CREATING TALLGRASS PRAIRIE CORRIDORS FOR SPECIES AT RISK USING GEOGRAPHIC INFORMATION SYSTEMS IN NORFOLK COUNTY, ON

Aditi Gupta

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ABSTRACT

Anthropological land use in Norfolk County, Southwestern Ontario, has resulted in fragmentation of tallgrass prairie habitats which several species at risk are dependent upon. This research aims to create connectivity between fragmented habitats through the development of tallgrass prairie ecological corridors in Norfolk County. Using Geographic Information Systems-based Multi-Criteria Evaluation, attribute layers were weighted according to their relative importance and combined. Five models were developed to represent the varying habitat requirements for ten at-risk species. The most suitable values in each model were combined to create one habitat index map illustrating the best suitability for all species considered in the study. The habitat index map forms the cost surface used to perform a least-cost path analysis which illustrates the optimal corridor connecting core areas. Ideal lands for acquisition for corridor development are low cost, distant from urban built up areas, existing in natural landscapes, and connected to large reserve patches.

DEDICATION

This thesis is dedicated to my mother who has an unwavering belief in my abilities and understood my true passions before I could even begin to comprehend them.

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First and foremost, I extend my most sincere gratitude to my supervisor, Dr.Justin Podur for his years of support and guidance. Thank you for helping me explore my interests while developing my skills and abilities. Throughout this process and the years prior, you have challenged, motivated and encouraged me. I am truly grateful for all that you have done. Thank you Dr. Sheila Colla for reading and advising me throughout. You have been a great source of knowledge from the conception of this project and through its completion. Thank you Dr. Gail Fraser for providing your insights but more importantly, thank you for inspiring me to pursue the study of conservation and ecology. I will treasure the experiences and lessons you have taught me forever.

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CHAPTER ONE: INTRODUCTION

1.1 Habitat Fragmentation and Species Decline

Habitat fragmentation breaks natural areas into smaller sections which can cause loss of ecosystem processes and available habitat for terrestrial species. Fragmentation can reduce core habitat sizes, increase species isolation and decrease patch sizes which greatly influences species' ability to occupy an area (Fahrig, 2003). Fragmentation increases edge effects which can alter microclimates, increase wind shear forces and negatively affect existing plant and animal communities (Fahrig, 2002; Fahrig, 2003; Laurence, 2008). Anthropogenic activities (including urbanization and agricultural intensification) are the major cause of habitat fragmentation and is the main threat to species' survival following climate change (Abrol, 2012; Riley et al., 2003). Species face extinction due to spatial and temporal variations of resources (Auffret, Plue & Cousins,2015) which are increasingly impacted by urban growth. Some terrestrial species are at risk of extinction due to the loss of habitat connectivity, which limits species' movement through or between communities, (Auffret, Plue & Cousins, 2015; Van Geert, Triest, & Van Rossum, 2014) and minimizes accessibility to resources.

Occurring near highways, roads and towns as populations grow, habitat fragmentation is a highly organized and structured human process (Laurence, 2008). This study is focused on Norfolk County, in Southwestern Ontario. Norfolk is fragmenting its vast natural spaces for human use, settlement and farming as the municipalities' population increases (NCC, 2016; Irvine, n.d.). Norfolk County is 1,607.60 km^2 and contains conservation sites, provincial parks and farmlands rowing a variety of crops. This region holds a great diversity of ecosystems, including Great Lakes marshes, Carolinian forests and tallgrass prairie.

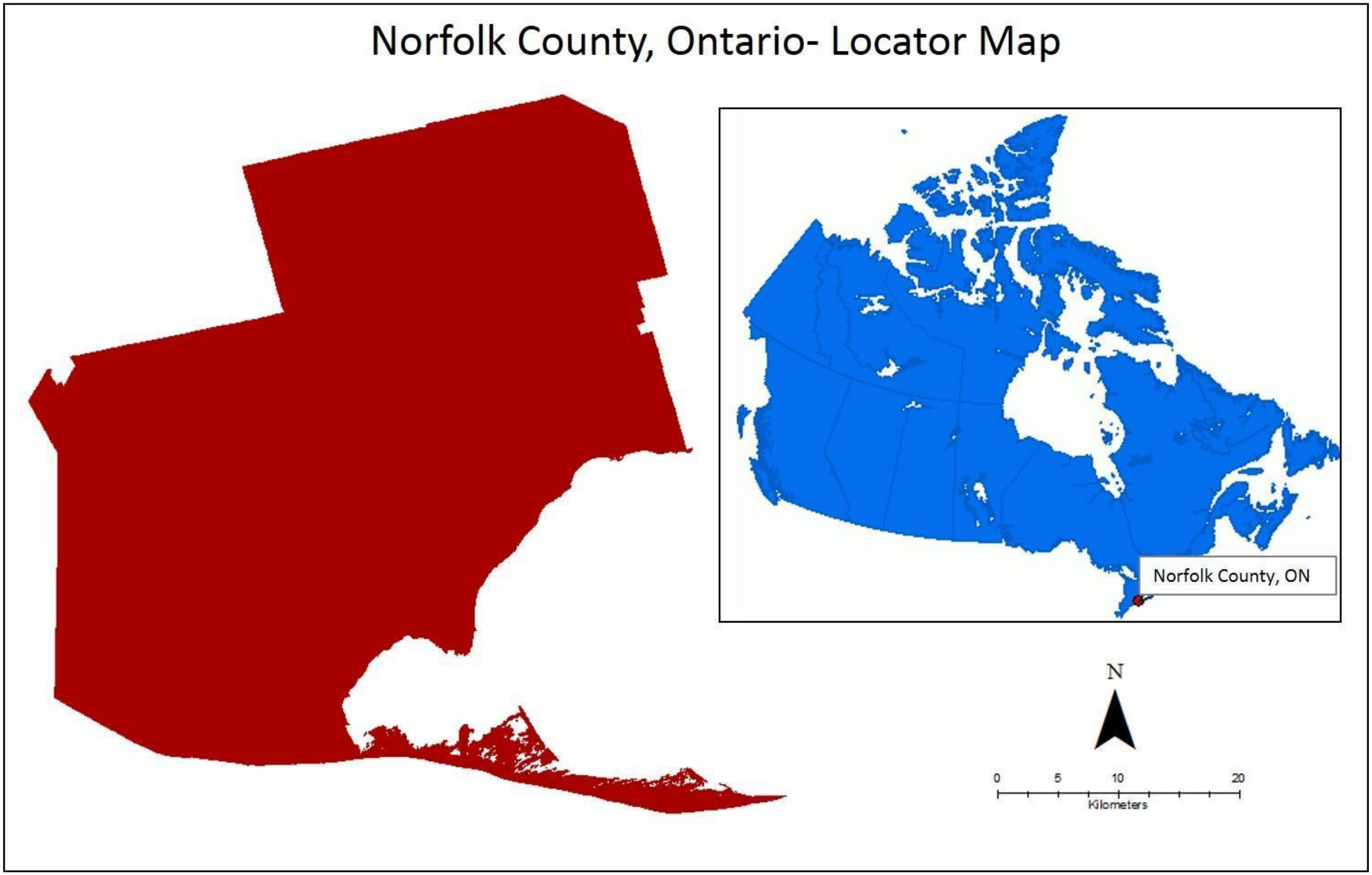


Figure 1. Map of Norfolk County-Locator Map

1.2 The Loss and Importance of Tallgrass Prairie Habitats

Tallgrass prairie functions as transition areas or ecotones. Prairie ecotones contain grasslands, shrub lands, and forested spaces (Loehle, Li & Sundell, 1996; Nelson 2013). The variety of vegetation promotes a diversity of floral and faunal populations (NCC 2016). Many species can use grasslands as dispersal corridors to safely travel through and reach patches of suitable habitat, i.e. shrubland and forest (MPPWG, 2011). Additionally, grasslands are also distinct habitats required by several species. The maintenance of tallgrass prairie requires natural disturbances (including fire, drought, and herbivores) which halt succession and ensure that grasses will continuously grow (MPPWG, 2011; Nelson, 2013).

Tallgrass prairie ecosystems host a great diversity of plants within Canada (NCC, 2016) and are attractive to a variety of wildlife including grassland songbirds, pheasants, pollinators, reptiles and more (University of Northern Iowa, 2018). The diversity of flora and fauna within prairie habitats provides an array of ecosystem services including but not limited to: prairie plants efficiently sequester carbon (University of Northern Iowa, 2018, USDA, 2018), dense prairie roots outcompete invading weeds and provide "soil anchors", protecting precious top soil from the effects of erosion (University of Northern Iowa, 2018, USDA, 2018), and prairie species provide pollination services (University of Northern Iowa, 2018, USDA, 2018) which result in billions of dollars worth of crop production annually (USDA, 2018). The prairie ecosystem once expanded throughout the American Midwest till Texas and throughout smaller portions of southern central Canada (NCC, 2016). Unfortunately, it is significantly smaller in size and occurrence today (see below, *Figure 2* and *Figure 3*).

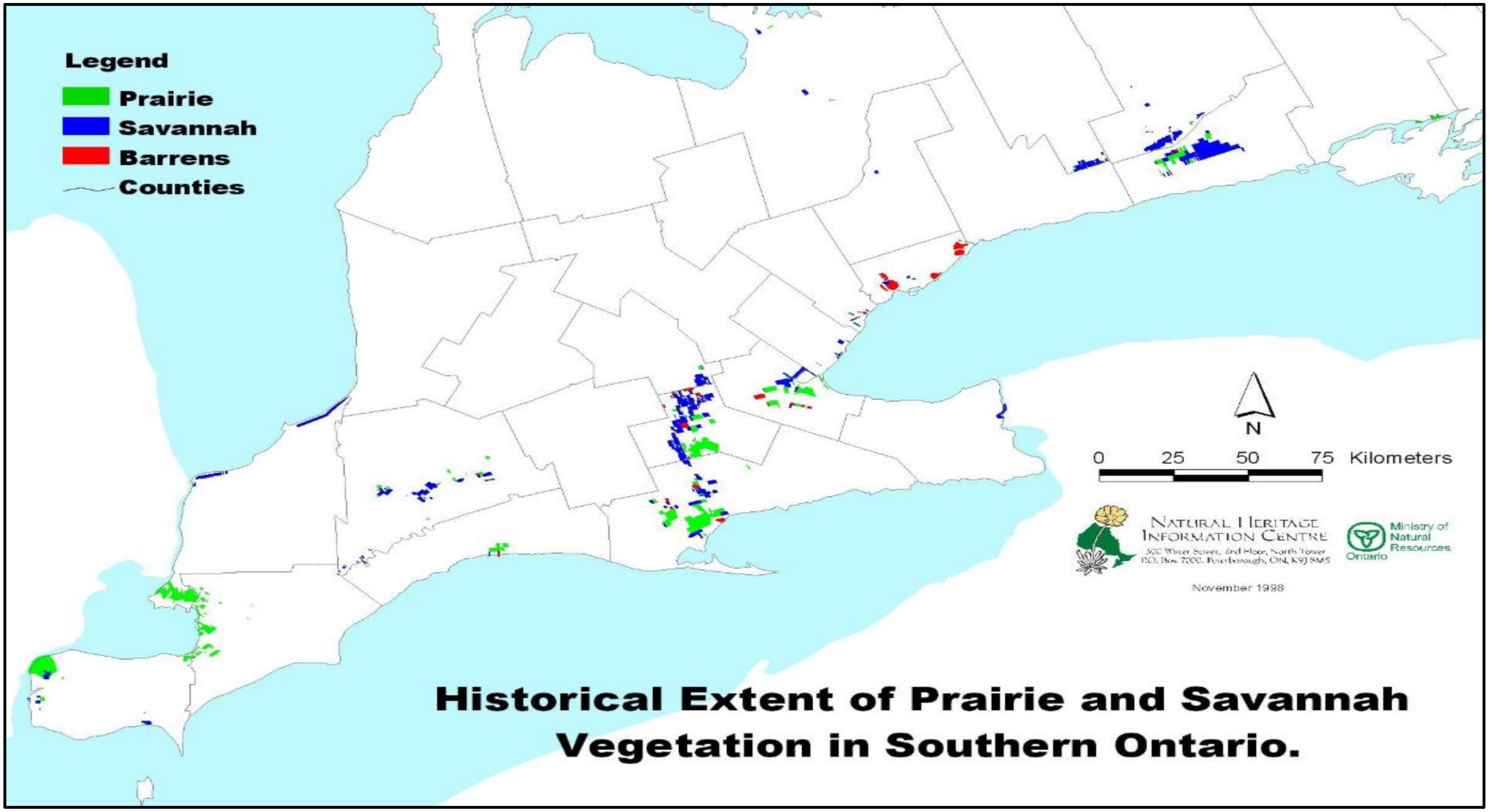
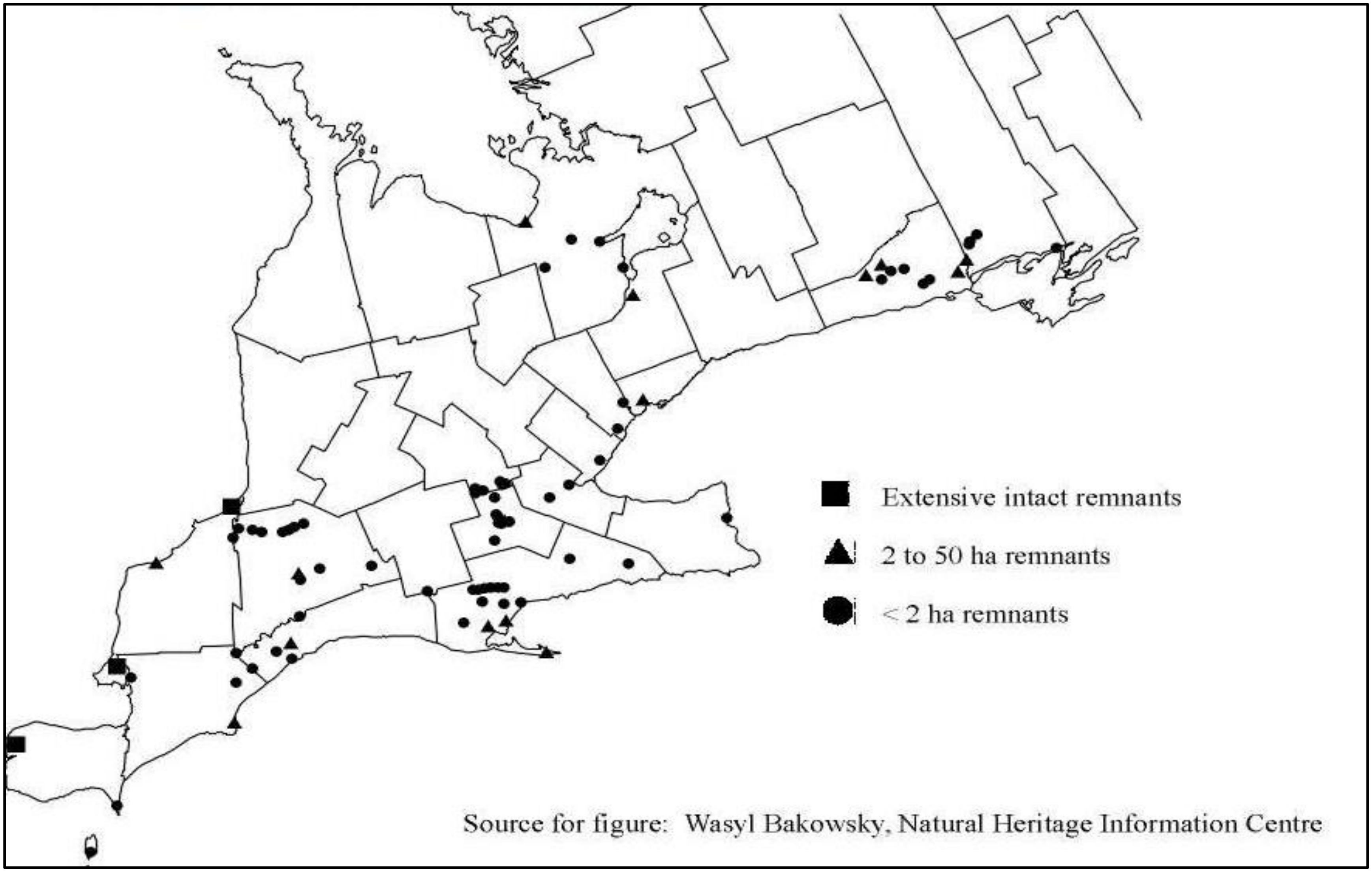


Figure 2. Estimated minimum historical extent of tallgrass prairie and savanna in southern Ontario. Adapted from, Tallgrass Communities of Southern Ontario A Recovery Plan by Rodger, L. and interpreted by Woodliffe, A. (1998). Retrieved from http://tallgrassontario.org/Publications/TallgrassRecoveryPlan.pdf. Adapted with permission.*

Historical extent of prairie and savanna in Southern Ontario. *This map provides a rough estimate from incomplete records. Other sources (e.g., see Lumsden 1966) suggest tallgrass communities may have occurred more extensively. Survey record mapping produced by Wasyl Bakowsky, Natural Heritage Information Centre. Survey mapping south of Rice Lake from Catling, et al. 1992. Source for "historic written description": taken from various sources.*



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1.2 Objectives

Studies have considered global declines of species (Klein et al., 2007) and the importance of tallgrass prairie habitats (Paiero, Marshall, Pratt & Buck, 2010); however, few studies have provided resolutions for species decline and prairie fragmentation. My project seeks to:

1. Create connectivity between fragmented habitats through the development of tallgrass prairie corridors. Connectivity will improve survival of species requiring these protected developments to forage and nest within.
2. Facilitate movement and geographic expansion. Species will be able to travel between core areas to feed, reproduce and mate (Klein et al., 2007; Semlitsch & Bodie, 2003).
3. Provide Norfolk County and The Nature Conservancy of Canada (NCC), a Canadian private not-for-profit environmental organization, information for future ecological planning. The NCC works through procurement of land, thus providing the possibility of creating corridors in partnership with Norfolk County landowners.
4. Develop a model for studies with similar criteria so that ecological planning and conservation management can be implemented in other locations.

CHAPTER TWO: LITERATURE REVIEW

The proposed study traverses three bodies of literature: habitat fragmentation, core areas, and corridor connectivity. **1)** Habitat fragmentation identifies the causes of habitat loss where areas are continuously decreased and isolated, negatively impacting wildlife species. **2)** Core areas provide a contrast to fragmentation; considering undisturbed and intact land **3)** Corridors offer insight on the importance of connectivity between core and fragmented patch networks (Singleton, 2013) to overcome issues of species dispersal, survival, and extinction.

2.1 Fragmentation

Species are a vital component of ecosystem functioning; however, destruction and fragmentation of habitats threaten their existence (Potts et al., 2010). The most significant driver of habitat depletion is human land-use change (Goulson, Lye, & Darvill, 2008; Steffan-Dewenter, Münzenberg, Bürger, Thies, & Tscharntke, 2002). Land alterations decreasing natural habitats to expand farmland are the growing trend within Norfolk County. According to Laurence (2008, p.1734), "farmers preferentially clear land in flatter lowland areas and in areas with productive, well-drained soils" characteristic of Norfolk County. Land use management of farmlands determine the amount of fertilizer and pesticide which alter soil characteristics and influence floral compositions in the cultivated and surrounding landscapes (Van Geert, Triest & Van Rossum, 2014). This affects fauna highly dependent on the existing natural spaces for food, reproduction, and stopovers through their migratory routes (Solymár, Kanter, & May, 2008). As the fertile land in Norfolk is transformed to suit the social and economic needs of the population, species habitats are destroyed. Species unable to adapt to the spatial and temporal variations of resources face extinction.

Specialist species which require specific environmental conditions for shelter and food are being impacted more severely by habitat fragmentation than their generalist counterparts (Potts et al., 2010). For instance, the Karner Blue butterfly (*Lycaeides melissa samuelis*) has been extirpated due to the destruction of their singular food source, Wild Lupine (*Lupinus perennis*) (Andow et al., 1994). Wild Lupine is a plant which usually grows in prairie habitats because the sandy soils and open, sunny spaces are optimal for its growth (CVC, 2013). Cultivation of prairie habitats reduces plant variety and wild plant growth necessary for several species. Therefore, increasing importance should be placed on the preservation of resources and core habitats.

2.2 Core Habitats

Core habitats, contain the most important requirements for the survival of species and when fragmented, can limit gene flow and even lead to local extinctions (Haag and Ebert, 2004). Core habitats and bordering habitats are positively correlated with species abundance and species heterogeneity (Cusser, Neff & Jha, 2016). Abundance and composition of all wildlife will be improved through the development of tallgrass prairie corridors. Corridors can provide movement between patches and act as essential core habitats necessary for the several species in this study as well as facilitate the movement of larger species at-risk like the Spiny Soft Shelled Turtle and the American Badger. Tallgrass prairie corridors will serve the dual purpose of acting as core habitats as well as passages leading to other core areas such as Carolinian forests, Great Lake marshes and larger patches of tallgrass prairie.

In an increasingly altered and fragmented landscape such as Norfolk County, importance must be placed on connecting core habitats to facilitate the movement of species. It is necessary to define and protect core habitats as they are the areas used for breeding, nursing and feeding of species (Semlitsch & Bodie, 2003). The core habitats considered in this study are those which are currently delineated as conservation areas managed by the NCC and other governing bodies. The aim is to increase connectivity between high quality habitat patches which will improve gene flow, increase the ability to fill niche requirements and improve viability of species.

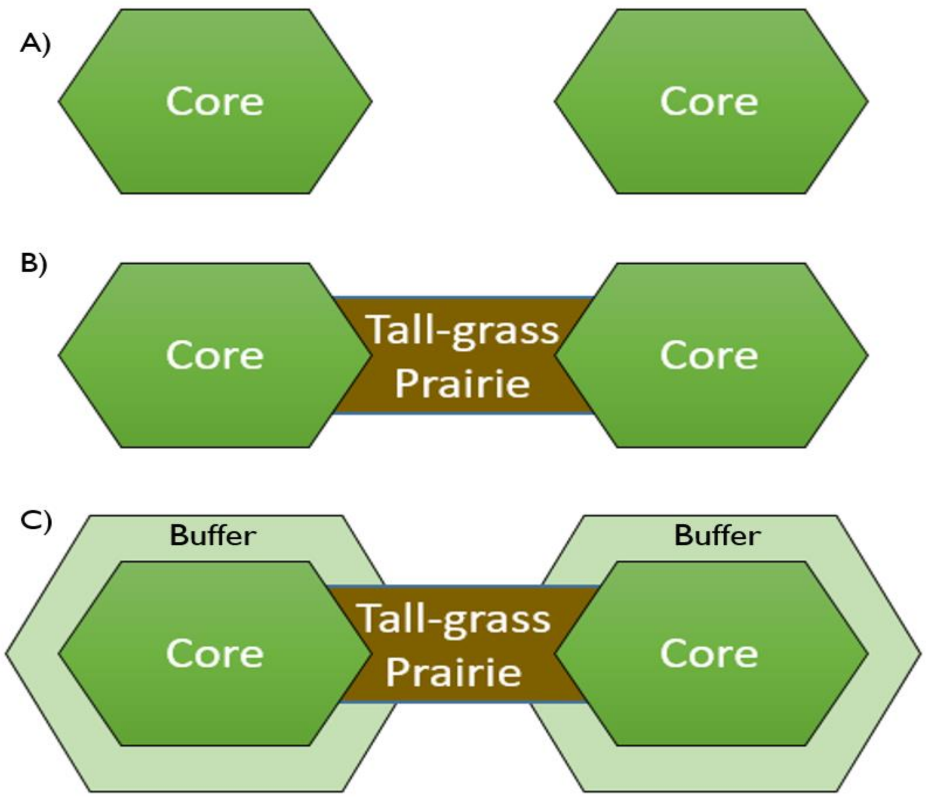


Figure 4. Diagram of connectivity between fragmented core habitats. A) Core areas without a connecting passage, B) Species dispersal is improved by the placement of a tallgrass prairie corridor, C) Protective measures are added to avert negative human and environmental influences

2.3 Connectivity

Species require the ability to move for food, shelter, mating and seasonal change (Klein et al., 2007). While fragmentation rapidly increases in the face of human expansion, ecological corridors are recommended to maintain connectivity between preserved landscapes (Craighead and Vyse, 1996; Walker & Craighead, 1997) and are shown to reduce rates of species loss, increase colonization and ameliorate the effects of anthropogenic disturbance (Collinge, 2000).

