Current State of Landscape Connectivity and Structural Fragmentation in Prince Edward Island

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Introduction

During the 40th Conference of New England Governors and Eastern Canadian Premiers, **Resolution 40-3** was passed, recognizing the significance of the Appalachian-Acadian forest. The resolution contributes to acknowledging the importance of the forest on local and global scales. Not only do many Indigenous and non-Indigenous communities rely on the forest for their livelihood, but the forest also presents itself as the most intact, contiguous broadleaf forest in the world. For Prince Edward Island, local commitment is crucial to ensuring the longevity of the Appalachian-Acadian forest. The signature of Wade MacLauchlan, Premier of Prince Edward Island and conference Co-Chair, in passing Resolution 40-3 established collaboration in maintaining and restoring ecological connectivity. Not only does this commitment invest in conservation, but Resolution also 40-3 contributes to *Pathway To Canada Target 1*, a nationwide ecological connectivity strategy. The work presented in this document aims to identify and understand ecological connectivity to further support future conservation measures in Prince Edward Island.

In broad terms, ecological connectivity can be referred to as the degree to which blocks of suitable habitat are connected in the landscape (Taylor, Fahrig, Henein, & Merriam, 1993). Ecological connectivity is generally characterized as two separate components: structural connectivity and functional connectivity (Brooks, 2003). Structural connectivity explains the relationship between landscape elements, while functional connectivity refers to the movement of species within the structure of the landscape (Brooks, 2003). Although ecological connectivity influences the movement of specific biological species in ecology, the work presented will primarily focus on the landscape's structural connectivity, otherwise noted as the "the shape, size, and locations of features in the landscape" (Brooks, 2003, p. 433).

The condition of landscape connectivity can be heavily influenced by fragmentation. Before the 19th century, the Acadian Forest region dominated the Province of Prince Edward Island (PEI) (Government of PEI, 2013). Due to the effects of agricultural activity within the last three centuries, clearing timber, farming practices, and road infrastructure resulted in removing 70 percent of the forest (Silva, Hartling, & Opps, 2005; Government of PEI, 2013). As such, processes affecting forest fragmentation have led to more significant environmental impacts such as habitat loss, ultimately preventing gene flow throughout the landscape (Silva, Hartling, & Opps, 2005). Certain species can experience different sensitives from the presence of roads (Benítez-López, Alkemade, & Verweij, 2010). While these impacts may have a greater localized impact, the effect of roads can extend varying distances. This work will introduce the road effect zone (REZ) to understand the impacts from road fragmentation on ecological connectivity.

The modelling of ecological connectivity across landscapes is a continuing research process that extends across multiple disciplines. Connectivity modelling involves a great deal of research, data compilation, GIS analysis and interpretation. Including various metrics can increase the likelihood and accuracy of determining connectivity patterns across a landscape as well as fill gaps that may be present in certain metrics. The benefit of having a variety of landscape connectivity methods and metrics across the province can provide a greater understanding of the conditions faced by the natural landscape (natural ecosystems, forest, and mature forest) and the influence of each of these with and without a road effect zone (REZ). In the scope of Prince Edward Island, this work builds on from the research conducted by Dalhousie University in Assessing Forest Connectivity in Nova Scotia, which includes using the method of the effective mesh size (m_{eff}) in a modified moving window analysis (Cunningham, 2020). Specifically, this project employs effective mesh size (m_{eff}), various fragmentation metrics (percentage class area, median patch size, edge density, and mean perimeter-area ratio), and Circuitscape analysis to assess connectivity in Prince Edward Island.

Methods

Study Area

In contrast to the Province of Nova Scotia, this work was not performed based on eco-regions or eco-districts due to the lack of definition and data regarding ecological land classification in PEI. Figure 1 represents the historical baseline of the natural landscape in Prince Edward Island. For this analysis, the study area refers to Prince Edward Island's whole province, where the landscape classifications are characterized by natural ecosystems, forests, and mature forests.

Figure 1: Historical baseline of the natural landscape of Prince Edward Island.

Although the classification for mature forests can be classified either through age-specific characteristics or defined by ecological functions, the mature forest classification was determined by height of the stand. The following tables (Table 1-3) outline the land cover classes used to characterize the landscape class areas. The data included for each of the class areas were determined based on the 2010 PEI Corporate Land use Inventory. Dominant classes, which include open water, were excluded from this analysis as this work focused on the structural connectivity of the landscape that is primarily associated with vegetation.

Natural Ecosystem

Table 1: Landscape types representing Natural Ecosystems in Prince Edward Island.

Land Use	Sub Use	Cover Type	Extract
Forestry	Clear cut Plantation Wetland		
		All forest cover classes	
Abandoned Land Wetland	Shrubs Forest		

Forestry

Table 2: Landscape types representing Forested areas in Prince Edward Island.

Land Use	Sub Use	Cover Type	Extract
Forestry	Clear cut Plantation Wetland Trees		
		All forest cover classes	

Mature Forest

Table 3: Landscape Types representing Mature Forested Areas in Prince Edward Island

Land use	Sub use	Cover Type	Extract
Forestry	Clear cut Plantation Wetland Trees		Everything greater than or equal to 15m in height
		All forest cover classes	

Determining the Road Effect Zone

The road effect zone (REZ) can be described as an ecological threshold where an abrupt change occurs from one landscape feature to another (Luck, 2005; Eigenbrod, Hecnar, & Fahrig, 2009; Cunningham, 2020). The REZ is clearly defined to address the impact roads have on local wildlife, which can be extended based on the type of roads and surrounding landscapes (Benítez-López, Alkemade, & Verweij, 2010). With consideration that the PEI landscape is founded on young and old-growth forests, there is a need to account for a broad range of species within landscape classes and fine-scale habitats (Baglole, 2016). An analysis of the distance to roads across the province of Prince Edward Island revealed that the maximum distance from a road is 6.289km, where a median of 0.328 km is within distance from a road (Figure 2, Table 4). In Nova Scotia, the maximum distance calculated between roads is 25.6km, with a mean distance of 1.8km (Cunningham, 2020).

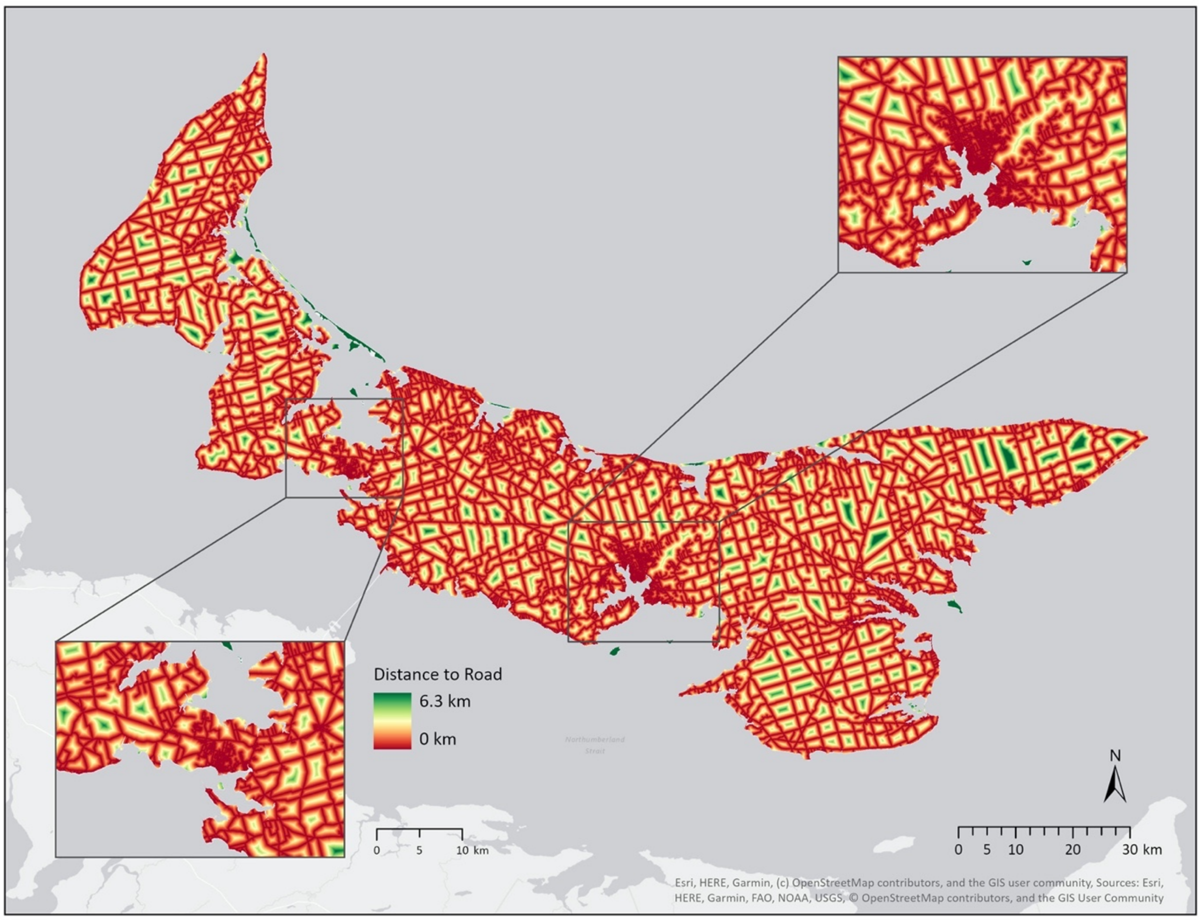


Figure 2: Distance to the road across Prince Edward Island based on a Euclidean Distance Analysis. The mean road distance across the entire province was 0.376km, and the maximum distance was 6.289km.

