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Canopy Cover of Sehome Aboretum

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COLLEGE OF THE ENVIRONMENT

WESTERN WASHINGTON UNIVERSITY

MAKE WAVES.

Internship Title: Visualization of Canopy Cover Change in Sehome Arboretum

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Internship Dates: 9/21-6/22

STUDENT SIGNATURE ______________________

DATE: 10/17/2022

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I. INTRODUCTION

Over the course of this internship, I was responsible for visualizing and analyzing data, focused on the canopy cover of Sehome Hill Arboretum. Under the advisement of Rebecca Bunn, and assistance of Stefan Freelan, Dave Knutson, and the City of Bellingham, I was able to obtain spatial imaging and remote sensing data. Using the ArcGISPro application, I categorized tree cover in the Arboretum over multiple years, through both remote sensing and visual delineation methods.

Project Overview

In 1990, William Cantrell published a master's thesis on fungal parasitism of Douglas fir trees in Sehome Hill Arboretum, in which he characterized the extent and impact of the fungal pathogen *Phellinus weirii* on the Arboretum. *P. weirii* infection, commonly referred to as laminated root rot, spreads through connected roots of susceptible trees, largely conifers (Cleary et al. 2011). Cantrell (1990) discovered that *P. weirii* infection was widespread throughout the Arboretum, occurring most commonly in Douglas fir trees. As Douglas fir has historically been the most common tree species that is susceptible to laminated root rot in the Arboretum, it is expected that tree death from the fungal infection has changed tree diversity from the time the pathogens were originally identified. To identify Douglas fir stands impacted by this laminated root rot and evaluate shifting canopy cover in the Arboretum, I was tasked to create maps that categorize tree canopy cover over time, either coniferous or non-coniferous, in the Arboretum.

II. DESCRIPTION OF DUTIES AND RESPONSIBILITIES

The overarching goal of my internship was to generate maps that illustrate canopy cover change over time in the Sehome Arboretum. To achieve this goal, I was responsible for obtaining and interpreting base data on the Arboretum, then comparing interpreted results. I created six total maps using two different methods, illustrated in this section.

Map Creation

Visual Delineation

From available spatial images obtained through the City of Bellingham (COB), I determined that digital images in the years 2008 and 2013 were fit for analysis, under advisement by Stefan Freelan and Rebecca Bunn. Images were captured during leaf off season and imaging datasets were available at a high enough resolution that individual trees could be identified as either bare-branch or evergreen.

Using the selected images, I categorized areas of the Arboretum in ArcGISPro based on the canopy cover that I could view at the individual tree scale. Each area was identified as either conifer or non-conifer. Human-made features such as clearings, buildings, and paved roads and foot trails were classified as non-conifer canopy in addition to bare-branch trees.

For the year 1975, I obtained hand-drawn maps of canopy cover designation in the Arboretum, created by Cantrell (1990) through translating infra-red photography by Walker and Associates (1975). ArcGISProI then digitized and georeferenced this map in ArcGISPro to correlate the data to a coordinate system, and to allow for comparison using the map.

Remote Sensing

I obtained un-edited remote sensing data from the years 2006, 2013, and 2018 from COB. Obtained datasets had existing polygon features identified as conifer or non-conifer, but much of the Arboretum's area could not be identified as a specific canopy cover in the original datasets. Adjustments to the data had to be made to allow for comparison and easily visualized tree cover. To adjust the original data, I clipped it to the bounds of the Arboretum, as data exceeded the park's boundaries. Next, I merged polygons that were adjacent to each other and had the same conifer or non-conifer designation. I then separated all individual pieces of data, so that I could manually identify each null datapoint. Manual identification of null data was conducted by delineating polygons that share a boundary with non-conifer or large data points as non-conifer, while I identified small polygons that are isolated from non-conifer cover as conifer.

Comparison

Change Over Time

Change over time was evaluated using all available data: remote sensing maps from the years 2006, 2013, and 2018, and visual delineation maps from the years 1975, 2008, and 2013. To accurately compare the data, I clipped each map to the area of the map that had the smallest total area, so that all maps had equal areas. Remote sensing data was not adjusted to correct for inconsistencies in total area, as making major adjustments to these datasets would create results that are not representative of the results found through remote sensing methods. Total area of conifer and non-conifer tree cover was generated and compared between each year in addition to change in classification.

III. OUTCOMES

I successfully obtained and analyzed data on the canopy cover of the Arboretum. The results of my work indicated that the canopy cover in Sehome Hill Arboretum has had a trend towards non-conifer dominance when visual delineation methods were used, and a slight trend towards conifer dominance when remote sensing methods were used.

Change Over Time Results

The first goal of my work, to visualize change in tree diversity over time, resulted in a trend towards conifer dominance using visual delineation methods, and a trend towards non-conifer dominance using remote sensing methods. Analyses using both sets of data were unsuccessful, as the two datasets trended in different directions.

Visual Delineation

Visually delineated maps were created for the years 1975, 2008, and 2013. Over the 38 year period, conifer tree cover generally declined throughout the Arboretum (Figure 1, Figure 2). Conifer cover was determined to decrease by 0.15%, a total of 5.9E5 square feet (Figure 1). Canopy cover significantly shifted away from conifer dominance between the years 2008 and 2013 as well.

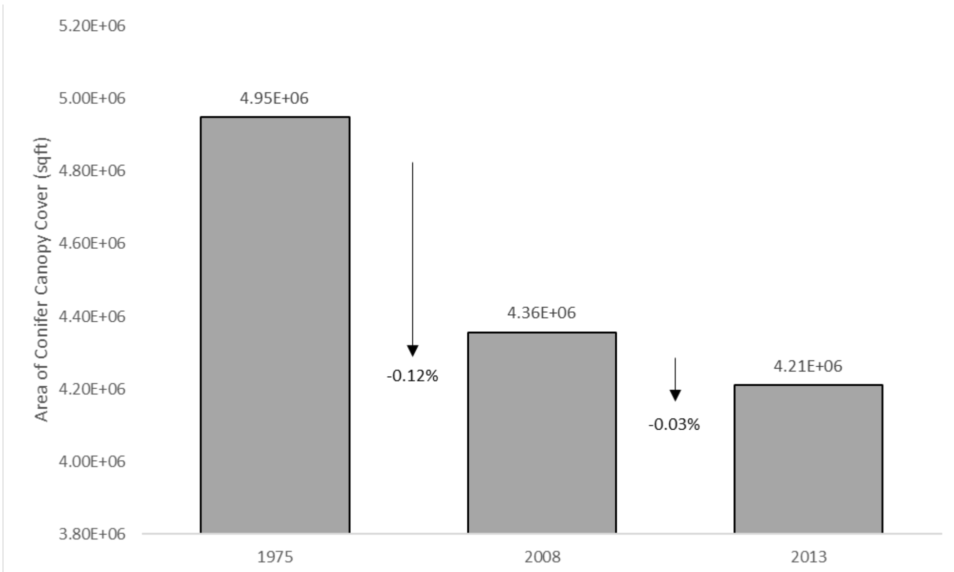

Figure 1. Total area and percent change in area (sqft) of conifer tree cover in Sehome Arboretum in 1975, 2008, and 2013, generated through visual delineation of spatial imaging data. Note that y axis does not start at zero.

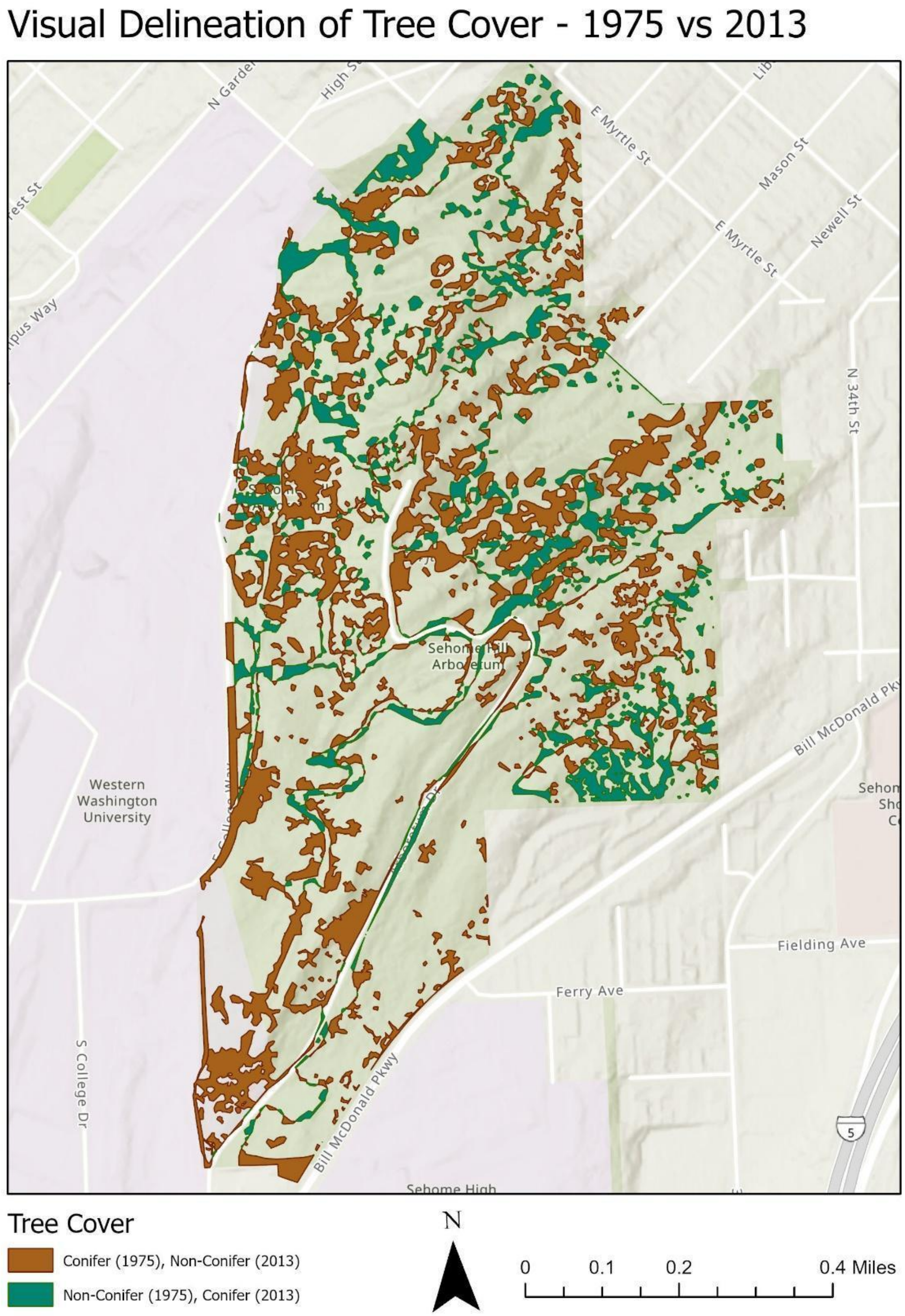

Figure 2: Comparison of tree cover in 1975 and 2013, as identified through visual delineation of spatial imagery (2013), or georeferenced from hand drawn map by Cantrell (1990) (1975)

Remote Sensing

Remote sensing maps were created using modified datasets obtained from the City of Bellingham in the years 2006, 2013, and 2018. Using this method, tree cover between the years 2006 and 2013 shifted towards conifer dominance, as shown in Figure 5. Total conifer area, in square feet, increased 0.09% over the 7 year period, for a total increase of 4.9E5 square feet that changed from non-conifer to conifer tree cover (Figure 3). However, this trend was not observed when comparing data from 2013 and 2018, where conifer tree cover decreased by 0.002%. The difference in trend between 2013/2018 and the overall trend is not significant, as less than 0.005% of the total area showed changes.

