Environmental Impact of Distribution Warehouses in a Residential Environment

ENVL 3308 - INTRODUCTION TO LIDAR / 4622 - GPS FOR GIS

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Introduction

Florence, NJ (Figure 1) is located in upper Burlington County with a population of about 13,000 and has historically been a foundry town with much emphasis on the steel mill in Roebling, a wharf along the Delaware River, and a sandy beachfront. In recent years, that has changed, and given the accessibility of Florence to various rail and highway corridors, the township's economy is tied to its evolving role as a center for logistics. Florence and nearby towns in Burlington County have become prominent regional warehouse centers, attracting corporations like Amazon to build such facilities there. Resident complaints have gone up exponentially since warehouses have been built and there have been strikes and petitions in Florence and surrounding towns to stop the construction of warehouses near residential zones.

Figure 1: Map showing study area of Florence, NJ and selected warehouses for analysis. Warehouse location points were collected in situ with ArcGIS field maps.

Warehouse construction disrupts daily life in small towns such as Florence, leading to increased air and noise pollution, as well as increased traffic flow (*Shearston et al.*). Heavy traffic as a result of industrial facilities negatively impacts air quality, a dangerous factor to consider when these facilities are being built so close to residential areas. The health effects of air pollution have been shown to be differentially harmful, such that worse outcomes are observed for populations with lower socioeconomic status and ethnic and racial minorities. Traffic related pollution, including both air pollution and noise, is of particular concern, as multiple interstate highways run through or near Florence, including the New Jersey and Pennsylvania Turnpikes, Route I-295, and Route 130. Although no statistical or peer-reviewed study has been conducted relating to employee demographics, it is well known within Florence Township that most employees at warehouses in the town commute from outside of town. A typical 1-million-square-foot warehouse has an average daily traffic rate of 1,740 trips, whereas a fulfillment warehouse (which constitutes most warehouses in Florence) of the same floor area has 8,180 vehicle trips per day — nearly 5 times as much (*Distribution Warehousing and Goods Movement Guidelines*). Furthermore, truck drivers that are unfamiliar with the area often drive into residential neighborhoods, putting children, pets, and residents at risk. Large tractor trailer trucks driving through narrow residential streets may increase vehicle collision incidents or property damage. Most residents also complain of increased stress due to excessive traffic at peaks hours, especially school pick-up and drop-off times, especially since truck routes coincide with local school routes and warehouse shifts rotate at peaks traffic times (*Florence, NJ Community Page*).

In addition to affecting local populations, human development on mostly undisturbed land often leads to adverse effects on local wildlife. While single land use change may result in negligible impact, the accumulation of individual changes over time within a region may constitute a major impact. Theobald et al. (1997) determined a functional relationship between effect on habitat and distance from development and found that within this building-effect distance, habitat degrades, and a disturbance zone is produced. Development affects wildlife habitat directly and wildlife indirectly. Native vegetation is often altered or removed during construction and landscaping activities, which may alter the occurrence of native wildlife species. In Florence in particular, land has been cleared in forest land, grassland, and early successional zones to make way for warehouse construction. In addition to reducing habitat area, human development fragments habitat by dividing it into smaller, spatially disjointed units. A highly fragmented landscape is less likely to have large, intact habitats. Furthermore, fragmentation isolates species, inhibits movement, and reduces the chance of recolonization in the event that a species disappears from a patch of habitat. Unfortunately, few studies have been conducted on the changing nature and scale of the demand for land needed for construction, and based on available data, it is not possible to estimate exactly how much or what kind of land they occupy nationwide.

However, in addition to storage space in buildings, there is also extensive use of land for outdoor storage of primary products and waste material. Shipping terminals also occupy significant expanses of land, some of which is shared with the movement of people. Over the past decade, there has been a strong demand for large new distribution centers with floorspace over 10,000 square meters and between 1996 and 2008, about 50 new distribution centers were built annually, their average size increasing from 20,000 square meters to 40,000 square meters (*McKinnon*). In 2006, there were approximately 151 million square meters of warehouse floorspace in England and Wales and assuming an average plot ratio of 45%, the amount of land on warehouse sites would have totaled 23,500 hectares, equivalent to 0.8% of non-agricultural and forestry land (*McKinnon*). We can assume and infer that this number is much higher in the United States due to our larger geographical area and ever-expanding economy.

It is inevitable for logistic centers to migrate into more residential territories as we embrace development but developers must find the best way to reduce risks and make local citizens safe and prosperous when determining warehouse sites. Globally, developers are typically concerned with environmental and social risks that come with industrial development and create siting models based on land use criterion, distance to residential zones, slope or elevation, and erosion (*Al-Hameedawi).* However, rarely do we see wildlife habitat or ecological species included in the list of criteria. As industry grows in an evolving American climate, we must recognize the importance of protecting residential culture and the natural resources that small towns are losing access to every day. This study aims to use GPS technologies and remote sensing to determine the environmental and socioeconomic impacts of distribution warehouses built in Florence, NJ over a relatively short period of time.

Methodology

Over a five-week period, I collected data and performed geoprocessing to analyze the change in landscape in Florence as well as determine what factors affect warehouse location and how wildlife has been potentially affected by construction (Figure 2).

