The Effects of Deer on the Regeneration and Carbon Dynamics of the Lehigh Forest

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Abstract

Deer are a major stress on Lehigh's forests. They are eating the saplings of common tree species like oak, resulting in a lack of their regeneration and allowing the growth of invasive grasses and shrubs. The Lehigh forest is currently thought to be a carbon sink, but may become a carbon source in the future due to these stresses.

We surveyed a plot in the Lehigh forest and made visual observations at pre-established deer exclosures within the Lehigh forest, the Wildlands conservancy, the Trexler Nature Preserve, and the Mariton Wildlife Sanctuary to determine the forest's sensitivity to deer herbivory. These long-term experiments show that deer only influence plant growth where there are gaps in the open canopy. We concluded that the Trexler Nature Preserve exclosures would be the best for future studies because they are the oldest, are relatively large, and contain experiments on invasive species and deer. Additionally, we collected data in our plot to better understand the Lehigh forest's current carbon dynamics. This included using the point quarter method to determine tree density and species distribution, measuring diameter at breast height of trees to determine biomass, measuring Leaf Area Index using the LI-2200 and hemispheric camera to scale from leaf to canopy level, running Loss On Ignition and Carbon-Hydrogen-Nitrogen analysis on soil samples to determine carbon and nitrogen stocks, measuring soil respiration with the LI-8100, and measuring photosynthesis and leaf respiration with the LI6400XT.

We hypothesize that deer herbivory is reducing or reversing the carbon sink in the Lehigh forest by reducing regeneration of new canopy tree species. Because we had limited time, this project serves as a preliminary study to determine the best location and methods for future study and will be used as a baseline for future proposals and research to determine the role of deer on Lehigh forest's species composition and carbon dynamics.

Objectives and Goals

Our objectives and goals were to:

- Conduct a survey of the Lehigh forest
- Assess the effectiveness of deer exclosures within the Lehigh forest and in the surrounding area
- Determine the carbon dynamics of the forest and if it is a source or a sink

Site

We chose a 30x30m site in Lehigh's secondary forest to take measurements. The spot we chose was just beyond the Experimental Forest and the Arboretum located near the South Mountain Park and Frisbee Golf Course. It is dominated by oak and hickory trees, making it a good representation of regional forests.

Figure 1a

Figure 1a: There is minimal undergrowth and any visible understory is the invasive species Japanese Barberry and a few Horse Chestnuts in our Lehigh plot.

