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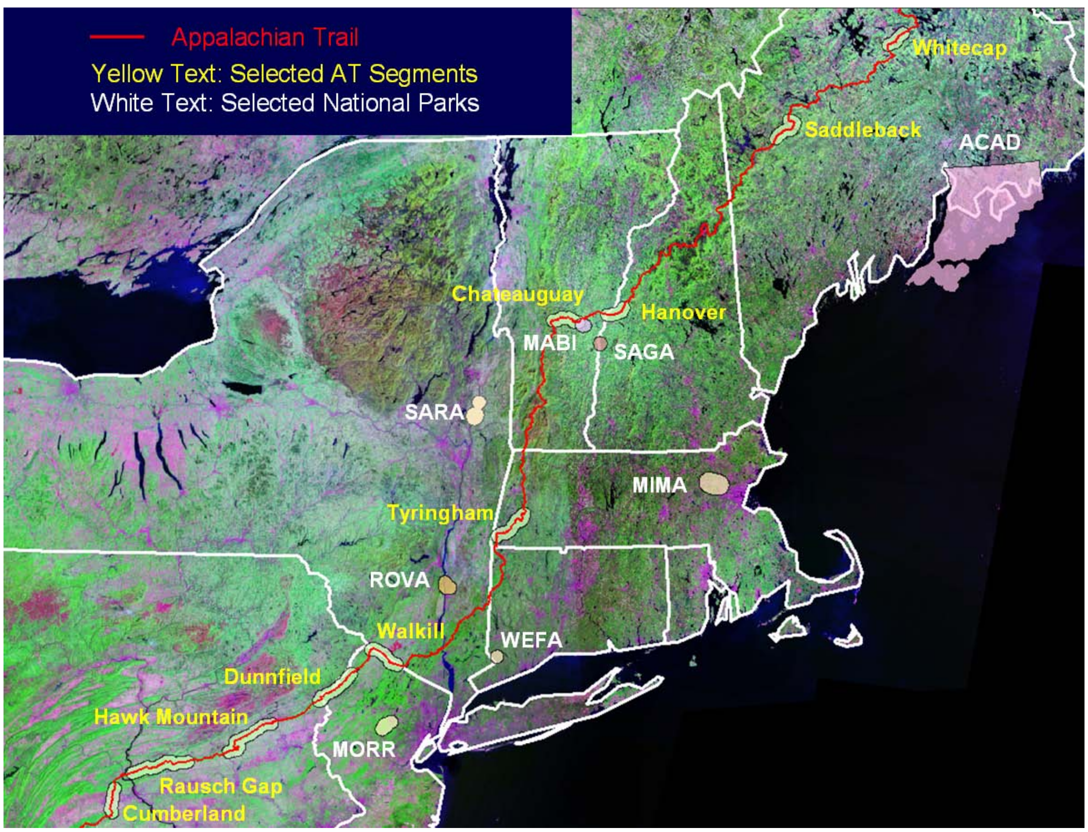
Land Cover Change in Northeast Temperate Network Parks 1973-2002

Natural Resource Technical Report NPS/NETN/NRTR—2009/238



ON THE COVER
Locations of selected NETN park units and Appalachian National Scenic Trail segments displayed on top of a mosaic of Landsat images. Image courtesy of Y. Q. Wang

Land Cover Change in Northeast Temperate Network Parks 1973-2002

Natural Resource Technical Report NPS/NETN/NRTR—2009/238

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Abstract

The Northeast Temperate Network (NETN) has identified landscape dynamics as a high-priority vital sign. Knowledge of historical trends of land cover change can help resource managers establish a landscape context for parks, identify key resources and ecosystem stressors, and prioritize resource management efforts.

The goal of this study was to provide baseline data regarding landscape change near selected NETN park units. We studied three time periods using Landsat remote sensing data to document general land cover types within and surrounding selected NETN parks, and we used selected buffer areas to quantify land cover change within and adjacent to the parks.

The selected National Parks included Acadia National Park; Marsh-Billings-Rockefeller National Historical Park (NHP); Saint-Gaudens National Historic Site (NHS); Minute Man NHP; Morristown NHP; Saratoga NHP; Roosevelt-Vanderbilt NHS; and Weir Farm NHS. The selected sites along the A.T., included segments from Maine to Pennsylvania and totaled about 362 km (225 miles).

We focused on areas within a 5-kilometer (3.1-mi) buffer of park boundaries and the A.T. central line. We started with Landsat data and extracted land cover information using supervised, unsupervised, and stratified classifications, as well as post-classification cross-checking with the NLCD, NWI and NPS vegetation mapping project data sets. We applied 500-meter, 1-kilometer, and 5-kilometer buffers to reveal the spatial pattern and magnitude of land cover changes for each site. We adopted the post-classification change detection methodology to derive change analysis results.

This project provided approximately 30 years of background information on land cover change for the selected NETN parks. Urban Land expansion and forest dynamics represent the main land cover changes in the studied sites. The baseline data provide a foundation for monitoring future changes in land cover. The template protocols could be applied elsewhere for monitoring and understanding the landscape dynamics within and adjacent to protected lands that have different sizes, shapes, and protection/management goals.

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Introduction

The Northeast Temperate Network and Project Background

The Northeast Temperate Network (NETN) consists of 11 parks with diverse cultural and natural resources across seven states (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, and New Jersey), two ecological divisions, and is also coordinating Inventory and Monitoring (I&M) activities for the entire Appalachian National Scenic Trail (A.T.) which runs from Maine to Georgia. Most of the NETN parks were established to preserve and protect significant natural and cultural resources. Minute Man National Historical Park (MIMA) and Saratoga National Historic Park (SARA) mark the beginning and end of the Revolutionary War, respectively, and Morristown National Historic Park (MORR) was a strategic military location for General George Washington. Saint-Gaudens National Historic Site (SAGA) and Weir Farm National Historic Site (WEFA) commemorate the lives of artists. The three park units at Roosevelt-Vanderbilt National Historic Site (ROVA) celebrate the legacy of one of the most significant Presidents in U.S. history, and life during the "Gilded Age" of the late 19th century. Marsh-Billings-Rockefeller National Historical Park (MABI) is the only National Park Service (NPS) unit to focus on conservation history and the evolving nature of land stewardship. Acadia National Park (ACAD) hosts a diverse array of cultural, natural, and geologic resources (Mitchell et al. 2006). The A.T. is a 2,175 mile footpath, envisioned in 1937 by forester Benton MacKaye, and established as the first National Scenic Trail by Congress in 1968. Other than the A.T., the parks that constitute the NETN are located within the temperate deciduous forest biome. This region is exposed to warm and cold air masses, causing it to have four distinct seasons. Temperature varies widely from season to season with cold winters and hot, wet summers. The average yearly temperature is about 10°C. The areas in which deciduous forests are located get about 29.5-59.1 inches of precipitation spread fairly evenly throughout the year (Shriver et al. 2005a).

The NETN intended to document how the general landscape has changed in the vicinity of its respective units. Suburban sprawl, timber harvests, and increasingly fragmented natural habitats are just a few of the factors outside of park boundaries that impact the ecosystems within the parks. Knowledge of historical trends of land cover change (not only how much has changed, but also where and when changes have occurred) can help resource managers identify key resources and ecosystem stressors, and prioritize resource management efforts to further promote the development of a Vital Signs Monitoring Program (Mitchell et al. 2006).

While the term "land use" refers to how the land is being used by humans, "land cover" refers to the biophysical materials found on the land (Jensen 2000). Understanding land cover change will help to establish a landscape context for the parks, offer resource managers a better understanding of how park ecosystems fit into the broader landscape, and will enable managers to better prioritize ecosystem management.

The NETN does not yet have a consistent record of land cover from which to start a network-wide monitoring program. The intent of this project was to provide these essential baseline data. The primary objectives were as follows:

- To document land cover types within and adjacent to the selected sites for three time periods: the early 1970s, mid-1980s, and early 2000s.

- To quantify land cover change within and adjacent to NETN parks using selected buffer areas for the three time periods.

Remote sensing is a proven technology that is effective for mapping and characterizing cultural and natural resources (e.g., Holz 1985, Lo 1986, Jensen 1996, Campbell 1997, Welch et al. 2002). The multispectral capabilities of remote sensing allow observation and measurement of biophysical characteristics (multispectral refers to the detection of multiple ranges or bands of electromagnetic radiation). The multitemporal (repeated over time) and multisensor (e.g., different satellites) nature of remote sensing allows tracking of changes in these characteristics over time (Wang and Moskovits 2001, Wang et al. 2003). Advances in sensor technology and analytical techniques have led to a dramatic increase in the range of applications of remotely sensed data for environmental monitoring (Kerr and Ostrovsky 2003, Turner et al. 2003).

Remote sensing change detection has become a critical and universal tool for natural resource managers in governmental agencies, conservation organizations, and private industry. Remote sensing change detection is a process for determining and evaluating temporal differences of land surface properties using multidate imagery, commonly acquired with satellite based multispectral sensors (Mouat et al. 1993, Coppin and Bauer 1996). The goal of change detection is to discern the areas on digital images that depict changing features of interest (Hayes and Sader 2001). The fundamental assumptions that govern remote sensing change detection include: (1) natural resource managers are interested in landscape phenomena that cause changes in electromagnetic radiation (EMR) values that can be remotely sensed, and (2) any major change over time in remotely sensed data can be associated with an alteration in the reflective characteristics of biophysical properties of the land surface. Many works of published literature summarize and compare the different methods of remote sensing change detection (Lambin and Strahler 1993, Muchoney and Haack 1994, Jensen 1996, Roberts et al. 1998, Mas 1999, Rogan et al. 2002, Woodcock and Ozdogan 2004, Healey et al. 2005).

In general, land cover changes are divided into conversions from one land cover type into another (i.e., between-class changes) and transformations within a land cover type (i.e., within-class change) (Yuan et al.1998). Between-class changes represent an abrupt disturbance of landscape that alters the cover type, such as deforestation. Remote sensing is very effective and has been broadly applied in detecting these kinds of changes. Examples range widely from regional deforestation (Skole and Tucker 1993, Pedlowski et al. 1997, Silapaswan et al. 2001) to suburban sprawl (Wang and Moskovits 2001, Lo and Yang 2002). Within-class change detection identifies gradual transformations within a land cover type. Examples include the degradation of forests and associated habitats due to a variety of natural and anthropogenic factors and forest succession over years with changing biophysical properties such as biomass accumulation (e.g., Hall et al. 1991, Melia et al. 1997). In this study, we focused on the between-class change only.

At the regional level, the potential advantages of satellite images over aerial photographs for change detection include greater cost effectiveness, greater extent of coverage, and the ability to reveal landscape processes at larger landscape scales. Satellite data is commonly used to produce land cover maps that indicate landscape pattern and process.

Study Areas

The study areas jointly selected by project personnel and NETN staff for this project consisted of eight park units in the NETN and 10 selected segments along the A.T. (Figure 1). The eight NETN park units selected were:

Acadia National Park (ACAD)
Marsh-Billings-Rockefeller NHP (MABI)
Saint-Gaudens NHS (SAGA)
Minute Man NHP (MIMA)
Morristown NHP (MORR)
Saratoga NHP (SARA)
Roosevelt-Vanderbilt NHS (ROVA)
Weir Farm NHS (WEFA)

Figure 1 illustrates the locations of the selected NETN park units and A.T. segments on a mosaic of Landsat images. The descriptions of the selected park units provided in this section were adapted from the NETN Vital Signs Monitoring Plan (Mitchell et al. 2006). Note that the issues identified for individual park units, for example invasive species and the impacts of woolly adelgid (*Adelges tsugae*) on forest ecosystems, are not among the primary interests of this study. The time, data, and techniques employed in this project would not allow us to map such subtle changes.

Acadia National Park

Acadia protects 47,498 acres of land, including the highest rocky headlands on the Atlantic shore of the United States. Situated in the Acadian Archipelago of “down east” coastal Maine, and within the Northeastern Coastal Zone ecoregion at 44 degrees latitude, the park is located in a broad transition zone between southern deciduous and northern coniferous forests. Acadia has local habitats ranging from seashore to mountaintop, including old growth spruce forests, wetlands, and jack pine forests. Natural resources in the park include old growth forests, sub-alpine communities, heaths, meadows and marshes, as well as a diverse flora and fauna. Acadia protects and conserves outstanding scenic, natural and cultural resources of glaciated coastal and island landscapes, biological diversity, clean air and water, and a rich cultural heritage. Urban development and increased activities associated with visitors are important concerns for resource management at the park.

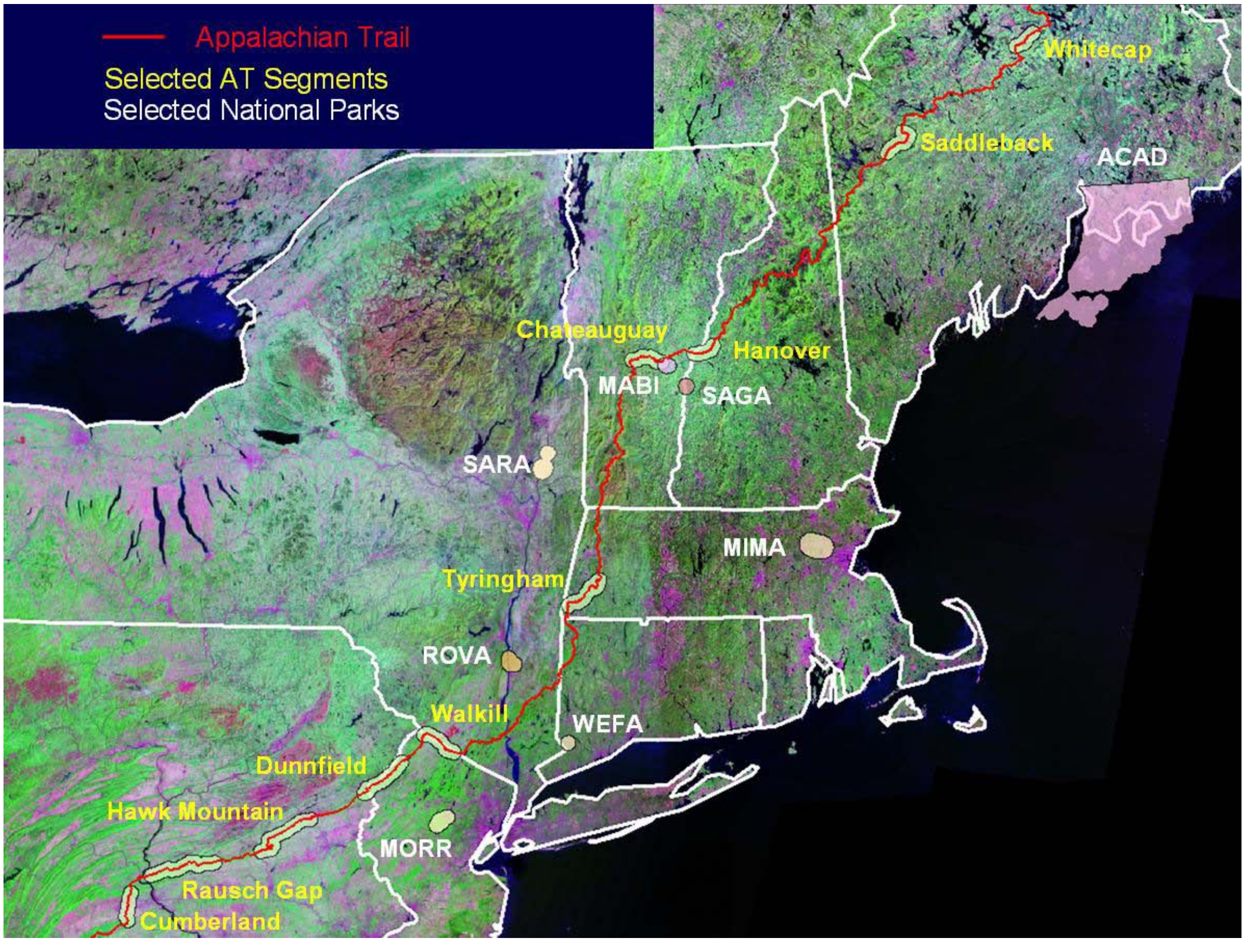

Figure 1. Locations of selected NETN park units and A.T. segments used in this project displayed on top of a mosaic of Landsat images.

Marsh-Billings-Rockefeller National Historical Park

Marsh-Billings-Rockefeller is the first unit of the National Park system to focus on the history of conservation and land stewardship in the United States. The park was gifted to the NPS by Laurence S. and Mary F. Rockefeller, established as a National Park in 1992, and opened to the public in 1998. The park was named for George Perkins Marsh, one of the nation's first global environmental thinkers and author of Man and Nature (1864), and is located in the Green Mountains of central Vermont. The park interprets the history of conservation with tours of the mansion and the surrounding 550-acre forest.

Marsh-Billings-Rockefeller is located in the Northeastern Highlands ecoregion and includes northern hardwoods, conifer plantations, cliff/rocky outcrop communities, open fields, streams, a pond, vernal pools, and seeps. The mansion is a National Historic Landmark and the residential complex and nearby farmlands are parts of a National Historic District. The park represents one of the earliest examples of active reforestation efforts in New England. Coniferous plantations of both native and non-native species were established beginning in the 1880s and presently comprise 26% of the park's area. Reforestation also occurred in many areas as a result of agricultural abandonment, resulting in naturally regenerated northern hardwood, hemlock, and mixed forests. The park's "patchy" forest mosaic reflects this history of alternate reforestation approaches and varied successional trajectories. The park includes a diversity of stand types as well as pronounced visual contrasts and view corridors created by open pastures and fields surrounded by dense forest plantations.

Minute Man National Historical Park

Minute Man was established in 1959 to consolidate, preserve, and selectively restore and interpret portions of the Lexington-Concord Battle Road in Concord, Lincoln, and Lexington Massachusetts. The 750-acre park is comprised of 3 units (i.e., Battle Road, North Bridge, and Wayside) where the opening battle of the American Revolution was initiated, and includes the site of "the shot heard around the world" at the North Bridge.

Minute Man is characterized by flat plains and low-rolling hills varying in elevation from 120 to 307 feet above sea level. The park lies along the watershed boundaries of the Concord River flowing north, the Shawsheen River flowing south, and the Charles River flowing east. The primary resource management objectives of the park are to preserve cultural resources and reestablish the historic landscape. Cultural resources at Minute Man consist of 17 buildings, numerous monuments and archaeological sites, and the historic landscape consists of fields, forest, and wetlands. About one-third of the park is comprised of wetlands, including forested wetland, shrub swamp, emergent wetlands, river/stream, ponds, and vernal pools; and approximately one-third of the park is upland forest. Remaining lands include agricultural lands (i.e., row crops, hay fields, orchards), meadow, lawn, structures, and roads and trails. Invasive exotic plants are a primary natural and cultural resource management concern due to their impacts on natural communities and the cultural landscape.

Morristown National Historical Park

Morristown was established in 1933 as the first National Historical Park to preserve the lands and resources associated with the winter encampments used by the Continental Army during the Revolutionary War. Historic sites within the park include the Jacob Ford Mansion, General Washington's military headquarters during the winter of 1779-1780; the Upper Redoubt site, built in 1777 following the battles of Princeton and Trenton, in the Fort Nonsense Unit of the park; the historic Wick House & Farm, headquarters of General Arthur St. Clair; and the 18th century Guerin House, home of a local farmer Joshua Guerin.

Morristown is located on the border between the Northeastern Highlands and the Northern Piedmont ecoregions and is comprised of 1,685 acres distributed across four geographically separate units. Washington's Headquarters occupies 10 acres, the Fort Nonsense Unit occupies 35 acres, the Jockey Hollow Encampment occupies 1,320 acres, and the New Jersey Brigade Unit occupies 321 acres. Vegetation on all four units is dominated by a mix of mowed fields, orchards, planted gardens, and forest stands. Changing land use patterns have dramatically altered the character of the area from farmed or hardwood forested areas intersected by streams to low-density residential development, expanding networks of roads, commercial development and recreational development.

Roosevelt-Vanderbilt National Historic Sites

Roosevelt-Vanderbilt consists of three sites: the Eleanor Roosevelt Mansion, the Home of Franklin D. Roosevelt, and the Vanderbilt Mansion in Hyde Park, New York. The sites, totaling 682 acres, are located within 3 miles of each other in western Dutchess County, and together host about 500,000 visitors per year.

The park is located in the Eastern Great Lakes and Hudson Lowlands ecoregion, and has a broad array of natural resources. Both the Home of Franklin D. Roosevelt and Vanderbilt Mansion border on the Hudson River, a brackish-water estuary until the dam at Troy, New York, 75 miles to the north. The presence of the river brings a marine influence far inland, resulting in unique plant communities and animal species otherwise uncommon to the region. The lands are primarily (55%) forested and include nearly 30% wetlands (i.e., open water, riverine, and freshwater tidal marshes). A 25-acre tidal marsh lies between the Home of Franklin D. Roosevelt and the Hudson River, and a dam built by the Roosevelt family in 1925 across the Fall-Kill Creek created an extensive wetlands complex at Eleanor Roosevelt. In addition, the park units contain approximately 4 miles of streams; 14 acres of permanent ponds; 40 acres of non-tidal wetlands; numerous unmapped vernal pools and intermittent streams; mature second-growth hardwood forests; numerous rock outcrops; a sphagnum swamp; and a wet sedge meadow. Significant threats from exotic species—especially Japanese barberry (*Berberis thunbergii*), Japanese knotweed (*Polygonum cuspidatum*), garlic mustard (*Alliaria petiolata*), tree-of heaven (*Ailanthus altissima*), and black locust (*Robinia pseudoacacia*)—are affecting the natural and cultural landscapes.

Saint-Gaudens National Historic Site

Saint-Gaudens, formally established in 1964, consists of 148 acres that include the home, gardens and studios of Augustus Saint-Gaudens (1848-1907), one of America's foremost sculptors. This was his summer residence from 1885-1897, and his permanent home from 1900 until his death in 1907. From 1885 to 1907, Saint-Gaudens lived and worked as an artist in the nearby Cornish Colony. The Park is located within the Northeastern Highlands ecoregion. This region is primarily dominated by hemlock and hemlock-beech transitional forest with pockets of semi-rich to rich mesic forest. The park borders a strip of rich sugar maple-ash-oak-hickory forest on river terrace slopes that were formed along the Connecticut River Valley from lake-bottom sediments of the former glacial Lake Hitchcock. Much of the site's acreage is on the lower slopes next to the river bottom and is covered with a coniferous and mixed deciduous forest.

The park is experiencing a decline in white ash (*Fraxinus americana*), a near extirpation of butternut (*Juglans cinerea*), and the hemlock woolly adelgid poses a potential threat to forest resources. Proliferation of purple loosestrife (*Lythrum salicaria*) and potential introduction of other exotics are management concerns for the park's wetlands. The park supports a diverse amphibian and reptile community, and is developing long-term monitoring protocols and vernal pool protection strategies.

Saratoga National Historical Park

Saratoga was established in 1938 to commemorate the first significant American military victory during the Revolutionary War. The Battles of Saratoga are considered by some to rank among the 15 most decisive battles in world history. In 1777, American forces met and defeated a major British army, an event which led France to recognize the independence of the United States and enter the war as a decisive military ally of the struggling American forces.

Saratoga preserves and protects the battlefield, sites associated with the 1777 surrender of British forces, and interprets these and other sites, events, and people related to the military campaigns in the Champlain-Hudson and Mohawk valleys. The park, located in the Eastern Great Lakes and Hudson Lowlands ecoregions, is comprised of three separate units: the 4-mile^2 battlefield in Stillwater, New York; the General Philip Schuyler House, located 8 miles north of the battlefield in Schuylerville, New York; and the Saratoga Monument in the nearby village of Victory. Saratoga is situated near the southern extent of the Adirondack Mountain region, which is characterized by cool summers and relatively long, cold winters. Snow often covers the ground from November through March. The majority of the park consists of the Battlefield Unit, which lies on rolling hills rising from the Hudson River alluvial floodplain. Elevations range from 85.3 feet above sea level along the river to 406.8 feet at the top of Fraser Hill. Numerous glacial ridges and ravines drain east into the Hudson River. A relatively low but steep escarpment marks the boundary between the hills and the alluvial floodplain of the Hudson River.

Forests dominate the Saratoga landscape. Grasslands are maintained through prescribed burns and mowing. Brush/shrub areas and wetlands make up the rest of the park landscape. The Hudson River floodplain, and associated streams and wet meadows support unique habitats within and around the park. The historic configuration of the fields and forests at Saratoga were important in the overall battle strategy of 1777. The sequence land acquisition and land use history has produced a mosaic of old field, shrub, and forest communities.

Weir Farm National Historic Site

Weir Farm, established in 1990, preserves the home of 19th Century American Impressionist Julian Alden Weir to protect one of the last intact landscapes associated with American Impressionism and maintains the integrity of an area that has inspired artistic expression. The 75-acre park is located in the Northeastern Coastal Zone ecoregion in the southern part of Connecticut, and is within 25 miles of the Long Island Sound Atlantic coast. The park contains open fields, successional forest, and several wetland complexes and ephemeral surface streams. The ecological value of this small park is enhanced by adjacent forested land protected by The Nature Conservancy.

Appalachian National Scenic Trail

The Appalachian National Scenic Trail extends along the entire Appalachian Mountain range in the eastern United States. The trail corridor is a minimum of 1,000 feet in width, spans 2,175 miles from Maine to Georgia, and repeatedly traverses the major elevation, latitudinal, ecological, and cultural gradients that characterize the eastern United States, which provides an exciting opportunity for ecological monitoring across habitats representative of the east coast of the United States. The A.T. is managed through a unique partnership between the NPS and the Appalachian Trail Conservancy (ATC).

Established as the first National Scenic Trail by Congress with passage of the National Trails System Act in 1968, the A.T. is the longest unit within the National Park System, stretching from Springer Mountain, Georgia to Mt. Katahdin, Maine. The A.T. passes through 14 states, six existing NPS units, seven National Forests, and numerous state parks and forests. The trail also passes through five NPS Inventory and Monitoring Networks. The recreational value of the A.T. is well understood. The trail is also a flyway for migratory birds, a corridor for wildlife and plants, and a headwater for much of the east coast's water supply. In addition, the trail supports more than 2,000 occurrences of rare, threatened, or endangered species. These ecological functions are not well understood and have only recently been incorporated into management decisions. The A.T. is an ideal transect to gauge changes in the environment caused by urbanization, recreational use, acid precipitation, exotic species, and climate change. Although the trail's central corridor is protected, the adjacent landscape has been changing over the past decades. A recent study analyzed the extent and spatial distribution of forest clearing along a 10-mile-wide corridor centered on the A.T., and concluded that managed forest harvests in northern New England accounted for 76.8% of forest clearing within the corridor (Potere et al. 2007). This result highlights the importance of documenting baseline conditions and monitoring changes in land cover types along the A.T. corridor.

The portion of the trail that extends from Mount Katahdin to the Pennsylvania-Maryland border comprises nearly 80% of the A.T. land owned by the NPS. This section of the trail covers 1,108 miles, including 155,972 acres of state and federally managed lands, and has yielded over 1,000 documented rare species occurrences and exemplary ecological communities (based on Natural Heritage Inventories). Within this section, the A.T. traverses four ecoregions, including habitats ranging from wetlands to alpine vegetation communities, and is representative of all terrestrial communities in the northeast United States. The A.T. contains some of the last remaining old growth forests in the East, some of which are subjected to high levels of human-caused disturbance including air pollution, land cover change, and exotic species invasion. For the purpose of developing an inventory and monitoring program strategy, the five networks through which the trail passes have identified the NETN as the lead network for the A.T. In return, the NETN has committed to working with other networks, parks, and agencies to develop long-term ecological monitoring priorities for the entire corridor.

The 10 A.T. segments included in this project, totaling about 225 miles, were selected based on observed and potential future changes in land cover as perceived by resource managers (Shriver et al. 2005b). Selected segments include: Whitecap Mountain and Saddleback Mountain segments in Maine; the Hanover segment in New Hampshire; the Chateauguay No-town Area segment in Vermont; the Tyringham Valley and Sheffield segment in Massachusetts; the Walkill Valley and Dunnfield Creek segments in New Jersey; and the Hawk Mountain Sanctuary, Rausch Gap/ St. Anthony's Wilderness, and Cumberland Valley segments in Pennsylvania. Descriptions of these sites from north to south are as follows:

Whitecap Mountain, Maine: This segment is about 13 miles long and is located between Gulf Hagas Mountain (western terminus) and Little Boardman Mountain (eastern terminus). These remote alpine summits are in a region where significant land conservation is likely to occur adjacent to the trail corridor. Whitecap is in the midst of land that has been historically logged, but conservation interest in the area is high. This interest may lead to land-use changes (e.g., cessation of logging adjacent to the corridor) in the near future. There is also a summit station that contains solar panels and antennae for radio repeaters. These facilities may make Whitecap more appropriate for a study area that requires installing equipment in a remote setting (e.g., an air quality monitoring station).

Saddleback Mountain Maine: This segment is about 4 miles long and is located between the western shore of Eddy Pond (western terminus) and the bottom of the valley between The Horn and Saddleback Junior. This area is known for its arctic-alpine vegetation community on the smooth bedrock dome. Ranked as one of the most important places on the A.T. for species rarity, the A.T. community is interested in Saddleback because it is near a ski area. Additional information about vegetation, watercourses, and other resources in Saddleback will help document changes in land use should the ski area operations expand. Alternately, should the ski area cease to operate, the community is interested in expanding protection for important habitats and providing additional buffers between the A.T. and areas of future potential land development.

Hanover, New Hampshire (White Mountain National Forest): This segment is approximately 13 miles long and includes the entire extent of the trail within the town of Hanover, New Hampshire. The effects of development on the A.T. are unclear at this point. As farms are converted into housing lots and/or fields revert to woods, wildlife will likely be affected, as will vistas for hikers. The town of Hanover has already highlighted the value of the A.T. corridor in their open space plan and has made the conservation of additional adjoining parcels of land their highest priority.
Chateauguay–No-town Area (Vermont Fish & Wildlife and Green Mountain National Forest): This section of the A.T. is about 21 miles long and passes through the towns of Barnard, Bridgewater, Killington and Stockbridge, Vermont. This section is in the midst of a large

undeveloped area between two popular resort communities (i.e., Killington and Woodstock) and is very primitive and isolated despite its proximity to areas where second home development is rampant and the historical farming and timber economy is starting to change in favor of development. The local community is very interested in preserving the Chateauguay-No-town Area in its current undeveloped state. The four towns included in the area have developed a working group that includes the regional planning commission, local land trusts, and the ATC. The working group aims to seek additional land protection for the area on a willing seller basis. Additional information about wildlife habitat, important watercourses, or the presence of rare species would aid the working group in their efforts to conserve natural resources. Also, if this area experiences development as a result of the proximity to growing population centers, monitoring data would help conservation groups and local communities understand the effects of those land use changes.

Tyringham Valley and Sheffield, Massachusetts: This section of the A.T. is approximately 30 miles long and passes through Tyringham, Massachusetts. This section is host to several Natural Heritage sites. In addition, rare aquatic animal species have been found in Hop Brook. Largely and historically agricultural, the trail passes through the floodplain of Hop Brook and includes several special use areas. The trail is enhanced by adjacent open areas and agricultural fields in Sheffield. Market pressures on agriculture and pressure from development are considered substantial in both of these areas.

Walkill Valley (NPS ATPO, NJ DEP and Walkill National Wildlife Refuge): Much of the Walkill Valley is protected by the public land acquisition efforts of the NPS, USFWS, and the State of New Jersey. The Walkill National Wildlife Refuge is currently acquiring lands to protect wetland and grassland bird habitat along the Walkill River, including the remnants of a large sod farm, commonly referred to as the “black dirt” area. The A.T. currently crosses the Walkill River on a county road bridge, but discussions are underway to construct a pedestrian-only bridge across the 120-foot river span sometime during the next 5-10 years. Numerous song bird and raptor species are present; a variety of reptiles and amphibians are associated with wetland habitats in the area. This segment is about 24 miles long and located between High Point and Waywayanda Mountain in Sussex County, New Jersey.

Dunnfield Creek–Sunfish Pond NPS–Delaware Water Gap National Recreation Area and ATPO, NJ DEP (Worthington State Forest): This segment is approximately 29 miles long. Dunnfield Creek is located on the New Jersey side of the Delaware Water Gap. This is an extremely popular tourist destination located between the Poconos and Manhattan. Historically, the steep banks of Dunnfield Creek were protected by the presence of large hemlock trees. Today, these trees are severely infested by the hemlock wooly adelgid. This segment of the A.T. offers an opportunity to observe the devastating effects of the adelgid, measure soil loss, and assess the subsequent effects of these impacts on the creek.

Hawk Mountain Sanctuary, Pennsylvania: The Kittatiny Ridge runs some 200 miles in length from New Jersey to almost the Maryland State Line. Kittatiny Ridge is a globally significant migration flyway for thousands of raptors and millions of songbirds, and is the focus of the Kittatiny Coalition, a consortium of interested environmental and public conservation agencies and private organizations. The Ridge provides visitors with recreational opportunities and scenic landscapes; links critical wildlife habitat within the Appalachian forest; and is the location of headwaters for many important public water systems and fish habitats. A 40-mile segment between the Schuykill River in Port Clinton (western terminus) and the Lehigh River near Palmerton (eastern terminus) in Pennsylvania was used in this project.

Rausch Gap/St. Anthony's Wilderness, Pennsylvania: This area is the largest undeveloped roadless section of the A.T. in the mid-Atlantic region. Although not a federally designated wilderness, this section constitutes a significant tract of unbroken public land in central Pennsylvania with a rich history. There are faint remnants of the long-gone village of Yellow Springs, including building foundations, mine infrastructure, and a handful of headstones in a deserted family cemetery. This segment is home to several rare plant communities identified in the A.T. Natural Heritage Site Inventory for Pennsylvania and the Allegheny wood rat, which is the only mammal species identified by the Inventory. An old rail bed, maintained by the Pennsylvania Game Commission for administrative access into their lands, traverses the center of this area. Two trout streams popular with anglers, Clarks Creek and Stony Creek, are located here. This segment is approximately 35 miles long. The western terminus is located directly north of the western point of Pennsylvania State Game Land #211; the segment ends at the eastern boundary of Pennsylvania State Game Land 80 (eastern terminus).

Cumberland Valley, Pennsylvania: Commercial and residential developments are rapidly expanding in the Cumberland Valley, due in part to major transportation corridors (i.e., Interstate 81, the Pennsylvania Turnpike, and US Route 11) traversing the area. Numerous trucking terminals are located in the center of the Valley where there is convenient access to major east/west and north/south transportation routes. Historically, deep limestone soils supported significant agricultural in the Valley. Today, farmland is being lost to development and there is a proliferation of invasive species including mile-a-minute weed, Japanese barberry, ailanthus, and others. This segment is about 17 miles long and is located between the northern borders of Cumberland County (northern terminus) and Center Point Knob (southern terminus).

Methods

Data Acquisition

We used Landsat remote sensing data as the primary data source for the derivation of generalized land cover information. The Landsat program is the longest running enterprise for the acquisition of medium resolution intra-annual and inter-annual imagery of the land surface from space. The first Landsat satellite was launched in July 1972; the most recent, Landsat 7, was launched in April 1999. Instruments on Landsat satellites have acquired digital images that are a unique resource for research and applications in agriculture, geology, forestry, regional planning, education and national security (Irons and Masek 2006). Landsat data from three types of sensors are available to the general public: Multispectral Scanner (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper Plus (ETM+).

Multispectral Scanner is a multispectral scanning radiometer that was carried on board Landsats 1–5. The instruments provided nearly continuous temporal coverage from July 1972 to October 1992, with an 18-day repeat cycle for Landsats 1-3 and a 16-day repeat cycle for Landsats 4-5. Multispectral Scanner image data consists of four spectral bands from within the visible green, visible red, and near-infrared wavelengths, although the specific band designations were changed from Landsats 1-3 to Landsats 4-5. The spatial resolution for all bands is 80 meters (approximately 262 feet), and the approximate scene size is 170 x 183 kilometers (115 x 106 miles).

Thematic Mapper is a multispectral scanning radiometer that was carried on board Landsats 4 and 5. The TM sensors have provided nearly continuous coverage from July 1982 to the present, with a 16-day repeat cycle. The TM data consists of seven spectral bands ranging from visible light to near infrared (IR), middle IR and thermal IR spectrums[1] with a spatial resolution of 30 meters (about 98 feet) for most bands (i.e., 1-5 and 7). Spatial resolution for the thermal IR (band 6) during image acquisition was 120 meters (394 feet). The approximate scene size is 170 x 183 kilometers (106 x 115 miles).

The ETM+ is a multispectral scanning radiometer on board the Landsat 7 satellite. This sensor has provided nearly continuous acquisitions since July 1999, with a 16-day repeat cycle. Due to an instrument malfunction on 31 May 2003, all Landsat 7 scenes acquired since 14 July 2003 (excluding a two-week interval from 9/3/03 to 9/17/03) have been collected in Scan Line Corrector (SLC)-off mode[2]. The ETM+ instrument provides image data from eight spectral bands. Spectral bands 1-5 and 7 of the ETM+ are identical to the TM sensor. The spatial resolution is 30 meters (about 98 feet) for the visible and near-IR (bands 1-5 and 7). Resolution for the added panchromatic (band 8) is 15 meters (49 feet), and the thermal IR (band 6) is 60 meters (197 feet). The scene size is approximately 170 x 183 kilometers (106 x 115 miles).

[1] Landsat TM sensor designations: *http://edc.usgs.gov/products/satellite/band.html* (verified on December 12, 2007)

[2] An instrument malfunctioned onboard Landsat 7 on 31 May 2003. The problem was caused by failure of the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite. More details can be found at (verified on 12 December 2007): *http://landsat.usgs.gov/data_products/slc_off_data_products/slc_off_background.php*

We chose Landsat data for several reasons. First, Landsat multispectral data provided coverage from the early 1970s to the early 2000s with nearly continuous coverage, which makes the study of land cover change for the selected time periods possible. Second, as the purpose of this project was to provide a general landscape characterization and change analysis instead of detailed vegetation and resource mapping, the spatial resolution of Landsat data was appropriate. Third, data availability and cost were also an important factor. A significant amount of Landsat data is available at no cost from on-line open resources such as the Global Land Cover Facility (GLCF, http://glcf.umiacs.umd.edu/index.shtml) or at low cost from other data archives such as the U.S. Geologic Survey (USGS) EROS data center. We searched for Landsat data that represented the best match in time frame and, if possible, selected to the anniversary of image acquisition in order to reduce seasonal effects. We made every effort to find scenes that had dates as close together as possible for a given time period for all the parks. We ultimately acquired and processed 33 scenes of Landsat images, 11 scenes for each of the three time periods: the 1970s (MSS data), late 1980s (TM data), and early 2000s (ETM+ data) (Table 1).

Table 1. Summary of Landsat imagery data used; every effort was made to find scenes that had dates as close together as possible for a given time period for all the parks.

Site Name	ETM+[1]	TM[2]	MSS[2]	Path/Row
ACAD	10-Sep-2002	05-Aug-1986	23-Jul-1976	11/29
A.T. Whitecap	24-Jul-2002	21-Jun-1987	11-Aug-1976	11/28
A.T. Saddleback	31-Jul-2002	13-Sep-1986	20-Sep-1972	12-13/29
A.T. Hanover	08-Sep-2002	28-Sep-1989	26-Sep-1978	13/30
A.T. Chateauguay	08-Sep-2002	28-Sep-1989	26-Sep-1978	13/30
MABI	08-Sep-2002	28-Sep-1989	26-Sep-1978	13/30
SAGA	08-Sep-2002	28-Sep-1989	26-Sep-1978	13/30
A.T. Tyringham	08-Sep-2002	28-Sep-1989	24-Jul-1973	13/31
WEFA	08-Sep-2002	28-Sep-1989	24-Jul-1973	13/31
ROVA	14-Aug-2002	12-Jun-1988	24-Jul-1973	14/31
A.T. Walkill Valley	14-Aug-2002	12-Jun-1988	02-Aug-1975	14-15/31
A.T. Dunnfield Creek	14-Aug-2002	12-Jun-1988	02-Aug-1975	14-15/31
A.T. Dunnfield Creek	06-Sep-2002	28-Jun-1988	02-Aug-1975	14-15/32
MORR	06-Sep-2002	28-Jun-1988	02-Aug-1975	14-15/32
A.T. Hawk Mt.	06-Sep-2002	10-Sep-1989	06-Oct-1973	15-16/32
A.T. Rausch Gap	06-Sep-2002	10-Sep-1989	06-Oct-1973	15-16/32
A.T. Cumberland	06-Sep-2002	10-Sep-1989	06-Oct-1973	15-16/32
MIMA	27-Sep-2000	16-Sep-1987	10-Sep-1974	12-13/30
SARA	08-Jun-2001	26-Aug-1986	07-Jul-1973	15/30
Total Scenes	11 scenes	11 scenes	11 scenes	33 scenes

[1] Scenes from the 1970s.
[2] Scenes from the late 1980s.
[3] Scenes from the early 2000s.

Image Pre-Processing

On receipt of the Landsat data, we imported each scene to match the file format required by our image analysis software. We used the ERDAS Imagine[3] software system for the preparation of the Landsat data and subsequent land cover classifications.

We projected all images into Universal Transverse Mercator (UTM) map coordinates, and then conducted geometric rectification when the geographic accuracy of the image scenes required it. After geometric rectification, the spatial registration errors among the images of the three time periods for each scene location were less than half of a single pixel.

We carefully selected the initial images to avoid those with cloud cover. For image data with unavoidable cloud cover, we replaced the cloud covered pixels during the post-classification process by referencing information from other sources, such as the classification result from Landsat data that covered the same study area with similar spectral properties.

Subset and Buffering Analysis

Subsetting is the process that extracts a selected portion, or subset, of an image from a larger parent scene of data. Instead of processing all of the complete scenes of Landsat imagery, the land cover classification can be performed on the subset images only, so that the analysis can be more focused. This process usually leads to results with higher classification accuracy values.

After consulting with park managers, we decided that a 5 kilometer (3.11 mi) buffer would be sufficient to study the land cover change adjacent to park boundaries. We applied the 5 kilometer buffer on the polygon boundary for each park from GIS files provided by the NETN and the same 5-kilometer buffer on each side of the A.T. segments to create the area of interest (AOI). We then applied the AOIs to subset the images for each study site and to prepare the data for land cover classifications.

As buffer analysis is a necessary step toward understanding the spatial pattern of land cover within and adjacent to the parks, we created additional 500-meter (0.31 mi) and 1-kilometer (0.62 mile) buffers based on the park boundaries and A.T. central line on the land cover classification data to extract land cover information within the buffer zones. We executed the buffering exercises using ArcGIS[4] Desktop 9.1 software system functions and used Microsoft Excel to process and summarize the statistics of land cover change. The buffer analysis generated four groups of land cover information:

1. Within the park boundary (not applicable for A.T. segments)
2. The zone within 500 meters (0.31 mi) of the park boundary/A.T. central line
3. The zone within 1 kilometer (0.62 mi) of the park boundary/A.T. central line
4. The zone within 5 kilometers (3.11 mi) of the park boundary/A.T. central line

Figure 2 illustrates an example of a subset image and the buffer zones for SAGA. Figures 3 and 4 illustrate examples of subset images and the buffer zones for the Whitecap Mountain and Hawk Mountain segments of the A.T.

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[3] ERDAS Imagine, Leica Geosystems Geospatial Imaging, LLC, Norcross, Georgia, USA
[4] Environmental Systems Research Institute, Inc. (ESRI), Redlands, California

The only exception to this procedure was Acadia National Park. ACAD contains islands and separated campuses either completely or partially surrounded by ocean and bay waters. We therefore chose to subset a larger section from the Landsat images that covered all segments of ACAD for the purpose of land cover classification. We applied the 5-kilometer buffer later for extraction of land cover types and changes within and adjacent to the ACAD boundary (Figure 5).

Classification System

We defined a generalized land cover classification scheme to accommodate as much of the USGS NLCD and NPS Vegetation Mapping Project as our data permitted. The final classification scheme included the following land cover categories.

Urban
Herbaceous Vegetation
Deciduous Forest
Coniferous Forest
Mixed Forest
Water
Wetlands
Barren Lands/Bare Rockface
Regrowth Forest

We applied the category of Regrowth Forest only for the Whitecap Mountain and Saddleback Mountain segments of the A.T. to reflect significant logging in the past and subsequent regrowth of forest. We named the barren land and bare rockface separately to reflect the landscape characteristics. We applied the term Bare Rockface only to the Whitecap Mountain and Saddleback Mountain segments of the A.T., and to ACAD because bare rockface is among the significant landscape features for those sites. Table 2 summarizes the land cover types and descriptions that were adopted by this project for conducting land cover classification.

