Identifying the Potential Extent of Invasive Phragmites in a Subsection of Norfolk County using Multi Criteria Evaluation

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Abstract

Invasive phragmites are a growing problem in Southern Ontario, especially due to its ease of spread, ability to crowd out native biodiversity and difficulty getting removed. Unfortunately, despite this problem, efforts to map the extent of phragmites in Southern Ontario have been limited, which this study seeks to address so that targeted management solutions can be implemented. Suitable habitat for phragmites was determined for a sub-section of Norfolk County using Multi-Criteria Evaluation. Proximity to water, development, sunlight, soil drainage, slope and topographic roughness were determined to be the most impactful criteria on phragmites habitat. It was found that the most suitable habitats lie on the Southern shore of Lake Erie near the Long Point sand spit, and the Eastern portion of the study area. This is most likely due to the proximity to wetlands and poorly draining soils in these areas. As such, these areas should be prioritized for identification and removal purposes in order to mitigate further spread and damage done by this species. When compared to existing phragmites observations, just over half of all observations were located near areas of high suitability, with the middle and end of the Long Point sand spit being the biggest exception. Several improvements could be made to improve the accuracy of the model, such as including roadside ditches and collecting data from the entirety of the Long Point Sand Spit. Overall, the model was able to determine areas of suitable phragmites habitat which should be targeted for identification and removal.

Introduction

Phragmites australis is a highly invasive species of reed that is increasing in number in the Southern parts of Canada, especially Southern Ontario (Wilcox et al., 2003; Tulbure et al., 2007). This plant is native to the Eurasian continent, and it is not known how it got transported to North America (Government of Ontario, 2022). It grows in dense sections, sometimes with as many as two hundred stalks per square meter, which crowds out native plant species, decreases biodiversity, makes living difficult for wildlife, alters hydrology, affects farming and much more (Ministry of Natural Resources, 2022). It grows very tall, dense, and on a large scale, preventing other species from receiving the necessary amount of sunlight (Great Lakes Commission, 2018). It is not to be mistaken with the native Phragmites, which does not grow in as large numbers as its invasive counterpart and can coexist with other plant species in the ecosystem (Great Lakes Commission, 2018). Phragmites reproduce through seeds and roots which can be spread through water, air, or transport on animals or equipment (Ministry of Natural Resources, 2011). However, the sprouting rate of the seeds are under 50% (Harris & Marshall, 1960) and the plant mostly expands through rhizome spread and clonal growth (Chambers et al., 1999). In addition, this species has the ability to tolerate and spread in roadside ditches, allowing roads to become vectors of spread (Brisson et al., 2010). These characteristics, the loss of biodiversity and a dramatic change in habitat means that invading Phragmites has become a serious problem (Odum et al., 1984, as cited in Chambers et al., 1999). Phragmites pose a serious risk to the natural environments of Southern Ontario, especially sensitive ecoregions such as wetlands, requiring the removal of this plant. However, invasive Phragmites are difficult to remove, usually requiring a combination of herbicides, cutting, rolling and burning for a specific period of time, which takes a lot of monetary and labour resources (Ministry of Natural Resources, 2011). The biological habitat of *Phragmites australis* is along the water's edge of shallow quiet water, marshlands, riverine lowlands and groundwater seepage points (Packer et al., 2017). So far it has been found along the shores of all Great Lakes, especially Lake Erie and Huron, and has managed to make its way further inland in Southern Ontario (Polluck, 2020).

While efforts to map phragmites in along the United States Great Lakes shorelines have been numerous using remote sensing (Bourgeau-Chavez, 2013) and species distribution modelling (Mazur et al, 2014), similar efforts on the Canadian side of the border have been minimal. Both types of models require the use of phragmites extent data, which is not widely available in Southern Ontario. The most widely available public map of phragmites is a user-based, invasive species monitoring effort called EDDMaps, which as a result of its public input is not as accurate. Independent efforts to map and destroy phragmites have been done on local/municipal/study scale (for example, Long Point and Rondeau provincial park (LPPAA, 2023)), but this data remains private or has yet to occur on a larger/more provincial scale. As such, multi-criteria evaluation was chosen a way to potentially map the extent of phragmites in a region in Southern Ontario.

The aim of this project was to map the potential extent of *Phragmites australis* in a subsection of Norfolk County, Ontario using suitability habitat modeling based on multi criteria evaluation. The mapped extent will be further used to analyze where resources for identification and removal should be prioritized. Identifying the area where Phragmites can exist and could spread in the future will help decision makers determine where to send teams for in-field identification and determine areas that are in urgent need of extirpation. The output map was used in conjunction with known phragmites outbreaks to determine areas most at risk for negative effects which would help prioritize where removal efforts should be targeted. As Canada's most invasive plant species (LPPAA, 2023), it is vital to know where these plants are located and could spread into the future in order to make effective management decisions and prevent further damage to species native to North America.

Objectives

The objectives of this project can be split into four broad categories as follows:

1. Identify factors and constraints that affect the habitat suitability for invasive Phragmites. Derive needed criteria from available datasets.
2. Standardize data on same scale, rank and assign weights to the identified criteria.
3. Obtain the potential extent of phragmites.
4. Accuracy analysis of the model output using existing phragmites observations and sensitivity analysis of the criteria weights.

Study Area

The study area chosen for this project is a subsection of Norfolk County, which exists along the northern shore of Lake Erie in Southern Ontario as seen in Figure 1. It contains the Long Point sand spit, which is comprised of Long Point Provincial Park, the Big Creek National Wildlife Area, and the Long Point National Wildlife Area. The Long Point sand spit is a large freshwater sand spit that is covered in wetlands and is home to many migrating birds making it an important ecological reserve (Ontario Parks, 2023). Since 2015, Long Point Provincial Park in addition to other provincial parks has been trying to eradicate Phragmites from their environment (LPPAA, 2023). This makes the area an ideal candidate for suitability modelling as it hosts a variety of sensitive habitats in need of protection, in addition to being along the shores of Lake Erie which is a major source of invasion (Polluck, 2020). The study area also contains the cities of Port Rowan and Long Point, a large portion of the Big Creek river and St. Williams Conservation Reserve. It was important to include areas outside of the shoreline of Lake Erie and the wetlands of Long Point as phragmites is also making its way inland (Polluck, 2020), so analysis of these environments will help with phragmites management in the interior.

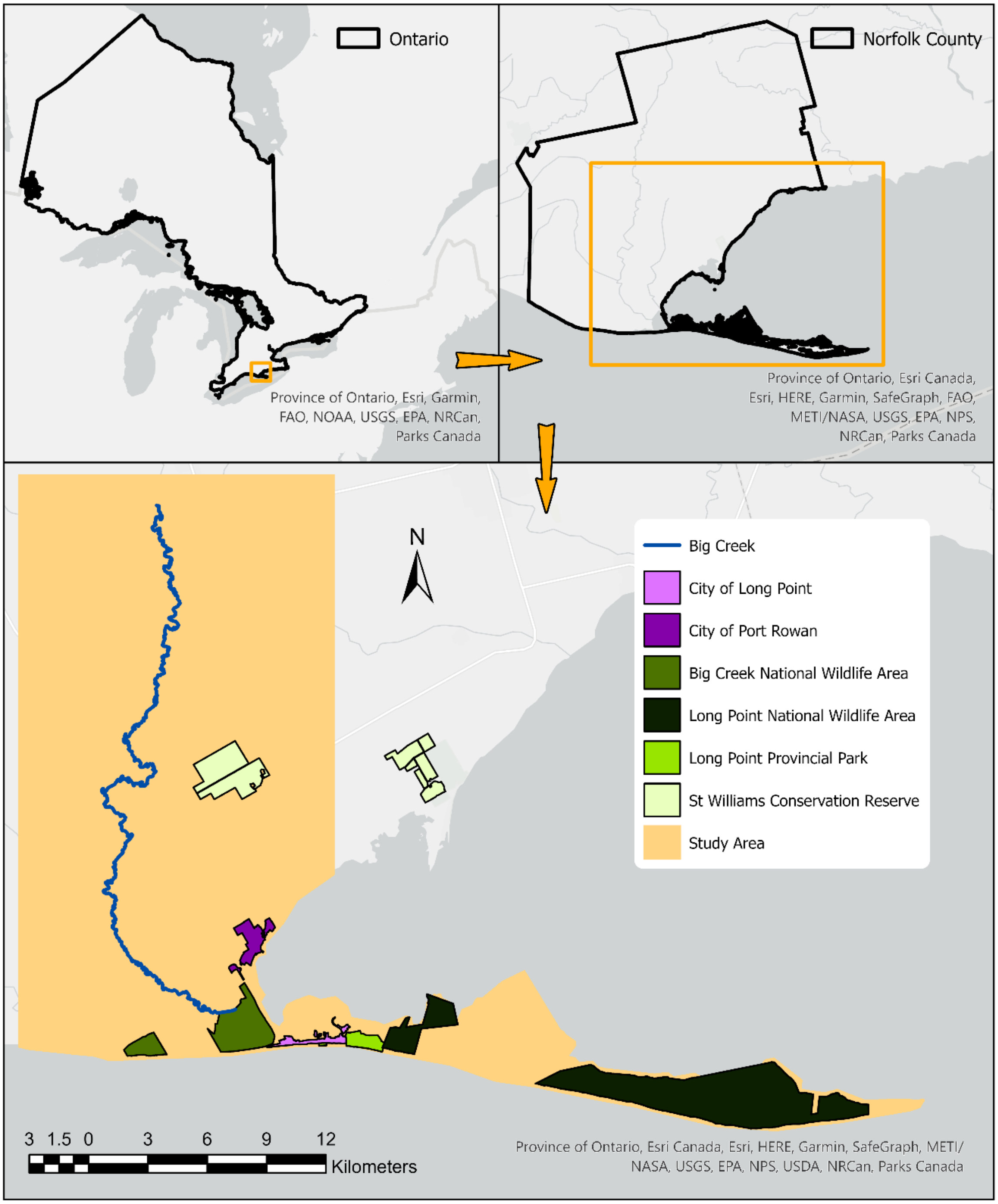


Figure 1: Study area including the Long Point sand spit and a subsection of Norfolk County. Coordinate System: NAD 1983 UTM Zone 17N. Created using data adapted from: Land Information Ontario (2018-2019, 2008-2022, 1893-2023), Map Norfolk (2017, 2017-2022) and Ontario Ministry of Natural Resources and Forestry (2010-2023).

Data Acquisition

Criteria for the model was determined from a review of the literature. It was found that sunlight (Packer et al, 2017), distance from development (roads and buildings) (Mazur et al, 2014), soil drainage (Mazur et al, 2014), slope (Jung et al, 2017), topographic roughness (Mazur et al, 2014), and proximity to water (open or ground) (Packer et al, 2017) were the most significant criteria affecting phragmites habitat. These criteria were derived from data listed in Table 1.

Table 1: Summary of the sources of the acquired data.

