AN INTRODUCTION TO GEOSPATIAL TECHNOLOGY AS IT RELATES TO CREATING BASELINE INFORMATION FOR CLIMATE, HEALTH, DISASTER, AND DISEASE MAPPING AND CHANGE
Overview

- Introduction to GIS
- Key attributes of GIS and geospatial technology
- Big trends in GIS
- Creating baseline information
- Resources

Note: Going to generically refer to these processes as “Change” or “Change Mapping”
“Simply put, a GIS combines layers of information about a place to give you a better understanding of that place. What layers of information you combine depends on your purpose—finding the best location for a new store, analyzing environmental damage, viewing similar crimes in a city to detect a pattern, and so on.”

From ESRI’s Web Page (www.esri.com)
Introduction:
What are GIS and Geospatial Tools?

Software, data, visualization, and human analysis working together, often tightly integrated with an IT infrastructure.
How do we convert reality...
Into a GIS modeling environment
Data Types

Or how do we convert reality into a spatial model...
Basic Spatial Data Types

- **Vector**
  - Point, line, polygon
    - Shape (.shp) or Feature Class
    - Google formats
      - .KML, .KMZ

- **Raster**
  - Pixel based with georeferencing
    - .img, .bmp, .tiff, and many more

- **Aspatial**
Basic data structures for GIS

Vector

Raster
Much of it can be placed in a geographic context based on some location attribute like:

- Address (geocoding)
- IP address
- Political or geographic boundaries:
  - Town, health district, state, census tract, etc...
  - Chloropleth mapping
What is a GIS good for?

- Visualizing data and putting data into community context (including non-spatial data)
- Exploring relationship between variables
- Creating and analyzing data
  - Vulnerability and management activities
- Scalable analyses
  - Aggregation at multiple scales
  - Geographic
- “Mash-ups” and integration of multiple data types with analytic models
  - Table linkages and joins
- Unique statistical approaches
- Environmental change modeling
Big Trends in GIS
Growth of Data and Spatial Data

- Rapid growth of data is creating “deluge of data”

- According to the Cisco Visual Networking Index, Global Mobile Data Traffic Forecast for 2012 to 2017, worldwide mobile data traffic will increase 13-fold over the next four years, reaching 11.2 exabytes per month (for an annual run rate of 134 exabytes) by 2017.
The ability to analyze unstructured data sets allows the linkage of many different kinds of data.
- Purchase data, health data, location data, video data, pictures, phone calls, movements can all be tracked.
- Location allows for integration and linkages of data.
- Hadoop

Privacy issues
- Information is power in both a good and bad sense.
- Examples
  - NSA has tracked swipe strokes of Google Maps
  - Be careful of that phone because Angry Birds is tracking you.
  - [http://www.salon.com/2013/01/18/the_spies_inside_our_smartphones/](http://www.salon.com/2013/01/18/the_spies_inside_our_smartphones/) (Salon.com, Jan 18th, 2012)
  - [http://blog.flurry.com/bid/92105/Mobile-Apps-We-Interrupt-This-Broadcast](http://blog.flurry.com/bid/92105/Mobile-Apps-We-Interrupt-This-Broadcast)
Geoportals

- Aggregation of GIS data is becoming oriented towards ever larger datasets in large integrated web-based environments
  - Geoportal at Tufts called GeoData @ Tufts
  - Military data sets
  - LIDAR
Community Crowdsourcing and “Distributed Knowledge”

SeeClickFix

New Haven, CT

ISSUES

Quad in Fairmont Park • Closed
94-166 Clifton St New Haven, Connecticut

Bright Green Quad, Adult Male and two Children riding it. Must live close as the kids walked up Clifton to get to park. Police called.

Would love to see some evening police presence around the park. Have had dirt bikes and quads a few times this week, first time I have had a camera close, or they ride after dark when I can’t get a good shot.

06-21-2013 • Reported by Anonymous (Guest) • Share • Flag

View all 9 Comments

REOPENED Original Poster (Guest)

DfB, despite the comments this has not been fixed, please don’t close it unless you can get the illegal quads and bike out of the park.

