Chapter 2

Materials

This chapter describes the image data, the physical land area, the air photos, and geographic information system (GIS) files used for this study. We begin by describing the specifics of the image data followed by some description of the land area covered by the images. Next, we review weather data used to check for consistent climate conditions during the extended time periods before the images' acquisition. Then we describe the air photos used as reference data and the ancillary data which will be used to assess the usefulness of the proposed change detection methods. Finally, there is a brief section describing the computing equipment and software used for the image processing and data analysis.

Image data

The satellite imagery used in this study are subset images extracted from four Landsat 5 Thematic Mapper (TM) images. (Landsat TM data are described in detail in nearly any remote sensing textbook, for example see Richards, 1993, section 1.3.5.) The image data used for this study will be the three color (red, green and blue) and three infrared (IR) bands from the Thematic Mapper images(see table 2.1). For simplicity, we will refer to these as bands one through six, which differs from the customary numbering for these bands. The thermal band is not included due to its 120 meter geometric resolution, course spectral resolution, and general inability to help detect changes in land cover at the same scale as the other six bands.

Table 2.1: Description of Landsat Thematic Mapper Imagery (adapted from Richards, 1993, Table 1.7)

Band Numbering (customary)	Band Numbering (this report)	Spectral Range wavelenght (μm)	Nominal range	Nominal Pixel Size (in Meters)
1	1	0.45 - 0.52	blue	28.5 x 28.5
2	2	0.52 - 0.60	green	28.5 x 28.5
3	3	0.63 - 0.69	red	28.5 x 28.5
4	4	0.76 - 0.90	near IR	28.5 x 28.5
5	5	1.55 - 1.75	mid/near IR	28.5 x 28.5
7	6	2.08 - 2.35	mid IR	28.5 x 28.5
6	(not used)	10.4 - 12.5	thermal	120 x 120

The original Landsat images were used in the NOAA C-CAP project mentioned in the introduction section (see also Khorram *et al.*, 1996 for additional details). The Landsat "World Reference System" (WRS) code (United State Geological Survey, 1982) and date of acquisitions for each scene are given in table 2.2. The "Header" files for each scene are in Appendix A. Also listed in table 2.2 is the name to which the subset images will be referred to throughout this dissertation. Note that while the later image for the Raleigh area was acquired on the fifth of January 1995, for consistency with the coastal scene, throughout this report this image is referred to as the 1994 Raleigh image.

Table 2.2: Information pertaining to original Landsat TM scenes

Subset Image Name	WRS	Date of Acquistion
Coastal Image '88	1436	5-Dec-88
Coastal Image '94	1436	20-Nov-94
Raleigh Image '88	1635	3-Dec-88
Raleigh Image '94	1635	5-Jan-95

The 1988 scenes were purchased for the Albemarle-Pamlico Estuary Study (Khorram, *et al.*, 1992) from Eosat and converted to state plane coordinates at the Computer Graphics Center to be consistent with other North Carolina state GIS data (Khorram *et al.*, 1992). The more recent scenes were purchased as part of the current C-CAP / DCM project through a statewide purchase agreement from the North Carolina Center for Geographic Information and Analysis. These data were purchased as geocoded in State Plane coordinates.

In order to keep the processing time and data storage manageable, we cut a 1024 pixel by 1024 pixel image from each of the four original Landsat scenes. Similar studies have used even smaller images and produce useful results; in a Ph.D. Thesis on change detection methods Choung (1992) uses one 512x512 pixel window from two different dates. In his Ph.D. Thesis dealing with the effects of tidal stage on wetland change detection for a study in South Carolina, Althausen (1994) uses image data covering two United States Geological Survey (USGS) 7.5 minute quadrangles. In the Carolinas, this translates into two subsets of approximately 400 by 500 pixels. Hall *et al.* (1991, p. 630) use three 512 subset windows in a study on large-scale forest succession. The coordinates of the subset images used in this study are listed in table 2.3. These coordinates and the images themselves are in State Plane meters. While State Plane coordinates are usually in feet, the meter unit is consistent with the original Landsat data (see the header file in Appendix A), which use NAD 83, as recommended by Khorram *et al.* (in press).

Each subset image was free of cloud. And the only visible haze is a slight strip in the Southeast corner of the 1994 coastal subset. The ‘88 images were atmospherically and geometrically corrected to the ‘94 imagery as described in Chapter 3. The subset images are shown on a location map of North Carolina in figure 2.1. The summary statistics and histograms for each band, for each image, are given in appendix B.

Table 2.3: Subset coordinates

	Coastal Subset	**Raleigh Subset**
Upper left X	796,974	622,782
Upper left Y	136,173	240,825
Lower right X	826,101	651,909
Lower right Y	107,046	211,698

A description and the type of land cover change occurring on these two areas are discussed in the following section.