This suggests that the wildlife in the province have adapted to be within that distance to the road. However, it must be acknowledged that this does not necessarily mean that these species live in optimal conditions, nor does it mean that the current suite of species would be the species present without roads. Benítez-López et al. (2010) determined that most mammal populations felt a REZ of 5km from the road. A REZ of 5 km across Prince Edward Island covers 99.9 percent of the land (Table 4). A comparison of a 0.3km REZ and a 0.5km REZ was completed to observe the size of landscape classification patches (Figure 3). A REZ of 0.3km was selected as it covers precisely 50.8 percent of the landscape. The road effect zones were created by a select distance buffer from the roads and erasing the buffer from the landscape classes (natural, forest, mature forest).

Table 4: Percentage of the province within a specified distance from a road. Percentages were calculated using the multi-ring buffer tool.

Distance (km)	Percentage of Province within Distance to Road
0.1	20.1%
0.3	50.8%
0.5	71.0%
0.8	88.5%
1.0	94.3%
3.0	99.8%
5.0	99.9%
6.3	100.0%

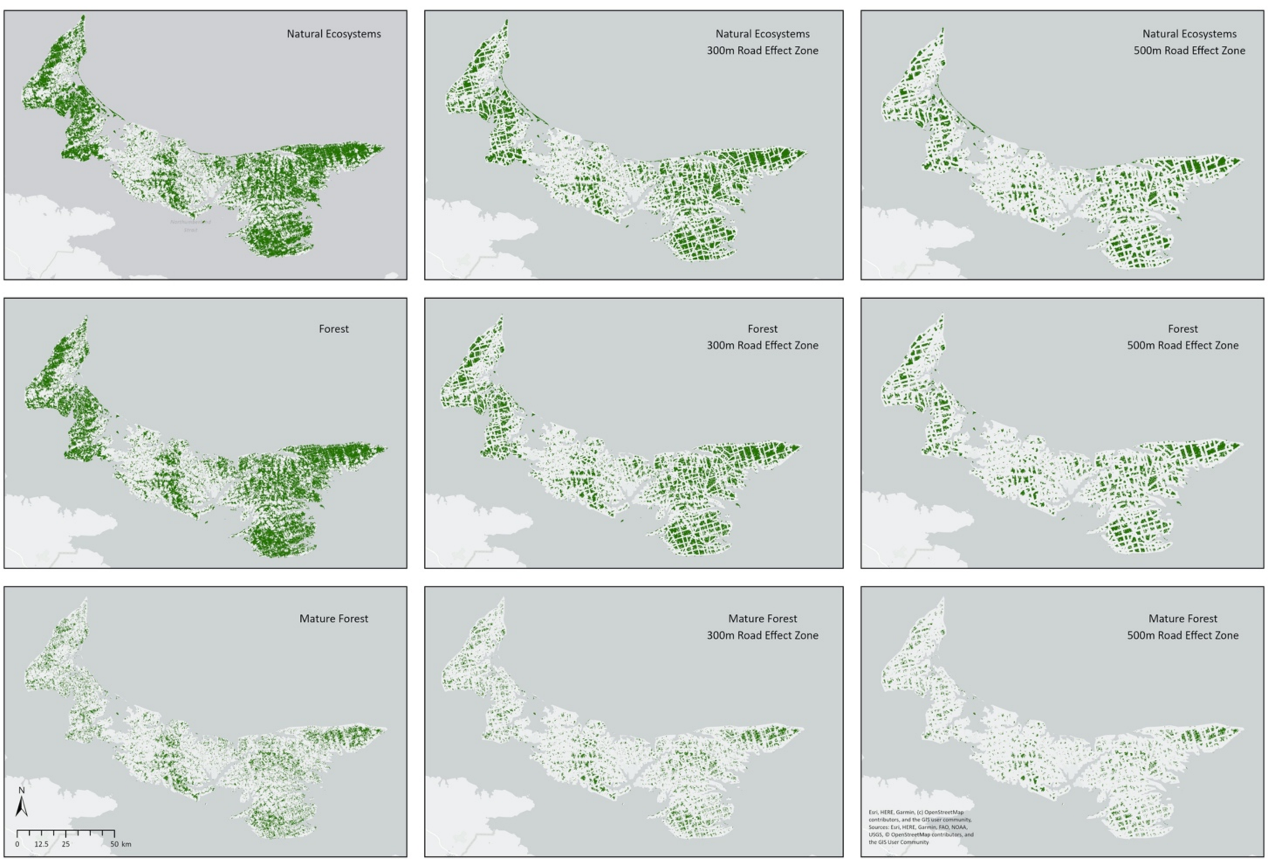


Figure 3: Landscape classifications for this analysis include Natural Ecosystems, Forest and Mature Forest with a road effect zone (REZ) of 300m and 500m.

Fragmentation Metrics

Fragmentation statistics are used to measure and quantify the patterns and attributes of different land cover classes (McGarigal & Marks, 1994). Although there are numerous fragmentation statistics, measurement should focus on four key categories: (i) class area; (ii) patches; (iii) edge and; (iv) shape (Leitão et al., 2012). We selected each category's metric to represent the different analytical units and landscape classifications for this work. The following metrics were examined:

I. Percentage Class Area: The class area (natural ecosystems/forest/mature forest) divided by the total landscape area measured in kilometres (km) were used to calculate the percentage of each analytical unit occupied by each landscape classification (Mcgarigal & Marks, 1994). The greater the percentage class area, the greater the class area occupies the landscape.

$$Percentage\ Class\ Area = \left(\frac{Sum\ Class\ Area\ (km^2)}{Total\ Landscape\ Area\ (km^2)}\right) x\ 100$$

II. Median Patch Size (MedPS): This metric was used to get a sense of typical sizes while avoiding outliers' influence in using mean patch size.

$$MedPS = Median\ of\ Sum\ Class\ Area\ (km)$$

III. Edge Density (ED): The edge of the class area (natural ecosystems/forest/mature forest) is measured as the meters of patch edge per hectare of the landscape (Mcgarigal & Marks, 1994). This metric is intended to give an indication of how fragmented the landscape is.

$$ED = \frac{Sum\ Patch\ Edge\ (metres)}{Total\ Landscape\ Area\ (Hectares)}$$

IV. Mean Perimeter Area Ratio (MPAR): This metric is intended to measure the class area patches' shape complexity. MPAR is calculated by dividing the sum of each patch's perimeter-area ratio by the number of patches for each class (Mcgarigal & Marks, 1994). Higher MPAR values indicate more complex patch shapes in the study area.

$$MPAR = \frac{\left(\frac{Sum\ of\ Patch\ Edge\ (m)}{Sum\ of\ Patch\ Area\ (ha)}\right)}{Number\ of\ patches}$$

Connectivity Metrics

Effective mesh size (m_{eff}) is a measure of landscape fragmentation based on the probability that two randomly chosen points will fall within the same patch of a landscape (Jaeger, 2000). m_{eff} (km^2) is calculated using Equation 1, whereA_{total} is the total study area (km^2) and $A_i$is the size of the patch (km^2). As the whole province of Prince Edward Island is classified as the study area (Figure 1; total study area), the m_{eff} resulting analysis calculates forest, mature forest and natural ecosystems, without accounting for the REZ, and accounting a 0.3 km REZ results in a total of 36m_{eff} analyses.

$$m_{eff} = \frac{1}{A_{total}}(A_1^2 + A_2^2 + \cdots + A_n^2)$$

Equation 1. Calculating effective mesh size (Jaeger, 2000).

Moving Surface Average

The method described above for calculating m_{eff} yields only one value per A_{total} cell, which creates a challenge for determining how m_{eff} changes across a landscape. This challenge is particularly prevalent. There are no considerable distinctive barriers in the landscape, such as mountain ranges or dense urban corridors, to easily divide the study areas into smaller sub-areas. To better understand m_{eff} Prince Edward Island's changes, this project uses a modified moving window approach developed by Cunningham (2020). The model uses 100 fishnets with the same grid size but random origins (Figure 3). Each fishnet layer is first clipped to the study area (i.e., PEI), and which then processes the Summarize Within tool in ArcGIS Pro and is used to calculate the sum of the patches' area squared in each square of the fishnet. This value is then used to calculate m_{eff} each square of the fishnet. Following the calculation, the resulting layer is converted to a raster. Once all 100 iterations of this process are complete, the output rasters are averaged together using the cell statistics tool to produce the final effective mesh size surface raster (Figure 4). The moving surface average will also process fragmentation metrics in conjunction to m_{eff}.

It is recommended that the model run a variety of different sizes and undergo a sensitivity analysis to determine the optimal fishnet size for the province of Prince Edward Island. This analysis used a 100km^2 fishnet as it corresponds to a previous biological analysis done by researchers for the province of Prince Edward Island (Maritime Breeding Bird Atlas, n.d.).