06-22-2013 • Flag

Ben Westermann-Clark (Verified Official)

Due to the nature of some of the comments in this issue (which have since been
Ureport (Uganda)

CURRENT POLL - 09/May/2014:

Hi U-reporters in Kasese! Have you experienced flooding during the past days? If yes, can you tell us what damage has been caused?
812 Responses out of 3,513 Participants (23%)

three hosp water destroyed died properties house lost destruction life town schools flooded nyamwamba damages river patients pple road loss houses peoples roads plantations flood people property led flooding hve mines kilembe washed kasese things destroyed hav death damaged dead lives buildings displaced closed bridge caused gardens kyarumba crops school swept yesterday help hospital homes displacement floods

PREVIOUS POLLS

09/May/2014: Hi U-reporters in Kasese! Have you experienced flooding during the past days? If yes, can you tell us what damage has been caused? See results

05/May/2014: Hi U-reporter! If you know what Child Days Plus is, share with us which three main health services are being offered to children and mothers in your community. See results
Web-based GIS and Crowdsourcing

- https://www.waze.com/
- https://www.movebank.org/
- http://www.ducks.org/migrationMap/?poe=migrationHome
- https://nchip.n3cn.org/
- http://www.healthlandscape.org/
Global AND Scalable Data Sets: Ex. Forestry Map

Creating Baseline Data for Change

Climate Change
Health
Disease and Disaster Mapping
### Similarities and Differences between Climate Change, Health, Disease and Disaster Mapping

<table>
<thead>
<tr>
<th>Climate Change and Health</th>
<th>Disease and Disaster Mapping/Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Longer time horizons</td>
<td>- Short time frames for processes and production</td>
</tr>
<tr>
<td>- Wide variety of scales</td>
<td>- Local scales (usually)</td>
</tr>
<tr>
<td>- Planning oriented issues and models</td>
<td>- Point data and imagery are critical data types</td>
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<tr>
<td>- Utilize a wide variety of analytic geospatial tools, approaches</td>
<td>- Rapid access and dissemination of data (web-based and cloudsourcing tools)</td>
</tr>
<tr>
<td>- Environmental data, satellite imagery, etc.</td>
<td></td>
</tr>
<tr>
<td>- Traditional GIS tools</td>
<td></td>
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</tbody>
</table>

- Traditional GIS tools
Background

- Climate change occurs over several relevant scales and extended time frames
- Disasters are typically in short time scales with local but severe impacts
- Diseases have underlying biological process at tiny scales but change is represented by point data that is aggregated
- Need tools that can handle scale issues (GIS!)
- Need visualization of the data or process to allow citizens to participate in crisis management decision making (GIS!)
Background

- Simple imagery does not allow for quantitative analysis
  - No counts, analytic assessments, etc.
- Health, climate change, and disaster mitigation are highly political so need defensible facts and data
- Planning models are critical for prediction and risk assessment
- Disasters require spatial infrastructure and preliminary analyses in place before disaster
Critical Issue

- There must be PREBUILT *baseline* data, information, and geospatial infrastructure so that an assessment of these change processes can be analyzed and described.
Components of Baseline Information

- Need:
  - 1. Understand the Community/Environment context and have critical data infrastructure
  - 2. Indicators of climate, health, or environmental change
  - 3. Identify relevant spatial and temporal scale
  - 4. Geospatial tools for interpreting, planning, and communicating change

Adapted from Community Tool Box, Community Assessment. Found at http://ctb.ku.edu/en/table-of-contents/assessment
Imagery and the Community/Environment of Interest

- GIS can provide detailed visualization and site context
- Global buildout of high resolution imagery already finished (see Bing Maps and Google Maps)
  - Ex. My mother-in-law’s house in India

Found at: Bing Maps, Aerial Satellite Imagery
Site Context and the Community/Environment of Interest

- Location based contextual, health, and social information now available through MNC, Census data, public health, crowd sourcing and Twitter
- Imagery infrastructure development highly dependent on MNC
- [Open Street Map](#)

Found at: Google Maps, Aerial Satellite Imagery
Methods for Creating Infrastructure

- Long-term planning and skilled technical staff
  - Mass GIS
- Mobilize volunteers
  - http://www.mapaction.org/about/about-us.html
Methods for Creating Infrastructure

- Open-source tools for geospatial research
  - Ushahidi

- Crowd sourcing imagery for the “last mile” or points in time
  - Mapillary
Ex: Methods for Creating Infrastructure

- Cloud-sourcing research
- Disaster mapping Blog
- Cyclone Center
Ex: Twitter/Health Map
Ex: HealthMap.org
Ex: HealthData.org
Ex: The National Map and National Atlas
Components of Baseline Information

- **Need:**
  - 1. Understand the Community/Environment context and have critical data infrastructure
  - 2. *Indicators of climate, health, or environmental change*
  - 3. Identify relevant spatial and temporal scale
  - 4. Geospatial tools for interpreting, planning, and communicating change