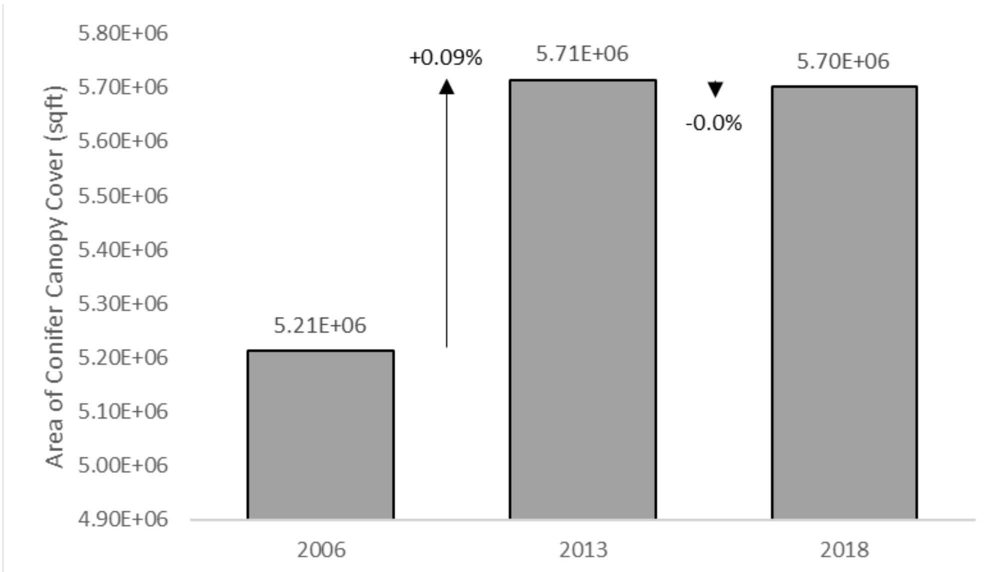

Figure 3. Total area (sqft) and percent change in area of conifer cover in Sehome Arboretum between 2006, 2013, and 2018 generated through remote sensing data. Note that y axis does not start at zero.

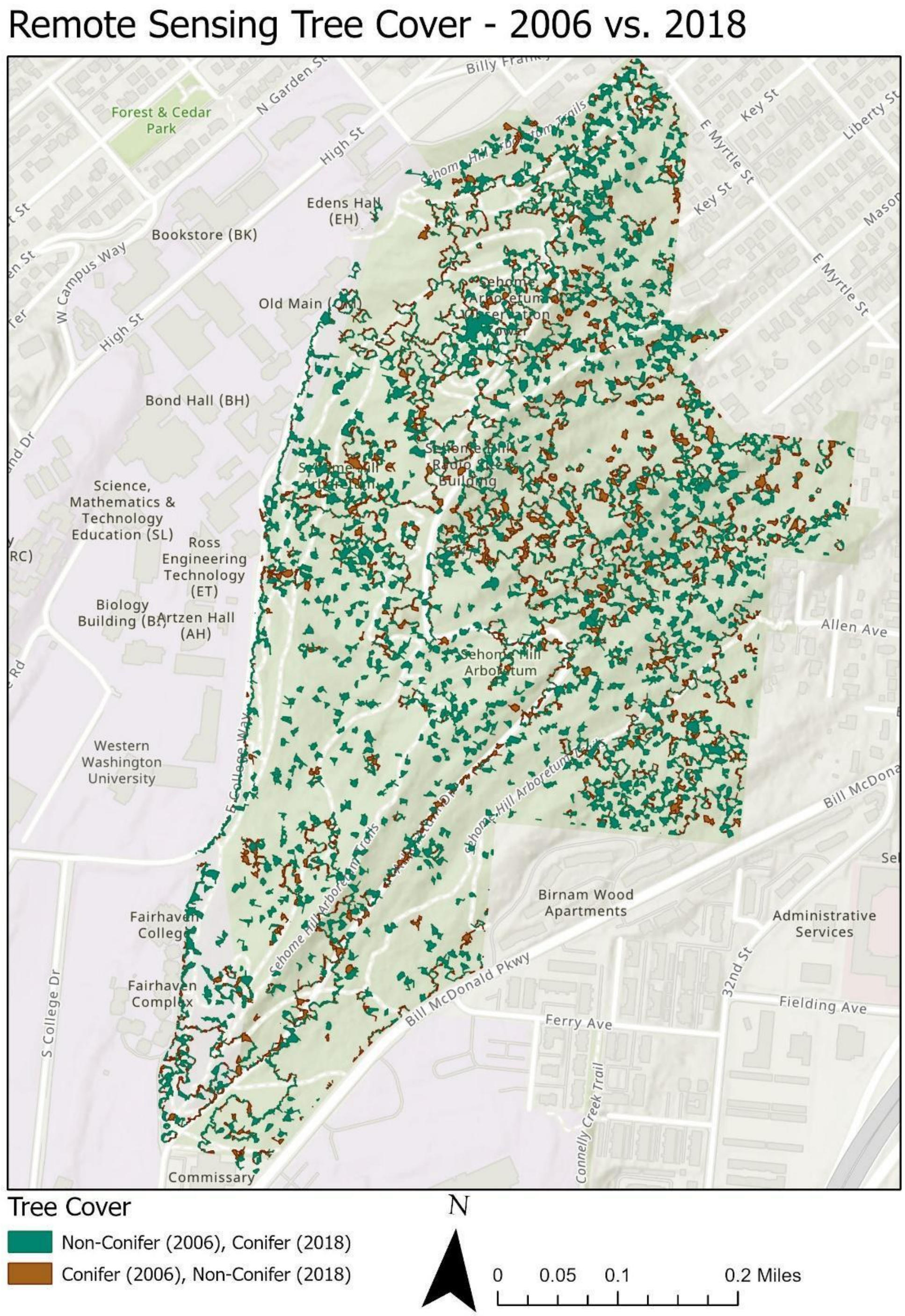

Figure 4: Comparison of tree cover in Sehome Hill Arboretum, as identified by remote sensing delineation methods in 2006 and 2018

Change Over Time Discussion

As tree cover delineation by way of remote sensing data was not adjusted to equal areas across maps, I chose to interpret the trends in the created spatial imaging dataset as representative of on the ground tree cover change. This decision corresponds to findings by Leckie et al. (2004), who recommended supplementing spectral analysis of infrared images of tree cover with visual analysis in order to better determine impacts of laminated root rot.

As non-conifer delineation encompassed all features in the Arboretum that were not evergreen tree cover, my results do not indicate that the area of deciduous tree cover has increased. In addition, it is likely that deciduous trees that are not impacted by infection and are abundant in the Arboretum, such the Bigleaf maple, have increased in number. As Douglas fir in the Arboretum are large trees that provide yearlong shade, these deciduous trees may have taken advantage of the newly found access to sunlight from gaps in the canopy.

The shift away from conifer dominance in the Sehome Hill Arboretum was predicted by Cantrell (1990). In his master's thesis, he identified laminated root rot in the Arboretum's Douglas fir population, attributed to the parasitic fungus Phellinus weirii. As Douglas fir is the dominant evergreen species in the Arboretum, death in the population would greatly change tree diversity patterns.

The maps that I created identified a total decrease of 13.62 acres of conifer tree cover and a parallel increase in non-conifer cover between the years 1975 and 2013. Cantrell (1990) originally identified 16.41 acres of the Arboretum as Phellinus root rot infection centers. Many of these infection centers had noticeable decreases in conifer tree cover area, most significantly to the east of the paved road bisecting the Arboretum (Figure 2). This area to the east of the paved road was designated by Cantrell (1990) as highly susceptible to root rot, with over 50% conifer cover and over 5% root rot when the paper was written. This area encompasses over 54 acres of the Arboretum and had a 74% loss of conifer tree cover between 1975 and 2013. The maps that I created identified areas of conifer loss that corresponded to previously identified root rot centers and susceptible areas, indicating that this change may be attributed to Phellinus root rot in the Arboretum's dominant Douglas fir population.

IV. ASSESSMENT

Success of Project

The project met the stated goals of categorizing and visualizing the shift away from conifer dominance in the Sehome Hill Arboretum. I successfully created six distinct maps, three using visual delineation techniques, and three using remote sensing data. Three of these maps proved to be useful to interpret trends in canopy cover change in the Arboretum, encompassing a total of 38 years.

Contributions to the Project

I believe that I contributed significantly to the main goal of my project, with considerable help from Stefan Freelan and Rebecca Bunn. The maps and corresponding data in this report were either created or interpreted by me.

Skills Gained

I developed many important skills throughout the internship, including communication, time management, and adaptation to challenges. As the work I was doing encompassed two different disciplines, ecology and GIS, I was regularly communicating with different professors. I learned how to present results, deliver updates, and come to a supervisor with concerns. Disseminating information to one professor from another kept me organized, as I needed to have clear messaging to keep all three of us on the same track. As GIS can be time consuming, especially the manual editing that I was often doing, I had to come up with ways to cut down on time in order to stay on track, and make sure that I was putting in work every day. I also had the opportunity to present my results in the form of a poster at the APCG 2022 conference, gaining experience in professional communication and improving my presentation skills.

In addition to professional skills, I also gained knowledge in technical aspects of GIS and forest ecology. Aided by Stefan Freelan, Assistant Director of the College of the Environment's Spatial Analysis Lab, I learned to interpret data, georeference historical maps, and correct mistakes in ArcGISPro. Before this internship, I had limited knowledge on the software through an introductory course, but now feel comfortable creating maps and using the software for work outside of canopy cover in Sehome Arboretum. I also spent time reading information on Phellinus weirii, collecting data on canopy cover in the field, and interacted with others involved in researching the ecosystem of the Arboretum. Through these activities, I learned about plant-fungus interactions that are relevant to local ecosystems, in addition to lab and field data collection practices, succession by way of parasitism, and the ecosystem of conifer-dominated mature forests.

V. LITERATURE CITED

Cantrell, William G. (William Gary), "Phellinus Weirii Root Rot of Douglas Fir in the Sehome Hill Arboretum: Distribution, Impact and Management Options" (1990). WWU Graduate School Collection. 881.

Cleary, Michelle, Rona Sturrock, and Janice Hodge. "Laminated root disease-stand establishment decision aid." *Journal of Ecosystems and Management* 12.2 (2011).

Leckie, D. G., et al. "Detection and assessment of trees with Phellinus weirii (laminated root rot) using high resolution multi-spectral imagery." International Journal of Remote Sensing 25.4 (2004): 793-818.

VI. APPENDICES

Report to the City of Bellingham Comparing Visual and Remote Sensing Canopy Cover Delineation Results

Background:

Western Washington University (WWU) is assessing possible die back of Douglas fir trees in the Sehome Arboretum by way of delineating conifer and non-conifer dominated regions of the arboretum at multiple points in time using spatial images from aerial photographs. The City of Bellingham (COB) is currently conducting an all city survey of its urban forests by using remote sensing data to determine tree cover and canopy class in the city.

Goal:

Compare categorization of conifer and non-conifer dominated regions via 1) manual delineation of categories on spatial images and 2) remote sensing data techniques, which will be disseminated via visual maps of tree cover.

Methods:

Maps were created using two methods of tree cover delineation, remote sensing data obtained from COB and visual identification of tree type through interpreting aerial photographs. Years mapped were chosen based on availability of each data type in Sehome Hill Arboretum. that could be easily categorized as conifer or non-conifer through visual means. In order to visually delineate the canopy cover of any year, aerial imaging must have been taken during leaf off season and be available as raster datasets in a resolution sufficient to distinguish conifer from bare branch canopy. Aerial photos from 2008 and 2013, obtained from COB, met these requirements, in addition to analogous remote sensing datasets in the years 2006 and 2013. All maps were made using ArcGIS Pro software.

