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Land Cover Change Analysis of the Mississippi Gulf Coast from 1975 to 2005 using Landsat MSS and TM Imagery

Amanda M. English
University of New Orleans

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A Thesis

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Dedication

I'd like to dedicate this thesis to my loving husband, Kyle,
the most supportive person in my life.

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List of Acronyms

BV	Brightness Values
C-CAP	Coastal Change Analysis Program
ERDAS	Earth Resource Data Analysis System
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
ISODATA	Iterative Self Organizing Data Analysis Technique
LULC	Land Use Land Cover
MRLC	Multi-resolution land characteristics
MSS	Multispectral Scanner
NDVI	Normalized Difference Vegetation Index
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NWI	National Wetland Inventory
SAR	Synthetic Aperture Sonar
SPOT	Satellite Pour l'Observation de la Terre
Tif	Tagged Imagery File
TM	Thematic Mapper
USGS	United States Geological Survey
WGS	World Geodetic System

Abstract

The population, employment and housing units along the Gulf Coast of Mississippi have been increasing since the 1970s through the 2000s. In this study, an overall increasing trend in land cover was found in developed land area near interstates and highways along all three coastal counties. A strong positive correlation was observed in Hancock County between developed land and population and developed land and housing units. A strong negative correlation was observed between vegetation and housing units. Weak positive correlations were found in Harrison County between developed land and population, marsh and population, and marsh and housing units. A weak positive correlation was found in Jackson County between bare soil and population. Several study limitations such as unsupervised classification and misclassification are discussed to explain why a strong correlation was not found in Harrison and Jackson Counties.

Land Cover Land Use, Land Cover Classification, Remote Sensing

1. Introduction

1.1 Overview of Land Cover / Land Use Research

Land use land cover (LULC) data is "an essential element for modeling and understanding the earth as a system" (Lillesand et al, 2008). Urban planners and government officials use this data for allocation of government resources and policies as well as planning and development purposes. High resolution satellite imagery is readily available and is collected continuously for visual interpretation as well as computer-assisted land cover classification. The term "land use" describes how land is being used by human activity, such as manufacturing or residential areas. Whereas the term "land cover" describes the feature covering the land, such as forest, wetlands, and impervious surfaces (Lillesand et al, 2008).

In the 1970s, United States Geological Survey (USGS) created a LULC classification system for remotely sensed data. Anderson stated that "the classification system has been developed to meet the needs of Federal and State agencies for an up-to-date overview of land use and land cover throughout the country on a basis that is uniform in categorization at the more generalized first and second levels and that will be receptive to data from satellite and aircraft remote sensors" (Anderson et al, 1976). In Anderson's classification system, there are four levels of LULC classifications; each level is derived from higher resolution remotely sensed imagery. For the purposes of this study, the first level of classification will only be discussed because it pertains to Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) data resolutions (imagery used in this study). Anderson's Level I classification types are used for nationwide, interstate and statewide issues because of the spatial resolution of 30 m, an analyst can not distinguish between smaller features measuring less than 30 m. Level I consist of nine types: urban or built-up land, agricultural land, rangeland, forest land, water, wetland, barren land, tundra and perennial snow or ice. Table 1.1 describes the definitions of each LULC type that pertains to Mississippi.

Table 1.1: Anderson's Level I definitions and examples of land use and land cover types
Source: Lillesand et al, 2008

LULC Classification Type	Definition/Examples
Urban or built-up land	Cities, towns, transportation
Agricultural land	Land used for natural resource production
Rangeland	Land were natural vegetation is grass and where natural grazing is important.
Forest Land	Land with tree crown density of 10 percent or more.
Water	Streams, canals, lakes, reservoirs, bays and estuaries.
Wetlands	Area includes marshes, mudflats, and swamps as well as shallow areas of bays and lakes.
Barren	Land with a limited ability to support life.

USGS has recently made all archived Landsat imagery from 1975 to the present available to scientific community in the US free of cost. The imagery used in this study was downloaded from USGS Earth Explorer website, further details on data collection can be found in the methodology section. To make this research topic manageable, a time interval was chosen to be five years from 1975 to 2005. The satellite imagery available for this time period was acquired by Landsat MSS and Landsat TM.

Three Landsat satellites were launched in the 1970s; the first Landsat satellite (Landsat-1) was launched in 1972 followed by Landsat-2 in 1975, and in 1978 Landsat-3. Each of these satellites carried a MSS that collected data in four wavelengths regions or spectral bands, Bands 4, 5, 6, and 7. Landsat-1, -2 and -3 had a temporal resolution of 18 days and spatial resolution of 79 m. The spectral resolution of Bands 4, 5, 6 and 7 are 0.5 – 0.6 µm, 0.6 – 0.7 µm, 0.7 – 0.8 µm, and 0.8 – 1.1 µm respectively.

The first Landsat TM satellite was Landsat-4, launched in 1982; however the TM data transmission failed in 1993. Landsat-5 TM, which was launched in March 1984 and collected the imagery from 1985 to 2005, was used in this study. Landsat-5 TM continues to acquire new imagery. Landsat-5 TM has a temporal resolution of 16 days and 30 m spatial resolution in Bands 1, 2, 3, 4, 5 and 7. The bands used in this study are Bands 2, 3, 4 and 5 which are associated with wavelengths considered appropriate for mapping urban features and vegetation types. The wavelengths associated with each Landsat TM band are: 0.52 – 0.60 µm for Band 2 (green), 0.63 – 0.69 µm for Band 3 (red), 0.76 – 0.90 µm for Band 4 (near-infrared) and 1.55 – 1.75 µm for Band 5 (mid-infrared) (Lillesand et al, 2008).

1.2 Land Cover Change Research

In 1993, several federal agencies created the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC purchased Landsat-5 imagery that covered the continental United States in order to create a National Land Cover Dataset (NLCD). This first NLCD was published in 1992 and the second NLCD was published in 2001 (Lillesand et al, 2008). These two land cover datasets were used to create the 1992-2001 Land Cover Change Retrofit Product by the USGS which combines the two NLCD datasets to find the change from 1992 and 2001.

1.3 Research Objectives

The purpose of this study was to analyze temporal change in land cover through unsupervised classification of satellite imagery from 1975 to 2005 along the Gulf Coast Counties of Mississippi. Correlation analysis was conducted on several socioeconomic characteristics to determine if there was a possible relationship with the land cover change.

1.4 Organization of the Thesis

The thesis is organized into six chapters, beginning with a literature review of several articles concerning LULC change. Following the literature review, the second chapter gives an overview of the Gulf Coast of Mississippi socioeconomic data from the 1970 through 2005. The third chapter describes the methodology for this study by detailing the data collection of the satellite imagery and socioeconomic data, data organization, and finally data analysis. This is followed by the results and discussion of

the research objective and issues with the study. Lastly, the conclusion summarizes the important findings of this study and what these findings could mean for Gulf Coast residents. References are listed at the end of the thesis. The raw socioeconomic data is found in tabular format in Appendix A.

2. Literature Review

LULC classification analysis has been performed for over thirty years in the government and research sectors. The focus of this chapter is to review relevant literature involving the analysis of satellite imagery to classify land cover types in coastal settings. In some of the research, other sources are coupled with the satellite imagery such as aerial photography, topographic maps, field work and other land cover databases. A general overview including the type of satellite imagery, study area, time frame, methodology, classification scheme and results are given for several articles.

The focus of Gourmelon et al (2001) article was on the change of landscape of Bregne, France from the 1800's to 1990's using historical documentation and aerial photographs. The cultivated land was found to be transformed into grazing and fallow land in this time period mainly due to sheep. Visual interpretation of the aerial photos from 1952 and 1992 allowed analysts to group the area into three types: grazing, no longer grazed and unsuitable land for grazing. These three types were further divided into land-use types: coastal vegetation and low heathlands, pastures, crops, scrubs and fallow, European gorse enclosures, wetlands, and built-up areas. The results were presented in the form of maps displaying the land-use types and calculation of the percentage of each type (crops, pastures, fallows and others). The main finding of this research was that as fallow land increased throughout this study area, the biodiversity decreased.

Campbell et al's article was based on LULC change of Loitokitok, Kenya (not a coastal area) using Landsat MSS, SPOT (Satellite Pour l'Observation de la Terre) and Landsat 7 ETM+ (Enhanced Thematic Mapper) images from 1973, 1984, 1994, 2000, and 2001. The visual interpretation of these images was coupled with socioeconomic data collection of household surveys, community workshops and interviews. Four land cover classes, forest, rangeland, irrigated agriculture, and rain-fed agriculture were studied. Land cover maps and the area of each type of LULC type were presented in the results. The conclusion can be summed up by the following sentence, "Patterns of land cover changes revealed by the imagery provide little info on the drivers of change, but they enable the investigators to better assess the findings of the field surveys" (Campbell et al, 2005). The socioeconomic data aided the analysts in developing drivers for the changes missing in the imagery analysis. The analysis of socioeconomic and imagery data allowed the authors to achieve one of their objectives, "to project future changes in LULC under different political and economic scenarios" (Campbell et al, 2005).

Ramsey et al's study focused on the Mermentau Basin of coastal Louisiana from 1990 to 1996 (2001). Eight Landsat images were geo-registered and mosaiked prior to analysis into sixteen classes. Other sources of data were color infrared photos, 1988 and 1990 National Wetland Inventory (NWI) habitat maps and USGS vector data. Field data was used to refine LULC classes and to calculate accuracy of the imagery analysis. The LULC classes used were developed from NOAA's Change Analysis Program (C-CAP). Unsupervised K-means clustering algorithms were used to classify the imagery into C-CAP classes. The water and urban areas were masked out prior to performing the analysis. Misclassification was found to be due to several sources, such as: crop rotation, seasonal changes, and the practice of marsh burning. Accuracy assessment was accomplished by calculating kappa statistics, omission and commission errors, and

verification by other NOAA personnel not involved in classification as well as field analysis.

Ramsey et al also conducted change detection analysis, which involved post classification analysis using all sixteen classes. A matrix of from-to land cover class was constructed. Two indications of class stability, location and residence were developed. Location stability was calculated from the percent of LULC class that stayed the same during the study period while the residence stability was calculated from the percentage change in each class within the study area. The results were presented as the area of each LULC class and the change between three time periods, 1990 to 1993, 1993 to 1996 and 1990 to 1996. LULC maps and the percentage of each type of the entire study were also presented. The change analysis revealed that about half of the LULC classes experienced little or no change. Five principal findings from this research are listed below:

1. "Land cover turnover is maintaining a near stable logging cycle, but grassland, scrub shrub and forest in cycle appeared to change.
2. Planting of seedlings is critical to maintaining cycle stability.
3. Logging activities tend to replace woody land mixed forests with woody land evergreen forests.
4. Wetland estuarine marshes are expanding slightly.
5. Wetland palustrine marshes and mature forested wetlands are relatively stable (Ramsey et al, 2001)."

The goal of the Kandus et al (1999) study was to create a LULC classification scheme "to understand the interaction between the natural and man-made ecosystems that coexist in the [Argentina] delta islands." Aerial photos and field data collected from 1984 to 1990 was analyzed along with three Landsat TM images from 1993. The Landsat imagery was corrected for geometric and radiometric distortion corrections using topographic maps in ERDAS (Earth Resource Data Analysis System). Unsupervised ISODATA (Iterative Self Organizing Data Analysis Technique) classification was conducted on the three images. The user's, producer's, and overall accuracy was calculated as the result of this study. The classification scheme was found to be flexible conceptually which allowed for aggregation and desegregation of land cover classes as required and not defined by satellite imagery.

The Klemas et al (1993) article focused on the development of a land cover classification scheme for the C-CAP covering coastal wetlands, uplands, and submerged habitats mainly for fisheries habitat and marine resources management. The scheme was adapted from several sources (Anderson et al, 1976; Cowardin et al, 1979; and USGS, 1992). C-CAP is a program to monitor areas of significant change and serves as a database for coastal land cover based on satellite imagery (Landsat MSS, TM, and SPOT). This classification scheme is compatible with NOAA's National Marine Fisheries Service and the NWI. Products of research with the C-CAP classification scheme are spatially registered digital images, hard copy maps, and summary tables. Five attributes of the C-CAP classification scheme are listed below:

1. "Emphasizes wetlands, vegetated submersed habitats, and adjacent uplands,"

2. Upland classes developed from Anderson et al (1976), USGS (1992) and modifications Cowardin et al (1979).
3. Classes defined primarily in terms of land cover vice land use
4. Hierarchical classification scheme
5. Scheme designed to use satellite (TM and SPOT) data and also be compatible with aerial and field data (Klemas et al, 1993).

Huang et al's 2008 study focused on Synthetic Aperture Radar (SAR) images from 2002 of coastal China. Radar was used because of the cloudy weather often found along the China coast. Six main steps were discussed in the methods section, such as 1) SAR noise despeckle, 2) dike extraction, 3) spatial zoning, 4) backscattering coefficient conversion, 5) textual analysis and 6) image classification. Two techniques were used for image classification, unsupervised ISODATA and supervised back-propagation neural network (an iterative gradient algorithm). The classification scheme used in this study was based on Anderson et al (1976) Level 1, 2, and 3. The results were presented in a percentage of each land cover type in five delineated zones. The SAR imagery was "able to produce almost identical and acceptable levels of class accuracy" (Huang et al, 2008).

Qi et al's study focused on Laizhou Gulf Coast of China, an area with fast economic development (2008). Landsat TM imagery from 1988 to 2002 was analyzed in IDRISI software to georeference the imagery to topographic maps and classify into six LULC classes modified from the USGS LULC classification system (2008). The six classes used for this study were cropland, forestland, grassland, urban and/or built-up land, water and barren land. Accuracy of the imagery classification was calculated from stratified random sampling methods to generate reference points for each classification images. Also, general LC delineations on topographic maps, municipal maps, and field surveys were also used to verify the imagery LULC classification technique. Field investigations also involved social, economic, and anthropogenic data. The conclusion of the study was summarized by the following statement, "the land-use pattern in saltwater intrusion areas was altered and the landscapes of coastal plains were modified in a considerably short period, owing to the impacts of both natural conditions and human activities, especially the saltwater intrusion induced by the latter" (Qi et al, 2008).

Hanamgond and Mitra's study focused on the morphological features of Mahashta, India using Landsat TM an ETM Images from 1989 and 1999. Five land classes were analyzed in the imagery, such as agriculture, forest, beach and alluvial sand, marshy/mangrove, and grassland/plantation. The methodology included supervised classification and image differencing. The change in area and percentage of each class was presented in the results of this study. Two generations of beach ridges were found to correspond with periods of accretion and erosion.

Everitt et al (2008) used Quickbird imagery for "mapping [of] black mangrove along the south Texas Gulf Coast." Each image used in this study was classified using supervised and unsupervised image analysis techniques. Five training sites coupled with a max likelihood classifier were chosen for the supervised classification technique. The max likelihood classifier method classified two images of the study sites using the signatures from each of the five classes extracted from the training sites. The five LULC

classes used for this study were black mangrove, wet soil, seagrass, mixed vegetation, soil or roads and water. ISODATA was used for the unsupervised classification technique. Ground truthing was used to calculate overall accuracy; producer's and user's accuracy as well as the kappa coefficient were also calculated. The accuracy of using these methods to classify the imagery was found to range from very good to excellent.

Carreno et al (2007) used multitemporal Landsat TM and ETM imagery acquired from 1984 to 2000 to study vegetal communities and hydrological dynamics in wetlands of the Mar Menor Lagoon in Spain. In 1979, the Tagus-Segura water transfer system opened and since then an increase in nutrient inputs has been recorded coming from the irrigated lands into the lagoon and surrounding wetlands. Temporal change was calculated by analyzing the land cover change in the initial imagery (1984) to final imagery (2001). Regression analysis between the wetland area and irrigated lands was also presented in the results of this study. A confusion matrix was created to characterize error and accuracy coefficients. In conclusion, an overall increase in total wetland area found to be a poor indicator of the increase in water input at the watershed scale because "the increase in hygrophilous vegetation observed overall…. [which] constitutes a good indicator of such water changes;" however, a significant relationship was found between the irrigated lands surrounding the lagoon and wetlands and the area of the salt marsh and reed beds in the wetlands (Carreno et al, 2007).

Brown et al (2005) focused on "dominant spatial and temporal trends in population, agriculture and urbanized land uses" through the United States from 1950 to 2000. A second focus of this article was to present the results of LULC change from remote sensing data from 1973 to 2000. The article did not go into detail describing the methodology for the remote sensing data; however the authors did mention that the USGS land cover data was manually interpreted from the imagery. The distribution of population served an indicator for demand for various goods and services provided by ecological systems. A pocket of loss in the MS Delta was interpreted in the data. Also the population all across the country moved to more metropolitan areas from the 1950s to 2000s. Urbanization defined as the "expansion of urban land uses, including commercial, industrial and residential" (Brown et al, 2005). A few agricultural trends worth noting are that overall area of cropland decreased by 11% from 1950 to 2000 (35% to 31% of the land); the Mississippi Delta was one of the exceptions of this trend. In summary, "remote sensing methodologies provide a means for better quantifying changes along the urban to rural gradient, but collection of land use data through on-the-ground surveys are also needed" (Brown et al, 2005).

Hilbert (2006) conducted LULC classification of the Grand Bay National Estuarine Research Reserve of Mississippi, an undisturbed estuarine marsh-pine savannah habitats surrounding the Gulf of Mexico. Three Landsat images from 1974, 1991 and 2001 were analyzed by unsupervised classification and change detection techniques. The LC classes used for this study were open water, herbaceous wetland, forest and barren land. NDVI (Normalized Difference Vegetation Index) was calculated and then the unsupervised classification method was run on the data. It relied on ISODATA to create the four clusters of LC. The change detection technique involved change matrices derived from post-classification pairs of successive image dates. There was no field work related to this study, the LC results were compared to the NLCD 1992

dataset. The change detection analysis amplified what was already known about the anthropogenic stressors that affect the biodiversity of the area; i.e. substantial land development, dredging and spoil placement in Pascagoula has led to estuarine habitat loss. The LULC maps developed from the study indicated “that the majority of land cover change between 1974 and 2001 occurred as a results of expansion of open water and a reduction in wetland” (Hilbert 2006).

Collins et al (2005) focused on Mississippi forest cover changes and regeneration dates. Five LULC classes were specifically developed for this study. The methodology involved ISODATA clustering as part of the first stage of post-classification followed by step-wise reduction of classification. The step-wise classification was used to determine the regeneration/origin date of the forest cover pixel by pixel. Temporal differences in vegetation were determined by analysis of NDVI and Tasseled Cap images. A Simultaneous Image Difference process was run on the imagery which involved: masking of pixels, stacking of masks, max likelihood processing applied to the signatures and data overlay to create a final forest age thematic map of the six different age classes. An accuracy assessment was also conducted that uncovered poor accuracy levels possibly due to the errors during the georectification process and the Tasseled Cap transformation (Collins et al, 2005).

Oivanki et al (1995) focused on Mississippi Gulf Coast Wetlands along four drainage basins and their total loss and gain from the 1950s to 1990s. Seven classes were used in this study developed by Cowardin et al in 1979. The methodology for this study involved airphoto interpretation and manual digitization of the 1990 data as well as the transfer of historical data from the 1950s and 1970s from tape to a machine. The historical imagery was also digitized into the LULC classes. The results included maps that depicted the total land area gained, total land area lost and total marsh (wetland) lost from 1950s to 1990s (Oivanki et al, 1995).

O’Hara et al (2003) focused on the Mississippi Coastal Counties and their urban areas from 1970s to 2000. Six LULC Anderson Level 1 and 2 classes were used in this study. The methodology to classify the land cover and find the changes involved unsupervised classification, supervised classification and thematic change and formal rule-based classification. The results of this analysis were two figures displaying the “Thematic Representation of Classified Areas in 1991” and the “Amount of Change in Each Area 1991 to 2000” (O’Hara et al, 2003). An accuracy assessment was also conducted on the LULC results presented in the study, values of 90% and 85% were found for the Level 1 and 2 classifications respectively (O’Hara et al, 2003).

3. Methods

3.1 Data Collection

3.1.1 Socioeconomic Data

The socioeconomic data used in this study included county level census population, employment, and housing unit data from 1970 to 2005. This data was compiled from several online resources, such as the Mississippi Center for Population Studies and U.S. Census Bureau. The raw data is found in Table A-1 in Appendix A. Estimates in population, employment and housing units were used for the intercensal years. It is important to note that housing unit data were not available for 1970, 1975, 1985, and 1995. Also, employment data was not available for 1970, 1975, and 1985. The main purpose of the socioeconomic data was to relate the results of the land cover analysis to possible reasons for land cover change; therefore an incomplete socioeconomic dataset is satisfactory for the purpose of this study.

The population data is defined as the number of people within each county for the census year (1980, 1990, and 2000). Employment is defined as the number of workers who were employed within the county for the census year. Housing units are defined by the U.S. Census as “a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters” for the census year (State Data Center, 2001). The 1985, 1995 and 2005 population estimates are averages as of July 1 of the corresponding year. The 2005 housing unit estimates were based on estimates as of July 1, 2005. The 1995 employment estimates were the average labor force by county (no specific date). The 2005 employment estimates were from Quarter 1 “total number of workers who were employed by the same employer in both the current and previous quarter” (U.S. Census Bureau, 2009).

Several spreadsheets in Microsoft Excel were created to organize the data and to determine which counties to focus on for this study. Differences between each decadal dataset were compiled, for example the 1990 population was subtracted from the 2000 population to calculate change between the two decades. Next, the dataset was sorted for each timeframe (2000 to 1990) from highest to lowest amount of change in population and county employment. Ten counties with the most and least amount of change in 2000 were then ranked for each of the other timeframes, 1990-1980 and 1980-1970, to see how each county changed over the study period. The coastal counties of Hancock, Harrison, and Jackson, were found to be in the top ten counties in the state of Mississippi with the most population growth. These counties were also found to have growth in county employment as well. From this analysis, these counties were selected for land cover analysis in this study.

3.1.2 Satellite Imagery

The satellite imagery used for this study was Landsat 4-5 TM and Landsat 1-5 MSS. This imagery was available for free of cost at the USGS website, Earth Explorer, http://edcsns17.cr.usgs.gov/EarthExplorer. Landsat Imagery is organized in paths and rows, and in order to determine the correct paths and rows that covered the study area, one image from each of the paths 20 through 23 and rows 38 through 39 were acquired.

These paths and rows were determined from analysis of the Landsat Path/Row Map shown in Figure 3.1. One band from each of these images was then displayed in ESRI (Environmental Systems Research Institute) ArcMap software along with the MafTiger Census 2000 County Boundaries shapefiles of Hancock, Harrison, and Jackson. The path/rows of Landsat TM that covered the Coast Counties of Mississippi were found to be paths 21 through 22 and row 39. The path/rows of Landsat MSS were found to be path 22 through 23 and row 39.

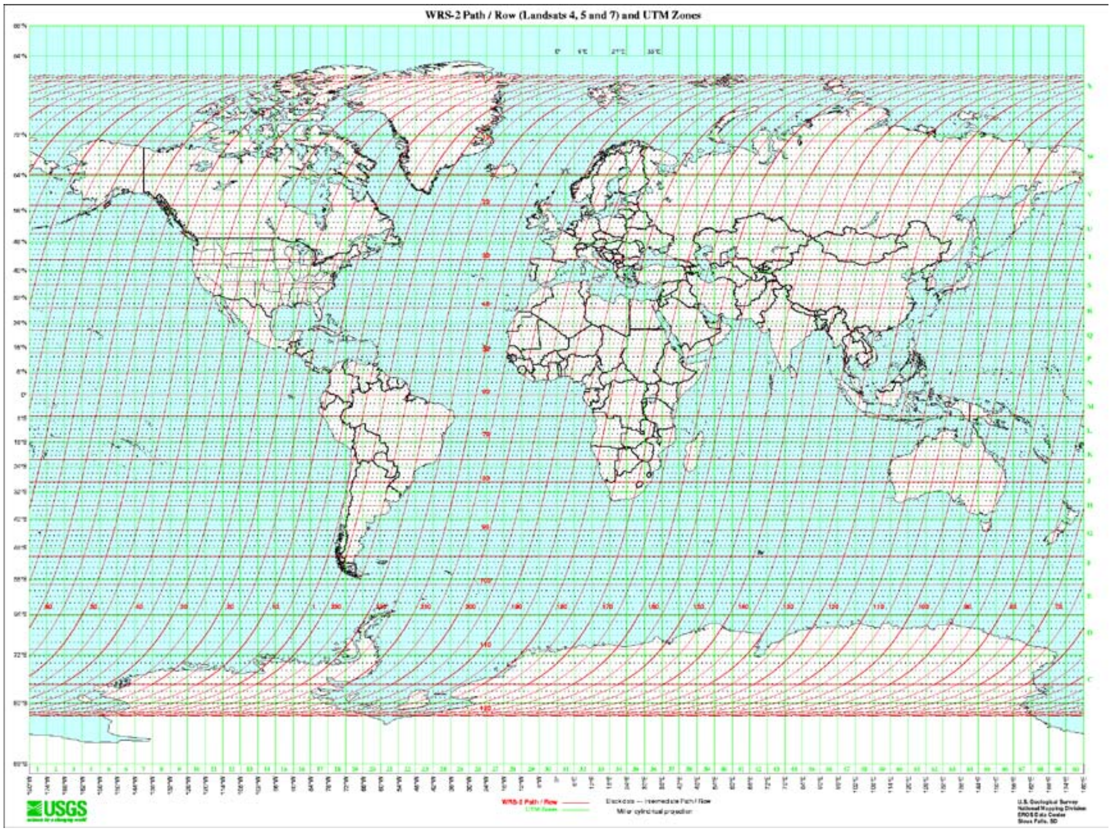

Figure 3.1: WRS-2 path /row (Landsats 4, 5, and 7) and UTM zones
Source: http://landsat.gsfc.nasa.gov/about/wrs2.gif

The next step was to define search criteria from the USGS Earth Explorer website in order to find the satellite imagery that covered the study area within the study's time frame, 1975 through 2005, in five year intervals. Images with less than 10 percent cloud cover were also added to the search criteria; however this information was not always recorded in the metadata therefore images with clouds were inadvertently downloaded. A summary of the image search criteria and the number of images returned are found in Table 3.1. All images were either available for immediate download or had to be ordered. If an image had to be ordered, it would usually take a few days to be staged for download. A total of 111 images were found to fit these search criteria. These files were then downloaded into path / row folders on to an external hard drive for extra storage.

