# Lecture 2

1

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# Outline

- Updates and Announcements
- Introduction to Spatial Analysis
  - Overview
  - Examples
- Demo

# Outline

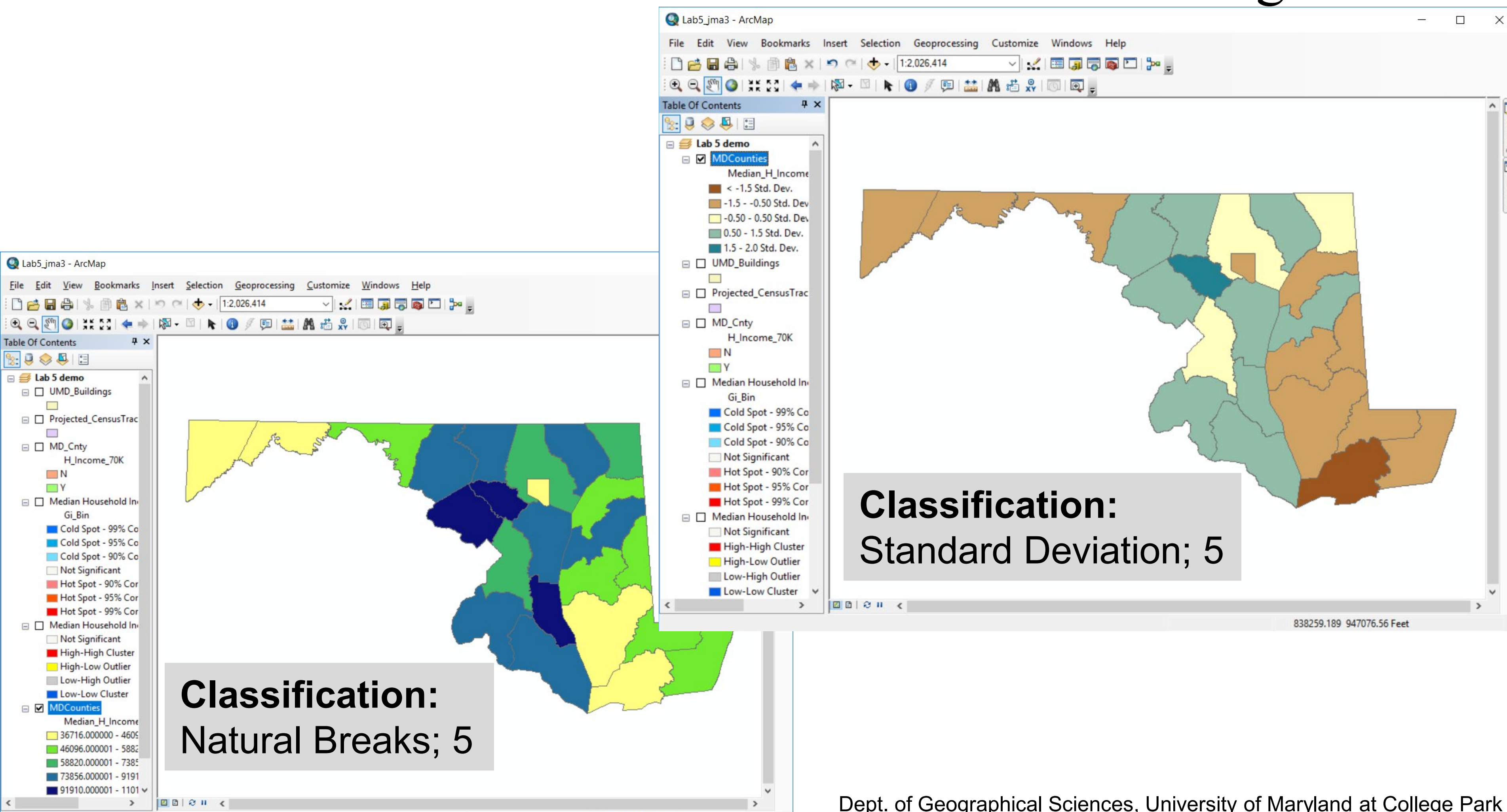
- Updates and Announcements
  - 9/7/2020 (Monday) is Labor Day.
    - The University will be closed and therefore, no classes on this day.
  - AGOL account created
  - ArcGIS Pro license pending.
  - Exercises #1, 2, and 3 have been posted.
    - Exercises are optional and for your practice only.
  - Lab 1 will be posted early (before Friday).

# Introduction to Spatial Analysis

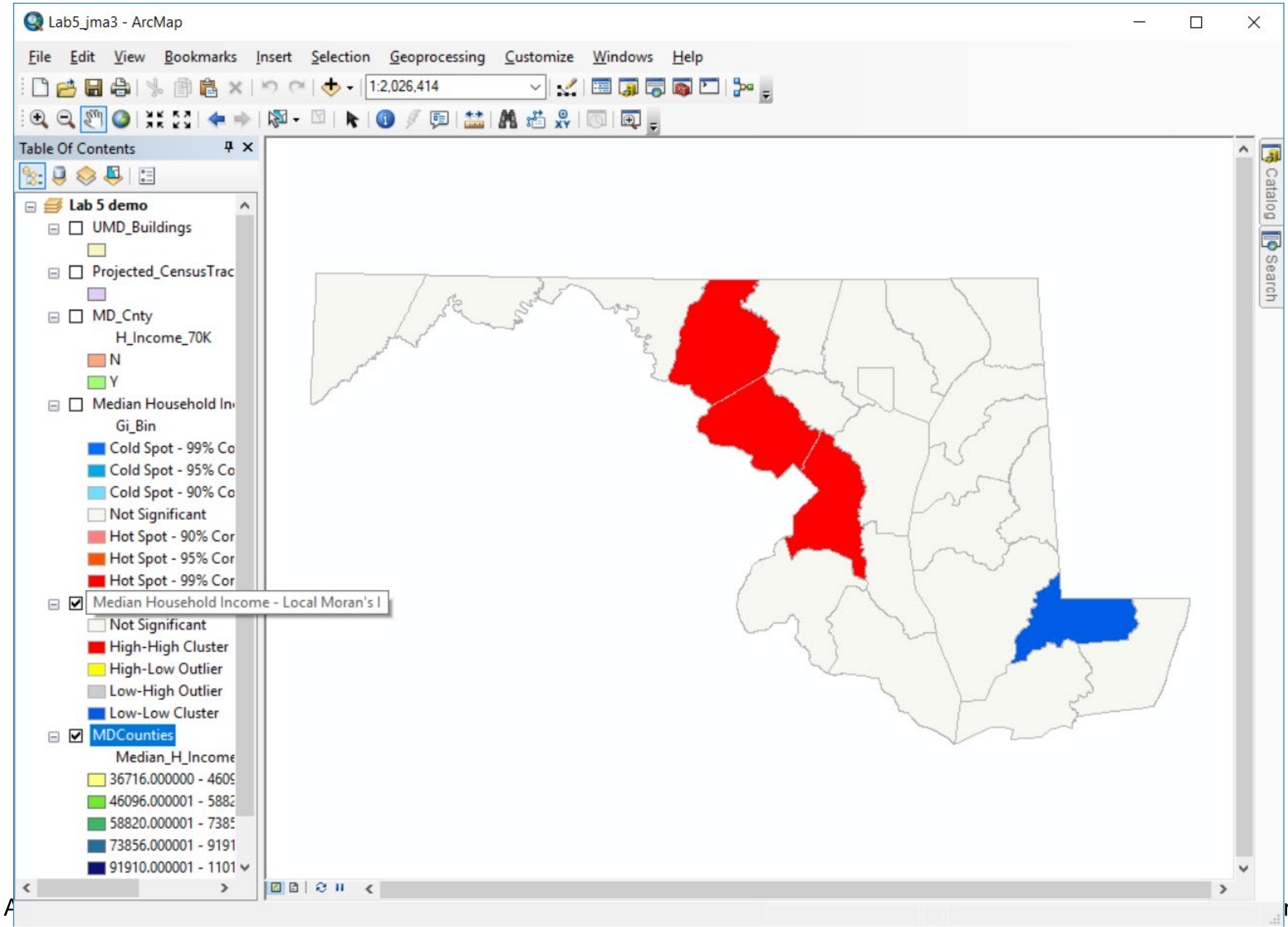
- Definition
  - Investigating the patterns that arises as a result of processes that may be operating in space.
    - O'Sullivan and Unwin
  - A process for looking at geographic patterns in data and at relationships between features.
    - Mitchell

# Introduction to Spatial Analysis

- Visualization can be misleading.
  - Same data with different visualization settings.



- Robust quantitative analysis is more reliable to discover spatial patterns.



- Types of Spatial Analysis
  - Based on ontology of the world
    - Vector vs. raster
  - Based on data types
    - Point, line, network, area, and surface
  - Based on analytical methods
    - Selection, cartographic, measurement, statistics, and models
  - Based on the spatial range of data to be included
    - Global vs. local

# Introduction to Spatial Analysis



- How to analyze spatial data?
  - Spatial data manipulation
    - Buffer, overlay, transformation, query
  - Exploratory spatial analysis
    - Visualization, description, summary, measurement
  - Statistical spatial analysis
    - (more complex than traditional statistics; depending on scale)
    - Spatial autocorrelation, hypothesis testing

# Examples: Spatial Analysis

- Examples of student's posters
  - Posters made for the final project
  - Examples have been posted on ELMS

# Examples: Spatial Analysis

## Analyzing Priority Areas for Future Seafloor Research and Exploration off the California Coast


Jennifer Kraus, NOAA

GEOG653/Spatial Analysis/Spring 2019

Dr. Jiangao Ma


### Introduction

Spatial information about the seafloor is critical for decision-making by marine research and management organizations. It is important for these agencies to convey where their data interests lie to better understand their individual objectives, mandates, and missions (Battista & O'Brien 2015). In order to effectively analyze data interests, a spatial framework and web-based tool was used to identify common spatial priorities among different organizations. Users are able to allocate a certain number of coins per cell and select a justification and product to associate with the input (Battista et al, 2017).

### Objectives

For this project, I will analyze the prioritization data collected off the coast of California to answer the following:

1) Where are the most coins allocated? Where are the top justifications and products located?
2) How do the higher concentrations of cells change when considering total coins, top justification, and product? This will be done using a Kernel Density Analysis
3) What areas of the (combined) hotspots have not been previously surveyed?

### Study Area

This project will focus on the data collected off the coast of California, ranging out to the 200 nautical mile Exclusive Economic Zone (EEZ). The figure to the right shows the extent of the prioritization, the sections of northern, central and southern California (merged together for this project), and the grid cells used for the analysis (10 x 10 minute grid).

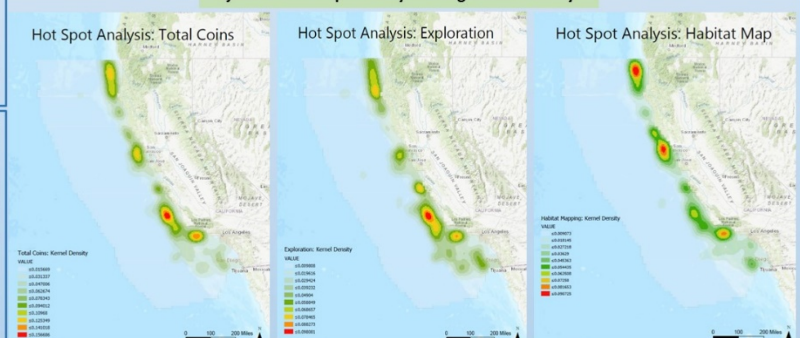
### Data

Most of the data used were produced in-house by NOAA's NCCOS Biogeography team. The prioritization grid and online tool was created by NCCOS using a GIS Web-based interface and digital atlas (Kendall et al, 2018). Results from the prioritization were provided as a data table with coin values for each grid cell (including 0-no input). These values corresponded with input from users on total coin number, coins per justification (ie exploration, fishing, cultural) and number of coins per product (ie habitat maps, sediment samples).

| Dataset Name | Source | File Type |
|---|---|---|
| California Prioritization AOI | NOAA/NCCOS | Shapefile |
| Grid 10x10 minute | NOAA/NCCOS | Shapefile |
| Prioritization Results | NOAA/NCCOS | Table |
| Hydrography Map Footprint | NOAA/NCEI | Shapefile |

**Objective 1: Spatial allocation of total coins, top justification and product**


**Objective 2: Hot Spot Analysis using Kernel Density**




### Results and Discussion

- The most coins were allocated in the nearshore areas, primarily within 200km offshore.
- There about 4 hot spots that were similar among total coins, the top justification (exploration) and desired product (habitat map).
- When previously surveyed areas are removed from the combined hot spot results, there is a total of 19,155 km$^2$ of high priority areas that have not yet been surveyed.
- The results of this study can provide agencies with insight as to where to focus their data collection and research, in order to better allocate limited resources (ie ship time and scientist availability) where data needs are highest.
- Published results will also encourage collaboration across (and within) organizations where data needs overlap.