Visual delineation

Spatial imaging datasets taken in 2013 and 2008 were used as a key to determine tree cover in Sehome Hill Arboretum. 2013 and 2008 spatial imaging consisted of four 0.325x0.325sqft raster datasets of northwest, northeast, southwest, and southeast extents of Sehome Hill Arboretum. Using the images as a basemap, areas were designated as "Conifer " or "Non-Conifer" by creating a polygon vector feature class. Delineation of tree cover was determined through greenery cover in an area, as the photos were taken during the leaf off period for deciduous trees.

Remote Sensing Data

Remote sensing data of tree cover in Sehome Hill Arboretum for 2006 and 2013 was obtained from the COB in the former of polygon vector datasets. Tree cover was designated by the City in the feature class's attribute table, in which a field, "Conifer", identified polygons as conifer, non-conifer, or did not contain data. Original data was adjusted to allow for ease of comparison through the ArcGIS geoanalyst tool "Dissolve" to fill in null values with nearby tree cover data, and the editing tool, "Explode", to break up large polygons. An "Identity" was run between the remote sensing and visual delineation layers so that the maps would have corresponding boundaries. To determine attributes of non-designated polygons, a definition query was put in place to remove polygons with the "Conifer" attribute. Null features that shared boundaries with "Non-Conifer" polygons and null polygons with large areas were designated "Non-Conifer". All other null polygons were designated as "Conifer", as it was assumed that error was more likely in conifer areas and because of the dominance of conifer trees in Sehome Hill.

Comparison

To compare tree cover designations between the two methods, the ArcGISPro analysis tool "Intersect" was run between the remote sensing and visual vector dataset for the two corresponding map years. Four categories were created based on cover class that determined by remote sensing data (COB) and visual delineation (WWU):

- Corresponding - Conifer (WWU, COB)
- Corresponding - Non-conifer (WWU, COB)
- Non-corresponding 1 - Conifer (WWU), Non-conifer (COB)
- Non-corresponding 2 - Non-conifer (WWU), Conifer (COB)

We created new maps for each year illustrating the cover of these four categories. In addition, we calculated the percent corresponding for each year.

Results:

We found remote sensing data generally identified the same areas of conifer tree cover as visual delineation, but classification of non-conifer tree cover differs. In maps from 2013, conifer identification generally matches between the two techniques (Figure 1), but visual delineation identifies more non-conifer areas than remote sensing data (Figure 2). A similar pattern is found in the 2006/2008 (Figure 3, Figure 4) comparison, albeit with larger discrepancies in both conifer and non-conifer categories.

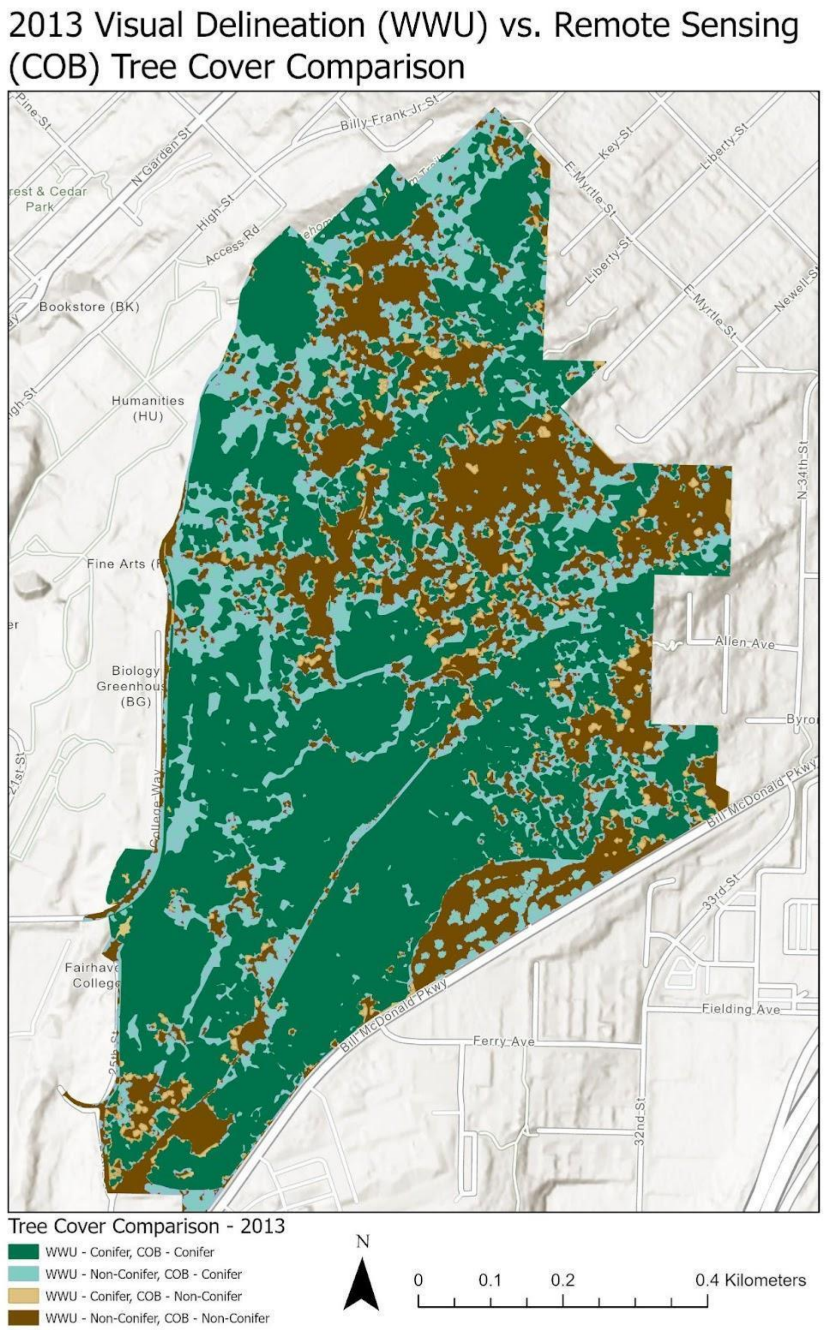

Figure 1: Mapped comparison of tree cover determination in Sehome Hill Arboretum by 2013 remote sensing (COB) data and 2013 visual delineation (WWU)

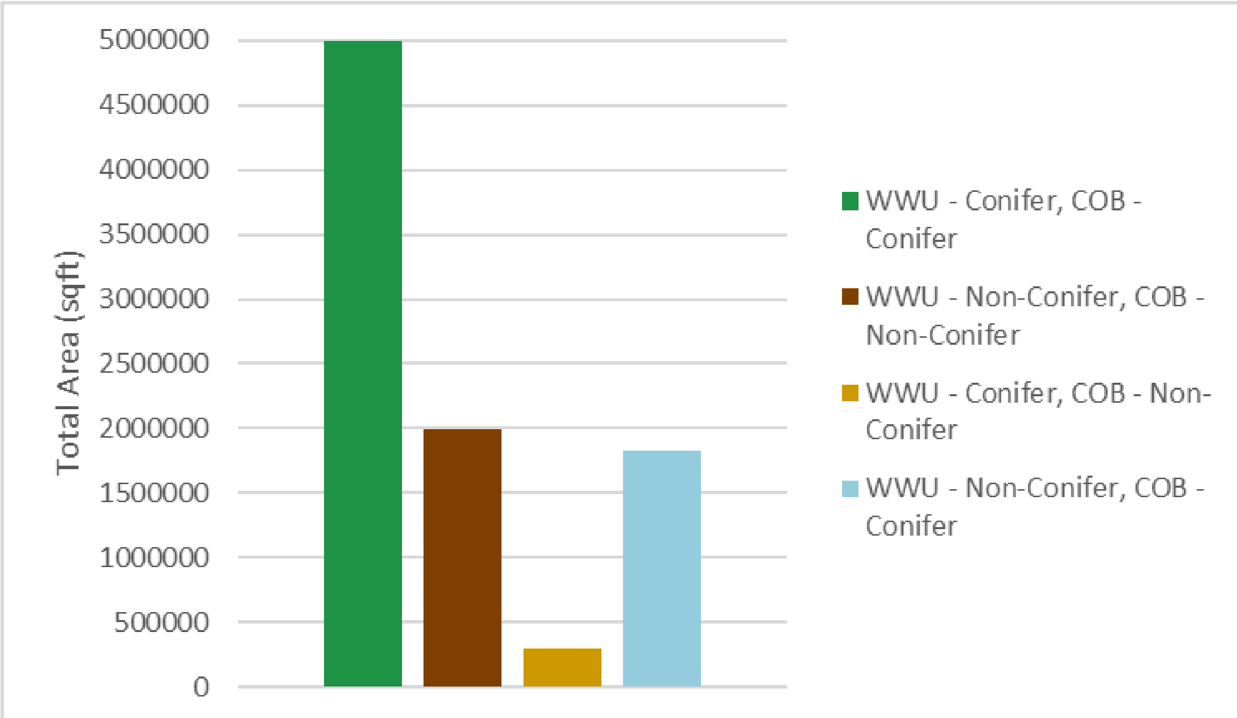

Figure 2: Comparison of total area (sqft) of tree cover class in Sehome Arboretum (2013), as determined by visual delineated (WWU) and remote sensing (COB) methods.

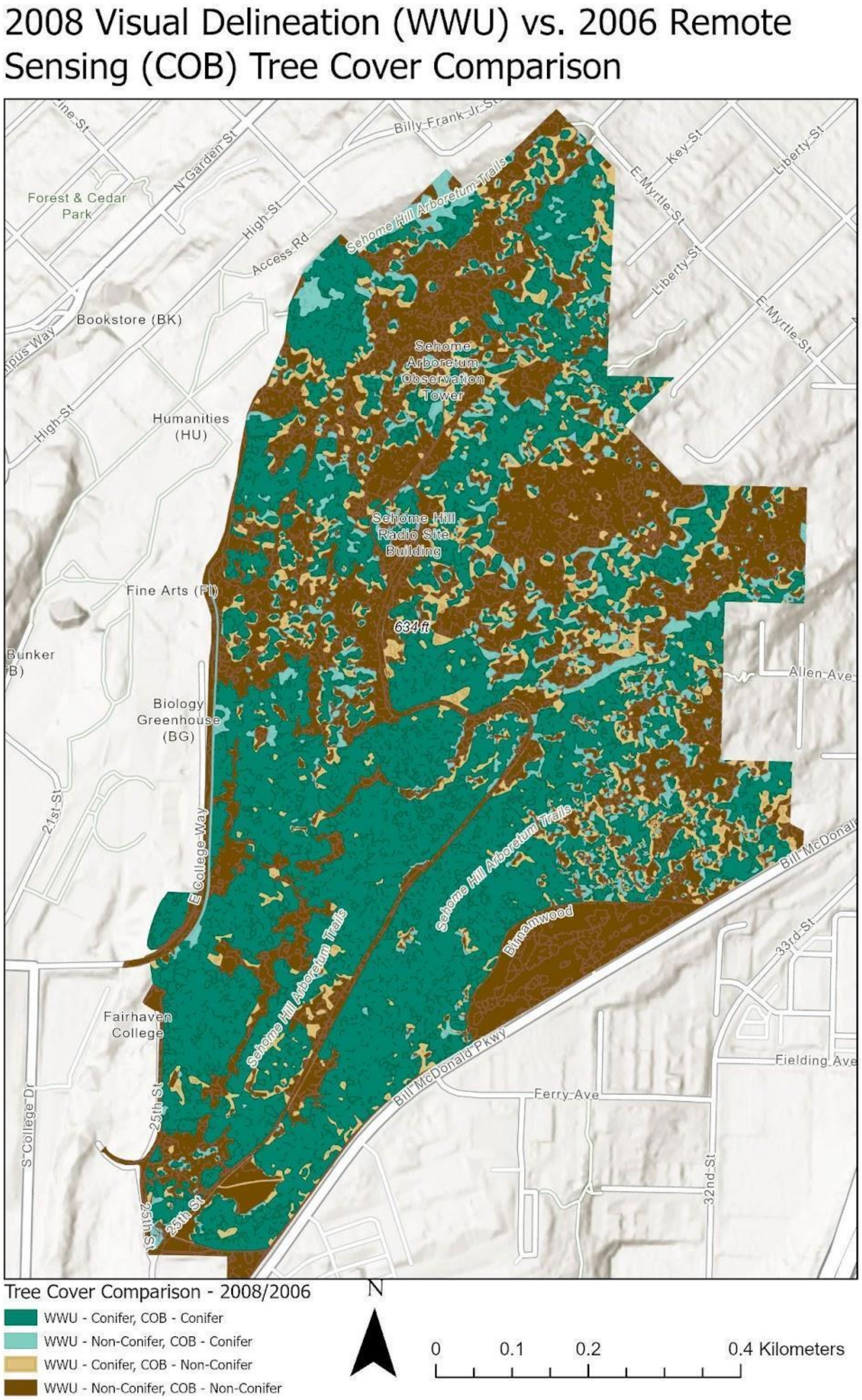

Figure 3: Mapped comparison of tree cover determination in Sehome Hill Arboretum by 2006 remote sensing (COB) data and 2008 visual delineation (WWU)