Adapted from Community Tool Box, Community Assessment. Found at http://ctb.ku.edu/en/table-of-contents/assessment
How to Pick Indicators of Change

- Need to utilize data sets that are reliable and consistent at the correct scale and the right temporal frequency
- Captures the phenomenon of interest
- Comparative data available (i.e., before and after)
- Prefer data sets that can provide numerical and analytic assessments of Change
Potential Indicators for Climate, Health, Disease, and Disaster Change

- **Infrastructure**
  - Health
  - Transportation
  - Housing
  - Security and military facilities
  - Government facilities

- **Disease**
  - Socio economic factors
  - Aggregated health data (time and area)
  - Tabular data (eg: doctors’ office locations)
  - Point data and epidemiological data
Potential Indicators for Climate, Health, Disease, and Disaster Change

- **Environment / Climate Impacts**
  - Sea level rise and change**
  - Temperature**
  - Precipitation**
  - Cloud cover**
  - Hydrology*

- **Land cover change**
  - Vegetation and topography**
  - Snowpack**

- **Biological**
  - Infection vectors patterns change

- **Health**
  - Pollution*
  - Point health/ disease data aggregated**

- **Note:** **Available from remote sensing and earth observation satellites, spatial analysis or part of key GIS functionality**
- Operating at vastly different scales
Indicators of Change (Raster data)

- An Example:
  - Raster data derived from satellites/imagery is particularly useful because
    - Comes in many different data formats
    - Can utilize consistent analytic procedures that have scientific validity
    - Have reliable formats
    - Crowd-sourced information highly variable and noisy
  - Relies on technical skill sets
Indicator of Change (Raster Data)

- Visualization and photo interpretation
- Relies on nonrectified imagery
- Very short temporal cycle
- Localized evaluation and phenomena

Oso, Washington: Incredible before and after images of mudslide disaster that buried a town

The Independent: May 18, 2014.
Indicator of Change: Land Cover Change Analysis

- Classic remote sensing analysis
- Uses orthorectified imagery, satellite data, or processed environmental data
- Accessible to wide variety of analytic methods.
Ex: Other Raster Datasets

Accumulated Rainfall Ghana, 2013 (TRMM 2B31)

- January and February
- March, April, and May
- June, July and August
- September and October
- November and December
Vector Data

- Point data
  - Aggregation
  - Spatial statistics
  - Descriptive methods
    - Centroids
- Vector Overlay Analysis
Components of Baseline Information

- **Need:**
  - 1. Understand the Community/Environment context and have critical data infrastructure
  - 2. Indicators of climate, health, or environmental change
  - 3. **Identify relevant spatial and temporal scale**
  - 4. Geospatial tools for interpreting, planning, and communicating change

Adapted from Community Tool Box, Community Assessment. Found at http://ctb.ku.edu/en/table-of-contents/assessment
Identifying Correct Scale and Temporal Resolution

- May be difficult task!
- Need to balance
  - Literature
  - Data available
  - Common sense
- Spatial statistics (Spatial Autocorrelation) may help provide a justification
Spatial and Temporal Scale

- Need to capture the correct phenomena at the finest possible resolution without losing accuracy or excessive accuracy.
- Too much detail and data load gets excessive and creates noise.

Detecting dominant landscape objects through multiple scales: An integration of object-specific methods and watershed segmentation.
MAUP and Point Data

- Modified Areal Unit Problem
- The arrangement of geographic space changes your results
- Crime example:
  - Case 1 (100/district)
  - Case 2
    - AREA A (wants more foot patrol)
    - AREA B
MAUP and Point Data

- Modified Areal Unit Problem
- The arrangement of geographic space changes your results
- Crime example:
  - Case 1 (100/dist)
  - Case 2
    - AREA A (131/dist)
    - AREA B (37/dist)
MAUP and Raster Data

- Fine scale data is typically aggregated up to coarser scales
  - Points or pixels to neighborhoods, towns, counties, states
  - Ex: Disease data

Problem: AGGREGATION CHANGES THE ANSWER
(Modified Area Unit Problem)
Components of Baseline Information

□ Need:

□ 1. Understand the Community/Environment context and have critical data infrastructure

□ 2. Indicators of climate, health, or environmental change

□ 3. Identify relevant spatial and temporal scale

□ 4. Geospatial tools and analytics for interpreting, planning, and communicating change

Adapted from Community Tool Box, Community Assessment. Found at http://ctb.ku.edu/en/table-of-contents/assessment
Geospatial Tools

- Visual information is good for short-term assessment but bad for assessment, evaluation, and planning.
- Geospatial tools working on spatial data are critical for analytics but require the greatest training.
- These tools allow for analysis to be PREBUILT.
- Results can be placed or distributed using web-based mapping.
Example 1: Aggregating Change Information

Conclusions

In the Midwestern region overall, it appears that there is an interesting relationship between the potential effect hogs, population and population density has on hospitalizations. This is indicated by the ability of the population density variable to change the direction or the hog density effect, but also visible in the regionally varied cluster maps. This is not surprising, as there are many potential pathways for disease transmission. Biologically, it is likely that these infectious diseases should increase with increasing population density and vary this pattern in...
Example 2: Aggregating Planning Data for Change

Paying for Climate Change - How is climate change adaptation aid distributed?

