GIS Analysis of Impervious Surface and Land Cover Change in Berks County
Final Report

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Abstract

Berks and Schuylkill Counties are located in southeastern Pennsylvania, a region traditionally known for agriculture. Due to suburban sprawl from the growing City of Philadelphia, and the demand for distribution centers to fill the need for deliveries and manufactured goods, there have been changes in land use and land cover (LULC) and impervious surfaces. These LULC changes in these counties and their respective watersheds is of particular interest to conservation groups such as Berks Nature. By using ArcPro geoprocessing tools, the exploration of overall land cover change, warehouse development, and percent imperviousness in HUC 10 and 12 watersheds and the active river area (ARA) was conducted. Various levels of change throughout Berks and Schuylkill Counties and their intersecting watersheds are observed in the study. The results show that change is more concentrated in specific watersheds and regions, rather than being widespread across the entire study area.

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Introduction

Berks Nature, a non-profit organization within Berks County, Pennsylvania, has identified the increase in impervious land cover as an issue of concern within the county. The goal of this study is to highlight areas of potential large-scale development and impervious surface increase, such as the I-78 Corridor in Bethel Township and the Tulpehocken watershed. Additionally, Berks Nature would like to identify hot spots, or locations of concentrated high levels of impervious surface change, in the Berks and Schuylkill County watersheds, as well as identifying impervious surface increases in active river areas. Locations of increased impervious surfaces can be at higher risk of runoff, erosion, and pollution. Identifying these areas can assist in conservation areas and focus. For Berks County and the surrounding region for the 2006-2019 time period, this study aims to address the following questions:

- What are the overall trends in land use/land cover change?
- What are the trends in impervious surface cover change for watersheds?
- What are the trends in impervious surface cover change for the active river area?

Study Area

Berks County is located in the southeastern corner of Pennsylvania, situated along the border of New Jersey and within the metropolitan area of Philadelphia, Pennsylvania. Land cover is highly heterogeneous due to the county's proximity to major urban areas, the I-78 corridor running through the county, as well having the Kittatinny Ridge Corridor along the Schuylkill and Berks Counties' borders; urban, suburban, and exurban land uses are interspersed with traditional and intensive agriculture as well as working and preserved forested landscapes. The Kittatinny Ridge Corridor is an especially high value landscape as it is part of an unbroken chain of forested mountains which form a vital link with the Appalachian Mountains. The Kittatinny Ridge Corridor has been identified as the most resilient landscape in the state for adapting to climate change, and is considered a biodiverse superhighway (The Nature Conservancy, 2021).

The specific area of interest for this study was determined by the HUC 10 and 12 watersheds that intersect Berks and Schuylkill Counties (Figure 1) and 2006-2019 was identified as the time period for assessing change. Berks Nature, an environmental organization works with local people, groups and governments to better the county and its environmental future. In one of their many efforts to educate the community and keep them involved in the improvement of their area, they publish a *State of the Environment* report. They have produced this report every five years since 2008, updating the community on how the county is doing based on a broad set of indicators. Based on the availability of National Land Cover Data, the years 2006 and 2019 were selected in order to best align the study with the Berks Nature publications.

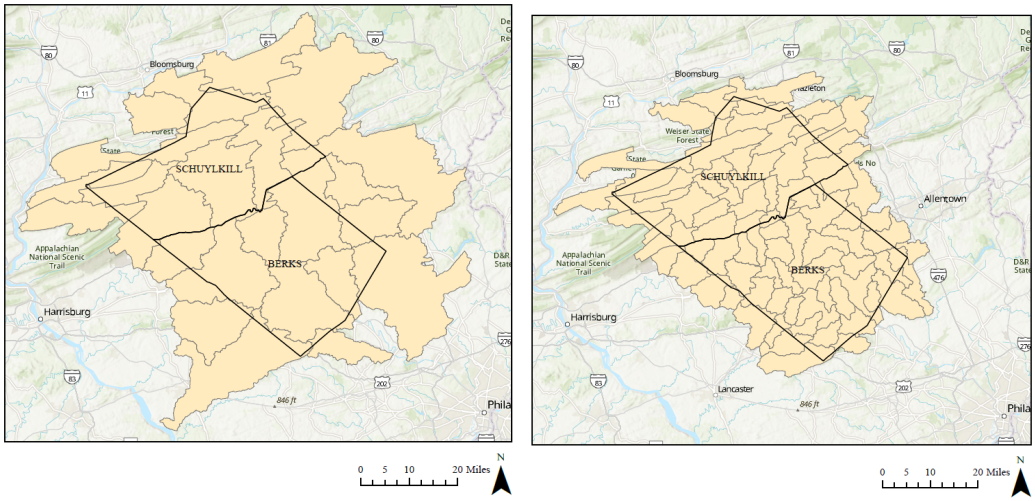

Figure 1: HUC10 and HUC12 watershed boundaries for Berks and Schuylkill Counties.