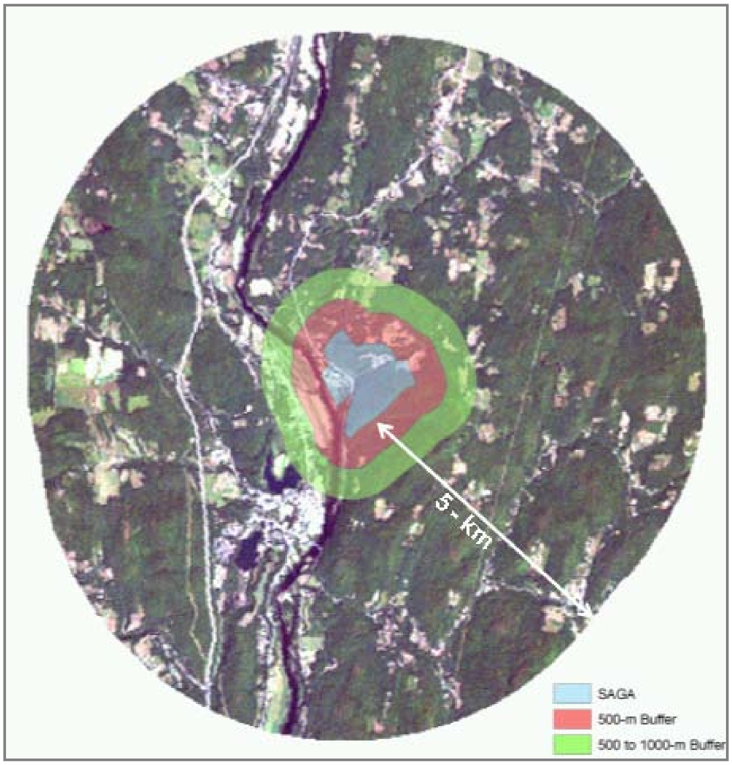

Figure 2. An example image, from SAGA, that has been buffered and subsetted. In display is a Landsat ETM+ image (Band 3, 2, 1 RGB) overlaid with park boundaries and buffer zones.

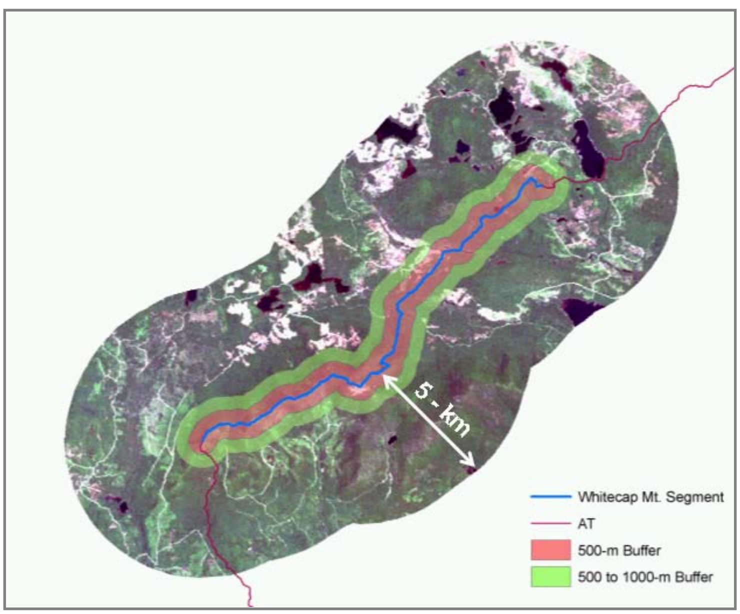

Figure 3. A Landsat TM image (Band 3, 2, 1 RGB) from the A.T. Whitecap Mountain segment, that has been subsetted and buffered, and overlaid with buffer zones.

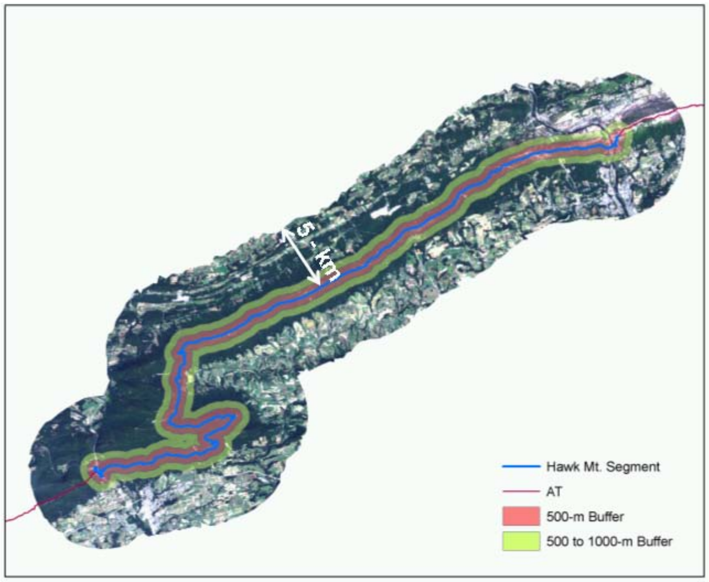

Figure 4. An example image, from the A.T. Hawk Mountain segment, that has been subsetted and buffered. In display is a Landsat ETM+ image (Band 3, 2, 1 RGB) overlaid with buffers.

Figure 5. An example image from ACAD that has been subsetted and buffered. In display is a Landsat ETM+ image (Band 3, 2, 1 RGB) overlaid with park boundaries and buffers. The subsetted image for the ACAD site is larger than the area covered by the 5-kilometer buffer.

Table 2. Land cover types and descriptions that were adopted by this project for conducting land cover classification.

Land Cover Type	Description
Urban (UR)	Areas characterized by constructed materials (e.g., asphalt, concrete, buildings, etc.) in urban and suburban settings. Urban grass is included in this category, including vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples of urban grass include parks, lawns, golf courses, airport grasses, and industrial site grasses.
Herbaceous Vegetation (HV)	Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber, or is maintained in developed settings for specific purposes.
Deciduous Forest (DF)	Areas dominated by tree species which shed foliage simultaneously in response to seasonal change.
Coniferous Forest (CF)	Areas dominated by tree species that maintain their leaves year round. Canopy is never without green foliage.
Mixed Forest (MF)	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the cover present.
Water (WA)	All areas of open water.
Wetlands (WL)	Areas where the soil or substrate is periodically saturated with or covered with water.
Barren Land/Bare Rockface (BL/BR)	Barren land represents the areas characterized by gravel, sand, or other earthen material; little or no "green" vegetation is present. Bare rockface represents areas characterized by bare rock on mountain and shoreline; this category was applied only to ACAD and two Maine A.T. segments.
Regrowth Forest (RF)	Areas where significant logging occurred in the past that are now experiencing subsequent forest regrowth. This category was applied only to the two segments of the A.T. in Maine.

Ground Verification

We conducted ground observation and verification of the classification during the summers of 2003 and 2004 under the guidance of NPS and ATC scientists, land managers and volunteers. This fieldwork supported Landsat image classification by helping us identify land cover types defined in the classification scheme. The field observations provided essential, independent reference data for verifying land cover types within the Landsat scenes and for the follow-up accuracy assessment. Since the ground referencing data were intended for supporting three time periods of Landsat images, we paid special attention to the locations where it was apparent or known that the landscape had been altered and land use had changed over the past 30 years. This fieldwork helped us ensure effective differentiation between the types of land cover and the history of land use within each area.

We visited NPS and ATC offices when possible to seek advice and guidance for each of the study sites. National Park Service and ATC resource managers and volunteers reviewed laminated hardcopies of the satellite imagery and identified areas of interest (Figure 6). We used Trimble® ProXR and GeoXT Global Positioning System (GPS) units (Figure 7) to record locations of field transects and points of interest. We recorded the general characteristics of the landscape and associated information with the help of a data dictionary uploaded to the GPS unit.

As part of this effort, we recorded georeferenced site photographs along transects and at points of interest using a Kodak® DC265 Field Imaging System (FIS). The FIS consisted of a 12 channel Garmin® GPS III unit connected to a digital camera (Figure 7). The FIS photographs identify both the photographer’s geographic location by latitude/longitude coordinates and the general compass bearing the photographer was facing when recording each image. We collected approximately 2,800 georeferenced digital photographs which, when augmented with our differentially corrected GPS data, effectively identified locations and characteristics of land cover types within each study site. Examples of the FIS site photographs illustrate the land cover types documented, such as forest, agricultural land, suburban residential area, open grassland, and landscape on and near the A.T. (Figures 8-15).

Figure 6. Fieldwork, guided by NPS and ATC resource managers and volunteers, confirmed the correspondence between spectral features on Landsat images and land cover types and patterns on the ground, and historic land use changes.

Figure 7. Equipment employed in the fieldwork included a Trimble® ProXR unit, a GeoXT GPS unit, and a Kodak® DC265 Field Imaging System to record the locations of points of interest and georeferenced field photos.

Figure 8. An example of a photo used to document the Deciduous Forest cover type. The GPS location and compass direction were recorded on the photo at the time of fieldwork.

Figure 9. An example of a photo used to document the agricultural land cover type. The GPS location and compass direction were recorded on the photo at the time of fieldwork.

Figure 10. An example of a photo used to document a suburban residential area. The GPS location and compass direction were recorded on the photo at the time of fieldwork.

Figure 11. An example of a photo used to document the open grassland cover type. The GPS location and compass direction were recorded on the photo at the time of fieldwork.

Figure 12. An example of a photo used to document the Deciduous Forest along the A.T. The GPS location and compass direction recorded on the photo at the time of fieldwork.

Figure 13. An example of a photo used to document Mixed Forest cover type. The GPS location and compass direction recorded on the photo at the time of fieldwork.

Figure 14. An example of a photo used to document the Mixed Forest cover type along the A.T. The GPS location and compass direction recorded on the photo at the time of fieldwork.

Figure 15. An example of a photo used to document a logged site. The GPS location and compass direction recorded on the photo at the time of fieldwork.

We combined the field photographs and GPS point data to create a virtual field reference database (VFRDB; e.g., Lunetta et al. 2001) for each study site. The locations of georeferenced photos for the selected park units and A.T. segments are illustrated in Figures 16 and 17, respectively. The VFRDB should provide benchmark reference data for long-term monitoring of landscape dynamics.

To facilitate ground verification, we created 3D views for selected A.T. segments, such as the Whitecap Mountain and the Hawk Mountain segments, so that the A.T. and the surrounding landscape could be viewed from different angles (Figures 18-19). We employed (Space) Shuttle Radar Topography Mission (SRTM)[5] data as the digital elevation model basis for the 3D views, then subsequently draped the relevant Landsat imagery on top.

Fieldwork confirmed the correspondence between spectral features on Landsat images and land cover types and patterns on the ground, and the changes which occurred in the past. For example, a comparison of Landsat images over three time periods (1976, 1987 and 2002) for the Whitecap Mountain A.T. segment reveals that logging and regrowth of forest have been the main factors influencing land cover change at this site. The patchy patterns of past logging practices and forest regrowth were evident during field observations (Figure 20-21). Landsat images reflected this change of land cover type (Figure 22).

At another site, Coniferous Forest within the Tyringham Valley segment was converted into open fields by human development. A comparison of Landsat images between 1989 and 2002 reveals this landscape change. In addition, the location of a damaged forest site (from a tornado touchdown in 1996) was located during the fieldwork. This site-of-interest was documented using GPS photos and identified on Landsat images (Figure 23).

[5] The SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. *http://srtm.usgs.gov/*

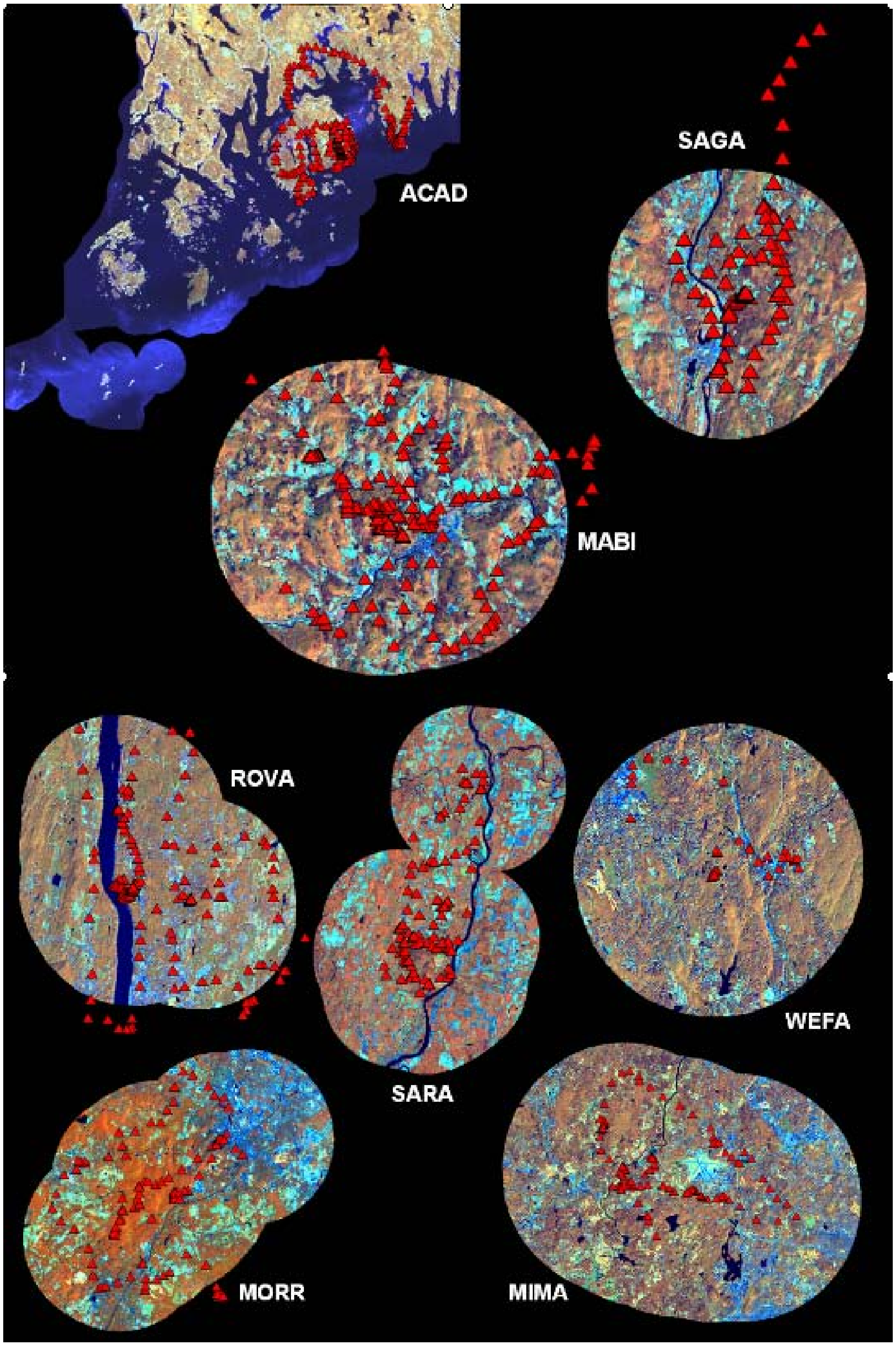

Figure 16. Examples of subsetted Landsat images for the eight selected NETN park units with the 5-kilometer buffer applied, based on the park boundaries. The red triangles are the ground referencing locations. Landsat images are displayed as pseudo color by Bands 4, 5, and 3 in RGB combination.

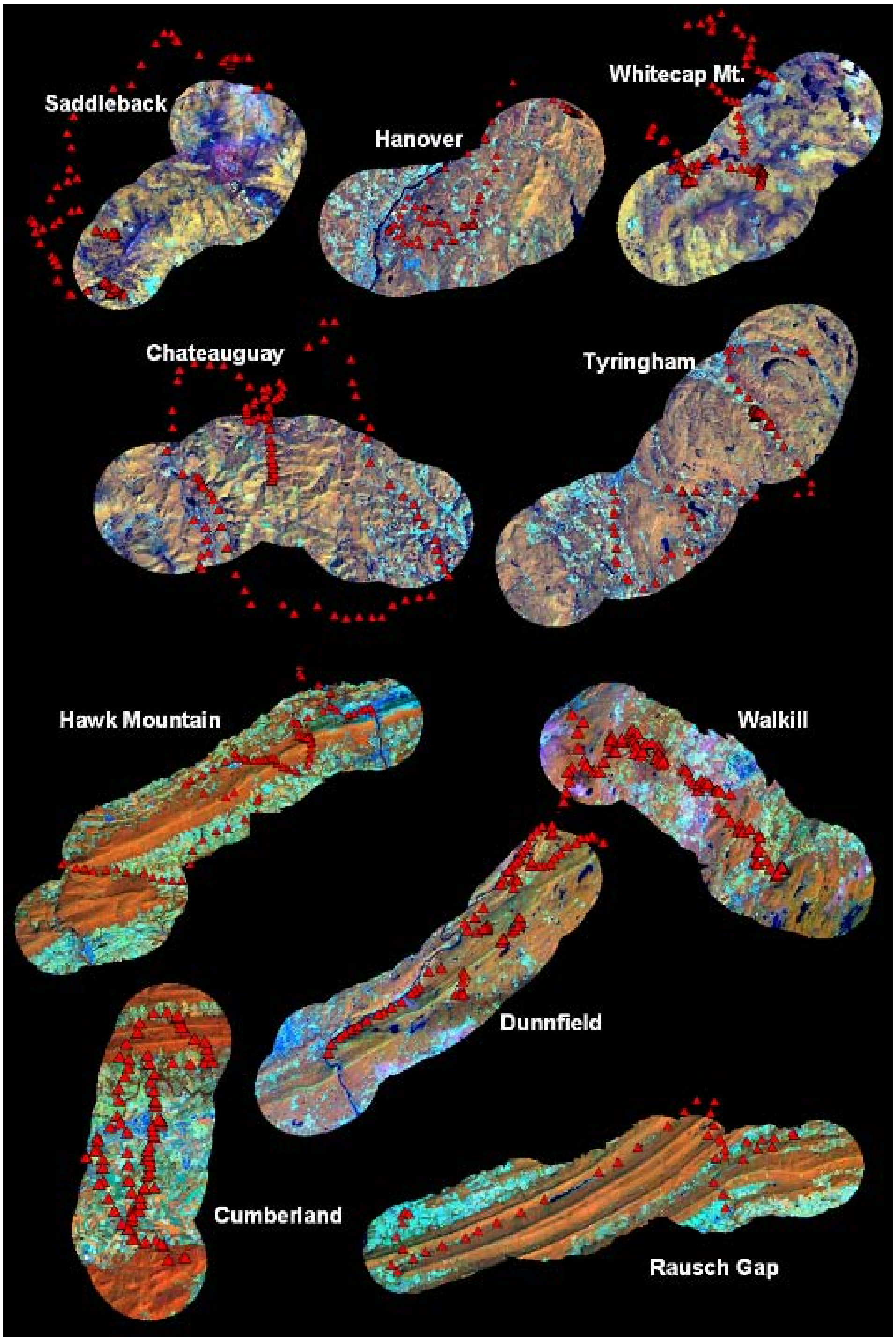

Figure 17. Examples of subset Landsat images for the 10 selected A.T. segments with the 5-kilometer buffer applied based on the A.T. central line. The red triangles are the ground referencing locations. Landsat images are displayed as pseudo color by Bands 4, 5, and 3 in RGB combination.

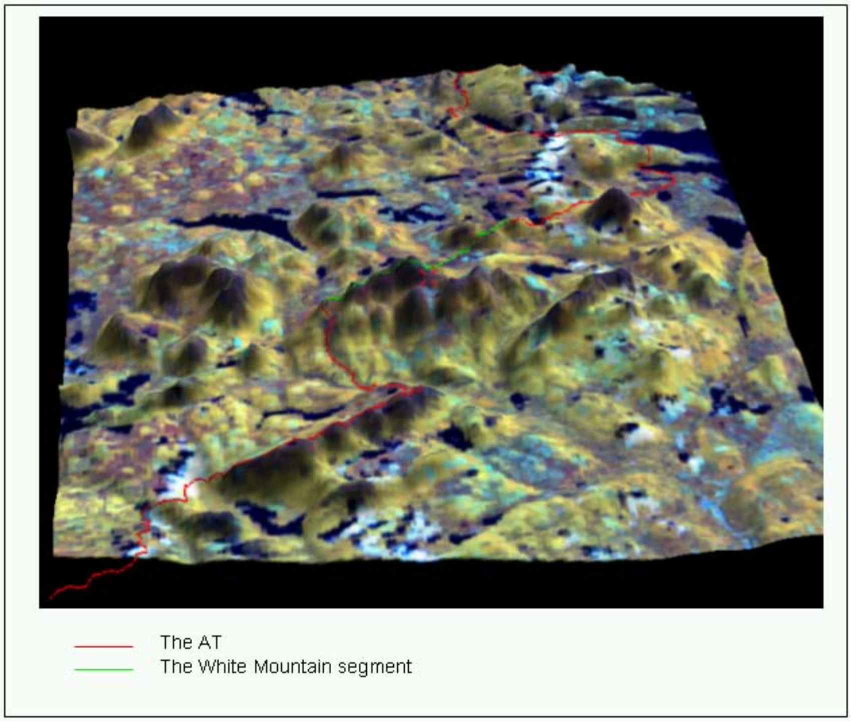

Figure 18. A 3D view of the Whitecap Mountain A.T. segment. This image was created by draping a pseudo color Landsat image over the SRTM topography data.

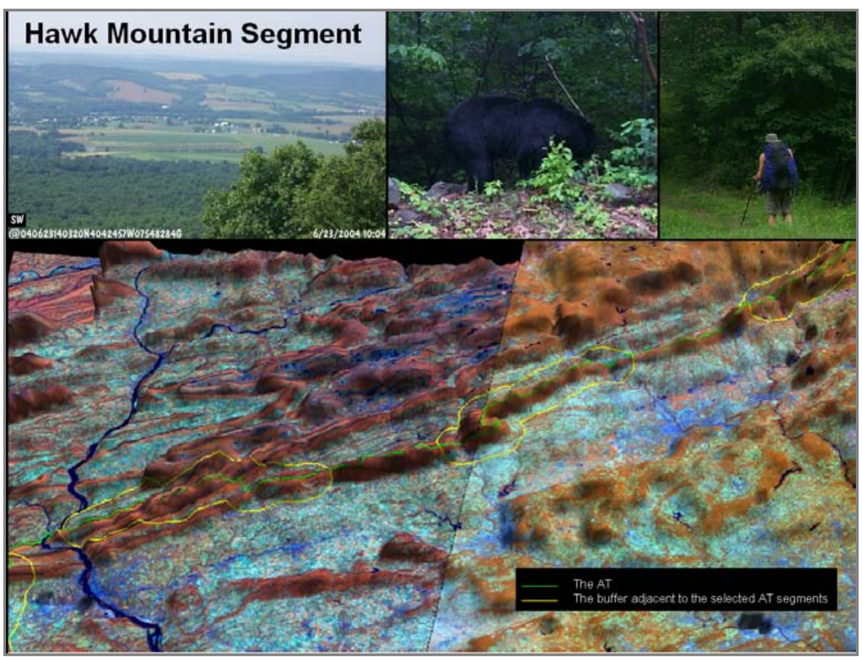

Figure 19. An aerial view (upper left) and 3D view (bottom) of the Hawk Mountain A.T. segment. This 3D image was created by draping a pseudo color Landsat image over the SRTM topography data. Also, a black bear (*Ursus americanus*) (upper middle) and through hiker (upper right) on this segment.

Figure 20. Patchy landscape patterns near the Whitecap Mountain A.T. segment resulting from past logging activities.

Figure 21. An example of regrowth forest observed near the Whitecap Mountain segment of the Appalachian Trail.

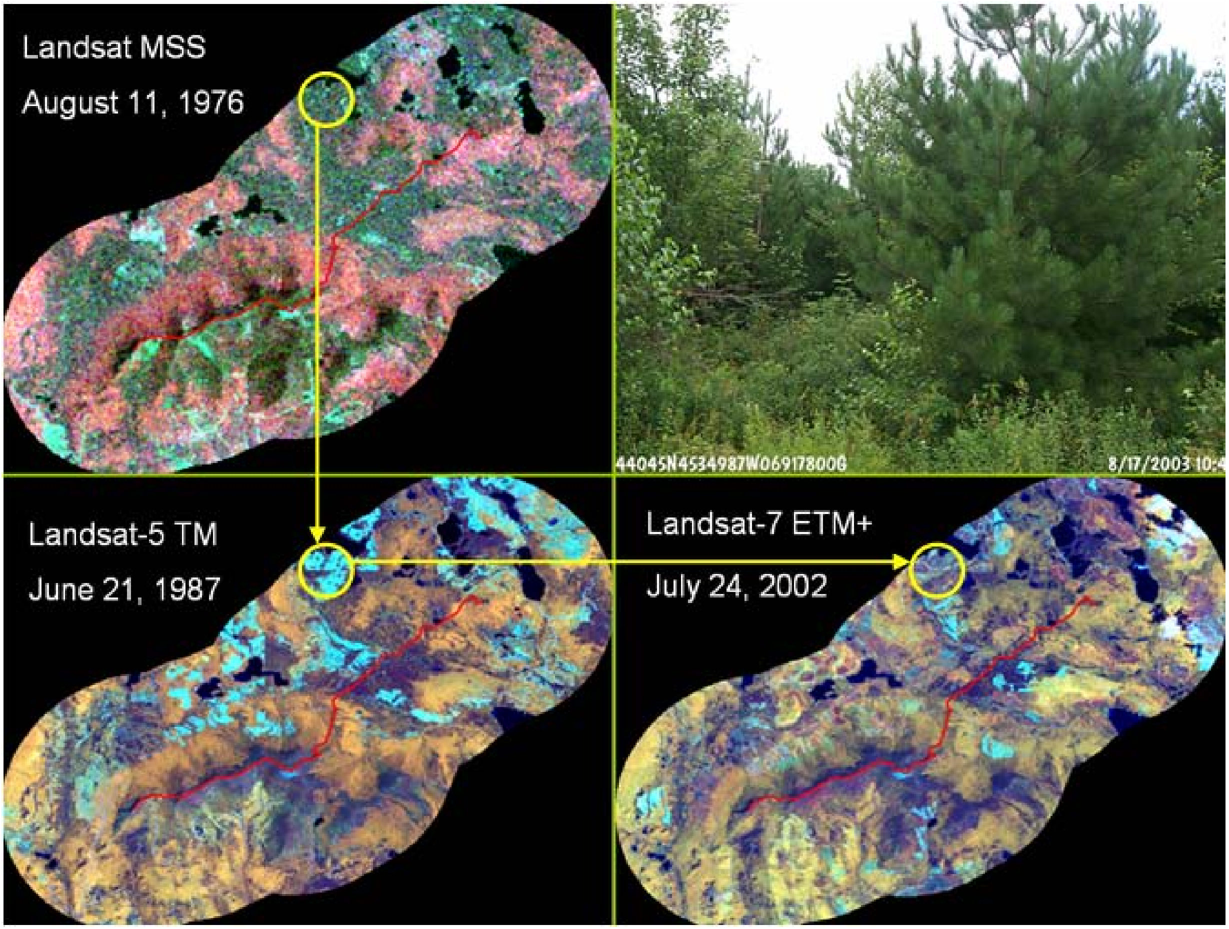

Figure 22. A comparison of Landsat images over three time periods reveals significant land cover change for the Whitecap Mountain A.T. segment. Logging and regrowth forest account for the majority of land cover change in the area. The yellow circles and arrows indicate a location that was forested in the 1976 image, logged and barren in the 1987 image, and reforested in the 2002 image (top left). Landsat images are displayed as pseudo color by Bands 4, 5, and 3 in RGB combination.

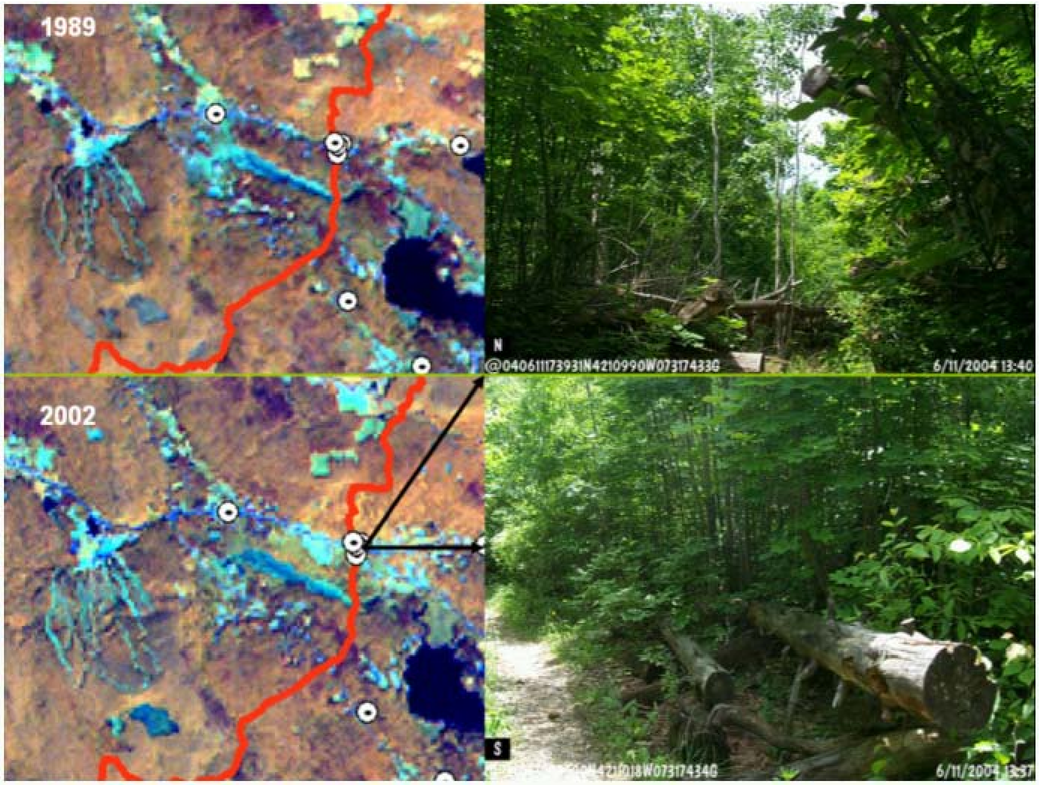

Figure 23. Coniferous Forest (dark red on Landsat images) within the Tyringham Valley A.T. segment was converted into open field by human development. A comparison of Landsat images from 1989 and 2002 reveals the change to the landscape. The location of a forest site damaged by a tornado touchdown in 1996 is identifiable through GPS photos (photos on left). Landsat images are displayed as pseudo color by Bands 4, 5, and 3 in RGB combination.

Reference Data Sources

We employed reliable available data from U.S. governmental agencies (Zhu et al. 2000) to improve land cover mapping. These consisted of the USGS National Land Cover Dataset (NLCD) of 1992 and 2001 (Homer et al. 2000), National Wetland Inventory (NWI) data, and USGS-NatureServe-NPS vegetation mapping project data. Although two time periods of NLCD data are available for general mapping purposes, the NLCD datasets would not be appropriate or recommended for conducting change analysis directly due to the image classification techniques that were employed in data development and other data quality issues. The NLCD data, however, can provide a good reference for selected land cover categories.

National Land Cover Dataset (NLCD)

The NLCD-1992 dataset was the culmination of a five-year effort by the USGS, Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Forest Service (USFS) to purchase and analyze the necessary Landsat satellite TM imagery. Scientists at the USGS used a variety of supporting information in addition to the satellite data, including topography, census, agricultural statistics, soil characteristics, other land cover maps, and wetlands data, all in an effort to determine and label a land cover type for each 30-meter pixel within the NLCD. Great efforts were made to improve the data quality and to assess the accuracy of the data (Vogelmann et al. 1998a, Vogelmann et al. 1998b, Zhu et al. 2000).

The NLCD-1992 data are provided on a state-by-state basis. The state data sets were subsetted from larger "regional" data sets that are mosaics of Landsat TM scenes. All of the NLCD state files are free and available for downloading as 8-bit binary files. Some states are also available on CD-ROM in Geo-TIFF format (Homer et al. 2000).

Starting in 1999, a second-generation National Land Cover Database 2001 (NLCD-2001) was initiated across all 50 states and Puerto Rico as a cooperative mapping effort of the MRLC 2001 Consortium (Homer et al. 2000). This land cover database contains standardized land cover components useful for a variety of applications with improved data quality over the NLCD-1992. The NLCD-1992 and NLCD-2001 data provided reliable referencing land cover information at the Landsat data level for land cover mapping. For example, the NLCD adopted the data from the census bureau to improve the Urban Land cover category, and should provide a reliable reference for pixel-based classifications of Urban Land.

National Wetlands Inventory (NWI) Data

Wetland is perhaps the most challenging category to map using Landsat data. The U.S. Fish and Wildlife Service (USFWS) is the principal federal agency that provides information to the public on the extent and status of wetlands in the United States. Through the National Wetlands Inventory (NWI), the agency has developed a series of topical maps to show wetlands and deepwater habitats. These maps have been used extensively to make resource management decisions at the federal, state and local government levels. In this project we referenced the NWI dataset[6] to reduce the level of confusion.

[6] http://www.fws.gov/nwi/ (verified on 12 December 2007)

USGS, NatureServe, and NPS Vegetation Mapping Project Data

The USGS and NatureServe are cooperating with the NPS I&M program to describe and map the vegetation of over 270 National Park Service units. Acadia, for example, was selected as one of several pilot parks to develop and refine the methodology and standards for the vegetation mapping program. The data consisted of vector GIS data that defined boundaries of vegetation types based on plot information and delineations from aerial photos with a standard minimum mapping unit of 0.5 hectares (1.25 acres). Although the data were developed for different purposes, using different source data with different scales, we were able to reference the available vegetation mapping project data to improve our land cover classifications in some instances. The NPS I&M program vegetation mapping project data for Acadia, Roosevelt-Vanderbilt, and Saratoga were available at the time of our image classification.

Digital Image Classification

Digital image classification is an automated grouping process that converts digital satellite remote sensing data into a summary of categories (i.e., land cover types). With the multispectral data available from Landsat imagery, we applied the multispectral classification technique during the data processing step.

Multispectral classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to those criteria. This process is also referred to as image segmentation. Depending on the type of information the user wants to extract from the original data, classes may be associated with known features on the ground or may simply represent areas that “look different” to the computer algorithms. An example of a classified image is a land cover map.

We employed unsupervised, supervised, and stratified classifications for data processing. While the unsupervised and supervised classification algorithms are commonly employed by remote sensing software and increasingly in GIS software, the stratified classification developed by this project team was for the purpose of improving traditional image classification by taking advantage of available reference GIS data. We employed algorithms provided by the ERDAS Imagine software systems for this project.

Unsupervised classification is a technique that searches for natural groupings of the spectral properties of pixel data, as examined in multispectral feature space. Unsupervised classification is also referred to as “clustering”. Unsupervised image classification requires only a minimal amount of initial input from the image analyst. However, the analyst needs to interpret the clusters of pixels (classes) that are created by the unsupervised classification.

Supervised training is more closely controlled by the analyst. In this process, the analyst selects representative clusters of pixels as training signatures that represent patterns or land cover features that the analyst can recognize, or can identify with help from third-party sources such as aerial photos, ground referencing data, or maps. Knowledge of the data, and of the classes desired, is required before supervised classification may begin. By identifying patterns, analysts can “train” the computer algorithms to identify clusters of pixels with similar characteristics. If a classification is accurate, the resulting classes represent the categories within the data that the user originally identified.

Training is the process of defining the criteria by which patterns in image data are recognized for the purpose of classification. A training sample, or the "signature," is constituted by a set of pixels selected by an analyst to represent a specific land cover class. The statistics of the selected sets of pixels serve as the "signatures" to guide the classification process. Supervised training uses different methods to generate signatures. Through signature selections an analyst's judgments on land cover categories can be directly involved in pattern recognition and classification.

After the signatures are defined, pixels of an image are sorted into classes based on the signatures and by employing a set of classification decision rules. Decision rules are mathematical algorithms that, using data contained in the signatures, perform the actual sorting of pixels into distinct class values. Pixels that are identified by a decision rule are then assigned to the class for that signature. We employed the commonly used maximum likelihood decision rule (ERDAS Imagine Field Guide[7]) for the image classification.

In this project, we started off with as many possible signatures as we could identify. Upon finishing the classification we recoded the signature classes into final land cover categories defined by the classification scheme. Some of the signature classes that had limited pixel numbers, such as brush land, were eliminated by recoding them into the most relevant land cover categories of the site.

Stratified Classification and Post-Classification Improvement

Stratification involves segmentation of the image into focused areas and categories in order to have spectrally similar classes separated and classified independently. Post-classification sorting solves the problem of pixels being assigned to unlikely categories. The reference data from other information sources can be used in the post-classification process to improve the overall classification accuracy.

We employed a stratified image classification technique in order to improve the extraction of land cover types for the three parks (ACAD, ROVA, SARA) where we had access to NPS vegetation mapping project data. We employed the stratified classification for the 1980s Landsat TM and 2002 ETM+ only. We took the vegetation mapping data as the baseline and masked out corresponding pixels for each vegetation/land cover category from the subset of Landsat images. This allowed the follow up classifications to focus on each of the vegetation/land cover types identified by the vegetation mapping projects. We used the follow up classifications to determine the final land cover type of the pixels. The classification results would not necessarily agree with the NPS vegetation mapping project results if the pixels' spectral signature did not match the spectral signatures of that particular type of vegetation or land cover. Therefore the NPS vegetation mapping project data provided a reference rather than a decisive label for those pixels masked out through each of the stratified subgroups.

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[7] http://gi.leica-geosystems.com/LGISub2x514x0.aspx (verified on December 22, 2007)

We began by rasterizing the vector GIS format vegetation data from ACAD, SARA and ROVA, matching the pixel size with the Landsat data. We then ran image-to-image geometric rectification on the rasterized vegetation map using the geo-referenced Landsat-7 ETM+ images as the base map. Next, we separated Landsat data into segmented images for further classification by using vegetation types and other land cover categories in the rasterized NPS vegetation map data as the mask to extract pixels from Landsat images. We repeated this step for each of the NPS vegetation and land cover types. We ran unsupervised classifications on each of the segmented images and then labeled the spectral clusters. The dominant category for each cluster should be the vegetation or land cover type defined by the masking type from the NPS vegetation map data. Pixels that had distinct spectral differences from the masked type were labeled into corresponding types defined by the classification scheme. We repeated this process until all the segmented images were classified and correctly labeled. We then put into mosaic form all classified segmented images to create the final land cover data, and conducted visual comparisons to assess the agreement between the NPS vegetation mapping project data and the classification results.

In this process, the NPS vegetation mapping data played an important role as a control data layer. The combination of the two information sources resulted in comprehensive information on land cover types. The vegetation mapping project data provided highly detailed information on vegetation types and communities. The land cover data generated from Landsat images provided more general landscape information. An added benefit of referencing the NPS vegetation mapping project data was a reduction in conflicts between data products. This stratified classification method could also provide a protocol for engaging NPS vegetation mapping project data with other types of remote sensing data to monitor landscape dynamics.

For those sites that had no USGS-NPS vegetation mapping data available at the time of our image processing, we referenced the NLCD-1992, NLCD-2001 and NWI data for post-classification improvement.

During the initial classifications, we selected more than one signature to represent a land cover category so that the spectral variation of a land cover category could be considered. Upon finishing the classification and the post-classification sorting, we recoded the classes into appropriate land cover categories, which resulted in final land cover types defined by our classification scheme.

Accuracy Assessment

There are always errors in land cover maps derived from the classification of remote sensing data. Accuracy assessment is the process of estimating how accurate the land cover data are in terms of thematic categories, in order to determine whether the product meets the requirements of the intended application. The way to quantitatively determine the accuracy of a dataset is through an accuracy assessment.

Accuracy assessment is the general term used for comparing the land cover classification results to geospatial data that are assumed to be true. The assumed-true data are derived from ground referencing data or other reliable data sources. It is not practical to ground reference or otherwise test every pixel of a classified image. Therefore, a set of reference pixels is usually used.

Reference pixels are points on the classified image for which actual data are known. The reference pixels are usually randomly selected to lessen or eliminate the possibility of bias (Congalton 1991).

Accuracy assessment can provide a comparison on a category-by-category basis of classification results vs. known reference data using an error matrix. An error analysis is only possible if the "truth" set is at least one step closer to reality than the remotely sensed product on which the map is based (Congalton 1991). In this case, we considered finer spatial resolution remote sensing data,(i.e., aerial photos and USGS digital orthophoto quadrangles (DOQs)[8], and rigorously collected field observations) to be our "truth" set.

We used the ERDAS Imagine accuracy assessment functions to conduct the accuracy analysis. We employed the "equalized random" sampling method, which randomly drew an equal number of sampling pixels from each land cover type derived from the classifications. The process creates an accuracy assessment CellArray, or Error Matrix, for each data file to compare the classified image with reference data. The CellArray is a square array of numbers laid out in rows and columns that express the number of sample units assigned to a particular category relative to the actual category as verified in the field. The columns normally represent the reference data, while the rows indicate the classification generated from remotely sensed data.

There are two types of accuracies reported: the producer's and user's accuracy. Producer's accuracy is a reference-based accuracy that is computed by looking at the predictions produced for a class and determining the percentage of correct predictions. In other words, if we know that a particular area is hardwood, what is the probability that the classification correctly classified the pixel in that area as hardwood? User's accuracy is a map-based accuracy that is computed by looking at the reference data for a class and determining the percentage of correct predictions for these samples. For example, if we select any hardwood pixel on the classified map, what is the probability that we'll be standing in a hardwood stand when we visit that pixel location in the field?

The results of an accuracy assessment typically provide an assessment of the overall accuracy of the map and the accuracy for each class in the map. For example, in a given land cover map some classes could be very accurate while others might be less accurate. These disparities can have a significant effect on the utility of the map, and they will be documented in the accuracy assessment.

The Kappa coefficient expresses the proportionate reduction in error generated by a classification process, compared with the error of a completely random classification. For example, a Kappa value of 0.82 would imply that the classification process was avoiding 82% of the errors that a completely random classification would generate (Congalton 1991).

In this project, we selected 50 reference pixels from each land cover category for each study site and for each time period. We then examined the agreement between the classification result and

[8] A digital orthophoto quadrangle (DOQ) is a computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map.

the visual interpretation for each of the reference pixel locations. Our knowledge for visual interpretation came from the experience that we gained from our fieldwork, the available finer spatial resolution remote sensing data products (e.g., air photos and DOQs), and our familiarity with the spectral features of the varying land cover types present within the Landsat images. Our determinations of "truth", like all other similar types of study, may not be perfectly accurate, which could add a certain level of uncertainty, particularly for the early time periods where contemporary photos and DOQs were not available. For example, the best DOQ data that we referenced for accuracy assessment at the ROVA NHS were acquired in August 1999. The time of aerial photo acquisition did not match with either the 1988 or 2002 Landsat images. We had to rely on our understanding of the landscape and the spectral features of reference points that showed up on the corresponding DOQ and Landsat images to make our best interpretation regarding the ground "truth." For ACAD, the 2001 DOQ provided the good reference for accuracy assessment for the classification of 2002 Landsat ETM+ data. However, there was no contemporaneous reference data for evaluation of the classifications of 1976 and 1986 Landsat data. Therefore, the accuracy assessment consequently represents a best-of-our-knowledge scenario for evaluation of the data.

Change Analysis

Post-classification comparison, also known as delta classification, involves independently produced spectral classification data from each end of the time interval of interest, followed by comparison of data to detect changes in cover type (Coppin and Bauer 1996). The principal advantage of post-classification comparison is that the images are separately classified, thereby minimizing the problem of radiometric calibration between dates (Song et al. 2001) and reducing the amount of data pre-processing. By choosing an appropriate classification scheme, post-classification comparison can also be made insensitive to a variety of transient changes. In addition, post-classification change analysis is flexible and easy to apply. However, because post-classification change analyses depend on separately classified land cover data for extracting the change analysis, error propagation is a major concern. The final accuracy of a change analysis is very close to the multiplied accuracy of each individual classification, and accumulated errors may mislead the interpretation of the change analysis.

Results

The results of the change analysis summarize differences between the land cover maps created for each time period. They document our estimation of changes in the general land cover types within and adjacent to the park units and A.T. segments for the time periods covered by the Landsat remote sensing data. Our change analyses were based on the total area of land cover categories and their changes within different buffer zones, rather than pixel-by-pixel-based change detection. Conducting pixel-based change analysis would require more comprehensive study. The land cover categories in the study sites were different due to the landscape characteristics. For example, the main factor driving land cover change at the Whitecap Mountain segment of the A.T. has been logging and forest regrowth. Therefore, the category of Regrowth Forest appeared in this study site. The following results have park-specific tables that demonstrate the comparisons of land cover types and their changes for each park and 5-kilometers buffer, in addition to comparisons of land cover types and their changes within the park boundary and in different buffer zones (500-m, 1-km and 5-km) adjacent to the park units and the A.T. segments. Detailed accuracy assessments for the land cover classifications are listed in Appendix A.

Acadia National Park (ACAD)

The land cover types and changes of the larger area covered by the subset image (Figure 3) indicate that there was an increase in the amount of area characterized as Urban Land between 1976 and 2002 (Table 3). This cover type increased from 11,601 acres in 1976 to 16,293 acres in 1986 and 25,160 acres in 2002. This represents a 40% increase (4, 692 acres) from 1976-1986, and a 54% (8,867 acres) increase over the 16 years between 1986 and 2002. In the 26 years between 1976 and 2002, Urban Land cover increased 13,559 acres (117%) in the region.

