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Revising a Habitat Suitability Model for Spotted Turtles (Clemmys guttata) in Upstate New York

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Revising a Habitat Suitability Model for Spotted Turtles (*Clemmys guttata*) in Upstate New York

by

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Abstract

In order to protect threatened and endangered species, their habitat needs to be adequately documented and assessed for conservation planning. The utilization of mapping programs such as ArcGIS can help researchers in determining the most optimal sites for a particular species in a given area. This research revises a previous habitat suitability model by Correa-Berger (2007) for the spotted turtle (*Clemmys guttata*) in nine counties of upstate New York. Using the same initial parameters for the creation of the seed sites and habitat requirements for spotted turtles that Correa-Berger used in his 2007 analysis, the model utilized updated Land Use/Land Cover (LULC) data, added a stream connectivity parameter, and added a calcium carbonate soil parameter in order to improve the model. The initial updated model did not fit well with the historical spotted turtle sightings from the NYSDEC. A second model was created using a simplified seed site methodology, an adjusted road width parameter, and eliminated the use of the DEC classified wetlands. The revised model captured 16 out of 33 turtle sightings within what was considered optimal sites. While the second model was more successful matching the historical spotted turtle sightings compared to the first model, analysis of model misses suggest the model could potentially be improved with the use of a locally created LULC classification using remote sensing techniques, expanding the stream connectivity parameters to include stream health, and using additional soil parameters.

Acknowledgements

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Introduction

Species throughout the world have suffered declines and extinction due to human influences such as habitat change and degradation, pollution, introduction of invasive species, and overfishing (Didham *et al.,* 2007; Gibbons *et al.,* 2000; Lesbarrères *et al.,* 2014; Payne *et al.,* 2013; Kleisner *et al.,* 2013). One group of animals suffering from declines are turtles (Gibbons *et al.,* 2000; Lesbarrères *et al.,* 2014). Approximately half of all turtle species are listed as threatened by the International Union for the Conservation of Nature (van Dijk, 2013). Habitat change, fragmentation, road mortality, and climate change are some of the major stresses linked to anthropogenic activities impacting turtle populations (Gibbons *et al.,* 2000; Gibbs & Shriver, 2002; Milam & Melvin, 2001; Millar & Blouin-Demers, 2012; Lesbarrères *et al.,* 2014).

Turtles and tortoises, which comprise the order *Testudines*, are important to their respective ecosystems as predators and prey. Some species of turtles and tortoises are also keystone species that are essential to an ecosystem, such as the Gopher Tortoise (*Gopherus polyphemus*). This tortoise creates and maintains burrows that provide habitat for many other species in its ecosystem (Witz *et al.,* 1991). Gopher Tortoises, as well as Desert Tortoises (*Gopherus agassizii*), also aid in soil formation from the creation of burrows, changing soil composition (Ernst & Lovich, 2009). Most turtle species that lay their eggs on land also aid in soil formation by disturbing the soil through the creation of a nest cavity (Ernst & Lovich, 2009). By creating nest cavities, turtles influence the hydrology of the area by creating depressions, mix soils when creating the cavity, and add organic material to the soil when adding nesting material. Old nests can even be used as shelter by other organisms. Other species of turtles aid in seed distribution such as the Florida Box Turtle (*Terrapene carolina bauri*), the Black River Turtle (*Rhinoclemmys funerea*), the Brown Wood Turtle (*Rhinoclemmys annulata*), and the Northern Diamondback Terrapin (*Malaclemys terrapin terrapin*) (Moll & Jansen, 1995; Liu *et al.*, 2004; Tulipani & Lipcius, 2014).

According to the New York State Department of Conservation (NYSDEC), 7 of the 11 native aquatic and land turtle species in New York State are endangered, threatened, or of special concern (NYSDEC, 2007; Breisch & Behler, 2002). One turtle species of special concern in New York is the spotted turtle (*Clemmys guttata*). Spotted turtles are located in eastern North America, from Ontario, Canada in the north to Florida in the south and are considered endangered overall (van Dijk, 2013). Like other turtle species, the spotted turtle faces population decline due to habitat change including wetland drainage, habitat fragmentation, road mortality, and the additional factor of collection for the pet industry (Ernst & Lovich, 2009; Gibbs *et al.,* 2007; Gibbs & Shriver, 2002; Lewis *et al*., 2004; Milam & Melvin, 2001; Millar & Blouin-Demers, 2012). Spotted turtles rely on multiple habitat types and must have an aquatic environment to secure food and keep hydrated as well as a terrestrial environment for nesting in both northern and southern climates (Litzgus & Brooks, 2000; Litzgus & Mousseau, 2004; Milam & Melvin, 2001; Steen *et al.*, 2012; Stevenson *et al*., 2015; Yagi & Litzgus, 2012).

Spotted turtles are omnivorous and scavengers, eating a wide range of plants and animals that are both terrestrial and aquatic. They have been documented eating both terrestrial and aquatic grasses, wild cranberries, leaves and seeds of higher plants, annelid worms, filamentous algae, terrestrial and aquatic insects, amphibians, small crustaceans, slugs and snails, and carrion such as dead ducks and fish (Ernst, 1976; Ernst & Lovich, 2009). Their varied diet is important in gaining sufficient minerals that turtles in general need in order to survive including calcium for their shells (Clark & Gibbons, 1969; Gilbert *et al.,* 2001; Kienzle *et al.,* 2006;). Spotted turtles have predators when they are both adults and as eggs. As adults, spotted turtles are prey for raccoons, crows, and coyotes, while their eggs are prey for raccoons, otters, skunks, foxes, feral dogs and cats, muskrats, snapping turtles, water snakes, large wading birds, and crows (Ernst, 1976; Ernst & Lovich, 2009; Gibbs et al., 2007). They also face threats from grass mowers as well (Ernst, 1976; Ernst & Lovich, 2009).

Spotted turtles use a variety of different habitats which depend on their location within their extensive range along the east coast. In the southern part of their range, spotted turtles have been documented using restored wetlands, vernal pools, blackwater creek swamps, river swamps, depressional wetlands, tidal wetlands, upland hardwood/pine forests, clear cuts, and even power line right-of-ways and ditches (Litzgus & Mousseau, 2004; Stevenson *et al.,* 2015). In the more northern reaches of their range, spotted turtles have been documented using wet meadows/cattail marshes, seasonal pools, upland forests, ponds, sphagnum swamps, shallow bays, emergent wetland, forested wetland, open upland, grass-sedge-rush, rock outcrops, and scrub shrub (Anthonysamy *et al.,* 2014; Joyal *et al.,* 2001; Litzgus & Brooks, 2000; Milam & Melvin, 2001; Rowe *et al.,* 2013).

Evidence suggests that populations of spotted turtles use a network of wetlands as far apart as 100 meters, and as small as 0.4 hectares in size. This suggests that spotted turtles do not limit themselves to one wetland and may use multiple, smaller wetlands to meet their needs (Joyal *et al.,* 2001). Since spotted turtles are semi-aquatic, they likely use stream networks to travel from one wetland to another, highlighting the importance of stream networks to connect distributed wetlands that could be utilized by spotted turtles. However, smaller interconnected wetlands may not be protected under current conservation management plans or wetland regulations due to their smaller size (Joyal *et al.,* 2001). This illustrates the need to protect not only single large wetlands, but multiple, smaller interconnected wetlands within a landscape.

Spotted turtles also need adequate habitat for life processes with a home range that varies from 0.5 hectares to 16 hectares containing a variety of land covers, with gravid females needing more space and terrestrial areas for nesting than their male counterparts (Ernst, 1976; Litzgus & Mousseau, 2004; Milam & Melvin, 2001). The variability of home ranges is primarily due to landscape composition, habitat quality, habitat change, annual variation in seasonal water levels, and available food resources for the turtles (Anthonysamy *et al.,* 2014; Ernst, 1976; Litzgus & Mousseau, 2004; Milam & Melvin, 2001; Yagi, & Litzgus, 2012). Additionally, in order to nest, spotted turtles need a sunny location with soft substrate that is well drained (Ernst & Lovich, 2009; Gibbs et al., 2007).

Owing in part to the variety of habitats and sizes of home ranges listed by the literature for spotted turtles, it can be difficult to determine, assess, and/or rank which areas should be protected to prevent further decline of this species. Habitat suitability models can be utilized to help address this problem, identifying and assessing a range of optimal habitats based on parameters which are in turn based on the literature of the species of interest and field observations.

Habitat Suitability Models and Conservation

Habitat suitability models (HSMs) are designed to assess and rank the suitability of a particular landscape for one or more organisms, often for conservation purposes. In regards to conservation, HSMs are used to determine where a species may occur in the wild and potentially where to release captive bred or relocated animals to bolster wild populations. They have been created for species all over the world including fish, mammals, birds, reptiles, amphibians, plants, and fungi (Bernal *et al.,* 2015; de Baan *et al.*, 2015; Donovan *et al.*, 1987; Fagundes *et al.,* 2016; Gibbs & Shiver, 2002; Hirzel *et al.,* 2006; Millar & Blouin-Demers, 2012; Reza *et al.,* 2013; Rondinini *et al.,* 2005; Segurado *et al.,* 2012; Store & Jokimäki, 2003). HSMs are created by combining different attributes of a particular species' needs such as home range size, land cover, elevation, water bodies, vegetation, and soil type.

The creation of HSMs are facilitated by using Geographic Information Systems (GIS), a mapping application that can store and display various spatial attributes of a landscape. GIS allows researchers to combine multiple layers of spatial information and select specific features of the landscape in order to form habitat suitability models in a more streamlined process than if done solely by field work. Using GIS does not eliminate field work, but shifts this time and resource intensive task to the validation and verification portions of a project. Habitat suitability models in GIS can be run on a local scale such as on a single wetland or span multiple counties, allowing for habitat suitability models to be applied on both local and regional scale (Bernal *et al.,* 2015; de Baan *et al.,* 2015; Donovan *et al.,* 1987; Hirzel *et al.,* 2006; Millar & Blouin-Demers, 2012; Reza *et al.,* 2013; Rondinini *et al.,* 2005; Segurado *et al.,* 2012; Store & Jokimäki, 2003).

Many studies have used habitat suitability models as tools for conservation and the management of wildlife. For example, de Baan *et al.,* (2015) conducted an assessment of land use impacts on biodiversity by utilizing habitat suitability models developed by the global mammals assessment (GMA), specifically concerning tobacco, coffee, and tea crop production impacts on mammal species in East Africa. The results from the study suggest that endemic areas with low habitat availability were the most negatively affected by the three crops. This is largely because commercial crops are often monocultures, becoming suboptimal habitat for most species. With further research into different crops and more species of concern, conservationists can determine ways to lessen the impact of these commercial crops on biodiversity (de Baan *et al.,* 2015).

Other studies have looked into the effectiveness of protected areas for a particular species. Fagundes *et al.* (2016) discovered the best potential combination of protected lands for 16 semi aquatic and aquatic Amazonian turtles by comparing three different scenarios of protection using species distribution models. Integrating protection areas, sustainable use areas, and indigenous land, all but two of the 16 turtle species were adequately protected (Fagundes *et al.,* 2016). Reza *et al.* (2013) created four separate habitat suitability models for four large mammals for the Malayan Peninsula to determine the suitability of areas for each of the mammals. The researchers then created a composite habitat suitability model of the four separate models to determine the suitability of the study site for all four mammals. These were then compared to established protected areas on the Malayan Peninsula to see if protected areas were optimal habitat for each of the four mammals individually and collectively (Reza *et al.,* 2013). While none of the protected areas were highly optimal for all four species, a few were optimal for the four species individually. This illustrates that a habitat suitability model may not always identify a single optimal area for multiple threatened species and therefore cannot provide a protected area that is optimal for all target species, given current land cover patterns. Instead, multiple protected areas with differing habitat may be needed to adequately protect threatened species. Protecting these large mammal species will also help protect other species that use the same habitat, further illustrating the importance of protecting species that utilize large areas of diverse habitat.

Habitat suitability models are also used to determine areas that are optimal habitats for one or multiple species for conservation purposes. In some cases, the animal in question is an invasive species in which its presence is a hindrance to other species in a particular area. In Bernal *et al.* (2015), a habitat suitability model was created for the Indo-Pacific lionfish (*Pterois volitans*) in Biscayne Bay, where it is an invasive species, in order to potentially predict where this invasive species might be present. When comparing the model to lionfish sightings, the results showed that the sightings did match the model and could be used by ecosystem managers to control this invasive species (Bernal *et al.,* 2015).

Both Graves and Anderson (1987) and Morreale and Gibbons (1986) provided suggestions for habitat suitability models for the snapping turtle (*Chelydra serpentina*) and the slider turtle (*Pseudemys scripta*) while Reza *et al.* (2013) created four separate habitat suitability models for four different large mammals. All three of these studies either provided or suggested models that would show potential habitat for these animals, some which are of conversation concern. Habitat suitability models like the ones mentioned can also be used to predict the presence of a species at certain locations based on habitat requirements (Hirzel *et al.,* 2006).

In New York, conservation efforts to protect or re-introduce threatened species like the spotted turtle are ideally suited for habitat suitability projects. Similar to the previously mentioned HSM studies, a model could be created using habitat preferences of spotted turtles to map out areas within a specific study site that are most likely to contain spotted turtle populations and should be protected. Using a GIS program like ArcGIS Pro, literature information on spotted turtles can be used to create weighted parameters from digital layers based on the percent of habitat used and map optimal habitat for spotted turtles for potential releases of captive breed spotted turtles and predicting wild spotted turtle locations.

For his 2007 Master's thesis, Correa-Berger created a habitat suitability model for spotted turtles for the Monroe, Orleans, Ontario, and Genesee counties of New York. The goal of Correa-Berger's thesis was to develop a habitat suitability model for this locally threatened species that used a diversity of habitat during its life cycle and at the time lacked local habitat information. The spotted turtle was also part of a conservation project organized by Seneca Park Zoo to reintroduce captive breed spotted turtles in the Rochester area (Correa-Berger, 2007). Another separate Master's thesis by Kate Cassim (2006) also looked into the feasibility of re-introducing captive breed spotted turtles into former habitat in the Rochester area.

The goal of this project was to update and improve Correa-Berger's original habitat suitability model and to better match known locations of spotted turtles and identify new areas for releases/introductions of spotted turtles in Upstate New York. Using the information Correa-Berger gathered through his expert survey on spotted turtles and his methods, a new model was created that utilized updated Land Use/Land Cover (LULC) data, additional available soil data, added stream connectivity parameters, and additional research on current information on spotted turtles.

The updated model is hypothesized to be more accurate in determining locations of spotted turtle populations and will better match up with actual spotted turtle sightings compared to the previous model. It is also hypothesized that model hits will be within home ranges containing optimal or near optimal mixes of land cover, as determined by literature review and parameter rankings. Successful model verification would identify potential habitat sites with high rankings for future field surveys to access spotted turtle populations in Upstate New York, as well as for releases/introductions of spotted turtles.

