Report: UEP189 Moose Hill Wildlife Sanctuary

Working Period:	November 15, 2022, to December 13, 2022
Date Due:	December 13, 2022
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Course:	UEP189 – Introduction to Remote Sensing
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ABBREVIATIONS:

NDVI: Normalized Difference Vegetation Index
EVI: Enhanced Vegetation Index
NDWI: Normalized Difference Water Index
NDBI: Normalized Difference Built-up Index
ROI: Regions of Interests
DN: Digital number
SWIR: Shortwave infrared
NIR: Near infrared

INTRODUCTION

Moose Hill Wildlife Sanctuary

The location selected for this project was the Moose Hill Wildlife Sanctuary, located in Sharon, MA, approximately 40 minutes south of Boston. This location is Mass Audubon's oldest wildlife sanctuary, providing several services such as hiking trails, an organic farm, and educational programs. The sanctuary is surrounded by several bodies of water, forested areas, agricultural land, and multiple municipal buildings such as Walpole High School and Walmart. This study area was selected due to its varied land cover within and around the site, while not being too urbanized. The study area is classified as a "Conservation Restriction" area and is owned by "Massachusetts Audubon Society".

Data

For the Moose Hill Wildlife Sanctuary, we downloaded two sets of Landsat 8 Level-2 data from USGS EarthExplorer,[1] each set containing eight bands (band 1-7 and band 10). The first set of bands was acquired on November 16, 2021, and the second set was acquired on July 22, 2022 (see below for their IDs). The images were provided in a projection of UTM Zone 19 North with a Datum of WGS 84. Each band downloaded has a spatial resolution of 30m, except for band 10 which has a spatial resolution of 100m.

- ID #1: LC08_L2SP_012031_20211116_20211125_02_T1
- ID #2: LC09_L2SP_012031_20220722_20220724_02_T1

Table 1. Landsat 8 Bands

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 – Coastal aerosol	0.43-0.45	30
Band 2 – Blue	0.45-0.51	30
Band 3 – Green	0.53-0.59	30
Band 4 – Red	0.64-0.67	30
Band 5 – Near Infrared (NIR)	0.85-0.88	30
Band 6 – SWIR-1	1.57-1.65	30
Band 7 – SWIR-2	2.11-2.29	30
Band 10 – Thermal Infrared (TIRS) 1	10.6-11.19	100

Source: USGS. N.d. "What are the band designations for the Landsat satellites?" USGS. Available at: https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites.

[1] USGS. N.d. EarthExplorer. USGS. Available at: https://earthexplorer.usgs.gov/.

METHODOLOGY

Pre-processing

Preprocessing prepares the quality of the image. This includes applying a map projection, georeferencing the image data, reviewing the data statistics, correcting geometric errors, minimizing raster data errors, and calibration (such as atmospheric correction). Since the satellite imagery was provided with a cloud coverage of less than 2% and an appropriate projection, we did not apply map projection, georeferencing, or atmospheric correction in this project.

We stacked all single-band layers to a multiple-band layer by using **Build Band Stack** so that we could view the image data in true and false color composites. We also evaluated bands with their univariate and multivariate statistics by using **Compute Band Statistics**. Since the Landsat images downloaded store surface reflectance in 16-bit integer, the data range of the images is from 1 to 65455, or 2^{16} (*See Appendix A, number 1).*[2] As none of the bands have a digital value outside of that data range, we determined that all bands are ready for further image processing and analysis.

We imported our buffer shapefiles made in ArcGIS Pro (in-site, 500m, 1000m, 1500m, 2000m, 2500m, 3000m buffers) into ENVI to mask the satellite images by using **Save As (ENVI, NITF, TIFF, DTED)** under File from the Menu Bar with an **Ignore Data Value of 0**. To make images more informative, we used **Stretch on View Extent** and applied a **Linear 2%** stretch on each buffer area (*See Appendix B*). We also created six **Regions of Interests (ROIs)** of the buffers for later use.

Vegetation Indices

An index is defined as the "combination of surface reflectance at 2 or more wavelengths designed to highlight a property of vegetation."[3] In other words, it is a band ratio and is unitless. In this project, four vegetation indices were applied to the in-site study location and six buffer areas to characterize the land cover in the region for both July and November. These indices take advantage of the different spectral characteristics of the land cover.

To create NDVI maps, we used the **NDVI** tool with the **MTL.txt** files (LC08_L2SP_012031_20211116_20211125_02_T1_MTL.txt & LC09_L2SP_012031_20220722_20220724_02_T1_MTL.txt), which contains wavelength information that is required by the NDVI tool (*See Appendix A, number 2*). First, the MTL text file must be saved as an ENVI file before applying NDVI. To create the other index maps, we used **Band Math** with the appropriate formulas on the same MTL text files. Then, we applied the **ROIs** to mask out the areas outside of the buffers by using **Save As (ENVI, NITF, TIFF, DTED)** under File from the Menu Bar with an **Ignore Data Value of 0** to exclude areas outside of the buffers.

[2] Landsat Missions. N.d. "Landsat Collection 2 Level-2 Science Products." USGS. Available at: https://www.usgs.gov/landsat-missions/landsat-collection-2-level-2-science-products.

[3] L3Harris Geospatial Solutions, Inc. 2022. "Vegetation Indices." L3Harris. Available at: https://www.l3harrisgeospatial.com/docs/vegetationindices.html.

NDVI

The first index applied was the Normalized Difference Vegetation Index (NDVI), which is dimensionless with values bounded between -1 to +1. It indicates the abundance of healthy vegetation, which typically has NDVI values of 0.2-0.8. As vegetation typically reflects NIR strongly, while absorbing red, values closer to +1 are typically healthy dense vegetation. Further, since water absorbs NIR, values closer to –1 indicate water.[4] More specifically, according to Akbar et al. the NDVI values usually correspond to the following categories:[5]

- -0.28 – 0.015: Clouds, water
- 0.015 – 0.14: Built-up
- 0.14 – 0.18: Barren Land
- 0.18 – 0.27: Shrub and Grassland
- 0.27 – 0.36: Sparse Vegetation
- 0.36 – 0.74: Dense Vegetation

$$NDVI = \frac{NIR - red}{NIR + red} = \frac{B5 - B4}{B5 + B4}$$

Figure 1. NDVI Equation

EVI

The Enhanced Vegetation Index (EVI) is an improved version of NDVI as it corrects for atmospheric conditions (distortions in reflected light, haze) and canopy background noise.[6] This is because EVI includes a blue band in its formula that makes it less sensitive to atmospheric effects, such as Rayleigh scattering.[7] Like NDVI, EVI values also range from -1 to +1, and healthy vegetation typically has an EVI value between 0.2 and 0.8.

$$EVI = G \times \frac{NIR - red}{NIR + C1 \times red - C2 \times blue + L} = 2.5 \times \frac{B5 - B4}{B5 + 6 \times B4 - 7.5 \times B2 + 1}$$

Figure 2. EVI Equation

*C1, C2, and L are constants

*NASA's MODIS sensor (which the EVI vegetation index was developed for) C1=6, C2=7.5, and L=1[8]

NDWI

The Normalized Difference Water Index (NDWI) resolves bodies of water that may be hidden by soil and vegetation. Again, the NDWI values range between –1 to +1. Positive values of NDWI indicate high water content as green is typically reflected by water and NIR is strongly absorbed.

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[4] GISGeography. Last Updated: May 30, 2022. "What is NDVI (Normalized Difference Vegetation Index)?" GISGeography. Available at: https://gisgeography.com/ndvi-normalized-difference-vegetation-index/.

[5] Akbar, Tahir & Hassan, Quazi & Ishaq, Sana & Batool, Maleeha & Butt, Hira & Jabbar, Hira. (2019). Investigative Spatial Distribution and Modelling of Existing and Future Urban Land Changes and Its Impact on Urbanization and Economy. Remote Sensing. 11. 105. 10.3390/rs11020105.

[6] NASA. August 30, 2000. "Measuring Vegetation (NDVI&EVI)." NASA. Available at: https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_4.php.

[7] Office for Outer Space Affairs UN-SPIDER Knowledge Portal. N.d. "Data Application of the Month: Vegetation Indices." United Nations. Available at: https://www.un-spider.org/links-and-resources/data-sources/daotm/daotm-vegetation.

[8] EOS Data Analytics. October 1, 2022. "Vegetation Indices To Drive Digital Agri Solutions." EOS DATA ANALYTICS. Available at: https://eos.com/blog/vegetation-indices/.

Negative values indicate drought conditions. The values usually correspond to the following categories:[9]

- -1 - -0.3: Drought, non-aqueous surfaces
- -0.3 - 0.0: Moderate drought, non-aqueous surfaces
- 0.0-0.2: Flooding, humidity
- 0.2 - 1: Water surface

$$NDWI = \frac{green - NIR}{green + NIR} = \frac{B3 - B5}{B3 + B5}$$

Figure 3. NDWI Equation

<u>NDBI</u>

The Normalized Difference Built-up Index (NDBI) highlights urban or man-made areas, ranging between values of –1 to +1.[10] Positive values represent urbanized land while negative values or non-urbanized land.[11] Since this index typically highlights areas where there is a higher reflectance in SWIR, compared to NIR, this index is often used for land use planning and watershed runoff predictions.[12] According to Zha et al., the NDBI values correspond to these categories:

- < 0: Water
- ~0: Woodland and farmland
- > 0: Built-up and barren land

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} = \frac{B6 - B5}{B6 + B5}$$

Figure 4. NDBI Equation

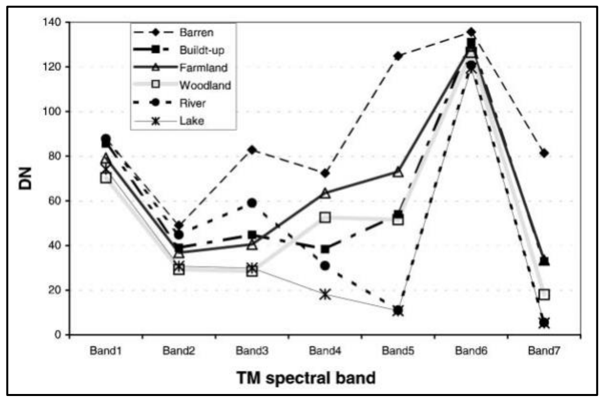

Figure 5. Spectral Profiles of TM Bands of Six Land Covers (Zha et al.'s Study Area)

Built-up or barren lands have a greater DN value for reflectance of SWIR compared to reflectance of NIR. Meanwhile, woodland and farmland only have a slightly greater DN value for reflectance of SWIR compared to reflectance of NIR.[13] Waterbodies have a negative NDBI value because it has a greater DN value for reflectance of NIR compared to reflectance of SWIR.[14] These characteristics are shown in Figure 5.