Figure 1b

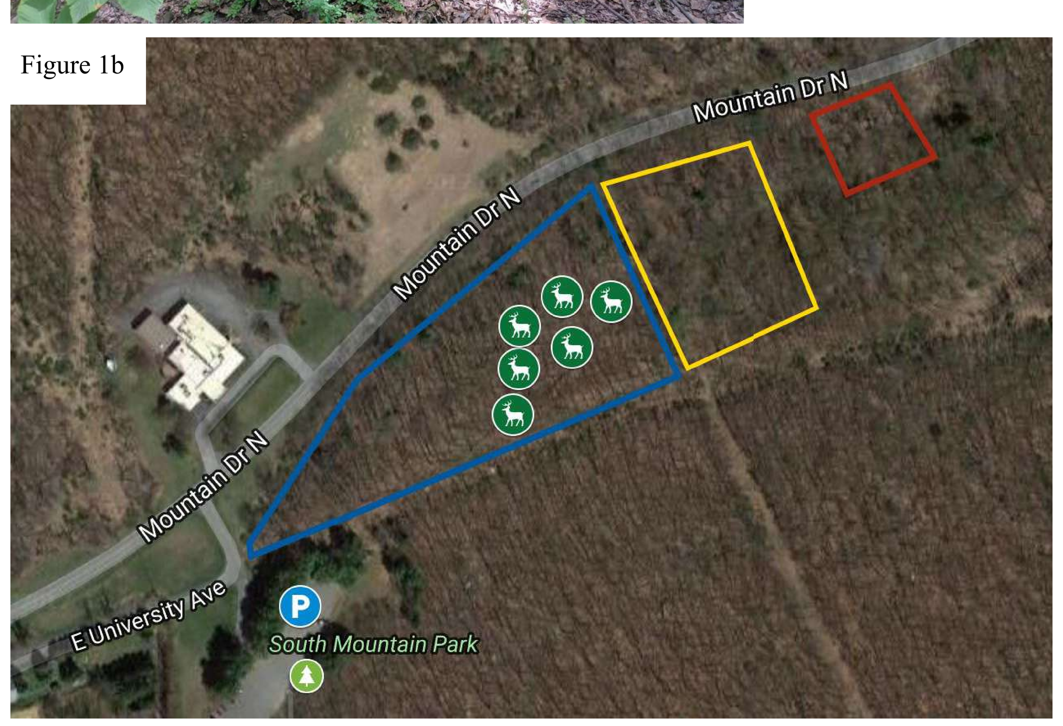

Figure 1b: Map of our site in relation to the Experimental Forest and the Arboretum. The blue box is the Experimental Forest, yellow is the Arboretum, and red is our plot. The deer icons represent the deer exclosures set up by Robert Mason, a Lehigh University graduate.

Other Sites in the Lehigh Area

To get a better sense of how larger deer exclosures work, we visited other sites in the Lehigh Valley that have established large deer exclosures. These sites all have aspects that make them good candidates for further study, but they all also have a few drawbacks.

- **Wildlands (Figure 2a):** Wildlands is the most problematic; the tree species are different than those at Lehigh, and no control plot has been established. However, it does demonstrate the importance of gaps, as we are able to see more growth in areas with gaps in the canopy that let in light. Along with the removal of deer, the gaps allow native species to outcompete invasives.
- **Trexler Nature Preserve (Figure 2b):** This site has five different large plots established in 2010, which makes it old enough for the treatment to show results. There are also factorial experiments exploring the effects of both invasives and deer. However, all treatments are kept in with the same fence, without separation. The leaves in the upper canopy of the control plot are also all absent, an anomaly that could skew the data. It is also located across from the Lehigh Valley Zoo's elk and bison exhibit, which could affect deer activity. Out of the three sites, this is likely the best for future study because of the inclusion of invasives as well as the relevant tree species.
- **Mariton Wildlife Sanctuary (Figure 2c):** This site has relatively healthy forest regrowth and contains three plots with different light levels. However, the deer population is reduced due to hunting in the area, and the dominant tree species differ from those seen in Lehigh's forest.

Figure 2a

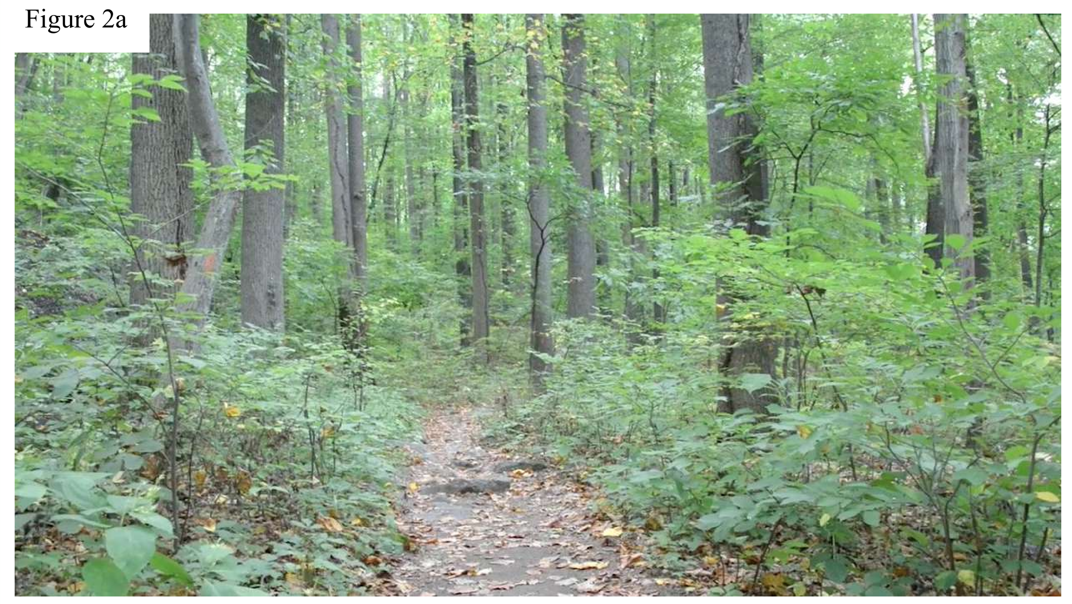

Figure 2a: Anon (n.d.), South Mountain from Wildlands Conservancy, *Wildlands Conservancy*, http://www.wildlandspa.org/south-mountain-preserve/ (Accessed 6 July 2017).

