

# **Overview of GIS**

## **Introduction**

Geographic Information System (GIS) is a computer based information system used to digitally represent and analyse the geographic features present on the Earth's surface and the events (non-spatial attributes linked to the geography under study) that taking place on it. The meaning to represent digitally is to convert analog (smooth line) into a digital form.

"Every object present on the Earth can be geo-referenced", is the fundamental key of associating any database to GIS. Here, term 'database' is a collection of information about things and their relationship to each other, and 'geo-referencing' refers to the location of a layer or coverage in space defined by the co-ordinate referencing system.

Work on GIS began in late 1950s, but first GIS software came only in late 1970s from the lab of the ESRI. Canada was the pioneer in the development of GIS as a result of innovations dating back to early 1960s. Much of the credit for the early development of GIS goes to Roger Tomilson. Evolution of GIS has transformed and revolutionized the ways in which planners, engineers, managers etc. conduct the database management and analysis.

## **Defining GIS**

A GIS is an information system designed to work with data referenced by spatial / geographical coordinates. In other words, GIS is both a database system with specific capabilities for spatially referenced data as well as a set of operations for working with the data. It may also be considered as a higher order map.

GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. (ESRI)

A Geographic Information System is a computer based system which is used to digitally reproduce and analyse the feature present on earth surface and the events that take place on it. In the light of the fact that almost 70% of the data has geographical reference as it's denominator, it becomes imperative to underline the importance of a system which can represent the given data geographically.

A typical GIS can be understood by the help of various definitions given below:-

A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on Earth

Burrough in 1986 defined GIS as, "Set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"

Arnoff in 1989 defines GIS as, "a computer based system that provides four sets of capabilities to handle geo-referenced data :

data input

data management (data storage and retrieval)

manipulation and analysis

data output. "

Hence GIS is looked upon as a tool to assist in decision-making and management of attributes that needs to be analysed spatially.

### **A revised definition of Geographic Information Systems For the purposes of Exploring GIS:**

A Geographic Information System (GIS) can be defined as:

The organized activity by which people

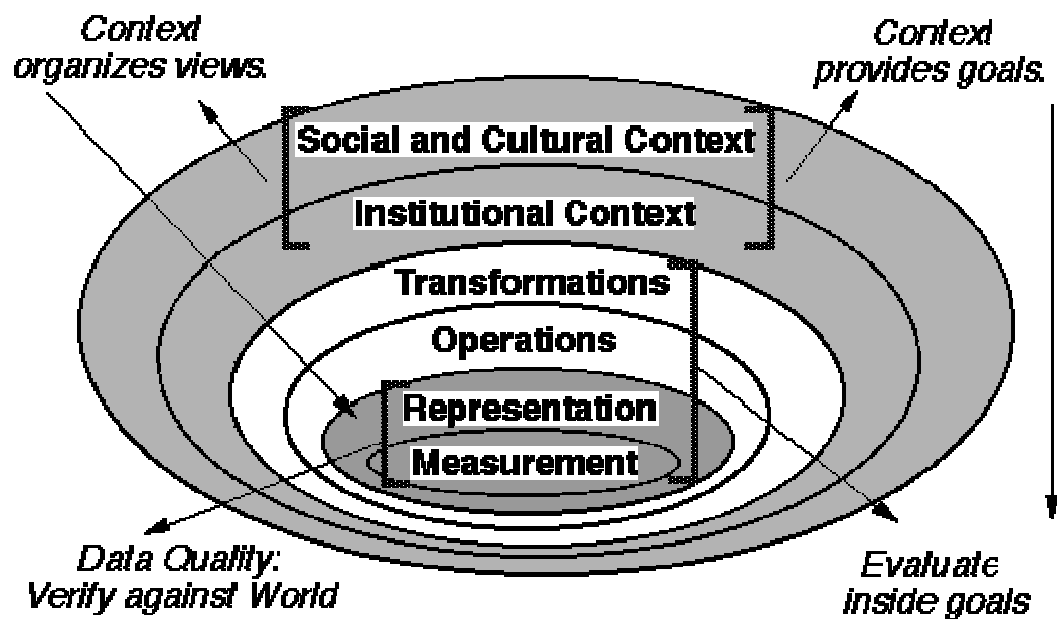
*measure* aspects of geographic phenomena and processes;

*represent* these measurements, usually in the form of a computer database, to emphasize spatial themes, entities, and relationships;

*operate* upon these representations to produce more measurements and to discover new relationships by integrating disparate sources; and

*transform* these representations to conform to other frameworks of entities and relationships.

These activities reflect the larger context (institutions and cultures) in which these people carry out their work. In turn, the GIS may influence these structures.



## How Is The Real World Represented Within A GIS ?

The real world is far too complex to model in its entirety within any information system, so only specific areas of interest should be selected for inclusion within a given GIS application. Once a particular application area has been chosen the next task is to select those features which are relevant to the application and to capture information about their locations and characteristics. The GIS, being computer based, needs to have all of this information in digital form. It is thus necessary to consider how each real world feature can best be modelled within the computer system. There are essentially only five different types of spatial object, also known as entity, feature or facility, which can be represented within a GIS.

### Point...

An object that occurs at one physical location in space and which has only one reference coordinate. Examples include trees, pylons, rainfall gauges, health clinics and hotels.

### Line...

An object which spans between points and thus requires at least two reference coordinates, its start and end, to define its spatial location. Examples include roads, rivers, pipes and cables.

### **Area...**

An object which has area and is defined by a continuous closed boundary. A number of coordinates are required to define its boundary. Area features are also known as polygons. Examples include fields, counties, lakes, planning sites, health districts and enumeration districts.

### **Surface...**

A feature which requires three dimensions to define it. Thus a series of spatially distributed x,y coordinates are necessary to define a surface, each with a vertical z value. The z value may represent physical terrain, population density or rainfall, for example.