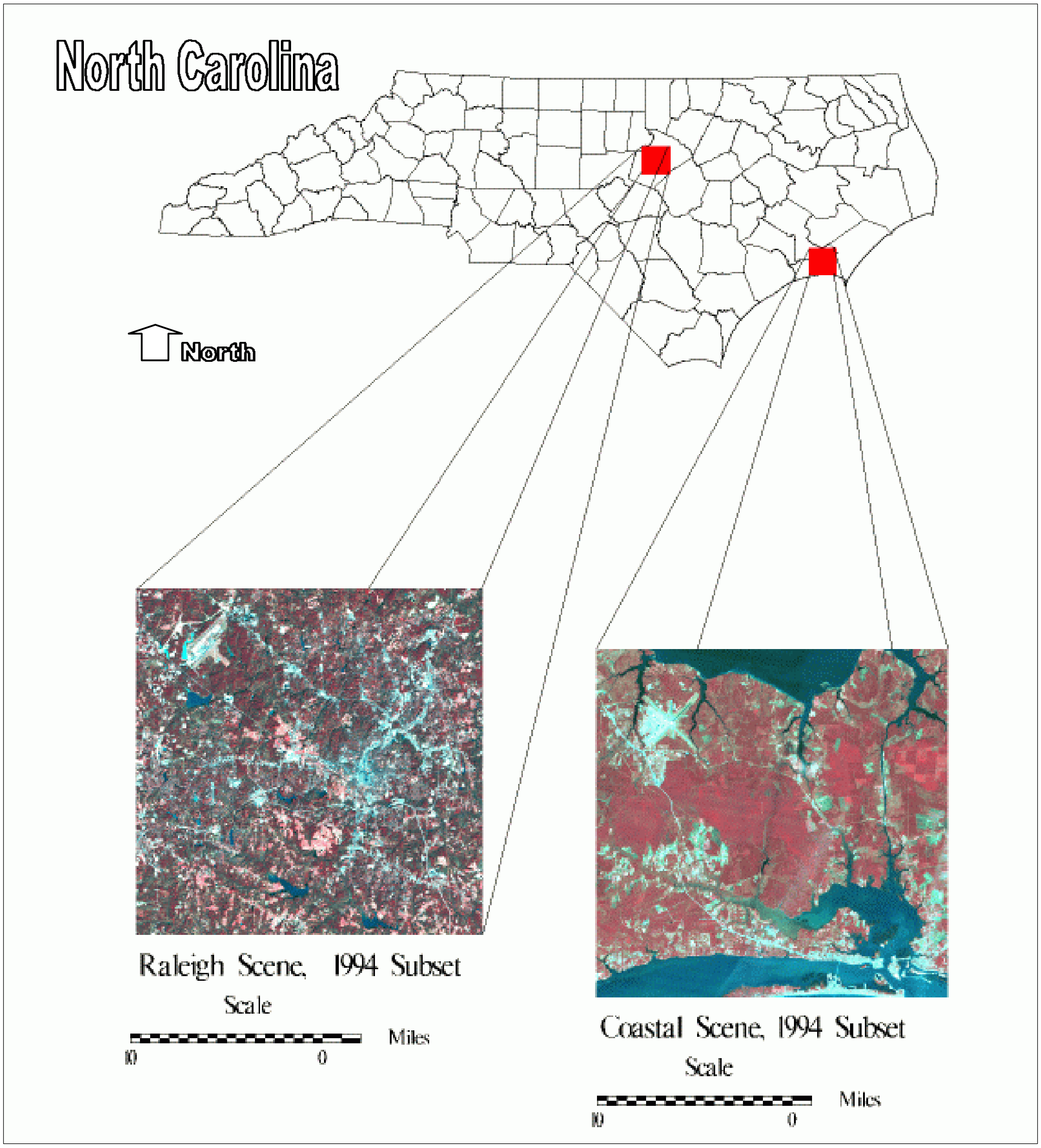
The use of TM data for this change detection study is certainly appropriate considering the amount of existing studies which have utilized this type of data for change detection studies (Dobson *et al.*, 1995 or Coppin and Bauer, 1996). Using Landsat data will:

- place our study in the context of existing work,
- make the results from the study applicable to a wide array of users, and
- be appropriate for use and/or future research using the proposed Landsat Enhanced Thematic Mapper or the similar Indian Remote Sensing (IRS) satellite data and Japanese JERS-1 (ASPRS, 1995 and 1995b).

The proposed method will also be useful for other satellite data at different scales. Indeed the use of GLM should serve any image-based change detection procedure. However, using our methods with other image data, derived from sensors with drastically different characteristics, will need further research before it is used in application. By using Landsat TM data, the research contained in this study will make the use of GLMs immediately available for application with one of the most widely used environmental remote sensors (Wagner, 1996). In addition to being an appropriate *type* of data we have also selected two areas which exhibit dynamics suitable for analysis with TM data. The 28.5 meter nominal resolution is sufficient for detecting changes larger than roughly one acre. The approximately 6 years between acquisition is long enough to expect some of these changes. The study areas and the particular change phenomenon of interest are detailed in the following section.

Study area

Both subset image areas are located in the state of North Carolina, United States. North Carolina is located in an area commonly referred to in the United States as the "South-East". The roughly one million pixels in each subset image cover 210,460 acres, or 329 square miles. The Raleigh and coastal areas are approximately 130 miles apart. They represent two different types of landscape and, therefore, two different types of change. The Raleigh area has and continues to go through increases in its population and urban area. This area was selected so our change detection method could be applied to urban growth change detection. The coastal area image contains mainly natural and managed forest land. This area was selected so our change detection technique could be applied to forest stands in and around sensitive wetland areas. In the following subsections we will describe the two areas with some details particular to each.