Study Objectives

Objective 1: Overall land cover change

- For the HUC 10 watershed study area, analyze overall land cover change, focusing on urban, forest, and agricultural land dynamics across the study time (2006-2019)
- Generate graphs and tables that illustrate changes in urban, forest, and agricultural land at the HUC 12 watershed scale

Objective 2: Impact of warehouse development in Bethel Township and the Tulpehocken Watershed

- Utilize land cover raster datasets to identify warehousing development
- Identify land types most impacted by warehousing development (forested, agricultural, etc).
- Estimate total footprint of warehousing development relative to total developed land/change in developed land

Objective 3: Impervious surface dynamics

- Report and map changes in average percent impervious surface in for both HUC 10 and HUC 12 watersheds
- Identify “hot spots” of impervious surface change at the HUC 12 watershed scale

Objective 4: Impervious surface dynamics in the active river area

- Calculate the percent of active river area in each HUC 12 watershed
- Identify areas of impervious surface cover and impervious surface change within the active river area

Data and Methods

To complete these analyses, two National Land Cover Data (NLCD) products were used to assess land use/cover and impervious cover changes between 2006 and 2019:

- NLCD categorical land cover data product: 30-meter resolution dataset containing a total of 95 different land use classifications nationwide (Wickham et al., 2014).
- NLCD impervious surface data product: Represents urban impervious surfaces as a percentage of developed surface over a 30-meter pixel (USGS, 2019).

Objective 1: Overall land cover change

The methodology for this investigation was performed by running GIS processes within ESRI's ArcGIS Pro software. Two primary GIS techniques were utilized: raster reclassification and tabulate area.

Four original raster datasets (2006, 2011, 2016, and 2019) from the NLCD land cover data product had a resolution of 30 meters and contained a total of 95 different land use classifications, 15 of which occur in Berks County, at an Anderson Level II classification. For development, there are four developed classes in the original NLCD classification: developed open space; low, medium, and high intensity developed. In order to gain a general understanding of the land use/cover dynamics within the study area and increase land cover classification accuracy, each raster was reclassified to a simpler Anderson Level I classification by using the Reclassify Tool. For example, instead of four developed classes, all development was reclassified into a single developed class. A total of eight new land use/land cover classifications were defined that included water, developed, barren, forested, shrubland, herbaceous, agricultural, and wetlands.

The newly classified raster datasets were then associated to the HUC 10 watershed layer by using the Tabulate Area tool, which recorded the area of each of the eight land uses within each of the HUC 10 watersheds that intersect Berks and Schuylkill Counties. The output of this tool is a standalone table that can be exported to Microsoft Excel for calculation of desired parameters. In this case, the percent of total area of each land cover was calculated for the entire study area. Given that multiple land uses such as barren, water, and wetlands comprised a negligible land area, they were filtered out to focus on the three main land cover classes of agricultural, forested, and developed for land cover change visualization. The remaining three land covers were added to a line graph for visualization of land cover change over the four study years.

Objective 2: Impact of warehousing development

To accomplish an analysis of warehousing development as a driver of land use/cover change, NLCD 30x30-meter raster datasets for the years of 2006, 2011, 2016, and 2019 were added to an ArcPro workspace and clipped to the extent of Bethel Township in Berks County, Pennsylvania. The four newly clipped raster datasets were reclassified to the Anderson Level I classification scheme by utilizing the Reclassify Tool. The reclassification resulted in a reduction from 15 land cover classes to 8 which included water, developed, barren, forested, shrubland, herbaceous, planted/cultivated, and wetland land covers.

The newly classified raster datasets were then associated to the Bethel Township boundary shapefile by utilizing the Zonal Statistics tool, which recorded the number of pixels for each land cover within the township boundary. The output of this process was four standalone tables, each of which

contained the pixel counts for each land cover class for all four years of rasters. The tables were exported to Microsoft Excel where the land cover pixel counts were converted to percent cover for Bethel Township and displayed on a line graph for land cover change visualization. Less dominant land cover classes were filtered from the line graph which left only agricultural, forested, and developed land cover classes for better visualization of change due to warehouse development. Cartographic presentation of warehouse development in Bethel Township was carried out by manual digitization of the footprint of developed land cover for warehouses on the raster datasets.

Objective 3: Impervious surface dynamics

NLCD Developed Imperviousness data set for 2006 and 2019 were clipped to the intersecting watersheds of Schuylkill and Berks counties. Once the subsets were created, mean percent impervious surface area (ISA) for both 2006 and 2019 was calculated at the HUC 12 and and HUC 10 watershed scales. This allowed for the calculation of the difference in average percent impervious between 2006 and 2019 for each watershed at each watershed scale.