Figure 5 Source: Zha, Y., J. Gao, and S. Ni. "Use of Normalized Difference Built-Up Index in Automatically Mapping Urban Areas from TM Imagery." International Journal of Remote Sensing 24, no. 3 (2003): 583-594.

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[9] EOS Data Analytics. N.d. "Normalized Difference Water Index." EOS DATA ANALYTICS. Available at: https://eos.com/make-an-analysis/ndwi/.

[10] Yuanmao Zheng, Lina Tang, Haowei Wang. 2021. "An improved approach for monitoring urban built-up areas by combining NPP-VIIRS nighttime light, NDVI, NDWI, and NDBI." Journal of Cleaner Production, 328, 129488. Available at: https://doi.org/10.1016/j.jclepro.2021.129488.

[11] Esri. N.d. "NDBI." Esri. Available at: https://pro.arcgis.com/en/pro-app/latest/arcpy/spatial-analyst/ndbi.htm.

[12] Zha, Y., J. Gao, and S. Ni. "Use of Normalized Difference Built-Up Index in Automatically Mapping Urban Areas from TM Imagery." International Journal of Remote Sensing 24, no. 3 (2003): 583-594.

[13] Zha et al., 2003.

[14] Zha et al., 2003.

Classification

Classification is an information extraction technique applied to multispectral data images. In this project, supervised classifications were performed on both the July and November image data of the Moose Hill Wildlife Sanctuary.

The supervised classification requires the selection of training sites that each have pixels to define a class. For example, a region may have several water bodies; however, an individual training site would consist of some pixels from one water body. Then, through an algorithm the computer will compute an undefined pixel's statistics and compare those to the defined classes. The computer will assign pixels to a class that it has the highest probability of belonging to. This method is called maximum likelihood classification. The training sites selected for both the July and November image data were water, deciduous forest, evergreen forest, agriculture, urban, and flat grass (associated with golf courses of country clubs).

To determine the training sites for deciduous and evergreen trees, the characteristics of each tree type had to be analyzed. Deciduous trees grow during the spring season while evergreen trees thrive in the winter.[15] According to the Smithsonian Science Education Center evergreen trees do not contain the same chemical compounds as deciduous trees that allow for their leaves to change color during the fall season. With this information, the two tree types can be differentiated in the November image data as the red land cover is assumed to be the deciduous trees changing colors and green land cover is the persistent evergreen trees (*See Appendix B*). However, these two tree types cannot be easily differentiated in the July image data as there is no red land cover due to the deciduous trees remaining green during that month (*See Appendix B*).

Another method that can determine the training sites for the deciduous and evergreen trees is to perform density slicing of the NDVI maps created from the July and November image data.[16] Evergreen trees will have a greater NDVI value while deciduous trees will have a lower NDVI value during the fall season. This is because deciduous trees will have a higher reflectance value at the red wavelength, resulting in a larger denominator of the NDVI equation and smaller NDVI value. Deciduous trees have NDVI values below 0.45, while evergreen trees have NDVI values above 0.45. A third method that can separate the two forest types is to create a false color composite data image of bands NIR (as red), red (as green), and green (as blue).

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[15] Susan Patterson & Master Gardener. Last Updated: June 14, 2021. "What Are Deciduous Trees And Shrubs: Types Of Deciduous Trees And Shrubs." Gardening Know How. Available at: https://www.gardeningknowhow.com/ornamental/trees/tgen/what-are-deciduous-plants.htm#:~:text=Warm%20spring%20temperatures%20and%20rainfall,plant%20and%20help%20with%20respiration.

[16] Laurynas Klimavičius, Egidijus Rimkus, Edvinas Stonevičius & Viktorija Mačiulytė. 2022. "Seasonality and long-term trends of NDVI values in different land use types in the eastern part of the Baltic Sea basin." Oceanologia. Available at: https://doi.org/10.1016/j.oceano.2022.02.007.

The rest of the training sites were selected based on cross-comparison between Google maps and ENVI. The waterbodies were easy to distinguish as they had a dark color, characteristic of the data value of 0.

Several validation methods were chosen to verify the supervised classification maps created for the July and November image data. These methods included comparing the supervised classification maps to Google maps, index results, and Isodata unsupervised classification maps. Isodata unsupervised classification is a method where the computer iteratively assigns pixels to a cluster/class based on minimum distance techniques. The user simply defines the threshold values for parameters, such as the number of iterations.

RESULTS AND DISCUSSION

Summarized Results

July, 22 2022												
Buffer	Total Area	NDVI	EVI	NDWI	NDBI	Water	Dec. Forest	Ev. Forest	Urban	Agriculture	Flat Grass	Wetlands
	(m^2)	Average				Area of Class within Buffer in m^2						
In-Site	3481348	0.886	0.667	-0.810	-0.450	0	0	2637759	97116	61726	337436	347312
500	12118217	0.845	0.614	-0.778	-0.412	0	0	6723156	2105604	315753	1848780	1124924
1000	20382216	0.820	0.590	-0.758	-0.388	17769	0	9410594	4530270	1001297	3799065	1623221
1500	29632953	0.795	0.567	-0.738	-0.368	168496	0	11264249	8094925	1763410	5766297	2575577
2000	40396836	0.781	0.554	-0.724	-0.362	752736	0	13939458	11877693	2407327	8228307	3191315
2500	52707621	0.776	0.549	-0.719	-0.357	1262672	0	17317030	16112484	3138796	11069843	3806796
3000	66579648	0.773	0.547	-0.718	-0.351	1466630	0	20824361	21123947	4109247	14584028	4471434

Table 2. Index and Land Classification of Moose Hill Wildlife Sanctuary in July

November, 16 2021												
Buffer	Total Area	NDVI	EVI	NDWI	NDBI	Water	Dec. Forest	Ev. Forest	Urban	Agriculture	Flat Grass	Wetlands
	(m^2)	Average				Area of Class within Buffer in m^2						
In-Site	3481348	0.648	0.306	-0.699	-0.190	0	1158803	888032	45266	333321	9053	1046873
500	12118217	0.640	0.298	-0.683	-0.200	0	2757339	3338710	383477	2263041	66845	3308806
1000	20382216	0.624	0.293	-0.667	-0.192	28431	3913677	5018924	961316	5132647	321623	5005597
1500	29632953	0.607	0.285	-0.646	-0.183	192566	4492327	6462567	1914967	8697587	658827	7214112
2000	40396836	0.597	0.279	-0.629	-0.179	801847	5528101	7897925	2673419	12500955	1093834	9900756
2500	52707621	0.579	0.273	-0.618	-0.169	1334212	7001929	8865533	3382924	17172163	1447781	13503081
3000	66579648	0.572	0.270	-0.614	-0.158	1593619	8835553	9680654	4388265	22536026	1898571	17646960

Table 3. Index and Land Classification of Moose Hill Wildlife Sanctuary in November

Vegetation Indices

Some index results were greater than 1.0 or less than –1.0 (*See Appendix C*). This is because "Landsat atmospheric correction and surface reflectance retrieval algorithms are not ideal for water bodies due to the inherently low surface reflectance of water. Similarly, surface reflectance values greater than 1.0 can be encountered over bright targets such as snow and playas. These are known computational artifacts in the Landsat surface reflectance products."[17] Thus, we can say

[17] USGS. N.d. "Why are negative values observed over water in some Landsat Surface Reflectance products?" USGS. Available at: https://www.usgs.gov/faqs/why-are-negative-values-observed-over-water-some-landsat-surface-reflectance-products.

that pixels with a data value greater than 1.0 are likely to be snow or dry lake and pixels with a data value less than -1.0 are likely to be a part of water bodies.

NDVI

As shown in Tables 3 and 4, the NDVI values were generally higher in July (ranging from 0.77 to 0.88) compared to November (ranging from 0.57 to 0.65). July and November both have healthy dense vegetation as all their NDVI values are between 0.36 and 0.74. July has greater NDVI values because this month is before the deciduous trees lose their leaves. Another pattern shown by the NDVI results is that as the buffer size increased, the NDVI value decreased. This makes sense as urban land increases and vegetation decreases when moving radially outward from the site.

EVI

Through the EVI results, we can see the role of EVI in reducing atmospheric effects. When we increased our buffer size, EVI was the only index that kept its value in between -1 and +1 (*See Appendix C*), which proved this index's stable nature. EVI was also the only index that maintained Lake Massapoag's classification as water (southeast of the site). For example, in the July NDVI color slice map the lake was correctly classified as water, but in the November NDVI color slice map this same lake was classified as vegetation (*See Appendix E*). This misclassification did not occur with the EVI color slice maps (*See Appendix E)*.

Although, EVI followed the same pattern as NDVI (values decreasing from July to November and decreasing as the buffer size increased), EVI generally had a lower value than NDVI. EVI values were generally lower due to EVI's formula having more terms in its denominator compared to NDVI. According to the EVI values, both July and November had healthy vegetation with all their EVI values between 0.2 and 0.8.

NDWI

In July, the NDWI values ranged from -0.81 to -0.72, and in November, the NDWI values ranged from -0.70 to -0.61. The NDWI values increased from July to November. This indicates there was more water content in November compared to July. This could be due to Massachusetts' greater rainfall during the winter season, increasing the water content of the land cover as water bodies form. Furthermore, as the buffer size increased the NDWI value also increased. This is most likely due to more pixels that represent water being included in the NDWI calculation as the buffer size increased. Overall, the NDWI value indicated that both July and November have mostly non-aqueous surfaces, as the values were predominately negative.

NDBI

In July, the NDBI values ranged from -0.45 to -0.35, and in November, the NDBI values ranged from -0.19 to -0.15. The NDBI values increased from July to November. Values closer to 0 indicate woodland, which makes sense as there is a loss of deciduous tree leaves in the winter months, causing more woodland land cover. Then, when the leaves grow back by July, the NDBI values became more negative, indicating higher water content from the leaves. Also, as the buffer size increased, the NDBI value also increased because more urban land was captured.