Images are displayed as false color composite:
band 2 - blue, band 3 - green, and band 4 - red

Figure 2.1: Location map of image subsets on North Carolina

Coastal area

This study area is located within the *Tidal Area* of the *Atlantic Coastal Flatwoods Section* as delineated by the United States Department of Agriculture (USDA) Forest Service ecological units of the Eastern United States (Keys *et al*., 1995). The geomorphology is flat with an elevation range of 1 - 100 ft. The Quaternary geology is marine sand, silt, and clay. The soils are Ochraquults, Umbraquults, and Ochraqualfs. The yearly precipitation ranges from 45 to 50 inches, the yearly average temperature ranges from 55 to 75 degrees Fahrenheit, and the growing season lasts from 200 to 300 days. The potential vegetation is Pond Pine - Atlantic White Cedar - Red maple Forest Alliance, Loblolly Bay - Pond Pine Forest Alliance, and Black Needle-rush Herbaceous Alliance. (Keys *et al.*, 1995, Subsection 232Ch: Tidal Area).

The study area is part of the greater Albemarle-Pamlico (A/P) U. S. Environmental Protection Agency (EPA) estuarine study (Khorram *et al.* 1992). The eastern portion of the Croatan National forest covers nearly half of the scene; part of which is managed and part of which is left as natural pocosin (USDA Forest Service, 1986). Much of the remaining area is managed forests or agriculture (Khorram et al., 1992; Hughes, 1996; Richardson and McCarthy, 1994). The southern half of the image lies in Carteret County while the northern half lies in Craven county. There are several small towns contained in the study area. Atlanta Beach, Morehead City, and Beaufort are all located on the coast. Newport and Havelock are located inland. (See table 2.4 for a list of the 1988 and 1994 populations for these cities.) Cherry Point Marine Corps Air Station is located in the Northwest corner of the area. There is also the relatively small Beaufort-Morehead City Airport to the southeast corner of the study area. Our coastal study area is framed to the north by the Neuse River and the Pamlico Sound and to the south by Bouge Sound, outer banks, and then Onslow Bay of the Atlantic Ocean. Figure 2.2 shows some of these specific areas on the 1994 imagery.

The changing features on the outer banks (Ferguson *et al*., 1993) are too narrow to be accurately monitored with the 28.5 meter resolution of Landsat imagery. Our interests for the coastal area are changes in forest cover and agricultural areas. The Neuse River has received increasing concern due to its decreasing water quality.

> The river has grown weaker with each season, and (in the summer of 1995) it went into spasms: Algae bloomed green and red, people got sick after swimming and 14 million fish went belly-up at the peak of a string of kills. Health officials closed a stretch of the Neuse near New Bern, and the river became famous not for its attractions, but for its pollution. American Rivers, an environmental group, named it one of the nation's 20 most threatened waterways. (Raleigh News and Observer, March 3, 1996)

In our examination of this area we will not be looking at the water itself but looking to changes in the forest and agricultural areas which make up part of the Neuse watershed. The existence of forested areas and the management practiced on the forest can have a dramatic effect on the type of run-off for the watershed (Richardson and McCarthy, 1994; Amatya, 1993). Also, agricultural areas tend to have much higher rates of non point source sediments, nutrients and toxins that enter in runoff (Hughes, 1996; NCDEHNR, 1994). While this thesis is primarily working with digital image processing and change-detection methods, concern for the Neuse River coupled with the effects of agriculture and forest management on water quality provides an environmental significance to the dynamics that we attempt to monitor in the coastal study area.