Dataset Used	First Publication Date	Last Update	File Format	Publisher
Ontario Digital Terrain Model (Lidar-Derived)	2019/08/23	2023/02/07	Disc Image File	Ontario Ministry of Natural Resources and Forestry
Ontario Digital Surface Model (Lidar-Derived)	2020/07/23	2023/02/07	Disc Image File	Ontario Ministry of Natural Resources and Forestry
Building Footprints	2017/12/20	2022/10/18	Shapefile(.shp)	MAP Norfolk
Soil Survey Complex	2015/11/20	2019/11/06	Shapefile(.shp)	Ontario Ministry of Agriculture, Food and Rural Affairs
Ontario Hydro Network (OHN) - Watercourse	2010/08/12	2019/10/10	Shapefile(.shp)	Ontario Ministry of Natural Resources and Forestry
Ontario Hydro Network (OHN) - Waterbody	2010/08/09	2018/07/12	Shapefile(.shp)	Ontario Ministry of Natural Resources and Forestry
Wetlands	1978/05/01	2019/05/13	Shapefile(.shp)	Ontario Ministry of Natural Resources and Forestry
Roads	2017/12/20	2022/01/18	Shapefile(.shp)	MAP Norfolk

Digital Terrain Model (DTM)

The Lidar-Derived Digital Terrain Model was downloaded through the Ontario GeoHub. The Lake Erie Package K was chosen as it contains the study area.

Digital Surface Model (DSM)

The Lidar-Derived Digital Surface Model was downloaded through the Ontario GeoHub. The Lake Erie Package 15 was chosen as it contains the study area.

Norfolk Building Footprints

The Building Footprints data was downloaded through the Norfolk County Open Data. It is a vector polygon dataset showing the buildings present in the study area.

Soil Survey Complex

The soil survey complex data was downloaded through the Ontario GeoHub. It is a vector polygon dataset containing different soil classifications and soil properties.

OHN Watercourse

The Ontario Hydro Network (OHN) Watercourse data was downloaded through the Ontario GeoHub. It is a vector line dataset showing water channels such as rivers and creeks.

OHN Waterbody

The Ontario Hydro Network (OHN) Waterbody data was downloaded through the Ontario GeoHub. It is a vector polygon dataset showing the waterbodies in Ontario.

Wetlands

The wetlands data was downloaded through Ontario GeoHub. It is a vector polygon dataset that shows the wetlands existing in Ontario.

Roads

The roads data was downloaded through the Norfolk County Open Data. It is a vector line dataset that displays all roads in Norfolk County.

Methods

A full flow chart detailing the data preparation and methods can be seen in Figure 2. The final model is at a 5m resolution.

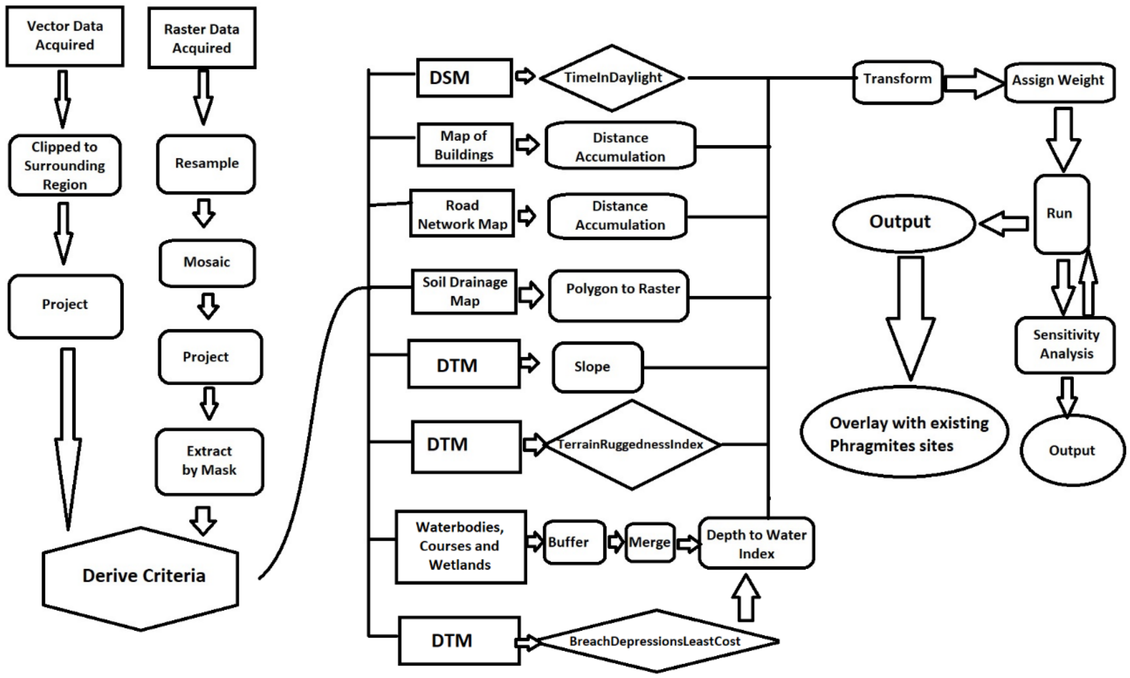


Figure 2: Flow chart showing the steps performed in the suitability model.

DTM/DSM

Data was obtained from the Ontario LiDAR DSM and DTM Lake Erie package around Long Point. These files are 1km by 1km tiles with 0.5m cell resolution. A script was run to reclassify the files into either 5m or 15m resolution. Following reclassification, the tiles were mosaiced together using a script and ArcGIS Pro's mosaic tool. The resultant 15m DTM contained a few lines of NoData gaps that were one pixel in width. These gaps were filled in using the raster calculator by identifying pixels of NoData and filling them in using the average of the eight surrounding cells. The 15m DSM and 5m DTM/DSM contained no gaps that required filling. Once the mosaics were completed, they were reprojected to the NAD 1983 UTM Zone 17N projected co-ordinate system. Finally, the DSM was clipped to the DTM using the Extract by Mask tool, and the DTM clipped to the resultant DSM using the Extract by Mask tool in order to receive the final study extent. The DTM will be used as the snap raster in the upcoming procedures where appropriate to ensure all the rasters align.

Deriving the Criteria

The identified criteria was derived from the found datasets, as seen in Table 2. Some of the files were Ontario wide and were clipped to Norfolk County using Make Layer From Selection first in order to reduce computation times. All files were reprojected to NAD 1983 UTM Zone 17N.

Table 2: Summary of data sources for criteria

Criteria	Datasets Used	Source
Daylight	DSM	Ontario Ministry of natural Resources and Forestry (2010-2023)
Distance to Buildings	Norfolk Building Footprints and DTM	Ontario Ministry of natural Resources and Forestry (2010-2023) Map Norfolk (2017-2022)
Distance to Roads	Norfolk Roads and DTM	Ontario Ministry of natural Resources and Forestry (2010-2023) Map Norfolk (2017-2022)
Soil Drainage	Soil Survey Complex	Ontario Ministry of Agriculture, Food and Rural Affairs
Slope	DTM	Ontario Ministry of natural Resources and Forestry (2010-2023)
Topographic Roughness	DTM	Ontario Ministry of natural Resources and Forestry (2010-2023)
Proximity to Waterbodies and Water Table	DTM and OHN Watercourse and OHN Waterbody and Wetlands	Ontario Ministry of natural Resources and Forestry (2010-2023) Ontario Ministry of natural Resources and Forestry (1978-2023)

Daylight

Using WhiteBoxTools, the DSM was inputted into the TimeInDaylight tool in order to derive the amount of daylight each raster cell received. The maximum search distance was set to 1000, latitude to 42.7110209, longitude to –80.4668503, UTC offset to –04:00, and start time to sunrise and end time to sunset. All other settings remained the default. It should be noted that the resultant raster showed forests receiving a lot of sunlight, as the LiDAR was taken during a time of year where leaves were in full bloom. This could affect the accuracy of the model as these forested areas would actually be much shadier on the ground (trees are much taller than phragmites).

Distance to Roads

Distance accumulation was used to find the distance from roads. The roads vector file was the input, while the DTM was the input surface raster and vertical cost.

Distance to Buildings

Distance accumulation was used to find the distance from buildings. The buildings vector file was the input, while the DTM was the input surface raster and vertical cost.

Soils

The detailed soil survey data was transformed from polygon to raster, using the drainage class as the raster value. Once the raster was created it was clipped to the study extent using the DTM and Extract by Mask. It should be noted that not all soils were surveyed around Long Point, resulting in some data loss especially around the middle of the Long Point sand spit.

Slope

Using WhiteBoxTools, the DTM was inputted into the Slope tool to calculate the slope. All values remained default.

Topographic Roughness

Using WhiteBoxTools, the DTM was inputted into the RuggednessIndex tool to calculate the topographic roughness based on Riley et al (1999). All values remained default.

Water Table

The watercourses data was buffered by 0.5m in order to transform the line vector into polygon form. Some accuracy was lost as streams vary in width and not all would be 1m. The waterbodies, watercourses and wetlands dataset were merged into one vector file containing surface bodies of water.

Using WhiteBoxTools, the DTM was pre-processed using BreachDepressionsLeastCost in order to smooth the DTM for hydrological analysis. The maximum search distance was set as 1000 and the rest was left as the default.

The Arc Hydro toolset extension was downloaded for ArcGIS Pro. This extension contains a Depth to Water Index tool which estimates the depth to the water table using proximity to waterbodies and elevation. The tool was created according to Murphy et al. 2009.

The merged waterbodies data was the input in addition to the smoothed DTM. The slope factor was set to the same size as the DTM's cell size. Waterbodies have a value of 0m in the output.

Suitability Modeller

ArcGIS Pro's suitability modeler was used to determine the suitability of phragmites habitat. The suitability modeler is a tool used for finding optimal locations based on input criteria (ESRI, 2023). This input criteria must first be transformed to a common suitability scale and then weighted based on ranked importance (ESRI, 2023). The output of the suitability modeler is a raster where each cell is given a suitability score, from which analysis of optimal habitats can be determined (ESRI, 2023).

All the criteria were transformed to the same scale, 10, using the transformations window in the suitability modeler. A summary of the transformation inputs can be seen in Table 3, while a visualization of these transformations can be seen in Figure 3. Most transformations use the MSSmall function which gives higher suitability to small values (ESRI, 2023), as opposed to the Large function which gives more suitability to higher values (ESRI, 2023) and the Unique Values function which assigns suitability based on distinct classes (ESRI, 2023). The mean and standard multipliers both affect the shape of the slope for the chosen functions, with the mean determining the range of most suitable values and the standard affecting the rate at which the slope changes (ESRI, 2023).