While Urban Land cover types increased, the Deciduous Forest cover type increased. The cover of Coniferous and Mixed Forests decreased. Coniferous Forest declined 58,958 acres between 1976 and 1986, and then increased 24,553 acres between 1986 and 2002. Overall, the Coniferous Forest cover type declined 34,405 acres from 1976 to 2002. The land cover type of Herbaceous Vegetation increased during the 26 years with 2,570 acres added between 1976 and 1986, 9,384 acres added between 1986 and 2002, and 11,954 acres added between 1976 and 2002. The Wetland category increased between 1976 and 1986 by 7,826 acres, and then decreased between 1986 and 2002 by 2,799 acres. Table 3 summarizes the land cover type changes in the Acadia National Park area.

Table 4 offers more details about the land cover changes within the ACAD property boundary and the immediately adjacent buffer zones. Urban Land increased from 141 acres in 1976, to 276 acres in 1986, to 469 acres in 2002 within the ACAD boundary. Within the 500-meter buffer area immediately adjacent to ACAD, Urban Land increased from 894 acres in 1976, to 1,331 acres in 1986, 1,687 acres in 2002. For the 1-kilometer buffer zone adjacent to ACAD, Urban

Table 3. Acreage of each land cover type with buffers applied at Acadia NP and subset areas for 1976, 1986, and 2002, and change in acreage of each land cover type between time periods.

	Acres in ACAD and the Subset Areas			Acreage Changes (percent change)					
Land Cover Type	**1976**	**1986**	**2002**	**1976-1986**		**1986-2002**		**1976-2002**	
Urban	11,601	16,293	25,160	4,692	(40%)	8,867	(54%)	13,559	(117%)
Deciduous Forest	74,970	88,651	89,851	13,681	(18%)	1,200	(1%)	14,881	(20%)
Coniferous Forest	264,402	205,444	229,997	-58,958	(-22%)	24,553	(12%)	-34,405	(-13%)
Mixed Forest	152,861	187,421	143,627	34,560	(23%)	-43,794	(-23%)	-9,234	(-6%)
Water	653,248	769,047	801,590	115,799	(18%)	32,543	(4%)	148,342	(23%)
Wetland	25,341	33,167	30,368	7,826	(31%)	-2,799	(-8%)	5,027	(20%)
Herbaceous Veg.	17,645	20,215	29,599	2,570	(15%)	9,384	(46%)	11,954	(68%)
Bare Rockface	27,577	17,168	25,366	-10,409	(-38%)	8,198	(48%)	-2,211	(-8%)

Table 4. Acreage of each land cover type within Acadia NP boundaries and within the 500-meter, 1-kilometer, and 5-kilometer buffers adjacent to the park boundary.

	Within ACAD boundary			500-m Buffer		
Land Cover Type	**1976**	**1986**	**2002**	**1976**	**1986**	**2002**
Urban	141	276	469	894	1,331	1,687
Deciduous Forest	9,325	7,364	5,915	4,068	2,503	2,353
Coniferous Forest	13,077	11,166	13,433	5,103	3,628	4,992
Mixed Forest	7,542	11,606	10,590	4,016	6,314	4,714
Water	1,156	1,130	1,016	12,338	13,131	12,924
Wetland	2,131	2,381	2,091	1,239	1,357	1,165
Herbaceous Veg.	454	281	801	421	280	907
Bare Rockface	2,707	2,326	2,226	778	313	98
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1976**	**1986**	**2002**	**1976**	**1986**	**2002**
Urban	1,668	2,621	3,598	11,460	16,017	24,691
Deciduous Forest	6,999	4,170	3,995	65,645	81,287	83,936
Coniferous Forest	9,427	6,798	8,989	251,325	194,278	216,564
Mixed Forest	7,210	11,392	8,401	145,319	175,815	133,037
Water	27,042	28,189	27,751	652,092	767,917	800,574
Wetland	2,064	2,251	1,952	23,210	30,786	28,277
Herbaceous Veg.	647	446	1,464	17,191	19,934	28,798
Bare Rockface	1,294	486	176	24,870	14,842	23,140

Land increased from 1,668 acres in 1976, to 2,621 acres in 1986, to 3,598 acres in 2002. For the 5-kilometer buffer zone adjacent to ACAD, Urban Land increased from 11,460 acres in 1976, to 16,017 acres in 1986, and then to 24,691 acres in 2002. Urban development along the gateway to the park, such as Route 3, and urban expansion around the Bar Harbor, Northeast Harbor, Southwest Harbor and the major transportation lines may contribute to the suburban sprawl adjacent to ACAD.

Deciduous Forest within the ACAD boundary declined from 9,325 acres in 1976, to 7,364 acres in 1986, to5,915 acres in 2002 (Table 4). The same trend occurred in 500-meter and 1-kilometer buffer zones adjacent to the park boundary. However, for the 5-kilometer (buffer areas adjacent to ACAD, the Deciduous Forest showed an increasing trend from 65,645 acres in 1976, to 81,287 acres in 1986, to 83,936 acres in 2002. The trend towards an increasing in the amount of Deciduous Forest within the 5-kilometer buffer zone adjacent to ACAD matched the pattern for the bigger area of the subset image (Figure 3) as summarized in the previous paragraph.

The category of Coniferous Forest declined from 13,077 acres in 1976 to 11,166 acres in 1986, and then increased to 13,433 acres in 2002 within the ACAD boundary. For the 500-meter buffer area immediately adjacent to ACAD, Coniferous Forest declined from 5,103 acres in 1976, to 3,628 acres in 1986, and then increased to 4,992 acres in 2002. The same pattern was observed in the 1-kilometer and 5-kilometer buffer zones. The Mixed Forest within the ACAD boundary was 7,542 acres in 1976, increased to 11,606 acres in 1986, and then declined to 10,590 acres in 2002. Similar trends were observed in the 500-meter, 1-kilometer and 5-kilometer buffer zones adjacent to ACAD. Changes in land cover type may reflect forest succession within the region; they may also be caused by spectral differences between years in satellite images.

There was little change in the amount of land assigned to the Wetland category in different years. Within the ACAD boundary, Wetland was 2,131 acres in 1976, increased to 2,381 acres in 1986, and then declined to 2,091 acres in 2002. For the 500-meter buffer zone, Wetland was 1,239 acres in 1976, increased to 1,357 acres in 1986, and then declined to 1,165 acres in 2002. We observed the same pattern in the 1-kilometer other buffer zones as well.

The Bare Rockface category in ACAD included areas of granite at the summit of Cadillac Mountain and rocky shorelines. Because digital image classification is pixel-based, we needed to add this category to identify areas associated with bare rock surfaces. Areas classified as bare rock surface declined from 2,707 acres in 1976, to 2,326 acres in 1986, to 2,226 acres in 2002. The same pattern was observed in all other buffer zones adjacent to ACAD. Increased vegetation cover in these areas and tidal dynamics may have contributed to the changes observed.

Within the park boundary, Herbaceous Vegetation decreased in 1986 and then increased in 2002. We observed 183 hectares (454 acres in 1976, 281 acres in 1986, and 801 acres in 2002. The same trend (decreasing in 1986 and then increasing in 2002) was observed within 500-meter and 1-kilometer buffer zones adjacent to ACAD. However, for the 5-kilometer buffer area, there was 17,191 acres in 1976, 19,934 acres in 1986, and 28,978 acres in 2002 (Table 4), a pattern similar to that illustrated in Table 3.

Figure 24 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods of 1976, 1986, and 2002, for the Acadia NP region. In addition, the results of the land cover types and change detection analysis is shown.

As reported from the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1986 Landsat TM, and 1976 Landsat MSS images of the bigger ACAD site achieved overall accuracies of 87.0%, 86.5% and 84.75%, respectively.

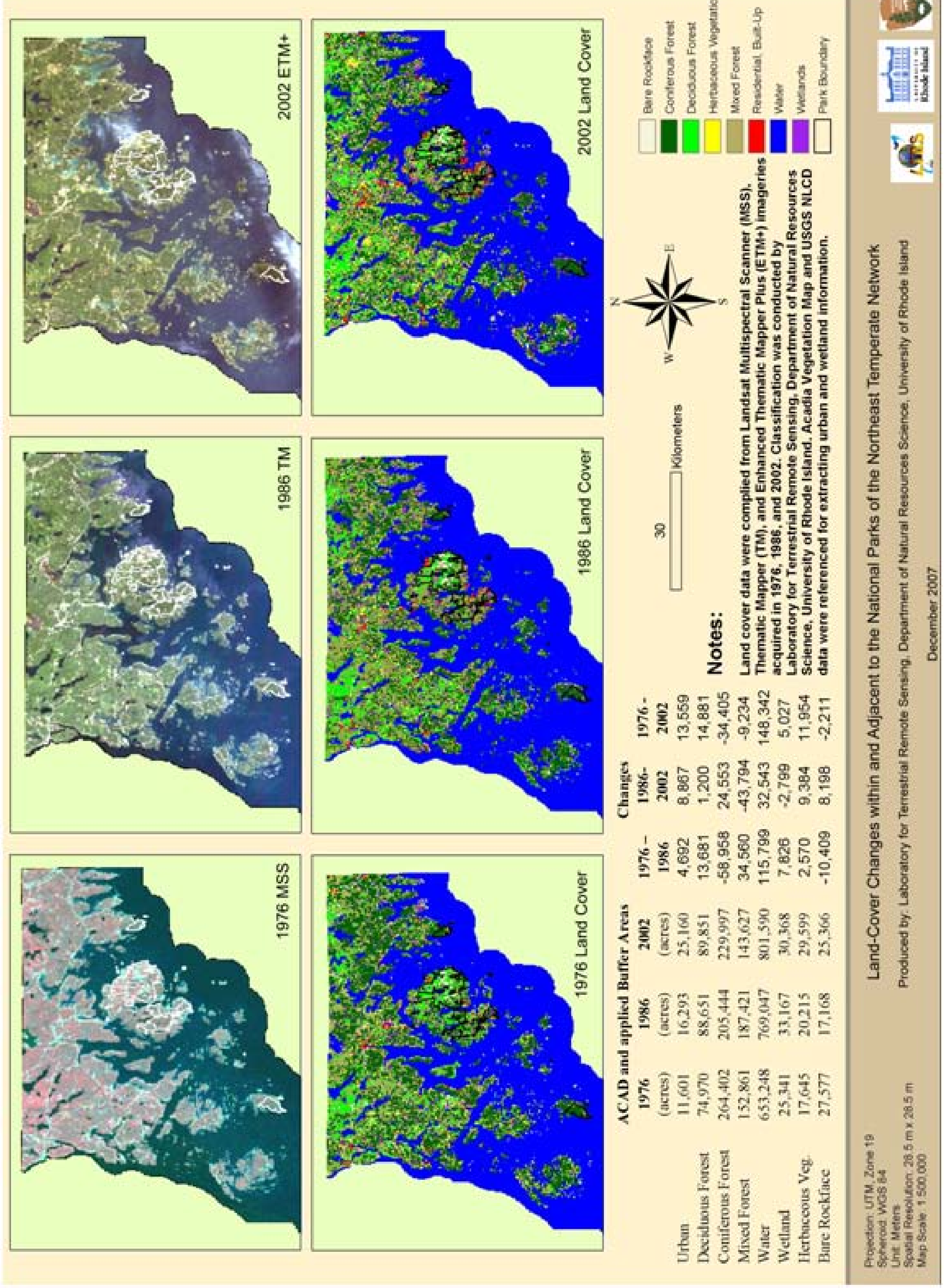


Figure 24. Land cover and change for Acadia National Park and adjacent areas.

Marsh-Billings-Rockefeller NHP (MABI)

The land cover types and changes for the MABI site, including the areas within the 5-kilometer buffer adjacent to the park, indicate that the area experienced urban expansion between 1978 and 2002 (Table 5). Urban Land increased from 123 acres in 1978, to 202 acres in 1989, and 1,099 acres in 2002. Urban Land increased by 79 acres between 1978 and 1989, and 897 acres between 1989 and 2002. In the 24 years between 1978 and 2002, Urban Land cover increased by 976 acres.

Deciduous Forest increased at the site as well, from 9,838 acres in 1978, to 11,805 acres in 1989, to 12,314 acres in 2002. Coniferous Forest declined from 5,109 acres in 1978, to 4,396 acres in 1989, and then increased to 5,395 acres in 2002. Mixed Forest declined from 9,188 acres in 1978, to 8,251 acres in 1989, to 5,000 acres in 2002.

Table 6 offers more details about the land cover changes within the MABI boundary and the immediately adjacent buffer zones. Urban Land increased slightly from one acre in 1978, to two acres in 1989, and eight acres in 2002. In the 500-meter buffer area immediately adjacent to MABI, Urban Land increased from 21 acres in 1978, to 51 acres in 1989, to 123 acres in 2002. For the 1-kilometer buffer zone adjacent to MABI, Urban Land increased from 98 acres in 1978, to 150 acres in 1989, to 349 acres in 2002. For the 5-kilometer buffer zone adjacent to the park, Urban Land increased from 122 acres in 1978, to 200 acres in 1989, and then to 1,091 acres in 2002. Urban development along Route 12 and Route 4 and near Woodstock may have contributed to the increase in the amount of Urban Land adjacent to the MABI site.

Table 5. Acreage of each land cover type within Marsh-Billings-Rockefeller NHP and the 5-kilometer buffer zone adjacent to the park for 1978, 1989, and 2002, and change in acreage of each land cover type between time periods.

	MABI and 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1978**	**1989**	**2002**	**1978-1989**	**1989-2002**	**1978-2002**
Urban	123	202	1,099	79 (64%)	897 (444%)	976(793%)
Deciduous Forest	9,838	11,805	12,314	1,967 (20%)	509 (4%)	2,476 (25%)
Coniferous Forest	5,109	4,396	5,395	-713 (-14%)	999 (23%)	286 (6%)
Mixed Forest	9,188	8,251	5,000	-937 (-10%)	-3,251 (-39%)	-4,188 (-46%)
Water	21	57	34	36 (171%)	-23 (-40%)	13 (62%)
Wetland	124	85	71	-39 (-31%)	-14 (-16%)	-53 (-43%)
Herbaceous Veg.	5,135	4,608	5,477	-527 (-10%)	869 (19%)	342 (7%)

Table 6. Acreage of each land cover type within Marsh-Billings-Rockefeller NHP park and the 5-meter, 1-kilometer, and 5-kilometer buffer areas during 1978, 1989, and 2002.

	MABI Boundary			500-m Buffer		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	1	2	8	21	51	123
Deciduous Forest	171	178	231	349	403	381
Coniferous Forest	175	157	175	238	176	257
Mixed Forest	185	180	105	418	373	209
Water	2	2	1	1	6	5
Wetland	6	3	3	10	7	5
Herbaceous Veg.	24	40	38	190	214	250
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	98	150	349	122	200	1,091
Deciduous Forest	735	897	807	9,667	11,627	12,083
Coniferous Forest	498	387	533	4,934	4,239	5,220
Mixed Forest	802	701	421	9,003	8,071	4,895
Water	2	24	16	19	55	33
Wetland	31	13	10	118	82	68
Herbaceous Veg.	584	581	618	5,111	4,568	5,439

Deciduous Forest within the MABI boundary changed slightly from 171 acres in 1978, to 178 acres in 1989, to 231 acres in 2002. For the 500-meter and 1-kilometer buffer zones adjacent to MABI, Deciduous Forest increased between 1978 and 1989 and decreased from 1989 to 2002. However, for the 5-kilometer buffer area adjacent to MABI, Deciduous Forest increased over the three time periods, from 9,667 acres in 1978, to 11,627 acres in 1989, to 12,083 acres in 2002.

Coniferous Forest within the MABI boundary didn't change over the 24-year time span. There were 175 acres of Coniferous Forest in 1978, which declined slightly to 157 acres in 1989, and then increased back to 175 acres in 2002. The changes observed for the 1989 time period might have been due to the spectral signatures recorded by satellite images. For the 500-meter, 1-kilometer and 5-kilometer buffer zones immediately adjacent to the MABI boundary, Coniferous Forests show the same pattern of decline to 1989 and increase by 2002. Mixed Forests declined for all the analyzed areas.

Wetlands also declined from 6 acres in 1978, to three acres in 1989 and 2002 within the MABI boundary. Declines were observed for the 500-meter, 1-kilometer and 5-kilometer buffer zones as well. However, when we combined the Wetland and Water categories, the acreage changes were not dramatic. The changes might have been caused by the influence of dry-year/wet-year alternations on the landscape and recorded by Landsat images.

As reported from accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1978 Landsat MSS images of the MABI site achieved overall accuracies of 88.57%, 85.71% and 89.00%, respectively.

Figure 25 illustrates the Landsat images and the corresponding maps of land cover classification at the three time periods (1978, 1989, and 2002) for the MABI NHP area, and the results of land cover types and change detection analysis.

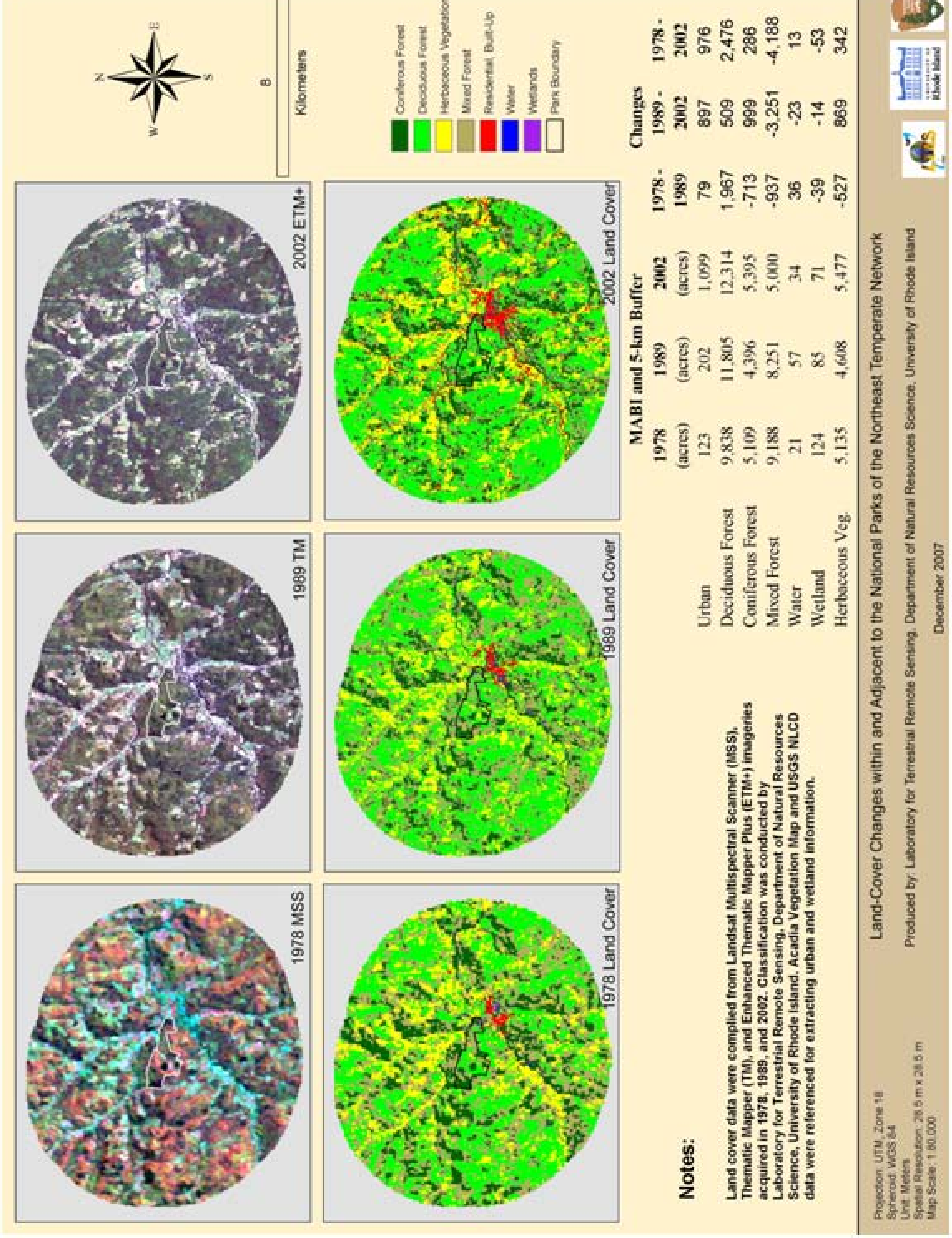


Figure 25. Land cover and change for Marsh-Billings-Rockefeller NHP and the adjacent 5-kilometer buffer zone.

Minute Man NHP (MIMA)

The land cover types and changes at the MIMA site (including the areas of 5-kilometer buffer adjacent to the park) indicate that the area experienced urban expansion between 1974 and 2000 (Table 7). Urban Land increased from 7,481 acres in 1974, to 22,734 acres in 1987, and 28,484 acres in 2000. Urban Land increased by 15,253 acres between 1974 and 1987, and 5,750 acres between 1987 and 2000. In the 26 years between 1974 and 2000, Urban Land cover increased 21,003 acres.

Deciduous Forest decreased at the site from 44,928 acres in 1974, to 30,088 acres in 1987, to 27,923 acres in 2000. Coniferous Forest declined from 16,209 acres in 1974, to 4,788 acres in 1987, and then increased to 6,225 acres in 2000. Mixed Forest totaled 10,255 acres in 1974, 13,461 acres in 1987, and 10,770 acres in 2000. Wetland increased from 3,737 acres in 1974, to 5,106 acres in 1987, to 5,406 acres in 2000.

Table 8 offers more details about the land cover changes within the MIMA boundary and the immediately adjacent buffer zones. Within the MIMA boundary, Urban Land increased from 16 acres in 1974, to 112 acres in 1987, and 151 acres in 2000. In the 500-meter buffer areas immediately adjacent to MIMA, Urban Land increased from 261 acres in 1974, to 801 acres in 1987, and to 1,039 acres in 2000. For the 1-kilometer buffer zone adjacent to MIMA, Urban Land increased from 652 acres in 1974, to 1,790 acres in 1987, to 2,256 acres in 2000. For the 5-kilometer buffer zone adjacent to the park, Urban Land increased from 7,465 acres in 1974, to 22,622 acres in 1987, to 28,333 acres in 2000.

Deciduous Forest within the MIMA boundary declined from 602 acres in 1974, to 538 acres in 1987, to 430 acres in 2000. For the 500-meter, 1-kilometer and 5-kilometer buffer zones adjacent to the MIMA, Deciduous and Coniferous Forests decreased.

Wetlands increased from 69 acres in 1974, to 73 acres in 1987, and 98 acres in 2000 within the MIMA boundary. The same general pattern was observed for the 500-meter, 1-kilometer and 5-kilometer buffer zones.

As reported from the accuracy assessment (Appendix A), the land cover classification for the 2000 Landsat ETM+, 1987 Landsat TM and 1974 Landsat MSS images of the MIMA site achieved overall accuracies of 81.71%, 91.43% and 85.14%, respectively. The relatively low overall accuracy of the 1974 and 2000 classifications, and the low producer’s accuracy (68.57%) for the Urban category and low user’s accuracy (76%) for the Wetland category may reduce the confidence of classification results for this MIMA site. The cause of the low classification accuracy may be because of the site’s primarily suburban setting, the quality of the image data available for the project, and the pixel size of the Landsat images leading to confusion between the Urban category and other land cover types, such as Wetland and Herbivorous Vegetation, that reduced the level of accuracy. Therefore the accuracy level must be considered when interpreting the results of the land cover change analysis for the MIMA site.

Figure 26 illustrates the Landsat images and the corresponding maps of land cover classification at the three time periods (1974, 1987, and 2000) for the MIMA NHP area, and the results of the land cover types and change detection analysis.

Table 7. Acreage of each land cover type within Minute Man NHP and the 5-kilometer buffer zone adjacent to the park for 1974, 1987, and 2000, and change in acreage of each land cover type between time periods.

	MIMA and 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1974**	**1987**	**2000**	**1974-1987**	**1987-2000**	**1974-2000**
Urban	7,481	22,734	28,484	15,253 (204%)	5,750 (25%)	21,003 (281%)
Deciduous Forest	44,928	30,088	27,923	-14,840 (-33%)	-2,165 (-7%)	-17,005 (-38%)
Coniferous Forest	16,209	4,788	6,225	-11,421 (-70%)	1,437 (30%)	-9,984 (-62%)
Mixed Forest	10,225	13,461	10,770	3,236 (32%)	-2,691 (-20%)	545 (5%)
Water	1,945	2,950	3,170	1,005 (52%)	220 (7%)	1,225 (63%)
Wetland	3,737	5,106	5,406	1,369 (37%)	300 (6%)	1,669 (45%)
Herbaceous Veg.	4,059	9,219	6,346	5,160 (127%)	-2,873 (-31%)	2,287 (56%)

Table 8. Acreage of each land cover type during 1974, 1987, and 2000 within the Minute Man NHP park boundary and the adjacent 500-meter, 1-kilometer, and 5-kilometer buffer areas.

	MIMA Boundary			500-m Buffer		
Land Cover Type	**1974**	**1987**	**2000**	**1974**	**1987**	**2000**
Urban	16	112	151	261	801	1,039
Deciduous Forest	602	538	430	1,516	1,074	867
Coniferous Forest	148	22	44	362	91	156
Mixed Forest	102	96	125	287	376	272
Water	5	11	16	33	70	72
Wetland	69	73	98	149	199	241
Herbaceous Veg.	23	116	104	252	250	214
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1974**	**1987**	**2000**	**1974**	**1987**	**2000**
Urban	652	1,790	2,256	7,465	22,622	28,333
Deciduous Forest	3,282	2,258	1,886	44,326	29,550	27,493
Coniferous Forest	735	173	321	16,061	4,766	6,181
Mixed Forest	546	787	570	10,123	13,365	10,645
Water	75	151	140	1,940	2,939	3,154
Wetland	283	390	431	3,668	5,033	5,308
Herbaceous Veg.	460	485	431	4,036	9,103	6,242

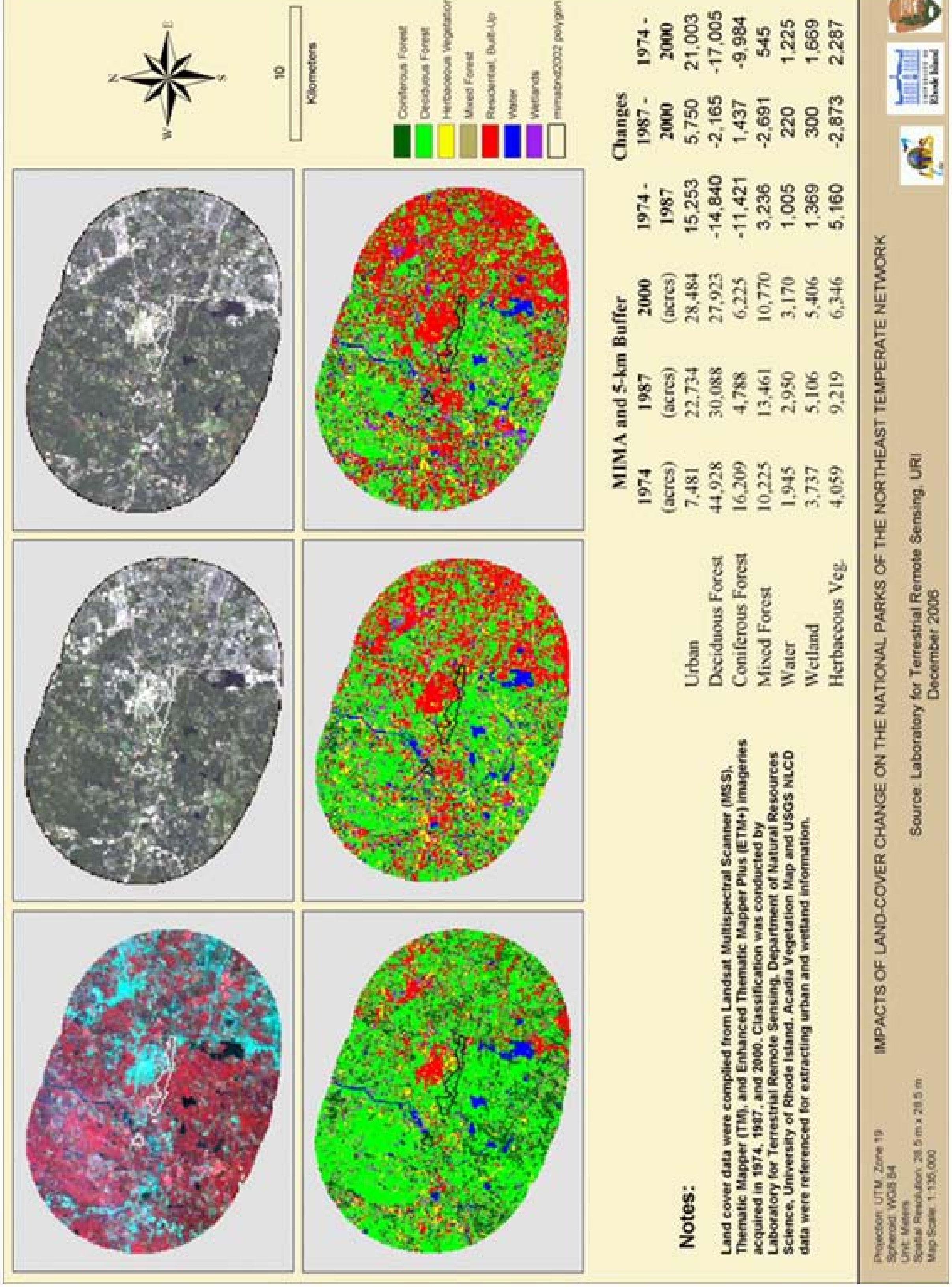


Figure 26. Land cover and change for Minute Man NHP and the adjacent 5-kilometer buffer zone.

Morristown NHP (MORR)

The land cover types and changes at the MORR site, including the areas of 5-kilometer buffer adjacent to the park, indicate that the area experienced urban expansion in the 26 years between 1976 and 2002 (Table 9). Urban Land covered 2,350 acres in 1976, 12,690 acres in 1988, and 14,112 acres in 2002. Urban Land increased by 10,340 acres between 1976 and 1988, and 1,422 acres between 1988 and 2002. In the 26 years between 1976 and 2002, Urban Land cover increased by 11,762 acres.

Deciduous Forest cover declined between 1976 and 1988, and then increased between 1988 and 2002. Coniferous and Mixed Forests decreased between 1976 and 2002. Wetlands covered 2,095, 3,081, and 2,353 acres, respectively, in 1976, 1988 and 2002.

Table 10 offers more details about the land cover changes within the MORR boundary and the immediately adjacent buffer zones. Urban Land increased from one acre in 1976 to 20 acres in 1988. The classification of Landsat data showed 16 acres of Urban Land within the MORR boundary in 2002. Within the 500-meter buffer areas immediately adjacent the MORR, Urban Land increased from 172 acres in 1976, to 672 acres in 1988, to 691 acres in 2002. Within the 1-kilometer buffer zone adjacent to MORR, Urban Land increased from 472 acres in 1976, to 1,816 acres in 1988, to 1,886 acres in 2002. Within the 5-kilometer buffer zone adjacent to the park, Urban Land increased from 2,349 acres in 1976, to 12,670 acres in 1988, and then to 14,096 acres in 2002.

Deciduous Forest within the MORR boundary decreased from 926 acres in 1976 to 666 acres in 1988, and then increased to 1,020 in 2002. Within the 500-meter, 1-kilometer and 5-kilometer buffer zones adjacent to the MORR, Deciduous Forest decreased between 1976 and 1988 and then increased between 1988 and 2002.

Coniferous Forest decreased for all the three buffer zones during the three time periods, except for a slight increase from 23 acres in 1976 to 25 acres in 1988 within the MORR boundary.

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1988 Landsat TM and 1976 Landsat MSS images of the MORR site achieved overall accuracies of 89.43%, 84.57% and 87.14%, respectively.

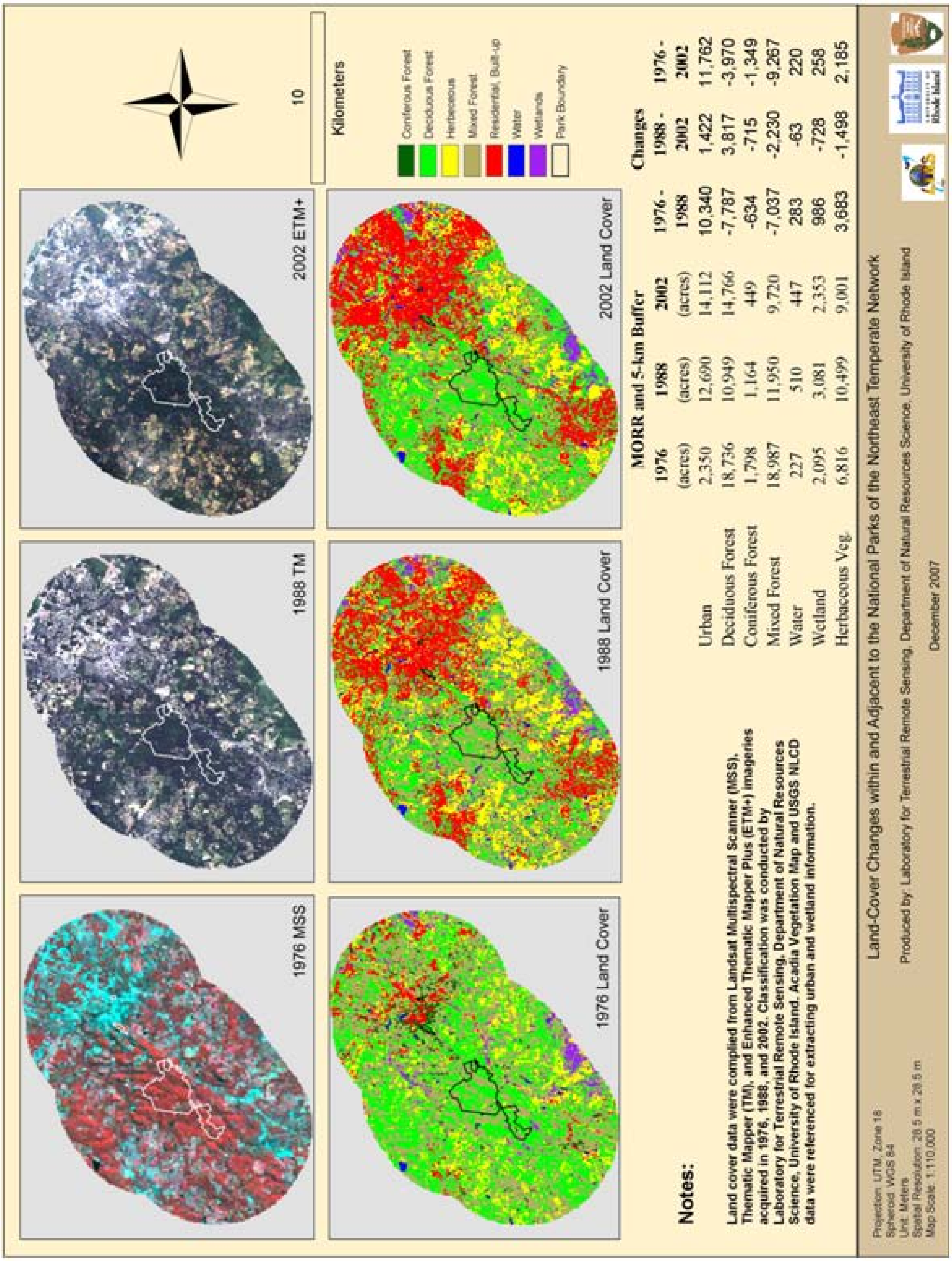
Figure 27 illustrates the Landsat images and the corresponding maps of land cover classification at the three time periods (1976, 1988, and 2002) for the MORR area, and the results of the land cover types and change detection analysis.

Table 9. Acreage of each land cover type within Morristown NHP and the adjacent 5-kilometer buffer zone for 1976, 1988, and 2002, and change in acreage of each land cover type between time periods.

	MORR and 5-km Buffer			Acreage Change (percent change)		
Land Cover Type	**1976**	**1988**	**2002**	**1976-1988**	**1988-2002**	**1976-2002**
Urban	2,350	12,690	14,112	10,340 (440%)	1,422 (11%)	11,762 (501%)
Deciduous Forest	18,736	10,949	14,766	-7,787 (-42%)	3,817 (35%)	-3,970 (-21%)
Coniferous Forest	1,798	1,164	449	-634 (-35%)	-715 (-61%)	-1,349 (-75%)
Mixed Forest	18,987	11,950	9,720	-7,037 (-37%)	-2,230 (-19%)	-9,267 (-49%)
Water	227	510	447	283 (125%)	-63 (-12%)	220 (97%)
Wetland	2,095	3,081	2,353	986 (47%)	-728 (-24%)	258 (12%)
Herbaceous Veg.	6,816	10,499	9,001	3,683 (54%)	-1,498 (-14%)	2,185 (32%)

Table 10. Acreage of each land cover type during 1976, 1988, and 2002 within the Morristown NHP park boundary and the adjacent 500-meter, 1-kilometer, and 5-kilometer buffer zones.

	MORR Boundary			500-m Buffer		
Land Cover Type	**1976**	**1988**	**2002**	**1976**	**1988**	**2002**
Urban	1	20	16	172	672	691
Deciduous Forest	926	666	1,020	1,368	886	1,221
Coniferous Forest	23	25	9	192	70	41
Mixed Forest	710	864	599	1,144	1,078	918
Water	0	3	0	5	13	26
Wetland	15	41	3	88	109	51
Herbaceous Veg.	33	83	57	158	308	189
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1976**	**1988**	**2002**	**1976**	**1988**	**2002**
Urban	472	1,816	1,886	2,349	12,670	14,096
Deciduous Forest	2,727	1,751	2,321	17,810	10,283	13,746
Coniferous Forest	536	180	105	1,775	1,139	440
Mixed Forest	2,476	2,027	1,846	18,277	11,086	9,121
Water	35	72	78	227	507	447
Wetland	195	248	128	2,080	3,040	2,350
Herbaceous Veg.	523	879	605	6,783	10,416	8,944



	MORR and 5-km Buffer			Changes		
	1976 (acres)	1988 (acres)	2002 (acres)	1976 - 1988	1988 - 2002	1976 - 2002
Urban	2,350	12,690	14,112	10,340	1,422	11,762
Deciduous Forest	18,736	10,949	14,766	-7,787	3,817	-3,970
Coniferous Forest	1,798	1,164	449	-634	-715	-1,349
Mixed Forest	18,987	11,950	9,720	-7,037	-2,230	-9,267
Water	227	510	447	283	-63	220
Wetland	2,095	3,081	2,353	986	-728	258
Herbaceous Veg.	6,816	10,499	9,001	3,683	-1,498	2,185

Figure 27. Land cover and change for Morristown National Historical Park and the adjacent 5-kilometer buffer zone.

Roosevelt-Vanderbilt NHS (ROVA)

The land cover types and changes at the ROVA site, including the areas of 5-kilometer buffer adjacent to the park, indicate that the area experienced urban expansion in the 29 years between 1973 and 2002 (Table 11). Urban Land increased from 2,801 acres in 1973, to 5,732 acres in 1988, and 6,492 acres in 2002. Urban Land increased by 2,931 acres between 1973 and 1988, and 760 acres between 1988 and 2002. In the 29 years between 1973 and 2002, Urban Land cover increased by 3,691 acres.

Deciduous Forest decreased at this site, from 19,488 acres in 1973, to 18,805 acres in 1988, and then back up to 18,964 acres in 2002. The Coniferous Forest declined from 4,290 acres in 1973, to 2,817 acres in 1988, to 1,674 acres in 2002. Mixed Forest increased from 6,084 acres in 1973, to 6,297 acres in 1988, and then declined to 3,482 acres in 2002. Wetlands decreased from 1,799 acres in 1973 to 1,475 acres in 1988, and to 3,063 acres in 2002.

Table 12 offers more details about the land cover changes within the ROVA boundary and the immediately adjacent buffer zones. Urban Land doubled from 99 acres in 1973 to 200 acres in 1988, and increased to 246 acres in 2002 within the boundary of the National Historic Sites. Within the 500-meter buffer area immediately adjacent to the ROVA boundary, Urban Land increased from 182 acres in 1973, to 486 acres in 1988, to 581 acres in 2002. For the 1-kilometer buffer zone adjacent to ROVA, Urban Land increased from 516 acres in 1973, to 1,020 acres in 1988, to 1,210 acres in 2002. For the 5-kilometer buffer zone, Urban Land increased from 2,702 acres in 1973, to 5,532 acres in 1988, and then to 6,246 acres in 2002.

Table 11. Acreage of each land cover type within the Roosevelt-Vanderbilt NHS boundary and the adjacent 5-kilometer buffer zone during 1973, 1988, and 2002, and change in acreage of each land cover type between time periods.

	ROVA and 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1973**	**1988**	**2002**	**1973 - 1988**	**1988 - 2002**	**1973 - 2002**
Urban	2,801	5,732	6,492	2,931 (105%)	760 (13%)	3,691(132%)
Deciduous Forest	19,488	18,805	18,946	-683 (-4%)	141 (1%)	-542 (-3%)
Coniferous Forest	4,290	2,817	1,674	-1,473 (-34%)	-1,143 (-41%)	-2,616 (-61%)
Mixed Forest	6,084	6,297	3,482	213 (4%)	-2,815 (-45%)	-2,602 (-43%)
Water	3,194	3,789	3,441	595 (19%)	-348 (-9%)	247 (8%)
Wetland	1,799	1,475	3,063	-324 (-18%)	1,588 (108%)	1,264 (70%)
Herbaceous Veg.	5,008	3,617	5,434	-1,391 (-28%)	1,817 (50%)	426 (9%)

Table 12. Acreage of each land cover type during 1973, 1988, and 2002 within Roosevelt-Vanderbilt NHS park boundary and adjacent 500-meter, 1-kilometer, and 5-kilometer buffer areas.

	ROVA Boundary			500-m Buffer		
Land Cover Type	**1973**	**1988**	**2002**	**1973**	**1988**	**2002**
Urban	99	200	246	182	486	581
Deciduous Forest	450	488	556	764	866	887
Coniferous Forest	315	147	102	363	110	78
Mixed Forest	246	316	143	514	479	286
Water	196	203	165	686	770	734
Wetland	94	55	111	72	44	107
Herbaceous Veg.	110	101	187	279	101	183
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1973**	**1988**	**2002**	**1973**	**1988**	**2002**
Urban	516	1,020	1,210	2,702	5,532	6,246
Deciduous Forest	2,211	2,407	2,453	19,038	18,317	18,390
Coniferous Forest	729	305	200	3,975	2,670	1,572
Mixed Forest	1,082	1,012	534	5,838	5,981	3,339
Water	1,208	1,359	1,301	2,998	3,586	3,276
Wetland	150	92	258	1,705	1,420	2,952
Herbaceous Veg.	614	315	555	4,898	3,516	5,247

Deciduous Forest within the ROVA boundaries increased from 450 acres in 1973, to 488 acres in 1988, to 556 acres in 2002. Within the 500-meter and 1-kilometer buffer zones adjacent to the park, Deciduous Forest increased over the three time periods; however, within the 5-kilometer buffer zone, Deciduous Forest declined from 19,038 acres in 1973, to 18,317 acres in 1988, to 18,390 acres in 2002.

Coniferous Forest within the ROVA boundary changed significantly during the 29 year span we evaluated. There were 315 acres of Coniferous Forest in 1973, which declined to 147 acres in 1988, and then to 102 acres in 2002. Within the 500-meter, 1-kilometer and 5-kilometer buffer zones, Coniferous Forest exhibited the same pattern of decline over the three time periods.

Wetland encompassed 94 acres in 1973, 55 acres in 1988, and 111 acres in 2002 within the ROVA boundary. However, if we included acres of Water (196 acres in 1973, 203 acres in 1988 and 165 acres in 2002), the total amount of Wetlands and water areas did not change that much, (from 296 acres in 1973, to 258 acres in 1988, to 276 acres in 2002). The same pattern was observed for the 500-meter, 1-kilometer and 5-kilometer buffer zones for the combined Wetland and Water categories. Fluctuations might be caused by the influence of dry and wet year alternations on the landscape and how water features were recorded by Landsat images.

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1988 Landsat TM and 1973 Landsat MSS images of the ROVA sites achieved overall accuracies of 90.57%, 92.00% and 91.43%, respectively.

Figure 28 illustrates the Landsat images and the corresponding maps of land cover classification at the three time periods (1973, 1988, and 2002) for the ROVA NHS area, and the results of the land cover types and change detection analysis.

