Increasing GIS resources for teaching and research

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Abstract. A GIS framework was implemented to help teaching and research on Boston College campus. The purpose is to assist academic departments with data analysis, and visualization tools in their programs of study. Federal spatial data available from the USGS, Census Bureau, ESRI, State of Massachusetts and other sources are available to campus community and are used in classroom projects in several disciplines: Social Work, Geology and Geophysics, Urban Ecology, Economics, and History. We present outstanding examples on GIS – based analysis in areas of Social Work, Environmental Research and Health studies, with application to New England Region. A remarkable example is the study of social dynamics in New England, using Census data, ArcGIS tools and statistical analysis. It is shown how traditional methods of teaching and research are greatly enhanced by GIS technology which opens opportunities to describe and analyze complex contemporary social systems.

Overview of GIS at Boston College

Geographic Information Systems (GIS) is playing a growing role in research and teaching at Boston College. The GIS project started as collaboration between the Libraries, Geology and Geophysics department, and the Academic Technology Services (ATS). The Geology and Geophysics department was among the first to use GIS in a series of classes and research projects in the last two decades. In recent years, other departments are integrating GIS as part of their fields of study. Thus, Urban Ecology Institute, Social Work, School of Nursing, School of Management, Economics Department, Political Science, History and the Library have expanded GIS use across disciplines in both research and teaching.

Meetings and discussions with faculty members to determine the goals, and data needs were essential in shaping the program. Data collection is one important component where the contribution of the Libraries was remarkable especially in the area of Social Work, Nursing, Health care and detailed terrain data. A focus on community analysis by the Social Work faculty and students, primarily in Massachusetts, was identified as a key element of the program with specific interest in demographic data and social indicators. Data available through ESRI were identified and customized for classroom presentations and workshops. On campus access to ESRI GIS software was expanded from the Geology and Geophysics department and two library workstations to workstations in the Social Work computer lab, Department of Economics, and the Urban Ecology Institute.

Current GIS Data Resources at Boston College

The Boston College O'Neill Library is a Federal Depository Library which supports access to Census Data and other government data. One of the frequently used data sets is the ESRI Census Data and Maps. Such data can be a starting point for many class projects, and can be combined with data from other sources, easy to use with ArcGIS software. Another collection owned by Boston College is the Census CD's series from GeoLytics, a collection of data that includes all layers of data from Tiger/Line files. The most current data purchase includes the Census CD Neighborhood Change Database (NCDB) which includes US Census data from 1970, 1980, 1990, and 2000 at the census tract level. GeoLytics data can be used with ArcGIS for a variety of projects. In addition, these data can be manipulated in spreadsheets and other statistical software (such as Matlab, Stata, SPSS and SAS) and then can be used in ArcView for further analysis and presentation. Massachusetts GIS data are also available along with a collection of econometric data and specific geophysical and environmental data (maintained by the Commonwealth's Office of Geographic and Environmental Information). Recently, the library acquired high resolution terrain data for United Kingdom, which are used in History studies, and Archeology.

Software, license and hardware

Currently Boston College uses the ESRI ArcView 3.x and ArcGIS (ArcView 9.0 and ArcInfo 9.0) for classroom and research. The distribution of the software is made through a Windows NT server and a Windows 2000 server supported by the Academic Technology Services. Current installations include: O'Neill Library, Bapst Library graduate study area, School of Social Work, Law School, Department of Geology and Geophysics, Department of Economics, Urban Ecology Institute, School of Nursing, several instructional classrooms, ATS and individual faculty members who develop GIS examples for their classes. Boston College supports a campus wide license for most of GIS applications at Boston College with technical support from ESRI. Local support is provided by technology consultants, and ATS staff. Currently the GIS data of general interest and data for special projects is housed on several computers on campus: i) Sun Fire 280R Server, two 750MHz UltraSPARC-III processors, 8MB E-cache, 2GB memory, 420 GB disk space; ii) a NT server and, iii) a Windows 2000 PowerEdge 4400 Dell server. In addition, other departmental computers hold data for specific projects.