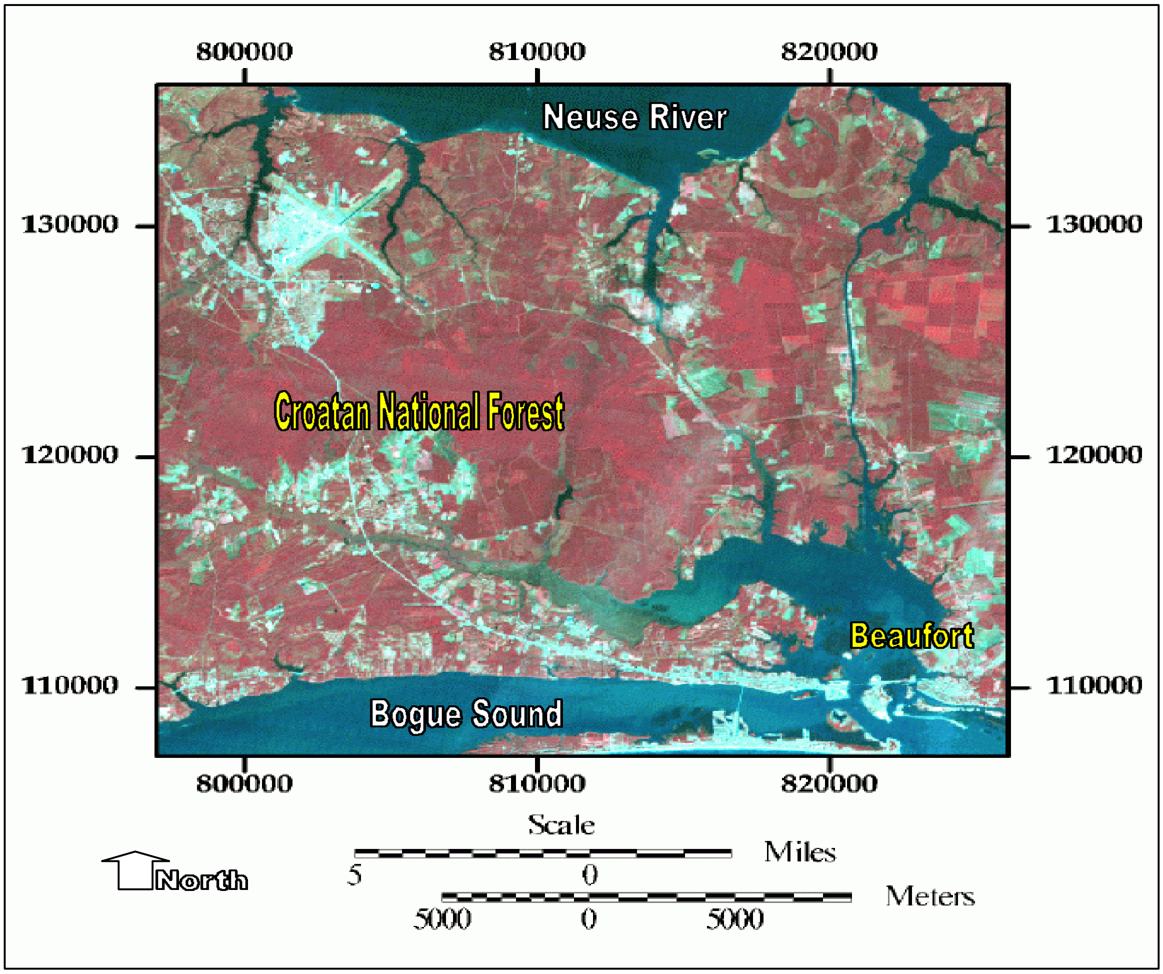


Image data is from the 1994 Landsat TM subset image,

displayed as false color composite: band 2 - blue, band 3 - green, and band 4 - red

Figure 2.2: Coastal Study area

Raleigh area

This study area is in the *Charlotte Belt of the Southern Appalachian Piedmont Section* of the USDA Forest service ecological units of the Eastern United States (Keys *et al*., 1995). The geomorphology is irregular plains with elevation ranging from 100 to 300 feet. The Quaternary geology is Tertiary silty to clayey sandy saprolite and undifferentiated micaceous saprolite. The soil taxa are Kanhapludults and Hapludults. The average precipiation is from 45 to 55 inches, the average temperature ranges from 57 to 64 degrees Fahrenheit, and the growing season lasts from 205 to 235 days. The potential vegetation is Oak (White and Northern Red) - Hickory (Shagbark - Pignut - Mockernut) - Forest Alliance and Pine (Shortleaf, Loblolly, Virginia) - Yellow-poplar Forest Alliance. The area contains intermittent and perennial streams. (Keys *et al.*, 1995, Subsection 231Ae: Charlotte Belt).

The area is located in the eastern "angle" of the Research Triangle Park (RTP) area that is comprised of North Carolina State University, University of North Carolina and Duke University. Our subset imagery is over the greater Raleigh area and also covers part of the adjacent towns of Cary and Garner. Our Raleigh study area contains all of the downtown Raleigh area and extends beyond the "beltline" freeway (U.S. I-440), surrounding the city, to the less developed sub-urban and even rural areas. A major landscape feature contained on our imagery is William B. Umstead State Park. The park's major attractions are the

> pine, hardwood, and mixed forests that demonstrate the process of old-field succession; diverse flora and wildlife; three man-made lakes; (and an) extensive system of bridle trails (Biggs and Parnell, 1989)

Of smaller extent but also significant is the Schenck Forest which provides an outdoor classroom and laboratory facility for NC State University (Spears, 1995). There are also several lakes and smaller natural area contained in the imagery. Some of the significant features are shown in figure 2.3.