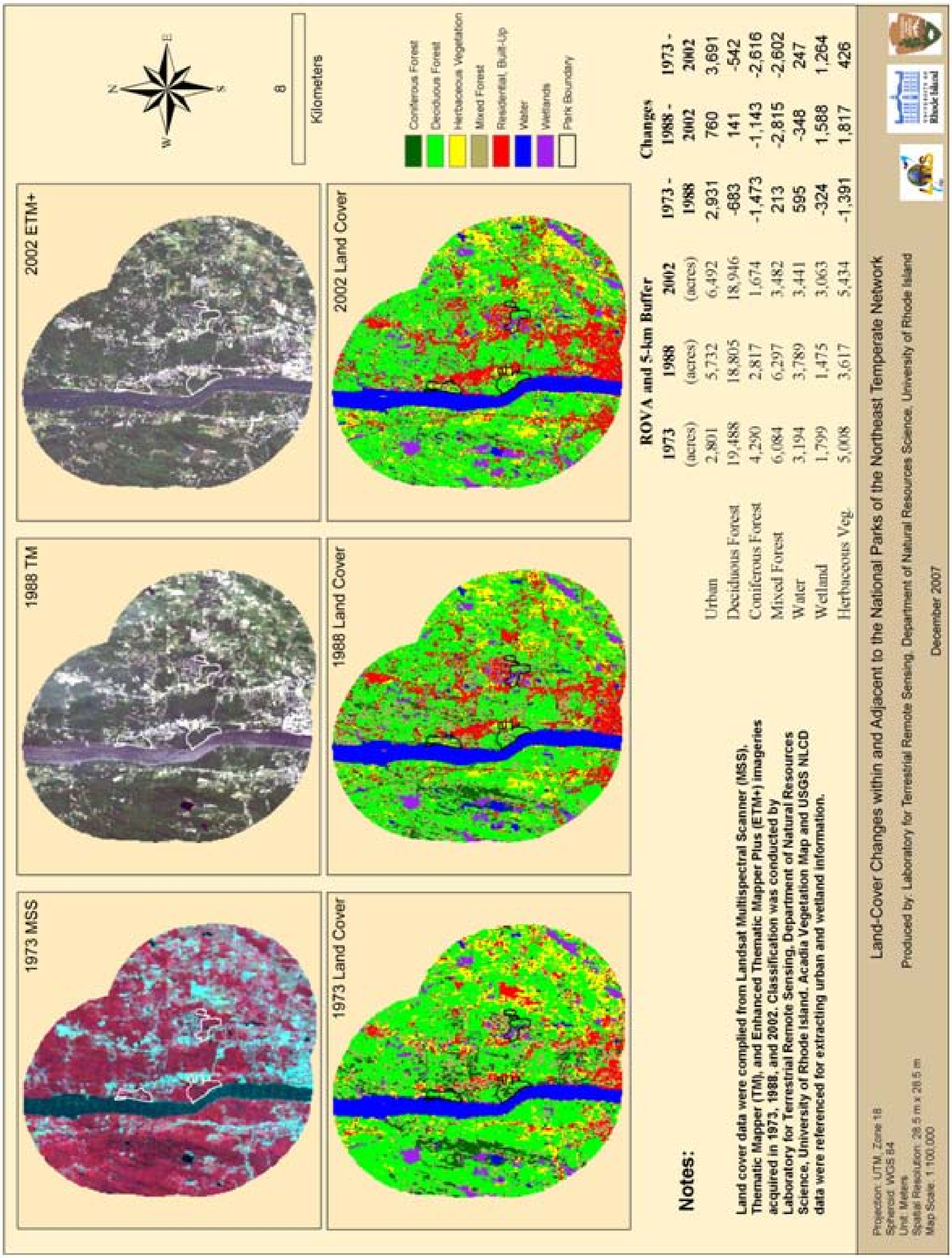


Figure 28. Land cover and change within Roosevelt-Vanderbilt NHS and the adjacent 5-kilometer buffer zone.

Saint-Gaudens NHS (SAGA)

The land cover types and changes at the SAGA site, including the 5-kilometer buffer adjacent to the park, indicate that the area experienced urban expansion between 1978 and 2002 (Table 13). The Urban Land increased from 380 acres in 1978, to 626 acres in 1989, and 743 acres in 2002. Urban Land increased by 246 acres between 1978 and 1989, and 117 acres between 1989 and 2002. In the 24 years between 1978 and 2002, Urban Land cover increased by 363 acres.

Deciduous Forest decreased between 1978 and 1989, from 6,246 to 5,957 acres, and then increased to 7,368 acres in 2002. Coniferous Forest declined from 5,881 acres in 1978, to 3,893 acres in 1989, to 3,501 acres in 2002. Mixed Forest increased from 8,555 acres in 1978, to 9,797 acres in 1989, and then declined to 7,585 acres in 2002. Variable changes occurred on Wetland and Water categories as well. The combined Wetland and Water categories were 1,197 acres in 1978, 1,243 acres in 1989, and 1,344 acres in 2002. The extent of Herbaceous Vegetation increased from 2,851 acres in 1978, to 3,678 acres in 1989, to 4,437 acres in 2002.

Table 14 offers more details about the land cover changes within the Saint-Gaudens boundary and in the immediately adjacent buffer zones. Urban Land changed from one acre in 1978 to five acres in 1989, and to four acres in 2002 within the boundary of this National Historic Site. The one acre decrease of Urban Land between 1989 and 2002 could be an error resulting from image classification. Within the 500-meter buffer areas immediately adjacent to the SAGA boundary, Urban Land increased from one acre in 1978, to 17 acres in 1989, to 22 acres in 2002. Within the 1-kilometer buffer zone adjacent to the park, Urban Land increased from 32 acres in 1978, to 67 acres in 1989, to 69 acres in 2002. Within the 5-kilometer buffer zone adjacent to the site, Urban Land increased from 379 acres in 1978, to 621 acres in 1989, and then to 739 acres in 2002.

Table 13. Acreage of each land cover type within the Saint-Gaudens NHS boundary and the adjacent 5-kilometer buffer zone during 1978, 1989, and 2002, and change in acreage of each land cover type between time periods.

	SAGA and 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1978**	**1989**	**2002**	**1978-1989**	**1989-2002**	**1978-2002**
Urban	380	626	743	246 (65%)	117 (19%)	363 (96%)
Deciduous Forest	6,246	5,957	7,368	-289 (-5%)	1,411 (24%)	1,122 (18%)
Coniferous Forest	5,881	3,893	3,501	-1,988 (-34%)	-392 (-10%)	-2,380 (-40%)
Mixed Forest	8,555	9,797	7,585	1,242 (15%)	-2,212 (-23%)	-970 (-11%)
Water	525	828	1,094	303 (58%)	266 (32%)	569 (108%)
Wetland	654	215	250	-439 (-67%)	35 (16%)	-404 (-62%)
Herbaceous Veg.	2,851	3,678	4,437	827 (29%)	759 (21%)	1,586 (56%)

Table 14. Acreage of each land cover type during 1978, 1989, and 2002 within the Saint-Gaudens NHS park boundary and the adjacent 500-meter, 1-kilometer, and 5-kilometer buffer areas.

	SAGA Boundary			500-m Buffer		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	1	5	4	1	17	22
Deciduous Forest	39	55	64	39	114	144
Coniferous Forest	194	139	117	363	199	171
Mixed Forest	102	124	108	258	314	263
Water	1	7	24	64	79	99
Wetland	13	4	4	46	10	9
Herbaceous Veg.	17	31	44	73	111	138
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	32	67	69	379	621	739
Deciduous Forest	193	355	413	6,207	5,902	7,304
Coniferous Forest	805	509	444	5,687	3,754	3,384
Mixed Forest	632	677	563	8,453	9,673	7,477
Water	106	140	185	524	821	1,070
Wetland	103	22	24	641	211	246
Herbaceous Veg.	181	283	355	2,834	3,647	4,393

Deciduous Forest within the SAGA boundary increased from 39 acres in 1978, to 55 acres in 1989, to 64 acres in 2002. Within the 500-meter and 1-kilometer buffer zones adjacent to SAGA, Deciduous Forest also expanded over the three time periods. However for the 5-kilometer buffer zone, Deciduous Forest declined from 6,207 acres in 1978, to 5,902 acres in 1989, and then increased to 7,304 acres in 2002.

Coniferous Forest within the SAGA boundary declined from 194 acres in 1978, to 139 acres in 1989, to 117 acres in 2002. Within the three buffer zones, Coniferous Forest exhibited the same declining trend over the three time periods.

Wetland Area decreased between 1978 and 1989 and then was stable between 1989 and 2002 for all the buffered areas, including the SAGA site itself. Combined, Wetland and Water encompassed 14 acres in 1978, 13 acres in 1989, and 28 acres in 2002 within the SAGA site. For the 500-meter buffer zone, Wetland and Water, combined, encompassed 100 acres in 1978, 89 acres in 1989, and 108 acres in 2002; the same pattern existed for the 1-kilometer and 5-kilometer buffer zones.

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1978 Landsat MSS images of the SAGA site achieved overall accuracies of 85.71%, 88.29% and 90.29%, respectively.

Figure 29 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1978, 1989, and 2002) at Saint-Gaudens, and the results of the land cover types and change detection analysis.

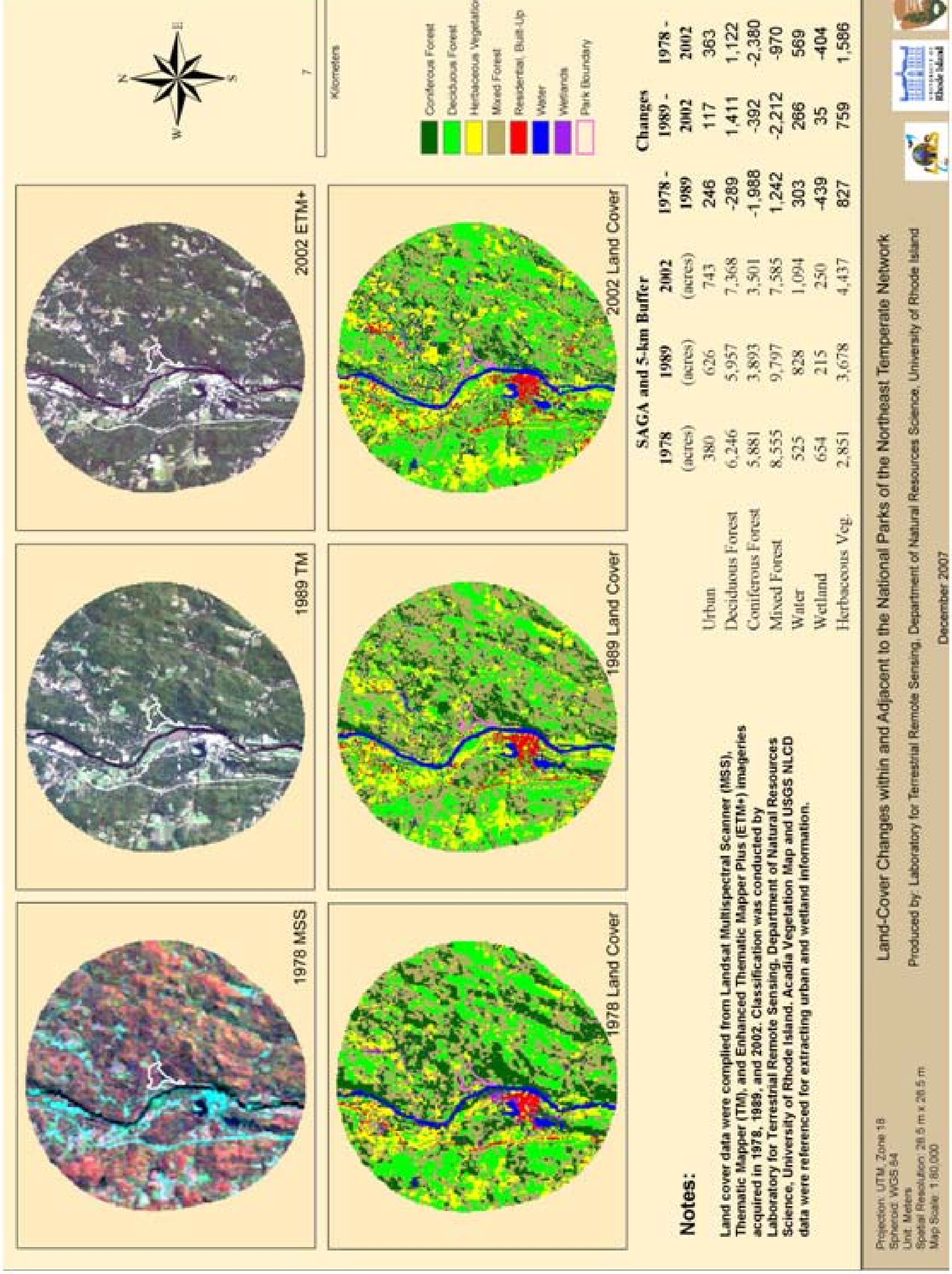


Figure 29. Land cover and change within Saint-Gaudens NHS and the 5-kilometer buffer zone.

Saratoga NHP (SARA)

The land cover types and changes at Saratoga, including the areas within the 5-kilometer buffer zone, indicate that the area experienced urban expansion between 1973 and 2001 (Table 15). Urban Land increased from 610 acres in 1973, to 1,086 acres in 1986, to 1,363 acres in 2001. Urban Land increased by 476 acres between 1973 and 1986, and 277 acres 1986 and 2001. Between 1973 and 2001, Urban Land cover increased by 753 acres.

Deciduous Forest declined from 11,284 acres in 1973, to 10,814 acres in 1986, to 9,768 acres in 2001. Coniferous and Mixed Forests declined as well. Combined, Wetland and Water encompassed 2,629 acres in 1973, 3,207 acres in 1986, and 3,022 acres in 2001. Herbaceous Vegetation increased from 27,605 acres in 1973, to 34,544 acres in 1986, to 38,947 acres in 2001.

Table 16 offers more details about the land cover changes within the Saratoga boundary and the immediately adjacent buffer zones. Urban Land within the boundary of this park increased from three acres in 1973 to 13 acres in 1986, and declined to 12 acres in 2001. The one acre decrease of Urban Land between 1986 and 2001 could be an error resulting from image classification. Within the 500-meter buffer areas immediately adjacent to the Saratoga boundary, Urban Land increased from 80 acres in 1973, to 162 acres in 1986, to 198 acres in 2001. Within the 1-kilometer buffer zone adjacent to the park, Urban Land increased from 137 acres in 1973, to 257 acres in 1986, to 319 acres in 2001. Within the 5-kilometer buffer zone adjacent to the park, Urban Land increased from 607 acres in 1973, to 1,073 acres in 1986, and then to 1,351 acres in 2001.

Deciduous Forest within the Saratoga boundary increased from 604 acres in 1973, to 615 acres in 1986, and then decreased to 377 acres in 2001. In all three buffer zones adjacent to SARA, areas of Deciduous Forest declined over the three time periods (Table 16).

Table 15. Acreage of each land cover type within the Saratoga NHP boundary and the adjacent 5-kilometer buffer zone during 1973, 1986, and 2001, and change in acreage of each land cover type between time periods.

Land Cover Type	SARA and 5-km Buffer			Acreage Changes (percent change)		
	1973	1986	2001	1973-1986	1986-2001	1973-2001
Urban	610	1,086	1,363	476 (78%)	277 (26%)	753 (123%)
Deciduous Forest	11,284	10,814	9,768	-470 (-4%)	-1,046 (-10%)	-1,516 (-13%)
Coniferous Forest	7,240	5,915	5,276	-1,325 (-18%)	-639 (-11%)	-1,964 (-27%)
Mixed Forest	17,274	10,868	8,059	-6,406 (-37%)	-2,809 (-26%)	-9,215 (-53%)
Water	2,064	2,058	1,875	-6 (0%)	-183 (-9%)	-189 (-9%)
Wetland	565	1,149	1,147	584 (103%)	-2 (0%)	582 (103%)
Herbaceous Veg.	27,605	34,544	38,947	6,939 (25%)	4,403 (13%)	11,342 (41%)

Table 16. Acreage of each land cover type during 1973, 1986, and 2001 within the Saratoga NHP park boundary and the adjacent 500-meter, 1-kilometer, and 5-kilometer buffer areas.

Land Cover Type	SARA Boundary			500-m Buffer		
	1973	1986	2001	1973	1986	2001
Urban	3	13	12	80	162	198
Deciduous Forest	604	615	377	549	398	289
Coniferous Forest	281	445	582	287	229	210
Mixed Forest	654	712	479	564	363	298
Water	25	29	5	434	413	390
Wetland	41	58	62	25	34	38
Herbaceous Veg.	1,762	1,495	1,849	1,230	1,570	1,746
Land Cover Type	**1-km Buffer**			**5-km Buffer**		
	1973	**1986**	**2001**	**1973**	**1986**	**2001**
Urban	137	257	319	607	1,073	1,351
Deciduous Forest	1,279	960	771	10,680	10,199	9,391
Coniferous Forest	638	530	487	6,959	5,470	4,694
Mixed Forest	1,395	866	677	16,620	10,156	7,580
Water	541	560	488	2,039	2,029	1,870
Wetland	60	99	100	524	1,091	1,085
Herbaceous Veg.	2,794	3,578	4,007	25,843	33,049	37,098

Area of Coniferous Forest within the Saratoga boundary increased from 281 acres in 1973, to 445 acres in 1986, to 582 acres in 2001. Outside the park boundary, however, Coniferous Forest declined in the 500-meter, 1-kilometer and 5-kilometer buffer zones. In the 500-meter buffer zone, Coniferous Forest declined from 287 acres in 1973, to 229 acres in 1986, to 210 acres in 2001. Within the 1-kilometer buffer zone, Coniferous Forest declined from 638 acres in 1973, to 530 acres in 1986, to 487 acres in 2001. Within the 5-kilometer buffer zone, Coniferous Forest declined from 6,959 acres in 1973, to 5,470 acres in 1986, to 4,694 acres in 2001. Within the buffer zones, Mixed Forest trends follow a similar declining pattern. Conversely, within the park boundary, areas of Mixed Forest increased from 654 acres in 1973 to 712 acres in 1986, and then declined to 479 acres in 2001.

Acreage of Wetlands increased slightly within the park, and in the buffer zones adjacent to the park boundary. Combining the Wetland and Water categories resulted in areas within the park boundary of 66 acres in 1973, 87 acres in 1986, and 69 acres in 2001. For the 500-meter buffer zone immediately adjacent to the park boundary, the combined Wetland and Water areas encompassed 459 acres in 1973, 447 acres in 1986, and 428 acres in 2001.

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2001 Landsat ETM+, 1986 Landsat TM and 1973 Landsat MSS images of the Saratoga site achieved overall accuracies of 87.71%, 89.43% and 86.86%, respectively.

Figure 30 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1986, and 2001) for the Saratoga NHP area, and the results of land cover types and change detection analysis.

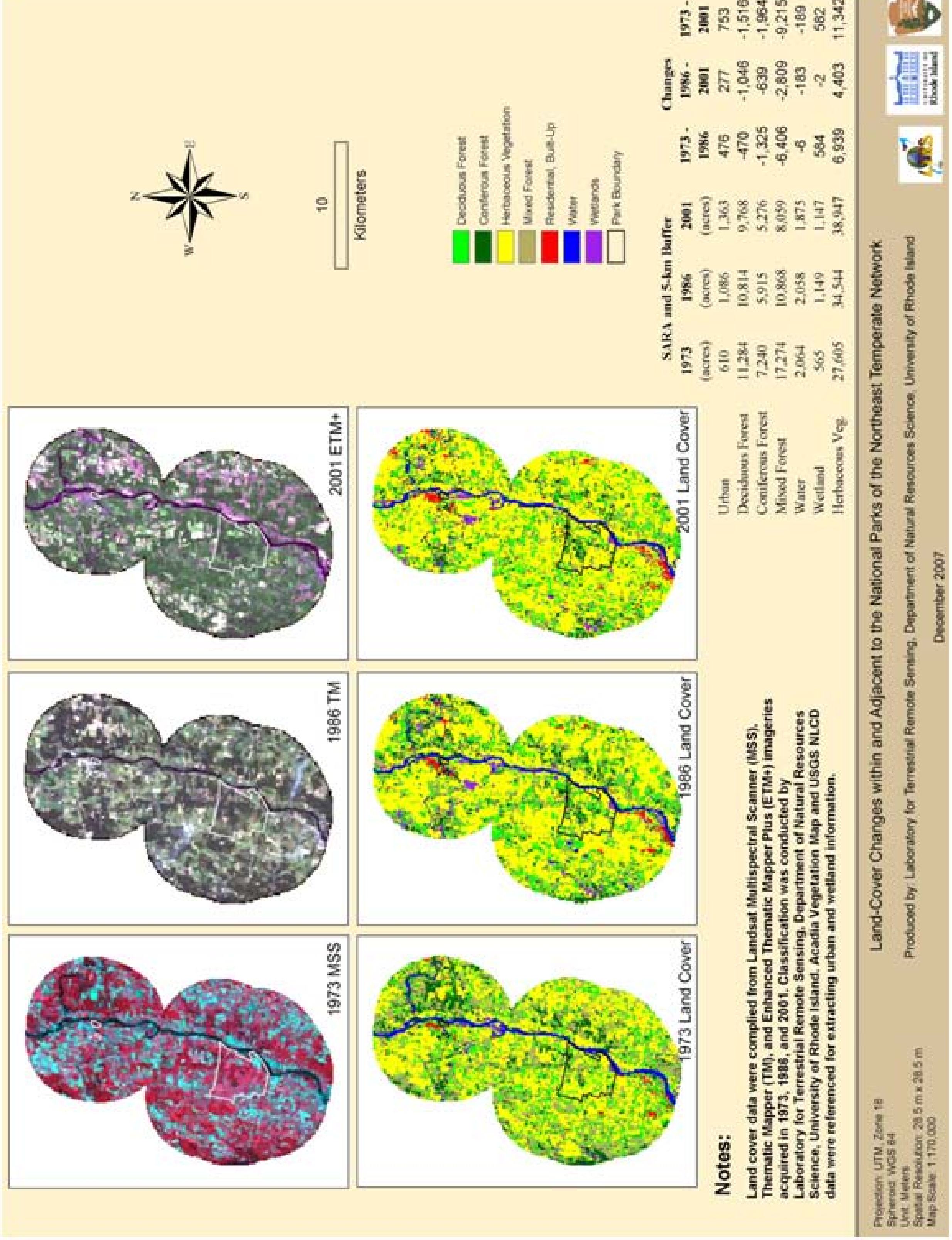


Figure 30. Land cover and change within Saratoga National Historical Park and the 5-kilometer buffer.

Weir Farm NHS (WEFA)

The land cover types and changes in the Weir Farm site, including the areas within the 5-kilometer buffer adjacent to the site, indicate that the area experienced urban expansion between 1973 and 2002 (Table 17). Urban Land increased from 781 acres in 1973, to 2,310 acres in 1989, to 4,378 acres in 2002. Urban Land increased by 1,529 acres between 1973 and 1989, and 2,068 acres in 13 years between 1989 and 2002. Between 1973 and 2002, Urban Land cover increased 3,597 acres.

Deciduous Forest increased between 1973 and 1989 from 9,236 to 12,379 acres, and then decreased to 9,844 acres in 2002. Coniferous Forest declined from 1,393 acres in 1973, to 713 acres in 1989, to 611 acres in 2002. Mixed Forests declined from 7,456 acres in 1973, to 4,472 acres in 1989, and then increased to 4,709 acres in 2002. Combined, the acreage of Wetland and Water was 1,067 acres in 1973, 1,572 acres in 1989, and 1,673 acres in 2002. Herbaceous Vegetation decreased from 2,436 acres in 1973, to 807 acres in 1989, and then increased to 1,026 acres in 2002.

Table 18 offers more details about the land cover changes within the Weir Farm boundary and the immediately adjacent buffer zones. Urban Land within the boundary of this site changed from one acre in 1973 to 3 acres in 1989, and then to six acres in 2002. Within the 500-meter buffer areas, Urban Land increased from two acres in 1973, to 39 acres in 1989, to 73 acres in 2002. For the 1-kilometer buffer zone adjacent to Weir Farm, Urban Land increased from 10 acres in 1973, to 116 acres in 1989, to 249 acres in 2002. For the 5-kilometer buffer zone adjacent to the site, Urban Land increased from 780 acres in 1973, to 2,307 acres in 1989, and then almost doubled to 4,372 acres in 2002.

Table 17. Acreage of each land cover type within the Weir Farm NHS boundary and adjacent 5-kilometer buffer zone in 1973, 1989, and 2002, and change in acreage of each land cover type between time periods.

	WEFA and 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1973**	**1989**	**2002**	**1973-1989**	**1989-2002**	**1973-2002**
Urban	781	2,310	4,378	1,529(196%)	2,068 (90%)	3,597 (461%)
Deciduous Forest	9,236	12,379	9,844	3,143 (34%)	-2,535 (-20%)	608 (7%)
Coniferous Forest	1,393	713	611	-680 (-49%)	-102 (-14%)	-782 (-56%)
Mixed Forest	7,456	4,472	4,709	-2,984 (-40%)	237 (5%)	-2,747 (-37%)
Water	163	198	170	35 (21%)	-28 (-14%)	7 (4%)
Wetland	904	1,374	1,503	470 (52%)	129 (9%)	599 (66%)
Herbaceous Veg.	2,436	807	1,026	-1,629 (-67%)	219 (27%)	-1,410 (-58%)

Table 18. Acreage of each land cover type in 1973, 1989, and 2002 within the Weir Farm NHS boundary and adjacent 500-meter, 1-kilometer, and 5-kilometer buffer areas.

	WEFA Boundary			500-m Buffer		
Land Cover Type	**1973**	**1989**	**2002**	**1973**	**1989**	**2002**
Urban	1	3	6	2	39	73
Deciduous Forest	35	44	33	274	313	259
Coniferous Forest	4	1	1	28	16	13
Mixed Forest	6	4	6	154	87	96
Water	0	2	2	4	4	3
Wetland	0	1	3	12	16	21
Herbaceous Veg.	9	1	4	8	5	14
	1-km Buffer			**5-km Buffer**		
Land Cover Type	**1973**	**1989**	**2002**	**1973**	**1989**	**2002**
Urban	10	116	249	780	2,307	4,372
Deciduous Forest	653	796	643	9,201	12,335	9,811
Coniferous Forest	97	55	37	1,389	712	610
Mixed Forest	486	285	287	7,450	4,468	4,703
Water	4	8	6	163	196	168
Wetland	38	58	64	904	1,373	1,500
Herbaceous Veg.	49	16	48	2,427	806	1,022

Deciduous Forest within the Weir Farm boundary fluctuated slightly, from 35 acres in 1973, to 44 acres in 1989, and then decreased to 33 acres in 2002. For the three buffer zones adjacent to Weir Farm, acreage of Deciduous Forest changed little over the three time periods (Table 18).

Coniferous Forest within the Weir Farm boundary declined from 4 acres in 1973 to one acre in 1989 and thereafter. Acreage of Coniferous Forest declined within the three buffer zones outside the park. In the 500-meter buffer zone, Coniferous Forest declined from 28 acres in 1973, to 16 acres in 1989, to 13 acres in 2002. Within the 1-kilometer buffer zone, Coniferous Forest declined from 97 acres in 1973, to 55 acres in 1989, to 37 acres in 2002. Within the 5-kilometer buffer zone, Coniferous Forest declined from 1,389 acres in 1973, to 712 acres in 1989, to 610 acres in 2002. Acreage of Mixed Forest decreased between 1973 and 1989, but changed little between 1989 and 2002 (Table 18).

For the 500-meter buffer zone immediately adjacent to the park boundary, combined acreage of Wetland and Water encompassed 16 acres in 1973, 20 acres in 1989, and 24 acres in 2002. Similar trends were observed for the 1-kilometer and 5-kilometer buffer zones.

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1973 Landsat MSS images of the Weir Farm site achieved overall accuracies of 86.29%, 85.14% and 87.14%, respectively.

Figure 31 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1989, and 2002) for the Weir Farm area, and the results of the land cover types and change detection analysis.

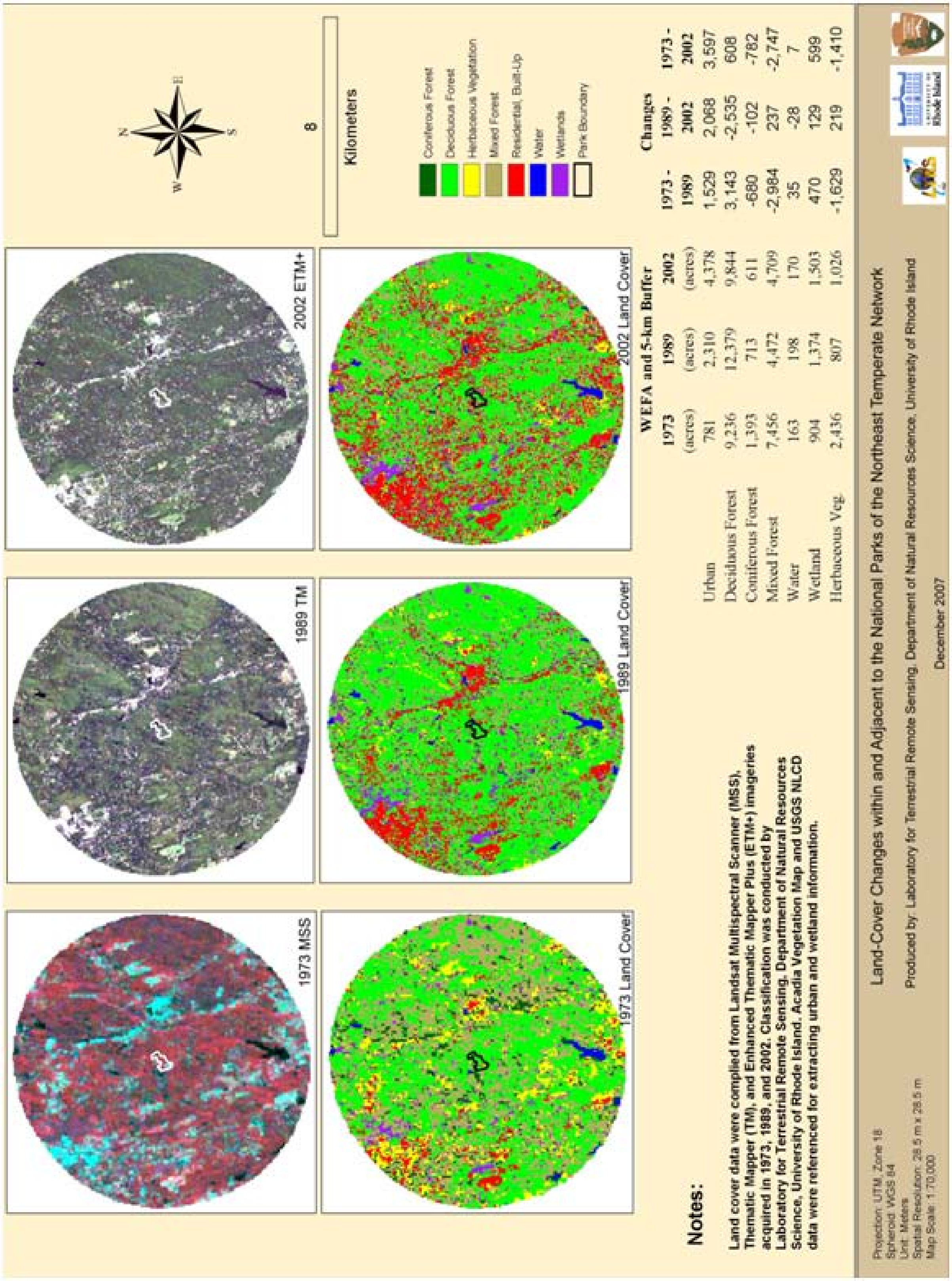


Figure 31. Land cover and change within the Weir Farm National Historical Site and the 5-kilometer buffer zone.

Appalachian National Scenic Trail

Whitecap Mountain Segment

Within the 5-kilometer buffer adjacent to the Whitecap Mountain segment, logging and subsequent regrowth of forests accounted for the majority of land cover type changes during the three time periods we evaluated (Table 19). Deciduous Forest increased between 1976 and 1987 from 22,456 to 23,611 acres, and then decreased to 20,979 acres in 2002. Coniferous Forest declined from 19,996 acres in 1976, to 11,326 acres in 1987, to 8,487 acres in 2002. Mixed Forest increased from 11,916 acres in 1976, to 14,348 acres in 1987, to 18,782 acres in 2002. The silvicultural alterations to the landscape were evident in Landsat images and during field observations (Figure 22). Wetland and Water categories, combined, accounted for 1,701 acres in 1976, 2,871 acres in 1987, and 2,760 acres in 2002. Barren Land increased from 4,388 acres in 1976 to 8,582 acres in 1987, and then decreased to 6,340 acres in 2002, which reflects the scope of logging and regrowth of forest in the area. In total, Regrowth Forest increased 577 acres between 1976 and 1987, 3,363 acres between 1987 and 2002, and 3,940 acres in 26 years between 1976 and 2002.

Table 20 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones immediately adjacent to this segment. Within the 500-meter buffer area, Deciduous Forest decreased from 1,257 acres in 1976, to 1,076 acres in 1987, to 791 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest decreased from 3,077 acres in 1976, to 2,880 acres in 1987, to 2,383 acres in 2002. The Coniferous Forest showed the same declining trends in the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer area, Coniferous Forest decreased from 2,262 acres in 1976, to 1,888 acres in 1987, to 1,588 acres in 2002. Within the 1-kilometer buffer, Coniferous Forest decreased from 3,937 acres in 1976, to 3,127 acres in 1987, to 2,390 acres in 2002. In contrast, Mixed Forest increased in both the 500-meter and 1-kilometer buffer areas. In the 500-meter buffer zone, areas of Mixed Forest encompassed 802 acres in 1976, 1,268 acres in 1987, and 1,723 acres in 2002. Within the 1-kilometer buffer, areas of Mixed Forest totaled 1,882 acres in 1976, 2,685 acres in 1987, and 3,726 acres in 2002. Regrowth Forest increased by 160 acres between 1976 and 1987, and by 386 acres between 1987 and 2002 within the 500-meter buffer zone. Regrowth Forest also increased 196 acres between 1976 and 1987, and 593 acres between 1987 and 2002 within the 1-kilometer buffer area. When calculating the acreage of Regrowth Forest, we assumed that the regrowth started in 1976 because we had no data from the previous years to compare with. Within the 500-meter buffer adjacent to this segment, Barren Land encompassed 322 acres in 1976, 185 acres in 1987, and 190 acres in 2002. Within the 1-kilometer buffer, Barren Land totaled 565 acres in 1976, 478 acres in 1987, and 412 acres in 2002 (Table 20).

Table 19. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Whitecap Mountain segment of the Appalachian Trail during 1976, 1987, and 2002, and change in acreage of each land cover type between time periods.

	Acres within 5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	1976	1987	2002	1976-1987	1987-2002	1976-2002
Deciduous Forest	22,456	23,611	20,979	1,155 (5%)	-2,632 (-11%)	-1,477 (-7%)
Coniferous Forest	19,996	11,326	8,487	-8,670 (-43%)	-2,839 (-25%)	-11,509 (-58%)
Mixed Forest	11,916	14,348	18,782	2,432 (20%)	4,434 (31%)	6,866 (58%)
Water	1,737	1,796	1,974	59 (3%)	178 (10%)	237 (14%)
Wetland	964	1,075	786	111 (12%)	-289 (-27%)	-178 (-18%)
Barren Land	4,388	8,582	6,340	4,194 (96%)	-2,242 (-26%)	1,952 (44%)
Regrowth Forest	-	577	3,940	-	3,363(583%)	-

Table 20. Acreage of each land cover type during 1976, 1987, and 2002 within the 500-meter and 1-kilometer buffer areas adjacent to the Whitecap Mountain segment of the Appalachian Trail.

Land Cover Type	500-m Buffer			1-km Buffer		
	1976	1987	2002	1976	1987	2002
Deciduous Forest	1,257	1,076	791	3,077	2,880	2,383
Coniferous Forest	2,262	1,888	1,588	3,937	3,127	2,390
Mixed Forest	802	1,268	1,723	1,882	2,685	3,726
Water	32	16	19	50	29	33
Wetland	71	160	54	129	236	94
Barren Land	322	184	190	565	478	412
Regrowth Forest	-	160	386	-	196	593

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1987 Landsat TM and 1976 Landsat MSS images of the 5-kilometer buffer of the Whitecap Mountain segment achieved overall accuracies of 90.57%, 92.57% and 86.33%, respectively.

Figure 32 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1976, 1987, and 2002) for the Whitecap Mountain segment, and the results of the land cover types and change detection analysis.

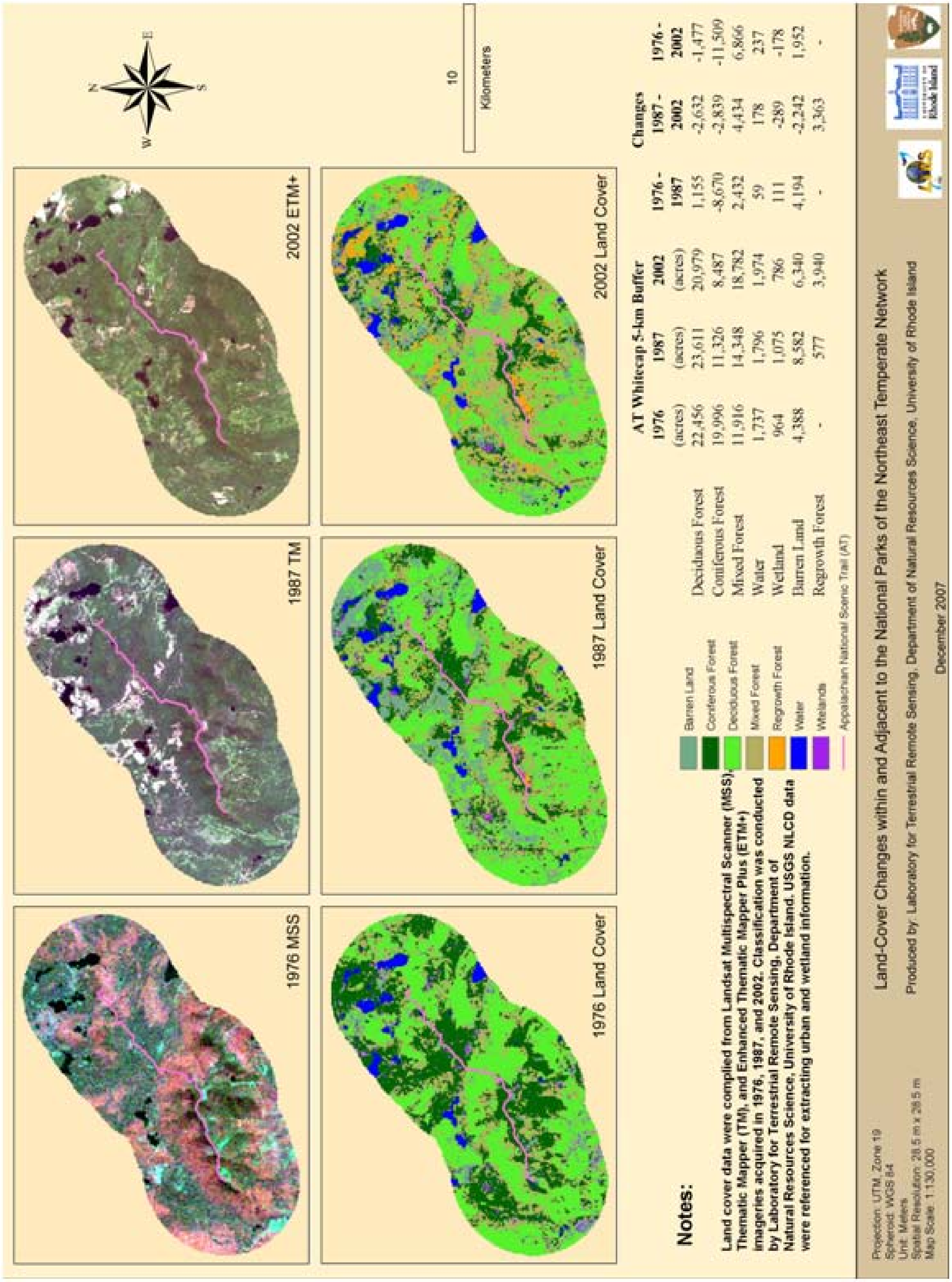


Figure 32. Land cover and change for the Whitecap Mountain segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Saddleback Mountain Segment

The land cover types for the three time periods within the 5-kilometer buffer adjacent to the Saddleback Mountain segment show that the area experienced urban expansion between 1972 and 2002 (Table 21). Urban Land increased from 83 acres in 1972, to 754 acres in 1986, to 1,822 acres in 2002. Urban Land increased by 671 acres between 1972 and 1986, and 1,068 acres between 1986 and 2002. Between 1972 and 2002, Urban Land cover increased 1,739 acres.

The amount of Deciduous Forest increased between 1972 and 1986 from 24,638 to 34,810 acres, and then decreased to 25,742 acres in 2002. Coniferous Forest declined significantly from 32,648 acres in 1972 to 20,664 acres in 1986, and then increased to 25,269 acres in 2002. Mixed Forest changed little during the 30 years we evaluated (Table 21). Combined, Wetland and Water encompassed 6,549 acres in 1972, 5,716 acres in 1986, and 7,283 acres in 2002. Barren Land decreased from 6,385 acres in 1972 to 5,545 acres in 1986, and then increased to 7,142 acres in 2002. Regrowth Forest fluctuated by 1,449 acres between 1972 and 1986, 2,867 acres between 1986 and 2002, and 4,316 acres in 30 years between 1972 and 2002. We assumed that forest regrowth started in 1972, because we had no data for the previous years for comparison.

Table 22 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones immediately adjacent to the Saddleback Mountain segment. Within the 500-meter buffer, Urban Land increased from one acre in 1972, to 41 acres in 1986, and to 126 acres in 2002.

In the 1-kilometer buffer area, Urban Land increased from eight acres in 1972, to 76 acres in 1986, and to 252 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 1,053 acres in 1972, to 1,792 acres in 1986, and then decreased to 1,142 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest increased from 2,470 acres in 1972, to 3,965 acres in 1986, and then decreased to 2,556 acres in 2002. We observed similar patterns for Coniferous Forest in the 500-meter and 1-kilometer buffer zones. Within the 500-meter buffer area, Coniferous Forest decreased from 4,318 acres in 1972, to 3,375 acres in 1986, and then increased to 4,310 acres in 2002. Within the 1-kilometer buffer, Coniferous Forest decreased from 8,490 acres in 1972, to 6,420 acres in 1986, and then increased to 7,755 acres in 2002. Mixed Forest, conversely, increased from 1,489 acres in 1972, to 2,218 acres in 1986, and then dropped to 1,668 acres in 2002. Within the 1-kilometer buffer, areas of Mixed Forest were 3,098 acres in 1972, 4,359 acres in 1986, and 3,529 acres in 2002. Regrowth Forest encompassed 211 acres between 1972 and 1986, and 452 acres between 1986 and 2002 within the 500-meter buffer area. Regrowth Forest expanded by 356 acres between 1972 and 1986, and 1,008 acres between 1986 and 2002 within the 1-kilometer buffer area. Within the 500-meter buffer Barren Land measured 1,128 acres in 1972, 340 acres in 1986, and 250 acres in 2002. Within the 1-kilometer buffer, areas of Barren Land were 1,886 acres in 1972, 757 acres in 1986, and 789 acres in 2002 (Table 22).

Table 21. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Saddleback Mountain segment of the Appalachian Trail during 1972, 1986, and 2002, and change in acreage of each land cover type between time periods.

	A.T. Saddleback 5-km Buffer			Acreage Changes		
Land Cover Type	**1972**	**1986**	**2002**	**1972-1986**	**1986-2002**	**1972-2002**
Urban	83	754	1,822	671 (808%)	1,068 (142%)	1,739(2095%)
2eciduous Forest	24,638	34,810	25,742	10,172 (41%)	-9,068 (-26%)	1,104 (4%)
Coniferous Forest	32,648	20,664	25,269	-11,984 (-37%)	4,605 (22%)	-7,379 (-23%)
Mixed Forest	23,680	23,731	22,399	51 (0%)	-1,332 (-6%)	-1,281 (-5%)
Water	164	171	141	7 (4%)	-30 (-18%)	-23 (-14%)
Barren Land	6,385	5,545	7,142	-840 (-13%)	1,597 (29%)	757 (12%)
Bare Rockface	-	182	385	-	203 (112%)	-
Regrowth Forest	-	1,449	4,316	-	2,867 (198%)	-

Table 22. Acreage of each land cover type in 1972, 1986, and 2002 within the 500-meter and 1-kilometer buffer areas adjacent to the Saddleback segment of the Appalachian Trail.

	500-m Buffer			Acres within 1-km Buffer		
Land Cover Type	**1972**	**1986**	**2002**	**1972**	**1986**	**2002**
Urban	1	41	126	8	76	252
Deciduous Forest	1,053	1,792	1,142	2,470	3,965	2,556
Coniferous Forest	4,318	3,375	4,310	8,490	6,420	7,755
Mixed Forest	1,489	2,218	1,668	3,098	4,359	3,529
Water	10	12	8	49	40	26
Barren Land	1,128	340	250	1,886	757	789
Bare Rockface	-	19	54	-	32	88
Regrowth Forest	-	211	452	-	356	1,008

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1986 Landsat TM and 1972 Landsat MSS images of the 5-kilometer buffer of the Whitecap Mountain segment achieved overall accuracies of 88.75%, 89.50% and 81.67%, respectively.