### **Layers...**

Regardless of the way the data are structured, all GIS separate the different types of information into data 'layers'. This means for instance that all the water features are held on one layer and all the roads on another. This allows for separate display and processing when necessary but does not prevent cross referencing between data layers during query and analysis. A number of data layers are thus built up into a sandwich within the GIS. Layers are referenced to a common spatial domain so that they can be scaled and overlain in such a way that any given reference point can be located on any of the layers and the data value extracted.

### **Network...**

A feature defined by a series of line segments connected to form a continuous branching system of links. This structure enables the calculation of optimal routes through road networks or the simulation of flow through rivers or pipes.

It is the first three features which are the most commonly used but occasionally it is necessary to model more complex entities which require the use of surface or network facilities.

The above features can then be represented within a GIS in one of two quite different ways:

- vector format
- or
- raster format.

- **Vector...**

Positional data in the form of x,y coordinates. Each feature has a coordinate or string of coordinates to represent a particular location within a specific spatial referencing system. Spatial objects are thus defined by points and lines, in a similar way to conventional paper maps and drawings. Examples of data in vector format include site plans, ordnance survey maps and Computer-Aided Design (CAD) drawings.

- **Raster...**

Data expressed as a matrix or array of grid cells or pixels. Each coordinate or value is represented by a cell in the regular array of cells. The position of spatial objects can thus only be defined to the nearest cell. Examples of data in raster format include scanned aerial photographs, satellite images and scanned documents or maps.

The two structures are each appropriate to different data sets and applications:

- **Vector**

A vector structure can provide a flexible and accurate representation of an object due to the fine resolution obtainable with coordinate points. Vector structures also tend to incorporate the topology and other spatial relationships between the individual entities and are therefore ideally suited to representing linked networks such as pipe or road systems. It is very accurate for the measurement of areas or lengths and ideal where there is a requirement for cartographic-quality pen plots. Computer data storage is very economical but certain operations such as overlay analysis and proximity calculations have high computational requirements, which result either in slow operations or high hardware specification requirements. Manipulation and analysis of digital images, which are essentially raster, is not feasible.

- **Raster**

A raster structure provides information at a much lower resolution since data can only be located to the nearest grid cell. Computer storage tends not to be economic, although data compression techniques are improving the situation. Operations such as overlay, buffering and neighbourhood analysis are, however, more efficiently accomplished with a raster structure. Raster structures are ideal where the source data is raster-based, such as satellite or scanned photogrammetric data, and particularly where the data also need to be output to a raster device.

Traditionally, commercial GIS were based on one format or the other and were not designed to handle both. Vector-based GIS tended to arise from CAD or automated cartography systems whilst raster systems grew from image processing technology. Most GIS software today will enable conversions between the two formats or will at least allow users to display vector data over the top of raster data, provided that the latter is geo-referenced first.

### **Answers GIS can give**

Till now GIS has been described in two ways:

Through formal definitions, and

Through technology's ability to carry out spatial operations, linking data sets together.

However there is another way to describe GIS by listing the type of questions the technology can (or should be able to) answer. Location, Condition, Trends, patterns, Modelling, Aspatial questions, Spatial questions. There are five type of questions that a sophisticated GIS can answer:

#### **Location What is at.....?**

The first of these questions seeks to find out what exists at a particular location. A location can be described in many ways, using, for example place name, post code, or geographic reference such as longitude/latitude or x/y.

#### **Condition Where is it.....?**

The second question is the converse of the first and requires spatial data to answer. Instead of identifying what exists at a given location, one may wish to find location(s) where certain conditions are satisfied (e.g., an unforested section of at-least 2000 square meters in size, within 100 meters of road, and with soils suitable for supporting buildings)

## **Trends What has changed since.....?**

The third question might involve both the first two and seeks to find the differences (e.g. in land use or elevation) over time.

Patterns What spatial patterns exists.....?

This question is more sophisticated. One might ask this question to determine whether landslides are mostly occurring near streams. It might be just as important to know how many anomalies there are that do not fit the pattern and where they are located.

## **Modelling What if.....?**

"What if..." questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local ground water supply. Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operation.

## **Aspatial Questions:**

"What's the average number of people working with GIS in each location?" is an aspatial question - the answer to which does not require the stored value of latitude and longitude; nor does it describe where the places are in relation with each other.

## **Spatial Questions:**

" How many people work with GIS in the major centres of Delhi" OR " Which centres lie within 10 Kms. of each other? ", OR " What is the shortest route passing through all these centres". These are spatial questions that can only be answered using latitude and longitude data and other information such as the radius of earth. Geographic Information Systems can answer such questions.

## **Need of GIS:**

Many professionals, such as foresters, urban planners, and geologists, have recognized the importance of spatial dimensions in organising & analysing information. Whether a discipline is concerned with the very practical aspects of business, or is concerned with purely academic research, geographic information system can introduce a perspective, which can provide valuable insights as

1. 70% of the information has geographic location as it's denominator making spatial analysis an essential tool.
2. Ability to assimilate divergent sources of data both spatial and non-spatial (attribute data).
3. Visualization Impact
4. Analytical Capability
5. Sharing of Information

## **Factors Aiding the rise of GIS:**

- Revolution in Information Technology.
  - Computer Technology.
  - Remote Sensing.
  - Global Positioning System.
- Communication Technology.
- Rapidly declining cost of Computer Hardware, and at the same time, exponential growth of operational speed of computers.
- Enhanced functionality of software and their user-friendliness.
- Visualizing impact of GIS corroborating the Chinese proverb "a picture is worth a thousand words."
- Geographical feature and data describing it are part of our everyday lives & most of our everyday decisions are influenced by some facet of Geography.

## **Philosophy of GIS:**

The proliferation of GIS is explained by its unique ability to assimilate data from widely divergent sources, to analyse trends over time, and to spatially evaluate impacts caused by development.