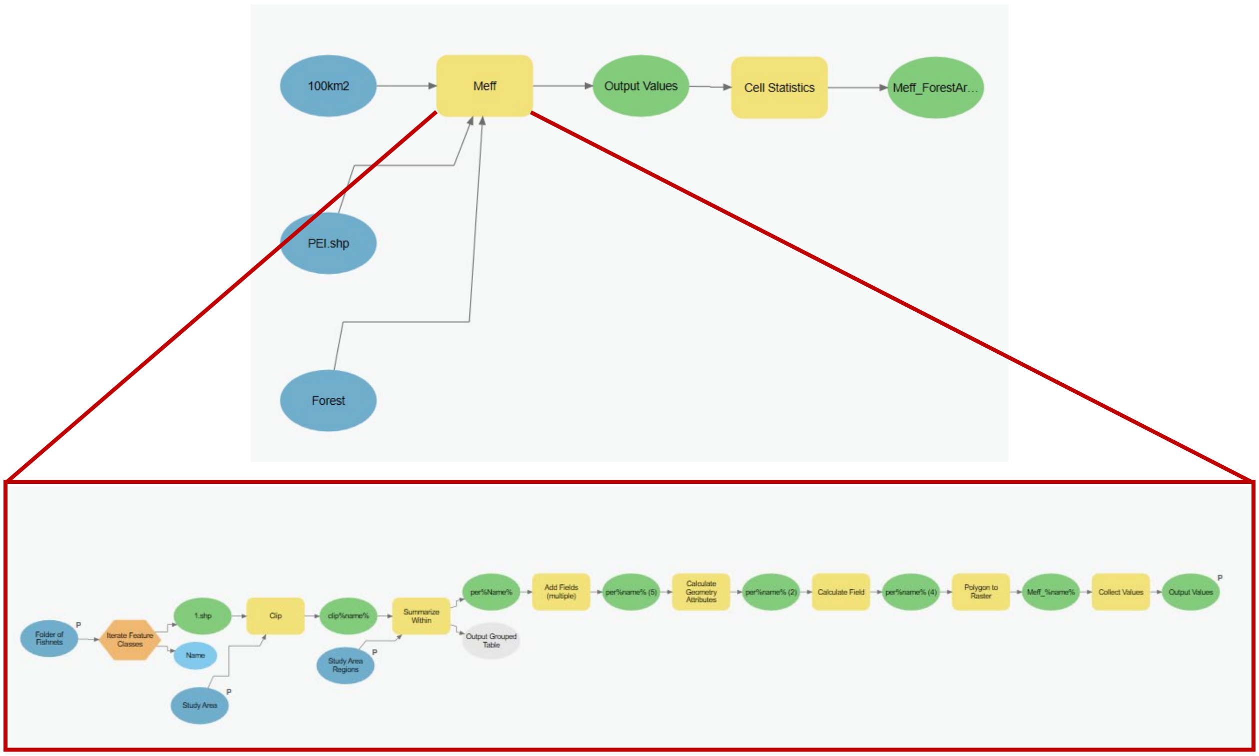


Figure 4: Model used to generate mesh size surfaces in ArcGIS Pro.

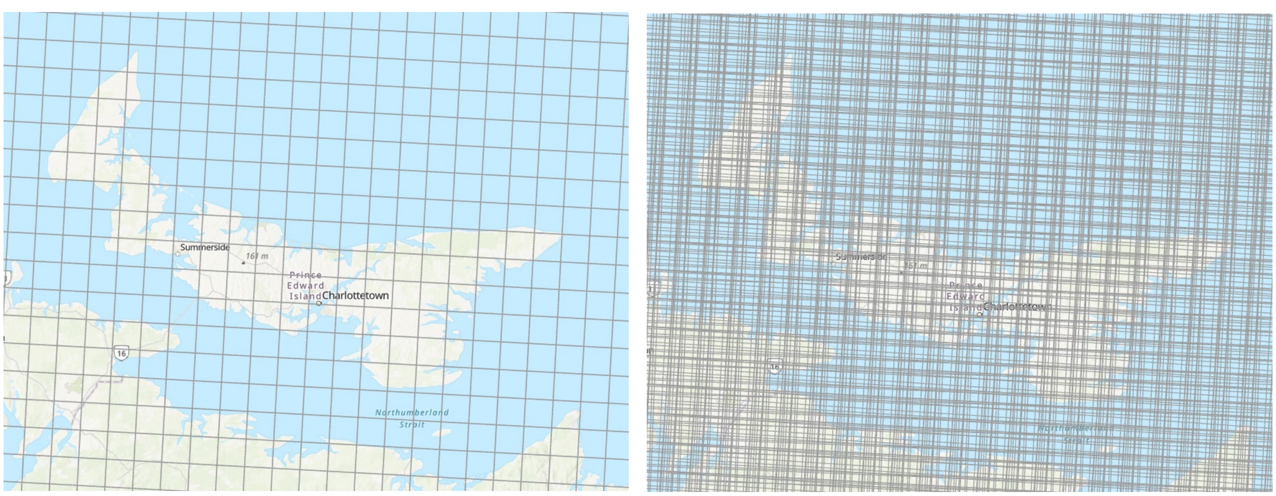


Figure 5: Study Area with one fishnet (left) and ten fishnets (right). The model used to generate the mesh size surfaces went through an iteration of 100 fishnets.

Circuitscape

The emerging method of analyzing ecological connectivity using circuit theory has been widely used across scholars in forest connectivity analysis (Pelletier, Lapointe, Wulder, White, & Cardile, 2017). Circuitscape is an open-source software package that integrates the algorithms from circuit theory to make predictions about connectivity patterns across heterogeneous landscapes (Circuitscape, n.d.). Modelling these landscapes is intended to understand how connectivity is affected by environmental features (Shah & McRae, 2008).

Circuitscape works hand in hand with GIS computational software. It requires raster-based data represented by pixels or cells and is typically represented by a digital elevation model (DEM). The larger the resolution of the cells, the less detailed the analysis. Circuitscape then codes the raster data and assigns values based on the landscape features to create a resistance surface (Shah & McRae, 2008). Circuitscape reflects the electric circuit theory and uses the resistance surface to measure the connections of electrical current flows along the surface that indicate a random walker's probability of passing through to reach a node, such as a habitat patch (Shah & McRae, 2008). Additionally, the voltages measured in circuits predict whether the “random walker will reach one destination before another” (Shah & McRae, 2008, p. 62).

Circuitscape works by using a raster habitat map that determines each cell's resistance in the landscape (Circuitscape, n.d.). The focal node map is typically associated with the core habitat patches (such as natural ecosystems or forested areas). The program creates a network by converting the habitat cells to nodes and connecting them to their immediate neighbors. It maps the movement based on current flows' resistance, which aligns with electric circuit theory concepts. As an example, roads will act as a dam, showing pinch points within corridors as areas that should be priorities for protection. Pinch points show highly constricted locations and strong current flow; however, once a network is severed, there is a loss of habitat movement. These potential areas can indicate the need for protection from habitat loss and degradation.

To evaluate the different structural habitat resistance maps, we examine the following resistances: Natural Ecosystems (forest and natural ecosystems resistance = 1 and all other land cover including roads = 1000) and Forests (forest resistance = 1 and all other land cover including roads = 1000).

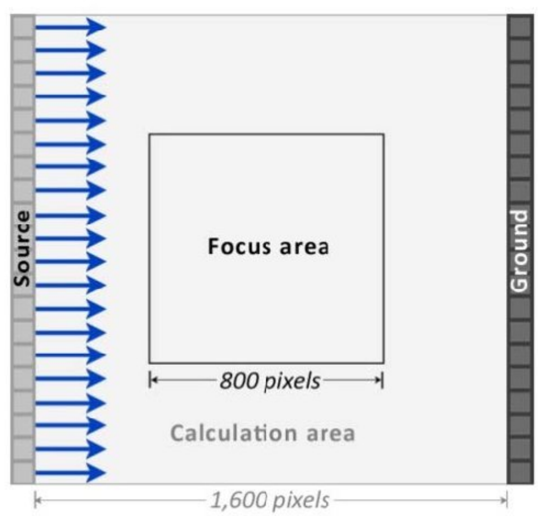


Figure 6: Wall-to-wall directional flow.

A wall-to-wall analysis was conducted to assess the flow or movement across these landscapes (or resistance maps). This approach involves assessing the flow from one side of a tile wall to the other side of the tile wall. Tiles were 25 km x 25 km. This size of tile was chosen to allow the whole province to be processed based in the most efficient way possible given modest computer processing power (i.e., new laptop 1.6 GHz Intel Core i5-8265U, 8GB RAM). This study assessed the flow from horizontal (East-West then West-East) and vertical (North-South and South-North) for each tile (Figure 3). To ensure that the tiles' edge effect did not influence the results by restricting flow, a 10 km buffer was created around each target title with the surrounding landscape data to form larger overlapping calculation areas. Buffer areas were then removed from each target tile following the wall-to-wall analysis. The directional tiles (both horizontal and vertical) were then combined to create omnidirectional connectivity mosaics.