Using the same datasets and the average ISA change for 2006 and 2019, a hot spot analysis was performed to identify any "hot" watershed clusters (where development rates are relatively higher) and "cold" watershed clusters (where development rates are relatively lower). Getis-Ord Gi* statistics were calculated to identify hot and cold areas (Getis and Ord 1992, Mitchell 2012). This analysis calculates both z-score and p-score for the data sets. The Gi* score (z-score) indicates how far the specified data point is from the mean. The range of results for z-scores are - 3 to +3, a score of 0 represents data points that are equal to the mean for the dataset. A map of Gi* scores show high or low areas relative to the determined mean change of average percent impervious surfaces. Z-scores display the high low values while p-scores are used to demonstrate statistical significance of clustering.

Objective 4: Impervious surface dynamics in the active river area

The active river area (ARA) refers to the areas of dynamic interaction between the water and land through which it flows. This allows for a systematic way to conceptualize and protect the river as a dynamic system with a broad range of conditions that are typical of natural river systems (Smith et al., 2008). The first part of this objective is to calculate the percent of ARA in each HUC 12 watershed for Berks and Schuylkill counties. This was done by downloading the Nature Conservancy's Northeast and Mid-Atlantic regional ARA map and reclassifying the data into ARA versus non-ARA classes. This dataset was also clipped to only include the HUC 12 watersheds that intersect with Berks and Schuylkill counties. The ArcPro 'tabulate area' geoprocessing tool was then used to cross-tabulate between the reclassified ARA and HUC 12 datasets. The output table was then joined to the HUC 12 dataset and two new fields were added in order to calculate the ARA area in square meters, and the percent ARA in each HUC 12 watershed.

Secondly, in order to understand the impervious surface dynamics within the ARA, the NLCD Developed Imperviousness dataset was first downloaded and set to a 0-100 scale. This dataset represents urban impervious surfaces as a percentage of developed surface over a 30-meter pixel (USGS, 2019). The 'raster calculator' geoprocessing tool was used in order to multiply the ARA by the impervious surface area (ISA). Once this was complete, the 'zonal statistics' geoprocessing tool was then used to calculate

the mean ISA for both the 2006 and 2019 datasets. The difference in mean ISA was then calculated using the ‘raster calculator’ geoprocessing tool again.

Results and Discussion

Objective 1: Overall land cover change

Results from the land cover change analysis for the HUC10 watershed area for Berks and Schuylkill Counties were as expected in that there was minimal change among all classes. The four land cover classes of developed, shrubland, herbaceous, and wetlands gained land area while the remaining five decreased in land cover (Table 1). All land covers experience changes by less than one percent with the three primary land covers of developed, forested, and agricultural showing the greatest changes. In some instances, the changes are so minimal that they may be a result of differences in technology during the year of data collection for each raster, however, some of these changes can also be attributed to human influence such as residential and commercial development, deforestation, and restoration efforts.

Table 1: Percent of total area for each land cover class for the HUC10 watershed boundaries of Berks and Schuylkill Counties.

	Water	Developed	Barren	Forested	Shrubland	Herbaceous	Agricultural	Wetlands
2006	0.76	19.05	0.85	47.66	0.62	0.40	29.69	0.95
2011	0.72	19.57	0.81	47.12	0.76	0.70	29.34	0.98
2016	0.72	19.85	0.75	47.03	1.00	0.52	29.16	0.98
2019	0.69	19.93	0.66	46.93	0.96	0.73	29.11	0.99

A line graph (Figure 2) displaying the data from Table 1 helps to visualize the changes to developed, forested, and agricultural land covers from 2006 through 2019. Developed land cover experienced an increase in land area in which it covered approximately 19.05% of the study area in 2006 and 19.93% in 2019 while forest and agricultural areas decreased from 47.66% to 46.93% and 29.69% to 29.11% respectively. Declines in forested and agricultural land cover are likely a function of increases in developed land cover as residential developments become more prevalent in forested areas and large commercial structures are constructed over agricultural lands.