Table 3: Summary of transformation inputs for each criteria

Criteria	Function	Mean	Standard	Reasoning
Daylight	Large	1	5	Larger values receive more light
Dist to Roads	MSSmall	0.05	0.15	Emphasis on distance closest to roads
Dist to Buildings	MSSmall	0.25	0.25	Emphasis on distance closest to buildings
Soil Drainage	Unique Values	-	-	Values chosen based on phragmites preference. Very poor/poorly draining soils emphasized.
Slope	MSSmall	1	1	Emphasis on low slopes
Topographic Roughness	MSSmall	0.5	0.5	Emphasis on smoother surfaces
Proximity to Water	MSSmall	0.25	0.5	Emphasis on waterbodies and areas with high water table

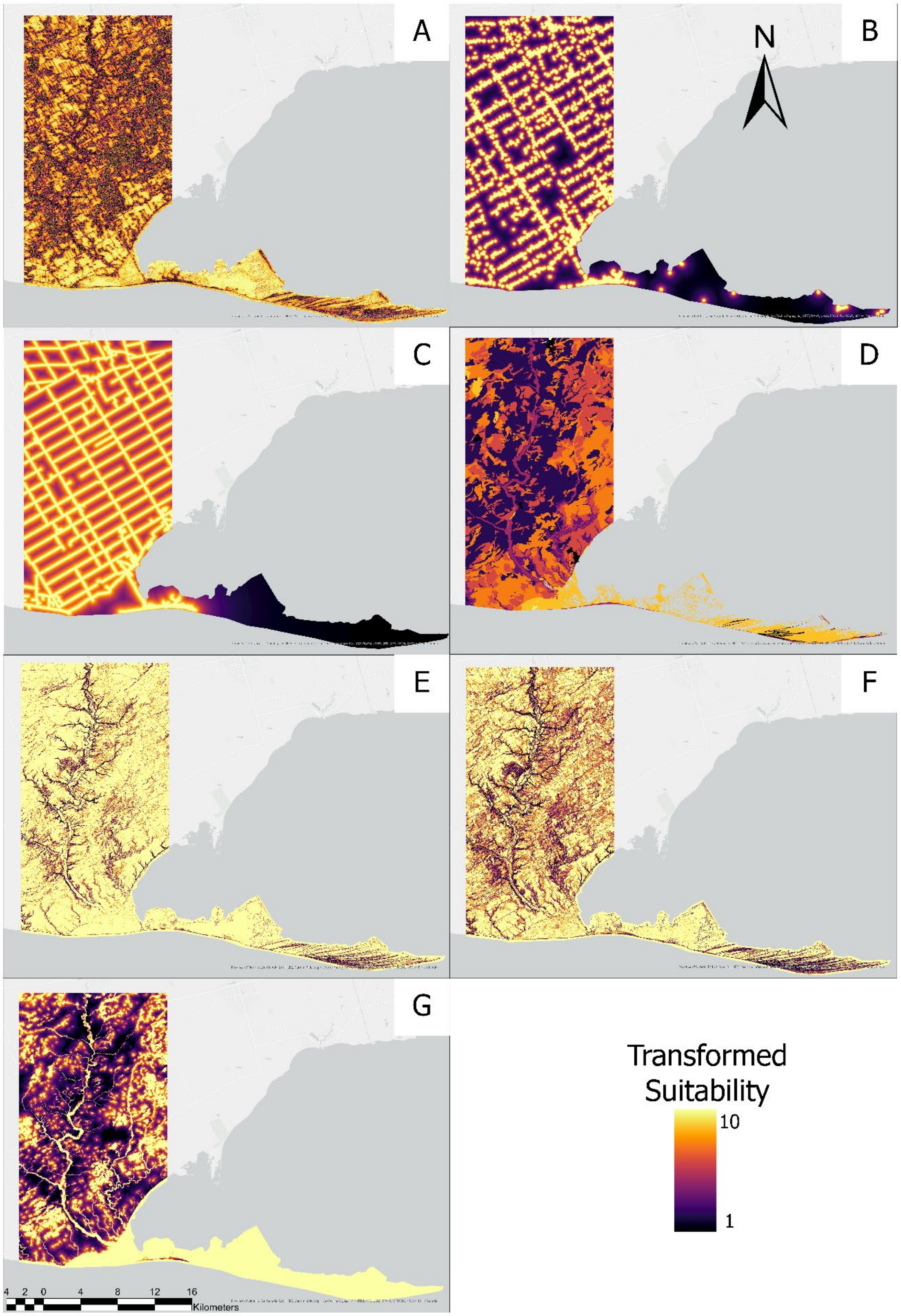


Figure 3: Transformed criteria used for analysis. Coordinate System: NAD 1983 UTM Zone 17N. A) Daylight B) Distance from buildings C) Distance from roads D) Soil drainage E) Slope F) Topographic Roughness G) Proximity to the water table.

After transforming the data, each criteria was ranked. Based on the literature, phragmites is most limited by hydrology (Packer et al. 2017) followed by topography and distance to development (Mazur et al. 2014). A summary of the weights chosen for the model can be found in Table 4.

Table 4: Summary of criteria weights used in analysis

Criteria	Weight	Reasoning
Daylight	1	Requires light, but can tolerate partial shade (Packer et al. 2017)
Dist to Roads	3	Proximity to development (Mazur et al, 2014). Roads were given higher weight then buildings as roads can also act as a vector of spread through roadside drainage (Brisson et al, 2010)
Dist to Buildings	2	Proximity to development (Mazur et al, 2014)
Soil Drainage	5	Related to hydrology, soil drainage has a major effect on available water. Soils with high runoff or low drainage have greater phragmites prevalence (Mazur et al, 2014)
Slope	2	Phragmites prefer low slopes (Jung et al, 2017)
Topographic Roughness	4	Phragmites prefer smoother terrain (Mazur et al, 2014)
Proximity to Water	8	Phragmites require access to water in order to grow, it is most limited by hydrology (Packer et al, 2017). Areas with surface water (depth = 0) have highest priority followed by areas close to waterbodies/near the water table

The model was run using ArcGIS's suitability modeler to receive the final suitability raster in addition to the optimal locations for phragmites using the Locate tab. In this tab, two regions were selected as the desired locations with a 0% shape/utility trade-off (natural shape is most desired) and the resolution set to high.

Sensitivity and accuracy analysis were performed. A map of current phragmites distributions was obtained from EDDMaps and overlain atop the final suitability and location rasters to see how well the model captured real data. Additionally, sensitivity analysis of the weights was performed by leaving all the weights the same as the final output, then changing each criteria to run through with the minimum weight value, 1, and the highest weight value, 8, in order to see how sensitive the model was to each variable. A suitability raster and optimal habitats raster was created for each evaluation, resulting in fourteen suitability and optimal habitat rasters. The top 15% most suitable cells were found from the suitability raster of each differing weight scenario and then summed together, resulting with a final raster showing how many times each cell has exceeded the 15% suitability threshold. Finally, the model was run at a 15m resolution to compare and see how sensitive the model was to resolution.

Results & Discussion

As expected, the final maps showed high suitability along waterbodies. The two most optimal habitats were in the South of the study area along the shoreline of Lake Erie including the beginning of the Long Point sand spit (Optimal Habitat 1), as well as the Eastern part of the study area (Optimal Habitat 2) as seen in Figures 4 and 5. The beginning of the sand spit had high suitability since the area is dominated by wetlands and is close to development. The Eastern part of the study area showed high suitability due to poorly draining soils and lots of waterbodies including ponds and wetlands.

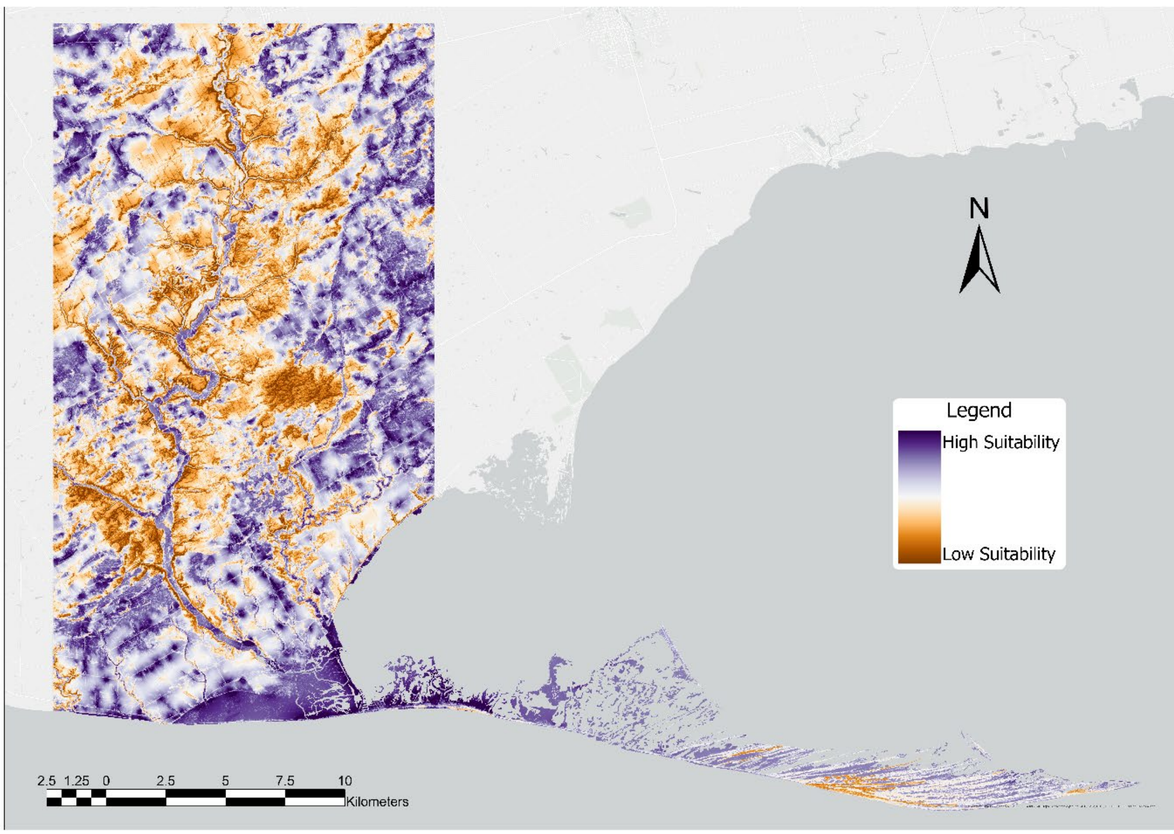


Figure 4: Final suitability raster for phragmites habitat at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

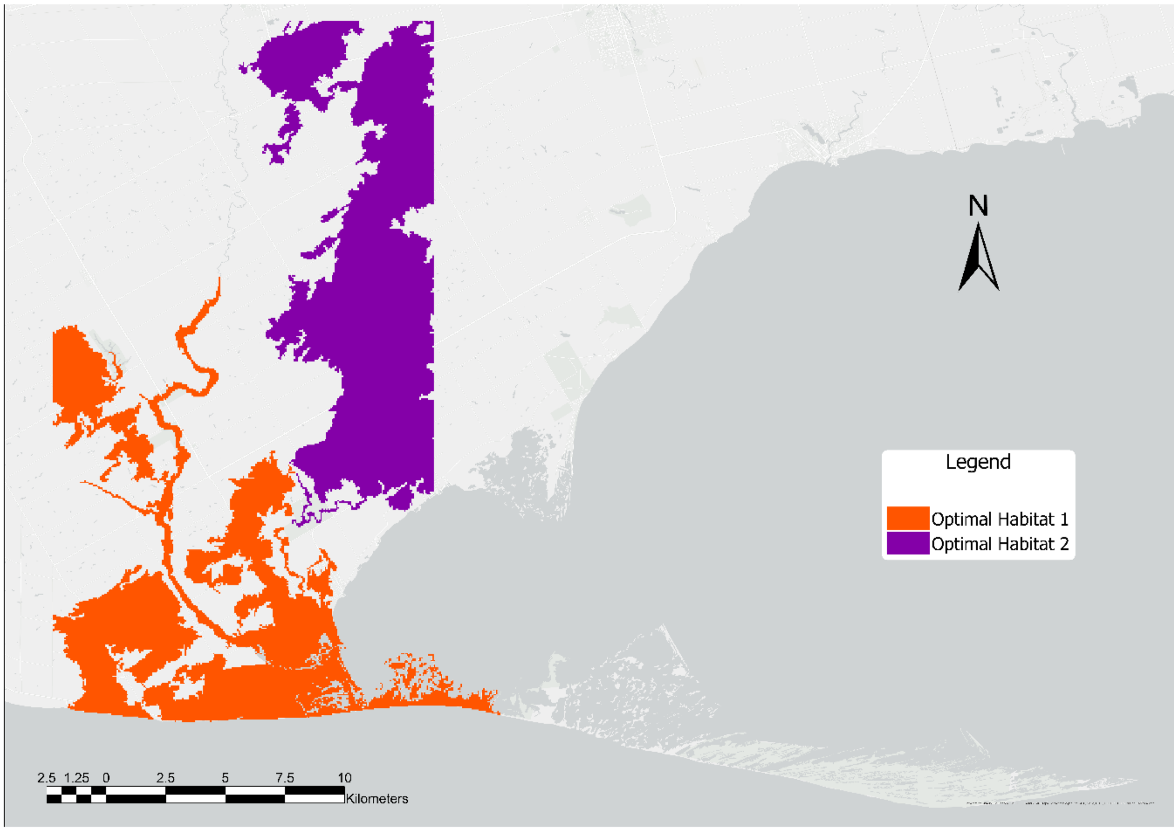


Figure 5: Optimal phragmites habitats at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