GIS projects

Study of population dynamics using Census data

Several departments are using Census data to analyze changes in the Boston area, in the state of Massachusetts and New England. For example, the School of Nursing uses Census data in connection with other federal health data sources to understand the relationship between population indicators, diseases spread and location of health care facilities. The Centers for Disease Control (CDC) and Prevention, an agency of the US

Department of Health and Human Services provides useful examples and guidelines on GIS uses in health care issues, and these resources proved very helpful in teaching students. The Graduate School of Social Work, and in the Department of Sociology use GIS to improve the social work practice, to solve planning and policy area problems. Thus, the School of Social Work promotes community analysis of population change, race, age, family structure, housing and economic indicators for locations in New England. Several courses make use of compiled data from the U.S. Census, and from federal, state and municipal government agencies, and from the National Center for Health Statistics (NCHS). Classes are co-taught by ATS members and librarians in collaboration with faculty members. An example of project is: Examine the relationship between family income and demographic characteristics in the state of Massachusetts. (Figure 1). Here is an example GIS use to analyze population distribution by tract and the average family income evolution from 1970 to 2000 in Massachusetts.

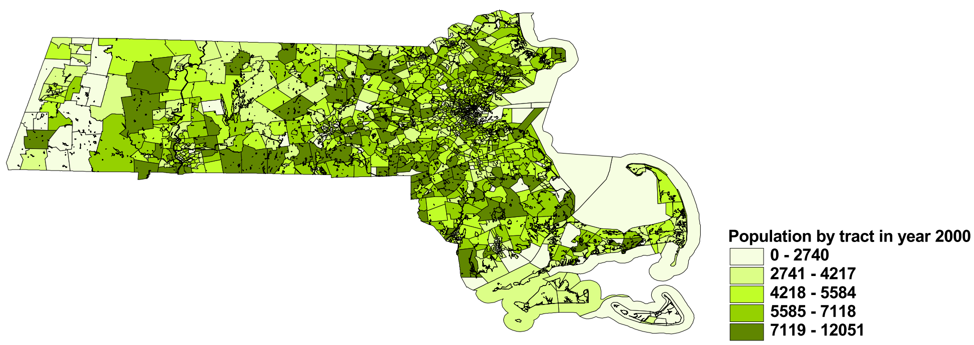

Figure 1. Distribution of the total population by tract in the State of Massachusetts in year 2000.

Illustrations given here are based on the GeoLytics NCDB data. We note that the ESRI Data and Maps 2000 can be used to illustrate similar features for year 2000. NCDB gives users rapid access to US Census data from 1970, 1980, 1990 and 2000 at the census tract level. This resource is useful for policy makers, community organizations, and researchers who want to analyze changes that have occurred in US neighborhoods over four decades. The NCDB contains 1970, 1980, 1990, and 2000 data with details such as: population, household, and housing characteristics, income, poverty status, education level, employment, housing costs, immigration, and other variables. The NCDB comes with built-in data viewing and exporting capabilities as well as thematically shaded, color-mapping capabilities. Maps or tables can be generated and data as dbf, ASCII, shape, or mid/mif files and can be used as input files for other programs e.g. statistical (SAS, SPSS), database (Access, Oracle), spreadsheet (Excel, 1-2-3), and mapping (Arc View). The Boston College community uses such data with ArcView for future processing of the files. For instance the family income versus total population distribution by tract in Massachusetts, for the years 1970, 1980, 1990, and 2000 is shown in Figure 2. We note the better correlation between average income and population in the earlier decades and a large dispersion of income in 1990 and 2000. Other features include: the most populated tracts tend to have a saturation or decrease of the average family income. The analysis of the population maps demonstrates that most significant population increase occurred generally in suburbs and in regions south of Boston. Histograms of the total population distribution by tract in Massachusetts are shown in Figure 3 for the same time interval. We note that distributions are similar, and the number of tracts is such that the most tracts have a population around 4000 people.

