Connecting land use decision makers to their changing landscape: integration of research with tools, training and outreach at the University of Connecticut

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Abstract

Land use in the United States is largely dictated at the local level, by decision makers serving at the municipal and regional units of government. Since under this system state and federal regulation and policies can play only a limited role in influencing land use decisions, assistance to local land use officials is a critical need for the economic, social and environmental health of American communities. The Center for Land Use Education and Research (CLEAR) at the University of Connecticut is dedicated to the task of assisting local land use decision makers, through effective integration of its landscape research with the creation of analytical tools, technology training, and on-the-ground community outreach. The Center's research focuses on characterizing and analyzing the landscape and changes to it, using remote sensing and other geospatial data processing techniques. CLEAR technical tools and training focus on geospatial technologies and applications that enhance, rather than complicate, local land use planning; the approach is to disseminate information in a variety of formats, in order to maximize access by citizen and professional planners. CLEAR outreach programs conduct workshops for local officials that cover a wide range of topics related to natural resource-based planning, from open space planning to low impact development. Most workshops are informed by Center remote sensing data, and many are supported by Center GIS and web tools. On-the-ground changes at the local level demonstrate that this integrated approach can reap real benefits, despite the many challenges inherent in the land use decision making process. More resources, effort and consideration must be invested in providing integrated assistance for communities if academia is to have meaningful impact on land use issues.

Key Words

GIS; integration; land cover; land use decision makers; outreach education; remote sensing

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Introduction

Land use decision makers in the United States are in great need of assistance. For the most part, they are not getting it. This state of affairs is due to a wide variety of causes, one of which is the inadequate translation of land use research into understandable, practical information that can be used at the local level by decision makers. This paper focuses on a continuing effort at the University of Connecticut to provide this translation, through the integration of research results with technical training, tool development, and outreach education. Thus, for this conference on 'the Science and Education of Land Use,' our emphasis will be more on education than on science; our research will be described not in terms of techniques or results, but in the context of its role within the overall public service effort. Through descriptions of our outreach, training, and tool development work, and how these programs interact with our landscape research, we seek to contribute to the discussion of *'…how science can serve society in making more rational local and regional land use decisions,'* as outlined in the description of this conference.

Land use change in the United States

Few dispute that making better land use decisions is critical to the economic, social, and environmental health of the country's communities. Certainly, America's agricultural and natural resources are under pressure from urbanization in almost every part of the United States. For example, according to the latest estimates by the U.S. Department of Agriculture (USDA), between 1982 and 2001 about 34 million acres – an area the size of Illinois – were converted to developed land from forest and farm land (USDA 2000). A report by the American Farmland Trust states that between 1992 and 1997, America lost approximately two acres of farmland per minute (Sorensen et al. 1997). A recent study by remote sensing researchers at the National Oceanic and Atmospheric Administration (NOAA) estimated that the total area of the continental United States covered by impervious surfaces, or the 'built environment,' is approximately the size of the state of Ohio (Elvidge et al. 2004).

The widespread impacts of this land use change are increasingly evident. A recent study funded by the National Aeronautics and Space Administration (NASA) concludes that the contribution of human-induced land cover change on climate is at least as important as that of carbon dioxide (Pielke et al. 2002). The Nature Conservancy reports that up to one-third of the country's animal

and plant species are at risk of extinction due to habitat loss and degradation from land use changes (Stein and Flack, 1997). There is a growing body of work documenting the public health impacts of the sedentary and automobile-dependent lifestyle associated with poorly planned community design (Killingsworth and Schmid 2001; Robert Wood Johnson Foundation 2001).

Water resources seem particularly at risk from urbanization. The U.S. Environmental Protection Agency (EPA) identifies urban runoff as a leading source of water quality impairment (EPA 2002). The Pew Commission reports that over 20,000 acres of coastal habitat disappear each year (Beach 2003). The National Coastal Condition Report graded the status of the nation's estuaries as 'fair' based on seven basic criteria of coastal condition (EPA 2005), and 78% of assessed estuarine areas in an ongoing national survey had moderate to high overall eutrophic (excess nutrient) conditions (Bricker et al. 2007). A report on the impact of urbanization on groundwater supplies estimates losses to groundwater recharge in 20 American metropolitan areas to be in the tens of billions of gallons per year (Otto et al. 2002).

On the hot seat: local land use decision makers

The decisions that dictate these land use changes are largely in the hands not of trained professionals, but of volunteers. Land use decisions in the United States are made, overwhelming, at the local level. 'Local' can mean several things, but most often translates to tribal, regional (county, township) and municipal (village, town, city) government. Local land use officials are comprised of residents sitting on various land use boards (*e.g.*, planning, zoning, conservation). Board members can be either elected or appointed, but are essentially citizen volunteers. Professional support for these volunteers varies widely, from well-staffed county offices to small towns with virtually no professional assistance in areas where county government is weak or nonexistent, such as in New England.

The decision making burden placed upon these individuals is a heavy one. They have specific legal responsibilities, complicated procedural requirements, and often tremendous time pressure to process the land development applications put before them. The issues are complex, and they often feel that the lion's share of professional expertise and technical support is brought to the table in support of applicants, rather than in support of their civic task of making balanced and well-informed decisions for their community (Arnold, 1999). Their decisions are haunted on one hand

by the specter of legal action by disgruntled applicants, and on the other by the possibility that they will incur the wrath of their friends and neighbors.

For those serving on boards that have joint planning (legislative) and regulatory (administrative) responsibilities, such as combined planning and zoning commissions, there is often little or no time to consider the 'big picture': their focus remains fixed on reviewing plans at the individual site level, and can rarely be lifted to the community, regional, or ecosystem level. Making decisions in this case-by-case manner, there is little time or ability to consider the long-term and cumulative impacts of any particular proposal.

The implications for community assistance efforts

In short, being a local land use decision maker is an extremely important and difficult task -- one that is worthy of assistance far beyond what is currently being provided by the federal, state, academia and nonprofit sectors. There are significant barriers to those who would provide this assistance. First of all, there are major logistical obstacles. The sheer number of communities in need of assistance is somewhat staggering. And, as might be expected, turnover on these boards is very high, so the "target audience" is a forever-changing one, with a continual need for assistance.

