Using Vegetation Sampling Protocol for invasive species monitoring in Thompson Tract, Hogsback, and Cliffs Forest

Megan Rowcliffe, Abby Leavens, Justin Gaudon, Jenna Quinn
***rare Charitable Research Reserve**, 1679 Blair Road, Cambridge, Ontario, N3H 4R8, Canada*

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The ***rare*** **Charitable Research Reserve** acknowledges and is grateful to all of the original stewards of the land in which ***rare*** resides, within the Haldimand Tract, spanning six miles on either side of the Grand River from source to mouth. Understanding that this land has been rich in diverse Indigenous presence since time immemorial, there are several Indigenous Nations that we would like to mention. We would like to honor and respect the sovereignty of both First Nations in our area: the Haudenosaunee Peoples of Six Nations of the Grand River and the Anishinaabe Peoples of Mississaugas of the New Credit First Nation. Nia:wen and Miigwech to these Nations who share their lands with us. We would also like to acknowledge the Neutral Peoples (and their ancestors) and the Indigenous Paleo hunters that we have archeological evidence for dating back 1,200 and 10,500 years, respectively. Lastly, we would like to acknowledge those Indigenous Peoples who currently live, work, and learn in the urban landscape around us such as other self-identified and status First Nations, Métis, and Inuit.

Cover photography by Megan Rowcliffe. Clockwise from the top: a yellow birch organic deciduous swamp in the Hogsback, a coniferous plantation with little vegetation in Thompson Tract, and a dense buckthorn shrub layer in yellow birch mineral deciduous swamp in Thompson Tract.

Executive Summary

With over 200 cumulative volunteer hours committed to the Vegetation Sampling Protocol (VSP) in 2018 and 2019, a total of 391 species of vascular flora were observed across three forest sites at ***rare***, including 18 new species observations (Appendix D). Two forests on ***rare's*** property were sampled in 2018, the Hogsback (N = 11 plots) and Thompson Tract (N = 24 plots). Cliffs Forest was sampled in 2019 (N = 28 plots).

VSP reiterated that the Hogsback is an extremely high-quality site. It had noticeably fewer invasive plant species and a higher percentage of native woody seedling regeneration than Thompson Tract and Cliffs Forest. Additionally, numerous species observed in the Hogsback indicate that it is a high-quality wetland, including brome-like sedge (*Carex bromoides*), cinnamon fern (*Osmunda cinnamomea*), tufted loosestrife (*Lysimachia thrysiflora*), swamp candles (*Lysimachia terrestris*), northern long-awned wood grass (*Brachyelytrum erectum var. glabratum*), and the provincially-rare Chinese hemlock parsley (*Conioselinum chinese*) (Figure A-1).

In Thompson Tract, parts of the yellow birch mineral deciduous swamps were found to have some high-quality species indicators, including low-sweet blueberry (*Vaccinium angustifolium*) and swamp fly honeysuckle (*Lonicera oblongifolia*) in addition to cinnamon fern, northern long-awned wood grass, and Chinese hemlock parsley (Figure A-1). Areas near the coniferous plantation in Thompson Tract appeared to be poor in quality, likely caused by the heavily-shaded understory created by dense stands of invasive buckthorn. Plots located in plantations contained large numbers of invasive plants and had low native tree regeneration. This was especially true in the southwest coniferous plantation. The southeast naturalized coniferous plantations were an exception, with greater native woody seedling regeneration and considerably fewer invasive plants. The old-growth, dry sugar maple-oak deciduous forests of Thompson Tract had relatively few invasive plant species and high native woody seedling regeneration despite being near highly-invaded plots. One exception was a plot that had the historic remnants of a deer enclosure [used in a study by Bubenik and Schams (1986)], which had higher percent cover of the invasive garlic mustard (*Alliaria petiolata*) and the potentially-invasive nipplewort (*Lapsana communis*). The eastern white cedar organic coniferous swamps of Thompson Tract were the most species-rich plots (*e.g.*, 105 different plant species observed in Plot 300). Despite high species diversity, these coniferous swamps also had some of the highest percent cover of buckthorn from the ground to sub-canopy layers.

In Cliffs Forest, high rates of non-native seedling recruitment and buckthorn were evident in many plots, with nearly three times the amount of buckthorn (as measured by basal area) found here than in the Hogsback or Thompson Tract. Nearly half of the plots in Cliffs Forest had > 48 % non-native seedling regeneration. High coverage of buckthorn from the ground to canopy was found in the buckthorn deciduous thicket, mixed forest, and silver maple mineral deciduous swamp showing that both wetland and upland ecosystems are affected by this highly-invasive shrub. Generally, the most pristine plots were in the sugar maple beech forest polygon that makes up over a third of Cliffs Forest. These plots had lower non-native seedling regeneration, buckthorn basal area, and priority invasive species cover than other sampled areas of the forest.

Table of Contents

Acknowledgements 1

Executive Summary 2

Background 4

Methods 4

- Study Sites 4
- Vegetation Sampling 6
- Data Processing and Analysis 6

Results 6

- Non-native Seedling Regeneration 6
- Invasive Forbes 7
- Invasive Grasses and Monocots 7
- Invasive Shrubs 8
  - Buckthorn Abundance and Basal Area 9
- Invasive Trees 10

Conclusions and Recommendations 11

Literature Cited 15

Appendix A: Supplemental Species Maps 16

Appendix B: VSP Plot Maps 73

Appendix C: Equipment List 76

Appendix D: New Species List 77

Appendix E: Invasive Species List 78

Background

Invasive species are any species that can spread to become ecologically, economically, and/or culturally damaging to a geographic region. They often present themselves as problematic and become unwanted as they threaten biodiversity as well as negatively impact ecosystems and our economy (Pimentel *et al.*, 2004). Invasive plants are no exception. To date, there have been over 200 non-native plant species recorded at the ***rare*** **Charitable Research Reserve**, of which 70 invasive species have been identified on ***rare's*** invasive plant list. As such, invasive species monitoring is an important facet of the ongoing research and ecological monitoring at the ***rare*** **Charitable Research Reserve.**

In a warming world, monitoring is even more important as species shift their geographic range. These range shifts can be one approach for species to adapt to a changing climate, and occurrences of non-native and invasive species at ***rare*** may in turn increase over the years. However, one challenge that remains is identifying an 'invader' from 'range shifter', and then deciding whether a 'range shifter' is prioritized for removal.

To help, the Vegetation Sampling Protocol or VSP (Puric-Mladenovic and Kenney, 2015) can be used to sample a range of vegetation types in the field. We used VSP to monitor invasive plant species over time across the ***rare*** **Charitable Research Reserve**. We report our findings for field work in 2018 and 2019.

Methods

Study sites

Plots were established between June and September 2018 in two woodlots within ***rare*** **Charitable Research Reserve**: the Hogsback (N = 11) and Thompson Tract (N = 24) (Figure 1A and1B). In 2019, plots were established between June and October within the Cliffs Forest (N = 28) (Figure 1C). Plots were randomly assigned on a systematic grid using GIS, eliminating agricultural fields and waterbodies. The number of plots established in each of the three areas were proportionate to the size of each of the different land classifications, and more plots were established in areas that had a greater number of land classifications. Thompson Tract is comprised of five different Ecological Land Classification (ELC) codes (eastern white cedar coniferous organic swamp, naturalized coniferous plantation, naturalized deciduous plantation, yellow birch mineral deciduous swamp, and dry-fresh sugar maple-oak deciduous forest), resulting in 24 plots established. The Hogsback is comprised of three ELC codes (yellow birch organic deciduous swamp, dry-fresh sugar maple-white ash deciduous forest, and fresh-moist oak-hardwood deciduous forest), resulting in 11 plots. Cliffs Forest is comprised of 16 ELC codes within 23 polygons, and 28 plots were established. VSP plots captured eight of the ELC communities across Cliffs Forest (buckthorn deciduous shrub thicket, mixed forest, dry-fresh sugar maple - beech deciduous forest, alvar shrub rock barren, dry-fresh sugar maple deciduous forest, silver maple mineral deciduous swamp, southern arrow-wood mineral deciduous thicket swamp, and black ash mineral deciduous swamp).

Following the VSP method outlined by Puric-Mladenovic and Kenney (2015), plots were 400 m^2 and circular with an 11.28-m radius, and the centre point of each plot was staked with a rebar post to to ensure accurate comparisons when plots are resampled every five years. Future plots have also been randomly generated in GIS for the remainder of the Blair property and can be found on ***rare's*** server.

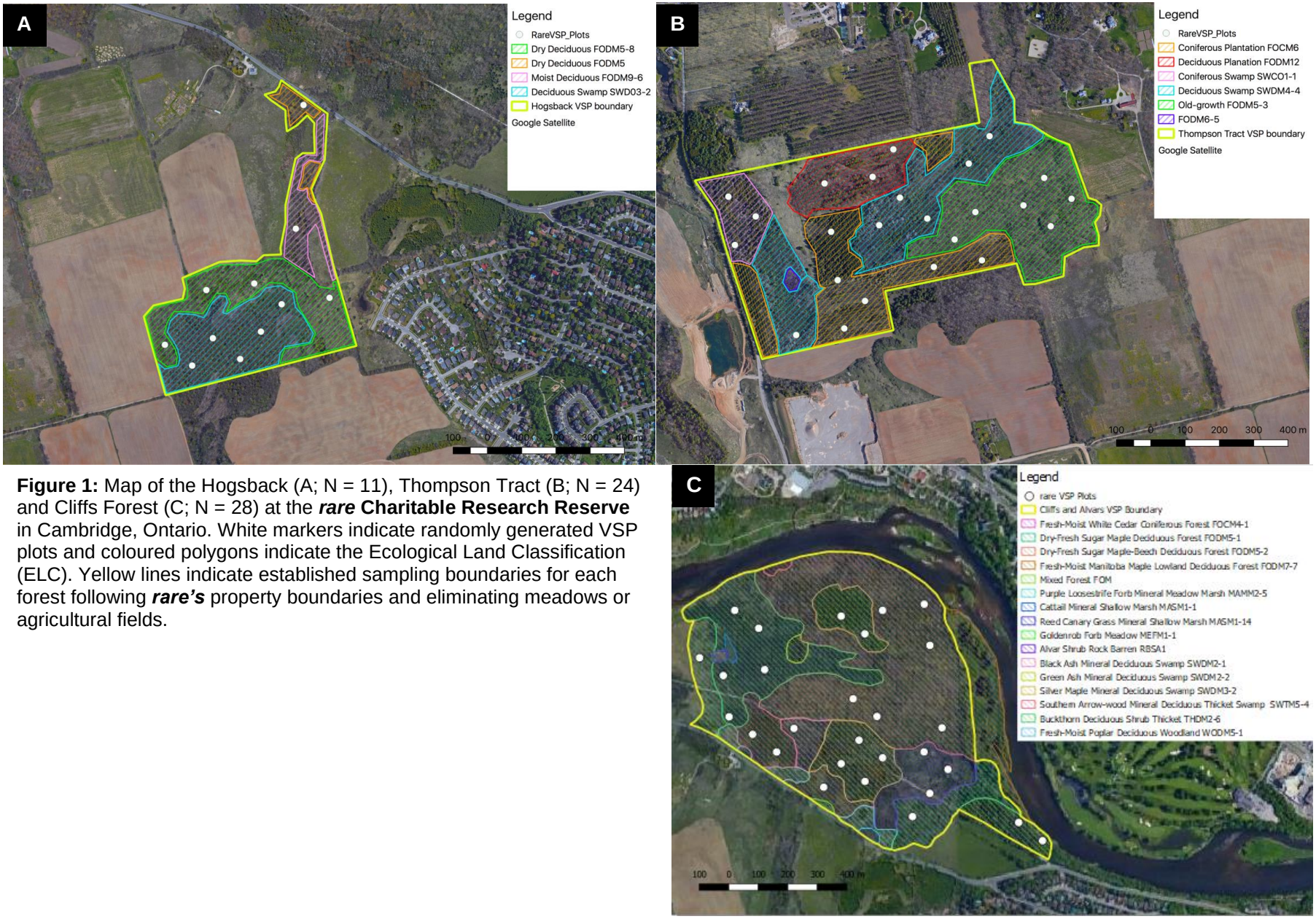

Figure 1: Map of the Hogsback (A; N = 11), Thompson Tract (B; N = 24) and Cliffs Forest (C; N = 28) at the ***rare*** **Charitable Research Reserve** in Cambridge, Ontario. White markers indicate randomly generated VSP plots and coloured polygons indicate the Ecological Land Classification (ELC). Yellow lines indicate established sampling boundaries for each forest following ***rare's*** property boundaries and eliminating meadows or agricultural fields.

Vegetation sampling

All plot sampling adhered to VSP methods (Puric-Mladenovic and Kenney, 2015). The presence and abundance (percent cover estimated as either 0.1 % (trace), 1 %, 2 %, 5 %, and then up to 100 % incrementally by 5 %) of vascular flora were recorded amongst four designated vertical strata within each plot (< 0.5 m, 0.5-2 m, 2-10 m, and < 10 m). As such, percentage cover by a species can exceed 100 % if totaled across the vertical strata. Sampling was separated into four quadrants following the main cardinal directions (north, south, east, and west), with 1-m^2 subplots falling on the middle of each cardinal direction and one at the centre of the plot. Subplots quantified the presence and abundance of all vascular flora less than or equal to 0.5 m in height, as well as seedling and sapling regeneration. For seedling regeneration, the number of seedlings were counted for each species and categorized by height (2.5-15 cm, 15-30 cm, 30-90 cm, 150-200 cm, and > 200 cm). Saplings with diameters at breast height (dbh, measured 1.3 m above the ground) between 2.5 cm and 5 cm were measured with a caliper. Browsing damage on seedlings and saplings was recorded.

All trees that fell 50 % or more within the plot boundaries with a dbh > 5 cm were measured to one decimal place. Species name, canopy dieback (on a scale of 0-3, where 0 = no dieback, 1 = up to 25 % dieback, 2 = up to 50 % dieback, and 3 = > 50 % dieback), the presence of pests and/or diseases, and the overall health of trees were recorded for all measured trees. Plot descriptions, such as ELC, canopy closure, community age class, topographical characteristics, slope position, hydrological characteristics, and evidence of anthropogenic and environmental disturbances were also recorded. Soil characteristics, coarse woody debris, and tree heights of three representative trees were not sampled in 2018, although they are other modules included in VSP. In 2019, coarse woody debris was sampled in three plots (Plots 55, 56, and 222) to be included in ongoing research projects at ***rare*** (J.M. Gaudon, personal communication). Heights were taken from three representative trees in each plot sampled in 2019 using a Haglöf Electronic Clinometer from a distance from which the top and bottom of the tree were visible. Horizontal distance to the tree was measured using a Haglöf DME instrument and placing the transponder on the tree. To minimize damage to vegetation within each of the subplots, all subplots were established and sampled first, followed by work at the ground layer and then higher strata (in order of shrub, sub-canopy, and canopy layers).

For a comprehensive explanation of the methods, refer to the “VSP Field Inventory and Monitoring Pocket Guide” (Puric-Mladenovic and Kenney, 2015). For additional information on VSP and VSP sampling occurring in southern Ontario, refer to http://forests-settled-urban-landscapes.org/. A full field equipment list is provided in Appendix C.

Data processing and analysis

Data were entered into Microsoft Access to reduce typos and maintain accuracy and consistency of species’ names throughout each year. Spatial analyses of invasive flora, significant or rare species, buckthorn basal area, and seedling regeneration were done using qGIS (version 3.2).

Results

Non-native seedling regeneration

The Hogsback typically had low non-native woody seedling regeneration, with 0-28 % of all seedlings counted in the subplots being non-native (Figure A-2). The old-growth, dry sugar maple-

oak deciduous forests of Thompson Tract also contained low non-native woody seedling regeneration, with 0-20 % of seedlings being non-native. On the contrary, the swamps of Thompson Tract typically contained high percentages of non-native seedling regeneration, with 36-98 % of seedlings being non-native. The plantations of Thompson Tract varied greatly between plots, ranging from 0-88 % of seedlings being non-native (Figure A-2). Variation was also observed in Cliffs Forest, where non-native woody seedling regeneration ranged from 3-94 %. The plots with the lowest levels of non-native seedling regeneration (*i.e.*, < 10 %) were all located in the same dry-fresh sugar maple-beech deciduous forest polygon, which extends throughout the property, primarily in the north-east of Cliffs Forest, and has the greatest area of all the ELC polygons. The highest levels (*i.e.*, > 90 %) of non-native seedling regeneration were found in the buckthorn deciduous thicket and the silver maple mineral deciduous swamp, indicating that in both the southeast wetlands and the northwest upland habitats invasive species are crowding out their native counterparts. High levels of non-native seedling regeneration were also observed in the mixed forest, particularly Plot 177 (83 %), and in Plot 172 (72 %) in the southern arrow-wood deciduous thicket swamp polygon (Figure A-3).

Invasive forbes

Six plots (Plot 94 in the Hogsback and Plots 236, 258, 284, 287, and 295 in Thompson Tract) contained > 5 % ground cover of garlic mustard (*Alliaria petiolate*) (Figure A-4). Plots 295 and 284 are adjacent to one another within naturalized plantations and contained 17.5% and 11.25% garlic mustard coverage respectively. Plot 236 is located in the old-growth dry sugar maple-oak deciduous forest, where historic remnants of a deer enclosure fence are found, and had 13.75% garlic mustard coverage. The remaining plots with high levels of garlic mustard were found in two naturalized coniferous plantations on opposite sides of the Thompson Tract. Plot 258 is off trail near the property boundary and had 7.5 % coverage, while Plot 287 is directly adjacent to the Maple Lane Trail and contained 45 % garlic mustard coverage, double the coverage of any other recorded plot. An additional eight plots in Thompson Tract contained < 5 % ground cover of garlic mustard. In the Hogsback, Plot 94 is located in the dry sugar maple-white ash polygon, close to the forest edge, and contained 5.025 % garlic mustard coverage. An additional six plots in Hogback contained between 0.05 % and 3.775 % ground cover of garlic mustard. In Cliffs Forest, the maximum ground cover recorded for garlic mustard was 2.55 % in Plot 56. Amounts ranging between 0.025 % and 1.8 % cover were found in 12 other plots throughout the Cliffs Forest (Figure A-5). The presence and gradients of other invasive ground vegetation were also mapped where they occurred (in order of most invasive to potentially invasive): purple loosestrife (*Lythrum salicaria*), dame's rocket (*Hesperis matronalis*), Canada thistle (*Cirsium arvense*), lily of the valley (*Convallaria majalis*), forget-me-nots (*Myosotis* sp.), common St. John's-wort (*Hypericum perforatum*), butter-and-eggs (*Linaria vulgaris*), coltsfoot (*Tussilago farfara*), nipplewort (*Lapsana communis*), birds-eye speedwell (*Veronica chamaedrys*), and greater celandine (*Chelidonium majus)* (Figures A-39 through A-57).

Invasive grasses and monocots

Invasive grasses and monocots were found primarily in Thompson Tract and occasionally in Cliffs Forest, while the Hogsback remained relatively free from these invaders. Common reed, also known as phragmites (*Phragmites australis*), was recorded in a single plot (Plot 270) in a yellow birch mineral deciduous swamp in the southwestern end of Thompson Tract (Figure A-6). As an effort to remove all phragmites from this plot, spading occurred on August 29, 2018. Regrowth was observed on October 9, 2018, however no additional stands of phragmites were observed within or adjacent to this plot.

Smooth brome (*Bromus inermis ssp. inermis*) is known to be highly invasive, although it dominates only certain niches (Urban Forest Associates Inc., 2002). It was recorded in four plots in Cliffs Forest (Plot 55, 103, 192, and 222) and in a single plot (Plot 295) in a naturalized deciduous plantation in Thompson Tract (Figure A- 7). Smooth brome made up 12.5 % of that plot, and it was well established outside of plot boundaries forming a dense monoculture in and around the area. In Cliffs Forest, only small amounts (< 0.3 %) were recorded in the majority of plots (Plots 55, 103, and 192). Smooth brome made up 10 % of the ground cover in Plot 222, which is close to the ECO Centre and main trail head, which was possibly the pathway of invasion (Figure A-8).

Trace amounts of invasive blue grasses, Kentucky bluegrass (*Poa pratensis ssp. pratensis*) and Canada bluegrass (*Poa compressa*) were found in three plots within the Hogsback (Plots 92, 94, and 125) (Figure A-9). In Cliffs Forest, Plot 224 contained trace amounts of Kentucky bluegrass, while two plots (Plots 101 and 35) contained 12.5 % and 8.75 % cover respectively (Figure A-10). The naturalized coniferous plantations in Thompson Tract experienced the most impact from these invaders with observations of one or both species in eight plots (Figure A-9). These grasses are considered moderately invasive but can still locally dominate an area (Urban Forest Associates Inc., 2002). The greatest percent cover of invasive bluegrasses within a coniferous plantation plot (Plot 259) was 80.05 %, allowing little ground vegetation to grow.

Invasive shrubs

Japanese barberry (*Berberis thunbergii*) was found in small amounts (< 1.325 %) in all three forests at ***rare***, with 11 of 17 total plots containing individuals reaching the shrub layer. In the Thompson Tract, the five plots that contained Japanese barberry (Plots 251, 262, 264, 265, and 275) were concentrated largely along the Bauman Creek corridor. Similarly, the three plots where this species was observed in the Hogsback (Plots 46, 70 and 72) were near or along the Cruickston Creek corridor (Figure A-11). In Cliffs Forest, nine plots (Plots 55, 56, 103, 107, 129, 133, 151, 155, and 156) contained small amounts of Japanese barberry all located on the eastern side of the forest (Figure A-12). Additionally, common barberry (*Berberis vulgaris*) was found scattered near the edges of both Thompson Tract and the Hogsback forests reaching the shrub layer in more than half of the plots where it occurred, with a maximum percent cover of 2.5 % in Plot 235 (Figure A-13). In Cliffs Forest, common barberry was present in trace quantities in 17 of 28 plots. It reached the shrub layer in 14 plots (with up to 3% cover in Plot 224) and the sub-canopy layer in 10 of the plots (with a maximum of 10.025 % cover in Plot 224) (Figure A-14). Both non-native barberries are considered moderately invasive (Urban Forest Associates Inc., 2002).

Invasive bush honeysuckles, tatarian honeysuckle (*Lonicera tatarica*) and Morrow's honeysuckle (*Lonicera morrowii*), were found in all three ***rare*** forests, typically in small amounts (< 2.5 %). In the Hogsback, three plots (Plot 45, 46, and 72) contained trace amounts of Morrow's honeysuckle, which reached the shrub layer only in Plot 46. All plots were concentrated along the Cruickston Creek corridor. In Thompson Tract, although invasive honeysuckles occur in eight plots (Plots 258, 262, 272, 274, 286, 287, 300, and 306) and reached the shrub layer in six of those plots, it is promising that none were observed in the old-growth section of the forest (Figure A-15). In Cliffs Forest, 16 plots contained at least one species of invasive bush honeysuckle. Heights reached the shrub layer in 12 of those plots, with a maximum percent cover of 2.25 % in Plot 55, and additionally reached the sub-canopy layer in five of those plots, with a maximum percent cover of 5.025 % in Plot 34 (Figure A-16). Both of these non-native bush honeysuckles are considered highly invasive and transformers on the landscape (Urban Forest Associates Inc., 2002).

Common privet (*Ligustrum vulgare*) was observed in Thompson Tract (Figure A-17), with half of the observations clustered in the old-growth section of the forest (Plots 235, 236, and 243).

Of the six occurrences of common privet in Thompson Tract, three individuals reached shrub level, two of which were in the old-growth forest; percent cover of common privet never exceeded 1.25 %. In Cliffs Forest, 17 plots contained common privet at the ground level, however percent cover never exceeded 0.75 %. Common privet was found at the shrub layer in 11 plots in Cliffs Forest, with a maximum of 2.55 % cover in Plot 35, and at the sub-canopy layer with ≤ 2.5 % in three plots (Plots 35, 55, and 192) (Figure A-18). No common privet was observed in the Hogsback. This shrub is moderately invasive, with the possibility of dominating locally under certain conditions (Urban Forest Associates Inc., 2002).

Across the three forests, white mulberry (*Morus alba*) was found in a single plot (Plot 222) (Figure A-19). The individuals were small; therefore, its presence and identity should be reconfirmed in the spring/summer when fruit are present. Pope (2014) recorded this species in the buffer zones surrounding the Hogsback and Thompson Tract, so these individuals should be included in any removal efforts. This shrub is considered an aggressive invader and a top priority for removal in areas where it could hybridize with a native and endangered congener, *Morus rubra* (Urban Forest Associates Inc., 2002). Although *M. rubra* has not been sighted on ***rare*** property, its native range does include the Carolinian zone and the closest known population is within 50 km of ***rare*** (COSEWIC, 2014). A proactive approach should be taken to help reduce spread of white mulberry across southern Ontario.

Multiflora rose (*Rosa multiflora*) was found in three plots in the Hogsback (Plots 44, 72, and 94), reached the shrub layer in Plot 72 along Cruickston Creek in a narrow, forested corridor. In Thompson Tract, six plots contained this species (Plots 244, 258, 272, 286, 275, and 295) with individuals reaching the shrub layer in half of the plots (Figure A-20). Additionally, Plot 295 had a large multiflora rose that was not entirely represented in the data as it occurred on the edge of the plot. In Cliffs Forest, multiflora rose was identified in four plots (Plots 56, 101, 156, and 192), with the highest percent cover found in Plot 56 at 0.3 %. One individual was found in the shrub layer in Plot 101 (Figure A-21). Multiflora rose is considered highly invasive in certain niches (Urban Forest Associates Inc., 2002), and has been identified as a first-priority invasive species for the ***rare*** reserve (Pope 2014).

Buckthorn abundance and basal area

All plots sampled on the ***rare*** property contained either common buckthorn (*Rhamnus cathartica*) or glossy buckthorn (*Rhamnus frangula*) in at least one stratum. In the Hogsback, all 11 plots contained at least one species of invasive buckthorn within the shrub layer, and six of those plots (Plots 44, 45, 46, 67, 68, and 72) also contained invasive buckthorn in the sub-canopy layer. It is concerning that coverage appears particularly high for glossy buckthorn in the internal forest plots, with a maximum of 52.5 % coverage in the shrub layer in Plot 45. No plots in the Hogsback exceeded 50 % cover of buckthorn in the ground layer (Figures A-22, A-23, and A-24).

