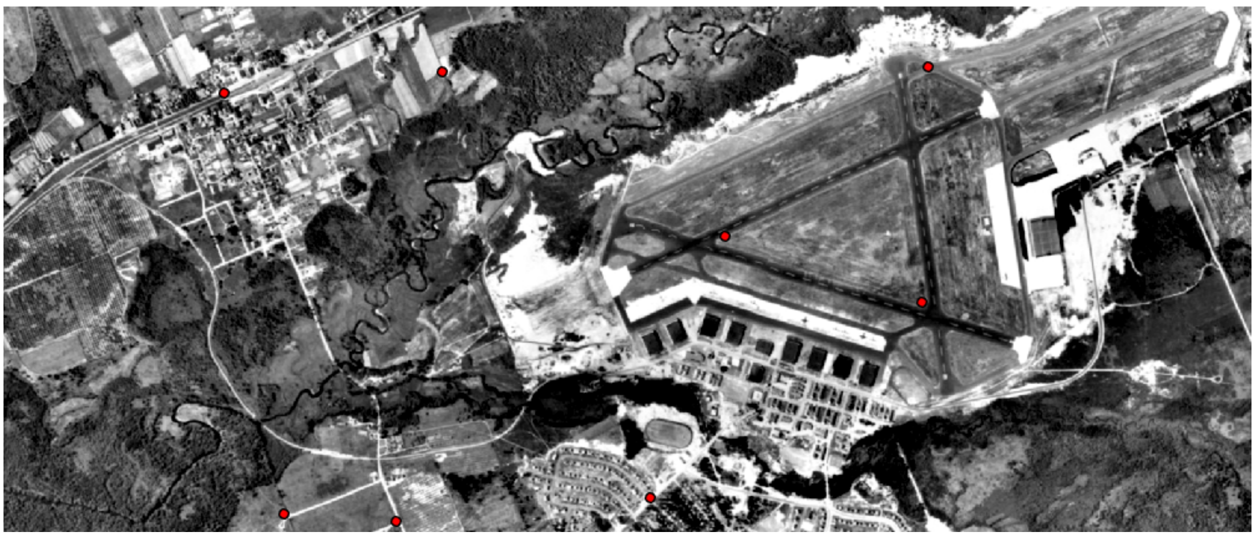
Sand Barrens Mapping Report



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Introduction

The Atlantic Coastal Sand Barrens is an endangered ecosystem found in the Annapolis Valley region of Nova Scotia, and the Cape Cod/Martha's Vineyard Region of New England. This ecosystem is found in locations with deep, fast-draining sands, and warm climates. The ecosystem is characterized by the presence of a variety of fire-dependent plant and lichen species notably, the globally endangered broom crowberry (*Corema conradii*), sand barren golden heather (*Hudsonia ericoides*), Rockrose (*Helianthemum canadense*) and Cladonia lichen (*Cladonia* spp.), succeeding into jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*). Closely associated with the sand barren habitats are peatlands, that occupy the depressions between the sand ridges.