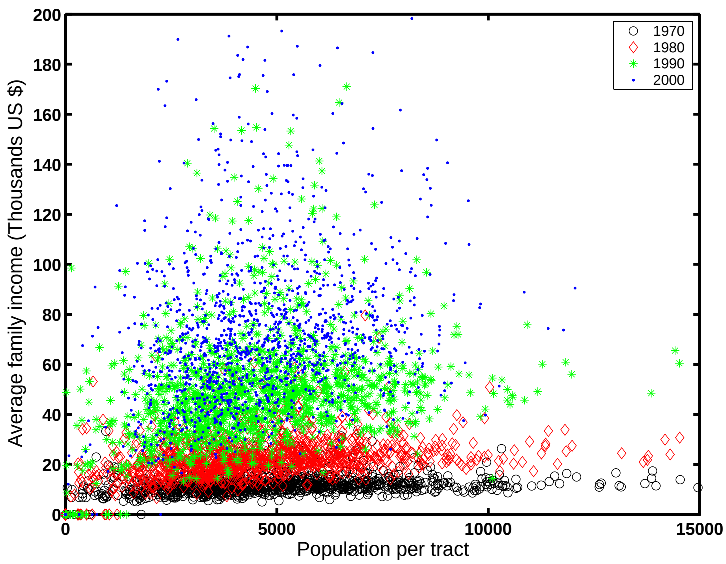

Figure 2. Average family income (in Thousands of US $) versus total population per tract in Massachusetts during 1970-2000.

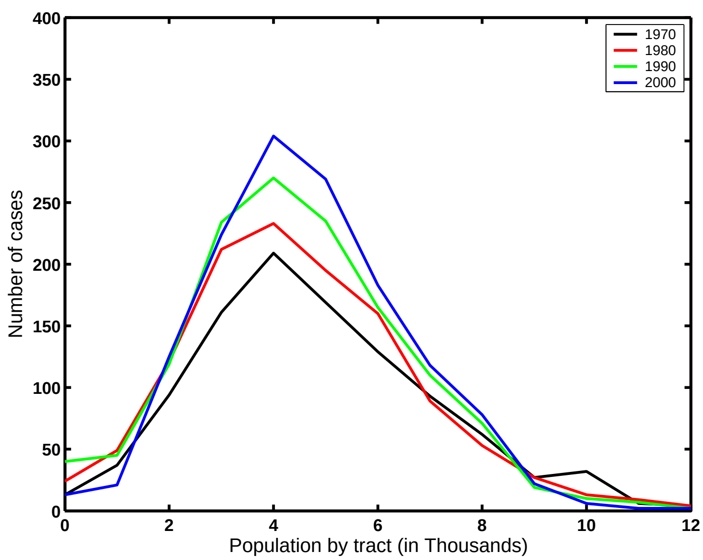

Figure 3. Distribution of total population per tract in Massachusetts during 1970 -2000.

The average family income per tract was also analyzed for Massachusetts during 1970 - 2000. A sample of map with the family income distribution is shown in Figure 4 for year 2000. We note larger average income in tracts located west of Boston, and the analysis of the maps for 1970 – 2000 showed a significant increase of average family income in all areas (an effect of the economic growth and inflation).