Figure 2b

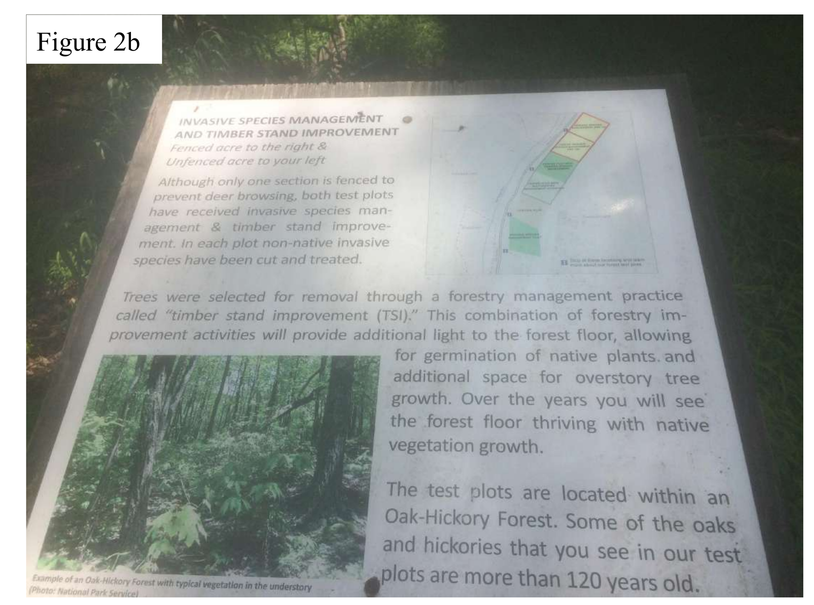

Figure 2b: Sign describing the plot at the Trexler Nature Preserve

Figure 2c

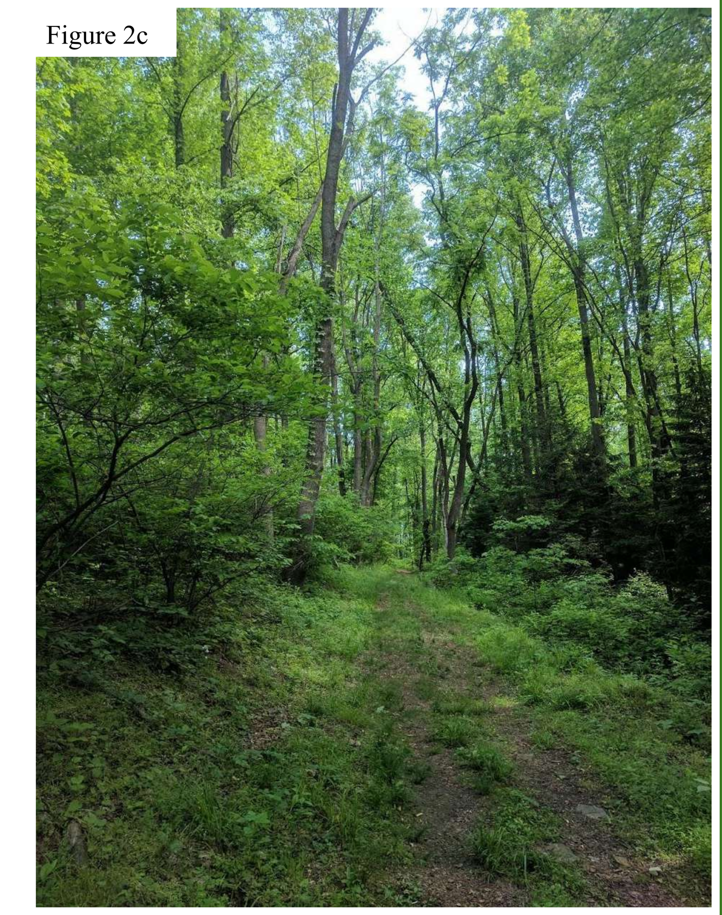

Figure 2c: the woods at the Mariton Wildlife Sanctuary. It is similar in composition to the Lehigh forest.

Data from the Lehigh Forest

Figure 3a: We surveyed 29 trees in our plot using the point-quarter method. There was a large number of tulip poplar and horse chestnut trees, as well as several oak and maple trees, which are common to the Pennsylvania forests.

