Business Plan
for
Land Cover and Land Use Data for Connecticut

Developed for the:

The Connecticut Geospatial Information Systems Council (CGISC)

September 24, 2008

Prepared by:

The Land Cover and Land Use Subcommittee of the Data Inventory and Assessment Working Group

Table of Contents

Connecticut Geospatial information Systems Council

The Connecticut Geospatial Information Systems Council (CGISC) was established by Public Act 05-3 of the June Special Session. The enabling legislation directs the CGISC to coordinate a uniform GIS capacity amongst the State, Regional Planning Organizations, municipalities, and others. Additionally, the CGISC is required to administer a program of technical assistance to these entities. The CGISC consists of 21 members representing state agencies, municipalities, Regional Planning Organizations, and a general GIS user.

Data Inventory and Assessment Working Group

The CGISC has created of four working groups: Data Inventory and Assessment, Education and Training, Financial, and Legal and Security. The Data Inventory and Assessment Work Group has identified 12 framework datasets for Connecticut, and established individual subcommittees tasked to evaluate, document and provide recommendations for each framework dataset. This includes establishing policies, standards and general procedures for the submission, evaluation, maintenance, on-line access, and dissemination of all geospatial data within the purview of the Council.

Framework Data Themes:

- Addressing
- Administrative and Political Boundaries
- Basemap Imagery
- Cadastral
- Census and Demographics
- Critical Infrastructure
- Elevation and Bathymetry
- Geodetic Control
- Geographic Names and Places
- Hydrology
- Land Use Land Cover
- Transportation

For more information about the CGICS, please visit www.ct.gov/gis

For more information on this business plan contact:
Emily Wilson
University of Connecticut, Center for Land use Education and Research (CLEAR)
1066 Saybrook Rd, PO Box 70

(860) 345-5226
Emily.wilson@uconn.edu

1 Executive Summary

In 2007, through grant funding provided by the Federal Geographic Data Committee CAP grant program, Applied Geographics, Inc. was hired by the Connecticut Geospatial Information Systems Council to develop Strategic and Business Plans for Connecticut's GIS Program. Under these plans, through a series of planning and information gathering sessions, and an on-line survey, several clear strategic goals were identified. One of these was the goal of developing a core set of framework data layers that can be shared across state agencies and with local government.

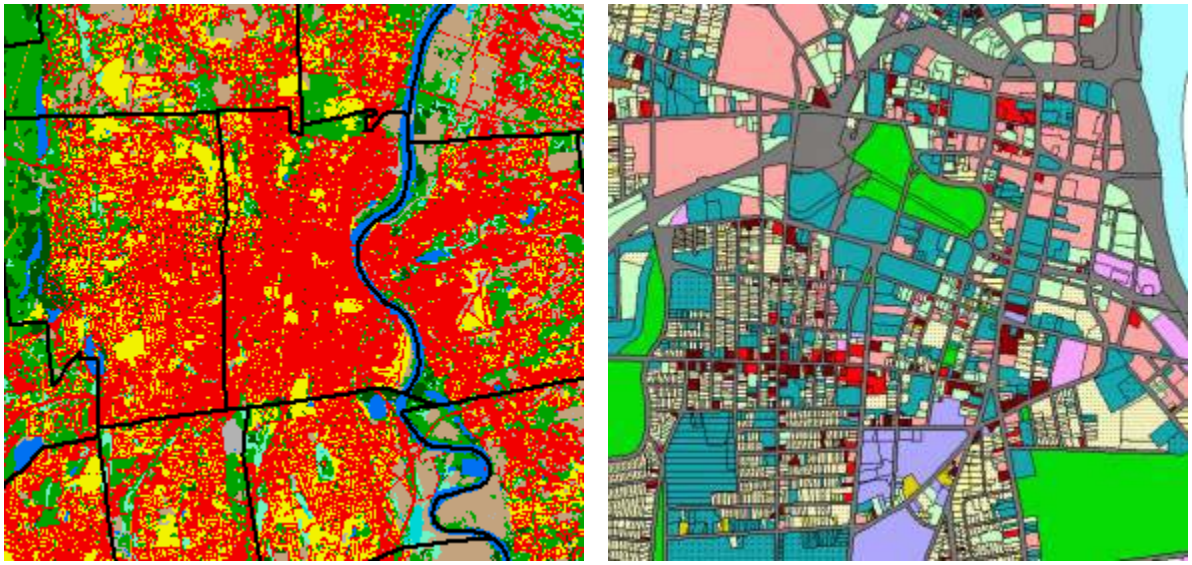
Goal Objective: The objective of this goal is to continue building out a Connecticut state spatial data infrastructure (SSDI) and thereby support the National Spatial Data Infrastructure (NSDI) initiatives of the Federal Geographic Data Committee. As part of this objective, it is envisioned that data generated by local government efforts would be aggregated in a coordinated way and then published for wider distribution at a statewide level. To begin this process, the CGISC data workgroup has determined twelve (12) core categories of data that are important across all levels of government.

The purpose of this document is to provide a more detailed implementation strategy for achieving the goal of developing a land cover and land use dataset.

1.1 Dataset Definition

Land Cover and Land Use are geospatial data layers that describe what is on the earth's surface at a given location. Often, land cover and land use are confused as interchangeable terms, but in actuality, they can describe very different characteristics of the landscape. **Land Cover** refers to natural and anthropogenic features that are observable on the earth's surface (examples include forest cover, developed/built, water, grass). **Land Use** involves human activities that take place on the land and therefore represents the current use of property (examples include residential, commercial, corn crop, reservoir, etc.). Land cover and land use can be cross-referenced and used together. Both land cover and land use are different from zoning. Zoning is generally the promoted or permitted use of the land. Land cover and land use are not dependent on property boundaries.

Often, maps and data that combine land cover classes (deciduous forest, brush, wetlands) with land use classes (residential, commercial, agriculture) are created and referred to as land use/cover maps.



Left: Satellite-derived 2002 Land Cover of the City of Hartford and surrounding municipalities. **Right:** Downtown Hartford Land Use and parcels, derived by the Capitol Region Council of Governments.

1.2 Recommendations

Needs Assessment. First and foremost, the subcommittee recommends that a thorough needs assessment be conducted. The needs assessment should list all the major users of both Land Cover and Land Use in the state and identify what are the priority, needed and absolutely required, criteria of each dataset for each user group. The needs assessment should ultimately drive the standards as well as the detailed methodology for creating and maintaining the dataset.

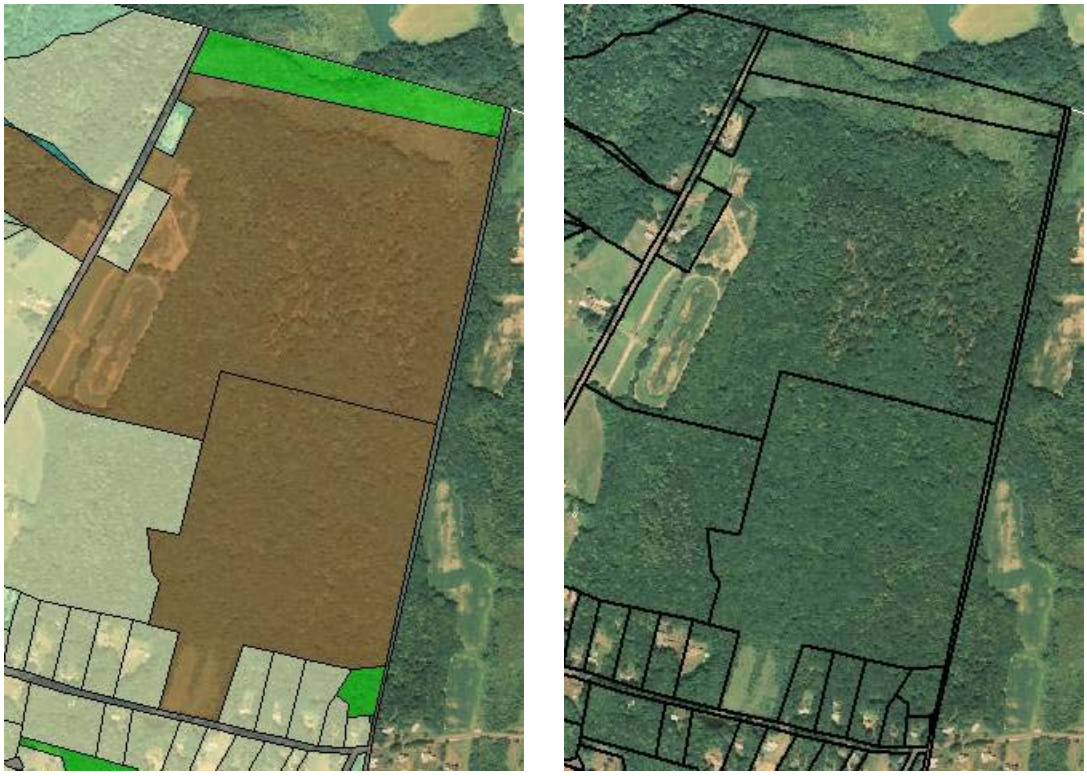
Proposed Dataset. This subcommittee proposes a tiered dataset to meet the needs of users at all levels of government. The tiered dataset will consist of at least three levels. Ideally, each level would fit, or nest, within the other levels.

