CHAPTER 10

LAND COVER AND CONSERVATION: FROM PROTECTED AREAS TO LANDSCAPES

John A. Wiens[*1], Mark G. Anderson†, and Timothy Boucher[*]

* The Nature Conservancy, 4245 North Fairfax Drive, Suite 100, Arlington, VA 22203.
† The Nature Conservancy, Eastern Resource Office, 11 Avenue de Lafayette, 5th Floor, Boston, MA 02111.

ABSTRACT

Protected areas are the foundation of conservation efforts at local to global scales. Although the development of formal reserve-selection procedures and conservation planning at multiple scales has made the identification of priority areas for protection increasingly data-based, the resulting areas are often treated as if they were internally homogeneous islands in an equally featureless but unsuitable landscape. Land-cover data, however, show that such conservation areas are not only internally heterogeneous, but that they are embedded in an equally heterogeneous landscape mosaic. The conservation value of a protected area is affected by this internal structure and by the spatial structure and dynamics of the landscape context. Because protected areas by themselves cannot ensure the persistence of biodiversity, it is necessary to include the broader surroundings of these areas in the conservation equation. These are the places where people live and work, so people and their activities are important features of landscape context. Land-cover data are essential to describing the internal and external texture of protected areas, but information on land use and land-use change is equally important if the conservation perspective is to be expanded from the traditional emphasis on protecting "pretty places" to include landscapes, people, and their uses of lands and waters.

Key words: *conservation, land cover, land use, landscape, protected areas.*

1 Present address: PRBO Conservation Science, 3820 Cypress Dr. #11, Petaluma, CA 94945

All organisms need a place to live. Recognizing this, governments and nongovernmental organizations have focused their conservation efforts on protecting important places. These protected areas – parks, nature reserves, wildlife refuges, wilderness areas, marine protected areas, and the like -- are the cornerstones of national and international efforts to preserve biodiversity and species. The emphasis on protected areas is understandable given the magnitude of land conversion and loss of native habitat in many areas of the world. Over the decade 1990-2000, for example, a yearly average of 16.1 million hectares of forest was lost to clearing (primarily for agriculture) or conversion to plantations (FAO 2000). In Brazil and Indonesia alone, forest loss averaged over 3.5 million hectares per year, but even more developed countries with "first-world" economies such as Australia lost over half a million hectares of forest cover annually. The Millennium Ecosystem Assessment (2005) reported that 2 of the World's 14 major terrestrial biomes (temperate grasslands and Mediterranean forests) had lost more than two-thirds of their area to habitat conversion (again primarily to agriculture) by 1990. It is little wonder that habitat loss has been called the greatest single threat to biodiversity (Wilcove et al. 1998).

Globally, the move to establish protected areas for conservation has gained impetus from the Convention on Biodiversity, which mandates that signatory countries will place 10% of each of the World's ecological regions under conservation protection by 2010. According to the International Union for the Conservation of Nature (IUCN), nearly 13% of the global land surface is now under some form of protection. Such global estimates are misleading, however. Not only is less than half of this in areas managed primarily for conservation (Brooks et al. 2004), but more often than not reserves are located in "the lands nobody wanted" (Shands and Healy 1977) – high elevation, low productivity areas (Scott et al. 2001). In the northeastern United States and Canada, 77% of alpine regions are secured primarily for nature while only 2% of low elevations and 1% of productive calcareous soils are similarly secured (M. G. Anderson, unpublished). Moreover, some of the world's major habitat types are severely underrepresented. For example, globally only 4.6% of temperate grasslands, savannas, and shrublands and 5% of Mediterranean forests, woodland, and scrub are under some form of conservation protection (Hoekstra et al. 2005).

How much is enough? The Convention on Biological Diversity set a goal of protecting 10% of the world's habitats, while The Nature Conservancy has a goal of protecting 10% of the world's major habitat types (or biomes) by 2015 (while recognizing that this level of protection may be insufficient as a long-term goal). Minimal estimates based on representation alone suggest that 16% to 27% will be necessary just to represent resilient examples of all ecosystem types and populations of vulnerable species (Anderson et al. 2006). Some projections (e.g., Svancara et al. 2005; Tear et al. 2005) suggest that protection of as much as 30% of the area of the world's habitats will be needed to ensure the persistence of contemporary biodiversity. Setting aside the question of whether such an ambitious goal is even feasible in a world of growing populations and accelerating demands on natural resources, it is our belief that setting aside protected areas *by itself* is not a realistic strategy to ensure the persistence of the earth's biodiversity. Instead, conservation efforts must be expanded to include the places where people live and work (Redford and Richter 1999, Miller and Hobbs 2002).

It is in this context that analyses of land cover, land use, and land-cover change become critically important to conservation. To understand what such analyses have to offer, however, it is first useful to consider how approaches to the protection of places for conservation have developed.