The model will aid in conservation planning for this species in upstate New York by informing researchers of potential habitat to protect for this threatened species. This could potentially lead to the discovery of previously unknown spotted turtle populations, protection of these habitats, monitoring habitat quality for spotted turtles, and for the reintroductions of captive bred or relocated spotted turtles. Considering the large potential home range and diverse habitat use of this species, the conservation of the spotted turtle could potentially protect other species that use these habitats.

Methods

Study Site

The original model that Correa-Berger (2007) developed was only able to map four out of six counties around Rochester, NY because of the lack of digital soil data for Wayne and Livingston counties at that time. With additional digital data coverages and improved remote sensing data and classification algorithms for determining land cover classes, it is now possible to expand the original model to encompass the Nine County Region of Greater Rochester (Homer *et al.,* 2012). The Nine County Region of Greater Rochester encompasses Monroe, Orleans, Ontario, Genesee, Wayne, Livingston, Seneca, Wyoming, and Yates counties (Figure 1). Spotted turtles have historically been found in most of the Nine County Region, although populations have declined in New York State as a whole and mostly likely in the Nine County Region as well (Gibbs *et al.,* 2007).

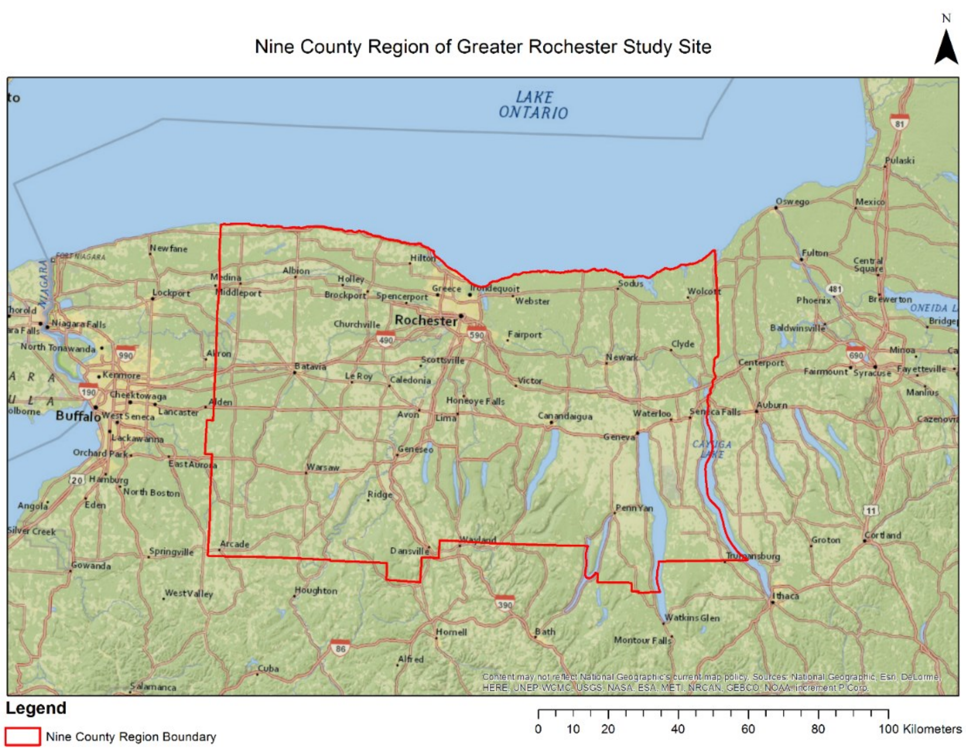


Figure 1: The Nine County Region of Greater Rochester in relation to the State of New York. The study site encompassed the following counties: Monroe, Orleans, Ontario, Genesee, Wayne, Livingston, Seneca, Wyoming, and Yates counties

Seed site Creation and Seed Site Buffer

ArcGIS 10.4.1 was used for this project as well as Microsoft Excel and Access. Over the course of creating the updated model, two versions were created. The first followed Correa-Berger's (2007) original model design for the seed sites. Similar to the original model, seed sites were created in ArcGIS 10.4.1 using the intersect command with hydric soils, Federal classified wetlands, and New York State classified wetlands being the constraints (Figure 2 and 3).

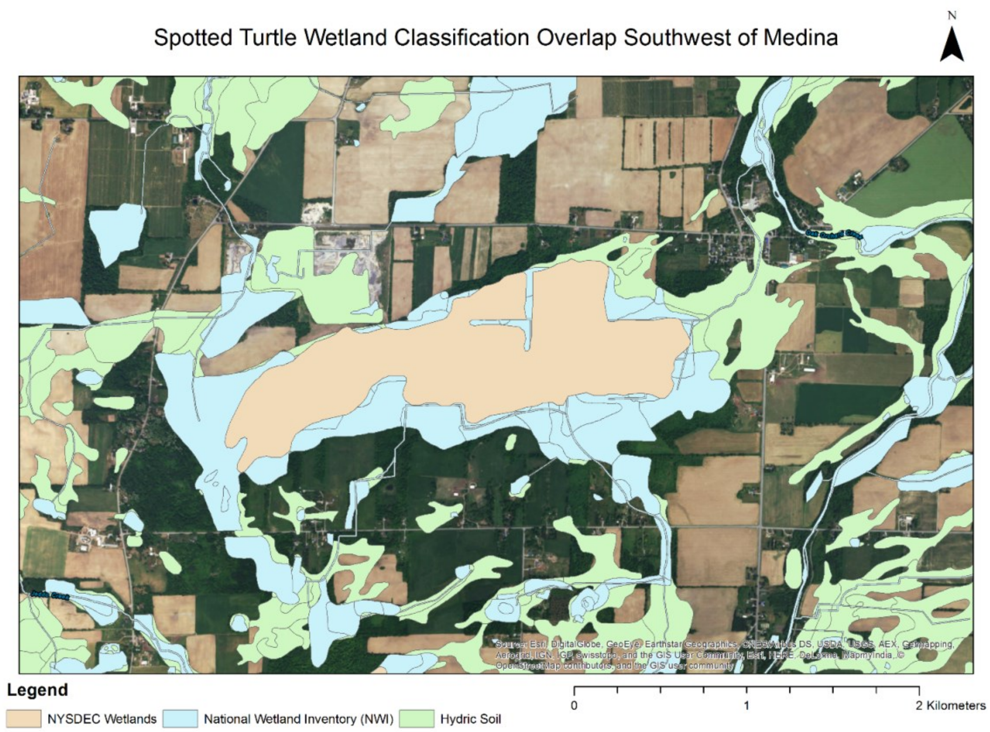


Figure 2: This figure illustrates the Nation Wetland Inventory (NWI) and the Department of Environmental Conservation (DEC) classification of wetlands along with a hydric soils layer. Where the NWI, DEC, and hydric soils overlap would become a seed site.

Seed sites represent potential sites for spotted turtle populations to inhabit based on a few major habitat requirements of the species. The hydric soil layer was acquired from the Geospatial Data Gateway (GDG), the Federal wetland layer was acquired from the National Wetland Inventory (NWI), and the State wetland layer was acquired from CUGIR (gdg.sc.egov.usda.gov; fws.gov/wetlands; fws.gov/wetlands; cugir.mannlib.cornell.edu). The approach here addresses differences in how the Federal (NWI) and State (NYSDEC) classify wetlands. For example, NYSDEC wetland data only map wetlands at least 5 hectares in size, while NWI classifies areas as small as 0.1 hectares as a wetland. The soil layer was added because turtles tend to prefer soft, mucky substrates which would contain a higher amount of organic material compared to other soil types (Ernst & Lovich, 2009; Gibbs *et al.,* 2007; Graves & Anderson, 1987; Joyal et al., 2001; Marchand & Litvaitis, 2004; Milam and Melvin, 2001).

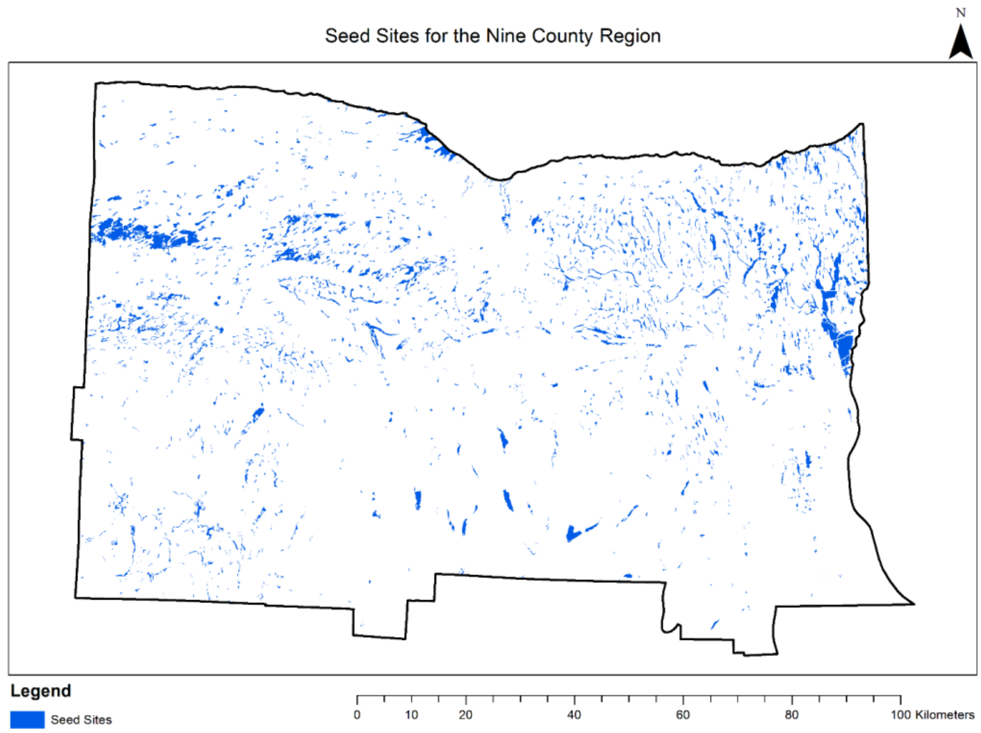


Figure 3: Seed sites for the Nine County Region that were created using the intersect command using NWI, DEC, and hydric soil layers.

Once seed sites were established, buffers were created around them based on reported spotted turtle home ranges. Spotted turtles have variable home ranges from 0.5 hectares to 16 hectares (Ernst, 1976; Litzgus & Mousseau, 2004; Milam & Melvin, 2001). Through the expert survey that he conducted, Correa-Berger (2007) also determined that the spotted turtle home range varied from 1.5 to 30 hectares. Because of this variability, an average minimum home range was determined by averaging the listed home ranges in several literature sources and Correa-Berger's expert survey. The average home range was calculated to be 174 meter buffer or 9.5 hectares around each site. This was then rounded to 178 meters buffer or 10 hectares around each site (Table 1 and Figure 4). The conversion from hectares to meter buffer was based on the geometric formula for the area of a circle. The dissolve command was then used on the potential site home ranges to merge overlapping areas.

Table 1: The original home range values as listed in the literature that were then converted into buffer sizes in meters. The average came out to b 174 meters or 9.5 hectares which was rounded up to 10 hectares or 178 meters for the seed site buffer.

Original value	Literature source	Home range buffer (meters)
0.5 hectares	Ernst, 1976	40
3.5 hectares	Milam & Melvin, 2001	106
5 hectares	Litzgus & Mousseau, 2004	126
16 hectares	Litzgus & Mousseau, 2004	226
100 meters*	Steen et al., 2012	100
200 meters*	Steen et al., 2012	200
20 hectares**	Correa-Berger, 2007	252
30 hectares**	Correa-Berger, 2007	309
30 hectares**	Correa-Berger, 2007	309
1.5 hectares**	Correa-Berger, 2007	69
		Avg. buffer = 174

*Listed as range distance around a wetland

**From expert survey; each entry represents a participant's answer

Roads are a known threat to turtle species with many being hit by cars when they cross to find optimal habitat for life processes, including spotted turtles (Ernst & Lovich, 2009; Gibbs & Shriver, 2002; Millar & Blouin-Demers, 2012). Using a road layer acquired from the GDG, 100 meter buffers were created around all the roads and then erased from the seed site home ranges (Figure 5 and 6). The 100 meter value was used because it was the smallest of the road buffers that Correa-Berger (2007) used in his model, based on his expert survey.

Once the road buffer was cut out of the seed site home ranges, any home range area smaller than 10 hectares was removed from the model. The roads within the study site crossed through many of the original seed site home ranges. Since roads were considered a threat to the spotted turtle and were then removed from the seed site buffer, seed site home ranges were often split into smaller sections and the areas needed recalculating to remain in the model.

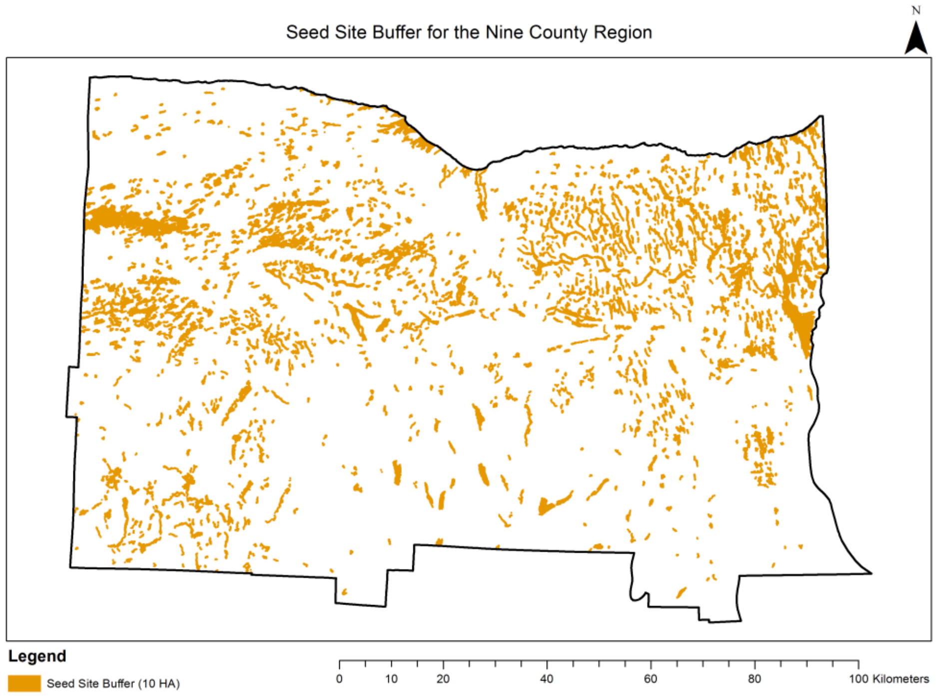


Figure 4: Buffers of 10 HA were made around each seed site. Above the figure shows the buffer areas that would appear around each seed site.