Second, because land use is a local issue, the significant resources of the federal and state governments are rarely brought to bear directly or even indirectly on the problem, because they have no clear statutory purchase with which to come to grips with it. This 'mission gap' means that the resources that are made available for assisting local land use decision makers are few, and paltry in comparison to the importance of the problem. For example, USDA is focused on promoting and protecting agriculture, NOAA is focused on wise use of the oceans, and EPA is focused on promulgation and administration of regulations to protect the environment. Each of these missions is highly dependent on local land use decisions, yet this realization has been somewhat slow to become accepted at the higher levels of the agencies. And, even armed with a recognition of the problem, federal and state agencies are often unsure of what to do about it, given their missions, their traditional avenues for expending resources, and their limited connection to the world of community-level decision making.

Third, local land use decision making is not only daunting for the decision makers themselves, but for those who would provide this much-needed assistance. This extends beyond governmental agencies to nonprofit groups, the private sector, and academia. The community decision making process is complicated, multifaceted, political, and time consuming. Much of it occurs at evening board meetings with a discouragingly long list of agenda items. This world is not one that is familiar to most people, including academics. Academic contributions to resolving the problems of land use, then, require a well-considered response that factors in the nature of land use decision making, and takes particular care to translate research into useful tools and assistance.

Outreach as the foundation of the University of Connecticut approach: NEMO

The University of Connecticut Cooperative Extension System has a long history of working with local land use officials, dating back almost 40 years to the creation of a 'community development' initiative similar to those created in other Land Grant institutions at that time. The true starting point of the CLEAR effort, however, was in 1991, when with funding from USDA Cooperative State Research, Education and Extension Service (CSREES), UConn faculty members from the three departments created the *Nonpoint Education for Municipal Officials* (NEMO) Program.

NEMO, which is still ongoing in Connecticut, was developed to educate local land use decision makers in Connecticut about the connection between their land use decisions and the health of their water resources. The catalyst for NEMO was research conducted by the UConn Laboratory for Earth Resources Information Systems (LERIS) that created the first land use/land cover map of Connecticut, for the purposes of estimating nonpoint source loadings of nitrogen to Long Island Sound. Extension faculty saw this dataset and realized the unique value that this information could provide to community decision makers, if it were folded into a well-designed educational program (Arnold et al., 1993).

NEMO was created within somewhat of a vacuum of guidance and structure for local land use decision makers. In Connecticut, land use decision making is truly local, occurring within each of the state's 169 municipalities. County government was abolished in the 1950's, and although regional planning organizations exist, they exert no regulatory influence on land use. There is no true office of state planning, and although the state mandates that each municipality develop a comprehensive plan and update it every 10 years, the state enabling legislation provides no legal

nexus between local land use plans and land use regulations (zoning, subdivision, etc.). And, unlike every other state in the Northeast, Connecticut has no centralized state geographic information system (GIS) repository as a resource for community leaders, professionals, and others.

This lack of a framework allowed considerable freedom for NEMO principals to develop a creative approach for the program. NEMO is designed to fit into the world of local decision making. The foundation of the program consists of workshops for local officials. Workshops are conducted by request, in the towns, and are kept brief (two hours or less), with half of the time devoted to question-and-answer and discussion sessions. It is our experience that it is this face-to-face hashing out of issues that is the most fertile ground to engender change. To date, NEMO has worked with about 75% of Connecticut's 169 towns, and NEMO educators give, on average, over 100 evening workshops per year.

It should be noted that accommodating the education to the target audience is not synonymous with acceding to their every wish. There are certain requirements that NEMO makes of the towns with which it works. First, as noted, the project must be invited to come to the town; there is no profit in forcing one's way into a town that is not, at least in small part, receptive to your message. Despite the busy schedule of our target audience, we usually require that a special night be set aside for the workshop, rather than have it slipped into the busy agenda of a regular meeting. In addition, we have found that it is critically important that as many of the land use commissions as possible be represented at the workshop, since one of the chief barriers to change is that these boards seldom communicate with each other. Based on our observations that these factors were critical to success, in 1998 the program shifted to a mode of operation in which support of the chief elected official, multi-commission participation, and clearly stated objectives and outcomes are all agreed to between NEMO educators and town officials before they jointly embark on a series of workshops (Giannotti and Arnold 2002).

NEMO's success is based on the combination of this traditional Extension education with geospatial technology and research. At the time that NEMO was developed, remote sensing was virtually unheard of outside of agency and academic circles, and GIS technology was just emerging from its infancy as a costly and unwieldy tool. The use of remotely sensed land cover was critical. Land cover is in many ways a new and useful type of information for local officials. In dealing with

issues of growth, nonpoint source pollution, forest fragmentation, etc., what physically comprises the land surface is an important piece of information to which few have access. Local officials are more familiar with maps that show land use -- what types of activities or development are planned or permitted, such as zoning or parcel maps. These maps deal with cultural information and administrative zones, but may not convey what is actually happening on the land. And, although high resolution satellite and aerial images are enormously useful at the local level as base maps and for a general reference, land cover is quantifiable, which makes it more useful for planning, modeling and educational purposes (Arnold et al. 2000).

The unique perspective provided by land cover information, in combination with carefully crafted GIS images of a community and its natural resources, helped to make NEMO an effective program (Stocker et al. 1999). Great care was taken to fold the geospatial information and maps into the 'narrative' of an educational program designed for a non-technical audience. The great analytical strength of GIS technology can often be its downfall in an educational context, and maps were simplified to the extent possible, in direct contrast to the tendency of most GIS experts to show complicated, multi-factor GIS overlays.

As part of the story emerging from the land cover data, NEMO relied on the literature that shows that impervious land cover is strongly correlated with the health of water resources (Arnold and Gibbons 1996; Brabec et al. 2002; Schueler 1994; Schueler 2003). Combining the impervious cover research with a standard planning technique, NEMO principals developed the *impervious surface buildout analysis*, which contrasts current levels of impervious cover, as estimated from land cover data, to potential future levels estimated from zoning regulations. As opposed to more traditional buildout analyses which forecast levels of population or housing units, this analysis predicts levels of impervious cover, which are then related to future water quality conditions, as indicated by research, with a simple color scheme (Figure 1).

From NEMO to CLEAR

By the mid 1990's, NEMO was expanding in several key ways. Topically, the program expanded beyond the emphasis on water resources to include a range of programs connected with the framework of natural resource-based planning. Much of this material was already in existence, through the work of one of the original NEMO founders, an Extension Land Use Educator who

works extensively with communities on comprehensive planning, open space planning, innovative zoning economic development and farmland protection. Other topics, such as watershed planning, conducting community resource inventories and low impact development, were added in response to feedback received during workshops.