In Cliffs Forest, all plots sampled contained at least one species of invasive buckthorn that reached the shrub layer and all but two plots had buckthorn in the sub-canopy level where it exceeded 50 % cover in five plots (Plots 78, 155, 194, 209 and 224) (Figures A-25, A-26, and A-27). Plot 224 is a dense buckthorn deciduous shrub thicket and had 82.5 % combined cover of buckthorn species in the shrub layer and was the only plot to exceed 50 % cover in this stratum (although Plot 211 was close with 48.025 % buckthorn cover). The maximum cover of common and glossy buckthorn observed at the ground layer was 28.75 % and 38.75 % respectively in Plot 177 (mixed forest). Six plots had buckthorn documented in the tree canopy (> 10 m), including Plot 209 with 28.75 % coverage in that layer. Plot 209 also had the greatest basal area of buckthorn (14.58 m^2/ha) with a total of 93 stems within the plot. Plots 155 and 224 were also dominated by

buckthorn, with basal areas of 8.55 m^2/ha and 46 stems and 4.91 m^2/ha and 39 stems respectively (Figure A-28).

Four plots in Thompson Tract (Plots 299, 300, 274 and 306) contained > 50 % buckthorn cover in the shrub layer, and 13 plots contained at least one species of invasive buckthorn that reached the sub-canopy layer (Figures A-22, A-23, and A-24). Plot 286 had the greatest buckthorn basal area (5.21 m^2/ha) with a total of 43 stems within the plot, followed by Plot 274 with a basal area of 3.60 m^2/ha and 15 stems, and Plot 299 with a basal area of 1.58 m^2/ha and 16 stems (Figure A-29). Multiple subplots had greater than 100 buckthorn seedlings (*e.g.*, Plot 300 contained > 200 glossy buckthorn seedlings in one subplot). The old-growth, dry sugar maple-oak deciduous forest had surprisingly little buckthorn cover in all layers, and ***rare*** should prioritize continual monitoring and removal of buckthorn from this area.

Trace amounts of alder-leaved buckthorn (*Rhamnus alnifolia*) were observed in a single plot in Thompson Tract (Figure A-30) and occurrences were also noted outside of the established VSP plots in the southwestern region of the yellow birch mineral deciduous swamps in Thompson Tract. Alder-leaved buckthorn was not observed in the Hogsback or Cliffs Forest.

Invasive trees

Manitoba maple (*Acer negundo*) was observed in five plots across the sampled areas at ***rare*** (Figure A-31 and A-32). Unsurprisingly, seedlings were found in the fragmented riparian zone of the Hogsback (Plot 72), and again in the forested edge of the eastern white cedar organic deciduous swamp near Langdon Drive where many established trees were found adjacent to the property (Plots 306). A mature Manitoba maple (dbh of 36.0 cm) was observed in Plot 287 (naturalized deciduous plantation). Although this tree was cut, it had many epicormic shoots and may explain the number of seedlings found in the interior of Thompson Tract (Plots 275 and 287). In Cliffs Forest, a trace amount (0.025 % coverage) of Manitoba maple seedlings were observed in the ground layer of Plot 102. Manitoba maple is considered highly invasive with the potential to transform a site indefinitely (Urban Forest Associates Inc., 2002).

Norway maple (*Acer platanoides*) was observed in Cliffs Forest in Plot 6 in trace amounts in the ground, shrub, and sub-canopy layers (Figure A-33). It was not recorded in Thompson Tract or the Hogsback forests. Similar to Manitoba Maple, Norway maple is considered highly invasive with the potential to dominate forest canopy if left unmanaged (Urban Forest Associates Inc., 2002). It is listed as a priority species for removal at ***rare*** (Pope, 2014).

Autumn olive (*Elaeagnus umbellata*) had high percent cover in the southwestern corner of the naturalized coniferous plantation in Thompson Tract, reaching up to 12.5 % cover in the sub-canopy layer (Plots 258 and 259) (Figure A-34). Most observations of autumn olive were within the naturalized plantations, although trace amounts of seedlings were also found in plots within the yellow birch mineral deciduous swamp adjacent to the plantations. Autumn olive was found in Cliffs Forest at the ground layer in trace amounts at the far edges of the forest (Plots 2 and 222), and in the shrub and sub-canopy layers at trace levels of coverage near the alvar (Plot 35) (Figure A-35). No observations were recorded in the Hogsback. Autumn olive is considered highly invasive within certain niches (Urban Forest Associates Inc., 2002), and it is listed as a first-priority invasive species for removal on the ***rare*** reserve (Pope 2014).

Although the native range of black locust (*Robina pseudoacacia*) is the central and eastern United States, it is highly invasive in certain niches in southern Ontario (Urban Forest Associates Inc., 2002). Known to invade primarily oak, beech-maple, and aspen forests, it may be important to

consider managing black locust as ***rare's*** high-valued, old-growth dry sugar maple-oak deciduous forest is nearby existing populations (Warne, 2016). Large black locusts were observed solely in the naturalized deciduous plantations in Thompson Tract (Plots 286, 287 and 295), although seedlings were found in the yellow birch mineral deciduous swamps (Plot 275), the eastern white cedar organic coniferous swamps (Plot 300), and the sugar maple-oak deciduous forests plots (Plot 244) (Figure A-36).

European mountain ash (*Sorbus aucuparia*) had one occurrence in the Hogsback (Plot 45), five occurrences in Thompson Tract, and ten occurrences in Cliffs Forest (Figures A-37 and A-38). Observations in Thompson Tract were trace counts (*i.e.*, < 0.1 % cover) of seedlings found primarily in plots clustering in the eastern white cedar organic coniferous swamp (Plots 299, 300, and 306). These occurrences are likely spread from the European mountain ash at the roadside adjacent to ***rare's*** property. Trace counts of seedlings were also observed along the Bauman Creek corridor (Plots 262 and 264). Within Cliffs Forest, European mountain ash was found in trace amounts at the ground layer in ten plots scattered throughout the forest and reached the shrub layer at trace levels in two of these ten plots (Plots 34 and 6). For a comprehensive list of all invasive species documented during VSP field sampling, see Appendix E.

Conclusions and Recommendations

Twelve plant species not known to be present at ***rare*** were added to ***rare's*** species list from our VSP work in 2018, and another five species and one subspecies were added in 2019 (Appendix D). The following invasive species observed during vegetation sampling in 2018 and 2019 are listed as management priorities at ***rare*** (Pope, 2014): common reed, autumn olive, multiflora rose, white mulberry, Norway maple, common buckthorn, glossy buckthorn, tatarian honeysuckle, Morrow's honeysuckle, common barberry, and Japanese barberry. Figures 2 and 3 depict the total percent covers of all priority species for removal at ***rare***. Both common and glossy buckthorn were excluded from these maps since their high abundances inflated the total percent cover values such that most areas were identified as high priority for invasive plant species management. We include Figures A-22 through A-27 for information on where large populations of buckthorn exist on the property. Based on mapping ***rare's*** invasive plant management priorities, sites for removal and restoration can be coordinated and are listed below (in no particular order):

Hogsback:

- Riparian zone along Cruickston Creek north of the Hogsback due to high levels of the most damaging invasive species identified for management at ***rare*** and their proximity to the Hogsback.

Thompson Tract:

- Southwestern naturalized coniferous plantations and naturalized deciduous plantations and bordering area of the yellow birch mineral deciduous swamp due to the most damaging invasive species identified for management at ***rare***.
- Southwestern yellow birch mineral deciduous swamp as it was the only plot where phragmites was observed.
- Southern region of the old-growth forest as it was the only plot in the old-growth area to have the most damaging invasive species identified for management at ***rare***. Removal and restoration should be prioritized over the next one to two years so that invasive species are prevented from spreading to the remainder of the old-growth forest
- Northeastern yellow birch mineral deciduous swamp and the northern part of the eastern white cedar coniferous swamp. Both plots in these areas were high-quality and species-rich sites,

and each in close proximity to provincially-rare species (Chinese hemlock parsley). Care should be taken to reduce the spread of invasive species to these areas.

Cliffs Forest:

- Eastern edge near the lookout within the small mixed forest polygon close to the George St. parking lot. This site is close to ecologically-sensitive features (cliffs). The site contains multiple damaging invasive plant species identified for management at ***rare***, but their populations are small in that removal would not be arduous or costly.
- The rock barren shrub alvar polygon is considered a rare habitat type and should be considered as a site for restoration following the removal of multiple invasive plant species.
- Plots within the sugar maple-beech deciduous forest polygon within Cliffs Forest were relatively free from invasive plants. Invasive plant species identified in ***rare's*** management priorities should be removed and these plots monitored for early detection of new invaders.
- Plot 222 contained the only known occurrence of white mulberry (*Morus alba*) in the Cliffs Forest as well as low amounts (*i.e.*, < 1% cover) of autumn olive and invasive honeysuckles. These invasive species could be easily removed to prevent further spread throughout the ***rare*** reserve.

In the future, it is recommended that tree height measurements be obtained for Hogsback and Thompson Tract plots and continue to be included in all new sampling efforts. Reliable tree height data in conjunction with basal area can give information on stand volume, crown length, carbon stocks, biomass, and site productivity and quality (Schreuder *et al.*, 1993; Juknys and Augustaitis, 1998; Andersen *et al.*, 2006). Traditional methods in measuring tree height can be accurate, with little error (*e.g.*, only $\pm$ 0.27 m) (Andersen *et al.*, 2006; Puric-Mladenovic, personal communication). However, since the establishment of EMAN (Environmental Monitoring and Assessment Network) forest plots at ***rare***, unrealistic changes in tree heights have been documented across the monitoring years (Abrams, 2017). The Vegetation Sampling Protocol measures heights of three representative trees within each plot, whereas EMAN measures the heights of every tree within a plot. Measurements from representative trees are perhaps more accurate since these trees may be on flat ground with a visible canopy (as opposed to trees on a slope or with a canopy that is difficult to define as may be measured in the EMAN plots). In 2019, tree height measurements were taken for three representative trees in each VSP plot in Cliffs Forest using an electronic clinometer and a distance measuring instrument by Haglöf. In plots with dense canopies, tree heights were assessed later than the VSP sampling dates. In one case, a reasonable height could not be obtained.

VSP has proven to be an extremely valuable protocol to add to ***rare's*** long-term ecological monitoring program. This in-depth method of vegetation sampling has added new species to our property list and has provided high-quality data to support Land Management's work through prioritizing sites for invasive species removal and restoration. With plans to resample these plots in the Hogsback, Thompson Tract, and Cliffs Forest five years after initial sampling, VSP will also provide valuable insight on any spatial or temporal shifts in vegetation on the property. With so many uses and benefits that can be applied to the data gathered through VSP, ***rare*** plans to expand its VSP efforts to include many open habitats across the main property and should be considered for newly acquired properties in Waterloo and Wellington.

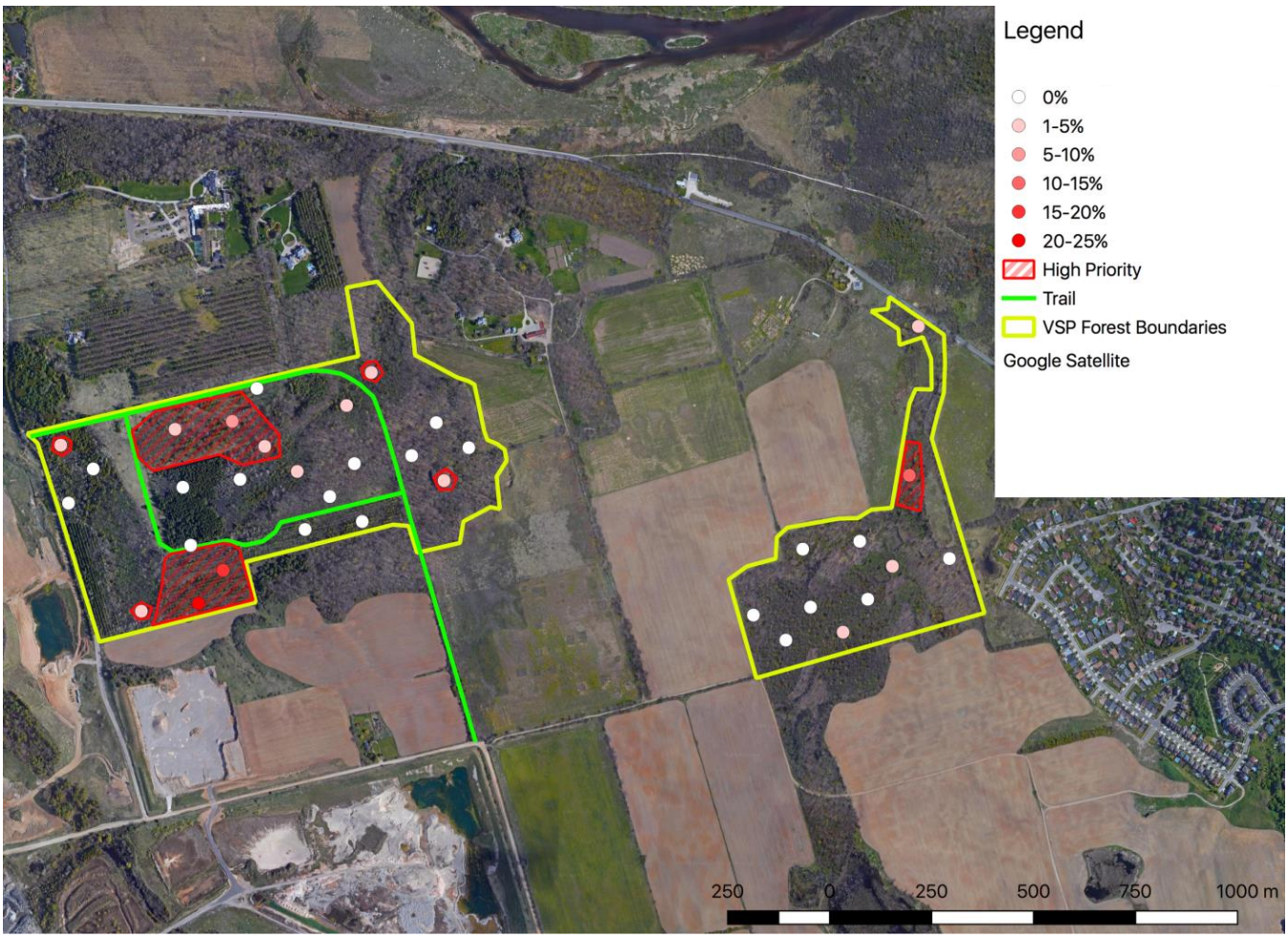

Figure 2: Map of Thompson Tract (left) and the Hogsback (right) depicting total percent cover of ***rare's*** top invasive species priorities: common reed, autumn olive, multiflora rose, invasive bush honeysuckles, common barberry, and Japanese barberry. Common and glossy buckthorn have been excluded. Total percent cover is expressed on a gradient, where plots that did not contain any priority species are depicted in white, lower percent cover of priority species are depicted in light red, increasing in colour intensity with increasing percent cover. Red polygons depict the areas of recommended restoration action priorities. Yellow lines indicate the boundaries of each VSP forest plots; green lines indicate trails. Combined cover was calculated by adding the percent cover of all priority species within a plot. Where a species was present in more than one stratum, the highest value among the strata was selected. Absolute percent covers for each priority invasive species were obtained during vegetation sampling following the Vegetation Sampling Protocol, from June-September 2018 at the ***rare* Charitable Research Reserve** in Cambridge, Ontario.

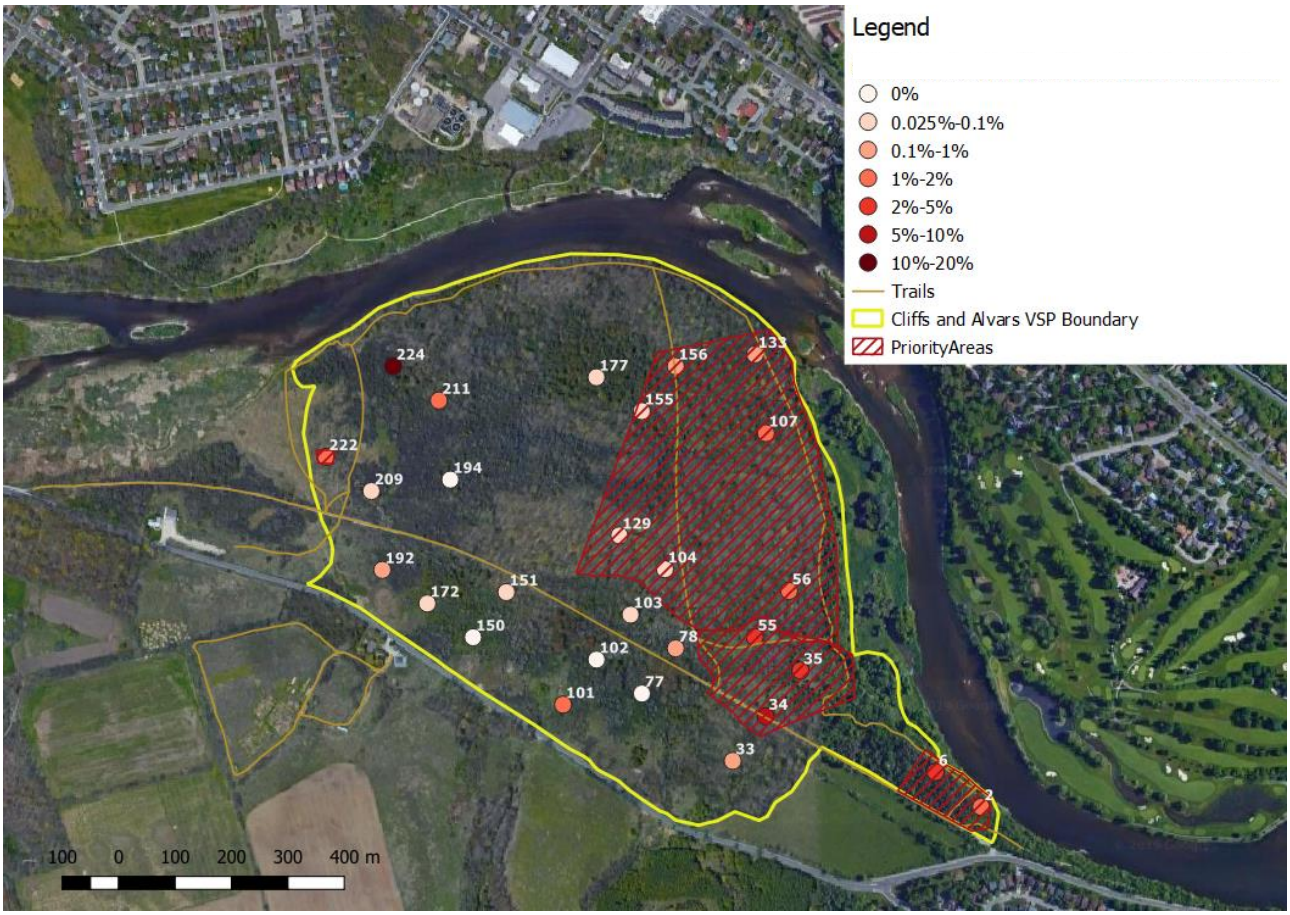

Figure 3: Map of Cliffs Forest depicting total percent cover of ***rare's*** top invasive species priorities: autumn olive, multiflora rose, Norway maple, invasive bush honeysuckles, white mulberry, common barberry, and Japanese barberry. Common and glossy buckthorn have been excluded. Total percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover, where plots that did not contain any priority species are depicted in white and plots with the highest combined cover of priority species are depicted in dark red. Red polygons depict the areas of recommended removal and restoration action priorities. Yellow lines indicate the VSP boundaries; light brown lines indicate trails. Combined cover was calculated by adding the percent cover of all priority species within a plot. Where a species was present in more than one stratum, the highest value among the strata was selected. Absolute percent covers for each priority species were obtained during vegetation sampling following the Vegetation Sampling Protocol, from June to October 2019 at the ***rare*** **Charitable Research Reserve** in Cambridge, Ontario.

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Appendix A: Supplemental Species Maps

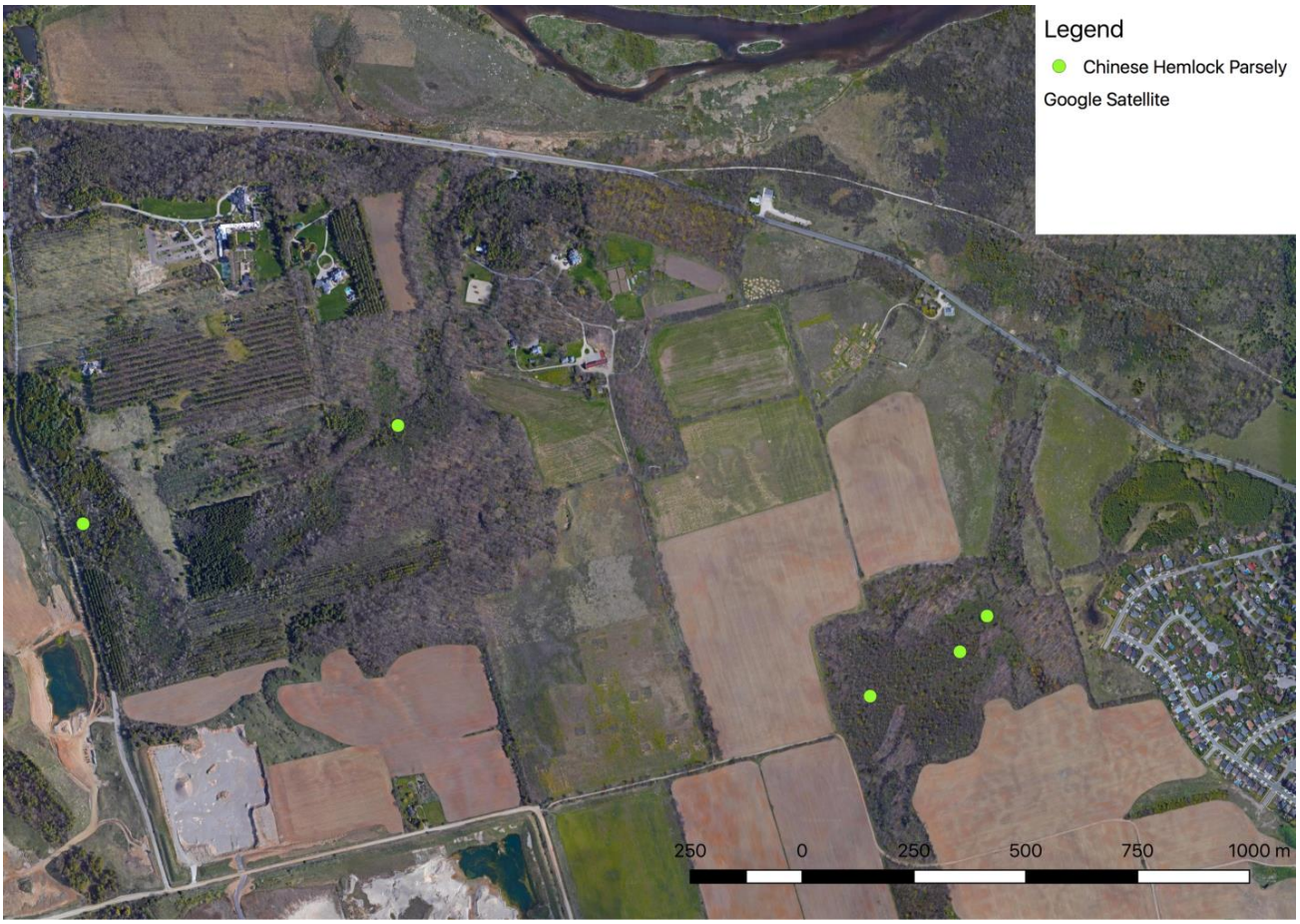

Figure A-1: Map of the ***rare*** **Charitable Research Reserve** depicting presence of Chinese hemlock parsley (*Conioselinum Chinese*; S2 rank) in two forests, Thompson Tract and the Hogsback. Most locations of species presence were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario (all points in the Hogsback), in addition to other GPS locations observed near established plots (both plots in Thompson Tract).