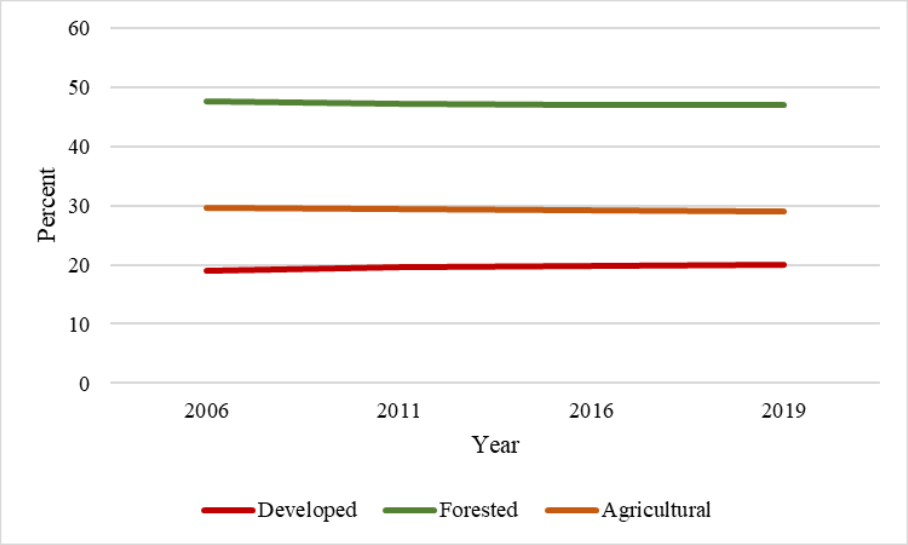

Figure 2: Illustration of percent land cover for the three major land use classes in the HUC10 watershed boundary of Berks and Schuylkill Counties from 2006 to 2019.

Objective 2: Impact of warehousing development

Over the four selected years of study, the development of warehouses in Bethel Township increased from zero warehouses in 2006 to five warehouses in 2019 (Figure 3). Although warehouses leave a large footprint of developed land cover on a land use map, the impact on impervious land cover at a watershed or township scale is minimal from a percent cover/area standpoint. For example, Table 2 below displays the percent land cover for each land use in Bethel Township for eight land cover classes. From 2006 through 2019 little land use change has occurred and all the land cover classes with the exception of developed and agricultural land covers have changed less than a tenth of a percent over the thirteen years.

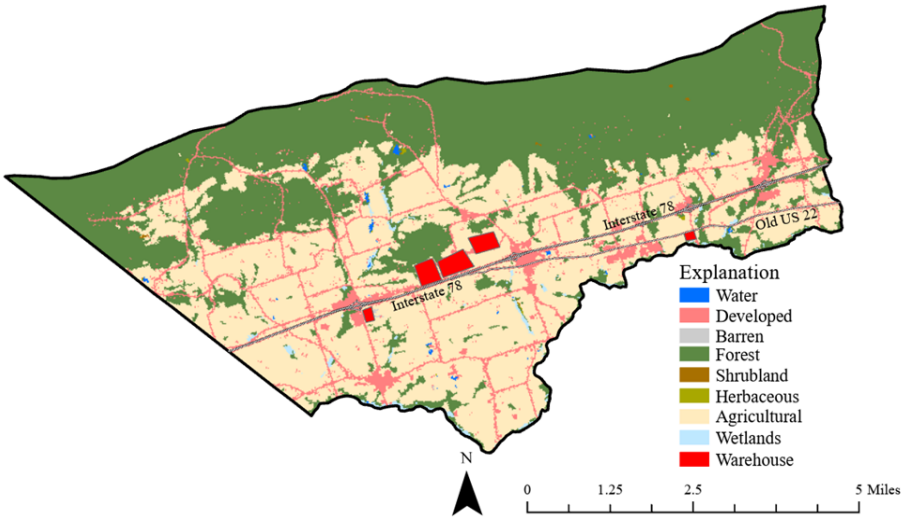

Figure 3: Distribution of warehouses and land cover in Bethel Township in Berks County for 2019.

Table 2: Percent of total area for each land cover class for Bethel Township in Berks County.

	Water	Developed	Barren	Forested	Shrubland	Herbaceous	Agricultural	Wetlands
2006	0.18	8.93	0.01	45.82	0.14	0.04	44.10	0.77
2011	0.17	9.12	0.01	45.77	0.16	0.03	43.95	0.80
2016	0.17	10.03	0.01	45.84	0.04	0.04	43.07	0.80
2019	0.17	10.04	0.03	45.83	0.04	0.05	43.04	0.80

The decline in agricultural land cover and increase in developed land cover is a good indicator that agricultural areas are most heavily impacted by warehouse development. A 1.06% decrease in agricultural land cover may not be a cause for concern, which is the same for a 1.11% increase in developed land cover over the span of thirteen years. The development of warehouses, however, has shown a significant impact in total developed land cover where they now comprise 8.19% of the total developed land area in Bethel Township (Table 3).

Table 3: Number of warehouses for each of the four years of study and the percentage of the total developed land cover comprising warehouses in Bethel Township.