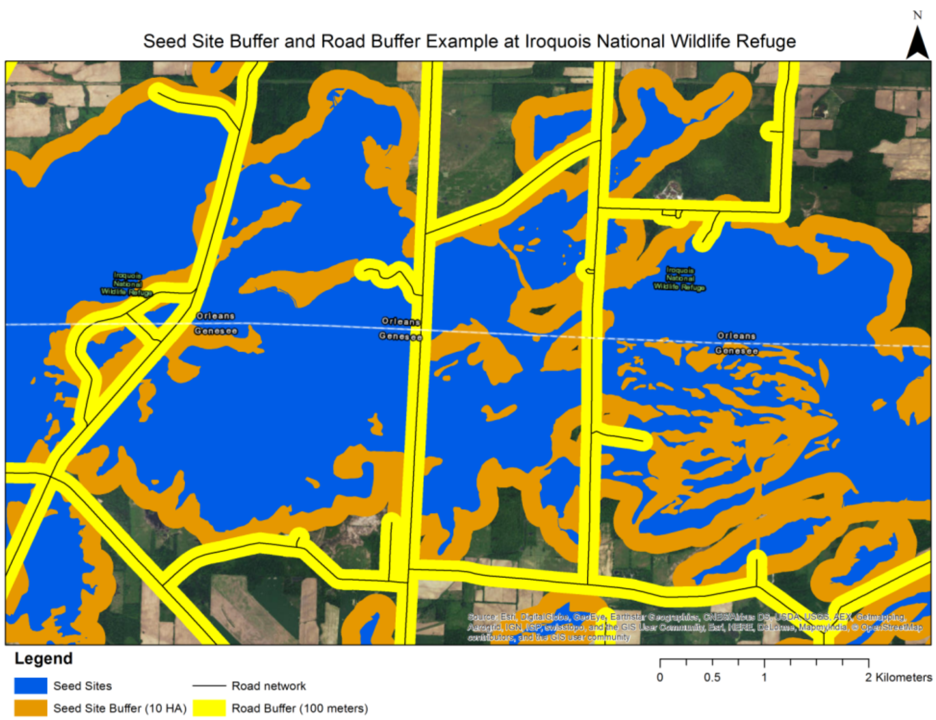


Figure 5: Example of 10 hectare buffered seed sites with a road buffer added in. Any area of the original seed site that became smaller than 10 hectares after the road buffer was erased from the seed site buffer would be removed from the model.

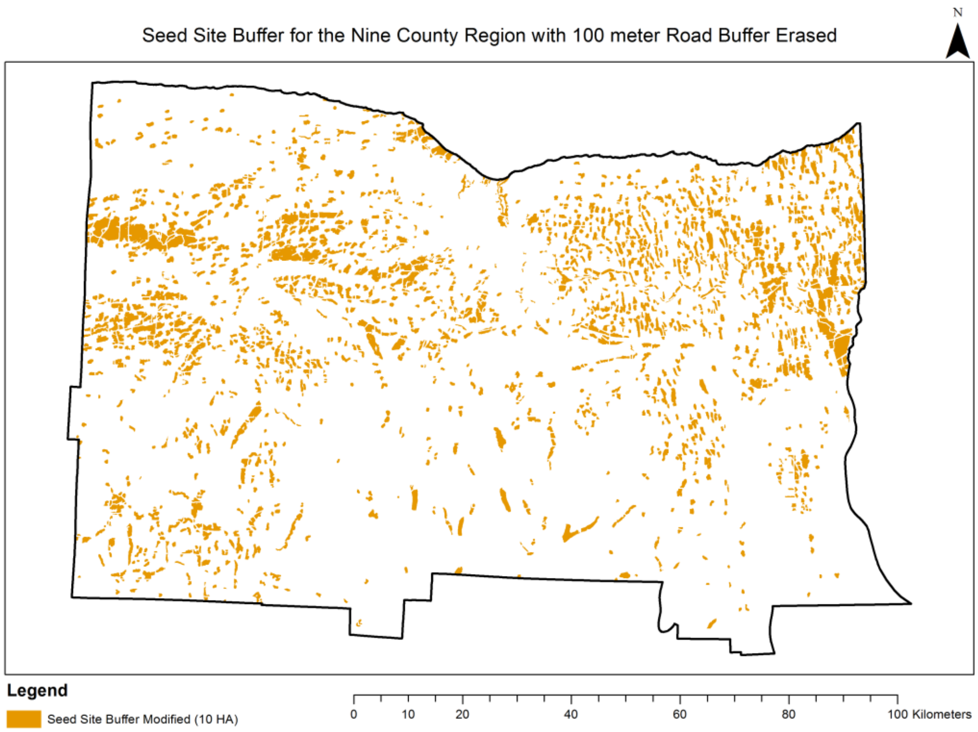


Figure 6: The seed site buffer was modified so that 100 meter areas around the road network in the region would be taken out of the seed site buffer and remaining seed site pieces smaller than 10 ha were also removed.

LULC

In order to access the suitability of the seed site home ranges for spotted turtle habitat, the land cover available in each seed site home range had to be quantified. The National Land Use/Land Cover (LULC) layer provided the various land cover and land use attributes for the model. Required percentages of these land covers were initially weighted based on Correa-Berger's original model parameters, derived from his expert survey responses (Tables 2 and 3).

Given advances in classification algorithms and updated LULC changes, the 2011 LULC layer was expected to be much more accurate than the 1992 LULC layer used in the initial analysis (Homer *et al.,* 2015; Homer *et al.,* 2012). By starting with Correa-Berger's original model parameters, the differences between the LULC layers could be assessed. The national LULC layer was acquired from the Geospatial Data Gateway and was modified using the clip command so that only LULC for the study area was shown. The 2011 LULC layer information was then extracted for each potential site by using the intersect command with the buffers around the seed site and the LULC layer (see Figure 7). This produced a layer that displayed LULC information within seed site home ranges only (referred to as LULC 2011 (10 HA) from here on). Unique ID numbers were assigned to each seed site for later pivot table analyses and to keep track of individual seed site home ranges.

Table 2: These are the codes used for the 2011 LULC layer according to the Multi-Resolution Land Characteristics Consortium (MRLC). Legend from http://www.mrlc.gov/nlcd11_leg.php

NLCD Land Cover Classification Legend
11 Open Water
12 Perennial Ice/ Snow
21 Developed, Open Space
22 Developed, Low Intensity
23 Developed, Medium Intensity
24 Developed, High Intensity
31 Barren Land (Rock/Sand/Clay)
41 Deciduous Forest
42 Evergreen Forest
43 Mixed Forest
51 Dwarf Scrub*
52 Shrub/Scrub
71 Grassland/Herbaceous
72 Sedge/Herbaceous*
73 Lichens*
74 Moss*
81 Pasture/Hay
82 Cultivated Crops
90 Woody Wetlands
95 Emergent Herbaceous Wetlands
* Alaska only

Table 3: The following table illustrates LULC codes used for each habitat type as well as the percent of each land cover used by spotted turtles that Correa-Berger determined in his original model.

Land Cover	2011 LULC	MEAN (%)	MIN (%)	MAX (%)
Upland Forest	41, 42, 43	14	5	30
Wetlands	90, 95	43	30	60
Meadows	71	6	5	15
Still Water	11	18	0	40
Transitional Area	52	15	0	30
Other	Variable	1	0	5

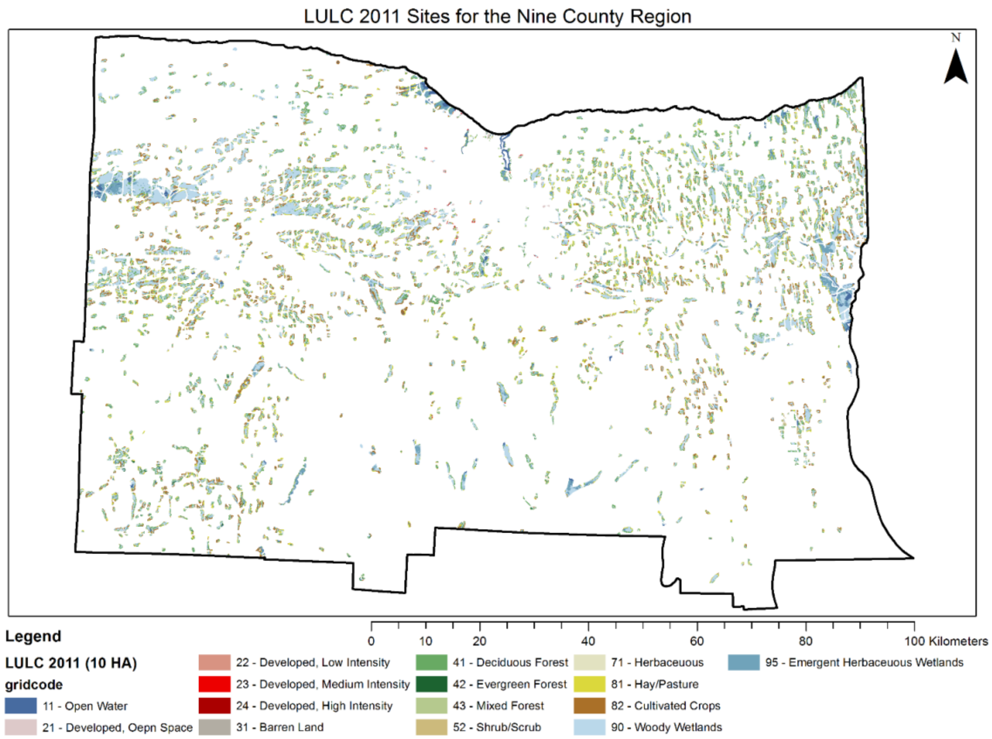


Figure 7: LULC information extracted for the seed site buffer by using the intersect command with the LULC layer.

Pivot Tables

A pivot table was created in Excel using exported information from the LULC 2011 (10HA) layer to determine if the seed site met the parameters determined initially by Correa-Berger for each LULC category of the habitat suitability model. There were seven combined land cover classes determined by Correa-Berger that would impact the likelihood of a spotted turtle being present: Upland forest, wetlands, meadows, still water, running water, transitional area, and other. All but running water were used in the model, and running water was included by looking at hydrologic connectivity in a later step. Each combined land cover class had a minimum and maximum range needed by spotted turtles for a given seed site, based on Correa-Berger's expert survey. Using the pivot table, the percentage of every land cover for each seed site from the model was compared to the spotted turtle requirements in Table 4. Each combined land cover category for all the seed site home ranges were given a rank of either 0 or 1. A rank of 1 meant the spotted turtle requirement for that particular land cover was met, while 0 meant the requirement was not met. The individual major land cover ranks were then summed into a site rank. A site with a ranking of 6 met all the requirements while a site with a ranking of 1 only met one requirement.

As well as the original parameters, two other modified modifications were created called Optimal 1 and Optimal 2 (Table 4). Optimal 1 had the meadows category include pasture as well as meadow land cover. This was primarily changed because of possible misclassifications of meadows as pasture which appear similar from a remote sensing standpoint. Optimal 2 had the modified meadows category as well as the maximum amount of wetland removed so only a minimum amount of wetland would be restricting for that land cover. This modification was made because of possible misclassifications of wetlands in the LULC as well. Once ranks were determined in Excel, the ranks were then imported and joined to seed site home ranges in the LULC 2011 (10HA) layer using ArcGIS.

Table 4: The following table illustrates the changes made to the original parameters from Correa-Berger's (2007) analysis. For Optimal 1 and 2, pasture was added to the meadows category. For Optimal 2, the maximum percent for wetlands was removed.

Land Cover	2011 LULC	MEAN (%)	MIN (%)	MAX (%)
Upland Forest	41, 42, 43	14	5	30
Wetlands	90, 95	43	30	60**
Meadows	71*	6	5	15
Still Water	11	18	0	40
Transitional Area	52	15	0	30
Other	Variable	1	0	5

* For Optimal 1 and 2, pasture (81) was added to the meadow's category
** For Optimal 2, the maximum percent for wetland was omitted along

Stream networks and Soil Calcium Carbonate Content

Spotted turtles may move to different wetlands because of overcrowding or lack of resources in a particular area. Because spotted turtles are semi-aquatic, they are more likely to use streams to travel to other large bodies of water. Because of this, a stream layer was added to the final model to help identify connectivity between wetland systems which could be used collectively as a network by spotted turtles (Joyal *et al.,* 2001). This was used instead of the running water parameter from Correa-Berger (2007), since the national LULC does not differentiate between running water and still water. Wetlands that are not connected to others via a stream network would be more isolated and therefore potentially less optimal sites for spotted turtles (Figure 8). The stream layer also provides appropriate aquatic habitat for the spotted turtles that may not show in the LULC layer due to resolution issues. Each seed site that contained a Turtle Sighting was examined to see the connectivity it had with surrounding seed site home ranges with streams (Appendix 1).

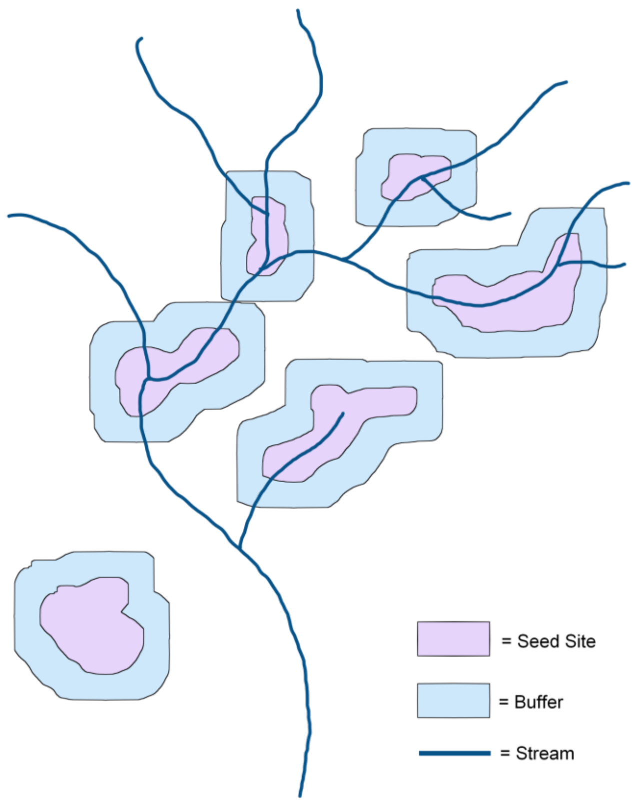


Figure 8: Example of how stream connectivity between wetlands can create a wetland network. The wetland on the lower left would be more isolated and less optimal that the others because it lacks any streams to connect it to the others.

Calcium carbonate ($CaCO_3$) content in the top layer of soils was also included using the soil layer database to see whether or not this potential requirement may have an effect on where turtles are found. Calcium is a necessary mineral for turtles in order to create the dermal bones for their shell and thus very important to their development (Clark & Gibbons, 1969; Gilbert *et* *al.,* 2001; Kienzle *et al.,* 2006). Using the Access database files that came with each of the Nine County soil layer files, information of the soil $CaCO_3$ content for the A horizon for each soil present in the counties was obtained and analyzed (USDA-NRCS, n.d.). All of the Nine County Region soil types that had a range that included at least 1% $CaCO_3$ content were considered soils of interest (Appendix 2). Based on this information, a map was created to display which areas of the study site could potentially have $CaCO_3$. This was then compared to known turtle sightings to determine whether calcium carbonate content in soil is a predictive factor for where spotted turtles are found.