Nevertheless, the effectiveness of corridors have been debated since few empirical studies have been able to validate the claim that ecological corridors facilitate movement, increase diversity or reduce extinction (Simberloff, 1992). The debate has focused upon whether continuous linear strips of habitat improve the abundance and diversity of isolated populations (Simberloff 1992; Bennett, 2003). However, corridors are spaces, which promote continuity of ecological process and a variety of movements such as foraging and stepping-stones in habitat mosaics (Bennett, 2003). For instance, within this study, the sporadic movements of butterflies looking for habitable patches are not complemented by the linear structure of the prairie corridor; but, resources within the corridor provide suitable habitats for butterfly larvae (Schultz, 2008). Additionally, the corridor acts as a stepping-stone between patches and other patch networks (Schultz, 2008).

Realistically, communities and ecological processes are more likely to be maintained in interconnected landscapes than in habitats, which are dispersed and fragmented (Bennett, 2003). Promoting habitat linkages between reserves and suitable habitats encourage the long-term viability of protected spaces; the ability of connected spaces to support and benefit wildlife species must be observed over lengthy periods to assess their feasibility and function (Bennett, 2003). Species at risk selected for this study are relatively small (<1kg) and it has been confirmed that even narrow corridors of approximately 3m widths can provide important conservation value (de Lima and Gascon, 1999; Nhijhuis, 2017; CWF, 2018) to support breeding, movement, forage and habitat for animals of this size (de Lima and Gascon, 1999).

It is reasonable to assume that natural landscapes will be altered to suit the needs of growing populations in Norfolk. The effects of fragmentation are less severe than those of habitat loss since connectivity between fragmented habitats can overcome the potential consequences fragmentation creates (Auffret, Plue & Cousins, 2015; Lienert, 2004). The creation of ecological corridors acknowledges human requirements for space and development while ideally reducing the effects of habitat destruction and loss.

CHAPTER THREE: METHODOLOGY

Multi Criteria Evaluation Methods (MCE) consider a variety of attributes to select land for specific purposes (Eastman, 1999). MCE is extremely useful when studying natural habitats which cannot be explained in binary terms of "suitable" and "unsuitable" land. While Boolean logic requires that all conditions under consideration be met completely, MCE avoids exclusionary criteria or constraints (Gemitzi, Tsihrintzis, Petalas, 2010). Binary understandings of suitability provide risk-averse and cautious strategies for conservative planning systems (Gemitzi, Tsihrintzis, Petalas, 2010) but do not deliver realistic approaches to conservation. MCE allows one to "express varying degrees of suitability for the decision under consideration" (Eastman, 1999, p.495) so that all factors can be measured for selecting ideal landscapes. MCE uses continuous and non-exclusionary criteria which can be high risk since each factor is not equally important in the decision-making process when considering habitat suitability models. To adjust for the variability and importance, the data is standardized to a common numeric range and then combined using a weighted average (Gemitzi, Tsihrintzis, Petals, 2010; Carver, Comber, McMorran & Nutter, 2012). A ranking system for factors of importance in the habitat suitability model has been developed with the knowledge and opinions of experts in fields considering prairie habitats and wildlife.

Using geographic information systems' (GIS) based multi criteria evaluation (MCE) methods, five habitat suitability models were created separately to meet the requirements of the individual species for which the model was intended (Figure 22, 23, 24, 25, 26). The five models were then combined to create the *Master Habitat Suitability Map* (*Figure 36*) which forms a portion of the cost surface that is used to find the optimal corridor connecting adjacent core areas (Shilling & Girvetz, 2006). The corridor created after combining the five models and a cost surface raster, is intended to be conducive to the movement and habitation of all ten species throughout each of the five models.

3.1 Data Collection

Pre-existing land cover data from the Norfolk County Planning Department, the Ministry of Natural Resources, the NCC and the Ontario Open Data Catalogue were collected to be used in the MCE. Vector data regarding Norfolk County road ways, county boundaries and community boundaries were provided by Richard Roberts of the Norfolk County Planning Department. Vector layers depicting significant natural areas, woodlands and wetlands in Norfolk County were provided by the Ministry of Natural Resources. Images of areas governed by the NCC and other conservation authorities were provided by the NCC. Those images were then used to manually digitize and create a vector layer identifying areas currently conserved by the NCC and various other organizations throughout Norfolk County.

Lastly, the Ontario Land Cover Compilation (OLCC) was attained through the Ontario Open Data Catalogue. The OLCC is a single layer which comprises "three separate land cover databases: Far North Land Cover v1.4, Southern Ontario Land Resource Information System (SOLRIS) v1.2, and the Provincial Land Cover 2000 Edition" (Radford, 2016) (*Figure 5*). While there are a variety of layers ranging in date, coordinate system and pixel resolution, the OLCC was published on January 21st 2016, has been standardized to have a pixel resolution of 15 metres, and a coordinate system of Ontario Lambert Conformal Conic (Radford, 2016).

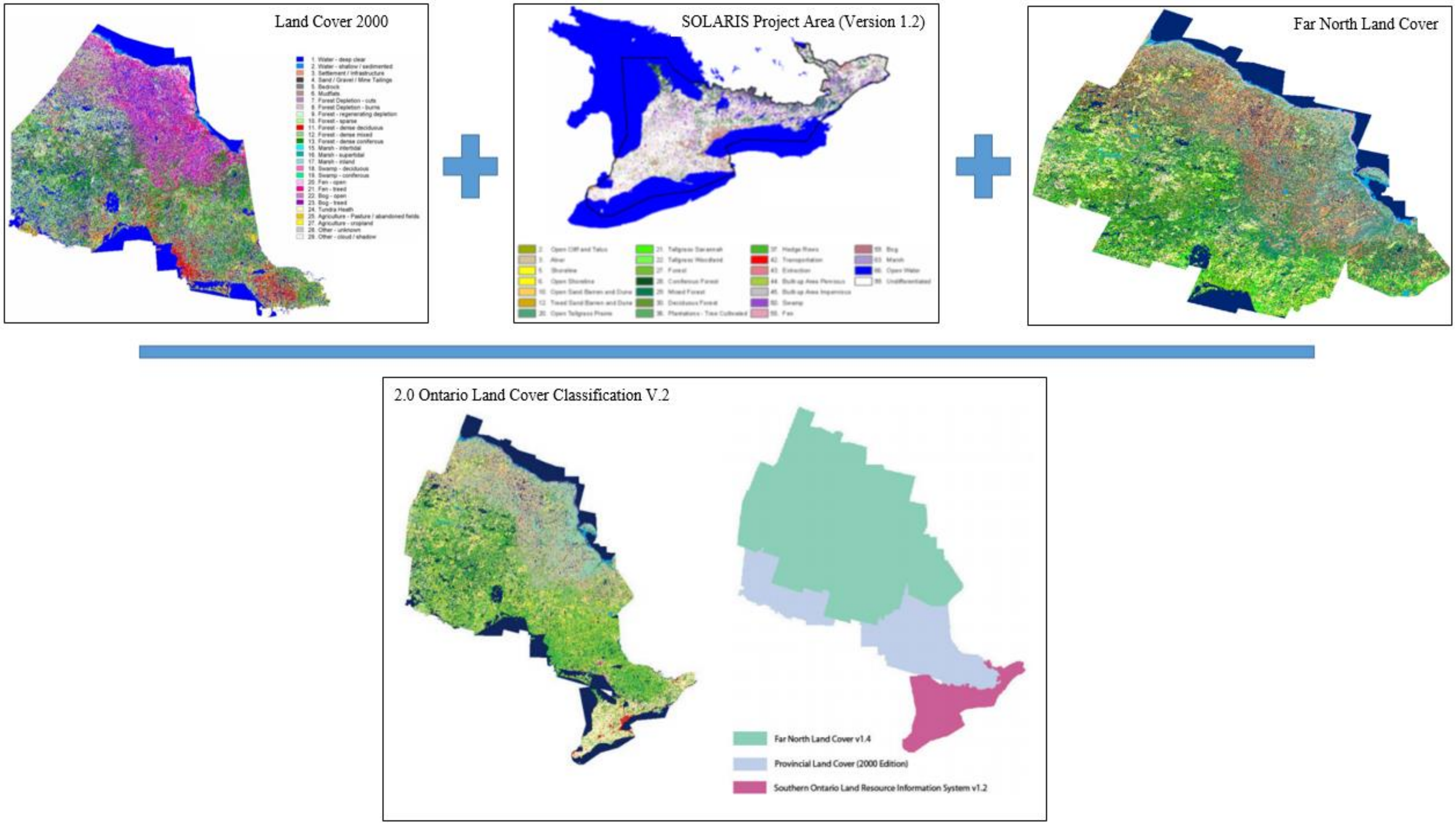


Figure 5. The development of the Ontario Land Cover Compilation (OLCC). Adapted from "Ontario Land Cover Compilation Data Specifications Version 2.0" by The Ontario Ministry of Natural Resources and Forestry. (2014). Adapted with permission.

3.2 Data Preparation

3.2.1 Land Type Reclassification

The OLCC was clipped to the Norfolk County Boundary perimeter so that any data outside the scope of study was removed. Within the clipped OLCC layer, 18 classes depicting various land cover types remained. To further consolidate these classes into more easily managed groupings, the 18 land cover types were reclassified so that 11 classes remained. *Figure 6* illustrates the reclassification of the 18 classes and *Figure 7* and *Figure 8* illustrate the transformation of the layer.

Figure 6. 18 original classes in the OLCC reclassified into 11 land categories

Original Attributes			Reclassified Attributes		
Value	Pixel Count	Attribute Label	Value	Pixel Count	Attribute Label
1	27,559	Clear Open Water	1	27,559	Water
3	7,042	Shoreline	3	7,042	Shoreline
5	314,722	Marsh	5	912,446	Marsh/Swamp/Bog
6	597,653	Swamp	13	621,510	Deciduous Treed
8	71	Bog	14	459,700	Mixed Treed
12	57,244	Treed Upland	15	14,805	Coniferous Treed
13	621,510	Deciduous Treed	17	79,324	Hedge Rows
14	331,480	Mixed Treed	21	36,692	Sand/Dune/Gravel/Mine Tailing
15	14,805	Coniferous Treed	22	2,532	Open Tallgrass/Tallgrass Savannah
16	70,976	Plantations - Treed Cultivated	24	3,717	Tallgrass Woodland
17	79,324	Hedge Rows	27	388,685	Community Infrastructure
21	28,366	Sand Barren and Dune	28	4,757,065	Agriculture and Undiffrentiated
22	1,142	Open Tallgrass Prairie			
23	1,390	Tallgrass Savannah			
24	3,717	Tallgrass Woodland			
25	8,326	Sand/ Gravel/ Mine Tailings			
27	388,685	Community Infrastructure			
28	4,757,065	Agriculture and Undiffrentiated			
Total	7,311,077		Total	7,311,077	

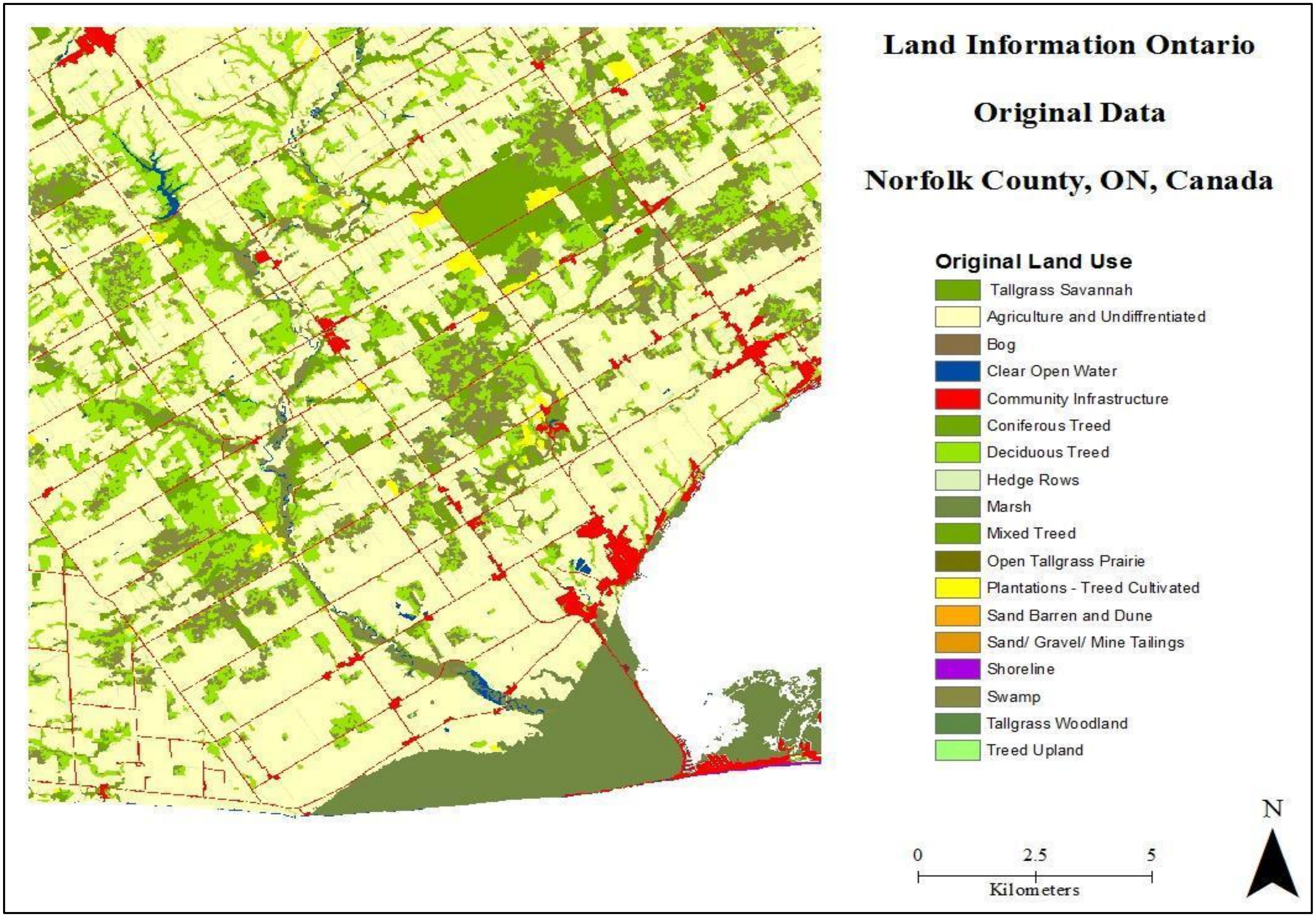


Figure 7. Map illustrating 18 original land type categories in the OLCC

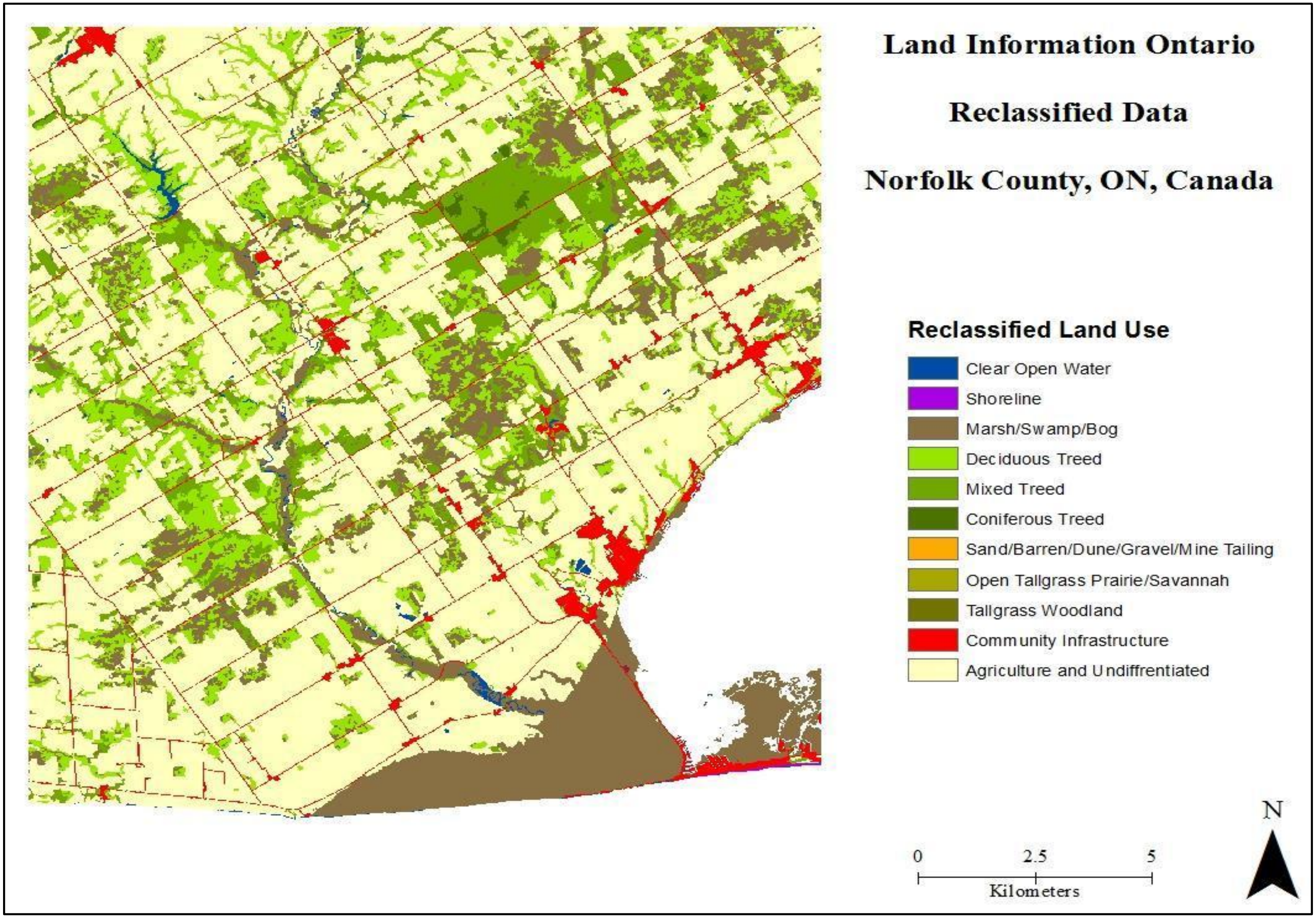


Figure 8. Map illustrating the reclassified OLCC to consolidate 18 land type categories into 11.

3.2.2 Buffer Zone

Buffer zones using the "Euclidean Distance Tool" found within the "Spatial Analyst" extension in the Arc Toolbox were used to create buffer zones around *conservancy properties, significant natural areas, roads, and community boundaries* layers. This resulted in four Euclidean distance output raster layers which measured 30m distance buffers, two pixels wide, away from the source cell, i.e. *conservancy properties*, *natural areas*, *roads*, and *community boundaries* layers. Each output layer identified buffer distances from 0-270m and greater using 30m intervals. It was crucial that habitats be built away from the source features *community boundaries* and *roads* to avoid the effects of anthropogenic activities. Buffer distances further away were favoured and selected over those directly on or adjacent to these features. Conversely, close proximity to source features *conservancy property*, and *natural areas* were preferred and selected since nearby protected spaces would improve the movement and habitat requirements of the varying species.

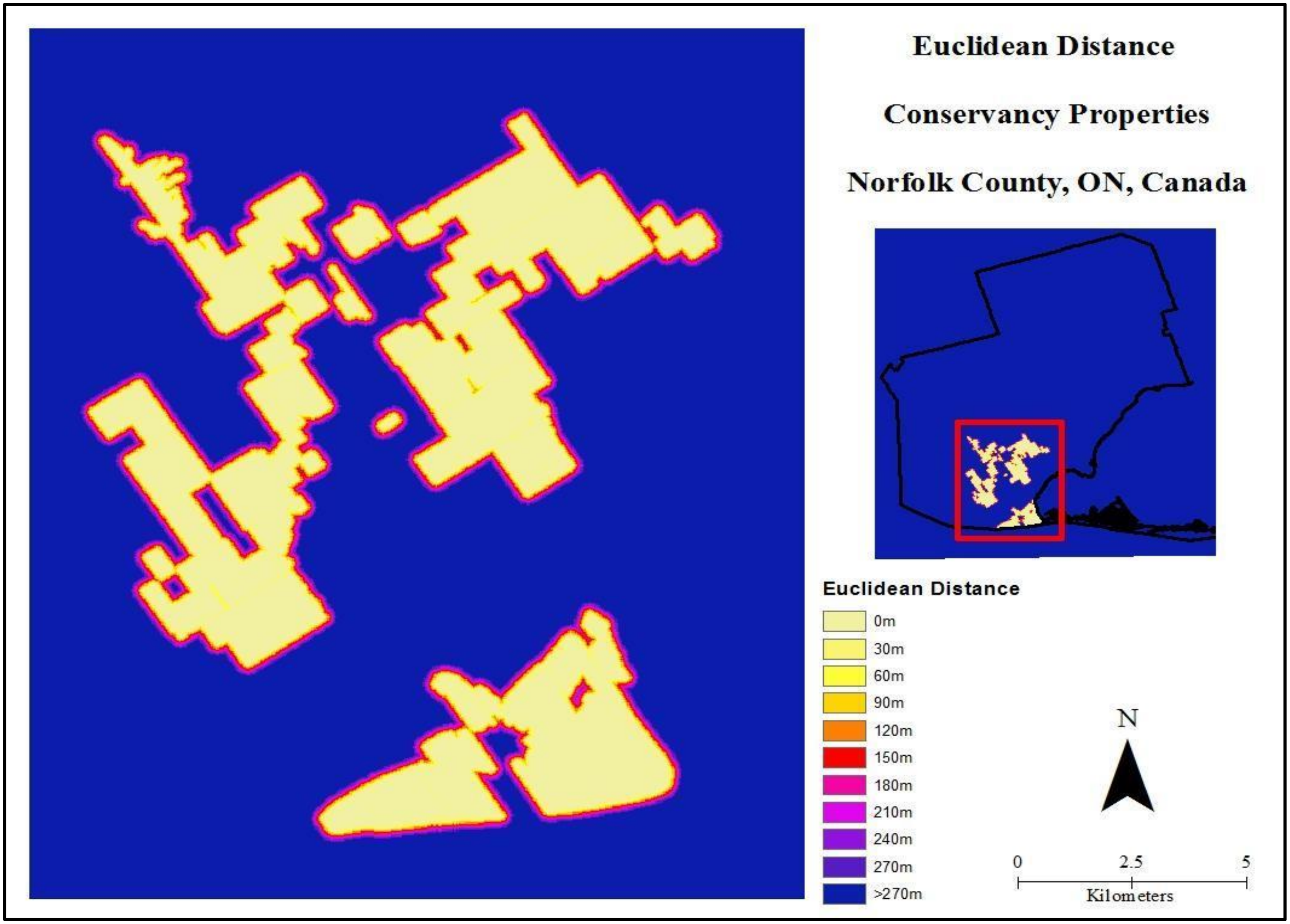


Figure 9. Map illustrating Euclidean distance at 30m intervals around existing conservancy properties.