Year	Number of Warehouses	Total Developed Land Cover (%)
2006	0	0.00
2011	1	0.52
2016	4	7.64
2019	5	8.19

Overall, the footprint of warehousing development in Bethel Township may not be a cause for concern from a broader land use management scale. At the same time, the fact that the footprint of new warehouses is approaching 10% of the total developed land cover in the Township demonstrates the growing impact of this type of development. The fact that warehouses are located in a highly visible location (along Interstate 78) also likely leads to a “drive-by effect” in which community members notice and remember the warehouses due to their size and location. Due to their size and unforgettable presence, the warehouses are what an individual will remember most about the area and believe that they take up a significantly larger footprint in the Township than they actually do.

Objective 3: Impervious surface dynamics

NLCD Developed Imperviousness data for both 2006 and 2019 were used to calculate the percent change in imperviousness in the intersecting counties for both HUC 10 and 12 watersheds levels. Figure 4 displays the percent change over the study time period in the HUC 10 watersheds. There is a particularly dark set of watersheds in the eastern portion of the study region that are showing a higher percent change

as compared to the whole study area. With a particularly high percent change in the watershed that is home to Allentown, Pennsylvania, a growing developed area that shows a 1.1%+ change in the overall watershed. This watershed does cross over into our focus region, Berks and Schuylkill counties. Taking a look at the counties we want to focus on, the largest change can be seen in central Berks county and the southernmost corner, in the Middle Schuylkill River (0.52%) and Conestoga River (0.92) watersheds. These watersheds have seen 0.51-0.75% increase in imperviousness, while most of Schuylkill county is below 0.50% increase in imperviousness.

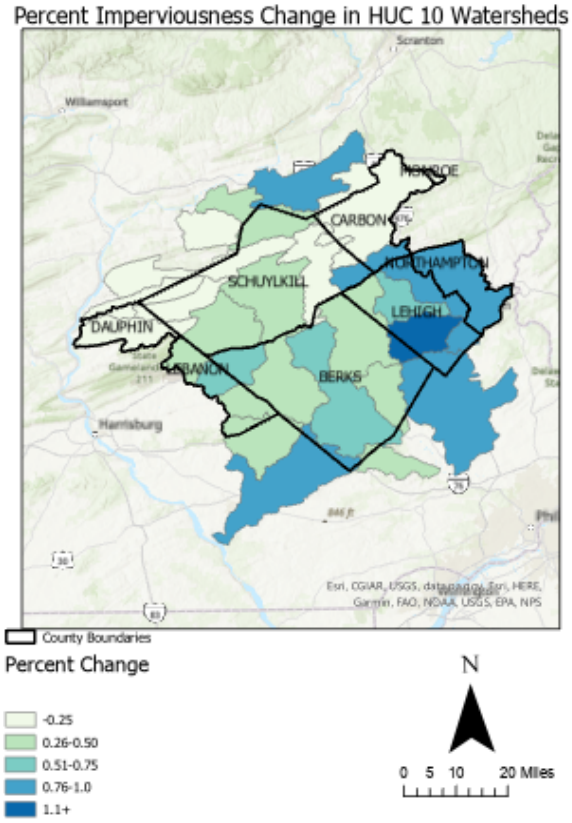

Figure 4: Percent Change of Imperviousness for HUC 10 Watersheds, 2006-2019.

The next figure, Figure 5 takes a look at percent imperviousness change in HUC 12 watersheds. Schuylkill county has a notable watershed, the West Branch Schuylkill River that has a higher level of change, seeing 0.84% compared to the surrounding watersheds; with smaller watersheds, areas of concentrated impervious surface change can be visualized. Many of the surrounding watersheds in Schuylkill county are in the less than .25% change range. As for Berks county, a similar effect can be seen where a larger HUC 10 watershed shows a 0.51-0.75% change, the HUC 12 watersheds show a concentration of impervious surface change in four central watersheds: Pigeon Creek-Schuylkill River (1.4%), Cacoosing Creek (1.2%), Willow Creek (0.83%) and Laurel Run-Schuylkill River (0.81%). Outside of the primary study counties, Lehigh County has a notable amount of dark coloration displaying the highest increase in imperviousness.