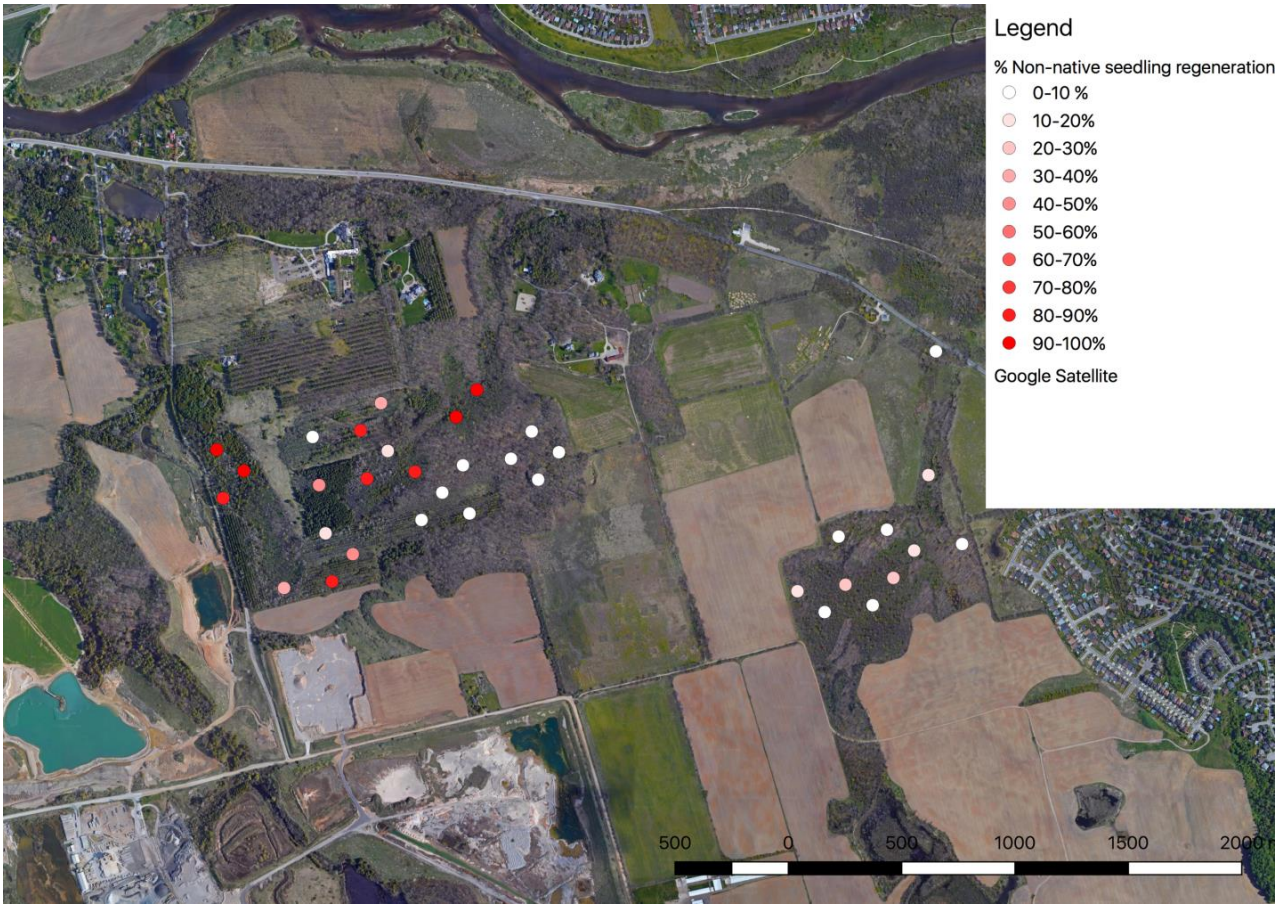

Figure A-2: Map of the ***rare*** **Charitable Research Reserve** depicting percent non-native seedling regeneration in two forests, Thompson Tract and the Hogsback. Percent non-native seedling regeneration is expressed on a gradient, with lower percent non-native seedling regeneration being white to light red, increasing in colour intensity with increasing percent of non-native seedling regeneration. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

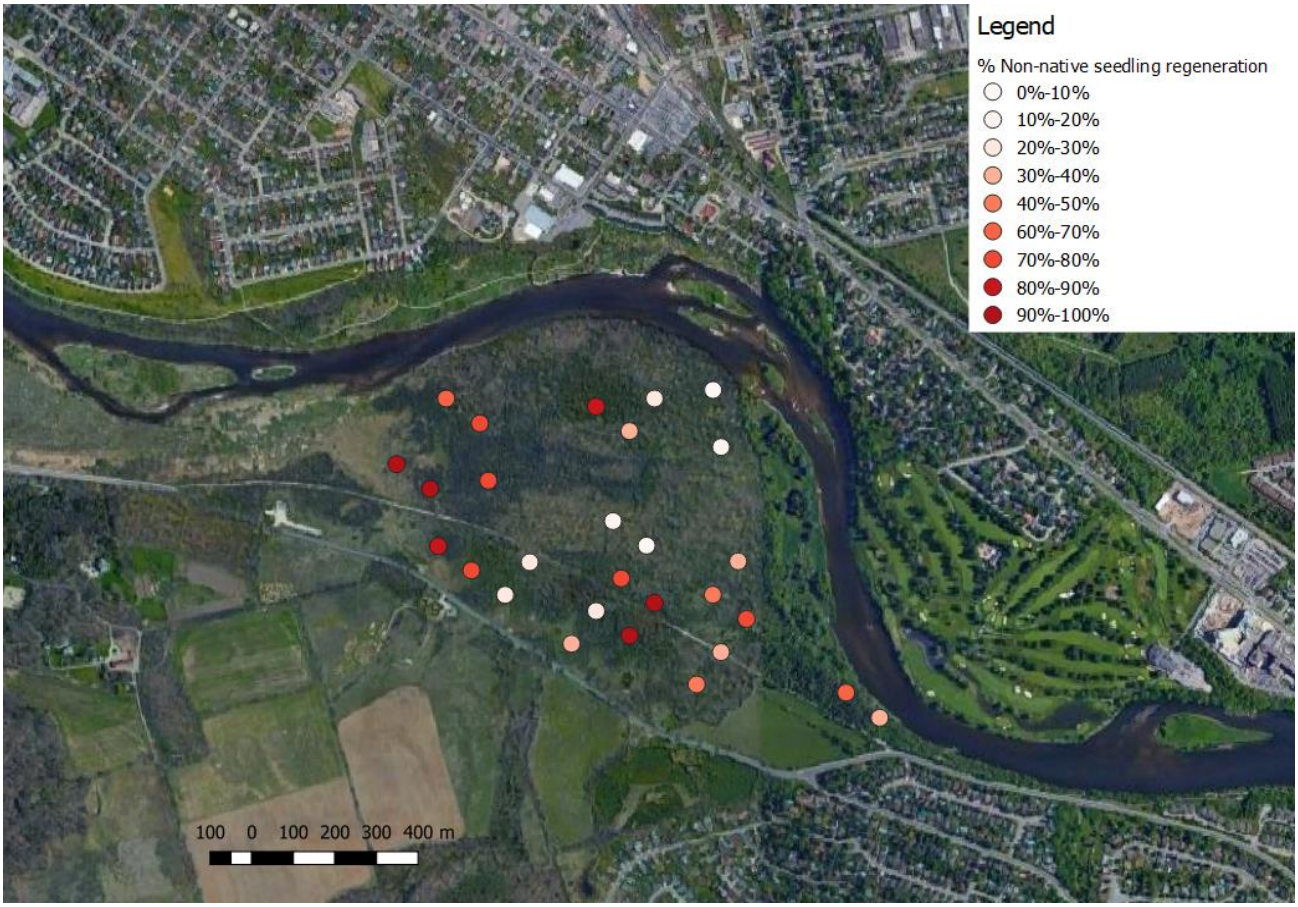

Figure A-3: Map of the ***rare*** **Charitable Research Reserve** depicting percent non-native seedling regeneration in Cliffs Forest. Percent non-native seedling regeneration is expressed on a gradient increasing in colour intensity with increasing percent of non-native seedling regeneration. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

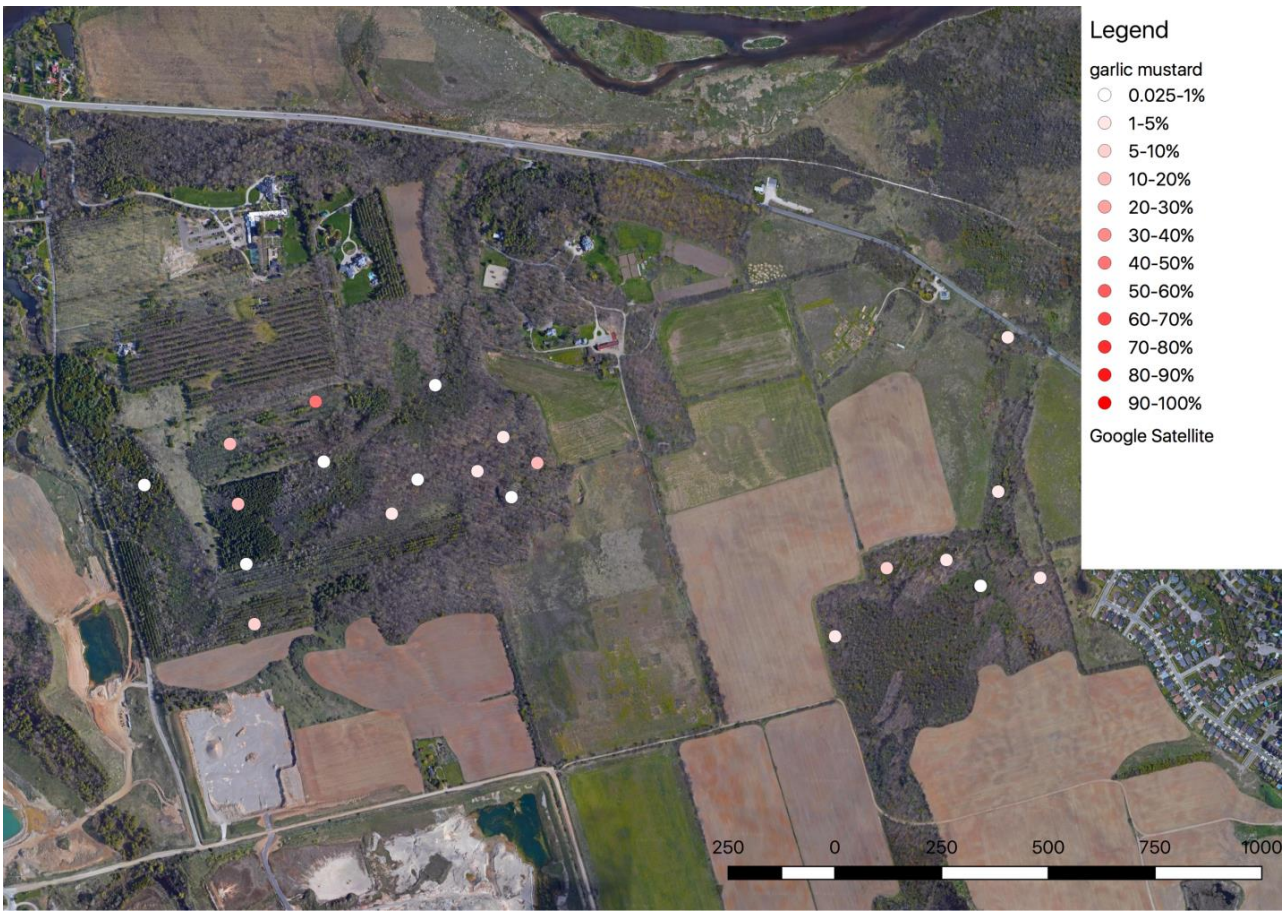

Figure A-4: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of garlic mustard, *Alliaria petiolata*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Twenty-one out of 35 plots in two forests, Thompson Tract and the Hogsback, contained garlic mustard, with the lowest being 0.025% and the highest being 45%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-5: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of garlic mustard, *Alliaria petiolata*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). In Cliffs Forest, the maximum ground cover recorded for garlic mustard was 2.55% in plot 56. Percent covers ranging between 0.025% and 1.8% were found in 12 other plots throughout the property. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

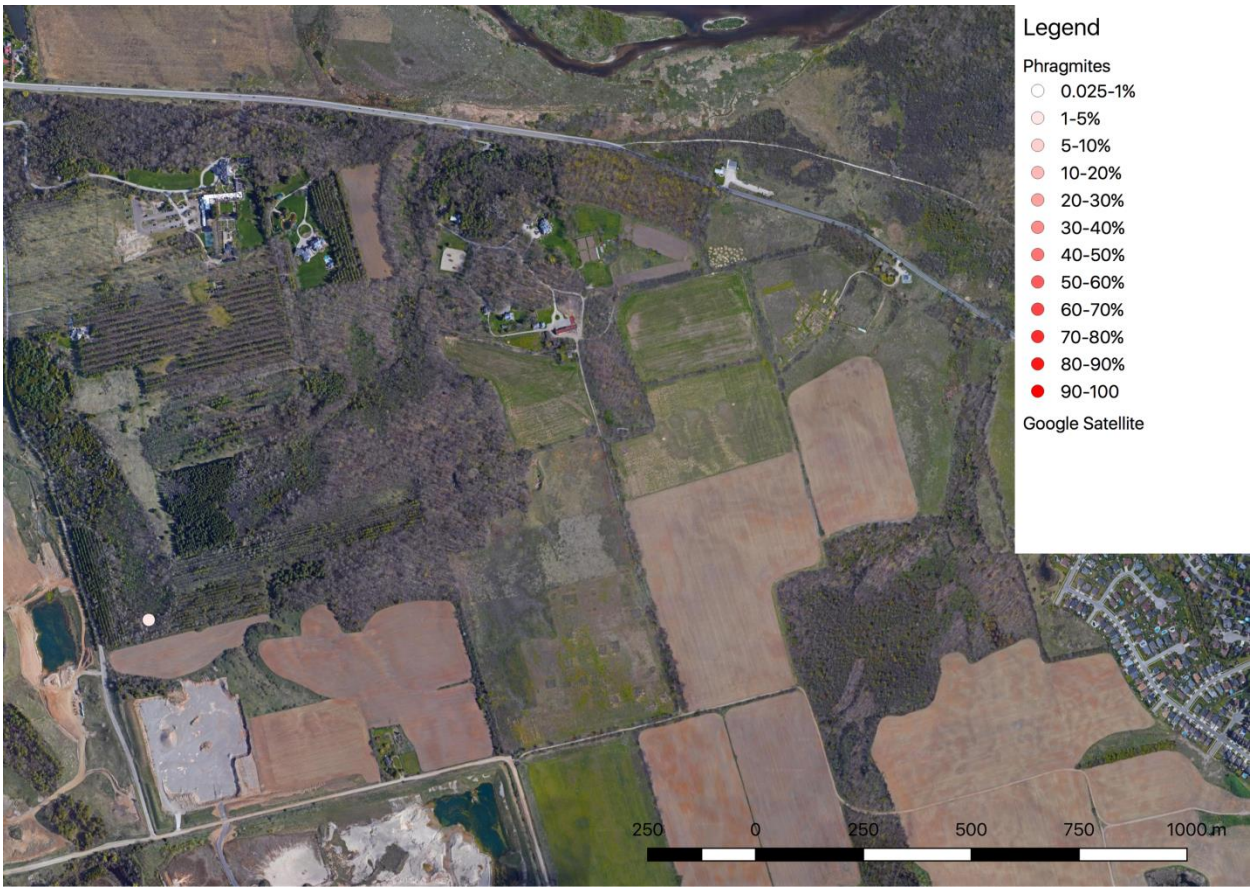

Figure A-6: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common reed/phragmites, *Phragmites australis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). One out of 35 plots in two forests, Thompson Tract and the Hogsback, contained phragmites, comprising of 2.525% of the plot. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

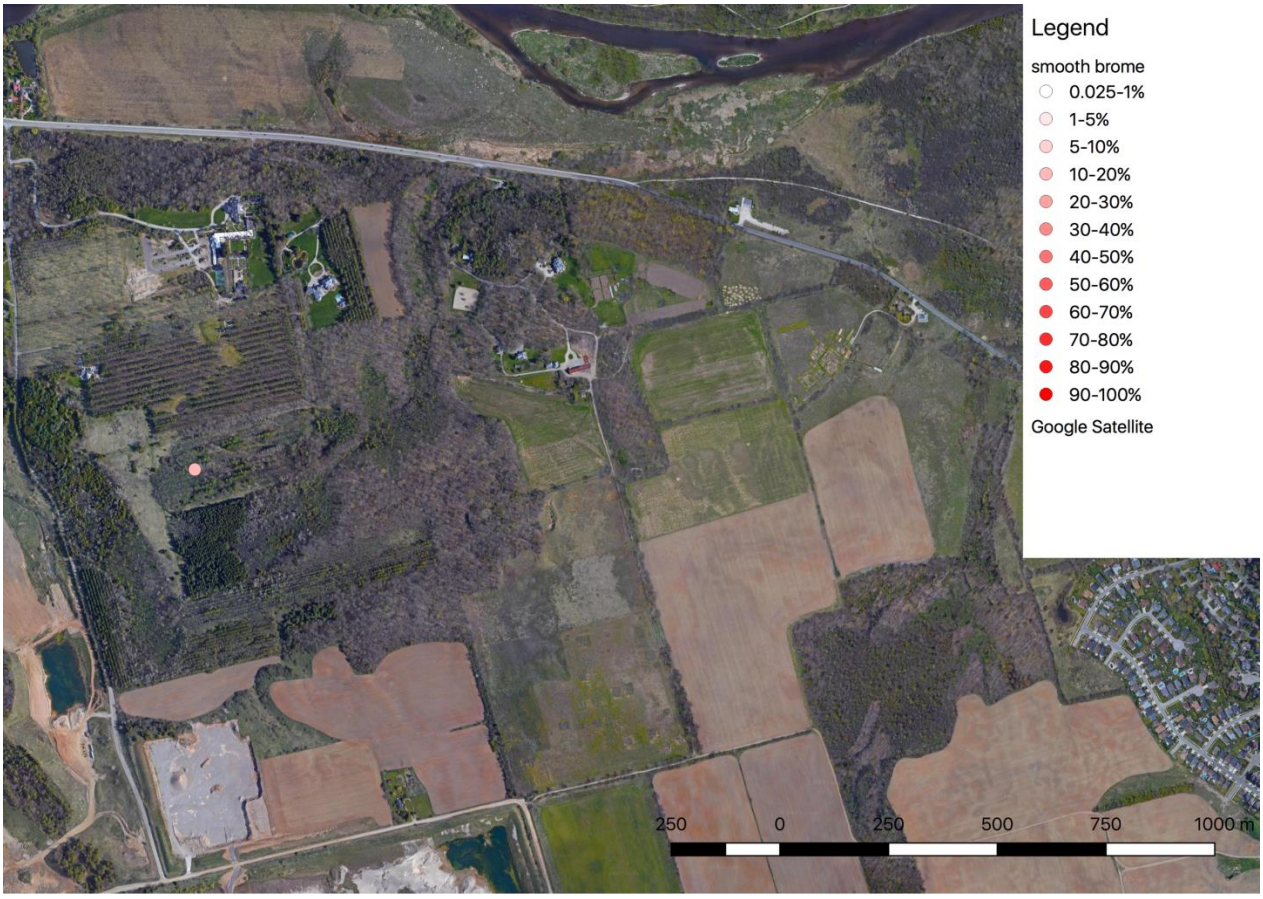

Figure A-7: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of smooth brome, *Bromus inermis ssp. inermis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). One out of 35 plots in two forests, Thompson Tract and the Hogsback, contained smooth brome, comprising 12.5% of the plot. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-8: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of smooth brome, *Bromus inermis ssp. inermis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Four out of 28 plots in Cliffs Forest contained smooth brome, with three plots containing trace amounts and one plot containing 10%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

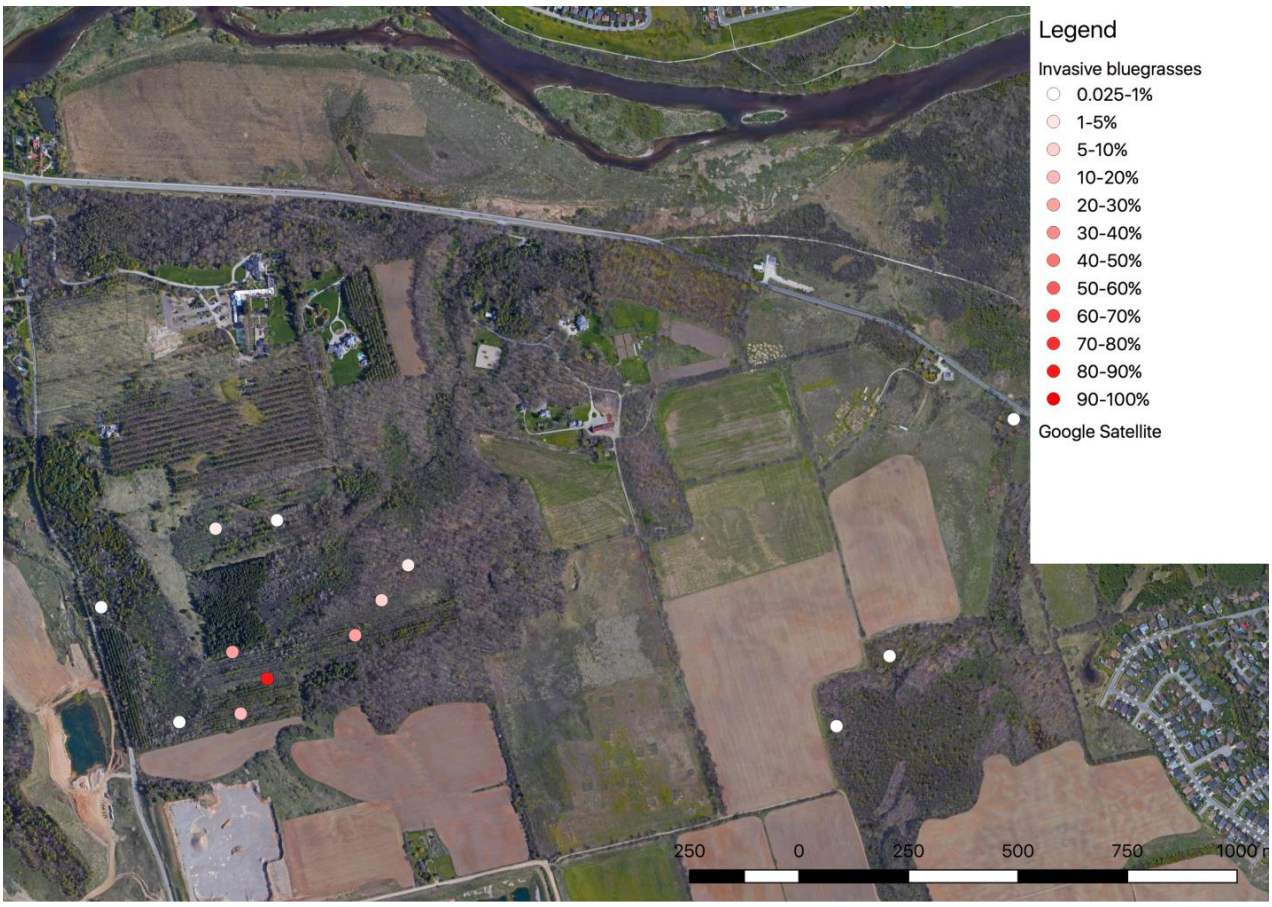

Figure A-9: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of invasive bluegrass, Kentucky bluegrass and Canada bluegrass, *Poa pratensis ssp. pratensis* and *Poa compressa*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Sixteen out of 35 plots in two forests, Thompson Tract and the Hogsback, contained Kentucky bluegrass and Canada bluegrass, with the lowest being 0.025% and the highest being 80.05%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-10: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of invasive bluegrass, Kentucky bluegrass, *Poa pratensis ssp. pratensis* in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Three out of 28 plots in Cliffs Forest contained Kentucky bluegrass: one plot contained trace amounts while two plots, 101 and 35, contained 12.5% and 8.75% respectively. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June to October 2019 in Cambridge, Ontario.

Figure A-11: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of Japanese barberry, *Berberis thunbergii*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Eight out of 35 plots in two forests, Thompson Tract and the Hogsback, contained Japanese barberry, with the lowest being 0.025% and the highest being 1.325%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

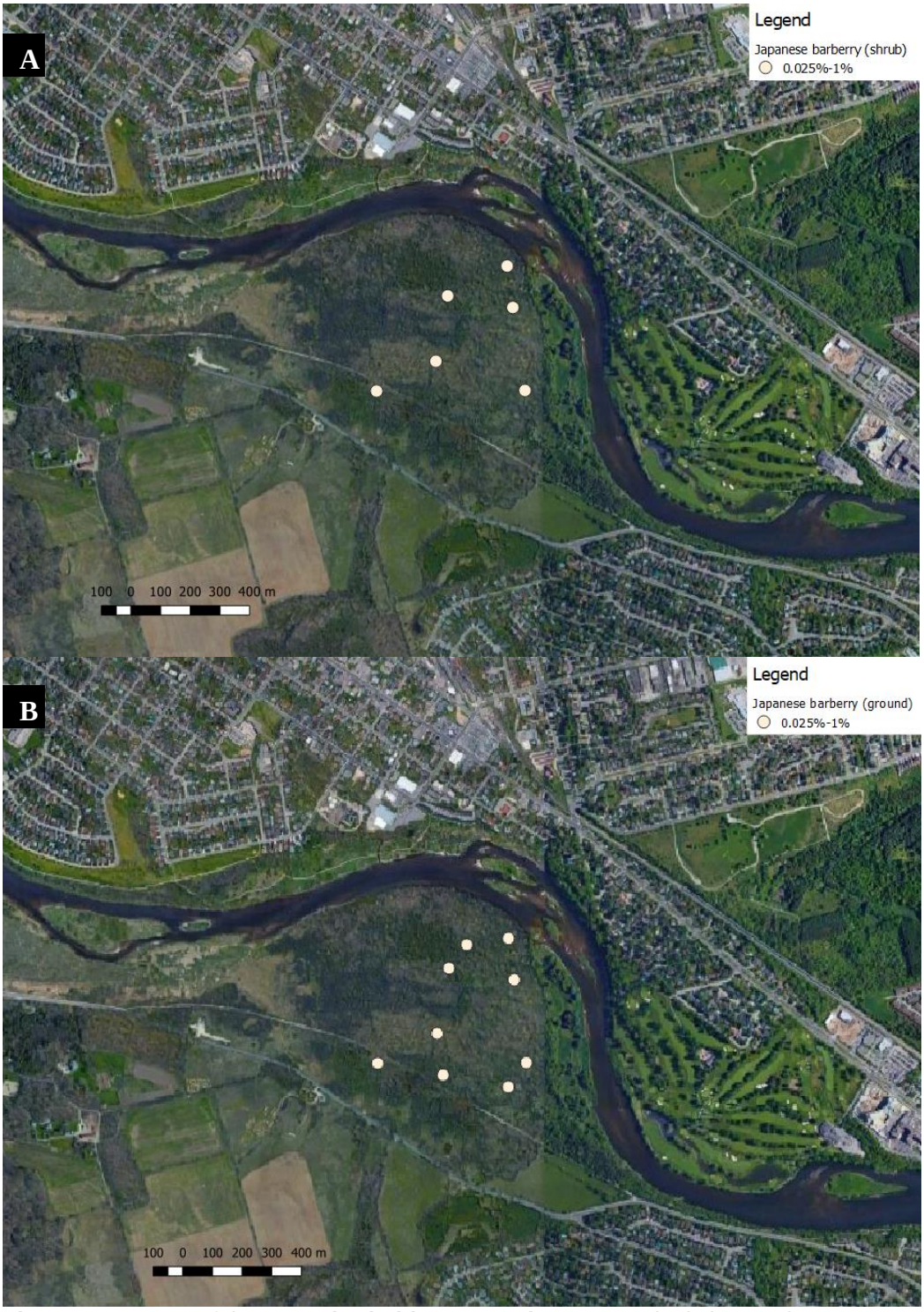

Figure A-12: Map of the ***rare* Charitable Research Reserve** depicting total percent cover of Japanese barberry, *Berberis thunbergii*, in shrub (Map A; 0.5-2 m) and in ground (Map B; 0-0.5 m) layers within a 400m^2 plot (11.28 m radius) in Cliffs Forest. Japanese barberry was present at the ground layer in nine of 28 plots, with the highest cover still within trace values (0.325%) in plot 133. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

