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DEPARTMENT *of* ENVIRONMENTAL SCIENCE

Land Use Change on the Erie National Wildlife Refuge

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Executive Summary

The history of Pennsylvania's landcover has been dynamic in the course of the past several centuries. Almost entirely forested at the turn of the 17th century, the majority of lands in the commonwealth were cleared over time for agriculture, fuel, or wood products before being largely restored to forests during the course of the 20th century. Agencies such as the United States Fish and Wildlife Service (USFWS) need to know land use history on managed lands to effectively manipulate habitats in support of waterfowl and wildlife conservation. interest. The Erie National Wildlife Refuge (ENWR), overseen by the USFWS, is an asylum of forests and wetlands in Crawford County near the town of Guys Mills, Pennsylvania, that is managed to protect and promote flora and fauna, especially those that are threatened, endangered, or considered to be species of special Prior to becoming a refuge in 1959, the ENWR underwent a dynamic land use history similar to that in surrounding areas. To best manage the ENWR for migratory waterfowl, federally endangered mussels, and other wildlife, it is important to quantify historical land use/land cover (LULC) trends on the refuge as well as lands immediately surrounding the refuge. Understanding how the land was used historically is important in understanding current vegetation composition and forecasting future ecosystem patterns and processes.

We used Geographic Information Systems (GIS) to visually interpret LULC in historical (ca 1939) and modern (ca 2015) aerial photography, manually digitize the LULC into seven categories, and quantify LULC change over time. From from 1939 to 2015, agricultural land in the surrounding area decreased 67%. On the refuge, agricultural crops are still grown in some areas to provide wildlife food sources, however large areas of the refuge are still covered by upland herbaceous vegetation (e.g. goldenrod) that have recolonized land previously used for nagriculture. Overall, agricultural land use on the refuge declined 83%. Forested area greatly

increased 70% in the surrounding area, and 220% on the refuge. Wetlands increased on the refuge (66%) but decreased in the area around it (84%). Developed land, although a relatively small portion of total land cover, more than doubled on surrounding lands, but decreased slightly on the refuge. Shrub/scrub land cover was dynamic, showing a slight decline on the ENWR (5%) and sharp decline off of the ENWR (61%). Although land use on and off the refuge follow similar trends, the refuge shows a greater return to forested and wetland ecosystems than adjacent areas, and as expected, is less influenced by development and agriculture. Agriculture still maintains a footprint on the refuge, with some activing cropping, and large areas that have yet to revert to forested land cover. With a landscape containing a larger proportion of forests and wetlands than the surrounding area, the ENWR represents an important sanctuary for wildlife protection and management.

Keywords: Land use, land cover, Erie National Wildlife Refuge, agriculture, forest, wetlands, history

Project Description

Prior to the European settlement of the Americas, there were over a billion acres of forested land in the United States, with over three quarters of all forest located in the eastern US. Clearing forests for agriculture, coupled with the demand for wood as fuel for cooking and heating, building homes, and construction of railroads, caused a drastic decrease in the amount of forested land in the US. The trend of decreasing forests in the United States continued over the course of several centuries. At the turn of the 20th century a decrease in demand for wood caused by mechanization and increased efficiency of farming techniques and coal-fired industrialization triggered a recovery of forestland in the US (MacCleery 1993). Overall forest cover in the United States has remained relatively stable since 1900 (Alvarez 2007) and today forests in the United States cover about 70% of the land area that was originally forested at the time of European arrival (MacCleery 1993).

In Pennsylvania, more than 90% of the commonwealth (more than 27 million acres) was forested at the time of European arrival. Centuries of forest clearance in Pennsylvania resulted in an all-time minimum forest cover of about 12 million acres after the end of WWI before forests

recovered over the course of the 20th century (Albright et al. 2017). Today, approximately 60% (17 million acres) of Pennsylvania is covered by forest (Albright et al. 2017).

The dynamic history of Pennsylvania's forests is not without consequences. Prior land use can have significant impacts on the characteristics of current forests. For example, land recovering from agricultural use will have a profoundly different vegetation composition than presettlement forests (Foster et al. 2004). In addition soil nutrient content can be altered drastically in response to long-term pasturage or plowing. For example, undisturbed forest soils have higher levels of carbon and of nutrients such as calcium, nitrogen, and phosphorous compared to forest soils in areas that had previously been logged for timber or managed as pasture (Fraterrigo et al. 2005).