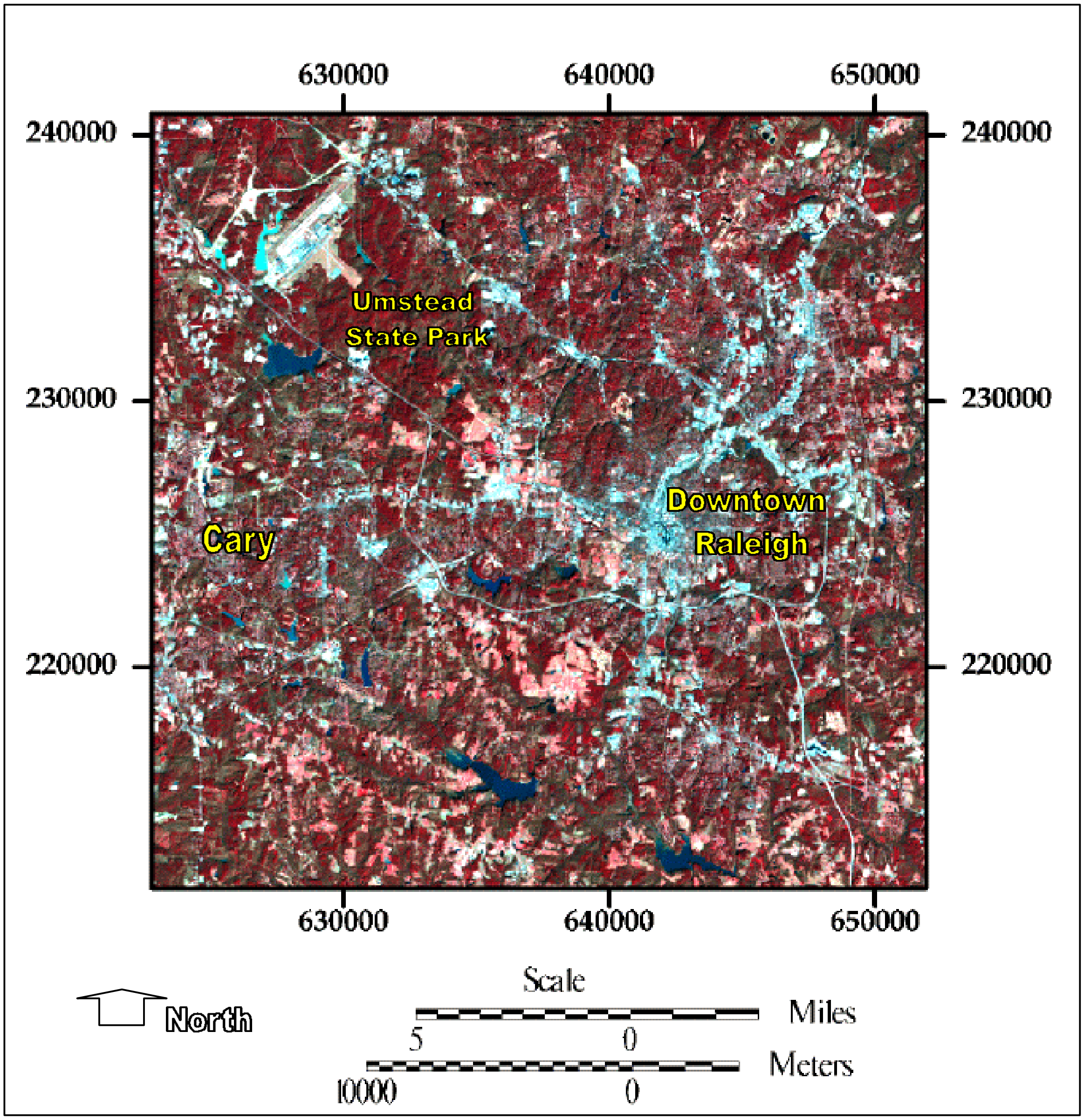


Image data is from the 1994 Landsat TM subset image,

displayed as false color composite: band 2 - blue, band 3 - green, and band 4 - red

Figure 2.3: Raleigh Study area

Raleigh is the Capital City of North Carolina and the RTP area was rated by Money Magazine as the "Best Place to Live in America" for the year of 1994. This is relevant to our study area because of the growing population being attracted to the area. As shown in table 2.4, the population for Cary has grown by 171% and the population for Raleigh had grown by 127%. We also see that Garner has grown in population by 125%. The growing number of people in the Raleigh area has put increasing pressure on the ever-decreasing natural area to be converted to housing, business, or transportation development.

Table 2.4 Cities and population estimates

Coast Area Cities				Raleigh Area Cities			
City	1988 Population*	1994 Population+	% Increase	City	1988 Population*	1994 Population+	% Increase
Atlantic Beach	1240	2366	191	Cary	35560	60775	171
Beaufort	4270	4119	96	Garner	13670	17116	125
Morehead City	6840	6287	92	Raleigh	186720	236707	127
Newport	2610	2776	106				
Havelock	23570	21121	90				

* From: "Current Population Reports: Local Population Estimates, North East, 1988 Population: 1987 Per Capita Income for Counties and Incorporated Places" Series P-26 No.88-NE-SC, U. S. Department of Commerce, Bureau of the Census

+ From: "http://www.census.gov/population/estimates/metro-city/scts94/sc94tsNC.txt"

Current land transformation modeling, as part of NASA's Mission to Planet Earth is attempting to see how policy, socioeconomic and ecological processes affect population demographic and growth. Remote Sensing of land transformation provides input to these models (Pijanowski, 1995). Also, remote sensing has proven helpful for monitoring urban forests and subsequently useful for city park management, municipal engineering, tree maintenance, and tree replacement (Mitchell, 1995). The primary objective for considering this area is to establish the usefulness of our method for monitoring urban growth. However, by having the Raleigh/Cary area as part of our study we have an area which has experienced urban expansion between the image acquisition dates. The change detection product could provide useful information for area planners.

Conclusions on the coastal and Raleigh study areas

We believe the ground area covered by our imagery is of ecological interest. As this study will be on satellite based change detection, we wanted imagery over dynamic areas. The Raleigh scene will provide insight into using our change detection technique for monitoring urban growth. The coastal scene will provide insight into using the methods to detect changes in both managed and natural forested areas.

Meteorological Data

In this section we will consider precipitation, temperature, and tidal stage data. The purpose of these considerations is to temper our interpretation of the image data.