Model Verification

After determining which seed site home ranges were the most optimal based on Correa-Berger's original weighted parameters as well as additional modified parameters, known sightings of spotted turtles were added to the model and then compared to the seed site home ranges to see how accurately the model predicts optimal spotted turtle habitat. There were a total of 33 turtle sightings, primarily located in the Northern half of the study site. This layer was made based on information from the National Heritage Program run by the New York State Department of Environmental Conservation (NYSDEC, 2005).

Results and Discussion

Complications with First Model and Creation of Second Model

After comparing the seed site home ranges to the spotted turtle sightings, it was evident that many of the sightings were outside of the seed site buffers. Out of the total 33 turtle sightings, 19 sightings were within 100 meters of the predicted seed site home ranges. Of these 19 sightings, 13 sightings were actually within the generated seed site home ranges (Figure 9). Each turtle sighting and nearest seed site buffer were analyzed to see potential causes to why the model failed to capture them inside the seed site home ranges (Appendix 3). It was determined that the two major limiting factors were the DEC designated wetlands, which limited the number of seed sites, as well as uniform, 100 meter road buffers. The DEC classified wetlands were sparser compared to the NWI, with few turtle sightings being found inside the State classified wetlands. The DEC classified 63,176 hectares as wetlands, compared to the 158,281 hectares of NWI classified wetlands. The 100 meter road buffer was considered too large and not refined enough for the different types of roads that are within the study site. It is unrealistic to put such a large buffer all of the roads considering smaller roads pose less of a threat than larger highway routes due to traffic and number of lanes.

After determining this, it was decided to create a new model with modifications to both the road buffer width and the initial seed site requirements. Instead of intersecting the hydric soil, federal wetland classification, and state wetland classification to create the seed sites, only the hydric soil and federal wetland classification layers were used (Figure 10). The road buffer was also refined to be more specific to each road type. Large roads such as freeways were given a buffer of 25 meters while smaller residential roads were given a 10 meter buffer (table 5). The modifications used for the second model increased the number of potential seed sites from 5,429 to 29,789 potential seed sites (Figures 11 and 12). The second model of the current analysis was expected to increase in number of seed sites compared to the first model due to removing the restrictive DEC classified wetlands.

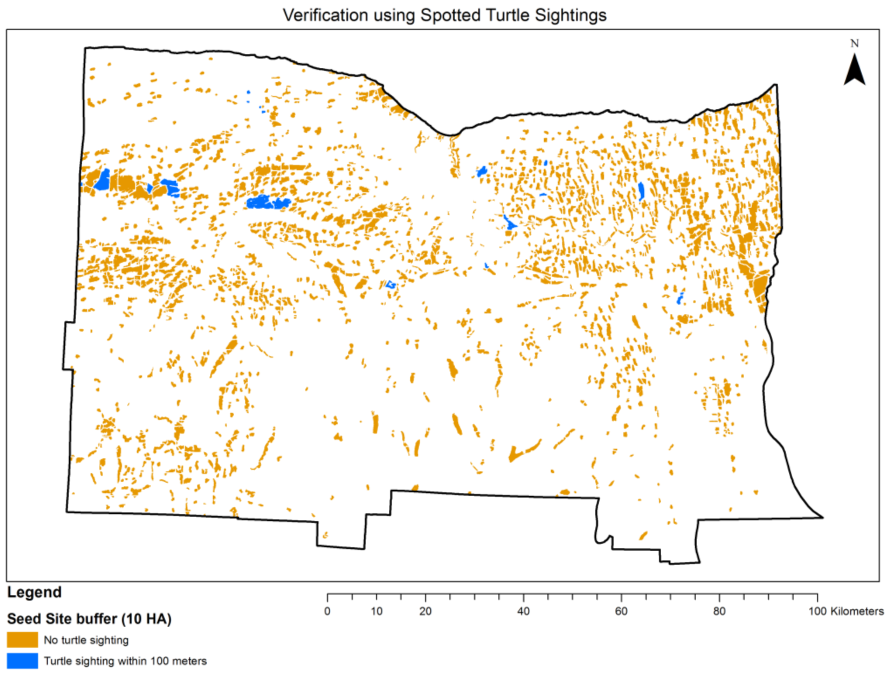


Figure 9: The above figure shows the seed site home ranges that were within 100 meters of a spotted turtle sighting in purple while the orange seed site home ranges possessed no spotted turtle sightings. Only 19 out of the 33 turtle sightings were within 100 meters of a seed site.

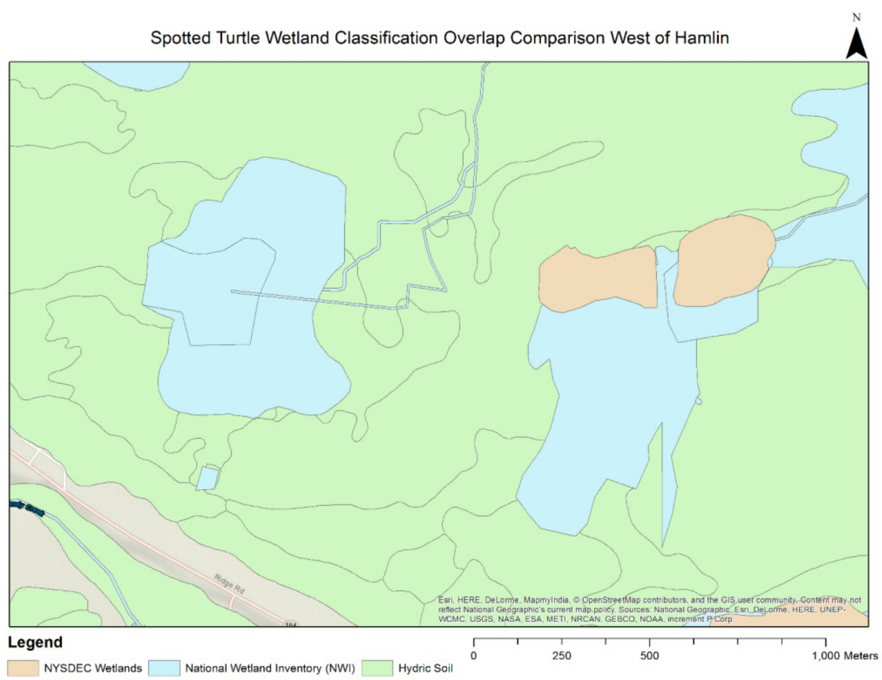


Figure 10: The above figure illustrates the problem of utilizing the DEC wetland classification when creating initial seed sites. In the first model, only the area where all three layers overlap would be considered a seed site, leaving large areas where only the NWI and Hydric soil overlap out of the model.

Table 5: This table details the size of the road buffers for all the road codes present in the study site. Larger roads were given a larger buffer distance while smaller roads were given a smaller buffer distance. The distances chosen were based on the approximate size of the road giving each road a buffer distance around it that was at least equal to the width of the road itself.

Road Grouping	Buffer distance	Road codes present	Road code names
Freeway	25 meters	S1100	Primary roads
Highway	20 meters	S1200	Secondary roads
Residential	10 meters	S1400	Local neighborhood road, rural road, city street
		S1630	Ramp
Miscellaneous	5 meters	S1500	vehicular trail
		S1640	Service drive usually along a limited access highway
		S1710	Walkway/pedestrian trail
		S1730	Alley
		S1740	Private road for service vehichles
		S1750	Internal U.S. Census Bureau Use
		S1780	Parking lot road
		S1820	Bike path or trail

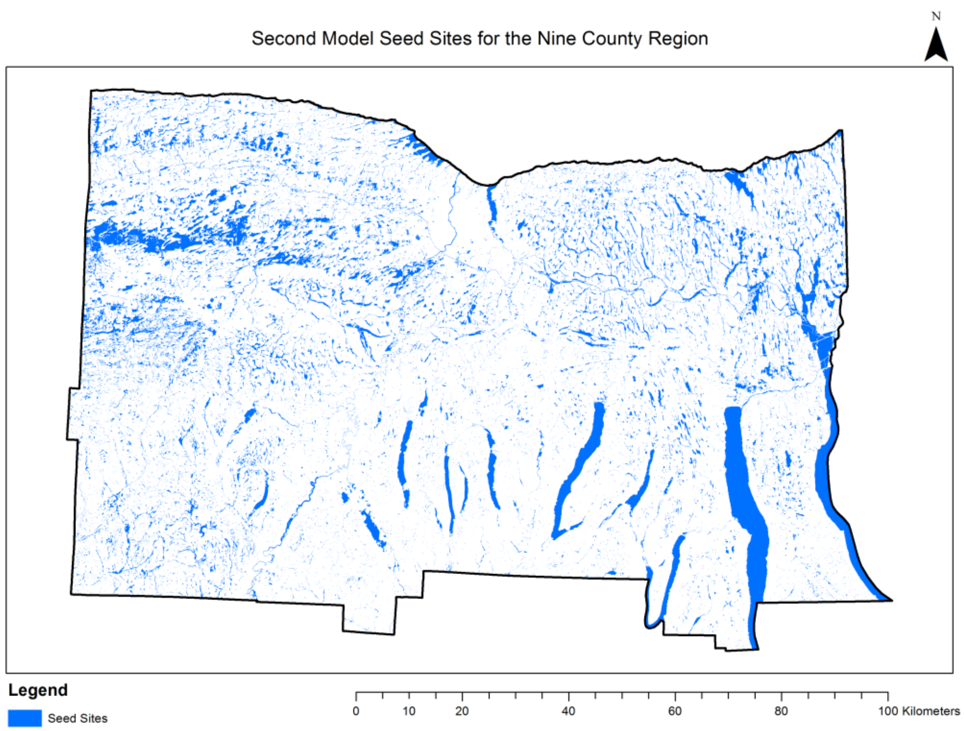


Figure 11: This figure shows the seed sites for the second model which was made using the intersect command with the hydric soils layer and the NWI layer. By excluding the DEC layer, 24,360 more seed sites were created.

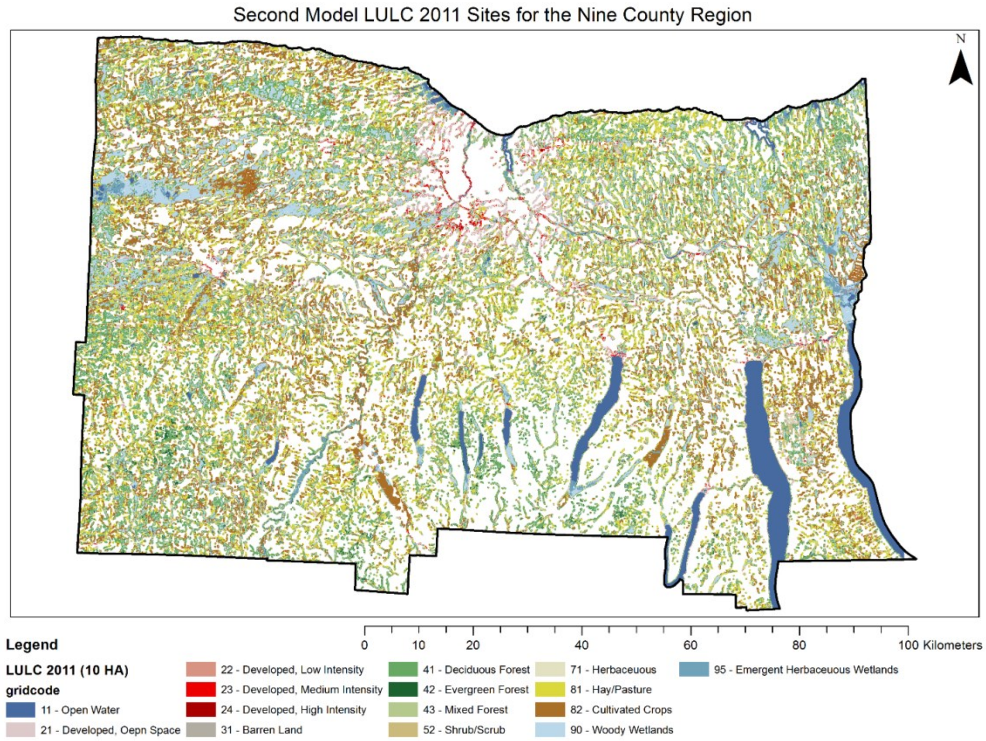


Figure 12: This figure depicted the seed site home ranges for the second model with LULC information displayed. Like with the first model, the second model home ranges was used to extract LULC information for each seed site buffer.

Similar to the first model, a Pivot table was used in Excel to determine the rankings of all the seed site home ranges and were then imported and joined to seed site home ranges using ArcGIS (Table 6). Unfortunately there were several complications while running the Pivot tables that were later discovered when creating the second model. The results from Excel would not match the LULC 2011 (10 HA) layer in ArcGIS for both the first model and the second model. This was later fixed in the second model by creating a separate ID field rather than using the default ID field created when a layer is made. Because it was found that the spotted turtle sightings did not match well with the first model, it was decided to focus on the Pivot table results for the second model only and not rerun the Pivot table results for the first model.

Table 6: The table below shows the first six seed site home ranges that were ranked based on whether or not they met each of the parameters for the Optimal 2 parameter set. A value of 1 means that the parameter was met while a value of 0 means that the parameter was not met. These were then totaled to determine the rank of the site.

Seed Site Home Range ID	Water	Other	Forest	Shrub	Meadows	Wetlands	total
4	1	1	0	1	1	0	4
5	1	0	0	1	1	0	3
6	1	0	1	1	0	0	3
7	1	0	0	1	1	0	3
8	1	0	0	1	0	0	2
9	1	0	0	1	0	0	2

After importing the ranks to ArcGIS, patterns in the site rankings were examined for the three parameter sets (Figures 13, 14, and 15). Seed site home ranges that had a ranking of 4 and above were determined to be the most optimal for spotted turtles (Figure 16). Ranks 3 and lower would have at most half of the parameters met and were later excluded from the final model in favor of focusing on sites with the best available habitat for spotted turtles. Most of the optimal sites were rank 4, with roughly 90% of all the optimal sites being rank 4 (779 sites for original parameters; 1,192 sites for Optimal 1; 1,188 sites for Optimal 2) for all three suitability parameters (Table 7).

Using the original parameters that were used in Correa-Berger's (2007) analysis, the model had 808 optimal sites out of 15,596 seed site home ranges. The modified parameter sets Optimal 1 and Optimal 2 resulted in an increase in optimal sites with 1,352 optimal sites for Optimal 1 and 1,367 optimal sites for Optimal 2 (Table 7). Correa-Berger (2007) only had four final sites that were considered the best. The reason this model had so many more optimal seed sites was largely due to the use of a ranking system as well as more potential seed sites initially. Correa-Berger focused on only the best sites that met all of the LULC requirements while this model focused on sites that met more than 50% of the LULC requirements (ranks 4-6).