The ENWR, established in 1959, has been no exception to Pennsylvania's dynamic land use history. To effectively understand forest ecosystems, it is important to understand prior land uses that will have contributed to present ecosystem patterns and processes. Managed by the United States Fish and Wildlife Service (USFWS), the Sugar Lake Division of the Erie National Wildlife Refuge (ENWR) is a natural asylum of forests and wetlands for waterfowl and other wildlife in Crawford County near the town of Guys Mills. Managers on the refuge routinely manage ecosystems on the site as a means to enhance wildlife conservation, particularly for migratory waterfowl and endangered mussels in streams that enter into nearby French Creek. Understanding present ecosystems will be most effectively accomplished by understanding prior land use. In addition, the refuge exists within a matrix of agriculture and forest, hence the unique habitat values of the refuge can be understood by knowing how land use on the refuge compares to land use in the surrounding area, both presently and in the past.

The objective of this study was to quantify spatial patterns and trends of historical land use and land cover in and around the Sugar Lake Division of the ENWR to inform the USFWS about the current state of the ENWR landscape in relation to previous LULC composition and serve to inform future forest management decisions.

Findings and Recommendations

There is a drastic increase from 1939 to 2015 in land area classified as dense forest both on and off the refuge (Table 1, Figure 2). Dense forest cover more than doubled on the refuge,

and increased nearly 5-fold off the refuge. Overall, sparse and dense forest increased from 36.7% of the landscape in 1939 on the refuge, to 62.5% in 2015. Similarly, the sparse and dense forest together increased from 17.1% of the landscape in 1939 to 54.9% in 2015. Land area covered in sparse forest decreased slightly, both on and off the refuge (Table 1, Figure 3). The decrease in sparse forest land cover is a result of areas shifting from previous classification as sparse forest in 1939 to classification as dense forest land cover in 2015 (Figure 4).

There was a decrease in the amount of agricultural land found on the ENWR and in the surrounding area (Table 1, Figure 4). On the refuge, agricultural crops are still grown in some areas to provide wildlife food sources. However some previously farmed land on the refuge is still covered by upland herbaceous vegetation (e.g. goldenrod) that has recolonized former agriculturally-used lands. These areas are currently classified as agriculture and have failed, even after nearly 60 years, to revert from farm land to forest land. Overall, agricultural land use on the refuge has declined 83%, in comparison to a 67% decline in the surrounding area.

Although land area classified as being developed decreased slightly on the ENWR from 1939 to 2015, it increased sharply off of the refuge. Most of this increase occurred in the town of Guys Mills, northwest of the refuge (Figure 1). LULC classified as water increased from 1939 to 2015 for both the ENWR and surrounding land (Table 1, Figure 6). The amount of land area classified as wetlands increased greatly on the ENWR from 1939 to 2015, while it decreased in the area surrounding the ENWR (Table 1, Figure 6).

On the ENWR, land area classified as having shrub/scrub landcover stayed relatively the same, decreasing by only a small margin (Table 1). Off of the refuge, the amount of land classified as shrub/scrub land decreased sharply (Table 1), from 24 to 9.4% of the landscape. The areas of the study region classified as being shrub/scrub in 1939 were not always found to be the same areas as in 2015. This is likely because some areas classified as agricultural fields in 1939 were in the preliminary stages of reverting back to forest and were classified as shrub/scrub in 2015 (Figure 7), whereas lands classified as shrub/scrub in 1939 grew back to forests by 2015 (Figure 8).

Table 1. Area (acres) of land area in each LULC category in 1939 and 2015 for the ENWR, the area surrounding the ENWR.

	ENWR				Surrounding Area				Total			
	1939		2015		1939		2015		1939		2015	
	acres	% of total	acres	% of total	acres	% of total	acres	% of total	acres	% of total	acres	% of total
Developed	47.8	2.2	35.3	1.6	119.5	8.0	268	17.9	167.3	4.5	303.3	8.2
Agriculture	779.6	35.1	130.4	5.9	740.3	49.5	243.9	16.3	1519.9	40.9	374.3	10.1
Shrub/Scrub	442.1	19.9	420.5	18.9	359.4	24.0	140.6	9.4	801.5	21.6	561.1	15.1
Sparse Forest	236.5	10.6	142.8	6.4	105.2	7.0	75	5.0	341.7	9.2	217.8	5.9
Dense Forest	579.9	26.1	1247.6	56.1	150.7	10.1	745	49.9	730.6	19.7	1992.6	53.6
Water	7.6	0.3	35.5	1.6	5.5	0.4	19.4	1.3	13.1	0.4	54.9	1.5
Wetlands	127.7	5.7	212.5	9.6	15.3	1.0	2.4	0.2	143	3.8	214.9	5.8
Total	2221.2	100	2224.6	100	1495.9	100	1494.3	100	3717.1	100	3718.9	100