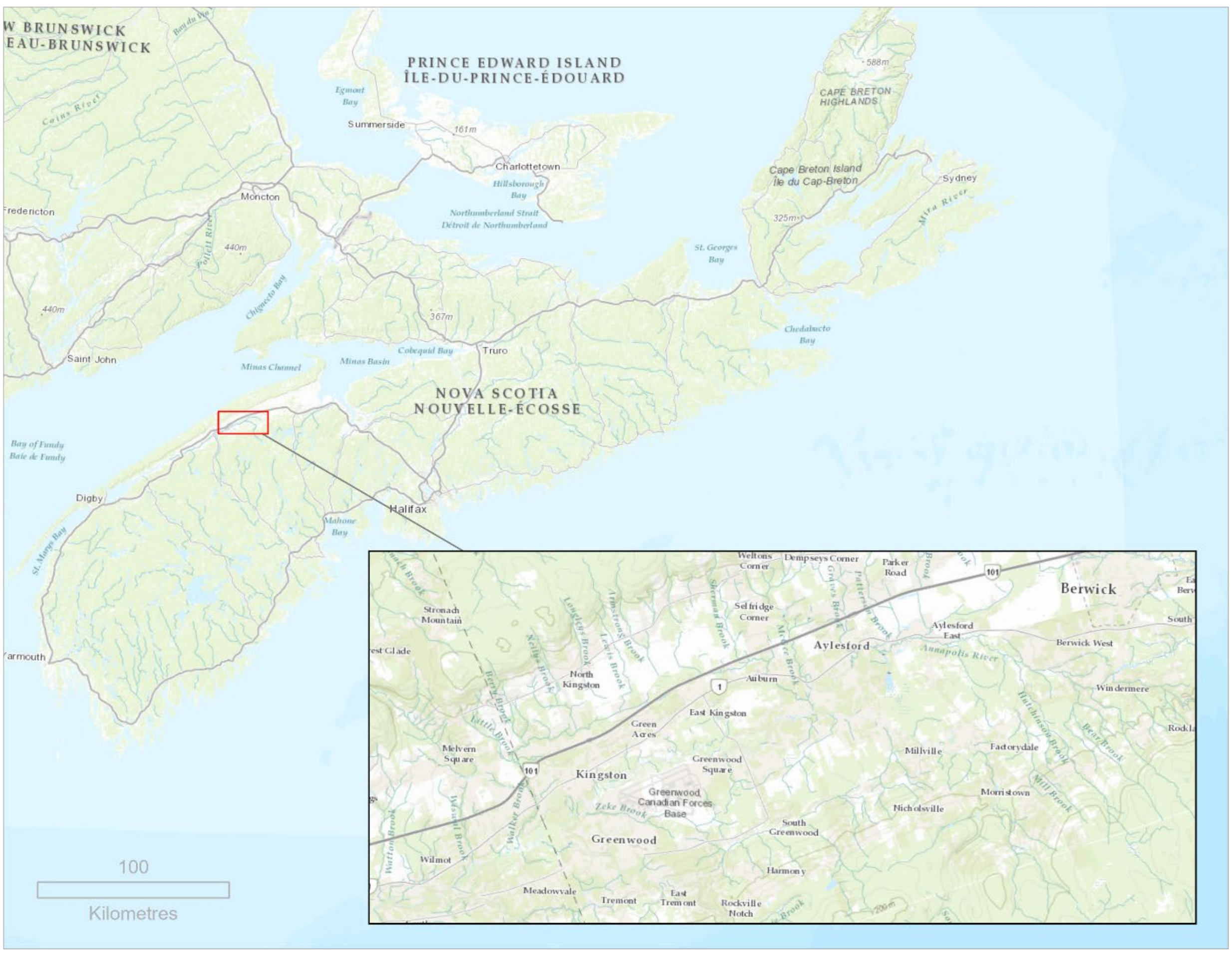

Figure 1. Study area showing the basic extent of the Annapolis Valley Sandbarren area. Basemap from Esri.

While there are no known dedicated maps or detailed descriptions that describe the historical extent of the sand barrens, it is widely understood that the total area of sand barrens has decreased over time. During a botanical expedition in 1920, Fernald writes of exploring the sand barrens collecting botanical specimens for the Harvard herbarium collection (Fernald, 1921):

> "Near Berwick and from there to Wilmot were vast uncultivated plains carpeted, wherever dry enough, with a close growth of the New Jersey pine barren Corema Conradii, and, although these barrens were the finest we say, we had to content ourselves with small and unspoiled remnants of them at Middleton. Unspoiled, because, although these Corema heaths are forbidding enough in appearance and at the surface are highly acid and barren, when deeply plowed and cultivated they are transformed into the great orchards for which "the Valley" is everywhere farmed."

Fernald's account describes a vaster, more prolific ecosystem than found in the region today, while also mentioning land-use pressures from agriculture. The conversion of sand barrens to agriculture persists today, along with other pressures including: wildfire management, construction of roads (notably the Provincial Series Highway 101), development from the air force base in Greenwood, and the slow increase of residential development in the neighboring area.

Historical aerial photography was used to document the invasion of scots pine (*Pinus sylvestris)* into sand barrens (Catling and Carbyn, 2005), however this analysis of land cover change has yet to be completed on a larger scale. The goal of this project is to analyze historical aerial photography across the sand barren region of the Annapolis Valley to create a digital map that can be used to examine historical changes in sand barren distribution over time.

Once the historic air photos have been analyzed and converted to a seamless photo mosaic, analysis will be done of 41 areas of interest to track change in land cover over time at those locations. These analyses and the raw photo product will be shared online as a webmap to guide research and provide local interest.

Methods

Image Preparation

The initial source information from this project were two aerial photography surveys centered around the Greenwood Airforce Base. Two flights were provided, one from 1945 and the other from 1955. Both surveys were black-and-white photography, captured in flight lines traveling in approximately East-West orientation. Attempts to determine the precise flight characteristics proved unsuscessful after an unsuccessful attempt to match flight line and survey numbers against records from the Canadian National Air Photo Library (NAPL).

Historic photographs were not in great condition, showing some warping, scuffs, and previous marking from acetate markers. Each image was scanned as 600 DPI Gray Scale images in the Tagged Image Format File (TIFF), following procedure documented by the University of Waterloo - University Map Library Historical Air Photo Digitization Project (Dodsworth, 2008).

Following the scanning of the historic air photos, digital images were processed by NSCC Applied Research Staff. Working with historical air photos can be a difficult process, especially when relatively little is known about the flight. The time difference between the flight period and processing date also creates challenges for creating control points to tie-down the images into geographic space.

The first step of the image analysis was to convert all the photos to the same size in order to accurately apply global analysis parameters to each photo. All images were cropped to a standard size using a batch edit in Irfan view. Because all photos had the same origin and were scanned in the same orientation (flight line number in bottom -left corner) images were cropped to a dimension of 5575 x 5520 pixels.

Photogrammetric Analysis I

Next a blanket mask was created in Agisoft PhotoScan (Version 1.2.3 Build 2399) that removed fiducials, flight line numbers, holepunch voids, and flight line numbers from the analysis extent.

Figure 2. Example image from survey before (left) and after (right) applying crop and mask.

After the mask was created, it was assigned to each image in the survey. With the masks set-up, the first steps were to determine whether the alignment was possible, and if so, whether the 1945 or 1955 datasets were better suited for this project. Photos were processed using image matching technology set at the following parameters.

Table 1. Processing steps for initial photogrammetry analysis in Agisoft PhotoScan.

Step	**Setting**
Align Photos	High (Pair Preselection Disabled) Key Points = 10,000 Tie Points = 1,000 Constrain Features by Mask = YES
Build Mesh	Surface Type = Height Field Source Data = Sparse Cloud Face Count = High Interpolation = Enabled Point Classes = All
Build Orthophotomosaic	Surface = Mesh Blending Mode = Mosaic

After running the previous steps, an unscaled, non-georeferenced image mosaic was created for both the 1945 (Figure 3) and 1955 (Figure 4) aerial surveys. These images were then roughly georeferenced in ArcGIS Pro to the Esri Imagery with Labels basemap through manual georeferencing, making use of road and rail-line features that were common between the historic photos and the modern Esri imagery. This was accomplished using the orthorectification toolbar. Following this step, it was determined that the 1955 survey better covered the study area than the imagery from 1945 and was therefore used in subsequent processing steps.