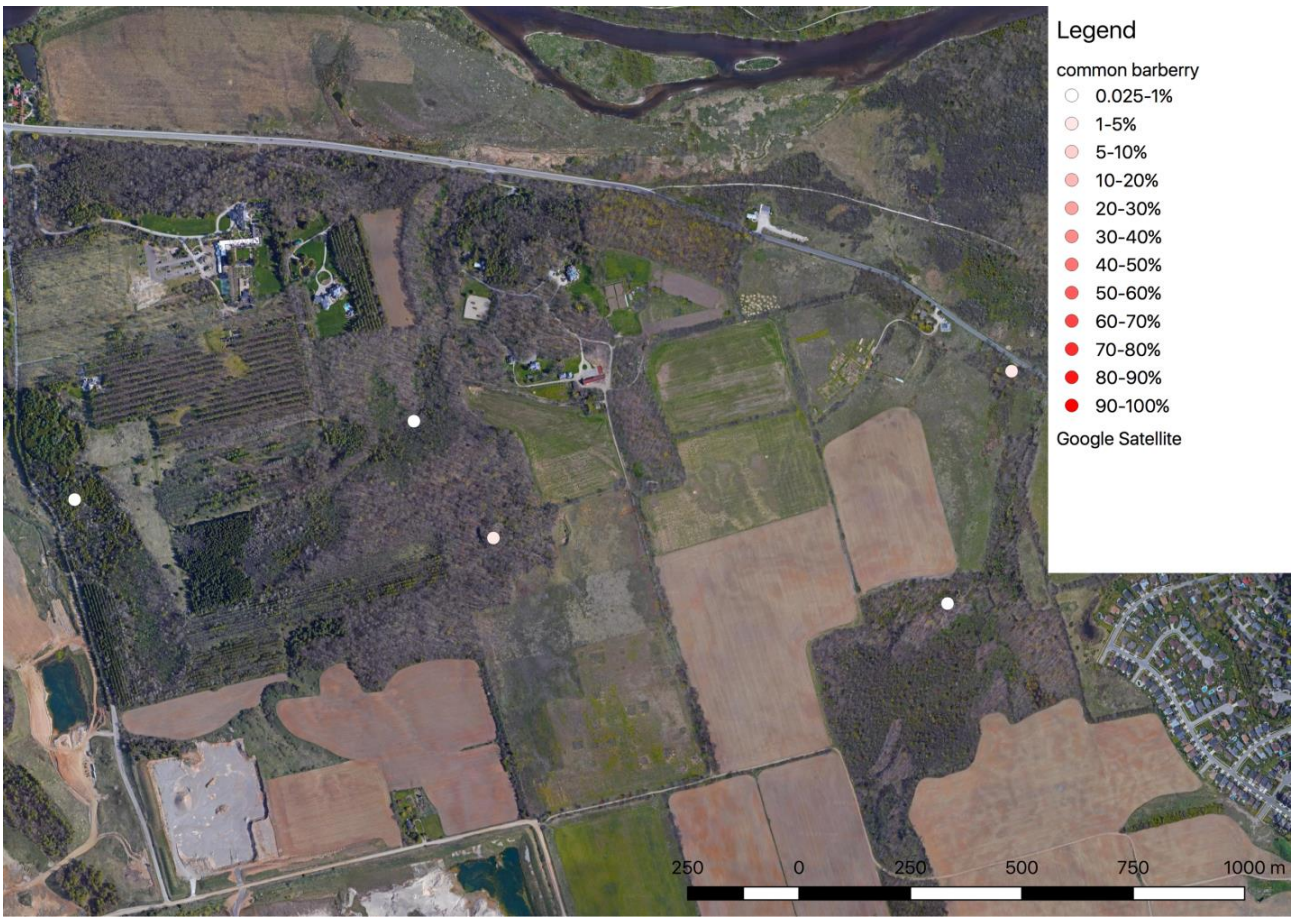

Figure A-13: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common barberry, *Berberis vulgaris*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Five out of 35 plots in two forests, Thompson Tract and the Hogsback, contained common barberry, with the lowest being 0.025% and the highest being 2.5%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-14: Map of the ***rare* Charitable Research Reserve** depicting total percent cover of common barberry, *Berberis vulgaris*, in sub-canopy (Map A; 2-10 m), shrub (Map B; 0.5-2 m) and ground (Map C; 0-0.5 m) layers within a 400m^2 plot (11.28 m radius) in Cliffs Forest. Common barberry was present at the ground layer in 17 of 28 plots, with the highest cover still within trace values (0.575% in plot 56). In half of plots sampled, Common barberry reached the shrub layer, up to 3% cover in plot 224 and reached the sub-canopy layer in ten of 28 plots, with the highest percent cover in plot 224 at 10.025%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

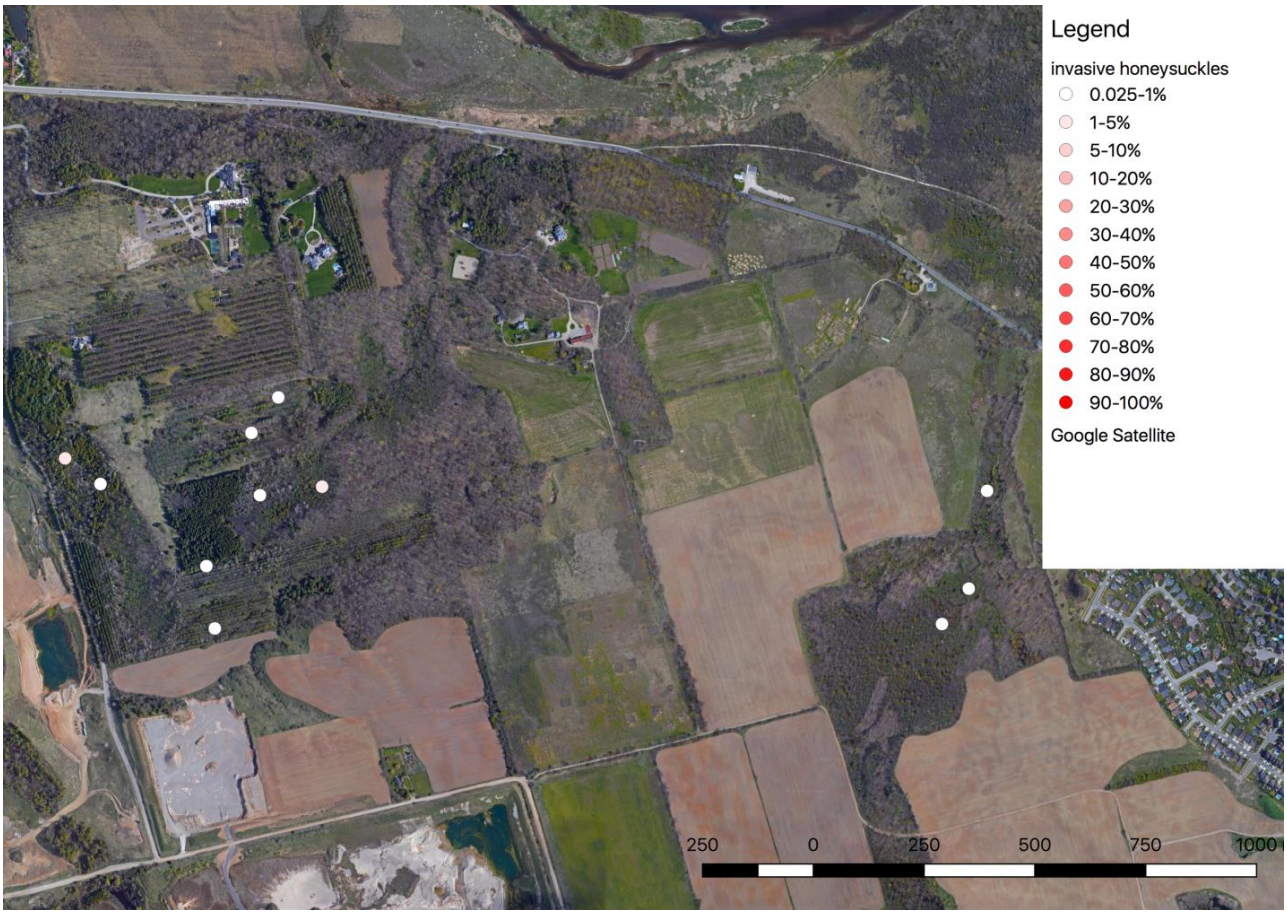

Figure A-15: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of invasive bush honeysuckles, tatarian and Morrow's honeysuckle*, Lonicera tatarica* and *Lonicera morrowii*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Eleven out of 35 plots in two forests, Thompson Tract and the Hogsback, contained one of these invasive honeysuckles, with the lowest being 0.025% and the highest being 1.25%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-16: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of invasive bush honeysuckles, tatarian and Morrow's honeysuckle*, Lonicera tatarica* and *Lonicera morrowii*, in sub-canopy (Map A; 2-10 m), shrub (Map B; 0.5-2 m) and ground (0-0.5 m) layers within a 400m^2 plot (11.28 m radius). Sixteen out of 28 plots in Cliffs Forest contained one of these invasive honeysuckles. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

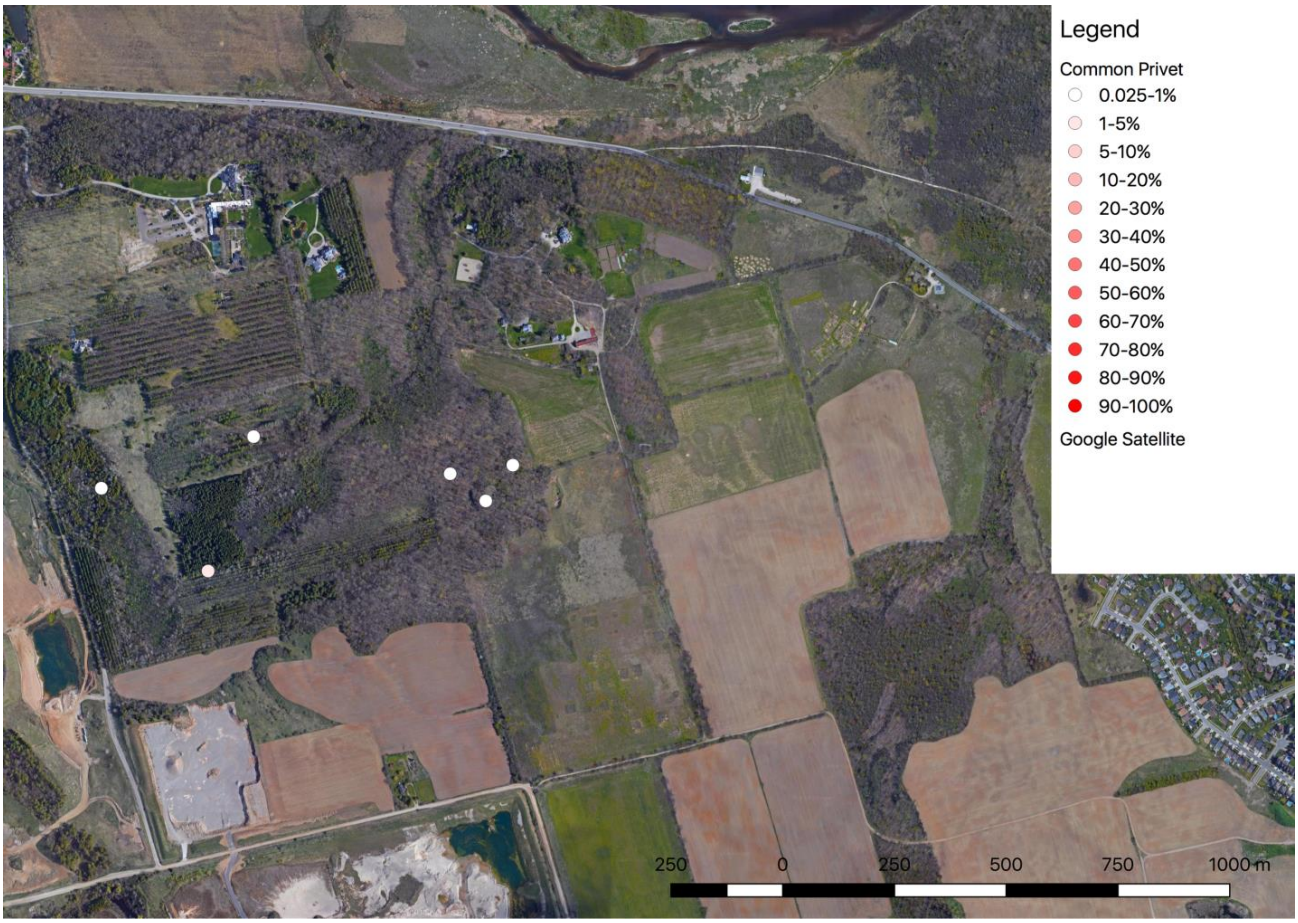

Figure A-17: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common privet, *Ligustrum vulgare*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 24 plots in Thompson Tract contained common privet, with the lowest being 0.025% and the highest being 1.25%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-18: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common privet, *Ligustrum vulgare*, in sub-canopy (2-10 m), shrub (0.5-2 m) and ground (0-0.5 m) layers within a 400m^2 plot (11.28 m radius). In Cliffs Forest, 16 of 28 plots contained Common privet at the ground level, however percent cover never exceeded 0.75%. Common privet was found at the shrub layer in eleven plots, with the highest percent cover in plot 35 at 2.55% and at the sub-canopy layer in three plots, with values ranging from .775 to 2.5%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

Figure A-19: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of white mulberry, *Morus alba*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). White mulberry was only found in plot 222 at trace cover (0.5%). Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

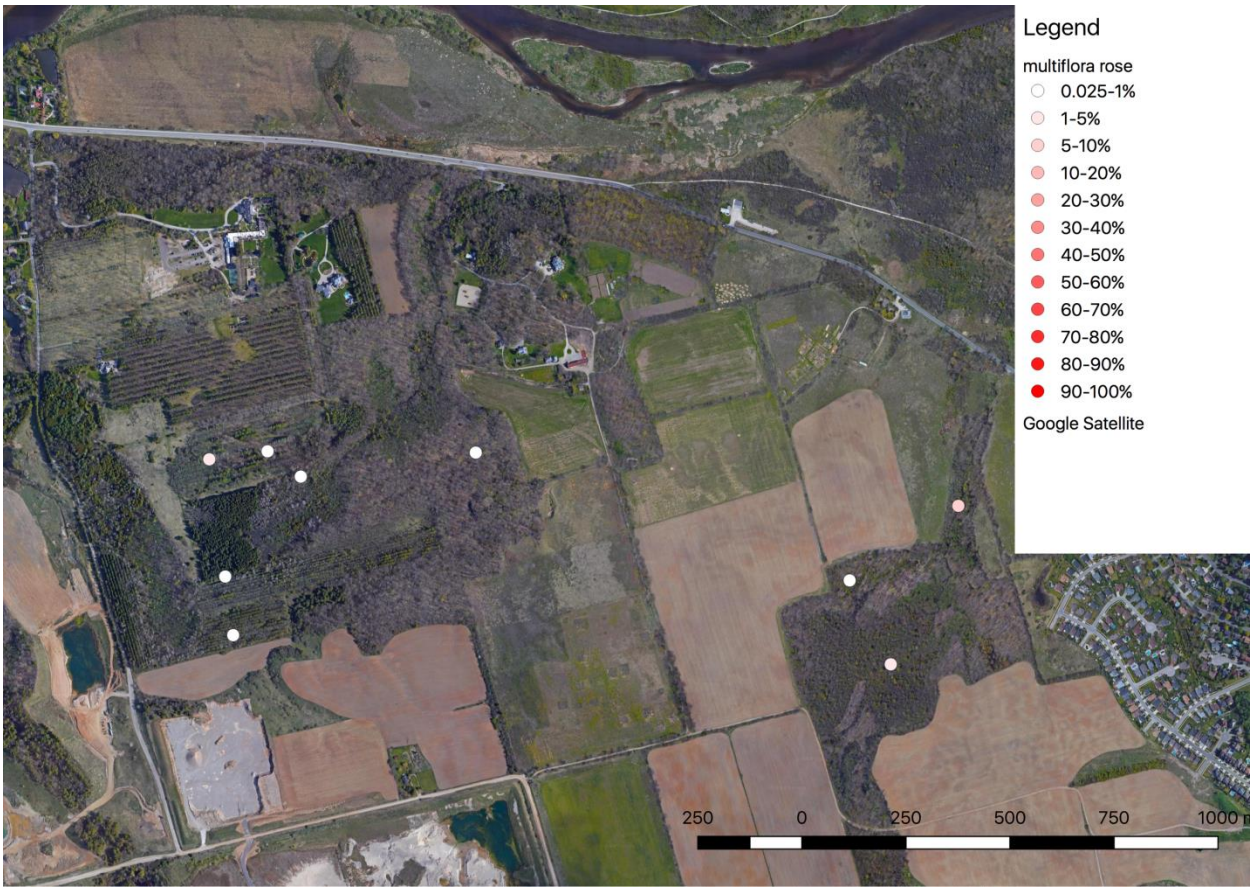

Figure A-20: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of multiflora rose, *Rosa multiflora*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Nine out of 35 plots in two forests, Thompson Tract and the Hogsback, contained multiflora rose, with the lowest being 0.025% and the highest being 10%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-21: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of multiflora rose, *Rosa multiflora*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Multiflora rose was identified in 4 of 28 plots in Cliffs Forest, with the highest percent cover found in plot 56 at 0.3%. One individual was also found at the shrub layer only in plot 101. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

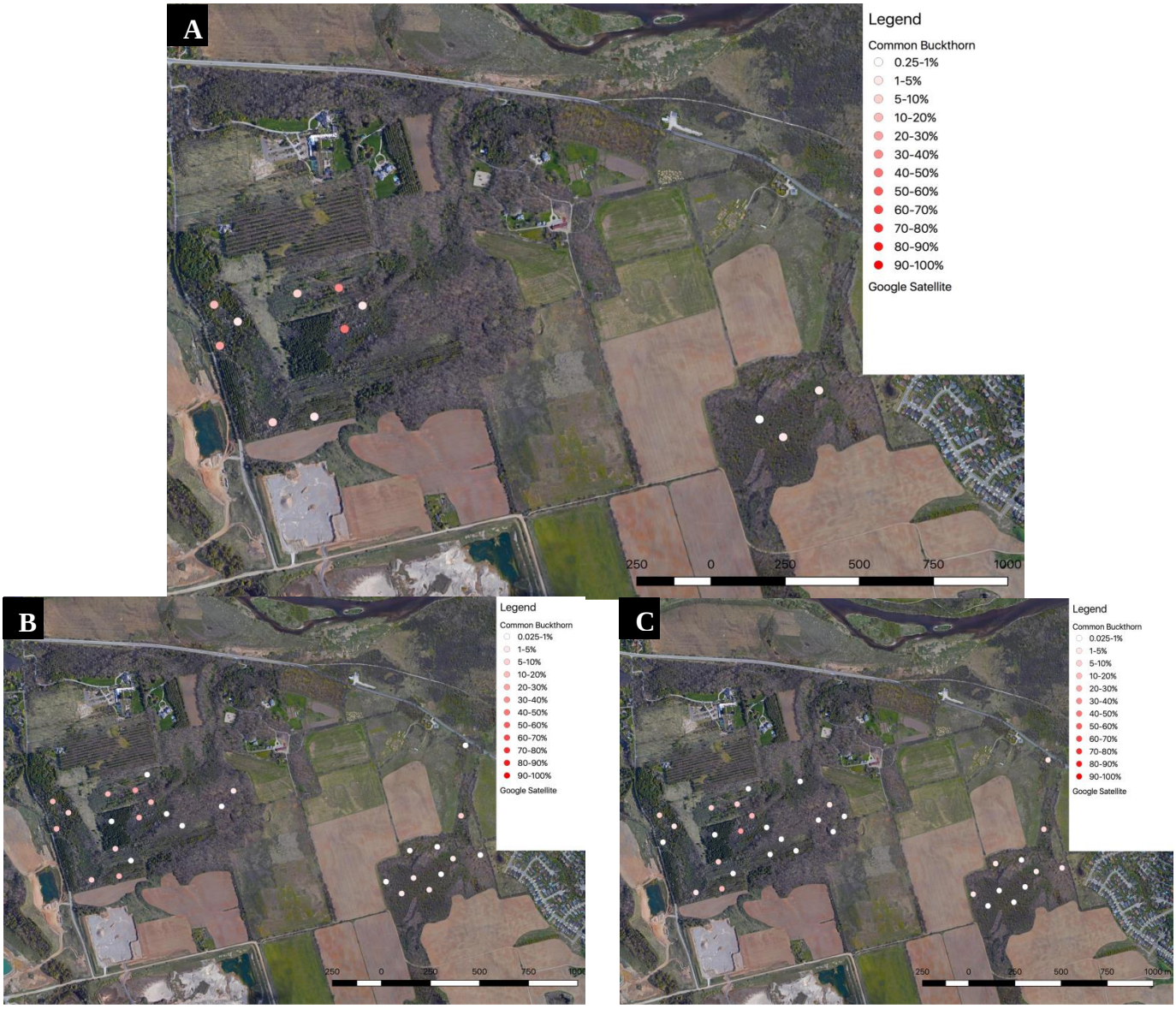

Figure A-22: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common buckthorn, *Rhamnus cathartica*, in sub-canopy layer (Map A; 2-10 m), shrub layer (Map B; 0.5-2 m) and ground layer (Map C; 0-0.5 m) within a 400m^2 plot (11.28 m radius). Thirty-three out of 35 plots in two forests, Thompson Tract and the Hogsback, contained common buckthorn. The sub-canopy had a maximum percent cover of 41.25%; the shrub layer had a maximum percent cover of 22.525%; and the ground layer had a maximum of 21.25%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

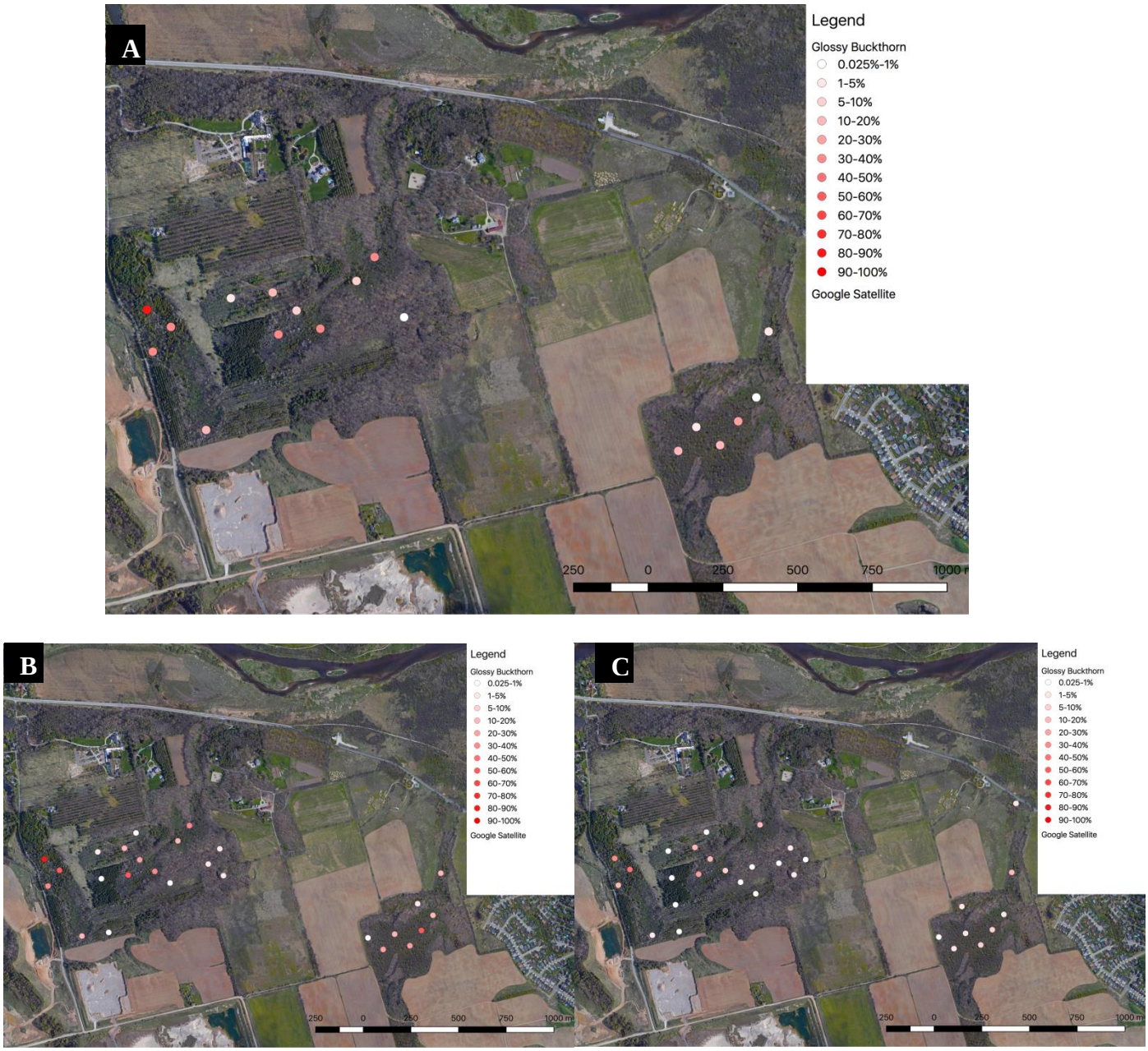

Figure A-23: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of glossy buckthorn, *Rhamnus frangula*, in sub-canopy (Map A; 2-10 m), shrub (Map B; 0.5-2 m) and ground (Map C; 0-0.5 m) layers within a 400m^2 plot (11.28 m radius). Thirty-three out of 35 plots in two forests, Thompson Tract and the Hogsback, contained glossy buckthorn. The sub-canopy had a maximum percent cover of 36.25%; the shrub layer had a maximum percent cover of 38.75%; and the ground layer had a maximum of 43.75%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