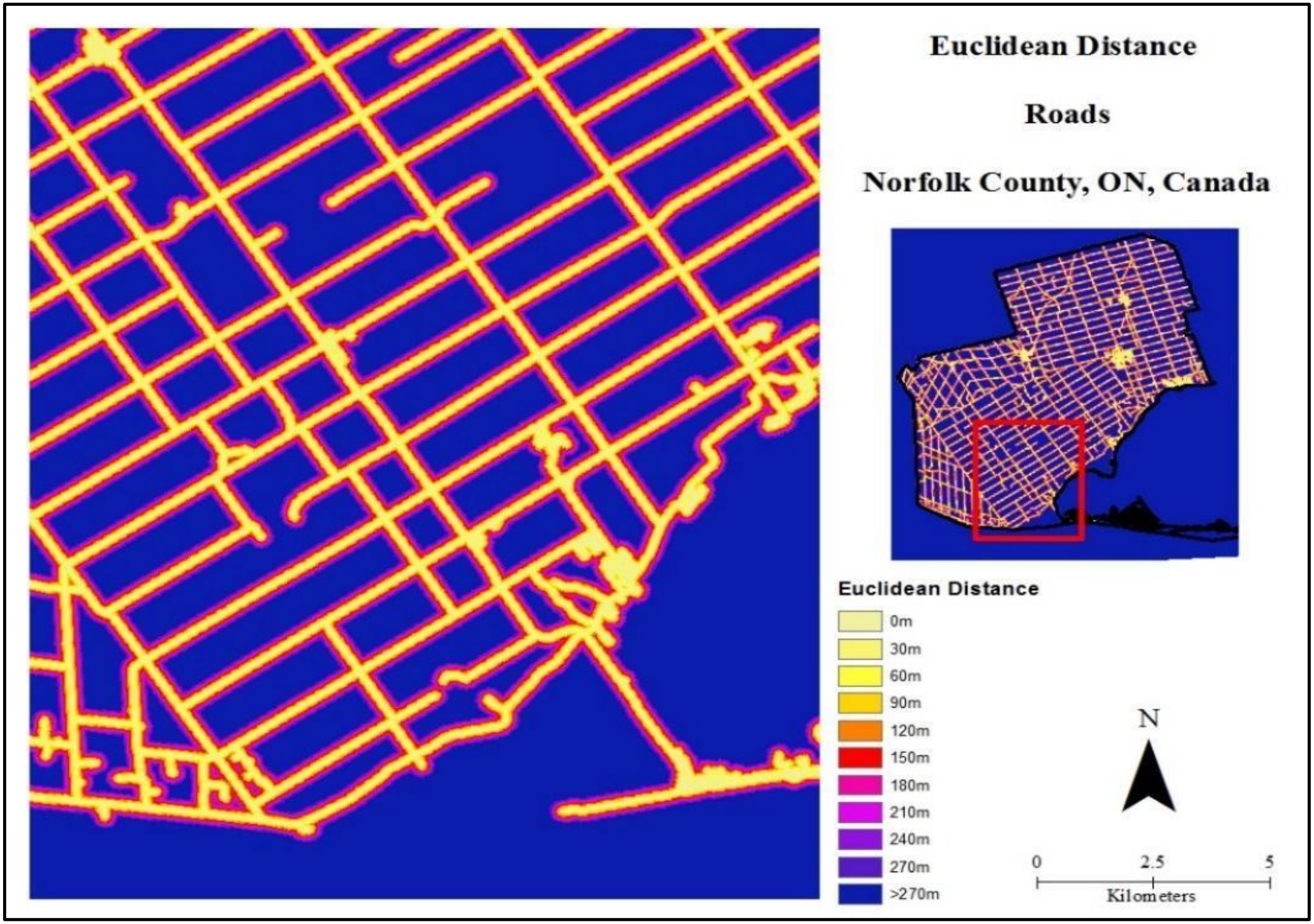


Figure 10. *Map illustrating Euclidean distance at 30m intervals around roads.*

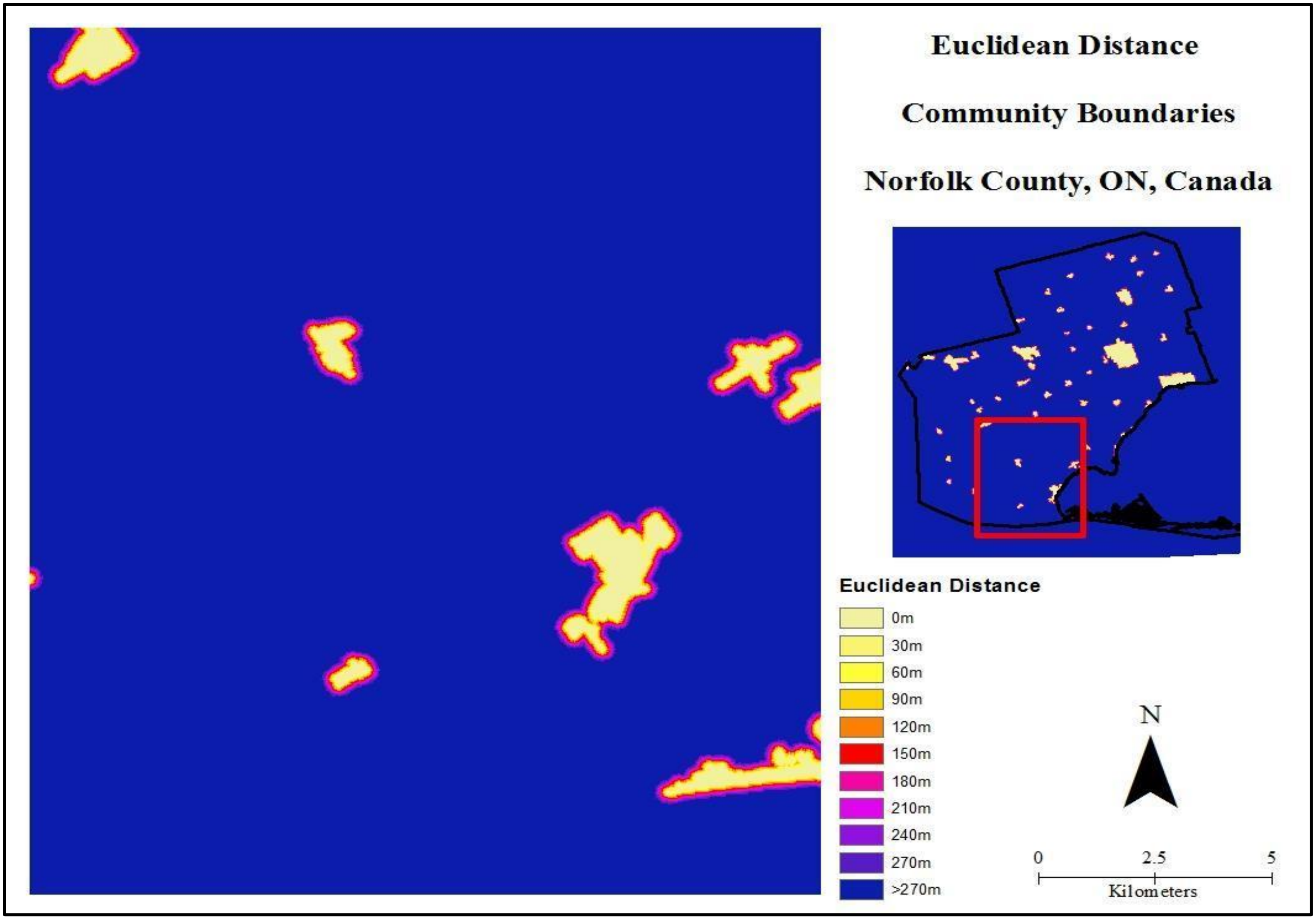


Figure 11. Map illustrating Euclidean distance at 30m intervals around community boundaries.

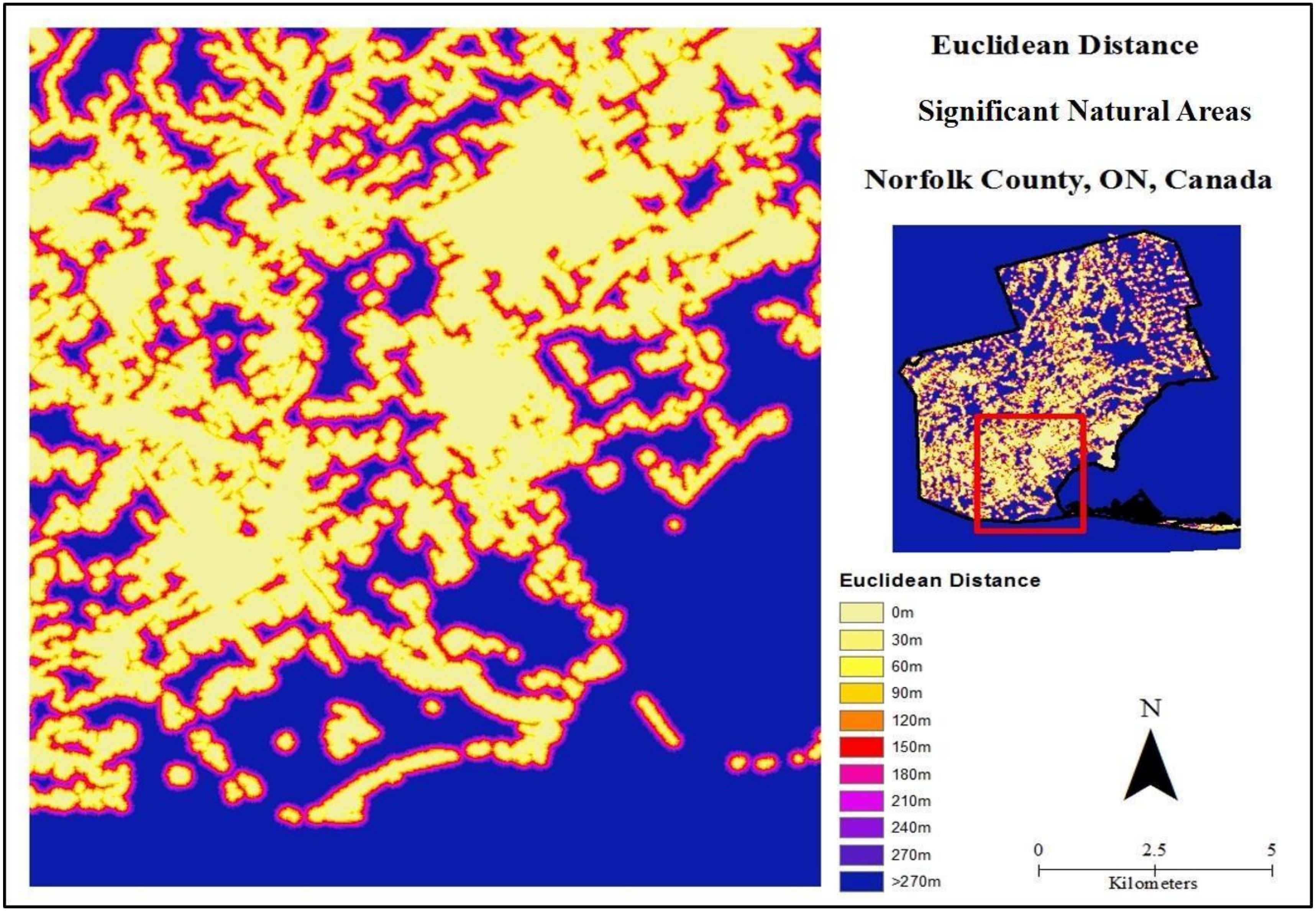


Figure 12. Map illustrating Euclidean distance at 30m intervals around Significant Natural Areas.

3.3 Model Development

3.3.1 Attribute Ranking and Weighted Overlay in ArcGIS' Modeler

Each attribute is not equally important in the decision-making process when considering habitat suitability models. A ranking system for factors of importance in the habitat suitability model was developed using the knowledge and opinions of experts in fields considering prairie habitats and the selected species at risk.

Reclassification Criteria for Six Attribute Layers

1. **Land Cover Layer**- This layer considers the categories of land identified in Norfolk County. Depending on the land type, categories will be weighted to meet the criteria for suitability based on the habitat requirements for each at-risk species. For example, the tallgrass prairie land type would be considered more important for wildlife than urban built up areas. Tallgrass prairie would therefore be weighted a higher value whereas urban/built up area would be weighted a value of 0 to characterize it as the least suitable area for corridor development. Alternatively, deciduous and mixed-treed woodlands would be most important for specific at-risk bird species within this study and be weighted a higher value than tallgrass prairie.
2. **Distance from Roads Layer-** Roads promote fragmentation and have been known to cause biodiversity loss and ecosystems degradation (Freudenerger, et al., 2013). For the purposes of conservation planning, it is important to select sites further away from roads to negate its effects. Using the Euclidean buffer tool, buffer distances at 30m intervals were applied to the roads vector file. Buffer distances closer to the roads were classified less suitable and the distances further away were classified as more suitable.

3. **Distance from Community Boundaries Layer-** Urban developments have severe and lasting effects on habitats and are known to cause local extinctions which can be detrimental to native flora and fauna (Shochat, et al., 2006). Furthermore, urban developments often expand through time and threaten more ecosystems as they grow. Norfolk County consists currently of a small rural human population, however; beautiful scenic land and waterfront properties make this small town an enticing area for living. As urban populations in neighbouring cities grow, the prospect of urban growth increases in Norfolk. To minimize the negative effects of urban growth on conservation and restoration habitats, buffer distances of 30m intervals were applied to the urban areas vector file. Buffers closer to existing urban areas were classified less suitable than areas further away.
4. **Proximity to Natural Areas Layer-** Proximity to existing natural area is an important function of conservation planning. Existing spaces have better developed resources and biodiversity than areas which are newly restored. Tallgrass prairie restoration sites bordering natural areas can become extensions of functioning core areas. Through time, successional development will lead to tallgrass woodlands and forests unless controlled burns are applied to sites. It is important to have a variety of natural land types near each other since many species require a diverse landscape and often reside in forest edges and transition zones. To account for these landscape characteristics and requirements, the *significant natural areas, significant woodlands* and *significant wetlands* layers provided by Norfolk County and the MNR were joined. Buffer distances of 30m intervals were applied to the newly combined "Natural Areas" vector layer. Buffers closer to existing

natural areas were classified as most suitable and areas further away were classified less suitable.

5. **Proximity to Protected Sites-** Locations which are closer to existing protected sites will be considered more suitable for habitat restoration and conservation. Conserving sporadic patches of land would be impractical since patches further away from one another and isolated are less likely to support a heterogeneous and highly abundant population of species (Woodley & Freedman, 1995). Populations and communities which are isolated, are less likely to disperse (Auffret, Plue & Cousins, 2015) and search for mates or resources. Existing protected sites would benefit from the addition of conserved land since this would result in the expansion of conserved and restored space.
6. **Land Cost Layer-** This layer concerns cost of the land in Norfolk County. Using data collected from various real estate websites, average cost of land per km^2 in Norfolk County was determined. Categories in the "Land Type Layer" were ranked least to most expensive. Land categories which are less expensive, are more suitable for corridor development and restoration. For example, agricultural land is less expensive than urban built up land and would therefore be more desirable. This layer was not used in the initial models creating habitat suitability indexes and was only incorporated during the least cost path model development.

Within ArcMap the "weighted overlay tool" was used to give each reclassified layer, a percentage of importance in the overall MCE. The "weighted overlay tool" combines data from several layers and coverts cell values to a standardized scale (Kahinda, Lillie, Taigbenu, Taute, Boroto, 2008). Percent influences, or "weights" can be assigned to each of these layers and then combined to create one map (Kahinda, Lillie, Taigbenu, Taute, Boroto, 2008). Percentages of importance are created by multiplying each map layer by its weight coefficient (Store & Jokimäki, 2003) to determine its influence in the overall MCE.

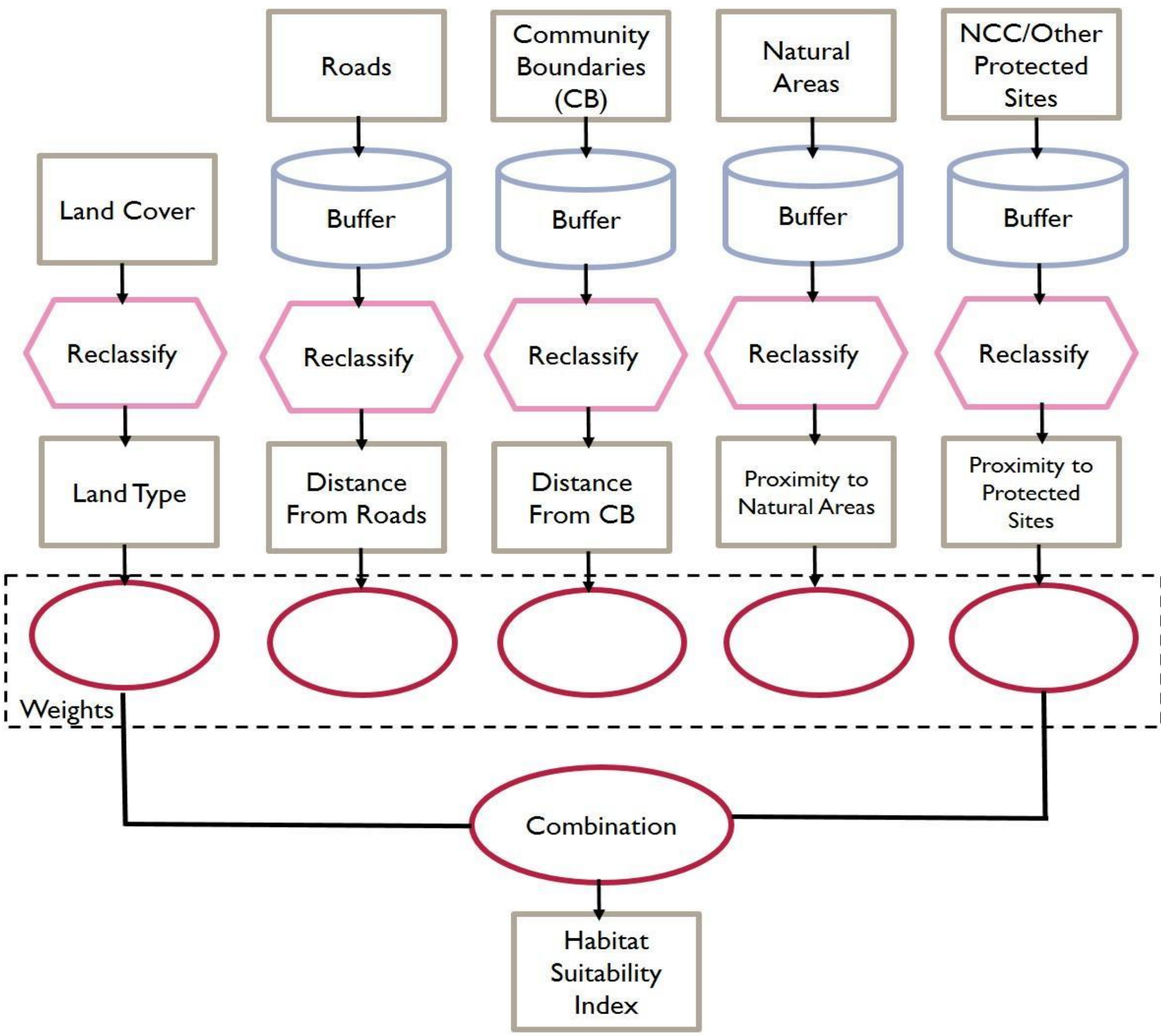


Figure 13. Flowchart of habitat suitability index (Models 1-5).

In Models 1-5, attributes were ordered 1-11 (least suitable to most suitable) depending on the criteria defined to meet the needs and requirements of each species (*Figure 14*). Layers *Distance from Roads, Proximity to Natural Areas,* and *Proximity to Protected Sites* (NCC/Other) were given the same layer weight, 19%, throughout all 5 models. The layer *Distance Away from Community Boundaries* was given a layer weight on 14%. It is not ideal for wildlife to reside within these areas but some species like *Bombus affinus*, and *Danaus plexippus* can make use of the resources within gardens, hedges and other sporadic vegetation found in neighbourhoods. The criteria for habitat suitability modeling throughout the 5 models did not vary within these 4 layers since reclassification requirements for species suitability did not differ.

The only variance in reclassification throughout each model was within the *Land Type* Layer. Species habitat suitability is species specific, and species are highly dependent on land cover types and the natural resources within those land types. The *Land Cover Type* Layer within all 5 models was weighted more heavily (28%) than the other layers due to its importance for species survival. *Figure 15* identifies which land cover types are most and least important for species within each of the five suitability models.

Figure 14. Reclassified ranking of buffers distances in layers throughout Models 1-5. Distance Away from Roads, Distance Away from Community Boundaries, Proximity to Natural Areas, Proximity to Protected Sites. Most Desirable (11) to least desirable (1).

	Layers				
Euclidean Distance	Distance Away from Roads	Distance Away from Community Boundaries	Proximity to Natural Areas	Proximity to Protected Sites	Land Cover Types
0m	1	1	11	11	*Variable by Model. Refer to Table 3 below.*
30m	2	2	10	10	
60m	3	3	9	9	
90m	4	4	8	8	
120m	5	5	7	7	
150m	6	6	6	6	
180m	7	7	5	5	
210m	8	8	4	4	
240m	9	9	3	3	
270m	10	10	2	2	
>270m	11	11	1	1	
	19%	14%	19%	19%	28%

Figure 15. The reclassification of the Land Cover Layer throughout Models 1-5. Ranking of Habitat type within each model varied

Land Types	Model 1 Reclass	Model 2 Reclass	Model 3 Reclass	Model 4 Reclass	Model 5 Reclass
	Setophaga cerulea (Cerulean Warbler) and *Empidonax virescens* (Acadian flycatcher)	*Bombus affinis* (Rusty patched bumblebee)	*Parkesia motacilla* (Louisiana waterthrush) and *Protonotaria citrea* (Prothonotary warbler)	*Dolichonyx oryzivorus* (Bobolink), *Sturnella magna* (Eastern meadowlark), and *Setophaga discolor* (Prairie warbler)	*Lycaeides melissa samuelis* (Karner blue) and *Danaus plexippus* (Monarch butterfly)
Water	6	1	8	1	1
Shoreline	5	2	7	3	4
Marsh/Swamp/Bog	7	6	6	4	3
Deciduous Treed	11	11	10	7	7
Mixed Treed	10	10	11	6	6
Coniferous Treed	8	3	9	5	5
Sand/Dune/Gravel/Mine/Tailing	2	4	2	8	8
Open Tallgrass/Tallgrass Savannah	4	8	4	11	11
Tallgrass Woodland	9	9	5	9	10
Community Infrastructure	1	5	1	2	2
Agriculture/Hedgerow	3	7	3	10	9

3.3.2 Species Selection-Species at Risk

Species of concern habituating South-western Ontario were selected for the study using the "Species at Risk Ontario" list. The at-risk species within this list were selected by the Committee on the Status of Species at Risk in Ontario (COSSARO) who identify species that may be at risk or declining. COSSARO uses the best available scientific information, including community knowledge and Aboriginal traditional knowledge, to determine which plants and animals are "at risk" in Ontario. A variety of sensitive species were selected from the list to ensure that habitat variety and quality was considered for a broad range of wildlife.

The representative diversity in species within this study increases the likelihood of species richness and increases the ability to conserve and restore habitats of more than one species at a time (Dufrene and Legendre, 1997). Habitat requirements for each of the identified species was collected and recorded and species with common habitat requirements were grouped.