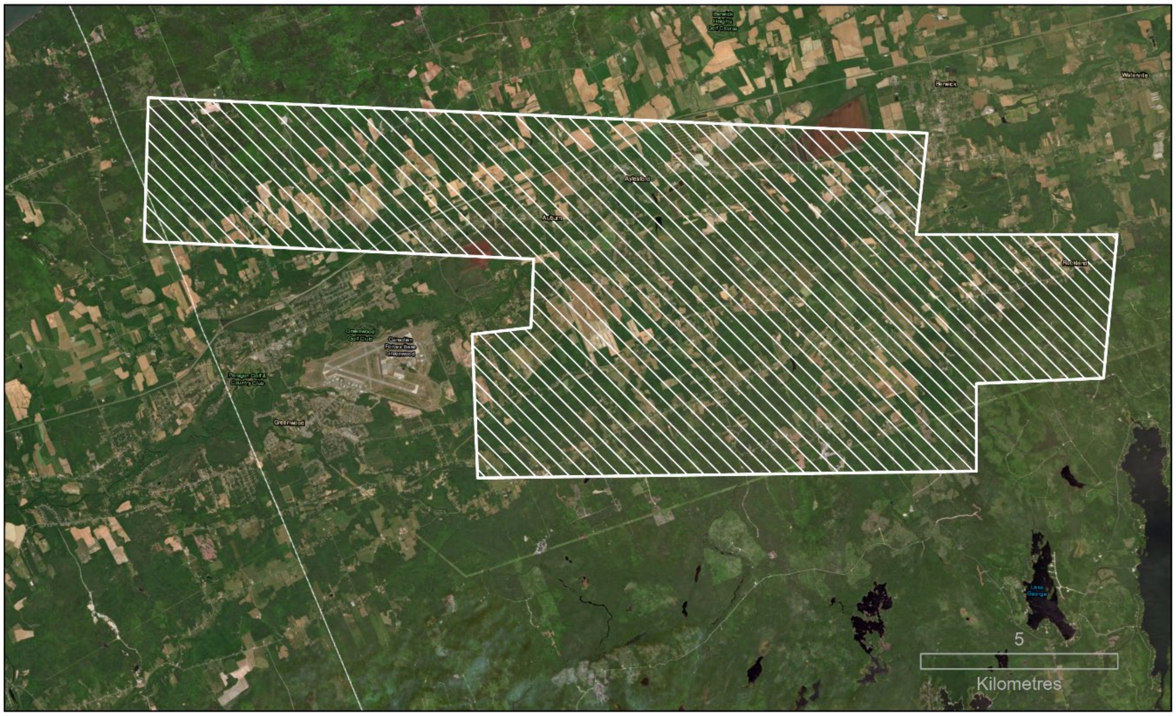

Figure 3. Approximate extent of 1945 historical imagery, showing inadequate coverage of area of interest.

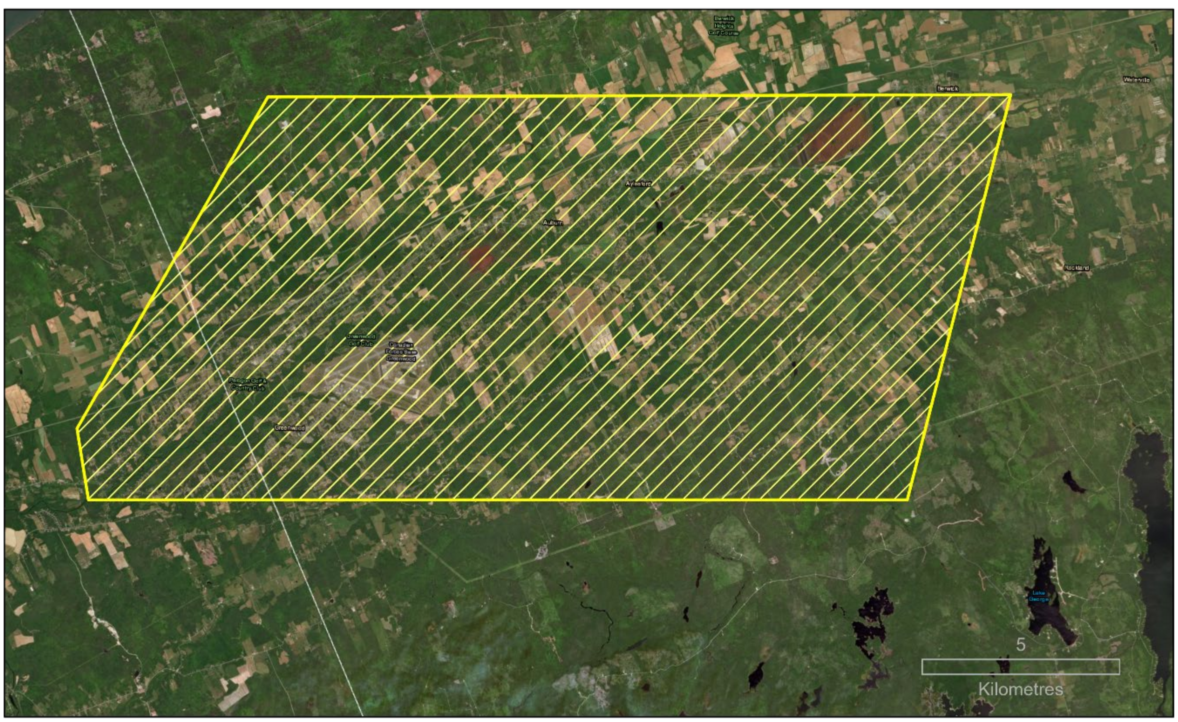

Figure 4. Approximate extent of 1955 historical imagery, showing inadequate coverage of area of interest.