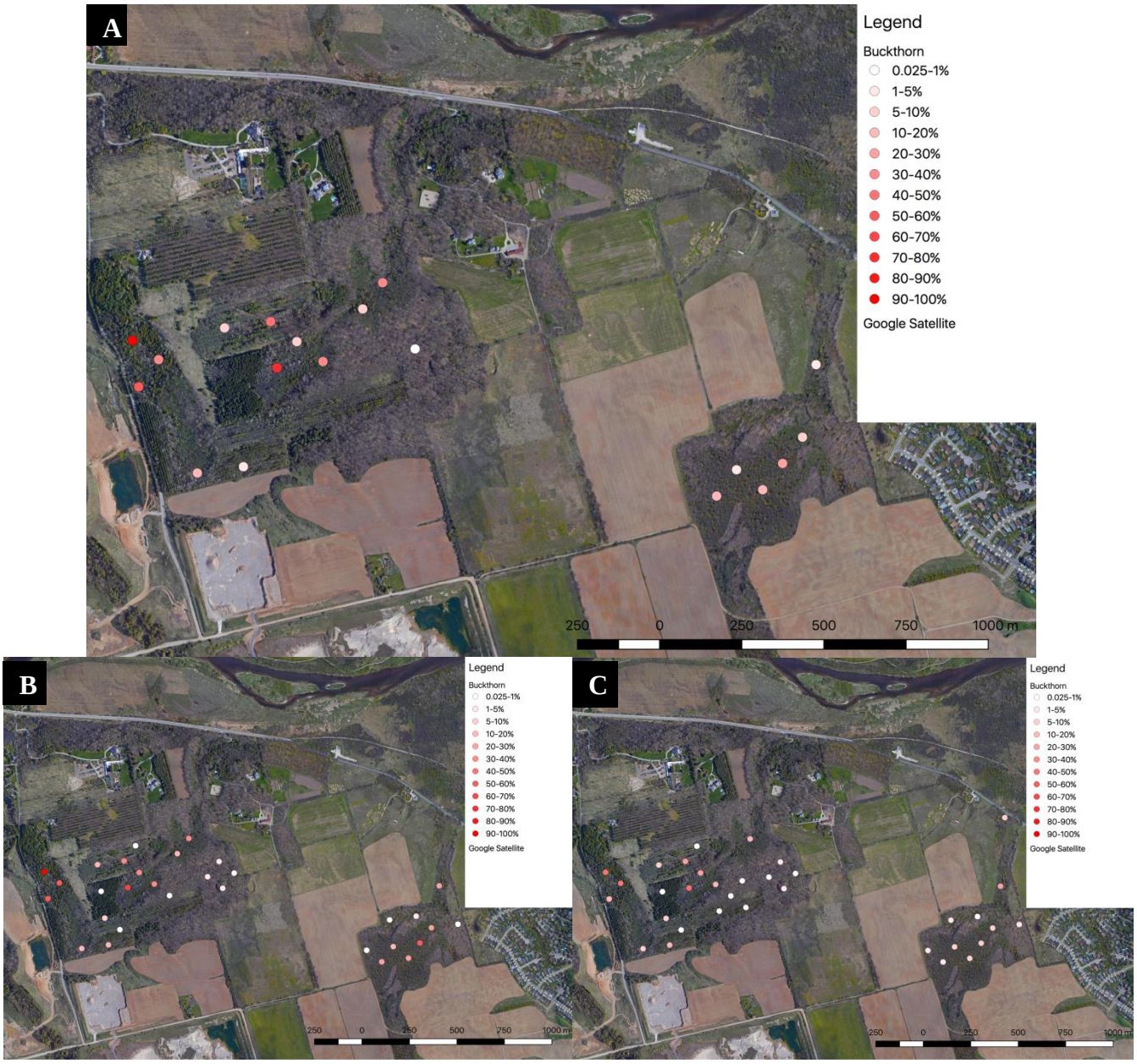

Figure A-24: Map of the ***rare* Charitable Research Reserve** depicting total percent cover of both common and glossy buckthorn, *Rhamnus cathartica* and *Rhamnus frangula*, in sub-canopy layer (Map A; 2-10 m), shrub layer (Map B; 0.5-2 m) and ground layer (Map C; 0-0.5 m) within a 400m^2 plot (11.28 m radius). All of the 35 plots in two forests, Thompson Tract and the Hogsback, contained at least one buckthorn species. The sub-canopy had a maximum percent cover of 78.75%; the shrub layer had a maximum percent cover of 96.25%; and the ground layer had a maximum of 48.75%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

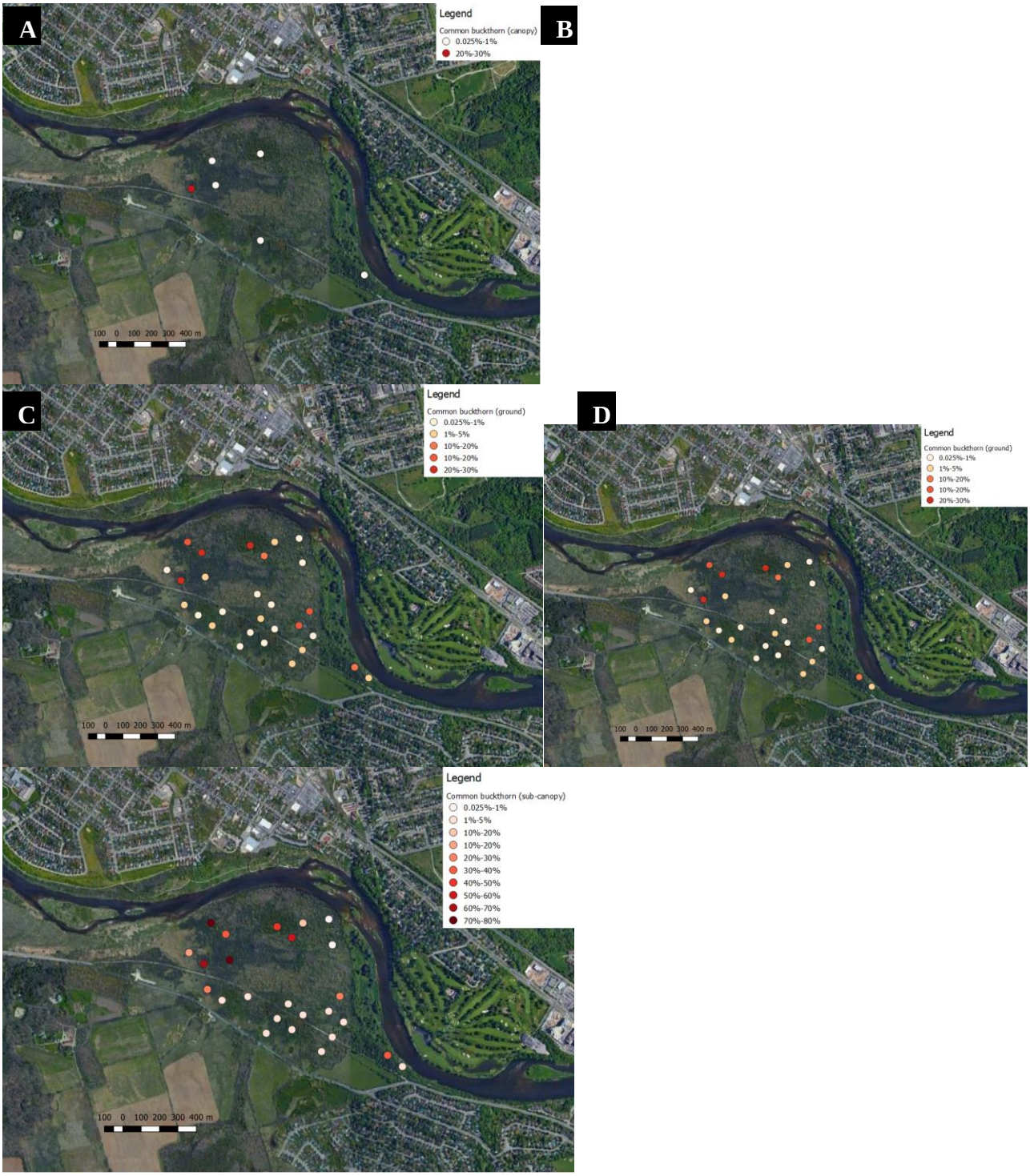

Figure A-25: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common buckthorn, *Rhamnus cathartica*, in canopy layer (Map A; >10 m), sub-canopy layer (Map B; 2-10 m), shrub layer (Map C; 0.5-2 m) and ground layer (Map D; 0-0.5 m) within a 400m^2 plot (11.28 m radius) in Cliffs Forest. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June to October 2019 in Cambridge, Ontario.

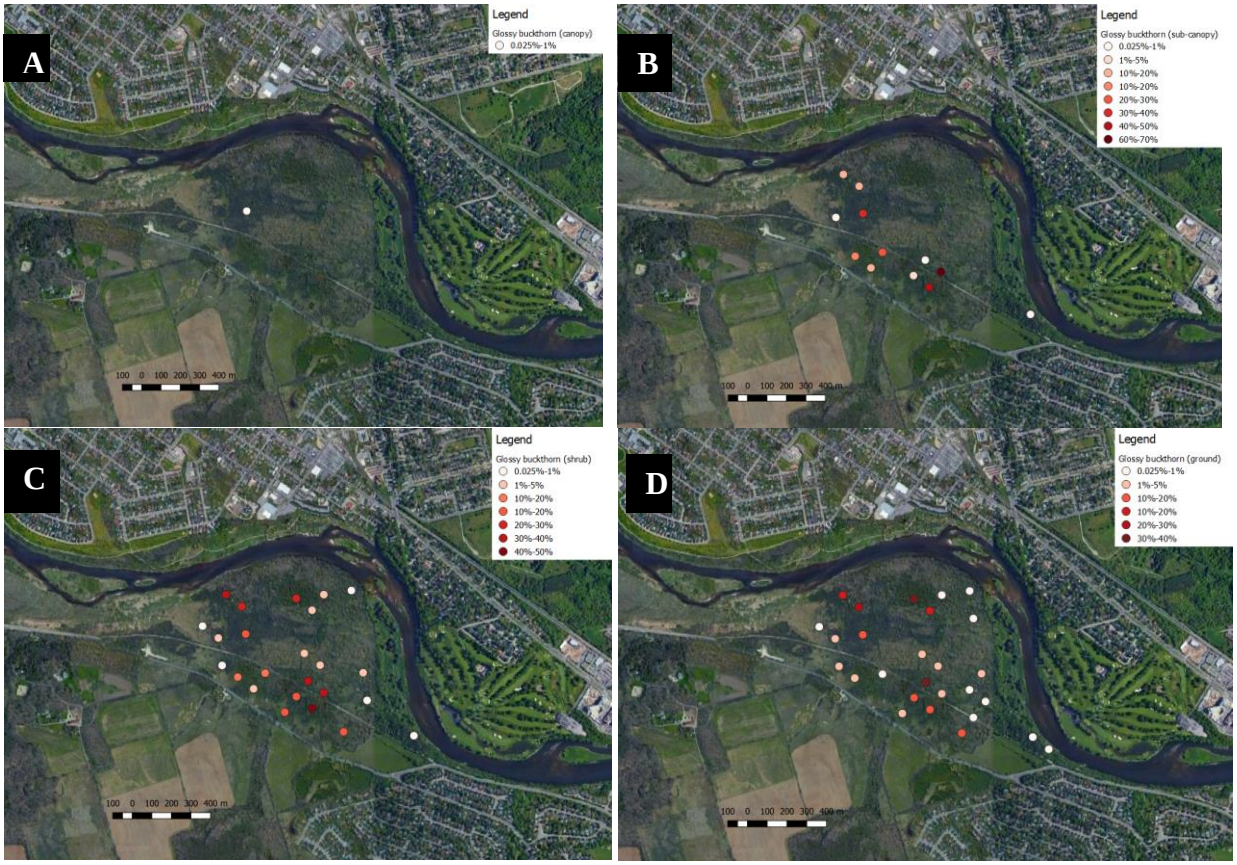

Figure A-26: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of glossy buckthorn, *Rhamnus frangula*, in canopy layer (Map A; >10 m) sub-canopy layer (Map B; 2-10 m), shrub layer (Map C; 0.5-2 m) and ground layer (Map D; 0-0.5 m) within a 400m^2 plot (11.28 m radius) in Cliffs Forest. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

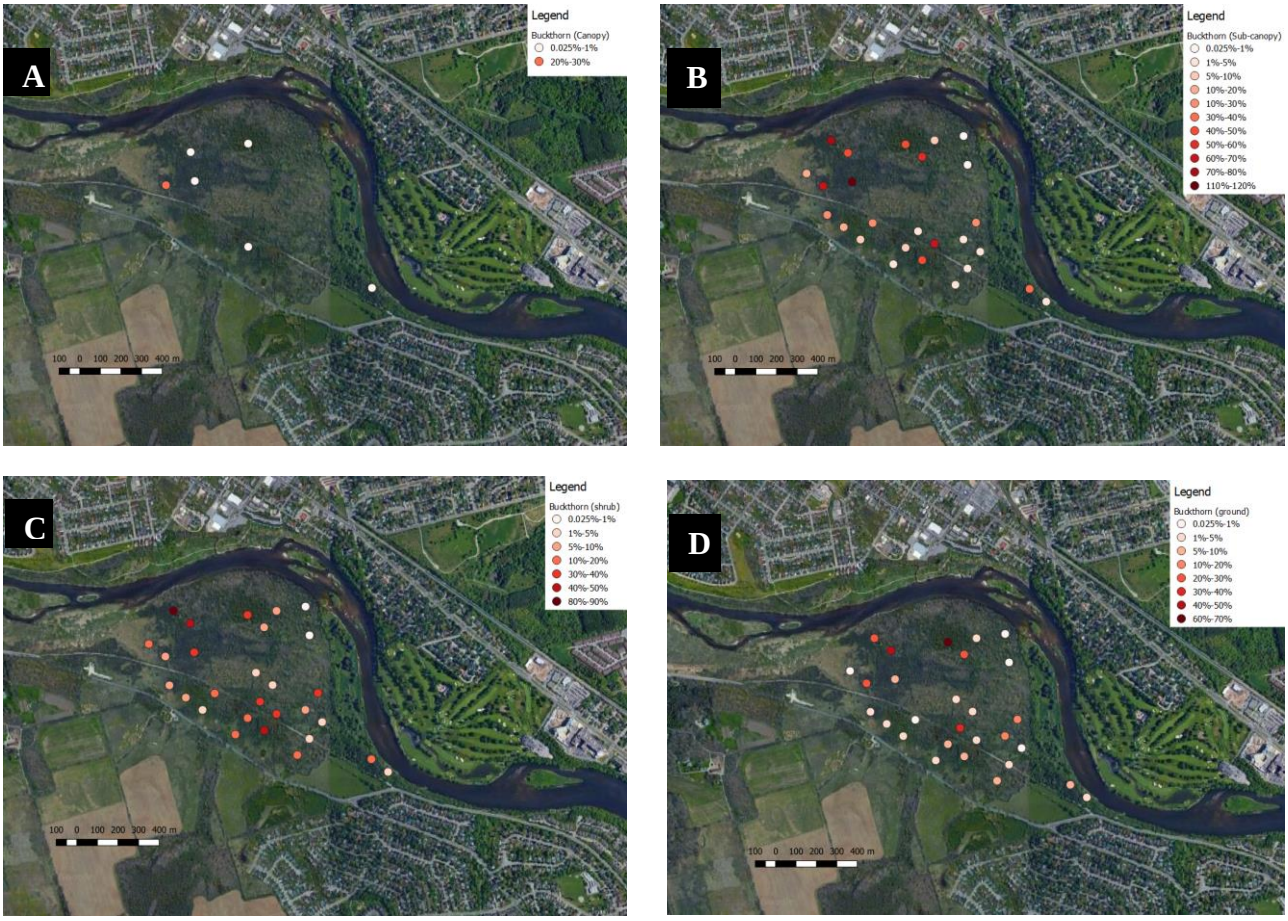

Figure A-27: Map of the ***rare* Charitable Research Reserve** depicting total percent cover of both common and glossy buckthorn, *Rhamnus cathartica* and *Rhamnus frangula*, in canopy (Map A; >10 m), sub-canopy layer (Map B; 2-10 m), shrub layer (Map C; 0.5-2 m) and ground layer (Map D; 0-0.5 m) within a 400m^2 plot (11.28 m radius) in Cliffs Forest. Combined cover for both species of buckthorn revealed the highest percent cover in the ground layer in plot 177, located in a pocket of mixed forest. In subcanopy, the highest Buckthorn cover was also in the same polygon, in plot 194 at 115%, followed by 77.5% in plot 224 and 66% in plot 78. Buckthorn only exceeded trace levels in the canopy layer in plot 209, where it was 28.75%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Combined cover values were calculated by adding together percent cover for the two species in each stratum, which were obtained from randomly generated plots sampled during June to October 2019 in Cambridge, Ontario. Note: Because percent cover is absolute and not relative, combined cover can exceed 100% to a maximum value of 200%.

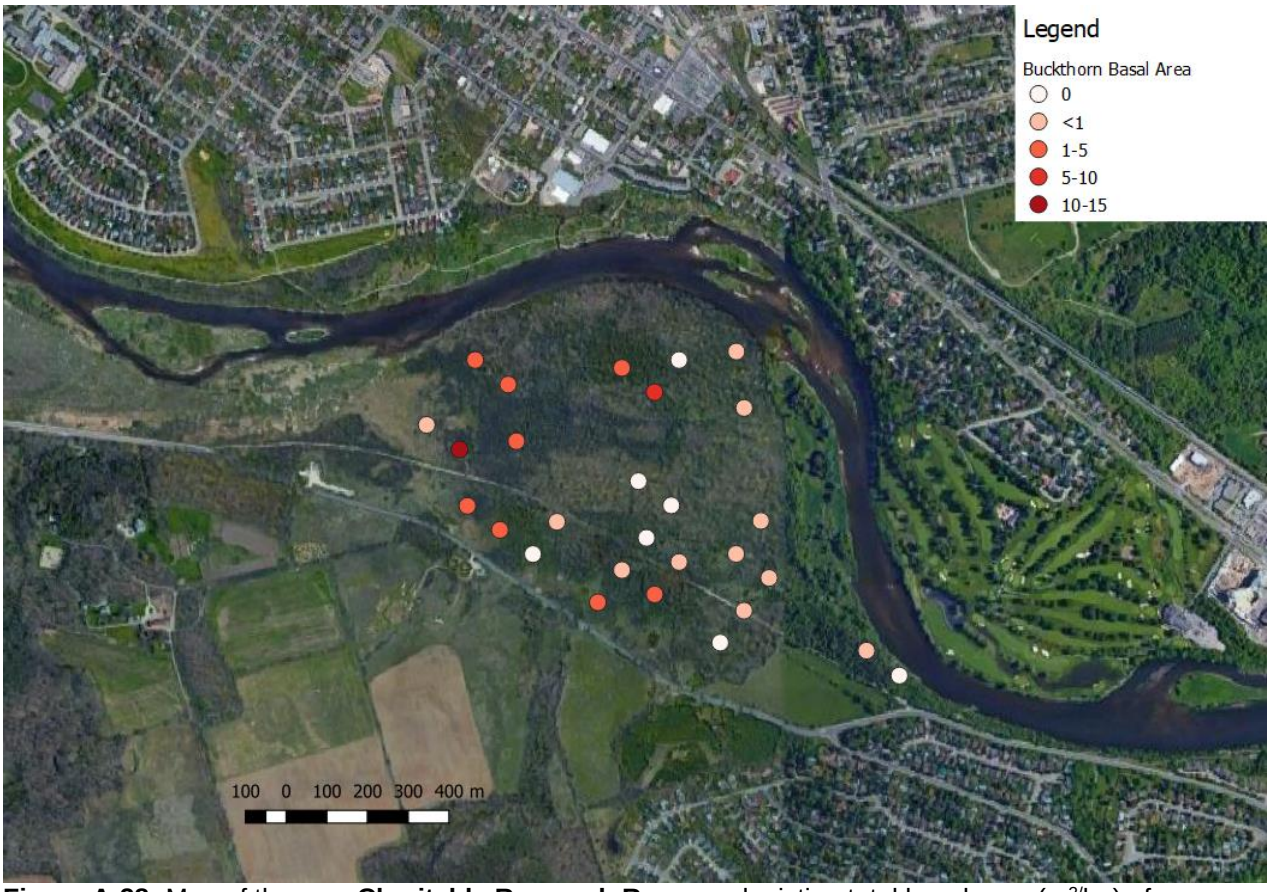

Figure A-28: Map of the ***rare*** **Charitable Research Reserve** depicting total basal area (m^2/ha) of common and glossy buckthorn, *Rhamnus cathartica* and *Rhamnus frangula,* within a plot based on diameter measurements at breast height of all buckthorn with a dbh greater than or equal to 5 cm. Twenty-one out of 28 plots in Cliffs Forest contained at least one buckthorn with a diameter greater than 5cm. Plot 209 had the greatest basal area of 14.58 m^2/ha with a total of 93 stems within a plot, followed by plot 155, with a basal area of 8.55 m^2/ha and 46 stems, and plot 224, with a basal area of 4.91 m^2/ha and 39 stems. Basal area is expressed on a gradient increasing in colour intensity with increasing basal area. DBH values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

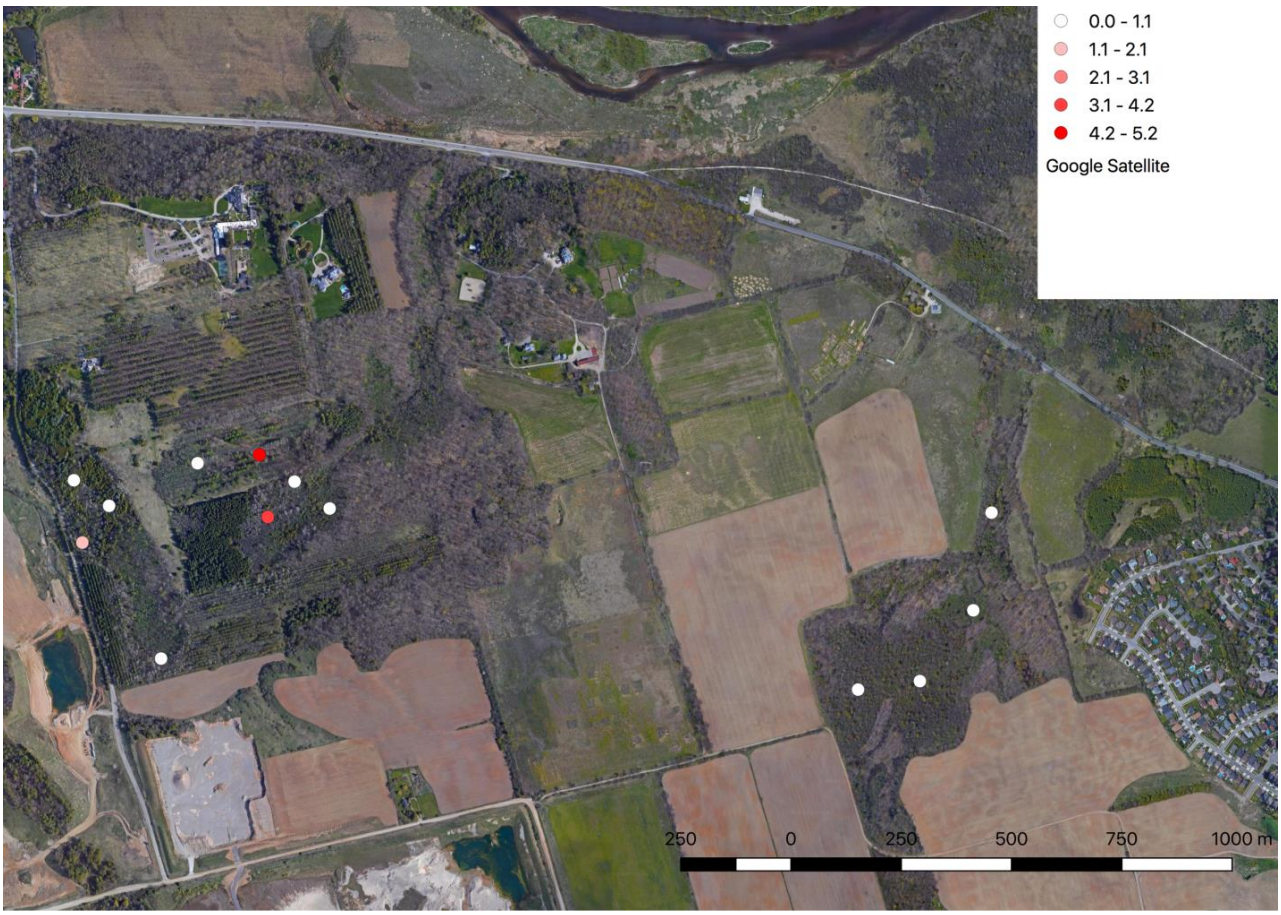

Figure A-29: Map of the ***rare*** **Charitable Research Reserve** depicting total basal area (m^2/ha) of common and glossy buckthorn, *Rhamnus cathartica* and *Rhamnus frangula,* within a plot based on diameter measurements at breast height of all buckthorn with a dbh greater than or equal to 5 cm. Thirteen out of 35 plots in two forests, Thompson Tract and the Hogsback, contained at least one buckthorn with a diameter greater than 5 cm. Plot 286 had the greatest basal area of 5.21 m^2/ha with a total of 43 stems; followed by plot 274, with a basal area of 3.60 m^2/ha and 15 stems; and plot 299 with a basal area of 1.58 m^2/ha and 16 stems. Basal area is expressed on a gradient, with lower basal area being white to light red, increasing in colour intensity with increasing basal area. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

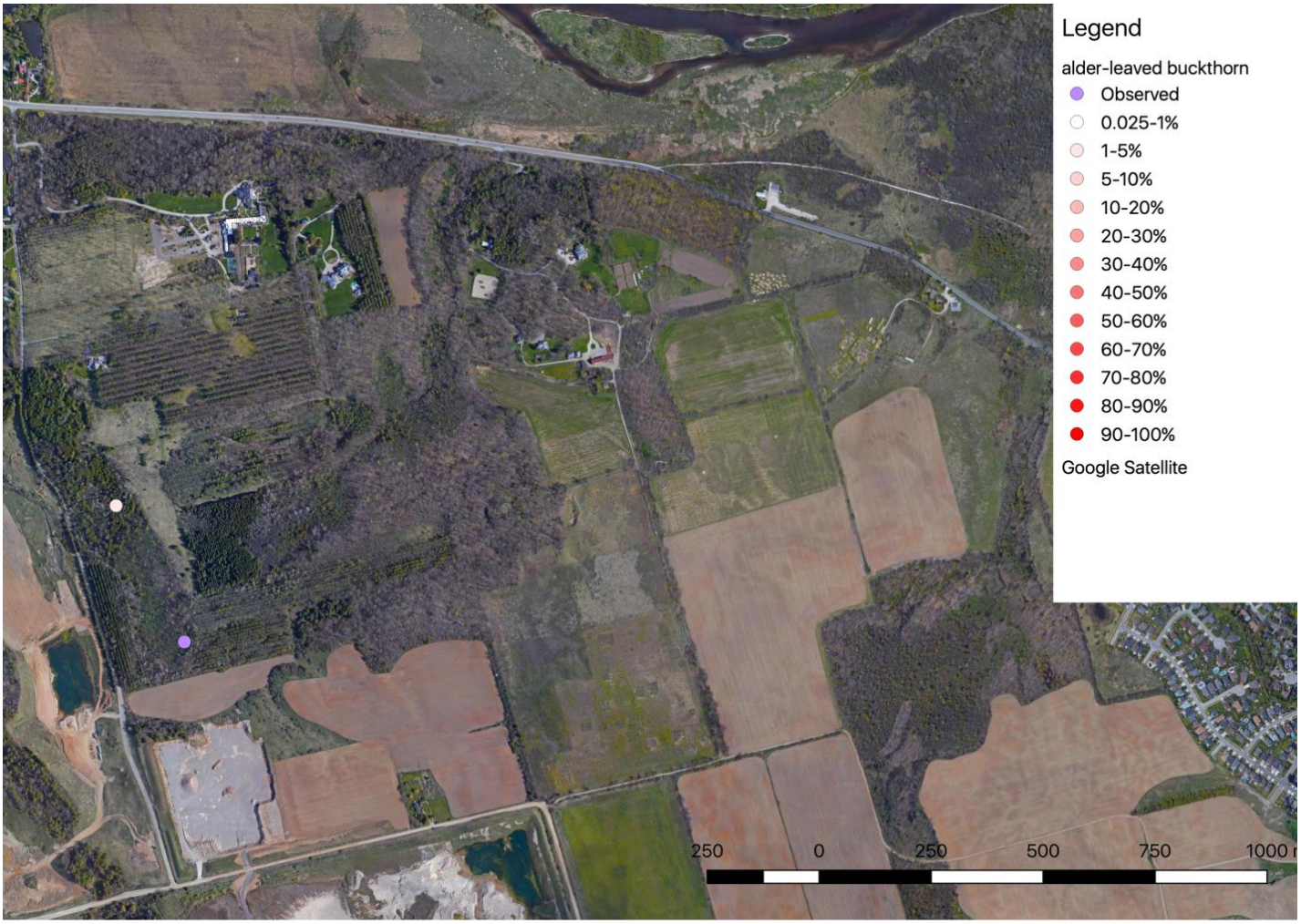

Figure A-30: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of alder-leaved buckthorn, *Rhamnus alnifolia*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). One out of 35 plots in two forests, Thompson Tract and the Hogsback, contained alder-leaved buckthorn, comprising of 1.25% of the plot. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Purple indicates the presence of Alder-leaved Buckthorn observed outside of defined plots. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