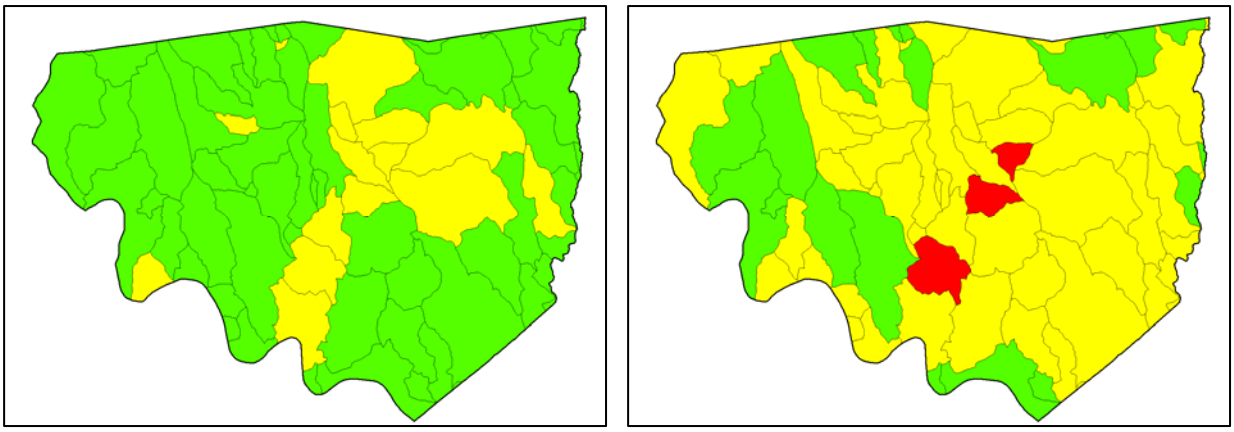

Figure 1. NEMO impervious surface buildout analysis for Southbury, CT. Left, current impervious levels estimated by land cover data, by local watershed (gray lines). Right, potential future levels as estimated from zoning regulations. Green denotes levels below 10%, which the national literature base suggests are protective of water quality. Yellow denotes levels 10% - 25%, where impacts are expected to occur, and red denotes levels >25%, which typically create serious water quality and quantity impacts.

NEMO was expanding geographically as well. Interest from university and agency colleagues in other states began to give rise to other NEMO programs, adapted from the Connecticut model to conditions in other states. These programs were initiated via onsite workshops conducted by the UConn principals. In 2000, the dozen or so existing NEMO programs met in Connecticut to develop and ratify the National NEMO Network, a confederation of like programs that now exist in 30 states. The Network exists to share experience, educational models, and technical tools between NEMO programs, and is a self-formed organization with no particular lines of affiliation or funding from any one agency. That being said, the majority of Network programs are led by Land and/or Sea Grant university outreach personnel. Each member program is something of a mini-consortium of agencies and organizations, and both partners and funding sources are diverse (Dickson and Arnold, 2005). Network coordination, which has become a separate effort under CLEAR distinct from the Connecticut program, is currently supported by competitive grants from USDA/CSREES and EPA Office of Water.

While the NEMO program expanded and evolved, new related UConn programs were being created. In the mid-1990's, NEMO and The Nature Conservancy collaborated on several watershed projects that eventually gave rise to the creation of the Green Valley Institute (GVI), a regional 35-town effort in Northeastern Connecticut and southern Massachusetts that is collaborative with the Quinnebaug-Shetucket National Heritage Corridor, a program of the National Park Service. The GVI focuses on conservation planning, working with local land trusts and conservation commissions, a land use board in Connecticut that advises the regulatory boards on conservation issues.

NEMO's emphasis on the use of remote sensing and GIS technology evolved in the early 2000's to the Geospatial Technology Program (GTP). The GTP develops geospatial tools and conducts training for community leaders, professionals and others in the use of remote sensing, GIS and global positioning system (GPS) technology. The GTP has since become part of a small national network also related to the Land, Sea and Space Grant university programs, the National Geospatial Technology Extension Program. At about the same time, LERIS, the research partner of NEMO, was chosen as a NASA Regional Earth Resources Applications Center. This stimulated an expansion of LERIS work to include not only basic remote sensing research, but an emphasis on remote sensing-driven tools to analyze land cover and land cover change. This work led more or less directly to the foundational research project of CLEAR discussed in a later section.

By the early 2000's, these programs – all sharing land use officials as a target audience and geospatial technology as a research base -- had reached 'critical mass' in the viewpoint of program principals. Accordingly, the University of Connecticut Center for Land Use Education and Research (CLEAR) was formed in 2002 as an umbrella organization for these programs, based on a close partnership between two academic departments at the College of Agriculture and Natural Resource, the Department of Extension and the Department of Natural Resources Management and Engineering, and the Connecticut Sea Grant College Program. CLEAR is dedicated to the task of assisting local land use decision makers through effective integration of its landscape research with the creation of analytical tools, technology training, and on-the-ground community outreach. As such, its mission is more public service-oriented than traditional academia, and in line with the tripartite research/education/outreach tradition of the USDA Land Grant university system. CLEAR also has strong ties to two similar nationwide university systems patterned after Land Grant, the NOAA

Sea Grant College Program and the National Aeronautics and Space Administration (NASA) Space Grant College Program.

CLEAR research uses remotely sensed data to characterize land cover and land cover change. Although most CLEAR research focuses on Connecticut, regional and even global projects are also conducted. For example, impervious cover characterization and change was conducted for the lower Long Island Sound watershed region, encompassing all of Connecticut, Westchester County, New York, and parts of Long Island, New York. On the global scale, the Center is working with New York University and Williams College on measuring the extent and expansion of urban areas for 120 cities with populations over 100,000, worldwide (Angel et al. 2007).

Most CLEAR projects make use of Landsat satellite imagery, which is moderate resolution imagery presented in 30-meter picture elements, or pixels. We have found land cover data derived from this imagery of this resolution to be very effective for characterizing the landscape at the town, watershed and state levels; as noted, it is also extremely useful information for outreach to communities. Contrary to what might be supposed, higher resolution is not always better, since creating quantifiable land cover data from high resolution imagery remains a cutting-edge technological challenge that does not always yield useful, or even appropriate results. In other words, when studying forest fragmentation, for instance, it is necessary to be able to see the forest for the trees, quite literally.

This does not mean that the Center ignores high resolution data, and in fact CLEAR has a number of projects that make use of both satellite and aerial high resolution imagery. These projects typically focus on analysis of finer landscape elements of particular concern or interest, for instance, invasive coastal plant species (Gilmore et al. in press).