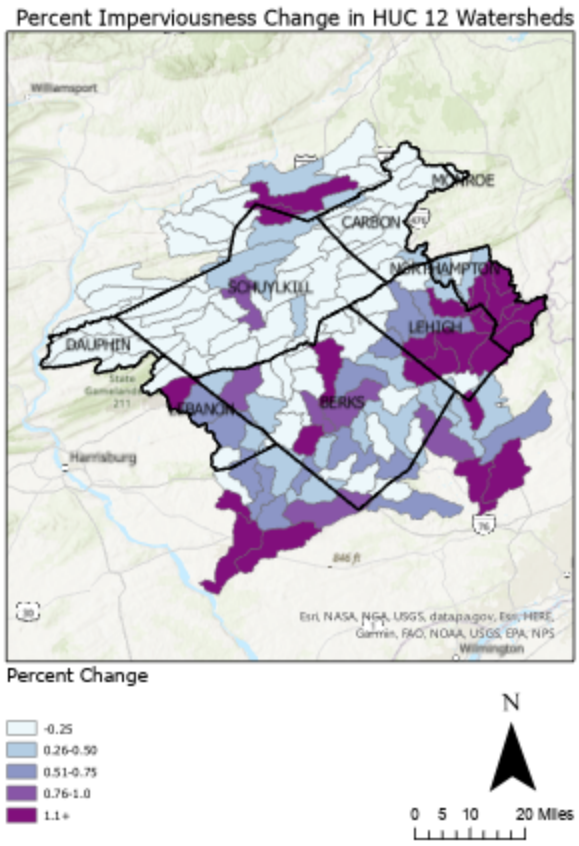

Figure 5: Imperviousness change in HUC 10 watersheds from 2006-2019

Finally, the last point of interest was a hotspot analysis performed on the study area, the results of which are shown in Figure 6. The results do display some consistency with the HUC 12 imperviousness increases. The central area of Berks County, in and around Reading, Pennsylvania is a notable hotspot, Much of this region is displayed as a hotspot with 99% confidence. The calculation is based on the percent change seen between the years 2006 and 2019. There are also a few watersheds around the Schuylkill and Berks counties' shared border that are identified as coldspots with 90% confidence. These areas did not see as much increase in imperviousness as compared to the rest of the study area. When looking outside of the primary focus counties, Lehigh and Northampton counties have a very high number of watersheds that are identified as hotspots with 99% confidence.

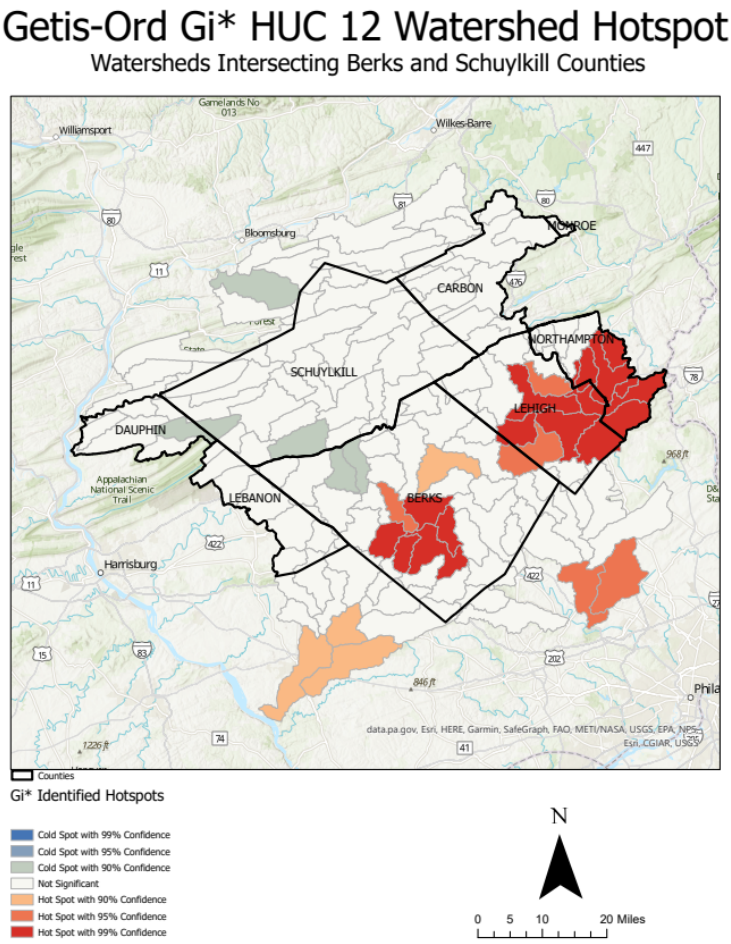

Figure 6: Hotspot analysis using Getis Ord Gi for HUC 12 Watersheds, 2006-2019*

It is important to keep in mind that the hotspot analysis is based on the percent change over the study time frame of 2006 to 2019 for the HUC 12 watersheds. It should be noted that changes in imperviousness in central Berks County range from 1.1% to a maximum of 3.4% in the Spring Creek watershed, while the cold spots show less than 0.25% increase in imperviousness, with a minimum of 0.01% impervious surface change. Taking this into account is important when assessing the results of the hotspot analysis.