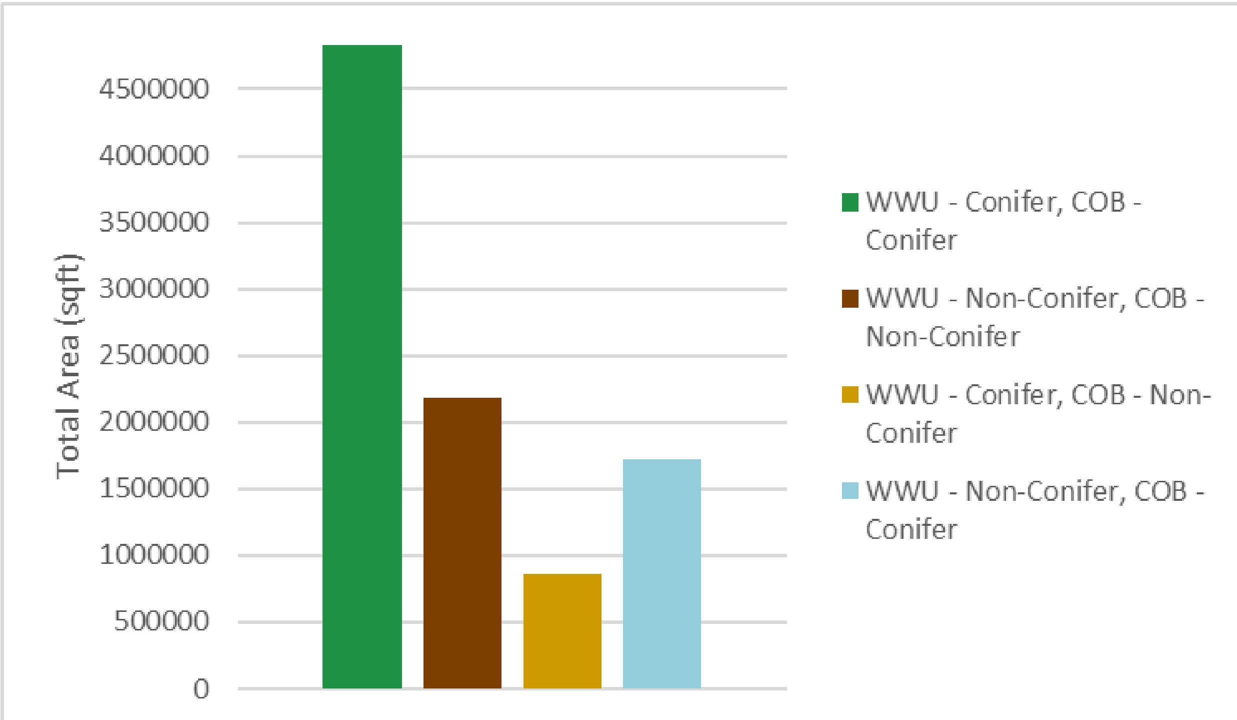

Figure 4: Comparison of total area (sqft) of tree cover class in Sehome Arboretum, as determined by visual delineated (WWU, 2008) and remote sensing (COB, 2006) methods.

When overlying comparison maps over spatial imaging, visual delineation has more success in aligning non-conifer areas to the images. Remote sensing data occasionally identifies clearings, pavement, or buildings as conifer, while visual mapping largely correctly determines these areas to be non-conifer. In general, the remote sensing data can successfully communicate trends in tree cover, but issues occur when more specific comparisons are made.

	Conifer - WWU	Non-Conifer - WWU	Conifer - COB	Non-Conifer - COB	Conifer - WWU, COB	Non-Conifer - WWU, COB	Conifer - WWU, Non-Conifer - COB	Non-Conifer - WWU, Conifer - COB	Percent Corresponding	Percent Non-Corresponding
2006/2008	$5.7*10^6$	$3.6*10^6$	$6.5*10^6$	$3.0*10^6$	$4.8*10^6$	$2.2*10^6$	$8.6*10^6$	$1.7*10^6$	73.12%	26.88%
2013	$5.3*10^6$	$3.8*10^6$	$6.8*10^6$	$2.3*10^6$	$5.0*10^6$	$1.2*10^6$	$3.0*10^5$	$1.8*10^6$	76.6%	23.4%

Table 1: Total area (sqft) of conifer/non-conifer tree cover in years 2006/2008 and 2013, as identified through visual delineation (WWU) and remote sensing (COB) methods.

	Conifer - WWU	Non-Conifer - WWU	Conifer - COB	Non-Conifer - COB	Conifer - WWU, COB	Non-Conifer - WWU, COB	Conifer - WWU, Non-Conifer - COB	Non-Conifer - WWU, Conifer - COB
Change	-6.7%	-2.0%	4.4%	-24.6%	3.6%	-8.8%	-64.8%	6.6%

Table 2: Percent change in tree cover class (sqft) from 2006/2008 to 2013, as identified through visual delineation (WWU) and remote sensing (COB) methods.

Appendix:

2006 Remote Sensing (COD) Tree Cover

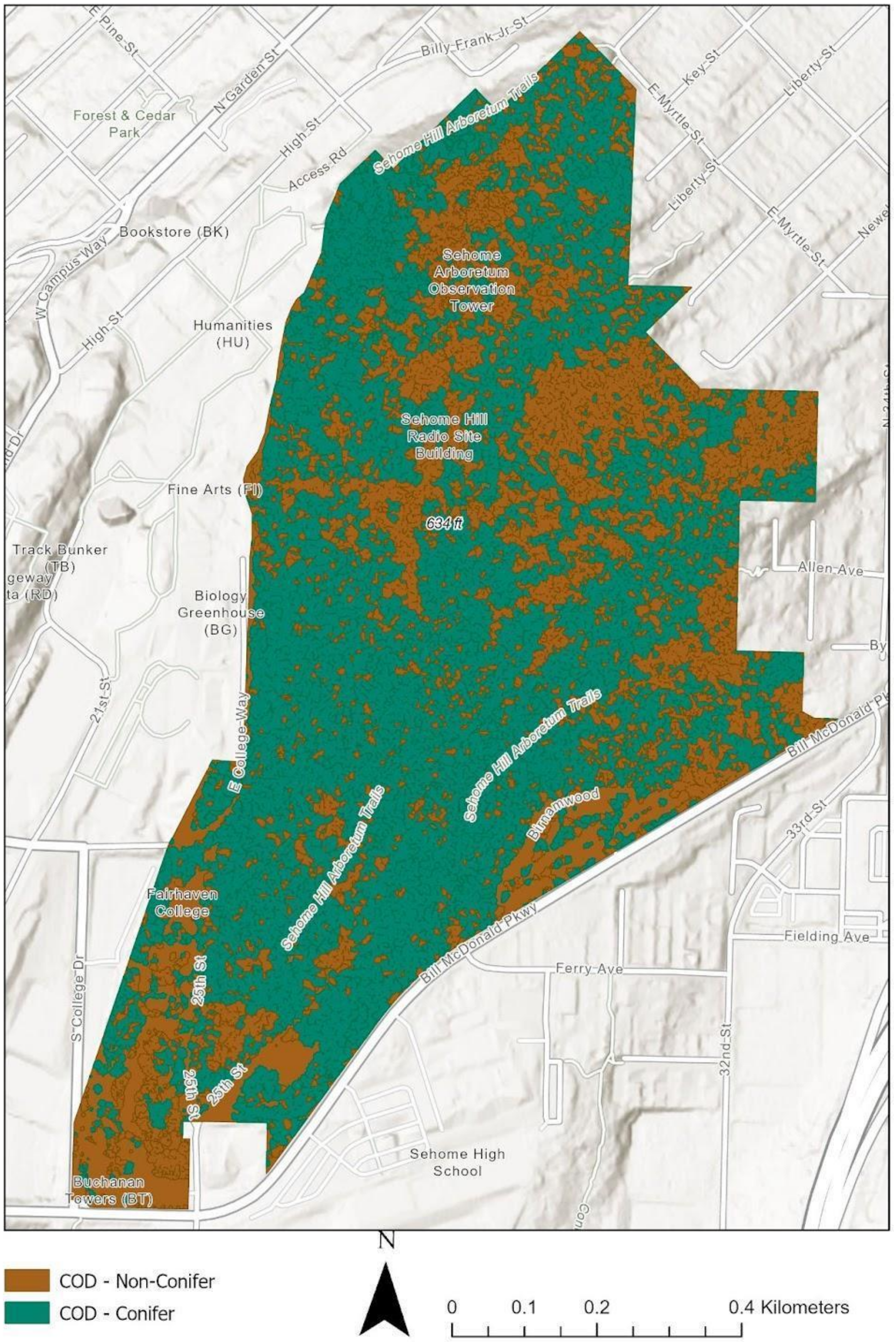

Figure 5: Tree cover of Sehome Arboretum in 2006, as delineated through remote sensing (COB) methods.