- The **general land cover level** would consist of land cover classes only and be designed for regional analysis. This would be similar in detail to the University of Connecticut's (UConn) Center for Land use Education and Research (CLEAR) land cover (Section 4.1) or an Anderson (1976) level 1 classification. The minimum mapping unit would be determined by the needs assessment.

- The **high resolution land cover level** would be created by classifying high resolution imagery. The number of classes would be constrained by what is evident and identifiable in the source imagery and would therefore likely lack specific land *use* classes. This would be similar to the land cover classes of the Rhode Island land cover/land use dataset (Section 4.2, Appendix 2).

- The **cadastral-based land use/cover level** would be the most detailed. It would be a marriage between the high resolution land cover (above) and the land use codes that exist in parcel Computer Assisted Mass Appraisal (CAMA) systems used by tax assessors throughout the state. This cadastral-based land use/cover dataset has the advantages of

being both geographically detailed (from the high resolution land cover) and thematically detailed (from the parcel land use information). The combined dataset would overcome the problem of parcel-based land use maps, where, especially in rural settings, parcels often contain more than one land use. Although multiple uses may be listed in the CAMA database, the geographic location of each use is missing. Incorporating the parcel codes with high resolution land use gives geography to all CAMA codes. See examples below.



Left: The CRCOG parcel-based land use map for a small area in the town of Granby, CT. The brown polygons represents agricultural land use. **Right:** a high-resolution, leaf-on (summer) aerial image of the same area. Notice that just a small piece of either of the brown polygons is actually being used for agriculture. The vast majority of the land area is forested. If image-based land cover was used with the parcel-based information, the forested area would be identified and separated from the agricultural areas.

Left: The CRCOG parcel-based land use map for a small area in the town of Granby, CT. The tan polygon represents single-family residential land use and the tan polygon with dots represents two-family land use. **Right:** a high-resolution, leaf-on (summer) aerial image of the same area. Notice that just one structure, presumably a house, exists on either of the tan parcels. Almost the entire area is forested. If image-based land cover was used with the parcel-based information, the forested area would be identified.

2 Program Goals

2.1 Goal: Create a Multi-Resolution Land Cover/Use Dataset

The goal of this program is to create and maintain a consistent, statewide multi-resolution land cover and land use dataset. The dataset would consist of tiers that would meet the needs of different users by representing regional land cover, high resolution land cover and cadastral-based land use/cover. The cadastral-based land use/cover would require cadastral information (currently not available statewide).

2.2 Tasks

The following tasks have been identified as necessary to complete this goal.

Task I: Account for requirements
Establish minimum requirements for the Multi-Resolution Land Cover/Use dataset. Ensure high quality data that is accessible to GIS professionals and the public.

Task II: Research Standards
Standards should be assessed and established. The standards should establish an avenue for research to integrate a variety of imagery-based methods for creating statewide, high resolution,

baseline data for Connecticut. Standards should include update criteria. Standards should set a minimum accuracy to ensure high quality data. Standards should include land use classes and codes to be implemented in CAMA databases in municipalities. The standards should ensure that the data is accessible.

Task III: Continue Updating Existing Land Cover Change Dataset
UConn CLEAR has created five dates of consistent land cover starting in 1985. Although this dataset is a coarse resolution, it is invaluable for identifying land cover change over time and should continue to be updated at approximately five-year intervals, depending on high quality image availability.

3 Program Benefits and Justification

There are numerous examples of land cover and land use datasets at multiple scales of state, regional and local levels that have been developed to meet the needs of a variety of users and user groups. A needs assessment is necessary in order to concatenate these needs into a complete list to provide the most appropriate data at a reasonable cost.

3.1 Benefits of a Single Dataset

The benefits of having a single hierarchical land cover and land use dataset are many.

Decision Making and Planning. This dataset would inform decision making and assist planning in every town and region in the state. Currently, the Connecticut Office of Policy and Management (OPM) requires land use information from municipalities for creation of the State Plan of Conservation and Development. This plan must be updated every five years. A standard land use dataset would streamline this process and significantly decrease the amount of work in making many different datasets fit together. Similarly, a consistent and frequently updated dataset could benefit every municipality when updating their Plans of Conservation and Development. Each municipality must update its local plan of conservation and development every ten years. These plans required by statute to include a land use map.

Consistency across Boundaries. A single dataset would provide consistency across jurisdictional boundaries which would be beneficial for regional or watershed planning, management and other activities. A statewide, consistent dataset could benefit all towns in Connecticut, especially the "have-nots" that lack the resources to create such information. Because natural resources don't end at jurisdictional boundaries, all natural resource applications would benefit from a single dataset. Common natural resource applications of land cover and land use data include: modeling wildlife habitat, forest and wildlife management, habitat suitability assessment, watershed modeling, air quality monitoring, ground water modeling, homeland security, determining cumulative upstream impacts relating to water quality, estimating imperviousness, assessing land cover/land use change, quantifying forest or habitat fragmentation and modeling future scenarios via "buildout" analyses.

Quality Control. A single dataset created using the same methodology and the same people trained in the same way allows for quality control. Disparate data makes quality control far more difficult.

3.2 Cost Saving

Currently, a statewide, coarse resolution dataset exists for Connecticut. It is useful for regional analysis and trends, but not for neighborhood analysis. Land use maps also are created on a town by town or region by region basis. Each land use map is created from different base information using different methods and at different times. Creating a single dataset from the same base information would both reduce redundancy in data creation while increasing the potential uses.

As recommended, the multi-resolution, hierarchical dataset would leverage two other framework datasets: imagery and cadastral, as well as, depending on methodology, other framework datasets such as transportation and hydrography. Leveraging and coordinating with imagery and cadastral data would further reduce redundancy and decrease the cost. In some cases, a large portion of the budget for the creation of photo-interpreted land use data is the acquisition of the base imagery.

3.3 Leveraging Other Framework Datasets

Base Map Imagery. Both the land cover and land use maps rely on different scales of base map imagery. The Multi-resolution Land Cover/Use dataset could not be created without the acquisition of base map imagery.

Cadastral Data Standard. The cadastral-based land use/cover dataset could not be created without parcel boundaries and land use codes. Ideally, a statewide, consistent cadastral dataset that contained a land use code or codes for every parcel should be used. The land use codes should be standardized to allow for easy aggregation.

Critical Infrastructure and Key Resources. The framework dataset, Critical Infrastructure and Key Resources, that currently doesn't exist, could become a component of the high resolution land cover and/or cadastral-based land use/cover datasets.

Other Framework Data Standards. The Multi-resolution Land Cover/Use dataset would make use of or contribute to other framework datasets, such as transportation, hydrography, and application-specific datasets such as state lands, open space, utility infrastructure and others.

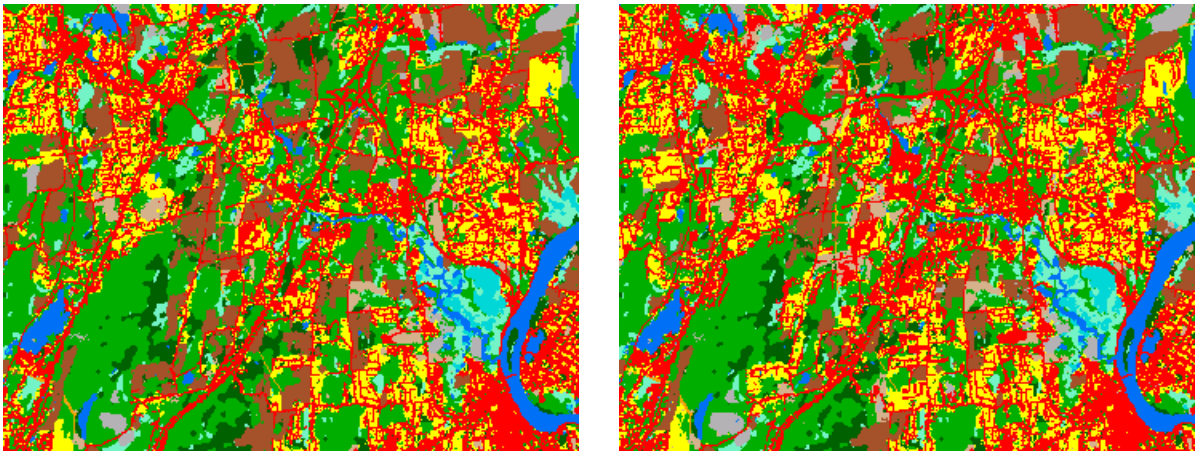
4 Program Requirements and Costs

4.1 Current Status: Land Cover

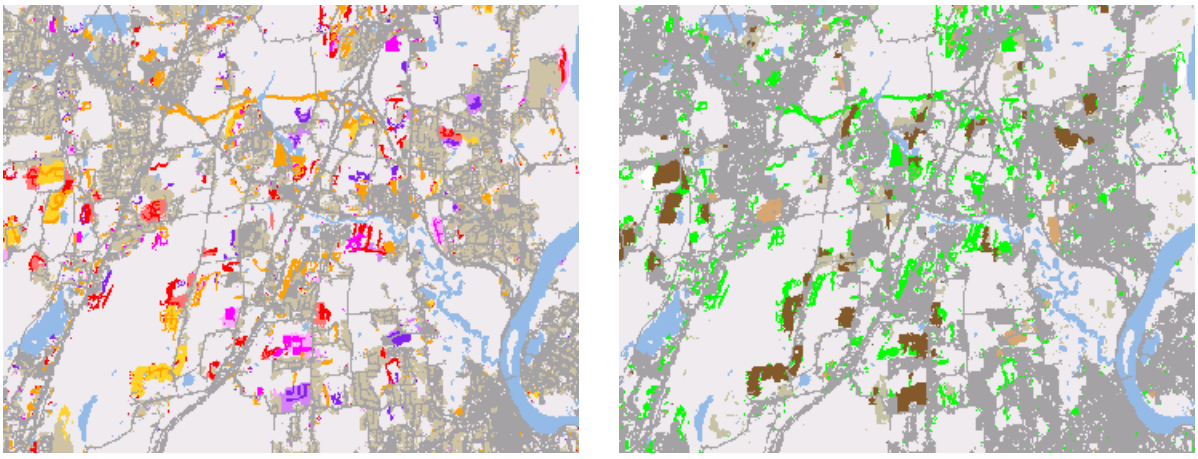
There are two statewide sources for land cover in Connecticut.