Objective 4: Impervious surface dynamics in the active river area

By reclassifying the Nature Conservancy's northeast and mid-Atlantic ARA data, the percent ARA in each HUC 12 watershed that intersects Berks and Schuylkill counties was calculated (Figure 7). There were three HUC 12 watersheds that had an ARA percentage greater than 2.5%: Middle Tulpehocken Creek (2.86%), Sixpenny Creek (2.56%), and Swamp Creek (3.06%). Much of the Middle Tulpehocken Creek watershed is covered by the State Game Lands 280; and, the Sixpenny Creek watershed contains French Creek State Park. Both of these areas contain large portions of waterways.

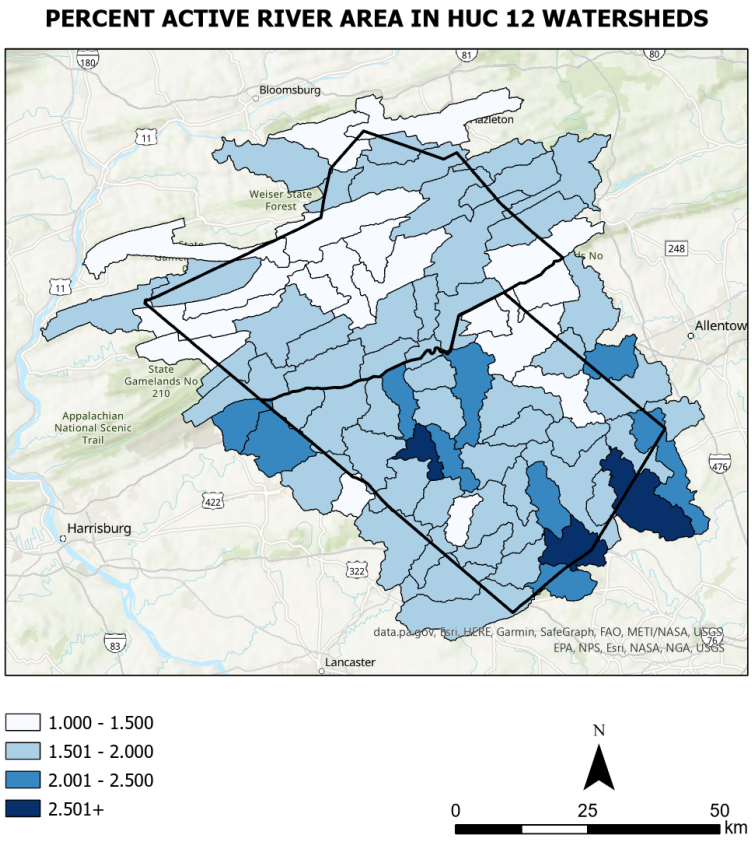

Figure 7: Percent ARA in HUC 12 watersheds intersecting Berks and Schuylkill counties.

In order to understand the impervious surface dynamics within the ARA, the NLCD Developed Imperviousness dataset was used in order to calculate the mean ISA for both the 2006 and 2019 datasets. In 2019 (Figure 8), there were eight HUC 12 watersheds that had a mean ISA within the ARA greater than 10.0%: Eisenhuth Reservoir (12.19%), Headwaters Tulpehocken Creek (11.01%), Spring Creek (21.47%), Willow Creek (13.40%), Laurel Run (22.96%), Antietam Creek (10.08%), Wyomissing Creek (18.14%), and Angelica Creek (11.46%). Five of these watersheds (Willow Creek, Laurel Run, Antietam Creek, Wyomissing Creek, and Angelica Creek) are located around the Reading area, which is a heavily developed area. Additionally, the Spring Creek watershed has a significantly higher mean ISA due to the warehouses that are present in Haafsville.