Further, for NDBI, it is recommended to perform density slicing as NDBI is meant to emphasize manufactured built-up areas. The November image might be better at detecting built-up areas (*See Appendix C*) because more built-up areas were captured in November compared to July (*See Appendix E)*.

Overall, the indices demonstrate the recurring theme that tree cover can change the index values calculated. As tree cover decreases due to deciduous trees losing their leaves in November, the NDVI and EVI decrease while the NDWI and NDBI increase.

<u>Classification</u>

<u>Deciduous Trees Vs. Evergreen Trees</u>

The results of the color slicing to separate the deciduous and evergreen trees based on NDVI values is shown in Figure 5. The tan color is deciduous trees, and the green color is evergreen trees. This is not a completely accurate method as the categorization includes other types of land cover, so this map cannot be exclusively used to separate deciduous and evergreen tree cover but used as source of comparison.

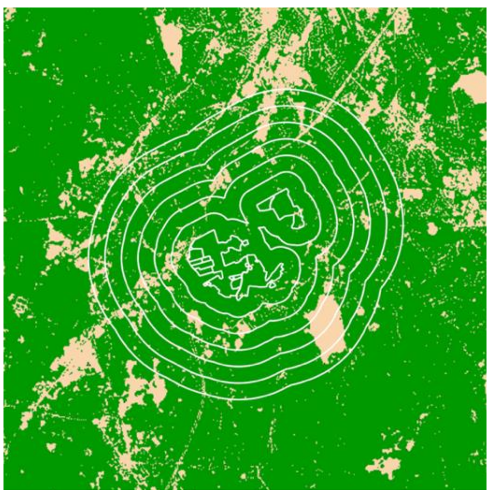

Figure 6. Density Slicing of NDVI map on November 16, 2021

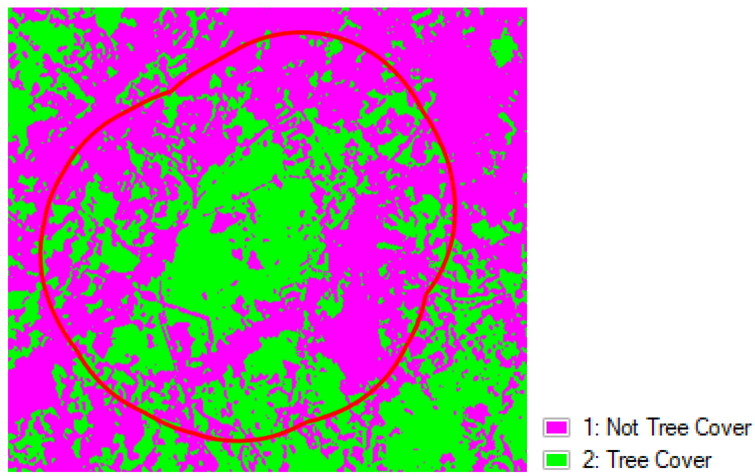

Figure 7. Tree Cover Supervised Classification on November 16, 2021

As the results in Figure 5 were not that informative, a new supervised classification map consisting of two classes ("tree cover" and "not tree cover") was created as shown in Figure 6. Comparisons between the Figure 5 and Figure 6 should be made to differentiate deciduous and evergreen trees. As shown above, most of the tree cover is consistent with evergreen trees.

Further, the false color composite images were not too helpful in separating deciduous and evergreen trees as both the July and November image data primarily just turned red (due to high forest content). While, in theory, the forested areas with a more intense red color would correspond to deciduous trees, this was not the case in practice (*See Appendix B)*.

Maximum Likelihood Supervised Classification

The training sites for the July and November image data were selected in a manner so that other classes were not included in the polygon (*see Appendix F*). Information for the training sites can be found in the tables below.

July, 22 2022		
Training Site Name	Number of Training Sites	Number of Pixels
Water	6	1184
Dec. Forest	0	0
Ev. Forest	20	3284
Urban	25	896
Agriculture	5	436
Flat Grass	11	86
Wetlands	8	651

Table 4. Training Sites (July 22, 2022)

November, 16 2021		
Training Site Name	Number of Training Sites	Number of Pixels
Water	8	939
Dec. Forest	9	659
Ev. Forest	19	656
Urban	47	536
Agriculture	5	572
Flat Grass	11	81
Wetlands	11	979

Table 5. Training Sites (November 16, 2021)

Once supervised classification was completed for both July and November, a majority analysis filter was performed on both images to lessen the “grain-like” texture of the image (shown in Figures 7 and 8). The original classification maps can be found in *Appendix F*. Supervised classification performed on the November image data resulted in a majority of agricultural land, deciduous and evergreen tree cover, several wetlands, some water, and a few urbanized areas (Figure 8). Meanwhile, the July image highly contrasts the November image as it presents a majority of urban land cover, greater tree cover, few wetlands, some water, and a few agricultural areas. The deciduous tree cover was not included in the July image as it was difficult to differentiate the tree cover during this summer month. The spectral reflectance characteristics of agricultural land cover were similar to the urban land cover. Further information about the classes can be found in the tables below.

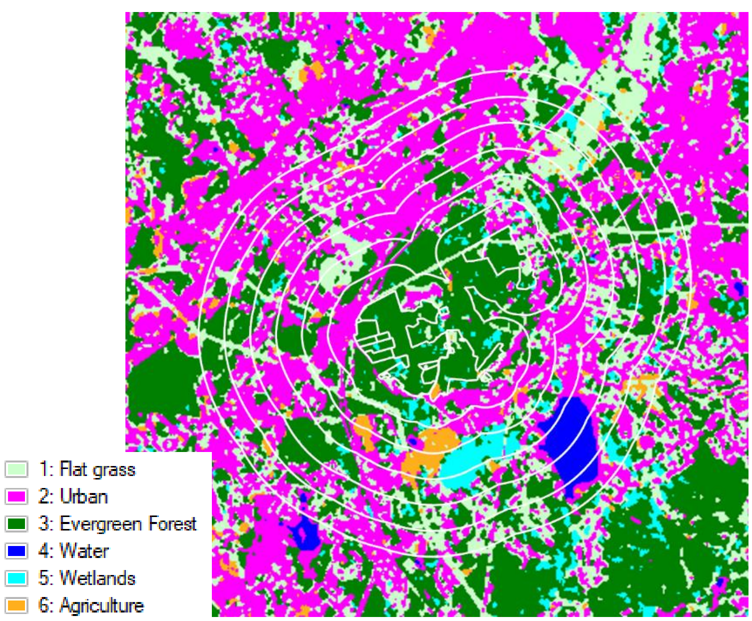

Figure 8. Maximum Likelihood Supervised Classification of July 22, 2022

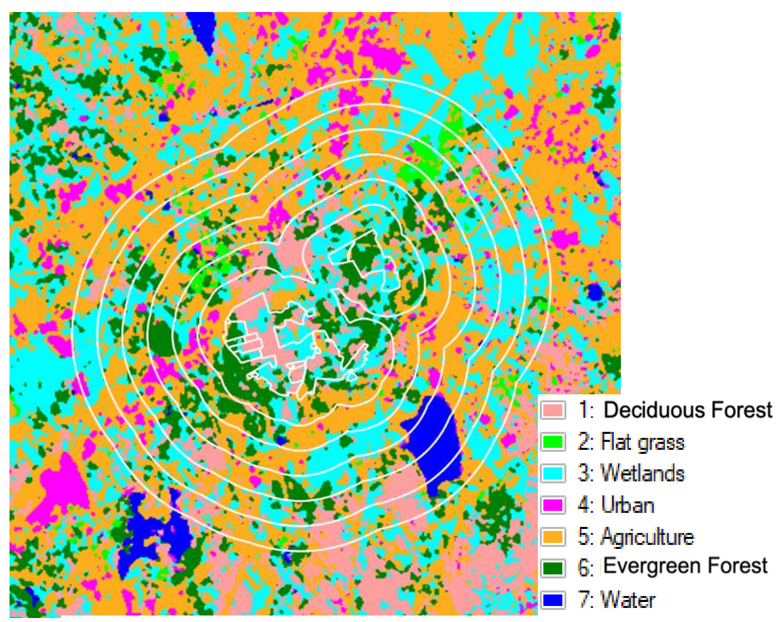

Figure 9. Maximum Likelihood Supervised Classification of November 16, 2021

July, 22 2022 (3000m Buffer)		
Class	Number of Pixels	Percent Cover
Water	1640	2.2
Dec. Forest	0	0.0
Ev. Forest	23286	31.3
Urban	23621	31.7
Agriculture	4595	6.2
Flat Grass	16308	21.9
Wetlands	5000	6.7

Table 6. Class Information (July 22, 2022)

November, 16 2021 (3000m Buffer)		
Class	Number of Pixels	Percent Cover
Water	1782	2.4
Dec. Forest	9880	13.3
Ev. Forest	10825	14.5
Urban	4907	6.6
Agriculture	25200	33.8
Flat Grass	2123	2.9
Wetlands	19733	26.5

Table 7. Class Information (November 16, 2021)

CONCLUSION

<u>Validation</u>

To validate the supervised classification maps made for the July and November image data, the Moose Hill Wildlife Sanctuary classification maps were compared to the site in Google maps, patterns of index results, and Isodata unsupervised classification maps.

<u>Google Maps</u>

From Google maps, it is clear most of the in-site land cover is tree cover. Tree cover also appears in all directions when expanding outward from the site. Furthermore, outward from the site the land cover has agricultural lands (south the site), roads (west of the site), municipal buildings (west and east of the site), neighborhoods (west and east of the site), country clubs (west and north of the site), a few water bodies and wetlands (west and south of the site).