2008 Visually Delineated (WWU) Tree Cover

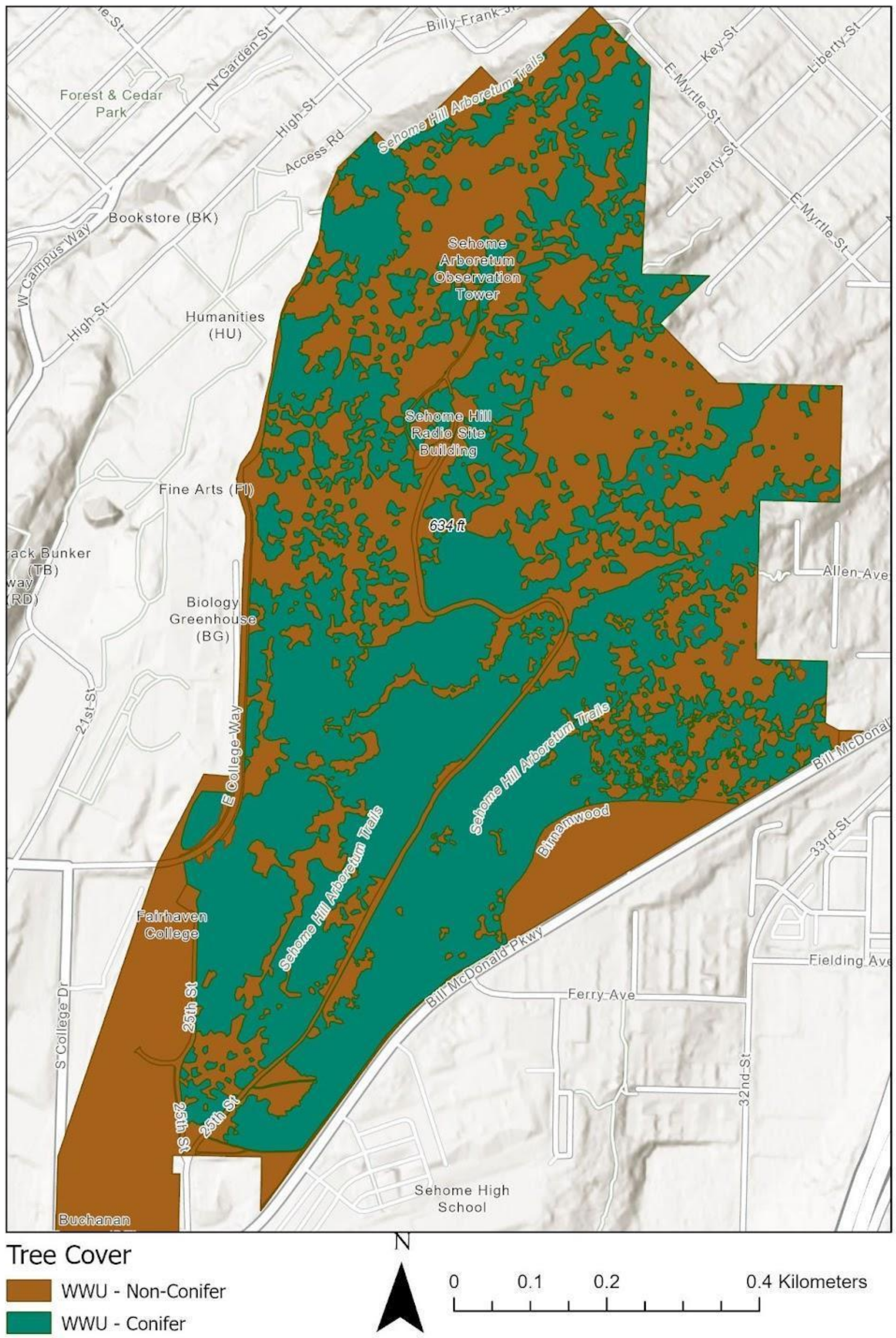

Figure 6: Tree cover of Sehome Arboretum in 2008, as delineated through visual delineation (WWU) methods.

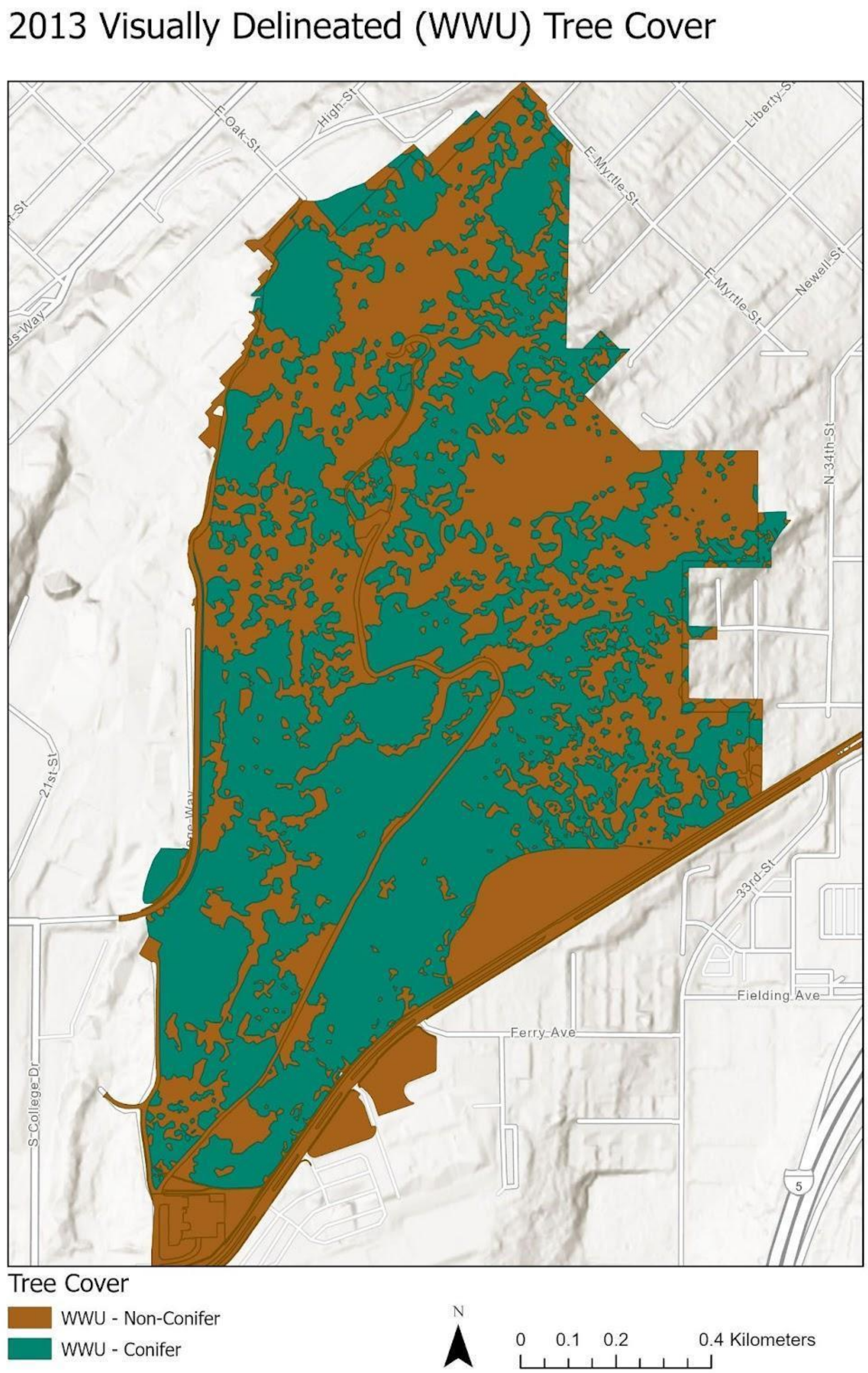

Figure 7: Tree cover of Sehome Arboretum in 2013, as delineated through remote sensing (COB) methods.

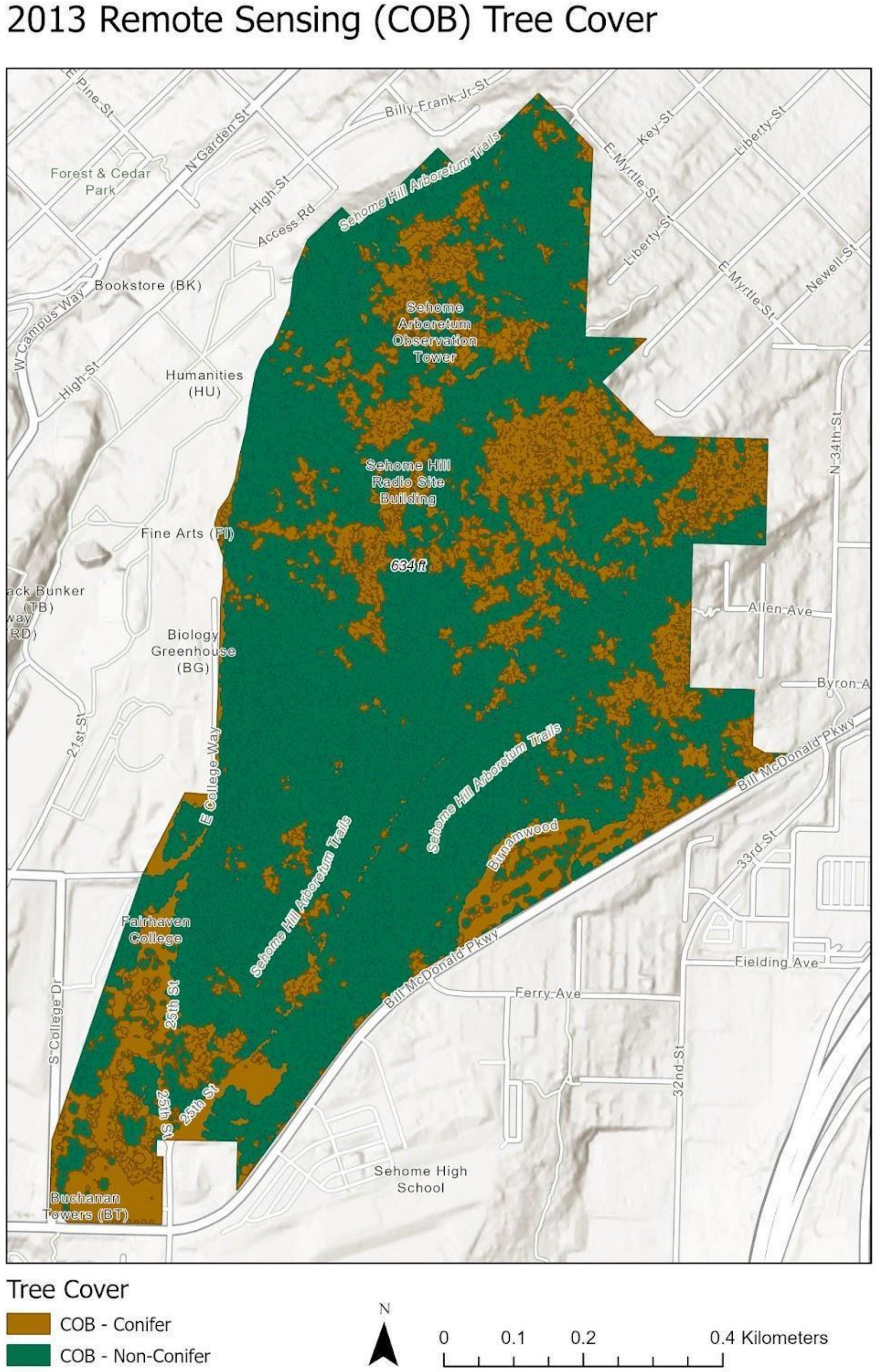

Figure 8: Tree cover of Sehome Arboretum in 2013, as delineated through visual delineation (WWU)

Additional maps and graphs

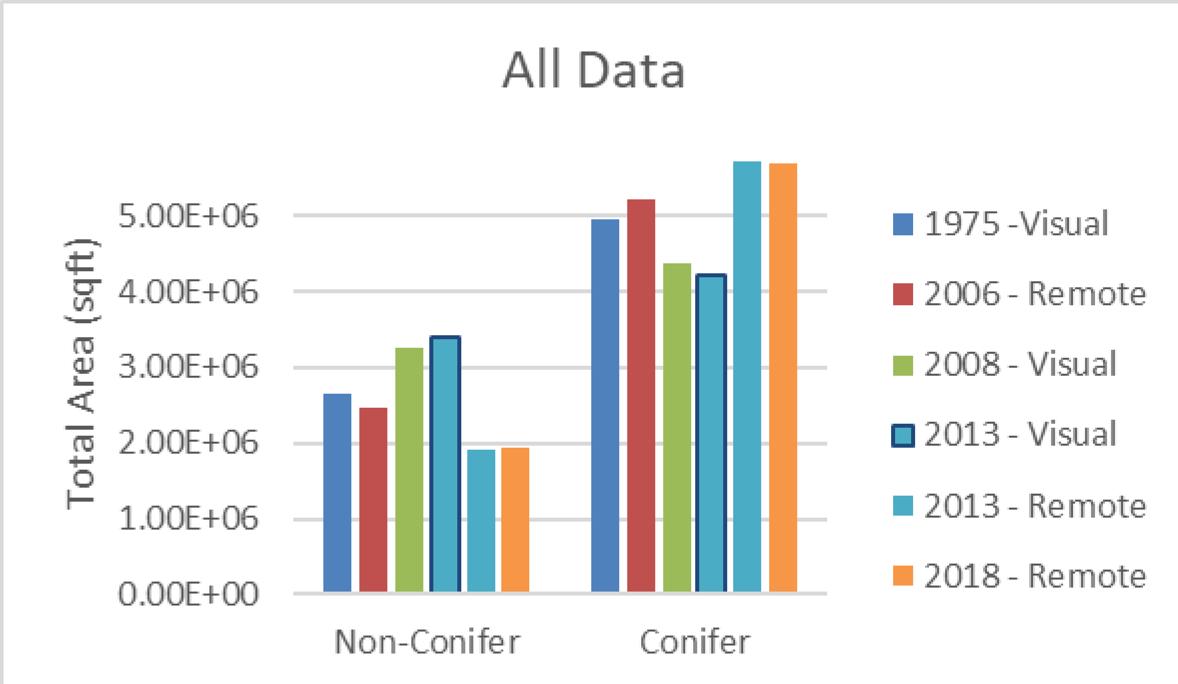

Figure 1: Comparison of tree cover area, in square feet, in Sehome Hill Arboretum between all visualization methods and years analyzed