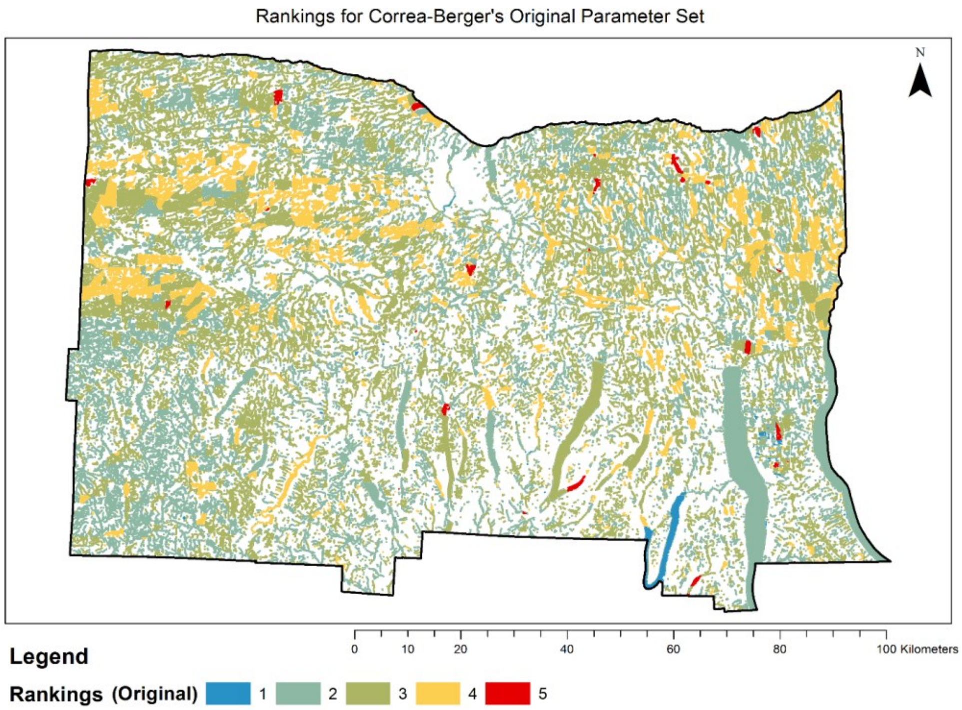


Figure 13: Ranking of all sites using the original Correa-Berger parameters. Note that there were no sites with a perfect ranking of 6.

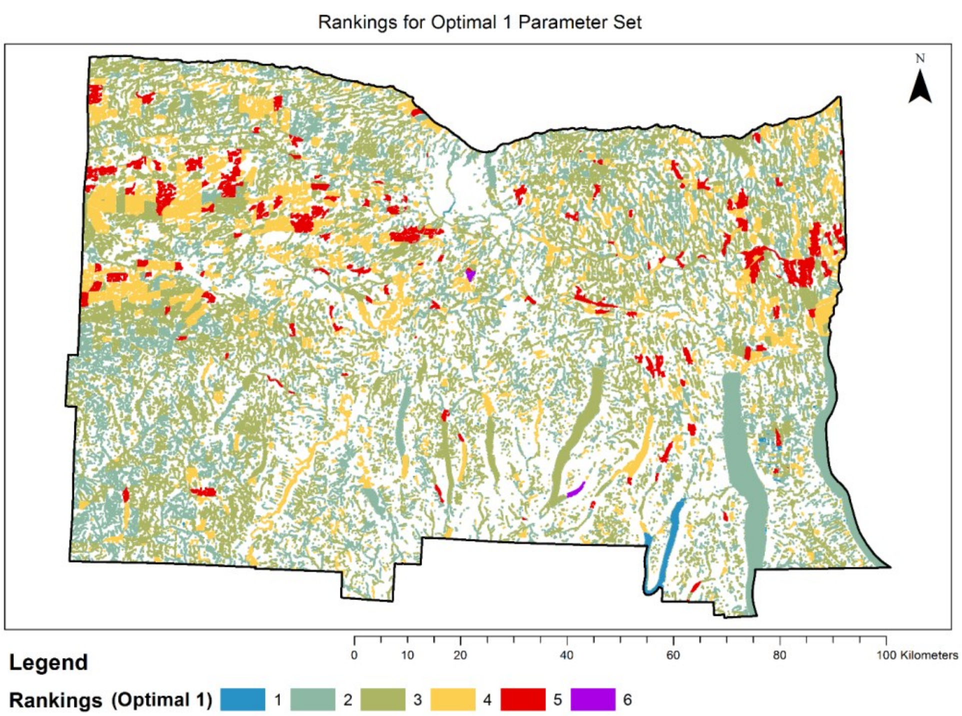


Figure 14: Ranking of all sites using the Optimal 1 parameter set (modified meadows parameter that included pasture).

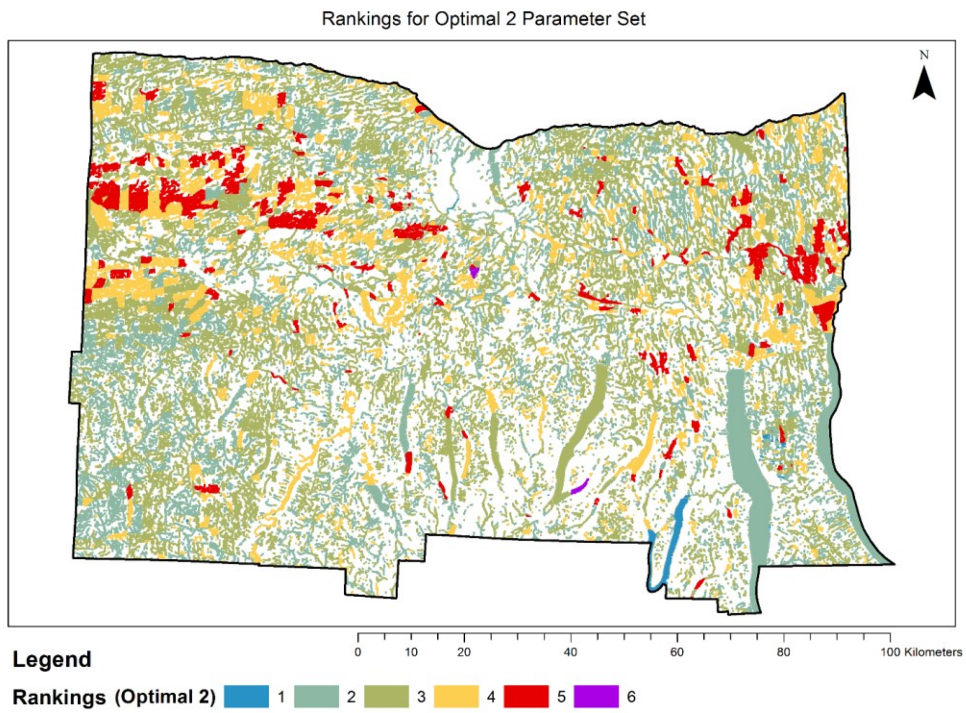


Figure 15: Ranking of all sites using the Optimal 2 parameter set (pasture and meadows as well as no upper limit to wetlands).

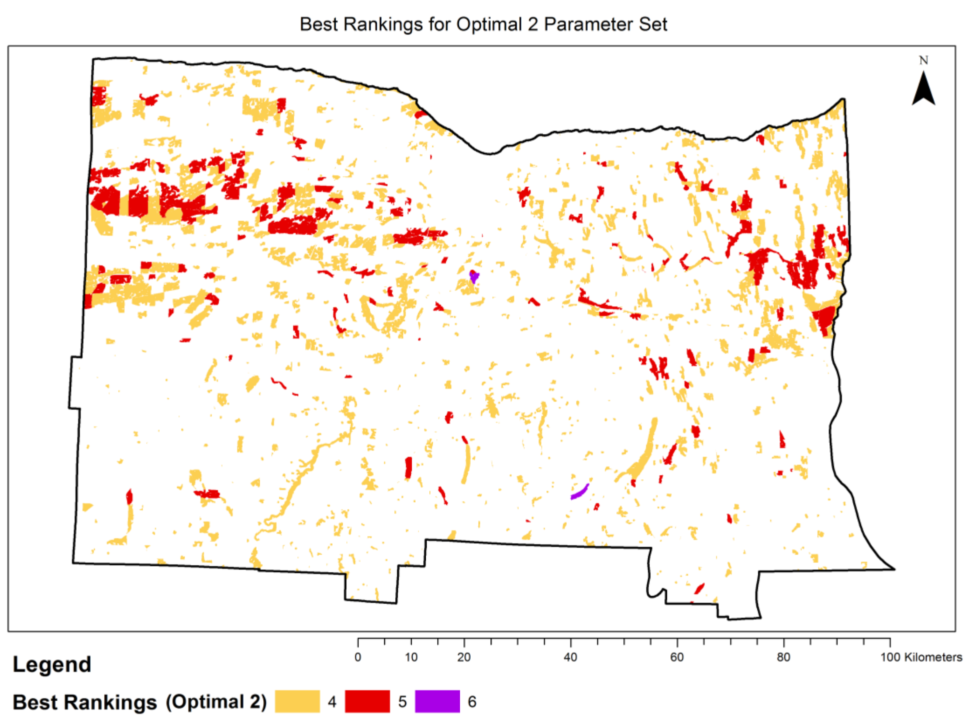


Figure 16: The above figure shows only the most optimal sites (rank 4-6) for Optimal 2 parameters. These sites were considered the best because they met at least more than half of the requirements if not all.

Table 7: The breakdown of the rankings for the optimal sites for each parameter set.

Model	# of 4 ranking	# of 5 ranking	# of 6 ranking	Total Optimal Sites
Original parameters	779	29	0	808
Optimal 1	1192	158	2	1,352
Optimal 2	1188	177	2	1,367

Like the previous model, the second model was verified using historical spotted turtle sightings and how closely the sightings match up with the seed site home ranges. With the increase in potential seed site home ranges, all 33 of the verified turtle sightings were within a seed site home range in the second model. Several spotted turtle sightings were within the same seed site home range, resulting in 28 seed site home ranges that had spotted turtle sightings. The first model only had 13 out of the 33 turtle sightings within the seed site home ranges with an additional 6 that were within 100 meters of a seed site home range. This suggests that turtle sightings that were not captured within the first model's seed site home ranges were not within areas that the DEC classified as wetlands, making DEC wetland delineations a limiting factor in this model.

After removing DEC wetlands from seed site creation, spotted turtle sightings that were 100 meters away from seed site home ranges in the first model were captured within seed site home ranges in the second model. This suggested that some turtle sightings were not being captured within the first model seed site home ranges because of the 100 meter road buffer. The reason why many of the sightings were near roads was because the locations for the spotted turtles were provided by cross roads or general descriptions based on roads, making the spotted turtle point data approximate locations to the actual observed locations.

While all of the turtle sightings were within a seed site home range in the second version of the model, not all of home ranges were considered optimal (ranks 4-6). Optimal 2 only had 16 out of the 33 turtle sightings within seed site home ranges with a suitability of rank 4 and above (Figure 17). Some of these turtle sightings were in the same seed site home range, resulting in 14 seed site home ranges that had turtle sightings within them. There were only two sites that had a perfect rank of 6 for Optimal 1 and 2, but neither of these sites matched the spotted turtle sightings utilized (Table 8). The low number of perfect scores may reflect developed regions within the study area. The LULC ranges used in the model caused most of the sites to "fail" at least one LULC parameter. This ended up causing the other parameter to fail for many sites, with 13,021 seed site home ranges not meeting the other parameter for Optimal 2 out of a total of 15,596 seed site home ranges.

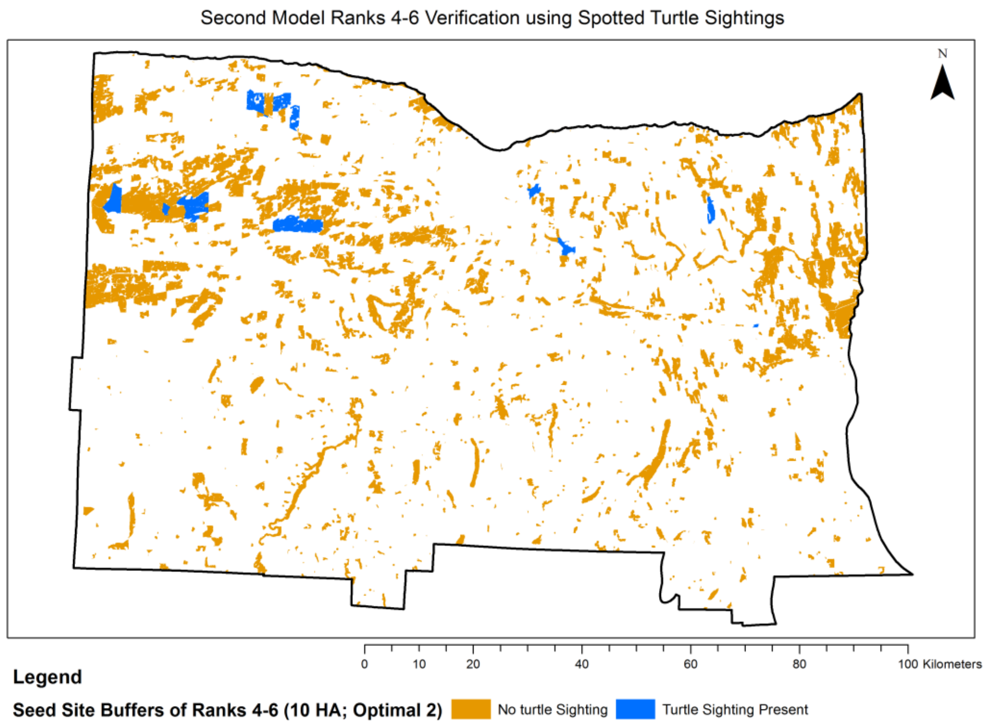


Figure 17: While all of the spotted turtle sightings were within a seed site home range for the second model, only 16 out of 33 turtle sightings were within optimal seed site home ranges for the Optimal 2 parameter set.

Table 8: Optimal sites versus the number of seed site home ranges that were initially made for the second model for each parameter set. Optimal sites were sites that had a ranking of 4 and above. The table also compares the number of optimal sites that match the spotted turtle sightings.