Figure 3b: We also found the Leaf Area Index of each species using the LI-2200 and Hemispheric Camera. The LAI per species was then calculated using the diameter at breast high data for each tree. The LAI data sets from the two instruments are significantly different, and we rejected the null hypothesis that these two sets are the same with a 99% confidence level. The reason for this difference is unknown, however, they have the same percentage per species to the total LAI.

Figure 3a

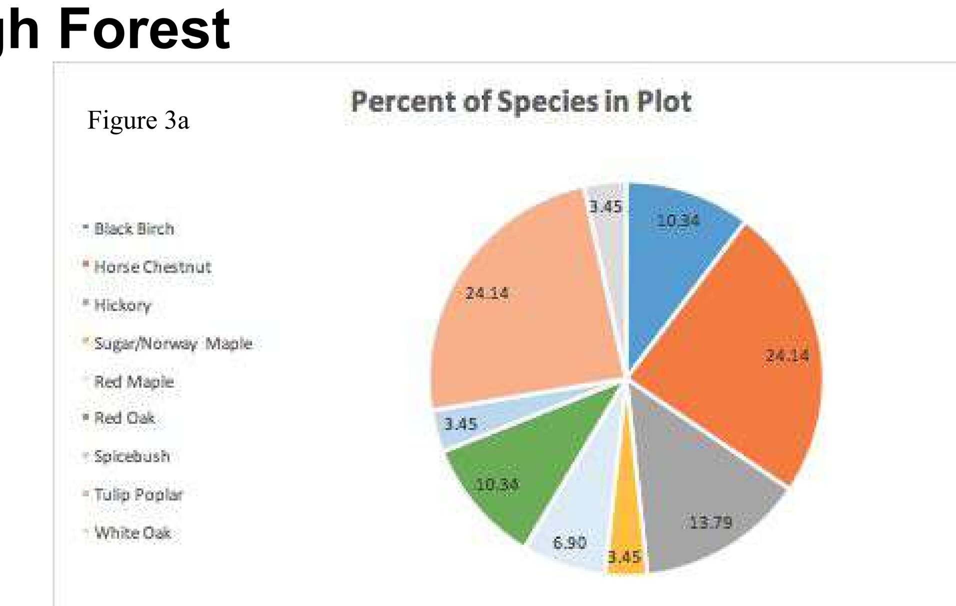

Figure 3b

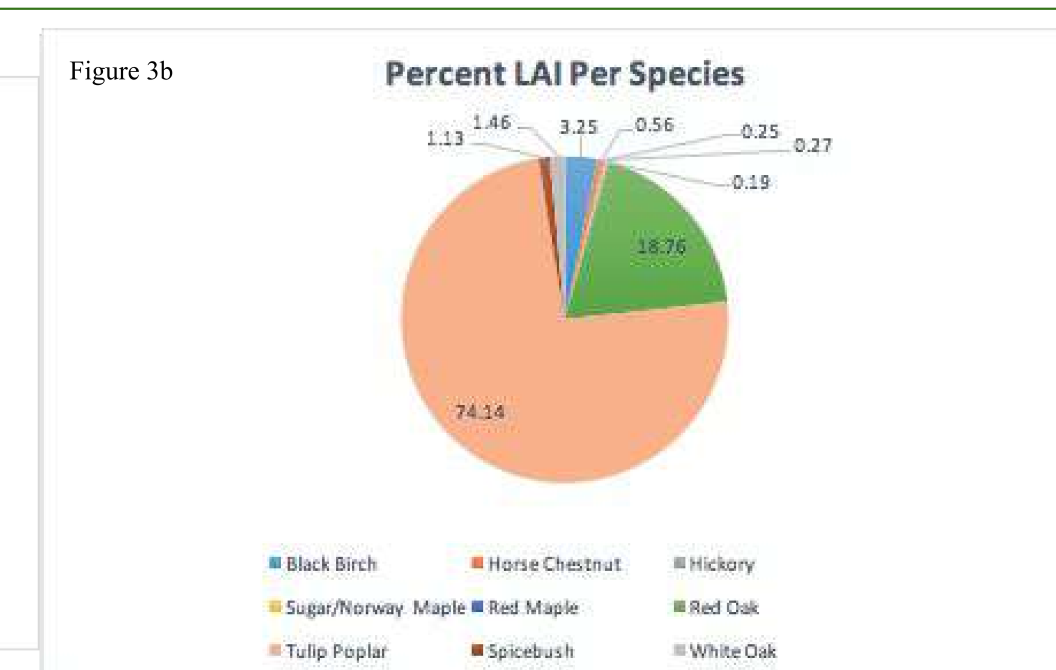

Table 1: Soil Respiration

Soil Respiration	
Sample	Respiration (gC/m2/year)
1	498.28608
2	629.856
3	571.06944
4	487.08864
5	646.65216
Average	566.590464

Table 1: We measured soil respiration at five sites within the plot. The average carbon flux was then used in the calculation of NEP.