Collection of Ground Control Points

Following the initial orthorectification of the image mosaic in ArcGIS Pro, the next step required a careful analysis of the historic air photos in combination with the Esri basemap. In ArcGIS Pro a new point feature class was created to hold control points. A field named "ID" was created, to hold information surrounding target IDs. Each point location was named accordingly (target 1, target 2) to match the default naming convention in PhotoScan.

In total, 195 reference points were created across the study area taking care to ensure the points were as well-spaced as possible. After creating a point location in ArcGIS Pro, the same point location was added in Agisoft PhotoScan, and carefully refined for each historical image.

Figure 5. Locations of Ground Control Points (GCPs) used to georeference historical aerial photography in Agisoft PhotoScan. Basemap from Esri.

Finally, an X, Y and Z field were assigned to the point feature class in ArcGIS Pro. The X, and Y field were calculated from the Northing and Easting of the UTM (CSRS UTM

Zone 20N and the Z field was extracted from the Provincial Enhanced Digital Elevation Model (DEM) (Nova Scotia Geomatics Centre, 2000). This data was exported as a CSV file.

Photogrammetric Analysis II

The CSV file was then imported in the reference pane in Agisoft PhotoScan, assigning an X,Y and Z location to each target. An accuracy of 1m was assigned to all the targets. The initial camera alignment was optimized based on the position of the 195 reference targets with a ten-parameter optimization transformation. At this point, the model was much more accurately positioned in geographic space. The whole photogrammetric analysis was completed, resulting in an orthophotomosaic with a spatial resolution of 0.7m by 0.7m (Table 2).

Table 2. Processing steps for initial photogrammetry analysis in Agisoft PhotoScan.

Step	Setting
Optimize Alignment	Fit f, Fit cx, cy, Fit k1, Fit k2, Fit k3, Fit k4, Fit b1, Fit b2, Fit p1, Fit p2
Build Dense Cloud	Quality = Medium Depth Filtering = Aggressive
Build Mesh	Surface Type = Height Field Source Data = Sparse Cloud Face Count = High Interpolation = Enabled Point Classes = All
Build Orthophotomosaic	Projection = UTM Zone 20 N Surface = Mesh Blending Mode = Mosaic Pixel size = 0.7m
Export Orthophotomosaic	Projection = UTM Zone 20 N Pixel size = 0.7m

Accuracy Assessment

Following the creation of the improved orthophoto rectification, twenty-five independent control points were created randomly throughout the scene. A copy of these control points was created. Control points were manually shifted to features that were identifiable in both the historic imagery and the current basemap. Using the Near (GeoProcessing) tool in ArcGIS Pro, the distance between the same feature in the basemap and the historical air photo was calculated, and analyzed to provide an estimate in error for interpreting the imagery.

Historic Air Photo Interpretation

With the orthophotomosaic finalized, the next step was to delineate historic landcover across the study. At this point in the study, analysis was limited to a smaller geographic area centred around some field locations. Land cover was interpreted into seven different land cover classes within these buffer areas (Table 3).

Table 3. Definition of Land Cover classes used for analysis.

CODE	Landcover	Description
1	Agriculture	All agriculture, excluding orchards
2	Barrens	Sand barren – open areas, scattered pine, sand wash-outs
3	Developed	Roads and urban areas
4	Forest	Forests
5	Open Water	Lakes, Rivers, Ponds
6	Orchard	Apple orchards (may contain some peach and cherry)
7	Wetland	Bogs, Swamps and Marshes

Interpreting historical air photos can be a difficult process. In a way to ensure consistency between land cover analysis now, and into the future. A series of rules was created to help with the analysis. These rules are defined in the following sections:

Agriculture

Agriculture was defined as all types of agriculture, except for orchards. This included areas of bare soil with square edges, vegetated fields and pasturelands (Figure 6).

Figure 6. Agricultural areas scattered through the area. Showing a combination of vegetated fields (darker) and bare soil (bright).

Barrens

Barrens were defined as areas, often near wetlands with scattered areas of bare sand, light coloured areas, that appear to correspond to mats of *Cladonia* interspersed with *Corema*. Barren areas also had scattered trees, likely pine. Many of the barren sites appear to have been historically managed for agriculture (Figure 7)