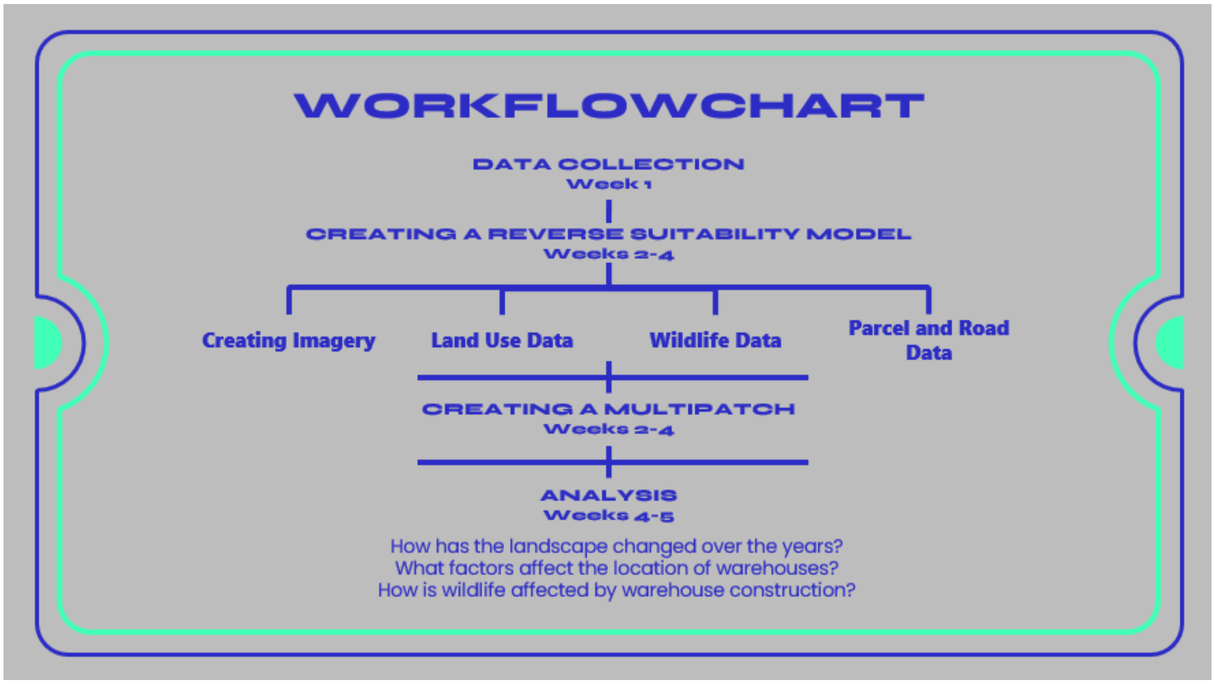

Figure 2: Basic project workflow and timeline.

To begin, I decided to focus on warehouses that have significantly impacted residential life in Florence based on proximity to residential zone and rate of construction, as well as public opinion on traffic nuisances. I wanted to make sure I also included warehouses that have had significant impact on the landscape of the town, particularly those that I could personally recall what the areas looked like prior to development. I collected the warehouse GPS points shown in Figure 1 in situ on November 6, 2022, using ArcGIS Field Maps including four sites that have been built in 2022 alone that are not shown in the most current orthoimagery. Following GPS point collection, I downloaded a variety of data from open sources (Table 1).

Table 1: Data downloaded for GIS analysis along with date and specific data source.

Date	Data Downloaded	Data Source
11/7/22	1930, 2007, 2015, 2020 Ortho-Imagery	NJGIN
11/7/22	Land Use Data	GeoFabrik OpenStreetMap Data
11/7/22	Road Data	GeoFabrik OpenStreetMap Data
11/7/22	Parcels and MODIV Composite of NJ	NJOGIS
11/16/22	DVRPC 2015 LAS Point clouds	NJGIN
11/21/22	Wildlife Natural Heritage Grid Map	ArcGIS Online- sourced from NJDEP
11/21/22	Landscape Data for Piedmont Plains Region of NJ	NJGIN and associated table
11/21/22	2015 NJ Impervious Surfaces	NJDEP Open Data

After downloading these datasets and importing them into ArcGIS Pro, I started a geoprocessing workflow designed to produce imagery of Florence Township over the years, categorize land use in Florence, classify warehouse parcels, visualize average warehouse distance from main roads and highways, determine the presence of endangered or threatened species at and around warehouse sites, and classify buildings and ground points from the LAS point cloud to create a building multi-patch for visualization (Figure 3).

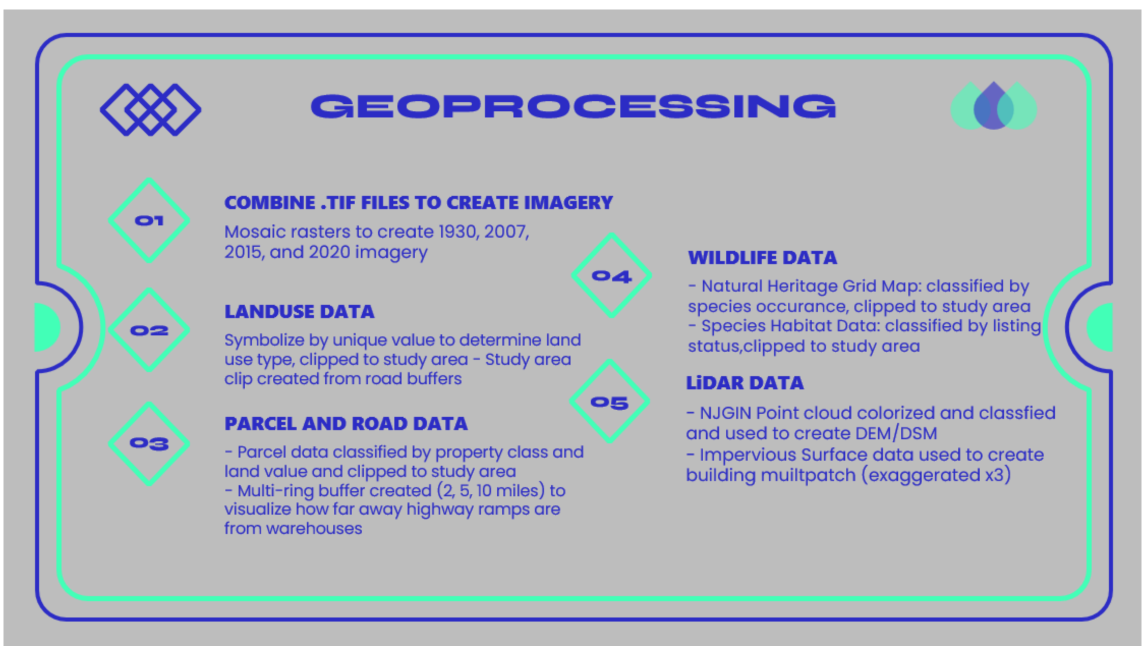

Figure 3: Basic geoprocessing workflow of project datasets.