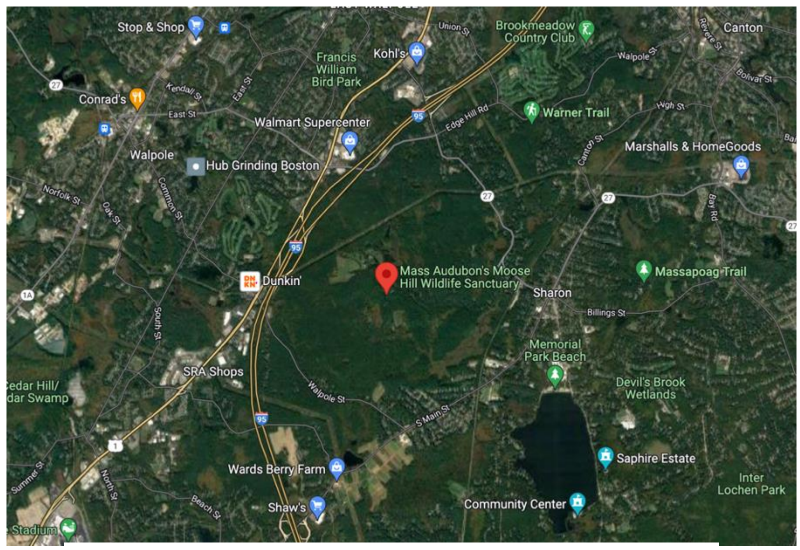

Figure 10. Moose Hill Wildlife Sanctuary (Google Maps)

The tree cover was separated into “deciduous” and “evergreen” classes, which should primarily show in-site on the classification maps. The roads, municipal buildings, and neighborhoods were combined into the “urban” class. Further, the country clubs were classified as “flat grass”.

The November supervised classification map is mostly consistent with Google maps. The biggest incorrect feature of the classification map is how much land was classified as agricultural as it appears in all directions from the site when it should be just south of the site. The July supervised classification map was determined to be more accurate as it was more consistent Google maps, with the exception of not including the deciduous tree cover class. The majority of the classification map should be “urban” as that class encompasses the most features and is most dominant outside of the site. However, a limitation of this validation method is that the season of the image data in Google Maps is unknown. Google Maps may be more consistent with the July image data simply because the Google Maps image data may have been collected during the summer.

Index Results

In terms of NDVI and EVI values, November should have less healthy vegetation as both indices decrease from July to November. This pattern is consistent with the supervised classification maps as the land cover classified as “trees” and “flat grass” decreases in the November. Then, the NDWI increases from July to November, meaning there are more water bodies. This is also consistent with the supervised classification maps as the November map has more wetlands compared to the July map. Lastly, the NDBI also increases from July to November as barren land is more prevalent due to the loss of vegetation. The NDBI results may explain why a majority of the November supervised classification map is “agriculture”, while the July classification map is not. Agriculture will strip the land of vegetation, like the natural processes that cause the loss of vegetation in the winter months, resulting in barren land.

Unsupervised Classification

For the July image, the unsupervised classification map was not very similar to the supervised classification map. While both had like water body classes, the patterns in the maps differed. In the unsupervised classification map (Figure 10), the majority class combined three types of land features (forest, wetlands, and flat grass). This map also added a class, which was named “Shore” as it bordered the water bodies. Also, the forest land cover was a part of two classes (5, 6), which may be due to different types of tree cover that resemble wetlands or flat grass. Meanwhile, in the supervised classification map, the largest land cover was “urban”. Overall, it seems the unsupervised classification was better at defining the “urban” class while the supervised classification defined the “forest” class well.

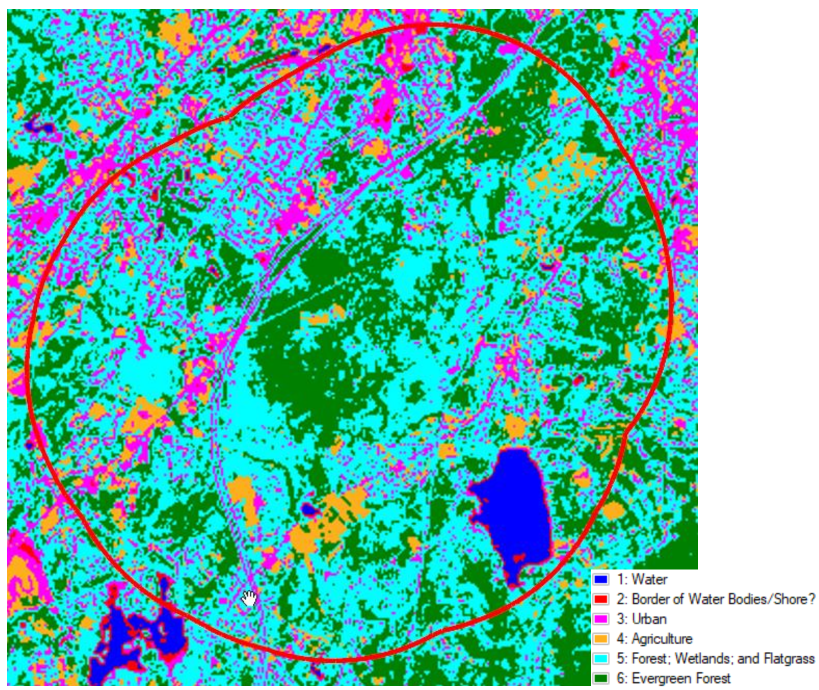

Figure 11. Isodata Unsupervised Classification of July 22, 2022

For the November image, the unsupervised and supervised classification maps severely differed. In the unsupervised classification map (Figure 11), there was no clear majority class. In contrast, in the supervised classification map the "agriculture" class was clearly the majority. Similar patterns arose with the unsupervised classification map in November. Agriculture and flat grass land cover were combined into one class, a "shore" class was added, and the wetlands land cover were a part of two classes.

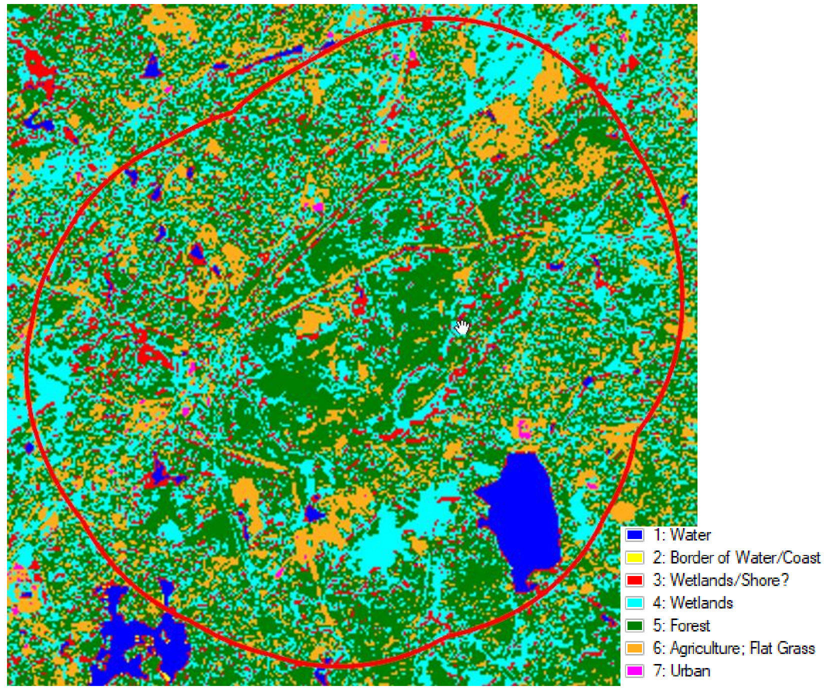

Figure 12. Isodata Unsupervised Classification of November 16, 2021

The unsupervised classification maps were determined to be less accurate as they typically combine multiple types of land features into one class while separating one type of land feature into different classes. The July and November unsupervised classification maps also do not follow the same index patterns explained earlier with decreasing NDVI and EVI from July to November and increasing NDWI from July to November. However, the unsupervised classification maps do show increasing NDBI from July to November as November has greater agricultural land cover. However, the supervised classification maps were considered more accurate as they followed the index patterns.

Overall, this project examined the land cover of the Moose Hill Wildlife Sanctuary in July and November by using the software ENVI to perform index calculations and create supervised classification maps. The results were analyzed and compared to understand how land cover changes from July to November. The supervised classification maps created were determined to be moderately accurate through several validation methods, but these maps could be improved. For example, in the future other classification methods such as minimum likelihood supervised classification should be pursued. Furthermore, to better distinguish between the deciduous and evergreen tree covers, a mask of the "not tree cover" class should be made (from Figure 6). This ensures that only the "tree cover" class is evaluated. Then, NDVI calculations and density slicing could be performed on just the "tree cover" class to separate the deciduous and evergreen trees. This method of creating a mask of one class can be done in ENVI Classic, outside the capabilities of ENVI.

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APPENDIX

Appendix A - Band Data

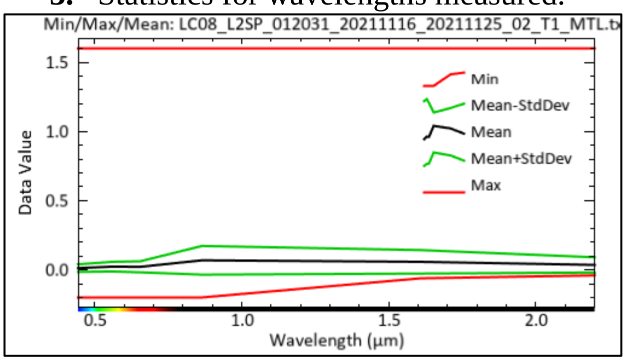
1. Basic statistics of all bands for the November 16, 2021.