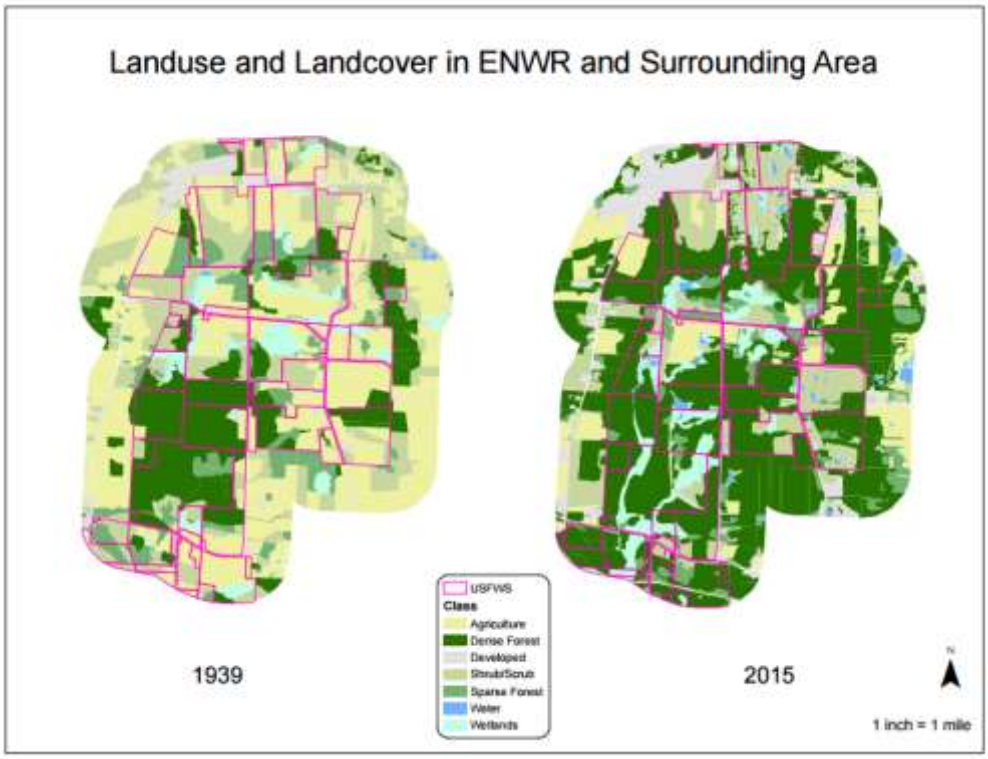


Figure 1. LULC on and around the ENWR in 1939 and 2015.

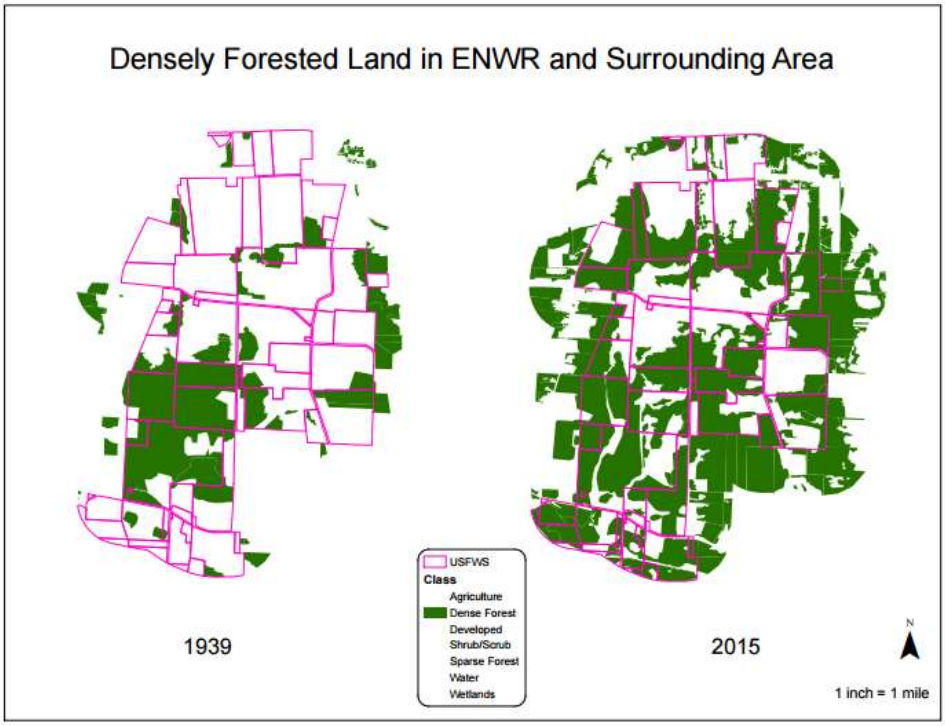


Figure 2. Dense forest on and around the ENWR in 1939 and in 2015.