### References

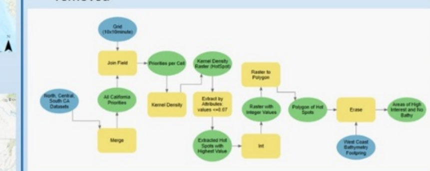

Battista, T.; O'Brien, K. Spatially Prioritizing Seafloor Mapping for Coastal and Marine Planning, *Coastal Management* **2015**, 43:1, 35-51. https://www.tandfonline.com/doi/pdf/10.1080/08920753.2014.985177

Battista, T.; Buja, K.; Christensen, J.; Hennessey, J.; Lassiter, K. Prioritizing Seafloor Mapping for Washington's Pacific Coast. *Sensors* **2017**, *17*, 701. https://www.mdpi.com/1424-8220/17/4/701/htm

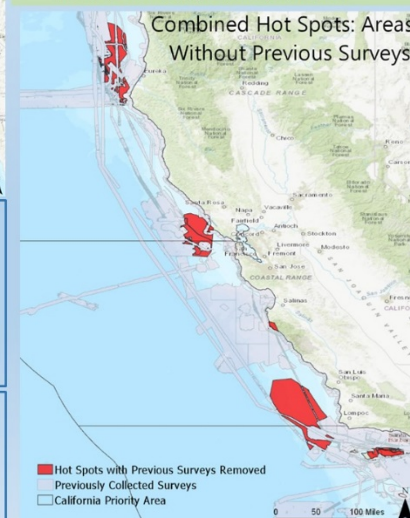
Kendall, M.S.; Buja, K.; Menza, C.; Battista, T. (2018) Where, What, When, and Why Is Bottom Mapping Needed? An On-Line Application to Set Priorities Using Expert Opinion. *Geosciences* **2018**, *8*, 379. https://www.mdpi.com/2076-3263/8/10/379


### Data Analysis Methods

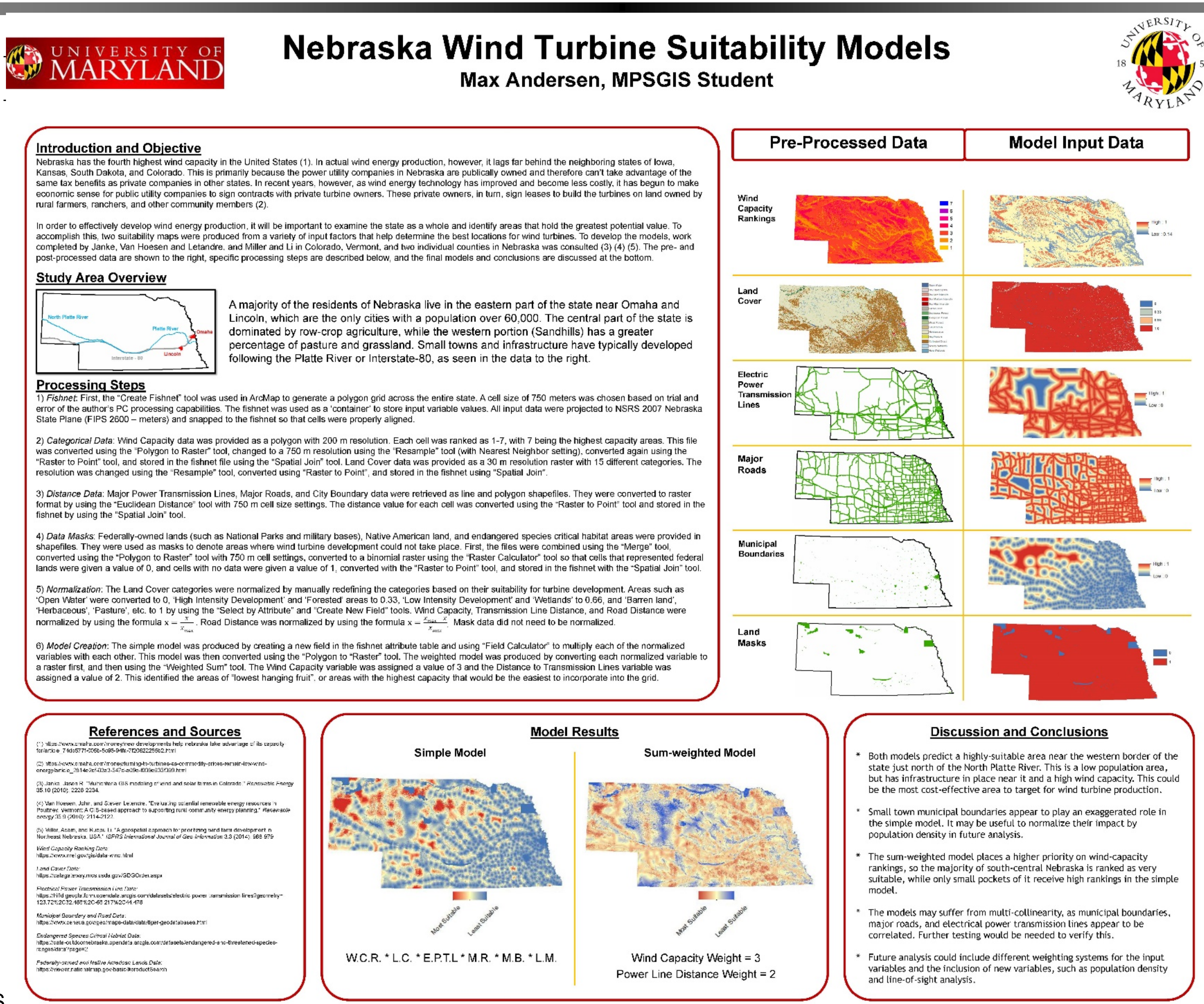
1) Tables for north, central, and south California were combined to get all of the prioritization input for California
2) Graduated symbols used to display total coins, top justification, and top product fields.
3) Table join: grid and coin data to get values per grid. Calculated top 5% and 10% (in excel) and displayed these as colored grids.
4) Kernel Density to calculate magnitude per unit area
5) Extract by Attribute values < or + 0.07 to extract hot spots
6) Int tool to convert floating point raster to integer
7) Raster to polygon: convert hotspot raster to polygon
8) Erase: remove bathy footprint from hotspot polygons
9) Final polygon: combined hotspots with previous surveys removed



**Objective 3: Areas of high priority (combined hotspots) that have not been previously surveyed.**



# Examples: Spatial Analysis

- 

# Examples: Spatial Analysis

## Marine Traffic Behavior In and Through the Bearing Strait

Vector Line and Point Analysis of Automatic Identification System(AIS) data.

Masters student at University of Maryland & Cartographer at Marine Chart Division NOAA : Guillaume Auclert

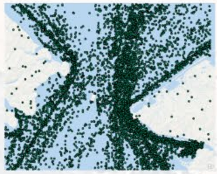
### Introduction

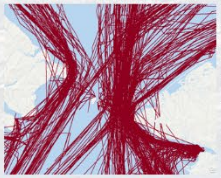
Boat shipping is the main avenue used for international goods trade, accounting for nearly 90% of total world trade. Marine traffic is fluid and will usually follow lines of least distance between destinations. International marine traffic is nonetheless impacted and limited by physical geography. The shape of shorelines and continents have a great impact on the path maritime traffic uses. There exist throughout the world several bottlenecks or "Strategic maritime passages" (2) These passages are important in geopolitics, usually the scene of convergent and dense marine traffic, and thus interesting areas to study.

### Area of Interest

The Bering strait is one of these " Strategic Maritime Passage". It is situated in the arctic, geographically isolated and limited by seasonal freezing. It therefore has much less dense maritime traffic than many other strategic maritime passages. This trend is changing. With recent political development spurred in part by climate change and the potential for economic gains, the arctic has seen a large increase in vessel traffic in the last few years. The Bering Strait is 82km wide and separates the Pacific Ocean from the Arctic Ocean. An interesting political element is that the Bering Strait is divided by the United States Russian maritime border. In addition to national and international commercial, military and scientific vessel traffic, the region also encounters extensive daily travel by locals. The challenging distances and isolation of this area of the world makes traveling by sea the medium of choice. The Strait is an underserviced and under-charted region that merits a closer look and attention.

### Data for the Analysis





I will be using data called AIS. AIS stands for *Automatic Identification System*. Its intended and main use is to prevent ship collisions. Each ship possesses a tracking system that emits its ID, position, bearing and speed in real time. This enables ships to know exactly what neighboring ship they are communicating with or passing near and therefore is very effective in preventing collisions. Additionally, this source data may be analyzed to identify other correlations. This data has only recently been made available to the public but has already sparked quite interesting studies and application.

AIS data may either be land or satellite collected. The land based data is free and publically available (http://marinecadastre.gov/ais/) but shows limitations for the Alaskan region especially. The land AIS data for the arctic region is picked up by stations that are on American soil only and also in sparse locations.

The second type of AIS data is satellite, which is the type used in this project. It is not limited by national borders or stations. The raw AIS data is extremely large and dense because it consists of a set of point data for each boat (shown top left) which can contain up to a point per boat per second.

The sheer size of the data set makes it impossible to check for absolute data accuracy but this is not a problem since the large amount of data should drown out the errors. With AIS data, the larger the dataset you use, the more accurate the result will be. This final project will use AIS data that has been filtered by boating seasons Summer of 2012, 2013 and 2014.

AIS data can easily be made as a line data by using the "date ant time" attribute it possesses (shown bottom left)

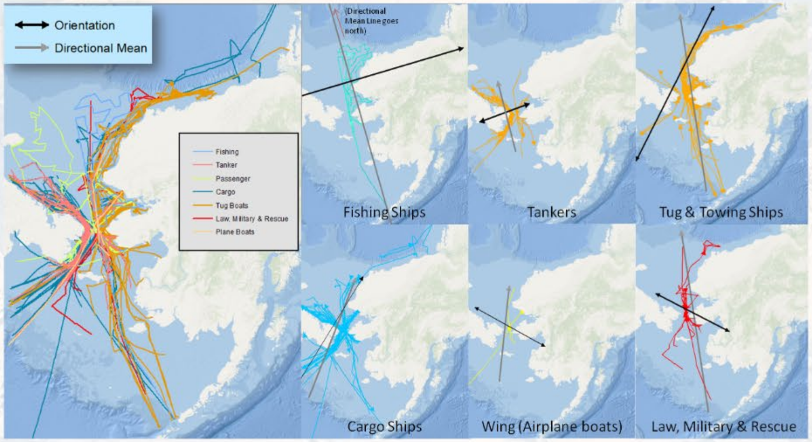
### Objective of the Project

The objective of this project is to determine vessel traffic patterns around the Bering Strait. By including the element of quality (types of ships) we should be able to see clear patterns of behavior emerge. The objective is to use line and point analysis to answer the question: How does the passage of the Bering Strait affect vessel traffic?

### References:

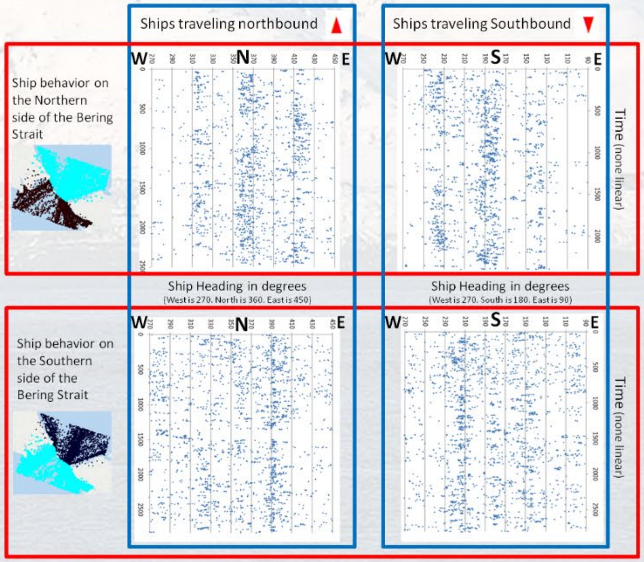
(1)AIS study in the Arctic Region2015. http://www.cmts.gov/downloads/CMTS_10-Year_Arctic_Vessel_Projection_Report_1.1.15.pdf
(2) The Geography of Transport Systems, HOFSTRA university.https://people.hofstra.edu/geotrans/eng/ch1en/appl1en/ch1a2en.html
(3)NOAA interna servers for the data., http://oceanservice.noaa.gov/

### Line Study of Ships Traveling Through the Bering Strait




### Point Analysis of Ships in the Bering Strait

The following graphs expresses the exported attribute table of the AIS points directly surrounding the Bering Strait (up to 150km away) They are created based on each point's direction attribute (horizontal axis) and also time (vertical axis).