Figure 33 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1972, 1986, and 2002) for the Saddleback Mountain segment, and the results of the land cover types and change detection analysis.

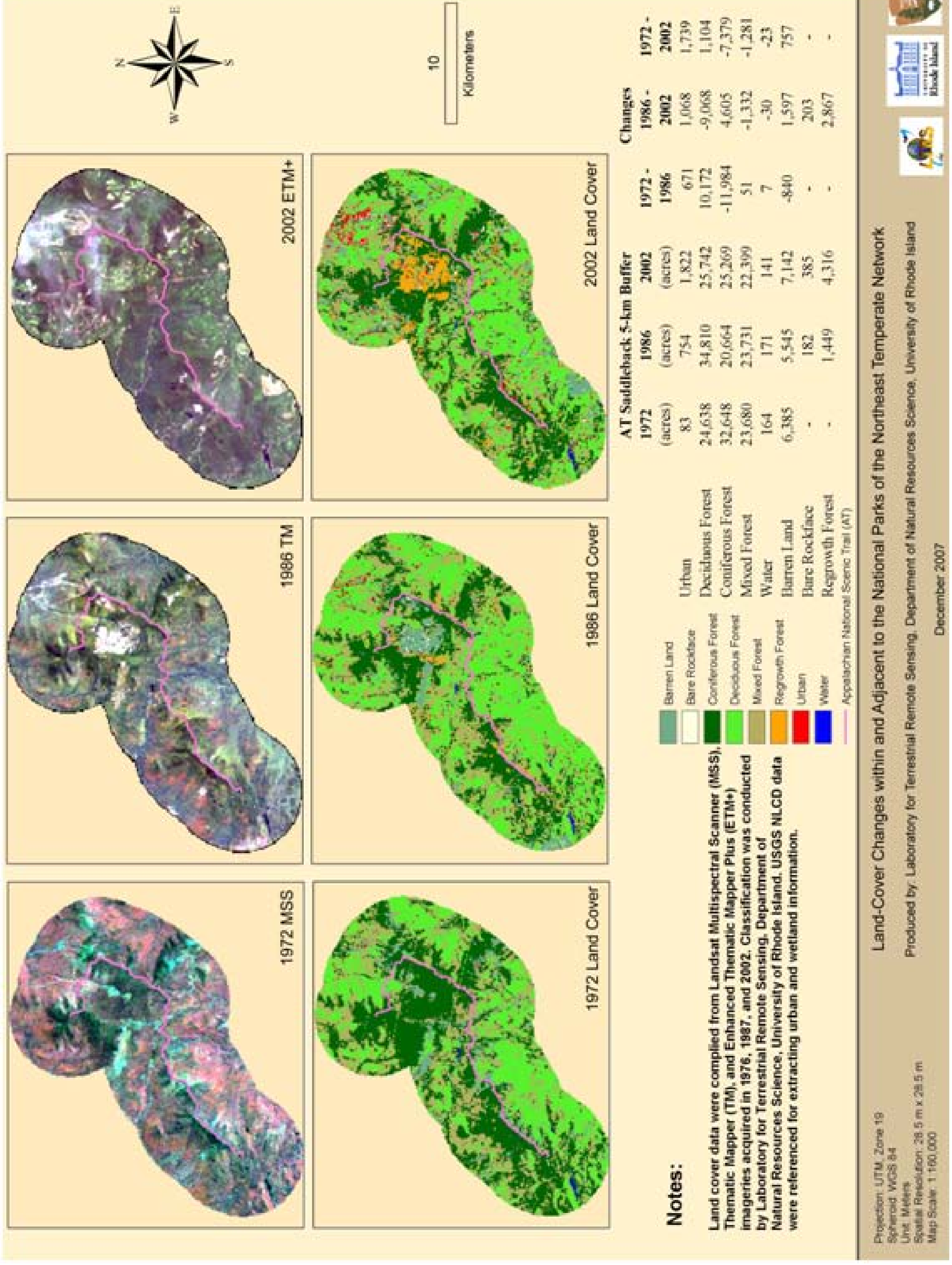


Figure 33. Land cover and change for the Saddleback Mountain segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Chateauguay - No-town Area Segment

The land cover types for the three time periods within the 5-kilometer buffer adjacent to the Chateauguay – No-town Area segment show that the area experienced urban expansion between 1978 and 2002 (Table 23). Urban Land increased from 640 acres in 1978, to 1,304 acres in 1989, to 1,621 acres in 2002. Urban Land increased by 664 acres between 1978 and 1989, and 317 acres between 1989 and 2002. Between 1978 and 2002, Urban Land cover increased 981 acres along this segment.

Deciduous Forest increased during all three time periods from 43,334 acres in 1978 to 53,221 acres in 1989, and 53,541 acres in 2002. Coniferous Forest declined from 10,953 acres in 1978, to 7,152 acres in 1989, and then remained steady at 7,159 acres in 2002. Mixed Forest decreased in area in the three time periods from 16,767 acres in 1978, to 8,490 acres in 1989, to 7,651 acres in 2002. Herbaceous Vegetation increased from 4,352 acres in 1978, to 5,276 acres in 1989, to 5,412 acres in 2002. Barren Land changed from 2,827 acres in 1978, to 511 acres in 1989, to 1,933 acres in 2002. We observed interesting change in the combined Wetland and Water categories, which increased from 931 acres in 1978 to 3,578 acres in 1989, and then declined to 1,769 acres in 2002. Landscape features, such as dry or wet conditions at the time of image acquisition, may have contributed to the variation in areas of Wetland and Water measured.

Table 24 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones immediately adjacent to the Chateauguay segment. Within the 500-meter buffer, Urban Land increased from 30 acres in 1978 to 55 acres in 1989 and to 89 acres in 2002. In the 1-kilometer buffer area, Urban Land increased from 104 acres in 1978 to 193 acres in 1989 and to 259 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 4,189 acres in 1978 to 5,367 acres in 1989, and then to 5,442 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest increased from 8,045 acres in 1978 to 10,227 acres in 1989, and then to 10,324 acres in 2002. Coniferous Forest decreased in the 500-meter buffer from 856 acres in 1978 to 517 acres in 1989, and then to 510 acres in 2002. In the 1-kilometer buffer zone, Coniferous Forest decreased from 1,688 acres in 1978 to 988 acres in 1989, and then increased to 1,005 acres in 2002. Mixed Forest showed a decreasing trend for all three time periods for both the 500-meter and 1-kilometer buffer areas. Within the 500-meter buffer zone, the extent of Mixed Forest was 1,365 acres in 1978, 625 acres in 1989, and 513 acres in 2002. Within the 1-kilometer buffer, Mixed Forest comprised 2,707 acres in 1978, 1,239 acres in 1989, and 1,056 acres in 2002. Within the 500-meter buffer, Barren Land totaled 310 acres in 1978, 35 acres in 1989, and 105 acres in 2002. Within the 1-kilometer buffer, Barren Land comprised 581 acres in 1978, 86 acres in 1989, and 256 acres in 2002. Herbaceous Vegetation changed little between the three time periods. For the 500-meter buffer area, Wetland and Water, combined, totaled 147 acres in 1978, 303 acres in 1989, and 180 acres in 2002 (Table 24).

Table 23. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Chateauguay – No-town Area segment of the Appalachian Trail during 1978, 1989, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1978**	**1989**	**2002**	**1978-1989**	**1989-2002**	**1978-2002**
Urban	640	1,304	1,621	664 (104%)	317 (24%)	981 (153%)
Deciduous Forest	43,334	53,221	53,541	9,887 (23%)	320 (1%)	10,207 (24%)
Coniferous Forest	10,953	7,152	7,159	-3,801 (-35%)	7 (0%)	-3,794 (-35%)
Mixed Forest	16,767	8,490	7,651	-8,277 (-49%)	-839 (-10%)	-9,116 (-54%)
Water	183	683	301	500 (273%)	-382 (-56%)	118 (64%)
Wetland	748	2,895	1,468	2,147 (287%)	-1,427 (-49%)	720 (96%)
Herbaceous Veg.	4,352	5,276	5,412	924 (21%)	136 (3%)	1,060 (24%)
Barren Land	2,827	511	1,933	-2,316 (-82%)	1,422(278%)	-894 (-32%)

Table 24. Acreage of each land cover type in within the 500-meter and 1-kilometer buffers adjacent to the Chateauguay – No-town Area segment of the Appalachian Trail during 1978, 1989, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	30	55	89	104	193	259
Deciduous Forest	4,189	5,367	5,442	8,045	10,227	10,324
Coniferous Forest	856	517	510	1,688	988	1,005
Mixed Forest	1,365	625	513	2,707	1,239	1,056
Water	83	136	98	103	200	132
Wetland	64	167	82	126	385	187
Herbaceous Veg.	248	242	269	711	765	792
Barren Land	310	35	105	581	86	256

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1978 Landsat MSS images of the 5-kilometer buffer of the Chateauguay – No-town Area segment achieved overall accuracies of 78.25%, 70.25% and 68.25%, respectively. The classification accuracies were relatively low, due to poor quality of the satellite images.

Figure 34 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1978, 1989, and 2002) for the Chateauguay – No-town Area segment, and the results of the land cover types and change detection analysis.

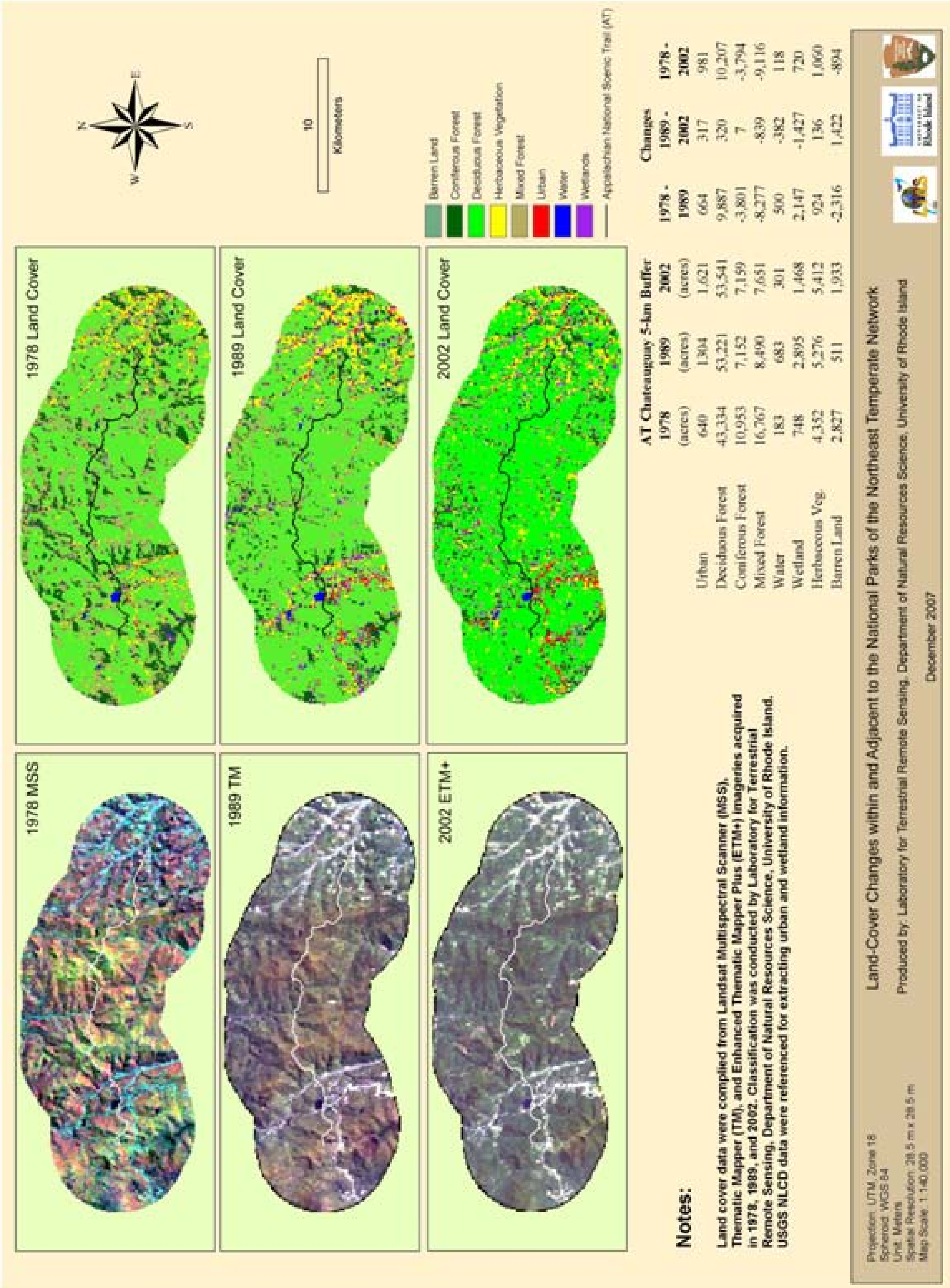


Figure 34. Land cover and change for the Chateauguay – No-town Area segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Hanover Segment

Land cover types for the three time periods within the 5-kilometer buffer adjacent to the Hanover segment indicate that the area experienced urban expansion during the time period we evaluated (Table 25). Urban Land increased from 1,354 acres in 1978 to 2,018 acres in 1989, to 3,816 acres in 2002, representing an increase of 664 acres between 1978 and 1989, and 1798 acres between 1989 and 2002. In the 24 years between 1978 and 2002, Urban Land cover increased by just over one acre per year.

Deciduous Forest increased between 1978 and 1989 from 23,583 to 27,525 acres, and then decreased to 22,776 acres in 2002. Coniferous Forest increased from 8,838 acres in 1978 to 11,361 acres in 1989, and then to 14,437 acres in 2002. Mixed Forest declined during the 24 years from 18,257 acres in 1978, to 10,324 acres in 1989, to 9,817 acres in 2002. Combined, Wetland and Water encompassed 2,575 acres in 1978, 4,822 acres in 1989, and 4,345 acres in 2002. Barren Land varied from 2,136 acres in 1978 to 563 acres in 1989, to 2,796 acres in 2002. Herbaceous Vegetation changed little much between 1978 and 1989, but decreased between 1989 and 2002 (Table 25).

Table 26 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones immediately adjacent to the Hanover segment. Within the 500-meter buffer, Urban Land increased from 147 acres in 1978 to 250 acres in 1989 and to 354 acres in 2002. For the 1-kilometer buffer area, Urban Land increased from 277 acres in 1978, to 430 acres in 1989, and to 688 acres in 2002. Also within the 500-meter buffer area, Deciduous Forest changed from 1,949 acres in 1978, to 2,437 acres in 1989, and then to 2,131 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest increased from 3,601 acres in 1978 to 4,470 acres in 1989, and then decreased to 4,024 acres in 2002. Coniferous Forest increased in the 500-meter buffer from 866 acres in 1978 to 974 acres in 1989, and then to 1,229 acres in 2002. For the 1-kilometer buffer zone adjacent to this segment, Coniferous Forest increased from 1,775 acres in 1978 to 2,003 acres in 1989, and then to 2,495 acres in 2002. We observed a declining trend in Mixed Forest for both the 500-meter and 1-kilometer buffer areas. Within the 500-meter buffer zone, areas of Mixed Forest totaled 1,430 acres in 1978, 745 acres in 1989, and 727 acres in 2002. Within the 1-kilometer buffer, Mixed Forest encompassed 2,885 acres in 1978, 1,514 acres in 1989, and 1,424 acres in 2002. Within the 500-meter buffer, Barren Land covered 143 acres in 1978, 21 acres in 1989, and 190 acres in 2002. Within the 1-kilometer buffer, Barren Land comprised 378 acres in 1978, 97 acres in 1989, and 413 acres in 2002. Herbaceous Vegetation decreased in all three time periods for both buffer zones we evaluated. Within the 500-meter buffer area, Wetland and Water, combined totaled 227 acres in 1978, 378 acres in 1989, and 364 acres in 2002. Within the 1-kilometer buffer area, Wetland and Water, together, totaled 508 acres in 1978, 813 acres in 1989, and 605 acres in 2002 (Table 26).

Table 25. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Hanover segment of the Appalachian Trail during 1978, 1989, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1978**	**1989**	**2002**	**1978-1989**	**1989-2002**	**1978-2002**
Urban	1,354	2,018	3,816	664 (49%)	1,798 (89%)	2,462 (182%)
Deciduous Forest	23,583	27,525	22,776	3,942 (17%)	-4,749 (-17%)	-807 (-3%)
Coniferous Forest	8,838	11,361	14,437	2,523 (29%)	3,076 (27%)	5,599 (63%)
Mixed Forest	18,257	10,324	9,817	-7,933 (-43%)	-507 (-5%)	-8,440 (-46%)
Water	1,435	1,821	1,660	386 (27%)	-161 (-9%)	225 (16%)
Wetland	1,140	3,001	2,685	1,861 (163%)	-316 (-11%)	1,545 (136%)
Herbaceous Veg.	5,745	5,703	4,316	-42 (-1%)	-1,387 (-24%)	-1,429 (-25%)
Barren Land	2,136	563	2,796	-1,573 (-74%)	2,233 (397%)	660 (31%)

Table 26. Acreage of each land cover type within the 500-meter and 1-kilometer buffers adjacent to the Hanover segment of the Appalachian Trail during 1978, 1989, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	**1978**	**1989**	**2002**	**1978**	**1989**	**2002**
Urban	147	250	354	277	430	688
Deciduous Forest	1,949	2,437	2,131	3,601	4,470	4,024
Coniferous Forest	866	974	1,229	1,775	2,003	2,495
Mixed Forest	1,430	745	727	2,885	1,514	1,424
Water	92	107	104	216	296	261
Wetland	135	271	136	292	617	344
Herbaceous Veg.	348	292	228	757	758	537
Barren Land	143	21	190	378	97	413

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1978 Landsat MSS images of the 5-kilometer buffer of the Hanover segment achieved overall accuracies of 80.00%, 83.25% and 82.00%, respectively.

Figure 35 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1978, 1989, and 2002) for the Hanover segment, and the results of land cover types and change detection analysis.

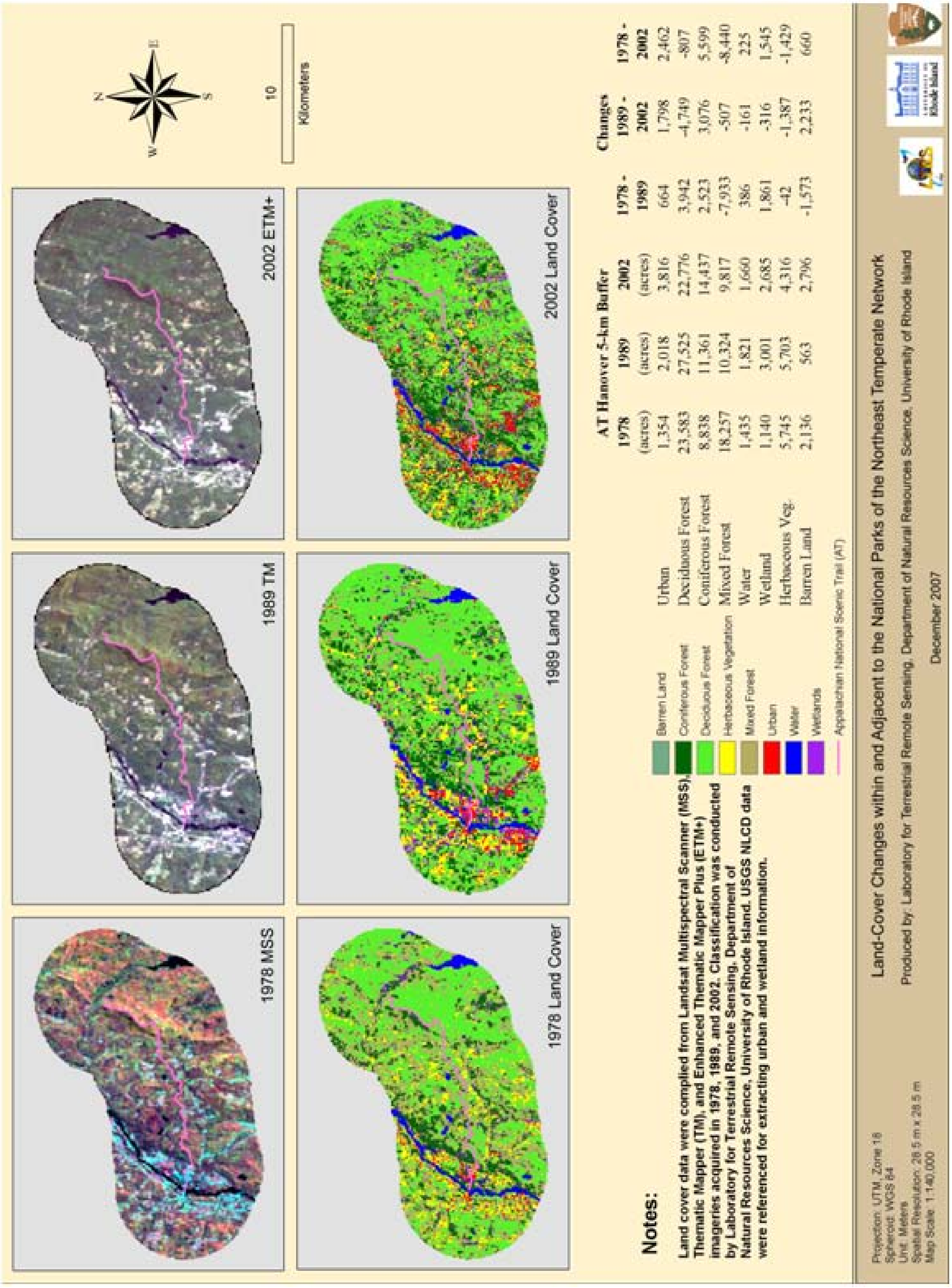


Figure 35. Land cover and change for the Hanover segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Tyringham Valley and Sheffield Segment

For this segment, both human induced land cover change and impacts from natural forces altered the landscape. GPS field photos helped to identify specific locations on the Landsat images of a damaged site by a tornado in 1996 (Figure 23). Land cover types for the three time periods within the 5-kilometer buffer adjacent to the segment indicate that the area experienced urban expansion between 1973 and 2002 (Table 27). Urban Land increased from 1,505 acres in 1973 to 2,883 acres in 1989 and to 4,493 acres in 2002. This cover type increased by 1,378 acres between 1973 and 1989, and 1,610 acres between 1989 and 2002; between 1973 and 2002, Urban Land cover increased by 2,988 acres.

Deciduous Forest increased between 1973 and 1989 from 48,228 to 52,883 acres, and then to 58,305 acres in 2002. Coniferous Forest decreased from 12,777 acres in 1973 to 8,657 acres in 1989, and then increased to 8,843 acres in 2002. Mixed Forests declined during from 18,271 acres in 1973 to 15,397 acres in 1989, and then to 10,512 acres in 2002. Combined, Wetland and Water encompassed 5,772 acres in 1973, 5,959 acres in 1989, and 8,073 acres in 2002. Areas of Barren Land were detectable in the 1989 and 2002 images, measuring 4,960 and 2,940 acres, respectively. Herbaceous Vegetation declined from 18,188 acres in 1973 to 13,217 acres in 1989, and to 10,516 acres in 2002 (Table 27).

Table 28 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones immediately adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 116 acres in 1973 to 274 acres in 1989 and to 320 acres in 2002. Within the 1-kilometer buffer area, Urban Land increased from 217 acres in 1973 to 519 acres in 1989 and to 695 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 5,743 acres in 1973 to 6,108 acres in 1989, and then to 6,677 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest increased from 10,652 acres in 1973 to 11,275 acres in 1989 and to 12,309 acres in 2002. Coniferous Forest decreased between 1973 and 1989, and then increased between 1989 and 2002 in both the 500-meter and 1-kilometer buffers. This cover types measured 704 acres in 1973, 471 acres in 1989, and 500 acres in 2002 in the 500-meter buffer zone. For the 1-kilometer buffer adjacent to this A.T. segment, Coniferous Forest decreased from 1,492 acres in 1973 to 968 acres in 1989, and then to 1,046 acres in 2002. Mixed Forest decreased for all three time periods in both the 500-meter and 1-kilometer buffer areas. Within the 500-meter buffer zone, Mixed Forest measured 1,578 acres in 1973, 1,285 acres in 1989, and 830 acres in 2002. Within the 1-kilometer buffer, Mixed Forest encompassed 2,946 acres in 1973, 2,441 acres in 1989, and 1,583 acres in 2002. Herbaceous Vegetation changed little between 1973 and 1989, but declined between 1989 and 2002. For the 500-meter buffer area, Wetland and water, combined, totaled 425 acres in 1973, 410 acres in 1989, and 500 acres in 2002. For the 1-kilometer buffer area, these two cover types totaled 1,013 acres in 1973, 993 acres in 1989, and 1,204 acres in 2002 (Table 28).

Table 27. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Tyringham Valley and Sheffield segment of the Appalachian Trail during 1973, 1989, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1973**	**1989**	**2002**	**1973-1989**	**1989-2002**	**1973-2002**
Urban	1,505	2,883	4,493	1,378 (92%)	1,610 (56%)	2,988(199%)
Deciduous Forest	48,228	52,883	58,305	4,655 (10%)	5,422 (10%)	10,077 (21%)
Coniferous Forest	12,777	8,657	8,843	-4,120 (-32%)	186 (2%)	-3,934 (-31%)
Mixed Forest	18,271	15,397	10,512	-2,874 (-16%)	4,885 (-32%)	-7,759 (-42%)
Water	2,040	2,131	3,389	91 (4%)	1,258 (59%)	1,349 (66%)
Wetland	3,732	3,828	4,684	96 (3%)	856 (22%)	952 (26%)
Herbaceous Veg.	18,188	13,217	10,516	-4,971 (-27%)	-2,70 1(-20%)	-7,672 (-42%)
Barren Land	-	4,960	2,940	-	-2,020 (-41%)	-
Bare Rockface	-	470	740	-	270 (57%)	-

Table 28. Acreage of each land cover type within the 500-meter and 1-kilometer buffer adjacent to the Tyringham Valley and Sheffield segment of the Appalachian Trail during 1973, 1989, 2002.

Land Cover Type	500-m Buffer			1-km Buffer		
	1973	**1989**	**2002**	**1973**	**1989**	**2002**
Urban	116	274	320	217	519	695
Deciduous Forest	5,743	6,108	6,677	10,652	11,275	12,309
Coniferous Forest	704	471	500	1,492	968	1,046
Mixed Forest	1,578	1,285	830	2,946	2,441	1,583
Water	113	116	198	425	422	584
Wetland	312	294	302	588	571	620
Herbaceous Veg.	1,536	1,553	1,274	2,995	3,122	2,479

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1973 Landsat MSS images of the 5-kilometer buffer of the Tyringham Valley and Sheffield segment achieved overall accuracies of 86.86%, 88.29% and 87.43%, respectively.

Figure 36 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1989, and 2002) for the Tyringham Valley and Sheffield segment, and the results of the land cover types and change detection analysis.

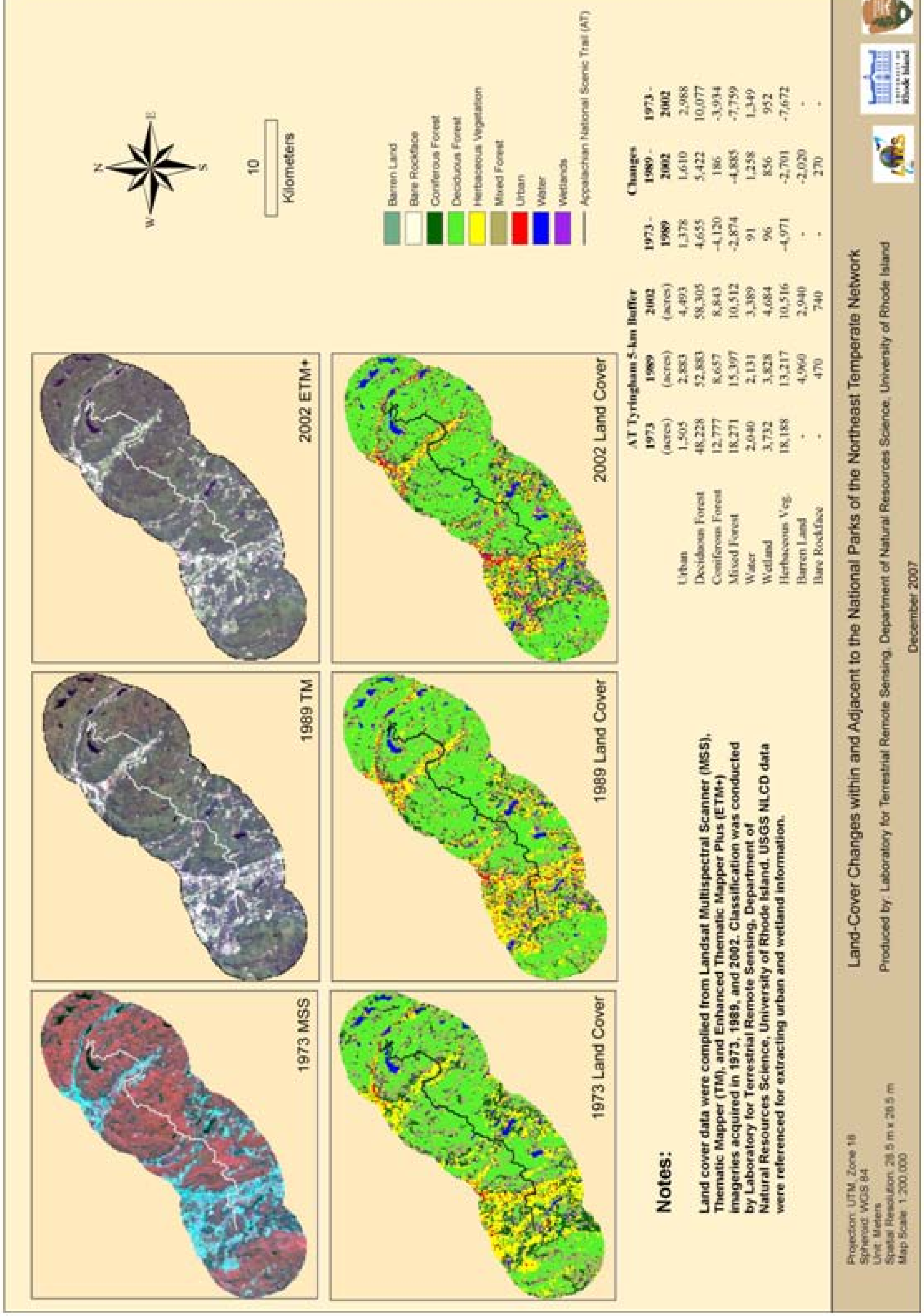


Figure 36. Land cover and change for the Tyringham Valley and Sheffield segment of the Appalachian Trail and the adjacent5-kilometer buffer.

Walkill Valley Segment

Land cover types for the three time periods within the 5-kilometer buffer adjacent to the Walkill Valley segment indicated that the area experienced urban expansion between 1975 and 2002, and in particular between 1975 and 1988 (Table 29). Urban Land increased from 2,194 acres in 1975 to 7,244 acres in 1988, and then to 7,485 acres in 2002. This represents an increase of 5,050 acres between 1975 and 1988, and 241 acres between 1988 and 2002. Between 1975 and 2002, Urban Land increased 5,291 acres.

Deciduous Forest decreased between 1975 and 1988 from 46,455 to 44,510 acres, and then increased to 45,526 acres in 2002. Coniferous Forest increased from 2,995 acres in 1975 to 2,721 acres in 1988, and then increased to 3,961 acres in 2002. Mixed Forests declined from 7,891 acres in 1975 to 5,822 acres in 1988, and then to 4,651 acres in 2002. Combined, Wetland and Water measured 3,741 acres in 1975, 5,560 acres in 1988, and 3,323 acres in 2002. The amount of Herbaceous Vegetation declined from 24,056 acres in 1975 to 21,010 acres in 1988, to 20,817 acres in 2002 (Table 29).

Table 30 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 222 acres in 1975 to 706 acres in 1988, and then declined to 597 acres in 2002. For the 1-kilometer buffer area, Urban Land increased from 432 acres in 1975 to 1,267 acres in 1988, and then to 1,169 acres in 2002. The cause for declines in the amount of urban land along this segment was not clear, but may be driven by changes in the acreage of urban grass, a subcategory of Urban Land. Within the 500-meter buffer area, Deciduous Forest was stable at 4,482, 4,472 and 4,477 acres for the three time periods, respectively. Within the 1-kilometer buffer, Deciduous Forest decreased from 8,907 acres in 1975 to 8,783 acres in 1988, and then increased to 9,361 acres in 2002. Coniferous Forest decreased between 1975 and 1988 and then increased in 2002 for both the 500-meter and 1-kilometer buffers. Coniferous Forest measured 312 acres in 1975, 207 acres in 1988, and 326 acres in 2002 for the 500-meter buffer zone. For the 1-kilometer buffer, Coniferous Forest decreased from 601 acres in 1975 to 439 acres in 1988, and then increased to 643 acres in 2002. Acreage of Mixed Forest remained relatively constant between 1975 and 1988, but declined between 1988 and 2002. Herbaceous Vegetation varied from 2,384 acres in 1975 to 1,963 acres in 1988, and then back to 2,050 acres in 2002 for the 500-meter buffer area. Within the 1-kilometer buffer, Herbaceous Vegetation declined from 4,612 acres in 1975 to 3,892 acres in 1988, and then increased to 4,003 acres in 2002. In the 500-meter buffer area, Wetland and Water, combined, totaled 302 acres in 1975, 350 acres in 1988, and 174 acres in 2002. In the 1-kilometer buffer area, these two categories totaled 545 acres in 1975, 737 acres in 1988, and 370 acres in 2002 (Table 30).

Table 29. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Walkill Valley segment of the Appalachian Trail during 1975, 1988, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1975**	**1988**	**2002**	**1975-1988**	**1988-2002**	**1975-2002**
Urban	2,194	7,244	7,485	5,050 (230%)	241 (3%)	5,291 (241%)
Deciduous Forest	46,455	44,510	45,526	-1,945 (-4%)	1,016 (2%)	-929 (-2%)
Coniferous Forest	2,995	2,721	3,961	-274 (-9%)	1,240 (46%)	966 (32%)
Mixed Forest	7,891	5,822	4,651	-2,069 (-26%)	-1,171 (-20%)	-3,240 (-41%)
Water	1,459	2,309	2,012	850 (58%)	-297 (-13%)	553 (38%)
Wetland	2,282	3,251	1,311	969 (42%)	-1,940 (-60%)	-971 (-43%)
Herbaceous Veg.	24,056	21,010	20,817	-3,046 (-13%)	-193 (-1%)	-3,239 (-13%)
Open Grassland	-	191	1,274	-	1,083 (567%)	-

Table 30. Acreage of land cover types within the 500-meter and 1-kilometer buffer adjacent to the Walkill Valley segment of the Appalachian Trail during 1975, 1988, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	1975	1988	2002	1975	1988	2002
Urban	222	706	597	432	1,267	1,169
Deciduous Forest	4,482	4,472	4,777	8,907	8,783	9,361
Coniferous Forest	312	207	326	601	439	643
Mixed Forest	544	554	329	1,175	1,148	716
Water	55	116	108	124	246	211
Wetland	247	234	66	421	491	159
Herbaceous Veg.	2,384	1,963	2,050	4,612	3,892	4,003

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1988 Landsat TM and 1975 Landsat MSS images of the 5-kilometer buffer of the Walkill Valley segment achieved overall accuracies of 80.00%, 83.14% and 70.00%, respectively. Lower accuracy for 1975 data was mainly caused by the low quality of the 1975 MSS data.

Figure 37 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1975, 1988, and 2002) for this Walkill Valley segment, and the results of the land cover types and change detection analysis.

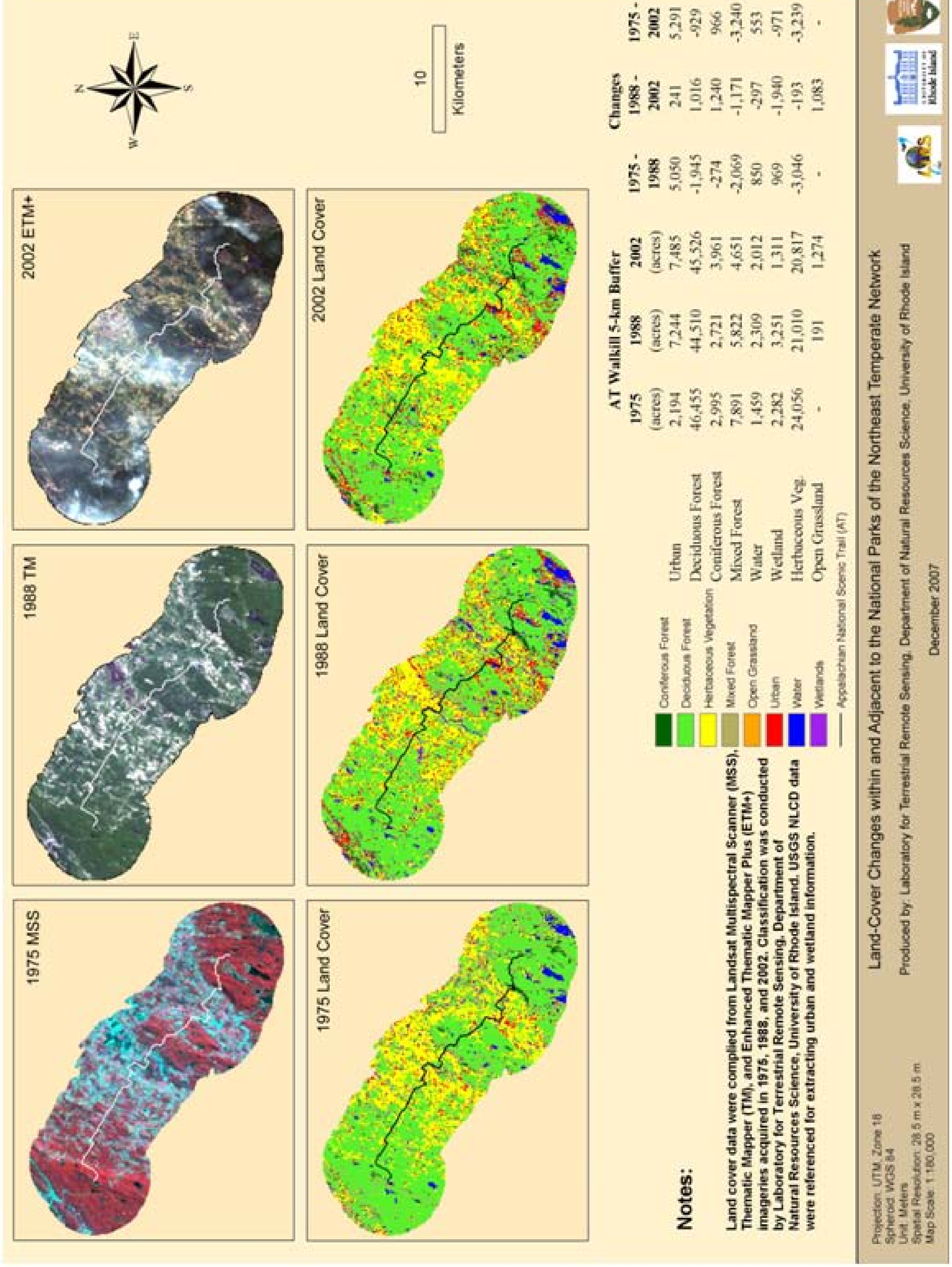


Figure 37. Land cover and change for the Walkill Valley segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Dunnfield Creek Segment

Land cover types for the three time periods within the 5-kilometer buffer adjacent to the Dunnfield Creek segment show that the area experienced urban expansion between 1975 and 2002, in particular between 1975 and 1988 (Table 31). Urban Land increased from 4,434 acres in 1975 to 4,696 acres in 1988, and then to 6,503 acres in 2002. This represents an increase of 262 acres between 1975 and 1988, and 1,807 acres between 1988 and 2002. Overall, Urban Land cover increased by 2,069 acres.

Acreage of Deciduous Forest varied during the period investigated. Between 1975 and 1988, acreage decreased from 60,608 to 53,226 acres, and then increased to 66,285 acres in 2002. Coniferous Forest decreased from 5,595 acres in 1975 to 4,933 acres in 1988, and then to 2,844 acres in 2002. Mixed Forests increased from 18,624 acres in 1975, to 21,772 acres in 1988, and then declined to 15,135 acres in 2002. Wetland and Water, combined, measured 6,495 acres in 1975, 7,663 acres in 1988, and 6,362 acres in 2002. Herbaceous Vegetation varied from 14,900 acres in 1975 to 17,067 acres in 1988, to 10,803 acres in 2002 (Table 31).

Table 32 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 167 acres in 1975 to 203 acres in 1988, and to 301 acres in 2002. In the 1-kilometer buffer area, Urban Land increased from 294 acres in 1975 to 439 acres in 1988, and then to 639 acres in 2002. Within the 500-meter buffer area, Deciduous Forest declined from 6,906 acres in 1975 to 5,940 acres in 1988, and then to 5,733 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest decreased from 12,391 acres in 1975 to 10,973 acres in 1988, and then increased to 11,593 acres in 2002. Coniferous Forest decreased between 1975 and 1988 and then increased in 2002 in the 500-meter buffer area. This represents an increase of 344 acres in 1975, 258 acres in 1988, and 321 acres in 2002 for Coniferous Forest in the 500-meter buffer zone. Within the 1-kilometer buffer, Coniferous Forest decreased from 728 acres in 1975 to 568 acres in 1988, and then to 556 acres in 2002. In the 500-meter buffer, Mixed Forest changed from 1,851 acres in 1975, to 2,329 acres in 1988, to 2,126 acres in 2002. In the 1-kilometer buffer, Mixed Forest varied between 4,713 acres in 1975, 5,062 acres in 1988, and 4,262 acres in 2002. Herbaceous Vegetation increased from 529 acres in 1975 to 858 acres in 1988, and then to 688 acres in 2002 in the 500-meter buffer area. In the 1-kilometer buffer, Herbaceous Vegetation varied from 1,069 acres in 1975 to 1,720 acres in 1988, and then to 1,150 acres in 2002. In the 500-meter buffer area, Wetland and Water, combined, totaled 476 acres in 1975, 592 acres in 1988, and 842 acres in 2002. For the 1-kilometer buffer area, these two categories totaled 1,026 acres in 1975, 1,285 acres in 1988, and 1,450 acres in 2002 (Table 32).

Table 31. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Dunnfield Creek segment of the Appalachian Trail during 1975, 1988, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1975**	**1988**	**2002**	**1975-1988**	**1988-2002**	**1975-2002**
Urban	4,434	4,696	6,503	262 (6%)	1,807 (38%)	2,069 (47%)
Deciduous Forest	60,608	53,226	66,285	-7,382 (-12%)	13,059 (25%)	5,677 (9%)
Coniferous Forest	5,595	4,933	2,844	-662 (-12%)	-2,089 (-42%)	-2,751 (-49%)
Mixed Forest	18,624	21,772	15,135	3,148 (17%)	-6,637 (-30%)	-3,489 (-19%)
Water	3,803	3,894	4,114	91 (2%)	220 (6%)	311 (8%)
Wetland	2,692	3,769	2,248	1,077 (40%)	-1,521 (-40%)	-444 (-16%)
Herbaceous Veg.	14,900	17,067	10,803	2,167 (15%)	-6,264 (-37%)	-4,097 (-27%)
Barren Land	-	839	1,938	-	1,099 (131%)	-
Bare Rockface	-	123	464	-	341 (277%)	-

Table 32. Acreage of each land cover type within the 500-meter and 1-kilometer buffer adjacent to the Dunnfield Creek segment of the Appalachian Trail, during 1975, 1988, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	**1975**	**1988**	**2002**	**1975**	**1988**	**2002**
Urban	167	203	301	294	439	639
Deciduous Forest	6,906	5,940	5,733	12,391	10,973	11,593
Coniferous Forest	344	258	321	728	568	556
Mixed Forest	1,851	2,329	2,126	4,713	5,062	4,262
Water	352	312	326	743	733	782
Wetland	124	280	416	283	552	668
Herbaceous Veg.	529	858	688	1,069	1,720	1,150
Barren Land	-	84	263	-	158	438
Bare Rockface	-	11	100	-	19	132

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1988 Landsat TM and 1975 Landsat MSS images of the 5-kilometer buffer of the Dunnfield Creek segment achieved overall accuracies of 81.43%, 81.43% and 76.00%, respectively. Lower accuracy for the 1975 data was mainly caused by the low quality of the 1975 MSS data.

Figure 38 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1975, 1988, and 2002) for the Dunnfield Creek segment, and the results of the land cover types and change detection analysis.