University of Connecticut's Center for Landuse Education and Research

Since 1990, The Center for Landuse Education and Research (CLEAR) at the University of Connecticut (UConn) has been the primary organization that has created satellite-derived statewide land cover data for Connecticut. A circa 1990 combination land cover/land use dataset (23 classes) and a circa 1995 combination land cover/land use dataset (28 classes) were created by way of specific grants and projects using 30-meter spatial resolution Landsat imagery. Different methods were used to create each of these initial datasets, so the results are not directly comparable. In 2004, CLEAR released Version 1 of a four-date dataset that was consistently created for 1985, 1990, 1995 and 2002, again based on 30-meter spatial resolution Landsat imagery. Although each land cover map contained only 11 categories, each date could be compared allowing for real measurements of land cover change over time. CLEAR is set to release Version 2 in 2008. Version 2 is an upgrade and an update. It contains a refinement of existing classes, a new "Agricultural Field" class and a new date – 2006. Information about the dataset can be found at http://clear.uconn.edu/projects/landscape/.



Left: 1985 CLEAR land cover. **Right:** 2006 CLEAR land cover. Red is developed, yellow is turf and grass, dark brown is agricultural field, light brown is other grass, green is forest, blue is water, cyans are wetlands.



CLEAR 1985-2002 change maps. Light gray is undeveloped and dark gray was developed before 1985. Blue is water. **Left:** increase in developed where colors indicate new development. **Right:** loss of vegetation where green is a loss of forest land and brown is a loss of agricultural field.

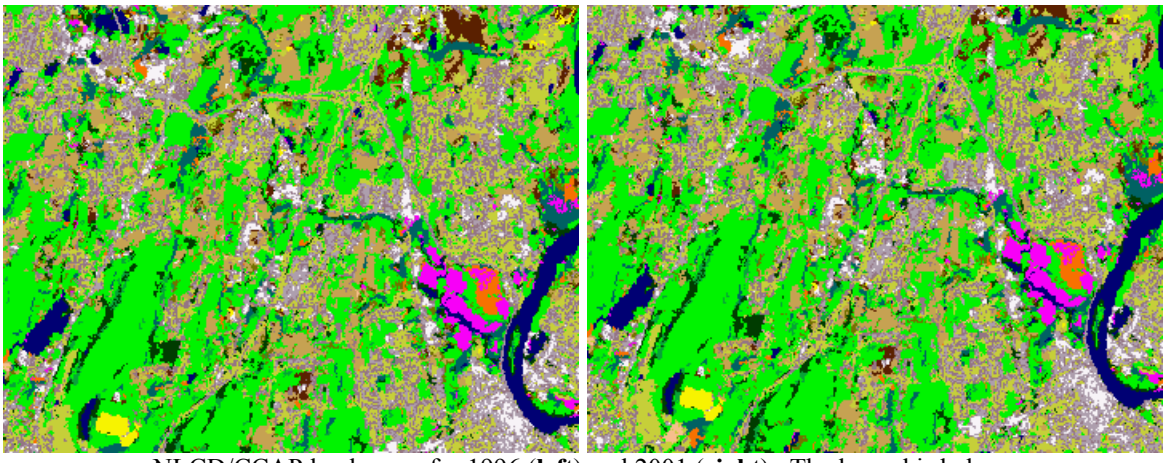
National Land Cover Dataset (NLCD)

The second source of land cover is the Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database (NLCD 2001) consisting of 21 classes. MRLC is a consortium of federal agencies that contributed to the creation of the national dataset. NLCD 2001 is a Landsat based land cover database with several independent data layers, which allow users a wide variety of potential applications. Primary components in the database include:

- normalized imagery for three time periods per path/row,
- ancillary data including a 30 meter digital elevation model, slope, aspect and a positional index,
- per-pixel estimates of percent imperviousness and percent tree canopy,
- 21 classes of land-cover data derived from the imagery, ancillary data and derivatives using a Decision tree, classification rules, confidence estimates and metadata from the land cover classification.

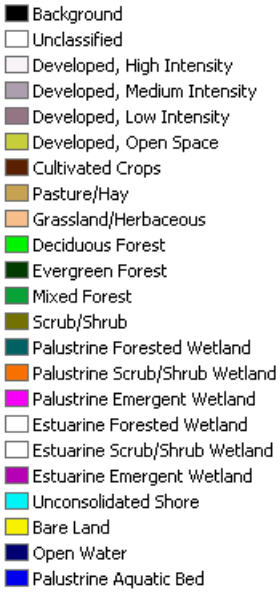
NLCD is a national dataset that is created by zone. Connecticut is part of zone 65, along with Rhode Island, Massachusetts, Long Island and parts of New York, Vermont and New Hampshire. NLCD has been created for both 2001 and 1992, however, different methods were used so the datasets can not be directly compared to identify change. The consortium has developed a changed dataset based on Level 1 land cover categories.

A related land cover classification has been developed by NOAA for the Coastal Change Analysis Program (C-CAP). This dataset focuses on the coastal regions of the United States, including all of Connecticut, to inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. Currently for Connecticut, classifications exist from 1996, 2001, and 2005.



NLCD/CCAP land cover for 1996 (**left**) and 2001 (**right**). The legend is below.

1996-2001 Change



In general, the NLCD and C-CAP products are adequate to meet the needs of the federal agencies that produced them, but it is not believed they would provide sufficient spatial detail to serve the general land cover user needs of Connecticut. Land cover data derived within state, such as that produced by CLEAR, provide a more accurate depiction of what is on the ground since better ground truthing and quality assurance is conducted. Additionally, data created within state would remain under control of the cooperators and could be tailored to meet the needs of the users of Connecticut.

Current User Community

A needs assessment is necessary to fully quantify the number and variety of both users and uses of land cover data. At the time of this writing, the only source of user groups available is the CLEAR download database where potential users fill out a short form before downloading CLEAR land cover data. The users are many and varied. Within the past five years, approximately 500 users are from educational institutions (K-12, University), 300 from government (municipal, regional, state, and federal), 130 non-profit organizations, 70 private organizations and 40 individual users.