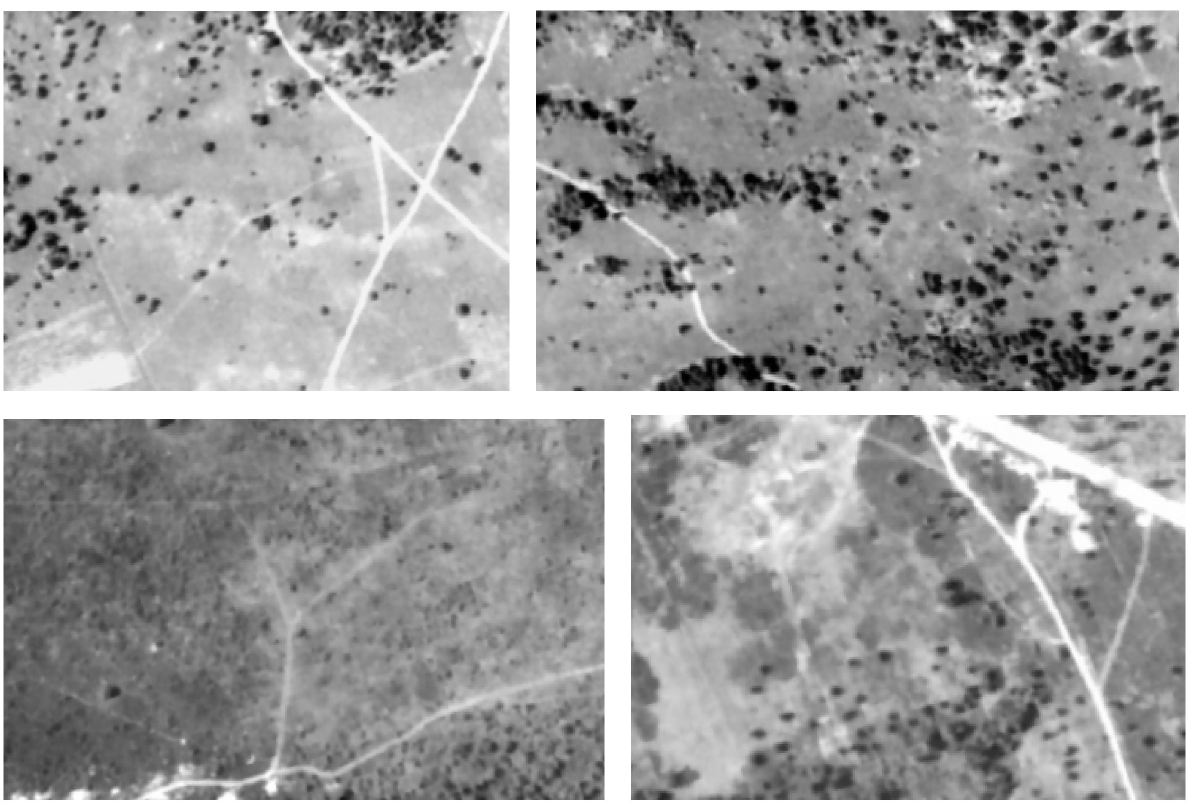

Figure 7. Barren areas throughout the study area. These shots show barrens typical for the study area, with all with the exception of the upper-right example, showing some evidence of past agricultural influence.

Developed
The developed features included roads, urban areas (back-yards), baseball/soccer fields, and parking lots (Figure 8).

Figure 8. Examples of developed areas from the 1955 imagery, left shows military housing in Greenwood, right shows the town of Kingston.

Forest
Forested areas where characterized by an unbroken area of trees, with a canopy cover of at least 50% (Figure 9).

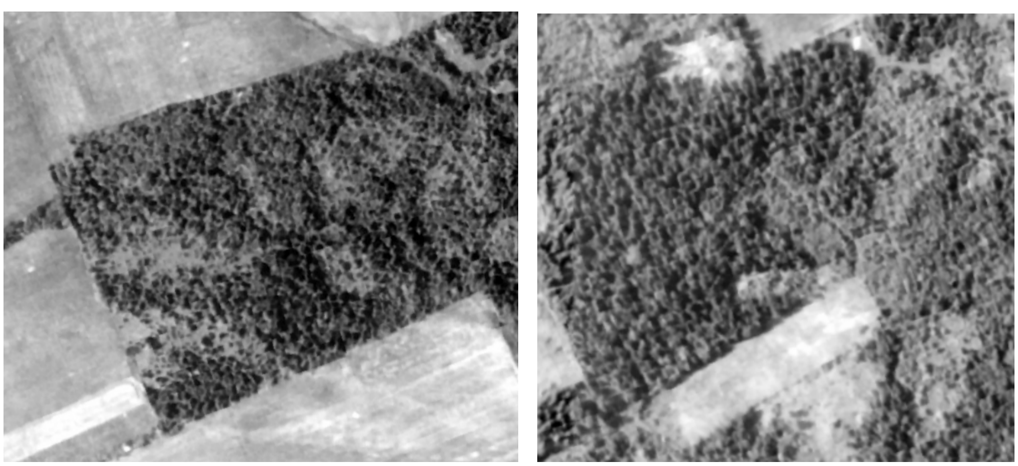

Figure 9. Examples of forested areas from the 1955 imagery, left shows predominately softwood forest right shows mixed wood forest, both adjacent to agricultural areas.

Open Water
Open water included ponds, rivers, and lakes. In the gray-scale imagery from the 1950s, these appear as very dark colours (Figure 10).

Figure 10. Examples of bare water areas from the 1955 imagery, left shows a holding pond of a dammed stream, right image shows a bend in the Annapolis River, near Kingston NS.

Orchard

Orchard was a main cover type in the study area. While the Annapolis Valley is known in present-day as an apple-growing region, the extent of fruit tree plantations in the Annapolis Valley was much greater in the past than present day (Figure 11).

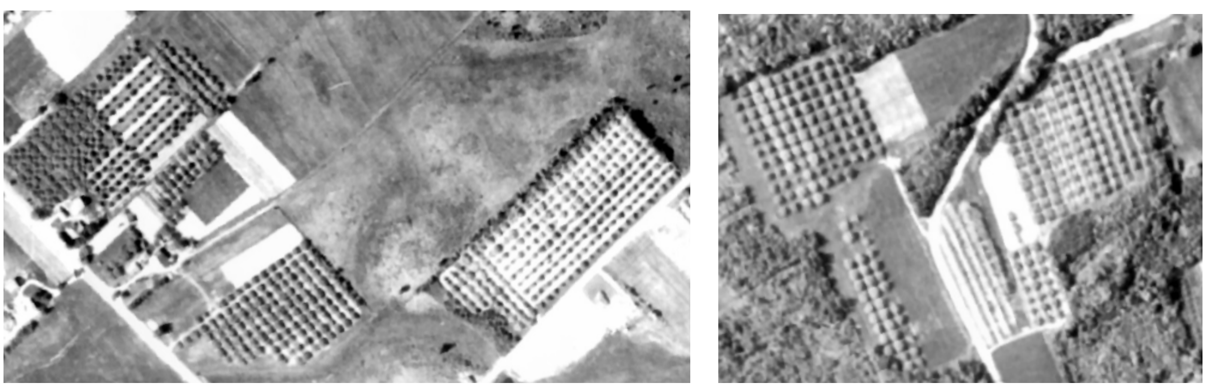

Figure 11. Examples of orchards from the 1955 imagery captured near Berwick on the eastern extent of the imagery coverage.