### Analysis of the Line Data Results

| | Distance(km) | Orientation | Orient adjusted |
|---|---|---|---|
| Tanker | 829 | 4.998023 | 4.998023 |
| Wing | 1150 | 340.248825 | -19.751175 |
| Law | 1470 | 340.315755 | -19.684245 |
| Cargo | 1501 | 26.235001 | 26.235001 |
| Tug | 2085 | 25.957744 | 25.957744 |
| Fish | 4596 | 1.339647 | 1.339647 |


Some of the short comings of the ASI data are quickly apparent when creating line data from the many points. Not all lines end up being perfectly attributed when joining with complex external tables of attribute. Nonetheless, and as I mentioned previously, the more AIS data you use, the better the results will be. In the line study (on the left and above here) we started with about 600,000 track lines! 500 of these lines go through the Bering Strait. 375 lines where attributed correctly and thus usable for this specific study. We can safely assume that these lines are a sample adequately representing the population. From these resulting lines some patterns emerge.

First by visual inspection: We clearly see that most of these lines "hug" the shoreline and act in function of the shoreline. This shows that the Shoreline as a whole has a significant impact on the AIS lines. We can also note that different types of traffic do not show the same patterns.

By looking at the table (top right) we can make some assumptions. "Wing boats" and "law, military and rescue" ships show similar orientation and mean distances. This could be due to the level of "freedom" these ships have, showing a sort of randomness in their movement due to the nature of their travels. "Tug" and "Cargo" ships also show strong similarities. This similarity in behavior could be due to their important role and extensive travel through the communities strewn along the shorelines.

It is interesting to notice that "Tankers" and "Fishing" boats have almost the same orientation yet very different mean distances. We can assume that Tankers have many short lines because they are using direct routs around Russia (thus the "flat" orientation). Fishing boats have few but lone distance lines, showing a random local travel tendency.

The point graph (shown here on the left) can look overwhelming and chaotic at first but after a closer look, clear patterns start to emerge. If we focus on traffic on the "north side"(graphs located in the top red rectangle) we can see that the traffic leaving the Bering (top left graph) has three major shipping routs. The major one is almost exactly due north (360 degrees) This is the route going to the north slop of Alaska. The other two are almost exactly 45 and 135 degrees going North East and North West. These are respectively the American route going to Kivalina and Kotzebue and the Russian route going West. This exact same pattern is found for ships going south towards the strait except it is with opposite angles.(top right graph)

A different pattern is apparent for ships located on the southern end of the Strait (bottom red rectangle)

The graph on the bottom left shows a strong line going approximately 60 degrees north East. The same line reappears in the bottom right graph but once again in an opposite angle. The rest of the point data in the "southern side" graphs seam relatively random.

We can therefore assume that the traffic on the "northern side" is very regular and structured and focuses on a few distinct routes. The southern side is much less structured but still shows strong tendencies.

If we focusing on the time aspect of the graphs we can see clear patterns as well. We see "groupings" of points passing the same Area at around the same time but a deeper study is necessary to find an apparent cause.

| VESSEL_FLAG | Count |
|---|---|
| United States | 271 |
| Russia | 156 |
| Panama | 35 |
| Canada | 19 |
| Marshall Islands | 17 |
| Liberia | 10 |
| Norway | 9 |
| Sweden | 9 |
| United Kingdom | 7 |
| Bahamas | 6 |
| Singapore | 6 |
| FIJI | 4 |
| China | 3 |
| Japan | 3 |
| South Korea | 3 |
| Neterlands | 2 |
| Cayman Islands | 2 |
| Hong Kong | 2 |
| Philippines | 2 |
| Cyprus | 1 |


### Conclusion & other Avenues of Study

It is very difficult to come to a categorical conclusion regarding the exact effect of the Strait on vessel traffic. On the other hand we were able to expose clear patterns. With the help of the line analysis we can see that the type of traffic greatly affects traffic patterns. Whether the traffic is tankers, cargo, tug boats ect, greatly changes its behavior around the Bering Strait. We have also seen with the help of the point data that vessel traffic behaves dramatically differently whether it is going to or leaving the strait and whether the ships are traveling south or north towards the arctic.

The complexity of the data used and the nature of the subject could, with a more mathematical approach, categorically conclude that the Bering Strait greatly affects vessel traffic.

Other approaches in the GIS realm that could support this conclusion could be based on line or point density. (shown here above right, these images already show a clear pattern with denser traffic and bottleneck areas in and around the Strait and clear "shipping lanes" coming and going through the Strait)

There is also a myriad of other attributes in the AIS data that could be interesting to study such as "ship tonnage", "ship size" or even "ship flag" (nationality of vessel shown in table above) We could also introduce the international border between Russia and the United states as a factor of ship behavior.

# Examples: Spatial Analysis

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## Utilizing Network Analysis for Emergency Preparedness & Response

Renee Dauerer
Center for Geospatial Information Science, University of Maryland

### Introduction

Hurricane Maria struck Puerto Rico on September 20, 2017, resulting in the worst storm to hit the island in over 80 years. The Category 4 storm sustained winds of 155 mph as it crossed the island, uprooting trees, downing weather stations and cell towers, and destroying roofs of homes. One hundred percent of the electricity on the island was cut off and access to clean water and food was extremely limited. Heavy rain and flash flooding worsened this devastation – streets filled with water and debris and in some areas, the floodwater rose more than 30 inches deep. [1]

Following the devastating losses accrued as a result of Maria, The Federal Emergency Management Agency (FEMA) released an after-action report – The agency experienced personnel shortages, lack of aid supplies, and difficulty coordinating logistics. In a letter included in the report, FEMA administrator, William "Brock" Long, stated that all emergency managers at all levels of government need to improve emergency plans and account for shortfalls that result in coordination and logistical breakdowns. [2]

### Objectives

This research addresses how agencies and first responders can leverage Network Analysis for emergency preparedness and response.

Additionally, this research demonstrates what is possible using *open data* to create a network dataset, making evident the power and utility open source data can have. Specifically demonstrating what is currently available for downloading source data and subsequently generating network datasets.

### Data Sources

| Source Data | Processed / Derived Data | References |
|---|---|---|
| OpenStreetMap Roads<br>OpenStreetMap Buildings<br>OpenStreetMap Waterways<br>OpenStreetMap Points of Interest | Network Dataset | Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org |
| NOAA High-Resolution Aerial Imagery 0.25 M GSD | Ground Truth | https://storms.ngs.noaa.gov/storms/maria/index.html#10/18.3219/-66.3904 |
| Hospitals | Destinations | U.S. Department of Homeland Security (2019). Hospitals of Puerto Rico, HydroShare, http://www.hydroshare.org/resource/56cd16e529e14f7dbf26016374d8df9f |
| Fire Stations | Destinations / Origins | U.S. Department of Homeland Security, Homeland Infrastructure Foundation-Level Data (HIFLD) |
| FEMA Damage Assessment | Destroyed Buildings | The FEMA Geospatial Response Office, https://disasters.geoplatform.gov/publicdata/ |

### References

[1] E. Schwartz, 'Quick facts: Hurricane Maria's effect on Puerto Rico', Mercy Corps, Sep. 23, 2019. [Online]. Available: https://www.mercycorps.org/articles/united-states/hurricane-maria-puerto-rico [Accessed: Oct. 28, 2019].

[2] A. Hernandez, 'FEMA admits failures in Puerto Rico disaster response, in after-action report', The Washington Post, July 12, 2018. [Online]. Available: https://www.washingtonpost.com/national/fema-admits-failures-in-puerto-rico-disaster-response-in-new-after-action-report/2018/07/12/b7900228-8636-11e8-9e80-403a221946a7_story.html [Accessed: Oct. 28, 2019].

### Study Area: San Juan, Puerto Rico

### Candidate Shelter Locations

Decision makers can utilize GIS to determine candidate shelter locations in the event of an emergency. In this scenario, the following requirements were used to identify two potential shelter areas during a disaster such as Hurricane Maria.

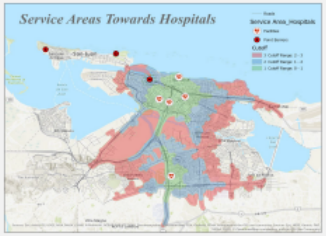
| Requirements |
|---|
| Within 0.25 Miles of Major Roads |
| At least 0.1 Miles away from Waterways (excludes Ocean) |
| Building Area Greater than or Equal To 200,000 Square Feet |

| Identified Location | Area |
|---|---|
| Puerto Rico Convention Center (TOP) | 400,922.0625 sq. ft |
| Multipurpose de Plaza Las Américas (BOTTOM) | 312,784.875 sq. ft |

### OD Cost Matrix

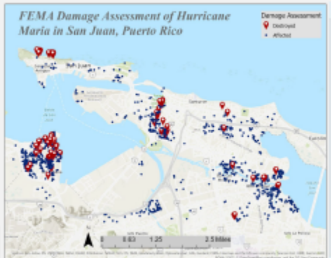
First responders need to determine how to allocate resources. In this scenario, GIS was utilized to create an OD Cost Matrix. Fire stations were used as origins and the mean centers of completely destroyed building clusters acted as the destinations. Network Analysis calculated three optimal destination points for each fire station.

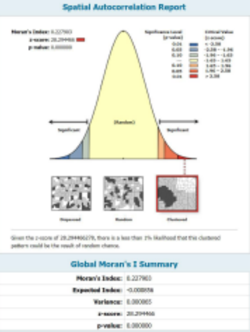

### Service Areas


Creating service areas is a useful tool with Network Analysis. It is significantly more useful and realistic than a buffer because it incorporates the actual roads of a study area. Using GIS, analysts can create two types of services areas: away from an origin, or to a destination. Cutoffs are used to calculate the service areas based on designated times or distances. For this scenario, both methods of Network Analysis service areas were generated. The top graphic shows the output of generating areas at 1, 2, and 3 minutes away from each fire station. The second graphic shows which areas are closest to each hospital at 1, 2, and 3 minutes going towards each location. These analyses show that the service areas for each, do not generally overlap each other.

### Damage Assessment

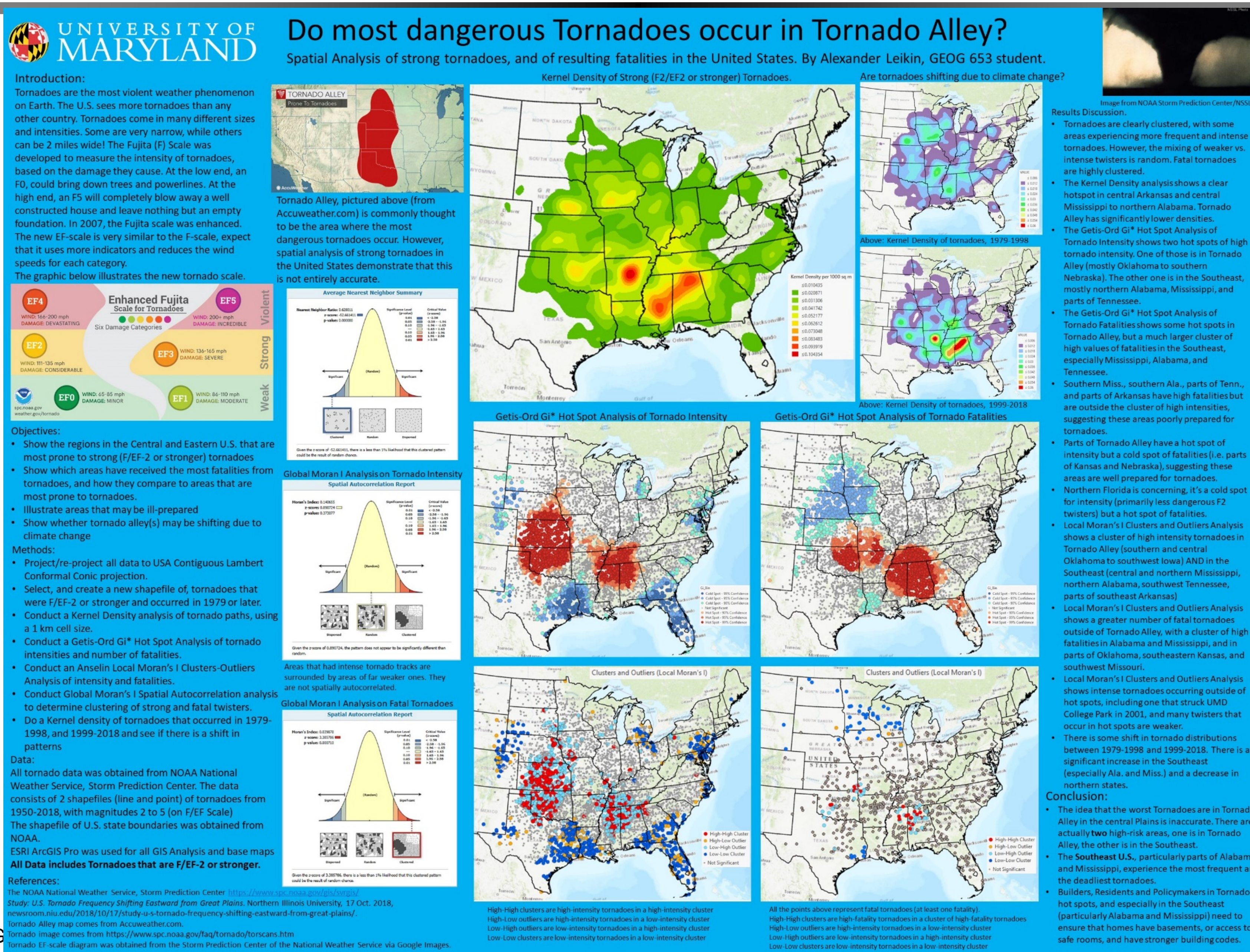



| Damage Assessment of Completely Destroyed Buildings | Number | Percentage |
|---|---|---|
| Residential | 71 | 84.5% |
| Commercial | 13 (One Church) | 15.5% |
| Total Buildings Destroyed | 84 | 100% |

After Hurricane Maria, FEMA conducted a damage assessment and created a dataset indicating which buildings were affected or destroyed after the storm. This research utilized that dataset to determine the percentage of destroyed buildings that were residential vs. commercial in the study area. Additionally, spatial autocorrelation was used to determine if destroyed buildings vs. affected buildings were clustered together. The results of this statistical analysis found that there is less than a 1% likelihood the clustered pattern is a result of random chance with a z-score of 28.3 and a p-score of 0.00. The map above visually demonstrates this clustered pattern.