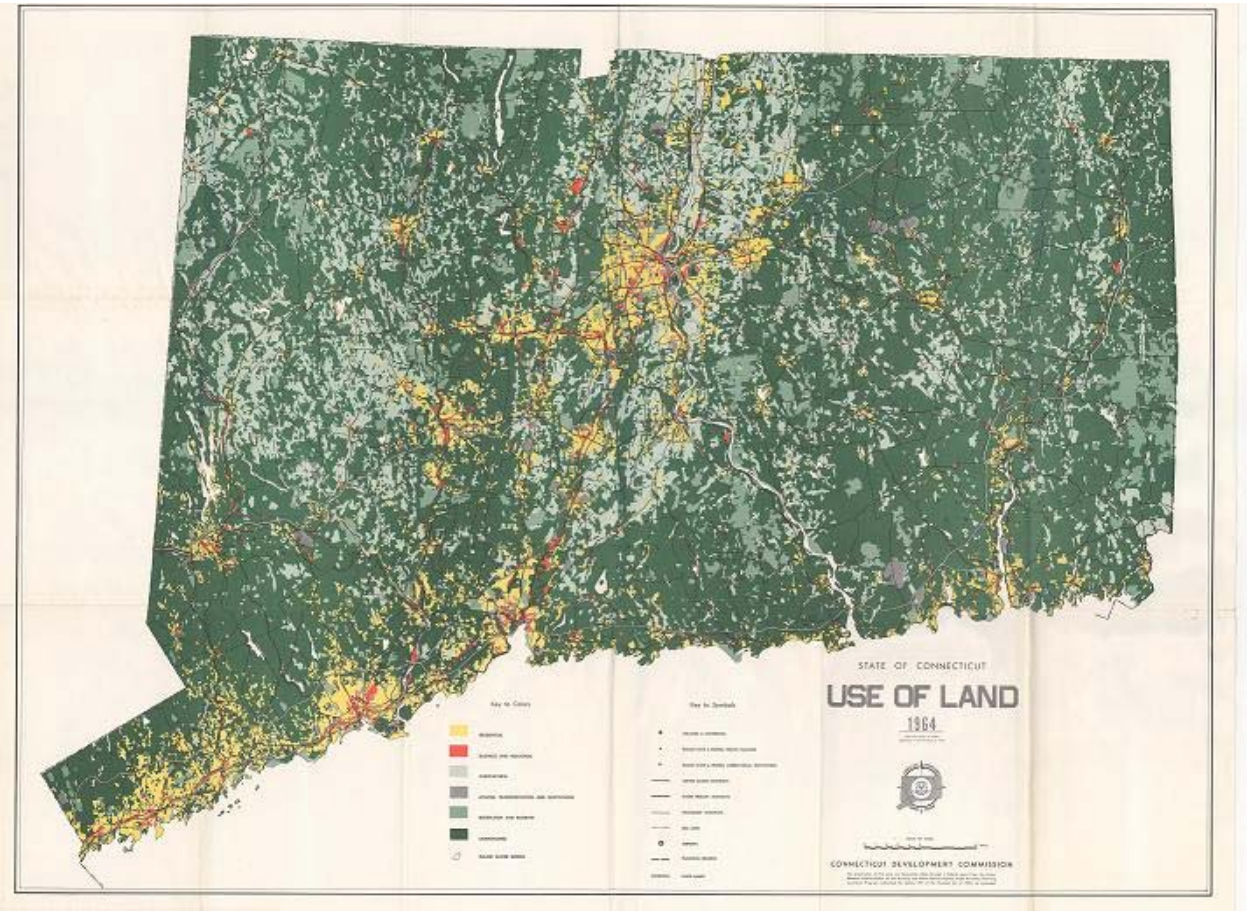
4.2 Current Status: Land Use

Statewide Land Use

There is no recent statewide, high resolution, land use data for Connecticut. Three historic, statewide land use *maps* exist. Maps are different from datasets. All data contained in a map is on the printed paper itself. Datasets, as referred to throughout this document, often contain more information than what is printed. Information is stored as "attributes" allowing a variety of analyses and maps to be created and printed.

1964 Land Use Map. The 1964 Land Use Map was developed as part of the Connecticut Interregional Planning Program. While information regarding the compilation method for this map is still under investigation, the data used for the map appears to have been developed in 1962. Land use categories in this map include:

- Residential,
- Business and Industrial,
- Agricultural,
- Utilities, Transportation and Institutions,
- Recreation and Reserves,
- Undeveloped

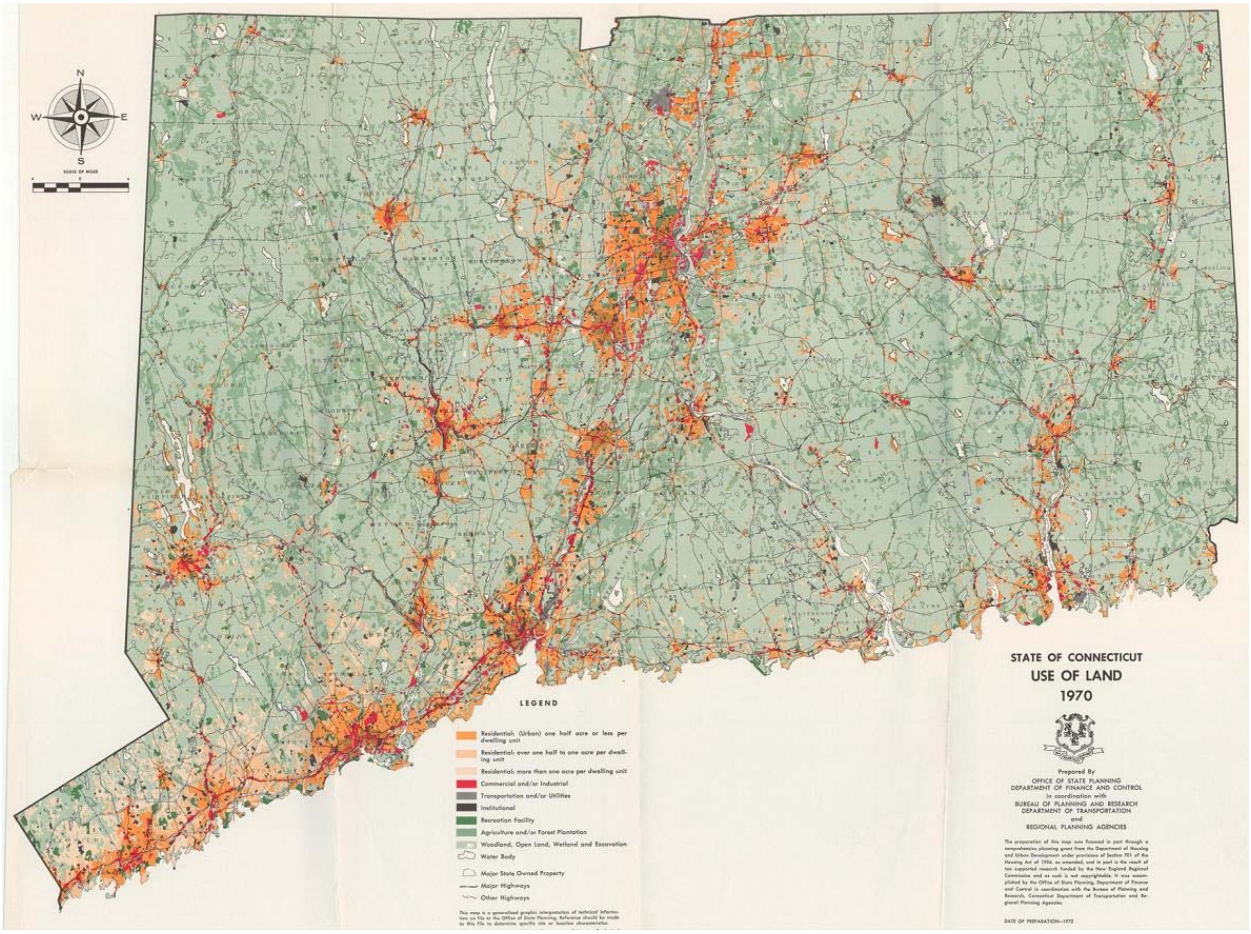


1964 Land Use Map for Connecticut

1970 Land Use Map. The 1970 Land Use map was part of Proposed State Plan of Conservation and Development prepared in 1972 which ultimately became the first State Plan of Conservation and Development in 1974. According to the document description, it was compiled through photo interpretation and displays urban land use 5 acres or greater and all other land uses 10 acres or greater. Land Use categories in this map include:

- Residential: (Urban) One half acre or less per dwelling unit
- Residential: Over one half acre to one acre per dwelling unit
- Residential: More than one acre per dwelling unit

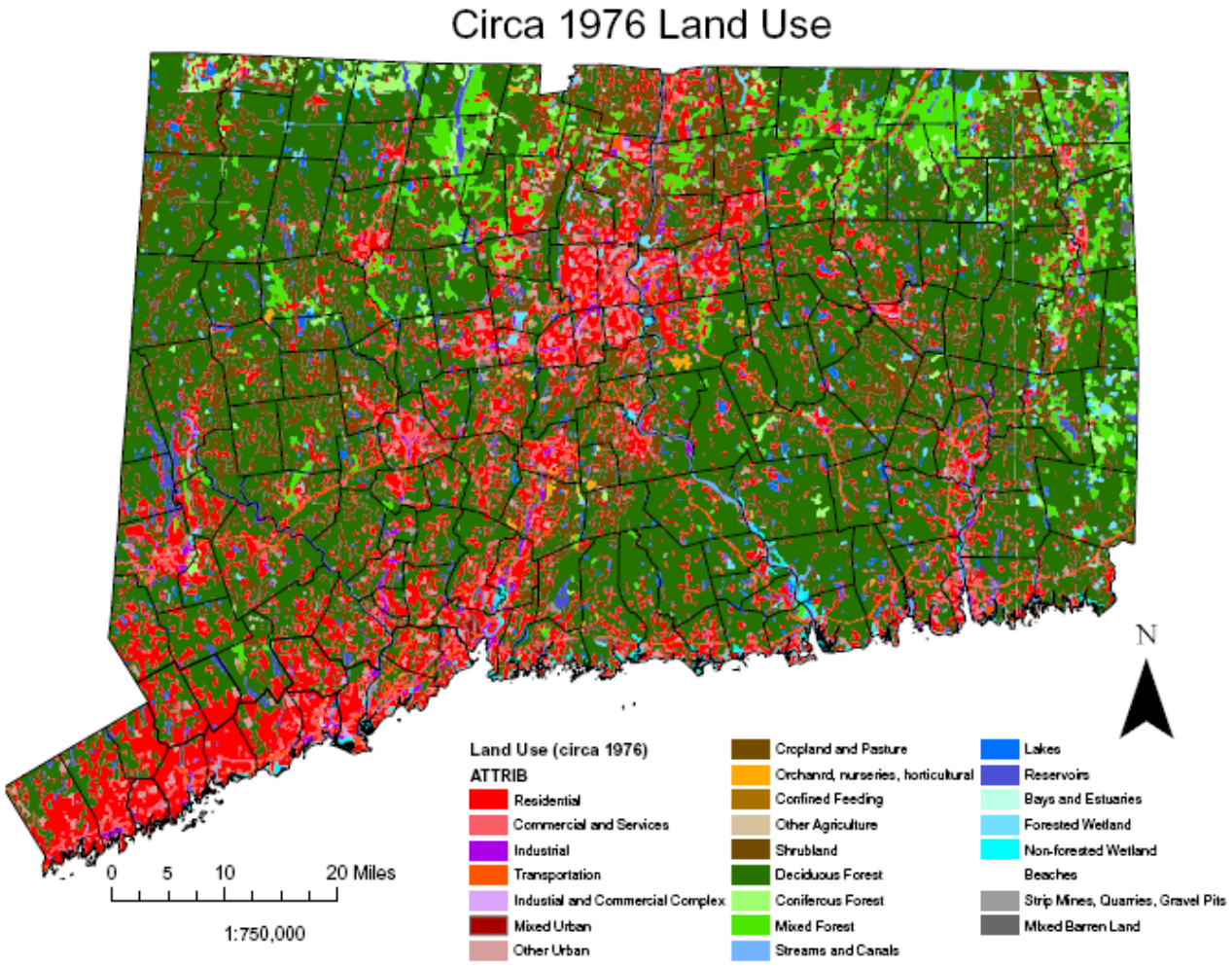
- Commercial and/or Industrial
- Transportation and/or Utilities
- Institutional
- Recreation Facility
- Agriculture and/or Forest Plantation
- Woodland, Open Land, Wetland, or Excavation