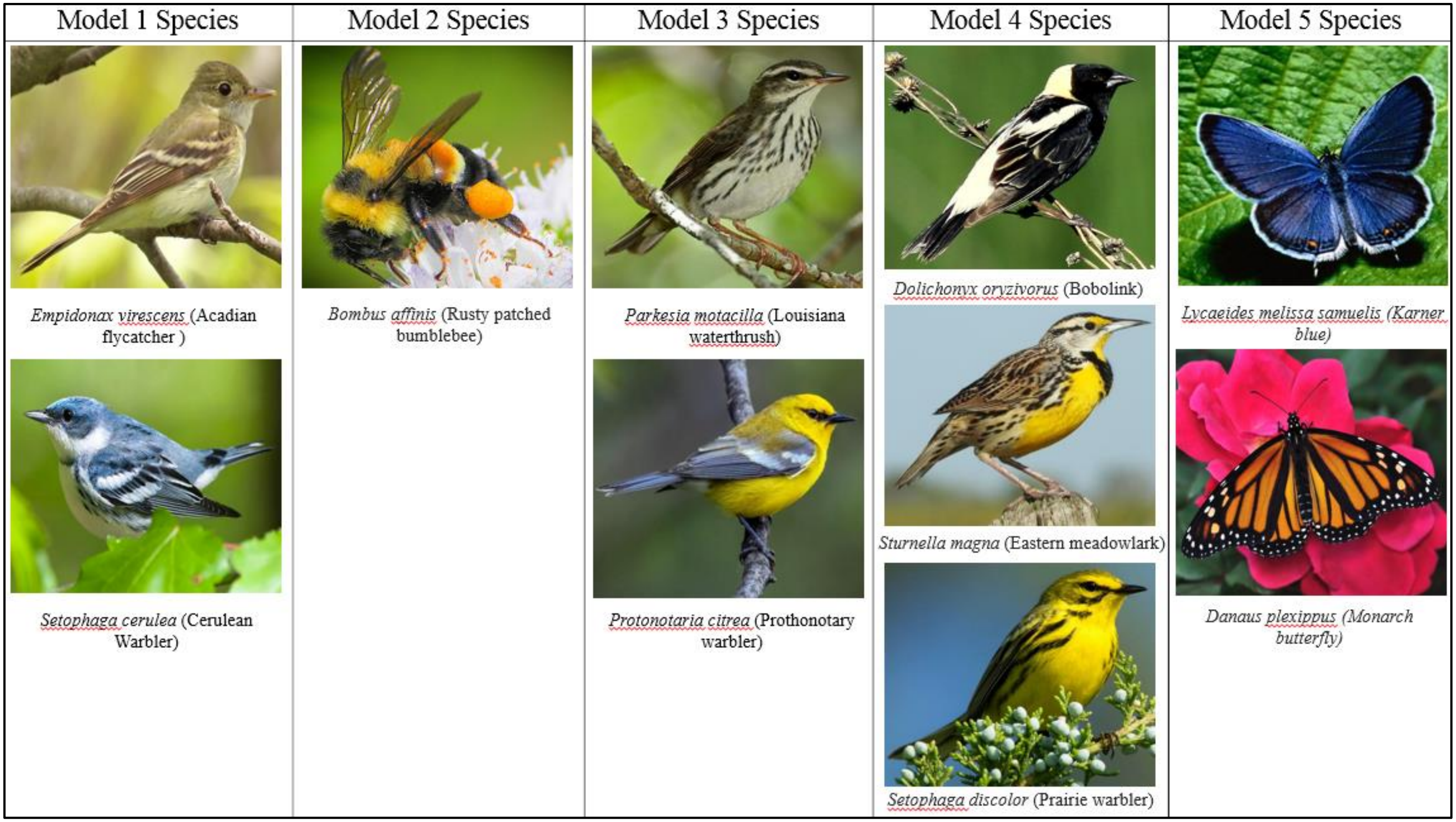


Figure 16. Species selected for this study from the Species at Risk Ontario list.

3.3.3 Species Requirements and Land Type Ranking Within Models 1-5

Following Carver, Comber, McMorran & Nutter's (2012) method, characteristics for most suitable landscapes were determined based on layers: *Land Type* (land cover, i.e. vegetation, water, urban, etc), *Distance from Roads* (distance away from harmful infrastructure, vehicles and human presence), *Distance from Community Boundaries* (distance from anthropogenic activities and developments), *Proximity to Natural Areas* (near forests, wetlands, lakes, etc) and *Proximity to Protected Sites* (protected areas, i.e. NCC and other environmental organizations, which would benefit from the addition of surrounding conserved space). These criteria were used to create an overall index of habitat suitability for the species being protected. Where all attributes have high values, the land is most suitable, and if one or more criteria do not match the necessary requirements for suitability, it has been lowered on the scale towards unsuitable. Using ArcMap, land cover attributes and Euclidean distances were weighted per degree of suitability and reclassified to meet species requirements.

Model 1: Acadian Flycatcher (*Empidonax virescens*) and Cerulean Warbler (*Setophaga cerulea*)

The Acadian Flycatcher exists throughout the Eastern United States but is restricted to southern Ontario by its northern limit. The Cerulean Warbler exists in a broad and patchy range throughout North America (IUCN, 2018). Within Ontario, both species are found almost exclusively in Elgin and Norfolk County's Carolinian forests (EC, 2014) and favour mature deciduous forests with large tall trees and open understory (MNRF, 2018). However, most original Carolinian forest has been removed and what remains are small isolated patches of forests. This is problematic since both species are regarded as area sensitive species with a preference for large expanses of deciduous forests, selecting large tracts of forests over small ones (Whitehead & Taylor 2002; U.S Fish and Wildlife Services, 2016). Both species have also been found in swampy areas, well wooded ravines and along major waterways. (Martin, McCracken & Cadman 1999; Wood et al., 2013). When selecting criteria for the reclassification of the *Land Type* Layer in Model 1, “Deciduous Forests” were ranked the most important followed by “Mixed Treed,” “Tallgrass Woodland,” and “Marsh/Swamp/Bog.”

Model 2: Rusty Patched Bumble-bee (*Bombus affinis)*

The Rusty-patched Bumble-bee is considered to be a habitat generalist (COSEWIC, 2010). The species is known to be found in “farmland, urban settings, savannah, open woods and sand dunes” (COSEWIC, 2010; Colla & Taylor-Pindar, 2011). It exists throughout southern Ontario and its range extends south to Georgia and westward to the Dakotas (Colla & Taylor-Pindar, 2011).

Southern Ontario is the most densely populated area in Canada and is subject to rapid urbanization and sprawl, but a large percentage of land is also used for agricultural purposes (COSEWIC, 2010). This combination of factors has been detrimental to the Rusty-patched Bumble-bee due to “the use of pesticides, particularly neonicotinoids, pathogen transmission and spillover, climate change, severe weather events, intensive agriculture, urban and suburban development, and the road network development” (ECCC, 2016). Nevertheless, the Rusty - patched Bumble-bee is a flexible generalist and suitable habitats for the species still exist. However, additional developments of restoration sites would prove beneficial to population restoration efforts (ECCC 2016).

Model 3: Louisiana waterthrush (*Parkesia motacilla*) and Prothonotary warbler (*Protonotaria citrea*)

The Louisiana waterthrush and Prothonotary warbler prefer riparian zones and deciduous-mixed forests (COSEWIC 2006; Mattsson, Master, Mulvihill & Robinson, 2009). Both birds breed in damp and moist areas near stream banks. They nest in moss covered logs and fallen trees (Prosser & Brooks 1998; Mattsson, Master, Mulvihill & Robinson, 2009) where nests are well camouflaged by thick vegetation and dense roots (Eaton 1958; Peck and James, 1987).

Both species are threatened by forest clearing, land cover change, the draining of wetlands, and loss of canopy and water pollution (McCracken, 2013; COSSARO, 2016). The Louisiana waterthrush is regarded an area sensitive species with a preference for large, non-fragmented expanses of forest (Prosser & Brooks, 1998) in steeply sloped areas near streams, ravines, swamps, and standing pools of water (Eaton 1958). It is estimated that the minimum forest area capable of supporting this population is 100 ha (COSEWIC, 2006) and the estimated territories for nesting pairs are 2ha in area (COSEWIC 2006). The Prothonotary warbler is also considered an area-sensitive species but little is known about how much area is required to support this species. It is estimated that forest patches ranging from 100m-500m wide could be sufficient for the species ((Hodges and Krementz, 1996; Kilgo, Sargent, Chapman & Miller, 1998).

It is crucial to protect and restore forests and wetland areas that these species are highly dependent upon. “Mixed Treed,” “Deciduous Treed,” “Water” and “Shoreline” land types were selected as the most important land categories within Model 3. While the purpose of this study is to focus upon species which inhabit tallgrass prairie, the Louisiana waterthrush and Prothonotary warbler do not. Nevertheless, tallgrass prairie corridors will facilitate safe passage between one core habitat and others, improving species range and access to resources.

Model 4: Bobolink (***(**Dolichonyx oryzivorus)*), Eastern meadowlark (*Sturnella magna)* and Prairie warbler (*Setophaga discolor)*

The Bobolink, and Eastern meadowlark reside in prairie environments, preferring tall and shrubby grasses (McCracken et al., 2013) whereas, the Prairie warbler favours second growth scrub and densely grown fields (Kaufman, 2017). Since the decline of prairie habitats throughout their North American range, these species have also been found in hayfields, croplands and on roadsides (McCracken et al., 2013). The Bobolink and Eastern meadowlark are threatened and verging on endangered in Ontario (McCracken et al., 2013) whereas, the Prairie warbler is currently listed as stable however, surveys show declining numbers of breeding pairs in recent decades (Kaufman, 2017; Southwell 2001). Threats to these species include the mowing of hay and harvesting of cropland which can coincide with nesting periods and inadvertently kill nesting adults and hatchlings while simultaneously destroying eggs and nests (McCracken et al., 2013). Decreases in early successional habitats due to reforestation and fire suppression have been damaging for these specie's populations which are highly dependent on grassland habitats. Additionally, the Prairie warbler is threatened by the brown-headed cowbird which acts as a nest parasite and can even cause female warblers to abandon their nests completely (Southwell, 2001).

Recovery strategies include educating the public on the habitats these species nest within, increasing habitat supply of native grassland and establishing strong links between grassland species to protect a greater variety and population of bird species (McCracken et al., 2013).

Thus, conserving and developing "Open Tallgrass/Tallgrass Savannah" and "Tallgrass Woodland" land types benefits and supports the existing recovery strategies provided for these species and several others.

Model 5: Karner Blue Butterfly (*Lycaeides melissa samuelis*) and Monarch butterfly (*Danaus plexippus),*

The Karner Blue and Monarch butterflies are both restricted by specialization of their larvae to specific plant species, Wild Lupine and milkweeds, respectively. Wild Lupine grows in areas with sandy soils, grasslands and in oak savannah (Mitchell & Carnes, 2018) whereas, milkweeds can grow in a variety of habitats depending on the type of milkweed species (CWF, 2018). These butterfly species suffer the consequences of habitat loss since their environments are often destroyed for developments or taken over by natural succession of plants which generate shaded spaces, limiting the required environments for milkweeds and Wild Lupine growth (COSSARO, 2010).

Monarchs are regarded a species of special concern in Ontario, but the scope of their survival is an international matter. Aside from fragmentation of habitat in North America, the Monarch's overwintering grounds in Mexico are being logged and converted into fields and pastures heavily sprayed by herbicides and pesticides (EC, 2014). Karner Blue butterflies are listed as extirpated and have not been consistently reported at any site in southern Ontario. Nevertheless, the Nature Conservancy of Canada and St. Williams Conservation Reserve are attempting to reintroduce the Karner Blue butterfly and recovery efforts are underway (COSSARO, 2010).

Both species would benefit from the development and maintenance of tallgrass prairie corridors. Amongst other grass and plant species, Wild Lupine and milkweeds can be planted within the corridors to support Monarch population growth and encourage the return of the Karner Blue butterfly.

3.4 Model Overlay-Optimal Habitat Suitability

In Models 1-5, the weighted overlay function ordered all cell values a rank of 1-11 (least suitable to most suitable) depending on the criteria defined in the function when ranking attributes. Each of the 5 models were reclassified in ArcGIS using the 'Reclassify' function within the Spatial Analyst toolbox. Numbers of different magnitudes were attributed to each of the suitability ranks in each model (*Figure 17*). Cells with higher suitability were given larger numbers and cells with lower suitability were given lower values. The five reclassified models were then summed in ArcGIS' raster calculator using the following expression "Model 1" OR "Model 2" OR "Model 3" OR "Model 4" OR "Model 5".

Figure 17. Reclassified of weighted overlay values (Models 1-5) to prepare for summing in the raster calculator.

Models	Unsuitable	Poor	Fair	Good	Optimal
Original Values (Models 1-5)	1,2,3	4,5	6,7	8,9	10,11
Reclass Values Model 2	10	20	30	40	50
Reclass Values Model 3	100	200	300	400	500
Reclass Values Model 5	1,000	2,000	3,000	4,000	5,000
Reclass Values Model 4	10,000	20,000	30,000	40,000	50,000
Reclass Values Model 1	100,000	200,000	300,000	400,000	500,000

Numbers with the lowest values, i.e. 111,110 are the result of summing the least suitable values in all 5 models (10+100+1000+10000+100000) whereas, 555,550 would be the result of summing the most suitable habitats in all 5 models (50+500+5000+50000+500000). Using the sum function, an output map was created which illustrates the optimal habitat suitability for all species, in all five models. This newly summed model was then used as the *Master Habitat Suitability Map*.

Habitat Suitability	Rankings Within Each Model
Unsuitable	10,100,1000,10000,100000
Poor	20,200,2000,20000,300000
Fair	30,300,3000,30000,300000
Good	40,400,4000,40000,400000
Optimal	50,500,5000,50000,500000

111,110 = Least Suitable
555,550 = Most Suitable

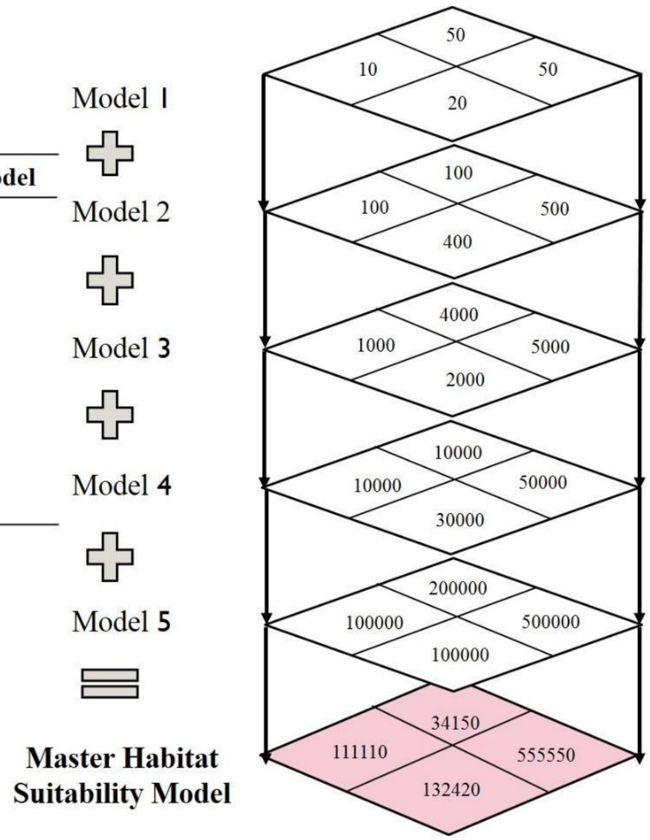


Figure 18. Reclassified values in Model 1-5 added in the raster calculator to create the Master Habitat Suitability Map.

3.5 Least Cost Path Analysis

Instead of determining cost based on a single factor, a cost surface model considering multiple criteria can approach a study in a realistic and effective manner (Howey, 2007). In ArcGIS' Modeler, the *Master Habitat Suitability Map* and *Land Cost* layer were combined.

The range of summed values within the *Master Habitat Suitability Map* was divided into 11 classes which were ranked 1-11 (most suitable to least suitable). The *Land Cost* layer, which includes 11 land classes was also ranked from least costly land (1) which would be most desirable, to most costly land (11) which would be least desirable (*Figure 19*).

After being ranked, both the reclassified layers were combined using the weighted overlay tool. When considering conservation and restoration, land cost can at times be more important to policy planners, governments and NGO's than land type and quality. Nevertheless, land type and quality are important factors in achieving conservation objectives. Thus, the "Master Habitat Suitability Model" and "Land Cost Layer" were equally weighted in the weighted overlay and the output resulted in the "Cost Surface Raster."

Each cell in the "Cost Surface Raster" grid contains information (Howey, 2007) about *Land Cost, Distance from Roads, Distance from Community Boundaries, Proximity to Natural Areas, Proximity to Protected Sites* and *Land Type*. Each criterion is measured when determining the cost for the proposed corridor. The "Cost Surface Raster" was then used to find the optimal corridor connecting adjacent NCC reserve areas.

Figure 19. Reclassified Master Habitat Suitability values and Land Cost Layer values. Both layers are weighted at 50% in the weighted overlay to develop the "Cost Raster."

Master Habitat Suitability (Sum Values)	Rank	Land Cost layer	Rank
455551-555550	1	Agriculture and Undiffrentiated	1
434541-455550	2	Open Tallgrass/Tallgrass Savannah	2
433441-434540	3	Tallgrass Woodland	3
344441-433440	4	Coniferous Treed	4
334341-344440	5	Mixed Treed	5
323431-334340	6	Deciduous Treed	6
312321-323430	7	Marsh/Swamp/Bog	7
233331-312320	8	Sand/Dune/Gravel/Mine/Tailing	8
223231-233330	9	Shoreline	9
122221-223230	10	Community Infrastructure	10
111110-122220	11	Clear Open Water	11
Layer Weight	50%	Layer Weight	50%

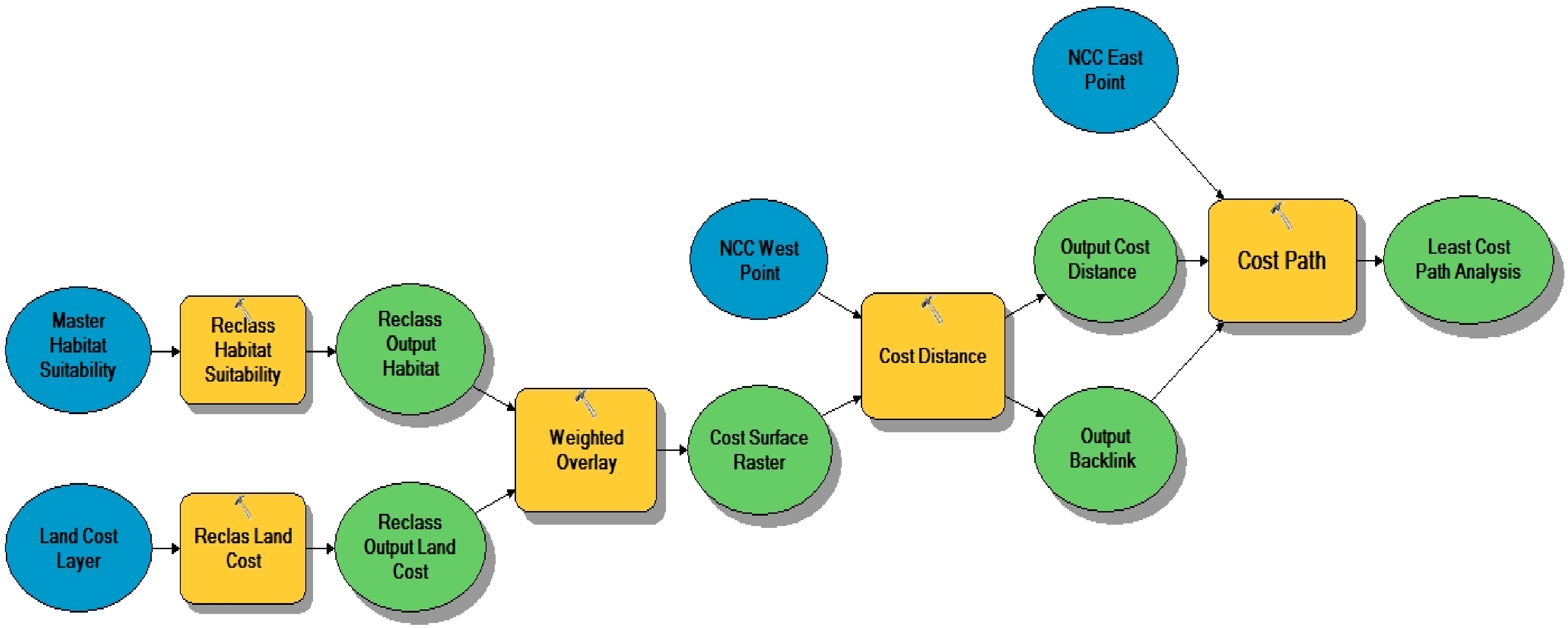


Figure 20. Least cost path model development in ArcGIS' Modeler.

CHAPTER FOUR: RESULTS

This section outlines the results of each individual model (1-5) and identifies which areas are best suited to support the specific species for each model. Subsequently, the models are reclassified and combined to determine which areas would be best suited for habitat restoration and tallgrass prairie corridor planning. The reclassification and combination of models determines which lands are best suited for all species needs throughout all 5 models. Models 1-5 do not consider land cost. Land cost is considered with the least-cost path analysis.

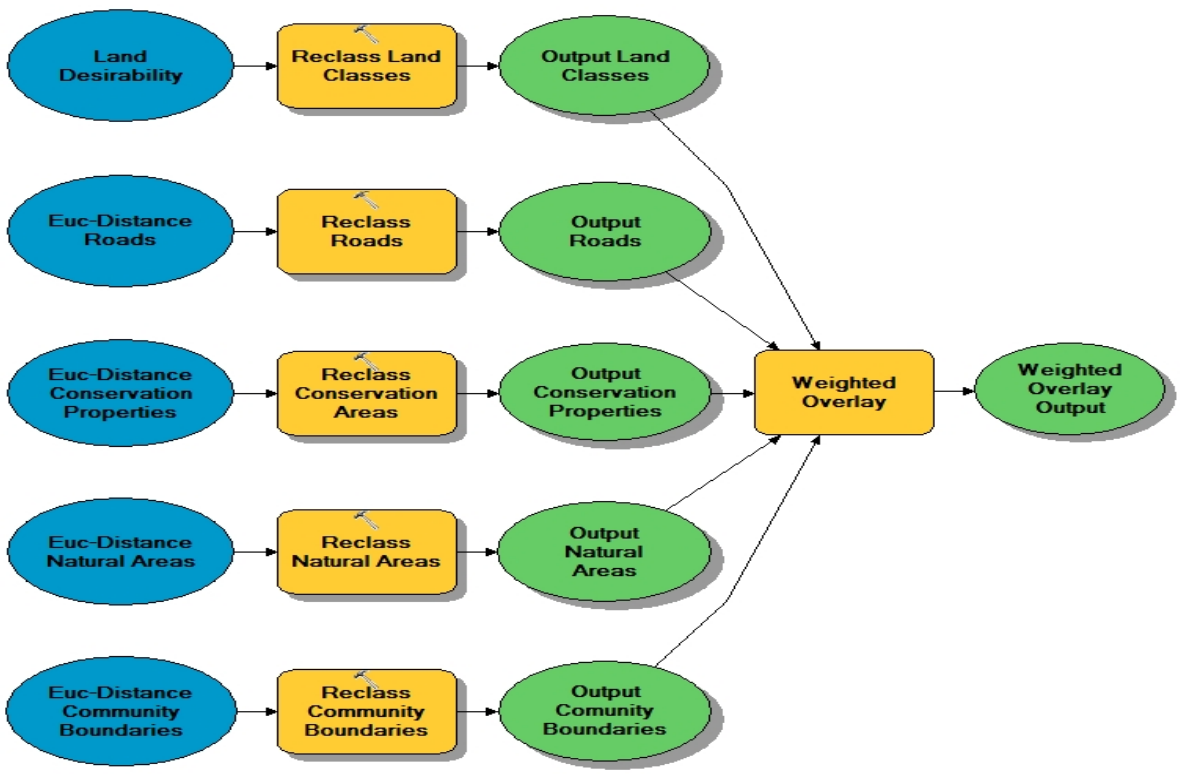


Figure 21. Weighted overlay model template for habitat suitability models (1-5).

4.1 General Observations

Habitat suitability maps were developed using the weighted overlay tool. A habitat suitability index, a unitless measure describing habitat appropriateness with respect to species requirements, has been provided in each map.

The Models are visually complex but several similarities between the models can be identified. Models 1 and 3 are alike since many of the habitat criteria for the species within these models, overlap. Models 2, 4 and 5 are also similar to one another since some of the habitat criteria for the species within these models intersect. Areas unsuitable for all species, for instance road ways, densely populated communities and city centres were ruled out throughout all five models. Predictably, naturally existing landscapes and existing conservation sites were most suitable throughout all 5 models.

4.2 Model Results

4.2.1 Model 1 Habitat Suitability Map.

Species in Model 1, the Acadian flycatcher and Cerulean warbler first and foremost require large deciduous forests with thick tree canopies (McCracken et al., 2013; Wood et al., 2013). Both species prefer to nest in deciduous upper canopy layers but require wetland areas to be in close proximity to their nesting sites (McCracken et al., 2013; Wood et al., 2013). It remains uncertain as to why these species prefer nest sites near water, but it is hypothesized that it is related to food availability and microclimates (Hartman, Maehr & Larkin, 2006).

Existing NCC properties were included in the weighted models and are regarded as important sites for the development of conservation efforts. Existing conservation sites hold a layer weight of 19% in the initial weighted model and heavily influence where the most suitable sites for habitat restoration will be selected. Nevertheless, it is important to note that additional factors such as, deciduous and mixed forests as well as several wetland areas contained within existing conservation sites influence the environmental suitability in Model 1. Since the Acadian flycatcher and Cerulean warbler both predominantly require deciduous forests near wetland areas, pre-defined conservation sites are regarded the most suitable lands for tallgrass prairie habitat restoration as these sites contain the mixture of habitat types required by these species.