# Examples: Spatial Analysis



# Examples: Spatial Analysis

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## Assessing the Impact of 2018 Wildfires on Seasonal Variations in Air Quality and Pollutant Levels in the State of California.

Afolarin Lawal, GEOG 653 (Spatial Analysis) Fall 2019

### Introduction

According to the California Department of Forestry and Fire Protection, in 2018 there had been an estimated 1,618,033 acres burned with about 310 wildfire incidents with greater than 10 acres in burn area. In addition, 93 fatalities were recorded with 23,145 structures damaged in the process. Wildfires are a large source of particulate pollution in western states (Liu et al., 2017), but with raging debate on the effects of climate change and global warming, the short- and long-term effects of the annual fires on the citizens is worth investigating. The pollutants discharged as a result of wildfires can pose a health risk to inhabitants of affected counties, especially among the younger and older generations. Unfortunately, these could also affect the public health of neighboring states as well, as winds direction and topography can aid pollutant transport (Malia et al., 2015).

### Objectives

The objective of this project is to assess the level of various pollutants across the seasons of the year 2018 in a bid to determine which counties are less conducive for extended outdoor activities, primarily as a result of wildfire pollution. This is of particular importance to young and old people who are more at risk of developing respiratory problems as a result of bad air quality and air pollution. For the purpose of this project, citizens below the age of 15 and above the age of 55 are deemed "Sensitive", as I feel they are more vulnerable to the effects of pollutants than other age groups.

### Data

The primary data for this project are:

I. Daily pollutant data (in concentration values) gotten from air monitoring stations scattered across the state of California. This pollutants are Ozone ($O_3$), Carbon monoxide (CO), Nitrogen dioxide ($NO_2$), Sulphur dioxide ($SO_2$), Particulate Matter 10 ($PM_{10}$) and Particulate Matter 2.5 ($PM_{2.5}$)
II. Demographic information for the year 2017 clipped to the state of California.

### Methods

For the purpose of this project, the year 2018 was broken down into four seasons, Winter: January, February and December; Spring: March to May; Summer: June to August; and Fall: September to November.

The pollution data was broken down into its constituent season based on the above description and aggregated by mean values by Station or Site ID per pollutant. This mean values were then normalized to account for the various scale of concentration values across the pollutants. For example, the range of $PM_{10}$ concentration values for winter is around 59 ug/m³ SC while the range of Ozone for the same season is 0.036 ppm. This normalization allows the magnitude of various pollutants to be directly compared irrespective of the scale of measurements. Subsequently, the normalized pollution values were interpolated and added to form a general pollution map for the state of California for each season.

### Result and Discussion

- Although the above maps doesn't exactly tell which of the pollutants are dominant, it provides an overview of the general air quality and pollutant level of the counties in the California. The circular symbols represent the ratio of "sensitive" population in each county to the total county population.
- This ratio was derived by adding the number of people aged below 15 and above 55 for each county, then dividing the result by the total county

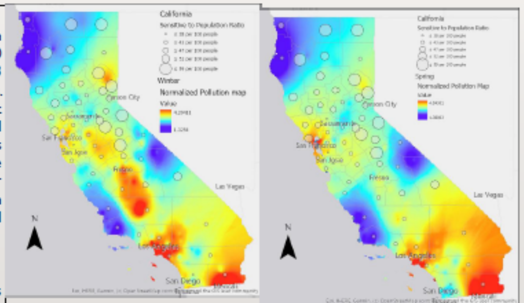


Figure 1. Winter Normalized Pollution Map

Figure 2. Spring Normalized Pollution Map

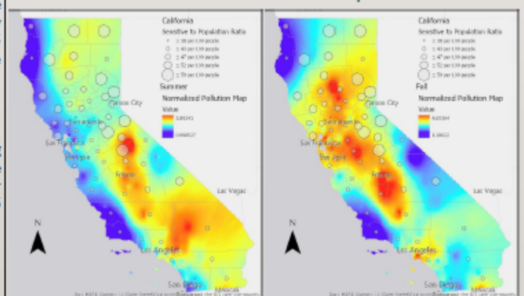


Figure 3. Summer Normalized Pollution Map

Figure 4. Fall Normalized Pollution Map

### Result and Discussion continued

population.

- Figure 1 shows that during the winter, most of the counties in the south were very polluted. These counties include, Imperial , Orange, Los Angeles and Fresno. The only good news is that these cities have a relatively low sensitive population.
- During the Spring, the southern parts of the state had a slight increase in intensity of the pollution. The counties affected were the same as those during the winter season. In addition, San Francisco, Marin and San Jose also had an increase in pollutant from winter to spring. The pollutants here are majorly Carbon monoxide and Sulphur dioxide which could be influenced by high vehicular movement and industries within the region.
- The Summer and Fall seasons indicate a northward shift in the pollutants. Central California were mostly affected by in the Summer while during the Fall season, more of the northern counties were engulfed. This trend was also perfectly captured in the hotspot analysis of the $PM_{2.5}$ pollutants as shown in Figure 5 and 6.
- $PM_{2.5}$ is one of the deadliest pollutant primarily due to its microscopic nature (about 3% the diameter of human hair) which enables it to penetrate the lungs of humans easily, causing breathing and respiratory illnesses.

### Result and Discussion continued

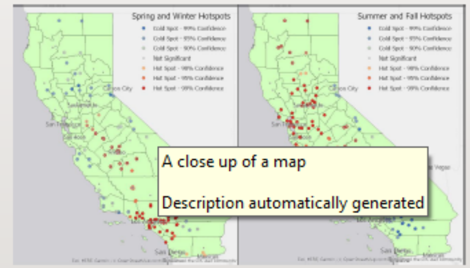



Figure 5. Spring and Winter Hotspots Analysis of $PM_{2.5}$ pollutants

Figure 6. Summer and Fall Hotspots Analysis of $PM_{2.5}$ pollutants

- Figure 5 and 6 above shows that during the Winter and Spring months, $PM_{2.5}$ levels were high in the south and low in north. But in Summer and Fall, reverse was the case. This indicates that throughout the year of 2018, most of the state were, at one time or the order, experiencing elevated levels of $PM_{2.5}$ putting all sensitive populations at risk irrespective of location.
- Based on Figure 1 – 4, it can be noticed that the western counties along the coastline generally exhibit low pollution values. The only exception is the Bay Area and its environs which could be attributed to high vehicular usage and industries driven by its high population density and activities rather than wildfires.
- It is also important to note that most of the counties with a relatively higher sensitive population (young and old) are in northern part of the state which is relatively safe till Summer and Fall.

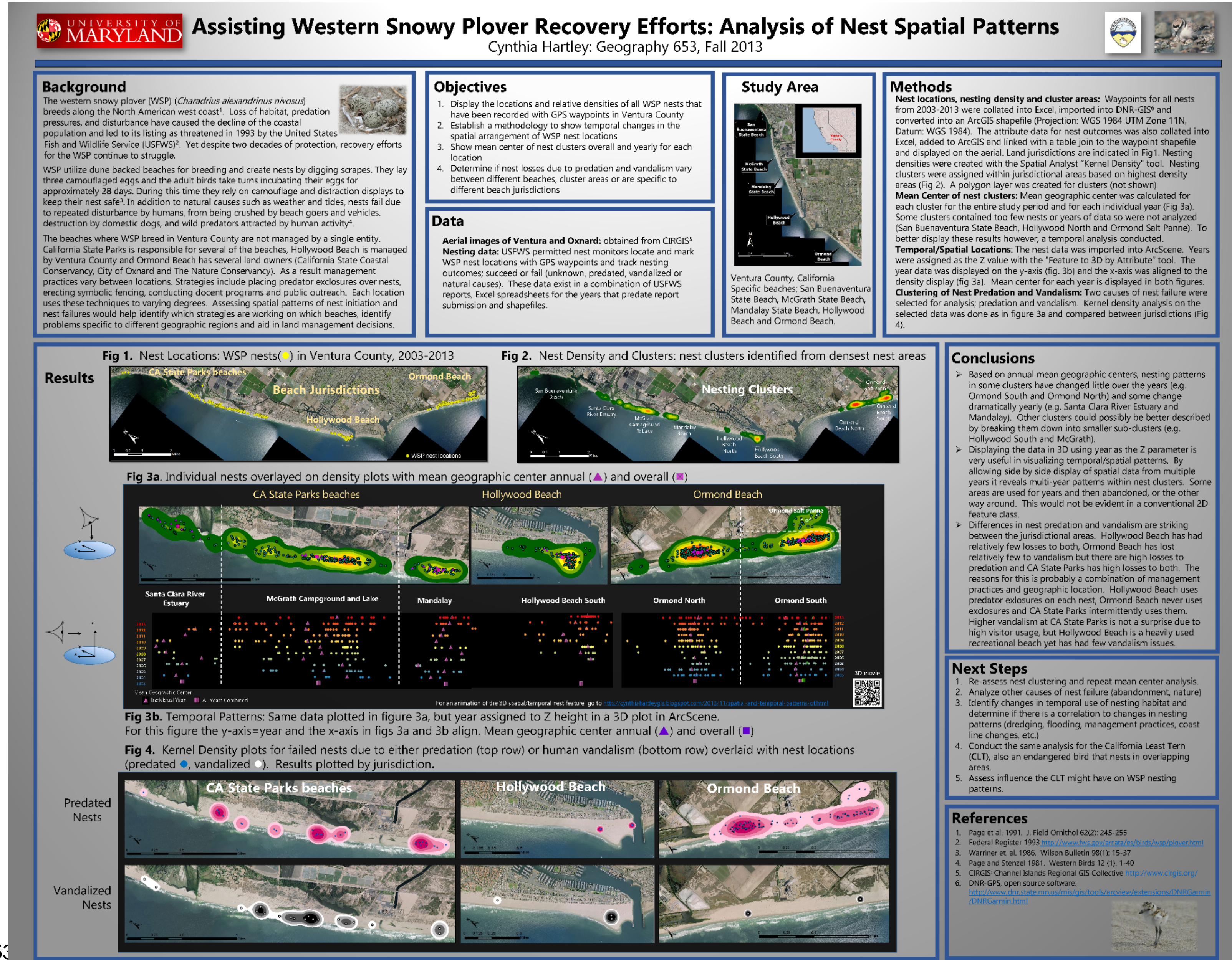
| Season | County | Major Pollutants | Number of Old or Young people per 100 people |
|---|---|---|---|
| Winter | Orange | PM10, Ozone, CO, NO2 | 39 |
| | Imperial | PM10, Ozone | 42 |
| | Los Angeles | PM10, Ozone, CO, NO2 | 39 |
| | San Francisco | SO2 | 34 |
| | Kings | PM25, PM10 | 40 |
| Spring | Imperial | PM25, PM10, Ozone | 42 |
| | San Francisco | SO2, CO | 34 |
| | Marin | SO2, CO | 48 |
| | Orange | PM25, PM10, NO2, Ozone | 39 |
| | Los Angeles | PM25, PM10, NO2, Ozone | 39 |
| Summer | Mariposa | PM25, PM10, Ozone | 54 |
| | San Bernardino | PM10, NO2, Ozone | 40 |
| | Madera | PM25, PM10, Ozone | 44 |
| | Tuolumne | PM25, PM10, Ozone | 51 |
| | Kings | PM10, Ozone | 40 |
| Fall | Stanislaus | PM25, PM10, SO2, CO | 42 |
| | Butte | PM25, CO, Ozone | 44 |
| | Kings | PM25, PM10, NO2 | 40 |
| | San Joaquin | PM25, PM10, SO2, CO | 41 |
| | Sutter | PM25, CO | 45 |