Although Big Creek river itself had high suitability, the areas right around the channels did not show high suitability for phragmites to grow. Outside of the weight values assigned to the criteria, this could be due to the steep slopes and rugged topography rivers create as they incise into the ground, meaning river escarpments could act as a barrier to spread. These areas also received less sunlight than other areas due to the steep slopes and rugged surface, in addition to being dominated by trees which means that little sunlight can reach the ground.

Surprisingly, regions of low suitability were observed throughout the middle and end of the Long Point sand spit, near the Long Point National Wildlife Areas, despite being a large wetland. This could be because of the presence of sand dunes, which create rugged, locally high areas of elevation composed of sand. The low suitability results could also be due to patchy soil data availability. Throughout the Long Point sand spit not all areas were surveyed, possibly due to being more open water than soil, leaving large expanses of the wetland as essentially NoData. This resulted in these wetlands not being taken into consideration in the suitability model, even though they would be suitable locations for phragmites to grow. The model was run removing the soil drainage criteria, which resulted in a larger portion of the wetlands being deemed as highly suitable as seen in Figures 6 and 7, especially with the expansion of Optimal Habitat 1. Unfortunately, this results in the loss of an important variable, so in the future it may be beneficial for the data collectors to sample soils for the whole area or assign the locations between soils as open water. Another reason the Long Point sand spit may not have shown a lot of suitability is due to its distance from roads and the weight given to that criteria.

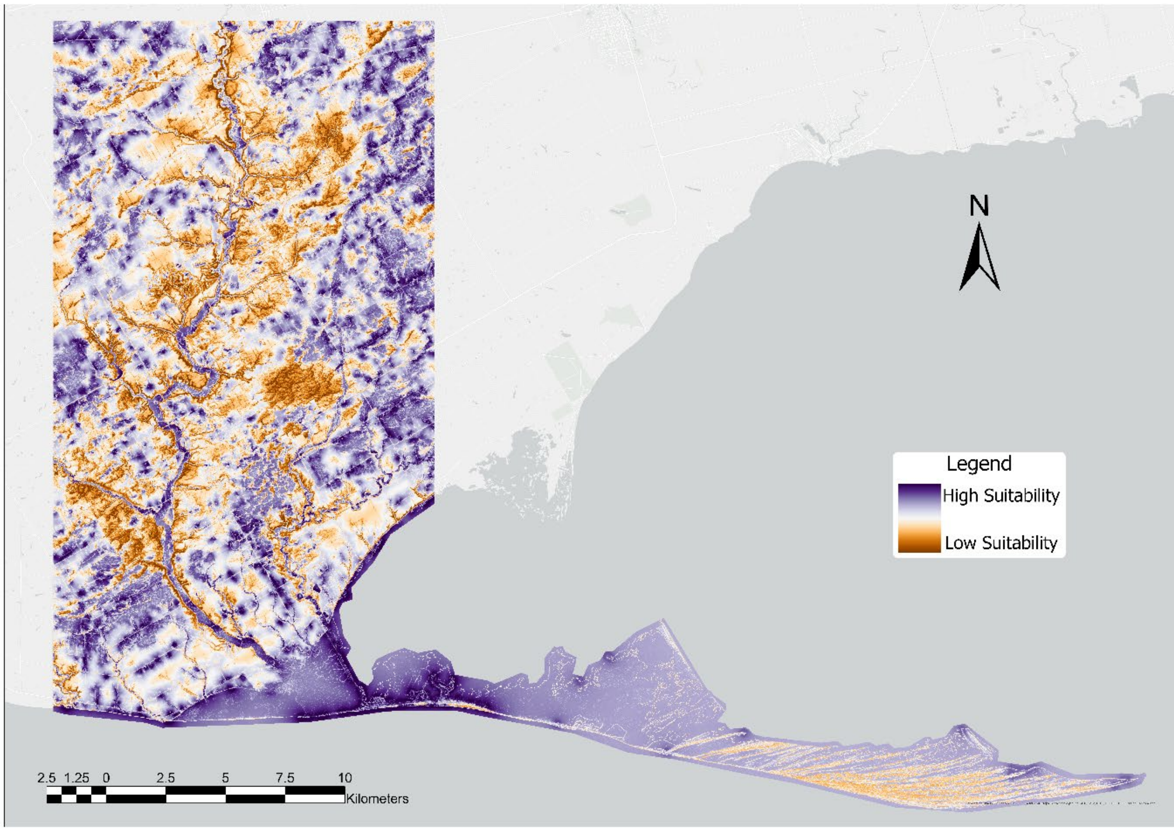


Figure 6: Final suitability raster with soil drainage criteria removed and showing observed phragmites at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

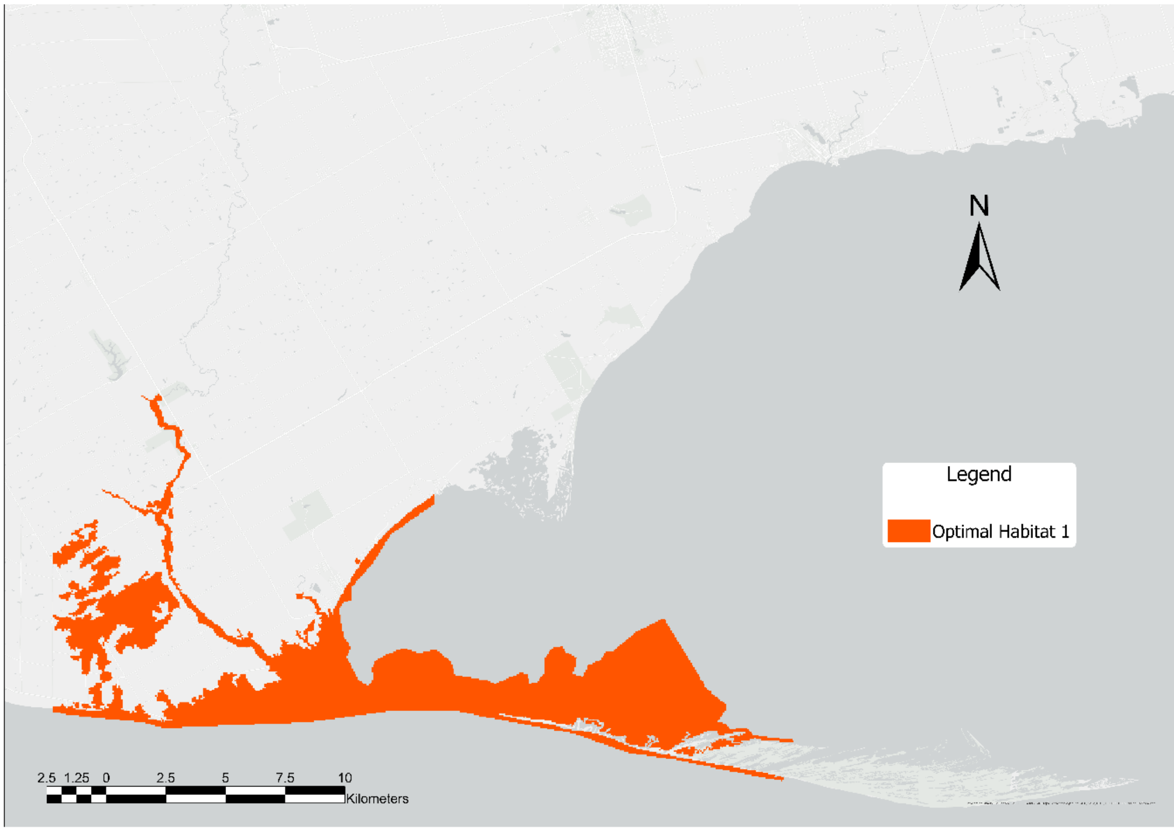


Figure 7: Final optimal locations with soil drainage removed and showing observed phragmites at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

Some accuracy was lost because phragmites cannot stand high water currents (Packer et al, 2017), and the map may be showing high suitability in some places where they may not be able to grow. Such regions would be rivers with high current velocity, and lakes with high currents and waves. This could be mitigated in the future with data on the flow velocity of these waterbodies.

Most highways have drainage systems to the side which are optimal vectors of spread for phragmites (Brisson et al. 2010). As there is no inventory of which roads have these drainage systems, it is difficult to determine where these drains are located, so they were left out of the model. One possible avenue to address this would be to create a buffer around the Roads vector data to include in the waterbodies shapefile, which would allow it to be used in the proximity to water calculations.

Observed phragmites from the EDDMaps were overlain atop the final suitability and optimal locations raster as seen in Figures 8 and 9. Overall, at least half of the observed phragmites in the study area were within one of the optimal locations. The exception are those located in the middle to end of the sand spit. This suggests that the model needs adjustment in order to increase accuracy in this region.