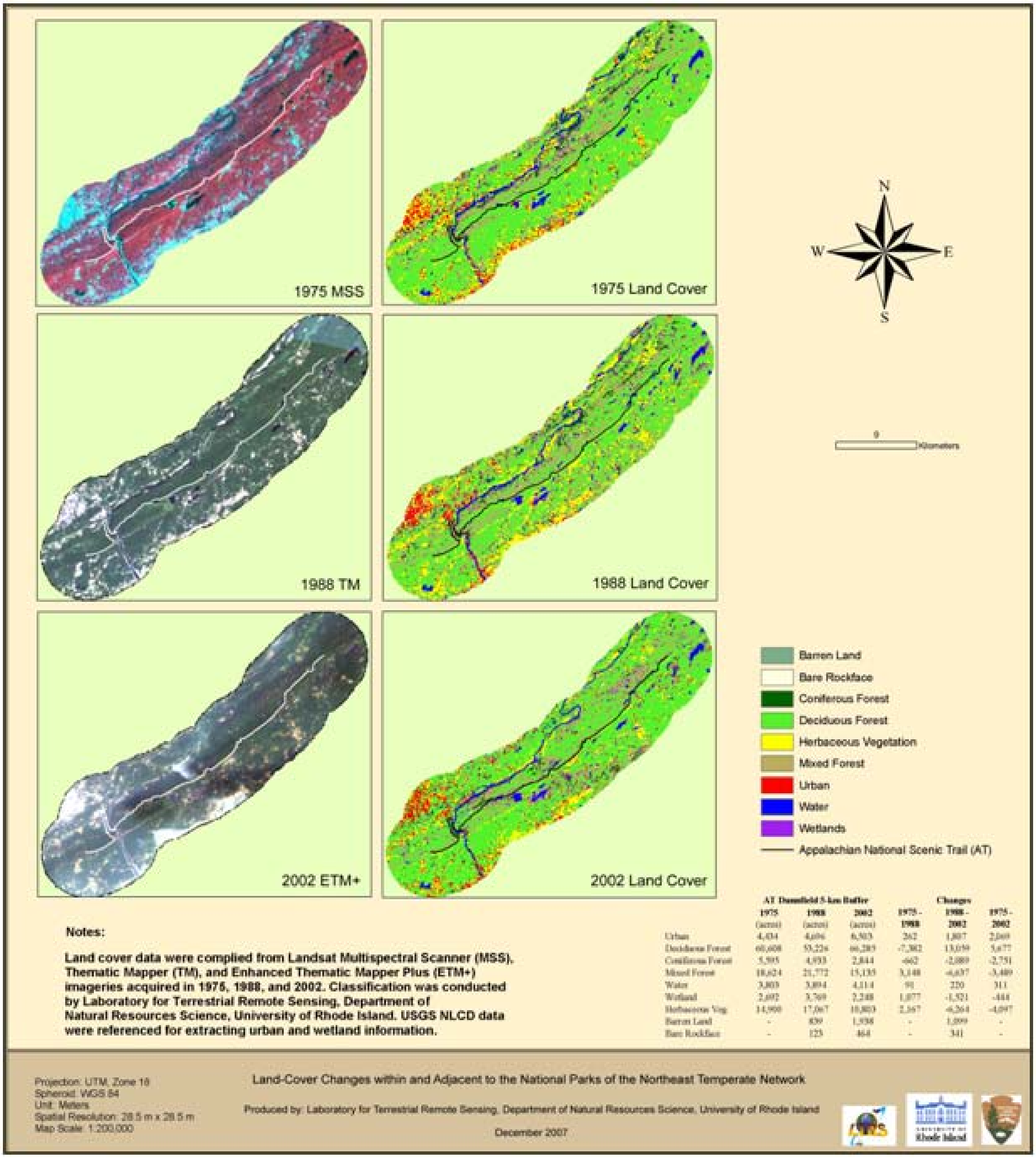


Figure 38. Land cover and change for the Dunnfield Creek segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Hawk Mountain Sanctuary Segment

Land cover types for the three time periods within the 5-kilometer buffer adjacent to the Hawk Mountain Sanctuary segment indicated that the area experienced urban expansion over the 29 years we evaluated, in particular between 1973 and 1989 (Table 33). Urban Land increased from 2,739 acres in 1973 to 6,248 acres in 1989 and to 6,385 acres in 2002. This represents an increase of 3,509 acres between 1973 and 1989, and between 1989 and 2002. Between 1973 and 2002, Urban Land increased by 3,646 acres.

Deciduous Forest declined from 93,831 acres in 1973 to 74,868 acres in 1989, to 73,843 acres in 2002. Coniferous Forest increased from 3,452 acres in 1973 to 4,253 acres in 1989 and to 4,749 acres in 2002. Mixed Forest decreased from 3,752 acres in 1973 to 1,969 acres in 1989, and then increased to 2,273 acres in 2002. Areas with Herbaceous Vegetation varied in extent from 27,949 acres in 1973 to 43,297 acres in 1989, to 43,975 acres in 2002 (Table 33). A reference site for the Wetland cover type was not available to act as a training signature for the land cover classification at this site. As a result, the Wetland cover type was omitted from the analysis for this segment. Water varied in extent from 633 acres in 1973 to 1,271 acres in 1989, to 829 acres in 2002. Barren Land measured 5,482 acres in 1973, 4,598 acres in 1989, and 4,825 acres in 2002.

Table 34 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 97 acres in 1973 to 134 acres in 1989, and then to 167 acres in 2002. For the 1-kilometer buffer area, Urban Land increased from 169 acres in 1973 to 307 acres in 1989, and then to 350 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 12,376 acres in 1973 to 13,382 acres in 1989, to 13,324 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest varied in extent from 24,114 acres in 1973 to 25,939 acres in 1989, to 25,580 acres in 2002. Coniferous Forest decreased between 1973 and 1989 and then increased in 2002 within the 500-meter buffer area Coniferous Forest encompassed 715 acres in 1973, 278 acres in 1989, and 314 acres in 2002 for the 500-meter buffer zone. Within the 1-kilometer buffer, Coniferous Forest decreased from 1,206 acres in 1973 to 501 acres in 1989, and then increased to 574 acres in 2002. In the 500-meter buffer, Mixed Forest decreased from 667 acres in 1973 to 474 acres in 1989, and then to 74 acres in 2002. In the 1-kilometer buffer, Mixed Forest declined from 1,283 acres in 1973 to 721 acres in 1989, to 201 acres in 2002. Herbaceous Vegetation varied from 756 acres in 1973, to 367 acres in 1989, and then to 708 acres in 2002 for the 500-meter buffer area. In the 1-kilometer buffer, Herbaceous Vegetation varied from 1,268 acres in 1973 to 781 acres in 1989, and then to 1,443 acres in 2002. In the 500-meter buffer area, of the extent of the Water remained consistent at 71, 74, and 76 acres for each of the time periods, respectively. For the 1-kilometer buffer area, Water measured 152 acres in 1973 and 170 acres in both 1989 and 2002. An appropriate wetland site was not available for use as a training signature for the land cover classification at this segment (Table 34).

Table 33. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Hawk Mountain segment of the Appalachian Trail during 1973, 1989, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent cover)		
Land Cover Type	**1973**	**1989**	**2002**	**1973-1989**	**1989-2002**	**1978-2002**
Urban	2,739	6,248	6,385	3,509 (128%)	137 (2%)	3,646 (133%)
Deciduous Forest	93,831	74,868	73,843	-18,963 (-20%)	-1,025 (-1%)	-19,988 (-21%)
Coniferous Forest	3,452	4,253	4,749	801 (23%)	496 (12%)	1,29 (38%)
Mixed Forest	3,752	1,969	2,273	-1,783 (-48%)	304 (15%)	-1,479 (-39%)
Water	633	1,271	829	638 (101%)	-442 (-35%)	196 (31%)
Herbaceous Veg.	27,949	43,297	43,975	15,348 (55%)	678 (2%)	16,026 (57%)
Barren Land	5,482	4,598	4,825	-884 (-16%)	227 (5%)	-657 (-12%)
Bare Rockface	-	878	492	-	-386 (-44%)	-

Table 34. Acreage of each land cover type within the 500-meter and 1-kilometer buffers adjacent to the Hawk Mountain segment or the Appalachian Trail during 1973, 1989, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	**1973**	**1989**	**2002**	**1973**	**1989**	**2002**
Urban	97	134	167	169	307	350
Deciduous Forest	12,376	13,382	13,324	24,114	25,939	25,580
Coniferous Forest	715	278	314	1,206	501	574
Mixed Forest	667	474	74	1,283	721	201
Water	71	74	76	152	170	170
Herbaceous Veg.	756	367	708	1,268	781	1,443
Barren Land	199	183	225	723	511	601

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1973 Landsat MSS images of the 5-kilometer buffer of the Hawk Mountain segment achieved overall accuracies of 79.71%, 83.43% and 72.86%, respectively.

Figure 39 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1989, and 2002) for this Hawk Mountain segment, and the results of the land cover types and change detection analysis.

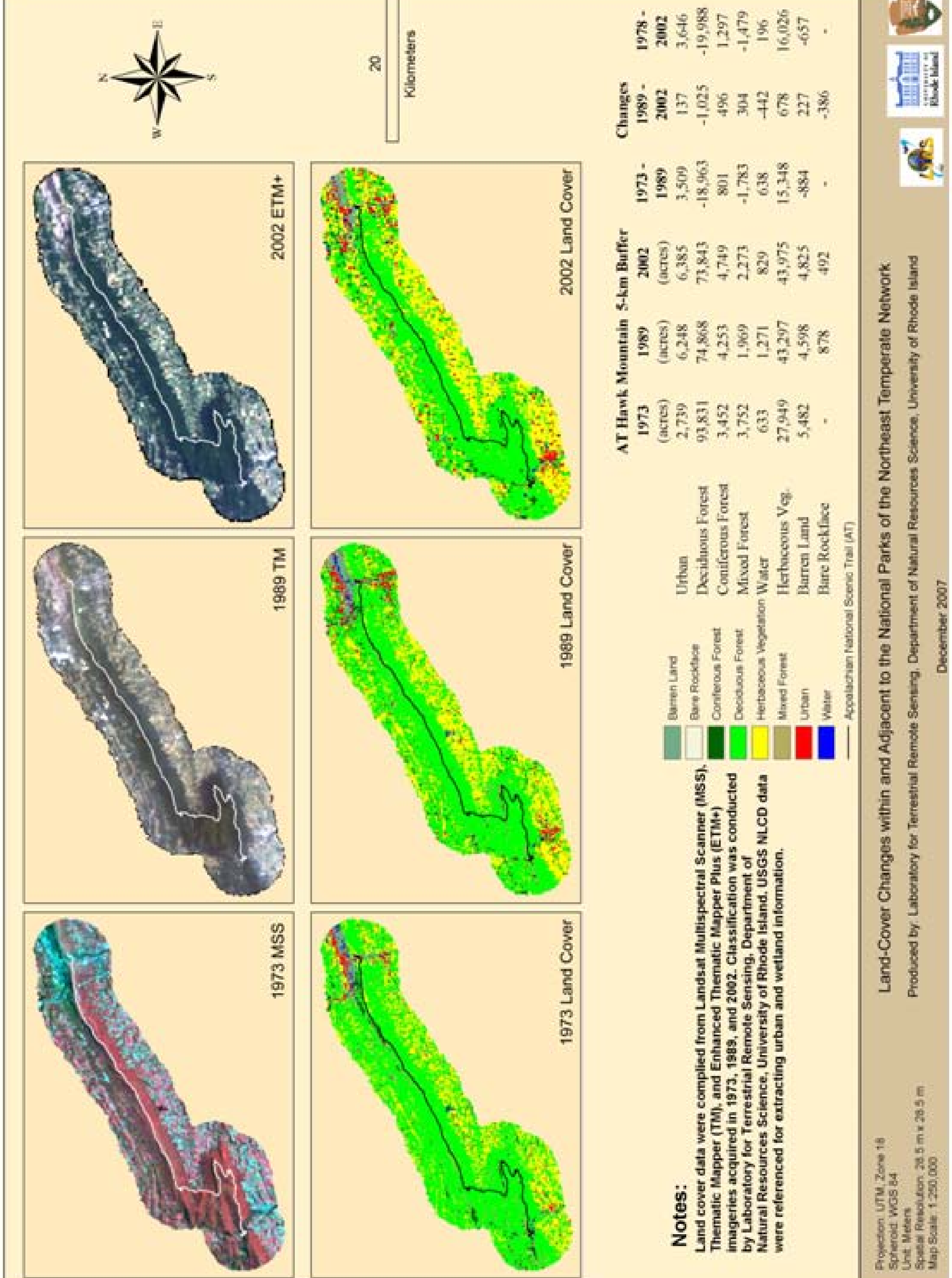


Figure 39. Land cover and change for the Hawk Mountain segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Rausch Gap/St. Anthony's Wilderness Segment

Land cover types for the three time periods within the 5-kilometer buffer adjacent to the Rausch Gap/St. Anthony's Wilderness segment indicate increases in urban development and in changes to the extent of coniferous forest (Table 35). Urban Land increased from 1,223 acres in 1973 to 2,420 acres in 1989, to 3,605 acres in 2002. This represents an increase of 1,197 acres between 1973 and 1989, and 1,185 acres between 1989 and 2002. Between 1973 and 2002, Urban Land cover increased by 2,382 acres.

Deciduous Forest declined from 102,736 acres in 1973 to 101,894 acres in 1989, to 99,464 acres in 2002. Coniferous Forest decreased from 6,408 acres in 1973 to 2,140 acres in 1989, to 1,865 acres in 2002. Mixed Forest varied from 3,946 acres in 1973 to 1,277 acres in 1989, and then increased to 2,118 acres in 2002. The extent of Herbaceous Vegetation increased from 23,517 acres in 1973 to 29,596 acres in 1989, to 30,938 acres in 2002. Water measured 979 acres in 1973, 1,129 acres in 1989, and 507 acres in 2002 (Table 35).

Table 36 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 20 acres in 1973 to 37 acres in 1989 and to 71 acres in 2002. Within the 1-kilometer buffer area, Urban Land increased from 39 acres in 1973 to 92 acres in 1989, and then to 163 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 11,668 acres in 1973 to 12,657 acres in 1989, and then decreased slightly to 12,513 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest varied from 23,661 acres in 1973 to 25,043 acres in 1989, to 24,818 acres in 2002. Coniferous Forest decreased between 1973 and 1989 and then increased in 2002 in the 500-meter buffer area. The extent of Coniferous Forest was 857 acres in 1973, 145 acres in 1989, and 218 acres in 2002 in the 500-meter buffer zone. In the 1-kilometer buffer, Coniferous Forest decreased from 1,315 acres in 1973 to 285 acres in 1989, and then to 309 acres in 2002. In the 500-meter buffer, Mixed Forest decreased from 360 acres in 1973 to 68 acres in 1989, to 124 acres in 2002. In the 1-kilometer buffer, Mixed Forest varied from 652 acres in 1973 to 137 acres in 1989, to 278 acres in 2002. Herbaceous Vegetation in the 500-meter buffer remained constant with 27 acres in 1973, 362 acres in 1989, and 355 acres in 2002. In the 1-kilometer buffer, Herbaceous Vegetation increased from 677 acres in 1973 to 813 acres in 1989, and then to 849 acres in 2002. In the 500-meter buffer area, Water declined from 49 acres in 1973 to 21 acres in 1989; no Water was detected in 2002. The Water cover type exhibited a similar pattern in the 1-kilometer buffer for water (Table 36).

Table 35. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail during 1973, 1989, and 2002, and change in acreage of each land cover type between time periods.

Land Cover Type	5-km Buffer			Acreage Changes (percent change)		
	1973	1989	2002	1973-1989	1989-2002	1973-2002
Urban	1,223	2,420	3,605	1,197 (98%)	1,185 (49%)	2,382 (195%)
Deciduous Forest	102,736	101,894	99,464	-842 (-1%)	-2,430 (-2%)	-3,272 (-3%)
Coniferous Forest	6,408	2,140	1,865	-4,268 (-67%)	-275 (-13%)	-4,543 (-71%)
Mixed Forest	3,946	1,277	2,118	-2,669 (-68%)	841 (66%)	-1,828 (-46%)
Water	979	1,129	507	150 (15%)	-622 (-55%)	-472 (-48%)
Herbaceous Veg.	23,517	29,596	30,938	6,079 (26%)	1,342 (5%)	7,421 (32%)

Table 36. Acreage of each land cover type within the 500-meter and 1-kilometer buffers adjacent to the Rausch Gap/ St. Anthony's Wilderness segment of the Appalachian Trail during 1973, 1989, and 2002.

Land Cover Type	500-m Buffer			1-km Buffer		
	1973	1989	2002	1973	1989	2002
Urban	20	37	71	39	92	163
Deciduous Forest	11,668	12,657	12,513	23,661	25,043	24,818
Coniferous Forest	857	145	218	1,315	285	309
Mixed Forest	360	68	124	652	137	278
Water	49	21	-	57	46	1
Herbaceous Veg.	327	362	355	677	813	849

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1973 Landsat MSS images of the 5-kilometer buffer of the Rausch Gap/St. Anthony's Wilderness segment achieved overall accuracies of 90.33%, 86.67% and 79.00%, respectively.

Figure 40 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1989, and 2002) for this Rausch Gap/St. Anthony's Wilderness segment, and the results of the land cover types and change detection analysis.

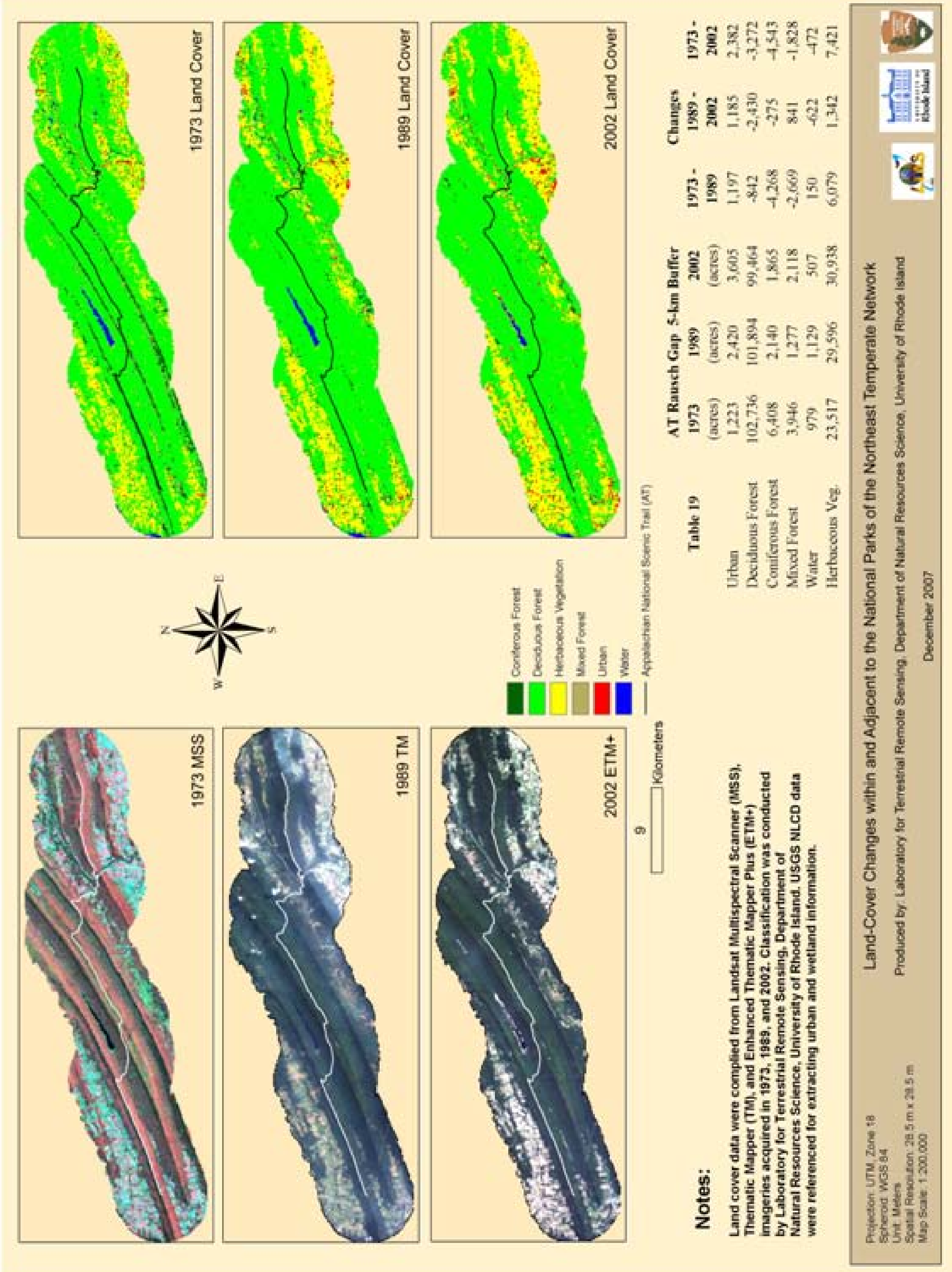


Table 19	AT Rausch Gap 5-km Buffer 1973 (acres)	1989 (acres)	2002 (acres)	Changes 1973 - 1989	1989 - 2002	1973 - 2002
Urban	1,223	2,420	3,605	1,197	1,185	2,382
Deciduous Forest	102,736	101,894	99,464	-842	-2,430	-3,272
Coniferous Forest	6,408	2,140	1,865	-4,268	-275	-4,543
Mixed Forest	3,946	1,277	2,118	-2,669	841	-1,828
Water	979	1,129	507	150	-622	-472
Herbaceous Veg.	23,517	29,596	30,938	6,079	1,342	7,421

Figure 40. Land cover and change for the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail and the adjacent 5-kilometer buffer.

Cumberland Valley Segment

Over the time period we evaluated, changes in the extent of land cover types within the 5-kilometer buffer adjacent to the Cumberland Valley segment point to an increase in urban development (Table 37). Urban Land increased from 1,974 acres in 1973 to 4,942 acres in 1989, to 6,902 acres in 2002. This represents an increase of 2,968 acres between 1973 and 1989, and 1,960 acres between 1989 and 2002. Between 1973 and 2002, Urban Land cover increased by 4,928 acres.

Deciduous Forest declined from 27,927 acres in 1973 to 25,166 acres in 1989, and then increased to 26,499 acres in 2002. Coniferous Forest decreased from 1,381 acres in 1973 to 965 acres in 1989, and then increased to 1,267 acres in 2002. Mixed Forest declined from 2,647 acres in 1973 to 1,839 acres in 1989, to 1,575 acres in 2002. The extent of Herbaceous Vegetation varied from 38,877 acres in 1973 to 39,540 acres in 1989, and 35,929 acres in 2002. Water measured 356 acres in 1973, 495 acres in 1989, and 764 acres in 2002 (Table 37).

Table 38 offers more details about the land cover changes within the 500-meter and 1-kilometer buffer zones adjacent to this segment. Within the 500-meter buffer, Urban Land increased from 215 acres in 1973 to 537 acres in 1989 and to 695 acres in 2002. For the 1-kilometer buffer area, Urban Land increased from 395 acres in 1973 to 998 acres in 1989, and then to 1,383 acres in 2002. Within the 500-meter buffer area, Deciduous Forest increased from 2,040 acres in 1973 to 1,854 acres in 1989, and then to 1,965 acres in 2002. Within the 1-kilometer buffer, Deciduous Forest varied between 3,878 acres in 1973, 3,452 acres in 1989, and 3,623 acres in 2002. Coniferous Forest decreased between 1973 and 1989, and then increased in 2002 within the 500-meter buffer area. Coniferous Forest measured 101 acres in 1973, 68 acres in 1989, and 183 acres in 2002 in the 500-meter buffer zone. In the 1-kilometer buffer, Coniferous Forest decreased from 187 acres in 1973 to 119 acres in 1989, and then to 267 acres in 2002. In the 500-meter buffer, Mixed Forest decreased from 214 acres in 1973 to 106 acres in 1989, to 102 acres in 2002. In the 1-kilometer buffer, Mixed Forest declined from 374 acres in 1973, to 184 acres in 1989, to 178 acres in 2002. The extent of Herbaceous Vegetation in the 500-meter buffer remained relatively with 3,545 acres in 1973, 3,540 acres in 1989, and 3,115 acres in 2002. For the 1-kilometer buffer, Herbaceous Vegetation varied from 7,381 acres in 1973, 7,438 acres in 1989, and 6,684 acres in 2002. In the 500-meter buffer area, Water increased from 51 acres in 1973, to 61 acres in 1989, to 106 acres in 2002. We observed a similar pattern for Water in the 1-kilometer buffer, with 78 acres in 1973, 103 acres in 1989, and 158 acres in 2002 (Table 38).

Table 37. Acreage of each land cover type within the 5-kilometer buffer adjacent to the Cumberland Valley segment of the Appalachian Trail during 1973, 1989, and 2002, and change in acreage of each land cover type between time periods.

	5-km Buffer			Acreage Changes (percent change)		
Land Cover Type	**1973**	**1989**	**2002**	**1973-1989**	**1989-2002**	**1973-2002**
Urban	1,974	4,942	6,902	2,968 (150%)	1,960 (40%)	4,928 (250%)
Deciduous Forest	27,927	25,166	26,499	-2,761 (-10%)	1,333 (5%)	-1,428 (-5%)
Coniferous Forest	1,381	965	1,267	-416 (-30%)	302 (31%)	-114 (-8%)
Mixed Forest	2,647	1,839	1,575	-808 (-31%)	-264 (-14%)	-1,072 (-40%)
Water	356	495	764	139 (39%)	269 (54%)	408 (115%)
Herbaceous Veg.	38,877	39,540	35,929	663 (2%)	-3,611 (-9%)	-2,948 (-8%)

Table 38. Acreage of each land cover type within the 500-meter and 1-kilometer buffers adjacent to the Cumberland Valley segment of the Appalachian Trail during 1973, 1989, and 2002.

	500-m Buffer			1-km Buffer		
Land Cover Type	**1973**	**1989**	**2002**	**1973**	**1989**	**2002**
Urban	215	537	695	395	998	1,383
Deciduous Forest	2,040	1,854	1,965	3,878	3,452	3,623
Coniferous Forest	101	68	183	187	119	267
Mixed Forest	214	106	102	374	184	178
Water	51	61	106	78	103	158
Herbaceous Veg.	3,545	3,540	3,115	7,381	7,438	6,684

As reported in the accuracy assessment (Appendix A), the land cover classification for the 2002 Landsat ETM+, 1989 Landsat TM and 1973 Landsat MSS images of the 5-kilometer buffer of the Cumberland Valley segment achieved overall accuracies of 83.00%, 83.33% and 82.33%, respectively.

Figure 41 illustrates the Landsat images and the corresponding maps of land cover classification for the three time periods (1973, 1989, and 2002) for the Cumberland Valley segment, and the results of the land cover types and change detection analysis.

Figure 41. Land cover and change for the Cumberland Valley segment of the Appalachian Trail and the adjacent 5-kilometer buffer area.

Discussion

Landscape dynamics is one of the NPS's vital signs for monitoring and reporting the ecological conditions of NETN parks and the Appalachian National Scenic Trail. Monitoring land cover changes will guide resource management decisions for these protected lands. This study provided information on historical land cover, going back approximately 30 years, for some parks and selected Appalachian Trail segments in the NETN. Historical land use information serves as a baseline for understanding how the landscape has changed within and adjacent to the parks. The baseline data established with this project will provide a foundation for monitoring future changes in land cover.

This study can also serve as an example of how to conduct a landscape change analysis among a group of park units that have different sizes and shapes, with different protection and management goals. The template protocols developed in this study can be applied elsewhere for monitoring and understanding the landscape dynamics within and adjacent to protected lands. For example, the analysis for linear-featured Appalachian Trail segments can be suitable for other linear protected areas such as river-based parks, roadways, habitat corridors, or other trails across the country.

Landsat images employed in this project represent snapshots of the landscape at the time of image acquisition. Many factors may affect the quality of the image and landscape features recorded (e.g., a dry year image vs. a wet year image, or tidal height at Acadia NP). The accuracy of land cover maps may also be affected by the complexity of landscapes at the study sites, and image processing and classification processes. Therefore, the land cover maps generated by this type of data and technology may differ from the understanding of the landscape by resource managers because the snap-shot view may sometimes capture atypical or transient conditions. In addition, the resolution and number of spectral bands of Landsat satellite sensors have improved over time. These changes could affect the interpretation of landscape change between time periods. For example, improvements in resolution from 90- to 30-meters enable detection of landscape features with smaller extents. Therefore, the land cover maps from this study represent only the best estimation of what the landscape looked like at different times. All of these limitations need to be considered when reviewing the maps and the results of change analysis.

Supervised and stratified classifications are appropriate approaches for extracting land cover information from Landsat sensor data. Because digital image classifications were pixel based, the stratified classification allowed us to extract more detailed features within delineated polygons of NPS vegetation mapping project data. Combining the information from two data sources resulted in more comprehensive land cover maps. The NPS has made a significant investment in vegetation mapping projects across the parks and the resulting products provide valuable information for resource management and reliable guidance for extended classification of Landsat remote sensing data. The advantages of this protocol include valuing the NPS vegetation mapping efforts, keeping the classification results consistent, meeting the goal of land cover mapping, improving classification accuracy, validity for change analysis and monitoring, and simplicity for future analyses. We only tested the stratified classification for three parks (ACAD, ROVA and SARA) because these were the only sites with available vegetation mapping data;

however, our methods can easily be extended to the other parks when the vegetation mapping project data become available. With the availability of NPS vegetation mapping project data, future landscape characterization of parks should take advantage of this important investment. The stratified classification described in this study is a practical tool for using NPS vegetation mapping project data to characterize landscape dynamics.

Post-classification change detection is a common and justifiable approach for a study of this type and scope. Such an approach is particularly merited when multiple Landsat sensor data types (MSS, TM and ETM+) are used. In addition, post-classification change detection significantly reduces the amount pre-processing for atmospheric corrections of Landsat data that must be done, which would otherwise tax the image processing capacity of park managers. However, there is a risk of propagating errors among individually classified land cover maps in different time periods, in particular for the land cover categories that have low agreement with reference data in the accuracy assessment.

In this study, we focused on evaluating the extent of different land cover types and assessing how they changed over time within different buffer zones (vs. a pixel-based change analysis). In a pixel-based change analysis, the detected changes could result from errors resulting from pixel misclassification, misinterpretation, or misregistration on original remote sensing images and the derivatives of thematic information. Consistency is another challenge with a pixel-based approach. Multi-date thematic data could be generated by different individuals, and resulting differences between classification or interpretation procedures may eventually cause a false change detection result. These factors contributed to our decision to avoid a pixel-based post-classification change analysis.

The land cover data developed from this project could be used to conduct a pixel-by-pixel based change detection analysis, that would illustrate detailed “from-to” transitions among land cover types at specific spatial locations in specific parks. This approach would enable evaluation of the proportion of real changes, versus changes that are unlikely from an ecological standpoint. Such unlikely changes would suggest that no real change in the actual character of the landscape occurred, but rather that phenological or processing differences caused apparent transient spectral changes. For example, a pixel-based change analysis could reveal the extent to which differences in tidal height among the images affected apparent acreage of coastal wetland. A complete matrix of “from-to” transitions on a pixel-by-pixel basis would help convey the most important transitions in each park unit or Appalachian Trail segment. Although a pixel-based approach does not directly address the more complicated question of how to evaluate false changes over time periods, it would get us one step closer to spatially explicit change analysis.

Given the need to assess map utility for many different areas at three points in time, we found it nearly impossible to conduct the type of error analysis recommended in most remote sensing texts. Standard texts suggest that a true error analysis is only possible if the “truth” set is at least one step closer to reality than the remotely sensed product on which the map is based. Although we often consider rigorously collected ground observation data, and finer spatial resolution aerial photography to be that set, year-appropriate air photos or field data for retrospective change analysis are usually not available. Thus, direct interpretation of satellite imagery, especially with the familiarity of spectral features on the image and supported by field observations, is a legitimate approach to conducting accuracy assessment.

Some land cover types, such as Urban and Wetland classes, are very difficult to extract from Landsat spectral information alone. By incorporating reliable reference data, such as the NLCD-1992/2001, the NWI, and NPS vegetation mapping project data, the final land cover data product and change analysis were improved. In the future, integration of additional data sources, such as GIS data from different state offices or research groups, will also help improve the quality of the data and the results of change analysis.

The NLCD-1992 and NLCD-2002 datasets would not be appropriate or recommended for conducting change analysis due to differences in data processing techniques and data quality issues involved in NLCD data development. The subset areas of this study were tightly focused and we had solid field knowledge and observations to support our signature selections during the classifications. Our final land cover data, after cross checking with NLCD and NWI data products for Urban and Wetland categories, respectively, should be more reliable than simply using NLCD data for land cover mapping and change analysis.

Appropriate buffer size is often a topic of debate when conducting this type of study. In this project, we subjectively applied a fixed-width 5-kilometer buffer to all the studied park units and Appalachian Trail segments. For small parks and linear trail segments this fixed-width buffer scheme could result in a much lower ratio of land inside the park relative to land outside the park, as compared to larger parks and segments. This effect may complicate the interpretation drawn from the data. In the future, using derived land cover data, more flexible buffers could be applied to individual parks, smaller ones in particular, to conduct more relevant buffering analyses.

This project has identified several potential points for improvement or for future studies. Although, in general, change analyses are informational, for future efforts, we recommend that Landsat data be used primarily for large parks that have natural areas as the dominant elements of the landscape. For smaller National Historic Sites and National Historical Parks, especially those located within established urban centers and suburban areas, the 30-meter spatial resolution of Landsat imagery may not provide sufficient information. We recommend that finer spatial resolution satellite remote sensing data be used in those cases. Our experiences have proven that high spatial resolution, multispectral digital satellite data are more effective in terms of providing useful information on vegetation cover as well as change analysis for inventory and monitoring purposes. This is particularly true when satellite data is teamed with data products from NPS vegetation mapping projects (Wang et al. 2007).

We recommend applying buffer zones around the NPS properties for future NPS data acquisition and mapping efforts. Buffer areas will make mapping results more accurately reflect the dynamic land use patterns of the surrounding communities, will help identify where the major stressors are located, and will assist park managers and the surrounding communities with land management planning.

The current Landsat satellites and sensor systems have reached the end of their designed life cycles so, future studies will need to consider techniques for updating land cover data from similar types of sensor systems. Recently, the Office of Science and Technology Policy released a National Land Imaging Program (NLIP) strategy that included a commitment to land-remote sensing. The NLIP is designed to meet U.S. civilian, moderate resolution land imaging needs for monitoring changes in land surface, polar regions, and coastal zones resulting from population growth, development, and climate change. The strategy establishes a program office in the Department of the Interior, reporting at the Secretary and Assistant Secretary level, to provide focused leadership and management for the nation's land imaging efforts. The NLIP will focus on maintaining a core, operational, government commitment and capability to collect moderate-resolution land imagery through the procurement and launch of a series of satellites owned by the United States. This will ensure the continuity of Landsat-like data, collected and managed by the U.S., well into the future. Once in operation, the NLIP will be an appropriate data source for supporting the continuation of this type of land cover change analysis.

Land cover change analysis can be a powerful tool for assessing landscape-scale impacts to park units, provided that we identify independent variables or processes that can be related to the changes observed with remote sensing data. For example, the impact of urbanization on invasive species in a given park would ideally be assessed by observing the spatial patterns of invasive species colonization over 30 years, and, using spatial statistics, the severity and scope of invasive species infestation could be correlated with the urbanization or fragmentation processes that can be estimated from maps. Identifying these independent variables requires multidisciplinary expertise, with ecologists, botanists, biologists, hydrologists, and others working together, and with land cover data to answer questions about landscape-level threats and processes.

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Appendix A. Land cover classification accuracy assessment.

The USGS classification system indicates that for land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85-90% of the time (Anderson et al., 1976). The USGS-NPS Vegetation Mapping Program adopted standards including a minimum mapping unit of 1.2 acres and classification accuracy of 80% for each map class (http://biology.usgs.gov/npsveg/about.html). This appendix contains a summary of the agreements between our classification results and the reference data.

Table A1. Error matrix for the classification of a 2002 Landsat ETM+ image of Acadia National Park; image file: acad/etm/acad_etm_20020910_class.img.

	Reference Data								
Classified Data	**U**	**DF**	**CF**	**MF**	**W**	**WL**	**HV**	**BR**	**Totals**
U	42	1	1	1	0	0	0	2	50
DF	0	45	1	2	0	0	1	1	50
CF	4	1	40	4	0	0	0	1	50
MF	3	2	0	43	0	1	1	0	50
W	0	0	0	0	49	0	0	1	50
WL	1	0	0	1	0	47	1	0	50
HV	5	1	0	1	0	0	43	0	50
BR	2	2	0	0	0	1	2	39	50
Totals	57	52	42	52	49	49	48	44	400

Table A2. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Acadia National Park; image file: acad/etm/acad_etm_20020910_class.img.

Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producer's Accuracy**	**User's Accuracy**
U	57	50	42	73.68%	84.00%
DF	52	50	45	86.54%	90.00%
CF	42	50	40	95.24%	80.00%
MF	52	50	43	82.69%	86.00%
W	49	50	49	100.00%	98.00%
WL	49	50	47	95.92%	94.00%
HV	48	50	43	89.58%	86.00%
BR	44	50	39	88.64%	78.00%
Totals	400	400	348		

*Overall Classification Accuracy: 87.00%

Table A3. Conditional Kappa (κ) statistics* for each category for the classification of a 2002 Landsat ETM+ image of Acadia National Park; image file: acad/etm/acad_etm_20020910_class.img.

Class Name	Kappa
U	0.8134
DF	0.8851
CF	0.7765
MF	0.8391
W	0.9772
WL	0.9316
HV	0.8409
BR	0.7528

*Overall Kappa: 0.8518

Table A4. Error matrix for the classification of a 1986 Landsat TM image of Acadia National Park; image file: /acad/tm/acad_tm_19860805_class_fixed.img.

	Reference Data								
Classified Data	U	DF	CF	MF	W	WL	HV	BR	Totals
U	50	0	0	0	0	0	0	0	50
DF	1	44	0	2	0	1	2	0	50
CF	0	1	45	2	0	2	0	0	50
MF	2	0	4	43	0	1	0	0	50
W	0	0	0	0	49	0	0	1	50
WL	0	0	0	0	0	50	0	0	50
HV	5	3	1	2	0	0	31	8	50
BR	3	1	1	3	0	7	1	34	50
Totals	61	49	51	52	49	61	34	43	400

Table A5. Accuracy totals* for the classification of a 1986 Landsat TM image of Acadia National Park; image file: /acad/tm/acad_tm_19860805_class_fixed.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	61	50	50	81.97%	100.00%
DF	49	50	44	89.80%	88.00%
CF	51	50	45	88.24%	90.00%
MF	52	50	43	82.69%	86.00%
W	49	50	49	100.00%	98.00%
WL	61	50	50	81.97%	100.00%
HV	34	50	31	91.18%	62.00%
BR	43	50	34	79.07%	68.00%
Totals	400	400	346		

*Overall Classification Accuracy: 86.50%

Table A6. Conditional Kappa (κ) statistics* for each category for the classification of a 1986 Landsat TM image of Acadia National Park; image file: /acad/tm/acad_tm_19860805_class_fixed.img.

Class Name	Kappa
U	1.0000
DF	0.8632
CF	0.8854
MF	0.8391
W	0.9772
WL	1.0000
HV	0.5847
BR	0.6415

*Overall Kappa: 0.8457

Table A7. Error matrix for the classification of a 1976 Landsat MMS image of Acadia National Park; image file: /acad/mss/acad_mss_19760723_class.img.

Classified Data	Reference Data								
	U	DF	CF	MF	W	WL	HV	BR	Totals
U	50	0	0	0	0	0	0	0	50
DF	0	44	1	1	0	1	1	2	50
CF	1	1	42	4	0	1	1	0	50
MF	1	2	2	44	0	0	0	1	50
W	0	0	0	0	50	0	0	0	50
WL	0	0	0	0	0	47	0	3	50
HV	8	5	0	1	0	1	26	9	50
BR	7	1	1	0	0	0	5	36	50
Totals	67	53	46	50	50	50	33	51	400

Table A8. Accuracy totals* for the classification of a 1976 Landsat MMS image of Acadia National Park; image file: /acad/mss/acad_mss_19760723_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	67	50	50	74.63%	100.00%
DF	53	50	440	83.02%	88.00%
CF	46	50	2	91.30%	54.00%
MF	50	50	44	88.00%	88.00%
W	50	50	50	100.00%	100.00%
WL	50	50	47	94.00%	94.00%
HV	33	50	26	78.79%	52.00%
BR	51	50	36	70.59%	72.00%
Totals	400	400	339		

*Overall Classification Accuracy: 84.75%

Table A9. Conditional Kappa (κ) statistics* for each category for the classification of a 1976 Landsat MMS image of Acadia National Park; image file: /acad/mss/acad_mss_19760723_class.img.

Class Name	Kappa
U	1.0000
DF	0.8617
CF	0.8192
MF	0.8629
W	1.0000
WL	0.9314
HV	0.4768
BR	0.6791

*Overall Kappa = 0.8257

Table A10. Error matrix for the classification of a 2002 Landsat ETM+ image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/etm/mabi_etm_20020908_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	2	0	0	0	0	3	50
DF	1	43	0	3	0	0	3	50
CF	1	1	46	1	1	0	0	50
MF	0	4	3	40	0	0	3	50
W	6	0	0	0	44	0	0	50
WL	1	0	0	2	0	47	0	50
HV	2	2	1	0	0	0	45	50
Totals	56	52	50	46	45	47	54	350

Table A11. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Marsh-Billings-Rockefeller National Historical Park; image file mabi/etm/mabi_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	56	50	45	80.36%	90.00%
DF	52	50	43	82.69%	86.00%
CF	50	50	46	92.00%	92.00%
MF	46	50	40	86.96%	80.00%
W	45	50	44	97.78%	88.00%
WL	47	50	47	100.00%	94.00%
HV	54	50	45	83.33%	90.00%
Totals	350	350	310		

*Overall Classification Accuracy: 88.57%

Table A12. Conditional Kappa (κ) statistics* for each category for the classification of a 2002 Landsat ETM+ image of Marsh-Billings-Rockefeller National Historical Park; image file: mabi/etm/mabi_etm_20020908_class.img.

Class Name	Kappa
U	0.8810
DF	0.8356
CF	0.9067
MF	0.7697
W	0.8623
WL	0.9307
HV	0.8818

*Overall Kappa: 0.8667

Table A13. Error matrix for the classification of a 1989 Landsat TM image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/tm/mabi_tm_19890928_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	0	0	0	1	0	4	50
DF	1	43	2	3	0	0	1	50
CF	0	0	43	1	4	0	2	50
MF	0	4	5	41	0	0	0	50
W	8	0	9	0	33	0	0	50
WL	0	0	1	0	1	48	0	50
HV	3	0	0	0	0	0	47	50
Totals	57	47	60	45	39	48	54	350

Table A14. Accuracy totals* for the classification of a 1989 Landsat TM image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/tm/mabi_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	57	50	45	78.95%	90.00%
DF	47	50	43	91.49%	86.00%
CF	60	50	43	71.67%	86.00%
MF	45	50	41	91.11%	82.00%
W	39	50	33	84.62%	66.00%
WL	48	50	48	100.00%	96.00%
HV	54	50	47	87.04%	94.00%
Totals	350	350	300		

*Overall Classification Accuracy: 85.71%

Table A15. Conditional Kappa (κ) statistics* for each category for the classification of a 1989 Landsat TM image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/tm/mabi_tm_19890928_class.img.

Class Name	Kappa
U	0.8805
DF	0.8383
CF	0.8310
MF	0.7934
W	0.6174
WL	0.9536
HV	0.9291

*Overall Kappa: 0.8333

Table A16. Error matrix for the classification of a 1978 Landsat MSS image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/mss/mabi_mss_19780926_class.img

Classified	Reference Data						
Data	U	DF	CF	MF	WL	HV	Totals
U	49	1	0	0	0	0	50
DF	0	41	0	4	0	5	50
CF	0	0	42	8	0	0	50
MF	0	7	4	38	0	1	50
WL	0	0	0	0	50	0	50
HV	0	2	0	1	0	47	50
Totals	49	51	46	51	50	53	300

Table A17. Accuracy totals* for the classification of a 1978 Landsat MSS image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/mss/mabi_mss_19780926_class.img

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	49	50	49	100.00%	98.00%
DF	51	50	41	80.39%	82.00%
CF	46	50	42	91.30%	84.00%
MF	51	50	38	74.51%	76.00%
WL	50	50	50	100.00%	100.00%
HV	53	50	47	88.68%	94.00%
Totals	300	300	267		

*Overall Classification Accuracy: 89.00%

Table A18. Conditional Kappa (κ) statistics* for the classification of a 1978 Landsat MSS image of Marsh-Billings-Rockefeller National Historical Park; image file: /mabi/mss/mabi_mss_19780926_class.img.

Class Name	Kappa
U	0.9761
DF	0.7831
CF	0.8110
MF	0.7108
WL	1.0000
HV	0.9271

*Overall Kappa: 0.8680

Table A19. Error matrix for the classification of a 2000 Landsat ETM+ image of Minute Man National Historical Park; image file: /mima/etm/mima_etm_20000927_class.img.