Background

Rapidly changing climate, increased weather events, and other novel effects of climate change are having a significant impact on people and the environment worldwide. This is especially true in the developing world, where many countries are already facing increasing economic and social challenges. In this study, we analyze the distribution of climate change adaptation aid to identify gaps and areas of need.

Methods

Data for 2010 was acquired from the Notre Dame Global Climate Change Vulnerability Index and the Organization for Economic Cooperation and Development (OECD) Aid Statistics. Tied aid data was joined to a layer of countries classified by climate risk to inform findings. This data was used to examine the current state of the distribution of climate change adaptation aid and to inform future funding decisions.

Results & Conclusions

Aid Matching — How well distributed is climate change aid?

The comparison of vulnerability and aid data shows that 45% of the 199 countries included in the study received aid that was well matched to their level of vulnerability. However, 50% of countries were poorly matched. All countries with a Level of Adaptation Aid of 1 or 2, received aid, while those with a Level of Adaptation Aid of 3 or 4, received no aid. This highlights the need for better targeting of aid.

The vulnerability score implicitly incorporates wealth in part because poorer countries have lower infrastructure and capacity to deal with climate impacts. Thus, as shown in the vulnerability maps, the most vulnerable countries are often the poorest. This study only includes aid from one organization, albeit a major one, and the vulnerability scores are speculative, based partially on projections. This study showed that there is a need for better targeting of aid based on need.

5 Factors of Climate Vulnerability

- Water
- Air
- Temperature
- Food
- Health

Figure 2: These factors were used to create factors that were weighted equally.

Level of Adaptation Aid

- Level of Vulnerability
- Level of Adaptation Aid
- Need for Adaptation

Figure 3: These factors were used to create factors that were weighted equally.

Figure 4: The vulnerability map on the left is a classification of the ND-GAIN vulnerability index score; the lighter the color, the higher the vulnerability. The OECD aid map on the right is a classification of OECD climate change adaptation aid; the lighter the color, the lower the amount of aid received.

Sheree Rascoe
Run 2014

Data sources: OECD Aid Statistics, ND-GAIN Climate Risk Index, Tufts University, U-M. Drive GCS_WG_5041 162,000,000
Suitability/Vulnerability Analysis

- Modeling approach allows for the comparison of contrasting or competing variables
- Data type flexibility
- Planning tool to determine
  - Most suitable area
  - Most vulnerable area
  - Highest priority area
Example 3: Vulnerability Analysis to Change

Rising Sea Levels and Environmental Justice Concerns in the San Francisco Bay Area, CA

**Background**

Rising sea levels, due to increasing global temperature, pose a risk to coastal populations in the coming century. Global average temperatures are expected to increase by 1.8 to 4.0 degrees Celsius by 2030 (IPCC, 2007). As temperatures increase, ice caps continue to melt at the poles, adding more water volume to the ocean and raising water levels. By applying the IPCC future warming scenarios, sea levels are expected to rise by 0.5 to 1.4 meters by 2030 (Houghton, 2000). These rising sea levels will result in the inundation of low-lying coastal areas, coastal erosion, elevated flood levels, and increasing intensity of storm events.

Communities in these inundated areas are likely to experience significant health, safety, and economic problems. Those in disadvantaged communities generally have fewer resources at their disposal to prepare for and react to natural disasters. Thus, they are more likely to suffer, creating an environmental justice problem (Page, 2007). Environmental justice is “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental regulations, and policies” (EPA, 2013). As part of the environmental justice movement, environmental justice communities have demonstrated that communities within the United States need to be understood and addressed to handle environmental justice concerns (Ellis, 2006).

The San Francisco Bay Area is a highly developed urban region with a racially and economically diverse population of 7.3 million people living within 1,500 miles of coastline. The most conservative estimates of the US Geological Survey’s CASCADe project predict extensive coastal inundation in the Bay Area from a 70 cm sea level rise during a 100-year storm event (Kowalik, 2010). The purpose of this project was to determine if coastal inundation from rising sea levels in the nine counties of the Bay Area would create any environmental justice concerns, adversely impacting low-income and minority communities more than sufficiency and disadvantaged communities.