Starting with the .tif imagery files, I imported them into ArcGIS Pro and defined the 1930 imagery projection as NAD-1983 NJ State Plane so it would appear accurately on the map. After importing all the rasters, I used the "Mosaic Rasters" tool to stitch each set of raster datasets together to create one dataset each for the years 1930, 2007, 2015, and 2020.

Next, I worked with the land use and roads shapefiles. Both shapefiles included the entire state of New Jersey, so my first step was to create a buffer around the warehouses I collected points for to establish a study area. My main interest was seeing how many major roads and ramps the warehouses had access to within a 2-, 5-, and 10-mile radius so I used the "Multiple Ring Buffer" tool to create multiple buffers at the specified distances around the input features. I merged and dissolved the buffers to create non-overlapping buffers.

Using the Roads shapefile, I used the "Select Layer by Attribute" tool to create a selection of the feature class based on an attribute query. This allowed me to select the road classes I wanted to focus on: motorways, trunks, secondary roads, and tertiary roads. These roads include all freeways, highways, regional roads, and local roads, which are the roads most often transited by trucks leaving or coming into distribution centers, as well as employees. The resulting feature class showed all major roads in New Jersey but did not include the ramps to access these roads, so I added the same feature again to my map, this time to isolate the ramps. Using the "Select by Attribute" tool again, I selected road classes that corresponded with highway and freeway ramps; 'motorway_link' and 'trunk_link' respectively. I used the multi-ring buffer layer I created earlier and the "Pairwise Clip" tool for my Major Roads layer and my Ramps layer to extract the input features that overlayed the clip features. This allowed me to create a smaller area of interest to focus on. Unfortunately, after running the clip, I realized that my study area was including a portion of Pennsylvania, so I imported a NJ county boundary layer from Stockton University's GIS ://H drive and clipped my study area to the layer to ensure my study are only included New Jersey.

Focusing on the land use shapefile next, I Symbolized the layer by Unique Values using the 'fclass' attribute, which categorized the layer by land use type, such as forest, farmland, industrial land, residential, etc. This feature layer included the entirety of NJ, so I used the "Pairwise Clip" tool again and the Multi-ring buffer I created to focus on my study area. However, a 10-mile radius was too large of an area, so I selected only the 2-mile buffer and ran the tool.

Next, I used the Parcel and MOD-IV dataset to evaluate the property class of parcels where warehouses are built as well as the value of the land. First, I clipped the layer to the 2-mile buffer to focus it into my study area. I used the "Select by Location" tool on the layer to select features using the location of features in another layer. Specifically, I selected parcels that contained my GPS collected Warehouses to isolate the warehouse parcels I wanted to work with. I made two new layers from the selected features. For one layer, I symbolized it by Unique Values, using the Property Class field to see what each parcel was classified as. For the other layer, I symbolized it by Graduated Symbols using the Land Value field and 5 manual intervals to visualize the difference in land value for each warehouse parcel. Going back to my original layer, I used the "Select by Attributes" tool to select all industrial and vacant parcels then symbolized the layer by Graduated Colors using the Land Value field and 5 natural breaks to see the spread of land values across the selected parcels.

I then began to focus on wildlife data. Both datasets were for the entire Piedmont Plains region of New Jersey, so my first step was, again, to clip the layers to the 2-mile buffer to focus it into my study area. I symbolized the Landscape Data dataset, which provides information on High-Risk Habitat Zones, by Unique Values using the LNDR field, which ranks the patch of land based on the status of the species present. I wanted to focus specifically on high-risk species, so I used the “Select by Attribute” tool to select LNDR ranks of 3, 4, and 5, which are state threatened, state endangered, and federally threatened or endangered species, respectively. Next, I symbolized the Natural Heritage Grid Map layer by Unique Values using the Precision field to show blocks where rare ecological species have been sighted both precisely and within 1.5 miles.

Finally, I worked with the LiDAR data. First, I used the “Convert LAS’ tool for each .las file to convert them to .lasd files in order to create LAS datasets I could work with. After converting all 10 .las tiles, I used the “Create LAS Dataset” tool to create a LAS dataset referencing all of the .las files to create one big point cloud of my study area. After creating a dataset, I used the “Classify LAS Ground” and “Classify LAS Building” tools to classify ground and building points from my LAS data. Using this resulting dataset, I ran the “Colorize LAS” tool, which applies color and near-infrared values from orthographic imagery to LAS points. Because my point cloud data was from 2015, I used my 2015 imagery layer as the input layer for this tool. Next, I used the “LAS Dataset to Raster” tool, which creates a raster using elevation values stored in the LiDAR points referenced by the LAS Dataset, to create a DEM raster to use for my building multipatch later.

Using the 2015 Impervious Surface dataset, I clipped my 2-mile buffer study area then used the “Select by Attribute” tool to select surfaces classified as “Buildings” and made a new layer from the selection. I used the “LAS Building Multipatch” tool to create building models from the rooftop points captured in my LiDAR data with my new Building feature class as the footprint. After creating the multipatch, I inserted a new Local Scene into my project with the building multipatch. In order to differentiate between residential buildings and warehouses, I symbolized the multipatch by Graduated Colors using 5 manual intervals. To make the difference in buildings a bit more obvious in visualization, I set the vertical exaggeration of the features to 3.0.