THE HISTORICAL VIEW

Traditionally, places were targeted for protection because they had some extraordinary aesthetic value (e.g., national parks), had recreational or indirect economic benefits (e.g., wildlife refuges for game species), because there was an opportunity to protect an area with some apparent conservation value (e.g., many nature preserves owned by land trusts or conservation organizations), or because other uses of the areas were not immediately apparent (e.g., some wilderness areas). Often such protected areas were viewed for simplicity as internally homogeneous areas embedded in a different, but equally homogeneous, matrix. Moreover, the matrix was usually considered as unsuitable or inimical to the organisms occupying the protected area. Of course, land managers and conservationists working on the ground have known and appreciated (and even managed for) the heterogeneity of habitats both within and outside of the protected areas, but it has been practical to ignore such details, for three reasons.

First, until recently most land management for conservation has been carried out in landscapes that have already suffered decades or centuries of human use. Natural habitats have been severely fragmented, and scattered pieces are all that is left to protect. These fragments are usually discrete, sharply bounded, and clearly different from their surroundings, which more often than not seem to be clearly unsuitable (agriculture, developments, and the like). It is easy to simplify the landscape into a black-and-white pattern of suitable patches immersed in an unsuitable matrix (Wiens 2007).

Second, thinking about reserves in the conservation community has been dominated by the island biogeography model. Patches of suitable habitat were often considered as analogs of real islands surrounded by ocean expanses. The formalisms of island biogeography theory (MacArthur and Wilson 1967), which model the species richness of islands as functions of colonization and extinction rates that are largely dependent on island size and isolation, provided a compelling rationalization for the design of nature reserves (Diamond 1975; Shafer 1990). This perspective was reinforced by the development of patch-matrix approaches in landscape ecology (Forman 1995; Wiens 1995; Poiani et al. 2000). Despite criticisms of the island biogeography model in the ecological and conservation literature (e.g., Zimmerman and Bierregaard 1986; Haila 2002; Lindenmayer and Franklin 2002), it continues to find an outlet in a good deal of conservation planning and management.

Third, because areas of remnant natural habitat are often small (especially in much of Europe, eastern North America, and Australia) and land ownership is diversified, land management has frequently been conducted at relatively fine spatial scales (tens to hundreds of hectares). At these scales, it is easier to view patches of habitats to be protected as being internally homogeneous than it is at broader spatial scales, where consideration (and management) of internal heterogeneity may be unavoidable.

FROM PLACES TO PLANNING

Over the past two decades, thinking about which areas to protect for conservation has progressed from an opportunistic focus on “pretty places” or places harboring remnant populations of particular species of concern to more targeted conservation planning. This planning, by both private groups and public land-management agencies, has advanced well beyond the simplistic view of “parks as islands” to consider a broader array of spatial and compositional factors. But in the end, it is still about protecting places.

Several approaches to prioritizing places for conservation have been advanced (reviewed by Groves 2003); here we briefly describe the approach developed by The Nature Conservancy (TNC).

Rather than organize planning efforts about political units (states, counties, etc.), *ecoregions* (relatively large regions distinguished by similar climate, macrotopography, and biota; Bailey 1998) are used as the basic areas within which conservation efforts are to be prioritized (Figure 1). Using structured assembly rules or formalized algorithms developed from the reserve-selection approaches de-