Table 3.1: Satellite image search criteria and results

Download Start Date	Search Criteria								
	USGS Saved Search #	Point 1	Point 2	Dataset	Search Date Range Start	Search Date Range End	Cloud Cover	Path	Row
7/7/2009	8	29.99, -91.7	35.1, -87.9	Landsat 4-5 TM	1/1/2005	12/31/2005	< 10%	21-22	39
7/18/2009	11	29.99, -91.7	35.1, -87.9	Landsat 4-5 TM	1/1/2000	12/31/2000	< 10%	21-22	39
8/16/2009	12	29.99, -91.7	35.1, -87.9	Landsat 4-5 TM	1/1/1995	12/31/1995	< 10%	21-22	39
8/21/2009	13	29.99, -91.7	35.1, -87.9	Landsat 4-5 TM	1/1/1990	12/31/1990	< 10%	21-22	39
9/13/2009	14	29.99, -91.7	35.1, -87.9	Landsat 4-5 TM	1/1/1985	12/31/1985	< 10%	21-22	39
10/30/2009	17	29.99, -91.7	35.1, -87.9	Landsat 1-5 MSS	1/1/1980	12/31/1980	< 10%	22-23	39
10/30/2009	18	29.99, -91.7	35.1, -87.9	Landsat 1-5 MSS	1/1/1975	12/31/1975	< 10%	22-23	39

3.2 Imagery Data Organization

The satellite imagery was downloaded from the website in zipped tar file format with the file extension .tar.gz. These files were saved into the appropriate path/row folders. Next, the tar files were uncompressed by a dos script that put them in file folders with the same name as the tar.gz file. The Landsat TM tar files were uncompressed into seven tifs (one for each band 1 through 7) and the appropriate metadata files. The Landsat MSS were compressed into four tifs (one for each band 4 through 7) and the appropriate metadata files. Tifs (Tagged Imagery File) is a file format for storing imagery files.

3.3 Imagery Data Analysis

3.3.1 Imagery Preprocessing

The multi-temporal comparison of LULC change required image analysis acquisition dates near the same time of year. In order to identify the images with acquisition dates within the same month, a spreadsheet was created to visualize all of the images collected and their acquisition dates effectively. The path/row combinations of the images were listed as column headers while the Julian dates were listed on the rows within the spreadsheet. Checks were used to mark the collection dates for each image. The potential images for analysis in this study were then imported into ERDAS to check the image quality. Each image was then examined for the amount and extent of cloud coverage. Imagery with serious clouds coverage or other quality issues was excluded from further analysis. Images acquired in the summer months were found to have clouds; therefore most of the images used in this thesis were acquired in the fall and winter months. Figure 3.2 shows the number images used in each year’s analysis and the season the image was acquired. A total of sixteen images were analyzed for this study, two per year for eight time periods.

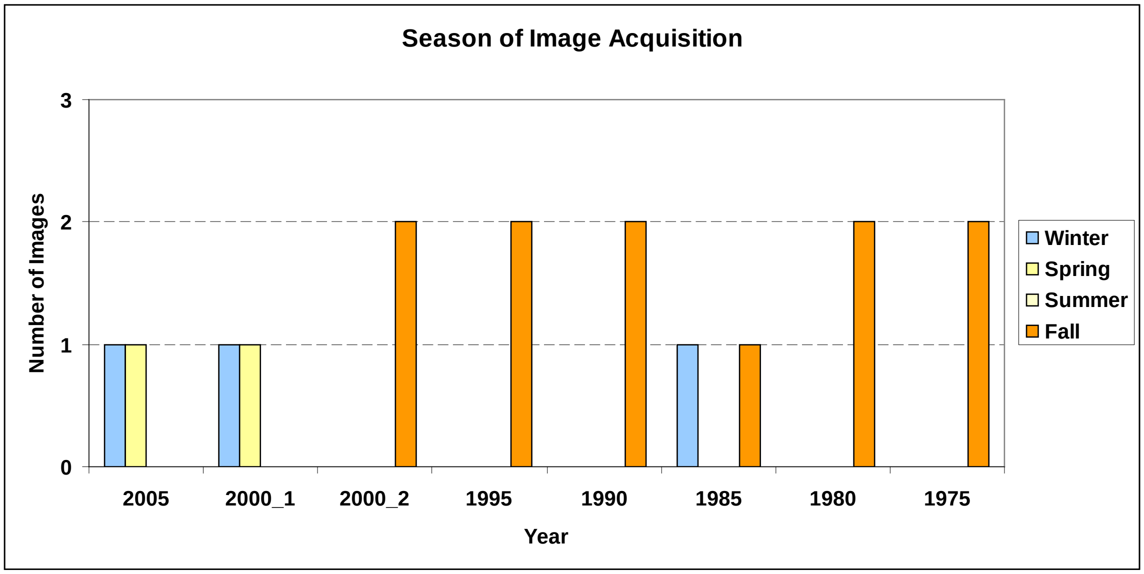

Figure 3.2: Season of image acquisition

Stripes were viewed in two of the three images from 1975. This is most likely due to a failure of radiometric adjustment in a detector on the Landsat MSS. These images were still used because they looked better (had fewer stripes) than the other 1975 images.

After the appropriate dates for each image were chosen, the tifs then had to be converted to img files. The img file format is suitable for processing using ERDAS Imagine image processing software and analysis software. A batch model was created to convert tifs of Landsat TM Bands 2, 3, 4, 5 and Bands 4, 5, 6, 7 of Landsat MSS to img (ERDAS native format); these bands are typically used in LULC analysis.

In order to enhance the ISODATA clustering algorithm to focus on the brightness values (BV) of the land, only, the land areas were delineated from Gulf of Mexico waters digitizing the land-water coastal interface. An area of interest was then used to delineate the water areas along the coast.

3.3.2 Unsupervised Imagery Classification

Virtual stacks, an ERDAS term, for a stack of all bands of each image were created to run ISODATA clustering algorithm, an unsupervised classification method based on K-means of pixel BV. This method assigns each pixel to a cluster of spectral classes based on how close its brightness value is to the mean brightness value of a cluster. Each iteration of the algorithm computes revised means of each cluster until all BV are clustered into user-defined criteria (Lillesand et al, 2008). The input criteria for this algorithm were determined through trial and error; thirty spectral classes were calculated from thirty iterations with a convergence threshold of 0.990. This convergence threshold is maximum percentage of pixels whose class values are allowed to be unchanged between iterations (Jensen 2005). After ISODATA clustering algorithm was completed, the land cover types were manually assigned to each of the thirty spectral classes in each image. This also required more trial and error to manually classify each spectral class into a land cover type of the Gulf Coast Counties. The main land cover

types that were identified and assigned for this study were water, marsh, developed, vegetation, and bare soil. Descriptions of each land cover are found in Table 3.2.

Table 3.2: Descriptions and examples of land use and land cover types

LULC Classification Type	Definition/Examples
Water	Streams, canals, lakes, reservoirs, bays, and estuaries
Marsh	Wetland and meander belts
Developed	Roads, highways, residential, commercial, and industrial development
Vegetation	All vegetation features such as forest, grasses, and shrubs.
Bare soil	Little to no vegetative growth including beaches and cleared areas

The classified raster data was converted to a vector ArcInfo file in ERDAS Imagine, and then each ArcInfo file was converted to a shapefile using ESRI's ArcCatalog. Each shapefile was then imported into ESRI's ArcMap and the individual polygons of each class were merged together into one polygon for each class. The classification shapefiles covered multiple counties because they were based off of the path/row images that covered multiple counties in one image. These shapefiles were clipped to their respective county: Hancock, Harrison, and Jackson. In order to calculate the area of each land cover type, the shapefiles had to be converted from WGS84 (World Geodetic System 1984) projection to a Mercator projection. Then the area was calculated for each class per county in square meters. A Microsoft Spreadsheet of the county-level land cover classes for each time period was finally compiled.

3.4 Statistical Analysis

Microsoft Excel was used to calculate the correlation between the area of each land cover type (developed land, marsh, bare soil, vegetation and water) with the available socioeconomic data (population, employment and housing units) from 1975 to 2005. Three tables were created, one for each socioeconomic factor under investigation. An example of the table used to calculate correlation of population with each of the land cover classes is shown in Table 3.3. Similar tables for employment and housing units were also created. Analyses were run with and without data from 1975 to see if there was an effect on correlation. Pearson's correlation coefficient formulae within Microsoft excel were used for this study. These statistical calculations were run even though there was not enough data to establish statistical significance. The results will only be discussed as an indicator of a relationship between variables.

Table 3.3: Population and land cover class correlation.

County	Variable	2005	2000	1995	1990	1985	1980	1975	Corr Coeff All	Corr Coeff no 1975
Hancock	Population	46088	42967	37802	31760	29091	24537	20000		
Harrison	Population	195756	189601	181553	165365	168762	157665	149300		
Jackson	Population	134243	131420	126626	115243	120119	118015	107700		
Hancock	Water	21.924	19.156	11.921	11.915	12.526	14.845	15.719	0.515	0.675
Hancock	Developed	170.674	159.442	153.043	124.435	124.435	120.057	61.117	0.935	0.941
Hancock	Marsh	14.772	23.609	18.051	20.018	53.921	25.225	52.885	-0.694	-0.505
Hancock	Vegetation	259.894	259.070	268.982	318.175	245.561	307.344	238.991	-0.187	-0.580
Hancock	Bare Soil	23.505	29.662	39.696	29.328	49.904	24.080	0.557	0.348	-0.276
Harrison	Water	17.918	18.743	26.761	21.457	26.384	20.936	24.518	-0.531	-0.462
Harrison	Developed	196.320	169.914	145.519	190.945	157.050	160.961	81.618	0.628	0.247
Harrison	Marsh	45.567	88.144	23.798	33.882	8.904	10.612	22.695	0.666	0.702
Harrison	Vegetation	324.518	264.411	365.713	332.249	377.899	375.894	283.799	-0.180	-0.645
Harrison	Bare Soil	8.686	51.632	31.079	14.289	24.580	24.934	1.283	0.515	0.256
Jackson	Water	24.753	22.388	51.675	32.154	58.598	26.172	51.378	-0.517	-0.361
Jackson	Developed	189.238	181.327	144.222	206.603	165.119	167.005	130.949	0.251	-0.231
Jackson	Marsh	85.162	161.467	113.227	122.946	70.264	130.915	109.292	0.099	0.068
Jackson	Vegetation	417.299	321.440	405.898	367.819	431.680	393.419	374.875	0.063	-0.066
Jackson	Bare Soil	25.477	55.785	28.251	14.265	18.339	18.188	22.060	0.656	0.735
ALL	Water	64.594	60.287	90.357	65.527	97.508	61.954	91.614	-0.462	-0.264
ALL	Developed	556.232	510.683	442.784	521.983	521.983	446.604	448.022	0.551	0.399
ALL	Marsh	145.502	273.219	155.076	176.846	133.089	166.752	184.872	0.225	0.337
ALL	Vegetation	1001.711	844.921	1040.593	1018.243	1055.140	1076.657	897.666	-0.169	-0.651
ALL	Bare Soil	57.668	137.079	99.026	57.881	92.824	67.202	23.901	0.656	0.424

4. Results

The purpose of this study was to analyze temporal change in land cover through unsupervised classification of satellite imagery from 1975 to 2005 along the Gulf Coast Counties of Mississippi. The results chapter is organized into three sections, one for each Mississippi Gulf Coast County, Hancock, Harrison and Jackson County. Within each section, land cover classification maps for each year 1975 through 2005 are presented after a description of the changes are detailed. The thematic maps are large therefore they follow the description of the changes observed starting in 1975. Following the thematic maps, charts showing the area of each land cover class (developed area, marsh, vegetation, and bare soil) are described in detail. A description of the water class was not included because the focus of this study was mostly on land cover types.

4.1 Hancock County Land Cover Analysis

Figure 4.1 shows Hancock County land cover classes in 1975. The marsh area is present along the southwest coast of the county and in the St Louis Bay area. Developed land appears to be located in Bay St Louis, and the area north of I-10 in the form of small patches. The State Road 607 and Highway 90 are also visible as developed area south of I-10. The bad data values are shown in grey and appear as diagonal lines through the other land cover classes.

Figure 4.2 shows Hancock County land cover classes in 1980. In 1980, the marsh area appears to be less around the Pearl River watershed than in 1975. Land previously classified as vegetation in 1975 was classified as developed in the 1980 map. Developed land cover appears to cover more area than the 1975 image especially in Bay St Louis, Waveland and northern part of the county, east of Highway 53. Stennis Space Center also appears to be more developed in 1980 than in 1975. Bare soil appears to around boundaries of the developed areas in the northern section of the county as well as within the marshes of Waveland and with the entrance to Diamondhead.

The 1985 land cover classification map of Hancock County is shown in Figure 4.3. Developed land cover in the northern section of Hancock County appears to have increased from 1980 to 1985. Some of the land cover south of I-10 in Waveland and in Diamondhead classified as developed land in 1980 was classified as bare soil in the 1985 map. This change in classification could mean that the developed land was converted to bare soil from 1980 to 1985.

Figure 4.4 shows Hancock County land cover classes in 1990. Developed areas in the northern section of the county appear to have been converted to the vegetation cover class from 1985 to 1990. Also, there does not appear to be as much bare soil classified around developed cover area in Bay St Louis and Waveland area. Vegetation land cover class appears to have increased along the central section of the county during the period from 1985 to 1990.

Figure 4.5 shows Hancock County land cover classes in 1995. When comparing the 1995 land cover classification map to the 1985 and 1990 maps, the developed area appears to have increased along the central section of the county near Highway 603 and Highway 53. Waveland also appears to have more developed land cover than vegetation land cover from 1990 to 1995.

Figure 4.6 shows Hancock County land cover classes in 2000. Developed area seems to be expanded from the same locations around the entire county. Bare soil land cover also seems to be co-located with the developed land cover class throughout most of the county. Vegetation land cover seems to have decreased throughout the entire county as well from the period 1995 to 2000.

Figure 4.7 shows a second land cover classification of Hancock County performed on two additional images from 2000 during a different time of year from the first classification. This second analysis was conducted to show the difference between land cover classifications conducted on images within the same year in an attempt to capture land cover variability within the same year. The second land cover classification (Figure 4.12) appears to have slightly more vegetation/less developed land cover than the first classification (4.11).

Figure 4.8 shows Hancock County land cover classes in 2005. Overall there appears to be more vegetation land than in the 2000 image within the central section of the county east of Stennis Space Center. Developed area appears to increase at the very northern boundary of Hancock County from 2000 to 2005. The developed area in Diamondhead (north of the St Louis Bay area) also appeared to grow from 2000 to 2005.

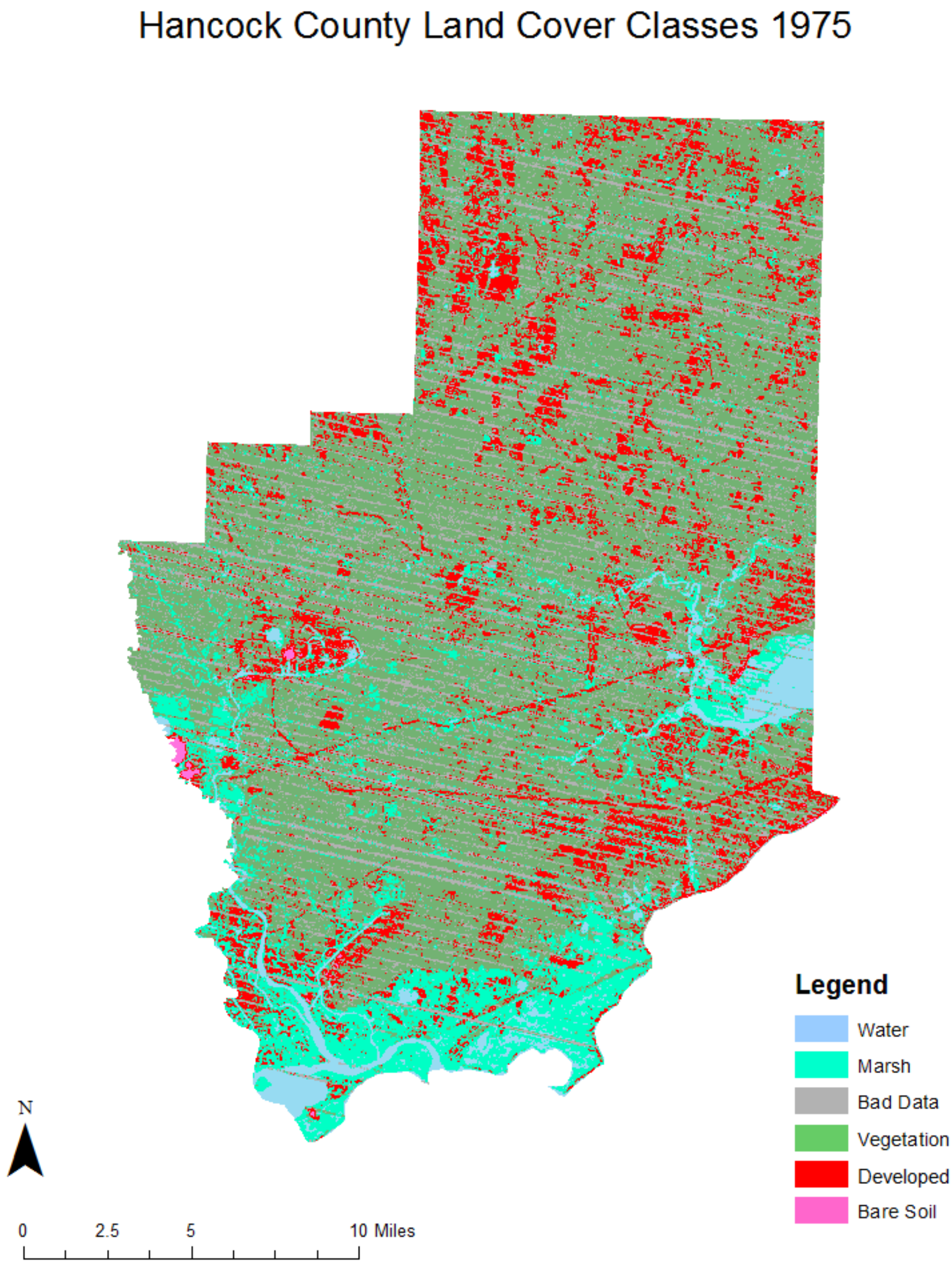

Figure 4.1: Land cover classification map of Hancock County (1975)

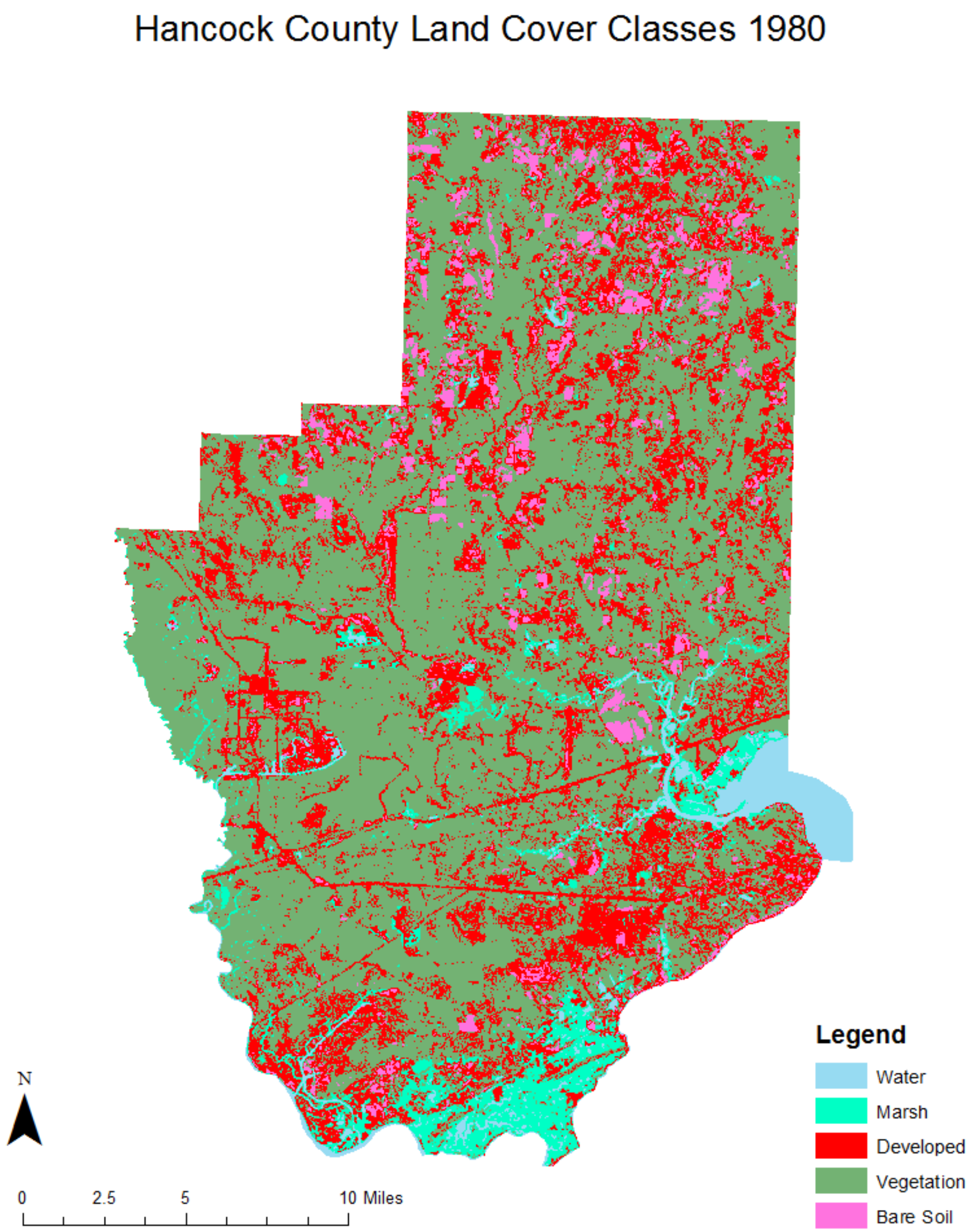

Figure 4.2: Land cover classification map of Hancock County (1980)

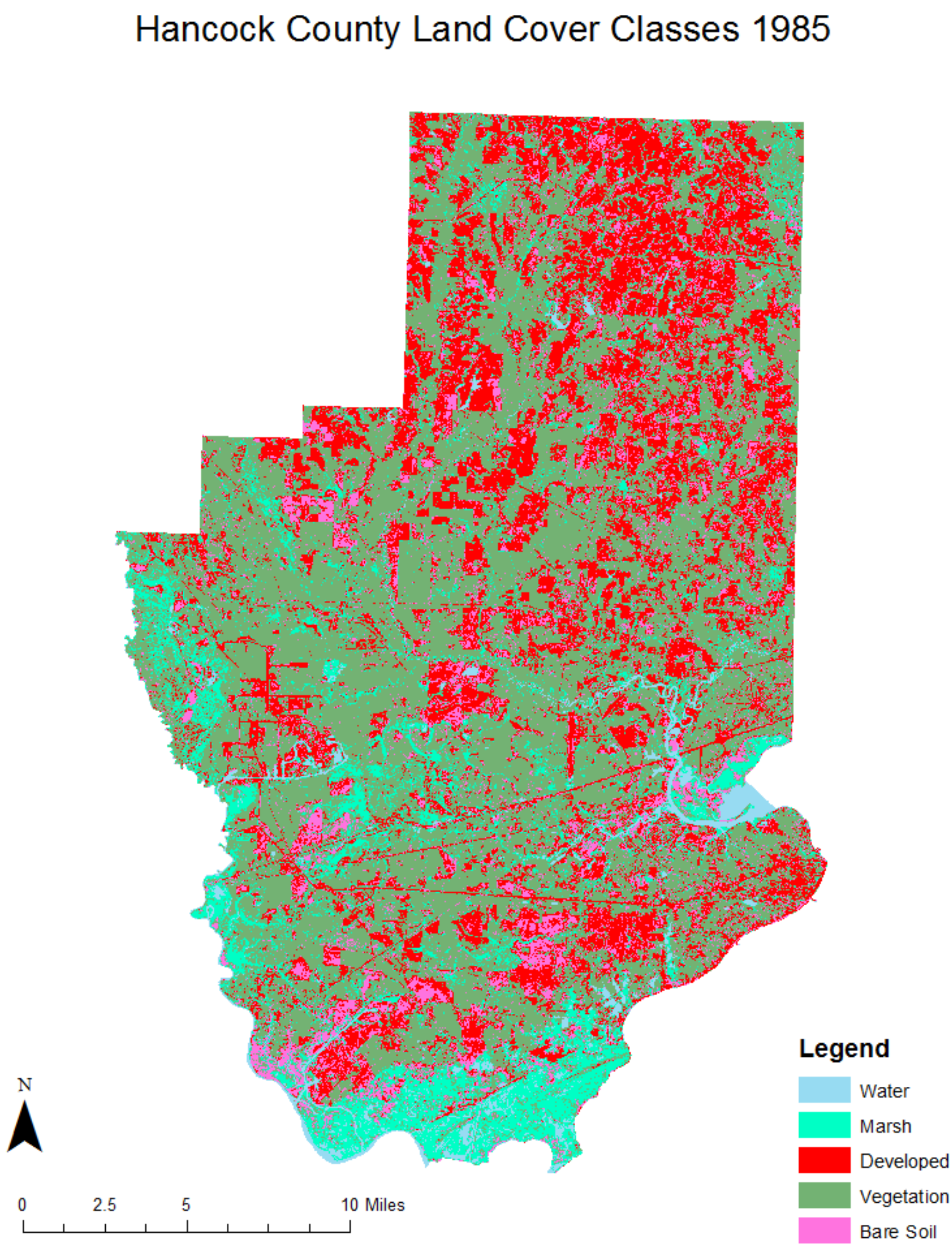

Figure 4.3: Land cover classification map of Hancock County (1985)