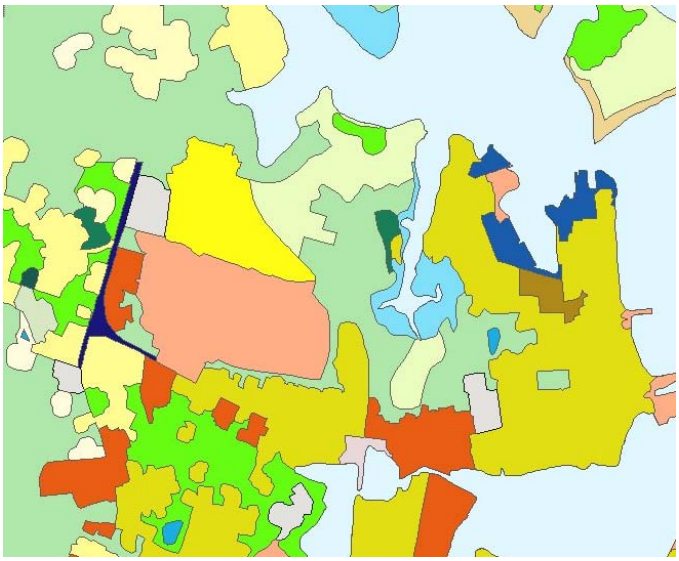
1970 Land use Map of Connecticut

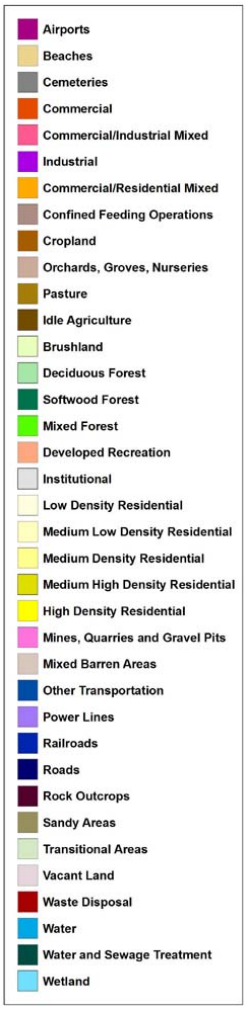
1976 Land Use and Land Cover. The GIRAS (Geographic Information Retrieval and Analysis System) Land Use and Land Cover (LULC) data consist of historical land use and land cover classifications based primarily on the manual interpretation of 1970's and 1980's aerial photographs. Secondary sources included land use maps and surveys. There are 21 possible categories of cover type, following the Anderson et al (1976) "*Land Use And Land Cover Classification System For Use With Remote Sensor Data*" (USGS Professional Paper 964). The land use data for Connecticut are based on *circa* 1976 aerial photographs, which were photointerpreted and subsequently digitized. Data for Connecticut are portrayed on 1:250,000 Scale Quadrangles. The spatial resolution for all LULC files will depend on the format and feature type. Files in GIRAS format will have a minimum polygon area of 10 acres (4 hectares) with a minimum width of 660 feet (200 meters) for manmade features. Non-urban or natural

features have a minimum polygon area of 40 acres (16 hectares) with a minimum width of 1320 feet (400 meters). Files in the CTG grid cell format have a resolution of 30 meters.

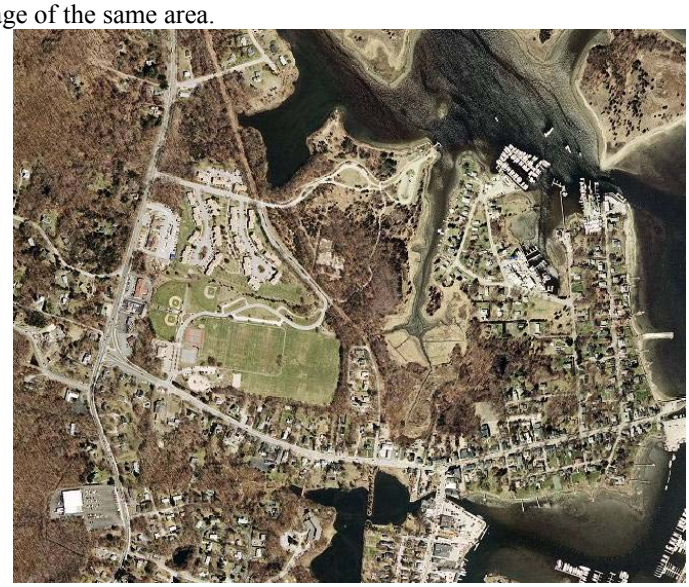


Rhode Island Statewide Land Use Map. Rhode Island used a hybrid approach in creating their statewide dataset that incorporated both automated image classification and aerial photo interpretation.

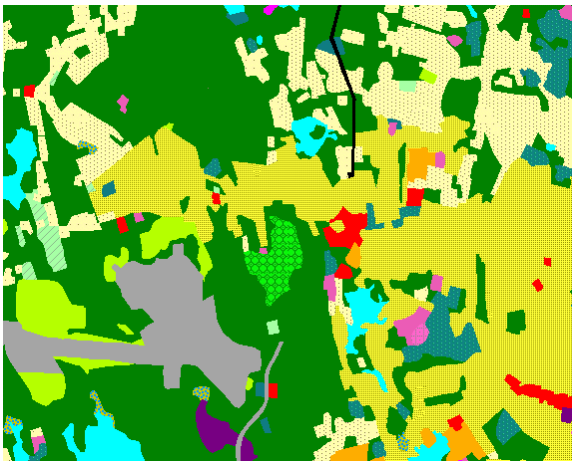


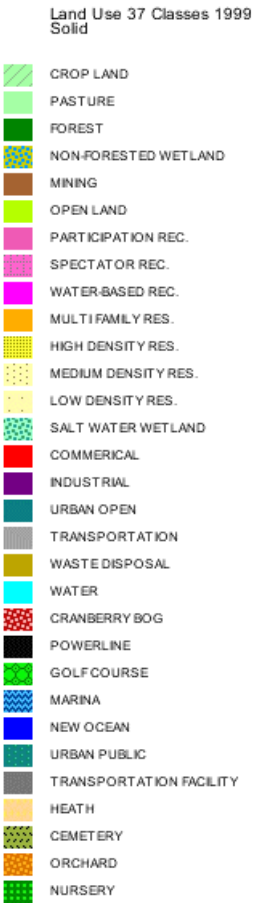


Above: Sample of the 2003-2004 Rhode Island Statewide Land Use Dataset**. Below:** Aerial image of the same area.



Massachusetts Statewide Land Use. Massachusetts and MassGIS have created statewide land use datasets (37 classes) for 1971, 1985 and 1999 using aerial photo interpretation. Visit http://www.mass.gov/mgis/lus.htm for more information.

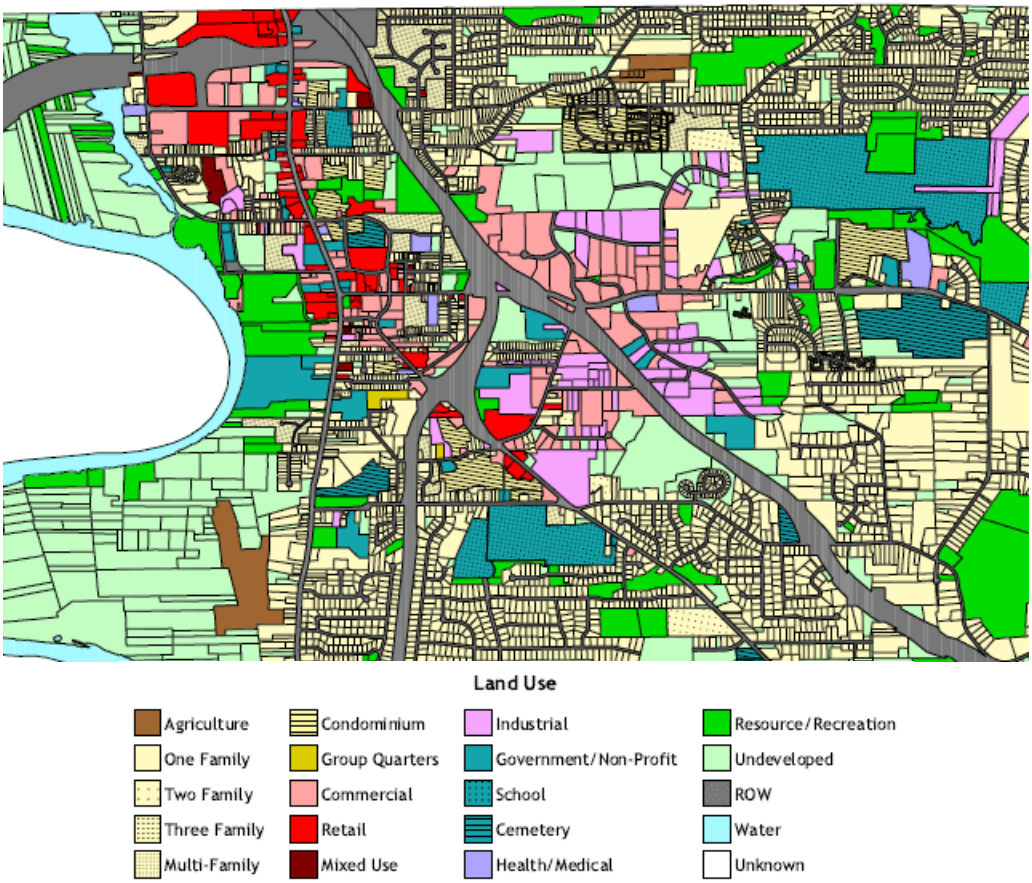




Above: Sample of the1999 Massachusetts photo-interpreted land use dataset.
Below: Aerial image of the same area.