For an experienced analyst, GIS is an extension one's own analytical thinking. The system has no in-built solutions for any spatial problems; it depends upon the analyst.

The importance of different factors of GIS in decreasing order is as under:

- **Spatial Analysis**
- **Database**
- **Software**
- **Hardware**

GIS involves complete understanding about patterns, space, and processes or methodology needed to approach a problem. It is a tool acting as a means to attain certain objective quickly and efficiently. Its applicability is realized when the user fully understands the overall spatial concept under which a particular GIS is established and analyses his specific application in the light of those established parameters.

Before the GIS implementation is considered the objectives, both immediate and long term, have to be considered. Since the effectiveness and efficiency (i.e. benefit against cost) of the GIS will depend largely on the quality of initial field data captured, organizational design has to be decided upon to maintain this data continuously. This initial data capture is most important.

## **Advantages of GIS:**

- The Geographic Information System has been an effective tool for implementation and monitoring of municipal infrastructure. The use of GIS has been in vogue primarily due to the advantage mentioned below:
- Planning of project
- Make better decisions
- Visual Analysis
- Improve Organizational Integration

## **Planning Of Project:**

Advantage of GIS is often found in detailed planning of project having a large spatial component, where analysis of the problem is a pre requisite at the start of the project. Thematic maps generation is possible on one or more than one base maps, example: the generation of a land use map on the basis of a soil composition, vegetation and topography. The unique combination of certain features facilitates the creation of such thematic maps. With the various modules within GIS it is possible to calculate surface, length, width and distance.

## **Making Decisions:**

The adage "better information leads to better decisions" is as true for GIS as it is for other information systems. A GIS, however, is not an automated decision making system but a tool to query, analyze, and map data in support of the decision making process. GIS technology has been used to assist in tasks such as presenting information at planning inquiries, helping resolve territorial disputes, and siting pylons in such a way as to minimize visual intrusion.

## **Visual Analysis:**

Digital Terrain Modeling (DTM) is an important utility of GIS. Using DTM/3D modeling, landscape can be better visualized, leading to a better understanding of certain relations in the landscape. Many relevant calculations, such as (potential) lakes and water volumes, soil erosion volume (Example: landslides), quantities of earth to be moved (channels, dams, roads, embankments, land leveling) and hydrological modeling becomes easier.

Not only in the previously mentioned fields but also in the social sciences GIS can prove extremely useful. Besides the process of formulating scenarios for an Environmental Impact Assessment, GIS can be a valuable tool for sociologists to analyze administrative data such as population distribution, market localization and other related features.

### **Improving Organizational Integration:**

Many organizations that have implemented a GIS have found that one of its main benefits is improved management of their own organization and resources. Because GIS has the ability to link data sets together by geography, it facilitates interdepartmental information sharing and communication. By creating a shared database one department can benefit from the work of another--data can be collected once and used many times.

As communication increases among individuals and departments, redundancy is reduced, productivity is enhanced, and overall organizational efficiency is improved. Thus, in a utility company the customer and infrastructure databases can be integrated so that when there is planned maintenance, affected people can be informed by computer-generated letters.

Components of GIS

### **GIS constitutes of five key components:**

- Hardware
- Software
- Data
- People
- Method

### **Hardware:**

It consists of the computer system on which the GIS software will run. The choice of hardware system range from 300MHz Personal Computers to Super Computers having capability in Tera FLOPS. The computer forms the backbone of the GIS hardware, which gets its input through the Scanner or a digitizer board. Scanner converts a picture into a digital image for further processing. The output of scanner can be stored in many formats e.g. TIFF, BMP, JPG etc. A digitizer board is flat board used for vectorisation of a given map objects. Printers and plotters are the most common output devices for a GIS hardware setup.

### **Software:**

GIS software provides the functions and tools needed to store, analyze, and display geographic information. GIS softwares in use are MapInfo, ARC/Info, AutoCAD Map, etc. The software available can be said to be application specific. When the low cost GIS work is to be carried out desktop MapInfo is the suitable option. It is easy to use and supports many GIS feature. If the user intends to carry out extensive analysis on GIS, ARC/Info is the preferred option. For the people using AutoCAD and willing to step into GIS, AutoCAD Map is a good option.

**Data:**

Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. The digital map forms the basic data input for GIS. Tabular data related to the map objects can also be attached to the digital data. A GIS will integrate spatial data with other data resources and can even use a DBMS, used by most organization to maintain their data, to manage spatial data.

**People:**

GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work. The people who use GIS can be broadly classified into two classes. The CAD/GIS operator, whose work is to vectorise the map objects. The use of this vectorised data to perform query, analysis or any other work is the responsibility of a GIS engineer/user.

**Method:**

And above all a successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization. There are various techniques used for map creation and further usage for any project. The map creation can either be automated raster to vector creator or it can be manually vectorised using the scanned images. The source of these digital maps can be either map prepared by any survey agency or satellite imagery.

## **GIS Applications:**

Computerized mapping and spatial analysis have been developed simultaneously in several related fields. The present status would not have been achieved without close interaction between various fields such as utility networks, cadastral mapping, topographic mapping, thematic cartography, surveying and photogrammetry remote sensing, image processing, computer science, rural and urban planning, earth science, and geography.

The GIS technology is rapidly becoming a standard tool for management of natural resources. The effective use of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system to transform this data into usable information.

The GIS technology is used to assist decision-makers by indicating various alternatives in development and conservation planning and by modelling the potential outcomes of a series of scenarios. It should be noted that any task begins and ends with the real world. Data are collected about the real world. Of necessity, the product is an abstraction; it is not possible (and not desired) to handle every last detail. After the data are analysed, information is compiled for decision-makers. Based on this information, actions are taken and plans implemented in the real world.