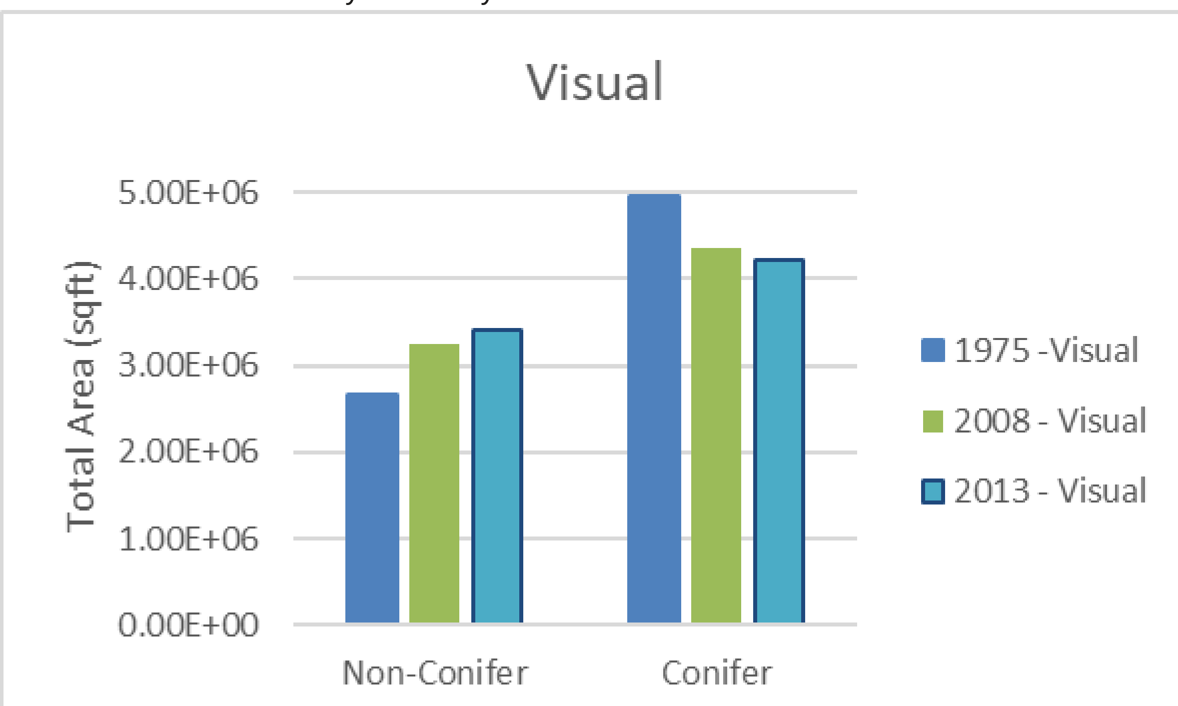

Figure 2: Comparison of tree cover area, in square feet, in Sehome Hill Arboretum between the years 1975, 2008, and 2013, created through visual analysis of spatial images

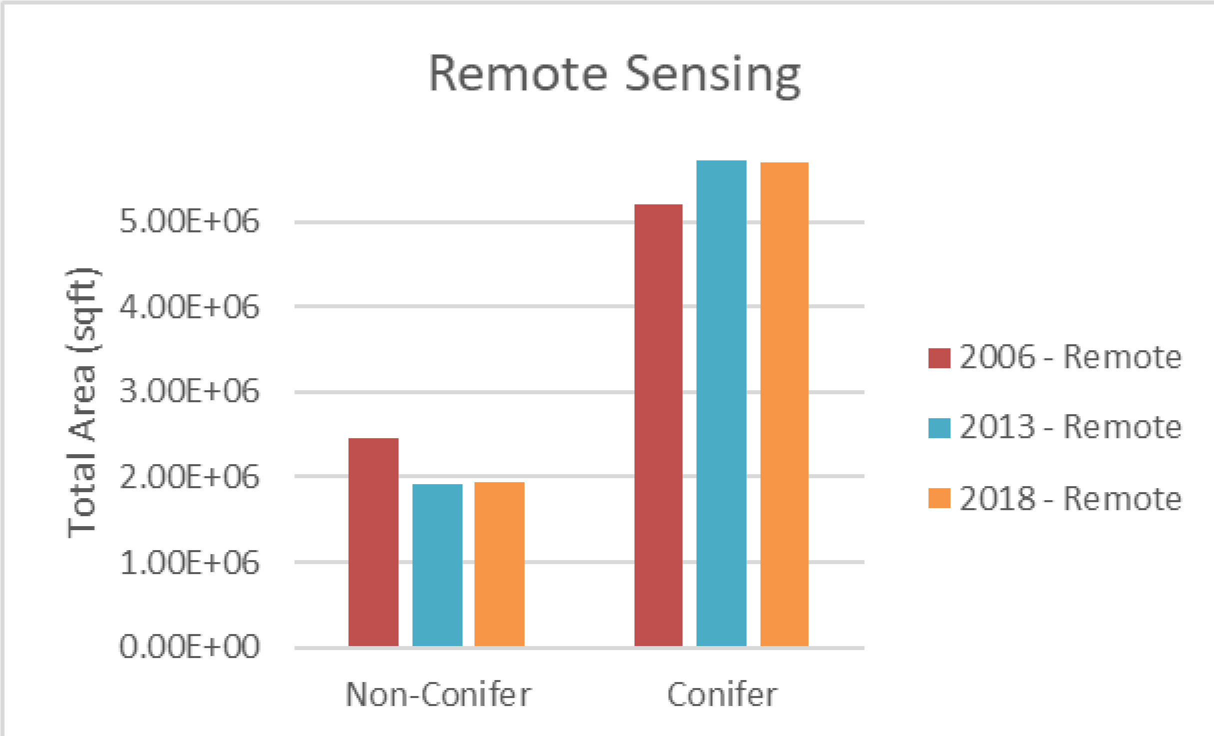

Figure 4: Comparison of tree cover area, in square feet, in Sehome Hill Arboretum using remote sensing data from 2006, 2013, and 2018

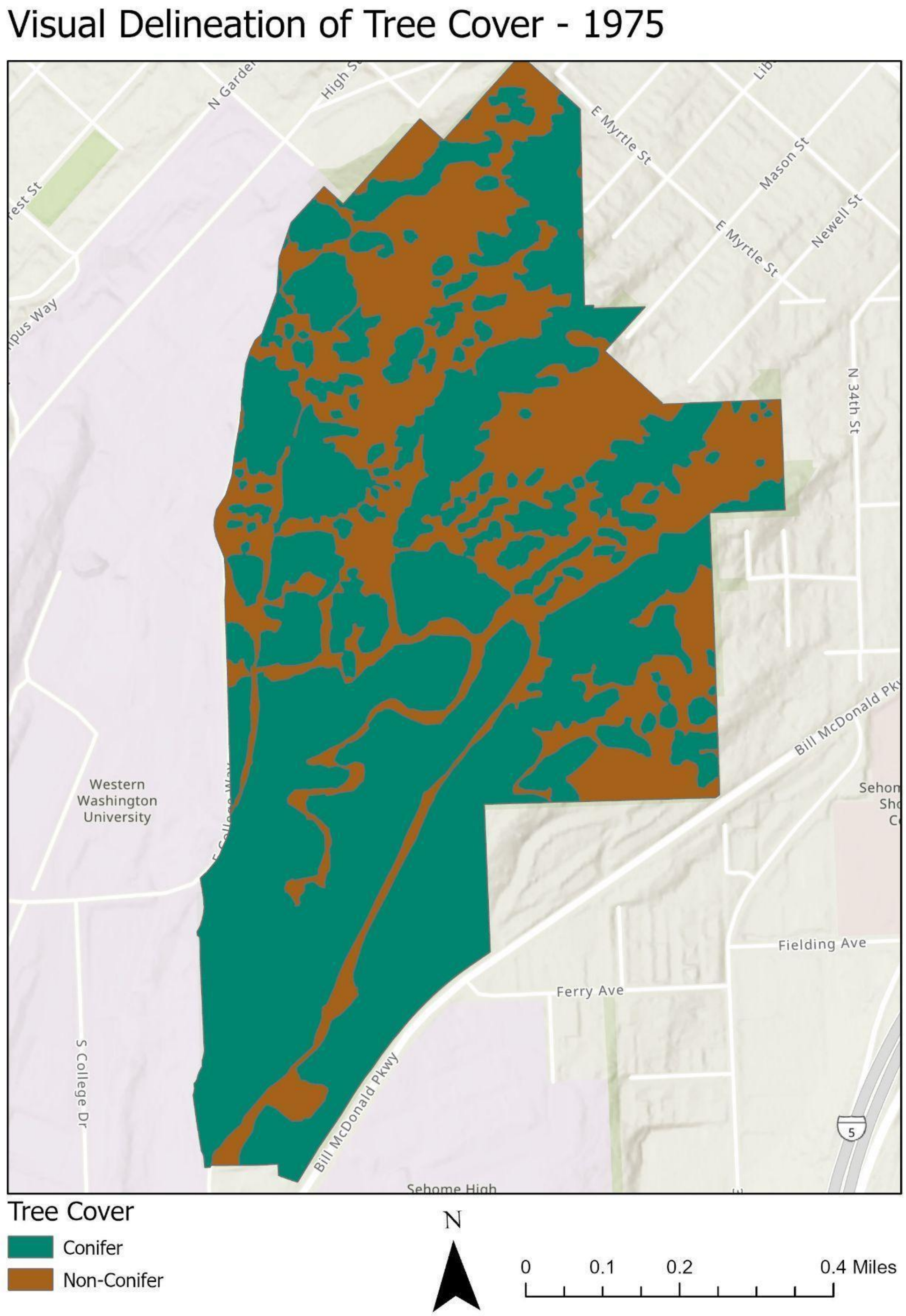

Figure 4: Tree cover of Sehome Arboretum in 1975, as georeferenced from 1975 visual delineation of spatial imaging