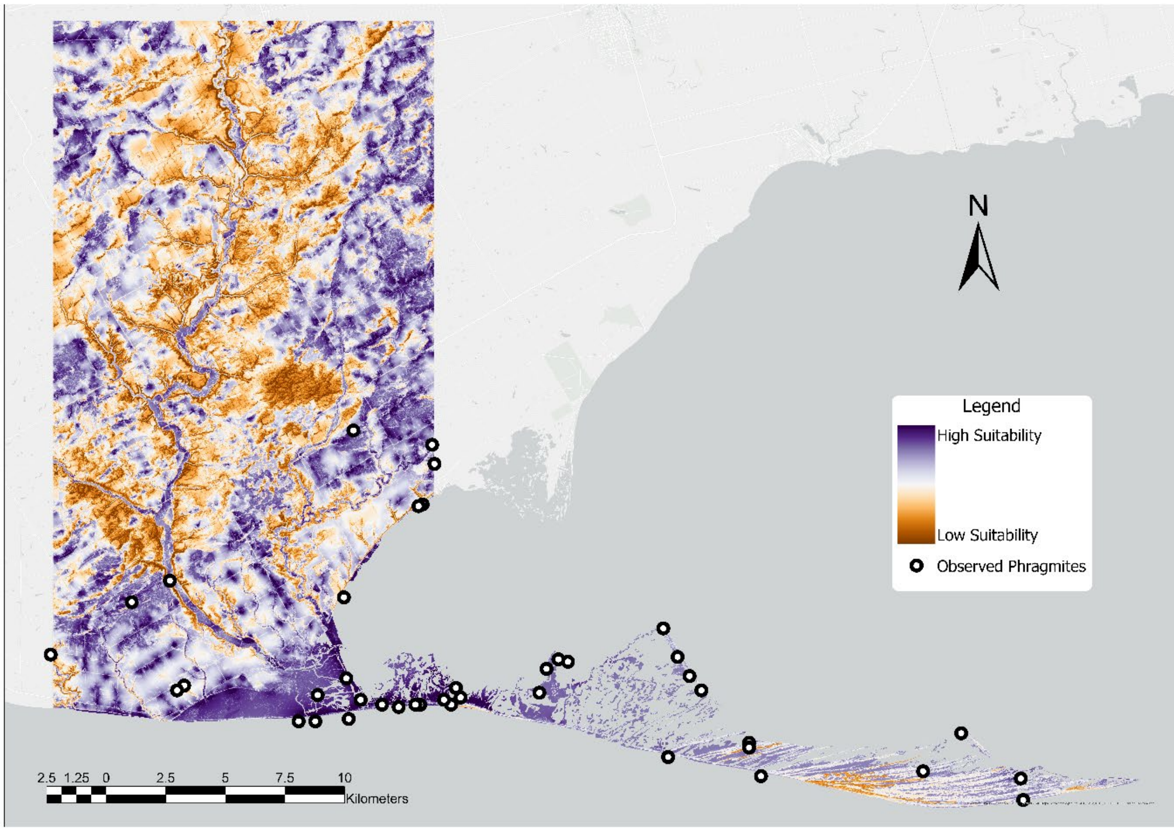


Figure 8: Final suitability raster showing observed phragmites at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

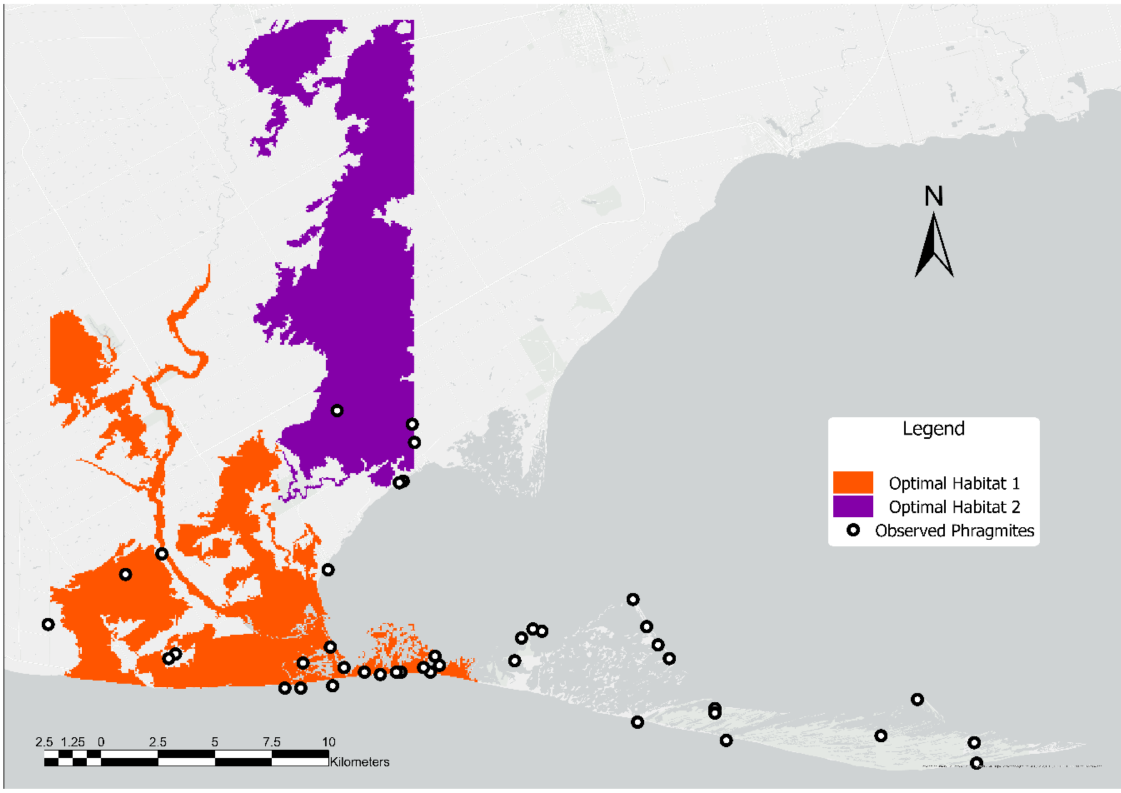
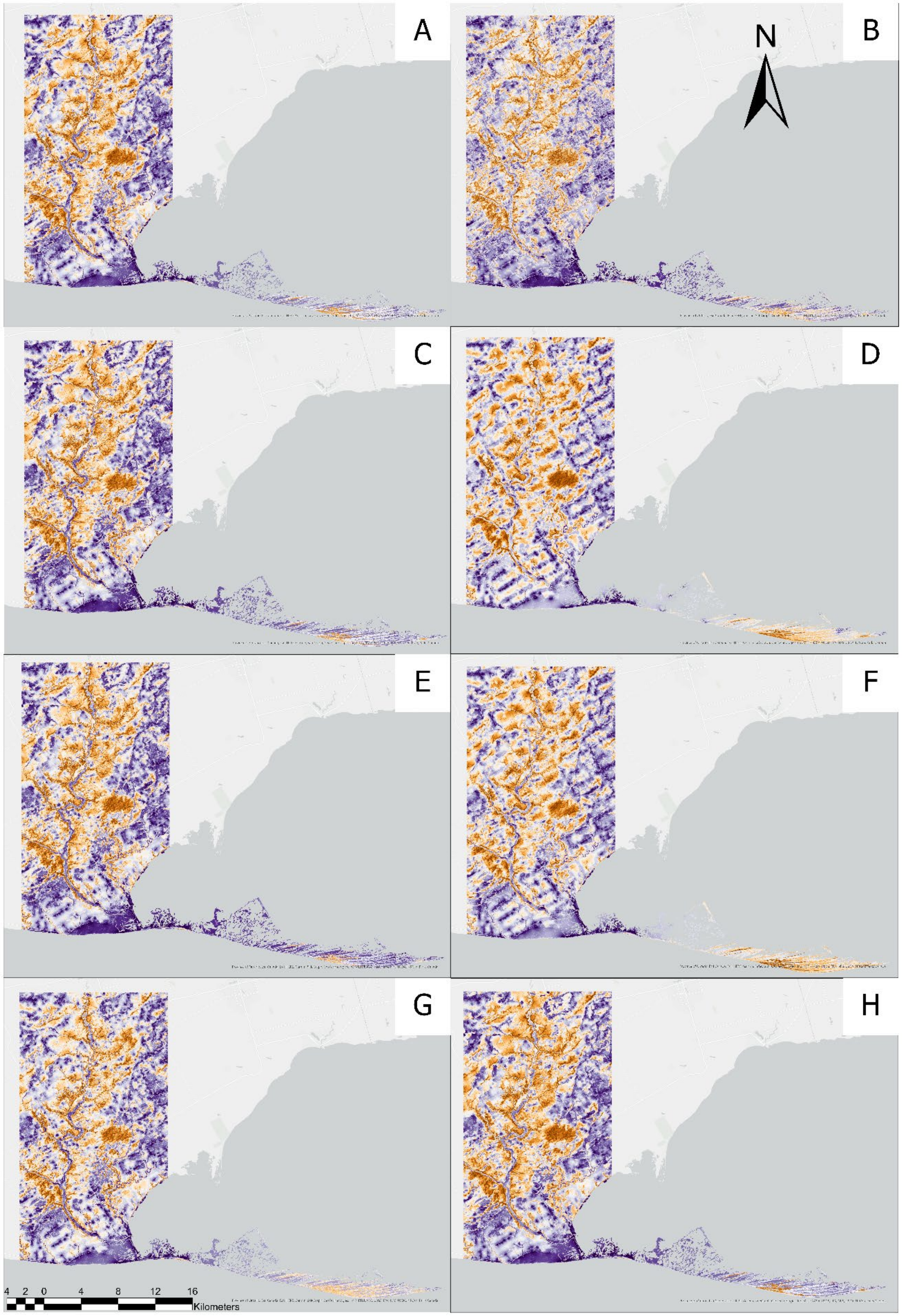


Figure 9: Final optimal locations showing observed phragmites at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

It should be noted that the accuracy of observed phragmites is not the most reliable as the observations were reported by citizens who may not have the expertise for identifying the plant correctly and likely do not have equipment that is highly accurate or precise. Still, these results are helpful for showing how well the model performed.