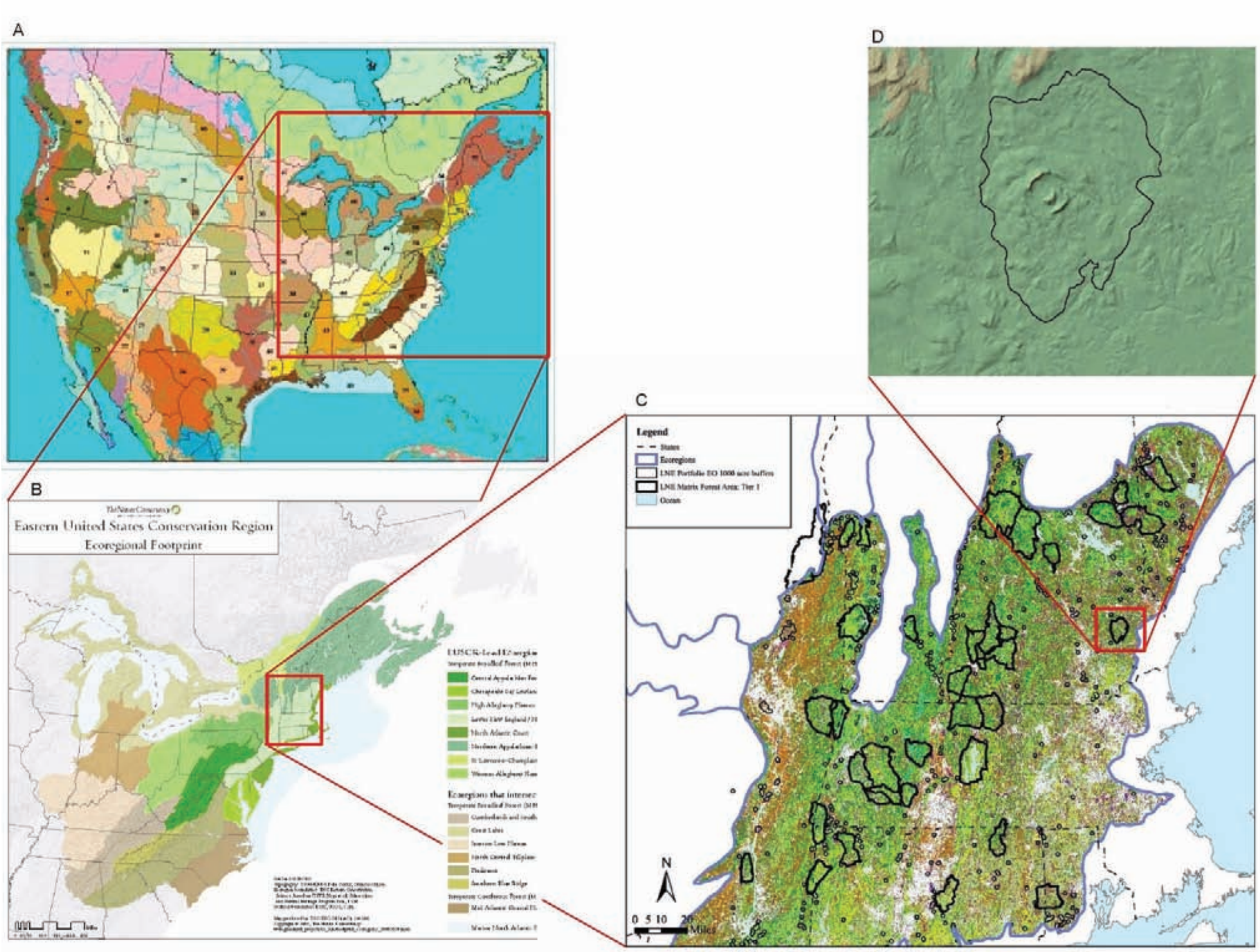

Figure 1. The sequence of The Nature Conservancy’s conservation planning. A. The ecoregions of North America (modified from Bailey 1995); B. The ecoregions of northeastern United States; C. The portfolio areas identified in the Lower New England/Northern Piedmont ecoregion by the process of ecoregional planning; D. A conservation action area within the Pawtuckaway Forest portfolio area in New Hampshire.

veloped by Australian scientists (e.g., Pressey et al. 1993; Margules 2005), ecoregional planning (or ecoregional assessment) compiles information on key targets (ecosystems, ecological communities, species of particular concern) and threats to identify a set of *portfolio areas* within an ecoregion that collectively contain the key elements of the biodiversity that characterizes the ecoregion. The portfolio areas are not themselves protected areas or necessarily areas slated for complete protection, but are areas within which local conservation actions to ensure protection of biodiversity are focused to conserve the critical features and populations identified. The initial action is usually some form of land protection, often through purchase and ownership (or transfer) of land or establishment of a conservation easement that restricts uses of an area in ways that protect the plants and animals living there (Byers and Ponte 2005). A conservation action plan is developed to guide management or restoration efforts by assessing the status of key biological targets and the factors that threaten their persistence. The sequence from ecoregions to portfolios to conservation areas is depicted for a site in the northeastern United States in Figure 1. To date, TNC has completed ecoregional plans for nearly all of the terrestrial ecoregions that occur in the United States as well as several dozen international ecoregions. Over the past 10 years, more than 500 conservation action plans have been developed.

EXPANDING THE PERSPECTIVE

So how do land-cover data figure into all this planning? Land-cover maps are the basis for determining priorities among areas and selecting sites at the scale of the ecoregion, and for addressing site-selection questions. Such information contributes the base data for landscape context and habitat suitability indices as well as being an integral part of predictive modeling of ecosystem types. Consider some examples from conservation planning in TNC's Eastern US Region. First, a land-cover index was used to evaluate the degree of human alteration of the landscape within and immediately surrounding each occurrence of a species or ecosystem for inclusion in a portfolio (Anderson et al. 2006). The index is calculated by assigning a weight to each land-cover class (0 for natural to 4 for highly developed) and averaging the scores across all pixels comprising the sample area. Second, fragmentation and con-