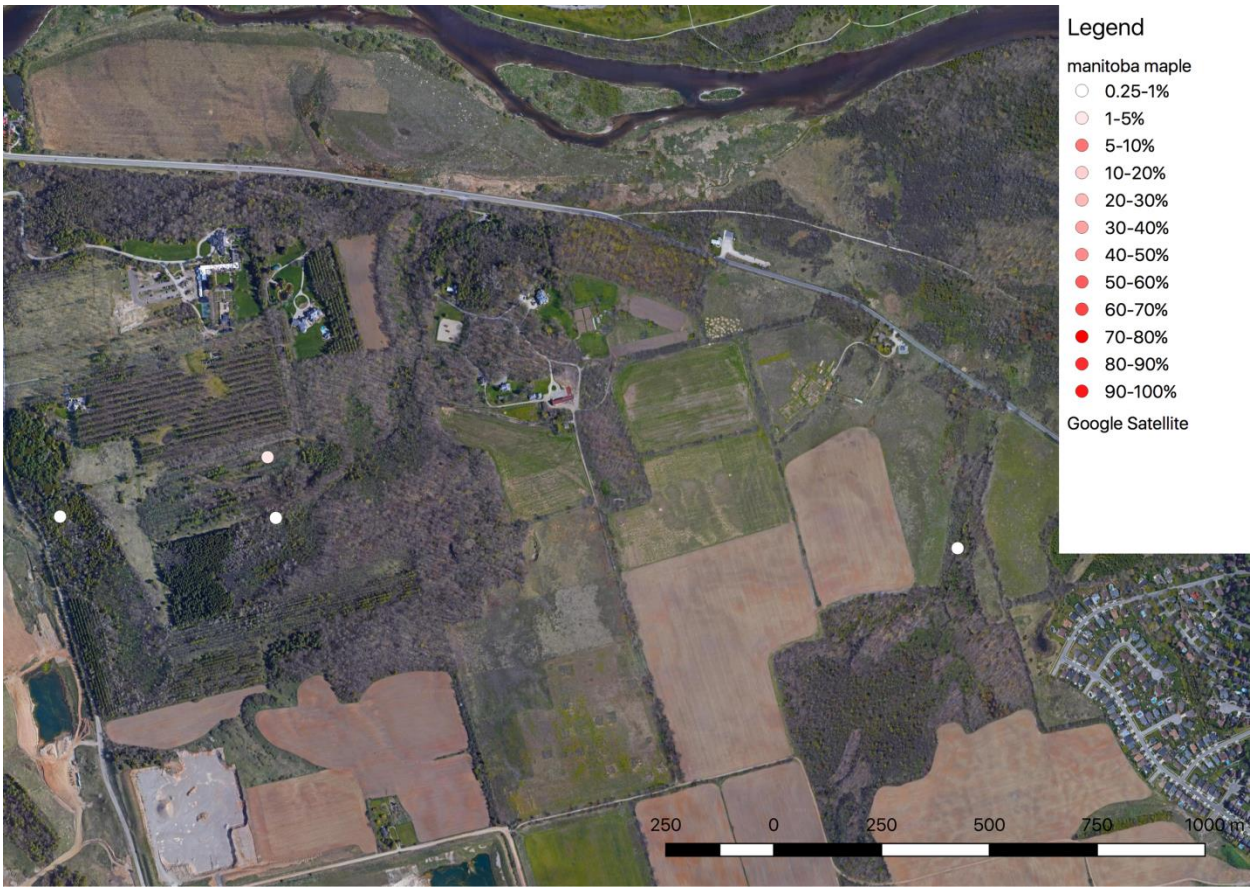

Figure A-31: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of Manitoba maple, *Acer negundo*, in both ground (0-0.5 m) and shrub (0.5-2 m) layers within a 400m^2 plot (11.28 m radius). Four out of 35 plots in two forests, Thompson Tract and the Hogsback, contained Manitoba maple, with the lowest being 0.025% and the highest being 2.5%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-32: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of Manitoba maple, *Acer negundo*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). A trace number of seedlings were identified in one plot in Cliffs Forest. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-October 2019 in Cambridge, Ontario.

Figure A-33: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of Norway Maple, *Acer platanoides*, in ground (0-0.5 m), shrub (0.5-2 m) and sub-canopy (2-10 m) layers within a 400m^2 plot (11.28 m radius). Norway Maple was observed in plot 6 in trace amounts in the ground, shrub and sub-canopy layers in Cliffs Forest. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-October 2019 in Cambridge, Ontario.

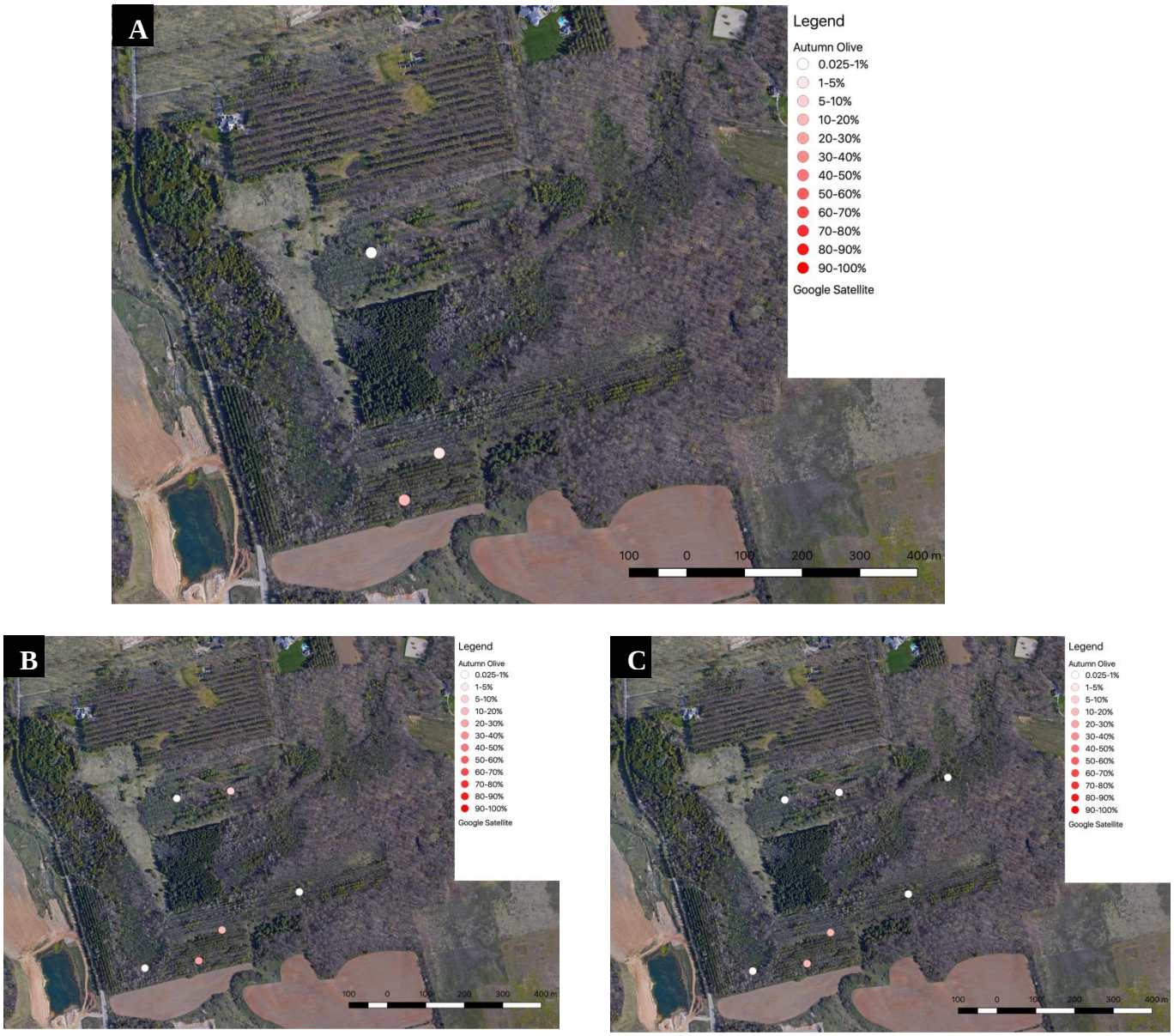

Figure A-34: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of autumn olive, *Elaeagnus umbellata*, in sub-canopy layer (Map A; 2-10 m), shrub layer (Map B; 0.5-2 m) and ground layer (Map C; 0-0.5 m) within a 400m^2 plot (11.28 m radius). Seven out of 35 plots in two forests, Thompson Tract and the Hogsback, contained autumn olive. The sub-canopy had a maximum percent cover of 12.5; the shrub layer had a maximum percent cover of 12.5%; and the ground layer had a maximum of 17.5%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-35: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of autumn olive, *Elaeagnus umbellata*, in ground (<0.5 m), shrub (0.5–2 m) and sub-canopy (2-10 m) layers within a 400m^2 plot (11.28 m radius). Autumn olive was found in Cliffs Forest at the ground layer in trace amounts within plots 2 and 222. It was also found at the shrub and sub-canopy layers at trace levels in plot 35. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June-October 2019 in Cambridge, Ontario.

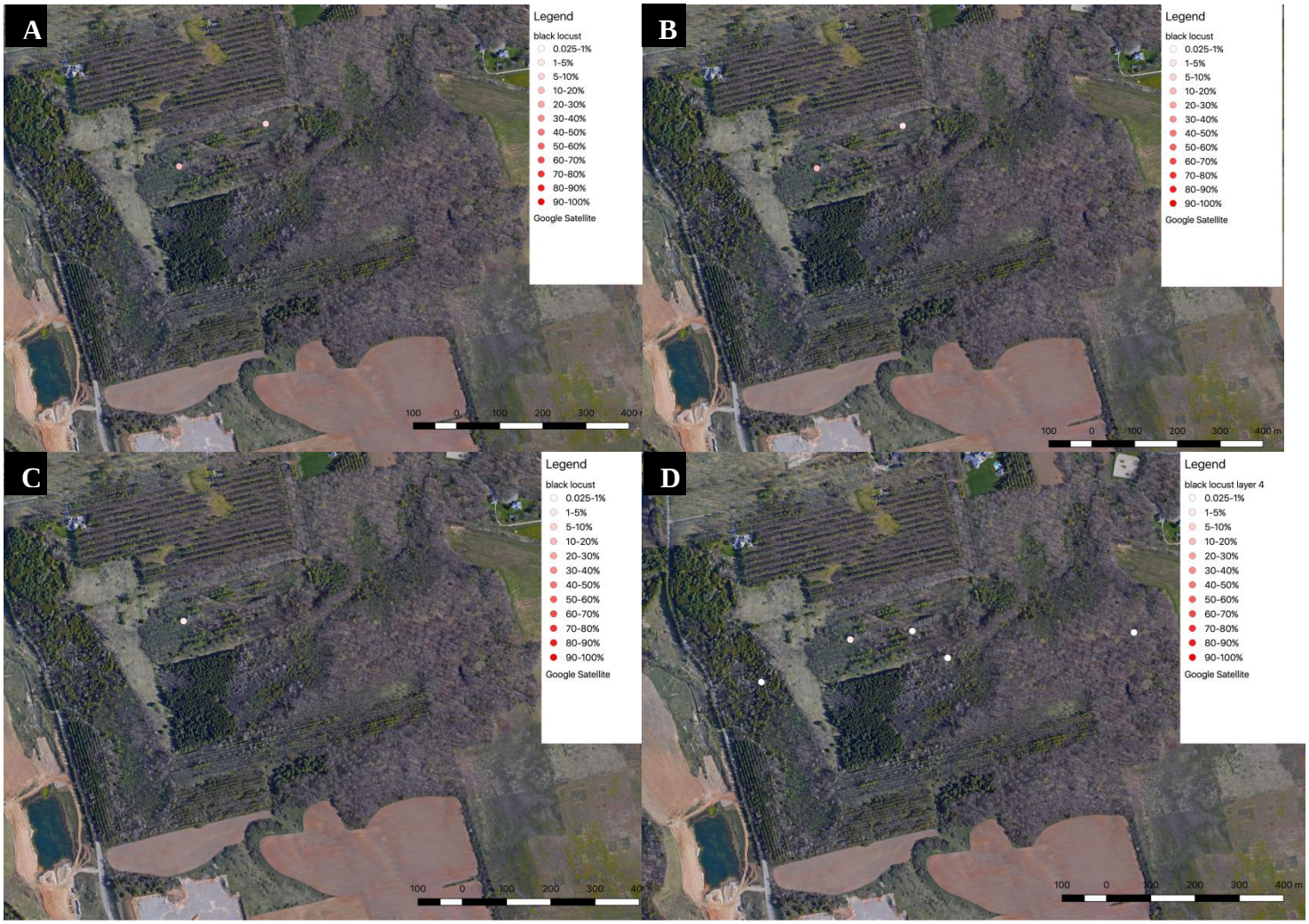

Figure A-36: Map of the ***rare* Charitable Research Reserve** depicting total percent cover of black locust, *Robina pseudo-acacia*, in canopy layer (Map A; >10 m), sub-canopy layer (Map B; 2-10 m), shrub layer (Map C; 0.5-2 m) and ground layer (Map D; 0-0.5 m) within a 400m^2 plot (11.28 m radius). Five out of 35 plots contained black locust in at least one of the layers. The canopy layer had a maximum percent cover of 15.025%; the sub-canopy had a maximum percent cover of 13.75%; the shrub and ground layer both had a maximum percent cover of 1.3. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

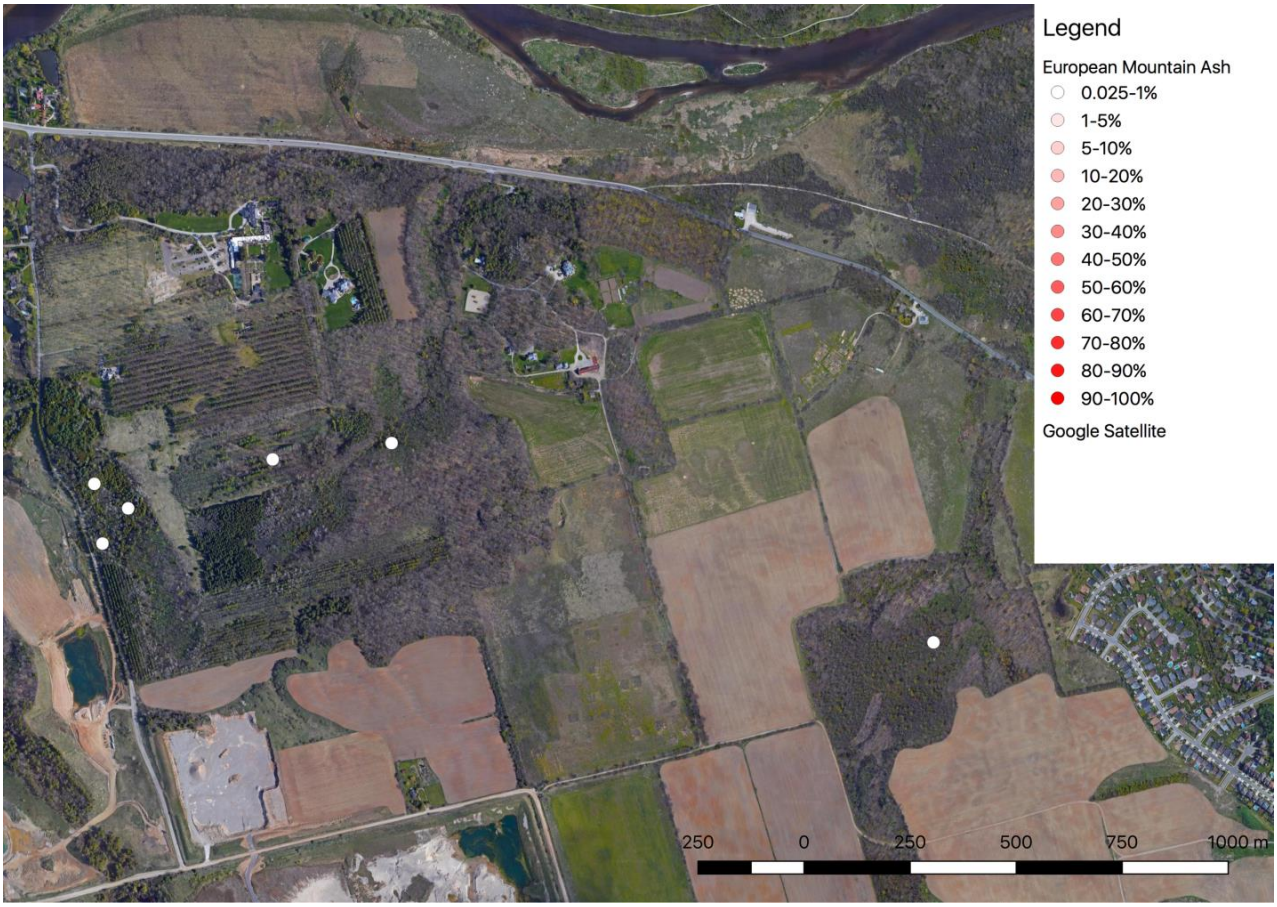

Figure A-37: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of European mountain ash, *Sorbus aucuparia*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 35 plots in two forests, Thompson Tract and the Hogsback, contained European mountain ash, with the lowest being 0.025% and the highest being 0.05%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-38: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of European mountain ash, *Sorbus aucuparia*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). European mountain ash was found in trace amounts (<0.1%) at the ground layer in ten plots and reached the shrub layer at trace levels (0.05%) in two of these ten plots in Cliffs Forest. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June to October 2019 in Cambridge, Ontario.

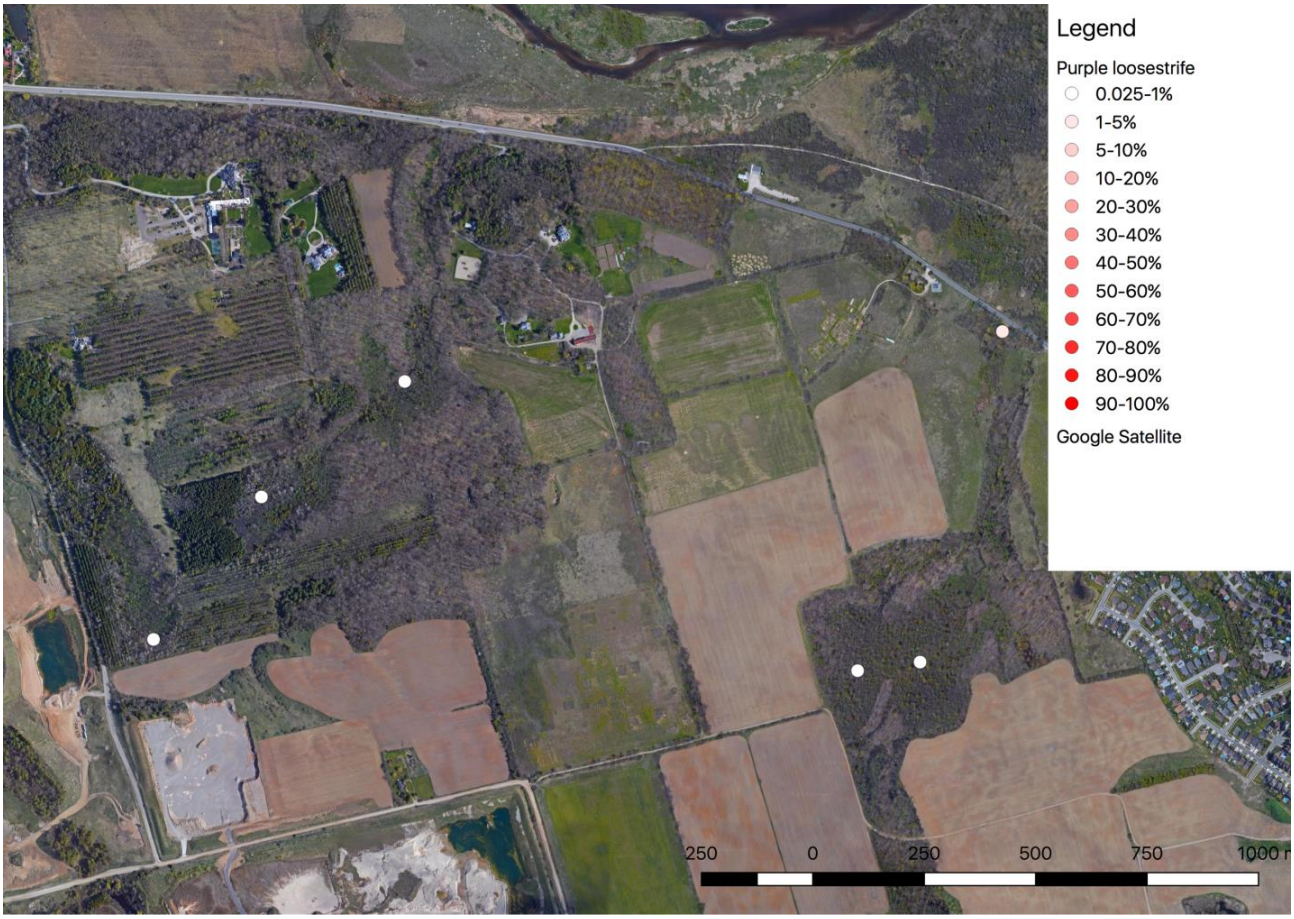

Figure A-39: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of purple loosestrife, *Lythrum salicaria*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 35 plots in two forests, Thompson Tract and the Hogsback, contained purple loosestrife, with the lowest being 0.025% and the highest being 1.275%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-40: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of purple loosestrife, *Lythrum salicaria*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Only two of 28 plots in Cliffs Forest contained purple loosestrife, with the lowest being 0.1% and the highest being 2.775%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

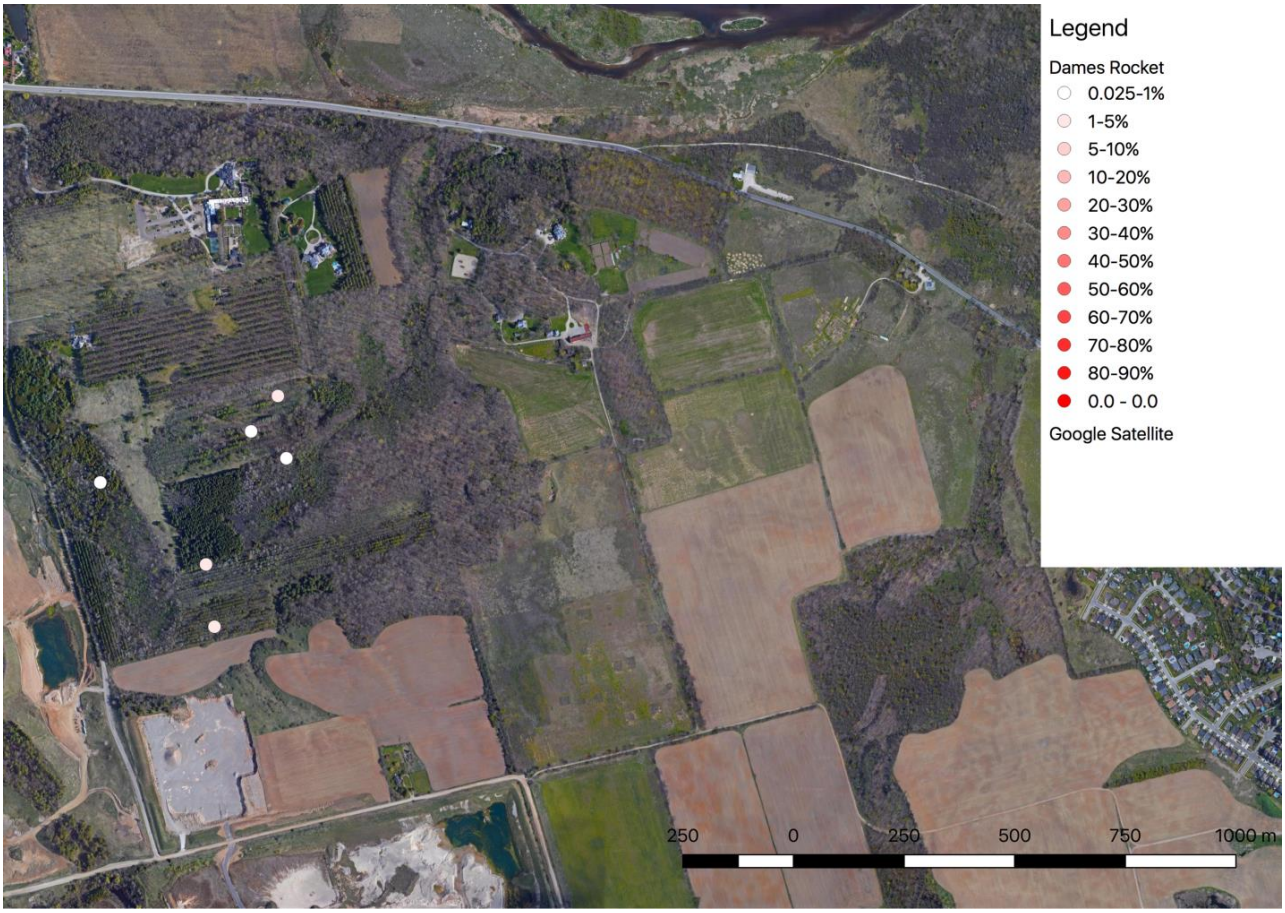

Figure A-41: Map of the ***rare*** **Charitable Research Reser**ve depicting total percent cover of dame's rocket, *Hesperis matronalis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 35 plots in two forests, Thompson Tract and the Hogsback, contained dame's rocket, with the lowest being 0.025% and the highest being 3.775%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-42: Map of the ***rare*** **Charitable Research Reser**ve depicting total percent cover of dame's rocket, *Hesperis matronalis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Eight out of 28 plots in Cliffs Forest contained dame's rocket, with values ranging between 0.025% and 0.1%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