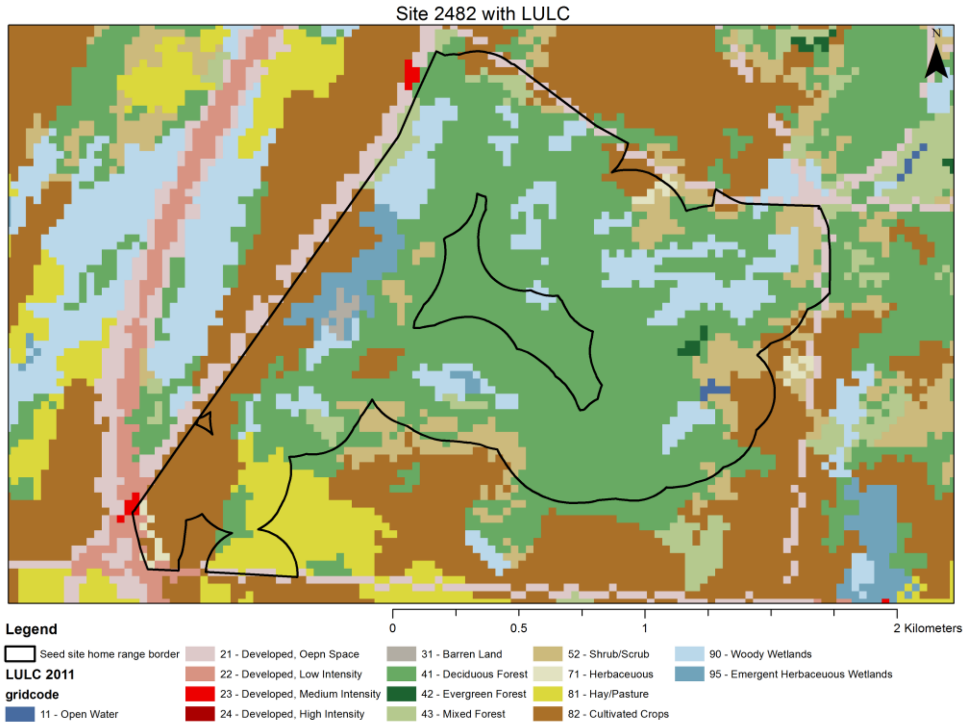
Model	# of optimal sites	Sites matching turtle sightings	Total # of sites
Original parameters	808	10	15,596
Optimal 1	1,352	14	15,596
Optimal 2	1,367	14	15,596

Complications with the Second Model

While 16 sightings fell within sites with a ranking of 4-6, 14 suboptimal seed site home ranges contained turtle sightings. The three land covers most often failing the habitat rankings were wetlands, forest, and meadow. Either too much or too little percent cover of each of the three land covers would cause the site to be considered non optimal. Sometimes the requirements for one of the land covers was only marginally off. For example, site 2482 contained 4% meadow which is only 1% below the requirement. On closer inspection, many of these sites contained significant areas of pasture cover that might substitute for the meadow requirement. The meadows category was subsequently expanded in Optimal 1 and 2 to include both meadows and pasture for spotted turtles because it appeared that there was not enough meadow in most sites to meet requirements, possibly due to misclassification of meadows and pasture in the NLCD LULC data.

The potential for misclassification appears to be a significant issue within the model. Upon inspection against aerial photos, some of the suboptimal sites depicted inaccurate LULC classifications in the 2011 NLCD. Examples include sites 2482 (rank 2 by Optimal 2), site 5431 (rank 3 by Optimal 2), site 5833 (rank 3 by Optimal 2), and site 5912 (rank 3 by Optimal 2). For site 2482, the aerial imagery shows what appears to be farm field (which may or not be abandoned) that was classified as wetland. It is possible that this field does flood and may appear as a wetland by a remote sensing stand point (Figure 18). For site 5431, the LULC misclassified low density urban for scrub shrub or pasture and misclassified a field for forest. It was also hard to tell for sure if some of the wetland is present because of forest cover (Figure 19). For site 5833, the LULC misclassified areas of forest and urban area for pasture as well as misclassifying developed areas for forest (Figure 20). For site 5912, the aerial imagery shows an open area with a section of forest that was misclassified as cropland. It is possible that this area may have once been pasture or that the land cover present appears to be the same as pasture from a remote sensing standpoint (Figure 21). Considering 4 out of the 14 suboptimal seed site home ranges that contained a turtle sighting had LULC misclassifications, it is reasonable to believe that other potential sites had LULC misclassifications as well.

A.



B.

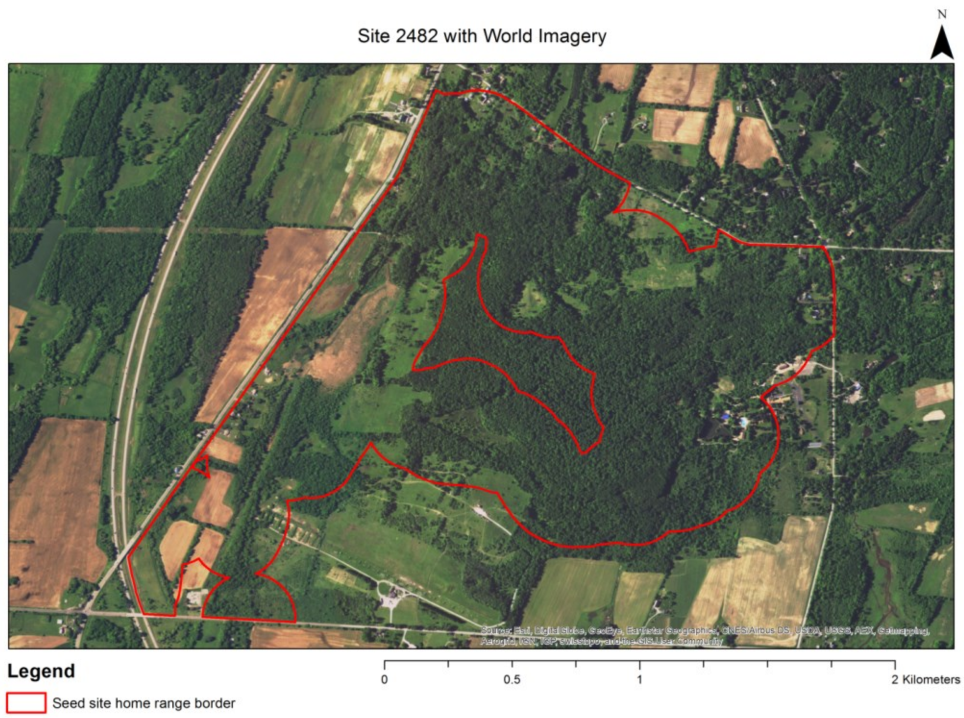
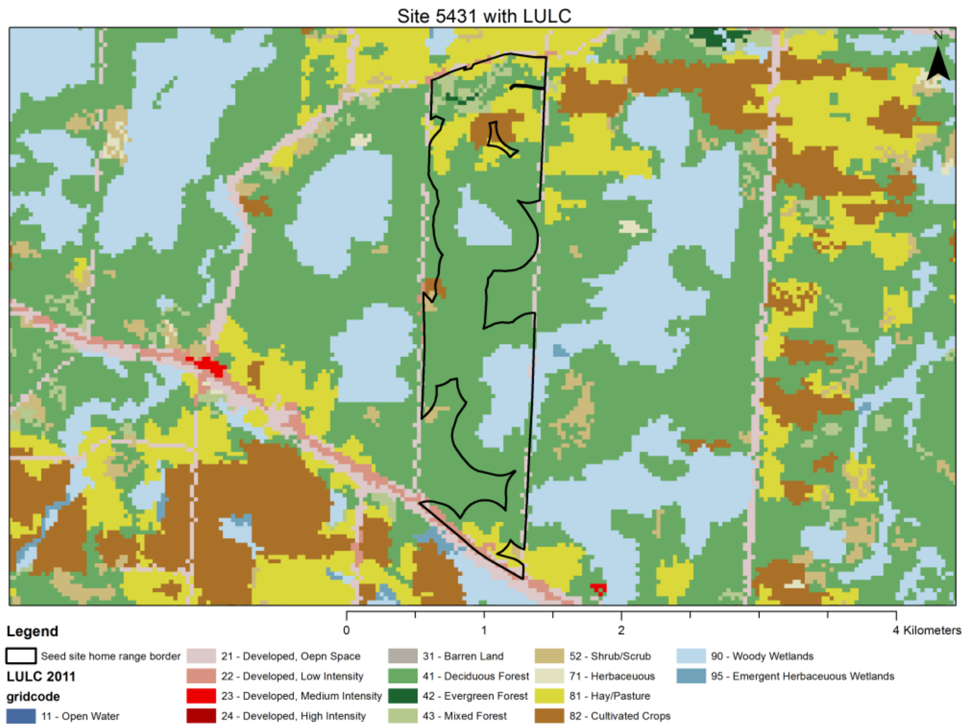


Figure 18: The above figures depict a misclassification of the LULC for site 2482. In figure A, Seed Site 2482 is depicted with the National LULC classification. Figure B shows the same site with aerial photography.

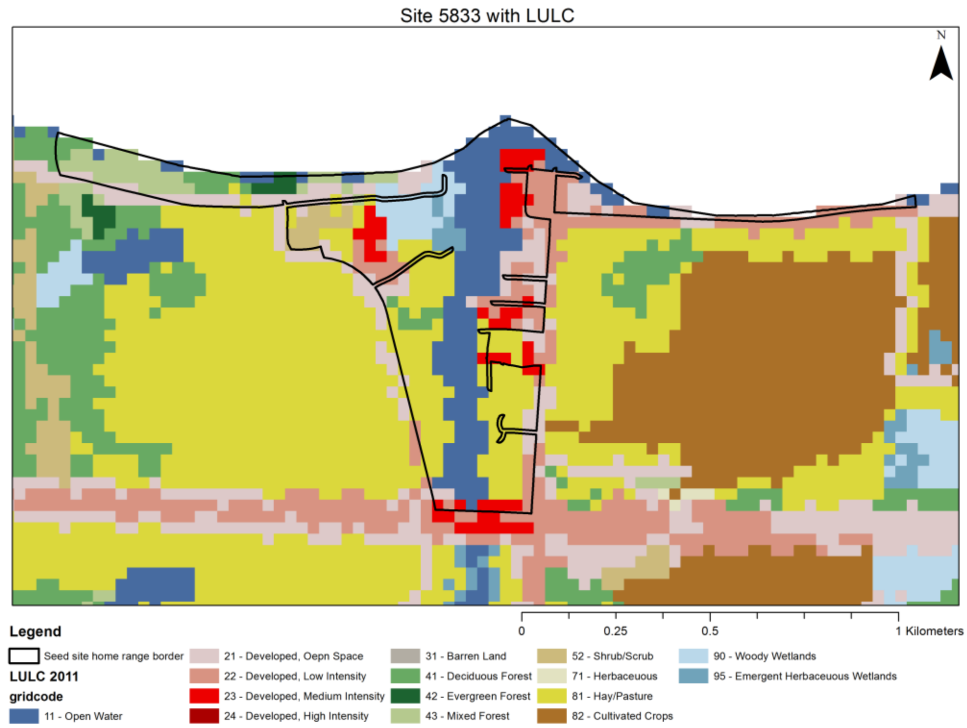
A.



B.

Figure 19: The above figures depict a misclassification of the LULC for site 5431. In figure A, Seed Site 5431 is depicted with the National LULC classification. Figure B shows the same site with aerial photography.

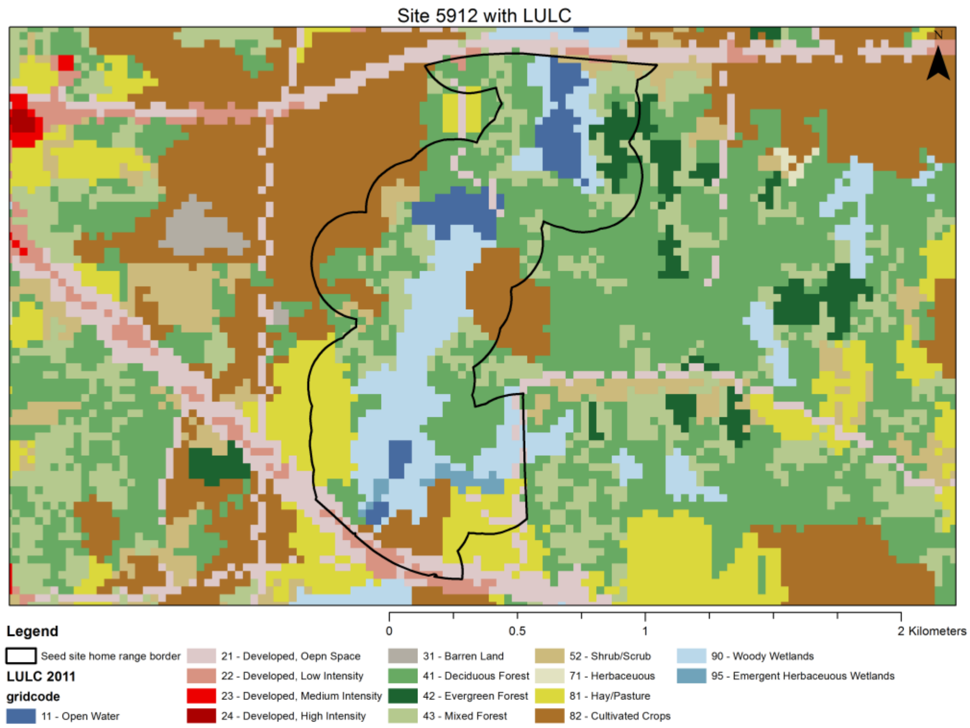
A.



B.

Figure 20: The above figures depict a misclassification of the LULC for site 5833. In figure A, Seed Site 5833 is depicted with the National LULC classification. Figure B shows the same site with aerial photography.

A.



B.

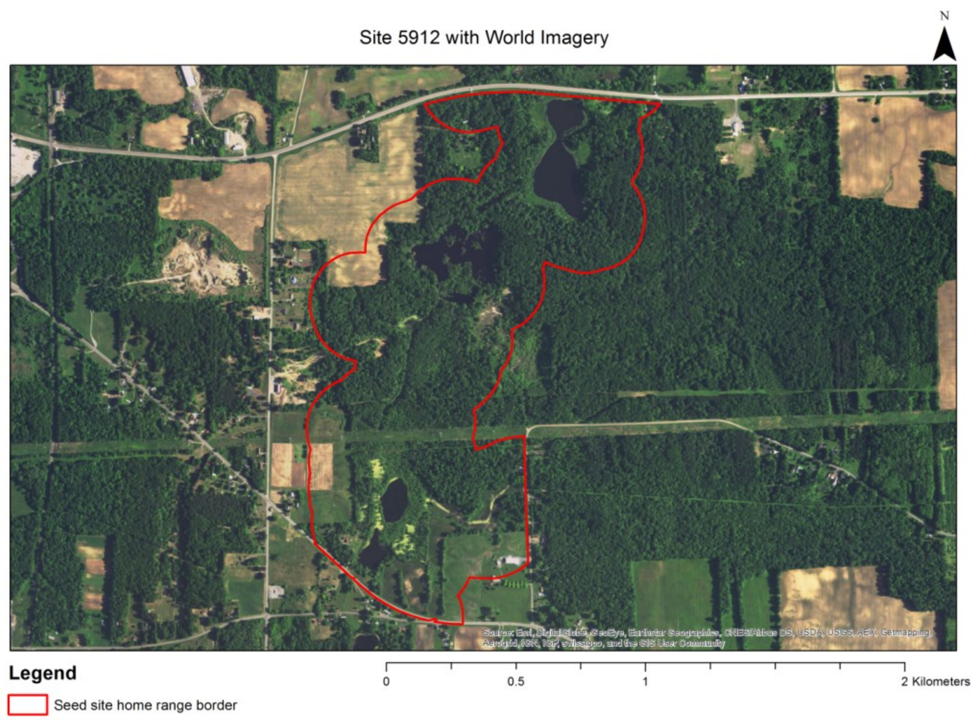


Figure 21: The above figures depict a misclassification of the LULC for site 5912. In figure A, Seed Site 5912 is depicted with the National LULC classification. Figure B shows the same site with aerial photography.