Results

Results for this analysis focused on landscape classifications (i.e. natural ecosystems, forest, mature forest) that have no road effect zone, and classifications with a 300m road effect zone. For each metric, a statistical mean of the surface area is provided for all classifications. The resulting maps from the effective mesh size (m_{eff}) can be found in Appendix I.

Effective Mesh Size

For the effective mesh size (m_{eff}) surface averages generated from the 100km^2 moving window analysis, m_{eff} was found to be highest in natural ecosystems (most connected) and lowest for the mature forest classes (least connected). Across all landscape classes, the values range from 0.006 km^2 (mature forest with a 300m REZ) to 0.036 km^2 (natural ecosystems with no REZ) (table 6). When calculated by forested areas alone, the highest m_{eff}surface average is 0.059 and is located by Inverness, Miscouche, Mount Carmel, Souris, and Elmira. The lowest m_{eff}values of 0.0042 were focused on settlement areas such as Summerside and Charlottetown (Appendix I).

Table 5: Statistical Mean Effective Mesh Size per class area across Prince Edward Island.

Statistical mean of m_{eff}	No REZ	300m REZ
Natural Ecosystems	0.036 km^2	0.024km^2
Forest	0.022 km^2	0.014km^2
Mature Forest	0.009 km^2	0.006km^2

Fragmentation Metrics

Median Patch Size (MPS)

Median patch size surfaces generated from the 100km^2 moving window analysis identified that median patch sizes are significantly larger for natural ecosystems than mature forests. Across the province, the smallest patch size is 1.24 km^2 (mature forest with a 300m REZ), and the largest patch size is 71.67 km^2 (natural ecosystems unaffected by REZ). An important note to consider in this analysis is that the median patch size surface average for the natural ecosystems and forested areas does not significantly differ (Table 6). The resulting maps from the median patch size (MPS) moving surface average can be found in Appendix II.

Table 6: Statistical mean of Median Patch Size Surface Average per class area across Prince Edward Island.

Statistical mean MPS	No REZ	300m REZ
Natural Ecosystems	38.67 km^2	24.36 km^2
Forest	36.03 km^2	22.63 km^2
Mature Forest	17.15 km^2	11.00 km^2

Percentage Class Area

Percentage class area surfaces generated from the 100km^2 moving window analysis identified that higher natural and forest class areas occupy a significant portion of the landscape (Figure 8). As the landscape classification patch size decreased (natural to forest to mature forest), the percent class area decreased across the landscape. The analysis found natural ecosystems to have covered a mean of 47.09 percent. The analysis determined that forested areas have a mean percentage class area of 43.61 percent, and mature forested classification had a mean percentage class area of 20.45 percent (Table 7). Once a REZ of 300m was considered, the percentage of natural ecosystems was affected by a 50 percent reduction, similar to the forested areas. Mature forest tree stands affected by a 300m REZ were 70 percent lower than the mature forest percentage without REZ. The resulting maps from percentage class area surface average can be found in Appendix III.

Table 7: Statistical mean Percentage Class Area per class area across Prince Edward Island.

Mean of Percentage Class Area Surfaces	No REZ	300m REZ
Natural Ecosystems	47.09%	29.34%
Forest	43.61%	26.90%
Mature Forest	20.45%	12.99%

Edge Density (ED)

The values generated from the edge density (ED) surface average across a 100km^2 moving window analysis revealed values between the ranges of 11.09 m/ha (Mature forest with a 300m REZ) and 253.08 m/ha (Natural Ecosystems with no REZ) within the landscape classes. Locations of edge density that proved to be most significant are in high-density settlement areas located in inlets and coves (Figure 7).

Forested areas unaffected by REZ had a maximum value of 230.01 m/ha. Compared to a 300m REZ, the highest value was 156.45 m/ha, resulting in a 68 percent decrease in edge density. These values are comparable for other class areas. Natural ecosystems experience a 65 percent decrease, and mature forests experience a 66 percent decrease in edge density between no REZ and a 300m REZ. An observation of the landscape classes' statistical mean demonstrates an apparent reduction between no REZ and a 300m REZ (Table 8). The resulting maps from edge density (ED) surface average can be found in Appendix IIV.

Table 8: Statistical mean Edge Density per class area across Prince Edward Island.

Mean Edge Density	No REZ	300m REZ
Natural Ecosystems	155.59 m/ha	97.37 m/ha
Forest	145.07 m/ha	90.83 m/ha
Mature Forest	67.99 m/ha	43.36 m/ha

Mean Perimeter-Area Ratio (MPAR)

The mean perimeter-area ratio (MPAR) surface average generated from the 100km2 moving window analysis revealed that higher MPAR values are distributed more frequently across the landscape (Figure 10). Class areas with greater percentages of the landscape showed low MPAR values, whereas patches of mature forest were characterized by higher MPAR values. The lowest value was 122.56 m/ha (natural ecosystems with a 300m REZ), and the highest value was 390.20 m/ha (mature forest with no REZ). Higher MPAR values were primarily located in locations where there is a strong presence of road fragmentation, agricultural activity, or urban settlement. Portions of the landscape that are consistently low in MPAR are areas near Souris, Elmira, and Murray Harbour. The resulting maps from mean perimeter-area ratio (MPAR) surface average can be found in Appendix V.

Table 9: Statistical mean Perimeter-Area Ratio per class area across Prince Edward Island.

Mean of MPAR Surfaces	No REZ	300m REZ
Natural Ecosystems	254.79 m/ha	251.67 m/ha
Forest	284.18 m/ha	280.56 m/ha
Mature Forest	299.93 m/ha	295.91 m/ha

Circuitscape

In addition to the results obtained from the fragmentation metrics, the application of Circuitscape to different resistance landscape classifications revealed several areas where potential flow for animal movement could be restricted (Appendix VI). Fragmentation and connectivity metrics used prior to Circuitscape analysis indicate channels of flow, such as diffuse flow; however, not all were highlighted until the application of electric circuit theory. As an example, intact areas, such as north of Souris, indicate pinch points. Pinch points represent high value energy due to barriers in the landscape which increase pressure to flow through these areas. The barriers are dependent on the type of resistance set-up in the landscape classifications. Circuitscape analysis was not completed on the mature forest classification following comparisons of fragmentation with the other landscape classifications, which revealed that mature forest was less applicable.

Natural Ecosystems

Natural ecosystems landscape classification created equal low resistance for wetlands and all types of forests, with barriers for roads, developments, non-natural land covers and natural water bodies. Circuitscape revealed key areas of channel flow and possible pinch points in the Northwest portion of Prince County around Miminegash-Saint Louis- Skinner Pond. Similarly, in southern Prince

County, areas around Hebron, Portage and Enmore also represent pinch points. The area surrounding Portage appears to be influenced by development barriers, waterbodies, and natural geometry of the land. In Queens County, the key channel flow focuses on the area around Brookvale Provincial Park and Green Bay. In Kings County, pinch points seem to be a focus on some areas in the north around Salvage Harbour and south of St. Peter's Bay.

Natural ecosystems landscape classification with the 300 REZ is more difficult to interpret. The REZ of 300m causes the flow to be interrupted throughout the landscape. Some channel flows are similar to the non-REZ natural ecosystems with channel flows in northwest Prince County and Portage.

Forests

The forested landscape classification revealed similar patterns to that of the natural ecosystems' classification. In Prince County, areas in the Northwest portion around Miminegash-Saint Louis- Skinner Pond were revealed as possible pinch points. Areas around Hebron, Portage and Enmore also indicate essential for ecological movement; however, some channels were narrower than those observed in the natural ecosystem classification. In Kings County, similar patterns can be observed, but with some variations in the widths or slight adjustments in the channels used to get through an area.

The forest landscape classification with the 300 REZ was again very difficult to interpret. The analysis seemed to identify many small pinch points across the whole province. This could highlight that the effect of fragmentation on the forested landscape are forced by increased barriers, indicating strong flow in small patches.

Conclusions

The landscape of Prince Edward Island is characterized by its highly fragmented network due to increased pressures from agriculture and development (Silva, Hartling, & Opps, 2005). The aim of this report intended to help identify the areas of PEI that are less fragmented than others, identify the remaining areas' important connectivity, while contributing to the knowledge gap on ecological connectivity in Prince Edward Island. This report analyzed three individual landscape classifications – natural ecosystems, forests, and mature forests – to understand the impacts from fragmentation and on ecological connectivity. These three landscape classifications represent broad structural habitats for various aquatic and terrestrial species.

From the presence of agricultural dependence and human settlement, undoubtedly, the influence of road infrastructure in Prince Edward is high. This report determined that over 50% of PEI is within 300m of a road, 94% of PEI is within 1km, and 99% is within 5km. The application of a 300m road effect zone (REZ) was included to evaluate the impact of fragmentation and connectivity across PEI.

Including various metrics can increase the accuracy of determining connectivity patterns while filling gaps that may be present in certain metrics. The fragmentation metrics provide the ability to quantity the fragmentation across various regions of the province. The values for each metric do not necessarily have any value for conservation efforts, but metrics can be used for comparisons between areas or for development projections to assess the increases or decreases in fragmentation. Connectivity metrics, such as the Effective Mesh Size analysis, helps identify areas of the province where some of the remaining forest and mature forest patches are better connected. These areas can be species specific with larger home ranges. The results from the Effective Mesh Size analysis from REZ demonstrate the negative influence of roads. Locations such as northwest Prince County lose most connected forest and mature forest when a 300m REZ is implemented.