Wetland

Wetlands identified in this analysis are mostly bogs/dry bogs These areas look quite similar to the barrens in that they are natural areas (no square edges), but are slightly darker in colour, tend to be bordered by small trees that have established on the margins of the wetland (Figure 12).

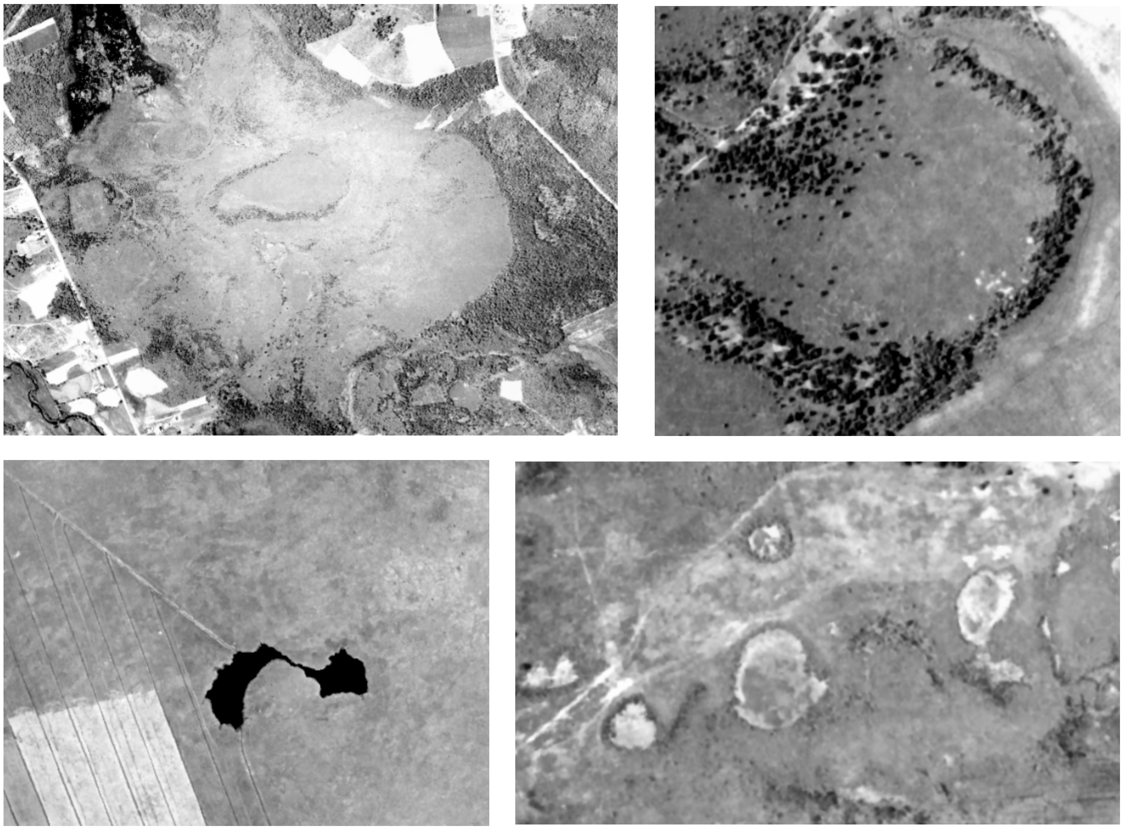

Figure 12. Examples of four different wetlands throughout the study area. Top left is a large peat bog, top right is a more typical peat bog surrounded by trees rooted on the wetland boundary. Bottom-left is the peatland at Caribou bog, flanked by peat harvesting and some open water, bottom right is some interesting wetlands south of Auburn.

Land Cover Analysis

After the land cover had been interpreted in the appropriate areas, analysis was completed for fourty-one field locations represented as a point feature-class, as chosen by sand barren researchers. These sites were broken into five different categories, representing successional stages of the sand barren ecosystem (

Table 4). Each of the fourty-one field locations were intersected with the interpreted land cover dataset derived from the 1955 imagery. This data was then analyzed to track the change in land cover across the sites. The swamp site was excluded from further analysis.

Table 4. Description and count of field sites, used in historic air photo analysis.

Landcover	**Description**	**Count ()**
Corema	Typical “Sand barren” habitat, low *Corema* bushes, *Cladonia*, with sparse pine coverage	(7)
Pine/Corema	Similar to *Corema* habitat, with a denser pine canopy	(11)
Pine	Dense pine canopy, red pine and jack pine.	(10)
Dry Bog	Wetland sites, normally found in depressions between sand ridges, dominated by ericaceous vegetation and sphagnum mosses.	(12)
Swamp	Treed wetland	(1)

Web-Mapping

With the orthophoto mosaic finalized, it was converted to a Map Tile Package. Tiles were generated in PNG format, with a detail level of 17 (Figure 13). Metadata were updated to allow for searchability in ArcGIS Online, and ArcMap.