Results

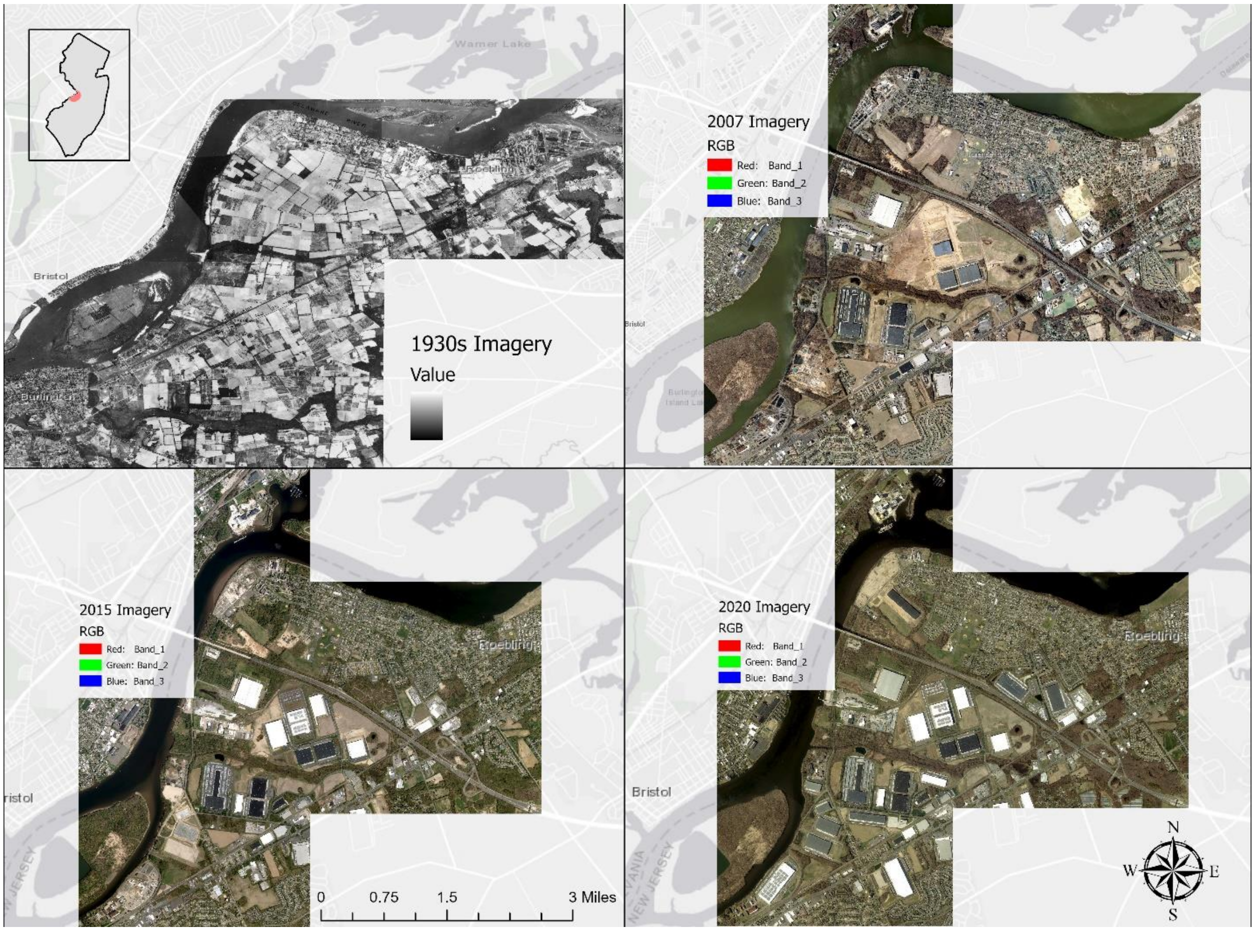

Figure 4: Comparative Imagery of Florence, NJ from 1930-2020 demonstrating changes in landscape

There has been a noticeable change in the landscape of Florence, NJ since 1930. The town has evolved from a small, rural township with large plots of empty land past its residential borders in its early years, to a booming industrial zone that has continuously encroached into residential territory since at least 2007 (Figure 4). The Pennsylvania Turnpike is considered to mark the end of the residential zone in Florence and beginning of the industrial zone of Burlington, but industrial land has slowly been encroaching into residential territory (Figure 5).

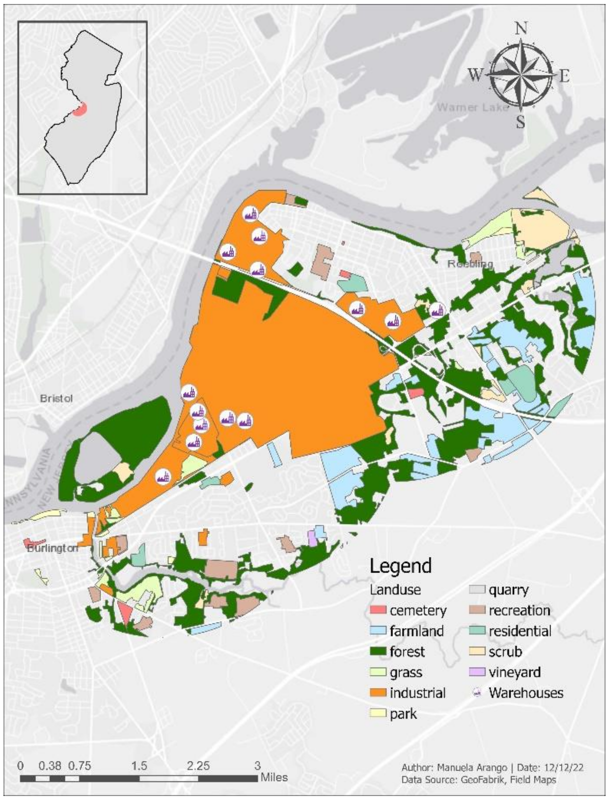

Figure 5: Land use relative to warehouse location. Thirteen of the selected warehouses are on industrial land, one is in forest land.