Sensitivity analysis was performed on the weights, resulting in suitability rasters and optimal habitats for each scenario as seen in Figures 10 and 11. In all scenarios except the water proximity criteria, an optimal habitat was found along the Southern shore near the sand spit. As a result, the proximity to water would be considered the model's most sensitive variable, as Optimal Habitat 1 changed from the North-Western part of the study area to the Southern shore. When the weights of distance to development were high the optimal locations showed preference towards a grid like pattern. When the soil drainage was a higher weight there was preference towards the Eastern portion of the study area, which is mirrored by distance to buildings. Overall, the model run with varying weights still found that the optimal habitats were along the Southern shore and on the Eastern side of the study area.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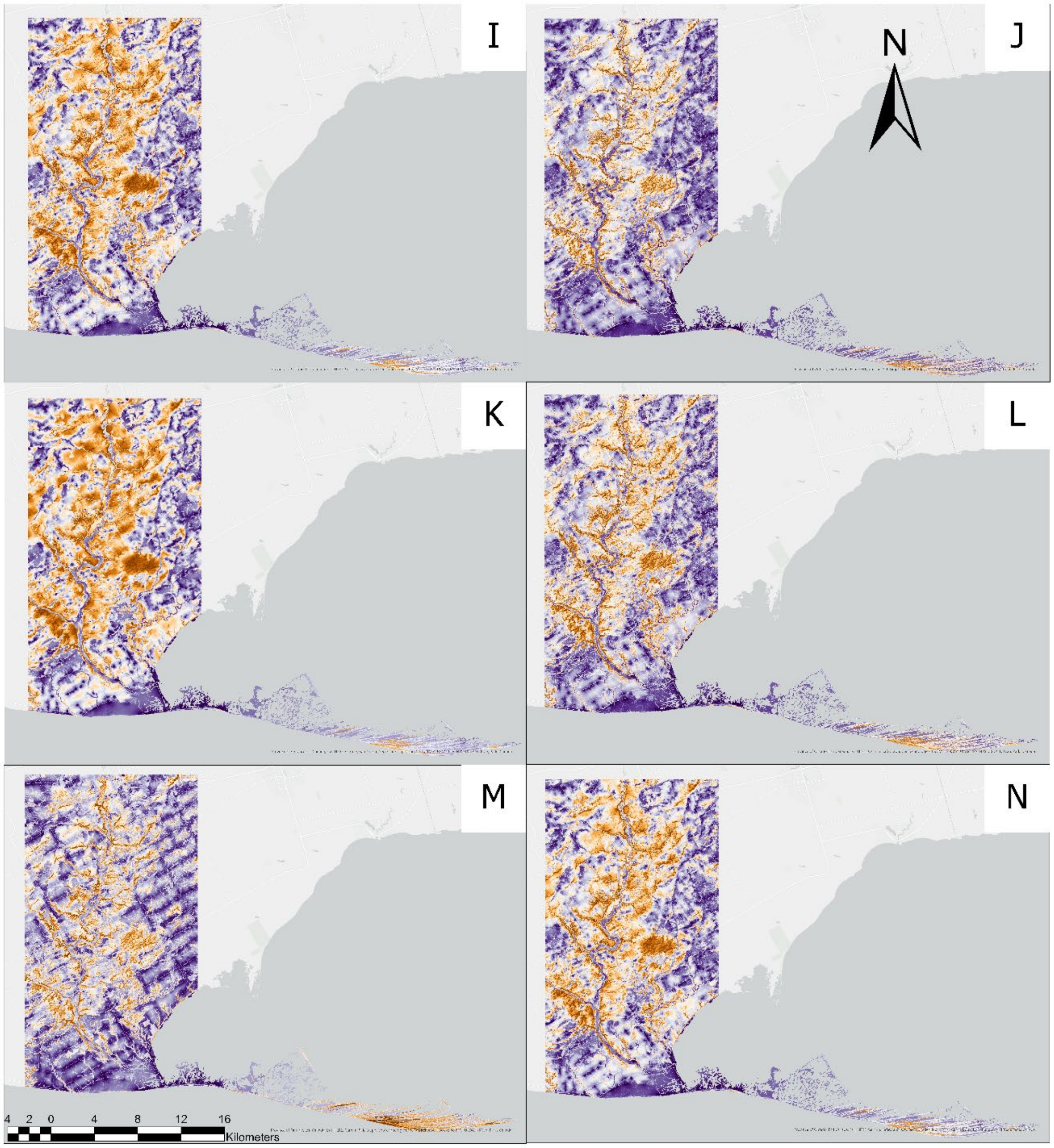
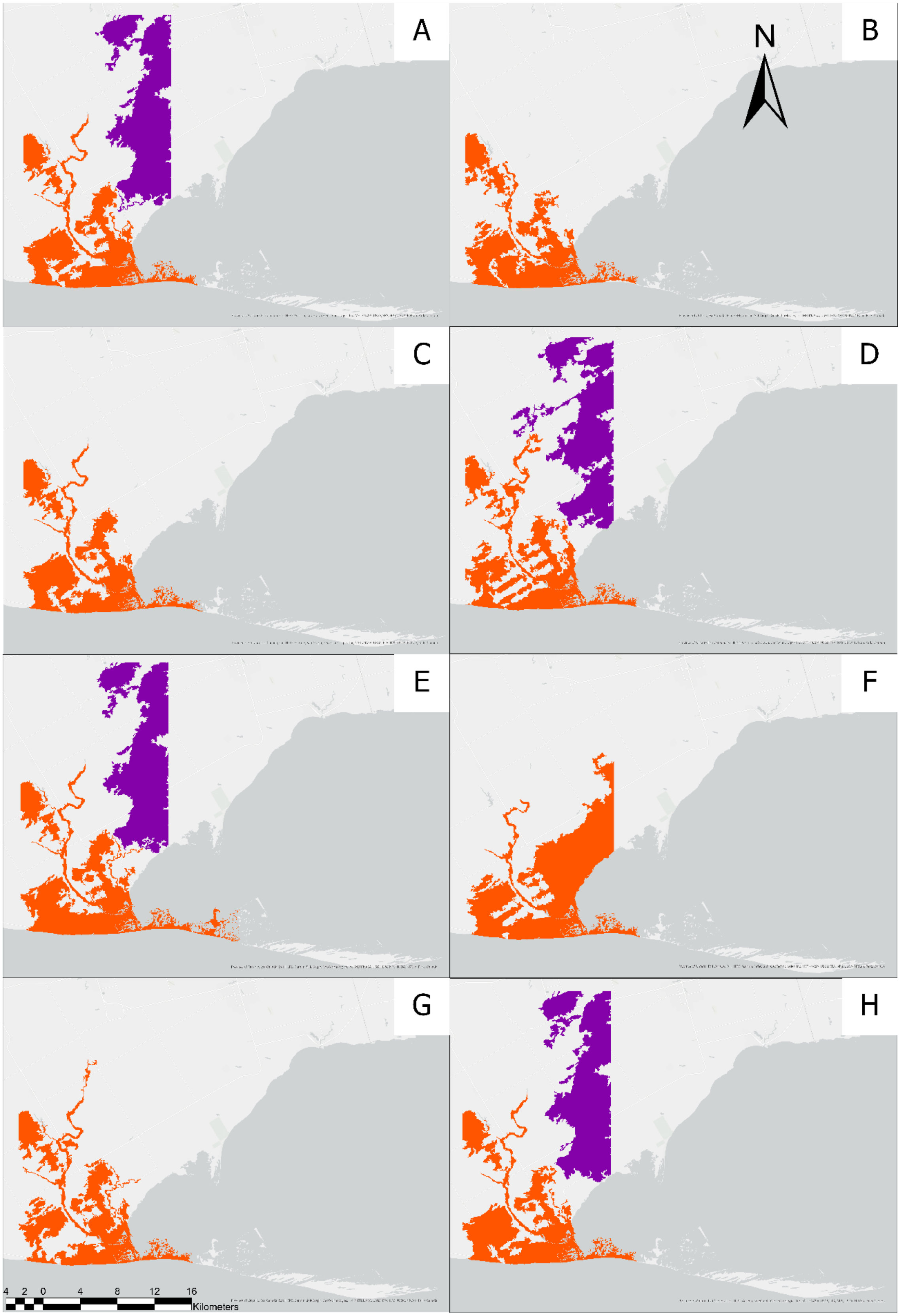


Figure 10: Final suitability rasters for phragmites habitat based on varying criteria weight at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N.A) Daylight weight of 1. B) Daylight weight of 8. C) Distance from buildings weight of 1. D) Distance from buildings weight of 8. E) Distance from roads weight of 1. F) Distance from roads weight of 8. G) Soil drainage weight of 1. H) Soil drainage weight of 8. I) Slope weight of 1. J) Slope weight of 8. K) Topography weight of 1. L) Topography weight of 8. M) Water table weight of 1. N) Water table weight of 8.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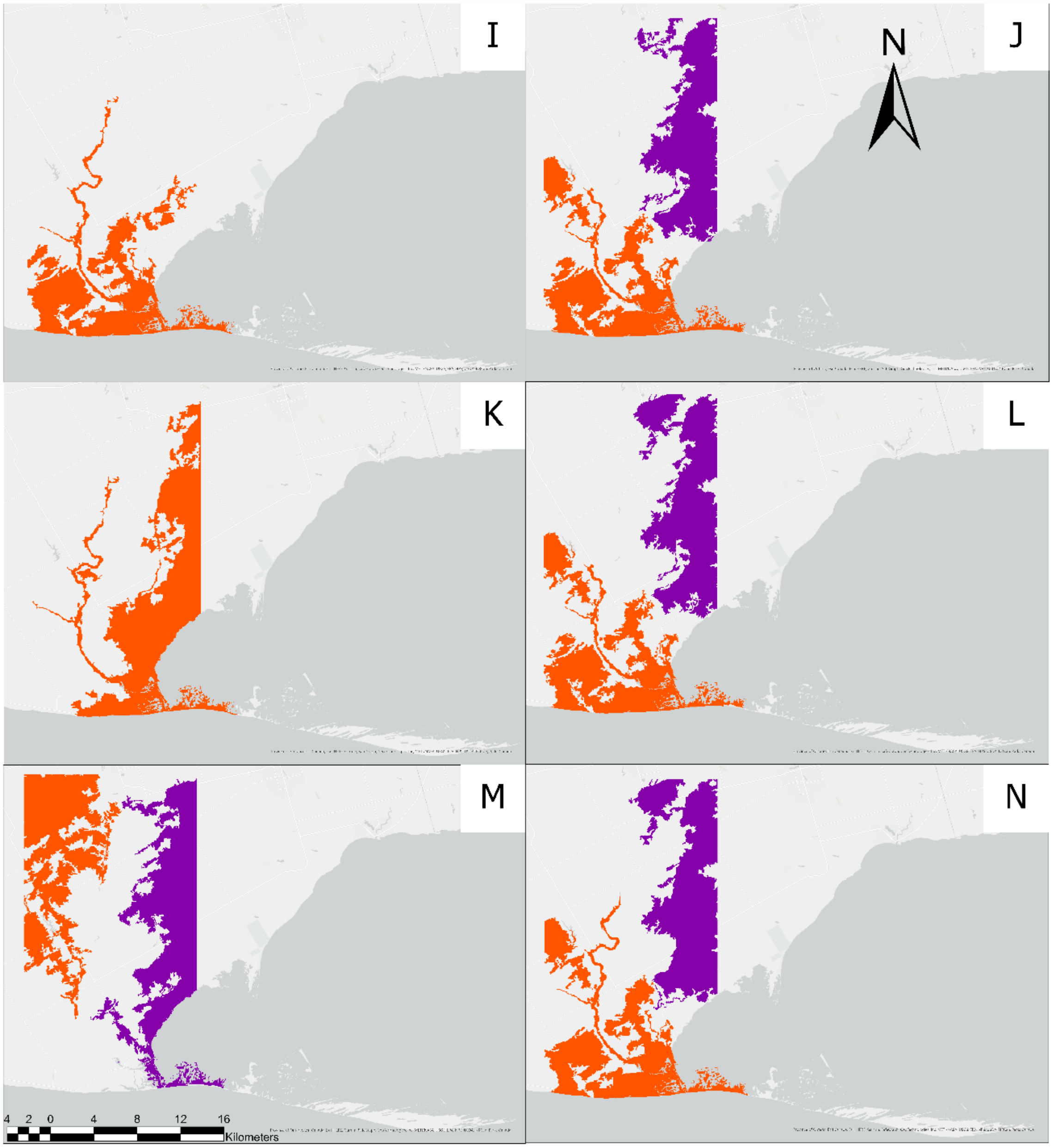


Figure 11: Optimal locations for phragmites habitat based on varying criteria weight at 5m resolution. Coordinate System: NAD 1983 UTM Zone 17N. A) Daylight weight of 1. B) Daylight weight of 8. C) Distance from buildings weight of 1. D) Distance from buildings weight of 8. E) Distance from roads weight of 1. F) Distance from roads weight of 8. G) Soil drainage weight of 1. H) Soil drainage weight of 8. I) Slope weight of 1. J) Slope weight of 8. K) Topography weight of 1. L) Topography weight of 8. M) Water table weight of 1. N) Water table weight of 8.

The final raster showing how many times each cell exceeded the top 15% suitability threshold is shown in Figure 12. Most of the study area did not exceed the threshold in any of the scenarios, but the areas around the beginning of the sand spit showed repeated high suitability. There is also a high number of phragmites observations in this area, as seen in Figure 13, suggesting that the model was very accurate at predicting this particular habitat. There were also many small clusters along some roads and waterbodies in the Southern, Eastern and North-Western interior. This shows that the model predicts high suitability for phragmites habitat in these regions regardless of weight configuration, meaning there is higher accuracy and they should be heavily monitored for future invasions.