Stream Network and Soil Calcium Carbonate Content

After analyzing each seed site home range with spotted turtles present, it became clear that stream connectivity did exist for all of the 28 home ranges with turtle sightings present except for one (Appendix 1). This one site however compromised a piece of Lake Ontario's shore and could be considered connected to other sites via Lake Ontario itself. Some of the sites were more isolated than others, even though they were connected via streams, such as site 13305, which only had one stream connecting the site with no branching (Figure 22). Other sites were not surrounded by what was considered very optimal sites or were not themselves rank 4 and above but still had various stream networks that connected them to other optimal sites. It is also important to note that some sites may be connected to optimal sites outside of the study site especially along the borders of the Nine County Region.

When compiling the soil types for the $CaCO_3$ content analysis, it became clear that none of the soil types were guaranteed to have calcium carbonate content in the A layer considering that all the ranges started with 0% $CaCO_3$ content. Most of the soils had a small amount of $CaCO_3$ with many being only 0 to 1% or 0 to 2% $CaCO_3$ content. Figure 23 shows a map of the $CaCO_3$ content, based on the soil A horizon. Most of the study site had large groupings of small individual patches of $CaCO_3$ containing soil, notably in the northern half of the study site. There was also a distinct lack of $CaCO_3$ at the most southern part of the study site, just below the large areas of $CaCO_3$ containing soils (Figure 23).

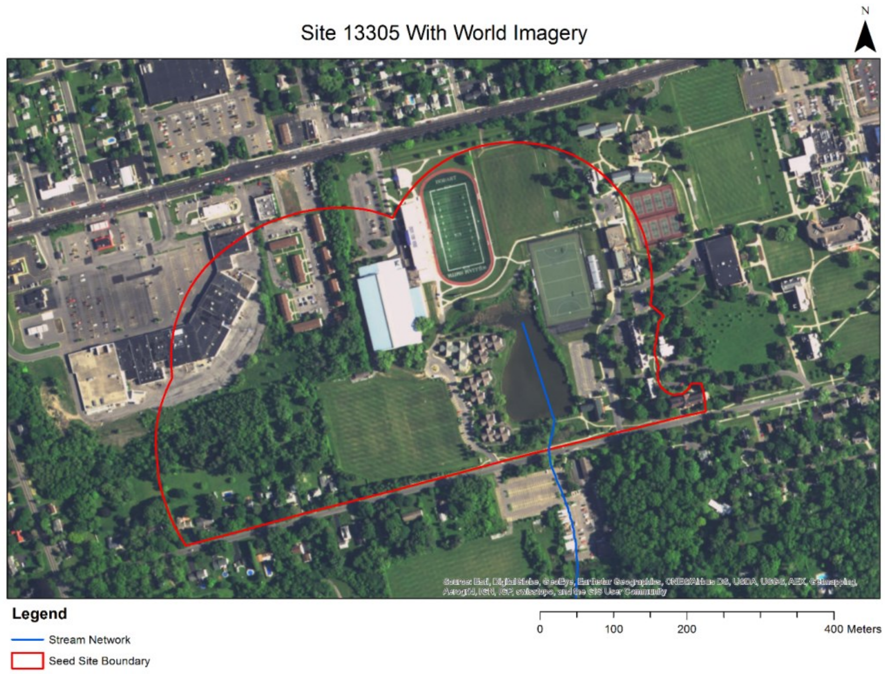


Figure 22: Site 13305 contained an unusual spotted turtle sighting in that the site was highly developed with what appears to be a man-made pond and only one stream connected to the site.

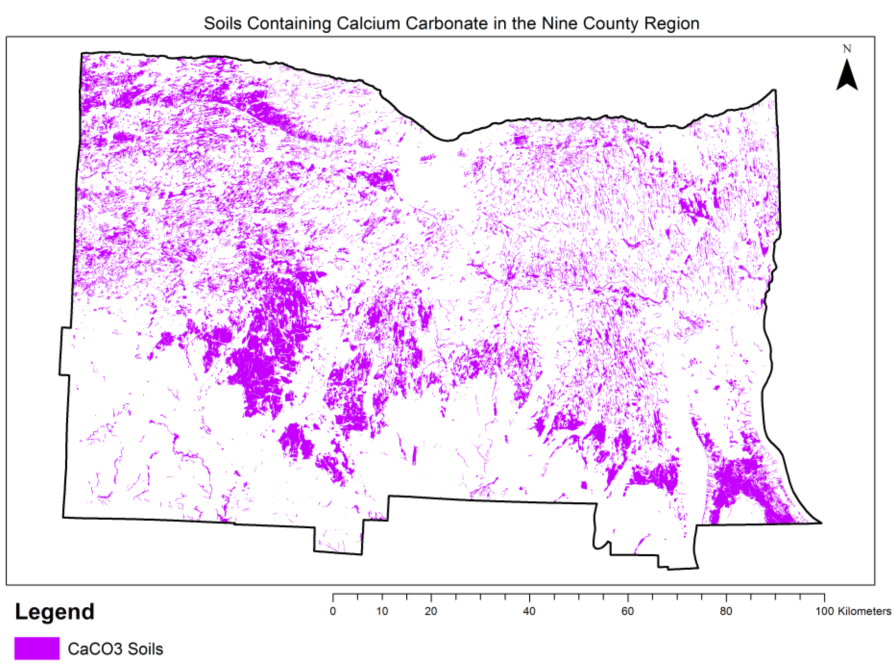


Figure 23: The above figure shows the location of all the soils that could potentially contain $CaCO_3$ in the A layer. Note that most of the study site has small patches of CaCO3 containing soils with most of the large patches being at the Northwest corner and Southern half of the study site.

Out of the 15,596 potential seed site home ranges produced from the second model, roughly half (8,073) contained $CaCO_3$ soil. When looking at the most optimal sites (rank 4-6), 995 sites out of the 1,367 optimal seed site home ranges contained $CaCO_3$ (Figure 24). The location of the optimal sites line up well with where the $CaCO_3$ is located, with a distinct lack of optimal sites in the southern reaches of the study site where there was a lack of $CaCO_3$.

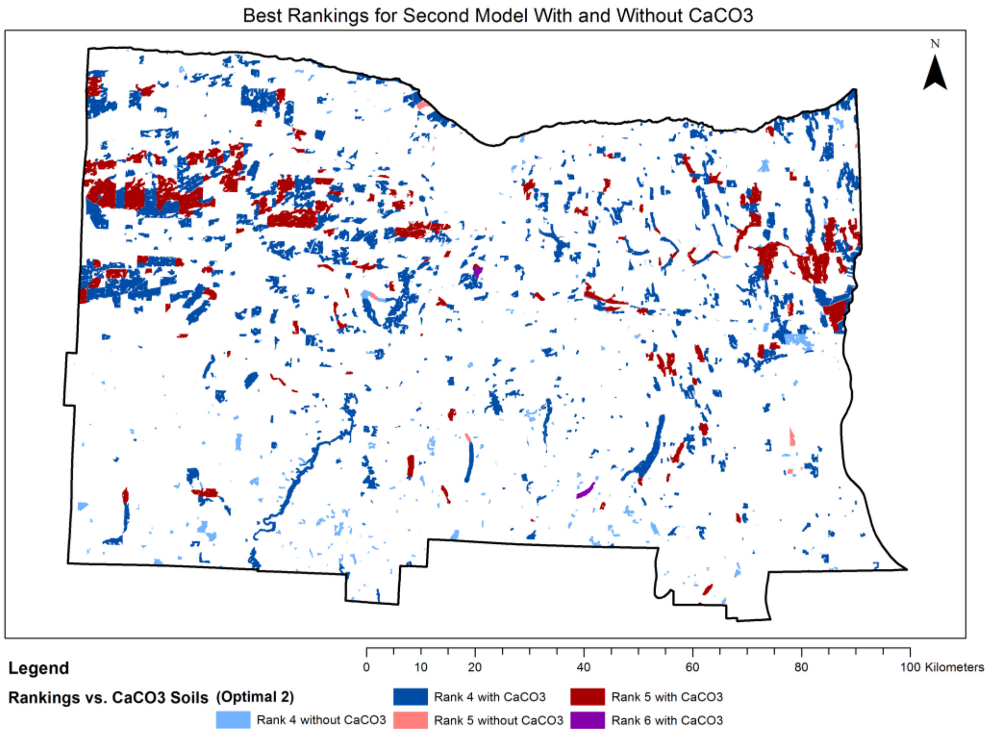


Figure 24: The figure above shows the most optimal seed site home ranges (rank 4-6) for Optimal 2 with and without $CaCO_3$. Out of the 1,367 optimal seed site home ranges, 995 sites contained $CaCO_3$. There were no rank 6 sites that did not have $CaCO_3$ within them.

When considering all 28 sites that contained turtle sightings regardless of rank, only one did not contain CaCO3 within it. Considering that 73% of the optimal sites and all but one of the 28 sites with turtle sightings contained $CaCO_3$, $CaCO_3$ appear to be a good predictor of optimal spotted turtle sightings in the Nine County Region and should be further explored in future studies to better incorporate this variable into spotted turtle HSMs. However, because the ranges for the $CaCO_3$ content for these soils include 0%, the results from these analyses should be taken with caution because it is possible that the soils have no $CaCO_3$ within them at all.

Conclusions

The second HSM model for the spotted turtle was successful in capturing all of the spotted turtle sightings used within seed site buffers. The second suitability model showed improvement compared to Correa-Berger's (2007) original model with a marked increase in potential seed sites and optimal seed site home ranges. With the increase in optimal seed site home ranges, more of the spotted turtle sightings were captured within the model with the second model capturing 16 out of the 33 spotted turtle sightings within optimal seed site home ranges compared to only four for Correa-Berger's (2007) original model. This supports the hypothesis that with the newer layers and modified parameters, this model was more successful in mapping potential spotted turtle population locations.

However, it was evident that many of these seed site home ranges were not the most ideal with 14 of the 28 seed site home ranges that contained turtle sightings considered less than optimal with rankings of 3 or 2. This result does not support the hypothesis that spotted turtle sightings will be at optimal seed site home ranges, although all of the sighting were within seed site home ranges that had stream connectivity to other sites. The reasons why the second hypothesis was not supported could be the following: misclassifications of the study site habitats by the national LULC, the parameters ranges used by the model, and the nature of the spotted turtle sighting data.

One reason why the 14 sites with spotted turtle sightings were ranked less than optimal could be due to misclassification of the land cover for the seed site home ranges. Site 2482, site 5431, site 5833, and site 5912 depict several misclassification issues that arose from using a national LULC, suggesting that other sites within the model could have misclassified LULC as well. Two major land cover classes, wetlands and pasture, were misclassified in many sites and ended up being the major reason sites in the study were not considered optimal.

Wetlands were sometimes found to be misclassified by the LULC layer as being something else, such as open water, forest, or meadows. Correa-Berger (2007) also noted this potential problem within the 1992 LULC data, stating that more than half of the wetlands were misclassified as forest while about one fifth were misclassified as pasture or hay within the DEC classified wetlands. While all of the seed sites for the second model were created using the NWI classified wetland layer and hydric soil layer, the 2011 LULC layer did not always classify the wetlands within the seed site home ranges similarly. Many sites failed to meet the wetland requirement for the optimal home range parameters, which was entirely based on the 2011 LULC classification of the land. For the model, the LULC classified 116,117 hectares as wetland. Only 81,096 hectares matched the seed sites for the second model.

The most likely reason why many of the sites failed the wetland requirement would be that the wetland classified by the NWI layer was being misclassified as a non-wetland land cover by the LULC layer. One potential problem with the wetland parameter is the possibility of forest wetlands being classified as an upland forest. Correa-Berger (2007) detailed this as being a potential problem with the 1992 LULC and it could continue to be a problem with the 2011 LULC. Due to misclassification problems in the LULC, it is possible that some of the sites that contained spotted turtle sightings were more optimal than their given rankings would suggest. In order to mitigate this problem of wetland misclassification, the maximum percent of the wetland parameter for Optimal 2 was eliminated. However, this only increased the optimal site count by 15.

Pasture was another major misclassification that appeared in sites considered not ideal for spotted turtles in Correa-Berger's original parameters. Misclassification errors for meadows and pasture arise because they are difficult to distinguish from each other from a remote sensing standpoint. Since meadows is a necessary land cover for spotted turtles and the meadow parameter was not being met for most of the seed site home ranges, it was decided in later suitability parameter sets Optimal 1 and Optimal 2 that pasture could act as a supplement to meadows. Unfortunately, many sites that became optimal with the addition of pasture could be considered less than ideal. Turtles and their nests can be negatively impacted by human or live stock activities in pastures such as trampling of nests or being disturbed by landowners (Beaudry *et al.,* 2010). While it is possible that the misclassifications of wetlands and pasture among other land covers are not as severe with the new LULC compared to the older one, it may be better to rely on local remote sensing data to classify the land cover types for the model rather than use a national LULC file.

Another reason for the model being unable to capture all of the spotted turtle sightings could be the constraints used to determine which site was optimal. Even though the second model did do better and the second adaption of Correa-Berger's parameters did increase the number of optimal seed site home ranges that contained spotted turtle sightings, there still could be further improvements after more detailed research and perhaps another expert survey. There could be local preference in certain parameters as noted by Correa-Berger (2007) in which it may be better to focus on a smaller study site and curtail the model to the local spotted turtle preferences based on field surveys. It is also possible that spotted turtles have a larger tolerance of the amount of specific habitat requirements than previously thought. According to O'Bryan (2014), spotted turtles have been found to live in intensively-managed forest landscapes. This suggests that they can adapt to their changing environmental conditions as long as there is habitat heterogenity to meet their varied habitat needs. Other studies have found that spotted turtles have utilized clear cuts, power line right of ways, and ditches as habitat as well (Litzgus & Mousseau, 2004; Stevenson *et al.,* 2015). With the study area including large, highly developed areas and lacking large tracts of land with pristine habitat, finding a large number of sites that would be considered perfectly optimal is highly unlikely. In order to improve the parameters used in the model, field surveys of the verification sites used in this analysis should be conducted to document current local conditions and re-assess land cover percentages.