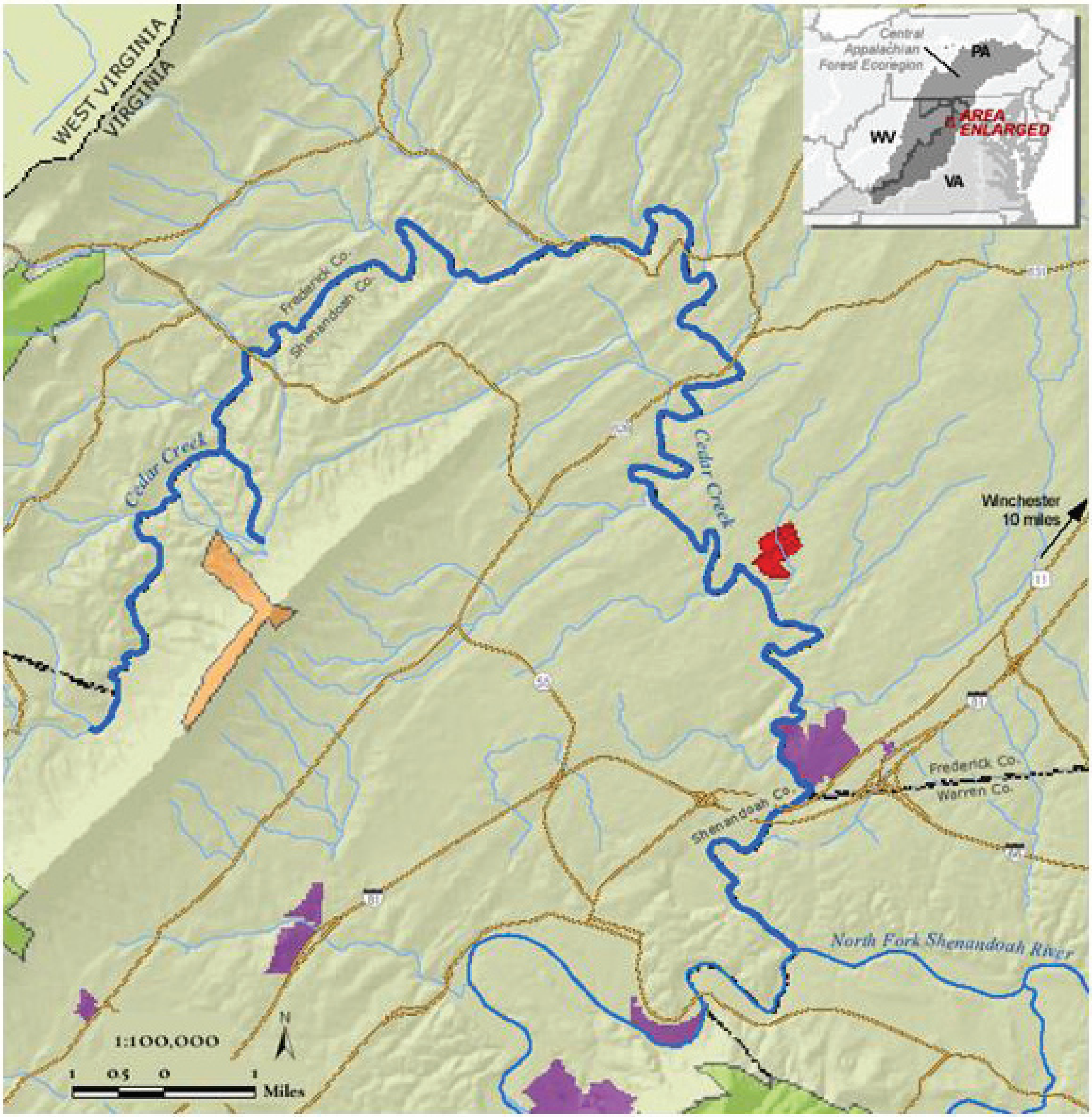

Figure 2. An example of a map accompanying a proposal to purchase a parcel of land (red) as a protected area. Green = National Forest; purple = conservation easement; orange = State Forest.

nectivity analyses (e.g., FRAGSTATS; McGarigal et al. 2002) have been used to measure the degree of continuous natural cover between conservation features based on the number, distribution and configuration of homogeneous patches. Third, high-resolution maps of ecosystems are being developed by combining National Land Cover Data (NLCD) and land-cover/canopy-closure maps with attributes of geology, elevation, and landforms to portray vegetation types such as "closed canopy conifer forest on granite ridges at high elevation" that can be linked to regional classification systems such as