Table 2: Tree Carbon

Species	Tree C (g/m2) LI-2200	Tree C (g/m2) Hemispheric Camera
Black Birch	2083.64	2083.64
Horse Chestnut	2.95	2.95
Hickory	6.43	6.43
Sugar/Norway Maple	108.51	108.51
Red Maple	7.92	7.92
Red Oak	80309.41	80309.41
Tulip Poplar	109588.78	109588.78
Spicebush	8.05	8.05
White Oak	4276.45	4276.45

Table 2: The diameter at breast height were used to calculate total tree carbon.

Table 3: Carbon Fluxes (GPP, NPP, and NEP)

Species	NET PHOTO (gC/m2/year)	Respiration (gC/m2/year)	Gross Photosynthesis (gC/m2/year)	GPP (gC/m2/yr)	NPP (gC/m2/yr)	NEP (gC/m2/yr)
Sum	991.9	-109.01	1100.91	1225.56	867.25	425.31
Norway Maple	3.67	-0.15				
Hickory	3.62	-0.08				
Black Birch	83.97	-3.65				
Red Maple	2.39	0				
Red Oak	526.78	-21.1				
Sugar Maple	2.11	-0.15				
Tulip Poplar	348.96	-83.39				
White Oak	20.4	-0.49				
		Respiration (root) - 22%	**Respiration (heterotrophic)**			
Respiration	**Soil respiration (gC/m2/year)**					
Site 1	566.59	124.65	441.94			

Table 3: Using the average soil respiration, LAI per species, and photosynthesis and respiration rates, we were able to calculate the Gross Primary Productivity (GPP), Net Primary Productivity (NPP), and Net Ecosystem Production (NEP). The positive NEP indicates that the forest is a carbon sink rather than a source. Note: because we were unable to find a photosynthesis value for horse chestnut and spicebush, we were unable to include it in the calculation. This is a possible source of error.

Table 4: Soil Carbon (LOI)

Depth	Trial 1 Average LOIC (550°C): organic	Trial 1 Average LOIC (1000°C): inorganic	Trial 2 LOIC (550°C): organic	Trial 2 LOIC (1000°C): inorganic
2 cm	8.47%	-	8.77%	-
3-20 cm	5.23%	5.82%	4.84%	5.36%
20-40cm	2.09%	3.06%	2.12%	2.67%

Table 4: We collected soil samples and ran a Loss on Ignition test to determine soil carbon. Soils were collected at five different sites at three different depths. While the 2 cm sample was heated at only 500 °C, the other two were heated at both 500°C and 1000°C to determine both organic and inorganic carbon. The table shows the averages of the five sites, with two trials each. There is less organic and inorganic carbon as the soil gets deeper..

Conclusions

The Lehigh forest contains few young trees growing with lots of invasives. Deer exclosures can be beneficial if there are gaps in the canopy allowing light in; otherwise new saplings cannot grow well. We can conclude deer exclosures need to be established where gaps exists, and require several years in order to show results. The Trexler Nature Preserve exclosures are the most ideal for future studies because of their tree species composition and exploration of both effects of deer and invasives.

Our data show that the Lehigh forest is currently a carbon sink. We calculated an NEP of 425.31 gC/m2/yr, indicating that the forest is currently taking in more carbon than it releases. However, we can see that many of the trees that contribute to this high NEP are older trees, and with little new tree growth, the Lehigh forest could become a carbon source in the future.

While our hypothesis that the deer are reducing or reversing the carbon sink in the Lehigh forest has not yet occurred, we can see the beginnings of this taking place. It is important that we continue to study the effects of deer on the Lehigh forest to take future action to create a healthier forest and avoid it becoming a carbon source.

Possible Sources of Error:

- We excluded some standing and fallen dead trees from our survey, and spicebush and horse chestnut were excluded from the NEP calculation.
- We also may have overestimated the size of the tulip poplars.
- We obtained two different LAI values with the two different instruments. We do not know the cause of this difference.

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