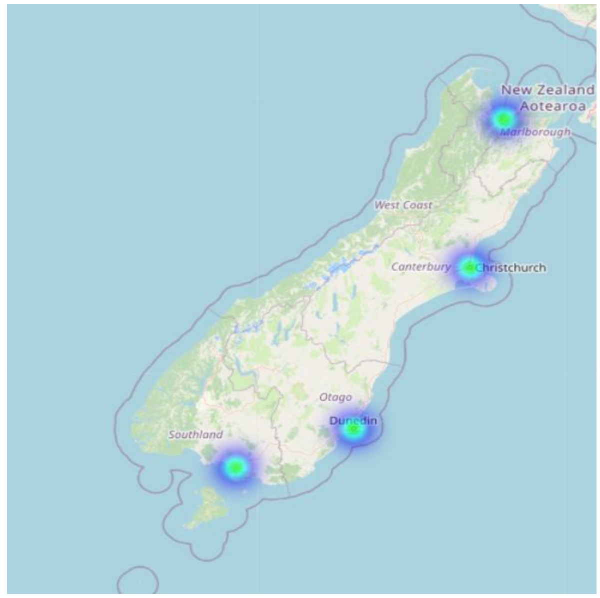

Figure 7: Population Density of Habitable Regions

(Note – Above images were generated using coordinates of the regions along with their population density using R programming)

The final map does have several limitations, due to various obstacles that have affected the accuracy of our results. One significant limitation of the map would be that it has excluded certain infrastructures based on our criteria. For example, houses which are built on slopes above 27 degrees would not be considered, particularly due to the difficulties involved in mapping these houses separately. Also, certain isolated structures like agricultural sheds and farmer's houses would not be located since it would be far away from major roads which get excluded from our criteria to only choose locations with access to the main road network.

These exclusion criteria could be the reason why Queenstown is not seen as a habitable region on the map. This tourist destination is situated on an elevated terrain, with many houses and tourist attractions being built on steep slopes and some areas do not have a good road network towards the outskirts of the area. These factors have made the habitability mapping in Queenstown challenging.

Another major limitation came while using MODIS datasets, which capture a resolution of 500 meters. This is a relatively low resolution to get a significant amount of detail and could have led to missing data and has the inability to differentiate between smaller regions and the small differences across areas. This was a significant obstacle while masking forest density. As forest density varies with seasons across the year, the dataset was not able to capture these changes in seasonality. As a result, the uninhabitable areas which were covered by dense forests can change according to the different seasons which can change their representation on the map.

Further, this map does not account for geologically active areas, like areas which are prone to landslides, volcanic eruptions, and earthquakes. Even though these factors cannot determine if a place can be deemed habitable or not, understanding these risk factors where they are present and how to avoid them is important. These areas should have better and improved safety measures in case of such calamities. Even though the exclusion of these areas is not a significant limitation, not considering this factor is an indication that this map does not give a complete picture of such calamities which pose a threat to human settlements.

There is not much information that could be supported to finding farming zones is an important limitation in this project. The areas which are used for such agricultural purposes are uninhabitable as they are used in vegetative zones. Since we had insufficient data and literature to locate these farming regions, we were unable to identify them and exclude these areas from the map. This limitation greatly affects the accuracy of the map, and they would look like habitable areas.

Finally, there is not much information about the conservation zones of the South Island, Due to missing literature and data about such areas, they could not be visualized and identified during the analysis. These conservation areas are important to understand which areas for sure are uninhabitable because of their importance in land preservation, and environmental impact across the South Island. This data further makes the map incomplete because of its importance in understanding the land cover.

Conclusions

The main objective of this study was to identify uninhabitable areas in South Island based on four factors such as elevation (> 1500m), slope (> 27 degrees), forest density and road presence. We have used Multi Criteria Evaluation (MCE) to analyze how the above four factors are related to identifying uninhabitable areas. As per the results of MCE, it was sufficiently able to identify uninhabitable areas in South Island of New Zealand with assigned ranks for the above criteria as Road (1), Forest Coverage (2), Elevation (3) and Slope (3).