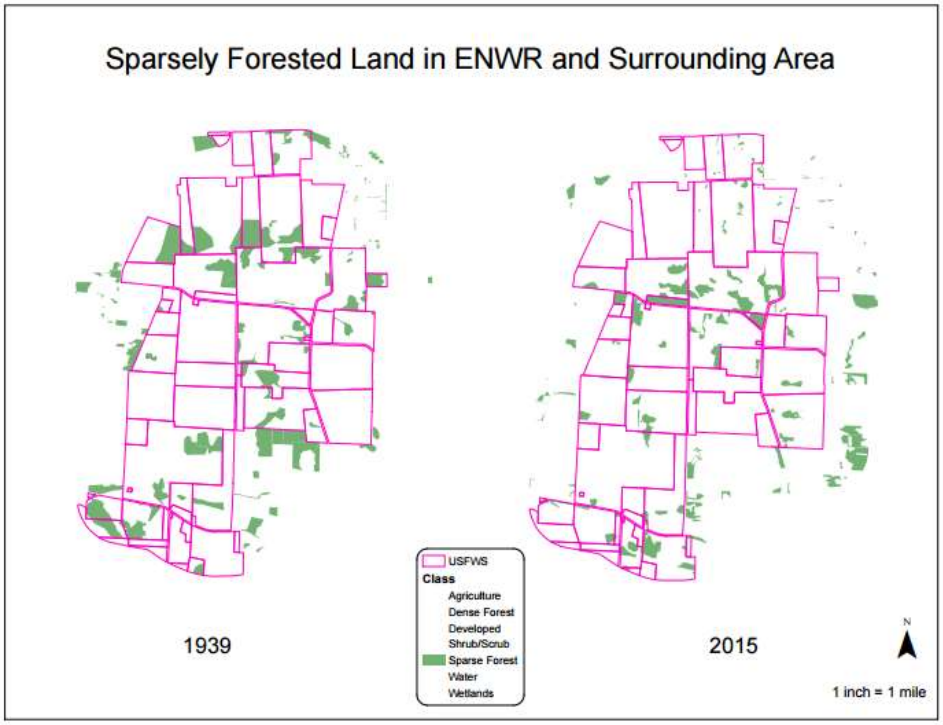


Figure 3. Sparse forest on and around the ENWR in 1939 and in 2015.

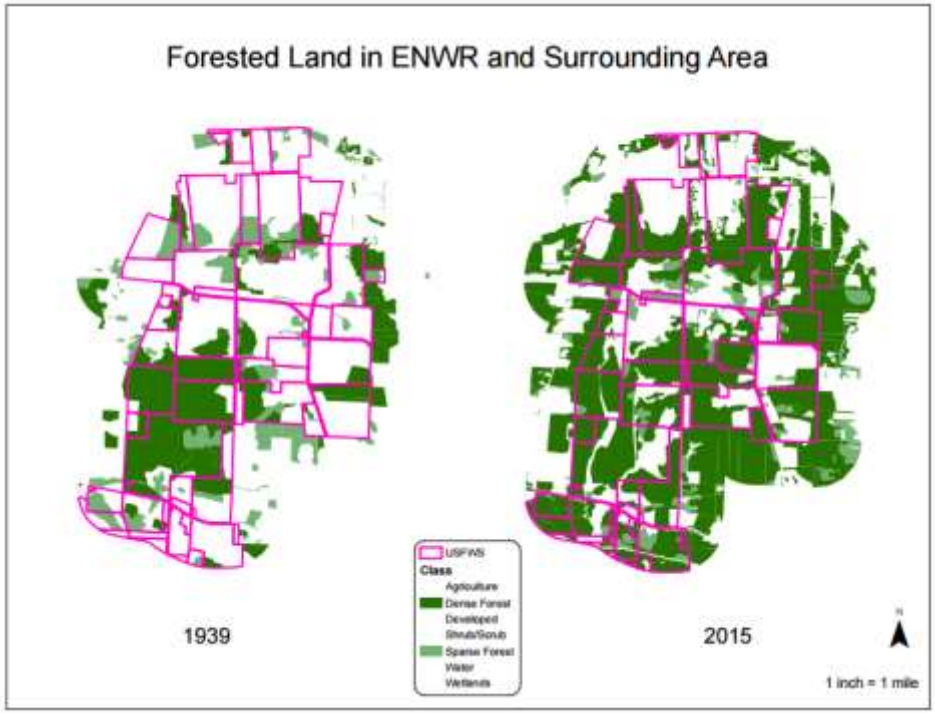


Figure 4. All forest, both (dense and sparse), on and around the ENWR in 1939 and in 2015.