Disseminating information on Connecticut's changing landscape

The seminal Center research project, dubbed *Connecticut's Changing Landscape* (CCL), was released in January 2004 as the first research effort conducted under the CLEAR banner. Since the advent of NEMO with the 1991 land use/land cover dataset, LERIS principals had created several additional statewide land cover or land use/land cover maps of the state; however, as is often the case, each research product was developed using slightly different cover classes and parameters. The CCL

project developed a uniform product for several year classes that would enable us to compare 'apples to apples' and thus characterize land cover change for the first time.

The project consists of four land cover maps of Connecticut from 1985, 1990, 1995 and 2002; a 2006 update and enhancement is nearing completion at the time of this writing. The land cover maps were created from 30-meter Landsat TM and ETM images using a method that allows for direct and accurate comparison of the maps from different years (Hurd et al. 2003). Each land cover map consists of 11 classes, far fewer than in previous mapping efforts. This is significant, because it represents a consensus by Center educators and researchers that for the intended audience and use of this study's data, more was not necessarily better. Consequently, the particular emphasis of the CCL is on the 'developed' class, a grouped land cover class which includes our more traditional land use/land cover categories of commercial, industrial, and residential.

Project results are in the form of data on land cover classes for each of the four years, plus change data for each of the three intervals and for the entire 17-year period; statewide, town and watershed level data are presented. It is beyond the scope of this paper to present research results, however, two examples of project maps are provided in Figures 2 and 3. Figure 2 shows statewide maps comparing percentage of developed land versus percent increase in amount of developed land, by town. This information, in effective, compares the historic pattern of land use over 350 years of settlement in Connecticut, to the 'hot spots' where growth is occurring most rapidly over the recent decades. Figure 3 shows a town level change map highlighting new development during the study period, which is depicted in various colors according to which time interval the development appeared. Thus, in addition to the spatial pattern of the new development, some information on temporal sequencing is provided.

CCL dissemination is an excellent example of CLEAR's determination to integrate its research, tools, and education components. Dissemination has been through CLEAR education programs, and through the CCL website. A surge of interest in the study during 2004 and 2005 resulted in special briefings and workshops for over 60 agencies, organizations and groups. In addition, the maps and data are folded into many of the Center's ongoing educational programs. NEMO educators report that, much like the novel view that static land cover maps provided for the original

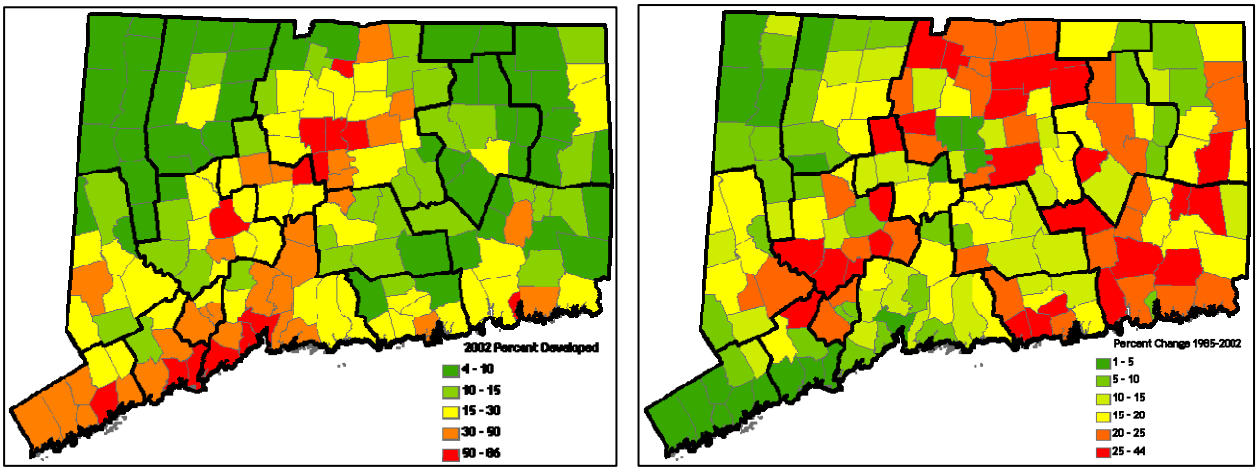

Figure 2. Example of statewide results of the CCL study. Left, 2002 percent developed class by town, with warmer colors depicting higher levels of development. Right, percent increase in developed class from 1985 to 2002, by town, with warmer colors representing higher rates of relative increase. Gray lines are town boundaries; thick black lines are the state's regional planning areas.

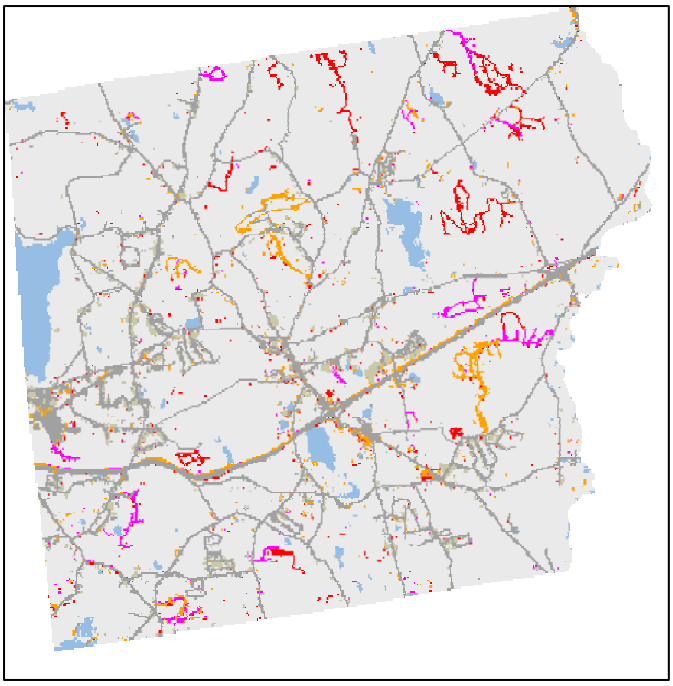

Figure 3. Land cover change map for Tolland, CT. Light gray areas are not developed, dark gray areas were developed before 1985. Colored areas show new development added between 1985 and 2002; the three colors depict the three study intervals of 1985-1990, 1990-1995, and 1995-2002. Although land use can only be inferred, most of the new development here can be assumed to be residential subdivisions.

NEMO program, CCL change maps are a unique piece of information for town officials, leading to much debate about land use policies and trends. Discussion of "visualization" techniques almost invariably focus on the future, and, in fact, CLEAR is involved in several projects that conduct build-out scenarios of various types. However, the CCL change maps indicate that visualizing past development is also a very useful educational and evaluative tool, and, unlike future scenarios, has the advantage of being factual rather than speculative.