The road data was considered as the most significant factor because areas lacking access to main roads seemed to be largely uninhabitable whereas forest coverage, elevation and slope plays important roles along with highly dense forest and high slopes being the major contributors towards identifying uninhabitable areas.

Analysis identified some areas as highly uninhabitable regions, particularly Westland borders which meant to be areas with less population density which is colored in dark red. Similarly, there are some green spots which depicted highly habitable areas such as Christchurch, Dunedin, Nelson and Invercargill (slightly visible) as well.

To validate the above findings, we compared our results with Wikipedia's population density of South Island, New Zealand (Wikipedia, n.d.) and the results were perfectly aligned with identifying regions like Christchurch, Dunedin, Nelson and Invercargill city which are spotted as highly habitable areas and

Tasman, Buller, Westland and Southland shown as highly uninhabitable regions in South Island New Zealand.

Finally, we further verified by calculating MCE uninhabitable score and it gave 74.14% of regions as uninhabitable areas in South Island of New Zealand.

References

Barry, R. G. (2002). The highest permanent human habitation. *High Altitude Medicine & Biology, 3*(3), 401-407. doi: https://doi.org/10.1089/15270290260512882

Bigham, A. W. (2016). Genetics of human origin and evolution: High-altitude adaptations. *Current Opinion in Genetics & Development, 41*, 8-13. doi:https://doi.org/10.1016/j.gde.2016.06.018

CC Architects. (2024, September 30). *How hard is it to build on a slope?* Retrieved from CC Architects: https://www.ccarchitects.co.nz/how-hard-is-it-to-build-on-a-slope/

ESRI. ((n.d.)). *How Weighted Overlay works*. Retrieved from ArcGIS Pro Documentation: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-weighted-overlay-works.htm

Google Earth Engine Data Catalog. (2024, 10 15). *MCD12Q1.061 MODIS Land Cover Type Yearly Global 500m* . Retrieved from Earth Engine Data Catalog: https://developers.google.com/earth-engine/datasets/catalog/MODIS_061_MCD12Q1

Google Earth Engine Data Catalog. (2024, 10 15). *SRTM Digital Elevation Model (DEM)(USGS/SRTMGL1_003) data*. Retrieved from Earth Engine Data Catalog: https://developers.google.com/earth-engine/datasets/catalog/USGS_SRTMGL1_003

Khan, A. (2023, April 1). *Why 80% of New Zealand is Empty*. Retrieved from Medium: https://eshananas.medium.com/why-80-of-new-zealand-is-empty-5eb5d7771b7f#:~:text=New%20Zealand%20is%20a%20country%20with%20a%20fascinating%20population%20pattern,for%20people%20to%20live%20in.

Koordinates. (2024, 10 03). *EcoSat Forest (South Island)*. Retrieved from koordinates: https://koordinates.com/from/lris.scinfo.org.nz/layer/48416-ecosat-forest-south-island/

Land Information New Zealand. (2024, 10 13). *NZ 8m Digital Elevation Model (2012)*. Retrieved from Land Information New Zealand: https://data.linz.govt.nz/layer/51768-nz-8m-digital-elevation-model-2012/

Land Information New Zeland. (2024, 10 03). *https://data.linz.govt.nz/data/*. Retrieved from NZ Roads: Road Section Geometry, New Zealand: https://data.linz.govt.nz/data/

Must Do New Zealand. (n.d.). *Must Do New Zealand*. Retrieved from South Island of New Zealand: https://mustdonewzealand.co.nz/south-island-new-zealand-things-to-do/

New Zealand Geotechnical Society (NZGS). (2023). Slope Stability Geotechnical Guidance Series: Unit 1 – General Guidance. New Zealand Geotechnical Society.

NZ DEM. (2024, 10 03). *Open Topo Data*. Retrieved from NZ DEM: https://www.opentopodata.org/datasets/nzdem/#public-api

Wikipedia. (2024, 10 1). *Effects of high altitude on humans*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Effects_of_high_altitude_on_humans

Wikipedia. (n.d.). *South Island*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/South_Island