When analyzing the proximity of warehouses to major road networks, I found that all recorded sites were within a 2- or 5-mile radius of an I-295 or intrastate Turnpike ramp, with the closest major road being the Pennsylvania Turnpike, which connects to the NJ Turnpike (Figure 6). All warehouses have access to multiple freeway and highway ramps, as well as important regional and local roads within a 10-mile radius (Figure 7). Easy access to important roads allows for increased traffic flows from both distribution center trucks and warehouse employees that travel from neighboring towns or states.

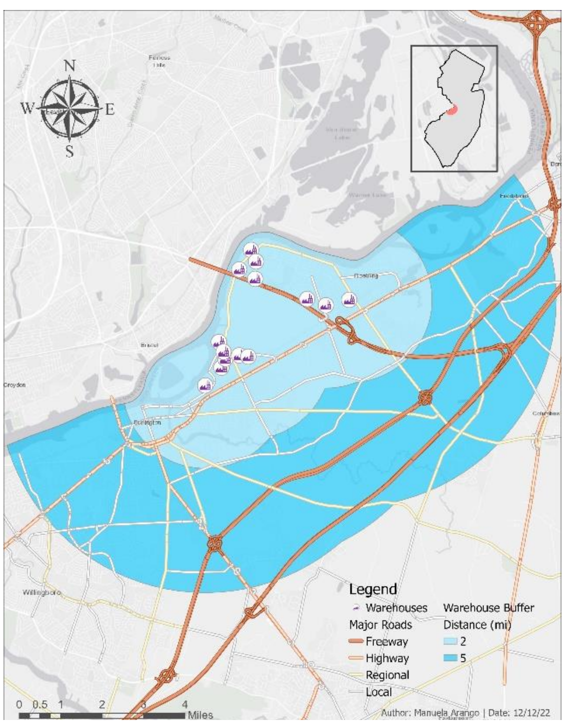

Figure 6: Warehouse distance from major highway and freeway ramps within a two- and five-mile radius

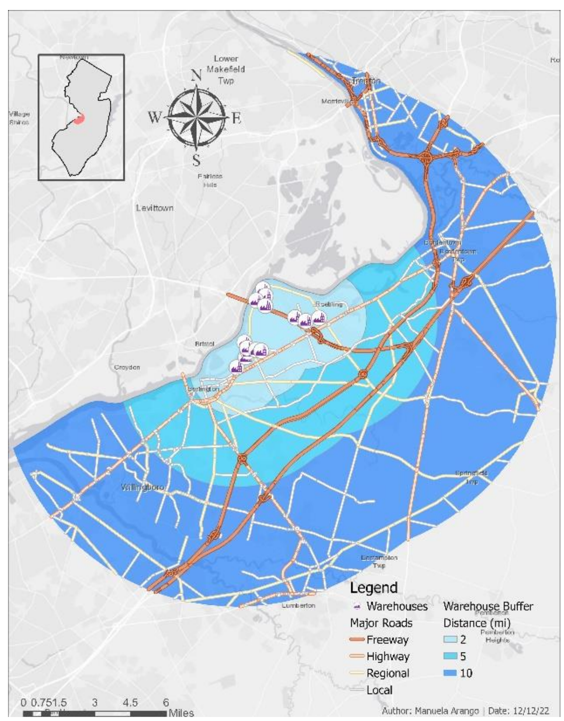

Figure 7: Warehouse distance from major highway and freeway ramps, as well as regional and local roads, with a two-, five- and ten-mile radius.

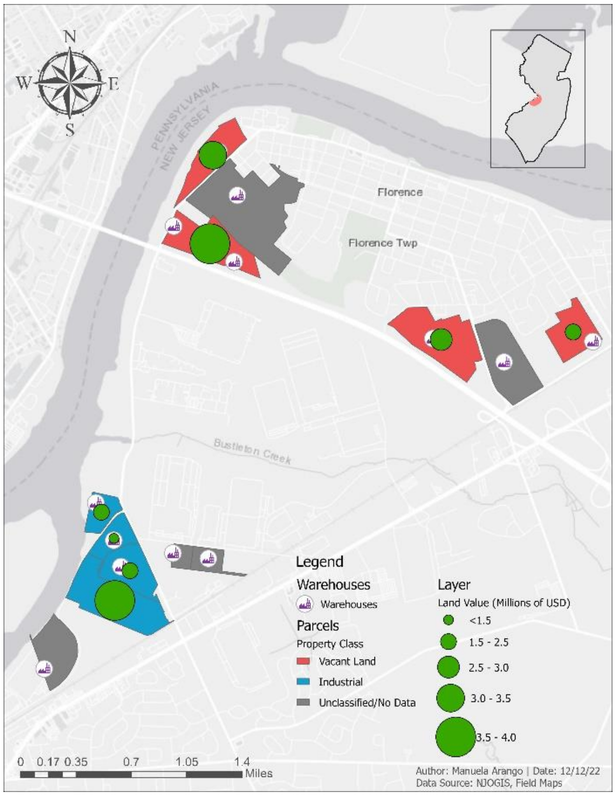

Figure 8: Warehouse land parcels classified by property class and associated land values ranging from less than 1.5 mil USD up to 4.0 mil USD.