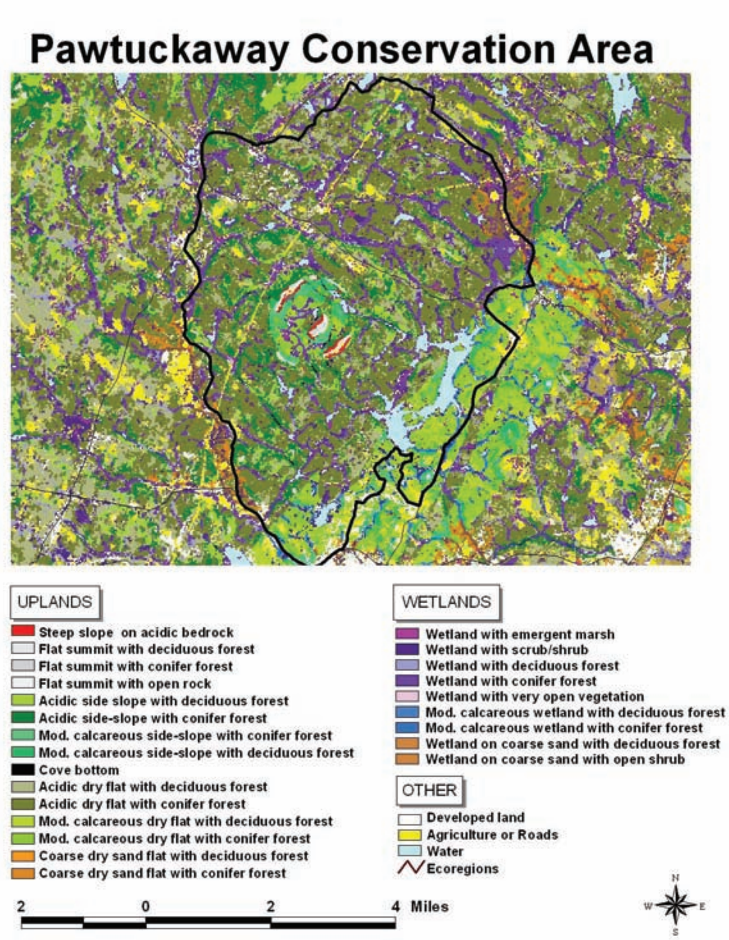

Figure 3. The Pawtuckaway Forest portfolio area, showing coverages of enhanced land-cover map. Land cover is subdivided by geology and landform to approximate an ecosystem type. For example, “acidic dry flat with conifer forest” is equal to “hemlock-white pine forest.”

NatureServe’s National Vegetation Classification (Anderson et al. 1998). In this example, the type corresponds to red spruce-balsam fir/mountain ash forest. Lastly, land-cover data are used to calculate the ratio of habitat conversion (loss) to protection across various ecological settings such as calcareous soils, flood plains, mountain slopes, or lowland valleys. This information is then used to prioritize action across the region (Anderson et al. 2006).

At the local site scale, however, land-cover data have generally been ignored. As an example, Figure 2 shows a map that accompanied a recent (successful) proposal to protect an area in the Central Appalachian Forest ecoregion in Virginia. The target area is shown (in red) along with some major landscape features (rivers and streams, roads, and other areas with some form of protection). But there is no indication of land cover (much less land uses), either within the targeted area or in the surrounding landscape.

Yet we know that such places are *not* internally homogeneous, and neither are the surroundings. Places invariably have an internal structure that matters to the organisms that live there (and which we are aiming to protect) and, more importantly for this discussion, the surroundings are not a featureless matrix but a richly textured mosaic. These are among the main messages that conservationists should glean from the discipline of landscape ecology (Wiens 2002), and they bring land cover to the forefront. The reality is not that shown in Figure 1D, but rather that depicted in Figure 3.

Why is this important? Landscapes are more than just large areas that are scaled in kilometers rather than hectares. Their structure is important. The ecologist Daniel Janzen observed some time ago that “no park is an island” (Janzen 1983), by which he meant that what goes on within a park or protected area is strongly influenced by what goes on and resides in the areas outside the park boundaries. Organisms – predators, competitors, pathogens, prey – move across the permeable boundary, and so also do disturbances such as fire or windstorms. The likelihood of persistence of a population of a species in a seemingly isolated patch of habitat that might be slated for protection may depend on whether