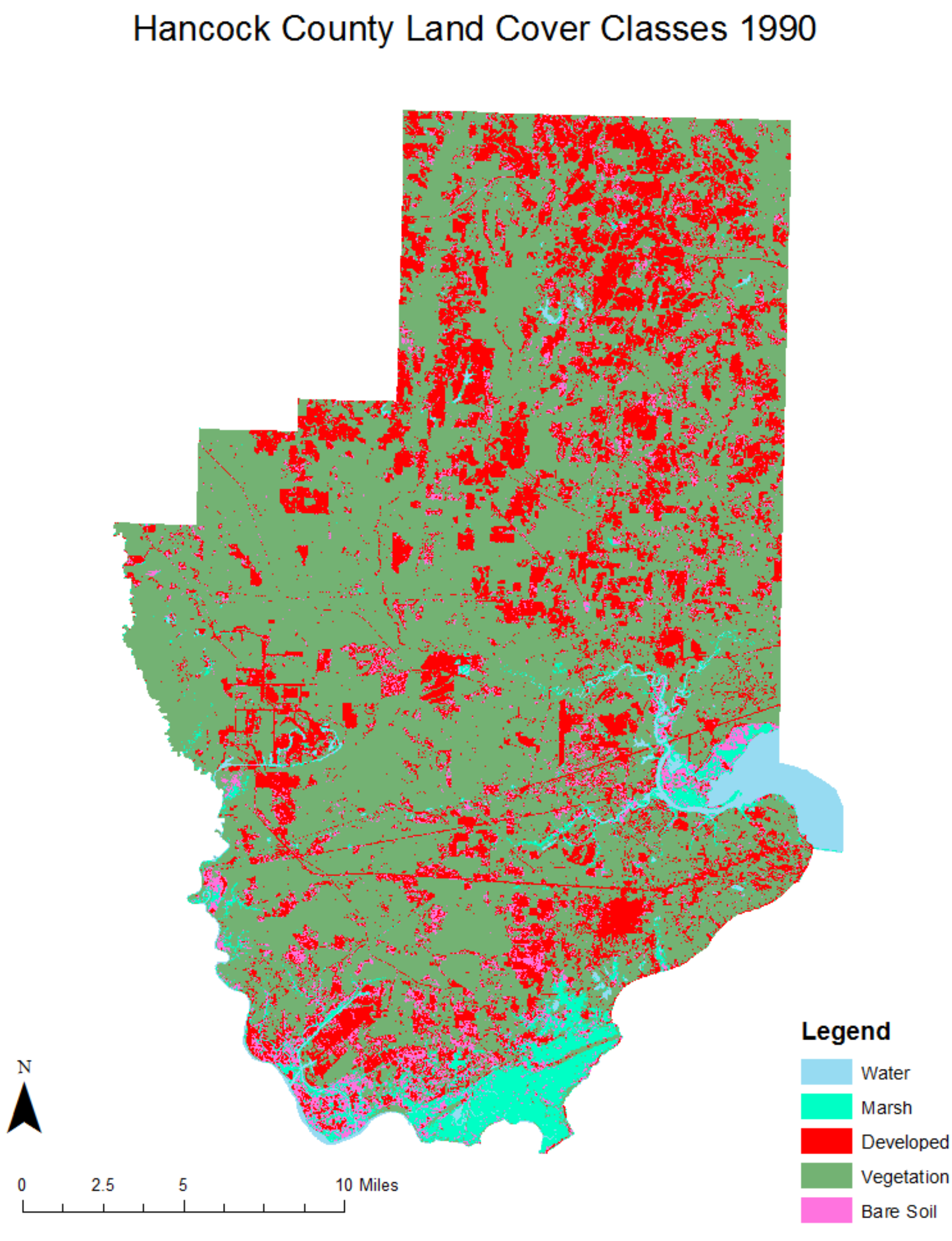

Figure 4.4: Land cover classification map of Hancock County (1990)

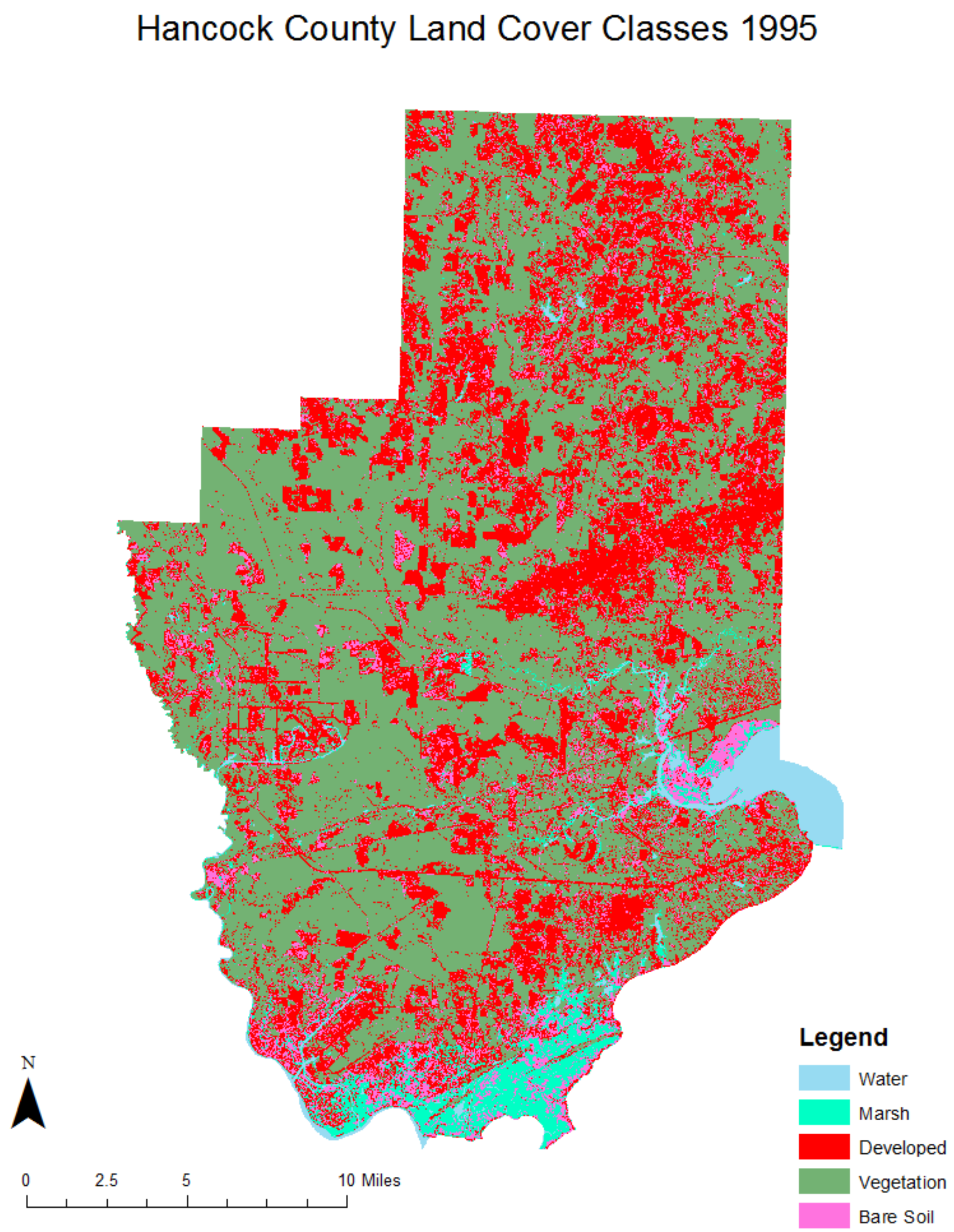

Figure 4.5: Land cover classification map of Hancock County (1995)

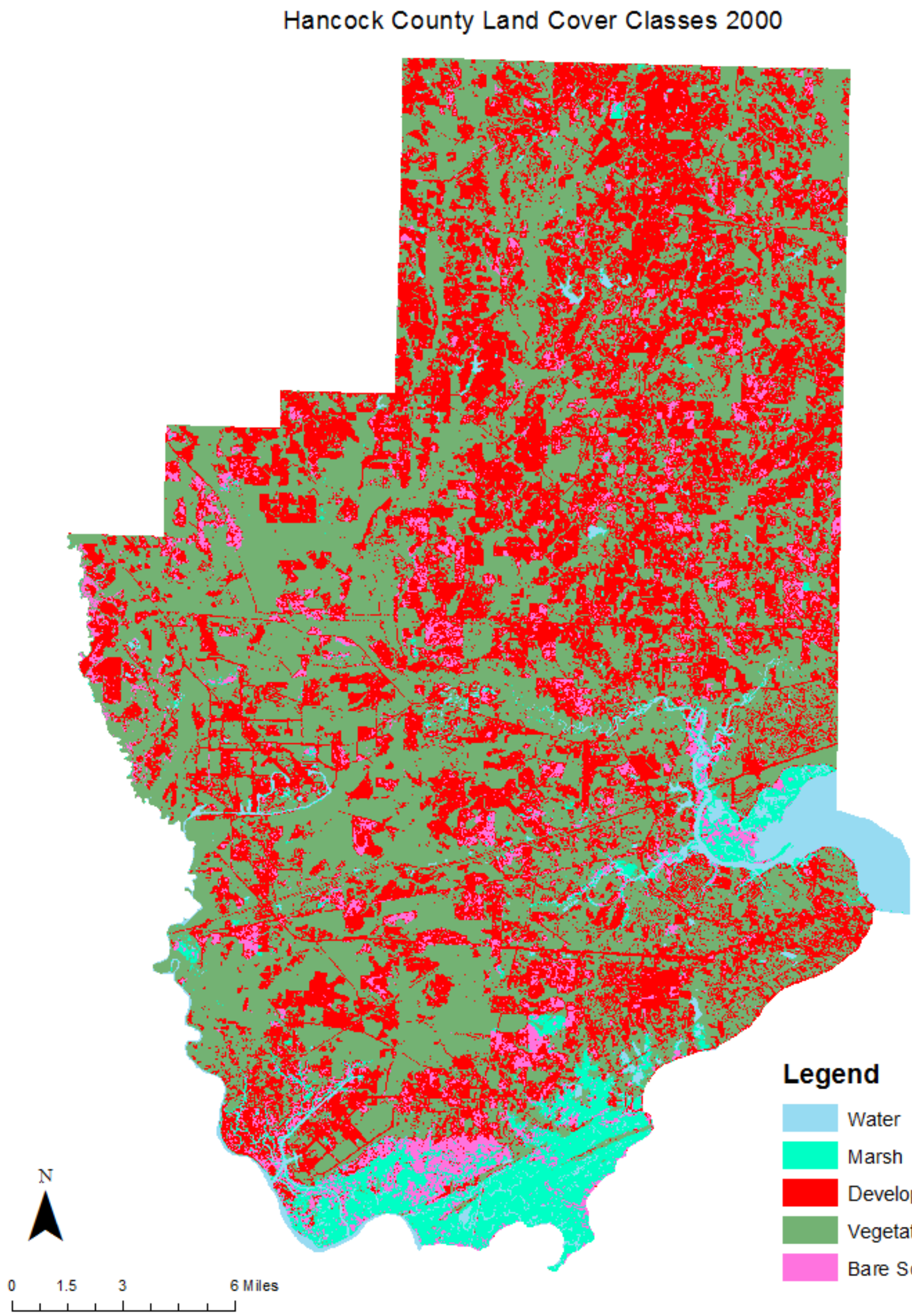

Figure 4.6: Land cover classification map of Hancock County (2000) (1st Classification)

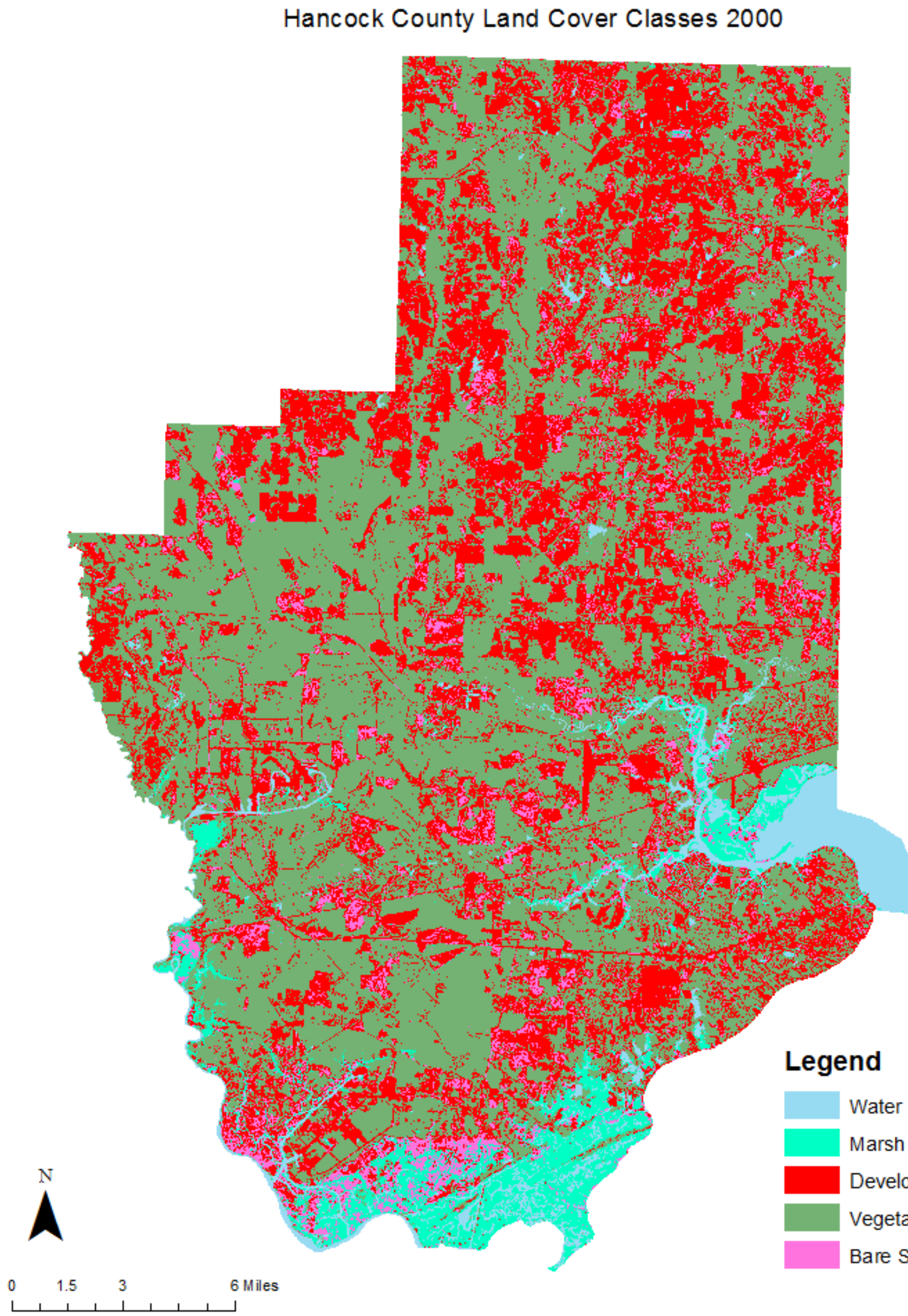

Figure 4.7: Land cover classification map of Hancock County (2000) (2nd Classification)

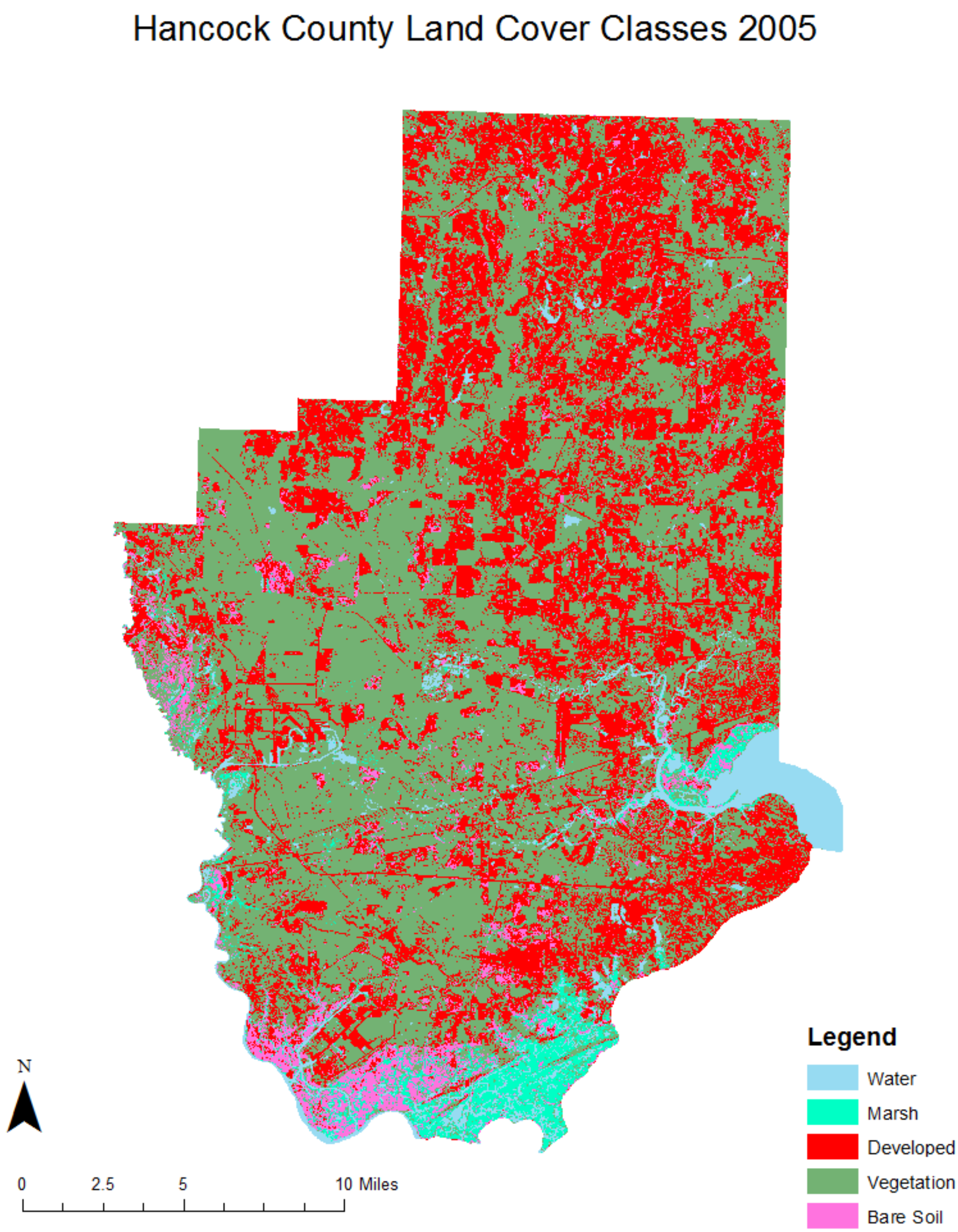

Figure 4.8: Land cover classification map of Hancock County (2005)

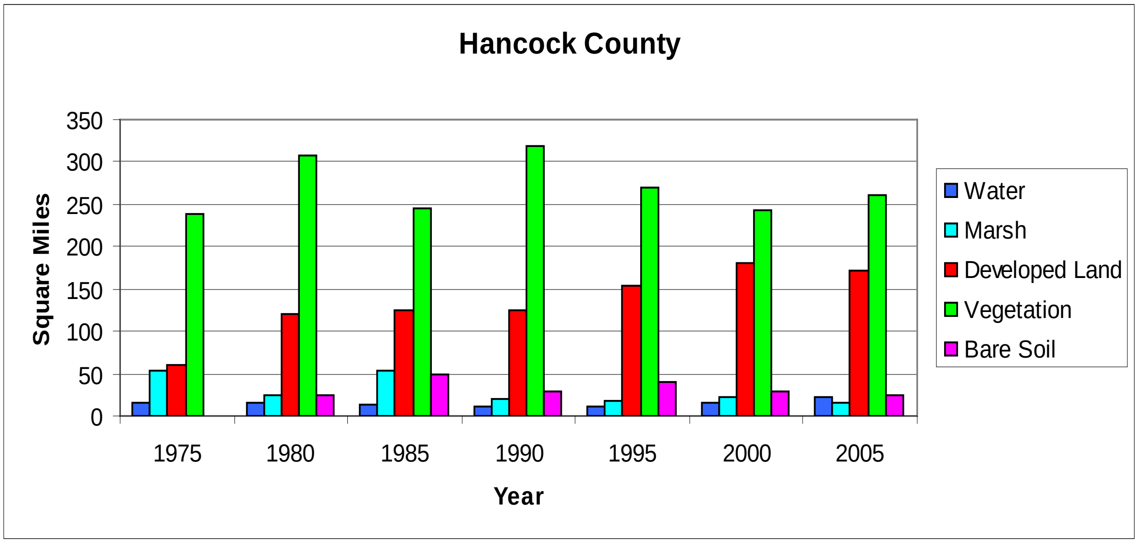

Figure 4.9: Area of each land cover classes in Hancock County (1975 to 2005)

Figure 4.9 shows the area of each land cover class from 1975 to 2005 in Hancock County. The land cover class with the most area for the entire time period is vegetation, followed by developed area. There was more marsh land cover than bare soil earlier in this time period (1980 and 1985) than 1995 through 2005.

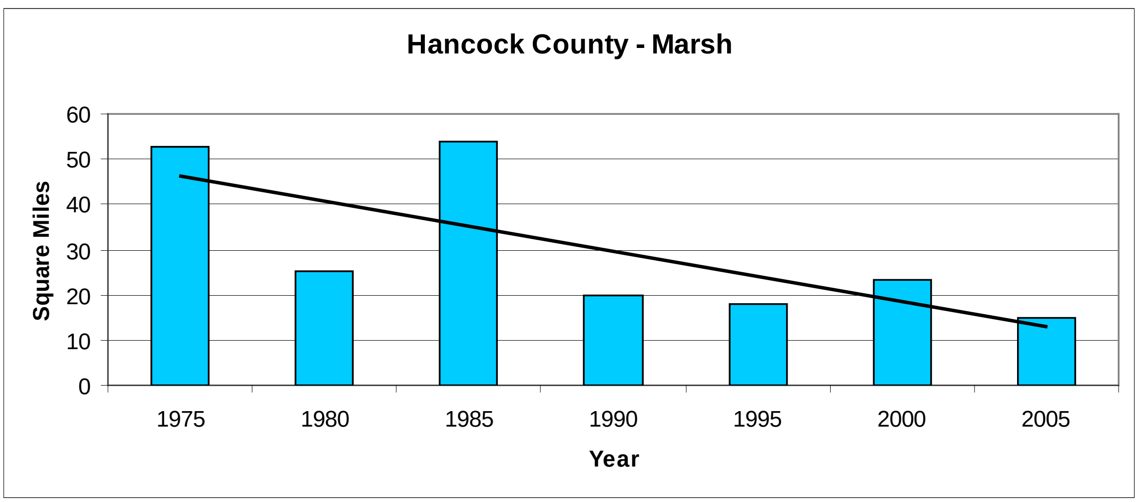

Figure 4.10: Area of marsh land cover in Hancock County (1975 to 2005)

Figure 4.10 shows that the decreasing trend of marsh land in Hancock County during the period from 1975 to 2005. In two years, 1975 and 1985, there appears to over twice the area (~52 and ~53 mi^2) of marsh land than during the rest of the study period (~14 mi^2 in 2005). The marsh land area decreases by almost half from 1975 to 1980 and then doubled from 1985 to 1990. As mentioned in the previous paragraph, the marsh land was used for developments along the Gulf Coast, especially Waveland; therefore it was most likely converted to bare soil. This trend may also be due to the water level may also be lower in the 1975 and 1985 images (more marsh exposed) than the 1980 image (less marsh exposed).

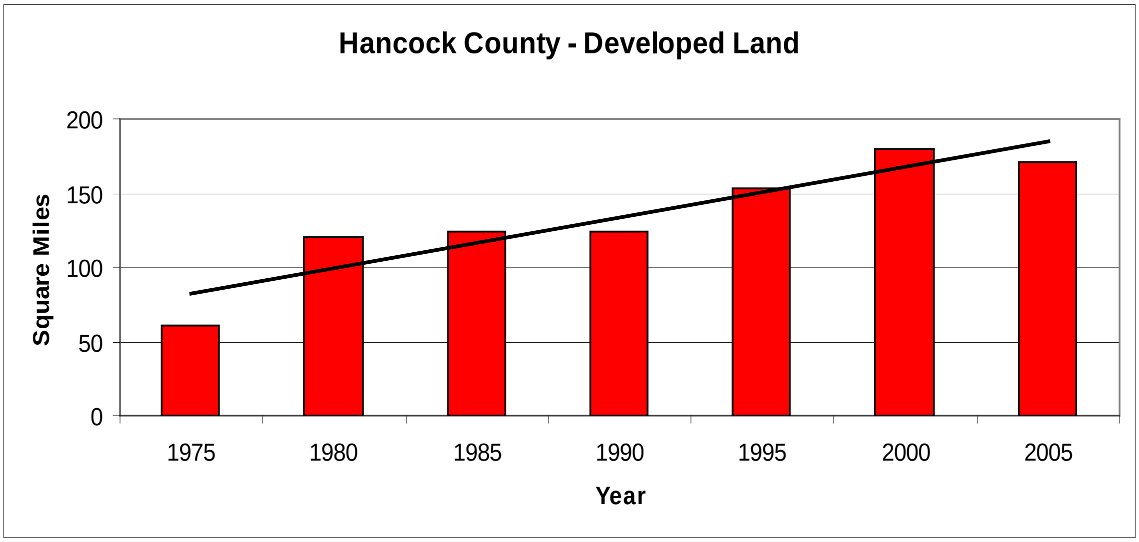

Figure 4.11: Area of developed land cover in Hancock County (1975 to 2005)

Figure 4.11 shows that from 1975 to 2005, the general trend of developed land cover is an increase in Hancock County. In 1975, there was 61 mi^2 of developed land cover and then within five years the amount of developed area increased to 120 mi^2. The time period from 1990 to 1995, also showed a dramatic increase in developed area (about 30 mi^2); however there was a decrease of ~10 mi^2 in developed area from 2000 to 2005.