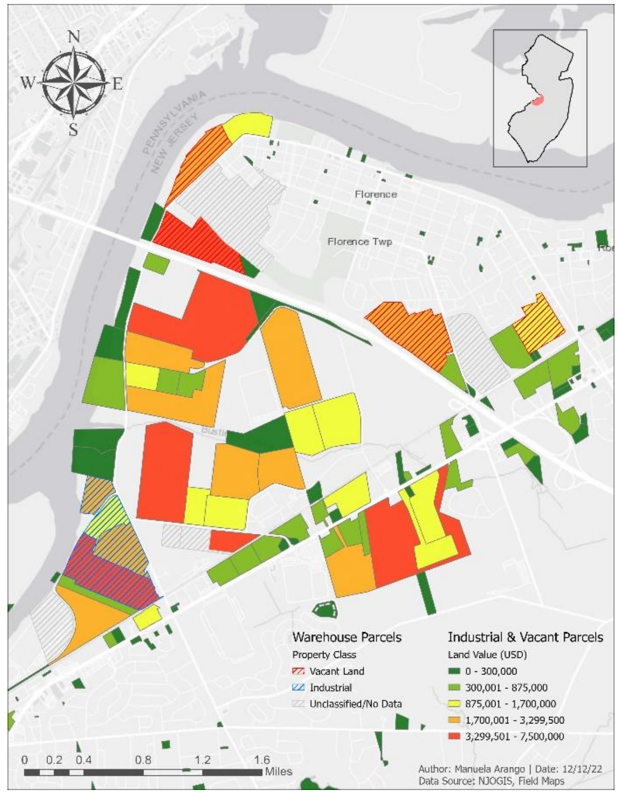

Figure 9: Values of industrial and vacant land within two-mile radius of selected warehouses.

In terms of land parcels, warehouse land is typically classified as industrial or vacant land, with the average value of the selected sites being $2.5 million USD (Figure 8). When looking at all industrial and vacant land within a 2-mile radius, the average land value is approximately $400K USD, which may factor into warehouse siting models (Figure 9).

When looking at wildlife occurrence relative to land use, I found that industrial land within a 2-mile radius of selected warehouses was being developed on land where rare ecological species have been precisely documented since at least 2021. Furthermore, most of Florence's industrial zone runs along the Delaware River, which contains wildlife species that are considered high-risk at the state and federal level (Figure 10). Figure 11 shows how warehouse location compares to areas with high-risk flora and/or fauna.

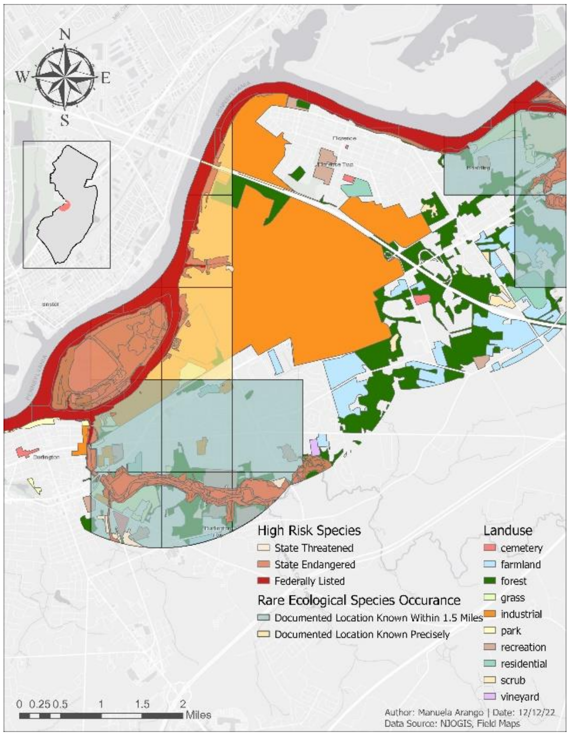

Figure 10: Wildlife occurrence relative to land use within Florence, NJ. High risk species refer to species that state or federally listed as threatened or endangered. Rare ecological species refer to rare plants that have documented according to map legend.

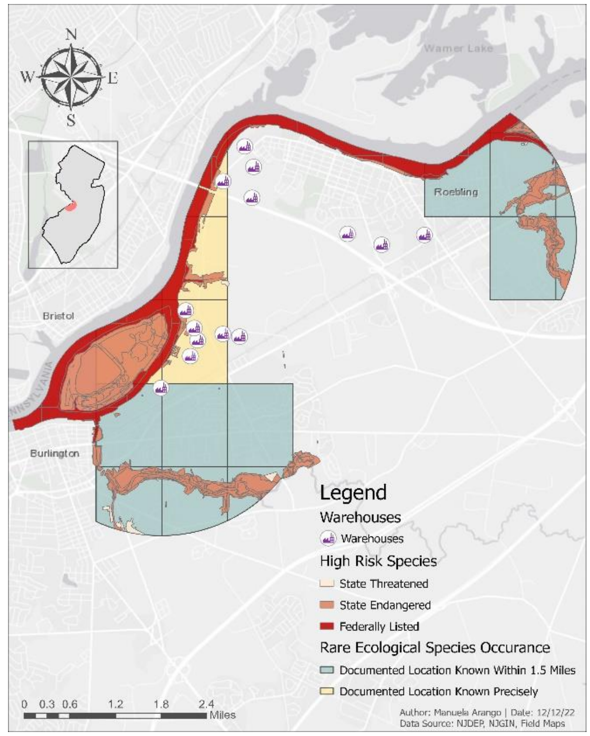

Figure 11: Wildlife occurrence relative to warehouse location within a two-mile radius. High risk species refer to species that state or federally listed as threatened or endangered. Rare ecological species refer to rare plants that have documented according to map legend