## **Major areas of application:**

- Different streams of planning  
Urban planning, housing, transportation planning architectural conservation, urban design, landscape.
- Street Network Based Application  
It is an addressed matched application, vehicle routing and scheduling: location and site selection and disaster planning.
- Natural Resource Based Application  
Management and environmental impact analysis of wild and scenic recreational resources, flood plain, wetlands, aquifers, forests, and wildlife.
- View Shed Analysis  
Hazardous or toxic factories siting and ground water modelling. Wild life habitat study and migrational route planning.
- Land Parcel Based  
Zoning, sub-division plans review, land acquisition, environment impact analysis, nature quality management and maintenance etc.
- Facilities Management  
Can locate underground pipes and cables for maintenance, planning, tracking energy use.

- *GIS* in agriculture  
GIS is used in a variety of agricultural applications such as managing crop yields, monitoring crop rotation techniques, and projecting soil loss for individual farms or entire agricultural regions.
- *GIS* in business  
A GIS is a tool for managing business information of any kind according to where it's located. You can keep track of where customers are, site businesses, target marketing campaigns, optimize sales territories, and model retail spending patterns. A GIS gives you that extra advantage to make you and your company more competitive and successful.  
A GIS enables you to better understand and evaluate your data by creating graphic displays using information stored in your database. With a GIS, you can change the display of your geographic data by changing the symbols, colors, or values in the database tables.
- *GIS* in electric/gas utilities  
Cities and utilities use GIS every day to help them map and inventory systems, track maintenance, monitor regulatory compliance, or model distribution analysis, transformer analysis, and load analysis.
- *GIS* in the environment  
GIS is used every day to help protect the environment. As an environmental professional, you can use GIS to produce maps, inventory species, measure environmental impact, or trace pollutants. The environmental applications for GIS are almost endless.
- *GIS* in forestry  
Today, managing forests is becoming a more complex and demanding challenge. With GIS, foresters can easily see the forest as an ecosystem and manage it responsibly.
- *GIS* in geology  
Geologists use GIS every day in a wide variety of applications. You too can use GIS to study geologic features, analyze soils and strata, assess seismic information, or create 3-dimensional displays of geographic features.
- *GIS* in hydrology  
You can use GIS to study drainage systems, assess groundwater, and visualize watersheds, and in many other hydrologic applications.
- *GIS* in land use planning  
People use GIS to help visualize and plan the land use needs of cities, regions, or even national governments.
- *GIS* in local government  
People in local government use GIS every day to help them solve problems. Often the data collected and used by one agency or department can be used by another.

- GIS in mapping  
Mapping is an essential function of a GIS. People in a variety of professions are using GIS to help others understand geographic data. You don't have to be a skilled cartographer to make maps with a GIS.
- GIS in the military  
Military analysts and cartographers use GIS in a variety of applications such as creating basemaps, assessing terrain, and aiding in tactical decisions.
- GIS in risk management  
A GIS can help with risk management and analysis by showing you which areas will be prone to natural or man-made disasters. Once identified, preventive measures can be developed that deal with the different scenarios.
- GIS in Site Planning  
People around the world use GIS to help them locate sites for new facilities or locate alternate sites for existing facilities.
- GIS in transportation  
GIS can be used to help you manage transportation infrastructure or help you manage your logistical problems. Whether monitoring rail systems and road conditions or finding the best way to deliver your goods or services, GIS can help you.
- GIS in the water/wastewater industry  
People in the water/wastewater industry use GIS with the planning, engineering, operations, maintenance, finance, and administration functions of their water/wastewater networks.

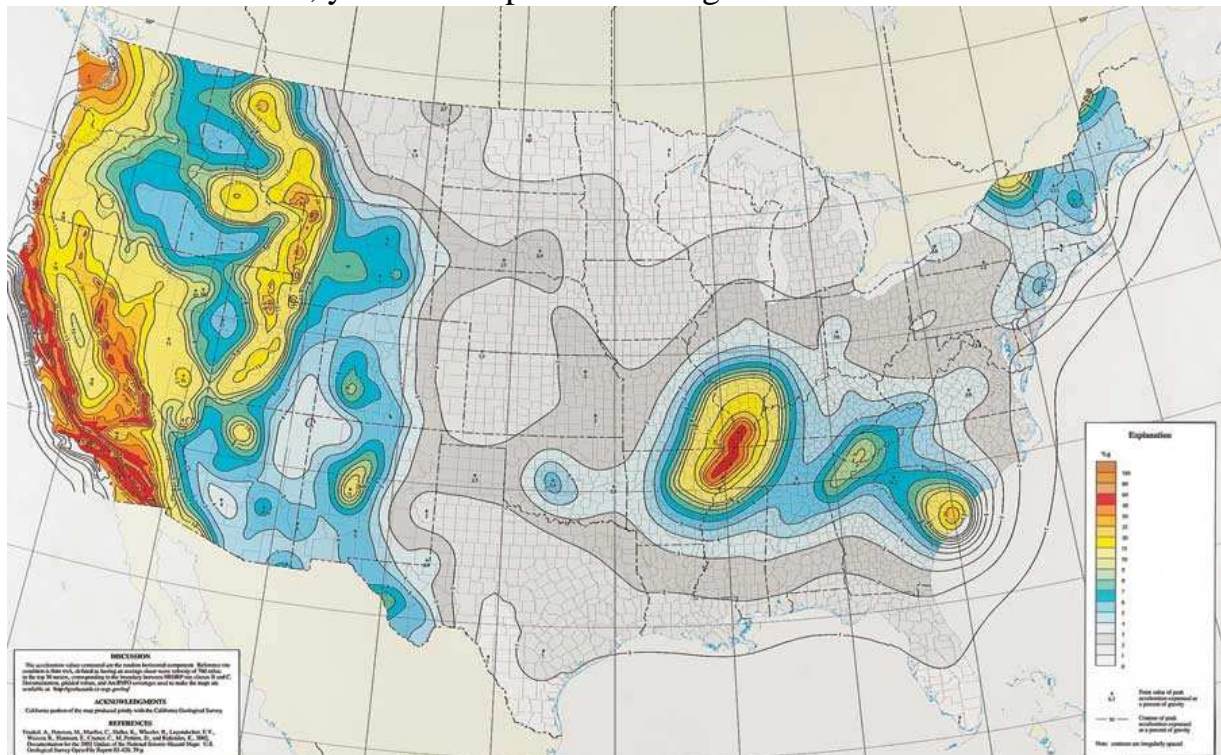
## What Can You Do with GIS?