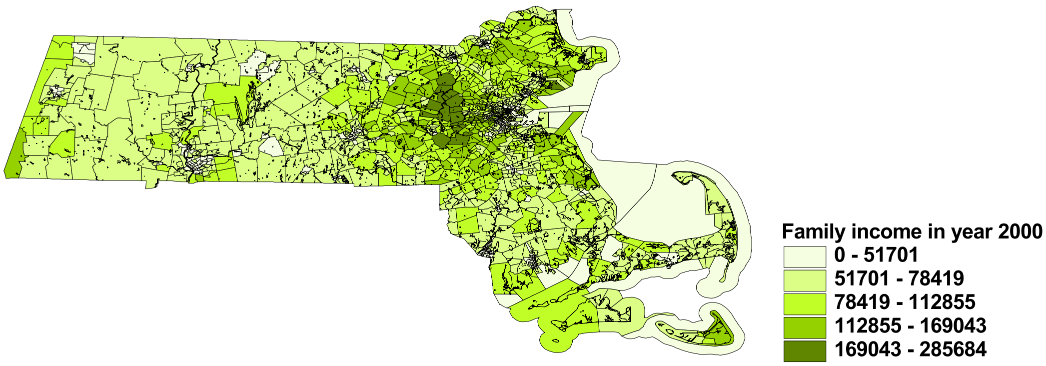

Figure 4. Average family income per tract for the State of Massachusetts for year 2000.

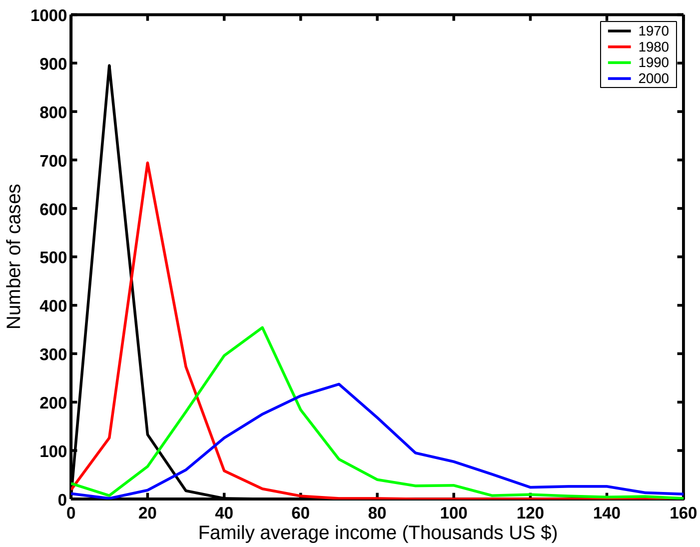

Fig. 5. Distribution of average family income per tract in Massachusetts.

Histograms shown in Figure 5 indicate an increase of the average family income in the last four decades and a significant increase of the spread of the average income.

Some of the conclusions of this study are: 1) There was an increase of the total population in Boston area between 1970-2000, with most growth in suburbs and in Census tracts located South of Boston; 2) There is a significant increase in the family average income; 3) The standard deviation of the average family income increased in the last four decades. Thus, year 2000 shows a larger gap between low and high income than the year 1970 for example. Similar analysis is performed to include variations by race, age, and other social indicators.

The Geology and Geophysics Department uses GIS technology to introduce students to practical environmental applications using the Spatial Analyst and the 3D Analyst, and data from the USGS, MassGIS center, as well as detailed geological/environmental data for the New England region. One GIS application is the study of the earthquake activity in New England. The New England Seismic Network of Weston Observatory of Boston College is a regional network of seismic stations to monitor all earthquake activities in New England and vicinity. Here we illustrate one recent study in the Geology and Geophysics Department in which GIS is used to address environmental problems.

Study of Arsenic in central Massachusetts

Elevated levels of arsenic in drinking-water supplies may be a cause of health problems and it is estimated that bedrock groundwater is a significant drinking water source in New England. Up to 35% of this source may not meet Environmental Protection Agency (EPA) standards for arsenic. Understanding geology's role in the occurrence and distribution of arsenic in ground waters is important: 1) in assessing health risk, and 2) in allowing water managers to keep their supplies in compliance with EPA guidelines. Some of the identified sources of arsenic in groundwater in New England include: a) naturally occurring sulfide minerals in rocks; b) disseminated sulfides in rocks and concentrated occurrences in vein deposits; and c) human contamination related to past pesticide and chemical use. The goals this New England study are to determine the regional range in concentration and variability of arsenic in surface waters, stream sediments, and representative rock samples, and to discriminate between natural and human-induced sources of arsenic. Boston College conducted field studies and data analysis or arsenic distribution at a landfill in central Massachusetts.