The Circuitscape analysis identified areas of the province where there are potential pinch points for species movements based on structural landscape resistance values. The analysis for natural ecosystems and forest highlighted several areas to pinch pints, including northwest Prince County, Portage area, and south of Salvage Harbour, and south of St. Peter's Bay. Note that some of the sites, like north of Souris, that were highlighted in the Effective Mesh Size and the Fragmentation metrics did not show up in the Circuitscape analysis. This is likely because these (and some other) areas are a bit more continuous block of forest (and wetlands) and have more diffuse flow across the region (not constricted).

Future Research and Recommendations

This report outlines state of landscape connectivity and habitat fragmentation in PEI. The results from the analysis and geodatabase can be used for provincial-level planning and conservation efforts. The research highlights key areas or regions of the province where protected areas, management and restoration can be targeted.

It is recommended that future work should be prioritized in two main areas. First, there is a lack of research on assessing landscape connectivity from a functional connectivity perspective (i.e. focal species movement, area of species concentrations or metapopulations). Secondly, it is recommended that finer scale connectivity assessments are prioritized in relation to conservation efforts. Long-term landscape planning should consider implementation of protected areas based on structural and functional connectivity patterns, as well as small-scale infrastructure to accommodate for connectivity networks. Locations surrounding the Portage area is highly recommended to consider as a new protected area, as the application of highway underpasses for migratory species routes.

References

Baglole, T. W. (2016). *PRINCE EDWARD ISLAND PUBLIC LAND MANAGEMENT Landscape-Level Habitat Descriptions, Spatially Explicit Patch Outputs, and Identified Tradeoffs between Old-Forest and Wood Supply using Linear Programming over a 100-Year Planning Horizon.* Honours Thesis, University of New Brunswick , Faculty of Forestry and Environmental Management.

Benítez-López, A., Alkemade, R., & Verweij, P. (2010). The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. *Biological Conservation, 143*, 1307-1316.

Brooks, C. P. (2003, July 4). A scalar analysis of landscape connectivity. *Synthesising Ecology, 102*(2), 433-439.

Circuitscape. (n.d.). *Circuitscape*. Retrieved from https://circuitscape.org/

Cunningham, C. (2020). *Assessing Forest Connectivity in Nova Scotia.* Unpublished.

Eigenbrod, F., Hecnar, S. J., & Fahrig, L. (2009). Quantifying the Road-Effect Zone: Threshold Effects of a Motorway on Anuran Populations in Ontario, Canada. *Ecology and Society, 14*(1), 1-18.

Government of PEI. (2013). *2010 State of the Forest Report.* Government of Prince Edward Island, Department of Agriculture and Forestry. Government of Prince Edward Island.

Government of PEI. (2014). *Ecosystem-Based Forest Management Standards Manual.* Government of Prince Edward Island, Department of Agricullture and Forestry.

Luck, G. W. (2005). An introduction to ecological thresholds. *Biological Conservation*(124), 299-300.

Maritime Breeding Bird Atlas. (n.d.). *Maritime Breeding Bird Atlas - Region 27*. Retrieved May 2020, from Martime Breeding Bird Atlas: https://www.mba-aom.ca/maps/pdf/mbba_region_27.pdf

Mcgarigal, K., & Marks, B. J. (1994). *Fragstats: Spatial Pattern Analysis Program for Quantifying Landscape Structure.* Oregon State University. Corvallis: Oregon State University.

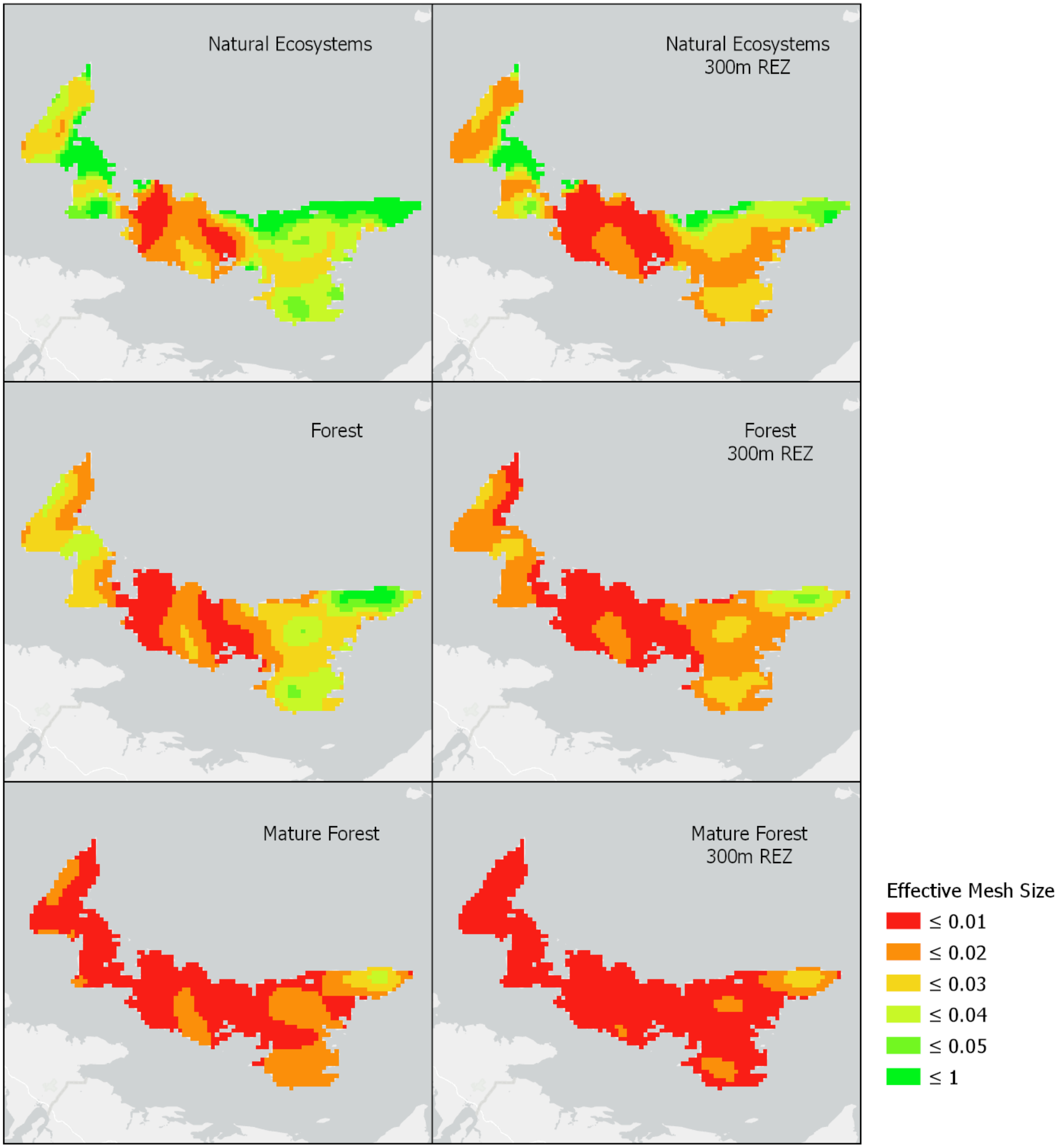
Pelletier, D., Lapointe, M.-É., Wulder, M. A., White, J. C., & Cardile, J. A. (2017, February 1). Forest Connectivity Regions of Canada Using Circuit Theory and Image Analysis. *12*(2).

Shah, V. B., & McRae, B. (2008). Circuitscape: A Tool for Landscape Ecology. *7th Python in Science Conference* , (pp. 62-66).