Basic Statistics	Min	Max	Mean	Standard Deviation
Band 1	26,683	42,884	39,098	958
Band 2	5,795	65,454	9,267	2,195
Band 3	5,031	65,454	10,528	3,319
Band 4	2,050	65,454	11,156	4,090
Band 5	1,105	65,454	8,492	1,649
Band 6	695	65,454	8,568	1,373
Band 7	16	65,454	8,168	1,243
Band 10	1	65,454	7,964	1,177

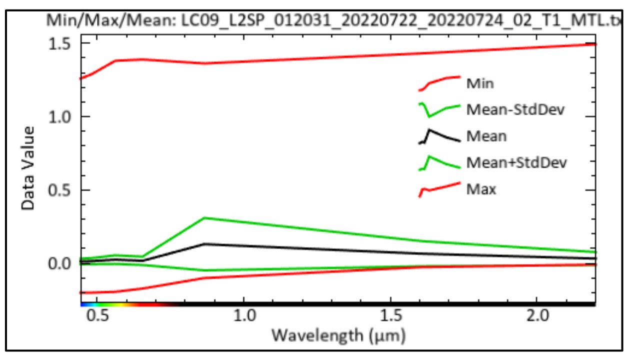
2. The Spectral Metadata for the July 22, 2022

	Band Names	Wavelengths	FWHM
Units		μm	μm
1	SRB1	0.4428	0.0154
2	SRB2	0.4819	0.0599
3	SRB3	0.561	0.0563
4	SRB4	0.6543	0.0367
5	SRB5	0.8646	0.0287
6	SRB6	1.6081	0.0861
7	SRB7	2.2001	0.1895

3. Statistics for wavelengths measured.

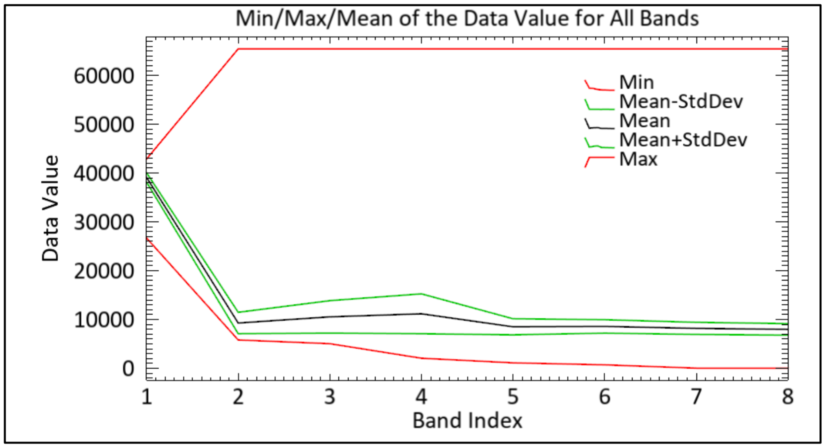


November 16, 2021

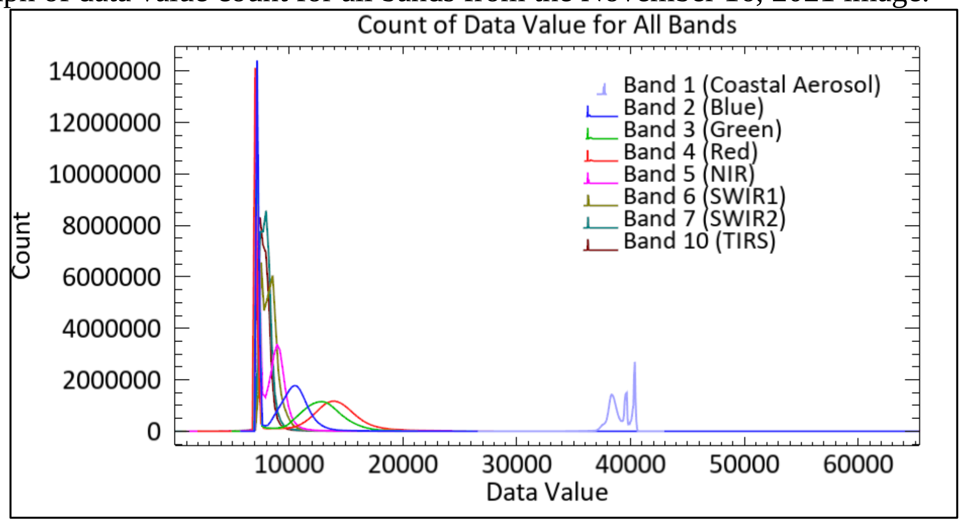


July 22, 2022

4. Statistics of data values for all bands from the November 16, 2021 data image (Band 8 in the graph represents a Landsat-8 band 10).



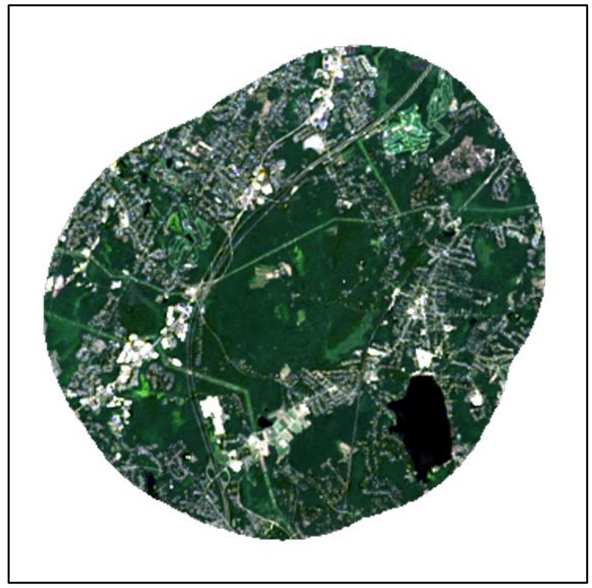
5. Graph of data value count for all bands from the November 16, 2021 image.



Histogram of Data Value Count for all bands from the November 16, 2021 image.

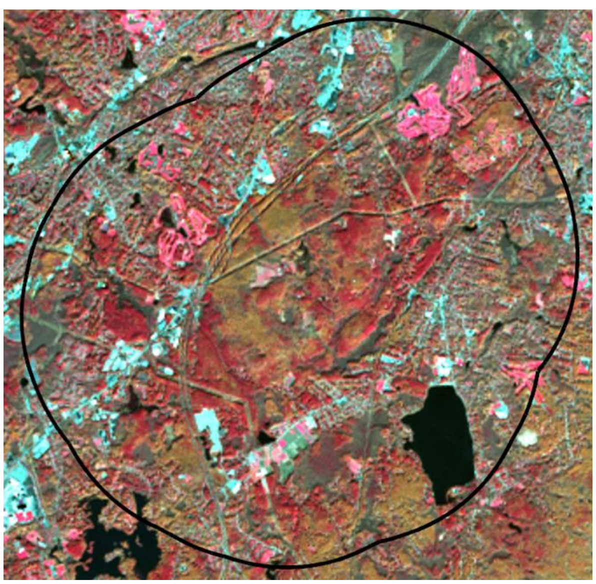
Appendix B – Moose Hill Wildlife Sanctuary

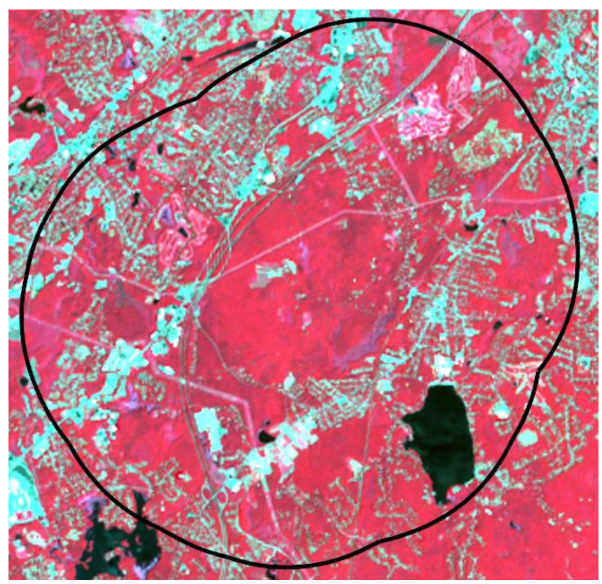
1. Images shown have Linear 2% applied and 3000m buffer around the site.



November 16, 2021 **July 22, 2022**

2. Images shown are false color composites with NIR (as red), red (as green), and green (as blue). Linear 2% was applied and the 3000m buffer is around the site.





November 16, 2021 **July 22, 2022**

Appendix C – Index Results

1. Vegetation index values for November, 16 2022. The highlighted layers (2000m, 2500m, and 3000m buffers) either have a minimum data value than -1.0 (green) or a maximum value greater than 1.0 (blue), or both (Pink).

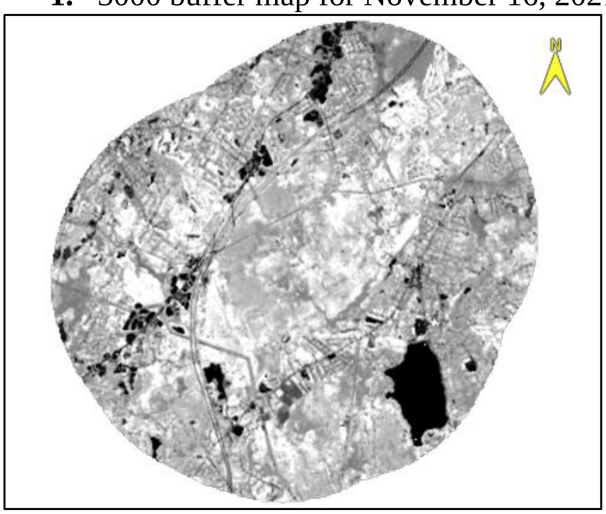
Area	Mean NDVI	Mean EVI	Mean NDWI	Mean NDBI
In-Site	0.64797	0.306256	-0.699309	-0.190374
500m	0.639776	0.297854	-0.683171	-0.199778
1000m	0.624047	0.292687	-0.666741	-0.192236
1500m	0.607031	0.284683	-0.646181	-0.182512
2000m	0.597061	0.278572	-0.628578	-0.178560
2500m	0.579083	0.273431	-0.618157	-0.169100
3000m	0.572286	0.269830	-0.613633	-0.157989

2. Vegetation index values for July 22, 2022

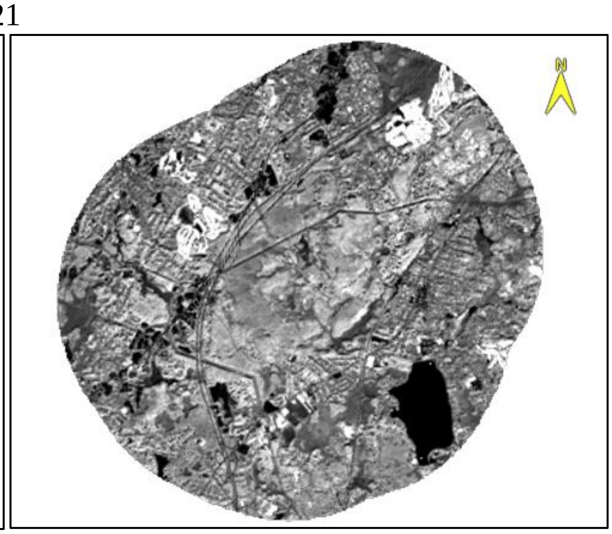
Area	Mean NDVI	Mean EVI	Mean NDWI	Mean NDBI
In-Site	0.886115	0.667392	-0.809744	-0.450076
500m	0.845211	0.613993	-0.777732	-0.411703
1000m	0.819588	0.589633	-0.758032	-0.388166
1500m	0.794778	0.566898	-0.737614	-0.368330
2000m	0.781396	0.553974	-0.723982	-0.361994
2500m	0.776074	0.548977	-0.718995	-0.356891
3000m	0.773422	0.546769	-0.717986	-0.350730