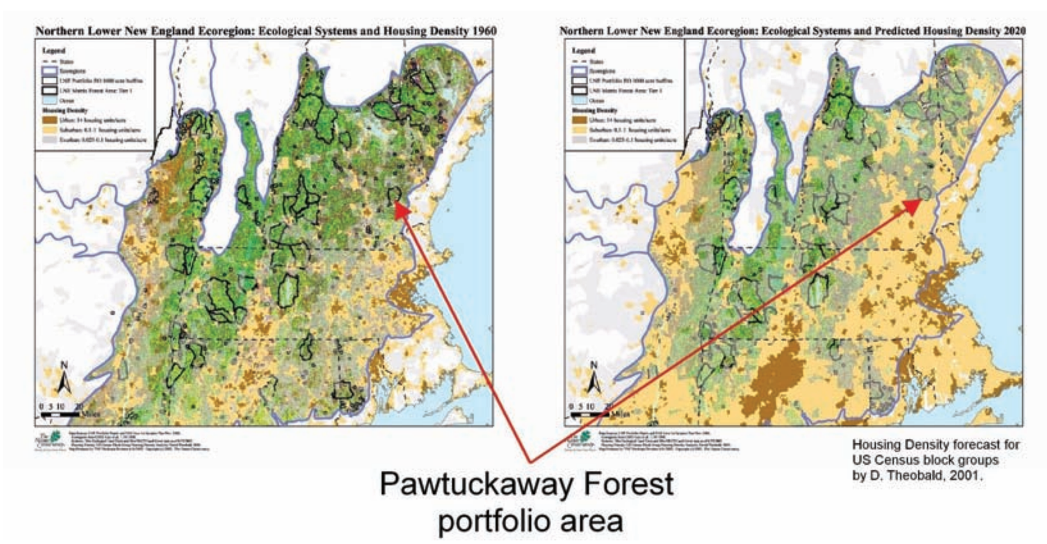

Figure 4. Left. Land cover in the Lower New England.Northern Piedmont ecoregion in 1960, when the area was predominantly rural. Right. Projected land cover in 2020, showing the expansion of urban, suburban, and exburban areas. Land-cover projections based on data developed by Theobald (2001).

the surrounding landscape provides sufficient connectivity to enable dispersing individuals to move to other suitable areas in the landscape (Hanski and Gaggiotti 2004; Crooks and Sanjayan 2006). This, in turn, depends on the composition and explicit spatial arrangement of landforms, vegetation types, and land cover in the landscape mosaic as a whole. This is the stuff of land-cover analysis.

Protected areas and the landscapes that contain them are not static. They are *dynamic*, changing over time as a result of disturbances (e.g., fire, hurricanes, insect outbreaks; Turner et al.1995), changes in human land uses (e.g., the abandonment of agriculture in areas of northeastern United States that resulted in increased forest cover; the conversion of areas of the Brazilian cerrado to soybean agriculture), or, increasingly, global climate change (Lovejoy and Hannah 2005). Models that use land-cover data from previous decades in conjunction with information on the socioeconomic factors driving land-use change to predict future changes in land cover (e.g., Theobald 2005) illustrate how dramatic these changes may be at multiple scales (Figure 4). Clearly, it is not just the landscape context of protected areas that determines their effectiveness in preserving biodiversity, but how that landscape is likely to change over time.

Another example comes from the work of the United States Geological Survey (USGS). USGS has identified the understanding and prediction of ecosystem change as one of its six strategic science goals for the next decade (see http://pubs.usgs.gov/circ/2007/1309/; last accessed 26 September 2007). This goal includes the spatial delineation of ecosystems based on the mapping of land-cover and land-use change at appropriate scales and over time. Toward this goal, USGS has been monitoring land-cover change and use in the eastern United States in order to understand the rates, patterns, and drivers of the changes occurring in the region. The spatial resolution of the analysis (entire ecoregions) is coarse and the land-cover categories very general (Anderson Level I); nonetheless, the analysis shows a 12.5% change in land cover over the region between 1973 and 2000 (Gallant et al. 2004; Loveland and Acevedo 2007). The methodology, which uses a both satellite and aerial imagery to assess land-cover changes in a subset of samples within ecoregions, is being refined and applied to other regions (Loveland et al 2002; Sohl et al. 2004)

WHY DOES CONSERVATION NEED LAND-COVER/LAND-USE INFORMATION, AND WHAT INFORMATION IS NEEDED?

We stated at the outset our belief that an exclusive focus on protected areas will be insufficient to realize the goal of preserving a substantial portion of the Earth's biodiversity. The vision must be expanded to include landscape context, texture, and dynamics. Land-cover data enable this vision. But there must be more.

Conservation will not succeed if it is cast as nature *vs.* people; it must be nature *with* people. People and their activities and uses of the landscape must be included in the vision and actions of conservation. This requires a shift from thinking about protected areas as being essentially pristine or totally natural. Such areas are undeniably important and *should* be protected where possible. Yet many human uses of landscapes have some degree of compatibility with biodiversity. By including places that people use, the overall conservation portfolio will be expanded. But there is more to it than this. Yes, it is important to protect natural biodiversity for its aesthetic and spiritual values and because we have a moral and ethical responsibility to do so (McCauley 2006; but see Reid 2006; Costanza 2006; Marvier, Grant, and Kareiva 2006). But natural ecosystems also provide many services – "ecosystem services" – that enhance human well-being (Daily and Ellison 2002; Millennium Ecosystem Assessment 2005; Kareiva and Marvier 2007), so protection of these systems goes beyond idealism to encompass economics and pragmatism.