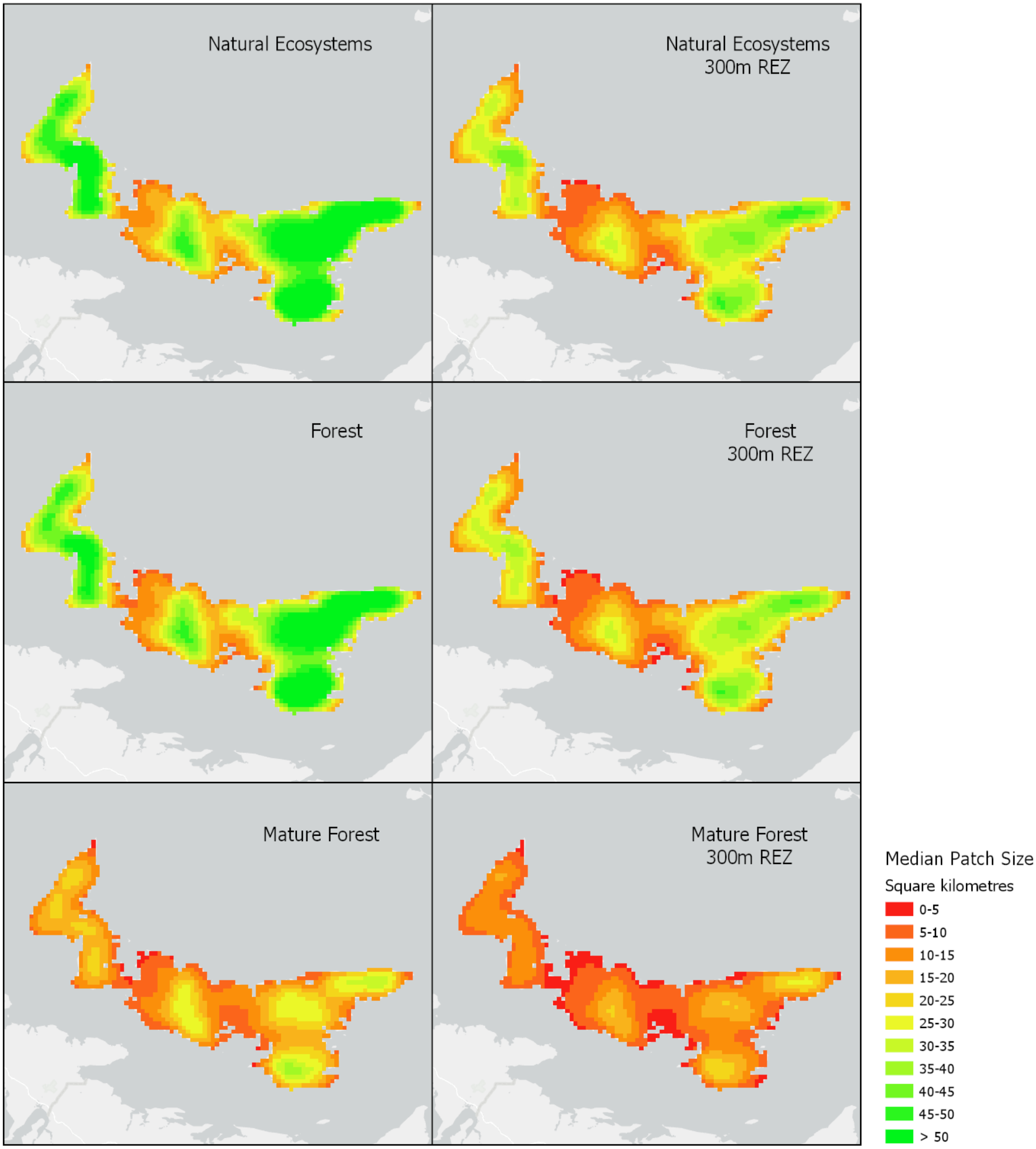
Silva, M., Hartling, L., & Opps, S. B. (2005, March 1). Small mammals in agricultural landscapes of Prince Edward Island (Canada): Effects of habitat characteristics at three different spatial scales. *Biological Conservation, 126*, 556–568.

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993, December). Connectivity Is a Vital Element of Landscape Structure. *Nordic Society Oikos, 68*(3), 571-573.