Figure 7. A table showing the 5 most polluted counties based on season. It also shows the major pollutants found in the counties as well as the number of sensitive people per 100 people in the counties. Again the winter and spring seasons contain majorly southern counties while Summer and Fall have mostly northern counties

### References


- Liu, X., et al. (2017). Airborne measurements of western U.S. wildfire emissions: Comparison with prescribed burning and air quality implications, J. Geophys. Res. Atmos., 122, 6108–6129, doi:10.1002/2016JD026315.
- Mallia, D. V., J. C. Lin, S. Urbanski, J. Ehleringer, and T. Nehrkorn (2015), Impacts of upwind wildfire emissions on CO, CO2, and PM2.5 concentrations in Salt Lake City, Utah, J. Geophys. Res. Atmos., 120, 147–166, doi:10.1002/ 2014JD022472.
- United States Environmental Protection Agency https://www.epa.gov/outdoor-air-quality-data/download-daily-data
- California Department of Forestry and Fire Protection (CAL FIRE) https://www.fire.ca.gov/incidents/2018/

# Examples: Spatial Analysis

- 

## Assisting Western Snowy Plover Recovery Efforts: Analysis of Nest Spatial Patterns

Cynthia Hartley: Geography 653, Fall 2013

### Background

The western snowy plover (WSP) (*Charadrius alexandrinus nivosus*) breeds along the North American west coast[1]. Loss of habitat, predation pressures, and disturbance have caused the decline of the coastal population and led to its listing as threatened in 1993 by the United States Fish and Wildlife Service (USFWS)[2]. Yet despite two decades of protection, recovery efforts for the WSP continue to struggle.

WSP utilize dune backed beaches for breeding and create nests by digging scrapes. They lay three camouflaged eggs and the adult birds take turns incubating their eggs for approximately 28 days. During this time they rely on camouflage and distraction displays to keep their nest safe[3]. In addition to natural causes such as weather and tides, nests fail due to repeated disturbance by humans, from being crushed by beach goers and vehicles, destruction by domestic dogs, and wild predators attracted by human activity[4].

The beaches where WSP breed in Ventura County are not managed by a single entity. California State Parks is responsible for several of the beaches, Hollywood Beach is managed by Ventura County and Ormond Beach has several land owners (California State Coastal Conservancy, City of Oxnard and The Nature Conservancy). As a result management practices vary between locations. Strategies include placing predator exclosures over nests, erecting symbolic fencing, conducting docent programs and public outreach. Each location uses these techniques to varying degrees. Assessing spatial patterns of nest initiation and nest failures would help identify which strategies are working on which beaches, identify problems specific to different geographic regions and aid in land management decisions.

### Objectives

1. Display the locations and relative densities of all WSP nests that have been recorded with GPS waypoints in Ventura County
2. Establish a methodology to show temporal changes in the spatial arrangement of WSP nest locations
3. Show mean center of nest clusters overall and yearly for each location
4. Determine if nest losses due to predation and vandalism vary between different beaches, cluster areas or are specific to different beach jurisdictions

### Data

**Aerial images of Ventura and Oxnard:** obtained from CIRGIS[5]
**Nesting data:** USFWS permitted nest monitors locate and mark WSP nest locations with GPS waypoints and track nesting outcomes; succeed or fail (unknown, predated, vandalized or natural causes). These data exist in a combination of USFWS reports, Excel spreadsheets for the years that predate report submission and shapefiles.

### Study Area



Ventura County, California
Specific beaches; San Buenaventura State Beach, McGrath State Beach, Mandalay State Beach, Hollywood Beach and Ormond Beach.

### Methods

**Nest locations, nesting density and cluster areas:** Waypoints for all nests from 2003-2013 were collated into Excel, imported into DNR-GIS[6] and converted into an ArcGIS shapefile (Projection: WGS 1984 UTM Zone 11N, Datum: WGS 1984). The attribute data for nest outcomes was also collated into Excel, added to ArcGIS and linked with a table join to the waypoint shapefile and displayed on the aerial. Land jurisdictions are indicated in Fig1. Nesting densities were created with the Spatial Analyst "Kernel Density" tool. Nesting clusters were assigned within jurisdictional areas based on highest density areas (Fig 2). A polygon layer was created for clusters (not shown)
**Mean Center of nest clusters:** Mean geographic center was calculated for each cluster for the entire study period and for each individual year (Fig 3a). Some clusters contained too few nests or years of data so were not analyzed (San Buenaventura State Beach, Hollywood North and Ormond Salt Panne). To better display these results however, a temporal analysis conducted.
**Temporal/Spatial Locations**: The nest data was imported into ArcScene. Years were assigned as the Z value with the "Feature to 3D by Attribute" tool. The year data was displayed on the y-axis (fig. 3b) and the x-axis was aligned to the density display (fig 3a). Mean center for each year is displayed in both figures.
**Clustering of Nest Predation and Vandalism:** Two causes of nest failure were selected for analysis; predation and vandalism. Kernel density analysis on the selected data was done as in figure 3a and compared between jurisdictions (Fig 4).

### Results

**Fig 1.** Nest Locations: WSP nests( ) in Ventura County, 2003-2013



**Fig 2.** Nest Density and Clusters: nest clusters identified from densest nest areas



**Fig 3a.** Individual nests overlayed on density plots with mean geographic center annual (▲) and overall (■)



**Fig 3b.** Temporal Patterns: Same data plotted in figure 3a, but year assigned to Z height in a 3D plot in ArcScene. For this figure the y-axis=year and the x-axis in figs 3a and 3b align. Mean geographic center annual (▲) and overall (■)

**Fig 4.** Kernel Density plots for failed nests due to either predation (top row) or human vandalism (bottom row) overlaid with nest locations (predated ●, vandalized ○). Results plotted by jurisdiction.



### Conclusions

- Based on annual mean geographic centers, nesting patterns in some clusters have changed little over the years (e.g. Ormond South and Ormond North) and some change dramatically yearly (e.g. Santa Clara River Estuary and Mandalay). Other clusters could possibly be better described by breaking them down into smaller sub-clusters (e.g. Hollywood South and McGrath).
- Displaying the data in 3D using year as the Z parameter is very useful in visualizing temporal/spatial patterns. By allowing side by side display of spatial data from multiple years it reveals multi-year patterns within nest clusters. Some areas are used for years and then abandoned, or the other way around. This would not be evident in a conventional 2D feature class.
- Differences in nest predation and vandalism are striking between the jurisdictional areas. Hollywood Beach has had relatively few losses to both, Ormond Beach has lost relatively few to vandalism but there are high losses to predation and CA State Parks has high losses to both. The reasons for this is probably a combination of management practices and geographic location. Hollywood Beach uses predator exlosures on each nest, Ormond Beach never uses exclosures and CA State Parks intermittently uses them. Higher vandalism at CA State Parks is not a surprise due to high visitor usage, but Hollywood Beach is a heavily used recreational beach yet has had few vandalism issues.

### Next Steps

1. Re-assess nest clustering and repeat mean center analysis.
2. Analyze other causes of nest failure (abandonment, nature)
3. Identify changes in temporal use of nesting habitat and determine if there is a correlation to changes in nesting patterns (dredging, flooding, management practices, coast line changes, etc.)
4. Conduct the same analysis for the California Least Tern (CLT), also an endangered bird that nests in overlapping areas.
5. Assess influence the CLT might have on WSP nesting patterns.

### References


1. Page et al. 1991. J. Field Ornithol 62(2): 245-255
2. Federal Register 1993 http://www.fws.gov/arrata/es/birds/wsp/plover.html
3. Warriner et. al. 1986. Wilson Bulletin 98(1): 15-37
4. Page and Stenzel 1981. Western Birds 12 (1), 1-40
5. CIRGIS: Channel Islands Regional GIS Collective http://www.cirgis.org/
6. DNR-GPS, open source software: http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html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# Examples: Spatial Analysis

UNIVERSITY OF MARYLAND

## Urbanization effects on stream temperatures in the Gwynns Falls Watershed in Baltimore, Maryland

BALTIMORE ECOSYSTEM STUDY

Hyunjin Kim University of Maryland, College Park

### Introduction

Urban streams are important and sensitive systems for assessing impacts of watershed urbanization because of their extensive, direct connections to Impervious Surface Cover (ISC) (such as road surface, parking lots, rooftops, etc.), and their sometimes buried nature. Stream temperature plays a key role in many stream processes. ISC is an important urbanization indicator that has been shown to be related to stream temperature (Center for Watershed Protection, 2003). During the summer, in particularly, impervious cover absorbs and stores solar radiation better than natural surfaces. When rainfall events occur, heated runoff from ISC is directly transported by road surfaces or stormwater drainage systems to urban streams (Arrington et al., 2003); then it causes stream temperature elevation. Imperviousness within a 50m buffer along the stream or within a 1.6km radius of the sampling site had more influence on stream conditions (Wang et al., 2001). Spatial patterns of stream temperature are associated with the distribution of fish. High water temperature can cause harmful effects on aquatic biota (Ward, 1985).

#### Objectives

1. To identify an overall trend of stream temperature as a function of space (along the urban gradient).
2. To identify effects of impervious covers and road density on stream temperature.
3. To identify spatial patterns of fish abundance.

### Study Area

Gwynns Falls watershed, Baltimore, MD


### Characteristics

**Urban-rural gradient** along the watershed

| Site | Area (ha) | Characteristic | Location |
|---|---|---|---|
| Baltimore | 15 | Urban pipe | |
| Lanvale | 15 | Urban pipe | Downstream |
| Carroll Park | 17068 | Urban stream | |
| Dead Run | 1429.7 | Urban stream | |
| Villa Nova | 8417.5 | Suburban | |
| McDonogh | 7.8 | Agricultural/spring | |
| Gwynnbrook | 1095.6 | Suburban | Upstream |
| Glyndon | 85.9 | Suburban | |
| Baisman Run | 380.7 | Suburban/Forested | |
| Pond Branch | 31.1 | Forested | Reference |

### Methods

• **Data**

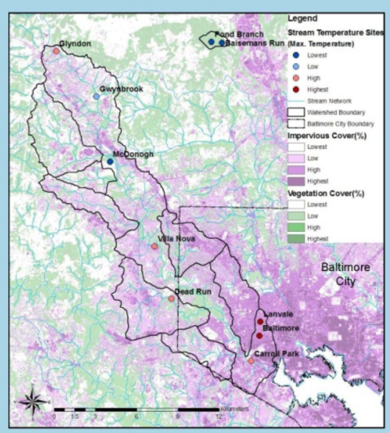
**Stream temperature** in summer 2004: Baltimore Ecosystem Study Long Term Ecological Research
**Fish abundance**: the number of individual fish from Maryland Biological Stream Survey (1995-1999)

• **Spatial Analyses**

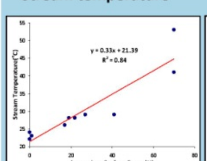
GIS (ArcMap 9.3, ESRI)
**Projection**: NAD 1983 State Plane Maryland
**Layers**: % Impervious covers (30x30m), % vegetation covers (30x30m), roads and stream networks
**Stream Buffer:** a 50m buffer along the stream and a 1.6km radius buffer of the sampling sites
**Road Density:** Total length of roads within a 1.6km buffer

• **Relationships between imperviousness and road density vs. stream temperature:** simple regression analysis (Data Analysis Tool in MS Excel 2003)

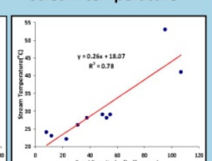
### Stream temperature monitoring sites & Maximum temperatures in summer 2004