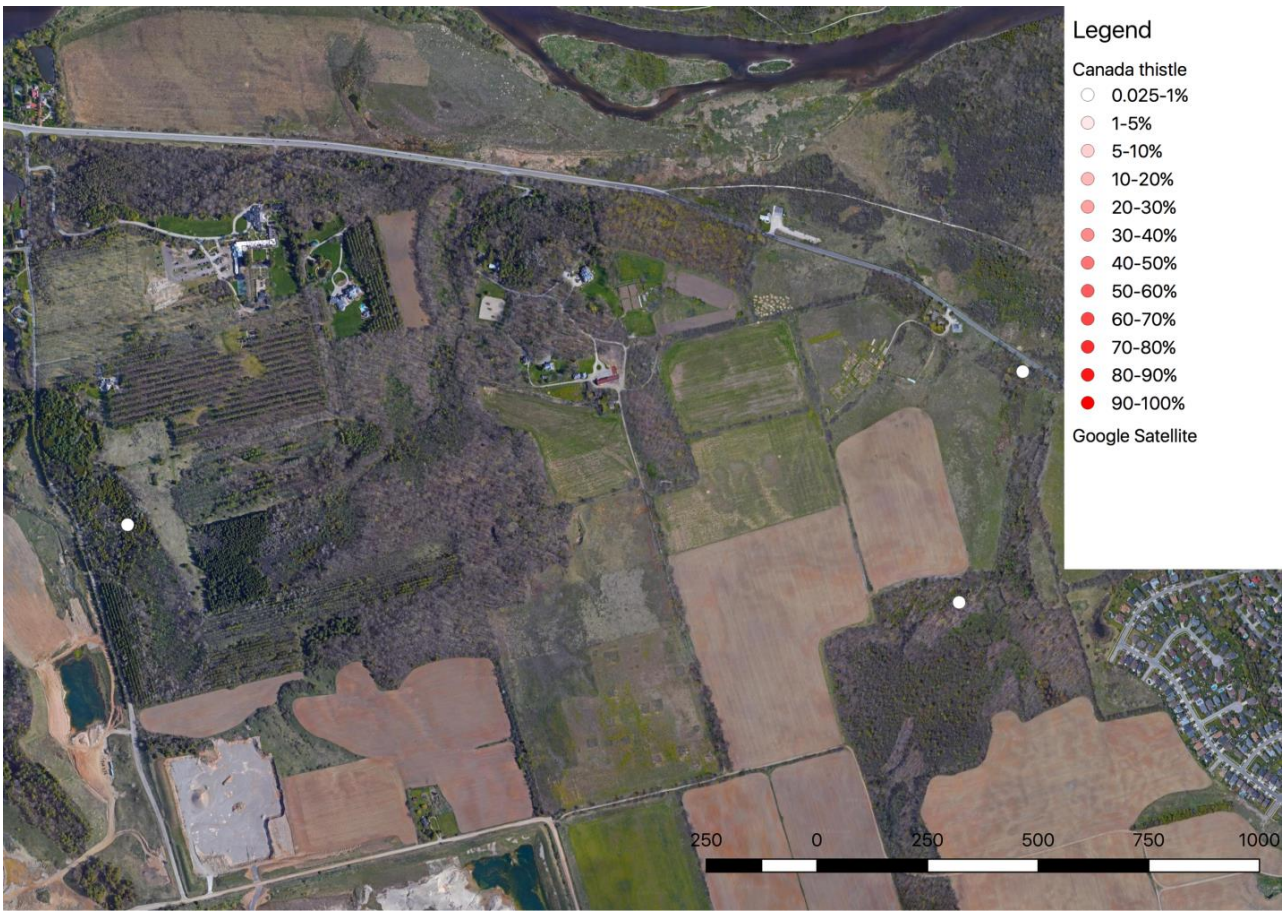

Figure A-43: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of Canada thistle, *Cirsium arvense*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Three out of 35 plots in two forests, Thompson Tract and the Hogsback, contained Canada thistle, with the lowest being 0.025% and the highest being 0.1%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

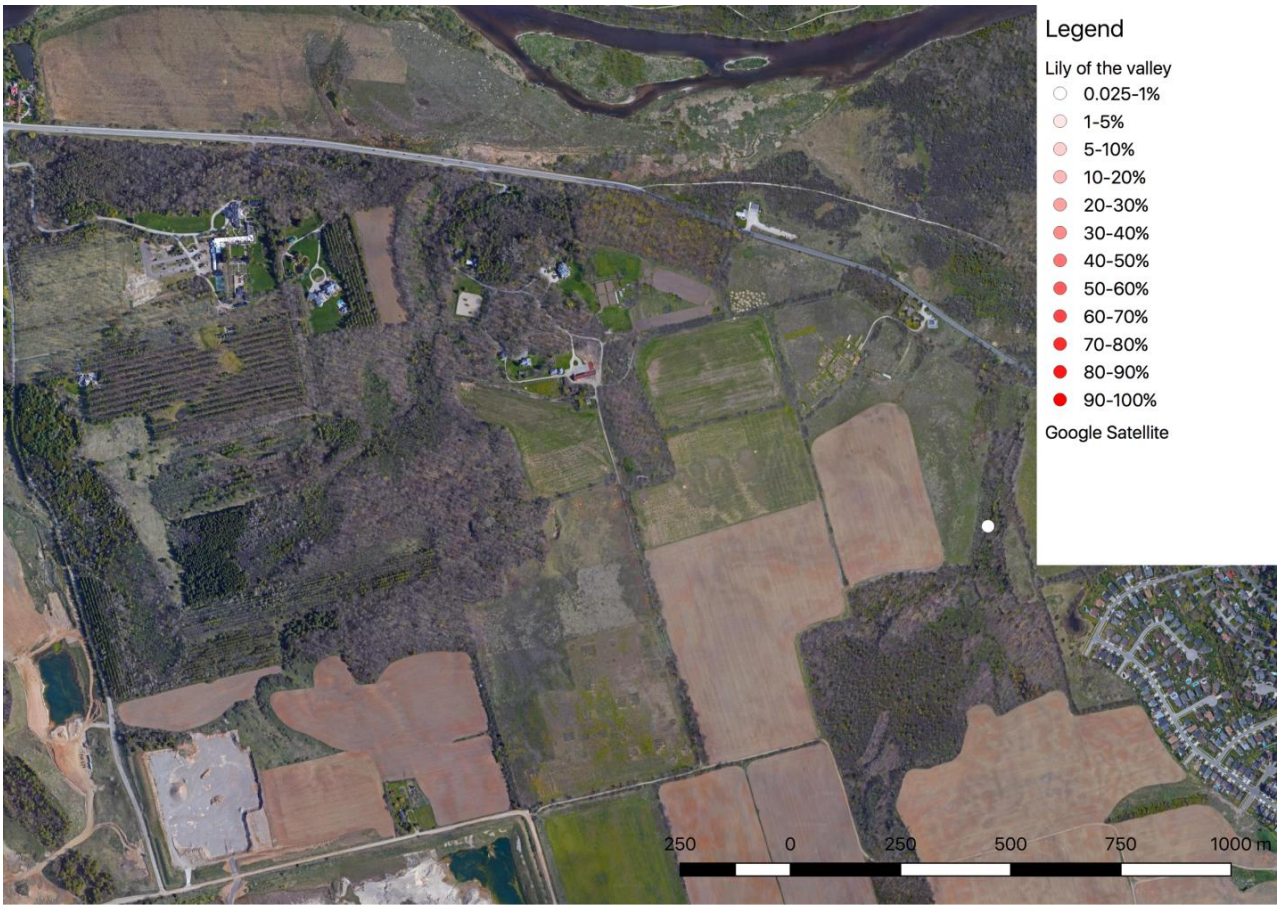

Figure A-44: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of lily of the valley, *Convallaria majalis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). One out of 35 plots in two forests, Thompson Tract and the Hogsback, contained lily of the valley, comprising 0.025% of the plot. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-45: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of lily of the valley, *Convallaria majalis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Lily-of-the-valley was found at trace levels (0.025%) in two plots in Cliffs Forest but made up 20% cover in the third plot. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

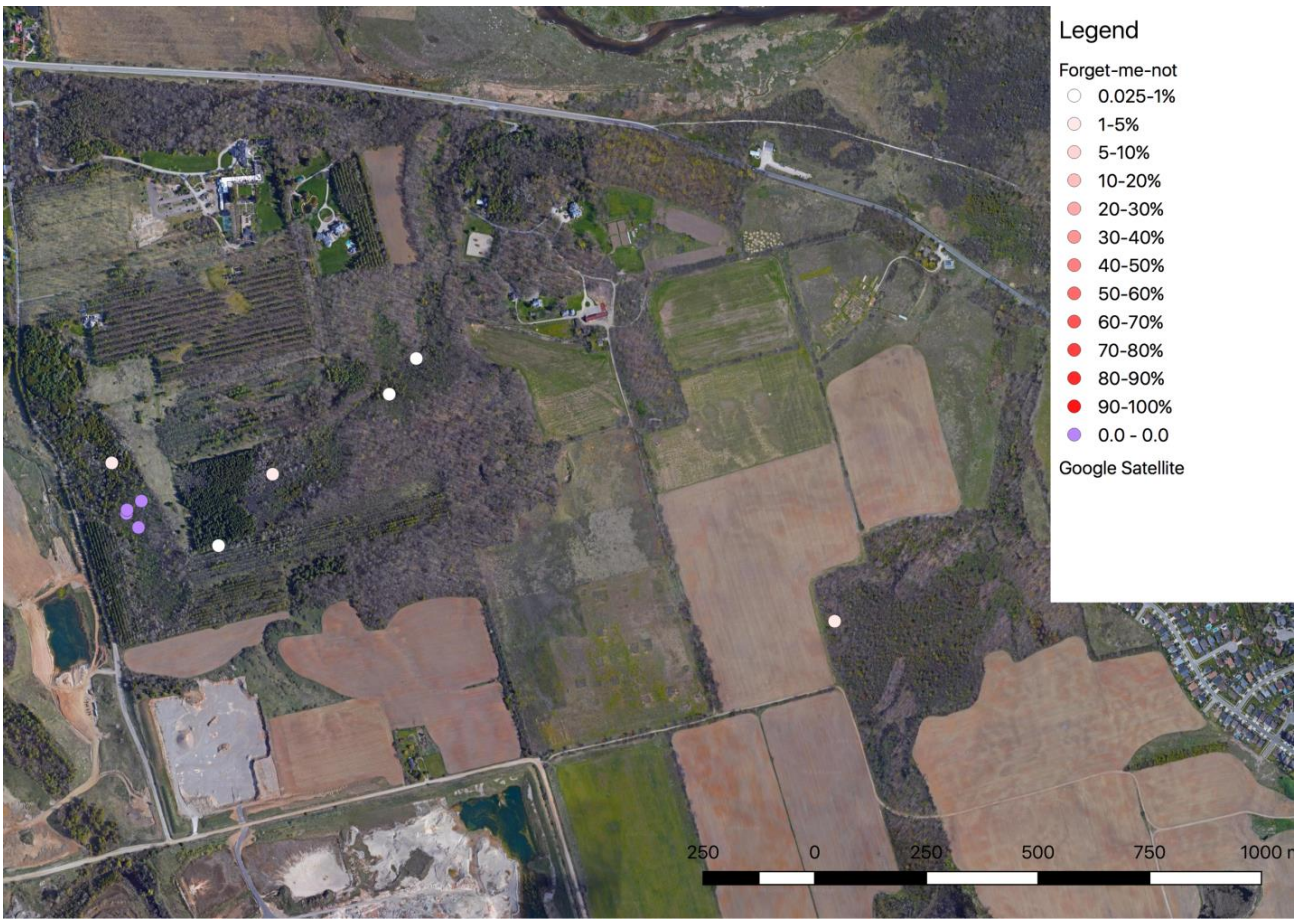

Figure A-46: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of forget-me-not species, *Myosotis sp.*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 35 plots in two forests, Thompson Tract and the Hogsback, contained forget-me-not species, with the lowest being 0.025% and the highest being 2.525%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Purple indicates additional large presence of forget-me-not species observed outside of defined plots, along a stream in Thompson Tract. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-47: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of forget-me-not species, *Myosotis sp.*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Trace amounts (.05%) of forget-me-not species were found in one plot in Cliffs Forest. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

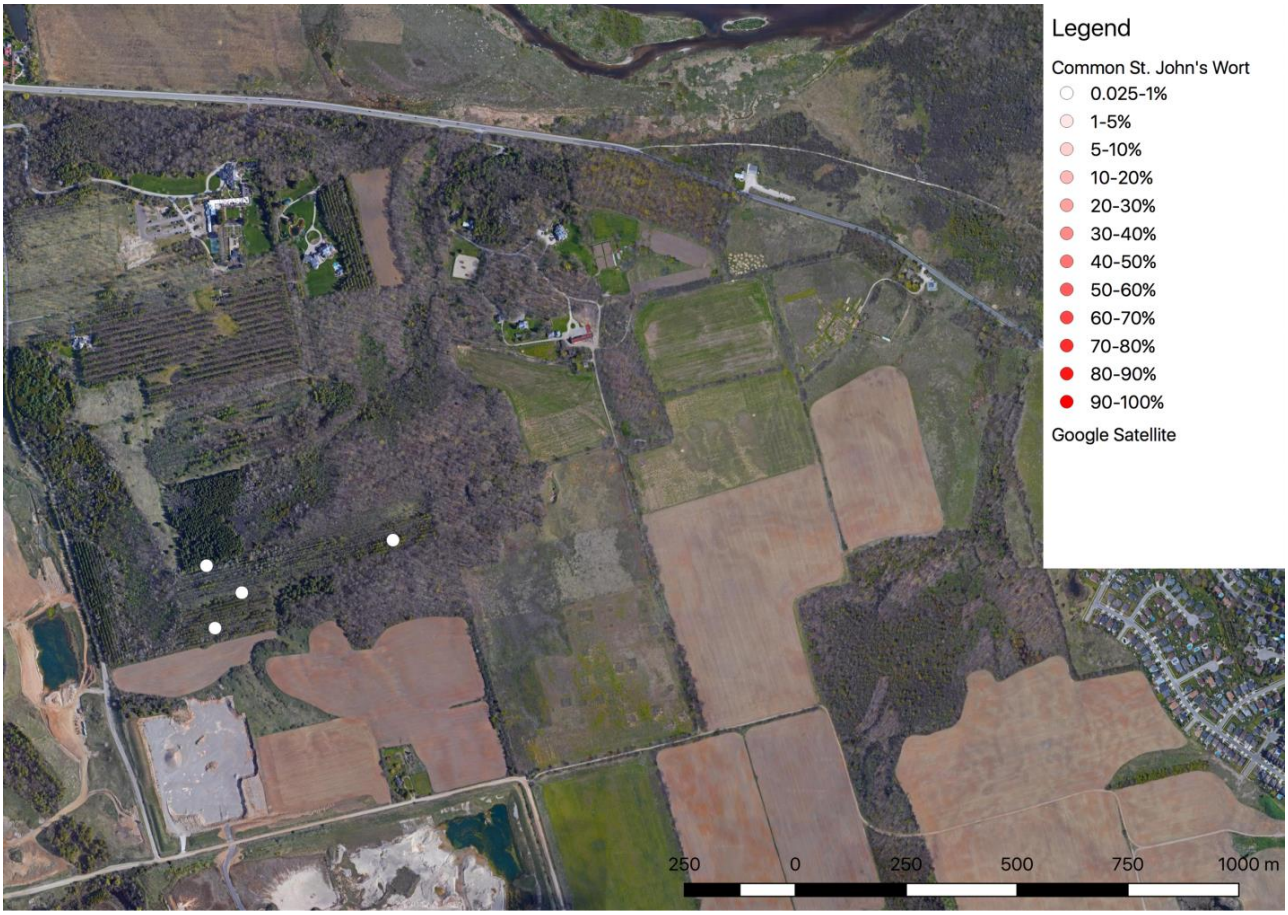

Figure A-48: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common St. John's-wort, *Hypericum perforatum*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Four out of 35 plots in two forests, Thompson Tract and the Hogsback, contained common St. John's-wort, with the lowest being 0.025% and the highest being 0.1%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-49: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of common St. John's-wort, *Hypericum perforatum*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Eight out of 28 plots in Cliffs Forest contained Common St. John's-wort, with the lowest coverage being 0.025% and the highest being 0.1%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

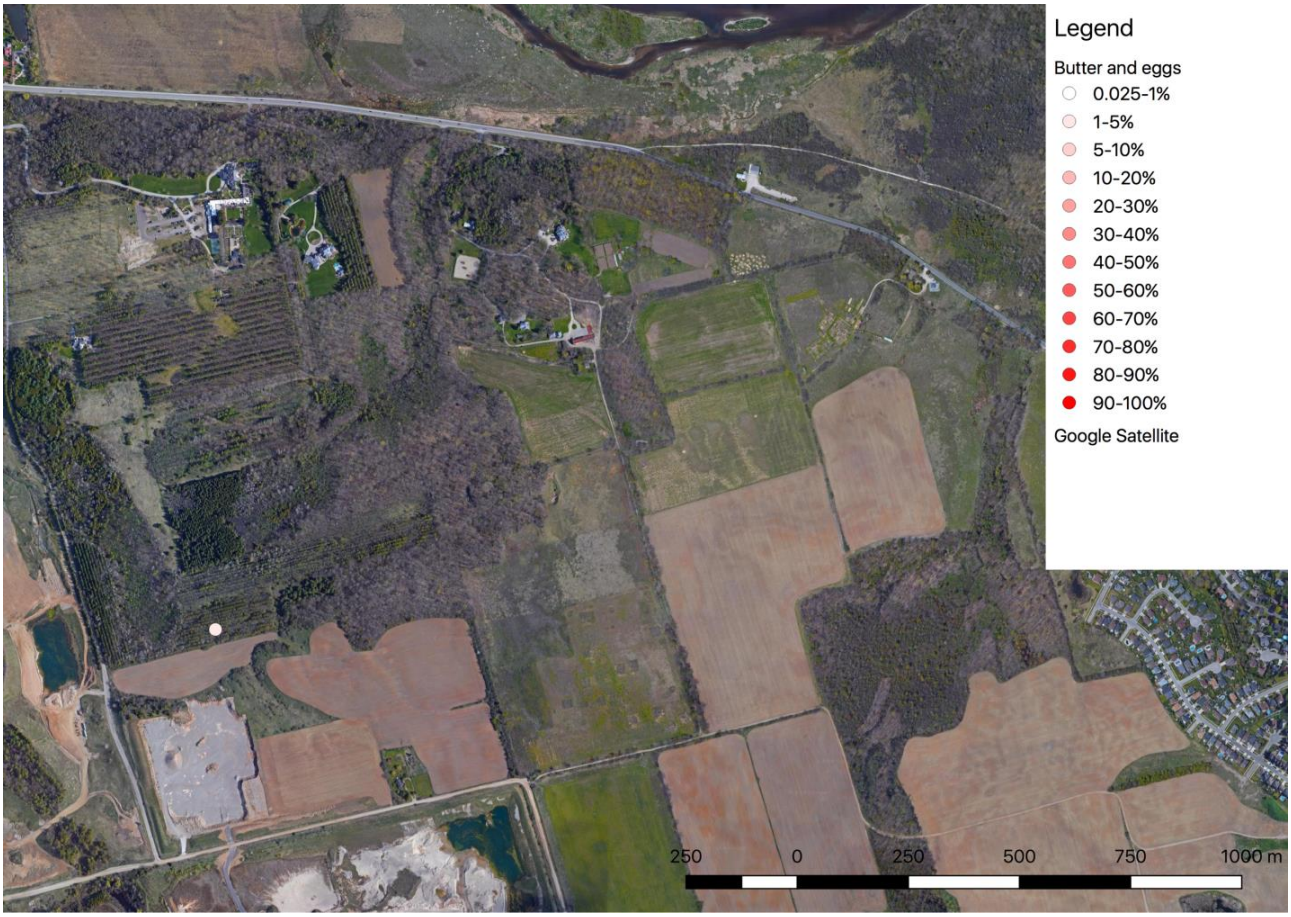

Figure A-50: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of butter-and-eggs, *Linaria vulgaris*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). One out of 35 plots in two forests, Thompson Tract and the Hogsback, contained butter-and-eggs, comprising of 1.275% of the plot. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-51: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of butter-and-eggs, *Linaria vulgaris*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Four out of 28 plots in Cliffs Forest contained butter-and-eggs, comprising of 1.275% of the plot. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

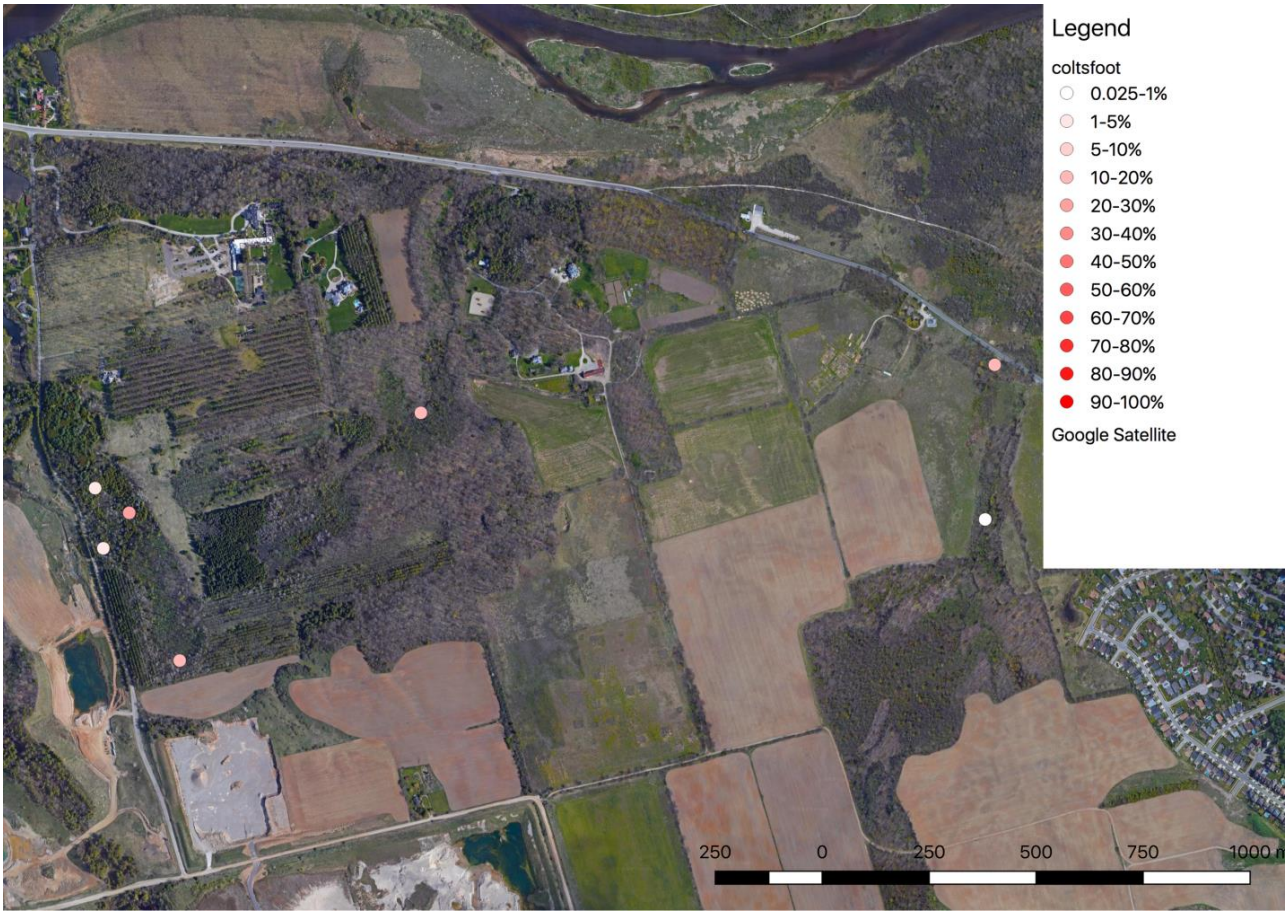

Figure A-52: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of coltsfoot, *Tussilago farfara*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Seven out of 35 plots in two forests, Thompson Tract and the Hogsback, contained coltsfoot, with the lowest being 0.075% and the highest being 28.75%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

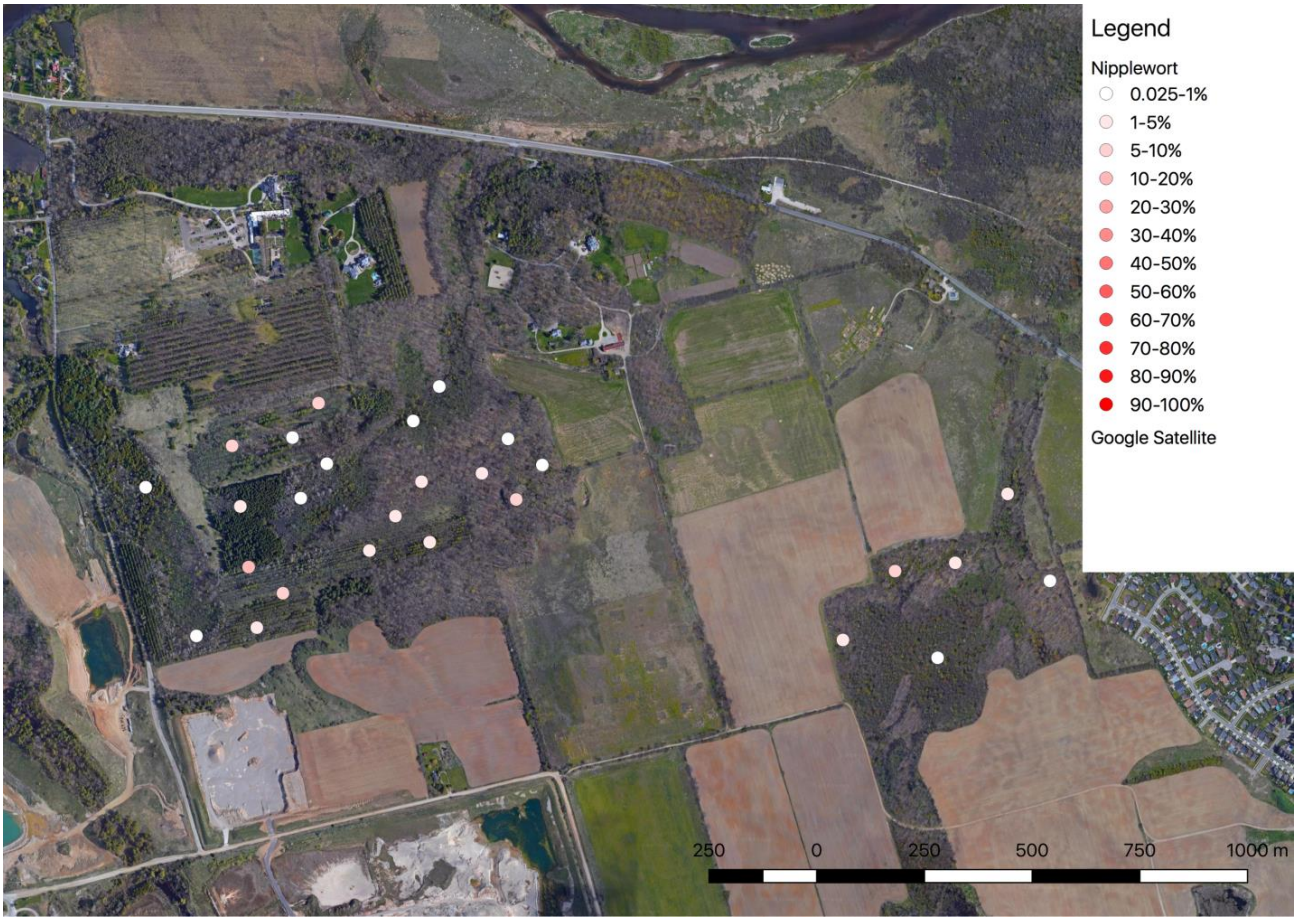

Figure A-53: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of nipplewort, *Lapsana communis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Twenty-seven out of 35 plots in two forests, Thompson Tract and the Hogsback, contained nipplewort, with the lowest being 0.05% and the highest being 12.5%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-54: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of nipplewort, *Lapsana communis*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Seven out of 28 plots in Cliffs Forest contained nipplewort, with the lowest being 0.025% and the highest being 0.575%. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