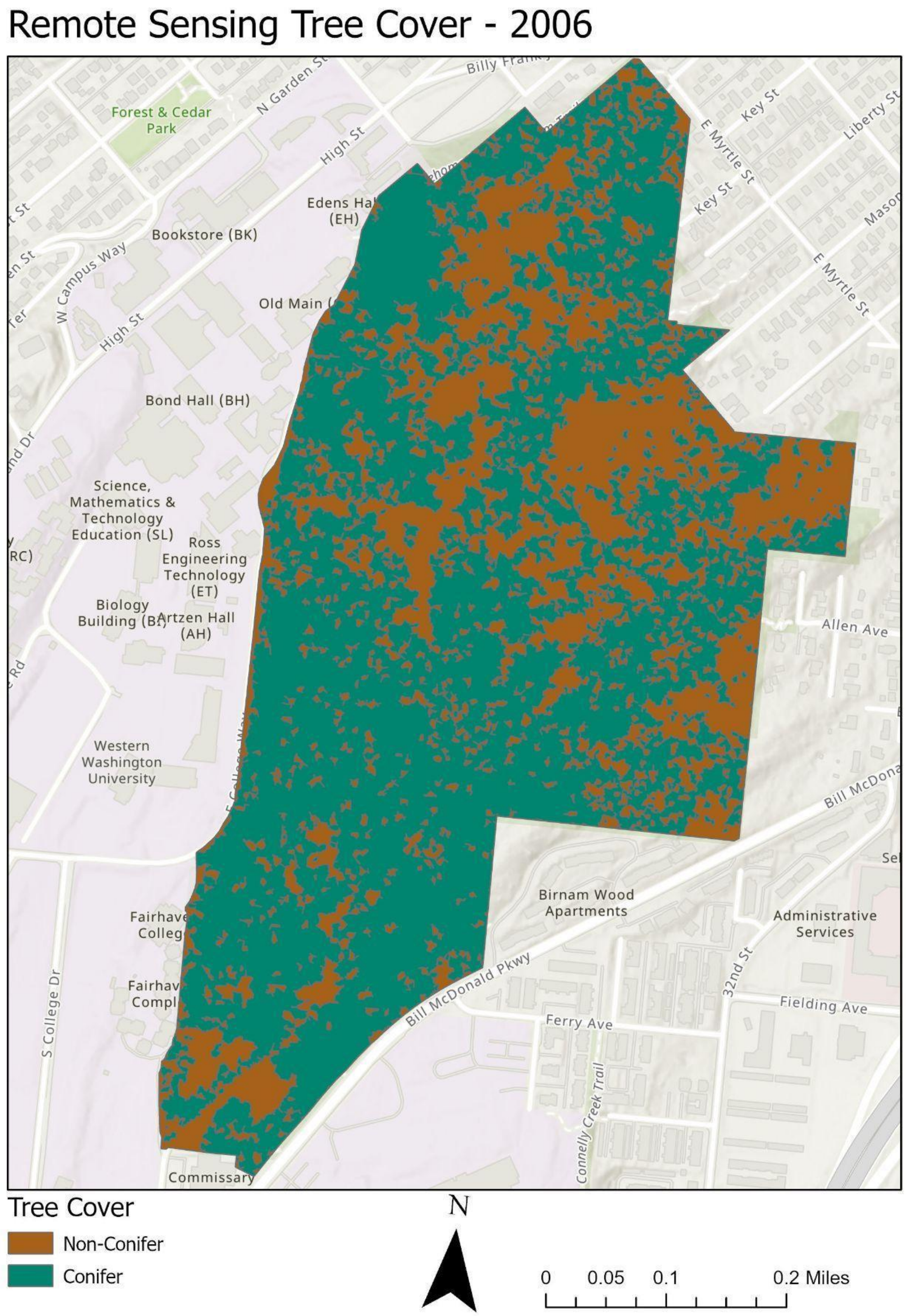

Figure 5: Tree cover of Sehome Arboretum in 2006, created using remote sensing d

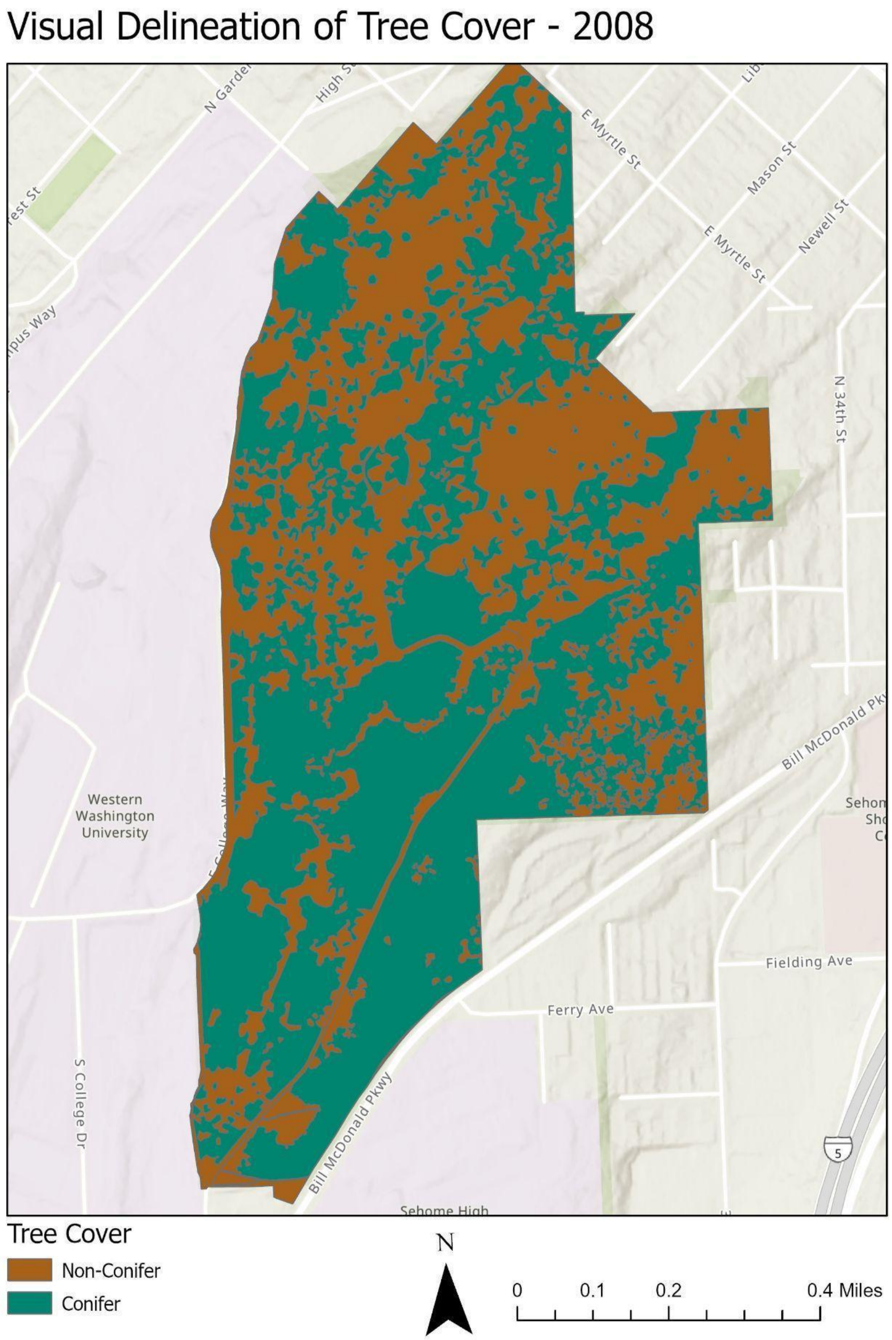

Figure 6: Tree cover of Sehome Arboretum in 2008, created through visual delineation of spatial imaging

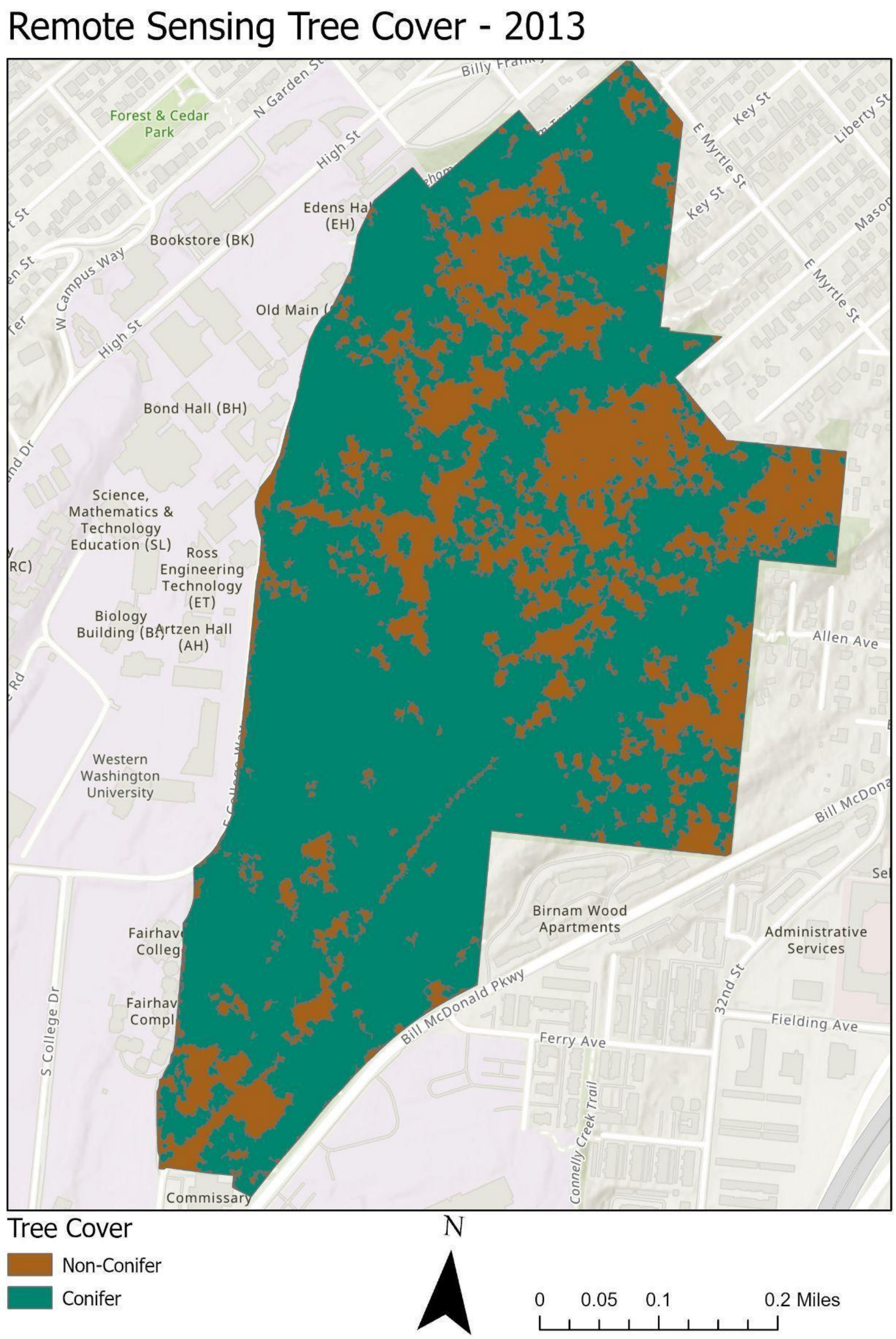

Figure 7: Tree cover of Sehome Arboretum in 2013, created using remote sensing data