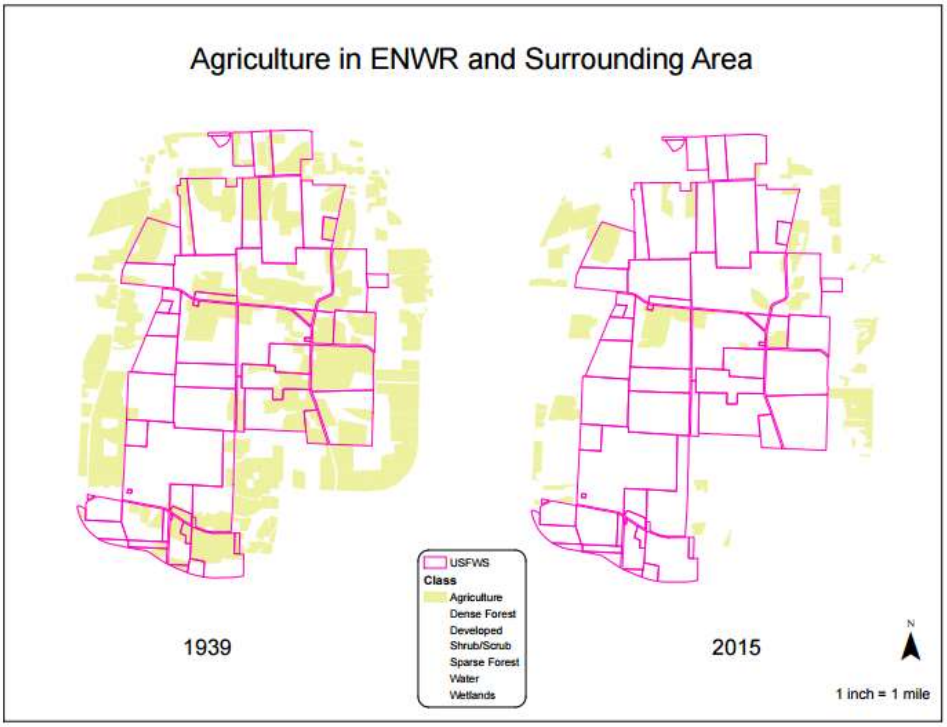


Figure 5. Agricultural land on and around the ENWR in 1939 and in 2015.

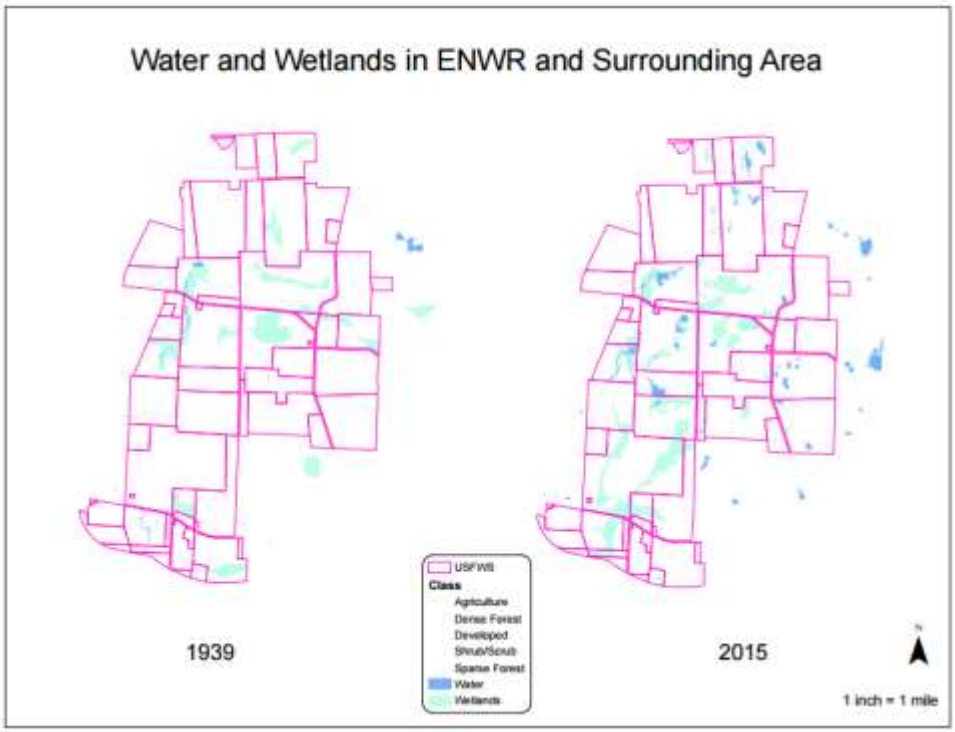


Figure 6. Water and wetlands landcover on and around the ENWR in 1939 and in 2015.