Regional

Some of the Regional Planning Organizations in Connecticut have created land use for their member towns. The largest region to create a land use dataset is the Capital Region Council of Governments (CRCOG). After doing a cost assessment, CRCOG worked with Applied Geographics Inc. to create a region-wide, 28-town land use map. The regional land use was mapped community by community at the parcel level by collecting parcel GIS data and CAMA database data. For communities in which digital parcel data was unavailable, or not matched with the CAMA data, GIS parcel datasets were created or modified in order to match with the CAMA data. Digital GIS or CAD data was matched to CAMA records for four of the 28 towns. Digital parcels were created and matched to the CAMA database for two communities. CRCOG set a standard of land use classification codes and matched all CAMA database codes to the standard codes.



CRCOG parcel-based land use for the northwest section of Glastonbury, CT.

Current User Community

Federal, state, regional and municipal governments are primary users of land cover and land use information. Other users include watershed management associations, lake management associations, non-governmental organizations and academia.

Business Processes that use Land Use

A few of the many business processes that use land use information include state, regional and municipal planning, economic development planning, natural resources management and conservation, greenways planning, transportation planning, source drinking water protection, to name a few.

4.3 Need

UConn CLEAR staff who create and maintain the current Connecticut land cover dataset are supported exclusively on project-related grants. To date, CLEAR has been able to piece projects together to cover salaries of key staff so they can create data that benefit many users in the state of Connecticut. Since these grants have been almost exclusively federal, little state funding has been used to support the land cover mapping efforts. In addition, since grant-funded land cover/land use projects must be research-oriented, there is sometimes divergence between

research goals and what would be optimal for statewide dataset creation. There is no security that CLEAR will be able to continue this service.

Additionally, NLCD and C-CAP are national programs that require collaboration among federal agencies to create national land cover data. The federal government and its programs can be influenced by changing administrations, budgets and other factors.

Land Use is created piecemeal by different levels of government using different methods and classification schemes.

The need for land cover and land use data is demonstrated by the sheer number of land cover and land use datasets that have been created. The problem is that the current, disparate nature of their creation creates many datasets that are incompatible thematically, spatially and temporarily and contain lots of holes. There is a real and significant need for Connecticut to standardize, create and maintain this extremely valuable type of information.

4.4 Data Requirements

The proposed dataset is a hierarchical, tiered dataset consisting of several scales with varying classification schemes. The coarse level creates the land cover information to be used for larger geographies and the finer levels create the land use to be used for small geographies. The data requirements differ.

General Land Cover. The most general land cover requires 30 meter satellite imagery which is free. If the needs assessment identifies that 30 meter data is too coarse, it would be necessary to explore other imagery sources and methodologies.

High Resolution Land Cover: High resolution land cover requires base map imagery. It is most practical to use the base map imagery and standards as recommended by the Base Map Imagery subcommittee. The Base Map Imagery subcommittee recommends capturing imagery every three years. This would be adequate for updating this dataset. As of this writing, the Base Map Imagery subcommittee had not recommended a time of year of data acquisition. For land cover mapping purposes, it would be beneficial to have

- imagery captured during both springtime, prior to tree leaf-out,
- and summertime of the same year and
- and, at a minimum, blue, green, red, and near-infrared spectral resolution.

Leaf-off imagery is necessary for classifying urban features such as roads that would otherwise be covered by tree canopy. Leaf-on imagery is necessary for separating vegetative covers such as agricultural fields, forests and turf or fields. It is very likely that imagery captured for the state through various programs such as the United States Department of Agriculture (USDA) National Aerial Imagery Program (NAIP) could also be utilized.

Cadastral-based Land Use/Cover. Both base map imagery, as discussed above, and parcel/cadastral land use information would be necessary to create true land use classes.

Currently, there is no state-wide cadastral dataset. The finest land use level of the hierarchical classification can not be created until a statewide cadastral dataset is completed.

Accessibility. The final dataset will be made accessible to all users.

4.5 Standards

Classification Scheme. Several standard classification schemes currently exist.

1. One such example is the Land-based Classification Standards (LCBS) of the American Planning Association (APA)[1]. This scheme would be difficult to implement and replicate because it emphasizes land owners.

2. The National Land Cover Dataset (NLCD) has a standard classification scheme[2]. It is quite comprehensive for national land cover, but does not contain enough detail for the land use levels of the Multi-Resolution Land Cover/Use dataset proposed here.

3. Anderson (1976) developed a set of land categories for use with remote sensing-derived land cover. It works as a hierarchy where the most basic nine classes are listed (urban and built-up land, agricultural land, brush or transitional between open and forest, forest, water, wetlands, barren land, tundra, permanent snow and ice). From there, each of the nine categories contains sub-levels with more detail. Sub-levels continue to level four which contains the most detail. Andersons' hierarchy of land cover fits nicely into the Multi-resolution Land Cover/Use dataset proposed here. The Rhode Island Land Use Land Cover dataset uses a modification of the Anderson classification System (Appendix 2). Vermont GIS has created a standard set of Land Use and Land Cover codes based on the Anderson System[3].

A needs assessment should refine and finalize the classes necessary at each level to be useful for all users. The classes used by Rhode Island in their Land Use/Land Cover map are an excellent starting point (Appendix 2). Once the classes are determined, land use codes are a key part of the standard that should be used by all municipalities. Standardized codes are an easy way to increase efficiency.

Regular Update Frequency
The Multi-Resolution Land Cover/Use dataset should be updated to correlate with base map imagery acquisition. The Base Map Imagery subcommittee recommends updating base map imagery every three years. It may also be advantageous to, when possible, synchronize land cover/use maps with the census data collection.

---

[1] http://www.planning.org/lbcs/standards/view.htm?Dimension=&Level=4&Keyword=&style=table&submit1=View+Results
[2] http://www.epa.gov/mrlc/classification.html
[3] http://www.vcgi.org/techres/standards/partii_section_c.pdf

Minimum Accuracy
Each level of the Multi-Resolution Land Cover/Use dataset should be assessed using accepted methodology. The accuracy assessment should measure errors of commission and omission for each class, as well as overall accuracy. Those conducting the assessment may elect a fuzzy accuracy approach where there could be more than one right answer. For example, deciduous forest labeled coniferous forest would not be as wrong as deciduous forest labeled as developed.

5 Organizational Approach

The needs assessment should inform the organizational approach.

5.1 The Multi-Resolution Land Cover/Use Dataset Organizational Approach

Flexible Framework. The hierarchical levels of the Multi-Resolution Land Cover/Use dataset lend themselves to a phased implementation that can be accomplished in a flexible organizational framework.

- Create or update general land cover for Connecticut. Ideally, this would occur after the high resolution land cover dataset was completed. Realistically, because a program and methodology is in place for creating general land cover and the fact that it will cost much less than creating a new high resolution land cover, the general land cover may be the first to receive attention.

- Create a statewide, high resolution land cover dataset from base map imagery. This requires statewide high resolution imagery, but does not rely on parcel information. Experienced image processors are best suited to create this layer.

- Marry the high resolution land cover (above bullet) with parcel-based land use codes. This could be accomplished in at least two ways.

    - One would be for municipalities and/or regions to use the high resolution land cover and combine it with their parcel-based land use codes. This is advantageous in that it does not require a completed state-wide cadastral dataset. The main disadvantage is that the cadastral-based land use dataset would not be consistent for the state. Only some towns or regions would be done and different land use codes and dates would be incorporated creating a patchwork dataset.

    - Ideally, the cadastral-based land use/cover dataset would be created after a temporally-consistent, statewide cadastral dataset was completed. When combined with high resolution statewide land cover, it will create a statewide, consistent, highly detailed and accurate land use dataset.