While deciduous forests and wetland areas are favoured, suitability decreases when these two habitat types are not next to one another. Consider the lower southern portion of Model 1 (*Figure 22*). The area in the south, extending southeast, is predominantly wetland and shoreline areas which are important habitat types for the species in Model 1. However, these areas are not as high on the suitability scale since they lack habitat characteristics required for the species under consideration. Thus, the existing conservation sites and small area before the southeast extension, where agricultural, deciduous, and mixed treed land types interlace with wetlands, are characterized as the most suitable habitats available for Model 1 species.

While it is noted that the species in Model 1 do not frequent tallgrass prairies, certain prairie restoration areas can be pre-delineated during conservation planning to ensure that successional growth is encouraged. The eventual development of treed lands can provide the required habitats these species need. Until then, tallgrass prairie developments can act as buffers to existing sites as the tallgrass grows into extensions of forested patches

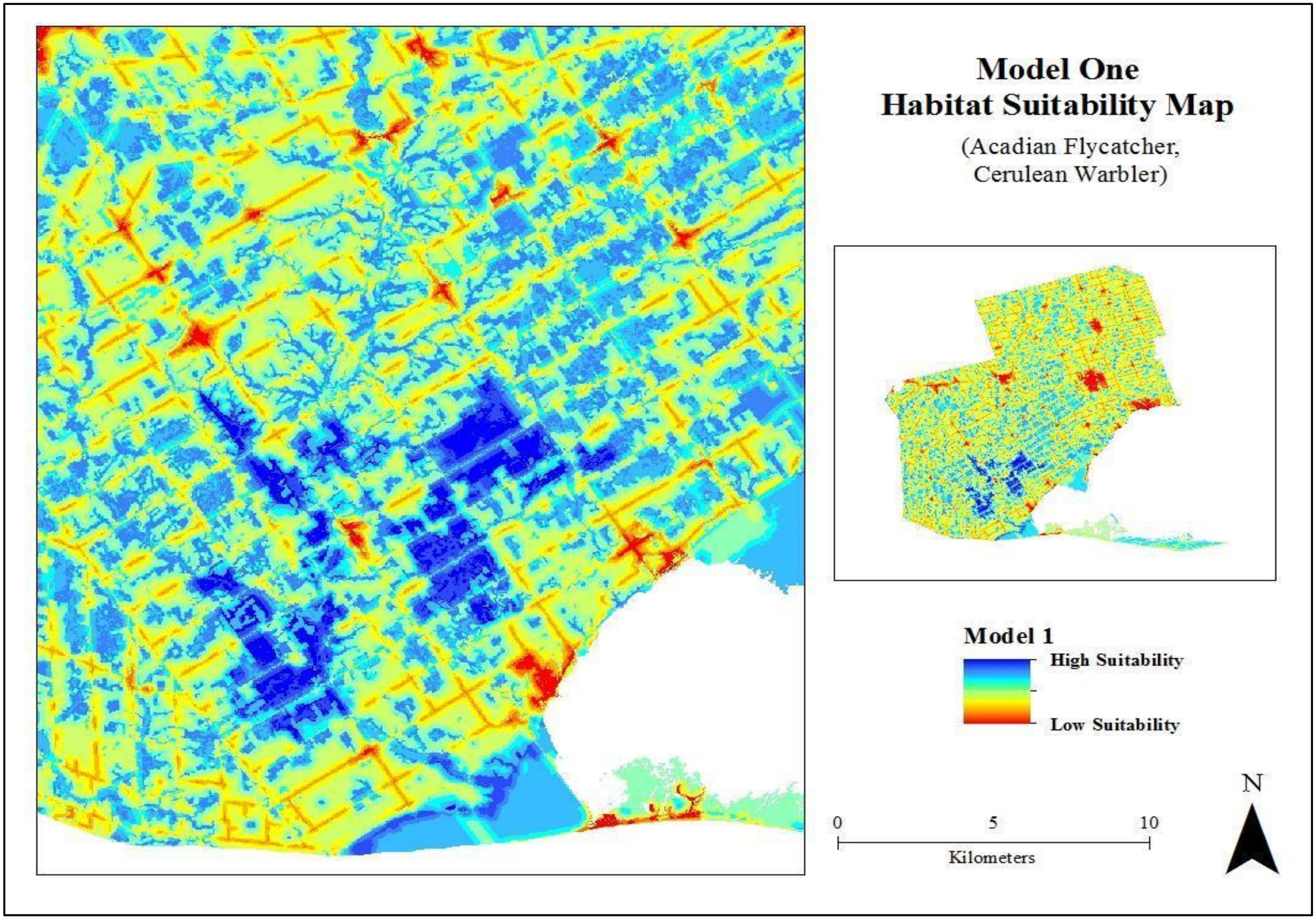


Figure 22. Map illustrating habitat suitability Model 1 (Acadian Flycatcher and Cerulean Warbler)

4.2.2 Model 2 Habitat Suitability Map

Model 2, regarding the Rusty-patched Bumble-bee, identifies the greatest amount of area for species suitability compared to any other Model. Majority of Model 2 is covered in blue, indicating highly suitability in habitats. Since the Rusty-patched Bumble-bee is a generalist forager (COSEWIC, 2010), it can use a variety of habitat types. The species has been found in "mixed farmland, sand dunes, marshes, urban and wooded areas" (COSEWIC, 2010) and forages from several different plants "including milkweed, sunflowers, clovers and fruit blossoms" (Colla & Dumesh, 2010).

Though there appears to be an abundance of land suited to the Rusty-patched Bumble-bee's habitation requirements in Norfolk county, the species has not been spotted in Ontario since 2009 (COSEWIC, 2010; WPC, 2018). Between the years 2000-2010, only three individuals were collected even though thousands of hours of bee surveying were carried out during this time frame (COSEWIC, 2010). There is a serious concern that the species status will change from endangered to extirpated as the bee becomes absent from its historical range.

Considering *Figure 23*, it is apparent that habitat availability for the Rusty-patched Bumble-bee is not a major concern for the species survival. Threats to the species are heavily associated with agricultural practices. Concerns include pathogen spillover, often from commercial Bumble-bees used in greenhouse pollination and neonicotinoids in pesticides (COSEWIC, 2010). Norfolk County contains approximately 795km^2 of cropland which annually generates $3.3 billion in total capital (Hoskin, 2016). This economic asset is one which is protected by fertilizers, herbicides, and pesticides (Hoskin, 2016) containing neonicotinoids which are particularly harmful to bees. The harmful substance is systemic and reaches the soil, plant roots, nectar and pollen which renders what would otherwise be suitable bee habitats, unsuitable (COSEWIC, 2010). Thus, delineated conservation sites are crucial to the survival of the Rusty-patched Bumble-bee since these sites would be void of the harmful substances affecting species survival.

Figure 23 identifies existing conservation sites as best suited areas for the species. The conservation sites are areas which would not use or require pesticides and would therefore be the safest sites for nesting. Furthermore, these areas would provide the bees with the uncontaminated resources they would require for survival. It would be best to expand on existing conservation sites and create tallgrass prairie corridors to facilitate the movement of these species and provide safe resources and habitats to nest within. Of course, protecting bees require changes in harmful anthropogenic and agricultural practices but tallgrass prairie restoration corridors are a step towards improving conservation efforts.

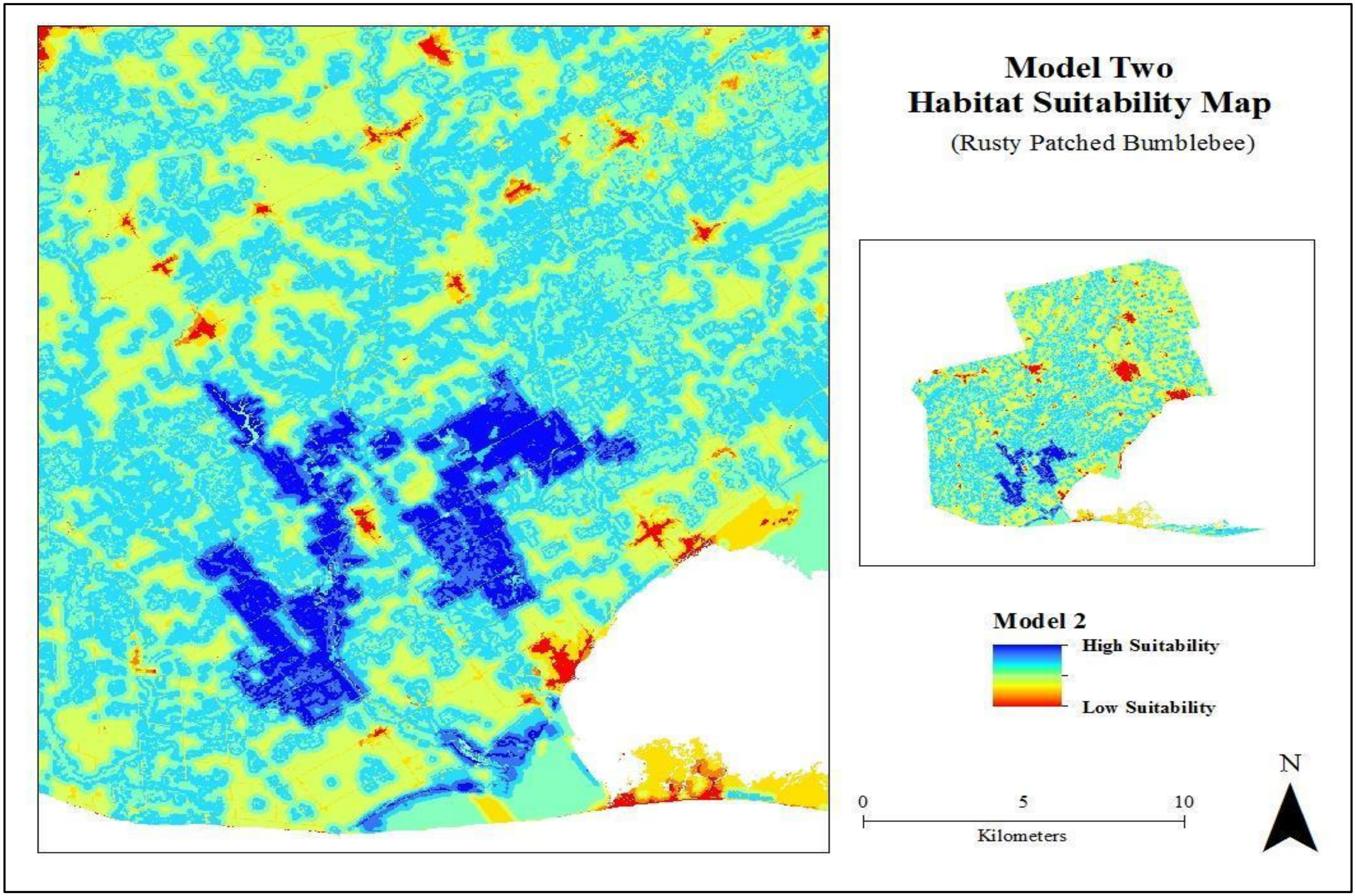


Figure 23. Map illustrating habitat suitability Model 2 (Rusty-patched Bumble-bee)

4.2.3 Model 3 Habitat Suitability Map

Species in Model 3, the Louisiana waterthrush and Prothonotary warbler have similar requirements to species in Model 1, the Acadian flycatcher and Cerulean warbler. While the species in Model 1 prefer to be in close proximity to water bodies and wetland areas, species in Model 3 are regarded wetland species and require habitats directly above or next to water. For instance, the Prothonotary warbler typically nests in areas entirely covered with "standing water… or [near] slowly flowing water… [where] nests are nearly always situated over or within 5 m of standing water or in low-lying, easily flooded areas" (MNR, 2012, p.4). The Louisiana waterthrush "occupies specialized habitat, showing a very strong preference for nesting along pristine, headwater streams and associated wetlands that occur in large tracts of mature forest" (COSEWIC, 2006, p.4).

Therefore, habitat requirements between Model 1 and Model 3 species are similar but, Model 3 species have more specialized habitat requirements which comparatively reduces the amount of suitable habitat for these wetland species. There are fewer areas identified as open water, shoreline and wetland. As a result, there is less suitable land available for the Louisiana waterthrush and Prothonotary warbler. Observing *Figure 24,* areas which are most capable of facilitating the habitation of the species in Model 3 are existing conservation locations. The existing conservation properties contain a variety of coniferous and mixed-tree forests, riparian floodplains and deciduous swamp forests which are the most suitable habitat characteristics for the Louisiana waterthrush and Prothonotary warbler (COSEWIC, 2006; Huang, 2013).

The Southern portion of the map is also a highly suitable space for Model 3 species since it is a wide expanse of wetland which provides the species with their dietary requirements and nesting materials (COSEWIC, 2006; MNR, 2012). Nevertheless, the southern extent lacks canopy cover and contains several ponds surrounded by a variety of grasses. Like the species in Model 1, the Louisiana waterthrush and Prothonotary warbler require a combination of forested and wetland spaces. While these species can use grasses and tallgrass prairie for habitation, grass is usually not a dominant or preferred cover type in their nesting sites (MNR, 2012). Tallgrass prairie restoration sites would most likely be used as safe passageways to larger core areas and protective spaces when acquiring resources.

Future conservation planning strategies specific to Model 3 species and other species alike should consider developing tallgrass prairie ecological corridors between existing conservation sites and the southern wetland extent. Furthermore, the successional growth of tallgrass prairie in certain areas should be considered during planning since these are the preferred land type characteristic for both the Louisiana waterthrush and Prothonotary warbler.

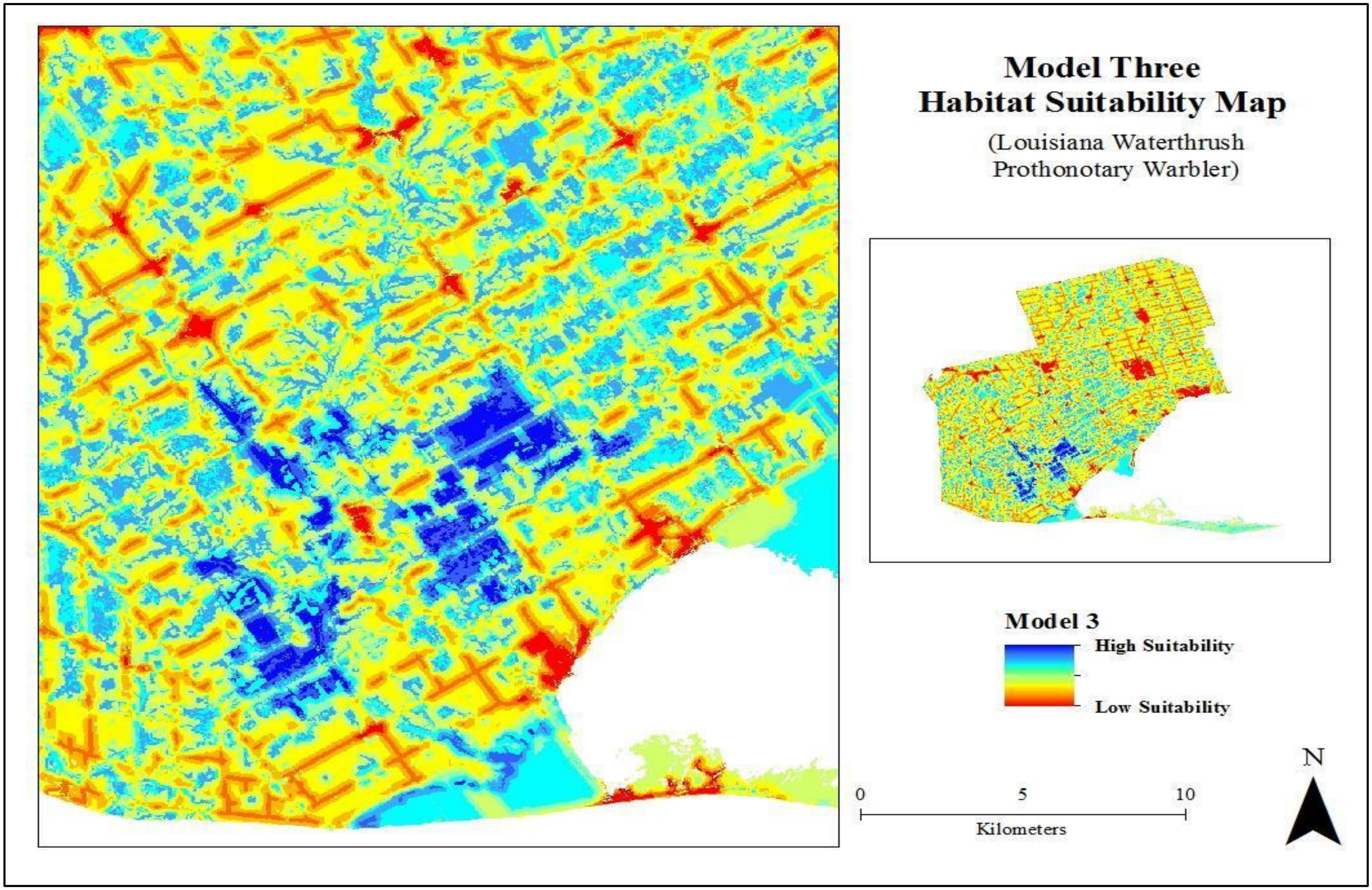


Figure 24. Map illustrating habitat suitability Model 3 (Louisiana waterthrush and Prothonotary Warbler)

4.2.4 Model 4 Habitat Suitability Map

Species in Model 4, the Bobolink, Prairie warble and Eastern meadowlark all require similar habitat qualities. All three species are threatened by the loss of tallgrass prairie and savannah habitats which have been reduced from thousands of hectares to only 3% of its historic extent (COSSARO, 2011). These species are known to do well in pastures and hayfields. Since Norfolk County's agricultural fields share similar habitat qualities required by these species, majority of the area in *Figure 25* is identified as suitable. Yet, the Bobolink, Eastern meadowlark and Prairie warbler are listed as threatened, endangered and declining, respectively (COSSARO, 2010; COSSARO, 2011).

Though it appears that there is ample habitat meeting the needs of the species in Model 4, agricultural management of these habitats severely impacts species survival. Farm lands have undergone large-scale conversions of forage crop into row crop (COSSARO, 2011). Row crops are usually tilled and cultivated by agricultural machinery which can be lethal (COSSARO, 2010) to the species in Model 4 and several other ground nesting species. Furthermore, row crops are most often sown by drilling which involves dragging a hoe through the soil and seeding the furrows created instead of burying individual seeds. Drilling is much more efficient in farming but can disrupt the sensitive microhabitats many creatures are dependent upon (COSSARO, 2011). Micro habitats required by the species in Model 4, include moderate litter cover and high forb cover (COSSARO, 2010) which is often stripped away by industrialized farming practices.

Another major threat to these species is the mowing of hayfields and industrial harvest of crop (COSSARO 2010). Warren and Anderson (2005) have found that vertical density of vegetation, vegetation height and depth of ground litter, are important habitat requirements for grassland bird nesting success. Mowing is known to destroy habitats, eggs, nestlings and nesting adults which leads to nest abandonment, increased predation and results in an overall increase of mortality rates (COSSARO 2010).

The development of tallgrass prairie corridors would directly benefit all species considered in Model 4, since tallgrass prairie compositions perfectly encompass the habitat requirements for these species. Of course, management of the tallgrass prairie corridors will need to be implemented to halt natural succession and growth of woody plants and trees. Plans should include grazing of prairie at the end of breeding season and controlled burns to maintain prairie compositions. According to *Figure 25*, the best areas for tallgrass prairie corridor developments would be the edges of existing conservation sites and the grassy narrows running through protected areas. The most southern portion of the map also includes grasslands, and wetlands which are highlighted as important spaces for the species within Model 4. The Bobolink in particular, can make use of the habitat in the southern extent since it moves to wetlands after nesting to molt and prepare for migration (Cornell University, 2017).

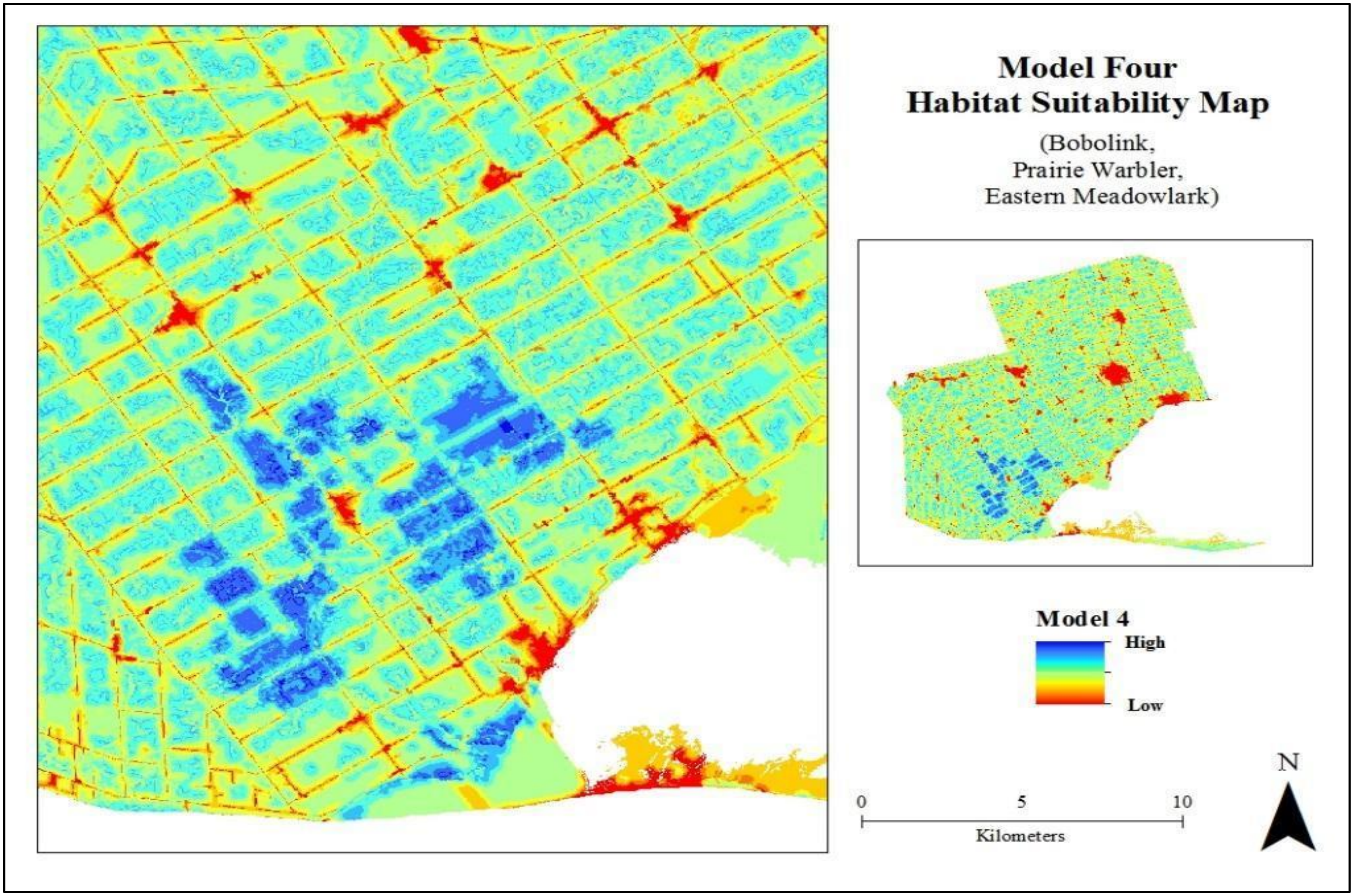


Figure 25. Map illustrating habitat suitability model 4 (Bobolink, Prairie warbler, and Eastern meadowlark)

4.2.5 Model 5 Habitat Suitability Map

Like the species in Models 2 and 4, the Karner Blue and Monarch butterflies, reside in meadows, and open areas but can also be found in open woodland habitats, sandy dunes, and scrubby habitats with sparse vegetation including roadsides and under powerlines (EC, 2014; ECCC, 2017). These butterflies are found in a broad range of habitats which is why several portions of *Figure 26* indicate there is suitable habitat available for the species in Model 5. Nevertheless, Monarchs are listed as a species of special concern (EC, 2014) and Karner Blue butterflies have been completely extirpated (ECCC, 2017).