Many landfills located in a northeasterly trending zone in Central Massachusetts had been previously noted for elevated levels of arsenic (As) in ground water down gradient from landfill sites. Recent data obtained from yet another landfill site, which is proximally located to a fault line separating two distinct major geotectonic zones show also elevated level of arsenic in ground water. The Clinton-Newbury fault system separates Nashoba Block to the east and Merrimack Belt to the west (Figure 6). The studied landfill site lies in the Town of Clinton just a short distance west of the Clinton – Newbury fault. All other earlier noted landfills are located some distance further west of the fault within the Merrimack Zone. Water quality data for ground water and from surface water discharge points down gradient from this landfill indicate very high concentrations of iron (up to 70 ppm) and arsenic (up to 4000 ppb). In October of 2001 the United States EPA announced that it was implementing a 10 ppb drinking water standard for arsenic and therefore any significant increase of As concentration in natural waters becomes an environmental concern.

A combination of measurements, modeling, and GIS techniques were employed to address the As transport in groundwater. These methods allowed to address several important questions related to arsenic source, mobility in soil, and processes that control As mobility, the role of environmental conditions, and the receptors. The study illustrates how the landfills evolve chemically over time as the leachate plume moves hydraulically down gradient and mixes with more oxygenated water.

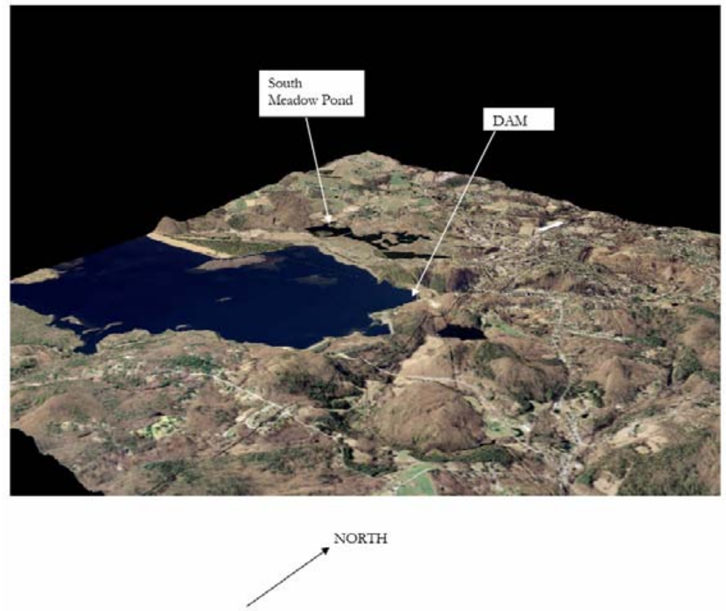

Figure 6. 3D view of the Clinton Landfill in central Massachusetts

Some of the conclusions of this study show that: 1) Chemically reductive conditions created by landfill waste and wetland areas can possibly mobilize iron, manganese and arsenic in ground water; 2) High concentrations of iron and manganese were found in the plumes originating at both the Clinton and Millbury Landfills; 3) Elevated arsenic concentrations were only found at the Clinton Landfill in the Merrimack Zone; and 4) The lower arsenic concentrations at the Millbury Landfill suggest that the arsenic in the Clinton Landfill plume may be of natural origin as there is no evidence that there are any differences in the type of waste material deposited at both sites. In this study, the use of GIS was instrumental in planning the measurements and monitoring the environmental variables.

Urban Ecology Institute and GIS

It is estimated that by 2030, about 60% of the global population will live in metropolitan areas. Complex interactions between non-living factors, such as sunlight or water, and biological factors, such as plants and animals, take place in all environments, including cities. Metropolitan areas alter soil drainage, water flow, and light availability and has a profound effect on environment. Understanding how urban ecosystems function is key to mitigating their negative effects on ecosystem, and assessing their impact on neighboring environments.