Classified Data	Reference Data							
	U	DF	CF	MF	W	WL	HV	Totals
U	48	2	0	0	0	0	0	50
DF	4	43	0	3	0	0	0	50
CF	2	0	44	4	0	0	0	50
MF	0	6	2	41	0	1	0	50
W	2	1	0	2	43	1	1	50
WL	6	2	1	1	1	38	1	50
HV	8	4	1	1	0	7	29	50
Totals	70	58	48	52	44	47	31	350

Table A20. Accuracy totals* for the classification of a 2000 Landsat ETM+ image of Minute Man National Historical Park; image file: /mima/etm/mima_etm_20000927_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	70	50	48	68.57%	96.00%
DF	58	50	43	74.14%	86.00%
CF	48	50	44	91.67%	88.00%
MF	52	50	41	78.85%	82.00%
W	44	50	43	97.73%	86.00%
WL	47	50	38	80.85%	76.00%
HV	31	50	29	93.55%	58.00%
Totals	350	350	286		

*Overall Classification Accuracy: 81.71%

Table A21. Conditional Kappa (κ) statistics* for the classification of a 2000 Landsat ETM+ image of Minute Man National Historical Park; image file: /mima/etm/mima_etm_20000927_class.img.

Class Name	Kappa
U	0.9500
DF	0.8322
CF	0.8609
MF	0.7886
W	0.8399
WL	0.7228
HV	0.5392

*Overall Kappa: 0.7867

Table A22. Error matrix for the classification of a 1987 Landsat TM image of Minute Man National Historical Park; image file: /mima/tm/mima_tm_19870916_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	49	0	0	1	0	0	0	50
DF	0	48	0	2	0	0	0	50
CF	0	0	50	0	0	0	0	50
MF	1	6	2	41	0	0	0	50
W	0	0	1	1	47	1	0	50
WL	4	0	0	1	0	43	2	50
HV	7	1	0	0	0	0	42	50
Totals	61	55	53	46	47	44	44	350

Table A23. Accuracy totals* for the classification of a 1987 Landsat TM image of Minute Man National Historical Park; image file: /mima/tm/mima_tm_19870916_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	61	50	49	80.33%	98.00%
DF	55	50	48	87.27%	96.00%
CF	53	50	50	94.34%	100.00%
MF	46	50	41	89.13%	82.00%
W	47	50	47	100.00%	94.00%
WL	44	50	43	97.73%	86.00%
HV	44	50	42	95.45%	84.00%
Totals	350	350	320		

*Overall Classification Accuracy: 91.43%

Table A24. Conditional Kappa (κ) statistics* for the classification of a 1987 Landsat TM image of Minute Man National Historical Park; image file: /mima/tm/mima_tm_19870916_class.img.

Class Name	Kappa
U	0.9758
DF	0.9525
CF	1.0000
MF	0.7928
W	0.9307
WL	0.8399
HV	0.8170

*Overall Kappa: 0.9000

Table A25. Error matrix for the classification of a 1974 Landsat MSS image of Minute Man National Historical Park; image file: /mima/mss/mima_mss_19740910_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	47	3	0	0	0	0	0	50
DF	1	47	0	2	0	0	0	50
CF	0	5	35	10	0	0	0	50
MF	0	6	0	44	0	0	0	50
W	0	0	0	0	49	1	0	50
WL	1	6	0	3	0	36	4	50
HV	7	2	0	1	0	0	40	50
Totals	56	69	35	60	49	37	44	350

Table A26. Accuracy totals* for the classification of a 1974 Landsat MSS image of Minute Man National Historical Park; image file: /mima/mss/mima_mss_19740910_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	56	50	47	83.93%	94.00%
DF	69	50	47	68.12%	94.00%
CF	35	50	35	100.00%	70.00%
MF	60	50	44	73.33%	88.00%
W	49	50	49	100.00%	98.00%
WL	37	50	36	97.30%	72.00%
HV	44	50	40	90.91%	80.00%
Totals	350	350	298		

*Overall Classification Accuracy: 85.14%

Table A27. Conditional Kappa (κ) statistics* for the classification of a 1974 Landsat MSS image of Minute Man National Historical Park; image file: /mima/mss/mima_mss_19740910_class.img.

Class Name	Kappa
U	0.9286
DF	0.9253
CF	0.6667
MF	0.8552
W	0.9767
WL	0.6869
HV	0.7712

*Overall Kappa: 0.8267

Table A28. Error matrix for the classification of a 2002 Landsat ETM+ image of Morristown National Historical Park; image file: /morr/etm/morr_etm_20020814_class_fixed.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	2	0	2	0	0	1	50
DF	0	47	0	2	0	0	1	50
CF	0	2	45	1	2	0	0	50
MF	2	2	0	45	0	0	1	50
W	7	0	0	0	42	1	0	50
WL	0	2	0	0	0	48	0	50
HV	8	1	0	0	0	0	41	50
Totals	62	56	45	50	44	49	44	350

Table A29. Accuracy totals for the classification of a 2002 Landsat ETM+ image of Morristown National Historical Park; image file: /morr/etm/morr_etm_20020814_class_fixed.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	62	50	45	72.58%	90.00%
DF	56	50	47	83.93%	94.00%
CF	45	50	45	100.00%	90.00%
MF	50	50	45	90.00%	90.00%
W	44	50	42	95.45%	84.00%
WL	49	50	48	97.96%	96.00%
HV	44	50	41	93.18%	82.00%
Totals	350	350	313		

*Overall Classification Accuracy: 89.43%

Table A30. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of Morristown National Historical Park; image file: /morr/etm/morr_etm_20020814_class_fixed.img.

Class Name	Kappa
U	0.8785
DF	0.9286
CF	0.8852
MF	0.8833
W	0.8170
WL	0.9535
HV	0.7941

*Overall Kappa: 0.8767

Table A31. Error matrix for classification of a 1988 Landsat TM image of Morristown National Historical Park; image file: /morr/tm/morr_tm_19880628_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	43	1	0	3	0	1	2	50
DF	0	50	0	0	0	0	0	50
CF	1	0	46	2	0	0	1	50
MF	2	6	0	42	0	0	0	50
W	1	1	3	0	43	2	0	50
WL	2	9	0	1	0	38	0	50
HV	12	1	1	2	0	0	34	50
Totals	61	68	50	500	43	41	37	350

Table A32. Accuracy totals* for classification of a 1988 Landsat TM image of Morristown National Historical Park; image file: /morr/tm/morr_tm_19880628_class.img

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	61	50	43	70.49%	86.00%
DF	68	50	50	73.53%	100.00%
CF	50	50	46	92.00%	92.00%
MF	50	50	42	84.00%	84.00%
W	43	50	43	100.00%	86.00%
WL	41	50	38	92.68%	76.00%
HV	37	50	34	91.89%	68.00%
Totals	350	350	296		

*Overall Classification Accuracy: 84.57%

Table A33. Conditional Kappa (κ) statistics* for classification of a 1988 Landsat TM image of Morristown National Historical Park; image file: /morr/tm/morr_tm_19880628_class.img.

Class Name	Kappa
U	0.8304
DF	1.0000
CF	0.9067
MF	0.8133
W	0.8404
WL	0.7282
HV	0.6422

Overall Kappa: 0.8200

Table A34. Error matrix for the classification of a 1976 Landsat MSS image of Morristown National Historical Park**;** image file: /morr/mss/morr_mss_19760831_class.img

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	49	0	0	0	0	1	0	50
DF	1	45	0	2	0	0	2	50
CF	2	0	40	8	0	0	0	50
MF	4	3	0	41	1	0	1	50
W	3	0	0	1	42	4	0	50
WL	1	0	0	5	0	42	2	50
HV	2	1	0	1	0	0	46	50
Totals	62	49	40	58	43	47	51	350

Table A35. Accuracy total* for the classification of a 1976 Landsat MSS image of Morristown National Historical Park**;** image file: /morr/mss/morr_mss_19760831_class.img

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	62	50	49	79.03%	98.00%
DF	49	50	45	91.84%	90.00%
CF	40	50	40	100.00%	80.00%
MF	58	50	41	70.69%	82.00%
W	43	50	42	97.67%	84.00%
WL	47	50	42	89.36%	84.00%
HV	51	50	46	90.20%	92.00%
Totals	350	350	305		

*Overall Classification Accuracy: 87.14%

Table A36. Conditional Kappa (κ) statistics* for the classification of a 1976 Landsat MSS image of Morristown National Historical Park**;** image file: /morr/mss/morr_mss_19760831_class.img.

Class Name	Kappa
U	0.9757
DF	0.8837
CF	0.7742
MF	0.7842
W	0.8176
WL	0.8152
HV	0.9064

*Overall Kappa: 0.8500

Table A37. Error matrix for the classification of a 2002 Landsat ETM+ image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/etm/rova_etm_20020908_class.img.

Classified	**Reference Data**							
Data	**U**	**DF**	**CF**	**MF**	**W**	**WL**	**HV**	**Totals**
U	49	1	0	0	0	0	0	50
DF	0	47	0	3	0	0	0	50
CF	0	3	44	2	0	1	0	50
MF	1	4	0	45	0	0	0	50
W	0	0	0	0	48	2	0	50
WL	2	0	2	1	0	42	3	50
HV	1	6	0	0	0	1	42	50
Totals	53	61	46	51	48	46	45	350

Table A38. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/etm/rova_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	53	50	49	92.45%	98.00%
DF	61	50	47	77.05%	94.00%
CF	46	50	44	95.65%	88.00%
MF	51	50	45	88.24%	90.00%
W	48	50	48	100.00%	96.00%
WL	46	50	42	91.30%	84.00%
HV	45	50	42	93.33%	84.00%
Totals	350	350	317		

*Overall Classification Accuracy: 90.57%

Table A39. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/etm/rova_etm_20020908_class.img

Class Name	**Kappa**
U	0.9764
DF	0.9273
CF	0.8618
MF	0.8829
W	0.9536
WL	0.8158
HV	0.8164

*Overall Kappa: 0.8900

Table A40. Error matrix for the classification of a 1988 Landsat TM image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/tm/rova_tm_19880612_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	49	1	0	0	0	0	0	50
DF	0	48	1	1	0	0	0	50
CF	2	0	41	4	1	2	0	50
MF	1	7	0	42	0	0	0	50
W	2	0	0	0	48	0	0	50
WL	0	1	0	0	0	49	0	50
HV	3	2	0	0	0	0	45	50
Totals	57	59	42	47	49	51	45	350

Table A41. Accuracy totals* for the classification of a 1988 Landsat TM image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/tm/rova_tm_19880612_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	57	50	49	85.96%	98.00%
DF	59	50	48	81.36%	96.00%
CF	42	50	41	97.62%	82.00%
MF	47	50	42	89.36%	84.00%
W	49	50	48	97.96%	96.00%
WL	51	50	49	96.08%	98.00%
HV	45	50	45	100.00%	90.00%
Totals	350	350	322		

*Overall Classification Accuracy: 92.00%

Table A42. Conditional Kappa (κ) statistics* for the classification of a 1988 Landsat TM+ image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/tm/rova_tm_19880612_class.img.

Class Name	Kappa
U	0.9761
DF	0.9519
CF	0.7955
MF	0.8152
W	0.9535
WL	0.9766
HV	0.8852

*Overall Kappa: 0.9067

Table A43. Error matrix for the classification of a 1973 Landsat MMS image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/mss/rova_mss_19730724_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	47	0	0	1	0	0	2	50
DF	1	47	0	2	0	0	0	50
CF	0	0	44	4	1	0	1	50
MF	7	3	2	34	0	0	4	50
W	0	0	0	0	50	0	0	50
WL	1	0	0	0	0	49	0	50
HV	1	0	0	0	0	0	49	50
Totals	57	50	46	41	51	49	56	350

Table A44. Accuracy totals* for the classification of a 1973 Landsat MMS image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/mss/rova_mss_19730724_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	57	50	47	82.46%	94.00%
DF	50	50	47	94.00%	94.00%
CF	46	50	44	95.65%	88.00%
MF	41	50	34	82.93%	68.00%
W	51	50	50	98.04%	100.00%
WL	49	50	49	100.00%	98.00%
HV	56	50	49	87.50%	98.00%
Totals	350	350	320		

*Overall Classification Accuracy: 91.43%

Table A45. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MMS image of Roosevelt-Vanderbilt National Historic Site; image file: /rova/mss/rova_mss_19730724_class.img.

Class Name	Kappa
U	0.9283
DF	0.9300
CF	0.8618
MF	0.6375
W	1.0000
WL	0.9767
HV	0.9762

*Overall Kappa: 0.9000

Table A46. Error matrix for the classification of a 2002 Landsat ETM+ image of Saratoga National Historical Park; image file: /saga/etm/saga_etm_20020908_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	1	1	2	0	0	1	50
DF	0	48	0	2	0	0	0	50
CF	0	0	44	5	0	0	1	50
MF	0	8	1	40	0	0	1	50
W	3	1	8	3	32	1	2	50
WL	0	1	1	1	0	46	1	50
HV	1	2	1	0	0	1	45	50
Totals	49	61	56	53	32	48	51	350

Table A47. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Saratoga National Historical Park; image file: /saga/etm/saga_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	49	50	45	91.84%	90.00%
DF	61	50	48	78.69%	96.00%
CF	56	50	44	78.57%	88.00%
MF	53	50	40	75.47%	80.00%
W	32	50	32	100.00%	64.00%
WL	48	50	46	95.83%	92.00%
HV	51	50	45	88.24%	90.00%
Totals	350	350	300		

*Overall Classification Accuracy: 85.71%

Table A48. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of Saratoga National Historical Park; image file: /saga/etm/saga_etm_20020908_class.img.

Class Name	Kappa
U	0.8837
DF	0.9516
CF	0.8571
MF	0.7643
W	0.6038
WL	0.9073
HV	0.8829

*Overall Kappa: 0.8333

Table A49. Error matrix for the classification of a 1989 Landsat TM image of Saratoga National Historical Park; image file: /saga/tm/saga_tm_19890928_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	38	6	0	2	1	1	2	50
DF	0	46	0	0	0	0	4	50
CF	0	0	47	1	2	0	0	50
MF	0	7	4	37	0	0	2	50
W	0	0	0	0	46	4	0	50
WL	0	1	0	0	0	49	0	50
HV	3	0	1	0	0	0	46	50
Totals	41	60	52	40	49	54	54	350

Table A50. Accuracy totals* for the classification of a 1989 Landsat TM image of Saratoga National Historical Park; image file: /saga/tm/saga_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	41	50	38	92.68%	76.00%
DF	60	50	46	76.67%	92.00%
CF	52	50	47	90.38%	94.00%
MF	40	50	37	92.50%	74.00%
W	49	50	46	93.88%	92.00%
WL	54	50	49	90.74%	98.00%
HV	54	50	46	85.19%	92.00%
Totals	350	350	309		

*Overall Classification Accuracy: 88.29%

Table A51. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of Saratoga National Historical Park; image file: /saga/tm/saga_tm_19890928_class.img.

Class Name	Kappa
U	0.7282
DF	0.9034
CF	0.9295
MF	0.7065
W	0.9070
WL	0.9764
HV	0.9054

*Overall Kappa: 0.8633

Table A52. Error matrix for the classification of a 1978 Landsat MSS image of Saratoga National Historical Park; image file: /saga/mss/saga_mss_19780926_class.img

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	50	0	0	0	0	0	0	50
DF	0	48	0	1	0	0	1	50
CF	0	1	43	5	0	0	1	50
MF	0	3	0	45	0	0	2	50
W	0	0	1	0	47	2	0	50
WL	0	0	1	0	0	45	4	50
HV	6	5	0	1	0	0	38	50
Totals	56	57	45	52	47	47	46	350

Table A53. Accuracy totals* for the classification of a 1978 Landsat MSS image of Saratoga National Historical Park; image file: /saga/mss/saga_mss_19780926_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	56	50	50	89.29%	100.00%
DF	57	50	48	84.21%	96.00%
CF	45	50	43	95.56%	86.00%
MF	52	50	45	86.54%	90.00%
W	47	50	47	100.00%	94.00%
WL	47	50	45	95.74%	90.00%
HV	46	50	38	82.61%	76.00%
Totals	350	350	316		

*Overall Classification Accuracy: 90.29%

Table A54. Conditional Kappa (κ) statistics* for the classification of a 1978 Landsat MSS image of Saratoga National Historical Park; image file: /saga/mss/saga_mss_19780926_class.img.

Class Name	Kappa
U	1.0000
DF	0.9522
CF	0.8393
MF	0.8826
W	0.9307
WL	0.8845
HV	0.7237

*Overall Kappa: 0.8867

Table A55. Error matrix for the classification of a 2001 Landsat ETM+ image of Saratoga National Historical Park; image file: /sara/etm/sara_etm_20010608_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	46	2	0	0	0	0	2	50
DF	0	48	1	1	0	0	0	50
CF	0	3	39	6	1	1	0	50
MF	3	7	0	39	0	0	1	50
W	0	1	0	0	46	3	0	50
WL	0	2	0	2	1	45	0	50
HV	0	5	0	1	0	0	44	50
Totals	49	68	40	49	48	49	47	350

Table A56. Accuracy totals* for the classification of a 2001 Landsat ETM+ image of Saratoga National Historical Park; image file: /sara/etm/sara_etm_20010608_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	49	50	46	93.88%	92.00%
DF	68	50	48	70.59%	96.00%
CF	40	50	39	97.50%	78.00%
MF	49	50	39	79.59%	78.00%
W	48	50	46	95.83%	92.00%
WL	49	50	45	91.84%	90.00%
HV	47	50	44	93.62%	88.00%
Totals	350	350	307		

*Overall Classification Accuracy: 87.71%

Table A57. Conditional Kappa (κ) statistics* for the classification of a 2001 Landsat ETM+ image of Saratoga National Historical Park; image file: /sara/etm/sara_etm_20010608_class.img.

Class Name	Kappa
U	0.9070
DF	0.9504
CF	0.7516
MF	0.7442
W	0.9073
WL	0.8837
HV	0.8614

*Overall Kappa: 0.8567

Table A58. Error matrix for the classification of a 1986 Landsat TM image of Saratoga National Historical Park; image file: /sara/tm/sara_tm_19860826_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	4	1	0	0	0	0	50
DF	0	43	0	3	0	0	4	50
CF	0	0	43	3	3	0	1	50
MF	1	4	3	42	0	0	0	50
W	1	1	0	0	45	1	2	50
WL	1	1	0	1	1	46	0	50
HV	1	0	0	0	0	0	49	50
Totals	49	53	47	49	49	47	56	350

Table A59. Accuracy totals* for the classification of a 1986 Landsat TM image of Saratoga National Historical Park; image file: /sara/tm/sara_tm_19860826_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	49	50	45	91.84%	90.00%
DF	53	50	43	81.13%	86.00%
CF	47	50	43	91.49%	86.00%
MF	49	50	42	85.71%	84.00%
W	49	50	45	91.84%	90.00%
WL	47	50	46	97.87%	92.00%
HV	56	50	49	87.50%	98.00%
Totals	350	350	313		

*Overall Classification Accuracy: 89.43%

Table A60. Conditional Kappa (κ) statistics* for the classification of a 1986 Landsat TM image of Saratoga National Historical Park; image file: /sara/tm/sara_tm_19860826_class.img.

Class Name	Kappa
U	0.8837
DF	0.8350
CF	0.8383
MF	0.8140
W	0.8837
WL	0.9076
HV	0.9762

*Overall Kappa: 0.8767

Table A61. Error matrix for the classification of a 1973 MSS image of Saratoga National Historical Park; image file: /sara/mss/sara_mss_19730707_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	46	3	0	1	0	0	0	50
DF	3	42	2	3	0	0	0	50
CF	0	0	41	5	2	2	0	50
MF	0	9	0	39	0	0	2	50
W	0	0	0	0	45	3	2	50
WL	0	0	0	2	1	47	0	50
HV	0	5	0	1	0	0	44	50
Totals	49	59	43	51	48	52	48	350

Table A62. Accuracy totals* for the classification of a 1973 MSS image of Saratoga National Historical Park; image file: /sara/mss/sara_mss_19730707_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	49	50	46	93.88%	92.00%
DF	59	50	42	71.19%	84.00%
CF	43	50	41	95.35%	82.00%
MF	51	50	39	76.47%	78.00%
W	48	50	45	93.75%	90.00%
WL	52	50	47	90.38%	94.00%
HV	48	50	44	91.67%	88.00%
Totals	350	350	304		

*Overall Classification Accuracy:86.86%

Table A63. Conditional Kappa (κ) statistics* for the classification of a 1973 MSS image of Saratoga National Historical Park; image file: /sara/mss/sara_mss_19730707_class.img.

Class Name	Kappa
U	0.9070
DF	0.8076
CF	0.7948
MF	0.7425
W	0.8841
WL	0.9295
HV	0.8609

*Overall Kappa: 0.8467

Table A64. Error matrix for the classification of a 2002 Landsat ETM+ image of Weir Farm National Historic Site; image file: /wefa/etm/wefa_etm_20020908_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	4	0	1	0	0	0	50
DF	0	49	0	1	0	0	0	50
CF	10	2	30	5	2	0	1	50
MF	8	2	0	40	0	0	0	50
W	0	0	0	0	50	0	0	50
WL	0	1	0	2	1	45	1	50
HV	2	3	0	1	0	1	43	50
Totals	65	61	30	50	53	46	45	350

Table A65. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Weir Farm National Historic Site; image file: /wefa/etm/wefa_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	65	50	45	69.23%	90.00%
DF	61	50	49	80.33%	98.00%
CF	30	50	30	100.00%	60.00%
MF	50	50	40	80.00%	80.00%
W	53	50	50	94.34%	100.00%
WL	46	50	45	97.83%	90.00%
HV	45	50	43	95.56%	86.00%
Totals	350	350	302		

*Overall Classification Accuracy: 86.29%

Table A66. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of Weir Farm National Historic Site; image file: /wefa/etm/wefa_etm_20020908_class.img.

Class Name	Kappa
U	0.8772
DF	0.9758
CF	0.5625
MF	0.7667
W	1.0000
WL	0.8849
HV	0.8393

*Overall Kappa: 0.8400

Table A67. Error matrix for the classification of a 1989 Landsat TM image of Weir Farm National Historic Site; image file: /wefa/tm/wefa_tm_19890928_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	45	5	0	0	0	0	0	50
DF	0	46	1	3	0	0	0	50
CF	3	3	40	1	2	1	0	50
MF	1	6	7	35	0	1	0	50
W	0	0	0	0	48	2	0	50
WL	4	0	0	2	1	43	0	50
HV	1	7	1	0	0	0	41	50
Totals	54	67	49	41	51	47	41	350

Table A68. Accuracy totals* for the classification of a 1989 Landsat TM image of Weir Farm National Historic Site; image file: /wefa/tm/wefa_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	54	50	45	83.33%	90.00%
DF	67	50	46	68.66%	92.00%
CF	49	50	40	81.63%	80.00%
MF	41	50	35	85.37%	70.00%
W	51	50	48	94.12%	96.00%
WL	47	50	43	91.49%	86.00%
HV	41	50	41	100.00%	82.00%
Totals	350	350	298		

*Overall Classification Accuracy: 85.14%

Table A69. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of Weir Farm National Historic Site; image file: /wefa/tm/wefa_tm_19890928_class.img.

Class Name	Kappa
U	0.8818
DF	0.9011
CF	0.7674
MF	0.6602
W	0.9532
WL	0.8383
HV	0.7961

*Overall Kappa: 0.8267

Table A70. Error matrix for the classification of a 1973 Landsat MSS image of Weir Farm National Historic Site; image file: /wefa/mss/wefa_mss_19730724_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	43	3	0	0	0	0	4	50
DF	0	46	0	4	0	0	0	50
CF	0	0	37	11	1	0	1	50
MF	0	3	0	42	0	0	5	50
W	0	0	0	0	48	2	0	50
WL	0	4	0	1	0	44	1	50
HV	0	1	0	4	0	0	45	50
Totals	43	57	37	62	49	46	56	350

Table A71. Accuracy totals* for the classification of a 1973 Landsat MSS image of Weir Farm National Historic Site; image file: /wefa/mss/wefa_mss_19730724_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	43	50	43	100.00%	86.00%
DF	57	50	46	80.70%	92.00%
CF	37	50	37	100.00%	74.00%
MF	62	50	42	67.74%	84.00%
W	49	50	48	97.96%	96.00%
WL	46	50	44	95.65%	88.00%
HV	56	50	45	80.36%	90.00%
Totals	350	350	305		

*Overall Classification Accuracy: 87.14%

Table A72. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of Weir Farm National Historic Site; image file: /wefa/mss/wefa_mss_19730724_class.img.

Class Name	Kappa
U	0.8404
DF	0.9044
CF	0.7093
MF	0.8056
W	0.9535
WL	0.8618
HV	0.8810

*Overall Kappa: 0.8500

Table A73. Error matrix for the classification of a 2002 Landsat ETM+ image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/etm/whitecap_etm_20020724_class.img.

Classified	**Reference Data**							
Data	**DF**	**CF**	**MF**	**W**	**WL**	**BL**	**RF**	**Totals**
DF	47	0	2	0	0	0	1	50
CF	0	48	1	0	1	0	0	50
MF	2	3	40	0	1	0	4	50
W	0	1	0	49	0	0	0	50
WL	0	4	0	0	43	2	1	50
BL	3	0	2	1	3	40	1	50
RF	0	0	0	0	0	0	50	50
Totals	52	56	45	50	48	42	57	350

Table A74. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/etm/whitecap_etm_20020724_class.img.

Class Name	**Reference Totals**	**Classified Totals**	**Number Correct**	**Producer's Accuracy**	**User's Accuracy**
DF	52	50	47	90.38%	94.00%
CF	56	50	48	85.71%	96.00%
MF	45	50	40	88.89%	80.00%
W	50	50	49	98.00%	98.00%
WL	48	50	43	89.58%	86.00%
BL	42	50	40	95.24%	80.00%
RF	57	50	50	87.72%	100.00%
Totals	350	350	317		

*Overall Classification Accuracy: 90.57%

Table A75. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/etm/whitecap_etm_20020724_class.img.

Class Name	**Kappa**
DF	0.9295
CF	0.9524
MF	0.7705
W	0.9767
WL	0.8377
BL	0.7727
RF	1.0000

*Overall Kappa: 0.8900

Table A76. Error matrix for the classification of a 1987 Landsat TM image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/tm/whitecap_tm_19870621_class.img.

Classified	Reference Data							
Data	DF	CF	MF	W	WL	BL	RF	Totals
DF	44	0	4	0	1	1	0	50
CF	0	50	0	0	0	0	0	50
MF	2	1	47	0	0	0	0	50
W	0	0	0	50	0	0	0	50
WL	0	1	0	0	45	1	3	50
BL	4	0	0	1	0	45	0	50
RF	0	4	3	0	0	0	43	50
Totals	50	56	54	51	46	47	46	350

Table A77. Accuracy totals* for the classification of a 1987 Landsat TM image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/tm/whitecap_tm_19870621_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
DF	50	50	44	88.00%	88.00%
CF	56	50	50	89.29%	100.00%
MF	54	50	47	87.04%	94.00%
W	51	50	50	98.04%	100.00%
WL	46	50	45	97.83%	90.00%
BL	47	50	45	95.74%	90.00%
RF	46	50	43	93.48%	86.00%
Totals	350	350	324		

*Overall Classification Accuracy: 92.57%

Table A78. Conditional Kappa (κ) statistics* for the classification of a 1987 Landsat TM image of Whitecap Mountain Segment of the Appalachian Trail; image file: /appa/whitecap/tm/whitecap_tm_19870621_class.img.

Class Name	Kappa
DF	0.8600
CF	1.0000
MF	0.9291
W	1.0000
WL	0.8849
BL	0.8845
RF	0.8388

*Overall Kappa: 0.9133

Table A79. Error matrix for the classification of a 1976 Landsat MSS image of Whitecap Mountain Segment of the Appalachian Trail; image file: appa/whitecap/mss/whitecap_mss_19760811_class.img.

Classified	Reference Data						
Data	DF	CF	MF	W	WL	BL	Totals
DF	44	0	5	0	0	1	50
CF	0	44	2	0	0	4	50
MF	9	0	41	0	0	0	50
W	0	0	0	40	10	0	50
WL	0	0	0	0	46	1	50
BL	2	1	1	0	2	44	50
Totals	55	45	49	40	58	53	300

Table A80. Accuracy totals* for the classification of a 1976 Landsat MSS image of Whitecap Mountain Segment of the Appalachian Trail; image file: appa/whitecap/mss/whitecap_mss_19760811_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
DF	55	50	44	80.00%	88.00%
CF	45	50	44	97.78%	88.00%
MF	49	50	41	83.67%	82.00%
W	40	50	40	100.00%	80.00%
WL	58	50	46	79.31%	92.00%
BL	53	50	44	83.02%	88.00%
Totals	300	300	259		

*Overall Classification Accuracy: 86.33%

Table A81. Conditional Kappa (κ) statistics* for the classification of a 1976 Landsat MSS image of Whitecap Mountain Segment of the Appalachian Trail; image file: appa/whitecap/mss/whitecap_mss_19760811_class.img.

Class Name	Kappa
DF	0.8531
CF	0.8588
MF	0.7849
W	0.7692
WL	0.9008
BL	0.8543

*Overall Kappa: 0.8360

Table A82. Error matrix for the classification of a 2002 Landsat ETM+ image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/etm/saddleback_etm_20020731_class.img.

Classified Data	Reference Data								
	U	DF	CF	MF	W	BL	BR	RF	Totals
U	39	0	1	1	0	3	6	0	50
DF	0	48	0	1	0	1	0	0	50
CF	2	1	46	0	0	1	0	0	50
MF	0	6	1	42	0	0	0	1	50
W	0	0	0	0	50	0	0	0	50
BL	4	2	0	1	0	41	1	1	50
BR	4	0	0	0	0	5	41	0	50
RF	1	0	1	0	0	0	0	48	50
Totals	50	57	49	45	50	51	48	50	400

Table A83. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/etm/ saddleback_etm_20020731_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	50	50	39	78.00%	78.00%
DF	57	50	48	84.21%	96.00%
CF	49	50	46	93.88%	92.00%
MF	45	50	42	93.33%	84.00%
W	50	50	50	100.00%	100.00%
BL	51	50	41	80.39%	82.00%
BR	48	50	41	85.42%	82.00%
RF	50	50	48	96.00%	96.00%
Totals	400	400	355		

*Overall Classification Accuracy: 88.75%

Table A84. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/etm/ saddleback_etm_20020731_class.img.

Class Name	Kappa
U	0.7486
DF	0.9534
CF	0.9088
MF	0.8197
W	1.000
BL	0.7937
BR	0.7955
RF	0.9543

*Overall Kappa: 0.8714

Table A85. Error matrix for the classification of a 1986 Landsat TM image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/tm/ saddleback_tm_19860913_class.img .

Classified	Reference Data								
Data	U	DF	CF	MF	W	BL	BR	RF	Totals
U	29	5	2	2	0	7	5	0	50
DF	0	50	0	0	0	0	0	0	50
CF	0	0	46	4	0	0	0	0	50
MF	0	2	2	46	0	0	0	0	50
W	0	0	2	0	48	0	0	0	50
BL	0	2	1	0	0	46	1	0	50
BR	0	0	0	0	0	0	50	0	50
RF	0	0	0	7	0	0	0	43	50
Totals	29	59	53	59	48	53	56	43	400

Table A86. Accuracy totals* for the classification of a 1986 Landsat TM image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/tm/saddleback_tm_19860913_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	29	50	29	100.00%	58.00%
DF	59	50	50	84.75%	100.00%
CF	53	50	46	86.79%	92.00%
MF	59	50	46	77.97%	92.00%
W	48	50	8	100.00%	96.00%
BL	53	50	46	86.79%	92.00%
BR	56	50	50	89.29%	100.00%
RF	43	50	43	100.00%	86.00%
Totals	400	400	358		

*Overall Classification Accuracy: 89.50%

Table A87. Conditional Kappa (κ) statistics* for the classification of a 1986 Landsat TM image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/tm/saddleback_tm_19860913_class.img.

Class Name	Kappa
U	0.5472
DF	1.0000
CF	0.9078
MF	0.9062
W	0.9545
BL	0.9078
BR	1.0000
RF	0.8431

*Overall Kappa: 0.8800

Table A88. Error matrix for the classification of a 1972 Landsat MSS image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/mss/saddleback_mss_19720920_class.img.

Classified	Reference Data						
Data	U	DF	CF	MF	W	BL	Totals
U	26	0	1	0	0	23	50
DF	0	45	1	2	0	2	50
CF	0	0	45	5	0	0	50
MF	0	8	0	42	0	0	50
W	0	0	1	0	49	0	50
BL	0	1	3	8	0	38	50
Totals	26	54	51	57	49	63	300

Table A89. Accuracy totals* for the classification of a 1972 Landsat MSS image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/mss/saddleback_mss_19720920_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	26	50	26	100.00%	52.00%
DF	54	50	45	83.33%	90.00%
CF	51	50	45	88.24%	90.00%
MF	57	50	42	73.68%	84.00%
W	49	50	49	100.00%	98.00%
BL	63	50	38	60.32%	76.00%
Totals	300	300	245		

*Overall Classification Accuracy: 81.67%

Table A90. Conditional Kappa (κ) statistics* for the classification of a 1972 Landsat MSS image of the Saddleback Mountain Segment of the Appalachian Trail; image file: /appa/saddleback/mss/saddleback_mss_19720920_class.img.

Class Name	Kappa
U	0.4745
DF	0.8780
CF	0.8795
MF	0.8025
W	0.9761
BL	0.6962

*Overall Kappa: 0.7800

Table A91. Error matrix for the classification of a 2002 Landsat ETM+ image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: /appa/chateauguay/etm/ chateauguay_etm_20020908_class.img.

Classified Data	Reference Data								
	U	DF	CF	MF	W	WL	HV	BL	Totals
U	41	3	1	1	0	0	2	2	50
DF	0	47	1	2	0	0	0	0	50
CF	0	0	43	5	1	0	1	0	50
MF	0	2	5	39	0	0	3	1	50
W	0	0	2	0	47	1	0	0	50
WL	4	2	3	7	0	24	5	5	50
HV	0	4	0	0	0	0	46	0	50
BL	8	2	1	1	0	0	12	26	50
Totals	53	60	56	55	48	25	69	34	400

Table A92. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: /appa/chateauguay/etm/ chateauguay_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	53	50	41	77.36%	82.00%
DF	60	50	47	78.33%	94.00%
CF	56	50	43	76.79%	86.00%
MF	55	50	39	70.91%	78.00%
W	48	50	47	97.92%	94.00%
WL	25	50	24	96.00%	48.00%
HV	69	50	46	66.67%	92.00%
BL	34	50	26	76.47%	52.00%
Totals	400	400	313		

*Overall Classification Accuracy: 78.25%

Table A93. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: /appa/chateauguay/etm/ chateauguay_etm_20020908_class.img.

Class Name	Kappa
U	0.7925
DF	0.9294
CF	0.8372
MF	0.7449
W	0.9318
WL	0.4453
HV	0.9033
BL	0.4754

*Overall Kappa: 0.7514

Table A94. Error matrix for the classification of a 1989 Landsat TM image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: /appa/chateauguay/tm/ chateauguay_tm_19890928_class.img.

Classified	Reference Data								
Data	U	DF	CF	MF	W	WL	HV	BL	Totals
U	31	1	3	0	0	0	11	4	50
DF	0	47	2	1	0	0	0	0	50
CF	0	0	50	0	0	0	0	0	50
MF	0	12	3	35	0	0	0	0	50
W	0	1	21	0	27	0	0	1	50
WL	2	2	8	10	0	15	4	9	50
HV	7	1	1	0	0	0	41	0	50
BL	4	0	3	2	0	1	5	35	50
Totals	44	64	91	48	27	16	61	49	400

Table A95. Accuracy totals* for the classification of a 1989 Landsat TM image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: /appa/chateauguay/tm/ chateauguay_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	44	50	31	70.45%	62.00%
DF	64	50	47	73.44%	94.00%
CF	91	50	50	54.95%	100.00%
MF	48	50	35	72.92%	70.00%
W	27	50	27	100.00%	54.00%
WL	16	50	15	93.75%	30.00%
HV	61	50	41	67.21%	82.00%
BL	49	50	35	71.43%	70.00%
Totals	400	400	281		

*Overall Classification Accuracy: 70.25%

Table A96. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Chateauguay – No-town Area segment of the Appalachian Trail; image file: //appa/chateauguay/tm/ chateauguay_tm_19890928_class.img.

Class Name	Kappa
U	0.5730
DF	0.9286
CF	1.0000
MF	0.6591
W	0.5067
WL	0.2708
HV	0.7876
BL	0.6581

*Overall Kappa: 0.6600

Table A97. Error matrix for the classification of a 1978 Landsat MSS image of the Chateauguay - No-town Area segment of the Appalachian Trail; /appa/chateauguay/mss/ chateauguay_mss_19780926_class.img.

Classified	Reference Data								
Data	U	DF	CF	MF	W	WL	HV	BL	Totals
U	13	2	0	3	0	0	30	2	50
DF	0	50	0	0	0	0	0	0	50
CF	0	0	45	5	0	0	0	0	50
MF	0	8	1	39	0	0	1	1	50
W	0	1	2	0	45	1	1	0	50
WL	0	0	14	12	0	19	3	2	50
HV	1	5	1	1	0	0	41	1	50
BL	2	11	4	3	0	0	9	21	50
Totals	16	77	67	63	45	20	85	27	400

Table A98. Accuracy totals* for the classification of a 1978 Landsat MSS image of the Chateauguay – No-town Area segment of the Appalachian Trail; /appa/chateauguay/mss/ chateauguay_mss_19780926_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	16	50	13	81.25%	26.00%
DF	77	50	50	64.94%	100.00%
CF	67	50	45	67.16%	90.00%
MF	63	50	39	61.90%	78.00%
W	45	50	45	100.00%	90.00%
WL	20	50	19	95.00%	38.00%
HV	85	50	41	48.24%	82.00%
BL	27	50	21	77.78%	42.00%
Totals	400	400	273		

*Overall Classification Accuracy: 68.25%

Table A99. Conditional Kappa (κ) statistics* for the classification of a 1978 Landsat MSS image of the Chateauguay – No-town Area Segment of the Appalachian Trail; image file: /appa/chateauguay/mss/ chateauguay_mss_19780926_class.img.

Class Name	Kappa
U	0.2292
DF	1.0000
CF	0.8799
MF	0.7389
W	0.8873
WL	0.3474
HV	0.7714
BL	0.3780

*Overall Kappa: 0.6371

Table A100. Error matrix for the classification of a 2002 Landsat ETM+ image of the Hanover Segment of the Appalachian Trail; /appa/hanover/etm/hanover_etm_20020908_class.img.

Classified	Reference Data								
Data	U	DF	CF	MF	W	WL	HV	BL	Totals
U	38	2	1	1	0	0	8	0	50
DF	0	45	1	4	0	0	0	0	50
CF	1	3	39	6	0	0	1	0	50
MF	1	7	0	39	0	1	2	0	50
W	0	0	0	0	50	0	0	0	50
WL	1	1	2	2	0	39	5	0	50
HV	0	3	0	1	0	0	46	0	50
BL	9	0	1	0	0	1	16	24	50
Totals	50	61	44	53	50	41	78	24	400

Table A101. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Hanover Segment of the Appalachian Trail; /appa/hanover/etm/hanover_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	50	50	38	76.00%	76.00%
DF	61	50	45	73.77%	90.00%
CF	44	50	39	88.64%	78.00%
MF	53	50	39	73.58%	78.00%
W	50	50	50	100.00%	100.00%
WL	41	50	39	95.12%	78.00%
HV	78	50	46	58.97%	92.00%
BL	23	50	24	100.00%	48.00%
Totals	400	400	320		

*Overall Classification Accuracy: 80.00%

Table A102. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Hanover Segment of the Appalachian Trail; /appa/hanover/etm/hanover_etm_20020908_class.img.

Class Name	Kappa
U	0.7257
DF	0.8820
CF	0.7528
MF	0.7464
W	1.0000
WL	0.7549
HV	0.9006
BL	0.4468

*Overall Kappa: 0.7714

Table A103. Error matrix for the classification of a 1989 Landsat TM image of the Hanover Segment of the Appalachian Trail; /appa/hanover/tm/hanover_tm_19890928_class.img.

Classified	Reference Data								
Data	U	DF	CF	MF	W	WL	HV	BL	Totals
U	47	0	0	1	0	0	2	0	50
DF	0	45	2	1	0	1	1	0	50
CF	1	1	47	1	0	0	0	0	50
MF	0	4	1	45	0	0	0	0	50
W	0	0	4	0	44	1	0	1	50
WL	9	5	4	4	0	25	2	1	50
HV	0	1	0	0	0	0	47	2	50
BL	5	0	3	0	0	3	6	33	50
Totals	62	56	61	52	44	30	58	37	400

Table A104. Accuracy totals* for the classification of a 1989 Landsat TM image of the Hanover Segment of the Appalachian Trail; /appa/hanover/tm/hanover_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	62	50	47	75.81%	94.00%
DF	56	50	45	80.36%	90.00%
CF	61	50	47	77.05%	94.00%
MF	52	50	45	86.54%	90.00%
W	44	50	44	100.00%	88.00%
WL	30	50	25	83.33%	50.00%
HV	58	50	47	81.03%	94.00%
BL	37	50	33	89.19%	66.00%
Totals	400	400	333		

Overall Classification Accuracy: 83.25%

Table A105. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Hanover Segment of the Appalachian Trail; /appa/hanover/tm/hanover_tm_19890928_class.img.

Class Name	Kappa
U	0.9290
DF	0.8837
CF	0.9292
MF	0.8851
W	0.8652
WL	0.4595
HV	0.9298
BL	0.6253

*Overall Kappa: 0.8086

Table A106. Error matrix for the classification of a 1978 Landsat MSS image of the Hanover Segment of the Appalachian Trail; /appa/hanover/mss/hanover_mss_19780926_class.img.

Classified	Reference Data								
Data	U	DF	CF	MF	W	WL	HV	BL	Totals
U	35	4	1	2	0	0	6	2	50
DF	0	48	0	2	0	0	0	0	50
CF	0	0	46	3	0	0	0	1	50
MF	0	3	3	44	0	0	0	0	50
W	1	0	0	0	45	4	0	0	50
WL	0	0	3	4	2	38	3	0	50
HV	0	5	0	2	0	0	40	3	50
BL	4	2	2	6	0	0	4	32	50
Totals	40	62	55	63	63	42	53	38	400

Table A107. Accuracy totals* for the classification of a 1978 Landsat MSS image of the Hanover Segment of the Appalachian Trail; /appa/hanover/mss/hanover_mss_19780926_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	40	50	35	87.50%	70.00%
DF	62	50	48	77.42%	96.00%
CF	55	50	46	83.64%	92.00%
MF	63	50	44	69.84%	88.00%
W	47	50	45	95.74%	90.00%
WL	42	50	38	90.48%	76.00%
HV	53	50	40	75.47%	80.00%
BL	38	50	32	84.21%	64.00%
Totals	400	400	328		

*Overall Classification Accuracy: 82.00%

Table A108. Conditional Kappa (κ) statistics* for the classification of a 1978 Landsat MSS image of the Hanover Segment of the Appalachian Trail; /appa/hanover/mss/hanover_mss_19780926_class.img.

Class Name	Kappa
U	0.6667
DF	0.9527
CF	0.9072
MF	0.8576
W	0.8867
WL	0.7318
HV	0.7695
BL	0.6022

*Overall Kappa: 0.7943

Table A109. Error matrix for the classification of a 2002 Landsat ETM+ image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/etm/tyringham_etm_20020908_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	38	0	0	0	0	0	12	50
DF	0	49	0	1	0	0	0	50
CF	1	0	47	1	1	0	0	50
MF	0	0	3	46	0	0	1	50
W	4	0	0	0	46	0	0	50
WL	4	2	0	7	0	34	3	50
HV	3	1	0	1	0	1	44	50
Totals	50	52	50	56	47	35	60	350

Table A110. Accuracy totals* for the classification of a 1978 Landsat MSS image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/etm/ tyringham_etm_20020908_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	50	50	38	76.00%	76.00%
DF	52	50	49	94.23%	98.00%
CF	50	50	47	94.00%	94.00%
MF	56	50	46	82.14%	92.00%
W	47	50	46	97.87%	92.00%
WL	35	50	34	97.14%	68.00%
HV	60	50	44	73.33%	88.00%
Totals	350	350	304		

*Overall Classification Accuracy: 86.86%

Table A111. Conditional Kappa (κ) statistics* for the classification of a 1978 Landsat MSS image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/etm/ tyringham_etm_20020908_class.img.

Class Name	Kappa
U	0.7200
DF	0.9765
CF	0.9300
MF	0.9048
W	0.9076
WL	0.6444
HV	0.8552

*Overall Kappa: 0.8467

Table A112. Error matrix for the classification of a 1989 Landsat TM image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/tm/ tyringham_tm_19890928_class.img .