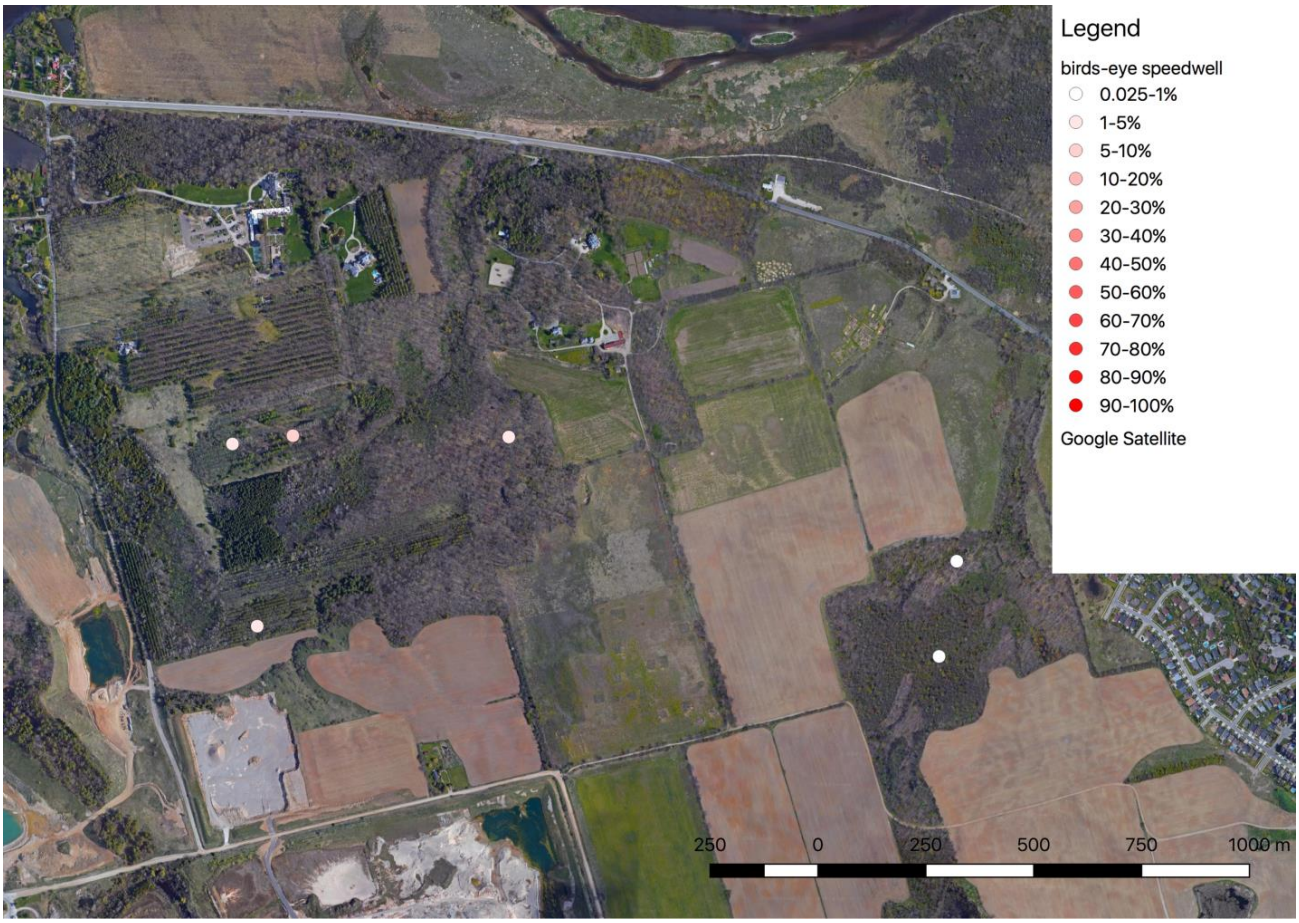

Figure A-55: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of birds-eye speedwell, *Veronica chamaedrys*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Six out of 35 plots in two forests, Thompson Tract and the Hogsback, contained birds-eye speedwell, with the lowest being 0.025% and the highest being 5.025%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Figure A-56: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of birds-eye speedwell, *Veronica chamaedrys*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Thirteen out of 28 plots in Cliffs Forest contained birds-eye speedwell, with the lowest being 0.025% and the highest being 18.75%. During sampling, *Veronica chamaedrys* was not always differentiated from its relative, *Veronica officinalis*, therefore these values likely underestimate its coverage. Percent cover is expressed on a gradient increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled from June to October 2019 in Cambridge, Ontario.

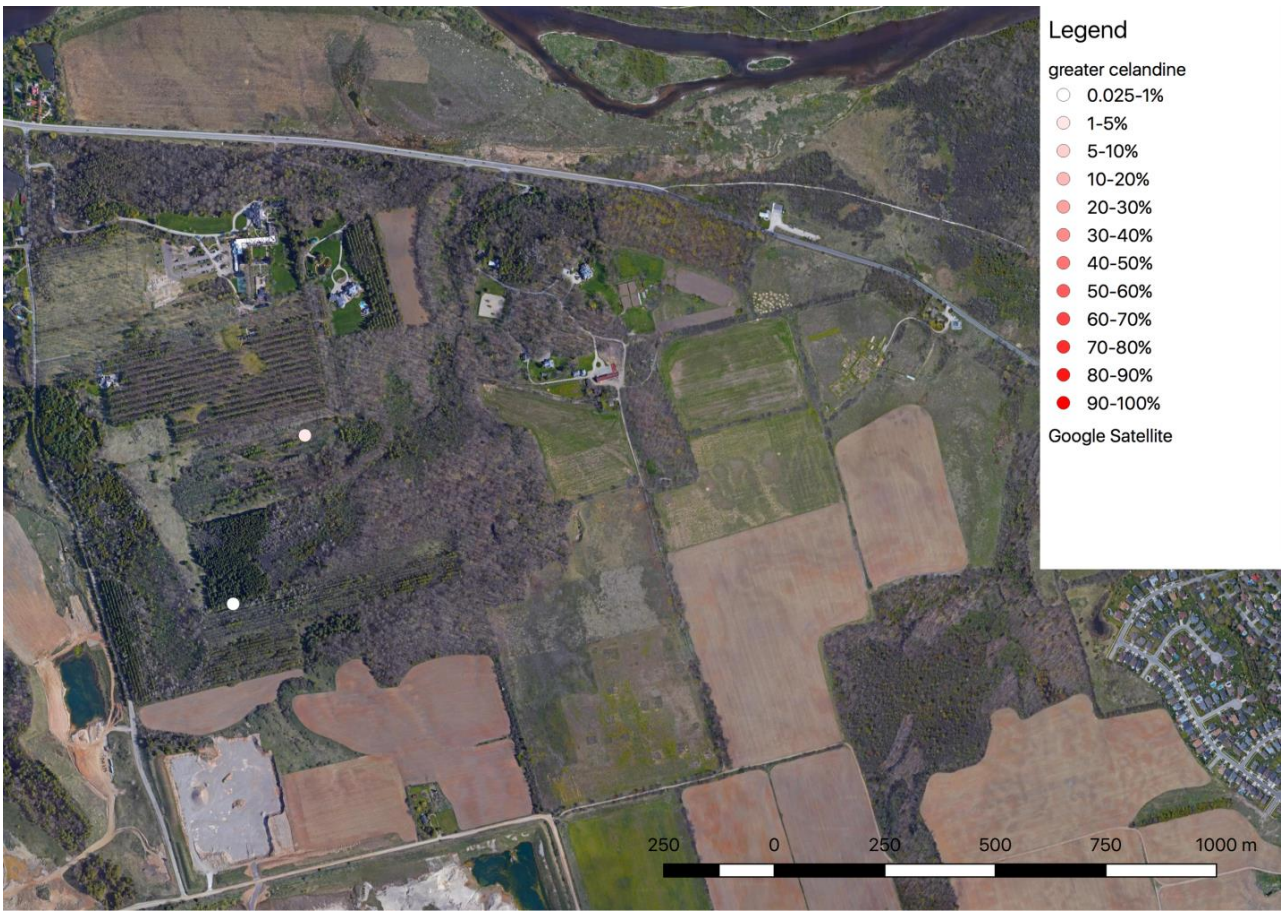

Figure A-57: Map of the ***rare*** **Charitable Research Reserve** depicting total percent cover of greater celandine, *Chelidonium majus*, in ground (0-0.5 m) layer within a 400m^2 plot (11.28 m radius). Two out of 35 plots in two forests, Thompson Tract and the Hogsback, contained greater celandine, with the lowest being 0.025% and the highest being 2.525%. Percent cover is expressed on a gradient, with lower percent cover being white to light red, increasing in colour intensity with increasing percent cover. Values were obtained from randomly generated plots sampled during June-September, 2018 in Cambridge, Ontario.

Appendix B: VSP Plot Maps

Figure B-1: Map of the ***rare*** **Charitable Research Reserve** depicting established VSP plots in the Hogsback with corresponding plot numbers.

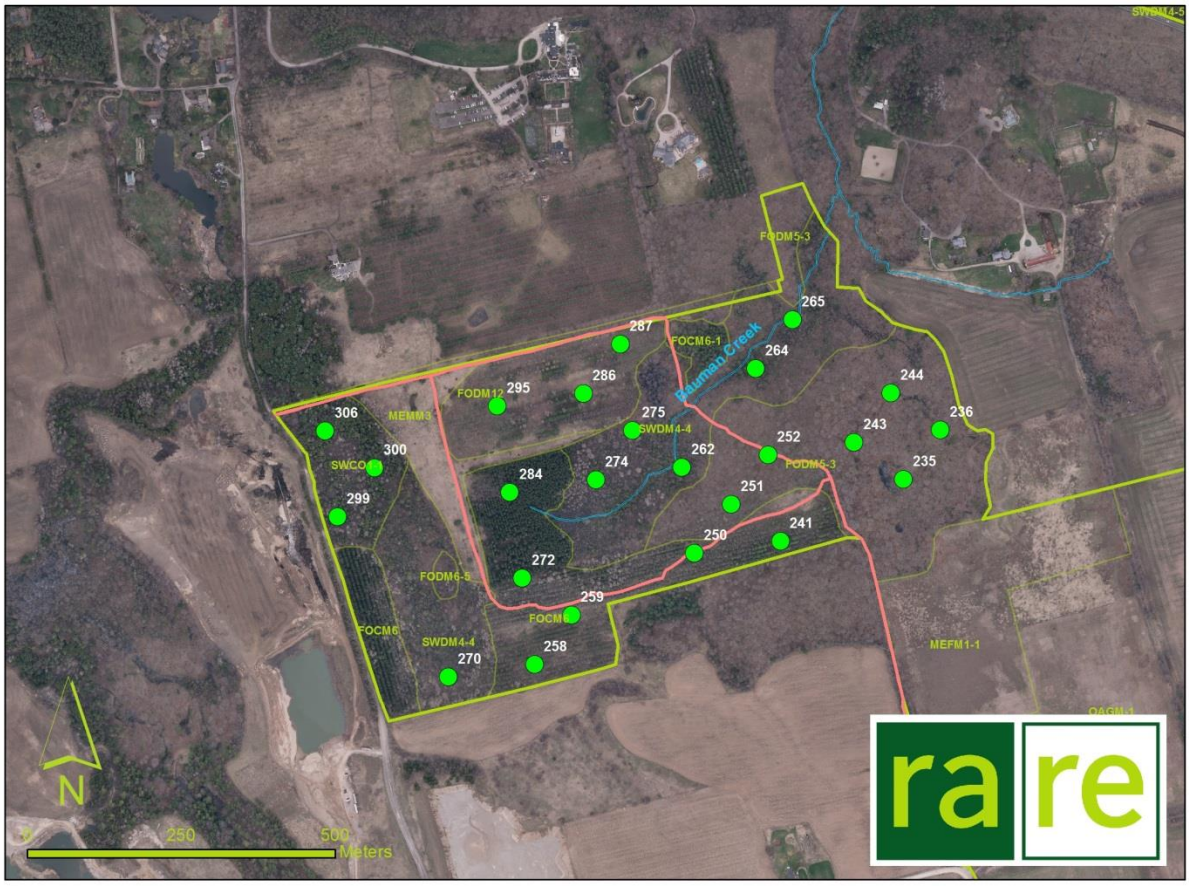

Figure B-2: Map of the ***rare*** **Charitable Research Reserve** depicting established VSP plots in Thompson Tract with corresponding plot numbers.

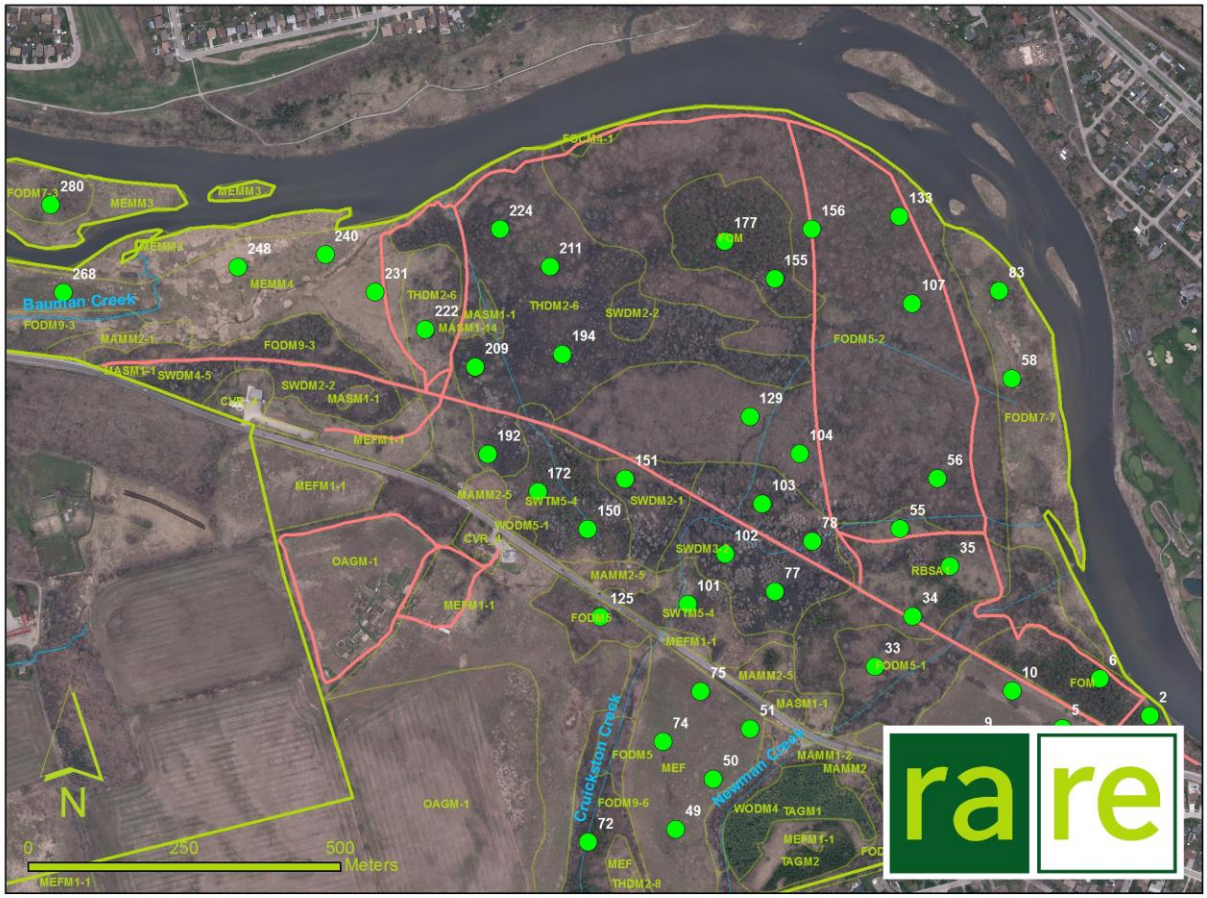

Figure B-3: Map of the ***rare*** **Charitable Research Reserve** depicting established VSP plots in Cliffs Forest with corresponding plot numbers. Plots sampled in 2019 were: 2, 6, 33, 34, 35, 55, 56, 77, 78, 101, 102, 103, 104, 107, 129, 133, 150, 151, 155, 156, 172, 177, 192, 194, 209, 211, 222, and 224.

Appendix C: Equipment List

The following is a comprehensive list of all necessary equipment and their purpose when following the Vegetation Sampling Protocol:

- Field data sheets (pages 1-7; found on ***rare's*** server)
- Waterproof paper and clipboard
- The VSP field inventory and monitoring pocket guide (Puric-Mladenovic and Kenney, 2015; also available ***rare's*** server)
- GPS (sub-metre GPS required for initial plot staking, at a minimum)
    - High-powered GPS with sub-metre accuracy (SX Blue II + GNSS) paired with a tablet synced to ArcPad to find the exact plot centre selected randomly in GIS
    - Garmin GPS (*e*trex 20) which typically has a 3-5 metre accuracy
- Flagging tape and florescent marking flags
- Rebar (and potentially a metal detector for resampling efforts to locate centre of plot)
- 2x CFE Measuring Chains (minimum 20m) (or pre-measured and pre-marked ropes, cut to 11.28 m) and clothesline clops
- 5x camping pegs to hold down the ends of each rope (N, S, E, W, and centre)
- Two-way ultrasonic range finder/laser distance meter
- 2x 2 metre collapsible sticks
- Caliper (2.5cm to 5 cm) to measure sapling dbh when sampling regeneration within the subplots
- dbh tape to measure the diameter of all trees greater than 5 cm within the plot
- Small cylinder with grid (i.e.: moosehorn densitometer, or something made with PVC pipe to assist with percent canopy closure estimates
- Binoculars
- Phone/Camera to assist with plant identification. Photos should aim to capture any fruiting heads, flowers, steam, leaf margins and roots (for sedges and grasses) and should be taken against a solid background (i.e.: clipboard) and labeled with habitat and Plot ID
- Masking tape, sharpie, plastic bag for collection of grasses or other plant material for ID
- Haglöf Electronic Clinometer to measure tree height

Helpful resources

- Books:
    - Farrar, J.L. 2017. *Trees in Canada*. Ottawa, Ontario: Fitzhenry and Whiteside Ltd.
    - Soper, J.H. and M.L. Heimburger. 1990. *Shrubs of Ontario*. Toronto, Ontario: Royal Ontario Museum.
    - Newcomb, L. *Newcomb's Wildflower Guide*. Little, Brown and Company
    - Voss, E.G. 1972. *Michigan Flora: Part 1 Gymnosperms and Monocots*. Michigan: Cranbrook Inst of Science.
- Websites:
    - Ontario Wildflower: http://www.ontariowildflowers.com/
    - Go Botany –New England Wild Flower Society: http://gobotany.newenglandwild.org/full/
- Apps:
    - iNaturalist: VSP teams can join the *VSP iNaturalist Project* to have experts assist with plant ID

Appendix D: New Species List

Scientific Name	Common Name	Form
Betula nigra	River Birch	SH
Carex aurea	Golden Sedge	SE
Carex debilis	Weak Sedge	SE
Carex radiata	Eastern Star-like Sedge	SE
Cinna latifolia	Drooping Woodreed	GR
Cynoglossum boreale	Northern Wild Comfrey	FO
Doellingeria umbellata var. umbellata	Southern Flat-topped White Aster	FO
Galium odoratum	Sweet Bedstraw	FO
Geranium molle	Dovefoot Geranium	FO
Geum macrophyllum	Large-leaf Avens	FO
Ilex mucronatus	Mountain Holly	SH
Lonicera hirsuta	Hairy Honeysuckle	VI
Ludwigia palustris	Marsh Purslane	FO
Prunus nigra	Canada Plum	SH
Ranunculus hispidus var. nitidus	Bristly Buttercup	FO
Ranunculus ficaria	Fig Buttercup	FO
Tanacetum balsamita	Costmary	FO
Viola pubescens var. scabriuscula	Smooth Yellow Violet	FO

Appendix E: Invasive Species Detected on *rare* Property during VSP Sampling

SCIENTIFIC NAME	COMMON NAME	HOGSBACK (2018)	THOMPSON TRACT (2018)	CLIFFS FOREST (2019)
Acer negundo	Manitoba Maple	x	x	x
Acer platanoides	Norway Maple			x
Achillea millefolium	Common Yarrow			x
Agrostis stolonifera	Creeping Bentgrass			x
Alliaria petiolata	Garlic Mustard	x	x	x
Arctium lappa	Great Burdock	x	x	x
Arctium minus	Common Burdock	x	x	x
Asparagus officinalis	Wild Asparagus			x
Barbarea vulgaris	Yellow Rocket			x
Berberis thunbergii	Japanese Barberry	x	x	x
Berberis vulgaris	Common Barberry	x	x	x
Bromus inermis	Smooth Brome		x	x
Carex spicata	Spiked Sedge			x
Centaurea nigra	Lesser Knapweed; Black Knapweed		x	
Chelidonium majus	Greater Celandine		x	
Cirsium arvense	Canada Thistle	x	x	
Cirsium vulgare	Bull Thistle		x	
Convallaria majalis	Lily-of-the-valley	x		x
Dactylis glomerata	Orchard Grass			x
Daucus carota	Wild Carrot	x	x	x
Dianthus armeria	Deptford Pink			x
Dipsacus follunum	Teasel			x
Echinacea purpurea	Eastern Purple Coneflower			x
Elaegnus umbellata	Autumn Olive		x	x
Elymus repens	Quack Grass			x
Epilobium hirsutum	Great Hairy Willow-herb		x	x
Epilobium parviflorum	Small-flower Willow-herb			x
Epipactis helleborine	Common Helleborine	x	x	x
Euonymus alata	Winged Euonymus		x	
Festuca rubra	Red Fescue			x
Galeopsis tetrahit	Common Hemp-nettle			x
Galium mollugo	Smooth Bedstraw		x	x
Galium odoratum	Sweet Bedstraw	x		
Geranium molle	Dove's-foot Crane's-bill		x	
Glechoma hederacea	Creeping Charlie			x
Hesperis matronalis	Dame's Rocket		x	x
Hieracium caespitosum	Yellow Hawkweed		x	x

Hypericum perforatum	Common St. John's-Wort		x	x
Lapsana communis	Common Nipplewort	x	x	x
Leonurus cardiaca	Motherwort		x	
Leucanthemum vulgare	Ox-eye Daisy			x
Ligustrum vulgare	Common Privet		x	x
Linaria vulgaris	Butter-and-eggs; Toadflax		x	x
Lonicera morrowii	Morrow's Honeysuckle	x	x	x
Lonicera tatarica	Tartarian Honeysuckle		x	x
Lotus corniculatus	Bird-foot Trefoil			x
Lythrum salicaria	Purple Loosestrife	x	x	x
Malus pumila	Common Apple			x
Medicago lupulina	Black Medick			x
Morus alba	White mulberry			x
Myostis sp.	Forget-me-not sp.		x	x
Nasturtium officinale	Watercress	x	x	x
Oxalis stricta	Yellow Wood-sorrel	x	x	x
Phleum pratense	Timothy		x	x
Phragmites australis	Common Reed		x	
Pinus sylvestris	Scots Pine			x
Plantago lanceolata	English Plantain			x
Poa compressa	Canada Blue Grass		x	x
Poa pratensis	Kentucky Blue Grass	x	x	x
Potentilla recta	Rough-fruited Cinquefoil			x
Prunella vulgaris	Common Heal-all	x	x	x
Prunus mahaleb	Perfumed Cherry			x
Ranunculus acris	Tall Buttercup	x	x	x
Rhamnus cathartica	Common buckthorn	x	x	x
Rhamnus frangula	Glossy buckthorn	x	x	x
Robinia pseudoacacia	Black Locust		x	
Rosa multiflora	Multiflora rose	x	x	x
Rumex obtusifolius	Bitter Dock		x	
Saponaria officinalis	Bouncing-bet			x
Silene latifolia	White Campion			x
Solanum dulcamara	Bittersweet Nightshade	x	x	x
Sonchus arvensis	Field Sow-thistle		x	
Sonchus oleraceus	Common Sow-thistle		x	
Sorbus aucuparia	European Mountain-ash	x	x	x
Syringa vulgaris	Common Lilac			x
Tanacetum balsamita	Costmary		x	
Tanacetum vulgare	Common Tansy			x
Taraxacum officinale	Dandelion	x	x	x

Tragopogon pratensis	Meadow Goat's-beard	x		
Trifolium pratense	Red Clover			x
Trifolium repens	White Clover		x	
Tussilago farfara	Coltsfoot	x	x	
Urtica dioica dioica	European Stinging Nettle			
Veronica chamaedrys	Bird's-eye Speedwell	x	x	x
Veronica officinalis	Common Speedwell	x	x	x