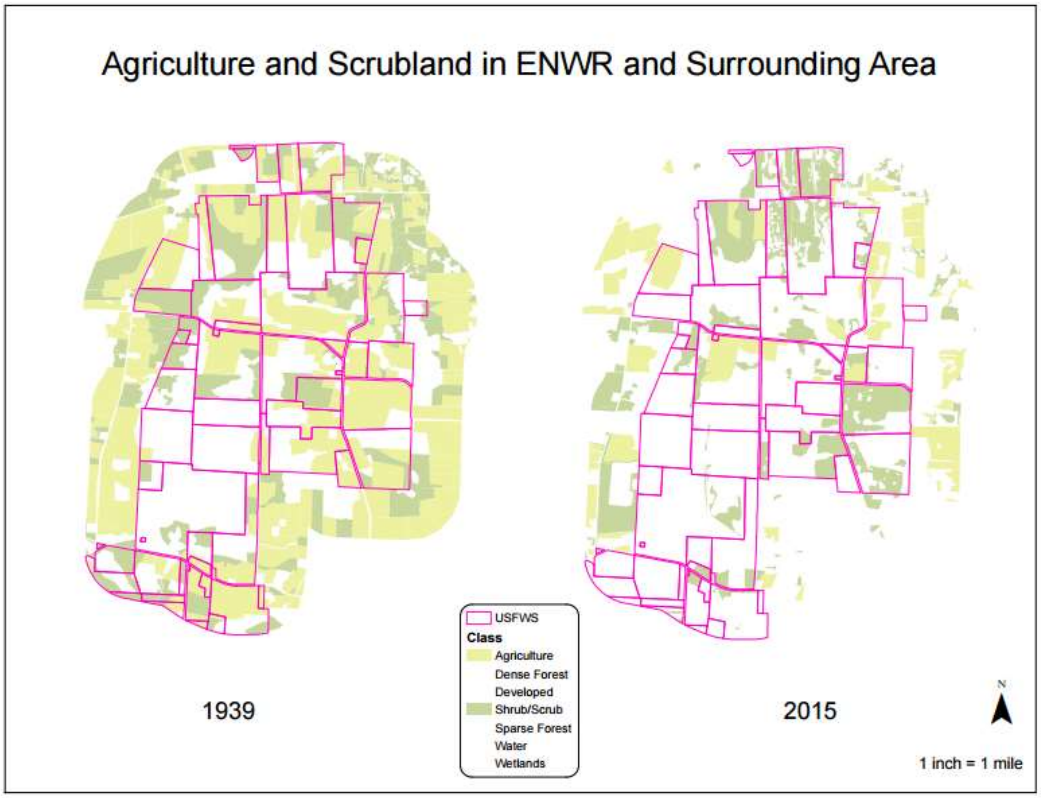


Figure 7. Shrub/scrub and agricultural LULC categories on and around the ENWR in 1939 and in 2015.

For the sake of simplicity, this study abridges LULC to seven general categories for the digitization process. However, not every land use and land cover visible in the aerial photography fits neatly into a perfectly defined, distinct category. The category in which a digitized land use polygon is placed is ultimately decided by the GIS user. Moreover, the process of visual interpretation was not standardized strictly, as it was performed by multiple individuals possessing GIS experience. Not all authors had prior experience in visual interpretation and manual digitization, which may have led to some discrepancies. This may have especially been the case of the historical aerial photography from 1939, which is in black and white. Without color cues to aid the GIS user, the process of visual interpretation and manual digitization of the LULC is difficult. In addition, this photography does not have as high of a resolution as modern aerial photography, further increasing the difficulty of interpretation and digitization. In general, categories such as wetlands were sometimes difficult to interpret owing to the fact that they can be obscured by canopy cover or are difficult to determine without color cues.