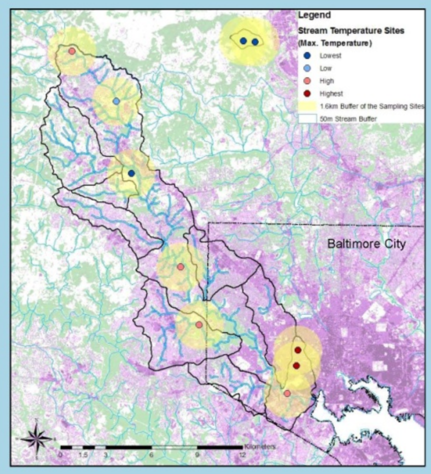

### Impervious cover vs. Stream temperature



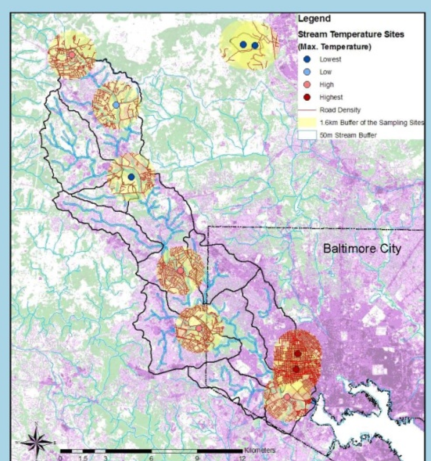

### Road density vs. Stream temperature



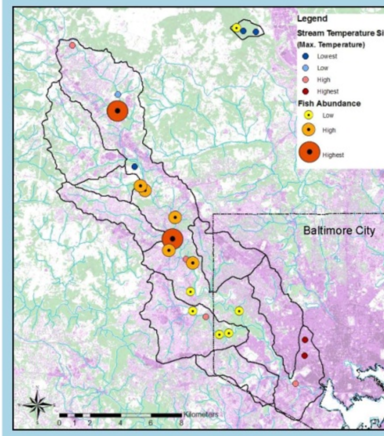

### 50m buffers along the stream & 1.6km radius buffers of the temperature monitoring sites




### Road density within a 1.6km buffer of the monitoring sites




### Fish Abundance (Maryland Biological Stream Survey, 1995-1999)




### Results & Discussion

• Overall downstream warming trend in stream temperature in the Gwynns Falls watershed

• Urban buried streams showed a extremely high water temperatures

• Strong positive relationship between ISC vs. Stream temperature ($R^2$=0.84, $p<0.01$): 0.33°C increase in max. stream temp with 1% increase in ISC

• 23-107 m of Road density within a 1.6km radius buffer comparing 8 m in a reference site

• Strong positive relationship between Road density vs. Stream Temperature ($R^2$=0.78, $p<0.01$): 0.26°C increase in max. stream temperature with 1m of road length increase within a buffer

• Fish abundance: 0-495 individual fish found at a site

• Overall, fish abundance decreases from upstream to downstream following the trend of stream temperature warming.

### References


- Baltimore Ecosystem Study http://beslter.org.
- Kim, H. J. 2007. Temperatures of urban streams: impervious surface cover, runoff, and the importance of spatial and temporal variations. M.S. Thesis. Marine, Estuarine, and Environmental Sciences, University of Maryland, Baltimore County.
- Maryland Biological Stream Survey http://www.dnr.state.md.us/streams/mbss/

# Examples: Spatial Analysis

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## Washington, D.C. Spatial Crime and Police Station Analysis

Michael Bender – University of Maryland GEOG653

### Abstract

Crime analysis is an analytical process providing useful statistics on crime patterns and trends. Crime can have a major effect on a population, especially in a major city. Analyzing crime in a specific study area can give citizens and police important information. Police stations must also be analyzed to show how they can improve their efficiency. It can show areas citizens might want to avoid and police where more force might need to be deployed. For a crime analysis proper data must be collected, analyzed, and evaluated. For this analysis Washington, D.C. is the study area. Crime narrowed down to assaults with a dangerous weapon from 2013-14 is the main data needed for the analysis. Police stations, neighborhoods, and streets data were also used for completeness and to provide the most useful information.

### Introduction

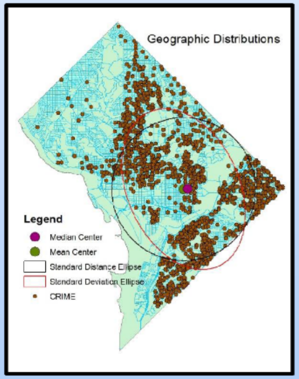
Although in the mid-2000s crime rates dropped to their lowest in 20 years it is still ever present in Washington, D.C. Since 1995, overall violent crime has decreased 50% to 1,330.2 violent crimes per 100,000 people. That number however, is three times the national average. To make matters worse law enforcement is poorly organized. Being the United States capital, the combination of federal and state agencies make coordination very difficult. They are also more experienced in crowd control and security rather than every day crime. From 2010 to 2012 criminal offenses had increased from 34,655 to 36,762. Clearly crime remains a significant issue for D.C. However, a crime analysis of the city can be a powerful tool to stop this trend of increasing criminal offenses. By thoroughly analyzing D.C. data there can be a determination of the most crime affected areas and valuable information can be provided to citizens and police forces. The main objective of this analysis is not only to provide useful information to the public, but also to determine the trends of crime in D.C. in order to knowledgably predict and prepare for the future.

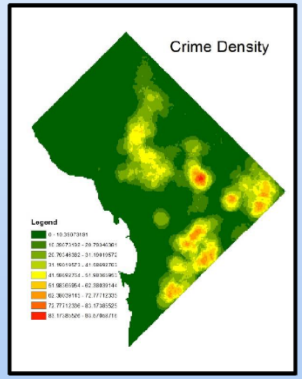
### Data

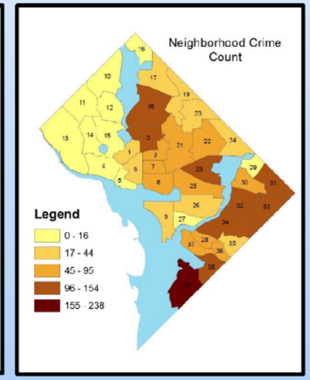
| Data Name | Source | Data Type |
|---|---|---|
| DC Boundary | UMD | Shapefile (polygon) |
| DC Streets | UMD | Shapefile (line) |
| DC Crime 2013 | data.dc.gov | csv |
| DC Crime 2014 | data.dc.gov | csv |
| DC Police Stations | data.dc.gov | shapefile (point) |
| DC Neighborhoods | data.dc.gov | Shapefile (polygon) |

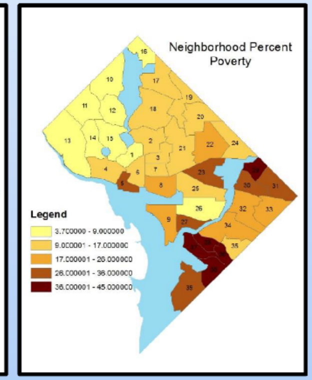
### Methods

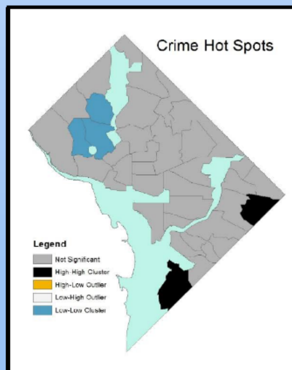
-Spatial Analysis → Point Density
-Spatial Autocorrelation → Moran's I, Cluster Analysis
- Spatial Statistics → Mean Center, Median Center, Standard Deviation Ellipse, Standard Distance Ellipse
- Network Analysis → Service Area
- 3-D Analysis
- Data Management

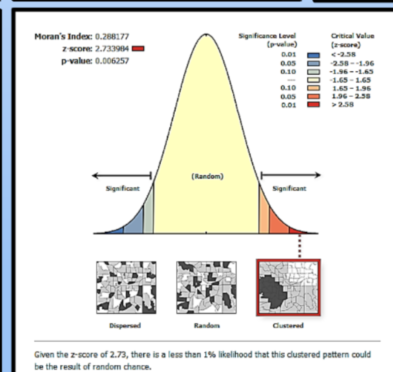


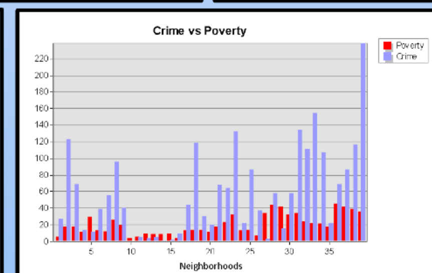



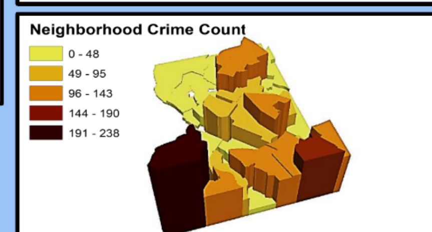



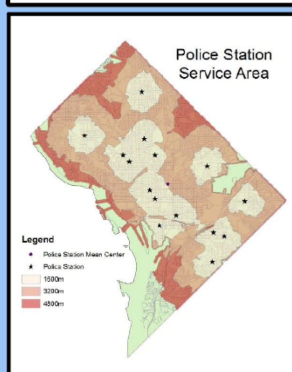



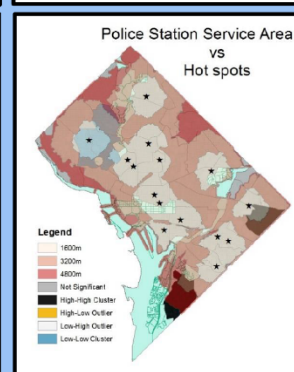



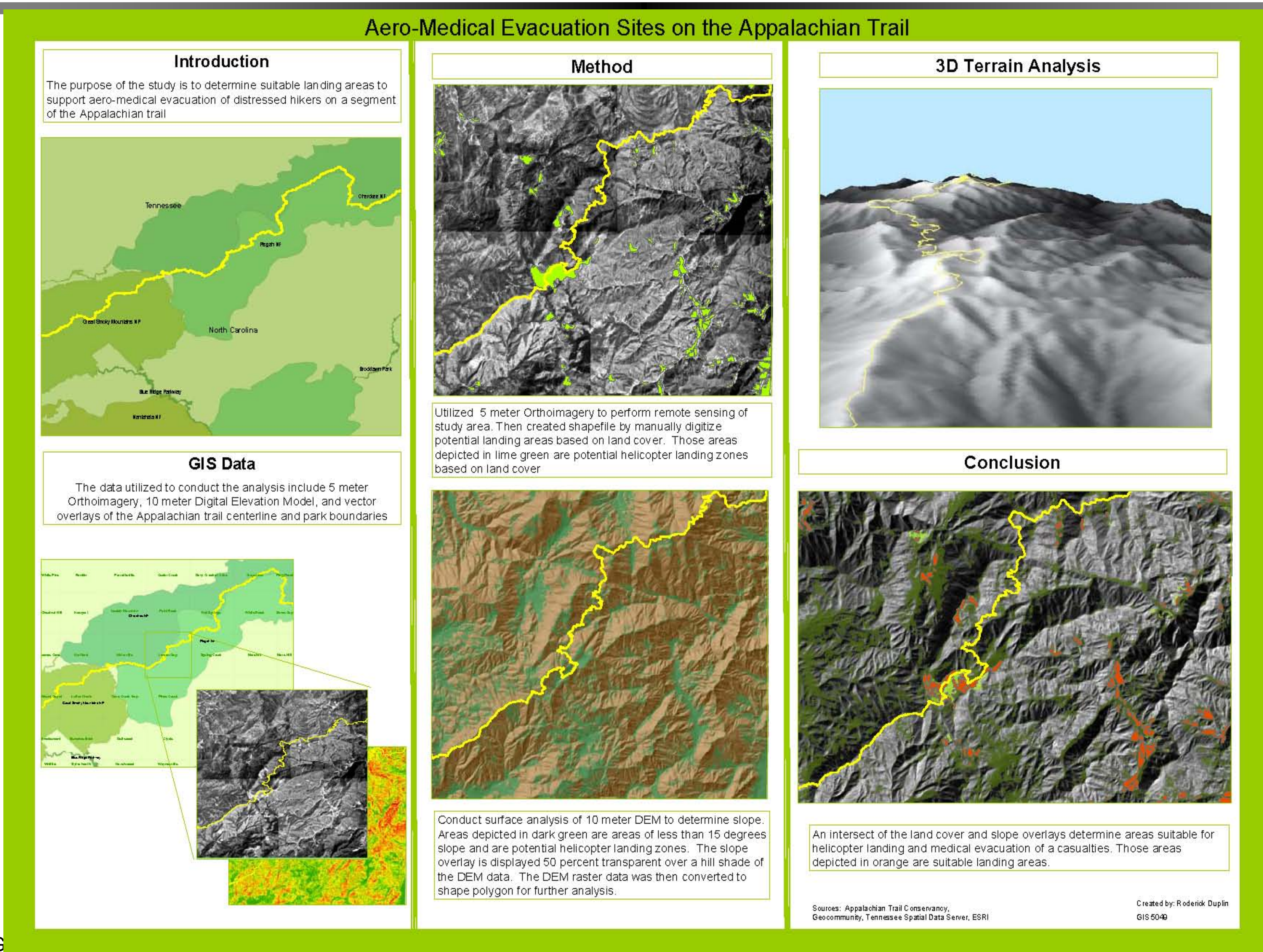




### Results and Conclusion

1. Crime is clustered in Washington, D.C according to Moran's I
2. Crime throughout D.C. neighborhoods is heavily correlated with their percent poverty
3. There are two main crime hotspots in the south and southeast regions of the city around where poverty is the highest
4. Police coverage as is does not adequately impede on these hotspots
5. Police stations mean center is towards the center of the city where crime is less of a problem
6. Police are more involved in protecting more affluent areas of the city rather than poverty stricken areas
7. There needs to be better police coverage of the overall city, especially areas of poverty, whether that means more stations, less clustering of stations, or better placement of stations across the city