Both these species can exist in a variety of habitats but only if their specific habitat criteria are met. Monarch butterflies use different habitats throughout their life span and adult butterflies can be found in varied habitats. However, caterpillars are restricted to areas in which milkweed grows. Monarch butterflies lay their eggs on milkweed plants (EC, 2014) and larvae feed exclusively on milkweed. The larvae store toxins from the plants to make themselves poisonous to predators (Giller, 2015) whilst pollinating milkweed plants during their feeding process (EC, 2014). Karner Blue butterflies are also habitat specialists since they require the presence of a larval host plant, Wild Lupine, to be present for oviposition (COSEWIC, 2006). Wild Lupine is the only plant that is consumed by Karner Blue larvae (ECCC, 2017). Unfortunately, Wild Lupine is rare to uncommon in Ontario and is vulnerable to succession without natural disturbances like fire and grazing (ECCC, 2017).

Though it seems there are a variety of habitats available for these species, their specialist requirements confine their extent to very specific areas. Without milkweed and Wild Lupine, they are unable to survive. Luckily, milkweed is being sold in nurseries and butterfly gardens where the plant is gaining in popularity and being grown by several concerned citizens

(COSEWIC, 2010). Additionally, spaces within Norfolk County are considered areas of high reintroduction potential for Karner Blue butterflies (ECCC, 2017) since the land is fit to grow Wild Lupine, a savannah and prairie plant. Tallgrass prairie corridor developments will complement existing recovery and reintroduction initiatives and accommodate the specialists species needs by including Wild Lupine and milkweed in the corridor development plans.

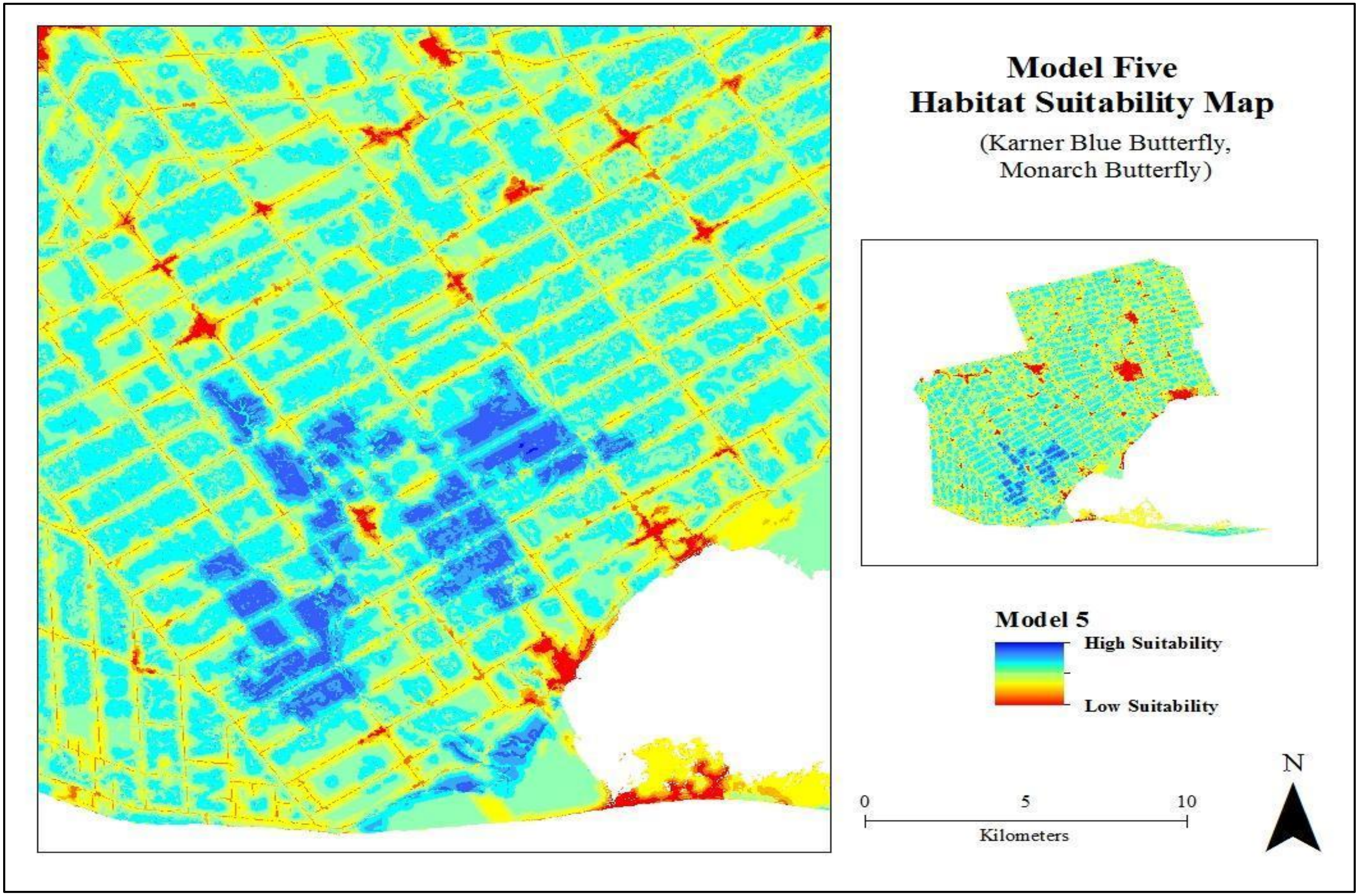


Figure 26. Map illustrating habitat suitability model 5 (Karner Blue Butterfly and Monarch Butterfly)

4.3 Data Smoothing

Multi-species conservation management is a complicated task since each specie's requirements vary. Nevertheless, species can be grouped to identify those which use similar environmental resources regardless of taxonomical difference (Block, Finch & Brennan, 1995). In Models 1-5, the weighted overlay function ordered all pixels a rank of 1-11 (least suitable to most suitable) depending on the criteria defined for optimal species habitats. These ranked pixel values were then reclassified within each model to simplify habitat suitability groupings and smooth the data so that important patterns were revealed (*Figure 28 and 29*).

Figure 27. Initial pixel values (1-11) from each model were reclassified (3rd column in Model 1,2,3,4 and 5) to group pixel level of suitability and prepare for the sum function.

Model 1

Old Values	Old Pixel Value	New Values
1	29,292	100,000
2	36,605	100,000
3	114,319	100,000
4	270,982	200,000
5	499,796	200,000
6	346,118	300,000
7	158,638	300,000
8	192,066	400,000
9	144,447	400,000
10	19,700	500,000
11	15,770	500,000
NoData	1,827,733	NoData

Model 2

Old Values	Old Pixel Value	New Values
1	736	10
2	36,318	10
3	12,196	20
4	97,229	20
5	521,362	30
6	561,394	30
7	534,374	40
8	28,452	40
9	35,672	50
10	N/A	N/A
11	N/A	N/A
NoData	1,827,733	NoData

Model 3

Old Values	Old Pixel Value	New Values
1	N/A	N/A
2	50,038	100
3	120,920	100
4	265,576	200
5	514,913	200
6	359,039	300
7	181,252	300
8	161,921	400
9	141,874	400
10	16,375	500
11	15,825	500
NoData	1,827,733	NoData

Model 4

Old Values	Old Pixel Value	New Values
1	23,612	10,000
2	16,185	10,000
3	34,194	10,000
4	46,320	20,000
5	149,520	20,000
6	335,183	30,000
7	681,254	30,000
8	429,073	40,000
9	87,330	40,000
10	22,863	50,000
11	2,199	50,000
NoData	1,827,733	NoData

Model 5

Old Values	Old Pixel Value	New Values
1	25,515	1,000
2	17,442	1,000
3	37,291	2,000
4	52,602	2,000
5	239,599	3,000
6	399,200	3,000
7	571,573	4,000
8	424,759	4,000
9	37,041	4,000
10	22,258	5,000
11	453	5,000
NoData	1,827,733	NoData

Reclassification was used to identify which models overlapped in habitat and resource requirements. After reclassification, similarities for habitat criteria in Models 1 and 3 and, Models 2, 4 and 5, became more apparent. The reclassified models were summed so that high and low suitability values throughout all 5 models could be identified on one *Master Habitat Suitability Map*.

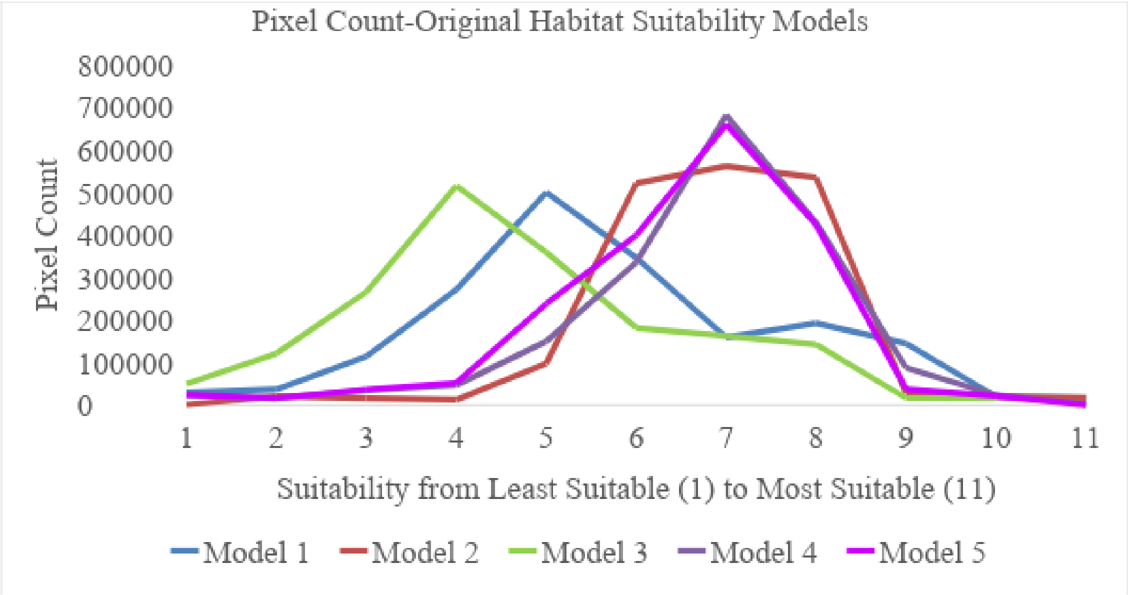


Figure 28. Original Pixel Suitability (Models 1-5)

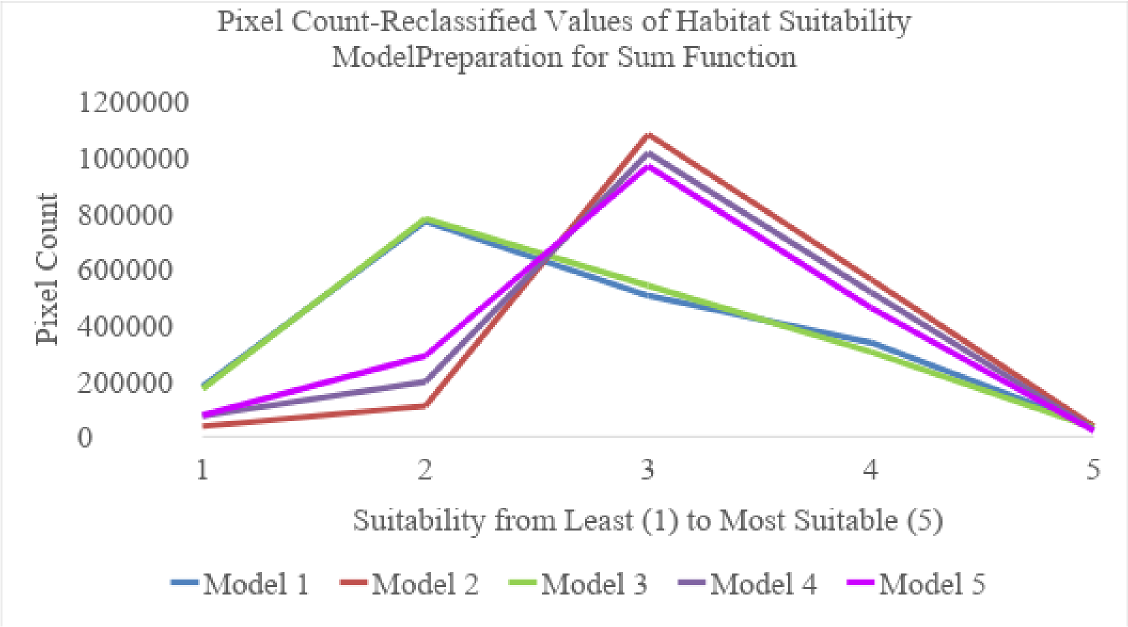


Figure 29. Reclassified Pixel Suitability (Models 1-5)

4.4 Master Habitat Suitability Map

Models 1-5 collectively identify pre-existing conservation areas as the most suitable lands to develop restoration sites on or beside. The models were developed placing great importance on the "*Proximity to Natural Areas"* Layer and the "*Proximity to Protected Sites"* Layer. Together these layers made up 38% of the overall weighted average. These areas are regarded most suitable since they reduce the cost of restoration planning. Conservation authorities and NGO's might already be burdened with high costs while implementing their conservation models and developing conservancy strategies. Instead of purchasing all lands required to fulfill conservation objectives, buying properties adjacent to existing sites reduces costs while expanding natural areas. Moreover, protecting areas surrounding existing conservation sites can create boundary zones shielding existing core areas. The restoration sites where tallgrass prairie will be developed can act as buffers for large core areas containing developed and mature resources with complex ecological functions.

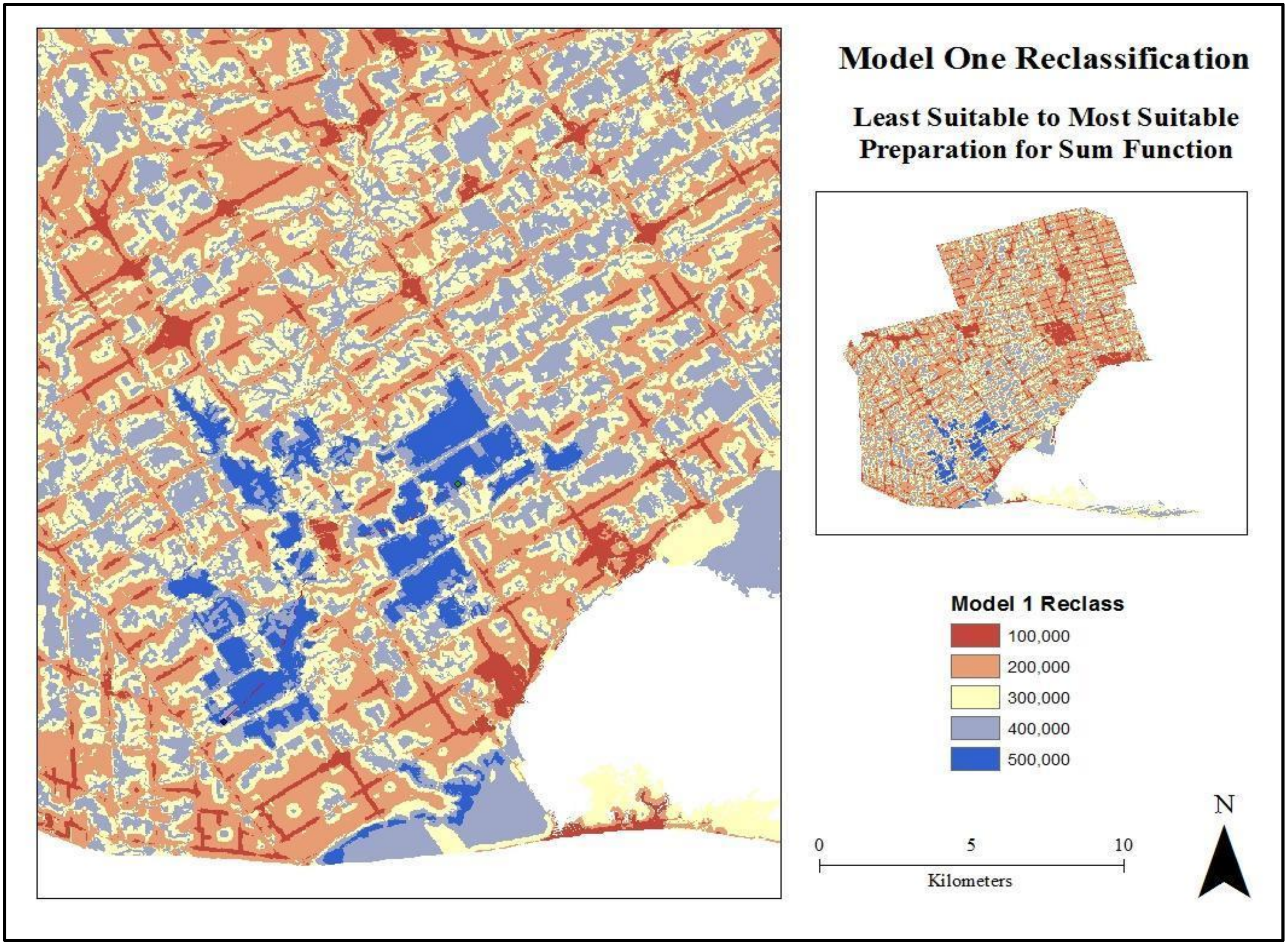


Figure 30. Map illustrating the reclassification of pixel values in Model 1. 100,000 least suitable, 500,000, most suitable.

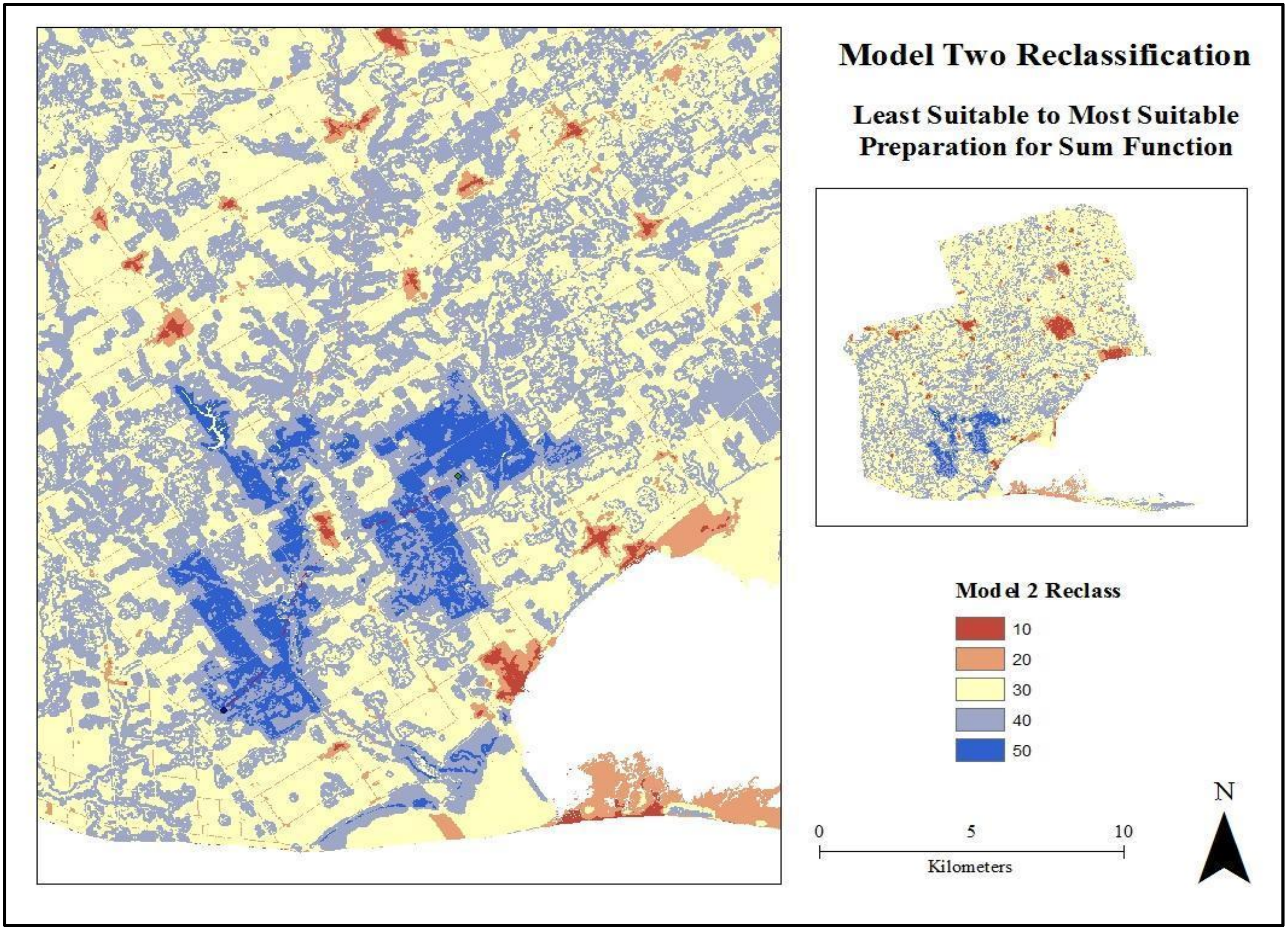


Figure 31. Map illustrating the reclassification of pixel values in Model 2. 10 least suitable, 50, most suitable.

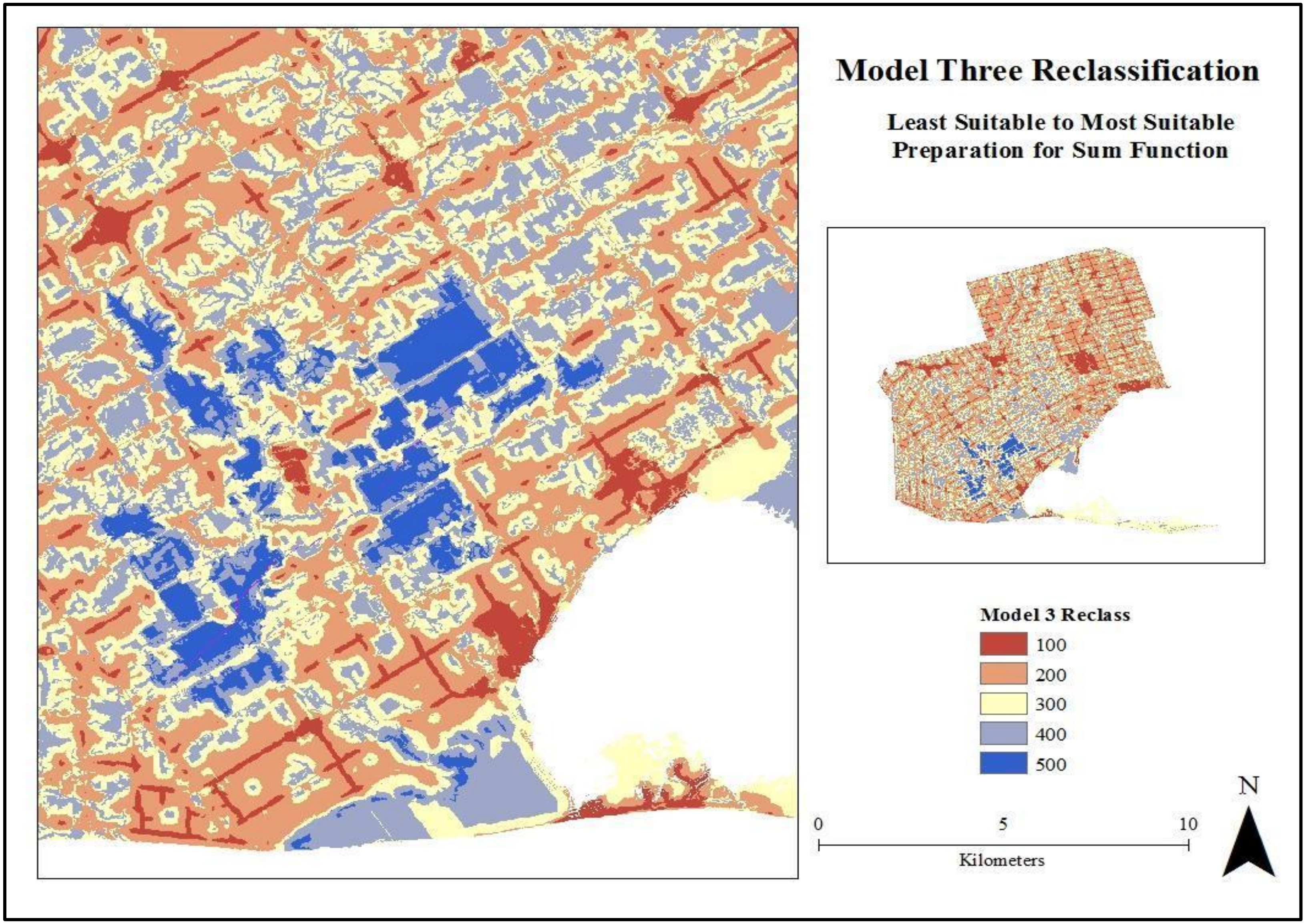


Figure 32. Map illustrating the reclassification of pixel values in Model 3. 100, least suitable, 500, most suitable.