On the CCL website, project data are presented as tables, charts, maps and downloadable data. It is worth noting that the website took several months of work by an internal CLEAR team consisting of an educator, a geospatial expert, and a graphic designer, advised by the other members of the overall Center team; the care and time taken to design and complete the website is emblematic of the type of integration and consideration that we espouse in this paper.

The CCL website also represents the first time that CLEAR and its predecessor programs had made actual data from our landscape research available to the public. Previously, land cover data and maps had been presented to towns within the carefully controlled framework of educational workshops. In the case of the CCL, Center principals felt that the data was so important, and could potentially be used in so many ways by a wide variety of organizations, that it necessitated more complete public access. This decision was arrived at despite concerns that people would misuse the data, either due to misunderstanding or, in rare cases, knowingly (to bolster a particular cause). Accordingly, we created a thorough 'What We're Measuring' section to help protect against the first scenario; for the second scenario there is no real protection, but our feeling is that the risks are more than counterbalanced by the benefits of making the data available to all.

The CCL website provides project results in multiple formats, in order to enhance accessibility to a wide spectrum of potential users. For local officials and the general public who do not have GIS software and may not have any experience with geospatial technology, results are presented in large format Adobe *Portable Document Format* (pdf) files that require only the free Adobe Acrobat Reader software. The zooming and panning functions of Reader allow for moving in, out and around each of the four statewide land cover maps, as well as change maps for each time period. A second user-friendly way to view CCL data is the online interactive map. ESRI's ArcIMS software is used to serve the data layers, including all four land cover maps, the change map, a town layer and watershed

layer. All the data layers along with simple tools for moving around the map are available in a basic web browser, and no special software is required.

The web site also features 'Your Town' and 'Your Watershed' sites that allow the user to select an area of interest and get project results for that area. Searchable database protocols are used to provide town- or watershed-specific reports that include maps, data tables, statistics and, in some cases, animations depicting growth during the 17-year project period. Finally, at the high tech end of the spectrum, GIS users can download the data in both ESRI grid format and ERDAS Imagine *.img format. The entire study area can be downloaded along with smaller areas of the state subset by county, planning region, or major watershed. In the future, the CLEAR team hopes to use ArcIMS software customization to enable real-time *clip and ship* capabilities so a user can define any area for download.

The visibility and accessibility provided by the website resulted in a considerable surge of publicity and interest. Project results were featured on the front page of the Hartford Courant newspaper right after its release in January 2004. In an editorial in the same paper two months later, the paper noted that *'…it is timely that policy-makers have an important tool to sharpen the conversation [on sprawl and smart growth] --computer maps made available by the University of Connecticut's Center for Land use Education and Research (CLEAR)... The maps speak louder than an army of "smart growth" advocates for the benefits of regional planning and property tax reform in protecting the environment, economy and quality of life.'*

The website is being used. For instance, the 'Your Town' site was used by an average of about 1500 visitors per month during the first six months of 2007. Since the debut of the website over 300 separate organizations have downloaded the data; the first two organizations to do so, in fact, were The Nature Conservancy and the Connecticut Home Builders Association, which is perhaps symbolic of our goal to provide unbiased, research-based information to all sides of the land use debate.

<u>Building on the changing landscape project: an iterative process of research and outreach</u>

The CCL project has led to a number of follow-up and derivative projects. CLEAR researchers had always planned to use the multi-date land cover data as input into the urban growth, impervious cover and forest fragmentation models that had been developed under the NASA Center. However,

our need to respond to the strong interest in the 'basic' CCL change data has delayed dissemination of the model results to the present time.

The forest fragmentation and urban growth analyses are meant to go beyond the quantitative focus of the land cover change data to a qualitative perspective on the impacts of the change. The models are based on a technique developed by the U.S. Forest Service for analyzing forests on a global scale (Riitters et al. 2000), and were adapted by CLEAR for use with 30-meter data. They systematically analyze the approximately 14 million pixels of the Connecticut CCL database, looking at each and every pixel in relation to the pixels surrounding it (Civco et al. 2002, Wilson et al. 2003). The forest fragmentation model, for instance, characterizes forest cover pixels on a scale from 'core forest' (forest completely surrounded by more forest) to 'patch forest' (forest completely surrounded by development) (Hurd et al. 2002). Comparing the fragmentation map to the simple forest cover map, both extracted from the 2002 land cover, provides insight as to how these types of analyses provide a more qualitative perspective (Figure 4).

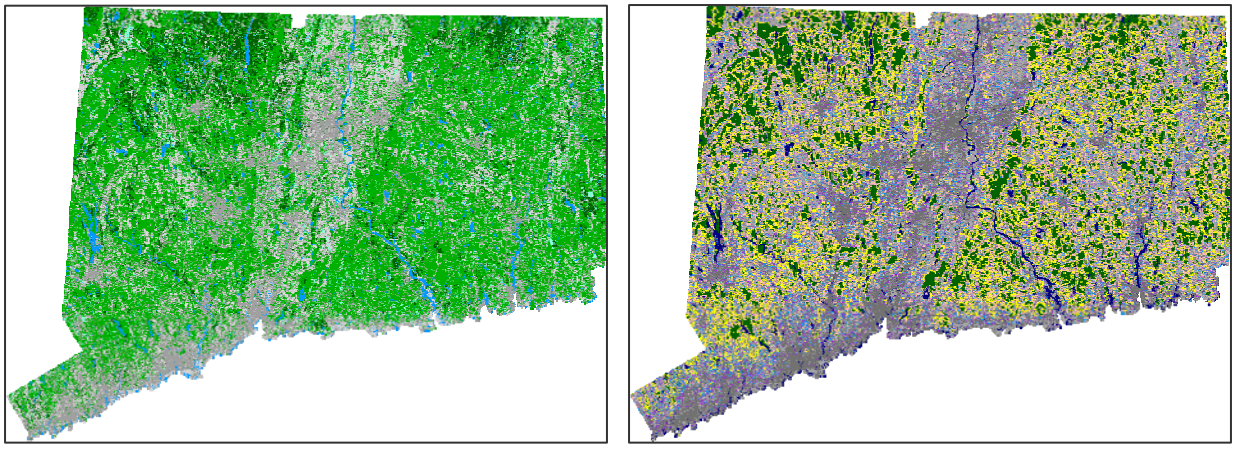

Figure 4. 2002 forest cover map of Connecticut shows 59.3% of the state in forest cover (green). A different perspective is provided by the 2002 map of the CLEAR forest fragmentation model, which shows 18.1% of the state in 'core forest,' (green) a category with minimal disturbance from development. Other colors on right depict other categories of forest.