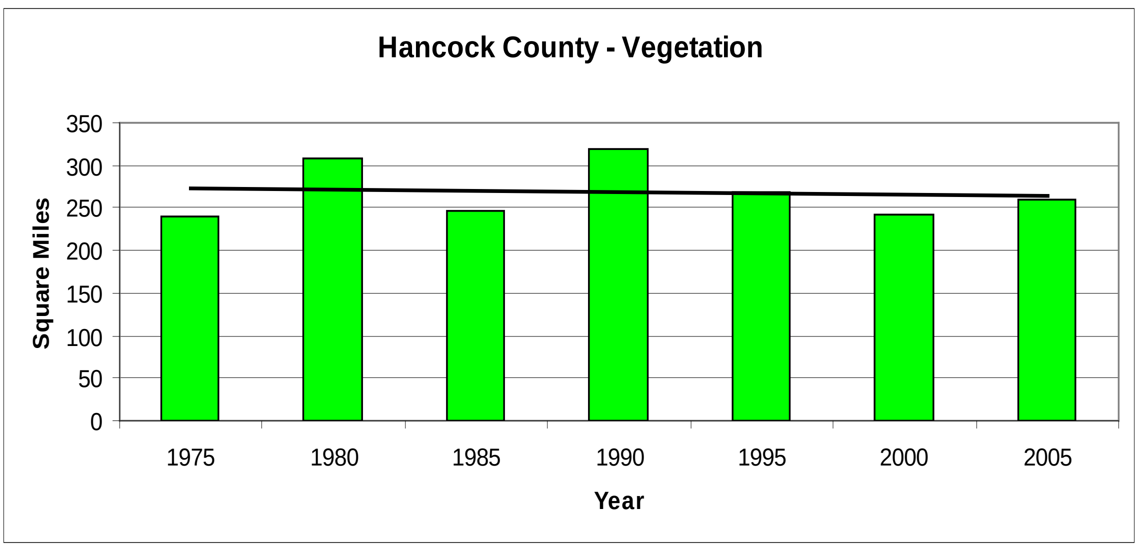

Figure 4.12: Area of vegetation land cover in Hancock County (1975 to 2005)

Figure 4.12 shows an overall trend of a slight decrease in the square miles of vegetation land cover class in Hancock County from 1975 to 2005. The vegetation land cover fluctuated every five years with an increase of vegetation on the order of 60 mi^2 in 1975 followed by a decrease of 50 mi^2 in 1980. Then vegetation decreased from1980 to 1985 by 60 mi^2 only to increase by 70 mi^2 from1985 to 1990. From 1990 to 2000, vegetation decreased and then an increase of vegetation was recorded from 2000 to 2005 (17 mi^2).

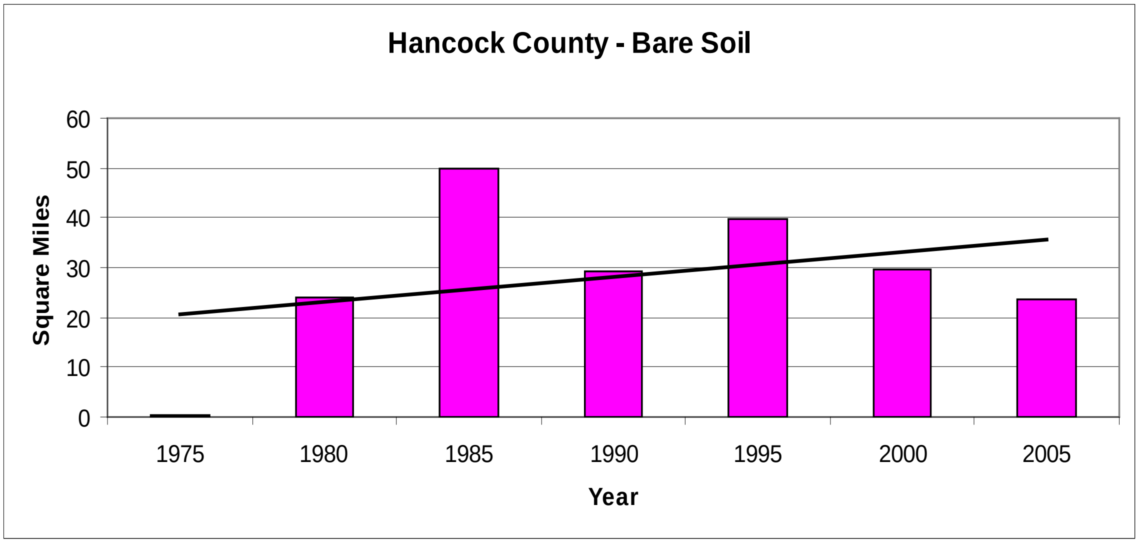

Figure 4.13: Area of bare soil cover in Hancock County (1975 to 2005)

Figure 4.13 shows an overall trend of an increase in the square miles of bare soil land cover class in Hancock County from 1975 to 2005 mi^2. The area covered by bare soil in 1975 is not representative of what was probably actually present because the image had bad data values due to a bad scan line. The BV of bare soil were the same as some of the bad data BV; therefore the BV that would have been classified as bare soil in an image without bad data was classified as bad data. A dramatic gain of 25 mi^2 of bare soil was observed from 1980 to 1985 then a loss of about 20 $mi^{2\ of}$ bare soil was observed in 1990. After 1990, gains and losses of 10 mi^2 in bare soil were present from 1990 to 1995 and then from 1995 to 2000. Approximately seven mi^2 of bare soil was lost from 2000 to 2005.

4.2 Harrison County Land Cover Analysis

Figure 4.14 shows land cover classes of Harrison County in 1975. Both major interstates in this county are visible in this classification map, I-10 (east-west) and Highway 49 (north-south). Most of the developed area associated with this county seems to be located around the coastal area, south of 1-10 along Highway 90 (also known as Beach Blvd). The marsh land was found to be located around St Louis Bay and Big Lake. Bad data values were assigned a grey color and can be seen as vertical stripes through the map.

Figure 4.15 shows land cover classes of Harrison County in 1980. As seen in the previous map, I-10 and Highway 49 are visible; however in this image, Highway 15 is now visible on the eastern side of the county running north-south. More developed and bare soil land cover types are observed in the 1980 image. The developed area along the coast seems to have grown and also filled in with bare soil. A cluster of developed area also appears in Saucier along Highway 49. Vegetation land cover seems to decrease because of an increase in developed and bare soil land cover. Figure 4.16 shows land cover classes of Harrison County in 1986. This classification map looks very similar to the 1980 classification map with very little differences in the location of developed and vegetation land covers.

Figure 4.17 shows land cover classes of Harrison County in 1990. The developed land cover along the coast remains about the same while most of the change appears in the northern section of the county. Developed area around Saucier appears to have been converted to vegetation while area in the northwest corner appears to be more developed. This area is most likely used for agriculture versus traditional developed area with homes and business buildings. The developed land cover doesn't appear to have straight lines that are a feature of man-made structures.

Figure 4.18 shows land cover classes of Harrison County in 1995. Developed and bare soil land cover area seems to have decreased from 1990. More vegetation land cover is present where land was previously classified as developed land. Highway 15 seems to have disappeared and changed to vegetation in some areas of the northern portion of the route.

Figure 4.19 shows land cover classes of Harrison County in 2000. More developed and bare soil land cover appears in this image than the 1995 image. Most of the developed area appears in the lower half of the county, along the coast and north to the middle of the map. Bare soil land cover was found to be attached to developed land cover area with a large cluster around the Gulfport Airport and Naval Seabee Base. Also, marsh land cover appears to be located throughout the county's small water bodies in the northeast section of the county; however the majority of the northeast section of the county still appears to be composed of mostly vegetation.

Figure 4.20 shows the second land cover classification maps shows of Harrison County conducted on second set of imagery from 2000. This second analysis was conducted to show the difference between land cover classifications conducted on images within the same year in an attempt to capture land cover variability within the same year. The second land cover classification (Figure 4.20) appears to have slightly more bare soil land cover that was classified as developed land cover in the first classification (Figure 4.19).

Figure 4.21 shows land cover classes of Harrison County in 2005. The amount of developed area in this map appears to be unchanged from 2000. The marsh area seems to have increased in areas formerly classified as vegetation located in the northwest section of the county in the 2000 map. Areas classified as bare soil in the first classification of 2000 imagery appears to be classified as developed land cover in the 2005 map, such as the Gulfport Airport and Naval Seabee Base.

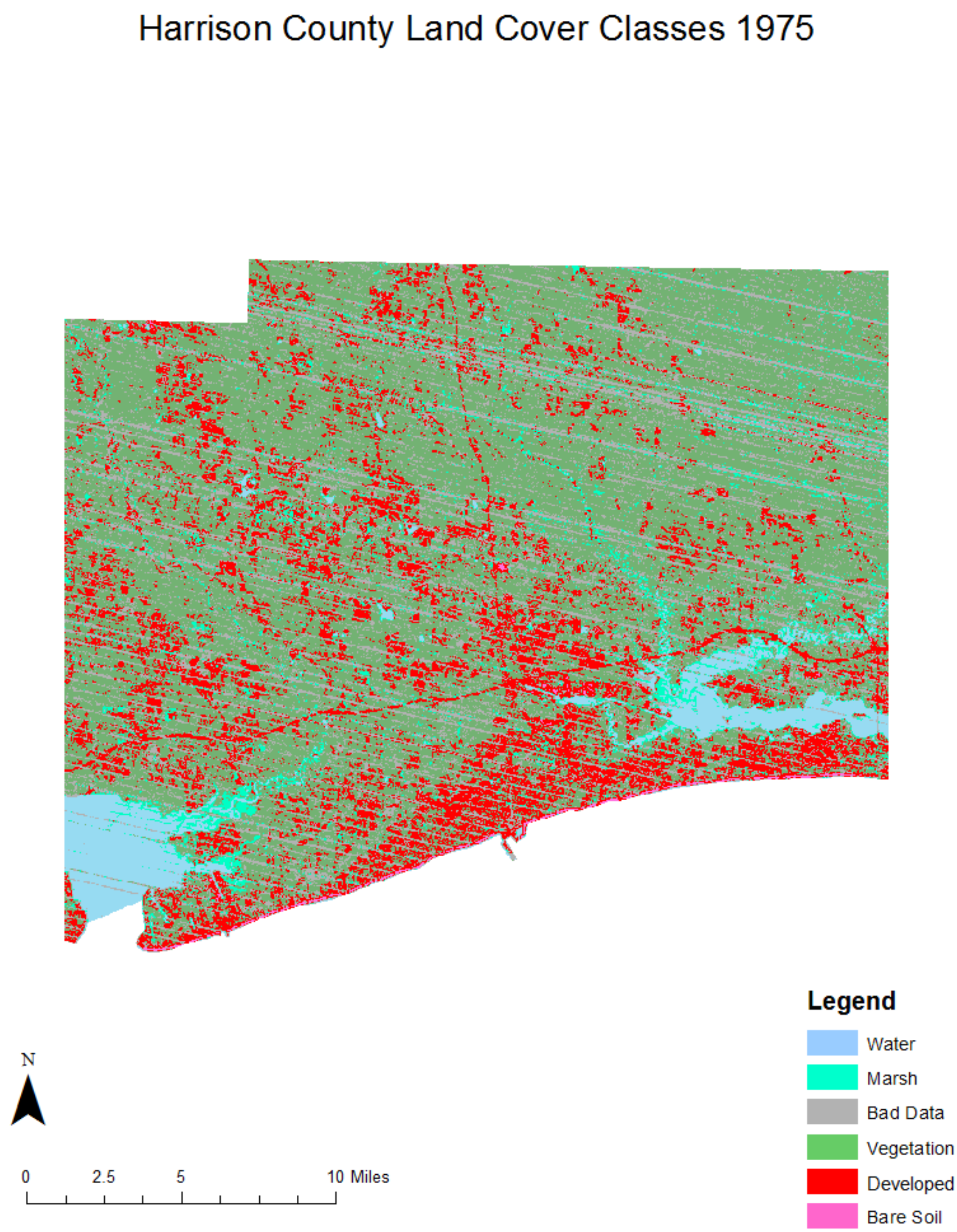

Figure 4.14: Land cover classification map of Harrison County (1975)

Harrison County Land Cover Classes 1980

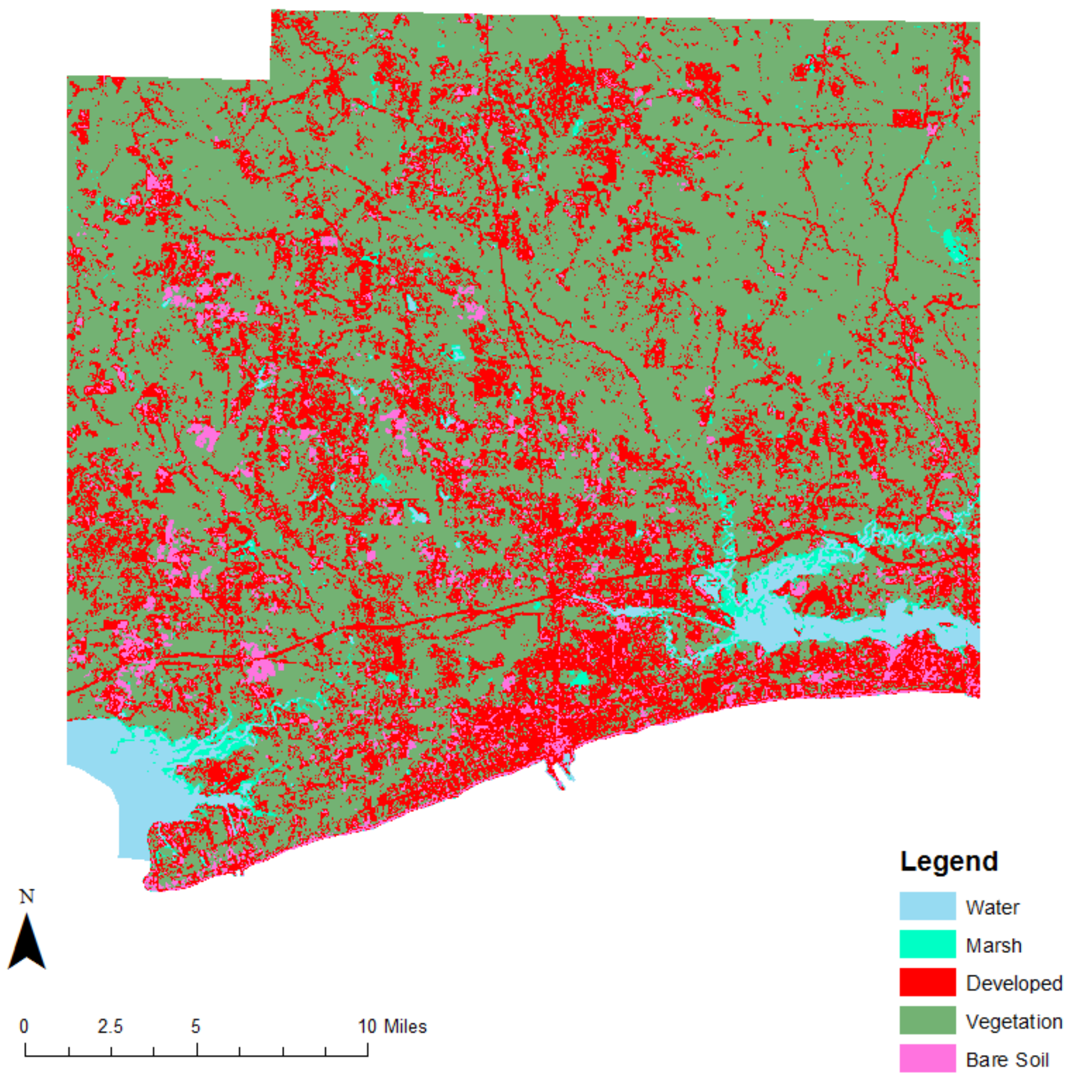

Figure 4.15: Land cover classification map of Harrison County (1980)

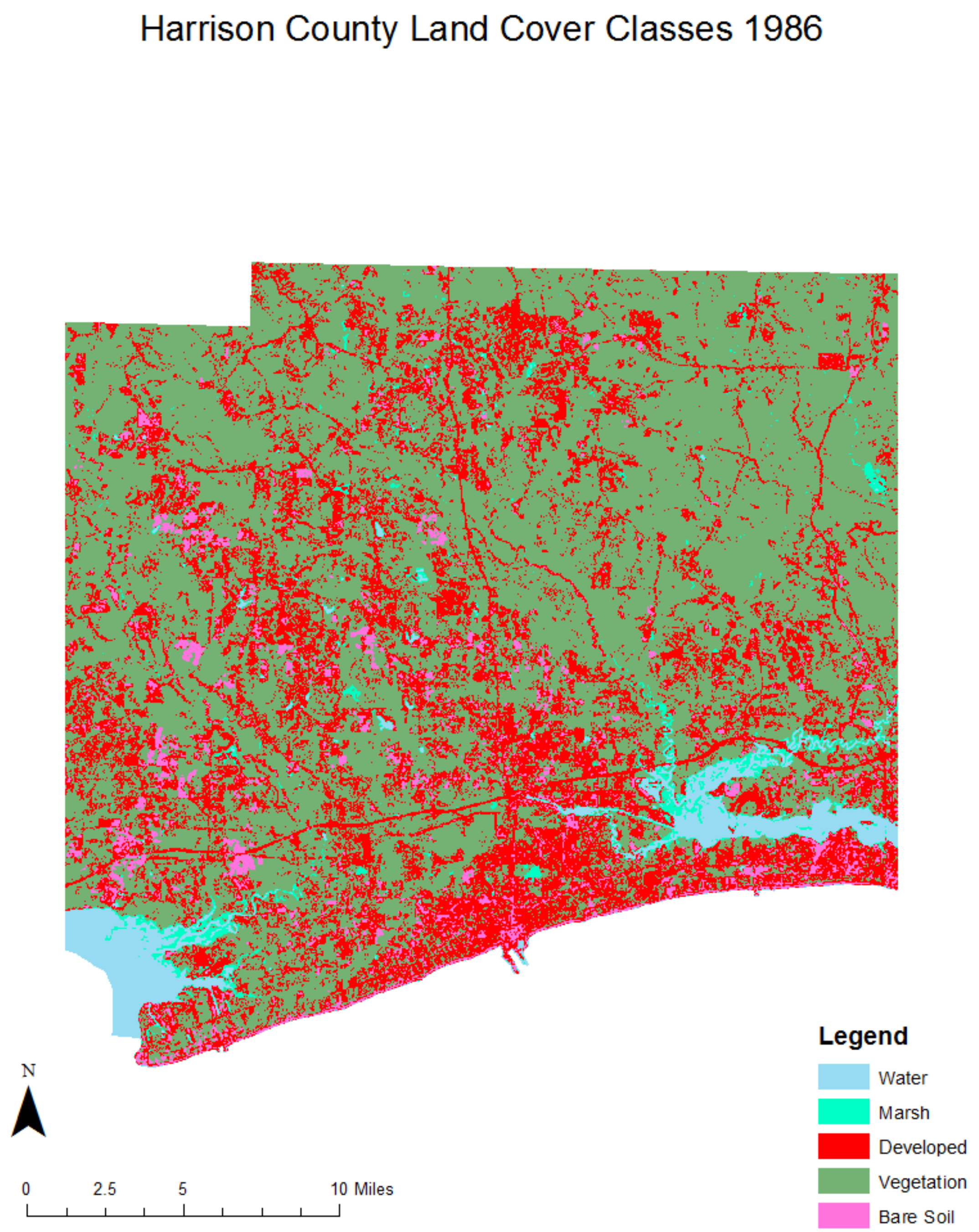

Figure 4.16: Land cover classification map of Harrison County (1986)

Harrison County Land Cover Classes 1990

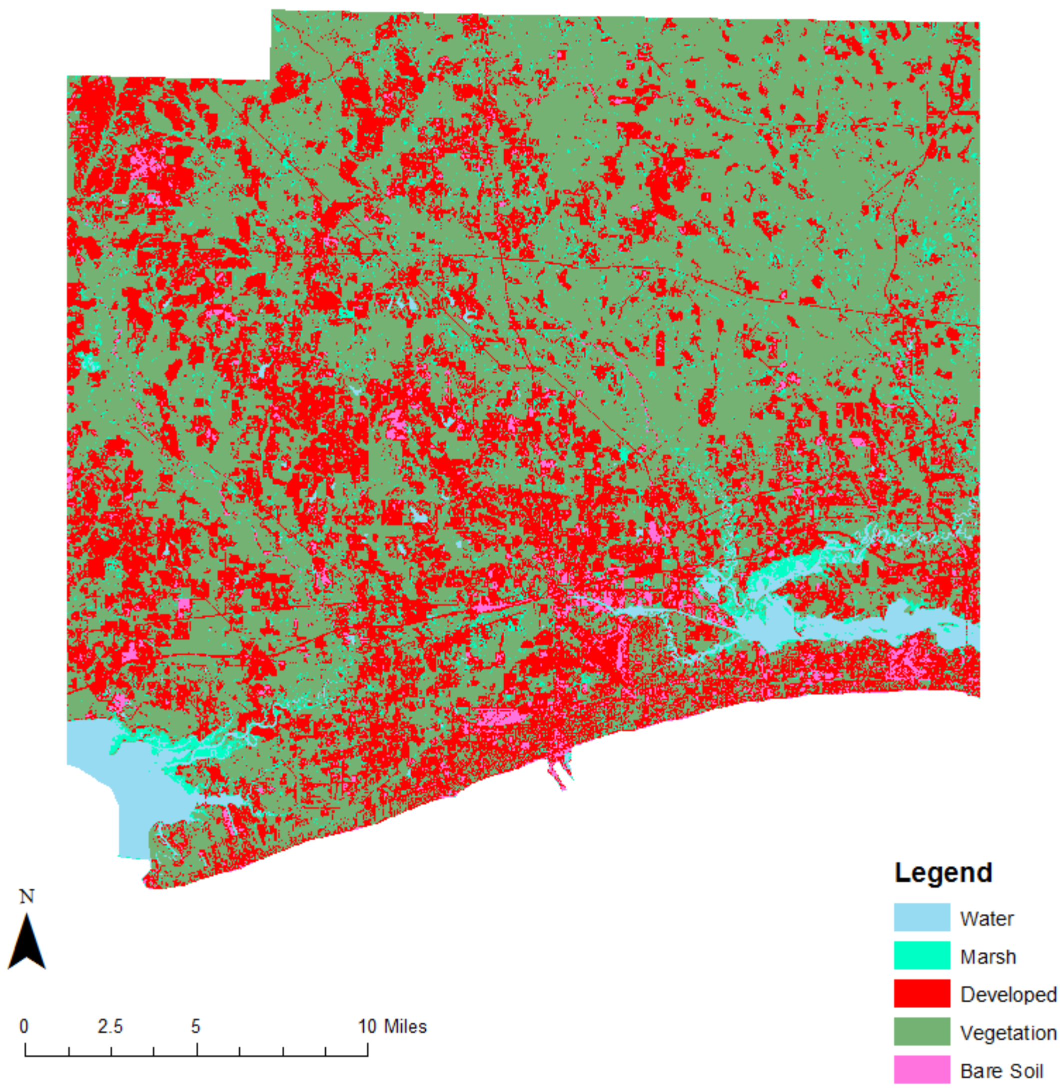

Figure 4.17: Land cover classification map of Harrison County (1990)

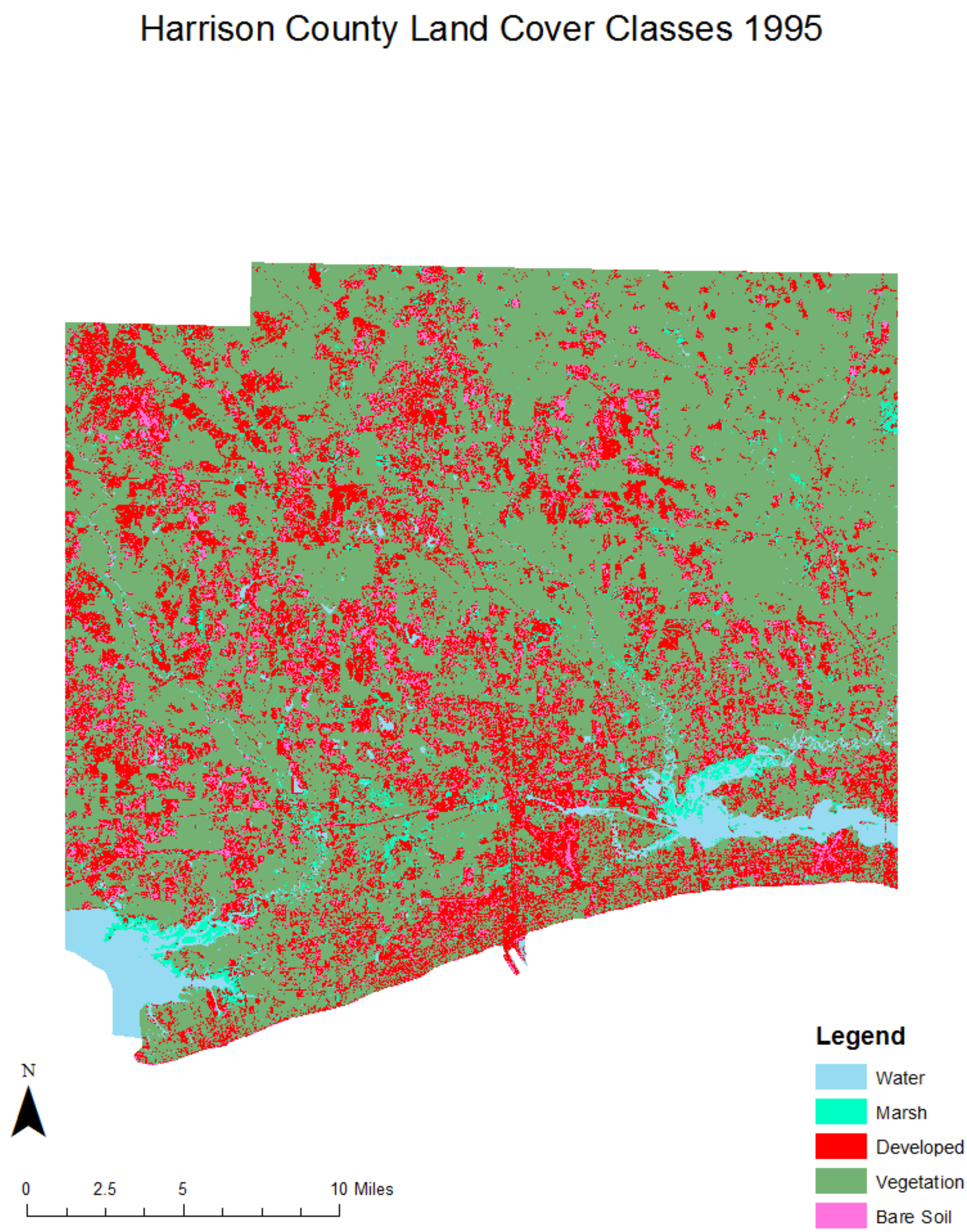

Figure 4.18: Land cover classification map of Harrison County (1995)