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	32	0	0	0	1	0	17	50
DF	0	48	0	2	0	0	0	50
CF	0	1	46	1	0	1	1	50
MF	0	0	2	48	0	0	0	50
W	0	0	0	0	50	0	0	50
WL	1	0	0	2	0	43	4	50
HV	5	0	0	2	0	1	42	50
Totals	38	49	48	55	51	45	64	350

Table A113. Accuracy totals* for the classification of a 1989 Landsat TM image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/tm/ tyringham_tm_19890928_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	38	50	32	84.21%	64.00%
DF	49	50	48	97.96%	96.00%
CF	48	50	46	95.83%	92.00%
MF	55	50	48	87.27%	96.00%
W	51	50	50	98.04%	100.00%
WL	45	50	43	95.56%	86.00%
HV	64	50	42	65.63%	84.00%
Totals	350	350	309		

*Overall Classification Accuracy: 88.29%

Table A114. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/tm/ tyringham_tm_19890928_class.img.

Class Name	Kappa
U	0.5962
DF	0.9535
CF	0.9073
MF	0.9525
W	1.0000
WL	0.8393
HV	0.8042

*Overall Kappa: 0.8633

Table A115. Error matrix for the classification of a 1973 Landsat MSS image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/mss/ tyringham_mss_19730724_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	38	0	0	0	0	3	9	50
DF	0	50	0	0	0	0	0	50
CF	1	1	41	6	0	0	1	50
MF	0	0	3	46	0	1	0	50
W	0	0	0	0	50	0	0	50
WL	0	1	0	15	0	34	0	50
HV	0	2	0	0	0	1	47	50
Totals	39	54	44	67	50	39	57	350

Table A116. Accuracy totals* for the classification of a 1973 Landsat MSS image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/mss/ tyringham_mss_19730724_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	39	50	38	97.44%	76.00%
DF	54	50	50	92.59%	100.00%
CF	44	50	41	93.18%	82.00%
MF	67	50	46	68.66%	92.00%
W	50	50	50	100.00%	100.00%
WL	39	50	34	87.18%	68.00%
HV	57	50	47	82.46%	94.00%
Totals	350	350	306		

*Overall Classification Accuracy: 87.43%

Table A117. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of the Tyringham Valley and Sheffield segment of the Appalachian Trail; /appa/tyringham/mss/ tyringham_mss_19730724_class.img.

Class Name	Kappa
U	0.7299
DF	1.0000
CF	0.7941
MF	0.9011
W	1.0000
WL	0.6399
HV	0.9283

*Overall Kappa: 0.8533

Table A118. Error matrix for the classification of a 2002 Landsat ETM+ image of the Walkill segment of the Appalachian Trail; /appa/walkill/etm/ walkill_etm_20020814_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	35	1	0	6	0	1	7	50
DF	0	48	0	0	0	0	2	50
CF	1	1	42	6	0	0	0	50
MF	4	5	0	39	0	0	2	50
W	1	0	1	0	45	2	1	50
WL	7	4	6	8	0	25	0	50
HV	3	1	0	0	0	0	46	50
Totals	51	60	49	59	45	28	58	350

Table A119. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Walkill segment of the Appalachian Trail; /appa/walkill/etm/ walkill_etm_20020814_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	51	50	35	68.63%	70.00%
DF	60	50	48	80.00%	96.00%
CF	49	50	42	85.71%	84.00%
MF	59	50	39	66.10%	78.00%
W	45	50	45	100.00%	90.00%
WL	28	50	25	89.29%	50.00%
HV	58	50	46	79.31%	92.00%
Totals	350	350	280		

*Overall Classification Accuracy: 80.00%

Table A120. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Walkill segment of the Appalachian Trail; /appa/walkill/etm/ walkill_etm_20020814_class.img.

Class Name	Kappa
U	0.6488
DF	0.9517
CF	0.8140
MF	0.7354
W	0.8852
WL	0.4565
HV	0.9041

*Overall Kappa: 0.7667

Table A121. Error matrix for the classification of a 1988 Landsat TM image of the Walkill segment of the Appalachian Trail; /appa/walkill/tm/walkill_tm_19880612_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	28	0	1	3	1	1	16	50
DF	0	47	0	3	0	0	0	50
CF	0	1	44	5	0	0	0	50
MF	1	3	0	45	0	0	1	50
W	0	0	0	0	50	0	0	50
WL	1	0	3	5	3	30	8	50
HV	1	1	0	0	0	1	47	50
Totals	31	52	48	61	54	32	72	350

Table A122. Accuracy totals* for the classification of a 1988 Landsat TM image of the Walkill segment of the Appalachian Trail; /appa/walkill/tm/walkill_tm_19880612_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	31	50	28	90.32%	56.00%
DF	52	50	47	90.38%	94.00%
CF	48	50	44	91.67%	88.00%
MF	61	50	45	73.77%	90.00%
W	54	50	50	92.59%	100.00%
WL	32	50	30	93.75%	60.00%
HV	72	50	47	65.28%	94.00%
Totals	350	350	291		

*Overall Classification Accuracy: 83.14%

Table A123. Conditional Kappa (κ) statistics* for the classification of a 1988 Landsat TM image of the Walkill segment of the Appalachian Trail; /appa/walkill/tm/walkill_tm_19880612_class.img.

Class Name	Kappa
U	0.5172
DF	0.9295
CF	0.8609
MF	0.8789
W	1.0000
WL	0.5597
HV	0.9245

*Overall Kappa: 0.8033

Table A124. Error matrix for the classification of a 1975 Landsat MSS image of the Walkill segment of the Appalachian Trail; /appa/walkill/mss/walkill_mss_19750802_class.img.

Classified Data	Reference Data							
	U	DF	CF	MF	W	WL	HV	Totals
U	9	0	0	1	0	0	40	50
DF	0	40	0	5	0	0	5	50
CF	0	0	39	3	0	6	2	50
MF	0	1	1	44	0	0	4	50
W	0	0	0	0	50	0	0	50
WL	0	1	1	7	0	20	21	50
HV	3	2	0	1	0	1	43	50
Totals	12	44	41	61	50	27	115	350

Table A125. Accuracy totals* for the classification of a 1975 Landsat MSS image of the Walkill segment of the Appalachian Trail; /appa/walkill/mss/walkill_mss_19750802_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	12	50	9	75.00%	18.00%
DF	44	50	40	90.91%	80.00%
CF	41	50	39	95.12%	78.00%
MF	61	50	44	72.13%	88.00%
W	50	50	50	100.00%	100.00%
WL	27	50	20	74.07%	40.00%
HV	115	50	43	37.39%	86.00%
Totals	350	350	245		

*Overall Classification Accuracy: 70.00%

Table A126. Conditional Kappa (κ) statistics* for the classification of a 1975 Landsat MSS image of the Walkill segment of the Appalachian Trail; /appa/walkill/mss/walkill_mss_19750802_class.img.

Class Name	Kappa
U	0.1509
DF	0.7712
CF	0.7508
MF	0.8547
W	1.0000
WL	0.3498
HV	0.7915

* Overall Kappa: 0.6500

Table A127. Error matrix for the classification of a 2002 Landsat ETM+ image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/etm/ dunnfield_etm_20020814_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	40	0	0	4	0	1	5	50
DF	1	47	0	0	1	0	1	50
CF	0	0	38	6	5	1	0	50
MF	1	4	0	45	0	0	0	50
W	0	0	0	1	48	0	1	50
WL	0	2	3	12	0	28	5	50
HV	2	7	0	2	0	0	39	50
Totals	44	60	41	70	54	30	51	350

Table A128. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/etm/ dunnfield_etm_20020814_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	44	50	40	90.91%	80.00%
DF	60	50	47	78.33%	94.00%
CF	41	50	38	92.68%	76.00%
MF	70	50	45	64.29%	90.00%
W	54	50	48	88.89%	93.00%
WL	30	50	28	93.33%	56.00%
HV	51	50	39	76.47%	78.00%
Totals	350	350	285		

*Overall Classification Accuracy: 81.43%

Table A129. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/etm/ dunnfield_etm_20020814_class.img.

Class Name	Kappa
U	0.7712
DF	0.9276
CF	0.7282
MF	0.8750
W	0.9527
WL	0.5188
HV	0.7425

*Overall Kappa: 0.7833

Table A130. Error matrix for the classification of a 1988 Landsat TM image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/tm/dunnfield_tm_19880612_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	38	1	0	4	2	0	5	50
DF	0	50	0	0	0	0	0	50
CF	0	0	43	5	2	0	0	50
MF	0	17	0	33	0	0	0	50
W	0	0	3	0	46	1	0	50
WL	3	2	0	6	2	35	2	50
HV	0	7	0	3	0	0	40	50
Totals	41	77	46	51	52	36	47	350

Table A131. Accuracy totals* for the classification of a 1988 Landsat TM image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/tm/dunnfield_tm_19880612_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	41	50	38	92.68%	76.00%
DF	77	50	50	64.94%	100.00%
CF	46	50	43	93.48%	86.00%
MF	51	50	33	64.71%	66.00%
W	52	50	46	88.46%	92.00%
WL	36	50	35	97.22%	70.00%
HV	47	50	40	85.11%	80.00%
Totals	350	350	285		

*Overall Classification Accuracy: 81.43%

Table A132. Conditional Kappa (κ) statistics* for the classification of a 1988 Landsat TM image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/tm/dunnfield_tm_19880612_class.img.

Class Name	Kappa
U	0.7282
DF	1.0000
CF	0.8388
MF	0.6020
W	0.9060
WL	0.6656
HV	0.7690

*Overall Kappa: 0.7833

Table A133. Error matrix for the classification of a 1975 Landsat MSS image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/mss/dunnfield_mss_19750802_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	WL	HV	Totals
U	22	0	0	1	0	0	27	50
DF	0	46	1	0	1	0	2	50
CF	0	3	37	5	2	2	1	50
MF	0	1	1	42	0	4	2	50
W	0	1	2	0	45	2	0	50
WL	0	0	4	15	0	31	0	50
HV	6	0	0	1	0	0	43	50
Totals	28	51	45	64	48	39	75	350

Table A134. Accuracy totals* for the classification of a 1975 Landsat MSS image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/mss/dunnfield_mss_19750802_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	28	50	22	78.57%	44.00%
DF	51	50	46	90.20%	92.00%
CF	45	50	37	82.22%	74.00%
MF	64	50	42	65.63%	84.00%
W	48	50	45	93.75%	90.00%
WL	39	50	31	79.49%	62.00%
HV	75	50	43	57.33%	86.00%
Totals	350	350	266		

*Overall Classification Accuracy: 76.00%

Table A135. Conditional Kappa (κ) statistics* for the classification of a 1975 Landsat MSS image of the Dunnfield Creek segment of the Appalachian Trail; /appa/dunnfield/mss/dunnfield_mss_19750802_class.img.

Class Name	Kappa
U	0.3913
DF	0.9064
CF	0.7016
MF	0.8042
W	0.8841
WL	0.5723
HV	0.8218

*Overall Kappa: 0.7200

Table A136. Error matrix for the classification of a 2002 Landsat ETM+ image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/etm/hawk_etm_20020906_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	HV	BL	Totals
U	41	1	0	1	0	3	4	50
DF	0	48	1	0	0	1	0	50
CF	1	8	38	1	1	0	1	50
MF	3	5	2	36	1	1	2	50
W	3	0	2	0	40	0	5	50
HV	2	1	0	0	0	47	0	50
BL	9	0	0	1	1	10	29	50
Totals	59	63	43	39	43	62	41	350

Table A137. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/etm/hawk_etm_20020906_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	59	50	41	69.49%	82.00%
DF	63	50	48	76.19%	96.00%
CF	43	50	38	88.37%	76.00%
MF	39	50	36	92.31%	72.00%
W	43	50	40	93.02%	80.00%
HV	62	50	47	75.81%	94.00%
BL	41	50	29	70.73%	58.00%
Totals	350	350	279		

*Overall Classification Accuracy: 79.71%

Table A138. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/etm/hawk_etm_20020906_class.img.

Class Name	Kappa
U	0.7835
DF	0.9512
CF	0.7264
MF	0.6849
W	0.7720
HV	0.9271
BL	0.5243

*Overall Kappa: 0.7633

Table A139. Error matrix for the classification of a 1989 Landsat TM image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/tm/hawk_tm_19890910_class.img.

Classified Data	Reference Data							
	U	DF	CF	MF	W	HV	BL	Totals
U	34	1	1	0	0	9	5	50
DF	0	41	5	0	0	4	0	50
CF	1	2	44	1	2	0	0	50
MF	0	7	1	42	0	0	0	50
W	0	0	1	0	46	0	3	50
HV	0	0	0	0	0	48	2	50
BL	4	2	0	0	6	1	37	50
Totals	39	53	52	43	54	62	47	350

Table A140. Accuracy totals* for the classification of a 1989 Landsat TM image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/tm/hawk_tm_19890910_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	39	50	34	87.18%	68.00%
DF	53	50	41	77.36%	82.00%
CF	52	50	44	84.62%	88.00%
MF	43	50	42	97.67%	84.00%
W	54	50	46	85.19%	92.00%
HV	62	50	48	77.42%	96.00%
BL	47	50	37	78.72%	74.00%
Totals	350	350	292		

*Overall Classification Accuracy: 83.43%

Table A141. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/tm/hawk_tm_19890910_class.img.

Class Name	Kappa
U	0.6399
DF	0.7879
CF	0.8591
MF	0.8176
W	0.9054
HV	0.9514
BL	0.6997

*Overall Kappa: 0.8067

Table A142. Error matrix for the classification of a 1973 Landsat MSS image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/mss/hawk_mss_19731006_class.img.

Classified	Reference Data							
Data	U	DF	CF	MF	W	HV	BL	Totals
U	26	0	0	1	0	9	14	50
DF	0	39	3	0	0	7	1	50
CF	0	5	41	4	0	0	0	50
MF	0	15	5	30	0	0	0	50
W	0	1	1	0	37	2	9	50
HV	1	3	0	0	0	45	1	50
BL	1	5	6	0	0	1	37	50
Totals	28	68	56	35	37	64	62	350

Table A143. Accuracy totals* for the classification of a 1973 Landsat MSS image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/mss/hawk_mss_19731006_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	28	50	26	92.86%	52.00%
DF	68	50	39	57.35%	78.00%
CF	56	50	41	73.21%	82.00%
MF	35	50	30	85.71%	60.00%
W	37	50	37	100.00%	74.00%
HV	64	50	45	70.31%	90.00%
BL	62	50	37	59.68%	74.00%
Totals	350	350	255		

*Overall Classification Accuracy: 72.86%

Table A144. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of the Hawk Mountain segment of the Appalachian Trail; /appa/hawk_mountain/mss/hawk_mss_19731006_class.img.

Class Name	Kappa
U	0.4783
DF	0.7270
CF	0.7857
MF	0.5556
W	0.7093
HV	0.8776
BL	0.6840

*Overall Kappa: 0.6833

Table A145. Error matrix for the classification of a 2002 Landsat ETM+ image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/etm/rausch_etm_20020906_class.img.

Classified	Reference Data						
Data	U	DF	CF	MF	W	HV	Totals
U	39	0	1	2	1	7	50
DF	0	49	0	0	1	0	50
CF	1	0	45	1	2	1	50
MF	1	5	1	43	0	0	50
W	0	0	0	0	49	1	50
HV	2	2	0	0	0	46	50
Totals	43	56	47	46	53	55	300

Table A146. Accuracy totals* for the classification of a 2002 Landsat ETM+ image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/etm/rausch_etm_20020906_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	43	50	39	90.70%	78.00%
DF	56	50	49	87.50%	98.00%
CF	47	50	45	95.74%	90.00%
MF	46	50	43	93.48%	86.00%
W	53	50	49	92.45%	98.00%
HV	55	50	46	83.64%	92.00%
Totals	300	300	271		

*Overall Classification Accuracy: 90.33%

Table A147. Conditional Kappa (κ) statistics* for the classification of a 2002 Landsat ETM+ image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/etm/rausch_etm_20020906_class.img.

Class Name	Kappa
U	0.7432
DF	0.9754
CF	0.8814
MF	0.8346
W	0.9757
HV	0.9020

*Overall Kappa: 0.8840

Table A148. Error matrix for the classification of a 1989 Landsat TM image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/tm/rauschgap_tm_19890910_gcc_class.img.

Classified	Reference Data						
Data	U	DF	CF	MF	W	HV	Totals
U	42	3	0	0	0	5	50
DF	0	48	0	1	0	1	50
CF	0	0	45	5	0	0	50
MF	6	2	1	30	7	4	50
W	0	0	0	0	50	0	50
HV	4	0	0	0	1	45	50
Totals	52	53	46	36	58	55	300

Table A149. Accuracy totals* for the classification of a 1989 Landsat TM image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/tm/rauschgap_tm_19890910_gcc_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	52	50	42	80.77%	84.00%
DF	53	50	48	90.57%	96.00%
CF	46	50	45	97.83%	90.00%
MF	36	50	30	83.33%	60.00%
W	58	50	50	86.21%	100.00%
HV	55	50	45	81.82%	90.00%
Totals	300	300	260		

*Overall Classification Accuracy: 86.67%

Table A150. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/tm/rauschgap_tm_19890910_gcc_class.img.

Class Name	Kappa
U	0.8065
DF	0.9514
CF	0.8819
MF	0.5455
W	1.0000
HV	0.8776

*Overall Kappa: 0.8400

Table A160. Error matrix for the classification of a 1973 Landsat MSS image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/mss/rausch_mss_19731006_class.img.

Classified Data	Reference Data						
	U	**DF**	**CF**	**MF**	**W**	**HV**	**Totals**
U	38	2	0	0	0	10	50
DF	2	42	2	4	0	0	50
CF	0	6	37	5	1	1	50
MF	0	15	0	35	0	0	50
W	0	11	0	0	36	3	50
HV	1	0	0	0	0	49	50
Totals	41	76	39	44	37	63	300

Table A161. Accuracy totals* for the classification of a 1973 Landsat MSS image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/mss/rausch_mss_19731006_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	41	50	38	92.68%	76.00%
DF	76	50	42	55.26%	84.00%
CF	39	50	37	94.87%	74.00%
MF	44	50	35	79.55%	70.00%
W	37	50	36	97.30%	72.00%
HV	63	50	49	77.78%	98.00%
Totals	300	300	237		

*Overall Classification Accuracy: 79.00%

Table A162. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of the Rausch Gap/St. Anthony's Wilderness segment of the Appalachian Trail; /appa/rausch_gap/mss/rausch_mss_19731006_class.img.

Class Name	Kappa
U	0.7220
DF	0.7857
CF	0.7011
MF	0.6484
W	0.6806
HV	0.9747

*Overall Kappa: 0.7480

Table A163. Error matrix for the classification of a 2002 Landsat ETM+ image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/etm/cumberland_etm_20020906_class.img.

Classified Data	Reference Data						
	U	**DF**	**CF**	**MF**	**W**	**HV**	**Totals**
U	43	0	1	1	0	5	50
DF	0	47	1	2	0	0	50
CF	0	13	37	0	0	0	50
MF	0	11	1	38	0	0	50
W	1	3	8	1	37	0	50
HV	0	2	1	0	0	47	50
Totals	44	76	49	42	37	52	300

Table A164. Accuracy totals* for the classification of a 1973 Landsat MSS image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/etm/cumberland_etm_20020906_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	44	50	43	97.73%	86.00%
DF	76	50	47	61.84%	94.00%
CF	49	50	37	75.51%	74.00%
MF	42	50	38	90.48%	76.00%
W	37	50	37	100.00%	74.00%
HV	52	50	47	90.38%	94.00%
Totals	300	300	249		

*Overall Classification Accuracy: 83.00%

Table A165. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/etm/cumberland_etm_20020906_class.img,

Class Name	Kappa
U	0.8359
DF	0.9196
CF	0.6892
MF	0.7209
W	0.7034
HV	0.9274

*Overall Kappa: 0.7960

Table A166. Error matrix for the classification of a 1989 Landsat TM image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/tm/cumberland_tm_19890910_class.img.

Classified Data	Reference Data						
	U	DF	CF	MF	W	HV	Totals
U	41	0	0	1	1	7	50
DF	0	43	1	2	1	3	50
CF	0	0	41	7	2	0	50
MF	0	8	4	37	1	0	50
W	0	5	4	2	39	0	50
HV	0	1	0	0	0	49	50
Totals	41	57	50	49	44	59	300

Table A167. Accuracy totals* for the classification of a 1989 Landsat TM image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/tm/cumberland_tm_19890910_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	41	50	41	100.00%	82.00%
DF	57	50	43	75.44%	86.00%
CF	50	50	41	82.00%	82.00%
MF	49	50	37	75.51%	74.00%
W	44	50	39	88.64%	78.00%
HV	59	50	49	83.05%	98.00%
Totals	300	300	250		

*Overall Classification Accuracy: 83.33%

Table A168. Conditional Kappa (κ) statistics* for the classification of a 1989 Landsat TM image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/tm/cumberland_tm_19890910_class.img.

Class Name	Kappa
U	0.7915
DF	0.8272
CF	0.7840
MF	0.6892
W	0.7422
HV	0.9751

*Overall Kappa: 0.8000

Table A169. Error matrix for the classification of a 1973 Landsat MSS image of the Cumberland segment of the Appalachian Trail; /appa/cumberland/mss/cumberland_mss_19731006_class.img.

Classified	Reference Data						
Data	U	DF	CF	MF	W	HV	Totals
U	41	2	0	1	0	6	50
DF	0	49	0	1	0	0	50
CF	0	0	45	4	1	0	50
MF	0	12	3	32	2	1	50
W	0	8	4	0	35	3	50
HV	1	3	0	1	0	45	50
Totals	42	74	52	39	38	55	300

Table A170. Accuracy totals* for the classification of a 1973 Landsat MSS image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/mss/cumberland_mss_19731006_class.img.

Class Name	Reference Totals	Classified Totals	Number Correct	Producer's Accuracy	User's Accuracy
U	42	50	41	97.62%	82.00%
DF	74	50	49	66.22%	98.00%
CF	52	50	45	86.54%	90.00%
MF	39	50	32	82.05%	64.00%
W	38	50	35	92.11%	70.00%
HV	55	50	45	81.82%	90.00%
Totals	300	300	247		

*Overall Classification Accuracy: 82.33%

Table A171. Conditional Kappa (κ) statistics* for the classification of a 1973 Landsat MSS image of the Cumberland Valley segment of the Appalachian Trail; /appa/cumberland/mss/cumberland_mss_19731006_class.img.

Class Name	Kappa
U	0.7907
DF	0.9735
CF	0.8790
MF	0.5862
W	0.6565
HV	0.8776

*Overall Kappa: 0.7880

Appendix B. Example metadata for land cover data.

Metadata based on the FGDC-STD-001-1998 standard were created for each of the 54 land cover datasets generated by this project. A representative metadata document follows:

Identification_Information:
Citation:
Citation_Information:
Originator: University of Rhode Island, Laboratory for Terrestrial Remote Sensing
Publication_Date: 20060620
Title: Land cover of Acadia National Park and surroundings for 2002 (acad_etm_20020910_class)
Geospatial_Data_Presentation_Form: raster digital data
Description:
Abstract:
This data set is a complete raster land use - land cover coverage of the XXXX Park and surroundings for 2002. It is a 10-class land cover classification of the park, with Anderson Level II modified attribute coding. Classified using 2002 USGS Landsat ETM+ auto-generated and stratified classifications.
Purpose:
Determination of land use land cover for planning, and spatial and statistical analysis of growth and development in Acadia and surroundings.
Supplemental_Information:
Originated from unsupervised and stratified classifications of Landsat ETM+ data 2002 (with 30-m resolution and 6 spectral bands). Based on National Land Cover Data for Urban and wetlands, and field data survey.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: September 10, 2002
Currentness_Reference: ground condition
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: planningCadastre
Theme:
Theme Keyword Thesaurus: none
Theme Keyword: land cover
Theme Keyword: land use
Theme Keyword: remote sensing
Place:
Place_Keyword: United States

Place_Keyword: New England
Place_Keyword: Maine
Place_Keyword: Northeast
Place_Keyword: Acadia National Park
Access_Constraints:
Access is at the discretion of the National Park Service.
Use_Constraints:
Users of these data should consider their spatial resolution and accuracy before use.
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: University of Rhode Island, Laboratory for Terrestrial Remote Sensing
Contact_Person: Y.Q. Wang, Joy Nugranad-Marzilli
Contact_Position: Professor, Post-Doctoral Researcher
Contact_Address:
Address_Type: mailing and physical address
Address: One Greenhouse Road
City: Kingston
State_or_Province: RI
Postal_Code: 02881
Country: USA
Contact_Voice_Telephone: (401) 874-4345; (401) 874-9035
Contact_Facsimile_Telephone: (401) 874-4561
Contact_Electronic_Mail_Address: yqwang@uri.edu; joy@uri.edu
Data_Set_Credit: University of Rhode Island, Laboratory for Terrestrial Remote Sensing
Native_Data_Set_Environment: Microsoft Windows 2000; ESRI ArcGIS Desktop 9.1; ERDAS Imagine 8.7

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: USGS Standards 87 percent - Ancillary GIS data collected from the States and the National Park Service, historical orthophotographs, and in-the-field verification were among reference data.
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value: .87
Attribute Accuracy Explanation: Accuracy assessment report was done using ERDAS Imagine software to generate equalized randomly sampling points of 50 points per class. Ancillary GIS data collected from the States and the National Park Service, historical orthophotographs, and in-the-field verification were utilized as reference data.
Completeness_Report: Considered complete to the date of publication
Lineage:
Process_Step:
Process_Description:

Land-use and land cover classification was performed based on automated and stratified classification protocol. This stratified classification protocol is to use the National Land Cover Data (NLCD) as the reference, so that the classification can be focused on the land cover types identified by the existing data. The procedures of stratified classification includes: reference the areas for defined land cover categories for unsupervised classification (Masking-and-Classification); and mosaic the recoded results from the classification to build the final land cover data.
Process_Date: 20060227

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Raster
Raster_Obect_Information:
Raster_Object_Type: Pixel
Row_Count: 3501
Column_Count: 4073
Vertical_Count: 1

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 19
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -69.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: row and column
Coordinate_Representation:
Abscissa_Resolution: 28.500000
Ordinate_Resolution: 28.500000
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: D_WGS_1984
Ellipsoid_Name: WGS_1984
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257224

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Lebel: Class_names

Entity_Type_Definition: Land cover/land-use as classified by automated and stratified classification protocol. This stratified classification protocol is to use the National Land Cover Data (NLCD) as the reference, so that the classification can be focused on the land cover types identified by the existing data. The procedures of stratified classification includes: reference the areas for defined land cover categories for unsupervised classification (Masking-and-Classification); and mosaic the recoded results from the classification to build the final land cover map. An extensive library of more than 2,800 geo-referenced digital photographs was compiled from our field surveys in August 2003 and June 2004. Ancillary GIS data collected from the States and the National Park Service, historical orthophotographs, and in-the-field verification were among reference data that supported our decisions during unsupervised and stratified land cover classifications of Landsat data.
Entity_Type_Definition_Source: map class – project derived
Attribute:
Attribute_Label: 10
Attribute_Definition: residential/commercial/transportation
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 41
Attribute_Definition: deciduous forest
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 42
Attribute_Definition: coniferous forest
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 43
Attribute_Definition: mixed forest
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 50
Attribute_Definition: water
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 60
Attribute_Definition: wetland

Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 20
Attribute_Definition: herbaceous/cultivated land
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 71
Attribute_Definition: barren land
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 72
Attribute_Definition: bare rockface/rocky shoreline
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: 73
Attribute_Definition: regrowth forest
Attribute_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Overview_Description:
Entity_and_Attribute_Overview: Items within the spatial database attribute table in addition to the default items (e.g. area, histogram, red, green, blue, opacity) include: 1) code - USGS Land Use and Land Cover Classification System (Level II, code), 2) class_names - USGS Land Use and Land Cover Classification System (Level II, name), 3) color - map class color.
Entity_and_Attribute_Detail_Citation: USGS Land Use and Land Cover Classification System (CODE): Anderson, J. R., E. Hardy, J. Roach, and R. Witter. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional paper 964. U.S. Government Printing Office, Washington. Note: Crosswalk to level 2 for all map classes.
Entity_and_Attribute_Detail_Citation: USGS National Land Cover Data (NLCD)
Entity_and_Attribute_Detail_Citation: National Park Service Vegetation Mapping Data

---

Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Northeast Temperate Network

Contact_Position: Inventory and Monitoring Data Manager
Contact_Address:
Address_Type: mailing address
Address:
Marsh-Billings-Rockefeller NHP
Address:
54 Elm Street
City: Woodstock
State_or_Province: VT
Postal_Code: 05091
Country: USA
Contact_Voice_Telephone: 802-457-3368 ext 40
Hours_of_Service: 8 am - 5 pm
Contact Instructions:
request in writing or email
Resource_Description: Digital imagery or spatial data.
Distribution_Liability:
The National Park Service shall not be held liable for improper or incorrect use of the data described and/or contained herein. These data and related graphics ("GIF" format files) are not legal documents and are not intended to be used as such. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data. The National Park Service gives no warranty, expressed or implied, as to the accuracy, reliability, or completeness of these data. It is strongly recommended that these data are directly acquired from an NPS server and not indirectly through other sources which may have changed the data in some way. Although these data have been processed successfully on a computer system at the National Park Service, no warranty expressed or implied is made regarding the utility of the data on another system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.000
Fees: may need to provide transfer media
Ordering_Instructions:
Request in writing or email
Turnaround: varies with operator's workload
Available_Time_Period:
Time_Period_Information:
Single_Date/Time:

Calendar_Date: 20090201

Metadata_Reference_Information:

Metadata_Date: September 6, 2006

Metadata_Contact:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: University of Rhode Island, Laboratory for Terrestrial Remote Sensing

Contact_Person: Y.Q. Wang; Joy Nugranad-Marzilli

Contact_Position: Professor; Post-Doctoral Researcher

Contact_Address:

Address_Type: mailing and physical address

Address: One Greenhouse Road

City: Kingston

State_or_Province: Rhode Island

Postal_Code: 02881

Country: USA

Contact_Voice_Telephone: (401) 874-4345; (401) 874-9035

Contact_Facsimile_Telephone: (401) 874-4561

Contact_Electronic_Mail_Address: yqwang@uri.edu; joy@uri.edu

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998

Appendix C. Example metadata for virtual field reference.

A Virtual Field Reference Database (VFRDB) constitutes point locations with which photographs and attributes of the land cover are associated. Such a database quickly permits remote sensing analysts to check and compare remotely sensed data against a known reference on the ground. A VFRDB was constructed and developed within a GIS for each of the 18 study sites using point locations and photographs recorded by the Kodak Field Imaging System used by the project team. After processing the point locations, descriptive attributes were added to each of the points within the context of the GIS. These attributes permit users to search and use the VFRDB, serving as ground reference data during image classification and accuracy assessment processes. Metadata based on the FGDC-STD-001-1998 standard (Appendix B) were created for each of the eighteen VFRDB's. More details about how the VFRDB was assembled are present in each database's metadata. Distribution information is left to be completed by the National Park Service. A representative metadata document follows:

ACAD-VFRDB
Identification_Information:
  Citation:
    Citation_Information:
      Originator: University of Rhode Island Laboratory for Terrestrial Remote Sensing
      Originator: National Park Service Northeast Temperate Network (NETN)
      Publication_Date: 20061226
      Title: A Virtual Field Reference Database of Acadia National Park
      Geospatial_Data_Presentation_Form: vector digital data
  Description:
    Abstract: These data consist of an ArcView shapefile that describes the location, quality, and content of the data's associated georeferenced digital photographs. Together, the photographs and these attribute data constitute a virtual field reference database (VFRDB). The VFRDB was used for ground referencing of land cover data in support of the project "Impacts of Land cover Change on the National Parks of the Northeast Temperate Network" fulfilled on behalf of the National Park Service by the University of Rhode Island Laboratory for Terrestrial Remote Sensing.
    Purpose: These data are intended for ground-referencing land cover classifications derived from Landsat ETM+ imagery. The images will support the tracking land cover changes over time within the geographic scope of the data.
  Time_Period_of_Content:
    Time_Period_Information:
      Range_of_Dates/Times:
        Beginning_Date: August 18, 2003
        Ending_Date: August 19, 2003
    Currentness_Reference: ground condition
  Status:
    Progress: Complete
    Maintenance_and_Update_Frequency: None planned
  Spatial_Domain:

Bounding_Coordinates:
West_Bounding_Coordinate: -68.409809
East_Bounding_Coordinate: -68.017494
North_Bounding_Coordinate: 44.539140
South_Bounding_Coordinate: 44.219550
Keywords:
Theme:
Theme_Keyword_Thesaurus: ISO 19115 Topic Category
Theme_Keyword: imageryBaseMapsEarthCover
Theme_Keyword: 010
Theme:
Theme_Keyword_Thesaurus: none
Theme_Keyword: Virtual Field Reference Database
Theme_Keyword: VFRDB
Theme_Keyword: georeferenced photograph
Theme_Keyword: land cover assessment
Theme_Keyword: ground truthing
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: United States
Place_Keyword: New England
Place_Keyword: Maine
Place_Keyword: Acadia National Park
Access_Constraints: Access is at the discretion of the National Park Service.
Use_Constraints: Users of these data should consider their spatial resolution and accuracy before use.
Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: University of Rhode Island, Laboratory for Terrestrial Remote Sensing
Contact_Person: Y.Q. Wang, Joy Nugranad-Marzilli
Contact_Position: Professor, Post-Doctoral Researcher
Contact_Address:
Address_Type: mailing and physical address
Address: Coastal Institute in Kingston
Address: 1 Greenhouse Road
City: Kingston
State_or_Province: RI
Postal_Code: 02881
Contact_Voice_Telephone: (401) 874-4345
Contact_Voice_Telephone: (401) 874-9035
Contact_Facsimile_Telephone: (401) 874-4561
Contact_Electronic_Mail_Address: yqwang@uri.edu
Contact_Electronic_Mail_Address: joy@uri.edu
Data_Quality_Information:

Attribute_Accuracy:
Attribute_Accuracy_Report: Relationship between photographer's location and point location for each photograph within this dataset are 100% accurate. Generated automatically. The assessment of spatial quality, photo quality, presence/absence of people in the image, whether or not the image was taken from the roadside, and additional notes have not been assessed for accuracy since the initial assessment of the photographs. No quantitative attribute accuracy tests were performed.
Logical_Consistency_Report: No logical consistency tests were performed. Casual qualitative assessments conclude these data are topologically complete.
Completeness_Report: Photographs and their associated point locations were removed from this dataset if determined to be completely unusable for assessing land cover. Examples include mistaken photographs of the ground, inanimate objects, or photographs whose geo-referencing information failed to record correctly.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
*The horizontal accuracy of each individual point has been qualitatively assessed. The reason for this is that the Kodak Field Imaging System (FIS) cannot take an image and a geographic coordinate simultaneously. Instead, the FIS requires the user to record a geographic location first, manually enter the compass bearing, then subsequently take a photograph. This system works well when the FIS user is standing still in one location. However, given the scope of this work, much of the VFRDB is generated from images photographed from a *moving* vehicle at varying rates of speed. Since there is a delay between when the geographic location is recorded by the FIS, and when the FIS users chooses to take the photograph, the geographic coordinate associated within a digital photograph taken from a moving vehicle could be dramatically inaccurate - as extreme as a 1/2 mile in rare cases. This is often of no consequence for landscape scale assessments when documenting large tracts of a similar land cover type. Regardless, the spatial accuracy of each photograph location has been individually assessed. See the "spatial_qu" attribute for more information.*

No quantitative spatial accuracy tests were performed on these data.
Lineage:
Process_Step:
Process_Description: A Kodak DC265 Field Imaging System (FIS) was used to record both photographs and their associated geographic location. The FIS consists of a digital camera (Kodak DC265) hardwired via a serial connection to a Garmin GPS III Global Positioning System unit. This 12-channel GPS unit is widely considered to be accurate to 10 meters. The data collection process consists of the user first instruction the FIS to record a geographic location. Next, the FIS prompts the user to manually enter a compass bearing. The user is then permitted to take a photograph. When the photograph is completed, the FIS records a unique ID value, latitude & longitude, UTC date & time, and compass bearing into the photograph's EXIF data and embeds the same information onto the image itself. The geographic coordinates are recorded in geographic coordinates using the WGS84 datum and spheroid.
Process_Date: August 18 & 19, 2003
Process_Contact:
Contact_Information:

Contact_Person_Primary:
Contact_Person: Y.Q. Wang
Contact_Organization: University of Rhode Island Laboratory for Terrestrial Remote Sensing
Process_Step:
Process_Description: After returning from the field, the images were downloaded to a computer equipped with ESRI ArcView 3.3 Geographic Information System software with an ArcView 3.3 software extension provided with the FIS by Kodak. The extension extracts each photograph's attributes from its EXIF data, including longitude & latitude, and subsequently creates a new point ArcView shapefile using these data.The shapefile was reprojected to UTM Zone 18 or 19, depending on the study site, maintaining the WGS84 datum and spheroid.
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Gregory Bonynge
Contact_Organization: University of Rhode Island Laboratory for Terrestrial Remote Sensing
Process_Step:
Process_Description: Each photograph individually assessed for the predominate land cover featured within the image, spatial accuracy, quality of the image itself (such as whether or not the image is blurry or framed well), presence/absence of people in the image, whether or not if the image was taken from the roadside, and miscellaneous notes considered to be useful by the interpreter.
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Y.Q. Wang
Contact_Organization: University of Rhode Island Laboratory for Terrestrial Remote Sensing
Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Entity point
Point_and_Vector_Object_Count: 357
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 19
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -69.000000
Latitude_of_Projection_Origin: 0.000000

False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000000
Ordinate_Resolution: 0.000000
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: D_WGS_1984
Ellipsoid_Name: WGS_1984
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257224
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: ACAD
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: LONGITUDE
Attribute_Definition: Longitude of the location in question in decimal degrees format.
Attribute_Definition_Source: none
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: -180.0000
Range_Domain_Maximum: 179.9999
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: LATITUDE
Attribute_Definition: Longitude of the location in question in decimal degrees format.
Attribute_Definition_Source: none
Attribute_Domain_Values:
Range_Domain:
Range_Domain_Minimum: -90.0000

Range_Domain_Maximum: 90.0000
Attribute_Units_of_Measure: decimal degrees
Attribute:
Attribute_Label: UTC_DATE
Attribute_Definition: Date of when the point and associated photograph in question were recorded.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Unrepresentable_Domain:
MM/DD/YYYY
Determined by the Kodak Field Imaging System after initial input by user during equipment configuration.
Attribute:
Attribute_Label: UTC_TIME
Attribute_Definition: Time of day when photograph in question was recorded. Time is in Coordinated Universal Time format - formerly known as Greenwich Mean Time.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Unrepresentable_Domain:
HH:MM:SS
Determined by the Kodak Field Imaging System after initial input by user during equipment configuration.
Attribute:
Attribute_Label: BEARING
Attribute_Definition:
Attribute_Definition_Source:
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: N
Enumerated_Domain_Value_Definition: North
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: NE
Enumerated_Domain_Value_Definition: Northeast
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: E
Enumerated_Domain_Value_Definition: East
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: SE
Enumerated_Domain_Value_Definition: Southeast
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: S
Enumerated_Domain_Value_Definition: South

Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: SW
Enumerated_Domain_Value_Definition: Southwest
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: W
Enumerated_Domain_Value_Definition: West
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: NW
Enumerated_Domain_Value_Definition: Northwest
Enumerated_Domain_Value_Definition_Source: none
Attribute:
Attribute_Label: IMAGE
*Attribute_Definition: Relative file path location to the photograph the given point references. ***SUGGESTION: Your GIS software may allow you to create a hyperlink based on this field, allowing you to click on a point within the context of your GIS in order to open the associated photograph. If you are using ArcGIS Desktop 9.2, you'll want to set your hyperlink base URL within your map document properties in order to help the hyperlinks to work correctly. Another ArcGIS Desktop 9.2 tip is to increase the selection tolerance to 10 pixels or so to make it easier to choose points off the map with your computer's pointing device.****
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Unrepresentable_Domain: Relative file path location to the photograph the given point references. If the point data are moved relative to the location of the photographs on your computer system, these pathnames will no longer be valid, so you'll need to update them accordingly.
Attribute:
Attribute_Label: LAND_COVER
Attribute_Definition: Land cover/land-use as classified by automated and stratified classification protocol. This stratified classification protocol is to use the National Land Cover Data (NLCD) as the reference, so that the classification can be focused on the land cover types identified by the existing data. The procedures of stratified classification includes: reference the areas for defined land cover categories for unsupervised classification (Masking-and-Classification); and mosaic the recoded results from the classification to build the final land cover map. An extensive library of more than 2,800 geo-referenced digital photographs was compiled from our field surveys in August 2003 and June 2004. Ancillary GIS data collected from the States and the National Park Service, historical orthophotographs, and in-the-field verification were among reference data that supported our decisions during unsupervised and stratified land cover classifications of Landsat data.
Attribute_Definition_Source: map class ?project derived
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 10
Enumerated_Domain_Value_Definition: residential/commercial/transportation

Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 20
Enumerated_Domain_Value_Definition: herbaceous/cultivated land
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 41
Enumerated_Domain_Value_Definition: deciduous forest
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 42
Enumerated_Domain_Value_Definition: coniferous forest
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 43
Enumerated_Domain_Value_Definition: mixed forest
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 50
Enumerated_Domain_Value_Definition: water
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 60
Enumerated_Domain_Value_Definition: wetland
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 71
Enumerated_Domain_Value_Definition: barren land
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:

Enumerated_Domain_Value: 72
Enumerated_Domain_Value_Definition: bare rockface/rocky shoreline
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Enumerated_Domain:
Enumerated_Domain_Value: 73
Enumerated_Domain_Value_Definition: regrowth forest
Enumerated_Domain_Value_Definition_Source: Anderson, et.al., 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey Profession Paper 964.
Attribute:
Attribute_Label: SPATIAL_QU
Attribute_Definition: A subjective assessment of the spatial accuracy of the point in question. Required in light of the fact that some of these locations were located from a moving vehicle, while others were recorded while not in motion. See Process Step 1 of this metadata document for more information.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0
Enumerated_Domain_Value_Definition: Poor. Coordinate is likely poorly georeferenced since the image was taken from a moving vehicle. Actual location of where the photograph was taken may be up to 1/2 mile away from where the point was recorded.
Enumerated_Domain_Value_Definition_Source:
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition: Good. Coordinate is likely a reliable position. Position is probably within 10 meters of where the photograph was recorded.
Enumerated_Domain_Value_Definition_Source:
Attribute:
Attribute_Label: PHOTO_QU
Attribute_Definition: A subjective interpretation of the quality of the photograph in questions. Useful if one is looking to locate high-quality photographs of a given area or certain type of land cover.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0
Enumerated_Domain_Value_Definition: Poor. Photograph is blurry, poorly framed.
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition: Decent. Photograph is likely in focus, but perhaps poorly framed or subject is unclear.
Enumerated_Domain_Value_Definition_Source: none

Enumerated_Domain:
Enumerated_Domain_Value: 2
Enumerated_Domain_Value_Definition: Good. Photograph is in focus, framed well, subject is clear.
Enumerated_Domain_Value_Definition_Source: none
Attribute:
Attribute_Label: PEOPLE
Attribute_Definition: Notation if whether or not people are present in the photograph. Useful if one is looking for images with people present for publications.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0
Enumerated_Domain_Value_Definition: No people present in the photograph.
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition: People present in the photograph.
Enumerated_Domain_Value_Definition_Source: none
Attribute:
Attribute_Label: ROADSIDE
Attribute_Definition: Notation of whether or not photograph was taken from alongside a road. This knowledge is useful in light of the fact vegetation alongside a road often shields the view of the landscape beyond.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Enumerated_Domain:
Enumerated_Domain_Value: 0
Enumerated_Domain_Value_Definition: Photograph not taken from alongside a road.
Enumerated_Domain_Value_Definition_Source: none
Enumerated_Domain:
Enumerated_Domain_Value: 1
Enumerated_Domain_Value_Definition: Photograph taken from alongside a road.
Enumerated_Domain_Value_Definition_Source: none
Attribute:
Attribute_Label: NOTES
Attribute_Definition: Miscellaneous comments regarding the photograph that could be useful to VFRDB users.
Attribute_Definition_Source: project derived
Attribute_Domain_Values:
Unrepresentable_Domain: Miscellaneous comments regarding the photograph that could be useful to VFRDB users.
Metadata_Reference_Information:
Metadata_Date: 20061227
Metadata_Contact:
Contact_Information:

Contact_Organization_Primary:
Contact_Organization: University of Rhode Island, Laboratory for Terrestrial Remote Sensing
Contact_Person: Y.Q. Wang
Contact_Position: Professor
Contact_Address:
Address_Type: mailing and physical address
Address: Coastal Institute in Kingston
Address: 1 Greenhouse Road
City: Kingston
State_or_Province: RI
Postal_Code: 02881
Contact_Voice_Telephone: (401) 874-4345
Contact_Facsimile_Telephone: (401) 874-4561
Contact_Electronic_Mail_Address: yqwang@uri.edu
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 962/100287, November 2009

National Park Service
U.S. Department of the Interior

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