Appendix D – Index Maps

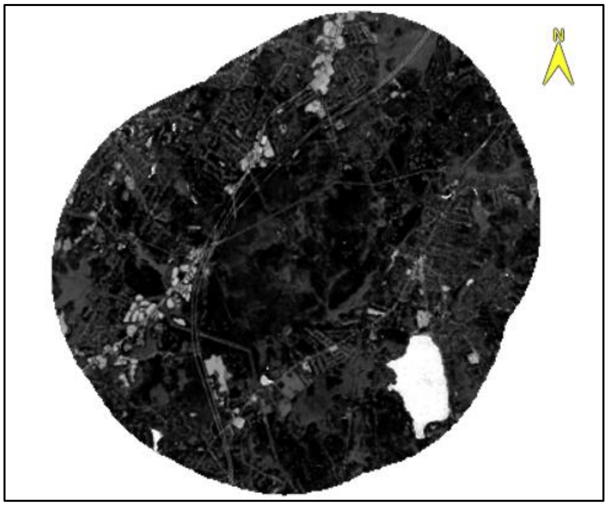
1. 3000 buffer map for November 16, 2021



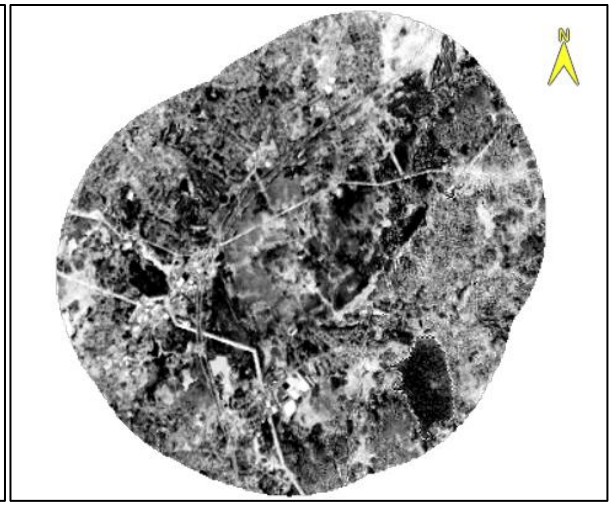
NDVI



EVI

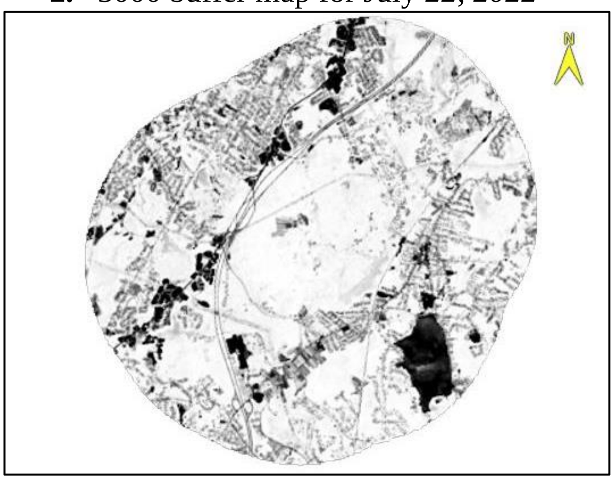


NDWI

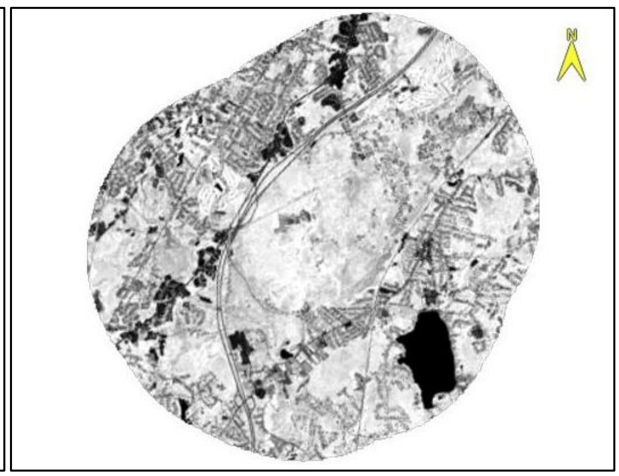


NDBI

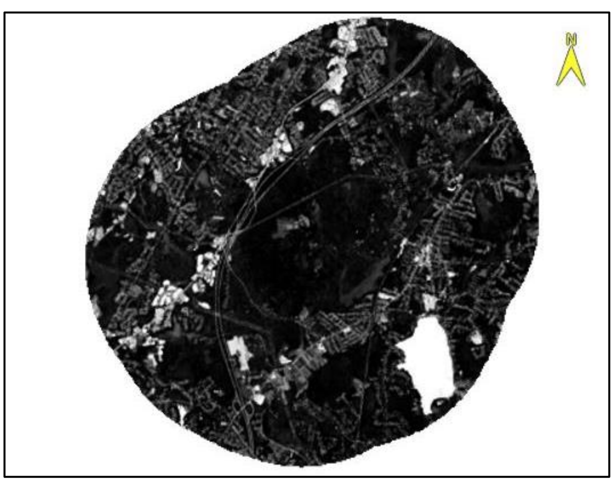
2. 3000 buffer map for July *22*, *2022*