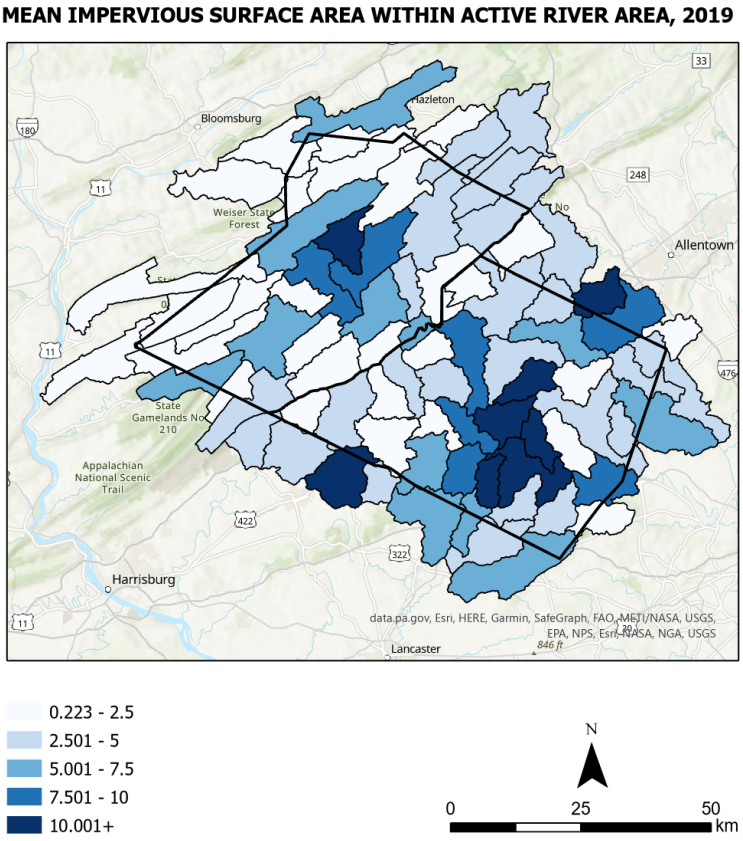

Figure 8: 2019 mean ISA within the ARA by HUC 12 watersheds.

After calculating the difference in mean ISA between 2006 and 2019, there was one HUC 12 watershed of particular interest - the Spring Creek watershed. This watershed is located on the northeastern border of Berks County (Figure 9). In 13 years, there has been a 3.76% increase in ISA for the Spring Creek watershed due to warehouse development, specifically in the Haafsville area. Additionally, the ISA for this watershed is likely to increase in upcoming years as a recent land development plan was submitted to build more warehouses totaling 2.6 million square feet in area (Jones, 2022). This watershed should be monitored in order to track hydrological trends such as runoff or surface water contamination.

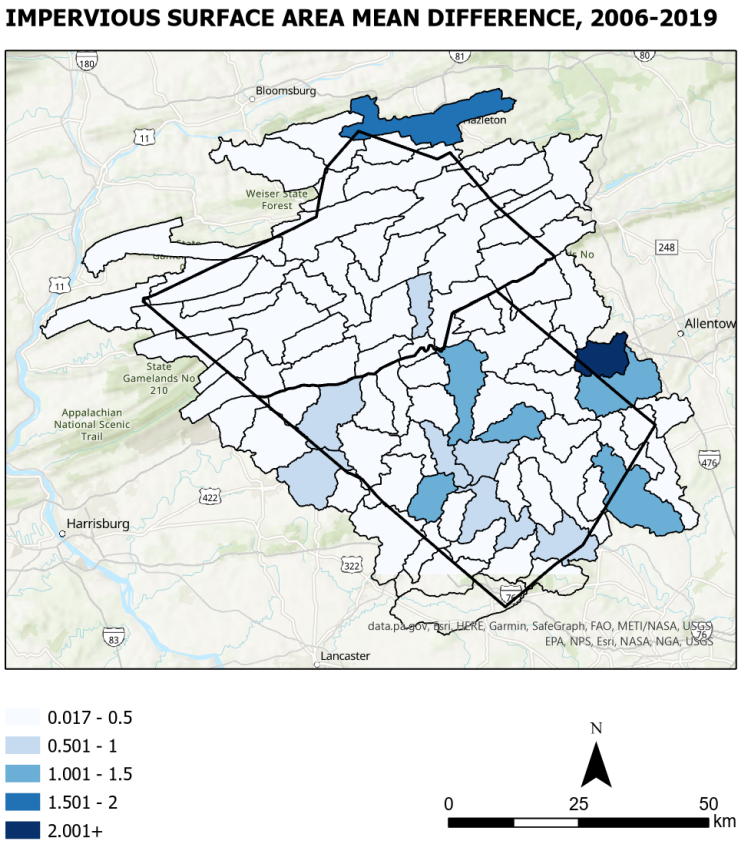

Figure 9: Mean difference in ISA, 2006-2019.

Summary and Conclusions

The Kittatinny Ridge Corridor is an incredibly important region to both Berks and Schuylkill Counties as it is resilient towards climate change and is considered a biodiverse superhighway (The Nature Conservancy, 2021). This is especially important considering LULC and impervious surface coverage is changing due to suburban sprawl from Philadelphia and the growing demand for distribution centers. By using ArcPro geoprocessing tools such as 'tabulate area,' 'reclassify,' and 'zonal statistics,' we were able to analyze and explore the overall land cover change, warehouse development, and percent imperviousness in HUC 10 and 12 watersheds as well as the ARA. Although there isn't significant change throughout the study area as a whole, the results do show that changes in impervious surface coverage and warehouse development are centralized in specific watersheds and regions.

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