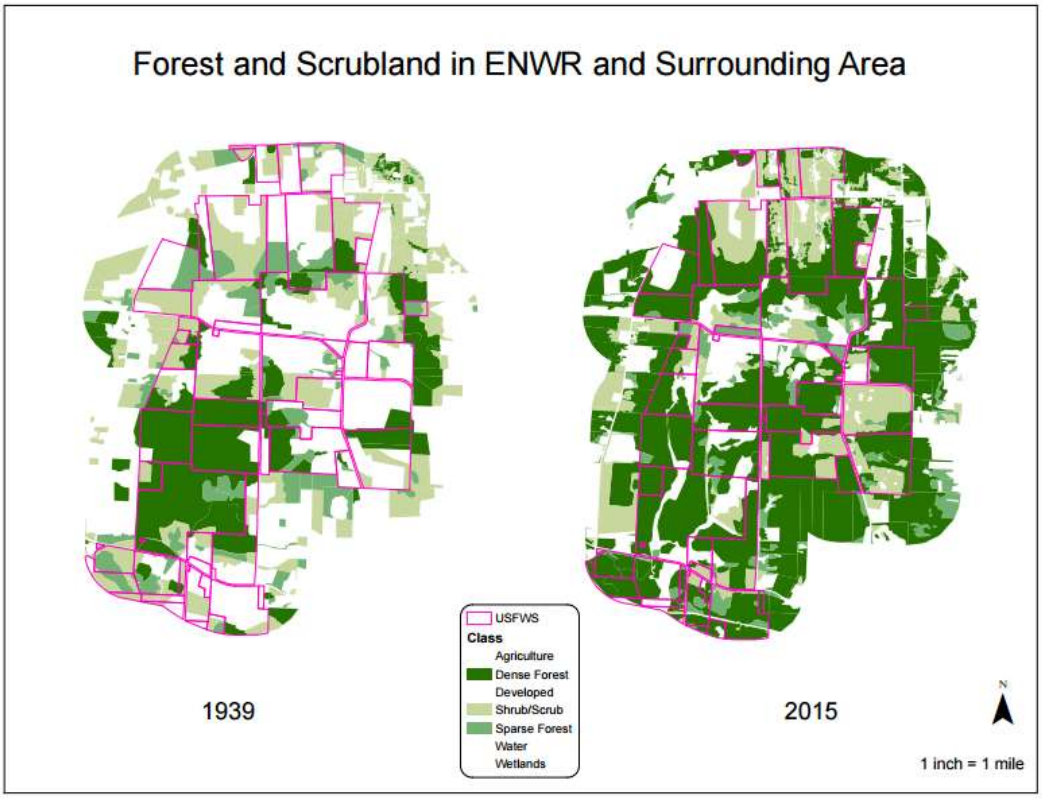


Figure 8. Shrub/scrub, sparse and dense forest LULC categories on and around the ENWR in 1939 and in 2015.

To verify the accuracy of the visual interpretation and manual digitization of LULC in this study, ground-truthing must be performed. Although this cannot be done to ensure the accuracy of 1939 digitization, ground-truthing to verify the accuracy of the 2015 LULC layer may help to gauge the accuracy of the 1939 LULC layer.

Understanding prior land use patterns can help to reveal and explain reasons behind the state of current land use patterns. For example, conversion of forest to agriculture can have a large influence on the composition and distribution of plant and tree species that inhabit present forests (Belllemare et al. 2002, Hermy and Veryheyen 2007). The results of this study cannot reveal specific differences between the species composition of older forests and the species composition of forests recently growing back upon former agricultural land. However, the results can be used to offer an explanation for why differences in species composition exist; that is, they

can indicate areas where forests have been present for at least nearly a century and where forests have grown back in former agricultural fields during the past few decades.

Despite limitations in quantifying aerial images, these results indicate that prior to formation of the refuge in 1959, land on and adjacent to the refuge had similar patterns of land use, dominated by agriculture. Presently, however, the refuge has a greater proportion of forest than is found in adjacent areas, due to land protection and cessation of commercial farming. In addition, the increase in wetland area on the refuge constitutes an important gain of this valuable habitat, particularly in light of reduced wetland area on the land surrounding the refuge. Increases on the refuge were likely driven by active construction, as well as to reversion of wetlands that had likely disappeared during the era of agricultural activity on the refuge. The ENWR contains habitats that are likely to be more conducive to wildlife than the surrounding region, with more than 80% of the landscape in woody vegetation, and remnant agricultural land representing a small proportion of the refuge. In contrast, surrounding land use is approximately 50% agricultural, with a smaller proportion of vegetated landscape than is found on the refuge. Hence, in the context of the region, the ENWR serves as a hotspot of forested and aquatic ecosystems that represent important habitats for wildlife.

Methods

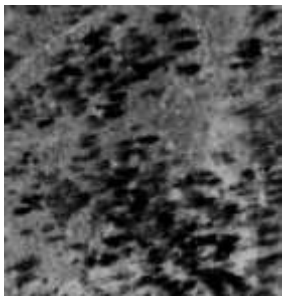
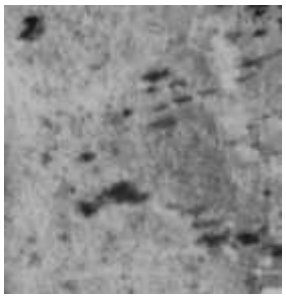
ArcGIS Desktop 10.3 (ESRI 2015) was used to visually interpret and manually digitize LULC at a scale of roughly 1:3,000 for both the 1939 and 2015 time series using aerial photography. The base for the 2015 digitized LULC layer was 2015 aerial photography streamed via ArcGIS online from the Environmental Systems Research Institute (ESRI). The 1939 digitized LULC layer was created using historical black and white aerial photography of the region acquired through the Penn Pilot project, a Pennsylvania State University online repository. This 1939 photography was downloaded as a series of images which were georeferenced using longstanding landmarks in the 2015 aerial photography such as road intersections, church steeples, and barns as spatial references for applying the coordinate system. Aerial photography from 1939 served as the historical LULC representation because it is the earliest publicly available historical photograph time series available through Penn State and it is situated at a time shortly after Pennsylvania's forests reached their all time minimum.