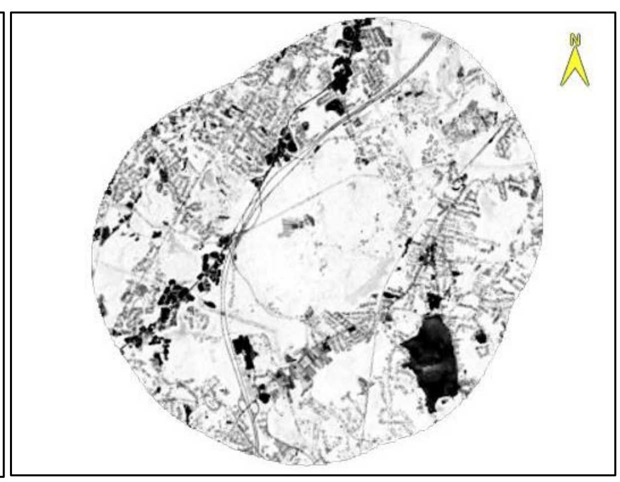
NDVI



EVI

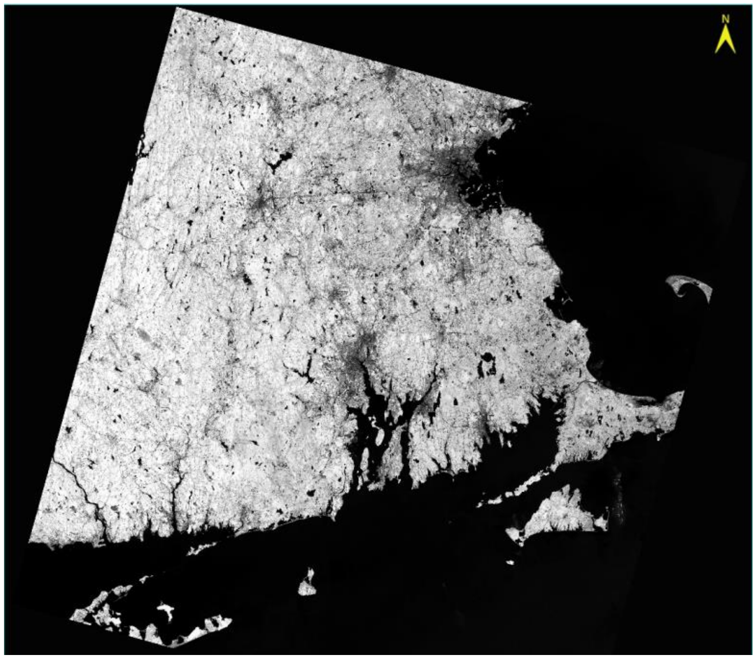


NDWI



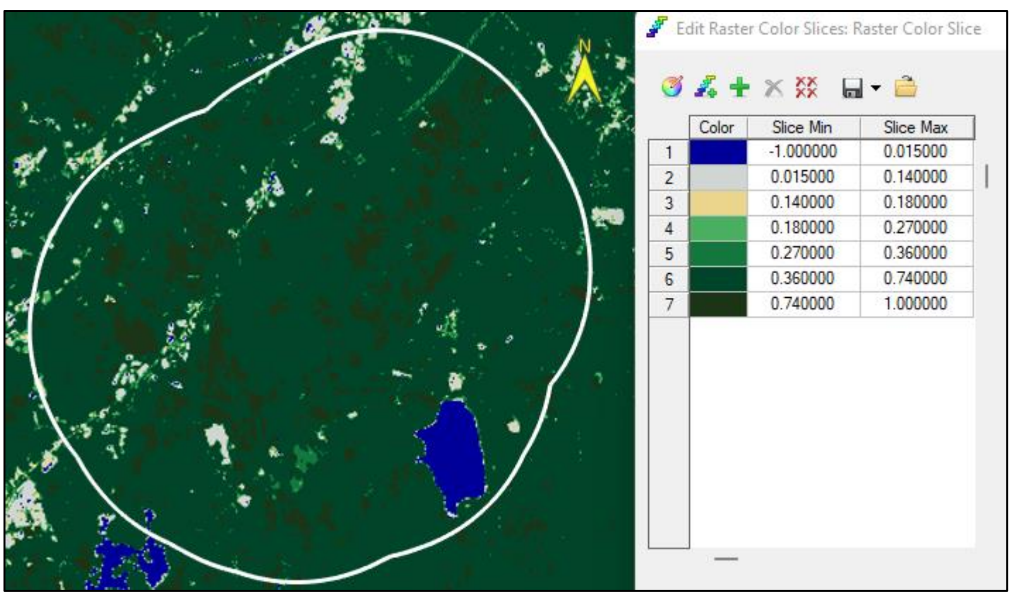
NDBI

3. EVI of the July 22, 2022 image (created by using **Band Math)**.

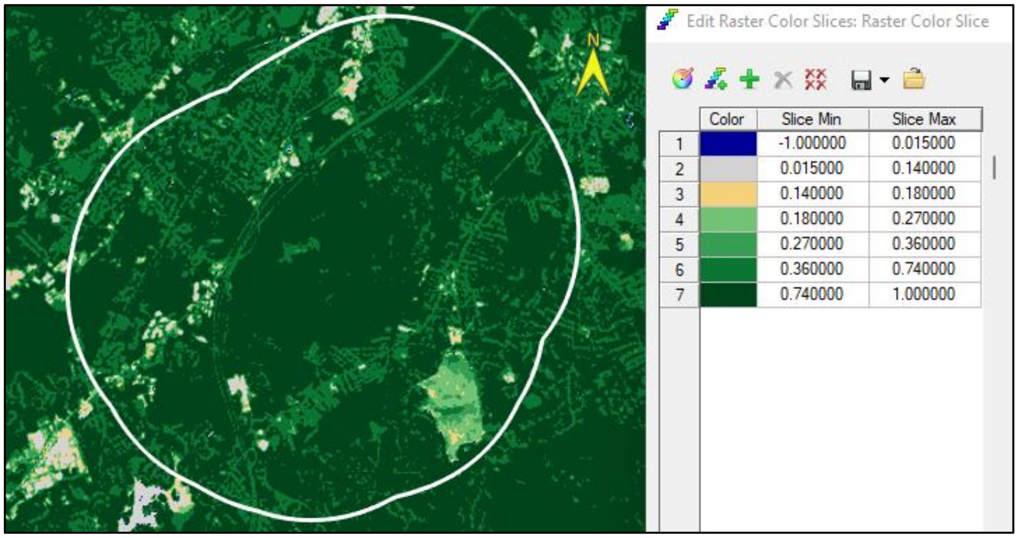


Appendix E – Index Density Slicing

1. NDVI 3000m Buffer Color Slice Map (using Akbar et al.'s NDVI index range)

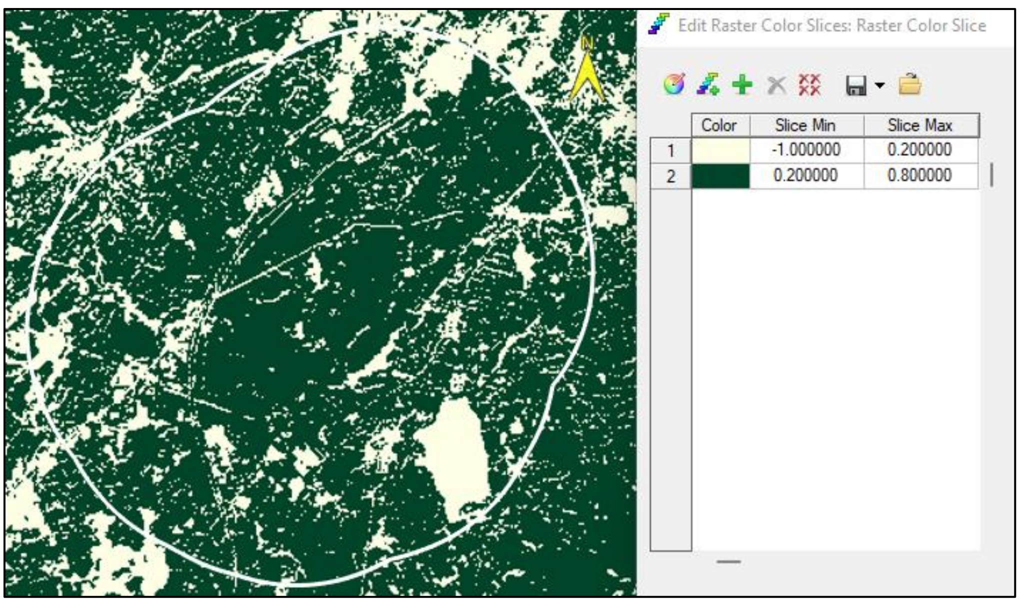


November 16, 2021

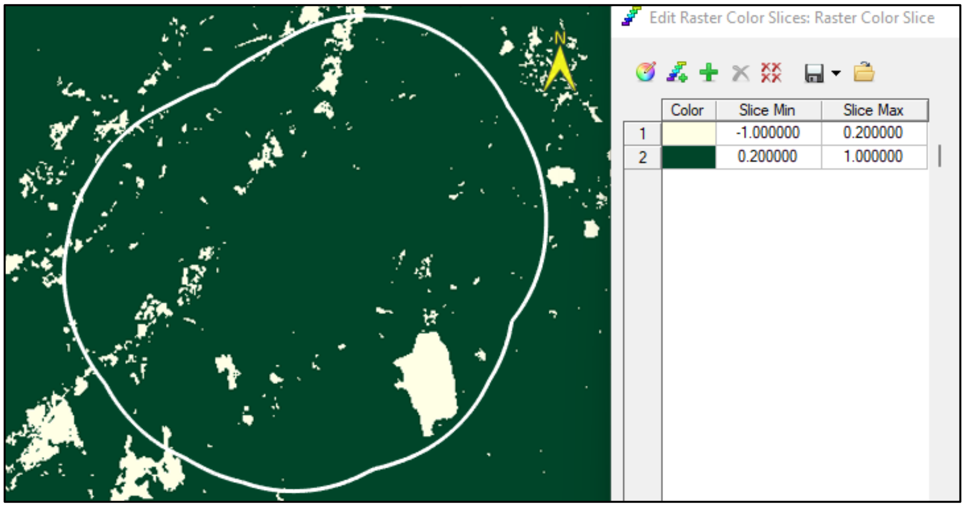


July 22, 2022

2. EVI 3000m Buffer Color Slice Map

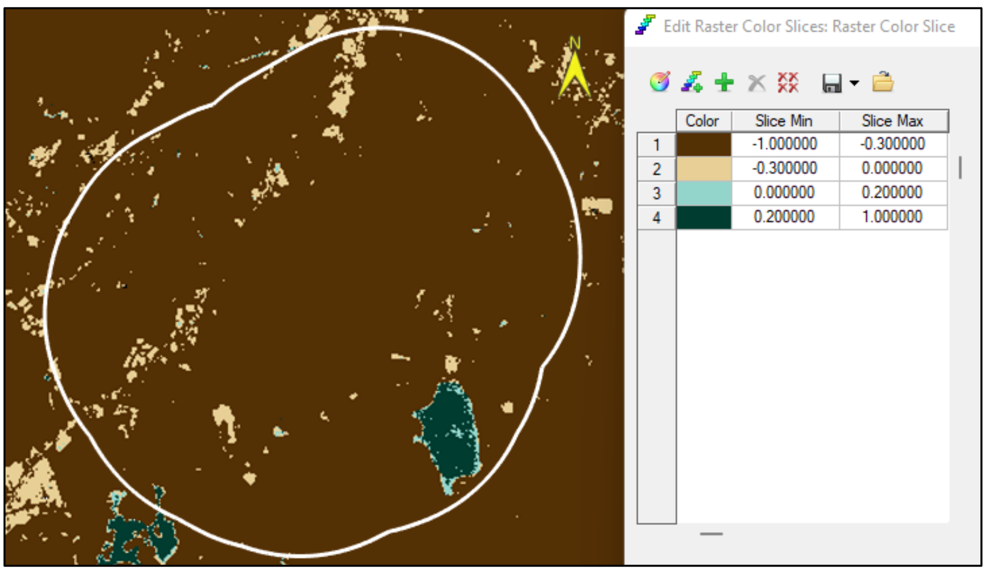


November 16, 2021

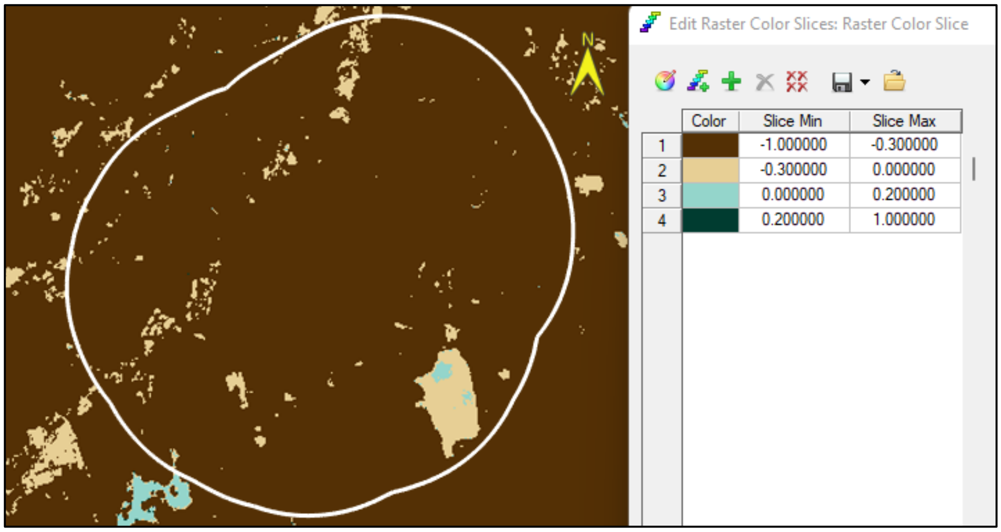


July 22, 2022

3. NDWI 3000m Buffer Color Slice Map