**Methodology**

To address the possibility of environmental justice concerns in the San Francisco Bay Area, spatial models of predicted inundation levels, spatial demographic data, and geographic data were combined and analyzed. The model of predicted inundation levels was obtained from the USGS CASCADe project. Socioeconomic level data was obtained from the US Census American Community Survey 2011 and showed increased incomes at the tract level; the smallest geographic grouping for the ACS. Race demographic data was obtained for Solano County from the block level from the 2010 US Census. The data was simplified to concentrate on disparity populations. Sensitivity analysis was conducted to determine which variables would have the most effect on the results. Impacted and unimpacted tracts and block data is presented below for Solano County. The data is broken down by race and gender, and the data is presented for Solano County.

**Results & Conclusions**

The analysis of the median household income data by tract showed statistically significant results (P<0.05) on the majority of the nine counties of the Bay Area. The income in these counties for those living in inundated tracts was lower than those living in unaffected tracts, representing a potential environmental injustice. The analysis of the racial demographics for Solano County by block yielded one conclusive result: the percentage of minorities over the total population per block was not statistically significantly different between impacted and unaffected blocks. However, there was a slight disparity with 6% minority population in inundated blocks and only 5% minority population in unaffected blocks.

Based on these results, the project, the San Francisco Bay Area is in danger of significant environmental injustices if sea levels rise according to current predictions. In order to prevent such injustices, policymakers should consider environmental justice concerns in order to make more educated and fair policy decisions. Government officials might create or improve emergency exit strategies and assistance plans for low-income populations in inundated areas.

To expand the information available about environmental injustices in the Bay Area, it would be useful to analyze income levels in inundated or unaffected areas on a city-wide basis. This way, policymakers would have more detailed information about the most pressing environmental injustice occurrences. Additionally, racial data should be analyzed to determine any statistically significant environmental justice concerns in all of the counties, not just Solano County.
Example 4: Prebuilding Proximity Information for Change Planning

- Determine closest evacuation routes prior to the event for each household
Web Visualization and Mapping Tool

https://www.mapbox.com/

Mapbox is an open source mapping platform for developers and designers at enterprise scale.
Model of an Ideal Solution for Capturing “Change”

- All components are available
- Emphasize particular components below based on scale, data, and temporal requirements
- **Combine the following ingredients:**
  - Build infrastructure of geospatial data at the proper scale with most useful predictor data and imagery/raster data
  - Conduct preliminary geospatial planning and analysis
  - Incorporate smart phone input and social media access
  - Quantify change with geospatial tools (See QGIS)
  - Web output
Resources
Free GIS Software

QGIS
A Free and Open Source Geographic Information System

Create, edit, visualise, analyse and publish geospatial information on Windows, Mac, Linux, BSD (Android coming soon)

For your desktop, server, in your web browser and as developer libraries

Download Now  Support QGIS
Free GIS Software
Free GIS Software

ArcGIS Explorer Desktop

Broaden the Reach of Your Spatial Information

Easily share data with people who are not GIS experts

ArcGIS Explorer Desktop is a free GIS viewer that gives you an easy way to explore, visualize, and share GIS information. ArcGIS Explorer adds value to any GIS because it helps you deliver your authoritative data to a broad audience.

With ArcGIS Explorer, you can:
- Access ready-to-use ArcGIS Online basemaps and layers.
- Fuse your local data with map services to create custom maps.
- Add photos, reports, videos, and other information to your maps.

What's New
ArcGIS Explorer 2500 is Now Available
See how ArcGIS Explorer Desktop helps you leverage ArcGIS Online capabilities.

Download ArcGIS Explorer

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Interpreting and Communication with GIS

- Web-based mapping
  - ArcMap Online
  - Mapbox
  - OpenGeo
  - Ushahidi

- Mapping and data software
  - Tableau Public

- Tutorials
  - Canadian RS Tutorial
  - NOAA RS List
  - GIS Learning
  - ESRI
  - Tufts GIS
  - Coastal Inundation
Questions???

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AN INTRODUCTION TO
GEOSPATIAL TECHNOLOGY
AS IT RELATES TO CREATING
BASELINE INFORMATION
FOR CLIMATE, HEALTH,
DISASTER, AND DISEASE
MAPPING AND CHANGE

Carl L. Zimmerman, PhD