Complex urban ecosystems are essential to the health, economy and quality of life of people who live in urban areas. The rivers, shorelines and open spaces throughout the Boston area are home to wild plants and animals and they need protection from pollution and other threats. The City of Boston is in the watersheds of three different rivers: the Charles, Mystic and Neponset (See map of Boston are in Figure 7 and a more detailed map of Mystic river park is shown below in Figure 8). Based on some recent statistics, Boston had also the best "park access" of seven major US cities studied by the Trust for Public Land, with 97% of children living within one-quarter mile of a park. In the context of improving urban life, access to healthy parks, beaches, lakes and rivers, the urban ecology studies play a valuable role.

Urban ecology seeks to understand the natural systems of urban areas and using traditional methods and GIS. Ecologists study the trees, rivers, wildlife and open spaces found in cities to understand the extent of those resources and the way they are affected by pollution, over-development and other pressures. Urban ecology research is helping people see their city as part of a living ecosystem with valuable resources that promote better health and quality of life. Research results is helping urban residents and policymakers make informed decisions and take action to restore these resources. Urban Ecology Institute (UEI) conducts a series of teaching and research programs at Boston College, including: 1) Field studies; 2) Natural Cities, and 3) Greater Boston Urban Forest Inventory.

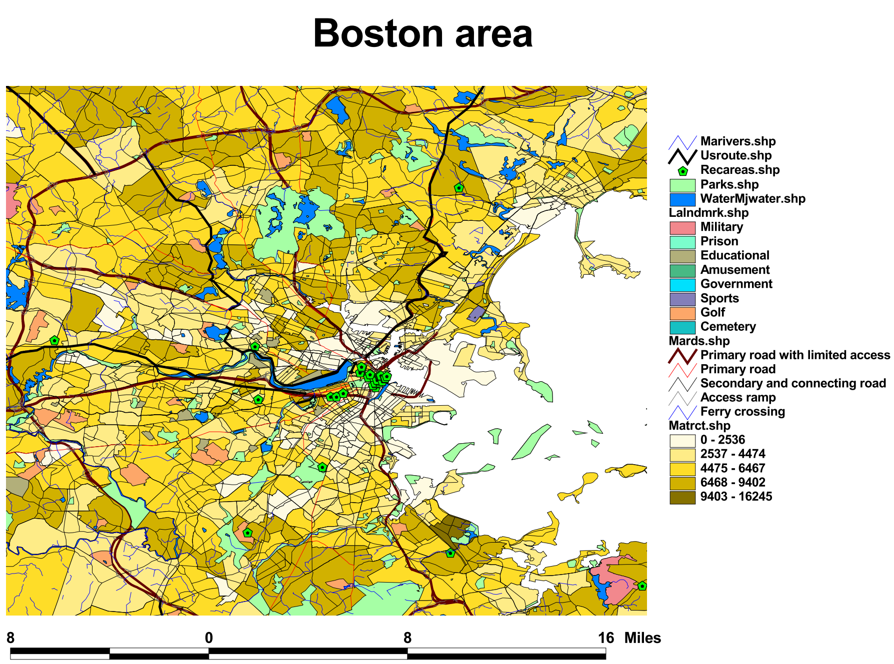

Figure 7. Boston area distribution of population by tract in year 2000, parks, recreational areas, lakes, rivers and other landmarks relevant to urban ecology.