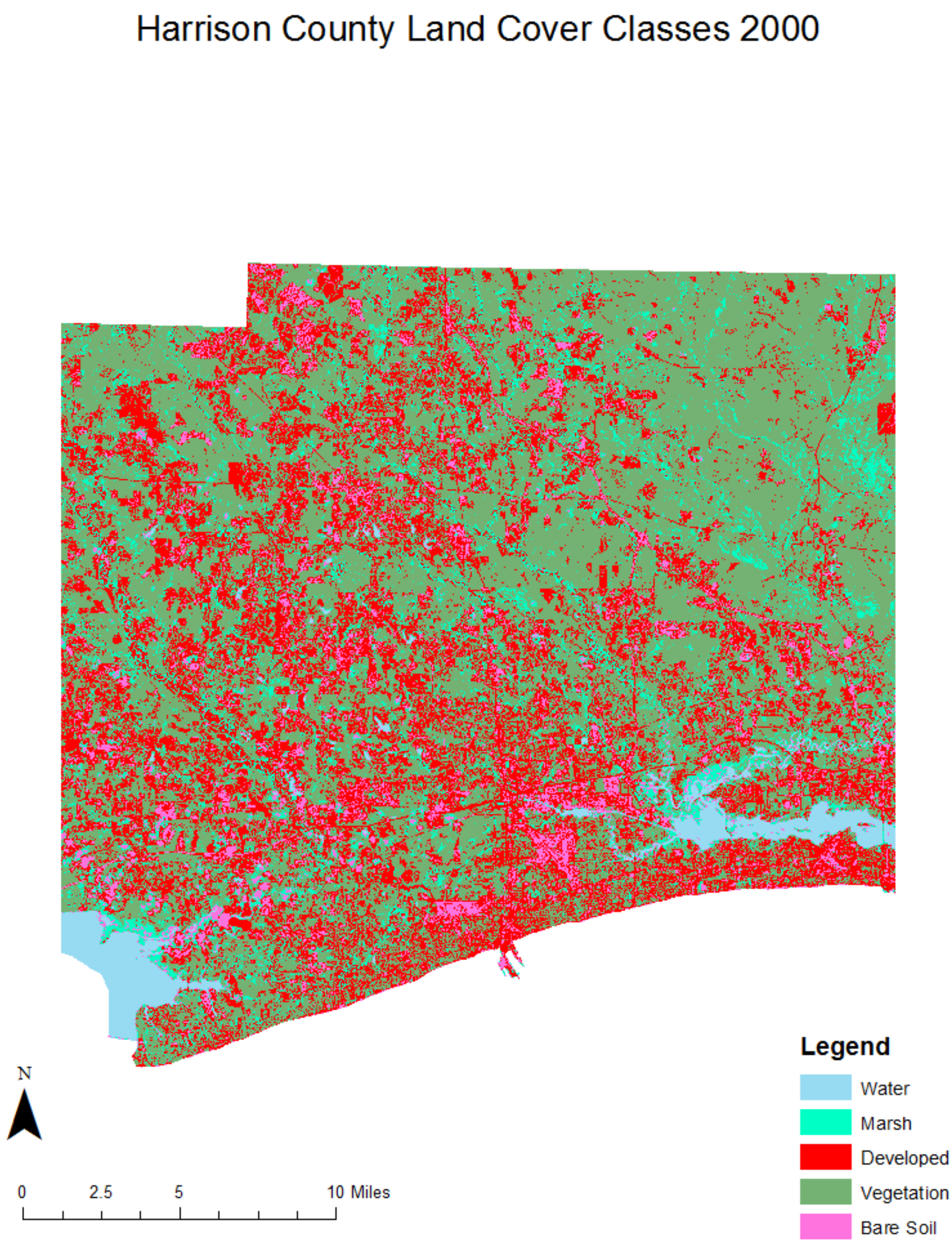

Figure 4.19: Land cover classification map of Harrison County (2000) (1st Classification)

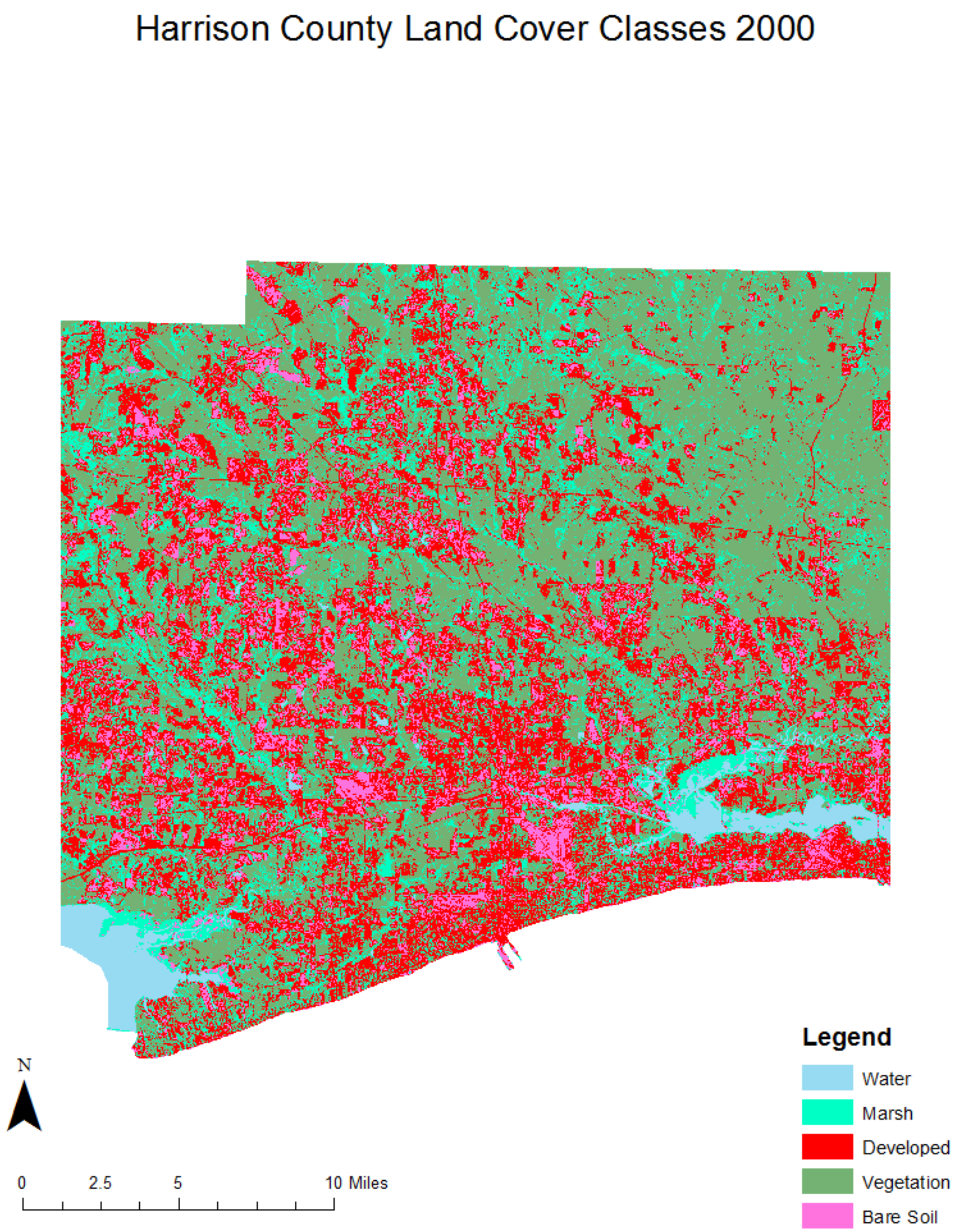

Figure 4.20: Land cover classification map of Harrison County (2000) (2nd Classification)

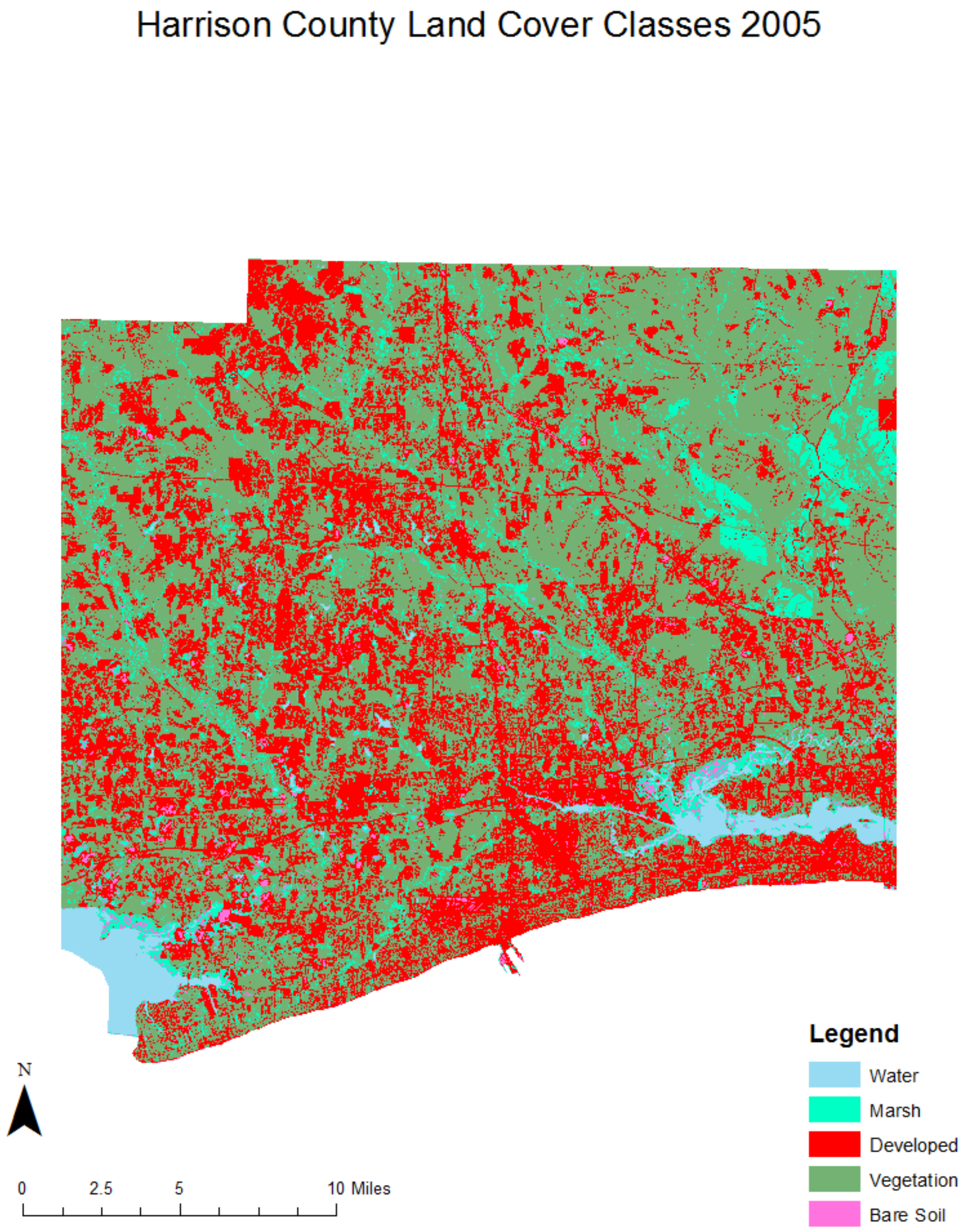

Figure 4.21: Land cover classification map of Harrison County (2005)

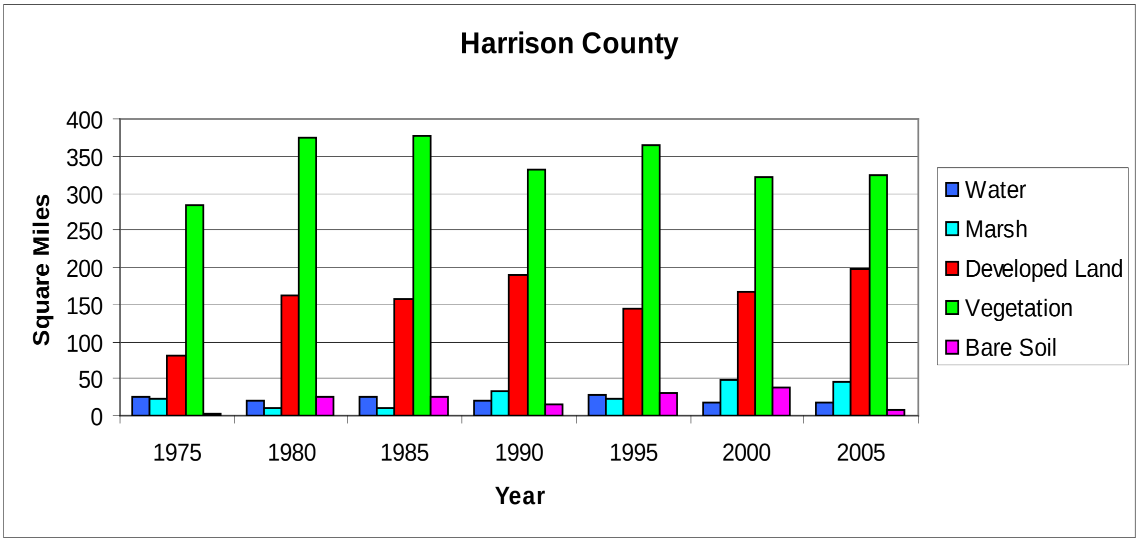

Figure 4.22: Area of each land cover classes in Harrison County (1975 to 2005)

Figure 4.22 shows the area of each land cover class from 1975 to 2005 in Harrison County. Similar to Hancock County, the land cover class with the most area for the entire time period is vegetation, followed by developed area. However, unlike Hancock County, there was less marsh than bare soil in 1980 and 1985 and then more marsh than bare soil in 2000 and 2005.

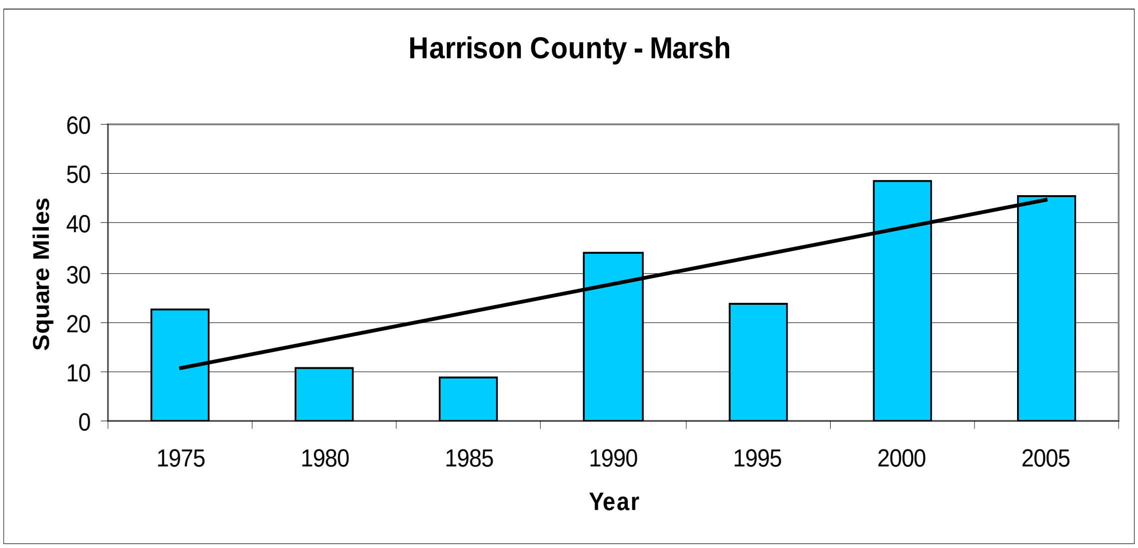

Figure 4.23: Area of each marsh land cover in Harrison County (1975 to 2005)

Figure 4.23 shows the area of marsh land cover from 1975 to 2005 in Harrison County. Overall there was a general increase in marsh land cover from 22 mi^2 in 1975 to 45 mi^2 in 2005. During the period from 1975 to 1985, marsh area decreased to only 8 mi^2. However, a dramatic increase was recorded in 1990 (33 mi^2). The total area fluctuated with a loss of about 10 mi^2 in 1995 and a gain of 25 mi^2 in 2000. From 2000 to 2005, a loss of 3 mi^2 was calculated in 2005.

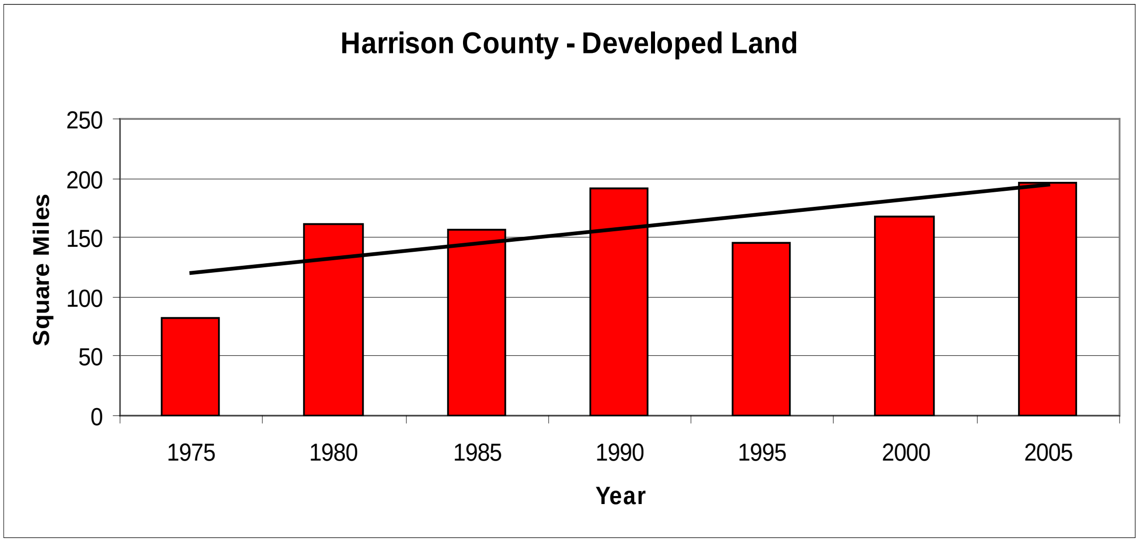

Figure 4.24: Area of each developed land cover in Harrison County (1975 to 2005)

Figure 4.24 shows the area of developed land cover from 1975 to 2005 in Harrison County. In 1975, 81 mi^2 of Harrison County was classified as developed land whereas in 2005, 196 mi^2 was classified as developed in 2005. Within this thirty year span, developed area nearly doubled from 1975 (81 mi^2) to 1980 (160 mi^2) and then decreased slightly to 157 mi^2 in 1985. A gain of 33 mi^2 was calculated from1985 to 1990. Then another loss of about 45 mi^2 from 1990 to 1995 was calculated. A gradual increase of developed land cover was recorded from 1995 to 2005.

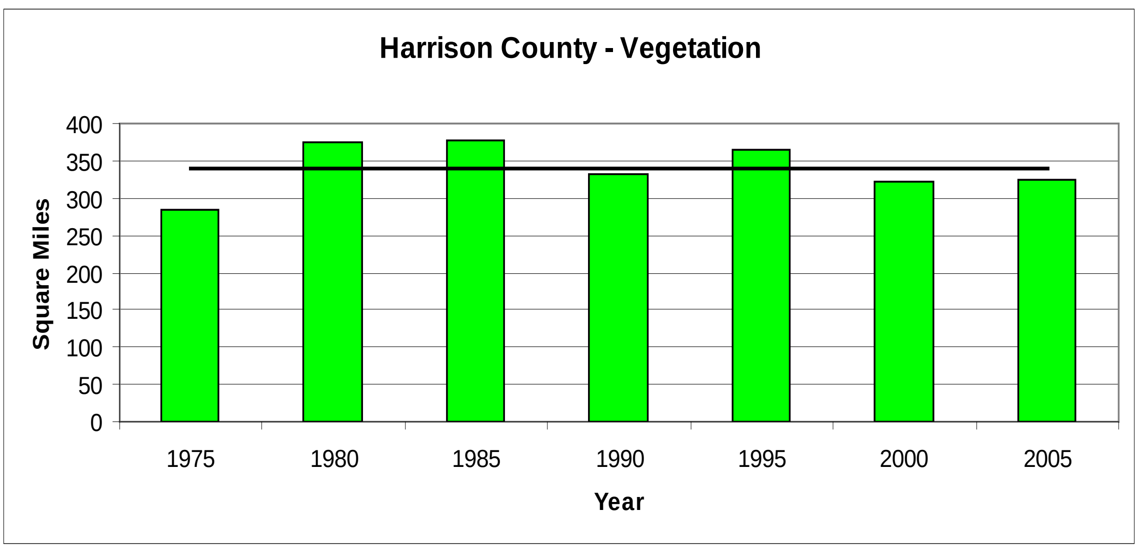

Figure 4.25: Area of each vegetation land cover in Harrison County (1975 to 2005)

Figure 4.25 shows the area of vegetation land cover from 1975 to 2005 in Harrison County. There was no overall trend of an increase or a decrease in vegetation over the thirty year time period; instead vegetation seemed to vary every five years. The greatest increase of 92 mi^2 in vegetation land cover was recorded from 1975 to 1980. There was a decrease of about 43 mi^2 in vegetation land cover from 1985 to 1990

followed by an increase of 33 mi^2 in 1995. A decrease of 44 mi^2 was recorded from 1995 to 2000. In 2005, a slight increase of about 3 mi^2 in vegetation land cover from 2000 to 2005.

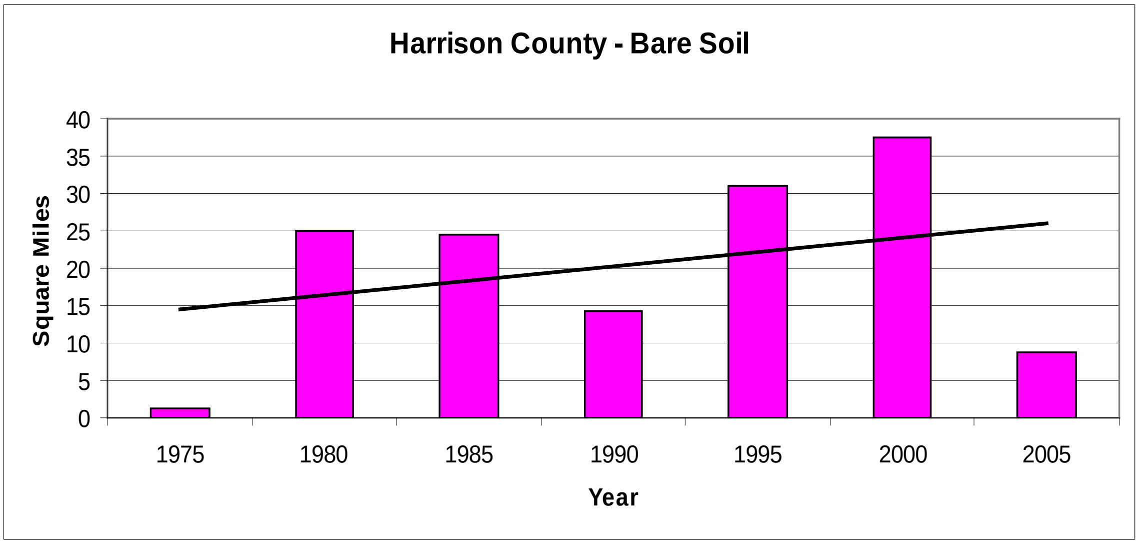

Figure 4.26: Area of each bare soil land cover in Harrison County (1975 to 2005)

Figure 4.26 shows the area of bare soil land cover from 1975 to 2005 in Harrison County. An overall trend of an increase was observed from 1975 to 2005. The 1975 bare soil land cover area is probably not a representative value of what was actually present because of the bad data present in the imagery. The area of bare soil land cover didn’t seem to change from 1980 to 1985; however this trend was followed by a decrease of 10 mi^2 of bare soil in 1990. An increase of 17 mi^2 was observed from 1990 to 1995 (14 and 31 mi^2 respectively). Another increase of 6 mi^2 was calculated from 1995 to 2000. A dramatic decrease of bare soil was observed from 2000 to 2005 with 29 mi^2 of bare soil lost over five years.

4.3 Jackson County Land Cover Analysis

Figure 4.27 shows the land cover classes in 1975 of Jackson County. The center of the county starting in Pascagoula Bay and north to the top of the county is made up of mostly marsh and vegetation land cover. Developed areas are mostly concentrated around Biloxi, Ocean Springs, Pascagoula and Moss Point. U.S. Highway 90 and Interstate 10 are visible as developed features in this image as well. On the west side of the marsh land, mostly vegetation land cover is observed while east of the marsh land, more developed land is visible. This developed land is most likely agricultural area because it lacks the linear appearance typically associated with man-made features. Some bare soil exists west of the marsh land east of Pascagoula.

Figure 4.28 shows the land cover classes in 1980 of Jackson County. Developed land cover appears to have increased on the east side of the marsh that divides the county. As stated previously, this is type of development is land cleared for agricultural area. Also, some of the land previously classified as vegetation in 1975 in Pascagoula and Moss Point seems to have patches of developed land cover in 1980. Ocean Springs also appears to have grown showing slightly increased developed area.

Figure 4.29 shows the land cover classes in 1986 of Jackson County. The amount of each land cover type in this map looks similar to the 1980 map; however some of the area classified as developed area in the 1980 map was classified as bare soil in the 1986 map. The BV for developed and bare soil are very close and these two classes are found to be co-located throughout the entire county. Also, the marsh area in the center of the county seems to have been converted to more vegetation land cover as the water body moves north from the Gulf of Mexico.

Figure 4.30 shows the land cover classes in 1990 of Jackson County. Developed area seems to have increase across the entire county, especially the western side of the county north of I-10. More roads also appear to be visible in this map than in the previous maps. With this increase in developed area, a decrease in vegetation is recorded throughout the county. As mentioned earlier, the majority of this area classified as developed land cover is not housing and/or business developments but areas cleared for agricultural development.

Figure 4.31 shows the land cover classes in 1995 of Jackson County. The trend of an increase in developed land cover across the county that was visible in the 1990 map seems to have reversed in the 1995 image. More vegetation land cover especially west of the marsh is present in this image when compared to the 1990 image. Also, some vegetation land cover is present within the Ocean Spring, Pascagoula and Moss Point developed areas. Marsh land cover seems to have regained the former vegetation land cover in the center of the county as the water body moves north. Bare soil land cover appears to be in the same areas where it was observed in the 1990 map.

Figure 4.32 shows the land cover classes in 2000 of Jackson County. More developed land cover appears to be present in this map than in the 1995 map. The land cover type that stands out with the most change from 1995 to 2000 is bare soil located in the marsh centered on either side of I-10. This image must have been taken during a low tide or drought period because as the water recedes more bare soil would be exposed because the health of the marsh has most likely deteriorated. If the marsh was healthy, as the water receded, the area would still be classified as marsh. This marsh land was classified as vegetation in the previous maps.