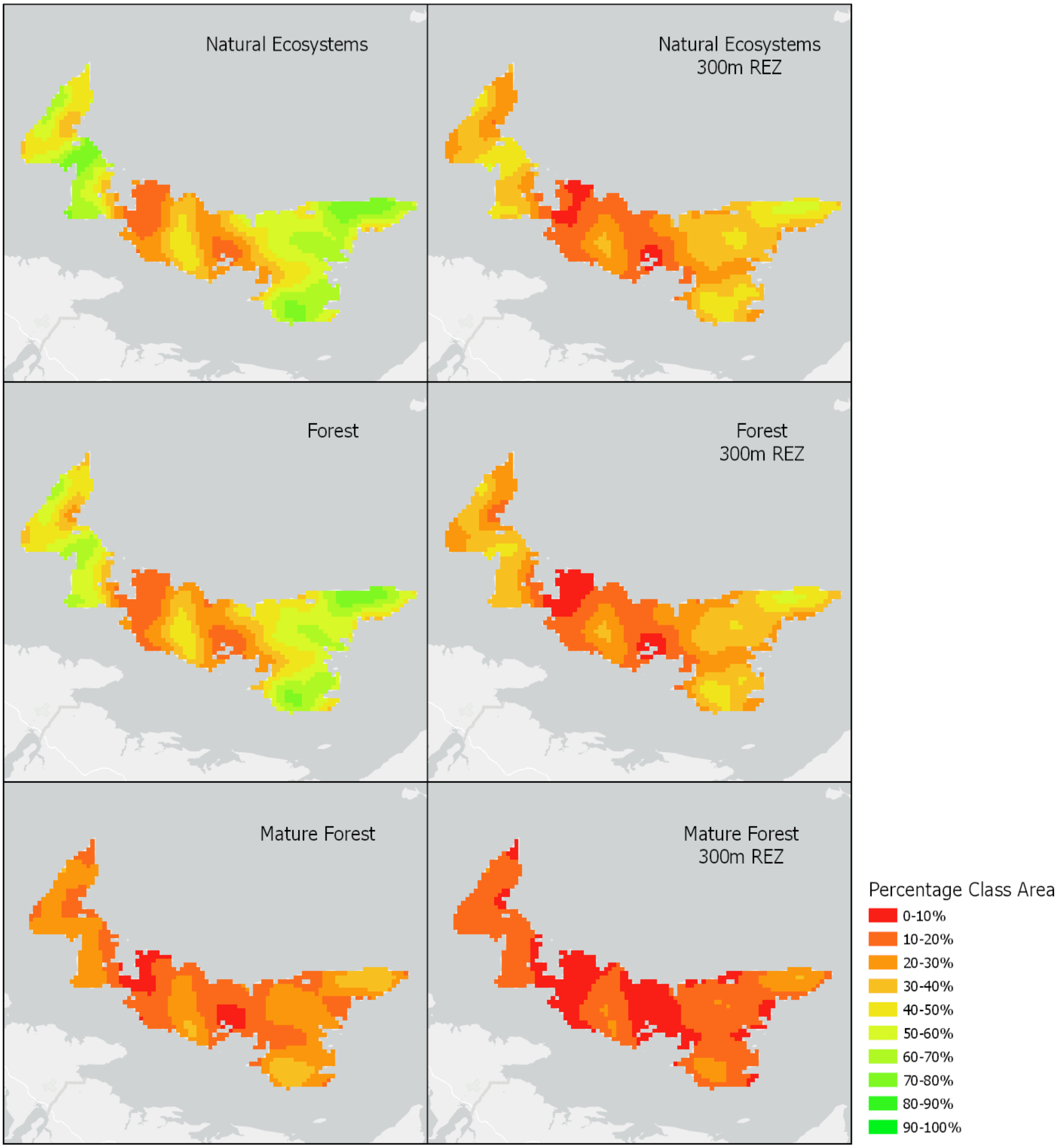
APPENDIX I: Effective Mesh Size



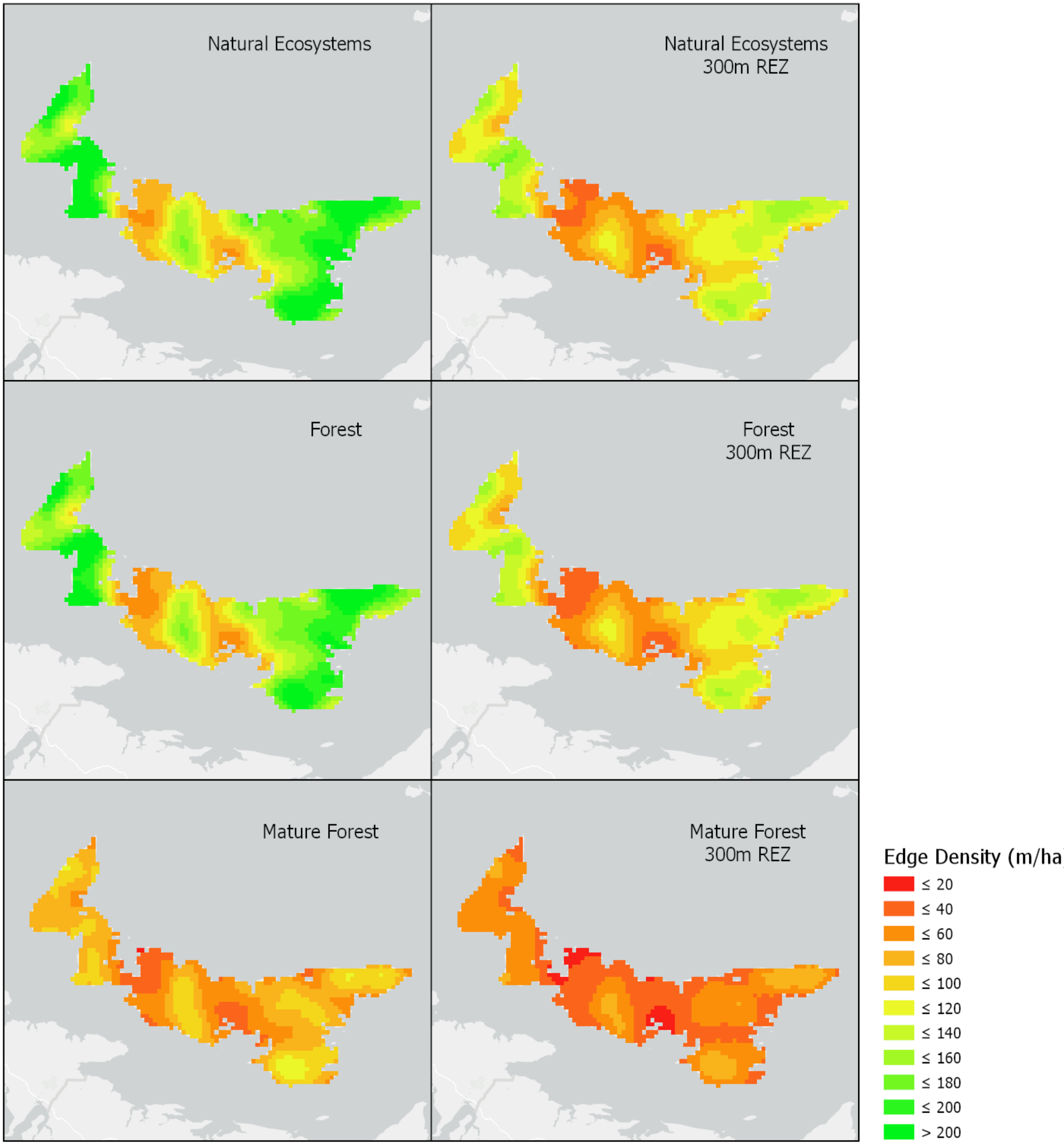
APPENDIX II: Median Patch Size



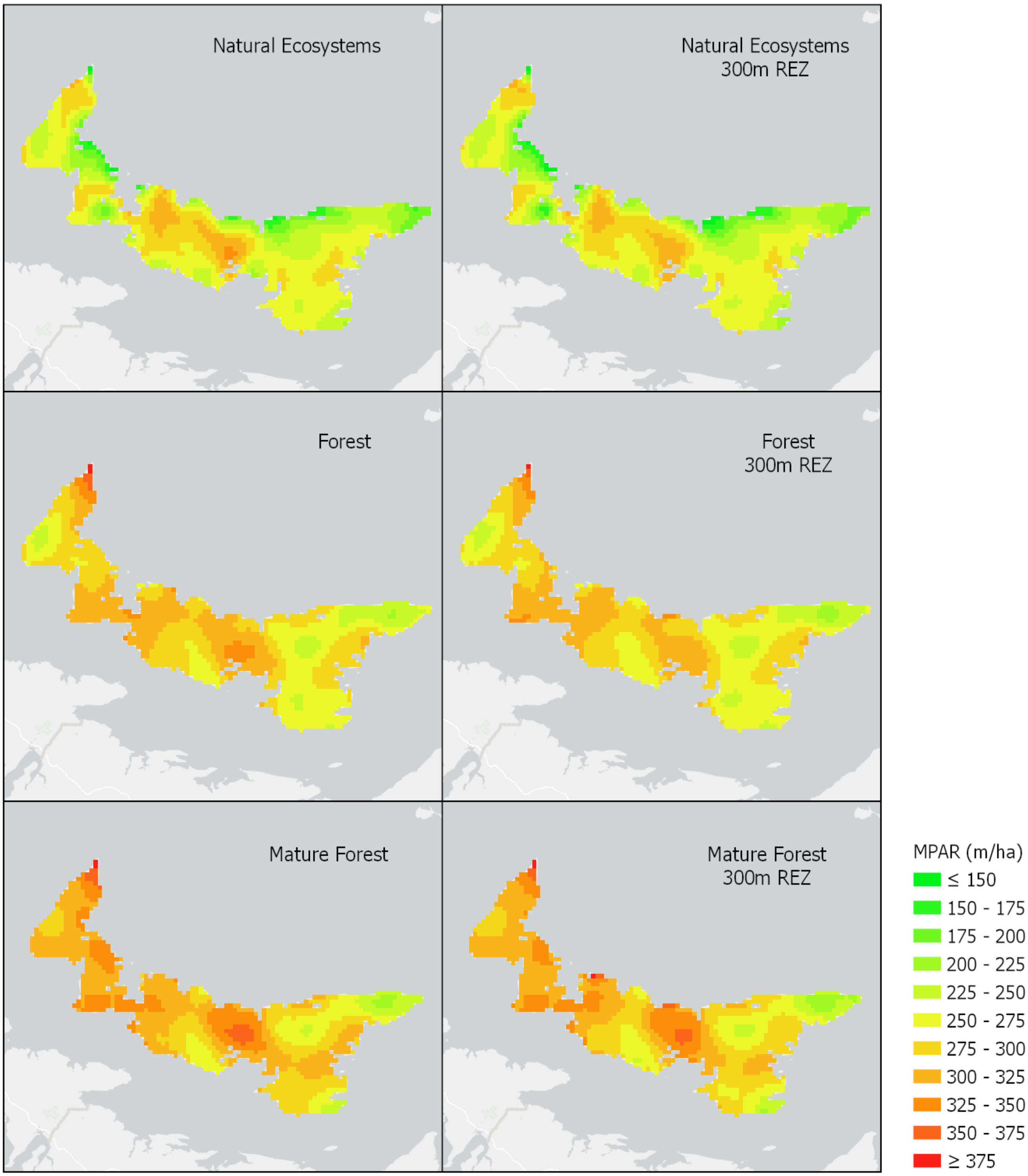
APPENDIX III: Percentage Class Area



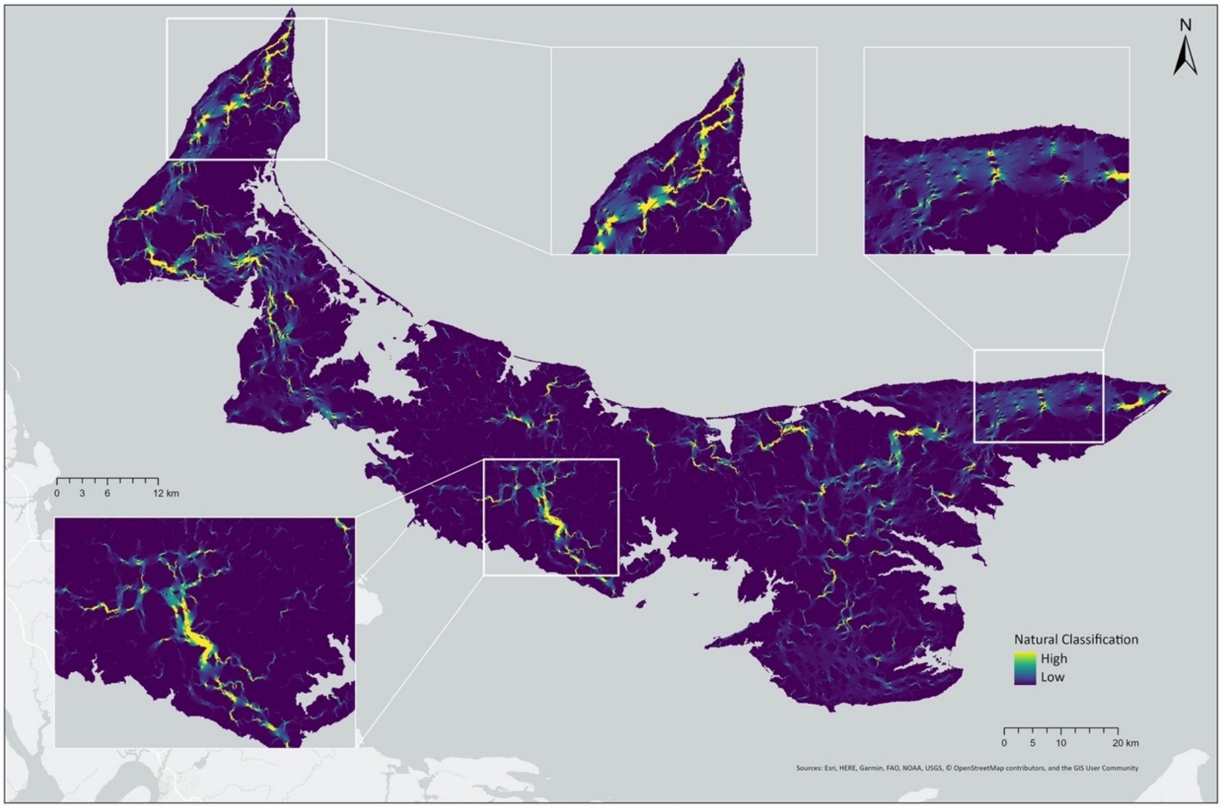
APPENDIX IIV: Edge Density

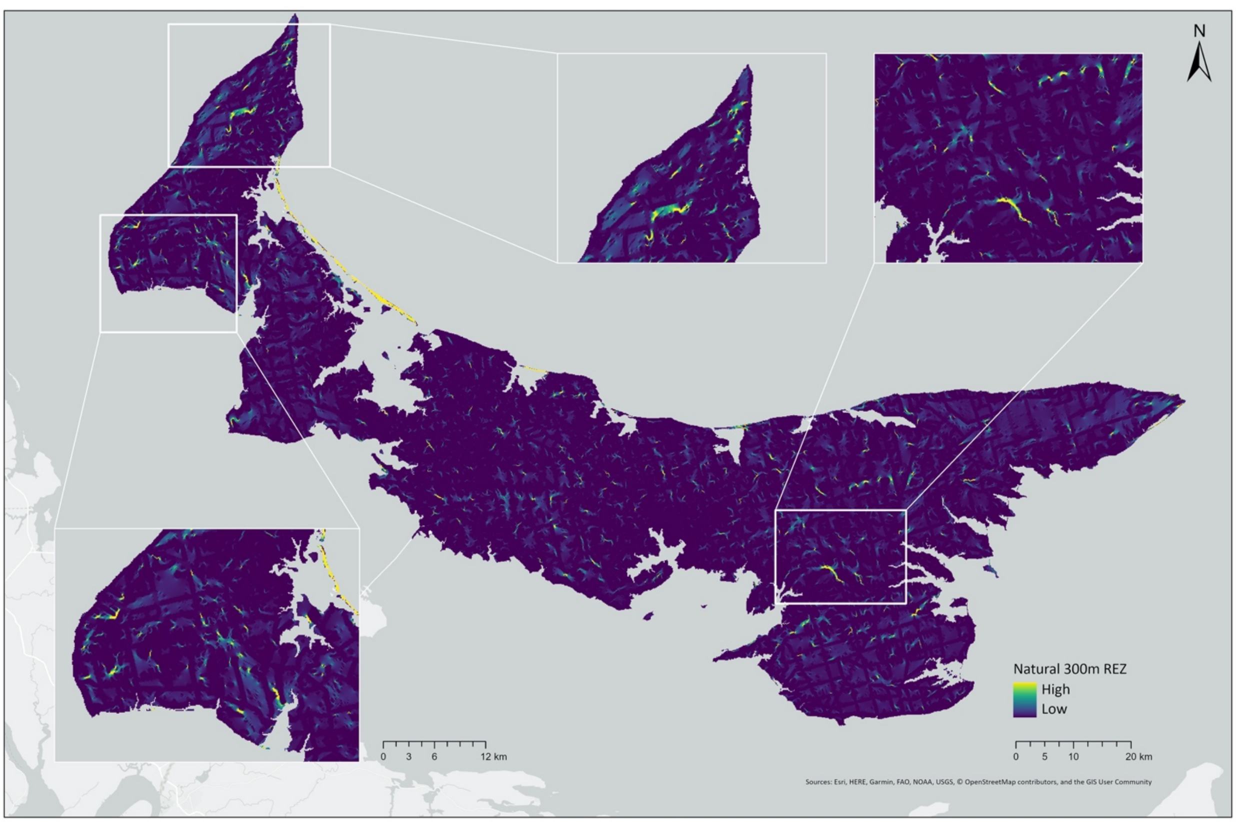


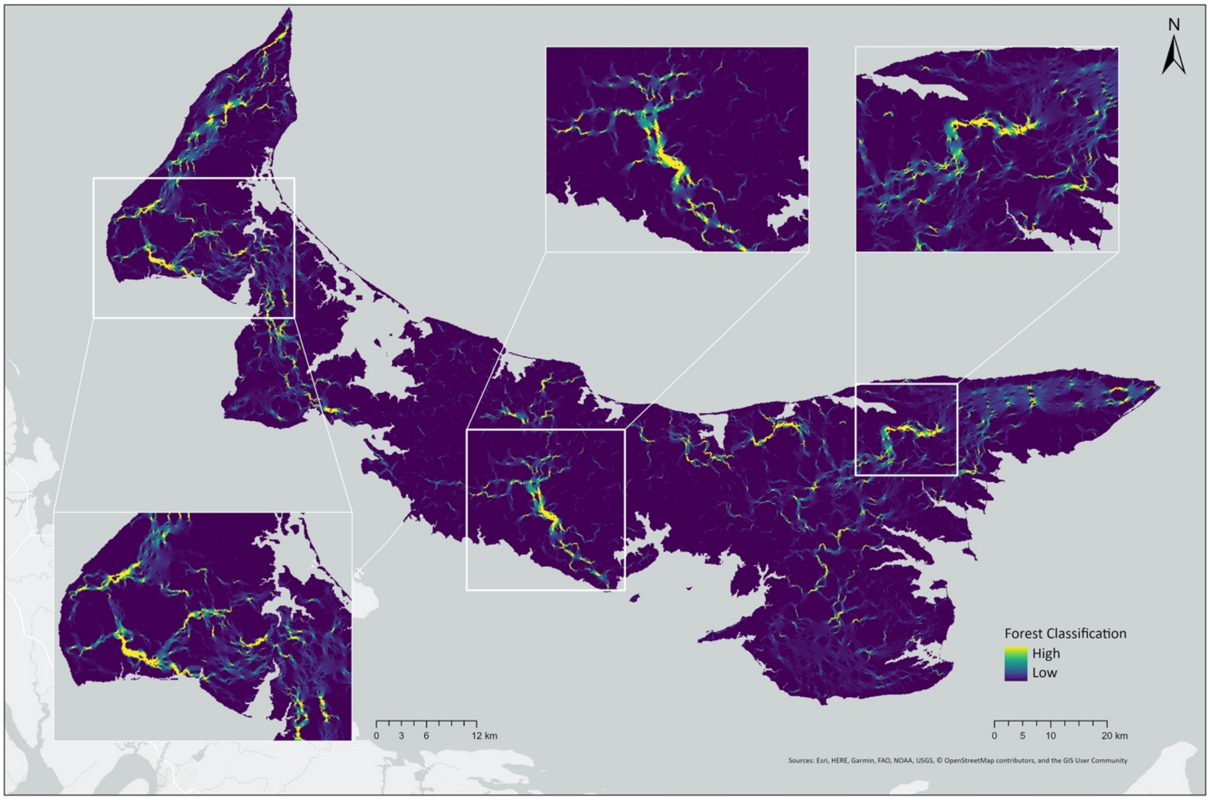