Explore Existing Methods and Techniques
Land cover/use mapping is a rapidly changing field. The availability of high resolution imagery has increased tremendously in recent years. At the same time, software and hardware designed to handle the high spatial detail, high variability and large file sizes continue to evolve. Because of this, the subcommittee cannot recommend a specific protocol. When it is time to create the statewide, high resolution baseline dataset, the data creators should:

1. Involve all levels of state government that have been involved in land cover mapping to date. At a minimum, this would include:

    - State personnel that may have worked on or be aware of past land use mapping (circa 1970, 1975)
    - Regional planning organizations
    - Municipalities
    - Universities that have been directly involved in land use and/or land cover creation

2. Research, at a minimum, the following for other states that have undergone statewide, high resolution land use mapping: (1) who did the work, (2) what classes were included and excluded in the final land use map, (3) methodologies used, (4) input imagery, (5) necessary ancillary data, (6) what hardware, software or other equipment and expense, (7) any customizations included for specific user groups. At a minimum, the following states should be included:

    - Rhode Island. Rhode Island contracted with Sanborn to use a hybrid approach (partially automated, partially manual) land use map.
    - Massachusetts. Massachusetts has three dates of statewide, aerial photo-interpreted land use data.
    - Maine. Maine worked with the NOAA Coastal Services Center and Sanborn to create a hybrid, high resolution land use dataset.

The baseline mapping from aerial imagery requires extensive expertise on image interpretation and software techniques. UConn CLEAR and highly skilled private consultants are capable of performing this work.

Fusing the High Resolution Land Cover with Parcel Data. Once a standard coding system is in place, the Regional Planning Organizations (RPOs) are well suited to add the parcel land use information to the finest level of the dataset. RPOs are intimately familiar with their member towns and this is an opportunity to build their GIS and mapping expertise.

When a State-wide Cadastral Dataset is Complete. The statewide amalgamation of parcel data with the high resolution land use/cover dataset requires a coordinating body. This is in the far future so the organizational approach should be revisited when the time is closer.

5.2 Existing Land Cover Change Data

Connecticut is fortunate to have a 5-date, consistently created land cover dataset, starting in 1985. This dataset should continue to be updated at approximately 5-year intervals, depending on the availability of high quality (cloud-free), satellite imagery. As of 2008, the version 2.0 land cover consists of twelve classes. These classes are defined in Appendix 1.

Although some minor modification may be necessary, the update methodology should follow that of the original data creator. The process used cross-correlation analysis (Koeln and Bissonnette, 2000) to identify pixels that have changed between time 1 and time 2. For unchanged pixels, time 1 land cover remains the same. For changed pixels, time 2 imagery is classified in order to determine the new land cover class. This methodology assures that subsequent datasets are built upon existing datasets allowing for comparison and change determination.

This update should not be costly. Although the dataset lacks spatial detail and land use, the ability to evaluate land cover change starting in 1985 is invaluable.

6 Definitions

Accuracy: the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the quality of data and the number of errors contained in a dataset or map.

Cadastral: a cadastral map is a map showing the boundaries and ownership of land parcels.

Capital Regional Council of Governments (CRCOG): a voluntary association of municipal governments serving the City of Hartford and 28 surrounding communities. Visit http://www.crcog.org/ for more information.

Coastal Change Analysis Program (C-CAP): a project of NOAA that is a nationally standardized database of land cover and land change information, developed using remotely sensed imagery, for the coastal regions of the U.S. C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. Visit http://www.csc.noaa.gov/crs/lca/ccap.html for more information.

Computer Assisted Mass Appraisal (CAMA): a generic term for any software application and database utilized in the assessment of real property.

Image resolution: describes the detail an image holds. The more detail, the higher the resolutions. The less detail, the lower the resolution.

Image classification: uses the spectral information represented by the digital numbers in one or more spectral bands, and attempts to classify each individual pixel based on this spectral

information. The objective is to assign all pixels in the image to particular classes or themes (e.g. water, coniferous forest, deciduous forest, corn, wheat, etc.).

Land cover: natural and anthropogenic features that are observable on the earth's surface (examples include forest cover, developed/built, water, grass).

Land use: involves human activities that take place on the land and therefore represents the current use of property (examples include residential, commercial, corn crop, reservoir, etc.).

Landsat: a series of satellites that, since 1972, have provided repetitive coverage of continental Earth surfaces in the visible, near-infrared, short-wave, and thermal infrared regions of the spectrum. Visit http://landsat.gsfc.nasa.gov/ for more information.

Minimum Mapping Unit: The smallest feature reported in an image.

National Land Cover Dataset (NLCD): the Multi-Resolution Land Characteristics (MRLC) Consortium is a group of federal agencies who first joined together in 1993 to purchase Landsat 5 imagery for the conterminous U.S. and to develop a land cover dataset called the National Land Cover Dataset (NLCD 1992). In 1999, a second-generation MRLC consortium was formed to purchase three dates of Landsat 7 imagery for the entire United States (MRLC 2001) and to coordinate the production of a comprehensive land cover database for the nation called the National Land Cover Database (NLCD 2001). Visit http://www.mrlc.gov/index.php for more information.

Orthophotography: digital imagery in which distortion from the camera angle and topography have been removed, thus equalizing the distances represented on the image.

Satellite imagery: an image of the earth's surface captured on a sensor that is onboard a satellite orbiting the earth.

7 Appendices

Appendix 1: UConn/CLEAR Land Cover Version 2 Classes

NOTICE: The CCL version 2.x land cover dataset consists of land cover data of the Connecticut area for the years 1985, 1990, 1995, 2002, and 2006. All five of these land cover maps, while very similar to the original CCL version 1.x land cover, are a different set of data. Not only does CCL v2.x include an agricultural land cover category, but significant edits and other spatial changes have been performed to improve the land cover dataset. ***THE CCL VERSION 2.x LAND COVER IS NOT COMPATIBLE AND/OR COMPARABLE TO THE PREVIOUS CCL VERSION 1.x LAND COVER.***

Developed - High-density built-up areas typically associated with commercial, industrial and residential activities and transportation routes. These areas can be expected to contain a significant amount of impervious surfaces, roofs, roads, and other concrete and asphalt surfaces.

Turf & Grass - A compound category of undifferentiated maintained grasses associated mostly with developed areas. This class contains cultivated lawns typical of residential neighborhoods, parks, cemeteries, golf courses, turf farms, and other maintained grassy areas. Also includes some agricultural fields due to similar spectral reflectance properties.

Other Grasses - Includes non-maintained grassy areas commonly found along transportation routes and other developed areas, and within and surrounding airport properties. Also likely to include forested clear-cut areas, and some abandoned agricultural areas that appear to be undergoing conversion to woody scrub and shrub cover.

Agriculture – Includes areas that are under agricultural uses such as crop production and/or active pasture. Also likely to include some abandoned agricultural areas that have not undergone conversion to woody vegetation.

Deciduous Forest - Includes southern New England mixed hardwood forests. Also includes scrub areas characterized by patches of dense woody vegetation. May include isolated low density residential areas.

Coniferous Forest - Includes southern New England mixed softwood forests. May include isolated low density residential areas.

Water - Open water bodies and watercourses with relatively deep water.

Non-forested Wetland - Includes areas that predominately are wet throughout most of the year and that have a detectable vegetative cover (therefore not open water). Also includes some small water courses due to spectral characteristics of mixed pixels that include both water and vegetation.

Forested Wetland - Includes areas depicted as wetland, but with forested cover. Also includes some small water courses due to spectral characteristics of mixed pixels that include both water and vegetation.

Tidal Wetland - Emergent wetlands, wet throughout most of the year, with distinctive marsh vegetation and located in areas influenced by tidal change.

Barren - Mostly non-agricultural areas free from vegetation, such as sand, sand and gravel operations, bare exposed rock, mines, and quarries. Also includes some urban areas where the composition of construction materials spectrally resembles more natural materials. Also includes some bare soil agricultural fields.

Utility Corridors - Includes utility corridors. This category was manually digitized on-screen from corridors visible in the Landsat satellite imagery. The class was digitized within the deciduous and coniferous categories only.

Prepared by J. Hurd
27mar2008
Updated 02jun2008

Appendix 2: Rhode Island Land Use – Land Cover Codes

111...High Density Residential (<1/8 acre lots)
112...Medium High Density Residential (1/4 to 1/8 acre lots)
113...Medium Density Residential (1 to 1/4 acre lots)
114...Medium Low Density Residential (1 to 2 acre lots)
115...Low Density Residential (>2 acre lots)

DESCRIPTION: All residential categories are based on the size of the maintained lot and includes the house and the yard area. Lot sizes are visually determined by comparing the houses in an area to the surrounding houses, observing the spacing between the houses and the relative amount of yard space between them. Other land cover types (such as forest, wetland or water bodies), even though they may be on a residential property, are mapped separately if they exceed the minimum mapping unit. Duplexes (usually with 2 front doors/pathways and sometimes 2 driveways) will be factored into this calculation while multi-unit complexes will generally be classified as high density residential unless surrounded by a significant amount of maintained yard (such as some condos), in which case it may calculate out to a lower density category. Building sizes of residences (except for some duplexes and multi-unit complexes) are significantly smaller than almost all commercial and industrial buildings.

120...Commercial (sale of products and services)

DESCRIPTION: Large commercial facilities (such as malls, shopping centers and larger strip commercial areas) are typically well landscaped with parking strategically arranged around the building in multiple areas. There are often a few loading docks. These land uses are usually found in residential areas or grouped with other commercial facilities. Parking areas are included. Smaller commercial facilities (such as neighborhood stores or smaller strip commercial areas) often look similar to residential areas but are sometimes distinguishable by their larger parking areas (compared to residential parking) often behind the building down a driveway with spaces for 5 or 10 vehicles or if in a dense residential area, they may actually be commercial at the ground level and apartments above. Without any of these distinguishing features, these will probably be classified as residential. Also included in this category are office parks and medical offices. Commercial buildings are almost always larger than residential structures.