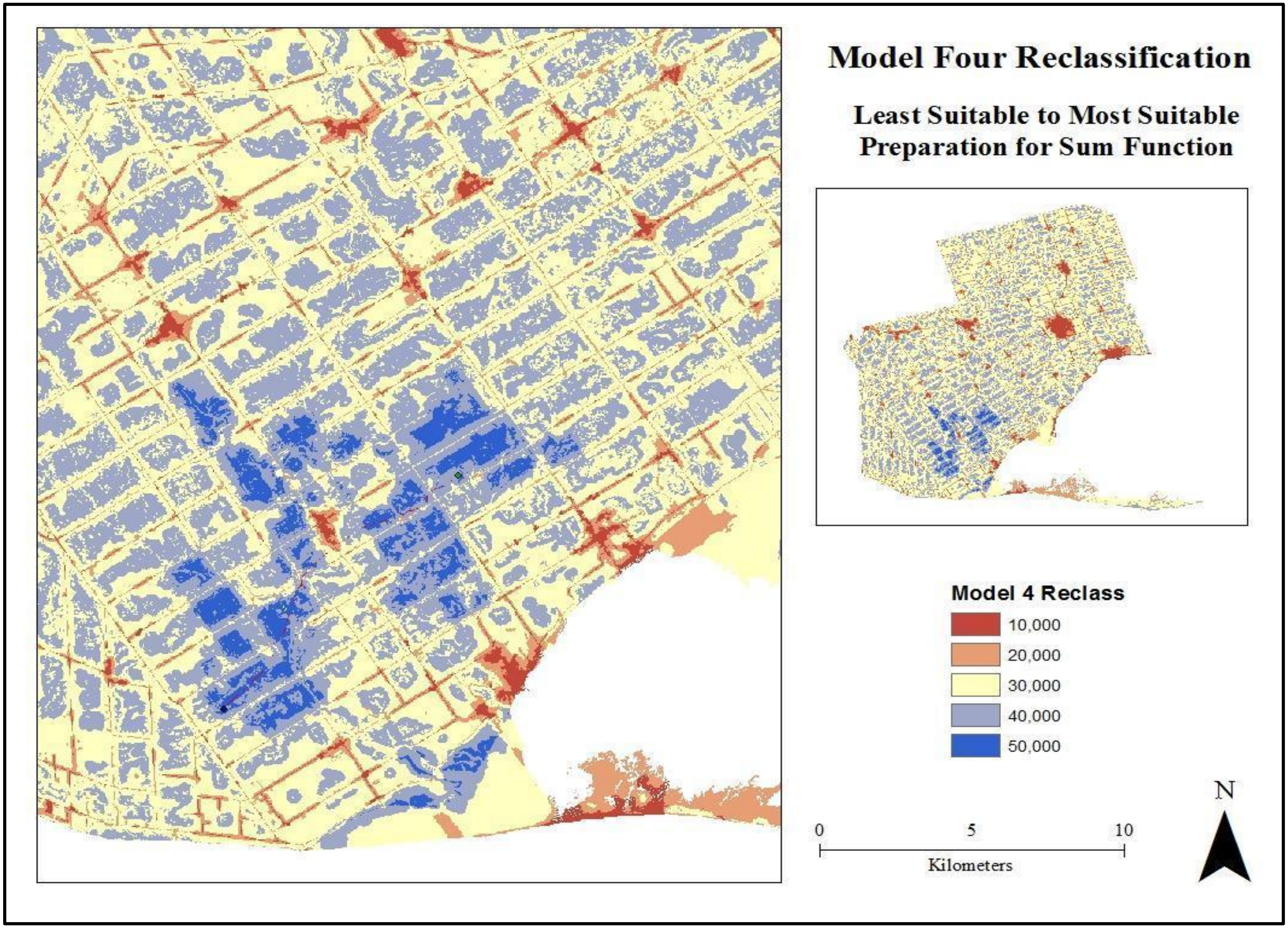


Figure 33. Map illustrating the reclassification of pixel values in Model 4. 10,000 least suitable, 50,000, most suitable.

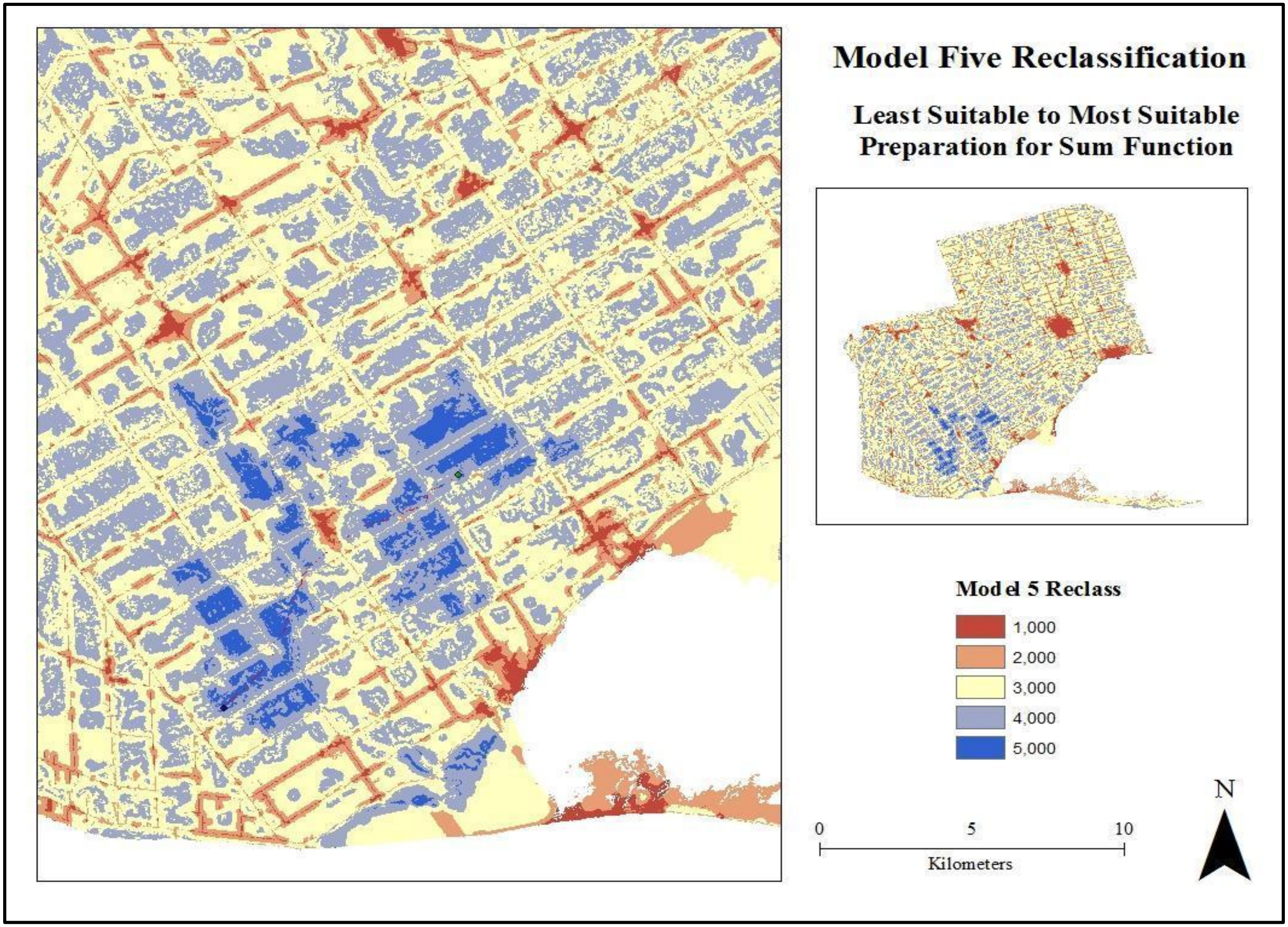


Figure 34. Map illustrating the reclassification of pixel values in Model 5. 1000 least suitable, 5000, most suitable.

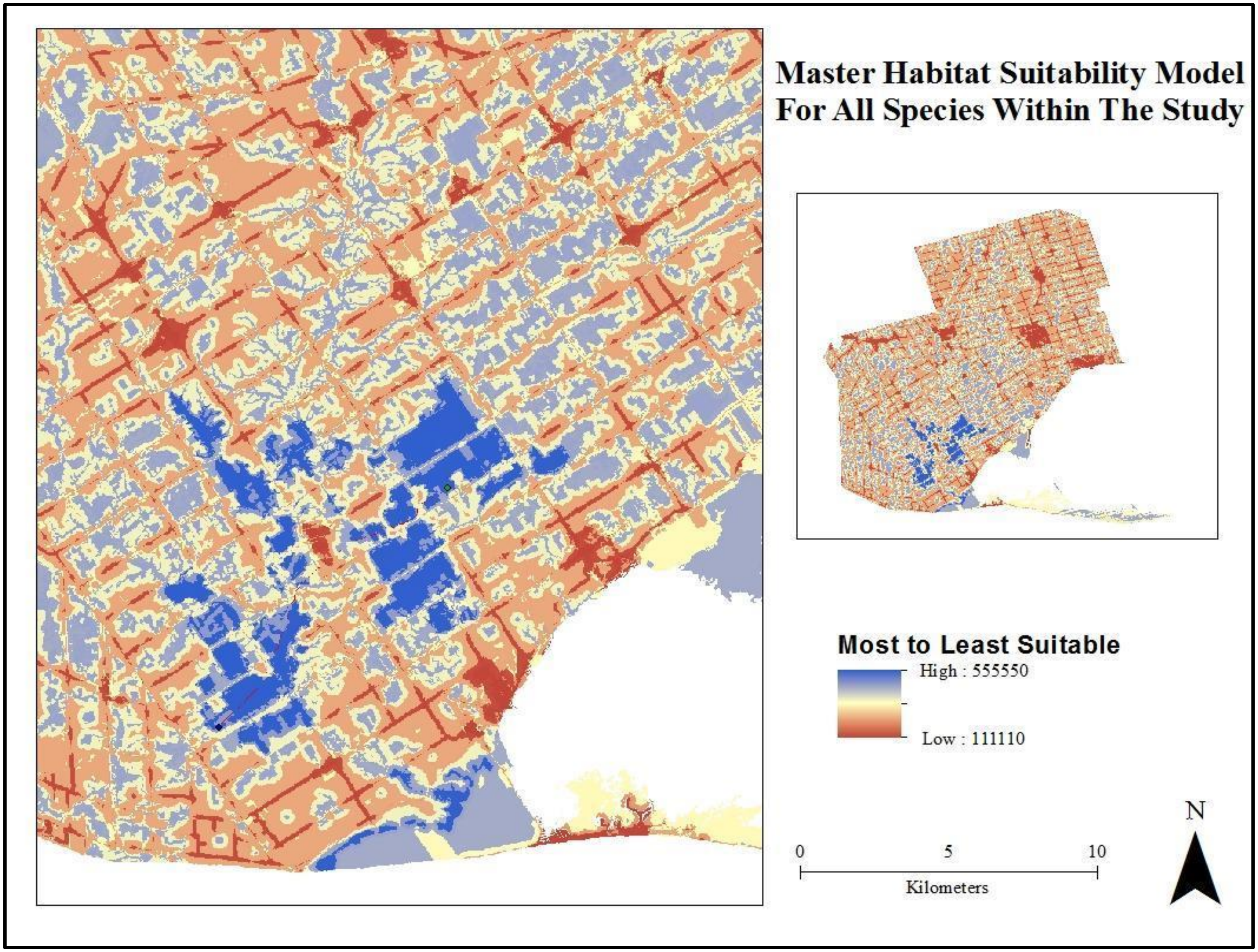


Figure 35. Map illustrating the reclassified pixel values in Model 1-5 summed in the raster calculator to develop the "Master Habitat Suitability Model.: 111,110 least suitable, 555,550, most suitable.

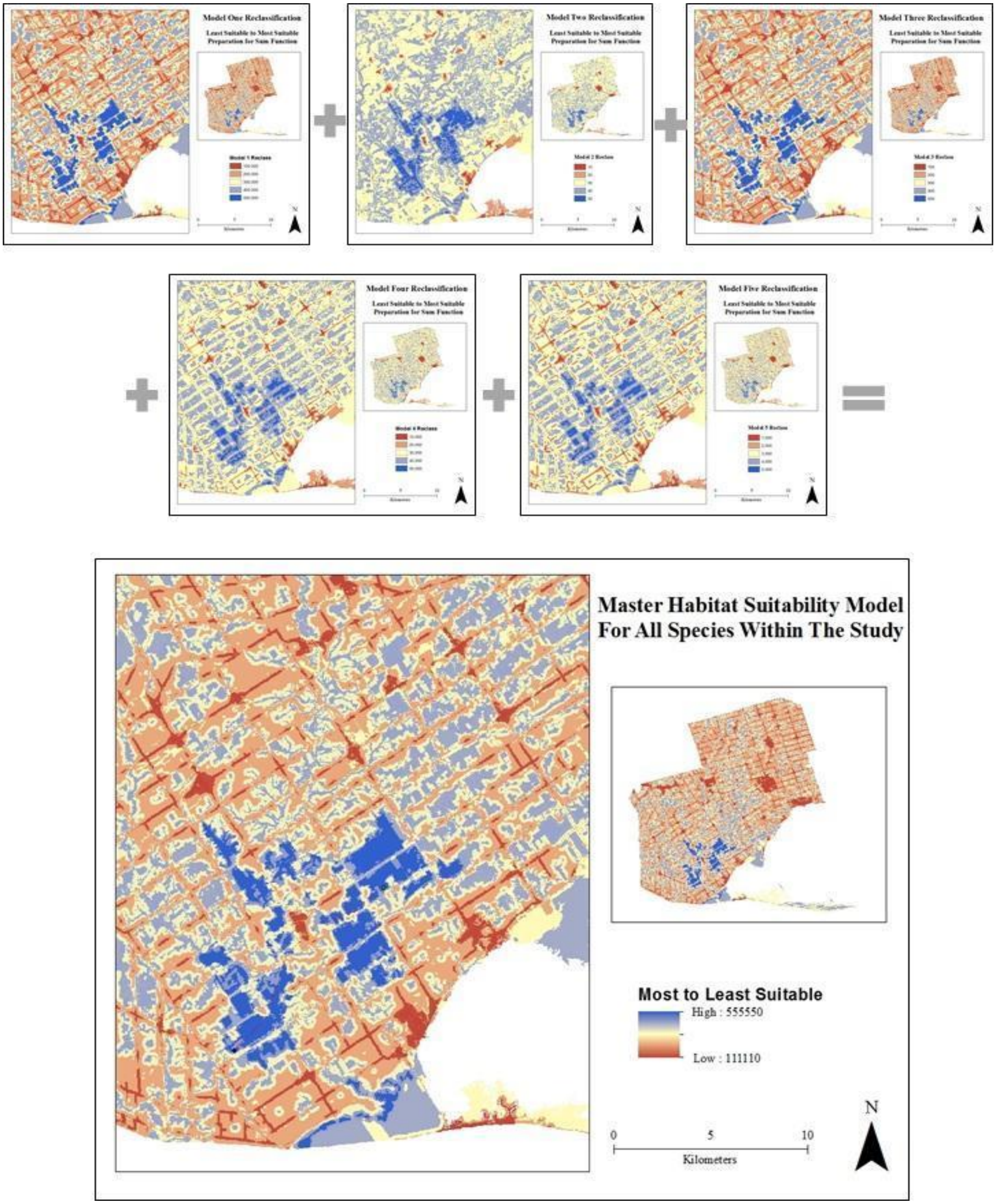


Figure 36. Illustration of the sum function. Models 1-5 were reclassified so that pixels in 11 categories were regrouped and consolidated into 5 categories of suitability. The reclassified models were added together to create one "Master Habitat suitability Map" which identifies pixels representing most to least suitable (555,550-111,110) pollinator habitats after all 5 layers were summed and consolidated.

4.5 Least Cost Path Analysis

Examining the least cost path analysis, the best route to develop tallgrass prairie corridors through, are farms lands, woodlots, and wet-land areas. *Figure 37* and *Figure 38* illustrate that majority of the least-cost path runs through existing conservation areas owned by the NCC (ten sites) and other conservation organizations (five sites). The path also runs through eight properties which are classified as "Significant Natural Areas" under the Provincial Policy Statement, 2005. The eight "Significant Natural Area" lots that the path runs through consist of significant marsh, swamp, bog, deciduous and mixed treed areas. Five other properties are privately owned, four of which are farmland and one which is a rural residential plot. The least cost path analysis also runs through two major road ways, Highway 59 and County Road 60. When developing the tallgrass prairie corridor, plans to mitigate the impacts of roadways and other anthropogenic developments and activities should be considered.

Figure 37. Types of properties included in the least cost path analysis.

NCC Property	Other Conservancy Properties	Privately Owned Properties	Significant Natrural Areas
1,2,7,8,10,19,20,23,24,28	3,6,15,22,25	11,14,16,18,21	4,5,9,12,13,17,26,27

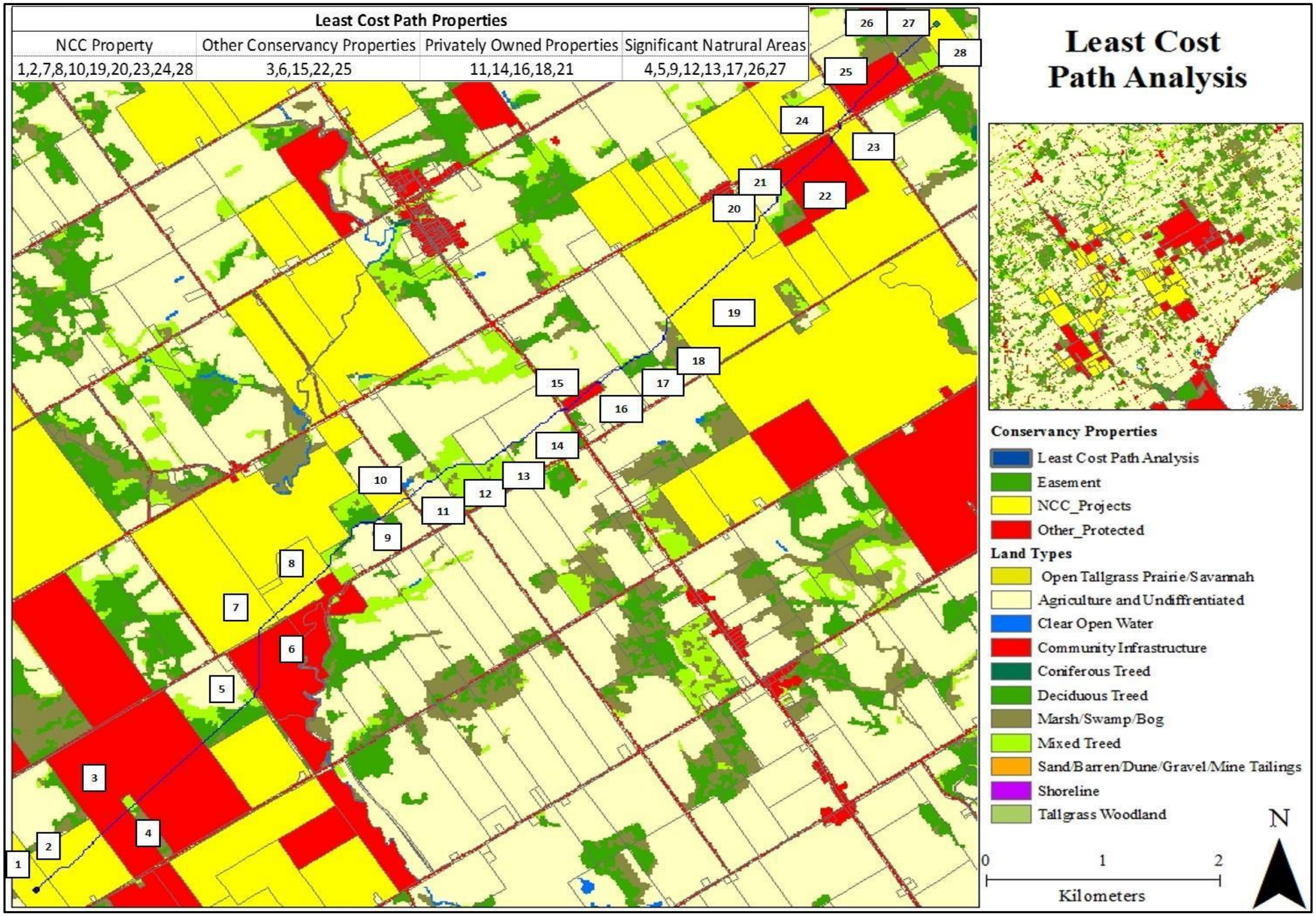


Figure 38. The least cost path analysis identifying the best route for tallgrass prairie corridor development to connect an NCC property in the southwest to a NCC property in the northeast corner of the map.

CHAPTER FIVE: DISCUSSION

5.1 Farming Properties- Least Cost Path

Majority of the least cost path runs through existing natural areas and conserved spaces, but five properties are farmland used for agricultural purposes: lot 11, 14, 16, 18 and 21, (*Figures 11* and *12)*. It will be the duty of the NCC to partner with Norfolk County land owners where the corridor runs through private property. Each of the private farmland properties are considered below.

5.1.1 Lot 11

The least cost path runs through lot 11 but the path could be moved higher on lot 11 so that the path would run through "clear open water" and "marsh/swamp/bog" land types without interrupting farming activities. Wetlands are important to larger species such as the Louisiana waterthrush and Prothonotary warbler. However, it is also extremely important for the well-being of small invertebrate species like the Rusty-patched Bumble-bee, Karner Blue and Monarch butterfly. The wetland area on lot 11 is surrounded by a thin outline of trees which leave the space exposed to sunlight for most of the year. Unshaded areas in wetland habitats tend to flower through the entirety of spring, summer and autumn, providing resources for many pollinators (Buglife, 2011). While open spaces in direct sunlight can be beneficial to the growth of a variety of plants required by several species, summer heat can be unbearable and deadly. Shaded areas are crucial for providing shelter and refuge from harsh environmental factors. Fortunately, the unshaded wetland area on lot 11 is directly adjacent to a wood lot. If the least cost path ran around the exterior of the wetland and into the woodlot, lot 11 would encompass the requirements for a suitable pathway and habitable space.

5.1.2 Lot 14

The path runs through the middle of lot 14 where there is very limited natural space available. The current proposed tallgrass prairie corridor would divide this property through the centre which would cost farmers productive farmland and impede their farming activities while reducing farming profit. For the time being, the NCC could negotiate moving the least cost path to the bottom of lot 14 so that it would eventually connect with the small woodlot located on the right bottom corner of this lot. Of course, this option would require that the path be moved closer to Highway 59, which would reduce species habitation, mobility and survival. Nevertheless, it is extremely important to include lot 14 in the development of the tallgrass prairie corridor because the exclusion of this space would reduce connectivity between conservancy properties and natural areas. Since lot 14 is the property which would cause the most difficulty in the implementation of the tallgrass prairie pathway, the NCC should prioritize acquiring this lot if the opportunity should arise.