### **Map Where Things Are:**

Mapping where things are lets you find places that have the features you're looking for, and to see where to take action.

Find a feature—People use maps to see where or what an individual feature is.

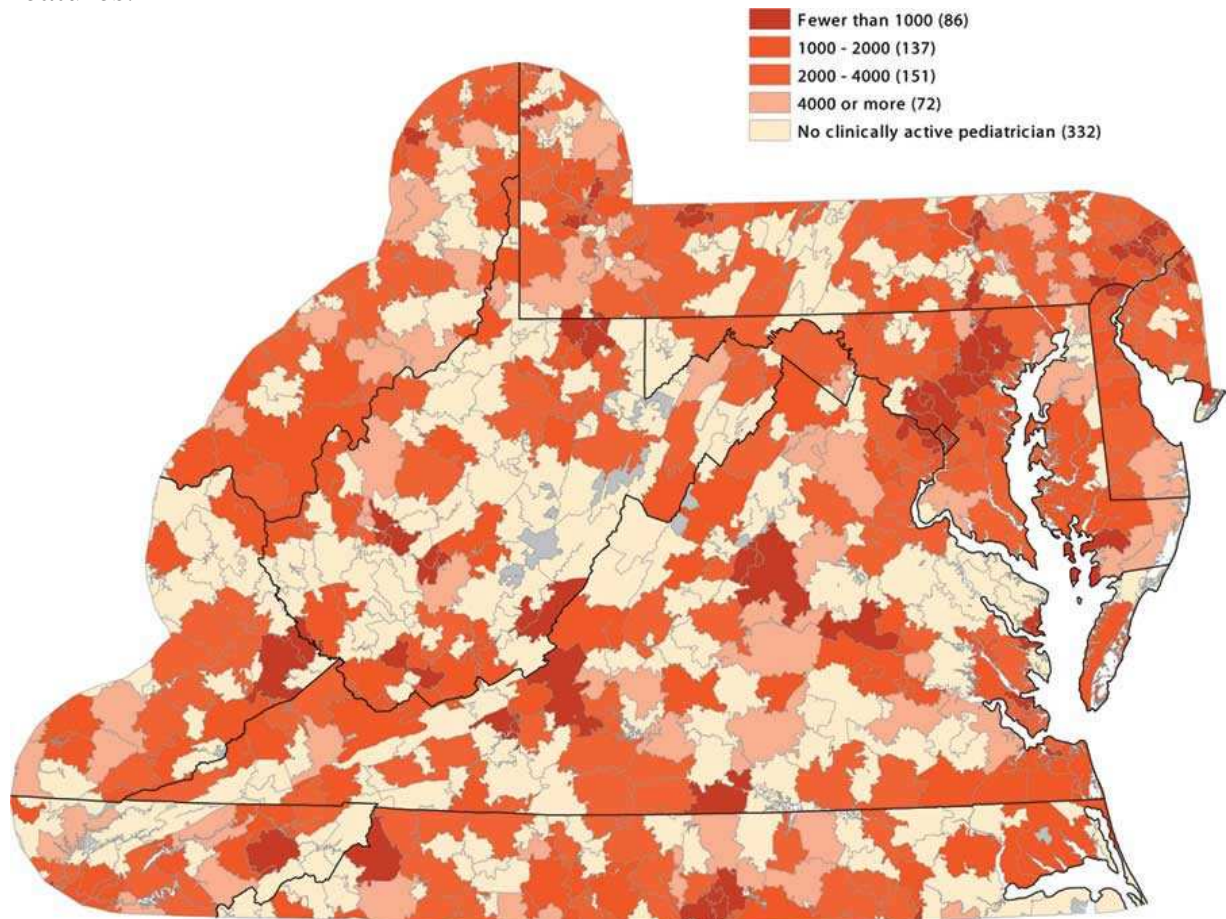
Finding patterns—Looking at the distribution of features on the map instead of just an individual feature, you can see patterns emerge.



Maps of the locations of earthquake shaking hazards are essential to creating and updating building codes used in the United States. Online, interactive earthquake maps, as well as seismicity and fault data, are available at [earthquake.usgs.gov](http://earthquake.usgs.gov).

## **Map Quantities:**

People map quantities, like where the most and least are, to find places that meet their criteria and take action, or to see the relationships between places. This gives an additional level of information beyond simply mapping the locations of features.



This map shows the number of children under 18 per clinically active pediatrician for a particular study area. It was created by the Center for the Evaluative Clinical Sciences at Dartmouth Medical School as part of an effort to develop a national U.S. database of primary care resources and health services.

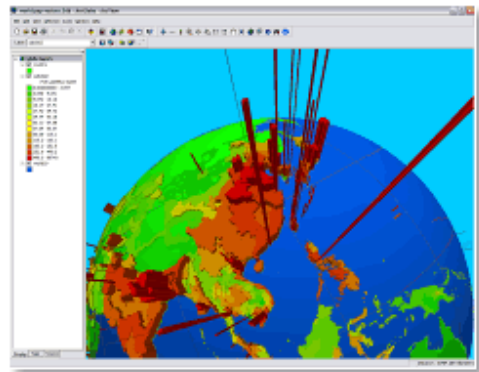
For example, a catalog company selling children's clothes would want to find ZIP Codes not only around their store, but those ZIP Codes with many young families with relatively high income. Or, public health officials might not only want to map physicians, but also map the numbers of physicians per 1,000 people in each census tract to see which areas are adequately served, and which are not.