130...Industrial (manufacturing, design, assembly, etc.)

DESCRIPTION: Industrial areas are typically not landscaped as thoroughly as a commercial facility. Parking is often in one large lot. These areas generally have many loading docks and there are often truck trailers parked on-site. These facilities are often far from residential areas, often surrounded by forests, but typically near major roads or highways. Parking areas are included. Industrial buildings are almost always larger than residential structures.

141...Roads (divided highways >200' plus related facilities)

DESCRIPTION: Related facilities would include rest areas, highway maintenance areas, storage areas, on/off ramps, and maintained grassy areas adjacent to the roadway.

142...Airports (and associated facilities)

DESCRIPTION: Airport facilities include runways, maintained grassy areas adjacent to runways, hangars, terminals, freight storage areas and buildings, roads, short and long term parking lots, observation towers and on-site commercial facilities.

143...Railroads (and associated facilities)

DESCRIPTION: Railroad facilities include all tracks, maintained rights-of-way adjacent to the tracks, terminals, stations, switching yards, storage facilities and buildings, and parking lots around the station.

144...Water and Sewage Treatment

DESCRIPTION: Water and sewage treatment facilities are typically characterized by circular sedimentation tanks, associated facilities include pump houses, filtration and aeration buildings, as well as parking lots.

145...Waste Disposal (landfills, junkyards, etc.)

DESCRIPTION: Landfills often can be mistaken for sand and gravel pits but do not have the "spider" shaped sorting/conveyor apparatus associated with sand and gravel operations. There is usually an area of recent activity with disturbed earth and piles of material (waste and cover material) nearby. There will often be large areas that haven't been disturbed for a while. Associated facilities for landfills, junkyards, and automobile dumps include all buildings, roads and parking areas. There are usually construction machines (such as front bucket loaders, road graders, bulldozers and dump trucks) on site. Once landfills are closed, they are covered, graded and often times venting pipes for methane gas can be seen arranged systematically throughout the landfill. There will generally be a high point in the middle of the landfill with moderate slopes out to the edges.

146...Power Lines (100' or more width)

DESCRIPTION: Powerlines generally follow straight lines across the landscape. Usually, the support towers are visible at a set interval and often, wires can be seen on an aerial photograph between the towers. Also included in this category are underground pipeline corridors. In both cases, the feature is mapped to the edge of the maintained vegetation. Where power lines or utility corridors pass over or through other land use categories, the other category takes precedence unless the area is managed specifically for the power line (such as forest).

147...Other Transportation (terminals, docks, etc.)

DESCRIPTION: This category is used for land-based truck terminals and warehouses (with many loading docks) as well as water-based docks and associated buildings used for industrial or commercial purposes not associated with other categories (such as recreation docks used at marinas), but includes commercial fishery facilities. Adjacent parking areas and storage facilities are included.

151...Commercial/Residential Mixed

DESCRIPTION: This category is used for land uses that are a mix of both commercial and residential. Although difficult to tell from aerial photographs, ancillary data may be provided to help classify areas into this type.

152...Commercial/Industrial Mixed

DESCRIPTION: Some facilities are not obviously commercial or industrial but a mix of the two. They are nicely landscaped yet have distinguishing characteristics of both commercial and industrial areas. Parking lots are included.

161...Developed Recreation (all recreation)

DESCRIPTION: Developed recreation facilities include stadiums, ballfields, tennis courts, urban parks, basketball courts, ski areas, golf courses, marinas, playgrounds, zoos, amusement parks, developed beach areas, drive-in theaters, fairgrounds, bike paths, race tracks and swimming pools plus associated parking lots. It does not include passive recreation areas such as state forests or parks, except for the developed facilities associated with these areas. These facilities, when associated with institutional land uses, will be pulled out into this category.

162...Vacant Land

DESCRIPTION: Land is classified as vacant if it is abandoned land that isn't being used for any other land use. It isn't being prepared for another use (see 750 Transitional Area below) and does not have enough tree growth to be classified as forest or enough vegetation to be classified as brushland. It may include structures and indicates that the land was previously used for one of the urban categories.

163…Cemeteries

DESCRIPTION: From small to large cemeteries, these features are obvious by the orderly grid of gravestones, monuments and road networks. Quite often, they are noted on USGS topographic maps. This category includes associated buildings, roads and parking areas.

170...Institutional (schools, hospitals, churches, etc.)

DESCRIPTION: Institutional land and buildings are public or quasi-public facilities with or without green space designed to serve large numbers of people such as schools, colleges, hospitals, prisons, churches, town halls, public works buildings, police stations or fire stations. The maintained areas around the facilities are included as are parking facilities. Some of the facilities at a large college, for example, may be pulled out into other categories (such as an athletic field). However, all dormitories and other buildings are included in this category. These are usually noted on USGS topographic maps.

210...Pasture (agricultural not suitable for tillage)

DESCRIPTION: Pasture land is generally used for grazing of animals and for the growing of grasses for hay. It is often hilly, may have poor drainage or stoniness, and the field boundaries may be less defined than cropland. There may be scattered trees or shrubs in the field. Associated facilities include barns and other outbuildings.

220...Cropland (tillable)

DESCRIPTION: Cropland is generally tilled land used to grow row crops. There is usually evidence of intense land management. The land is often flat, well drained and the field boundaries are generally very well defined. This category also includes turf farms that grow sod. Associated facilities include barns and other outbuildings.

230...Orchards, Groves, Nurseries

DESCRIPTION: This category includes fruit orchards, greenhouses, plant nurseries, Christmas tree farms, vine crops (such as vineyards, strawberry and blueberry patches), and cranberry bogs. The orderly pattern of the vegetation generally indicates that one or more of these land uses is present. Associated facilities include barns, other outbuildings and parking lots. Orchards and greenhouses are often symbolized on USGS topographic maps.

240...Confined Feeding Operations

DESCRIPTION: Confined feeding operations are intensive facilities used for raising livestock or poultry in a small space where there are minimal adjacent grazing lands. This category includes the feeding areas, stables, barns, outbuildings and waste management facilities as well as equipment storage areas.

250...Idle Agriculture (abandoned fields and orchards)

DESCRIPTION: When pasture, cropland and other agricultural uses have not been active for a few years, it is classified as idle agriculture. Often, early successional vegetation is seen growing in around the edges and there is no evidence of any land or vegetation management. Eventually, it will become brushland.

300...Brushland (shrub and brush areas, reforestation)

DESCRIPTION: Brushland is characterized by lots of shrubs and very few trees (< 50% canopy). It includes areas that are being reforested but the trees are not large or dense enough to be classified as forests. It also includes areas that are more permanently shrubby, such as heath areas, wild blueberries or mountain laurel.

410...Hardwood Forest (>80% hardwood)
420...Softwood Forest (>80% softwood)
430...Mixed Forest

DESCRIPTION: Trees are classified as forests when the tree canopy covers at least 50% of the space when viewed from above on an aerial photograph. The four different categories depend upon the composition of hardwood vs. softwood trees. On an aerial photograph, most softwood trees have conical shapes (except for pines) with dense needles and tight branching with dark spectral signatures whereas hardwood trees have a more open or freeform shape with leaves (during the growing season) that give the tree a coarser texture or pattern and a looser or more open branching arrangement. Hardwood spectral signatures are generally lighter than softwood signatures.

500...Water – *Burned in from Previous RIGIS Ponds5k Data* *–Ocean and Bay Shoreline taken from RIGIS 5K and RIDEM Shoreline Data*

DESCRIPTION: This category includes open water, such as lakes, ponds, lagoons, bays or rivers wide enough to be mapped as a polygon instead of a line. This includes any open water feature on the land sid*e of* the ocean coastline.

600...Wetland – Non-Forested Wetlands Only

710...Beaches

DESCRIPTION: This category includes fresh and saltwater sandy beaches. If it is a highly developed beach facility with buildings and parking lots, it should be classified as 161 Developed Recreation.

720...Sandy Areas (not beaches)

DESCRIPTION: These are sandy areas that are not beaches, with very little visible vegetation. These are generally small patches of sand in shrub-scrub areas that indicate highly permeable soils with very little organic material.

730...Rock Outcrops

DESCRIPTION: These are areas of rock with very sparse visible vegetation, usually found in steep areas with a lot of topographic relief, usually cliffs.

740...Mines, Quarries and Gravel Pits

DESCRIPTION: Sand and gravel pits usually have a "spider" shaped sorting/conveyor apparatus. Mines and quarries usually have very steep sides where there is evidence of some sort of extraction activity. Associated facilities include all buildings, roads and parking areas. There are usually construction machines (such as front bucket loaders, bulldozers and dump trucks) on site. USGS topographic maps will usually mark these features with appropriate symbols.

750...Transitional Areas (urban open)

DESCRIPTION: Some areas are in the process of being developed from one land use to another. Since these are transitional lands, it is not always apparent what the new land use will be so they are classified as this category. Typically, these areas are being developed for residential, commercial or industrial use. Comparison to older imagery shows that if was previously another land use or land cover category.

760...Mixed Barren Areas

DESCRIPTION: Mixed barren areas are areas that are very sparsely vegetated but clearly can not be classified as either rock outcrops or sandy areas. They may be a combination of rock and sand but are characterized by little or no vegetation and a visible rock or sandy surface.