What this means is that conservation needs more than information on land cover alone. Land-cover information should be linked with spatially referenced data on land *use*, in sufficient detail to distinguish different uses of the same cover type that may have different impacts on biodiversity and thus confer different conservation values on places. To help conservation planning move to the next level, we need multi-scale data on both land cover and land use to facilitate seamlessly integrated analyses. For example, information from local /site-level projects using very high-resolution data (such as Ikonos or Quickbird) could be incorporated into regional planning exercise using high-resolution data (e.g., Landsat and ASTER) that would be directed by global-scale prioritization analyses (derived 250 m – 1 km data such as MODIS). Such data sets must be spatially and temporally consistent and compatible, or else such integration will encounter roadblocks wherever there is a change from one data set to another. To minimize these disruptions, it is also vital to have continuity of existing sensor platforms (such as the current Landsat sensor series) and to make sure that future sensor information is comparable. Sensors that have different resolutions (either higher or lower) should be designed with the compatibility of a wide range of scales in mind. If we are interested in projecting land-cover changes (and we must be, if we are to make conservation investments that hold their value into the future), we will need time-series data sets that enable change detection and on which robust modeling of future scenarios can be founded. Because conservation dollars are hard to come by and the needs are great, the land-cover and land-use information derived from such sources must also be inexpensive and readily available.

The future of the Earth's biodiversity depends on our ability to weave protected areas into the broader tapestry of landscapes and human activities. This, in turn, is predicated on a comprehensive understanding of land cover and land use – past, present, and future. Ultimately, conservation is a geographical as well as a biological and social science.

REFERENCES

Anderson, M. G., P. Bourgeron, M. T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D. H. Grossman, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A. S. Waekley. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume II: The National Vegetation Classification System: List of types. Arlington VA: The Nature Conservancy.

Anderson, M. G., B. Vickery, M. Gorman, L. Gratton, M. Morrison, J. Maillet, A. Olivero, C. Ferree, D. Morse, G. Kehm, K. Rosalska, S. Khanna, and S. Bernstein. 2006. The Northern Appalachian/Acadian Ecoregion: Ecoregional Assessment, Conservation Status and Resource CD. The Nature Conservancy, Eastern Conservation Science and The Nature Conservancy of Canada: Atlantic and Quebec Regions.

Bailey, R. G. 1995. *Description of the Ecoregions of the United States.* 2nd ed. Misc. Publ. No. 1391 (rev.). Washington DC: USDA Forest Service.

------. 1998. *Ecoregions. The ecosystem geography of the oceans and continents.* New York: Springer.

Brooks, T. M., M. I. Bakarr, T. Boucher, G. A. B. da Foinseca, C. Hilton-Taylor, J. M. Hoekstra, T. Moritz, S. Olivieri, J. Parrish, R. L. Pressey, A. S. L. Rodrigues, W. Sechrest, A. Sattersfield, W. Strahm, and S. N. Stuart. 2004. Coverage provided by the global protected-area system: is it enough? *BioScience* 54: 1081-1091.

Byers, E., and K. M. Ponte (eds.). 2005. *The conservation easement handbook*. Washington DC: Land Trust Alliance.

Costanza, R. 2006. Nature: ecosystems without commodifying them. *Nature* 443: 749.

Crooks, K. R., and M. Sanjayan. 2006. *Connectivity conservation*. Cambridge (UK): Cambridge University Press.

Daily, G. C., and K. Ellison. 2002. *The new economy of nature*. Washington DC: Island Press.

Diamond, J. M. 1975. The assembly of species communities. In *Ecology and evolution of communities*, edited by M. L. Cody and J. M. Diamond, 342-444. Cambridge MA: Harvard University Press.

FAO. 2000. On definition of forest and forest change. *FRA Working Paper No. 33*. Rome: Food and Agriculture Organization of the United Nations.

Forman, R. T. T. 1995. *Land mosaics.* Cambridge, U.K.: Cambridge University Press.

Gallant, A. L., T. R. Loveland, T. L. Sohl, and D. E. Napton. 2004. Using an ecoregion framework to analyze land-cover and land-use dynamics. *Environmental Management* **34**: S89-S110.

Groves, C. R. 2003. *Drafting a conservation blueprint: A practitioners guide to planning for biodiversity.* Washington DC: Island Press.

Haila, Y. 2002. A conceptual genealogy of fragmentation research from island biogeography to landscape ecology. *Ecological Applications* 12: 321-334.

Hanski, I., and O. E. Gaggiotti. 2004. *Ecology, genetics, and evolution of metapopulations.* New York: Elsevier.

Hoekstra, J. M., T. M. Boucher, T. H. Ricketts, and C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* 8: 23-29.

Janzen, D. H. 1983. No park is an island: Increase in interference from outside as park size decreases. *Oikos* 41: 402-410.

Kareiva, P., and M. Marvier. 2007. Conservation for the people. *Scientific American* (October): 48-55.

Lindenmayer, D. B., and J. F. Franklin. 2002. *Conserving forest biodiversity: A comprehensive multi-scaled approach*. Washington DC: Island Press.