Field studies program. As the human population increases, an understanding of how urbanization will affect the environment is crucial. Overall, the North American continent's population has grown at a relatively slow pace over the last thirty years (2% per year since the early 1970s), the consumption of goods has grown at a higher rate

(2.3% per year) in part due to increases in affluence. In the greater Boston area, the population growth was about 6% in the last decade, making Boston one of the most dense cities in US. Without information on the impact of urbanization on environment, planning and managing healthy, sustainable cities is impossible to imagine in the near future. However, studying human influenced systems has inherent ethical, economic and social implications. Therefore, rigorous scientific investigation is a necessary tool to begin establishing an understanding of these urban ecosystems. The Urban Ecology Field Studies Program engages students in urban public schools in the scientific process by combining the immediate relevancy of urban backyards with basic scientific research. Built upon the educational process of inquiry, each study is framed around the question: What is the Health of Boston's Urban Ecosystem? In Boston and Massachusetts, issues of sprawl, traffic congestion, loss of bio-diversity, loss of forest and agricultural land, and the depletion of water and fish stocks are all recognized concerns. In the end this synthesis of science, education and urban ecosystems creates interesting, relevant studies for students to conduct.

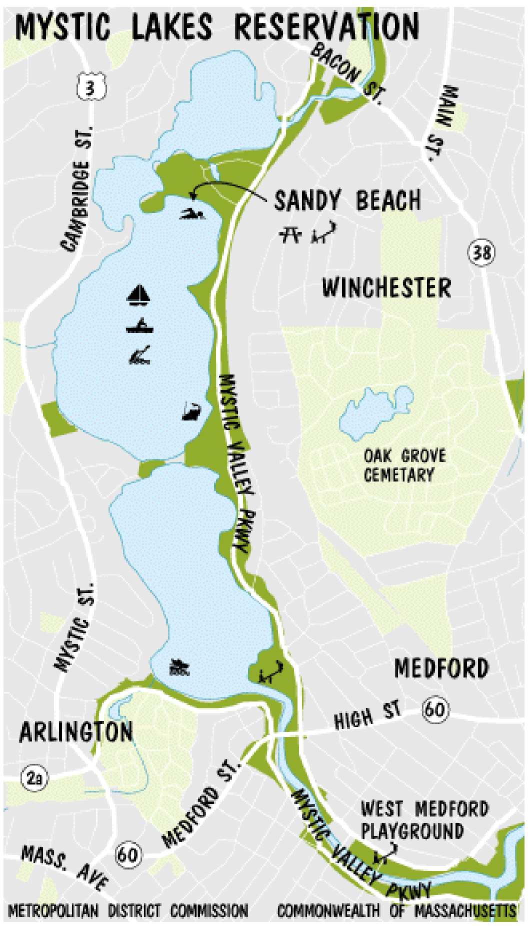

Figure 8. Mystic Lakes Reservation and several townships located Northwest of Boston.

Natural cities. Protecting and restoring urban ecosystems will likely be one of the most important environmental issues of this century. Urban natural resources, such as urban watersheds, should be and can be sources of educational, recreational, economic, and public health benefits for all urban residents. There is an urgent need for a community-based, ecological research and advocacy program geared toward the enhancement of critical environmental resources in urban areas. Boston's environment is shaped by the relationship between land and water. Boston sits at the confluence of the Charles, Neponset and Mystic Rivers. The combined watersheds of these three rivers include 57 cities and towns and drain an area of more than 400 square miles (Figure 9). These rivers come together in Boston at Boston Harbor, with waters and waterfronts that are experiencing a renaissance after a clean-up effort More than thirty islands that dot the harbor have been joined into the Boston Harbor Islands National Park. The city's extensive network of more than 7,000 acres of publicly- and privately-owned open spaces includes more than 215 city-managed parks and playgrounds, 2,200 acres managed by the state Department of Conservation and Recreation, 175 community gardens, and more than 30 urban wilds.

The Natural Cities Program (applied to Boston area) seeks to aid community groups and nonprofit organizations in researching, restoring, and protecting urban natural resources by providing ecological, community planning, and legal services and tools. These tools can be used collectively within the Natural Cities process to select the most critical sites in an urban area and devote limited resources towards protecting and restoring those priority sites. Alternatively, they may be used individually to explore specific questions that a community may have about the natural resources that directly affect their neighborhood.