For the satellite-based change detection techniques which use the observed reflectance values as the primary indictor of change the idea is to detect change from one ground cover to another by observing changes in reflectance values. Different weather patterns can cause an area to reflect differently, and thus appear to have changed when the actual ground cover is essentially the same. Moist bare soil has a different spectral appearance from dry bare soil (Devine, 1992; Drury, 1990, p. 35). Differences in temperature and precipitation can cause different amounts of stress on plants (Wilson, 1984) making certain areas appear to have changed when actually they have maintained essentially the same ground cover. Because weather related conditions are confounded with actual changes in land cover class it is important to account for these differences and use this accounting to assist in meaningful interpretation of the change detection. In this section we review meteorological data which can later be used to help with our interpretation of the image data and modeling results.

In appendix C we present monthly average precipitation, low, and high temperatures for the two years previous to the images' acquisition as well as daily precipitation, low, and high temperatures from September to the date of acquisition. In appendix C we test the hypothesis of equivalent meteorological conditions as well as consider visual interpretation of plots of the data.

By examining the data plots and statistical analysis we reach the following conclusions:

- For the coastal area, due to rainfall in the days previous to image acquisition, the 1994 scene will contain more moist or wet areas. So, for the 1994 scene, in general it is likely that the bare ground will appear darker. There was not enough rain to expect significant amounts of standing water. Also, 1994 had, at least until the time of acquisition, a rather mild fall compared to 1988, which had significantly colder weather including ten days with low temperature below freezing. With this, there may be more vegetation present in the 1994 scene due to the warmer weather.
- For the Raleigh area, although the data also show a warmer fall in 1994, the later acquisition date for the "1994" image (January 5th, 1995) should reduce the effects of the mild weather. It is late enough in the year and temperatures did go below freezing several times before image acquisition. The precipitation data do not suggest any difference in reflectance values for the two years.

Another weather-related consideration for change detection studies over a marine area is the tidal stage. For the coastal area we gathered the time of high and low tides on the dates of image acquisition. This information, as measured at the Beaufort Duke Marine Lab, NC, was provided by the NOAA National Ocean Service. The tidal stage was based on the nominal local time of day of image acquisition at 9:45am (Lillesand and Kiefer, 1994, section 6.7). The mean low tide (MLT) for the two dates is 2.61 feet above sea level. For the 1994 scene, a linear interpolation between the 9am and 10am readings produce a 9:45am measurement of 3.47 feet above sea level, which is 0.86 feet above mean low tide. For the 1988 scene, the interpolated 9:45am measurement is 2.36 feet above sea level, which is 0.25 below mean low tide. Together, these reading show approximately one-foot difference in water level for the two image dates. Jensen (1996) states that for images used in change detection it is best to use images acquired at mean low tide and 1 or 2 feet above MLT are acceptable. By this criterion, our image data are acceptable. However, because of the structural dynamics in the outer banks and the coastal shoreline, we will avoid interpreting changes in areas where the dynamics are at a finer spatial and temporal resolution than can be detected with TM data acquired 6 years apart.

Reference Data

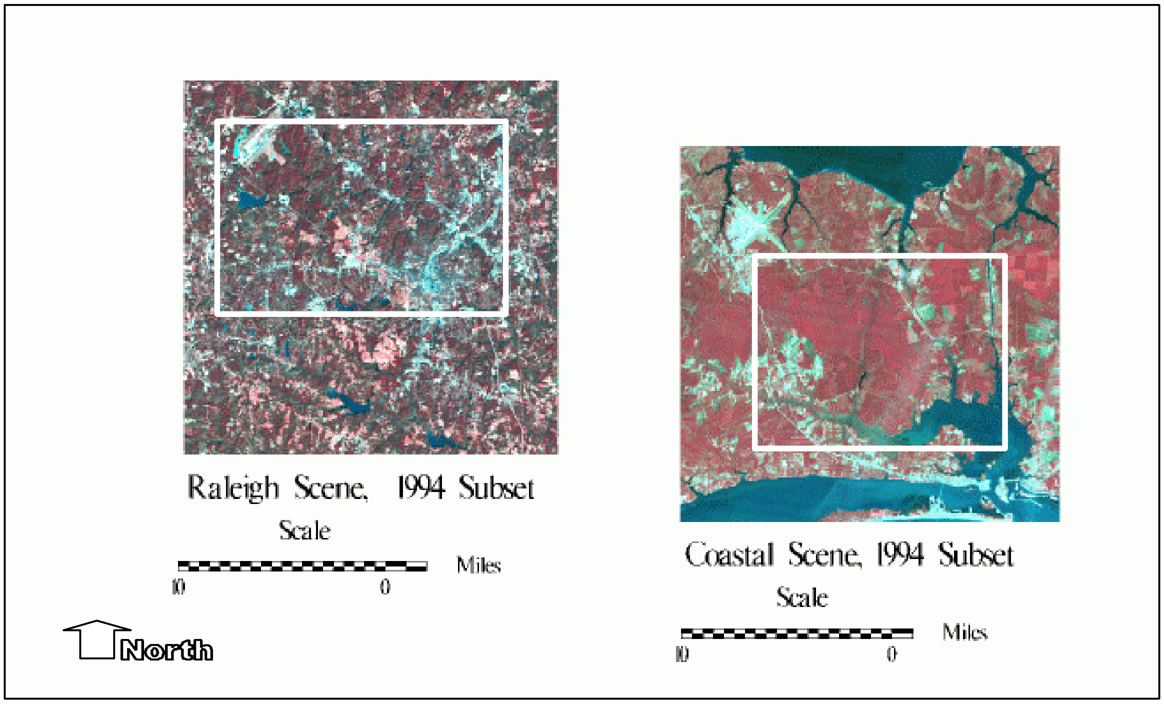
For each TM scene we will use a corresponding higher resolution air photo to interpret the land cover for particular sample areas for each time (details are given in Chapter 6). By "corresponding" we mean acquired at roughly the same time and over the same area. For the 1994 TM data we have corresponding Digital Orthophotographic Quadrangles (DOQs). For the 1988 TM data we have corresponding privately flown air photos. Both the DOQs and the privately flown air photos will be used for interpretation used to derive the reference data, while the DOQs will also be used to geometrically register the reference data to the TM data. The digital orthophotos are