Lovejoy, T. E., and L. Hannah. 2005. *Climate change and biodiversity*. New Haven CT: Yale University Press.

Loveland, T. R., and W. Acevedo. 2007. Land cover change in the Eastern United States. In *Status and Trends of Eastern United States Land Cover*, ed. W. Acevedo and P. J. Jellison. U.S. Geological Survey Professional Paper (in press).

Loveland, T. R., T. L. Sohl, S.V. Stehman, A. L. Gallant, K. L. Sayler, and D. E. Napton, 2002. A strategy for estimating the rates of recent United States land cover changes. *Photogrammetric Engineering and Remote Sensing* **68**: 1091-1100.

MacArthur, R. H., and E. O. Wilson. 1967. *The theory of island biogeography*. Princeton NJ: Princeton University Press.

Margules, C. 2005. Conservation planning at the landscape scale. In *Issues and perspectives in landscape ecology*, ed. J. Wiens and M. Moss, 230-237. Cambridge, U.K.: Cambridge University Press.

Marvier, M., J. Grant, and P. Kareiva. 2006. Nature: poorest may see it as their economic rival. *Nature* 443: 749-750.

McCauley, D.J., 2006. Selling out on nature. *Nature* 443: 27-28.

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002**.** FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at: www.umass.edu/landeco/research/fragstats/

fragstats.html (last accessed 26 September 2007).

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: Synthesis*. Washington DC: Island Press.

Miller, J. R., and R. J. Hobbs. 2002. Conservation where people live and work. *Conservation Biology* 16: 330-337.

Poiani, K. A., B. D. Richter, M. G. Anderson, and H. E. Richter. 2000. Biodiversity conservation at multiple scales: Functional sites, landscapes, and networks. *BioScience* 50: 133-146.

Pressey, R. L., C. J. Humphries, C. R. Margules, R. I. Vane-Wright, and P. H. Williams. 1993. Beyond opportunism: key principles for systematic reserve selection. *Trends in Ecology and Evolution* 8: 124-128.

Redford, K. H., and B. D. Richter. 1999. Conservation of biodiversity in a world of use. *Conservation Biology* 13: 1246-1256.

Reid, W. V. 2006. Nature: the many benefits of ecosystem services. *Nature* 443: 749.

Scott, J. M., F. W. Davis Jr., R. G. McGhie, R. G. Wright, C. Groves, and J. Estes. 2001. Nature reserves: Do they capture the full range of America's biological diversity? *Ecological Applications* 11: 999-1007.

Shafer, C. L. 1990. *Nature reserves: Island theory and conservation practice*. Washington DC: Smithsonian Institution Press.

Shands, W. E., and R. G. Healy. 1977. *The lands nobody wanted*. Washington DC: The Conservation Foundation.

Sohl, T. L., A. L. Gallant, and T. R. Loveland. 2004. The characteristics and interpretability of land surface change and implications for project design. *Photogrammetric Engineering and Remote Sensing* **70**: 439-448.

Svancara, L. K., R. Brannon, J. M. Scott, C. R. Groves, R. F. Noss, and R. L. Pressey. 2005. Policy-driven versus evidence-based conservation: a review of political targets and biological needs. *BioScience* 55: 989-995.

Tear, T. H., P. Kareiva, P. L. Angermeier, P. Comer, B. Czech, R. Kautz, L. Landon, D. Mehlman, K.

Murphy, M. Ruckelshaus, J. M. Scott, and G. Wilhere. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. *BioScience* 55: 835-849.

Theobald, D. M. 2001. Technical description of mapping historical, current, and future housing densities in the US using census block-groups. Fort Collins CO: Natural Resource Ecology Laboratory, Colorado State University.

------. 2005. Landscape patterns of exurban growth in the USA from 1980 to 2020. *Ecology and Society* 10(1): 32 [online]. http://www.ecologyandsociety.org/vol10/iss1/art32/ (last accessed 26 September 2007).

Turner, M. G., R. H. Gardner, and R. V. O'Neill. 1995. Ecological dynamics at broad scales. *BioScience Supplement* S-29 to S-35.

Wiens, J. A. 1995. Landscape mosaics and ecological theory. In *Mosaic landscapes and ecological processes*, ed. L. Hansson, L. Fahrig, and G. Merriam, 1-26. London: Chapman & Hall.

------. 2002. Central concepts and issues of landscape ecology. In *Applying landscape ecology in biological conservation*, ed. K.J. Gutzwiller, 3-21. New York: Springer.

------. 2007. The dangers of black-and-white conservation. *Conservation Biology* 21: 1371-1372.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* 48: 607-615.

Zimmerman, B. L., and R. O. Bierregaard. 1986. Relevance of equilibrium theory of island biogeography and species-area relations to conservation with a case study from Amazonia. *Journal of Biogeography* 13: 133-143.