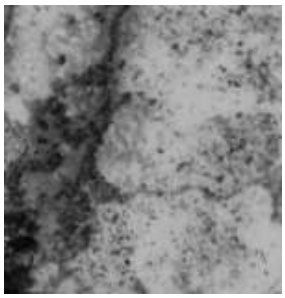
The border of the ENWR was created by querying parcel data provided by Crawford County to identify all parcels owned by the United States Fish and Wildlife Service between Pennsylvania Route 198 and Pennsylvania Route 27. All parcels, public and private, within 500 meters of the selected ENWR parcels were included in the LULC change study.

During the visual interpretation and manual digitization process, the LULC was divided into dense forest, sparse forest, shrub and scrub, agriculture, wetlands, open water, and developed (Table 2). These categories are loosely related to categories described in the National Landcover Dataset (NLCD) (U.S. DOI & USGS 2015). In addition, each digitized polygon was coded as either being owned by the USFWS or by a private landowner in order to facilitate calculation of LULC patterns of change both on and off the refuge.

After digitization was complete, the total land area classified under each LULC category on and off the ENWR for both time series was calculated.

Table 2. Land Use/Land Cover (LULC) digitizing categories and their descriptions with examples given for both 1939 and 2015 time series.

LULC Category	1939 Example	2015 Example	Description
Dense Forest			Categorized by dominating tree canopy cover with minimal gaps. Deciduous, coniferous, or mixed forest.
Sparse Forest			Categorized by prevalent tree canopy with some gaps and spaces between trees. Deciduous, coniferous, or mixed forest.
Shrub/Scrub			Herbaceous shrub, scrub, or grassland dotted with woody vegetation. This layer may include some sporadic trees. This layer may include agricultural fields in the process of transitioning back to forest.
Agriculture			Fields with no or nearly no tree presence. Large open areas that are geometric in nature and are near structures. This layer includes both cultivated and pasture agriculture, as well as formerly cultivated fields on the ENWR that are in a goldenrod-dominated state of arrested succession.

LULC Category	1939 Example	2015 Example	Description
Wetlands			Wetlands bordering streams or ponds. Characterized by seasonal water bodies.
Water	*No Significant Examples*		Category reserved for open, standing water bodies that do not appear to be seasonal.
Developed			Residential or commercial areas that have a prevalence of man-made structures intermixed with lawns and some trees. This layer contains farmhouses and golf courses as well as impervious surfaces such as sidewalks, driveways, and roads.

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Literature Cited

Albright, T. A., W.H. McWilliams, R.H. Widmann, B.J. Butler, S.J. Crocker, C.M. Kurtz, S. Lehman, T.W. Lister, P.D. Miles, R.S. Morin, R. Riemann, J.E. Smith 2017. Pennsylvania forests 2014. Resour. Bull. NRS-111. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 140 p.

Alvarez, M. (2007). The State of America's Forests. Society of American Foresters. Bethesda, MD.

Bellemare, J., G. Motzkin, D.R. Foster. 2002. Legacies of the agricultural past in the forested present: an assessment of historical land - use effects on rich mesic forests. Journal of Biogeography, 29(10 - 11), 1401-1420.

ESRI. 2017. What is GIS? Web. Retrieved from http://www.esri.com/what-is-gis. Accessed July 2017.

Foster, D, G. Motzkin, J. O'Keefe, E. Boose, D. Orwig, J. Fuller, B. Hall. 2004. The environmental and human history of New England. pp 43-100. IN Forests in Time. Foster, D.R. and J.D. Aber, eds. Yale Univ. Press.

Fraterrigo, J. M., M.G. Turner, S.M. Pearson, P. Dixon. 2005. Effects of past land use on spatial heterogeneity of soil nutrients in southern Appalachian forests. Ecological Monographs, 75(2), 215-230.

Hermy, M., K. Verheyen. 2007. Legacies of the past in the present-day forest biodiversity: a review of past land-use effects on forest plant species composition and diversity. Ecological Research, 22(3), 361-371.

MacCleery, D. W.1993. American forests: a history of resiliency and recovery. Forest History Society issue series.

Rooney, T. P., D.W. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management, 181(1), 165-176.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. The Journal of Wildlife Management, 524-532.

U.S. DOI and USGS. 2015. *Multi-Resolution Land Characteristics Consortium (MRLC) - NLCD*. Retrieved from http://www.mrlc.gov/. Accessed February 2016.