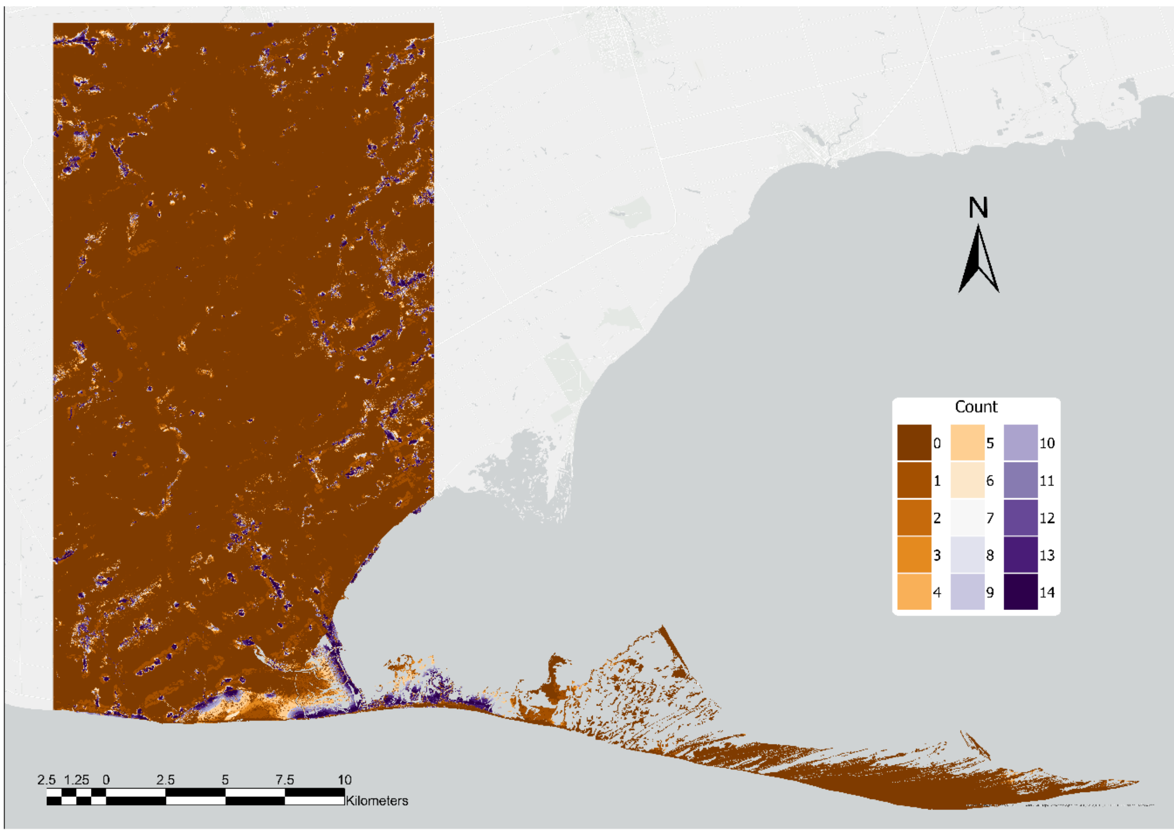


Figure 12: Raster showing how many times each cell exceeded the top 15% suitability threshold. Coordinate System: NAD 1983 UTM Zone 17N.

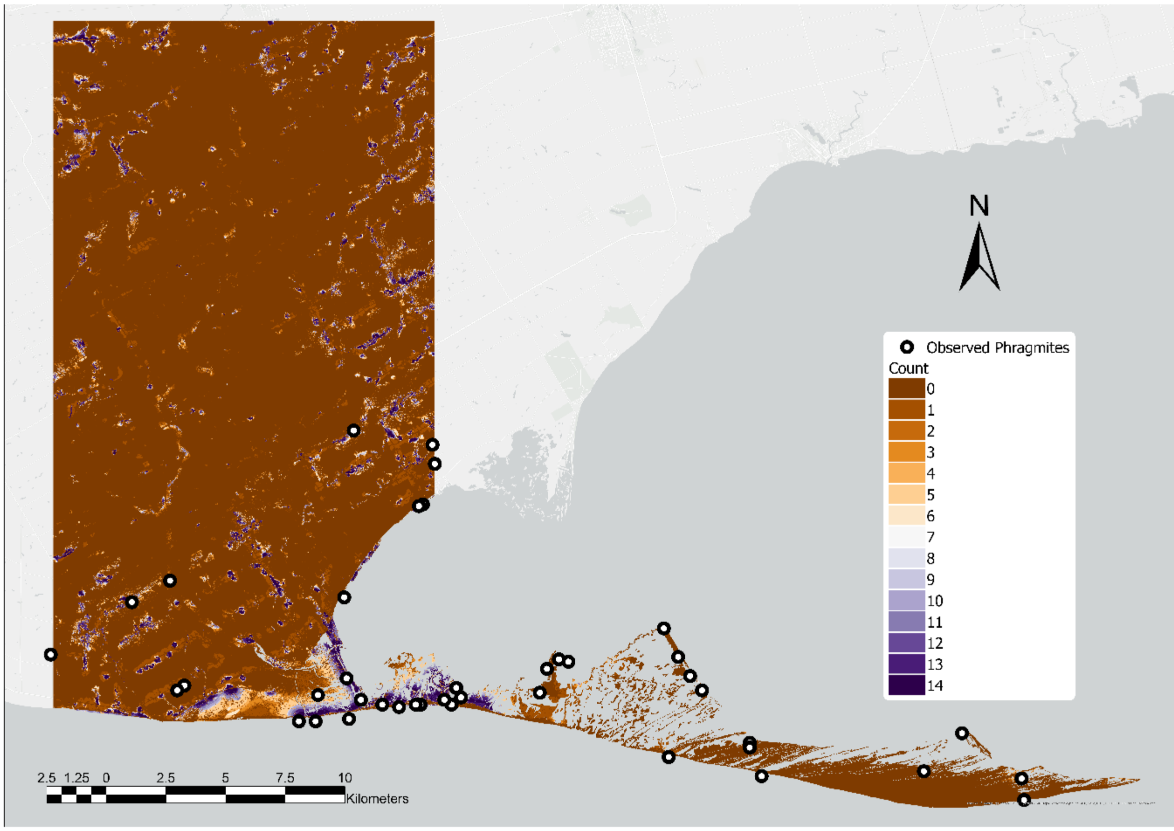


Figure 13: Raster showing how many times each cell exceeded the top 15% suitability threshold and observed phragmites. Coordinate System: NAD 1983 UTM Zone 17N.

Finally, the model was run at a 15m resolution to test how sensitive the model was to changes in resolution. The final suitability and optimal locations rasters, Figures 14 and 15, show similar results to the 5m resolution, though the 5m optimal locations did show slightly more suitable habitat around the edges. Where there was a remarkable difference between resolutions was the effect on changing the weights, as seen in Figure 16. In particular the distance to roads, water table, topography and slope changed the optimal locations dramatically in a very different manner to the 5m resolution.

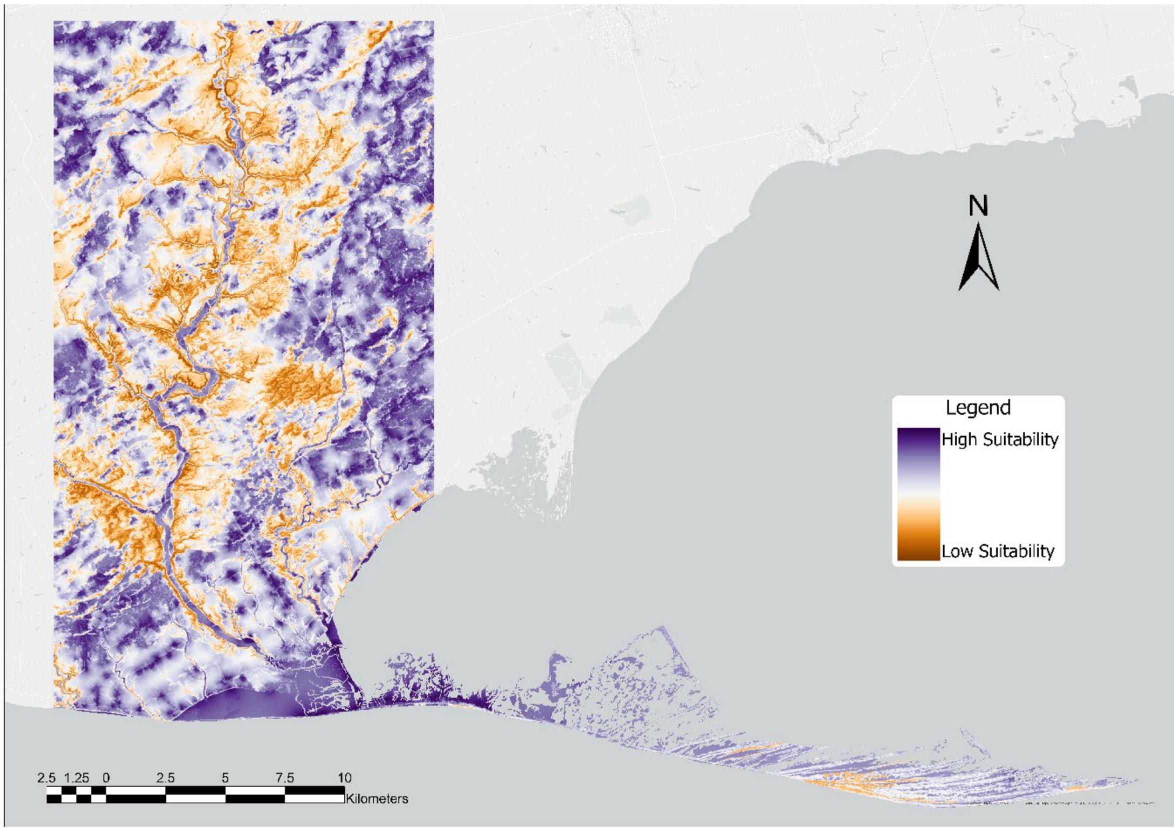


Figure 14: Final suitability raster of phragmites habitat at 15m resolution. Coordinate System: NAD 1983 UTM Zone 17N.