Figure 4.33 shows the graphical representation of the second land cover classification of an imagery acquired in 2000 of Jackson County. This map shows an increase in bare soil compares to the 1995 map; however, the bare soil land cover is not observed in the same place as the first 2000 map. The bare soil in the second 2000 map is mostly located next to developed areas throughout the entire county. The area in the first 2000 map classified as bare soil was classified as marsh land cover in the second 2000 map which supports the conclusion that the first 2000 image was taken during a period of low tide or drought.

Figure 4.34 shows the graphical representation of the land cover classes in 2005 of Jackson County. The 2005 land cover classification map appears to be similar to the first 2000 map; however there does appear to be more developed land cover in the northwest corner of the county. Bare soil appears to be present in the marsh immediately north and south of I-10 towards Pascagoula Bay.

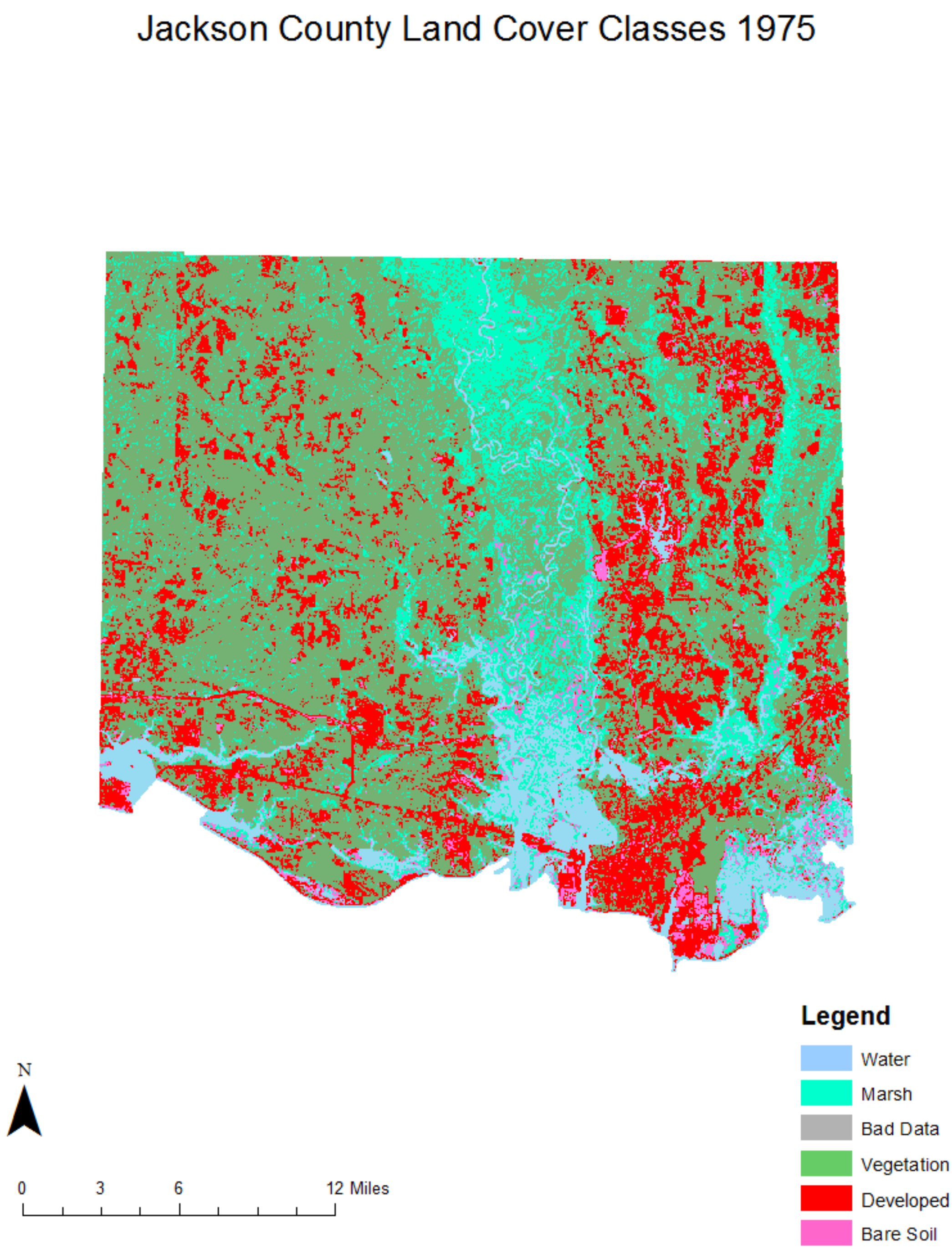

Figure 4.27: Land cover classification map of Jackson County (1975)

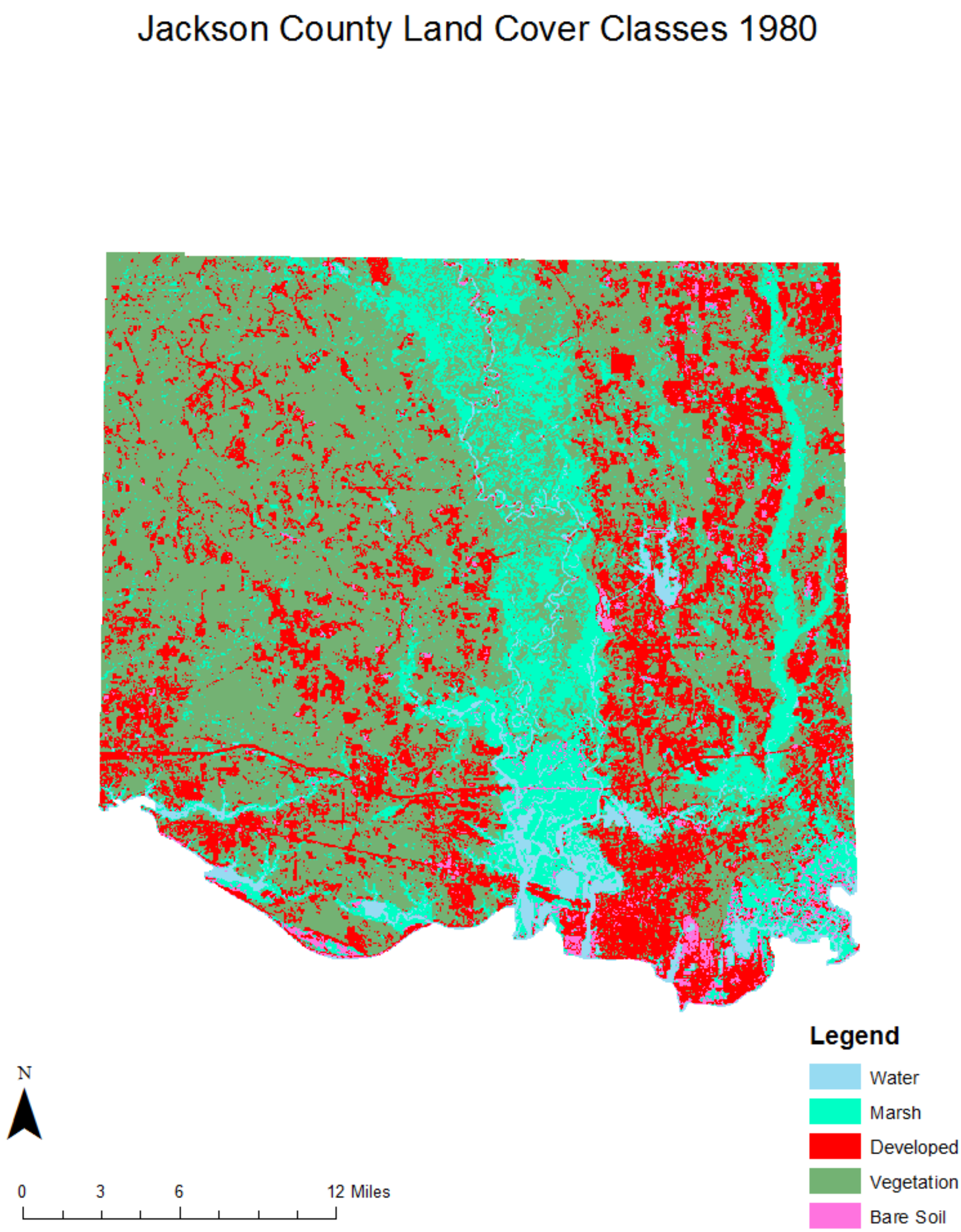

Figure 4.28: Land cover classification map of Jackson County (1980)

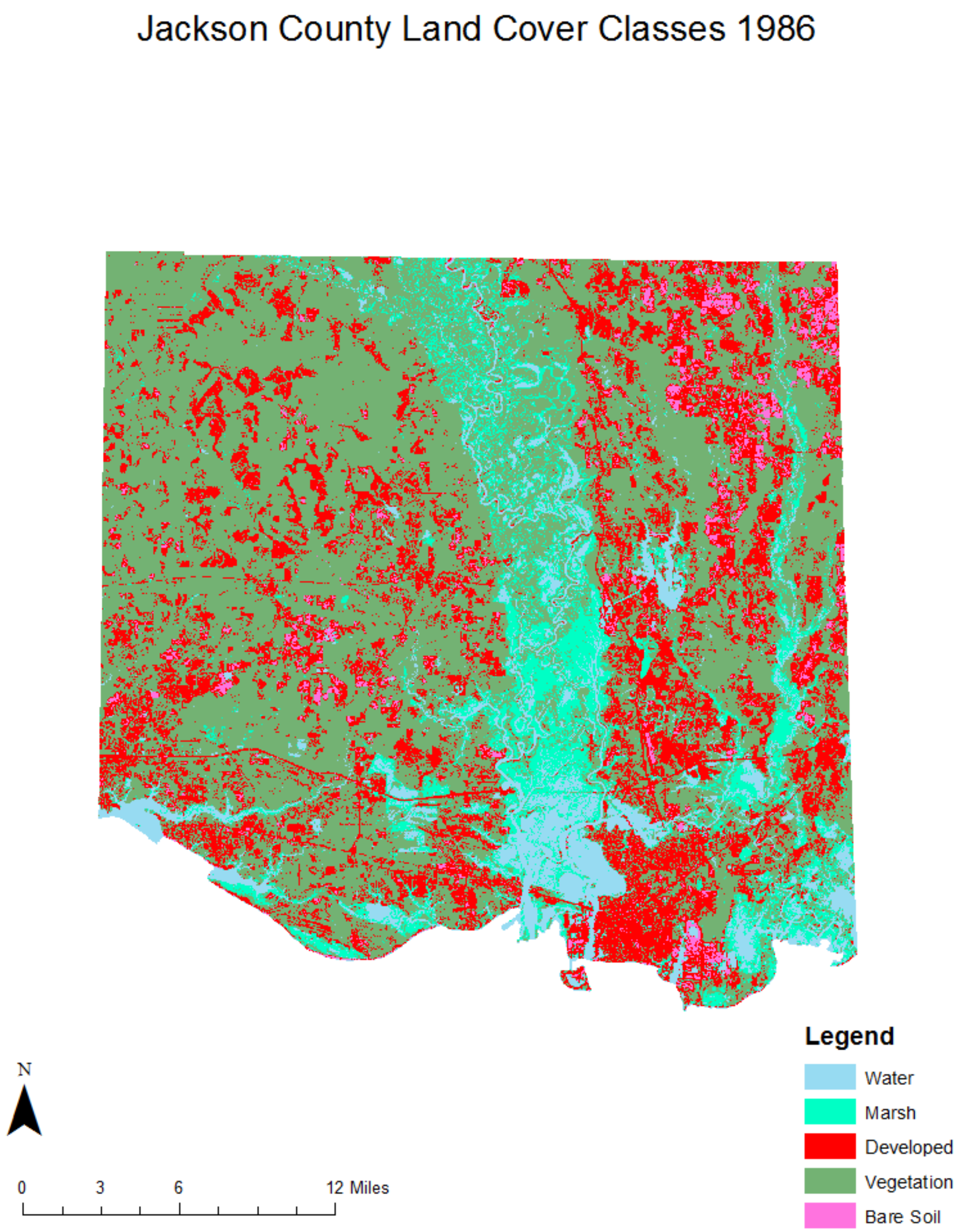

Figure 4.29: Land cover classification map of Jackson County (1986)

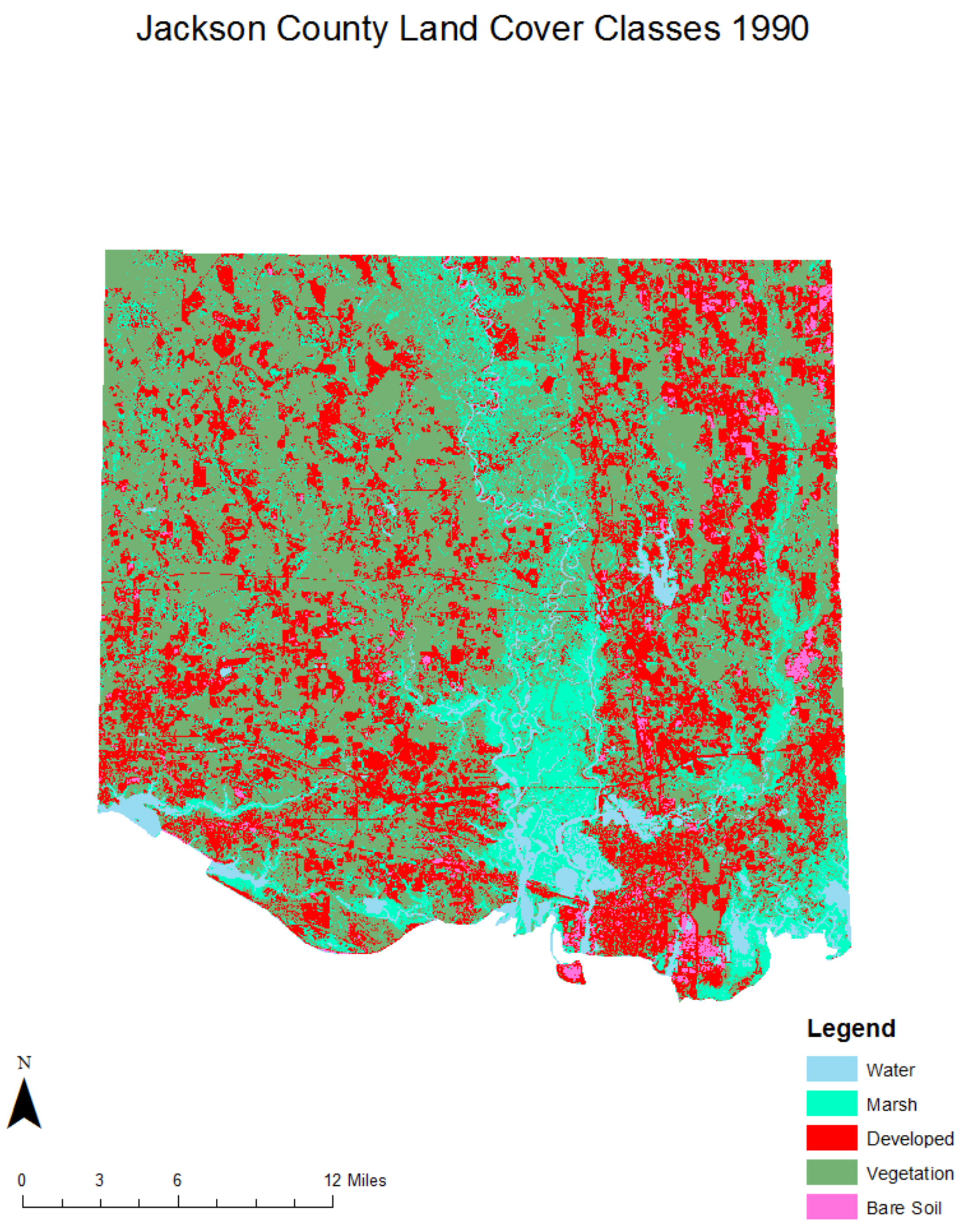

Figure 4.30: Land cover classification map of Jackson County (1990)

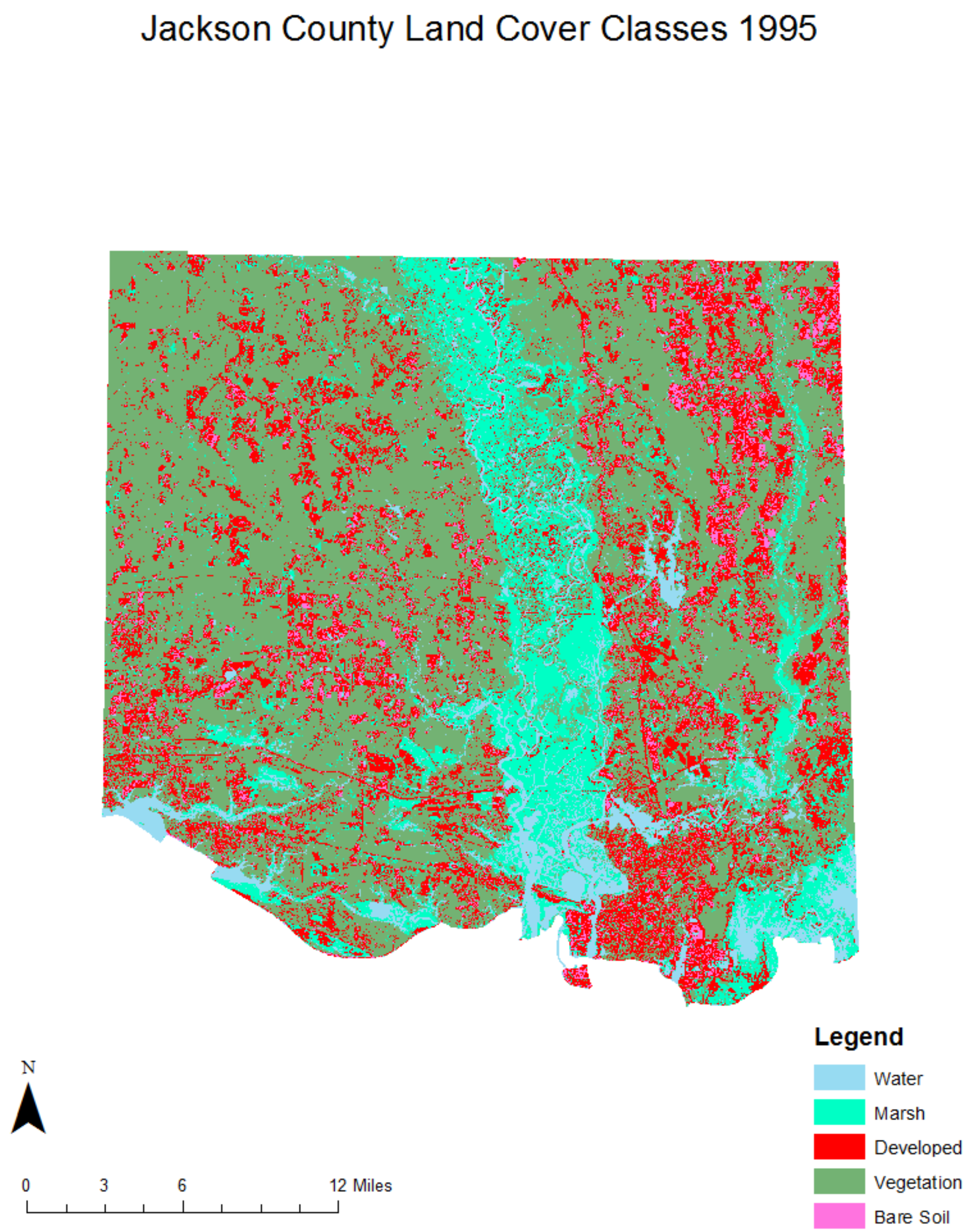

Figure 4.31: Land cover classification map of Jackson County (1995)

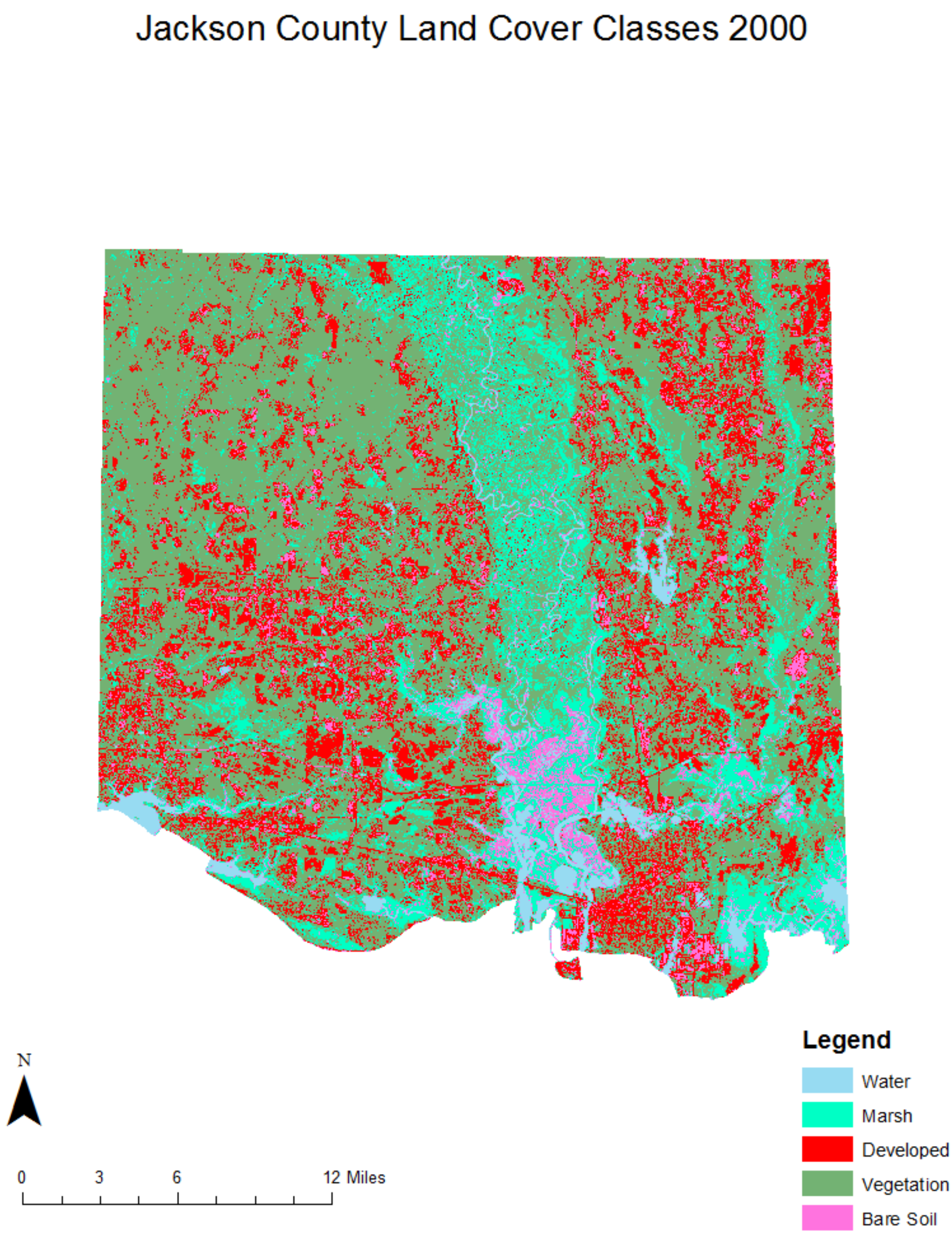

Figure 4.32: Land cover classification map of Jackson County (2000) (1st Classification)

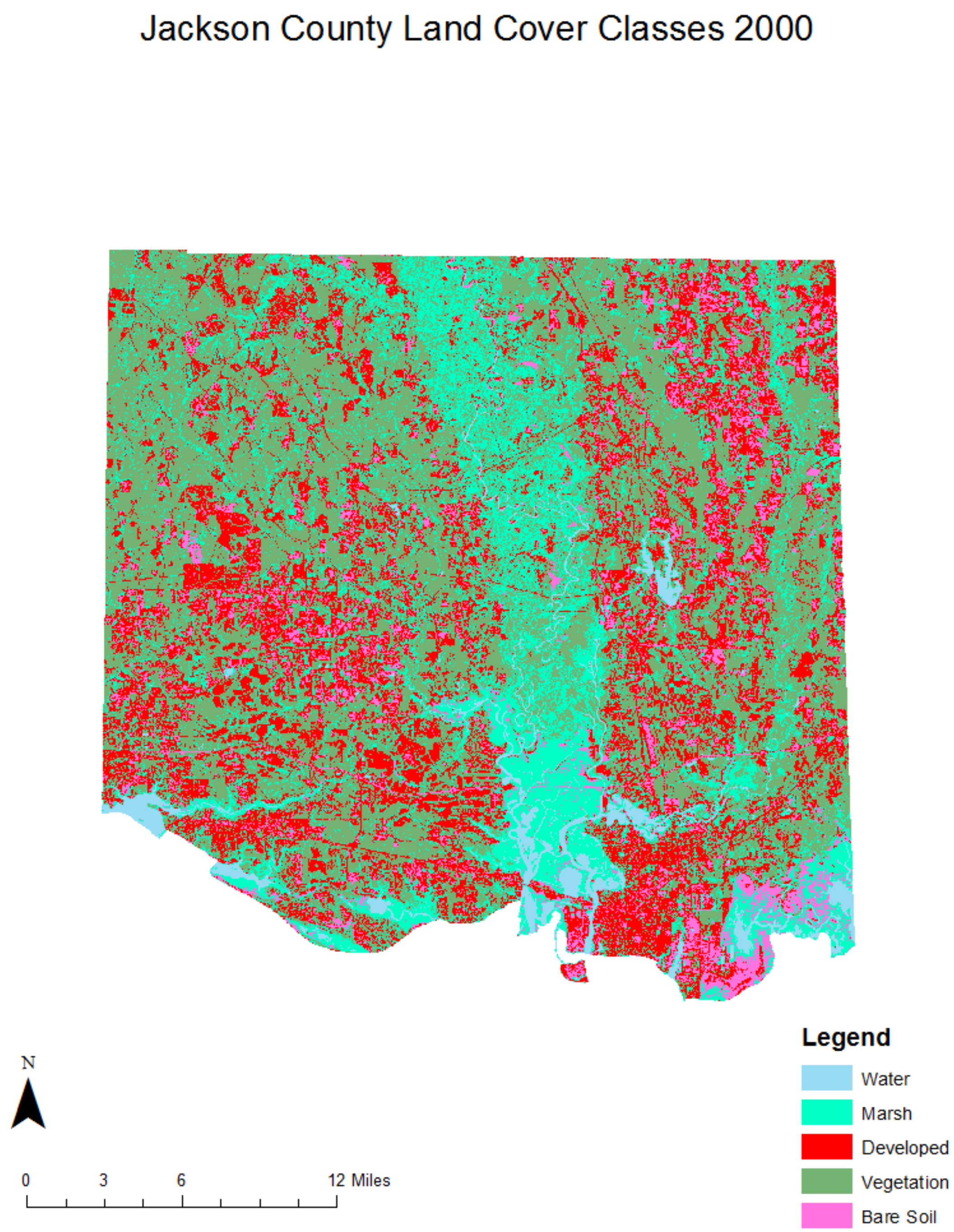

Figure 4.33: Land cover classification map of Jackson County (2000) (2nd Classification)