Some spotted turtle sightings may never be captured within optimal seed site home ranges. This could be due to some of the sightings being in highly unusual areas such as site 13305 which is located on the campus of Hobart and William Smith Colleges with the only water feature appearing to be mostly manmade with one stream for access to other sites (Figure 25). This sighting appears rather isolated with no nearby sightings with rank 3 or above. The site is also highly developed with only a small section of forest within the seed site home range. Considering how developed the site is, the spotted turtle may not live in the area and was perhaps even a released pet. Because of this, the seed site the turtle was found in should not be considered ideal even though a sighting was found there.

The model indicates that there are some potential optimal sites in the southern portion of the study site but there are no confirmed sightings of spotted turtles in that area. This suggests that while the habitat in the southern part of the study site may be optimal according to the current model, there may be something else that is preventing spotted turtles from thriving there. It's important to note that the spotted turtle sightings that were used for the current model are over ten years old due to data requesting problems. Because of how old the sightings are, they may not adequately reflect where current populations of Spotted Turtles are located within the study site. New and more recent spotted turtle field surveys are recommended in areas that are deemed optimal by the model in order to both confirm the model's predictions and to collect more data on the necessary habitat needs of the spotted turtle.

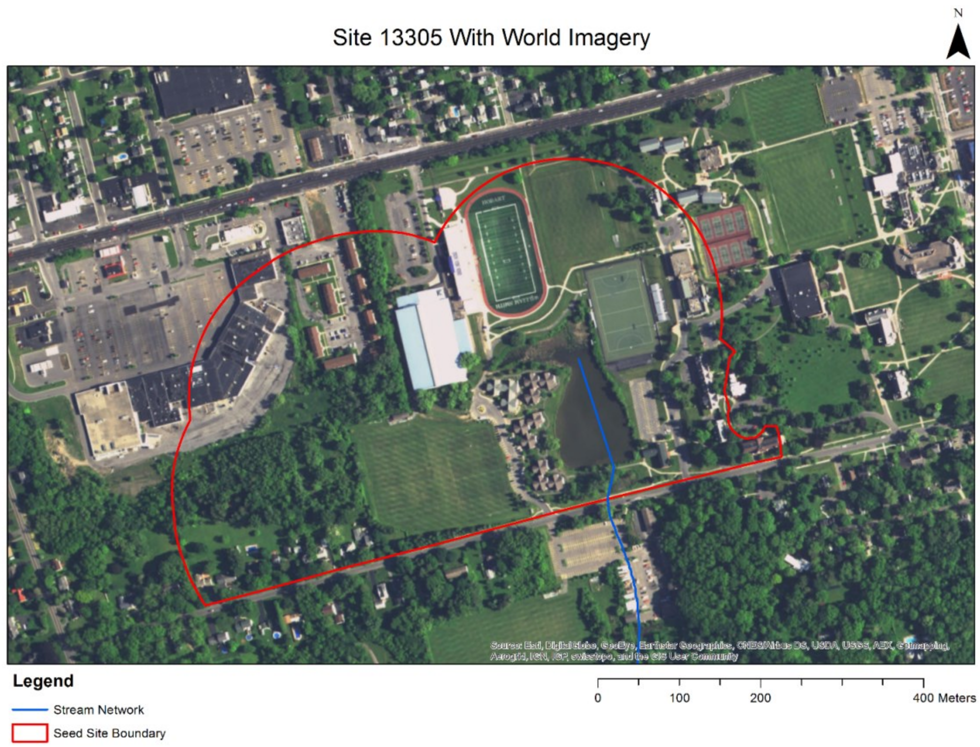


Figure 25: This site was unusual in that a spotted turtle sighting was found in the seed site despite it being suboptimal and highly developed. While there is a body of water found within the seed site and it is connected to other areas via the stream, it highlights the problem that spotted turtle sightings may not always reflect where they inhabit.

With these setbacks in mind, improvements to the model may be possible in future studies with several modifications. One modification would be utilizing a specific LULC classification system for the Nine County Region of Greater Rochester rather than using a national LULC classification which can have inaccuracies. This can be achieved using the national LULC as a starting point and later refining the classification of the LULC using Land Remote-Sensing Satellite (LANDSAT) imagery and remote sensing techniques. By using training sites of known land covers and land uses within a limited area (the nine counties), a more accurate local LULC classification could be made for the study site area. The parameters used to determine which seed site home ranges are the most optimal should also be re-evaluated with the assistance of another expert survey and further research of spotted turtles, especially in the New York State area. Considering that the creation of the seed sites is based on the wetland classification, the wetland parameter should be omitted for the ranking of optimal seed sites.

The results from the stream network and Calcium Carbonate parameters also revealed possible improvement for future studies. While all but one of the turtle sightings sites had stream connectivity, this parameter should be modified to include the quality of the stream network which would then influence habitat quality. Considering the findings with the CaCO3 analysis, the soil properties of the study site should further be explored. Beyond the CaCO3 content, sand content and well as how well the soils drain could also be important parameters to look into considering soft substrate and well drained soils are necessary for spotted turtle nesting (Ernst & Lovich, 2009; Gibbs et al., 2007).

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Appendix

Appendix 1. This table details the hydro connectivity of all the sites that had spotted turtle sightings present. For connected hydro, an * means that the site is not surrounded by seed site home ranges within 3 or higher ranking and are considered semi isolated. It is also important to note that the # of streams that are independent of one another within the seed site. Often stream networks may appear separate within the seed site but connect outside of it. Smaller offshoots from primary streams were not counted for the number of streams category but were noted. Only the Optimal 2 rankings were listed for comparison.

Site ID	Connected hydro	# of streams	Rank of site (Optimal 2)	Comments
3917	yes	2	5	One stream has several offshoots and crosses the width of site
4134	yes	2	5	No offshoots; one stream right along border of site
4342	yes	3	5	several offshoots and also large bodies of water (~4)
5513	yes	2	5	No offshoots; doesn't cover much of the seed site
5952	yes	2	4	three bodies of water (one very large); one offshoots; no nearby ranks of 4 or above but near a rank 3
7171	yes	1	4	All the streams within the seed site connect; several offshoots; several small bodies of water

7776	yes	2	4	Two bodies of water (one relatively large); some offshoots.
7945	yes	2	5	A few bodies of water; two offshoots for one stream
3988	yes	2	5	Many offshoots for one stream that stretches along the entire width
4243	yes	1	5	Many offshoots; almost grid like pattern for stream offshoots near the northeast end of the site
5440	yes	2	4	Some offshoots; limited to edges of the site
5507	yes	1	4	one offshoot; limited to northern end of the site
5517	yes	6	4	Four of the "individual streams" actually connect outside of the seed site. Some small bodies of water
5548	yes	1	4	several offshoots and some small bodies of water
8879	yes	2	3	Right next to Lake Ontario. Not surrounded by sites 4 or above but one other rank 3 site nearby
14581	yes	1	3	Nearby sites that are considered optimal; A few offshoots
2482	yes	2	2	Nearby sites that are considered optimal; several offshoots and small bodies of water.

4148	yes	7	3	Nearby sites that are considered optimal; several offshoots and little pieces of streams that are not connected to anything within the study site (might be connected beyond the 9 county region; a few small bodies of water)
5366	yes	1	3	Nearby sites that are considered optimal; stream limited to east side of site.
5430	yes	6	2	Nearby sites that are considered optimal; one offshoot for one stream. Several "individual streams" connect outside of seed site
5431	yes	1	3	Nearby sites that are considered optimal; one offshoot
5532	yes	2	2	Not surrounded by sites 4 or above but one other rank 3 site nearby; technically only one stream but it goes out of seed site and back in
5833	yes	1	3	Not surrounded by sites 4 or above but one other rank 3 site nearby; lake Ontario is right next to seed site
5912	yes	2	3	Nearby one site that is considered optimal; larger bodies of water (5) with one being connected via stream to a optimal site

7567	yes	2	2	Nearby sites that are considered optimal; several bodies of water (two relatively large). Technically just one stream that is connected outside of seed site; one offshoot for one stream.
8039	yes	1	3	Not surrounded by sites 4 or above but a few rank 3 sites nearby; one offshoot
13305	yes*	1	3	No nearby sites with rank of 3 or above; rather isolated though has one large body of water
15594	no	0	3	No streams but next to Lake Ontario so technically turtles could use lake to go to other nearby shore sites; no nearby optimal site along the coast though some rank 3 along the coast somewhat nearby

Appendix 2: This table details all of the soil types that were found within the study site that had at least 1% possibility of having CaCO3. Listed in the table below is each soil name, the average depth of the A layer of the soil type, the average amount of CaCO3 present in the soil by percent, and the counties that the soil type is found in.

Nine County Region of NYS			
Soil name	**Average CaCO3 (%)**	**Average Depth (in)**	**Counties Found In**
Angola	0-2.5	0-7.8	Genesee, Livingston, Ontario, Yates, Wyoming
Appleton	0-2	0-8	Orleans, Seneca, Wayne, Monroe, Wyoming, Genesee,
Arkport	0-1	0-8.4	Livingston, Orleans, Wyoming, Yates
Benson	0-1	0-8	Genesee, Monroe, Livingston
Canandaigua	0-1	0-8.3	Monroe, Ontario, Wayne, Genesee
Carlisle	0-5	0-75	Ontario
Conesus	0-2	0-9	Genesee, Livingston, Ontario, Seneca, Wyoming, Yates
Cosad (Cs)	0-1	0-8.5	Orleans, Seneca
Farmington	0-2	0-5	Orleans, Seneca

Fluvaquents	0-5	0-2	Ontario
Galoo	0-5	0-8	Ontario
Geneseo	0-1	0-10	Ontario
Hemlock	0-10	0-11	Ontario
Joliet	0-15	0-5	Wayne
Junius	0-1	0-11	Yates
Kendaia	0-2	0-8	Genesee, Livingston, Ontario, Orleans, Yates
Lairdsville (LaB)	0-8	0-9	Orleans
Lamson	0-1	0-11.5	Genesee, Livingston, Monroe, Orleans, Wayne
Lansing	0-2	0-8	Genesee, Livingston, Ontario, Seneca, Wyoming, Yates
Lima	0-1	0-9.6	Genesee, Livingston, Monroe, Seneca, Yates

Lockport	0-1	0-6.3	Monroe, Orleans, Wayne
Lyons	0-2	0-10	Genesee, Livingston, Monroe, Ontario, Orleans, Seneca, Wayne, Wyoming, Yates
Massena	0-8	0-8	Orleans
Minoa	0-1	0-8.5	Genesee, Orleans
Newstead	0-1	0-9.4	Genesee, Orleans, Wayne
Nuhi	0-1	0-10	Ontario
Oatka	0-1	0-20	Genesee
Ovid	0-1	0-8	Livingston, Orleans
Palatine	0-1	0-9	Genesee
Palmyra	0-2	0-8	Ontario
Papakating	0-1	0-8	Wyoming

Phelps	0-2	0-10	Ontario
Sloan	0-1	0-17	Seneca
Sun, moderately shallow	0-1	0-8	Monroe
Udorthents	0-13.3	0-10.4	Genesee, Monroe, Ontario, Wayne, Wyoming, Yates
Wallkill	0-1	0-16	Livingston, Seneca, Wyoming
Wamers	0-1	0-18	Genesee
Wayland	0-1	0-8	Livingston, Yates

Appendix 3. The below table details suboptimal seed site home ranges with turtle sightings and why they may be ranked lower than they should. It also highlights the importance that spotted turtles may not be as particular about their habitat needs and can more readily adapt to changed ecosystems. It's important to note that the spotted turtle sightings are outdated and may not be as applicable to the model.

	Turtle sightings with rankings below a four				
Seed site ID	**Original**	**Optimal 1**	**Optimal 2**	**Match aerial**	**Comments**
2482	2	2	2	no	While it does have mostly forest like the NCR states, some of the supposed wetland is farm field which may or not be abandoned (some cannot be seen since it is covered by forest; might be there might not). However mostly correct. Does have a large percent of forest (57%), too little meadow (4%), and too little wetland (16%) according to parameters.
4148	3	3	3	yes	Too much forest (40%) and not enough meadows (4%) according to parameters. Match well to aerial photography. Could have been thrown out because of two restrictive of parameters.
5366	3	3	3	yes	Hard to tell for sure if wetland is present in some areas because of forest cover. Too much forest (54%) and too little meadows (0%) according to parameters.
5430	2	2	2	no	Misclassified low density urban for scrub shrub or pasture (mostly correct). Hard to tell for sure if wetland is present because of forest cover. Too much forest (52%) and too little wetland (10%) according to parameters. Meadows is met with the addition of pasture technically (for some reason did not hit for parameters; may be because it was at 15% not sure). Without pasture, the meadows category would be zero since there is no actual meadows. Also must consider that some of the low density urban was misclassified as pasture.
5431	2	3	3	no	Misclassified low density urban for scrub shrub or pasture. Misclassified a field for forest. Didn't capture the stream to the north. Hard to tell for sure if some of the wetland is present because of forest cover. Too much forest (66%) and too little wetland (14%) according to parameters. Meadows was all pasture.

5532	2	2	2	no	Misclassified low density urban for pasture and some forest or forested wetland seems to be misclassified as pasture. Too little forest (2%), too little wetland (9%), and too much meadows (which is all pasture; 28%) according to parameters. Most of the site is covered in farmland either pasture (28%) or cropland (50%) according to parameters.
5833	3	3	3	no	Misclassified developed and some forest area for pasture. Some urban area misclassified as forest though those areas are surrounded by trees. Too little forest (11%), too little wetland (7%), too much meadow (all pasture; 23%) according to parameters. Way less pasture than classified.
5912	2	3	3	no	Misclassified open area in forest as cropland (may had once been cropland prior but later reclaimed by forest). Other minor misclassifications but otherwise accurate. Too much forest (41%) and too little wetland (24%) according to parameters.
7567	2	2	2	yes	Some minor misclassifications (little bit more forested wetland than depicted). Too little forest (4%), too little wetlands (22%), and too much meadows (20%) according to parameters. All the meadows was pasture.
8039	3	3	3	yes	Too much meadow (48% with 1% of that being actual meadow, the rest being pasture) and too little wetland (21%) according to parameters.
8879	4	3	3	no	Misclassified urban area for pasture. Most of the area is suburban development with some trees but the LULC does not really match this very well. What it considers to be forest is just a grouping of trees. Too much meadows (41%) and too little wetlands (3%)
13305	3	3	3	yes	High amount of development (73%; looks like some sort of school grounds). Water feature that is classified as open water looks like it's manmade. Too little wetland (0%) and too much meadows (17%; all pasture) according to parameters.
14581	4	3	3	yes	Matches well with aerial photography. Part of area classified as pasture appears to be open area with some sort of water feature. Hard to tell for sure if some of the wetland is present because of forest cover. Too little wetlands (22%). Meadows is met with the addition of pasture technically (for some reason did not hit for parameters; may be because it was at 15% not sure).
15594	3	3	3	yes	The only thing misclassified is a golf course (which is hard to classify anyways; misclassified as pasture). Too much meadows (48%; 2% of that is actually meadows the rest pasture) and too little wetlands (0%) according to parameters.