# Examples: Spatial Analysis



# Examples: Spatial Analysis

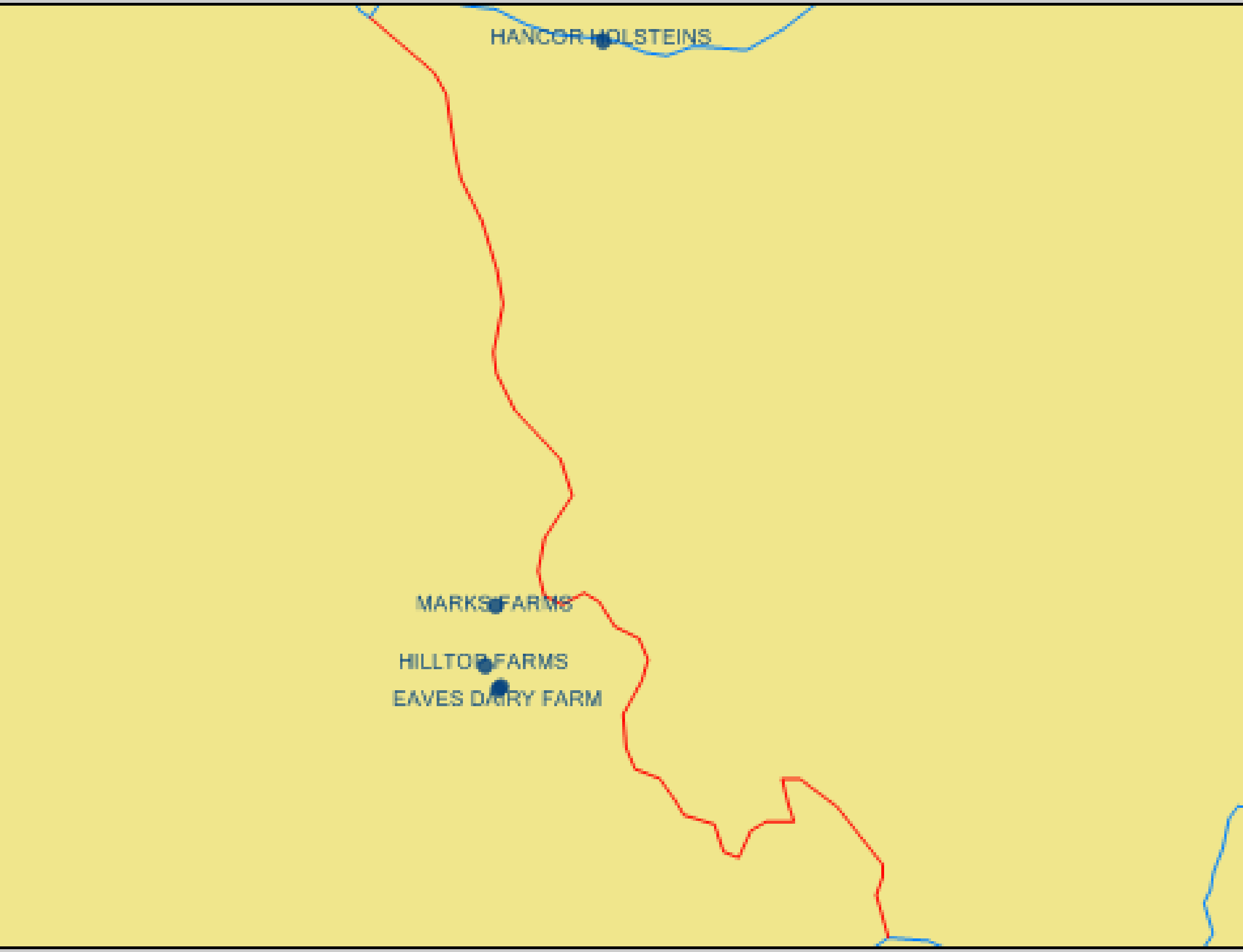
- More class project examples have been posted on ELMS.
  - Assignments > About Final Project > Final Project: Examples

# Examples: Spatial Analysis

- My GIS project while in grad school:
  - Siting analysis of farm-based anaerobic digester systems for distributed generation
  - Reminder:
    - GIS is just a tool. The research question is the most important part.
    - A GIS project needs to have a clearly spatial component.
    - A GIS project needs to based on a real world issue so that it can be ACTUALLY useful.

# Examples: Spatial Analysis

- Study Background
  - Animal waste is a BIG problem both environmentally and economically.
    - NYS is the 3rd largest dairy state
    - 7,388 dairy farms with 670,003 milk cows




Zoom Box | 75°48.991' W:42°46.777' N | 1:5400000

Right click below to export the querying results to Excel file (Windows XP users).

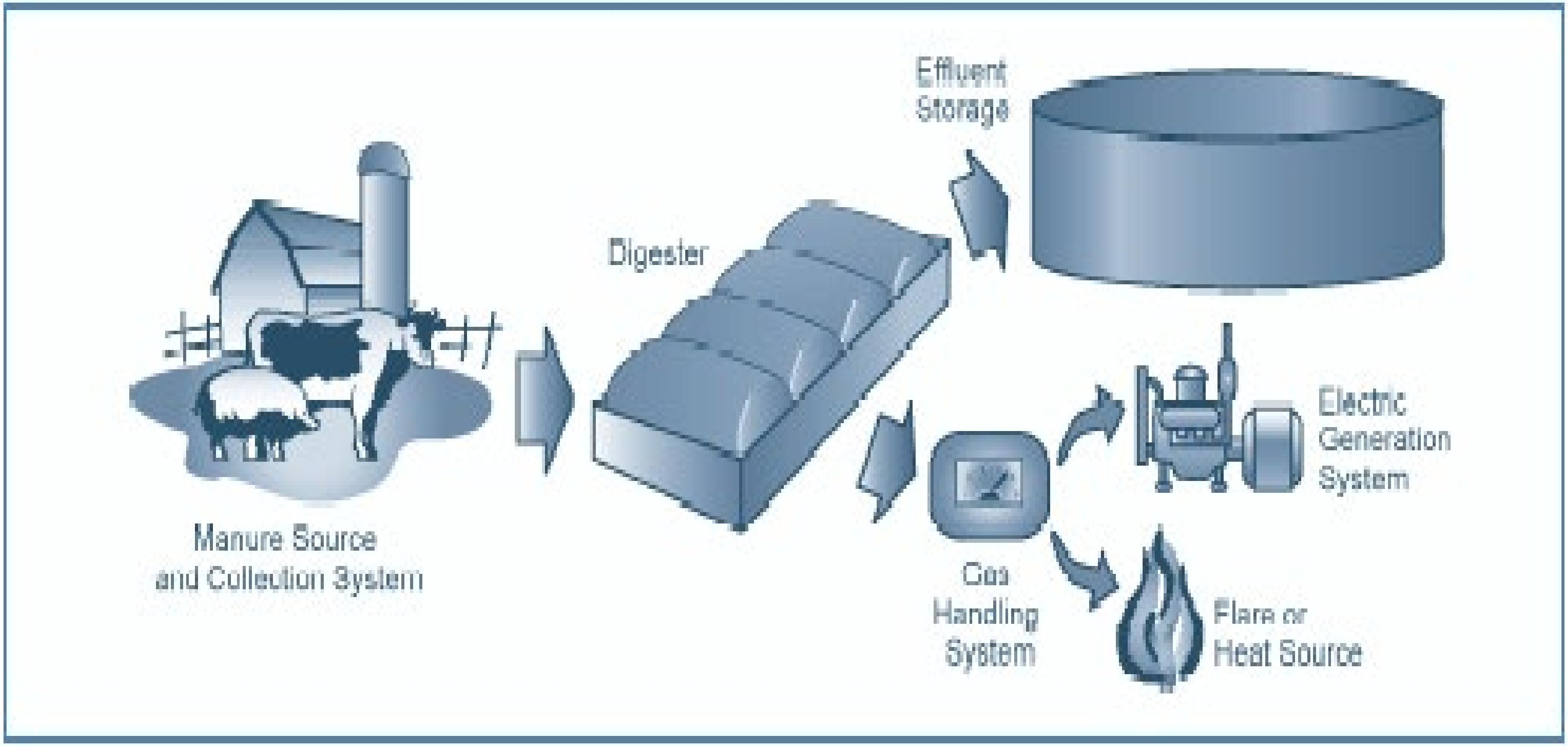
| NAME | FEATURE | LENGTH_ft |
|---|---|---|
| Black River | Stream | 23218.93 |

# Examples: Spatial Analysis

- Study Background
  - Waste to energy through anaerobic digestion is a promising approach.
    - Biogas: 85 $ft^3$/cow/day (60% $CH_4$)
    - Electricity: 140 Watts/cow
  - Growing interest from government, industry, and the public.