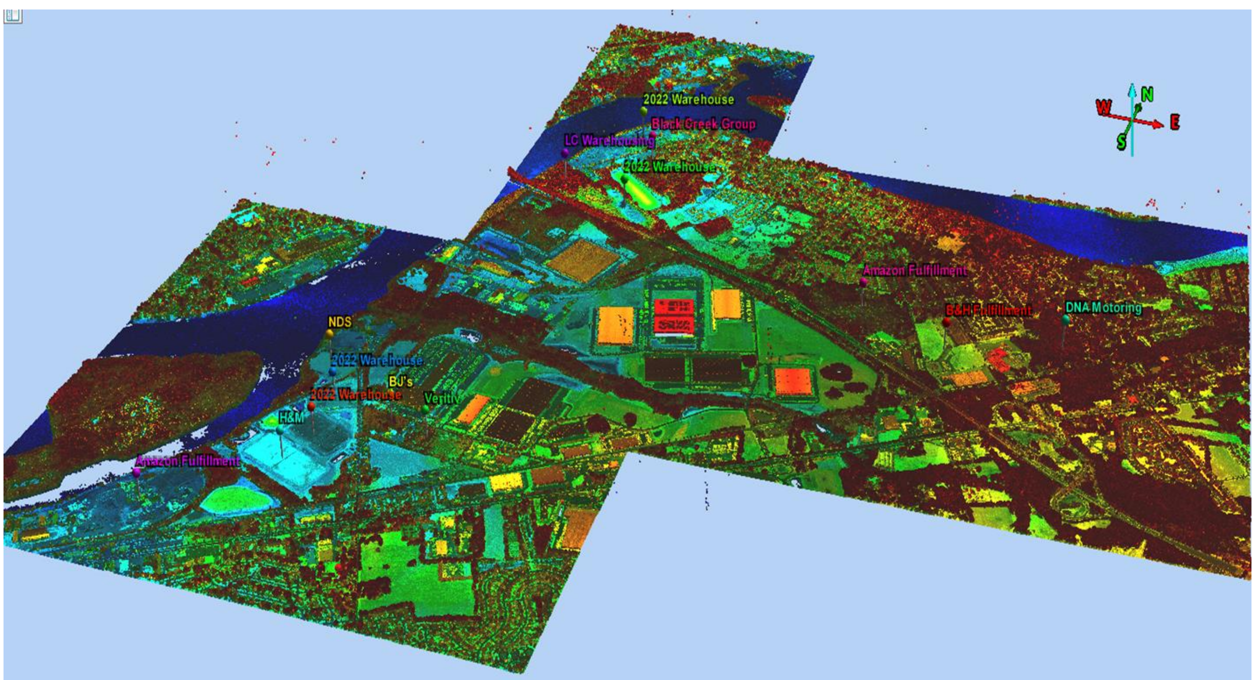

Figure 12: QTM Reader view of LiDAR point cloud of Florence, NJ in 2015. Warehouses collected with GPS points shown and labeled. At the time of generation for this model, some warehouses have not been named or bought by distributors and are labeled as "2022 Warehouse".

Using Quick Terrain Model Reader, I synthesized a colorized point cloud of Florence, NJ and placed markers where I collected GPS points for my warehouses to create a visual representation of the elevation of the town (Figure 12). While this provided a nice RGB representation of my data, my building multipatch provides a clear view of warehouses surrounded by residential buildings (Figure 13) and the difference in acreage of building types.

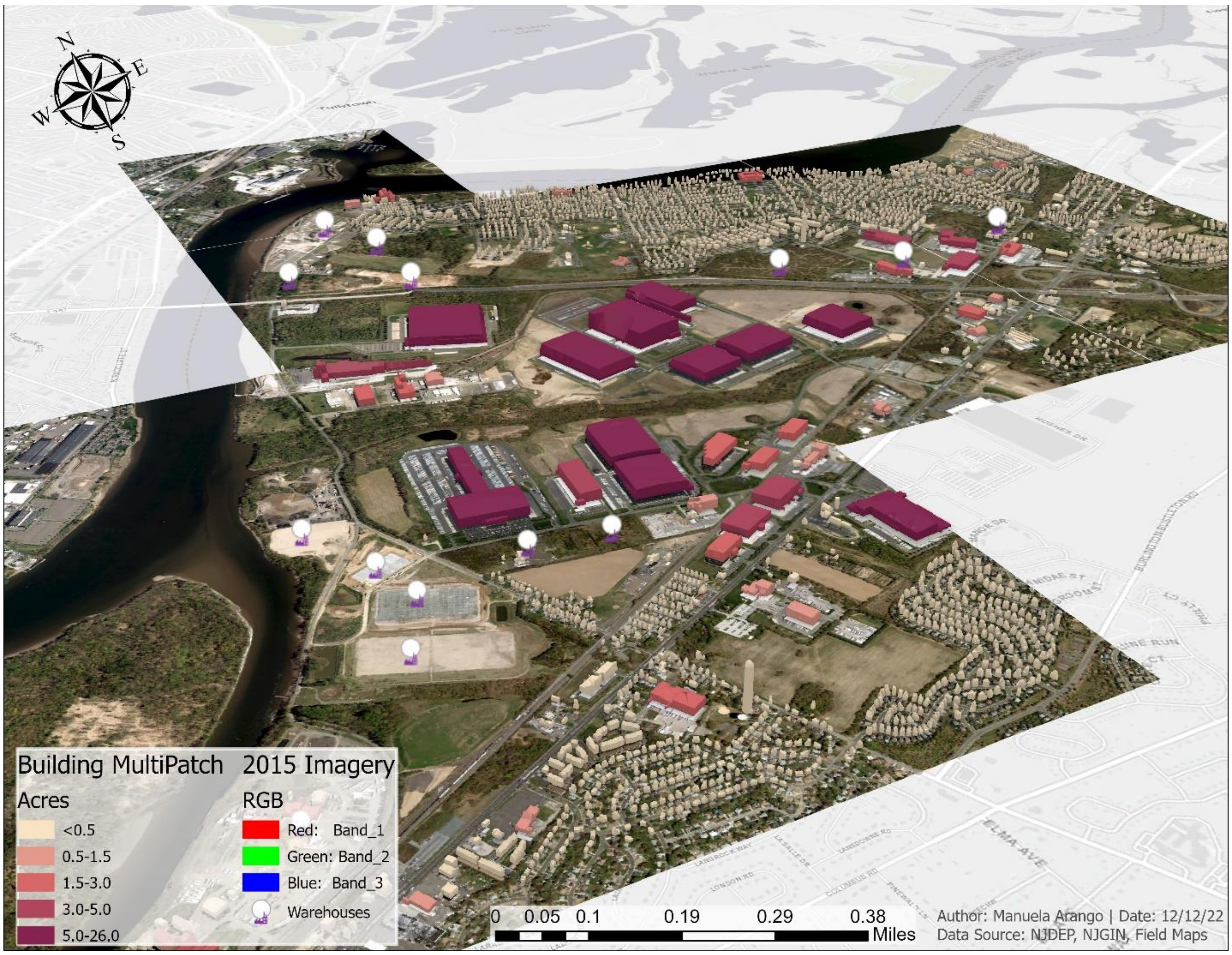

Figure 13: Visualization of warehouses in Florence, NJ in 2015. Building multipatch is classified by acreage, showing a clear distinction between warehouses and residential buildings. Vertical exaggeration has been set to 3.0 to demonstrate building height differences.