## **Map Densities:**

While you can see concentrations by simply mapping the locations of features, in areas with many features it may be difficult to see which areas have a higher concentration than others. A density map lets you measure the number of features using a uniform areal unit, such as acres or square miles, so you can clearly see the distribution.

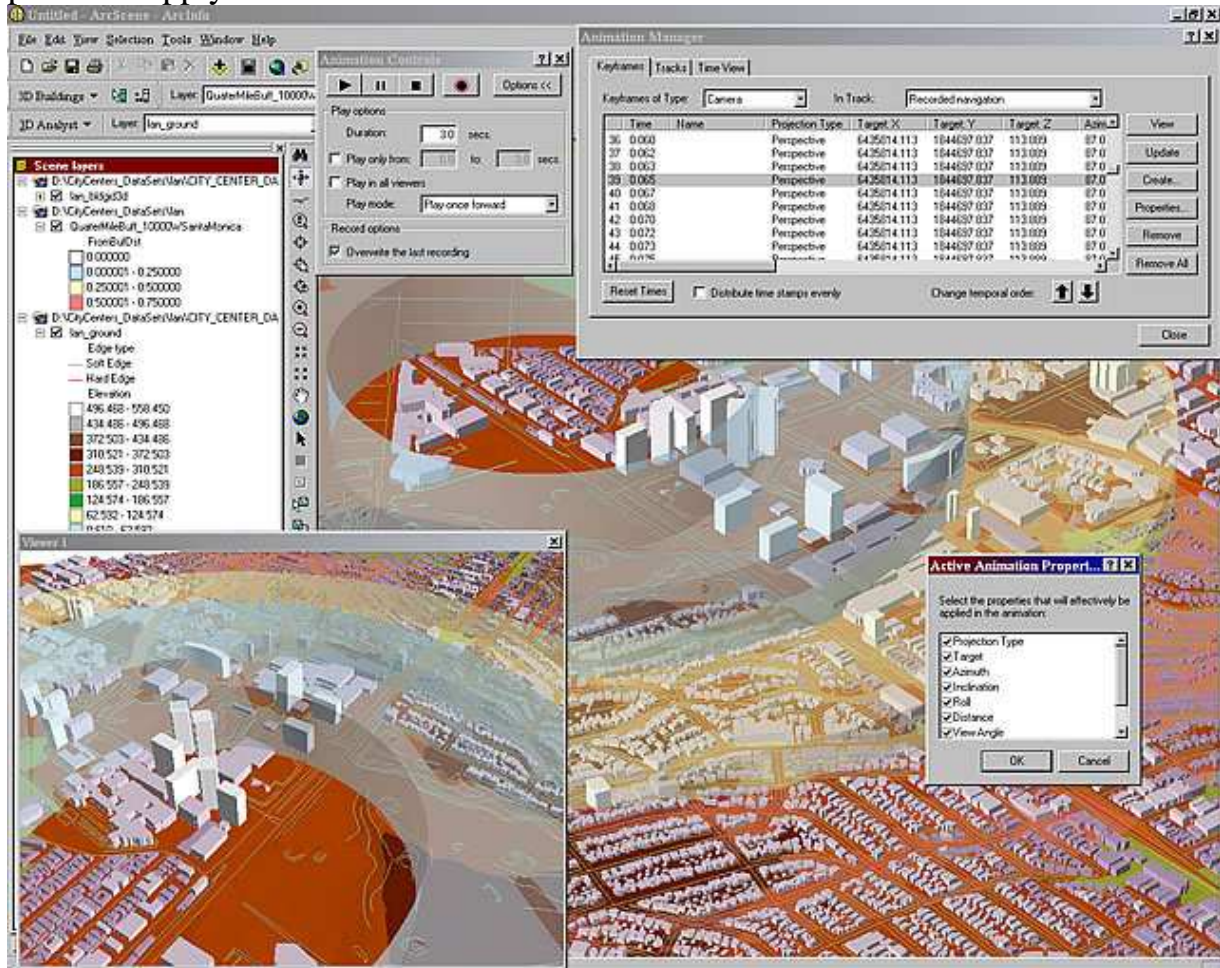
Mapping density is especially useful when mapping areas, such as census tracts or counties, which vary greatly in size. On maps showing the number of people per census tract, the larger tracts might have more people than smaller ones. But some smaller tracts might have more people per square mile—a higher density.

This map shows population density in the east Asian and Indian Ocean regions.