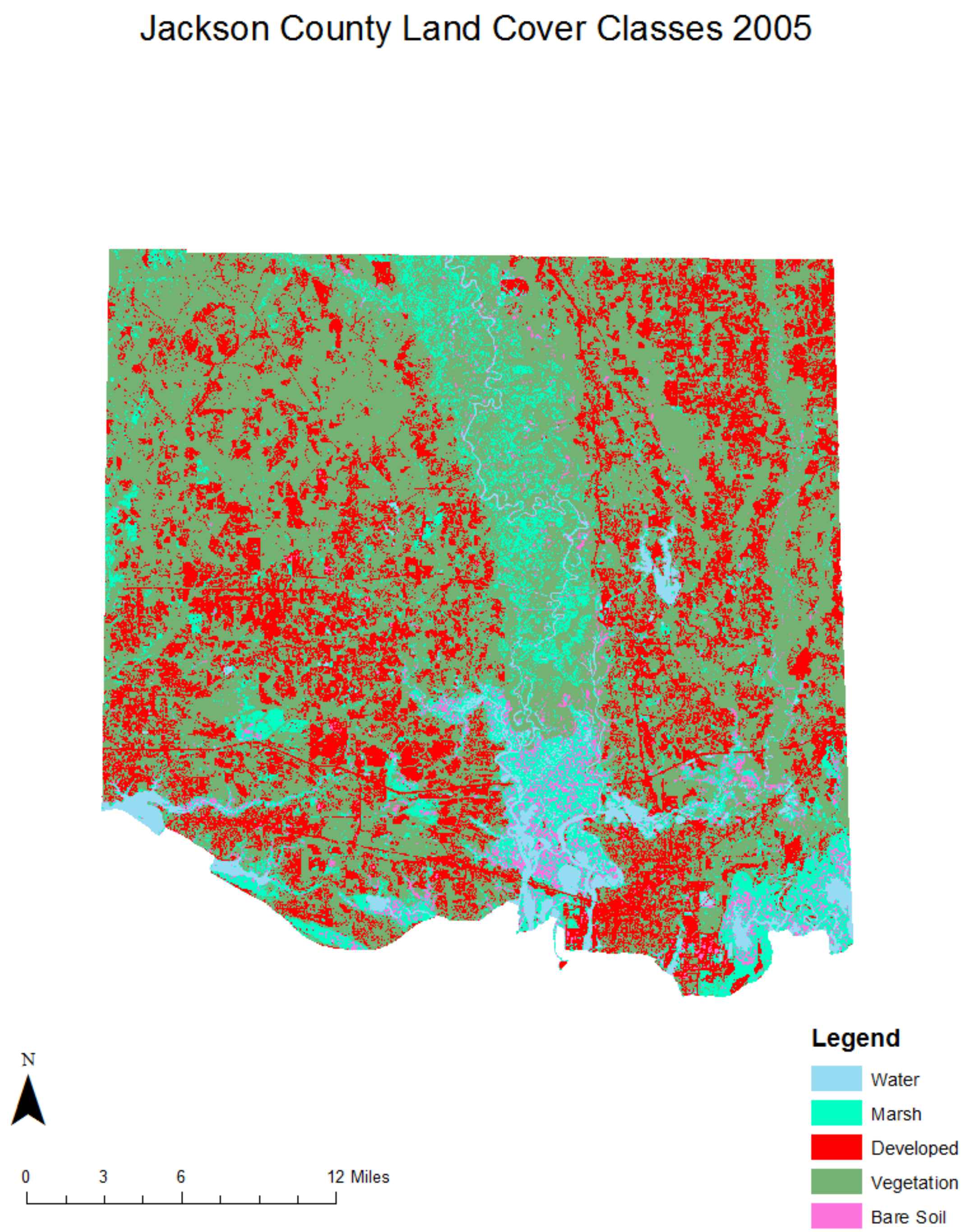

Figure 4.34: Land cover classification map of Jackson County (2005)

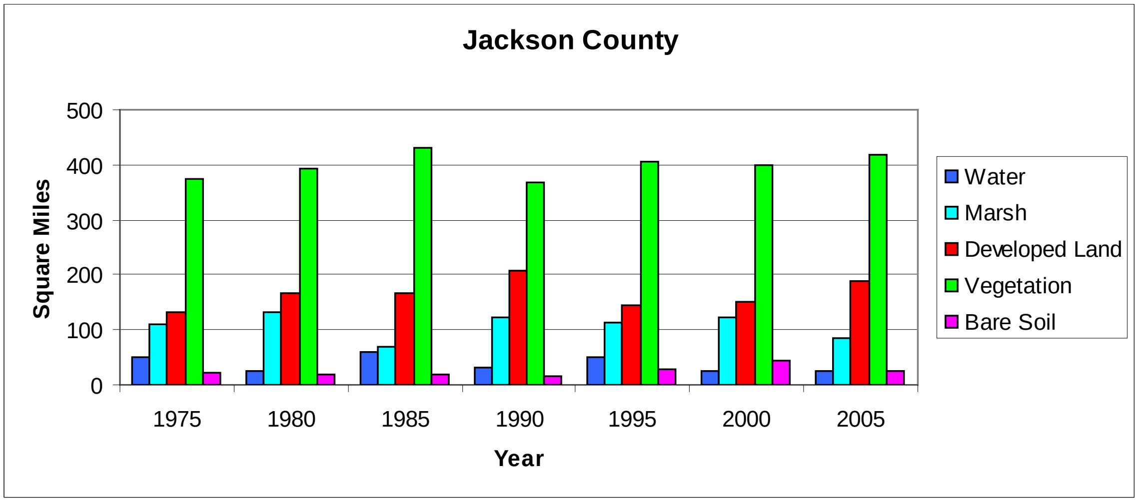

Figure 4.35: Area of each land cover classes in Jackson County (1975 to 2005)

Figure 4.35 shows the area of each land cover class from 1975 to 2005 in Jackson County. Similar to Hancock and Harrison Counties, the most widely distributed land cover class for the entire time period is vegetation, followed by developed, marsh and bare soil land cover areas.

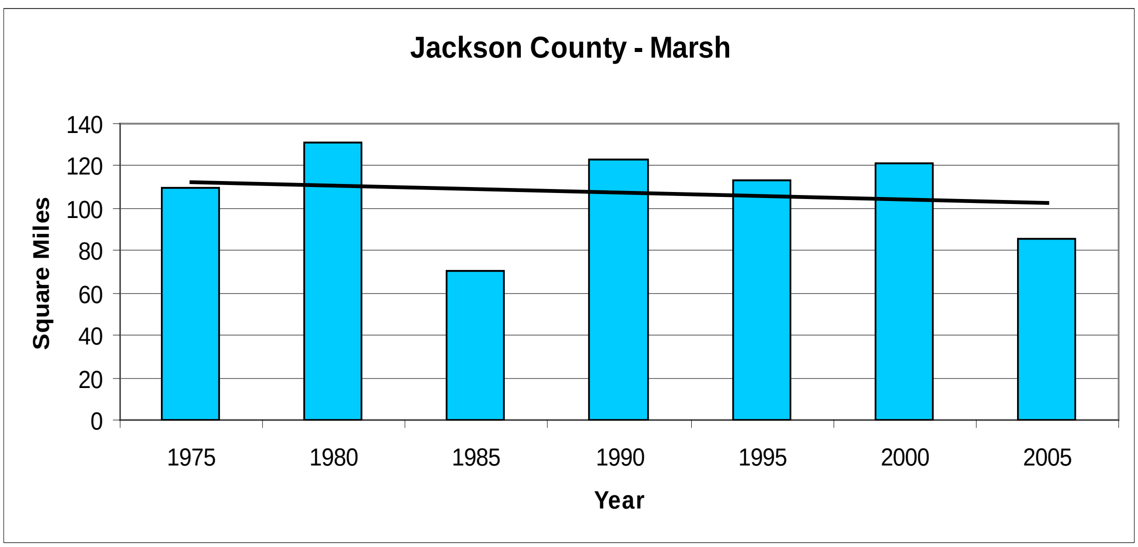

Figure 4.36: Area of marsh land cover in Jackson County (1975 to 2005)

Figure 4.36 shows the area of marsh land cover class from 1975 to 2005 in Jackson County. Overall there appears to be a declining trend in the area of marsh land cover over this thirty year time period. A sharp decline of 60 mi^2 during the period from 1980 to 1985 and then gain of 52 mi^2 during the period between 1985 and 1990 in marsh land cover was recorded. A second period of substantial decline of about 36 mi^2 in marsh land cover was recorded from 2000 to 2005.

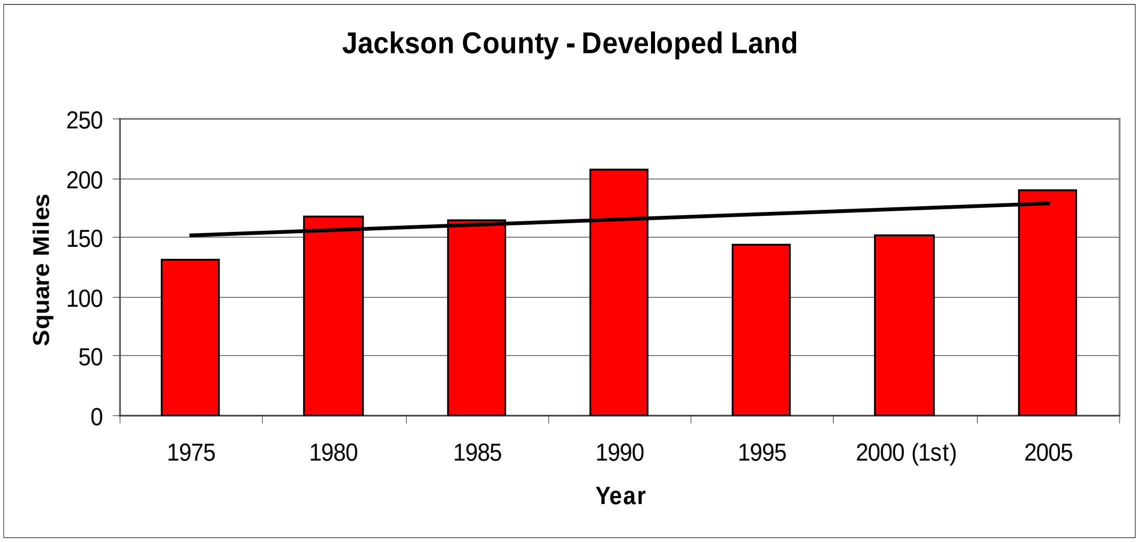

Figure 4.37: Area of developed land cover in Jackson County (1975 to 2005)

Figure 4.37 shows the area of developed land cover class from 1975 to 2005 in Jackson County. The general trend of developed area land cover was an increase in area over this thirty year time span. Three time periods of a gain in developed land were recorded, from 1975 to 1980 (37 mi^2), 1985 to 1990 (41 mi^2), and 2000 to 2005 (38 mi^2). The largest decline in developed area appears to have occurred between 1990 and 1995 (68 mi^2).

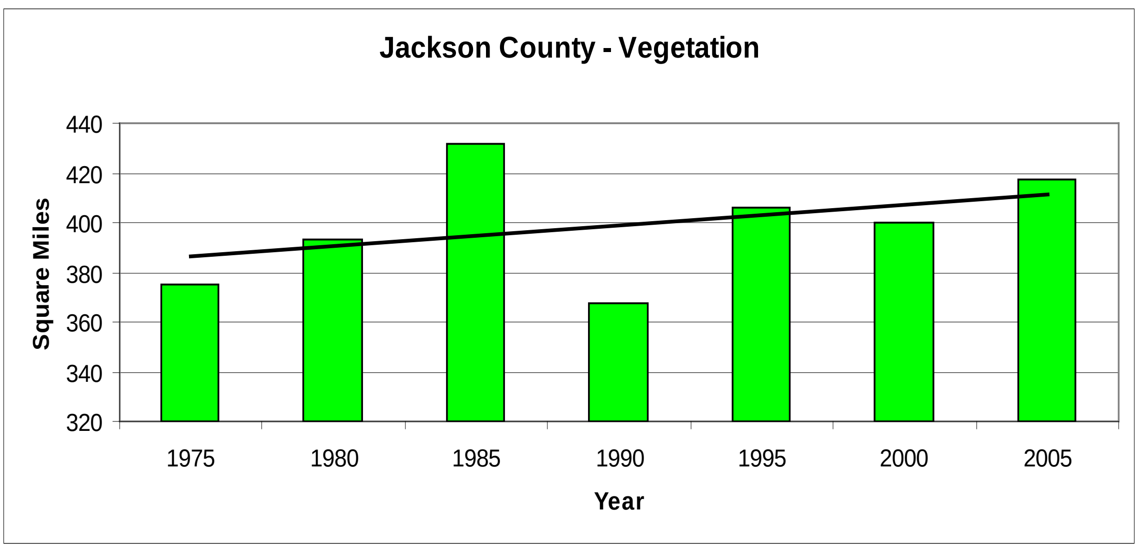

Figure 4.38: Area of vegetation land cover in Jackson County (1975 to 2005)

Figure 4.38 shows the area of vegetation land cover class from 1975 to 2005 in Jackson County. The general trend of vegetation area land cover was an increase in area over this thirty year time span. During the period from 1975 to 1985 vegetation land cover steadily increased from 374 mi^2 in 1975 to 431 mi^2 in 1985. This ten year period of increase was followed by a sharp decrease in vegetation in 1990 when it reduced down to 367 mi^2. Thus recording a loss of 64 mi^2 within a five year period vegetation land cover

had increased to 405 mi^2 (gain of 38 mi^2). By 2005, 417 mi^2 of area was classified as vegetation land cover.

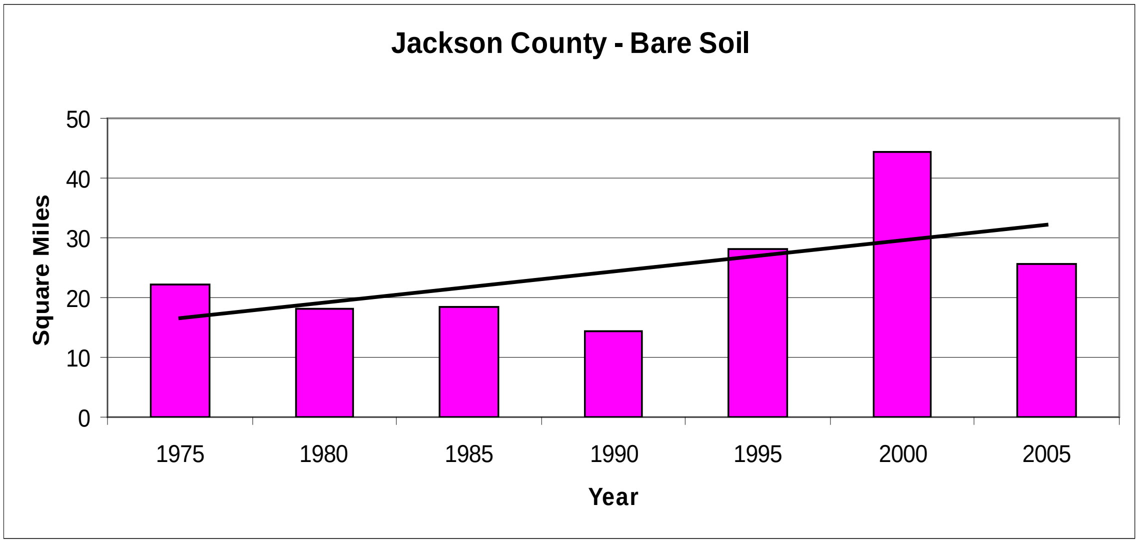

Figure 4.39: Area of bare soil land cover in Jackson County (1975 to 2005)

Figure 4.39 shows the area of bare soil land cover class from 1975 to 2005 in Jackson County. The general trend of bare soil area land cover was an increase in area over this thirty year time span; however this wasn't the case for the first 15 years where a general decrease in bare soil was recorded (22 to 14 mi^2). From 1990 to 2000, the amount of bare soil land cover nearly quadrupled from 14 to 44 mi^2 only to decline to 25 mi^2 in 2005.

4.4 Summary of Overall Land Cover Analysis

Figure 4.40 through Figure 4.47 shows the land cover classes in all Gulf Coast Counties combined during the period from 1975 to 2005. Each county was described in detail in the previous sections; therefore this analysis will not be repeated. These figures were included to show the continuity of each land cover type within each thematic map and summarize the overall trend along the Gulf Coast.

Figure 4.40 (1975 Thematic Map) and Figure 4.41 (1980 Thematic Map) show an increase in developed land cover and decrease in vegetation land cover along the Gulf Coast south, near I-10. North of the interstate, developed area also increased along major highways, such as Highway 49. Some of this developed land cover may be attributed to clearing the land for agricultural purposes i.e. bare soil may have been classified as developed land cover. These trends (increase in developed land, decrease in vegetation) continue through 1990 (Figure 4.43) and stall out in 1995 (Figure 4.44). An increase in development is observed in the 2000 (Figure 4.45) and 2005 (Figure 4.46) images.

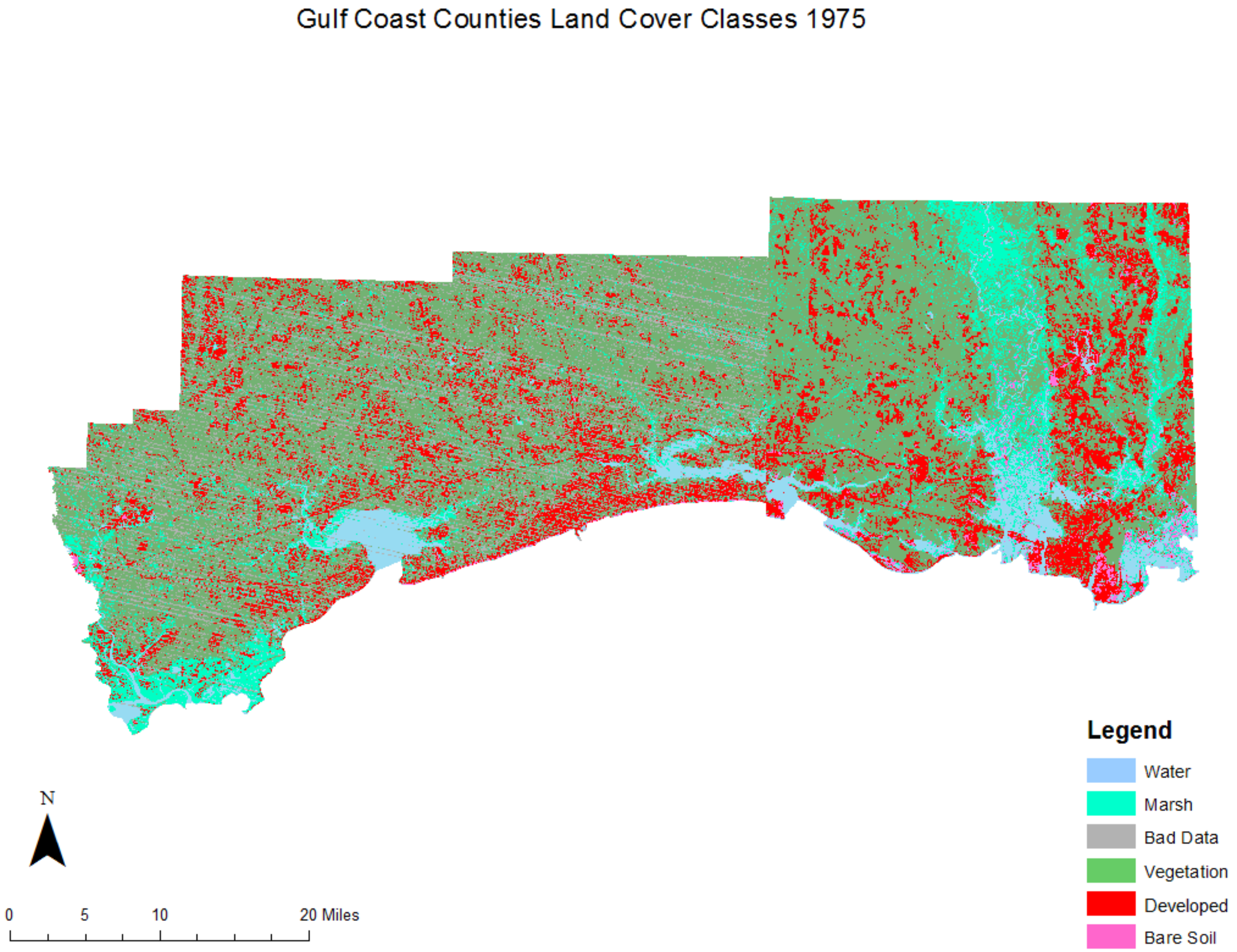

Figure 4.40: Land cover classification map of the Gulf Coast Counties (1975)

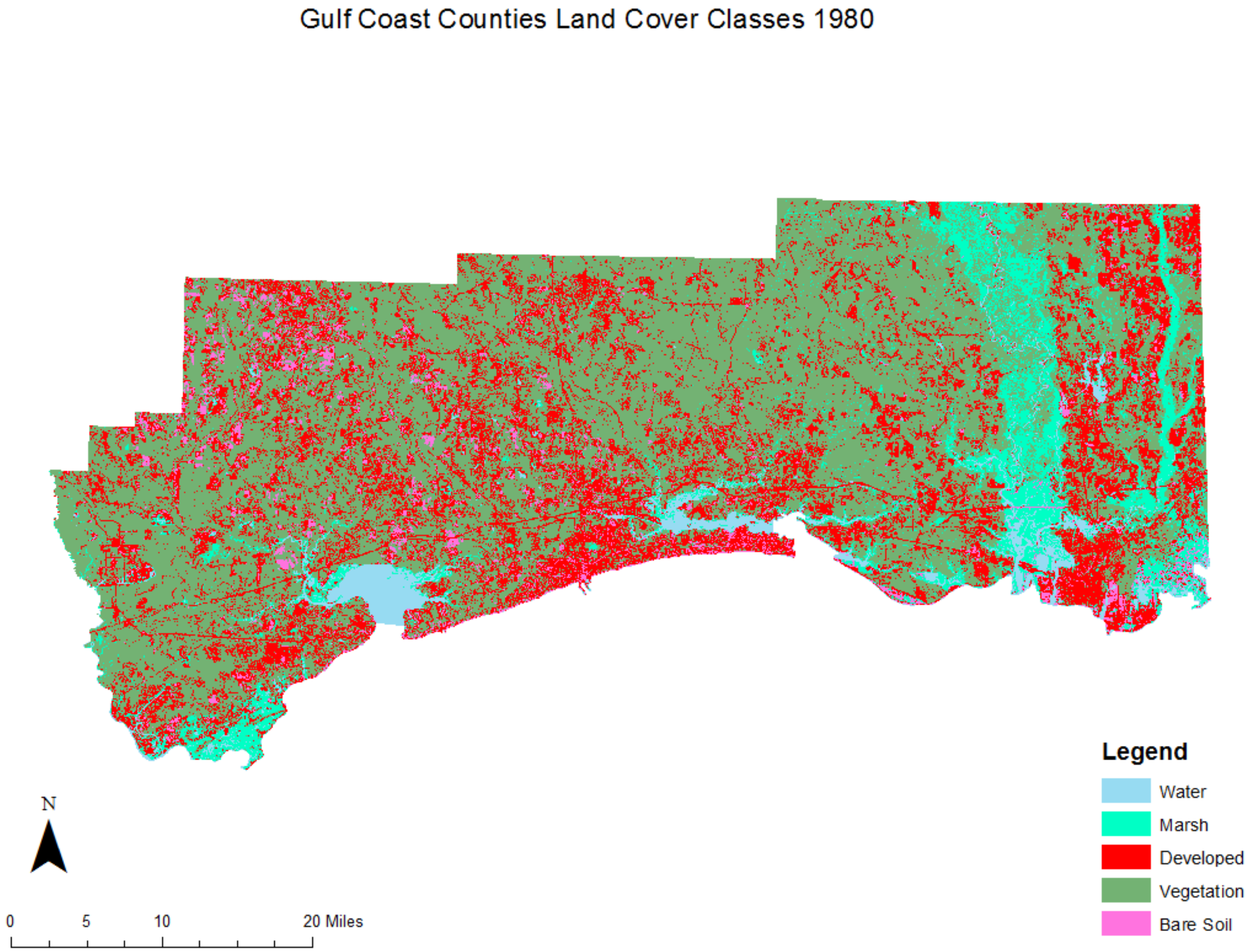

Figure 4.41: Land cover classification map of the Gulf Coast Counties (1980)