APPENDIX V: Mean Parameter Area Ratio

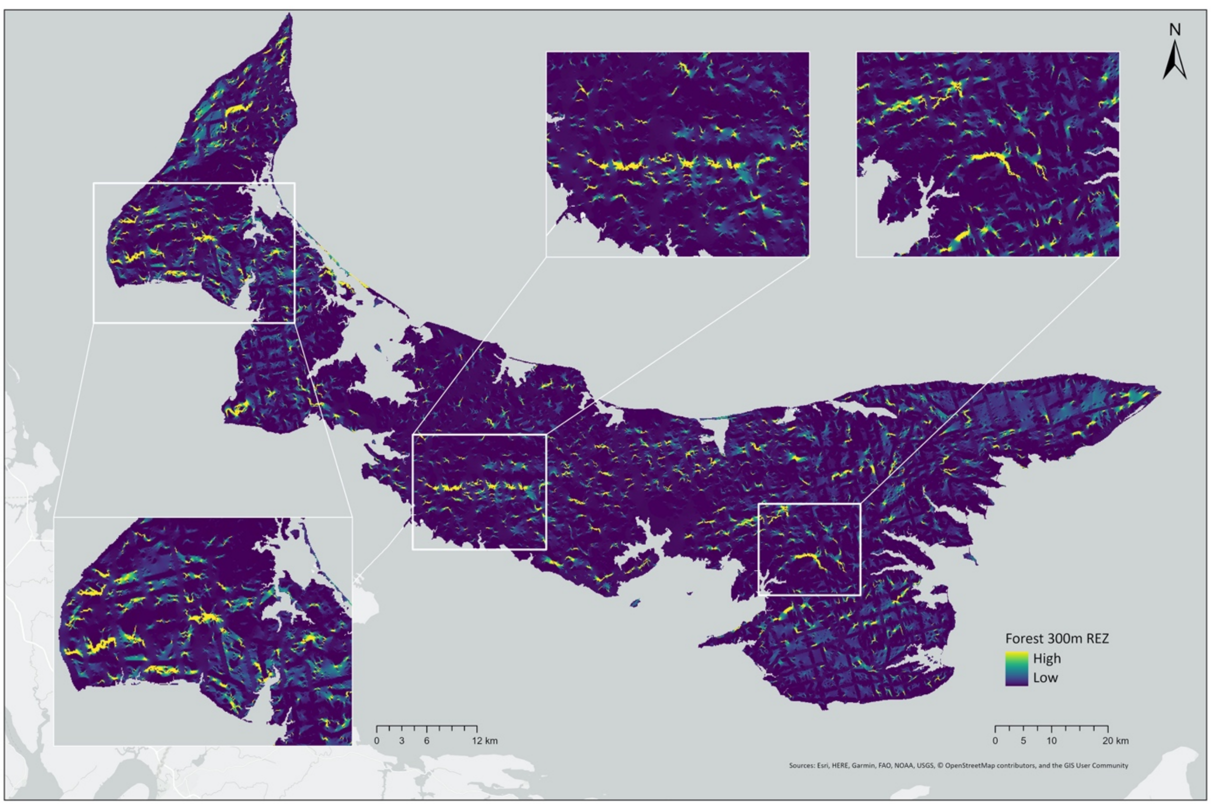


APPENDIX VI: Circuitscape






N
Forest Classification
High
Low
0 3 6 12 km
0 5 10 20 km
Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community


N
Forest 300m REZ
High
Low
0 3 6 12 km
0 5 10 20 km
Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community