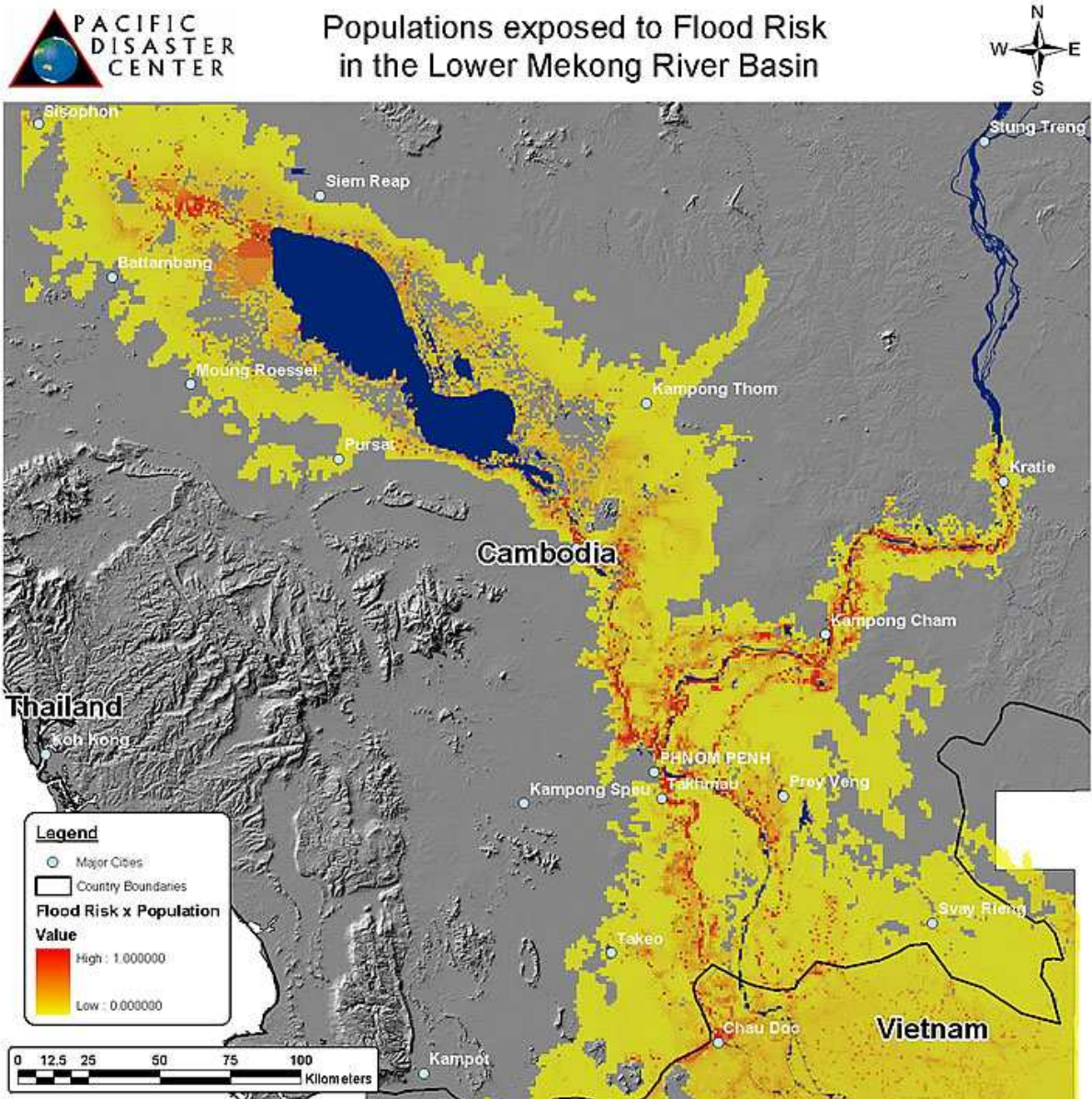
## Find What's Inside:

Use GIS to monitor what's happening and to take specific action by mapping what's inside a specific area. For example, a district attorney would monitor drug-related arrests to find out if an arrest is within 1,000 feet of a school--if so, stiffer penalties apply.



This image from The Sanborn Map Company, Inc., shows a geoprocessed sample explosion radius around an area in California. Each separate zone represents 1/4-mile, the outermost perimeter being 1 mile away from the source.

## Find What's Nearby:



Find out what's occurring within a set distance of a feature by mapping what's nearby.

The Pacific Disaster Center has developed and applied a Vulnerability-Exposure-Sensitivity-Resilience model to map people and facilities (what's nearby) exposed to flood risk in the Lower Mekong River Basin (the feature).