> digital image(s) of… aerial photograph(s) in which displacement caused by the camera and the terrain have been removed. (They) combine the image characteristics of a photograph with the geometric qualities of a map…The standard digital orthophoto produced by the USGS is a black -and-white, color or color-infrared, 1-meter ground resolution quarter-quadrangle image covering 3.75 minutes of latitude by 3.75 minutes of longitude, at a scale of 1:12,000. This image is called a DOQ. DOQ's are cast on the Universal Tranverse Mercator projection based on the North American Datum of 1983. They also have between 50 and 500 meters of overedge image beyond the primary and secondary datum corner tick extremes to facilitate tonal matching for mosaicking of adjacent images. (USGS Fact Sheet, no date)

The DOQs are derived from the United State Geological Survey (USGS) National Aerial Photography Program black and white photos flown during February and March of 1993 (USGS, no date). Digital Orthophoto Quarter Quadrangles (DOQs) meet horizontal national Map Accuracy Standard accuracy requirements of "90 percent of the well-defined points tested must fall within 40 feet" (USGS Fact Sheet, no date). The DOQ are available through the USGS on 8 mm tape. We will use 14 DOQs: eight are within the Raleigh area and six are within the coastal area. This resulted in 1994 reference data over two USGS 7.5 minute quadrangles for the Raleigh area and one and one-half USGS 7.5 minute quadrangles for the coastal area. In figure 2.4 the areas covered by the DOQs are shown on the TM image data.

The 1988 reference photos differ for the two study areas. For the coastal scene, the photos are black and white 9” by 9” photos from the Weyerhaeuser company acquired during January and February of 1989 at a nominal scale of 1:15,840 (1” = 1/4 mile). For the Raleigh scene the reference photos are privately flown air photos acquired in January and February 1989 available through the Wake County Planning Department at a nominal scale of 1:1,200 (1” = 100’).

The DOQ provide geocorrected digital reference data that can be analyzed and queried within Imagine™ software. This will allow for sample selection from both the DOQs and the image data using a set of sample point locations created as an Arc/Info™ point coverage. Once located on the DOQs, sample points are located on the 1988 photo to find land cover for that point at that time. Error in the interpretation of land cover from the reference data will be considered negligible because of their one-meter resolution as compared to the 28.5 meter resolution of the TM imagery. That is, the reference data will be considered as "ground truth". This will be used as reference data against which to compare the TM data. The reference data will be used to generate the dependent, or response, variable in the Generalized Linear Modeling (detail are given in Chapter 6).



The image data is the 1994 imagery and the white boxes indicate the area covered by the DOQs. The imagery is a false color composite: band 2 - blue, band 3 - green, band 4 - red.

Figure 2.4: Location of DOQs shown on the 1994 image data

Ancillary data

We will use three different ancillary GIS files in our study:

1. Natural Heritage Area polygon map
2. Stand-level map of silvicultural examination and prescription for the Croatan National Forest
3. Town of Cary zoning map

Currently these data are in use and serve to monitor and evaluate certain areas for particular reasons. They are used in our study in an attempt to relate the change detection data to the level of information used for decision making. By incorporating our satellite-based data with these files we can get an idea of how our proposed method can be integrated into existing information.

Natural Heritage Areas

In the spring of 1996 we obtained the most recent GIS coverage of the North Carolina Natural Heritage Areas (NHAs). According the North Carolina Center of Geographic Information and Analysis, the NHAs are

> areas containing ecologically significant natural communities or rare species...Due to its dynamic nature, this data becomes out-dated very quickly. The Natural Heritage Program MUST authorize release of this data, in writing, prior to distribution, access or hardcopy output of this layer. Data managed by the NC Department of Environment, Health and Natural Resources - Division of Parks and Recreation, Natural Heritage Program. This data is available for portions of northeastern North Carolina with a base scale of 1:24,000 and a compilation period of 1988-1991. Available from NC Center for Geographic Information and Analysis.
>
> (http://cgia.cgia.state.nc.us/corpmeta.dir/corplayer.html)

After obtaining written permission, we acquired the NHAs map as an Arc/Info™ coverage via ftp (file transfer protocol) from the North Carolina Division of Coastal Management. Due to time and personnel constraints within the Natural Heritage program it is impossible to constantly check each of the NHAs (Pearsall, 1996). There are several NHAs in both the Raleigh and coastal study areas. We will consider two particular NHAs, one in each study area. In our examples of possible uses for the GLM derived change product (Chapter 8), we use the NHAs to locate ecologically significant area where we compare the change product with the management level GIS files described next.