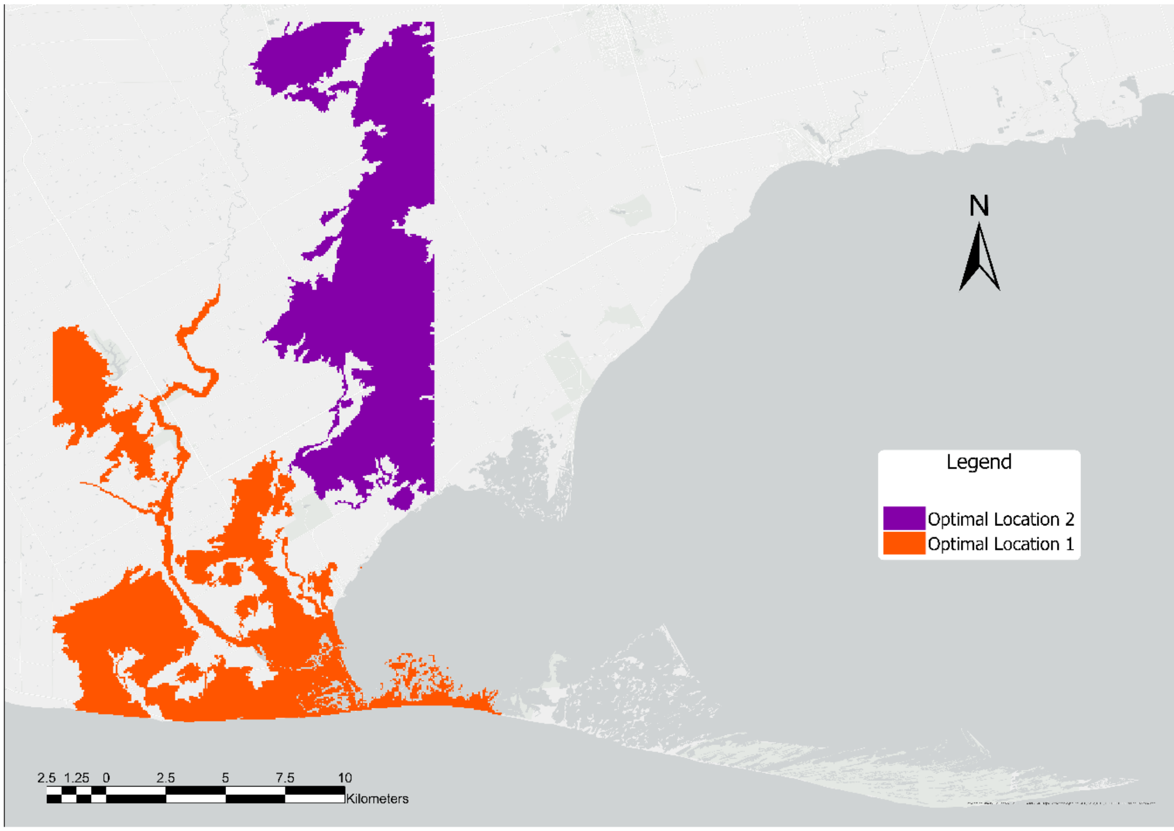
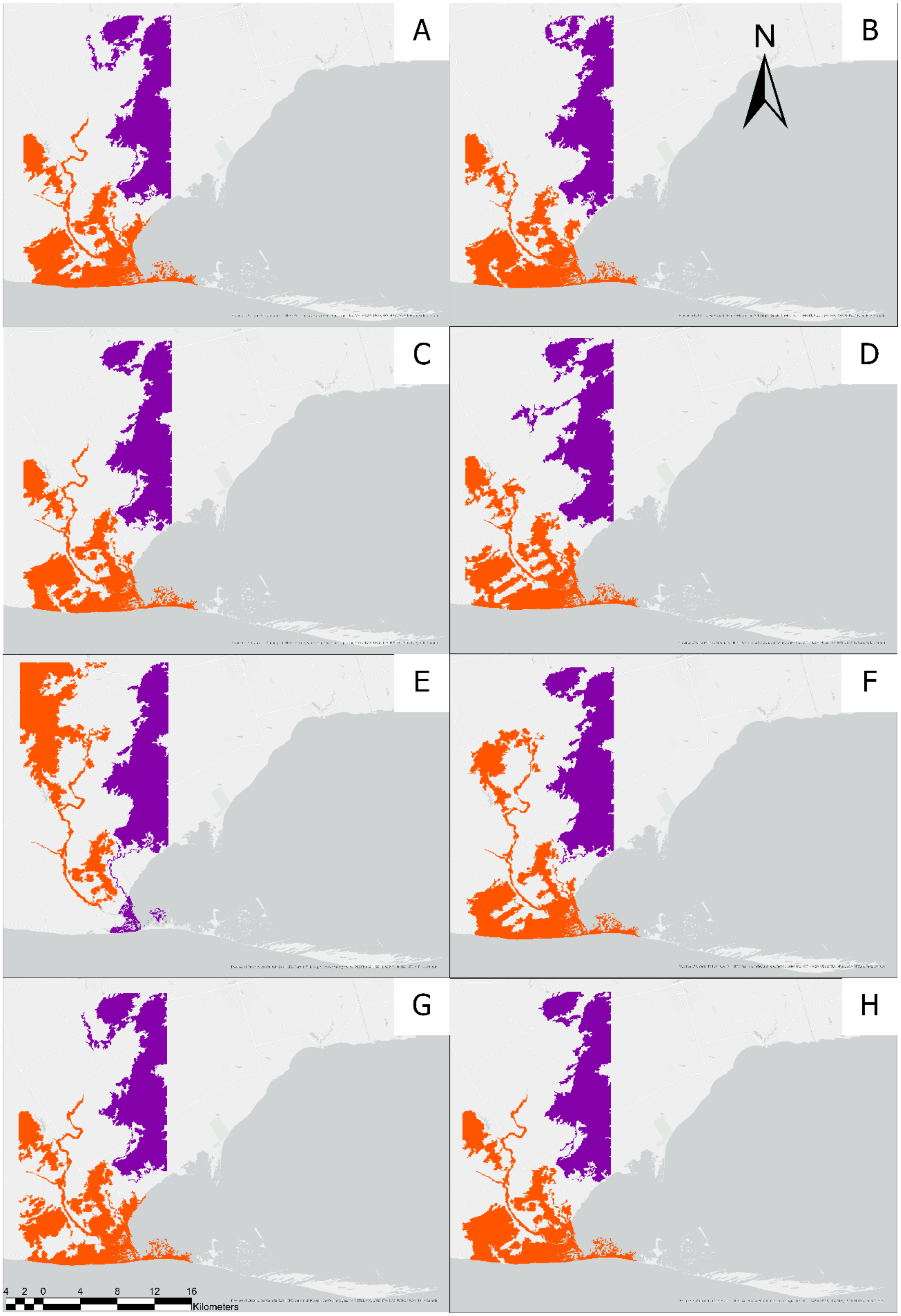


Figure 15: Final optimal locations for phragmites at 15m resolution. Coordinate System: NAD 1983 UTM Zone 17N.


A
B
N
C
D
E
F
G
H
4 2 0 4 8 12 16
Kilometers

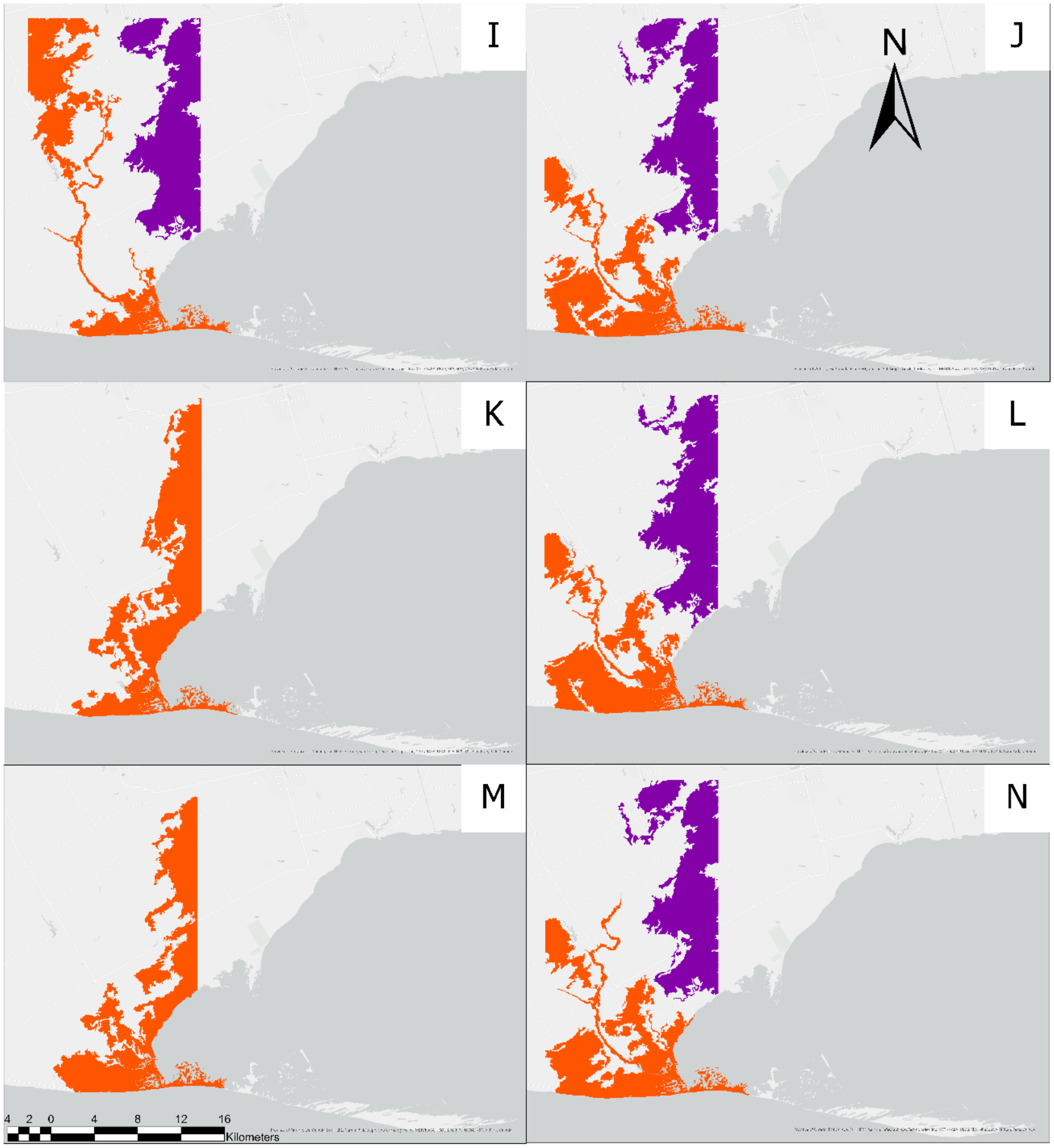


Figure 14: Optimal locations for phragmites habitat based on varying criteria weight at 15m resolution. Coordinate System: NAD 1983 UTM Zone 17N. A) Daylight weight of 1. B) Daylight weight of 8. C) Distance from buildings weight of 1. D) Distance from buildings weight of 8. E) Distance from roads weight of 1. F) Distance from roads weight of 8. G) Soil drainage weight of 1. H) Soil drainage weight of 8. I) Slope weight of 1. J) Slope weight of 8. K) Topography weight of 1. L) Topography weight of 8. M) Water table weight of 1. N) Water table weight of 8.

The results of this model imply that management efforts for the identification and eradication of phragmites should be focused on the two identified optimal locations, along the Southern shore of Lake Erie into the Long Point sand spit in addition to the Eastern portion of the study area. Both of these areas contain poorly draining soils and plenty of wetlands making them particularly susceptible to this invasive species.

Conclusion

In conclusion, the model was able to perform reasonably well for finding the suitable habitat for phragmites. Some missing pieces of data did decrease the quality of the final produced map, however the comparison with the existing phragmites location showed that the model was able to find optimal phragmites habitat for at least half of the reported observations. Based on the results from the model, areas along the Southern shore of Lake Erie near the Long Point sand spit, on the Long Point sand spit and on the Eastern portion of the study area should be prioritized for identification and removal efforts as they are the most suitable habitats for invasive phragmites to grow.

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