Discussion

My analysis led to the creation of a warehouse siting model, and I realized that some of the common factors of current warehouse sites included the zoning of the land, proximity to major roads, and, although to a lesser extent, cost of land parcel. According to my analysis and subsequent results, warehouses in Florence, New Jersey are built on vacant lots or land zoned for industry while maintaining a proximity of 2-5 miles from a major freeway or highway. Vacant lots generally cost less than lots that have experienced development, making them favorable for developers who wish to build logistic centers on the land. As more warehouses are built, the land around industrial zones increase in value and drive marketability. Furthermore, a developer is more likely to purchase a plot of land for development if warehouses already exist in surrounding lots. As seen in Figure 9, the value of land zoned for industry and vacant lots varies a great deal, but the majority of these lots are valued between 875K-3.3M USD.

To be clear, just because a parcel of land is zoned for industry does not make it adequate for industrial development. Zoning evolves to keep up with the changing variety of uses and trends and these differences could mean dramatically different impacts and outcomes, and whether a project is compatible with a site and beneficial to a community. Many towns in New Jersey, like Florence, are finding that their communities are particularly vulnerable to poorly sited and scaled warehousing projects because they zoned large areas of their community, particularly farmland in rural areas, for broadly applied “light industrial” uses without consideration or limitation on the size and intensity of today’s distribution warehouses. As a result, many land-use plans and zoning ordinances may be inadequate in their present form to address the pace and scale of new warehousing proposals and their impacts on neighborhoods, local roads, adjacent communities, and finite resources.

Typically, warehouse-related zoning in New Jersey should exclude areas or avoid sites containing State regulated areas, including flood hazard areas, freshwater wetlands, riparian zones, transition areas, steep slopes, and threatened and endangered species habitats as identified under NJDEP's Landscape Project (*Distribution Warehousing and Goods Movement Guidelines*). The data analyzed and compiled in this study shows a clear violation of these guidelines (Figures 10 & 11). The area surrounding the industrial zone of Florence and Burlington consists of riparian zones, tidal rivers, marshes, wetlands, inland bays, and other tidal waters as well as forests in addition to housing several threatened and endangered species including, but not limited to, Barred Owls, Bald Eagles, Ospreys, Northern Harriers, Peregrine Falcons, and Short-nose Sturgeon (*Landscape Species Table*). Federally listed species are present in the immediate vicinity of a massive industrial zone that produces unprecedented amounts of runoff into the Delaware River from construction and daily activities.

The NJ State Planning Commission Warehouse Siting Guidance document includes plans on how to mitigate possible negative impacts on traffic and roads, noise impacts, and air quality and greenhouse gas impacts from construction, but there is no mention on the mitigation of habitat fragmentation or wildlife displacement. As industry becomes more prevalent, we must take into consideration how development practices affect vulnerable ecological communities and actively work towards incorporating these aspects into plans.

Another key factor of this analysis was brought up in the visualization of this data (Figure 13) which shows a clear dissonance in the landscape surrounding residences. With the visualization of a building multipatch, it is clear to see that as industry grows, the total area of industrial zones grows to match or exceed the total area of residential buildings. It is important to note that the LiDAR data at my disposal is from 2015 and is the latest available data from the region. LiDAR data is not collected regularly enough to perform an analysis for thirteen of the warehouse sites I collected using current GPS points. To reiterate, the buildings visualized in the model do not include the thirteen warehouses that have been constructed in the past seven years, nor does it include current sites that are under planned development.

The results of this study could prove useful to the residents of Florence Township when presenting zoning board members and local politicians with evidence and arguments against further industrial development in the town. Further research into this topic could potentially uncover violations of greenhouse gas emissions tolerance and other construction related pollution. As mentioned earlier, the effects of a single development event may be negligible but there has been a minimum of 4 distribution centers built on the edge of residential zones in Florence in 2022 alone, with more being built on the outskirts of town and within the same conditions in Columbus, Mansfield, Burlington, and Bordentown. In continuation of this study, I would like to survey the residents of Florence to gain a better understanding of their grievances and where they see the negative impacts of warehouses the most. It would also be useful to investigate the changes in traffic data from 2010 to the present and evaluate how road conditions have changed in response to increased heavy traffic patterns. I would also like to repeat this study in the future once NJ GIS databases update the state’s orthoimagery and LiDAR data, as it is difficult to perform a concise analysis with outdated information.

There are clear violations of warehouse siting guidelines in terms of mitigation of environmental and social impacts. Industrial zones are slowly encroaching into residential areas, reducing the air quality of the region as a whole and decimating the natural landscape, once lush with forests and wildlife. Residents of the region are experiencing lower quality of life as their roads are being invaded by massive trucks and their landscapes being desecrated by enormous blocks of industrial development. Traffic conditions have worsened at times where they were already at their peak and residents have begun to discourage others from even coming into town. Using GPS and remote sensing techniques, I was able to consolidate and analyze what I felt were some of the most important factors of warehouse siting and determine how these factors compared to the ecological implications of development. Florence Township has always been a residential town and while industry may be a good thing for the future of our nation, developers and planning committees must be aware of the environmental and social impacts of their decisions.

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