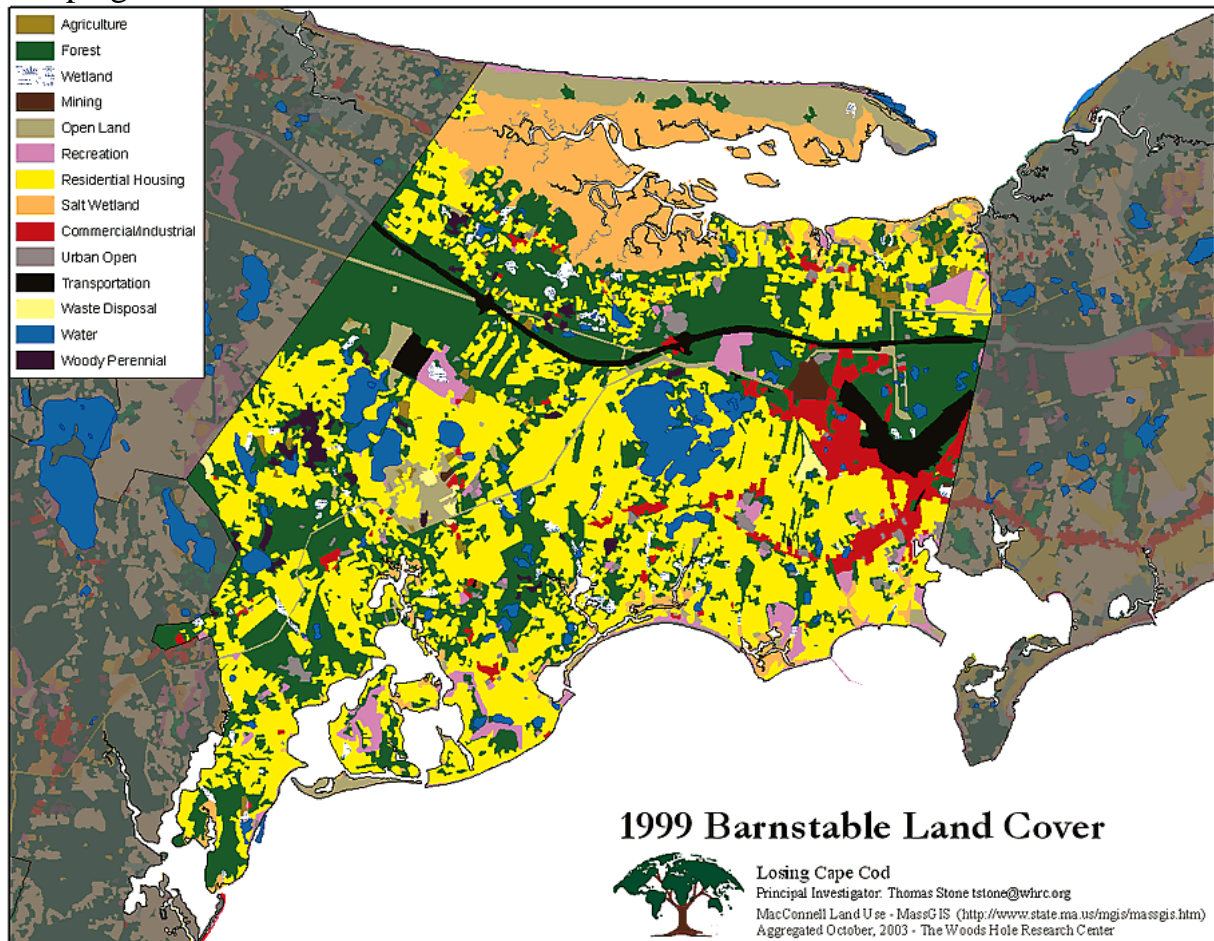
## **Map Change:**

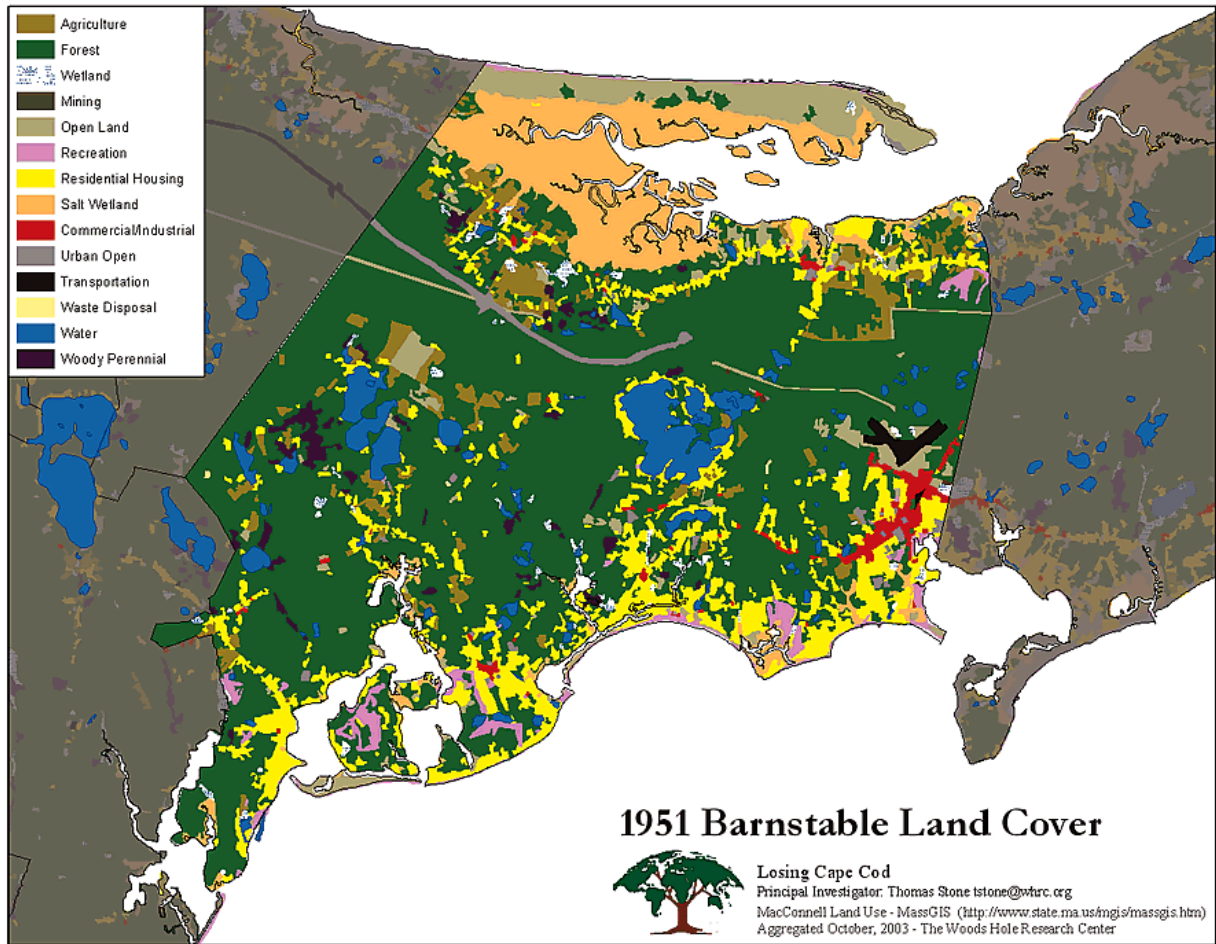
Map the change in an area to anticipate future conditions, decide on a course of action, or to evaluate the results of an action or policy.

By mapping where and how things move over a period of time, you can gain insight into how they behave. For example, a meteorologist might study the paths of hurricanes to predict where and when they might occur in the future.

Map change to anticipate future needs. For example, a police chief might study how crime patterns change from month to month to help decide where officers should be assigned.

Map conditions before and after an action or event to see the impact. A retail analyst might map the change in store sales before and after a regional ad campaign to see where the ads were most effective.





## 1951 Barnstable Land Cover



Losing Cape Cod  
 Principal Investigator: Thomas Stone (stone@whrc.org)  
 MacConnell Land Use - MassGIS (<http://www.state.ma.us/mgis/massgis.htm>)  
 Aggregated October, 2003 - The Woods Hole Research Center