# Examples: Spatial Analysis

- Study Background
  - A schematic diagram of farm-based AD system



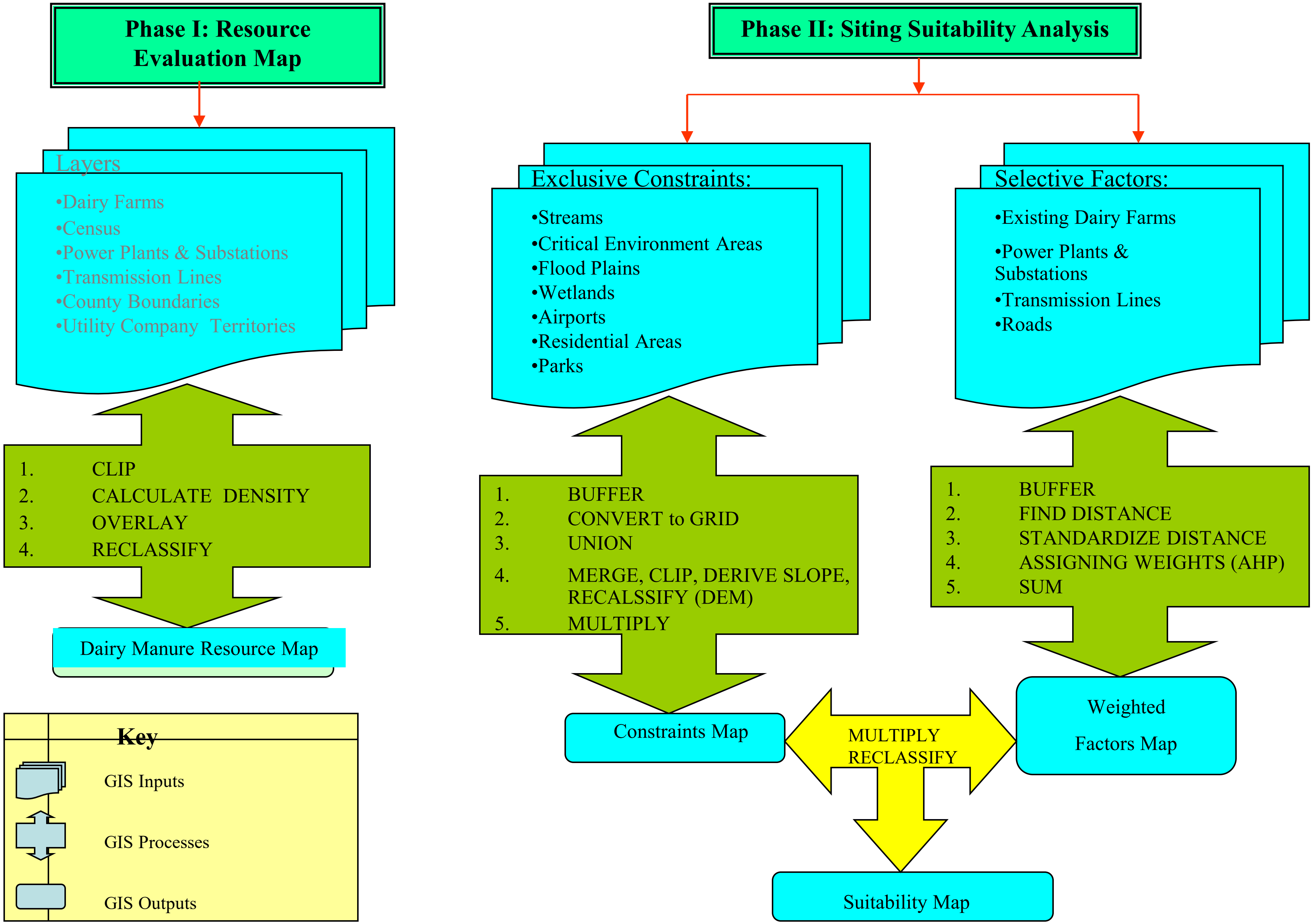
# Examples: Spatial Analysis



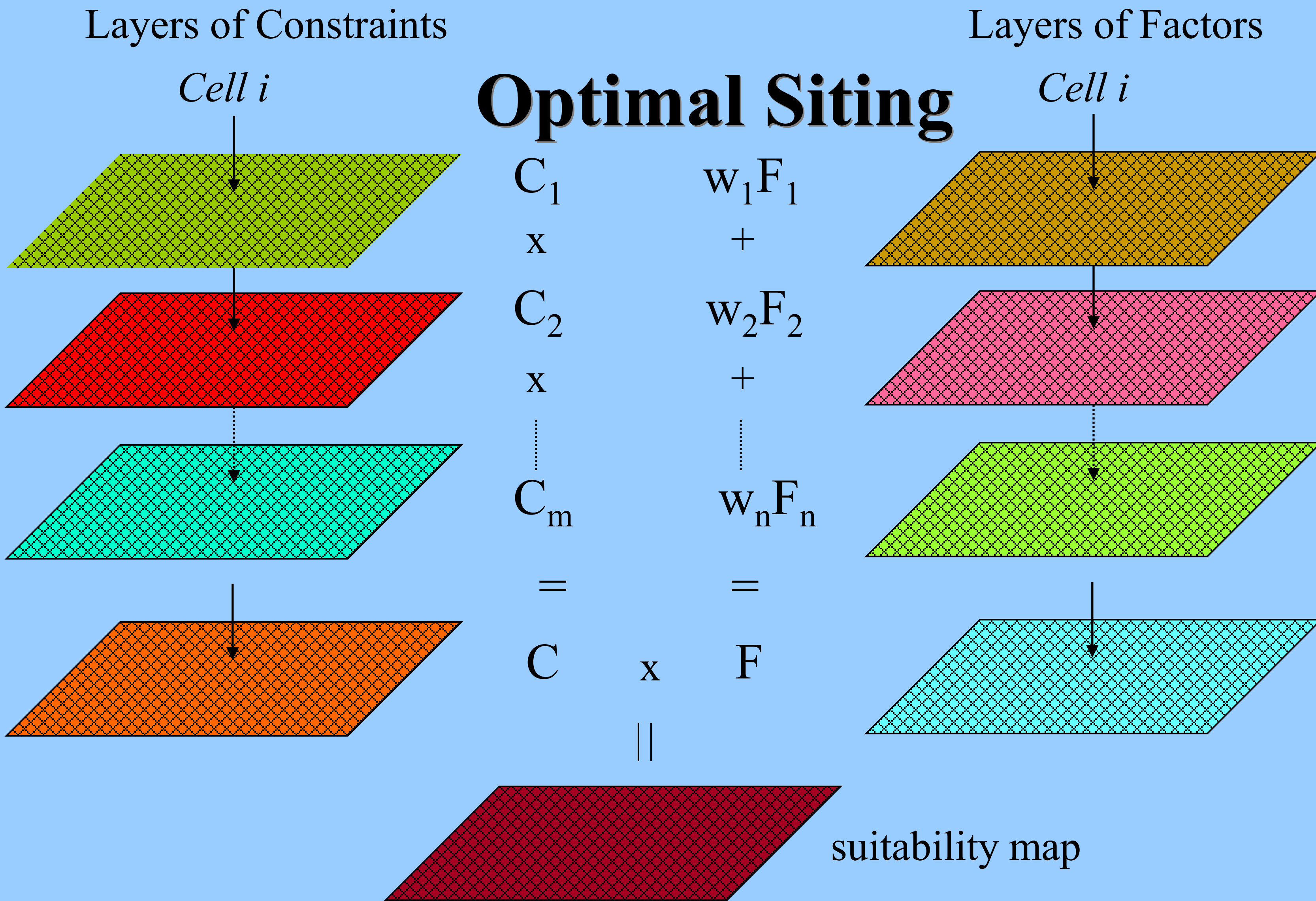
# Examples: Spatial Analysis

- Objective
  - Develop a GIS model for determining optimal sites for potential dairy farmed-based distributed generation facilities
- Multi-criteria decision making analysis
  - Constraints (environmental)
  - Factors (technical and socio-economic)

# Flowchart of GIS Database & Analyses



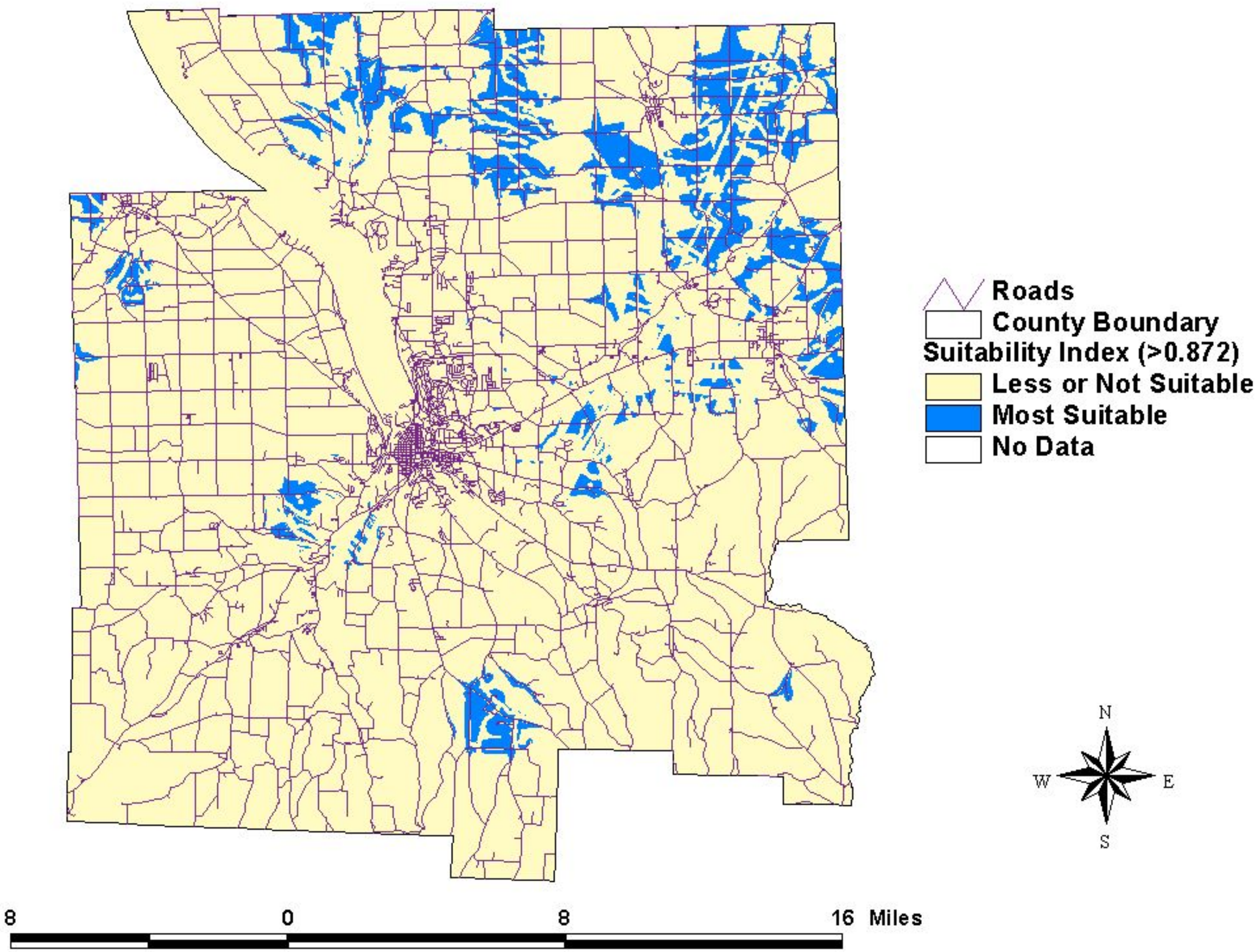
# Optimal Siting




Schematic diagram of calculating suitability map

# Examples: Spatial Analysis

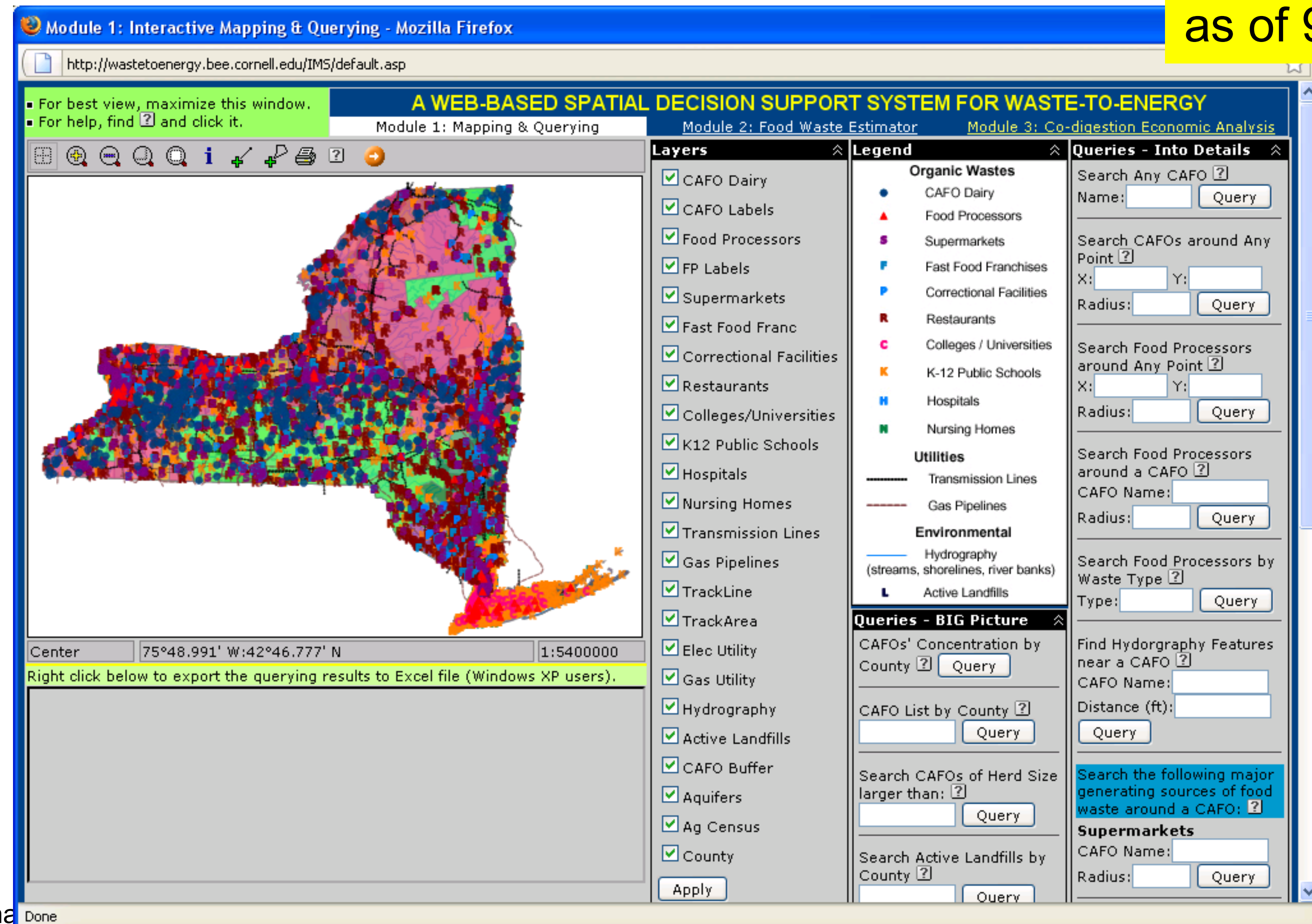
- Final Suitability Index Map



# Examples: Spatial Analysis

- Next level
  - A Web-based Spatial Decision Support System
    - http://wastetoenergy.bee.cornell.edu/

The server is down as of 9/5/2011.



# Demo

- ArcGIS Pro vs. ArcMap
  - Network analysis
  - 3D Visualization and Analysis
- ArcGIS Online
  - Spatial Analysis
  - Web map and web mapping app

# THE END