5.1.3 Lot 16

A small portion of lot 16 contains a protected site owned by a conservation organization other than the NCC. The remainder of the lot is predominantly farmland. According to the land classifications (*Figure 38*) and google image (*Figure 39*), the lot is mowed and planted with crop rows on either side of the conservation site. While the lot is shown as one large and continuous property in Figure 38, the site where the conservation property exists divides the space into two sections separating the top and bottom half (*Figure 39*). Ideally, the NCC would partner with farmers and the owners of the conservation site on lot 16 to develop an extension of the conserved space.

5.1.4 Lot 18

Lot 18 is similar to lot 11 in that there are natural boundaries around the entirety of the property. Instead of the least cost path running through farmland, as depicted in *Figure 40*, the path should act as an extension or buffer around the "marsh/swamp/bog," "mixed treed" and "deciduous treed" land categories existing on lot 18. While farmers may be concerned with the loss of valuable field space for crop production, "crops planted within 20 feet or more of an abrupt woodland edge often grow poorly because adjacent tree roots out-compete crops for moisture" (Judd, Schwartz, Peterson, & Elliot, 2018). On lot 18, the development of woodland edges will be used for corridor development and provide wildlife habitat with little to no crop loss. The perimeter area used for the corridor development will remain uncultivated and unmown till the end of autumn when wildlife has migrated (Quinlan, 2005).

Wildlife corridors do not need to be exceptionally wide and a corridor width of approximately 3m should suffice (Nhijhuis, 2017; CWF, 2018). Minimal space is required for prairie development and connectivity of pathways can be easily maintained (Nhijhuis, 2017; CWF, 2018) to allow species movement, protect wildlife and reduce the possibility of intermittent threats (Nhijhuis, 2017). Of course, some species like the Louisiana Waterthrush (Robbins, 1979) and Acadian flycatcher (Woolfenden & Stutchbury, 2004) require larger spaces to reside within, however, narrow passages still function as transitionary routes and encourage safe movement between habitats (de Lima and Gascon, 1999; Nhijhuis, 2017; CWF, 2018). Thus, the dividing boundary between farms on lot 18 should be transformed into a tallgrass passageway connecting the conservation property and the tree lot to the right.

5.1.5 Lot 21

The least cost path model places high importance on treed/natural spaces and the low cost of farming properties. The proposed path most often runs along wooded edges located on farming properties which connect to large expanses of forest. Spaces meeting this specific criterion are ideal for the development of the tall grass prairie corridor. They are low cost, transitionary spaces, progressing into mature natural areas, and provide a variety of habitat elements useful for a diverse range of species. Lot 21 is similar to lots 11, 14, 16 and 18, in that it is categorized as "Agricultural and Undifferentiated Land" but differs since it is actually comprised of several rural residential properties. The lot mainly consists of residential properties and sporadically growing deciduous trees (*Figure 40*). Lot 21 contains a wooded area at the southern end of the property, but the path does not run along the forest edge and does not follow the trend set according to the model criteria. The path runs through a small wetland area, connects to the deciduous trees through the residential properties, and then to the woodlot on the upper right-hand corner. While this may be the most cost-efficient way to develop the path, it is not the most ecologically viable and sustainable option. The easiest and most effective solution to connect the path from lot 21 to lot 22 is to run the corridor on the edge of the woodlot existing on lot 21.

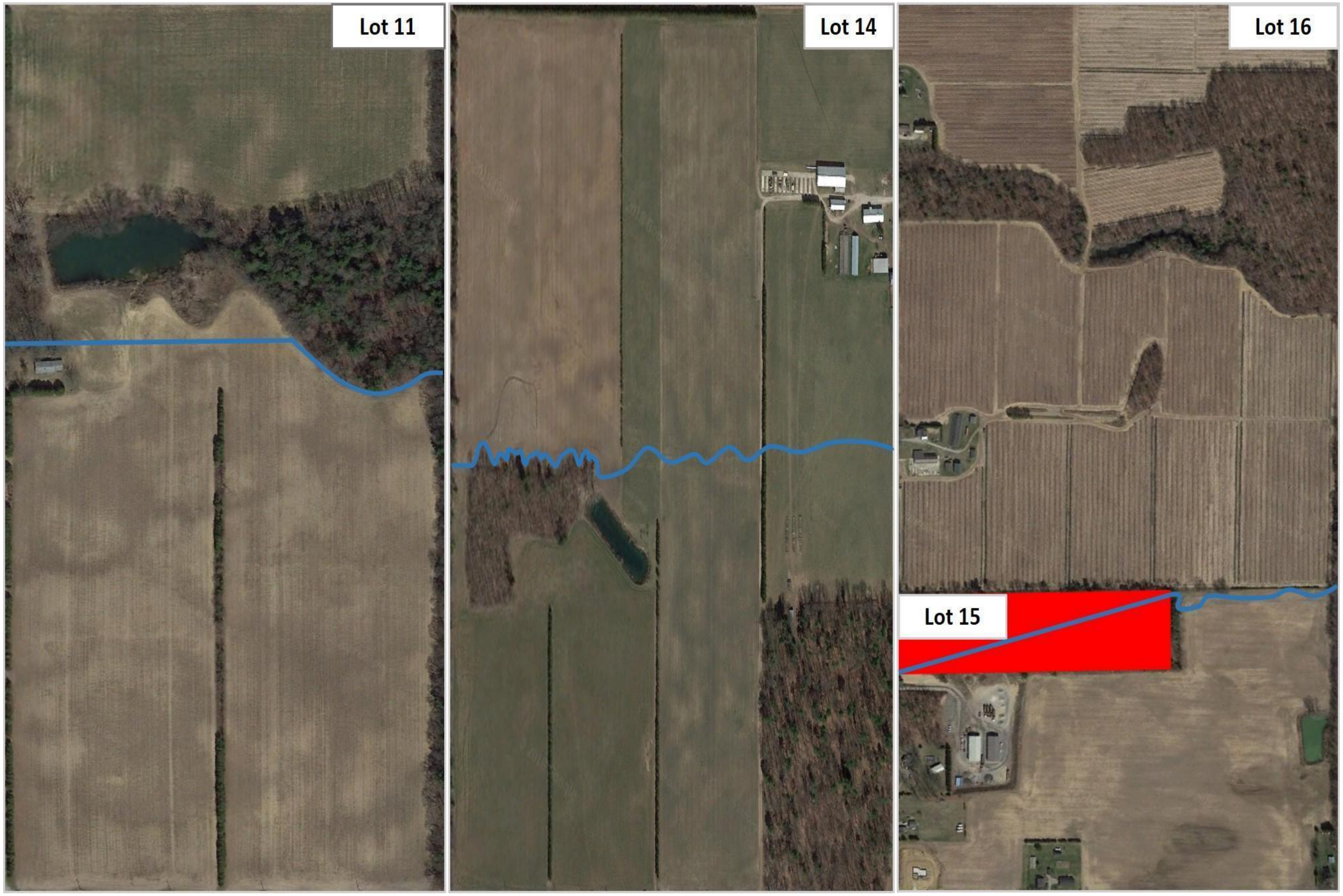


Figure 39. Lots 11, 14, 16 Google Earth View illustrating the route of the Least Cost Path (blue line) on private agricultural/residential properties.

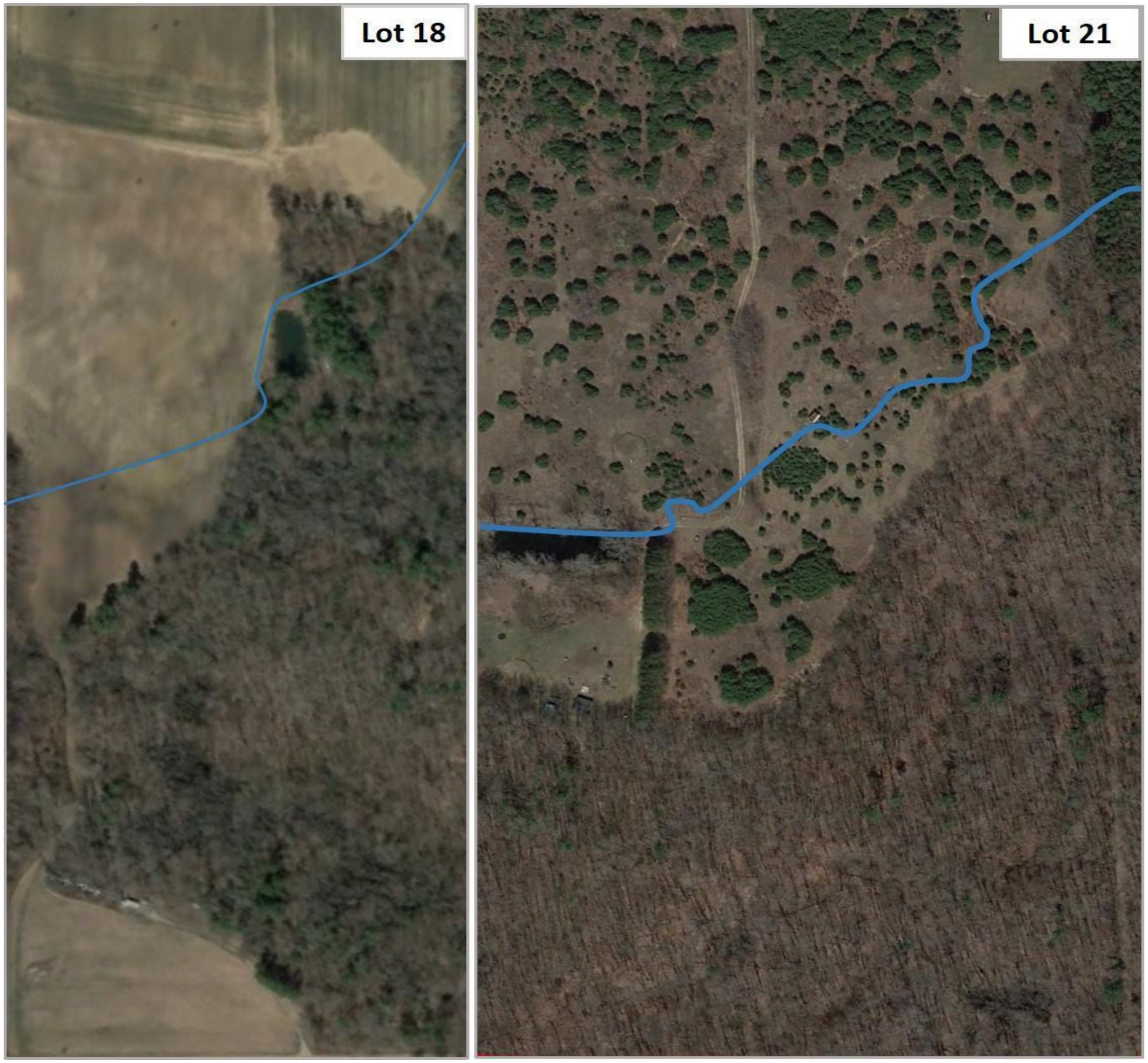


Figure 40. Lots 18 and 21 Google Earth View illustrating the route of the Least Cost Path (blue line) on private agricultural/residential properties.

5.2 Significant Areas- Least Cost Path

The least cost path analysis runs through 8 properties (lot: 4, 5, 9, 12, 13, 17, 26, 27) which are termed "Significant Natural Areas," according to the Ontario Ministry of Natural Resources Provincial Policy Statement, 2005. These sites are protected under the policy and development on significant wetlands, woodlands and natural areas are not permitted under section 2.1.4. Site alterations are not permitted on land classified as significant, nor on adjacent lands unless it can be "demonstrated that there will be no negative impacts on the natural features or their ecological function" (OMNR, 2010, p.6). The policy aims to maintain and restore significant natural area vegetative buffers with the planting of native plant species (OMNR, 2010). Fittingly, tallgrass prairie ecological corridors specifically function to meet policy objectives by providing essential buffers to "Significant Natural Areas." Tallgrass prairie corridors contribute towards restoring lost habitat and developing habitat linkage using native plant species.

5.3 Hard and Soft Edges

The prairie corridors will soften hard edges between two or more land use types and act as buffers separating built up areas from natural features. Borders created by farming and human development create hard edges between two or more land cover types. This limits permeability or movement of species from one land cover type, to another (Larrivee, Drapeau & Fahrig, 2005). Tallgrass prairie ecological corridors can improve hard-edged landscapes by creating transitionary soft edged habitats. Corridors buffering significant natural areas, conservation sites and farmlands provide transitionary habitats which resemble more naturally induced edges (Larrivee, Drapeau & Fahrig, 2005). These edge habitats encourage varying stages of succession to occur between differing land type margins and allow a mixture of ecological features to come together to create a more heterogeneous landscape.

Tallgrass prairie corridors will create a gradual transition between forests and fields consisting of small plants, trees and shrubbery (Judd, Schwartz, Peterson, & Elliot, 2018). Diversity of vegetative phases within prairie habitats and between prairie and boundary habitats, benefits several species. Within this study, edge habitats are required by several species including the Rusty-patched Bumble-bee, Bobolink, Prairie warbler, Eastern meadowlark, Karner Blue butterfly and Monarch butterfly in Models 2, 4 and 5. Species are dependent on a mixture of resources which can only be provided by the assorted composition of soft edged habitats. For example, the Bobolink may benefit from the meadow-like qualities of tallgrass (McCracken et al., 2013), Karner Blue and Monarch butterflies make use of spaces containing successional thicket (Mitchell & Carnes, 2018) and Acadian flycatchers will inhabit tallgrass woodlands (McCracken et al., 2013; Wood et al., 2013). The mixture of natural features provided by tallgrass prairie edge habitats will contribute to a more dynamic edge ecosystems, thereby improving heterogeneity of species residing within these diverse spaces (NFR, n.a).

5.4 Developing and Maintaining the Tallgrass Prairie Corridor

Tallgrass prairie is composed of a rich diversity of plants and forbs and its growth is controlled by three non-biological stresses: climate, fire, and grazing. To ensure natural processes can take their course, prairie habitats need to be composed of a 50:50 grass to forb ration (Packard & Mutel, 2018). Areas containing too much grass may become dense and limit wildflower growth whereas areas without enough grass may not comprise enough kindling to burn properly (Tallgrass Ontario, 2018). A 50:50 ration allows for a diverse array of wildflowers to bloom throughout the seasons and dry grasses encourage grazing and the ignition of wild fires to cut down woody debris and limit succession (Hickson, 2014; Packard & Mutel, 2018).

Grazing and fires remove dead grasses, non-native plants and return nutrients to soil (Hickson, 2014) however, the requirement of burn periods can unsettle residents and landowners.

To ensure the growth and upkeep of the tallgrass prairie corridors, landowners, especially where the corridor runs through private property, must agree to partner with the NCC to manage and maintain the corridor developments. Fortunately, the NCC already has an extensive management strategy in place for prescribed burns which should contribute to the development of promising partnerships between landowners and the conservation organization. Prior to the burn, Operation Prescribed Burn Plans are developed which include prescription parameters, burn unit preparation, ignition plans, smoke management plans, personnel equipment, tool and personal protective equipment, contingency plans, burning permits and communication plans (NCC, 2018). After each burn, assessments are carried out to measure the characteristics of the burn, severity and direct influence on biodiversity so that management goals and objectives can continuously be improved and updated (NCC, 2018).

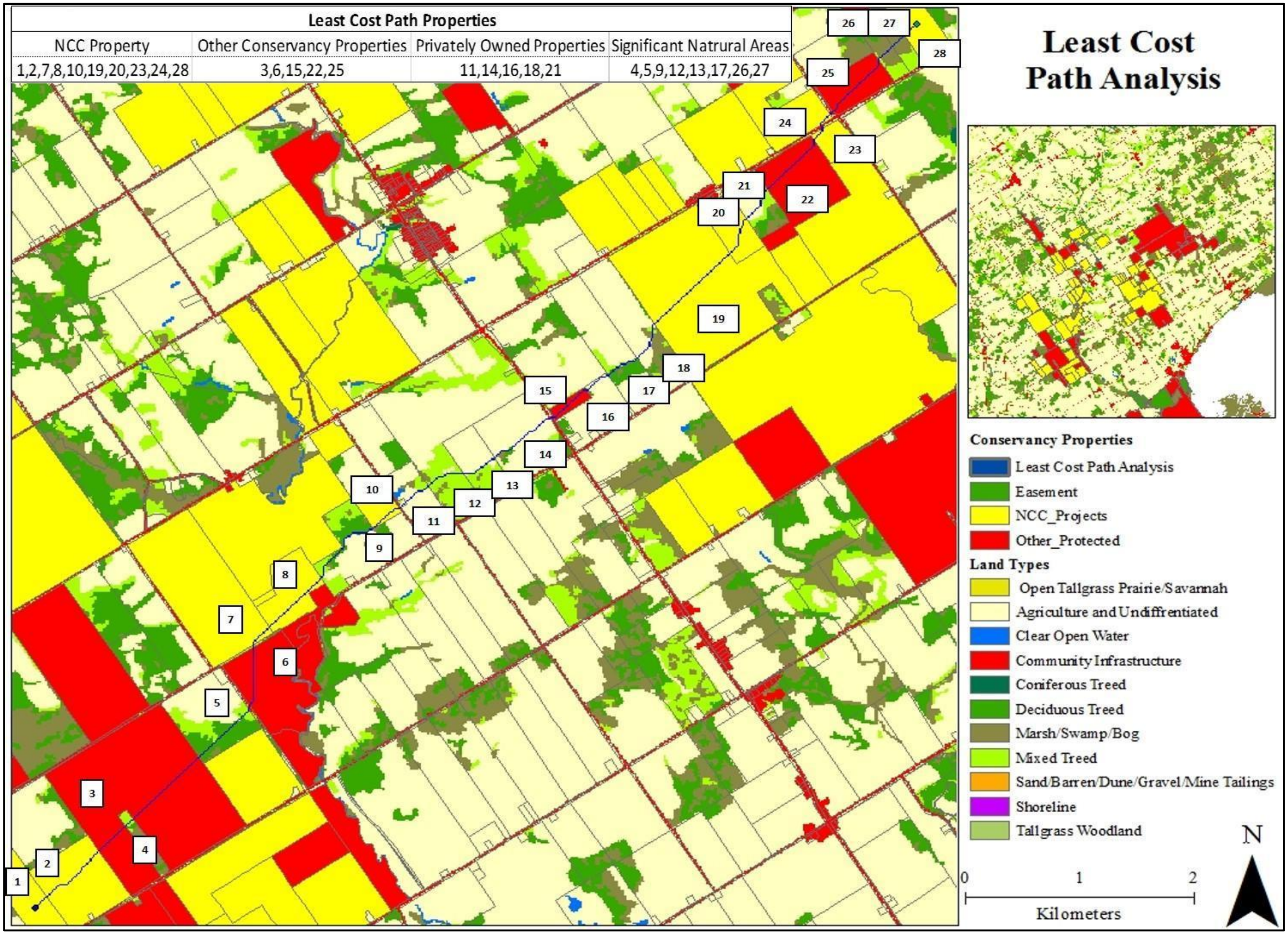
Grazing is also an important management component attributed to the growth and maintenance of tallgrass prairie. Historically, grazing was carried out by bison but European settlement eliminated majority of the bison population and replaced it with cattle which met settler's agricultural and dietary requirements (Hickson, 2014). Today, cattle can carry out the same function as bison and unite historical grazing requirements for tallgrass prairie maintenance and current agricultural land use practices (Hickson, 2014). Tallgrass corridors and buffer strips can be established for the purposes of delayed forage and rotational grazing which would afford farmers an array of benefits. Prairie developments and buffers can be managed through rotational grazing which allow lands to rest and recover between periods of foraging. During periods of rest, prairie systems are less stressed, able to rebuild plant shoots and deepen roots (Beetz & Reinhart, 2010) contributing to the reduction of soil erosion.

Rotational grazing can help cattle and livestock meet their energy and nutritional requirements without supplemental foods often requisite in continuous grazing systems (Undersander, Albert, Cosgrove, Johnson & Peterson, 2002). Reduced costs to feed and supplements lower costs for the maintenance of livestock and increase net farmer income per unit of livestock. Conversely, rotational farming can cause Ruminal Typany, more commonly known as bloat, in ruminants consuming plants with foam producing compounds (Sullivan, DeClue, Emmick, 2000) typically found in prairie grasses. Fortunately, an easy solution is available which not only eliminates bloating but increases fertilization of the lands. By planting tall grass prairie corridors with 40% legumes, concerns over Ruminal Typany become reduced (Barnhart & Moore, 1998) along with fertilization costs. Commercial nitrogen fertilization becomes unnecessary since legumes are able to provide nitrogen for themselves and surrounding plants (Bertsten et al., 2006). Grazing cattle and livestock release the nitrogen into pastures through manure and return nutrients to the land (Bertsten et al., 2006). This process can reduce nutrient over loading in farmlands and waterways and can be completed with on farm resources which reduces costs by decreasing or eliminating the requirement to purchase fertilizers.

CHAPTER SIX: SUMMARY REPORT

Tallgrass prairie corridor developments are easily grown habitats, requiring little space (3m width) and are essential for the survival and habitation of several at-risk species. There are numerous benefits to growing prairie developments including but not limited to: reductions in the cost for livestock feed and pollination services, stronger root development resulting in fertile and productive soils, buffered properties less likely to be impacted by erosion, reduced pesticide and fertilizer runoff in waterways, and environmental connectivity which improves biodiversity and wildlife movement. Connectivity of habitats will encourage wildlife movement, habitation, species access to various resources, mates and nesting grounds (Semlitsch & Bodie, 2003). Improved connectivity will progress landscape heterogeneity, (Levin, 1974); Potts et al., 2010; Van Geert, Triest & Van Rossum., 2014) ideally intensifying species biodiversity.

A variety of ten at-risk species were selected for the study using the "Species at Risk Ontario" list. The representative diversity in species within this study increases the likelihood of species richness and increases the ability to conserve and restore habitats of more than one species at a time (Dufrene and Legendre, 1997). Habitat requirements for each of the identified species was collected and recorded and species with common habitat requirements were grouped. Using Geographic Information Systems (GIS)-based Multi-Criteria Evaluation (MCE), attribute layers were weighted according to their relative importance and combined to create the Master Habitat Suitability Map. The Master Habitat Suitability Map provides a non-numerical index for habitat suitability for all at-risk species within all five models. The Master Habitat Suitability Map was then combined with the Land Cost Layer to form the cost surface used to perform a least-cost path analysis to find the optimal corridor connecting adjacent NCC owned sites. (See figure below).



Least Cost Path Properties			
NCC Property	Other Conservancy Properties	Privately Owned Properties	Significant Natrural Areas
1,2,7,8,10,19,20,23,24,28	3,6,15,22,25	11,14,16,18,21	4,5,9,12,13,17,26,27

The least cost path analysis joining the two NCC sites runs through 28 different properties. Of those 28 properties, 15 are conservancy sites, 10 of which are currently managed by the NCC. 8 properties are classified as "Significant Natural Areas" and under the 2005 Provincial Policy Statement; no one is permitted to alter these lands or the lands adjacent to these properties. The policy aims to maintain and restore significant natural area vegetative buffers with the planting of native plant species such as tallgrass prairie. Lastly, 5 properties are considered agricultural land and it will be the duty of the NCC to partner with Norfolk County land owners where the corridor runs through private property.

Presently, the data provided in this document will serve to act as guidelines on which areas will best support the habitation and movement of at-risk species. If the proposed corridor runs through farmland, an attempt should be made to inform property owners on the importance of wildlife, the requirement of tallgrass prairie corridors, and property owner's importance in collaborating with organizations protecting the land. The long-term goal is to provide Norfolk County and the NCC with crucial information on the best methods for developing tallgrass prairie corridors, and identifying which properties suit the needs of the species. The NCC will procure identified land for the corridors, and partner with land owners where the corridors run through private property.

Next steps and future research:

- Research which prairie plants should be incorporated into the corridor. Plants and shrubs can be heavily dependent on the environments they are grown in such as soil, sun exposure, slope and terrain. Thus, it is important to select plant species based on surrounding environmental factors.

- Research which variety of plants would best suit the needs for the wildlife identified in this document and other species requiring prairie habitats.
- Create a funding model to determine which types of prairie plants can be purchased according to a set budget. Costs for prairie plant seeds vary significantly and a financial plan should be outlined to determine costs pertaining to seeds, site preparation and prairie management.
- Monitor the effectiveness of the corridor and assess the importance and feasibility of developing additional corridor systems within this document where restoration initiatives could be focused upon.

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