The Center also has responded to CCL-related research requested by state and federal agencies. For example, the Long Island Sound Study National Estuary Program requested that CLEAR use the CCL data to investigate land cover and land cover change within riparian (streamside) corridors along the Connecticut coast. This study is meant to be provide a 'triage' of which coastal

watersheds are in most imminent danger, and thus candidates for protection and/or restoration. In addition to its intended use for management purposes, the riparian corridor study is providing the research base for a new NEMO educational program for coastal municipalities on riparian buffer protection. This, in turn, has stimulated interest by the CLEAR research team in looking at high resolution imagery for buffer analysis, as a potential management tool for coastal towns. This type of iterative loop, where research, application and outreach each generate further ideas and possibilities for the other parts of the organization, is an objective of all CLEAR programs.

Training & tools

Training in the use of geospatial technologies is a small but very active portion of CLEAR conducted by the Geospatial Technology Program (GTP). The goal of GTP training is to help municipal officials, professional staff and other interested citizens understand and apply GIS, global positioning system (GPS) and remote sensing technologies to the task of planning their communities. GTP conducts approximately four five-day GIS and six two-day GPS courses per year for a mixed audience of local land use officials, town staff, nonprofit and agency staff, and academics; this is a full schedule for a program that consists of only two full time staff who are also involved in research and tool development.

From 2002 to early 2007, the GTP trained about 175 people in GIS technology, and 150 in GPS technology. About 54% of the GIS trainees were from local government. The idea that increasing numbers of volunteer decision makers, as well as professional staff, would want to learn GIS technology is something that most CLEAR principals did not foresee even in the early 2000's. However, it is clear that this trend is continuing, and other Land Grant universities that provide this type of training see a similar trend. This is one factor in the growth of the National Geospatial Technology Extension Network, a group of geospatial experts now residing at 14 Land and Sea Grant universities.

CLEAR technical tool development involves not only the GTP, but the research and outreach programs as well. Three brief examples of Center work in this arena are given here.

ISAT

As has been noted, many CLEAR programs have an interest in impervious cover, which has been shown by national studies to be a reliable and useful landscape indicator of the impact of development on water resources. CLEAR researchers have a long history of investigating this particular land cover (Chabaeva et al. 2007, Civco and Hurd 1997, Civco et al. 2006, Flanagan and Civco 2001). In an effort to turn this research into useable tools, in 2000 the GTP and National NEMO Network developed a prototype GIS analysis of impervious cover that could be used by local planners, managers and decision makers in land use and watershed planning. Using impervious surface coefficients with land cover and factoring in population density data, the analysis estimates the percentage of impervious cover for any geographic area (typically a watershed) selected by the user (Figure 5); it can also be used to estimate future levels of imperviousness under various development scenarios. However, turning this prototype into a robust tool suitable for widespread use was a task outside the capabilities of CLEAR staff, so we turned to the NOAA Coastal Services Center, who partnered with UConn to create the *Impervious Surface Analysis Tool* (ISAT), which is an "extension" that can be used as part of the popular GIS software ArcView.

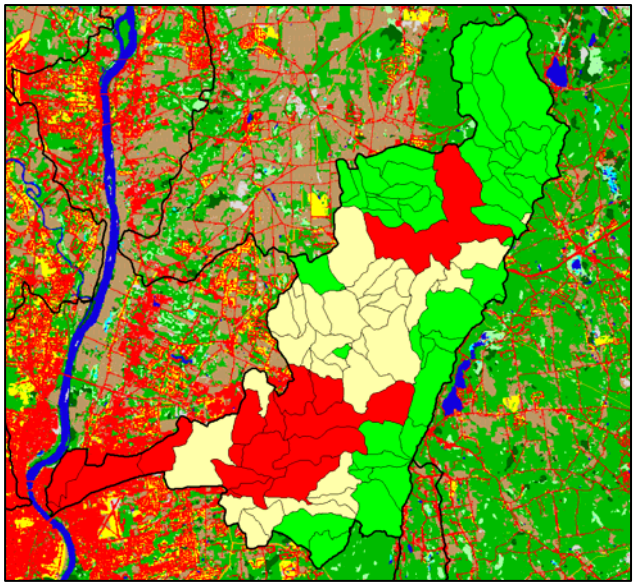

Figure 5. ISAT analysis for the Hockanum River in the urbanized Hartford, CT area. The data is depicted by local basin area (gray lines) and the color scheme is the same as in Figure 1, based on the thresholds found in the literature. Land cover provides the regional backdrop for the watershed map.

After the ISAT was tested in-house by NOAA and UConn, the two partners held a National NEMO Network workshop in October 2002. The workshop had three objectives: (1) to train interested Network projects in the use of ISAT; (2) to solicit feedback from GIS savvy NEMO Network staffers, and; (3) to encourage NEMO programs to develop local datasets to drive ISAT, since the tool is most accurate when region-specific impervious surface coefficients are used. Launched by the workshop, ISAT is being used widely around the NEMO Network, and is available for free download at the NOAA CSC website; an evaluation of who is using the tool for what

purposes is being planned by CSC. In addition, CLEAR research has nearly completed an improved version of ISAT that uses a regression model to factor in census tract population density data (Chabaeva et al. 2004).

Forest fragmentation tool

The ISAT example encouraged CLEAR principals to convert other CLEAR research models to practical GIS tools. In this case, the subject was the forest fragmentation analysis described in the previous section; again, CLEAR needed a partner with the code-writing expertise to make the conversion. To do this, CLEAR formed a public-private partnership with Placeways, LLC. Placeways designs, develops, and distributes interactive analysis and visualization software. Placeways' flagship product, *CommunityViz,* is a GIS-based software package developed in partnership with the Orton Family Foundation that is widely used by land use planners and resource managers to analyze and visualize potential development scenarios.

The fragmentation tool is being made available in two forms. Similar to the ISAT collaboration, the tool has been converted to a 'stand-alone' GIS tool suitable for use by more advanced users of ESRI's ArcGIS software; the tool is available for free download on both the CLEAR and Placeways websites. It has also been incorporated into the latest version of *CommunityViz,* in the form of a largely-automated 'wizard' that makes it easy for CommunityViz users to use. The hope is that a CommunityViz 'landscape toolbox' populated with other CLEAR-based models will eventually be completed. From the standpoint of the authors, this collaboration has two major benefits: first, it will put CLEAR tools into the hands of professionals across the globe, thus widening our audience, and; second, it will provide the opportunity for CommunityViz users, who use the software most frequently for site-level planning and design, to 'step back' and put their site considerations within the context of larger scale landscape considerations – an overall CLEAR objective. A National NEMO Network training in the use of the tool is being planned for 2008, as part of a USDA-funded Network initiative to help NEMO programs fold the topic of forest protection into their educational programs.