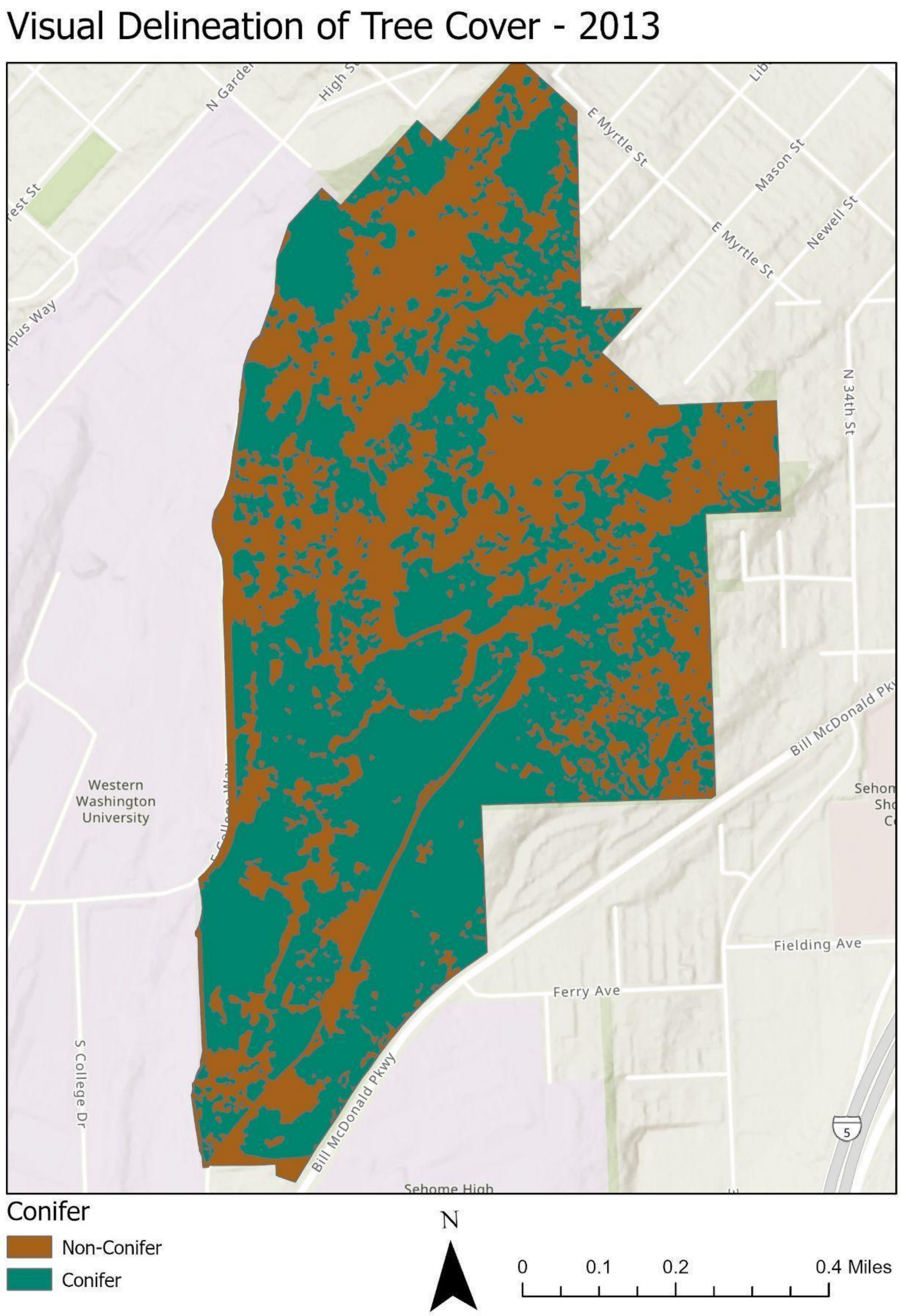

Figure 8: Tree cover of Sehome Arboretum in 2013, created through visual delineation of spatial imaging

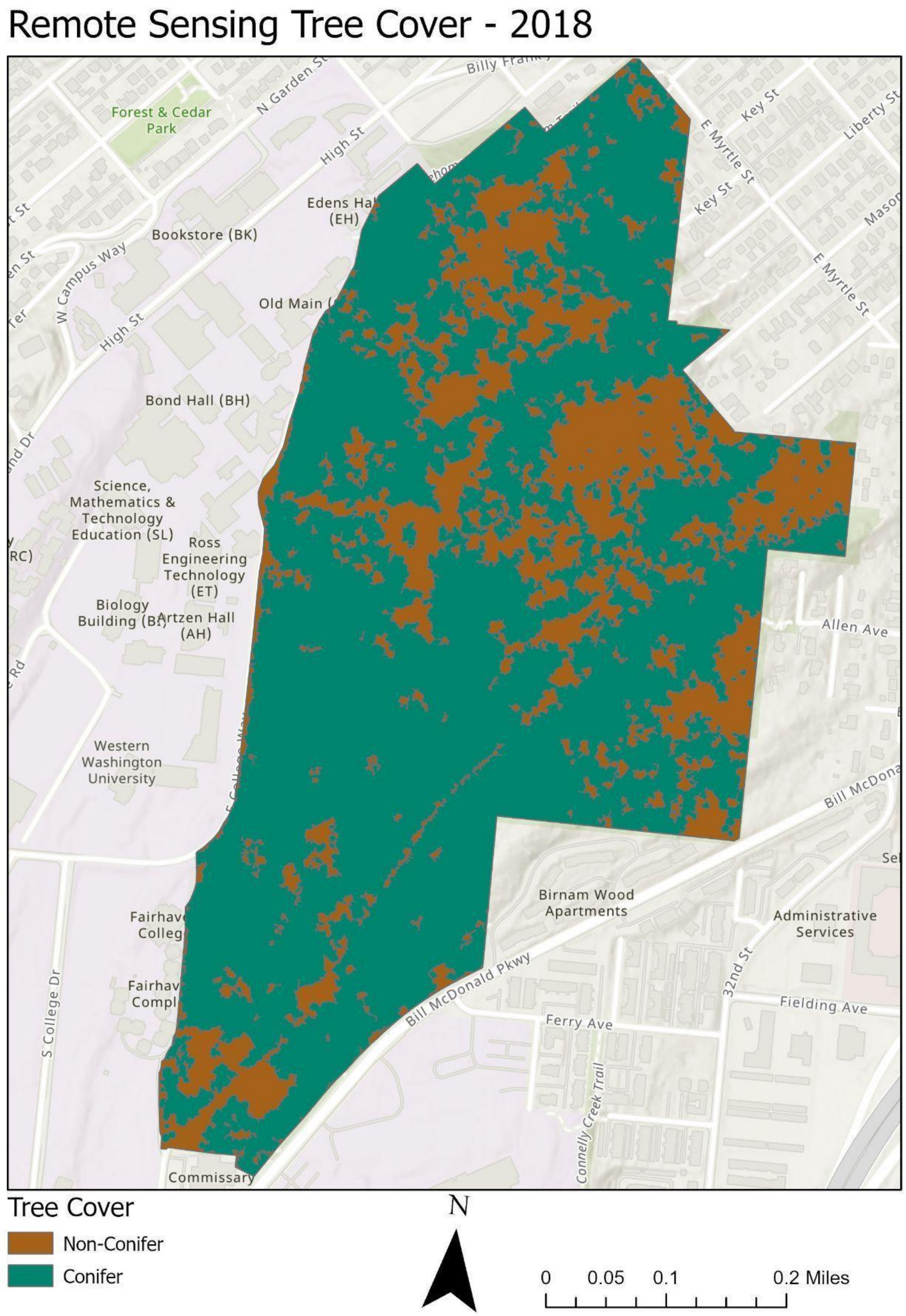

Figure 9: Tree cover of Sehome Arboretum in 2018, created using remote sensing data

Timesheets

Month	Hours	
Oct	6	
Nov	6.5	
Dec	3.5	
Jan	12	
Feb	19	
March	14.5	
April	14	
May	20	
June	8	
	Total Hours	103.5

Oct-21		
Day	Hours	Activities
4-Oct	3	Data collection at greenhouse for grad student
5-Oct	2	Data collection at greenhouse for grad student
24-Oct	1	Literature review - Cantrell
Total Hours	6.00	

Nov-21		
Day	Hours	Activities
8-Nov	0.5	Researching spatial imaging access
9-Nov	0.5	Researching spatial imaging access
11-Nov	1	Research on map digitizing
12-Nov	1.5	1975 map digitizing attempt
15-Nov	1	1975 map digitizing attempt
16-Nov	1	1975 map digitizing attempt
20-Nov	1	Researching spatial imaging access
Total Hours	6.5	

Dec-21		
Day	Hours	Activities
5-Dec	0.5	Access to spatial imaging, imagery review
8-Dec	1	Meeting with Stefan on map creation
9-Dec	1	Review of Stefan's methods for delineation
10-Dec	1	2008 imagery attempt
Total Hours	3.5	

Jan-22		
Day	Hours	Activity
4-Jan	1.5	Delineation of 2008 tree cover using spatial imaging
5-Jan	1	Delineation of 2008 tree cover using spatial imaging
6-Jan	2	Delineation of 2008 tree cover using spatial imaging
7-Jan	1	Delineation of 2008 tree cover using spatial imaging
10-Jan	1	Delineation of 2008 tree cover using spatial imaging
11-Jan	1	Delineation of 2008 tree cover using spatial imaging
12-Jan	1.5	Delineation of 2008 tree cover using spatial imaging
13-Jan	1	Delineation of 2008 tree cover using spatial imaging
14-Jan	1	Delineation of 2008 tree cover using spatial imaging
17-Jan	1	Delineation of 2008 tree cover using spatial imaging
Total Hours	12	

Feb-22		
Day	Hours	Activity
1-Feb	1	Meeting with Stefan on GIS methods
2-Feb	1	Delineation of 2013 data using spatial imaging
3-Feb	1	Delineation of 2013 data using spatial imaging
4-Feb	1	Delineation of 2013 data using spatial imaging
7-Feb	2	Delineation of 2013 data using spatial imaging
8-Feb	1	Meeting with Rebecca
9-Feb	1.5	Delineation of 2013 data using spatial imaging
10-Feb	1	Delineation of 2013 data using spatial imaging
11-Feb	1	Delineation of 2013 data using spatial imaging
14-Feb	1	Delineation of 2013 data using spatial imaging
15-Feb	1	Delineation of 2013 data using spatial imaging
16-Feb	1.5	Delineation of 2013 data using spatial imaging
17-Feb	1.5	Delineation of 2016/2008 data using spatial imaging
18-Feb	1	Delineation of 2016/2008 data using spatial imaging
21-Feb	1	Delineation of 2016/2008 data using spatial imaging
22-Feb	1	Delineation of 2016/2008 data using spatial imaging
24-Feb	0.5	Meeting with stefan and rebecca
Total Hours	19	

Mar-22		
Day	Hours	Activity
1-Mar	2	Meeting with Stefan on translating remote sensing data, editing 2013 remote sensing data
2-Mar	1.5	Editing 2013 remote sensing data
3-Mar	1	Editing 2013 remote sensing data
4-Mar	1	Editing 2013 remote sensing data
7-Mar	1	Editing 2013 remote sensing data
8-Mar	1	Editing 2013 remote sensing data
9-Mar	1	Editing 2006 remote sensing data
10-Mar	1	Editing 2006 remote sensing data
11-Mar	1	Editing 2006 remote sensing data
14-Mar	2	Comparison analysis
15-Mar	1.5	Comparison analysis
31-Mar	0.5	Meeting with Brigid on projects
Total Hours	14.5	

Apr-22		
Day	Hours	Activity
1-Apr	0.5	Meeting with Rebecca on project updates
5-Apr	1	Layout creation for field measurements
6-Apr	1.5	Field measurements with Brigid
7-Apr	0.5	Meeting with Stefan
8-Apr	0.5	Meeting with Rebecca
11-Apr	1	Data comparison
13-Apr	2	City report
14-Apr	2	City report, map creation
15-Apr	1.5	Layout creation, data comparison
18-Apr	2	1975 digitizing, map creation
19-Apr	1.5	City report, data comparison
Total Hours	14	

May-22		
Day	Hours	Activity
2-May	1.5	1975
3-May	1	1975
4-May	1	1975
5-May	0.5	1975
6-May	1	2018
9-May	1	2018, meeting with Marion Brodhagen and biology students
10-May	1	2018
11-May	1	2018
12-May	1	2018
13-May	1.5	Data comparison
18-May	1	Data comparison
19-May	0.5	Data correction
20-May	0.5	Data correction
23-May	1	Data correction
26-May	2	Meeting with Stefan, data correction
27-May	1	Data correction
28-May	1.5	Data correction
29-May	2	Data correction
Total Hours	20	