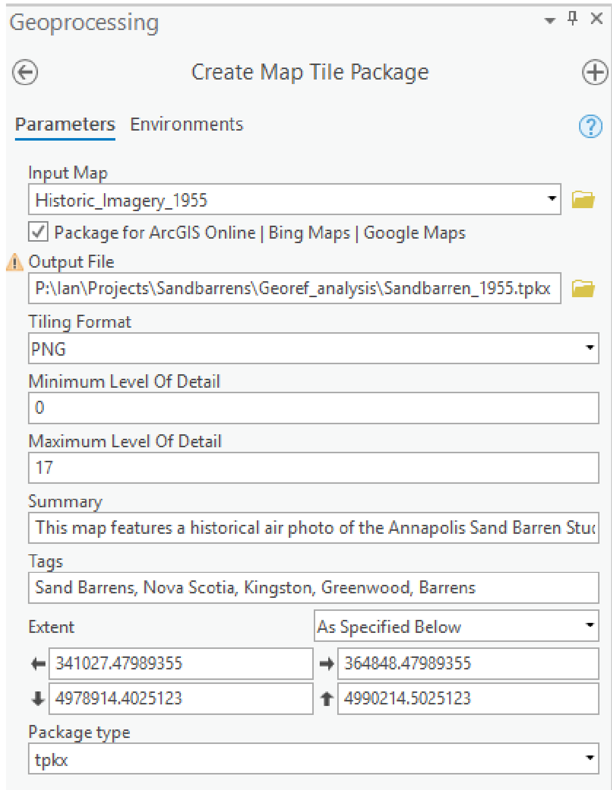

Figure 13. Parameters used to create Map Tile Package

After the map tile package was created, the package was uploaded to ArcGIS Online and published so it was available to all. It was added to a Web-map, which was then referenced in a custom web-app in WebApp Builder, allowing anyone with access to the internet to access the imagery. The link to the web-app was shortened using the bitly link editor to bit.ly\historicsand, and is compatible with computers, cellphones and tablets without any specialized software.

Results & Discussion

Photogrammetric Analysis II

Overall the photogrammetric analysis turned out well. There were a few holes in the imagery, and some artefacts among image seamlines, especially in forested areas. These results are consistent with other work worth historical aerial photography. The same workflow will later be completed with imagery from the 1970s and

Accuracy Assessment

After running the near analysis between the two set of reference points, the mean error was found to be 9.89m with a standard deviation of 5.63m. In pixels, this translated to a mean error of 14 pixels and a standard deviation of 8 pixels (Table 5).

Table 5. Accuracy assessment of independent control points.

ID	Error (m)	Error (pixels)
1	9.01	13
2	12.93	18
3	7.39	11
4	13.19	19
5	6.88	10
6	2.11	3
7	16.01	23
8	16.30	23
9	17.01	24
10	14.84	21
11	1.90	3
12	4.64	7
13	3.69	5
14	16.84	24
15	15.17	22
16	18.68	27
17	4.55	6
18	2.13	3
19	6.75	10
20	8.98	13
21	6.85	10
22	19.40	28
23	10.14	14
24	2.24	3
25	9.67	14
Mean Error m/pixels	**9.89**	**14**
Standard Deviation m/pixels	**5.63**	**8**

Historic Air Photo Interpretation

Historic air photo interpretation was completed for the area adjacent to the 41 sites. A total of 1,328 hectares (3,281 acres) were delineated into the seven predefined categories. For the initial analysis, barren was the most common land cover (31%), followed by Wetland (30%) agriculture (21%), forest (15%), orchard (2%), developed (1%) and open water (<1%) (Figure 14).

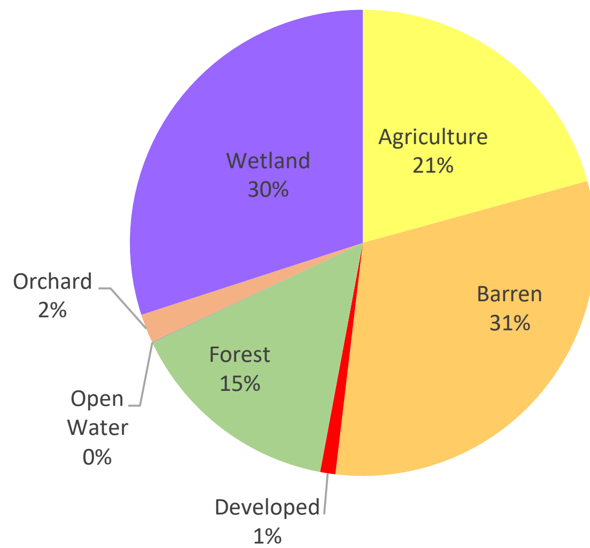

Figure 14. Percentage of land cover for initial analysis of 1955 imagery surrounding 41 initial study sites. Total area coverage of 1328 hectares (3281 acres).

Land Cover Analysis

After examining the 41 sites, results were summarized by land cover type (Table 5). Charts were made to show the transition between sites.

Table 6. Present data habitat type compared with image-derived land cover from 1955.

Present Day	1955 Imagery Derived Landcover				
Habitat Type	Agriculture	Barren	Forest	Wetland	Total
Corema	3	4	0	0	7
Pine\Corema	2	8	0	1	11
Pine	1	8	1	0	10
Dry Bog	0	0	0	12	12
Total	6	20	1	13	40

Corema

For the seven current-day corema sites, four are found in historic sand barren sites. The remaining three current-day corema sites are found in what was historic agricultural areas (Figure 15)

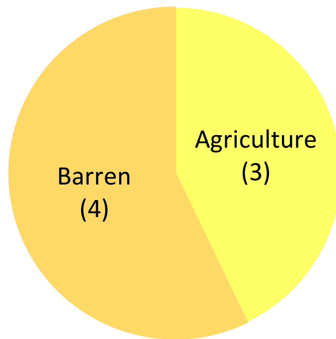

Figure 15. Proportional historic land use (1955) of current-day corema barrens in the Annapolis Valley, Sand Barren Study Area (n = 7).

Pine/Corema

For the eleven current-day pine/corema sites, eight are found in historic sand barren sites, two sites are found in what was historic agricultural areas , and one site was found in a historic wetland (Figure 16). This is somewhat expected, as the pine/corema stage, is somewhat of an intermediary stage between corema and forest. While the transition from wetland to pine/corema might seem like an odd transition, upon further inspection it has occurred in part of the landscape that has undergone a large amount of wetland alteration, and is not expected to be a regular trend when the remainder of the landscape has been analyzed.