Online Community Resource Inventory

While there has been a proliferation of geospatial tools in recent years, many of these technologies are only available to communities with sufficient resources to invest in the software and staff

necessary to support their proper application. For other communities dependent solely on volunteer citizen planners, the greater potential may not be in traditional geospatial tools such as ISAT or Forest Fragmentation, but in new web-enabled technologies that do not require GIS expertise (Rozum et al. 2005). The last example of CLEAR technical tools is the 'poster child,' to date, of our increasing effort to provide easily used and accessed web tools that do not require any specialized expertise. The Online Community Resource Inventory (CRI) (http://nemo.uconn.edu/tools/cri) is a website created by the Connecticut NEMO Program that enables visitors to create a series of key natural and cultural resource maps for any of the state's 169 municipalities, without any specialized knowledge of mapping or computer mapping technology.

Technically, the CRI is an expansion of the multiple access methodology first attempted for the CCL website (previous section). Topically, however, it is quite different than the CCL website. While the CCL was designed to disseminate and convey research results, the CRI is designed specifically as a technical enhancement to CLEAR educational programs.

In the course of their work with Connecticut communities, NEMO, GVI and other CLEAR outreach programs have long espoused the need for a natural resource inventory, as the first step toward natural resource-based land use planning. The CRI attempts to support this process by providing a simple series of maps that depict essential information for land use planning at the local level. The maps are based on statewide available data from state agencies and the university, and include water resources, land cover, protected open space, and wetland and farmland soils, in addition to such cultural information as roads and utility service areas. In addition to providing easy access to maps, a major purpose of the CRI is to winnow the sometimes overwhelming number of maps and data layers now available to the basically proficient internet and GIS user. Thus, much debate between the CLEAR team and an advisory committee had to occur before the final map series was determined.

Once a user chooses the town of his or her interest, the website searches databases of statewide resource information to create a series of 14 key resource maps for the town. The user can page through the maps over the web (Figure 6) and print them out in pdf format. The newer version of Adobe Acrobat allow multifactor pdf maps in which the user can turn data layers on and off, thereby creating a document that mimics some basic GIS functionality.

As with the CCL website, the CRI contains an interactive mapping site so users can create, view and print customized maps of the geographic area of their choice, and combine two or more of the data layers together; this goes from the simple inventory function to support more analytical planning tasks. Finally, while the site is specifically designed to give access to non-technical types, it can also be a resource for GIS users, who can connect their desktop data layers to all CRI datasets on the internet mapping site through the use of the free ArcExplorer ESRI software. In this way, a local planner or volunteer can combine the CRI data with key local data layers like parcels and zoning.

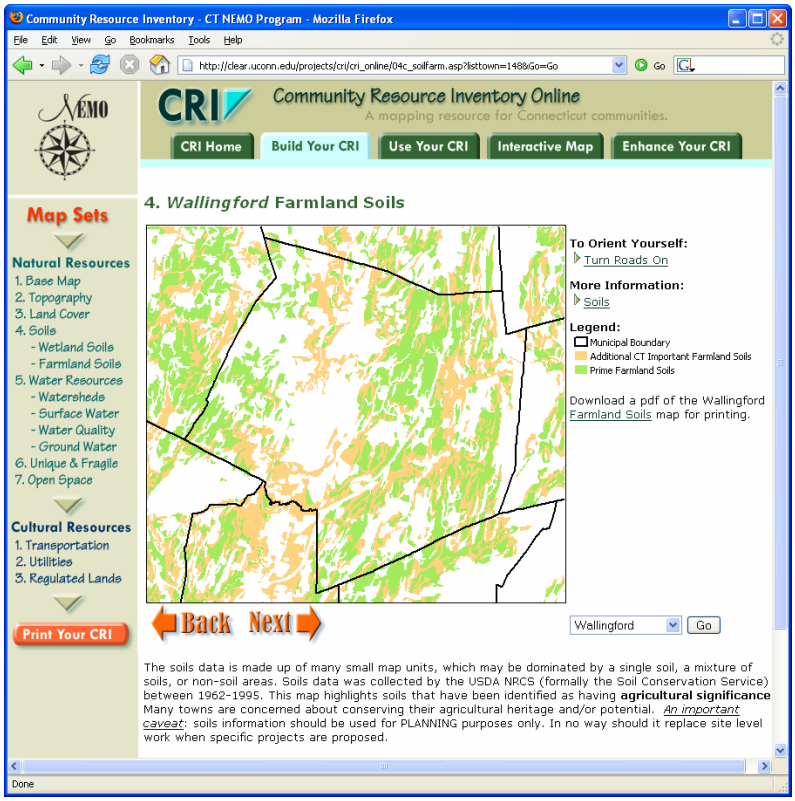

Figure 6. Screen capture from Online Community Resource Inventory, showing the Farmland Soils map for the town of Wallingford, CT. The screen has links to metadata, and a pdf file can be downloaded and printed by the user. The entire inventory map series can also be downloaded and printed together, in one pdf file.

The CRI has been in place only since January of 2007, but is being used at the rate of about 100 unique visitors per month. In the future, a high priority for the NEMO team is to link CRI data layers to Google Earth, so that users can view the data overlain on a base image of their town.

Center impacts

CLEAR programs have helped to address land use issues at a number of levels. On the national level, through conference presentations, journal and popular articles and constant pestering of agency officials, CLEAR principals have sought to highlight the critical importance of local land use officials as a target audience, the absolute necessity of employing outreach education as the primary

framework with which to address these issues, and the vast potential of geospatial science and technology to help inform and enhance that outreach.

Of more import is our work on the ground. National NEMO Network programs are working with communities in 30 states (Figure 7), catalyzing changes to local plans, regulations, and land use procedures (Dickson and Arnold 2005; Rozum and Arnold 2003). The CLEAR-based Network 'Hub,' which formerly had concentrated on starting new NEMO programs, is now heavily engaged in providing both topical and technical training to Network members in order to improve their effectiveness in effecting local change. For instance, network training on open space planning education was conducted in collaboration with the EPA 'Smart Growth' Office in 2002, and NEMO Network members will be trained in incorporating forest resource protection into their programs in September 2007, in collaboration with USDA/CSREES and USDA Forest Service. On the technical side, the Network Hub is partnering with the NOAA Coastal Services Center, the National Geospatial Technology Extension Network, the National Association of Counties and others on several training programs involving geospatial technology and tools. For instance, with NOAA support the Online Community Resource Inventory is being 'franchised' and adapted to at least three other NEMO programs within the Network.