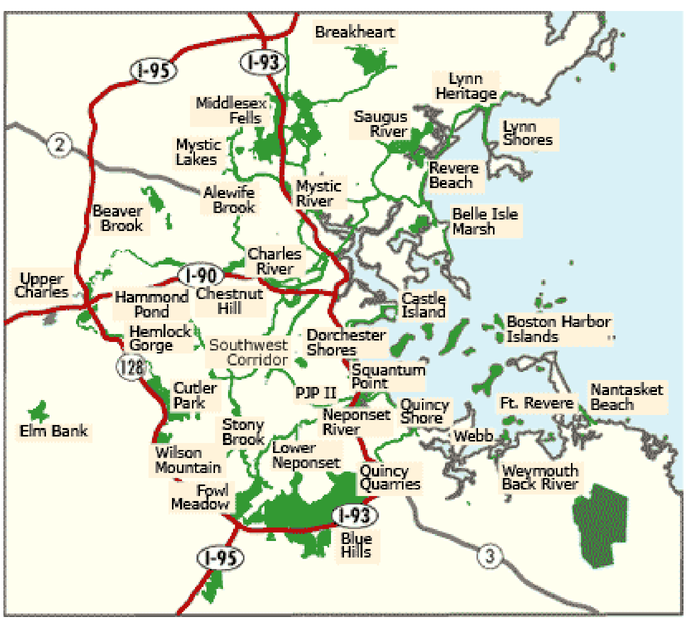

Figure 9. Urban parks and seashore distribution in the greater Boston area.

Greater Boston urban forest inventory. Green areas can make a neighborhood safer, ensure a balance of development and green open space, enhance the value of real estate, and inspire us with the beauty of nature. The Urban Ecology Institute at Boston College has recently begun a project called the Greater Boston Urban Forest Inventory (GBUFI). This inventory is generating the data that are needed to understand the urban forest in metropolitan Boston (Figure 10). GBUFI is a continuous complete inventory of the urban forest in Boston and the surrounding municipalities that includes both a remote sensing component and an inventory of individual trees along streets and in parks. Taken together, these two layers of data create a complete picture of the urban forest within the urban ecosystem. Such data are valuable to scientists, policy makers, and residents alike.

The inventory has been designed based on the data requirements of several municipal and state agencies and organizations, and is the first of its kind in the Boston area. It will give organizations access to a powerful advocacy and maintenance tool, and will also serve as an effective educational tool for volunteers involved in conducting the inventory. The inventory will allow to identify areas most in need of green infrastructure, set goals for increasing the urban canopy cover, and allow project partners to focus plantings in areas of critical need. An inventory of street trees that will provide data critical for routine management of public trees, such as tree health, species, and location. In recognizing the potential of this project to raise awareness and build the stewardship capacity of Boston area communities, we have designed a volunteer-based data collection process that includes comprehensive training on tree identification and inspection.

Figure 10. Part of Boston area where the tree inventory is conducted.

Each tree is given a unique identifier (that identifies the city in which the tree is located) and entered into a central GIS housed at Tufts University, a GBUFI partner. From the GIS we create a tree data layer that can be sent electronically to the municipalities in which data are collected. Municipalities use the ArcPad software to create work orders on specific trees, and are able to update these data daily to reflect maintenance activities.

Future developments

The GIS team plans to expand on campus GIS services and training to students, faculty and staff to allow them take advantage of the GIS technology. In the area of teaching support, there is interest in further integration of GIS into the Social Work program, introduction into the Biology classes of Urban Ecology and Animal Behavior, Law School, School of Nursing, Department of Economics, School of Management and History Department. There is an increase of class instruction in the Geophysics Department and the trend will continue to attract students from other schools. The group plans to increase the use of GIS ESRI software in classes and integrate training into more areas. Another goal is to expand access to GIS datasets via the server and web. Collection goals include enhancing data in the areas of human health care, detailed population data, and high resolution terrain data to be used in conservation and environmental studies.

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