Croatan stand-level map

> The Croatan national Forest contains 157,000 acres of Federal land near the Atlantic Coast of North Carolina. Like most National Forests in the eastern United States, the Croatan contains much private land within its boundaries -- in this case 49%. Some 95,000 acres of Federal land are pocosin -- a swamp or marsh ecosystem in an upland setting, often referred to as a "swamp on a hill". Because of their topographic position, pocosins are relatively easy to drain to improve tree growth, and their peat soils can be mined or used for agriculture. As a result, natural pocosin ecosystems are becoming increasing rare. The Croatan also supports uncommon plant communities and habitats for wildlife. Southern pine stands on the Croatan support many colonies of red-cockaded woodpecker, an endangered species. Thus, maintenance of valued ecological condition is particularly important in managing this Forest. (USDA Forest Service, 1986a)

The Croatan stand map is a primary tool used to document what has been done to each forest stand and used for inventory and planning. Unfortunately, due to time and personnel constraints within the USGS Forest Service it is impossible to constantly check and update this GIS coverage. Also, no detailed information is available for the private land within or adjacent to the forest (Hayden, 1996). Roughly the eastern one-third of the Croatan Forest is contained in our coastal image scene (see figure 2.2).

The stands map for the Croatan forest in contained in an Arc/Info™ coverage. We obtained the "arc exchange file" or "eOO" file (ESRI, 1994), from the USDA Forest Service on 8mm tape in Spring of 1996. Image data can be integrated with stand maps to provide useful "sub-stand" information (Coppin and Bauer, 1995).

Cary zoning maps

The zoning map of Cary was also available from as an Arc/Info coverage. The zoning map is a standard planning tool used to determine which type of development is suitable and allowed on the different tracts of land within the town. We will compare the zoning around one of the Natural Heritage Areas. We do this in light of the change detection product. This is done to show a possible application of the change detection product.

In general, these GIS files will help assess the usefulness of our change detection technique. Each of these three ancillary GIS files will help us connect our proposed method of change-detection to management level information. That is, they will allow us to bring our change-detection method up to the user lever -- to those interested in the dynamics we are attempting to detect.

Computing Equipment

The image analysis and computing were done within the Unix environment on a Sun Sparcstation 5 running Solaris 2.4 operating system. The Sun workstations are connected to two file servers, one belonging to the CGC and the other being the North Carolina State University campus-wide system. CGC uses an Alpha 2100 Server running on the Open Software Foundation (OSF) 3.2c operating system using the Andrew File System (AFS). The campus-wide system runs on multiple servers using AFS.

The two systems hold different software. The software we used is listed here followed by the corresponding server holding that software and the general purpose of that software:

- Environmental Resources Digital Analysis System (ERDAS) Imagine™ 8.2 within the CGC system -- to be used for the image processing and display,
- Environmental Systems Research Institute (ESRI™) Arc/Info™ 7.03 and Arc/View™ 2.1a, both within the CGC -- used for manipulation of vector map files and display,
- Statistical Analysis Software (SAS™) 6.10 within the campus-wide system -- used for statistical modeling and graphics,
- GSLIB program (Deutsch, 1992) within the campus-wide system -- used for calculating the empirical variogram values for the spatial statistical analysis.

The word processing was done on a personal computer using WindowsNT™ and Microsoft Office 97 software.

These facilities proved to be adequate for our image analysis, statistical analysis, and display and word processing.

Summary of Material Section

The image data are four 1024 by 1024 pixel images; two overlapping images over the Raleigh, N.C., area, two over a coastal area near Beaufort, N.C. The areas exhibit changes which are of interest to forestry and general ecology. The weather data show no extreme climate difference for the extended time period prior to the images' acquisition. However, for the Coastal area, there are some statistically significant differences in the temperatures previous to the image acquisition and there will be more moisture present in 1994 image. These will be kept in mind as we interpret the data and model results. Also, because of rainfall in the proceeding four days before the 94 coastal image acquisition we should be aware that there could be moist ground conditions for this image.

Hard-copy air photos as well as U.S.G.S Digital Orthophoto Quarter Quadrangles will be used as reference data. This high-resolution data will be used to calibrate change detection models and for accuracy assessment. The ancillary GIS data for the Croatan National Forest, the Natural Heritage Areas, and Cary zoning map will be used in our example of possible uses of the proposed change detection product. The computing hardware and software have been described and were suitable for this study.

We used data which is available to the general public and did not need any pre-processing beyond common procedures (see the next chapter, Chapter 3, for more details of the preprocessing). TM data have been used in many previous change-detection studies. Using TM will set this study in the context of existing work. By using Landsat data and by requiring no special preprocessing or image selection other than "cloud free", our study will be applicable to a large community of users. We believe our data is appropriate for monitoring the changes in landscape exhibited by the two areas covered by our study and that these changes are of ecological interest.