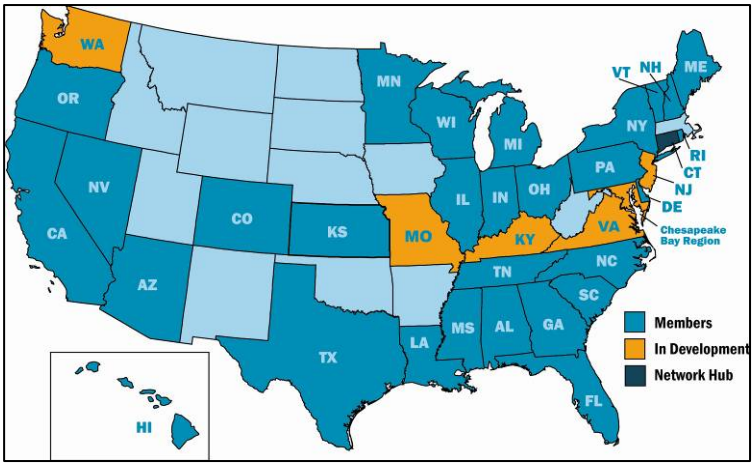

Figure 7. States with a charter program of the National NEMO Network are shown in dark blue. Orange depicts states that are considering a program.

At the state level, as has been described, CLEAR land cover data is being used by a wide range of entities, from academia to state government to local government. About 4800 unique visitors go the CLEAR web site each month for imagery, data, and information. The GTP is training local officials, land use professionals and others in the use of geospatial technology. The NEMO program has had an influence over several state plans and programs, including the state coastal zone management plan, nonpoint source pollution plan, and stormwater quality manual. And GVI and NEMO are working on a daily basis with communities, providing education on a variety of topics and processes

related to better land use planning and natural resource protection; both have won national awards for their work.

NEMO, in particular, has a well-documented history of assisting communities. Community actions include: foundational research and/or information gathering; changes to the land use decision making procedure or structure; changes to plans; changes to regulations, and; on-the-ground changes, such as open space preservation and the construction of low impact development subdivisions. Examples of all of these can be found in the latest NEMO impact report (Rozum and Arnold 2004).

Discussion and recommendations

Educating and assisting land use decision makers is an overwhelming task. The authors would like to think that CLEAR has made a small but noticeable dent in the problem, but challenges and frustrations remain.

A major frustration is the usual lament – lack of resources. At this point, there are about 15 faculty and eight staff that spend more than half of their time on CLEAR programs. All but five of these 23 people are on 'soft money,' dependent on grants. The struggle to keep these people on board is emblematic of the agency 'mission gap' discussed earlier in this paper, but universities cannot exclude themselves from this charge. A strong case can be made that the Land and Sea Grant systems, despite the fact that they have the ideal mission and structure with which to tackle the subject of land use, are not, as a system, truly embracing this issue (Arnold 2000).

Integration and iterative feedback between the three 'bins' of CLEAR remains the ever-present goal, the greatest success, and yet also the greatest frustration of the Center. To the extent that the Center works as a cohesive unit, it is due to considerable effort on the part of the component program principals to communicate and coordinate. At CLEAR, despite our emphasis on outreach we remain 'dissemination limited.' In other words, our core research shop of four people can create information faster than the rest of us can plan and implement ways to disseminate it to the Center's standard of usefulness and accessibility.

The authors feel that academia, and the Land and Sea Grant Universities in particular, can still fill a critical niche in the land use equation. Research and education, when painstakingly and thoughtfully coupled, provide a resource for local officials that cannot be duplicated by broad-brush legislative solutions or by narrowly focused regulatory programs. The U.S. General Accounting Office came to the same conclusion, stating that financial incentives, technical assistance, and education of local governments were the three keys to land use decisions that better protect air and water resources (U.S.G.A.O. 2001).

Our conclusions as to how science can serve society in making more rational local and regional land use decisions, then, not surprising mirror our own hopes and goals for CLEAR. First, there must be greater commitment of resources at the federal and state levels toward community land use assistance. This is largely out of the control of academia, and yet there needs to be more education of these agencies to help them find creative ways to grasp the issue within the confines of their missions. Given the nature of the target audience described in the beginning of this paper (*e.g.*, high turnover, lack of technical support), these federal resources must be sustained, rather than applied as a quick pulse.

Second, a greater commitment must also be made by academia, especially the Land and Sea Grant systems. Tenure track lines may be at a premium, but committing 'hard money' resources to land use research and outreach programs will allow not only for greater efforts, but for greater integration, as faculty become less at the mercy of patching together disparate grant-funded projects and more able to spend time on planning and coordination. We see this starting to occur within the National NEMO Network: five years ago, virtually all Network projects were grant funded, but now over half of Network programs get at least partial support from their host university.

Third, there should be renewed effort on the part of academia to foster and reward integrated programs. The same level of creativity, effort and thought typically expended for research needs to be applied to the other two sides of the triangle, applications and outreach. And, it also needs to be applied to the integration of the three, which is almost a separate discipline in itself. It is the authors' opinion that this type of integration is absolutely necessary if academia is to have impact on the world of land use decisions. Admittedly, it holds academia to a higher (or at least different)

standard, that of the *engaged university* long promoted by the sponsor of this conference, the National Association of State Universities and Land Grant Colleges (NASULC 1999).

Fourth, work on tools/applications to assist land use officials should focus more on access rather than on analysis. Land use decisions are made with imperfect knowledge, and the tasks with which communities need help are often simple, such as assembling a natural resource inventory. Our efforts, therefore, should focus on web-enabled tools and other techniques that will be used, rather than on complex analytical models to satisfy the technical and scientific mind.

Last, we must not shy from the fact that face-to-face education is the most effective means with which to influence land use decisions. Technical tools can bring much to the table and provide great assistance, but our experience at CLEAR is that the real change is engendered in those 9:30 pm discussions in town hall, when all of the complexities and consequences can be laid on the table and examined. Education means bodies, which means considerable resources, but such is the need if academia is to truly weigh in on the land use issue. Our experience at CLEAR and across the nation demonstrates that communities can accomplish any number of great things, once catalyzed and supported by an integrated program of research, tools, training and education.

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