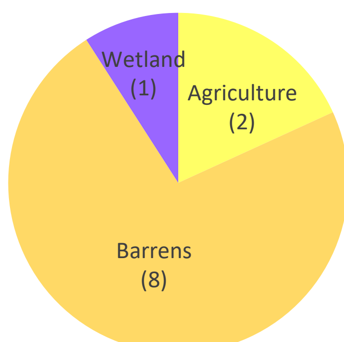

Figure 16. Proportional historic land use (1955) of current-day corema barrens in the Annapolis Valley, Sand Barren Study Area (n = 11).

Pine

Of the ten current-day pine sites, the majority (8) of sites were sand barrens in 1955. This shows that without regular disturbance, some barren locations succeed to pine forests. Of the ten surveyed sites, one site had been agriculture in 1955, and another persisted as forest (Figure 17). It was surprising to see that at one location, succession could have progressed at such a rapid pace from agriculture to forest. It will be interesting to see the land-cover change during the intervening years, and what frequency of intervention has led to this rapid change.

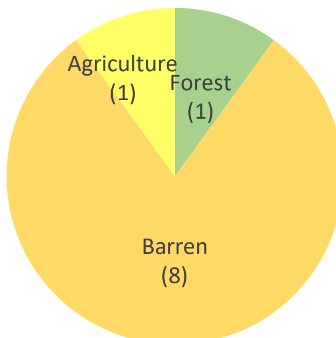

Figure 17. Proportional historic land use (1955) of current-day Pine forest in the Annapolis Valley, Sand Barren Study Area (n = 10).

Dry Bog

A total of twelve current-day dry bog sites were analyzed for historic land use. Unsurprisingly, all these locations had been wetland sites historically. This is consistent with prevailing patterns of land use in the area; in that we tend to lose wetlands due to development pressures on the landscape rather than gain wet areas.

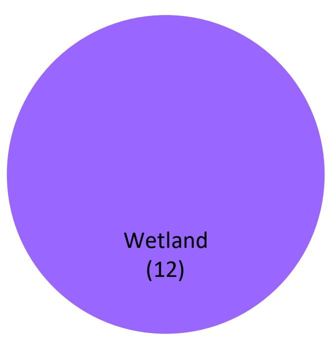

Figure 18. Proportional historic land use (1955) of current-day Dry bogs in the Annapolis Valley, Sand Barren Study Area (n = 12).

Web-Mapping

Web-mapping allowed for the creation of a simple web-app to share the imagery, regardless of having any GIS/computer expertise. The web-app can be accessed at ArcGIS Online at: https://cogsnscc.maps.arcgis.com/apps/webappviewer/index.html?id=de800540e0134ee09727791cf4adf263 or via the Bitly shortened link: www.bit.ly\historicsand. The app allows the user to toggle visibility of layers (Figure 19 -A), swipe between the historical imagery and the basemap (B), measure distance (C), share your map extent (D) and view bookmarks (E).

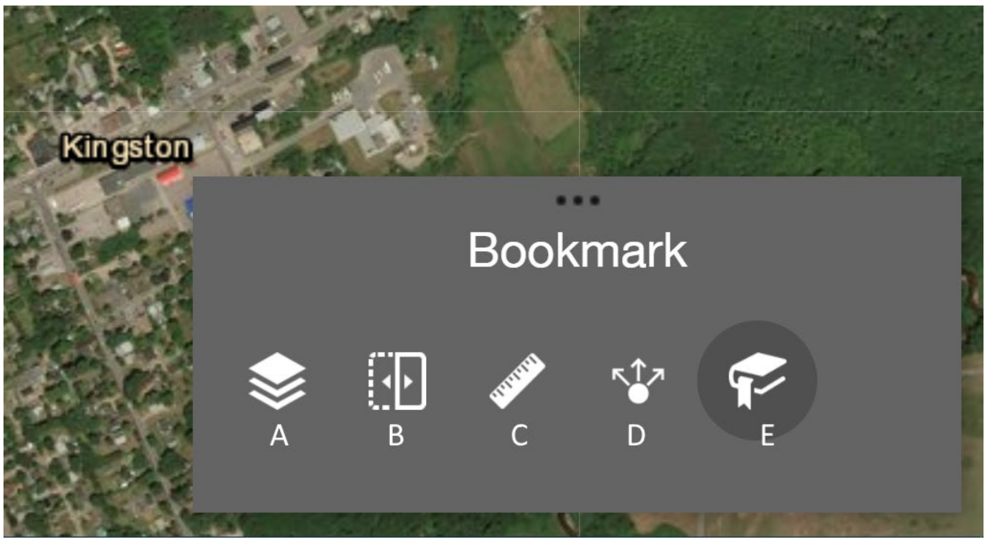

Figure 19. Web App Builder Widgets, added to the web-app. A – Controls Layer Visibility, B – Swipe between historic imagery and current imagery, C – Measure Distance and Area, D – Share your extent within the app, E – Bookmarked places.

This simple app, and associated link tracking capability through Bit.Ly should be a useful tool to help gauge awareness and interest of the ecosystem and the land-use patterns that drive it's change.

Conclusion

The historical air photo mapping technique worked well. While there were some georeferencing differences between the historic air photos and the current satellite mosaic, the differences were within acceptable tolerances for air photo delineation at the chosen scale. Sharing the photogrameetric analysis products online, should help define some new interesting research questions and guide field work throughout the course of this project.

This initial piece of work represents an important first step in piecing together the temporal disturbance scale for the Sand Barrens Study area. At this stage, the evidence suggests that agriculture has acted as a driver of succession in the study area, allowing for persistence of the sand barrens in the absence of fire. Many of the sand barren locations delineated in the analysis, while showing textural patterns of sand barren land use, seem to indicate abandoned agricultural practices from an earlier era (Figure 6). Of interest are the land-use patterns during intervening years, separating past land use – with current day land use.

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