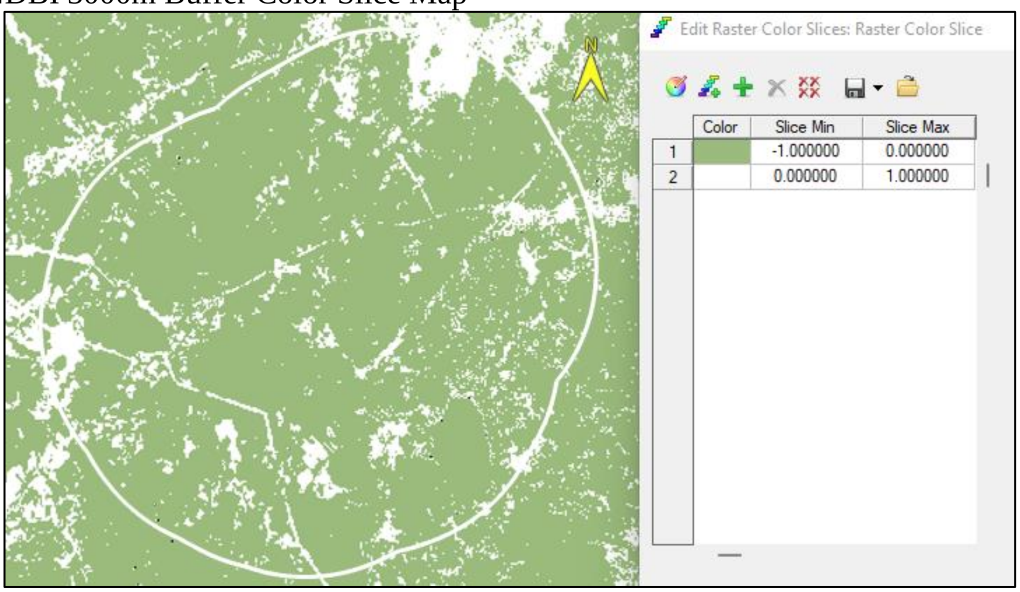


November 16, 2021

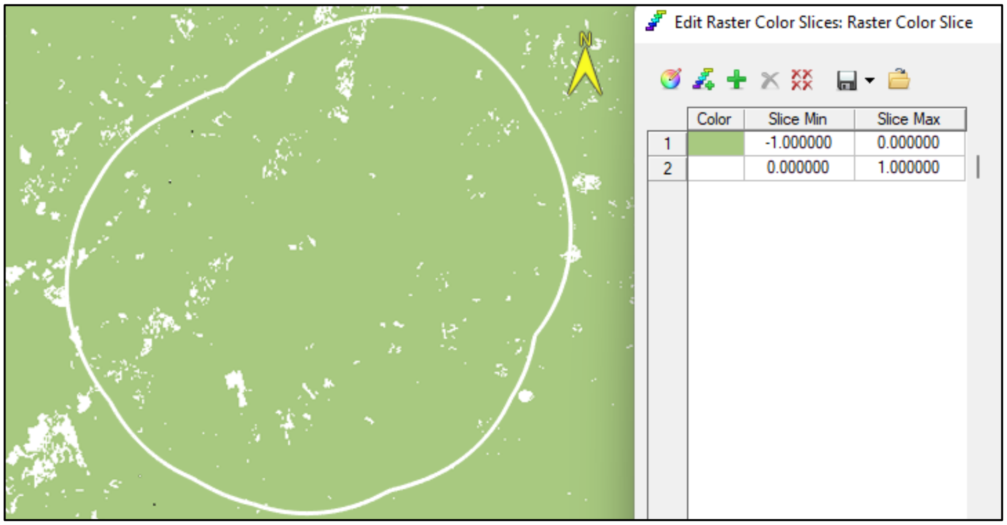


July 22, 2022

4. NDBI 3000m Buffer Color Slice Map



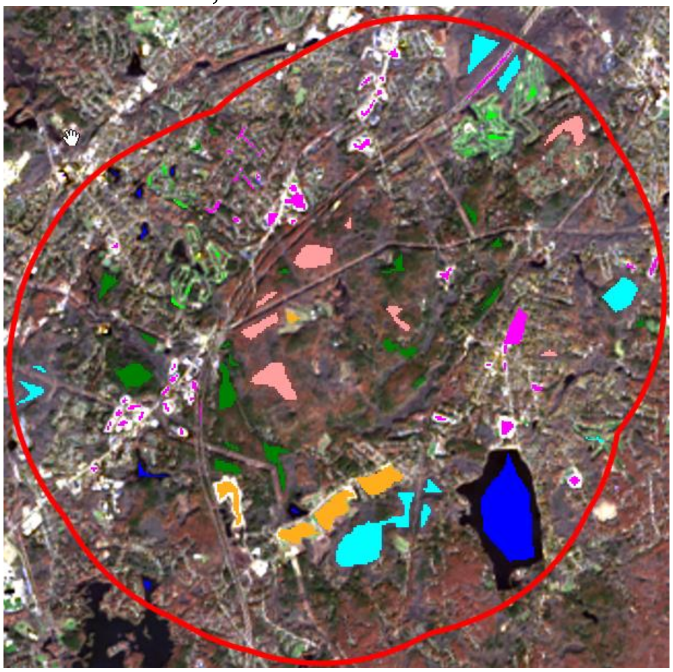
November 16, 2021



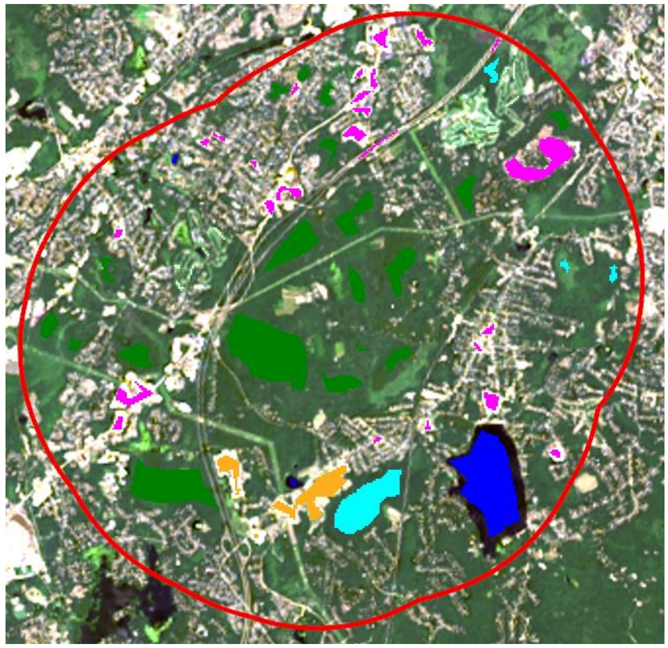
July 22, 2022

Appendix F – Supervised Classification Maps

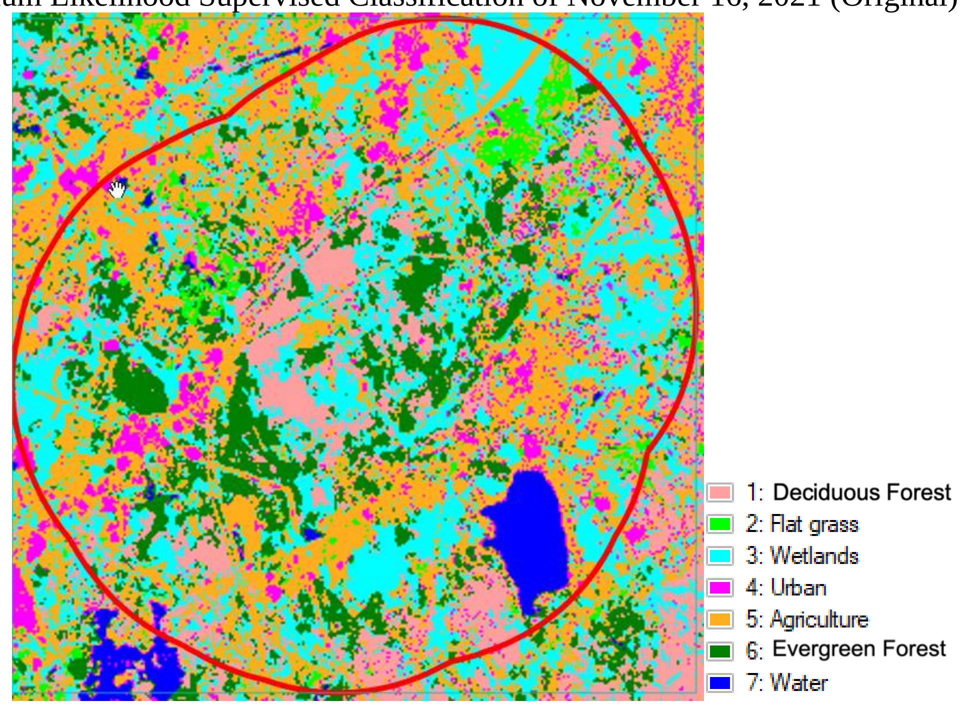
1. Training sites for November 16, 2021



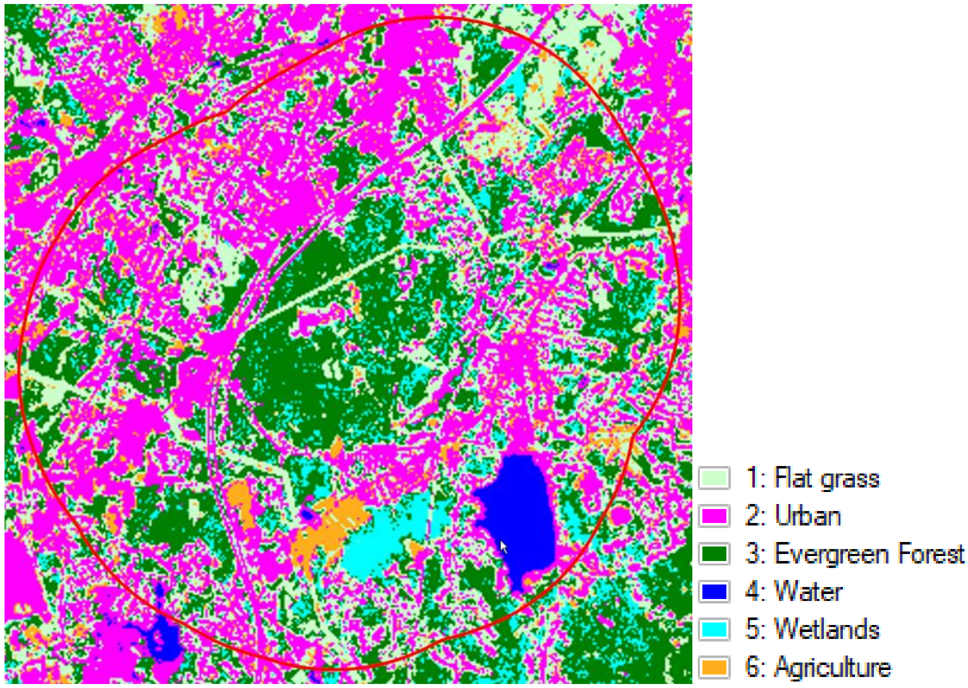
2. Training sites for July 22, 2022



3. Maximum Likelihood Supervised Classification of November 16, 2021 (Original)



4. Maximum Likelihood Supervised Classification of July 22, 2022 (Original)


1: Flat grass
2: Urban
3: Evergreen Forest
4: Water
5: Wetlands
6: Agriculture