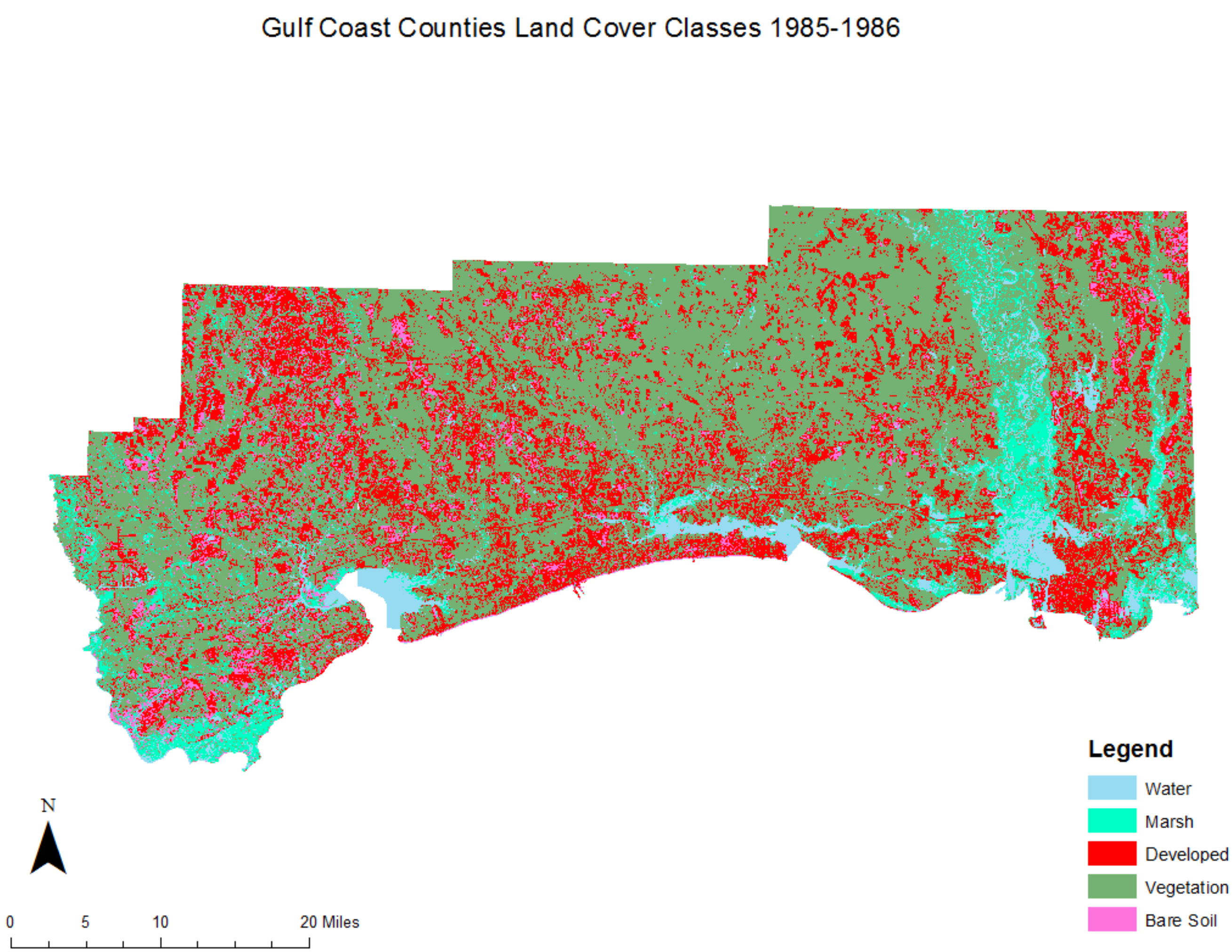

Figure 4.42: Land cover classification map of the Gulf Coast Counties (1985-1986)

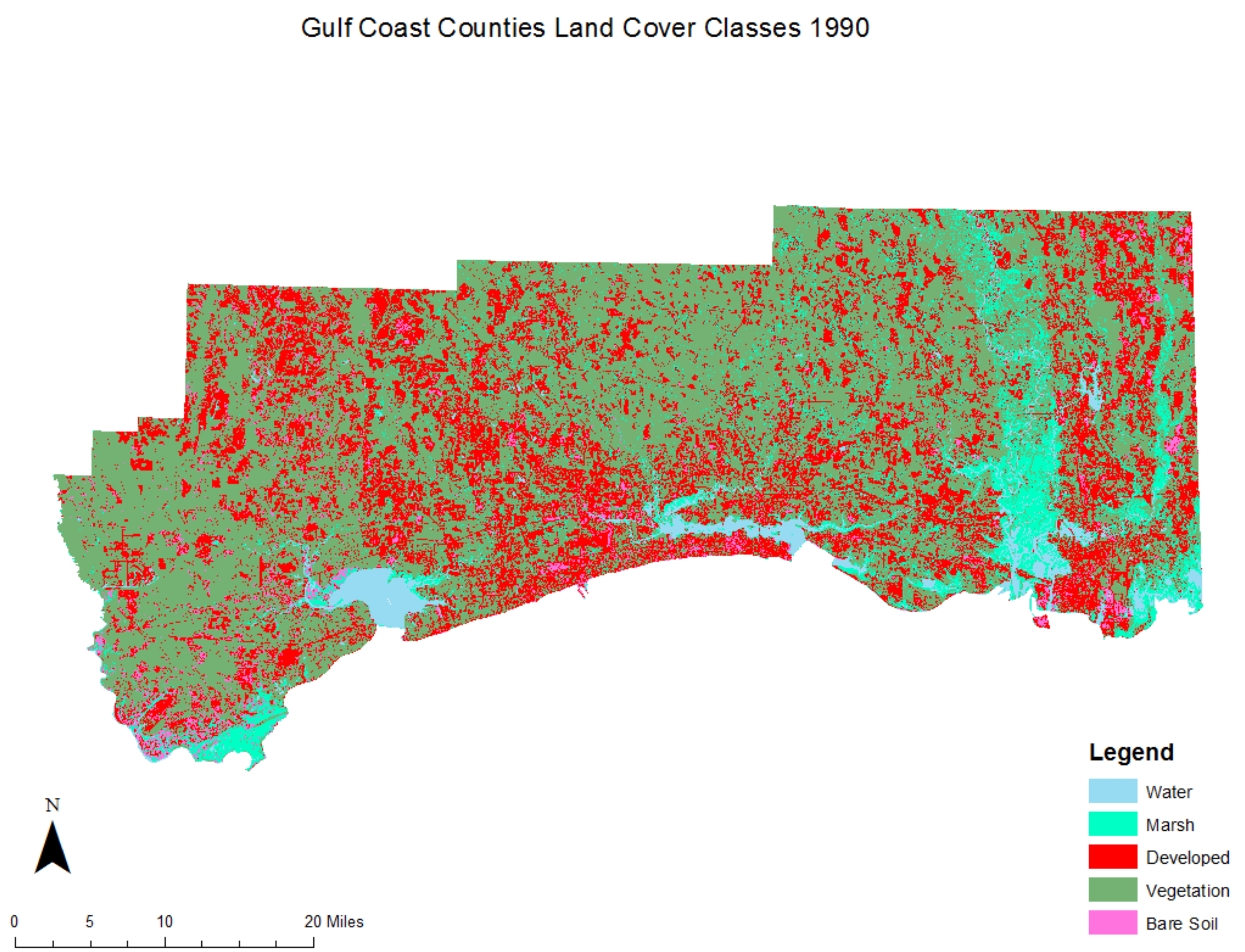

Figure 4.43: Land cover classification map of the Gulf Coast Counties (1990)

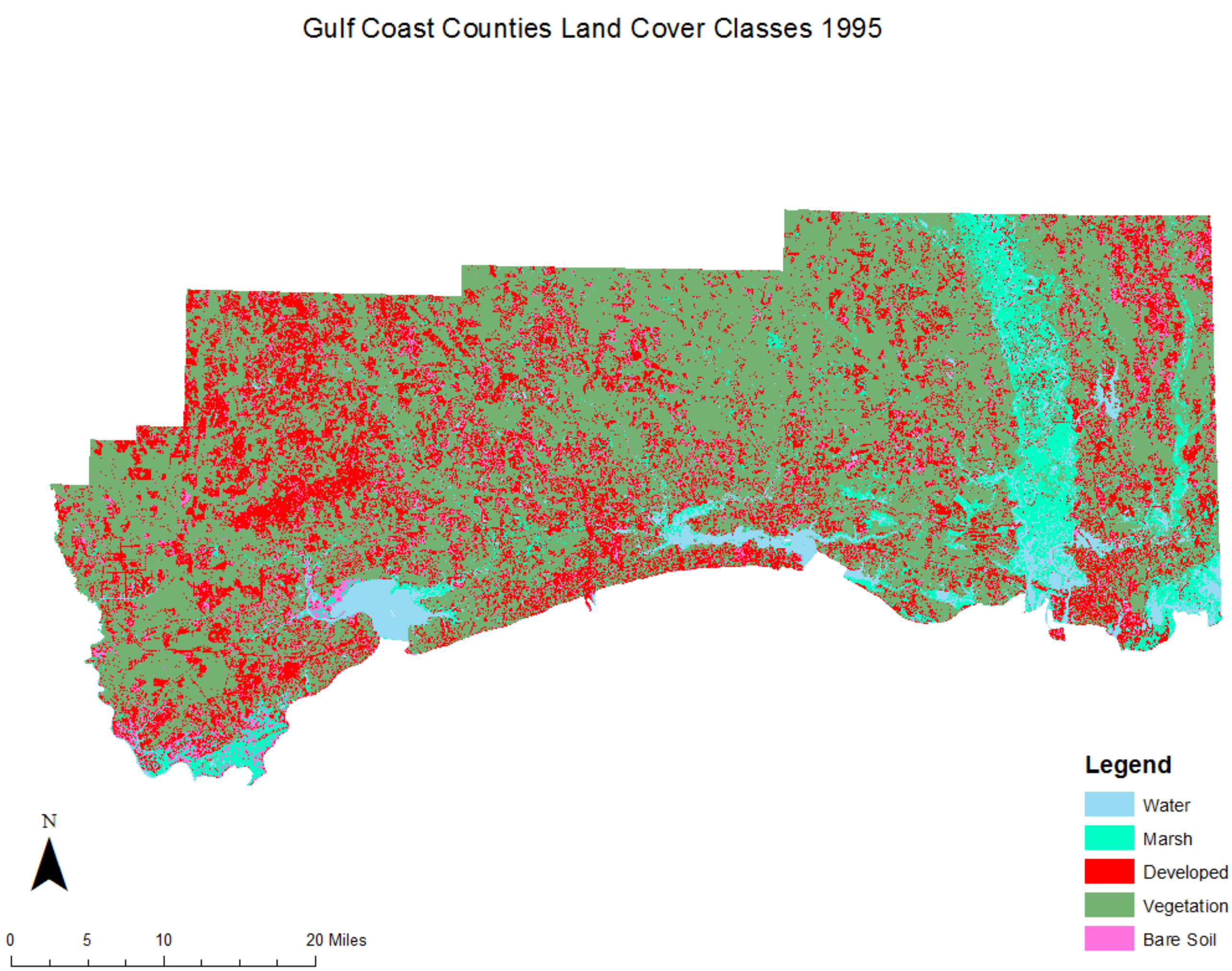

Figure 4.44: Land cover classification map of the Gulf Coast Counties (1995)

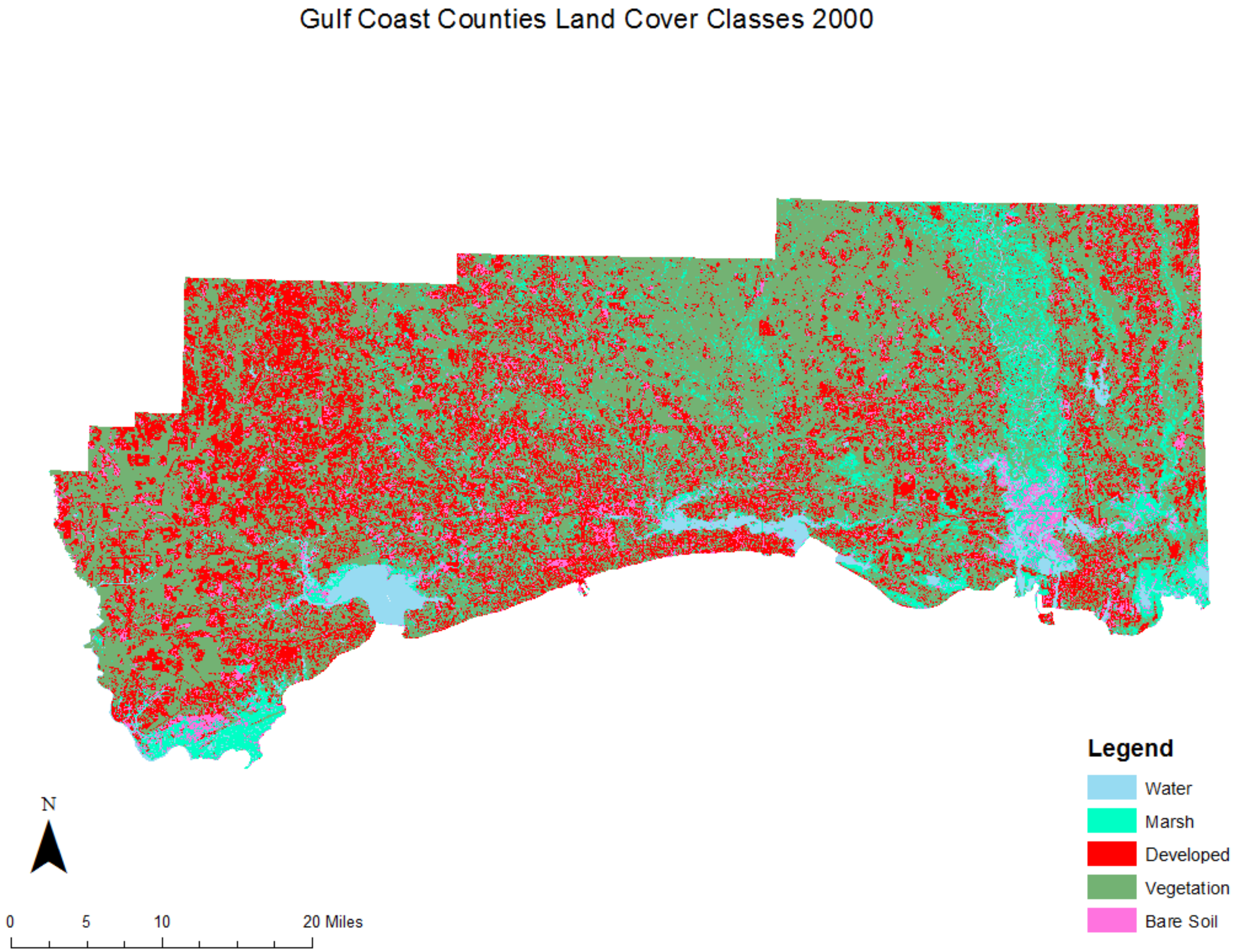

Figure 4.45: Land cover classification map of the Gulf Coast Counties (2000) (1st Classification)

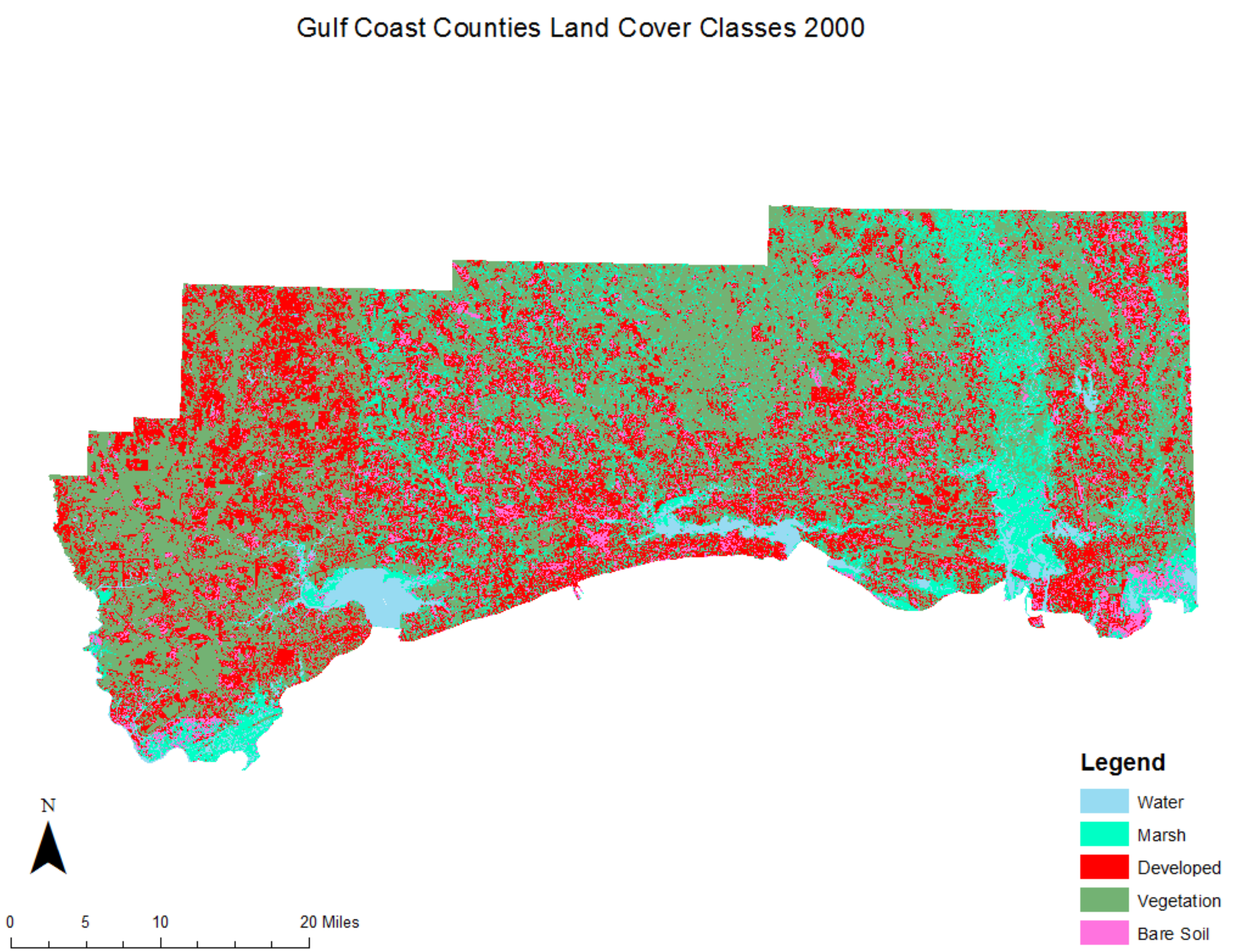

Figure 4.46: Land cover classification map of the Gulf Coast Counties (2000) (2nd Classification)

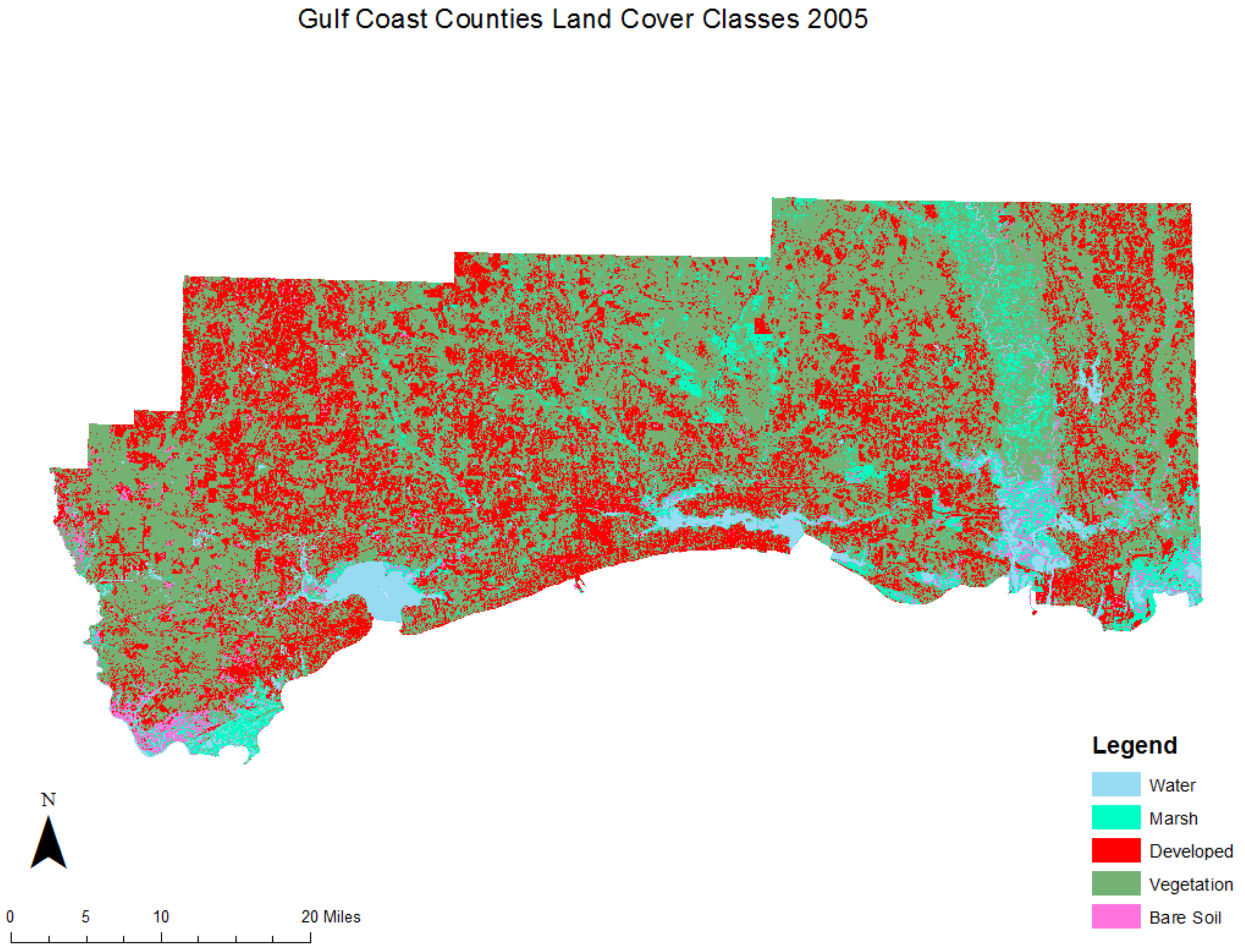

Figure 4.47: Land cover classification map of the Gulf Coast Counties (2005)

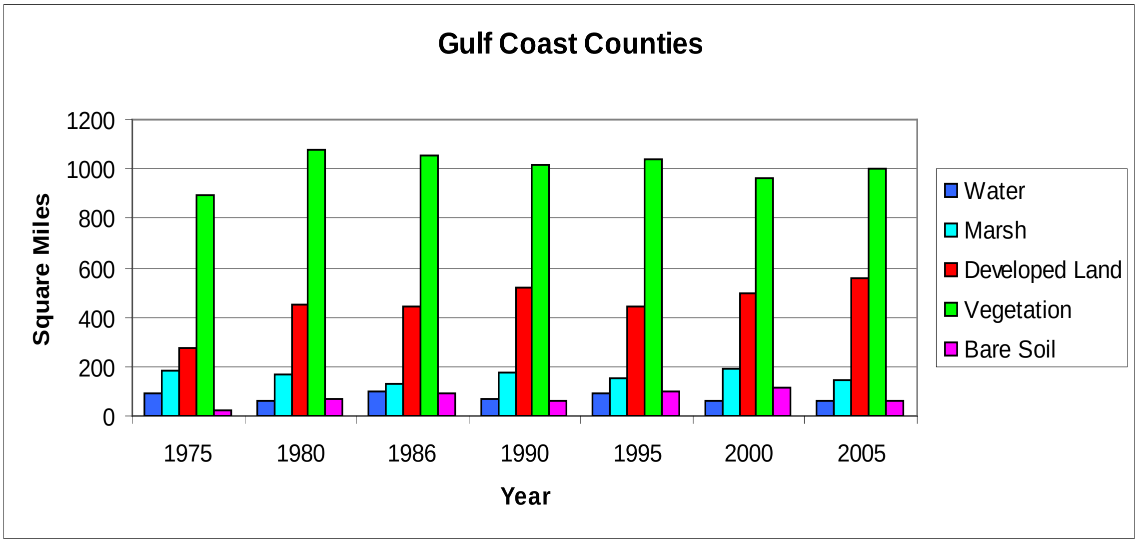

Figure 4.48: Area of each land cover classes of the Gulf Coast Counties (1975 to 2005)

Figure 4.48 shows the area of each land cover class from 1975 to 2005 in all Gulf Coast Counties combined. The land cover class with the most area for the entire time period is vegetation, followed by developed, marsh and bare soil land cover areas.

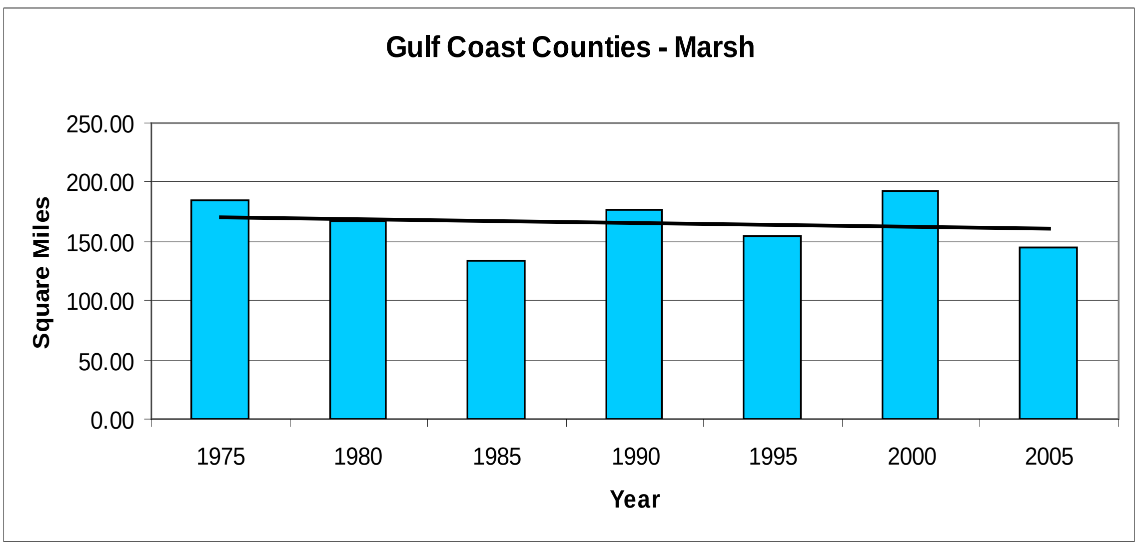

Figure 4.49: Area of marsh land cover in the Gulf Coast Counties (1975 to 2005)

Figure 4.49 shows the area of marsh land cover class in all Gulf Coast Counties combined during the period from 1975 to 2005. Over the thirty year time span, there does not appear to be a clear trend, instead fluctuation of losses and gains of marsh land cover is more evident. Marsh land appears to decrease in area from 1975 to 1985 (184 to 133 mi^2), then shows an increase of 176 mi^2 in 1990. Marsh land decreased from 1990 to 1995 by 21 mi^2 only to increase by 38 mi^2 in 2000. In 2005, the marsh land decreased again by 48 mi^2.

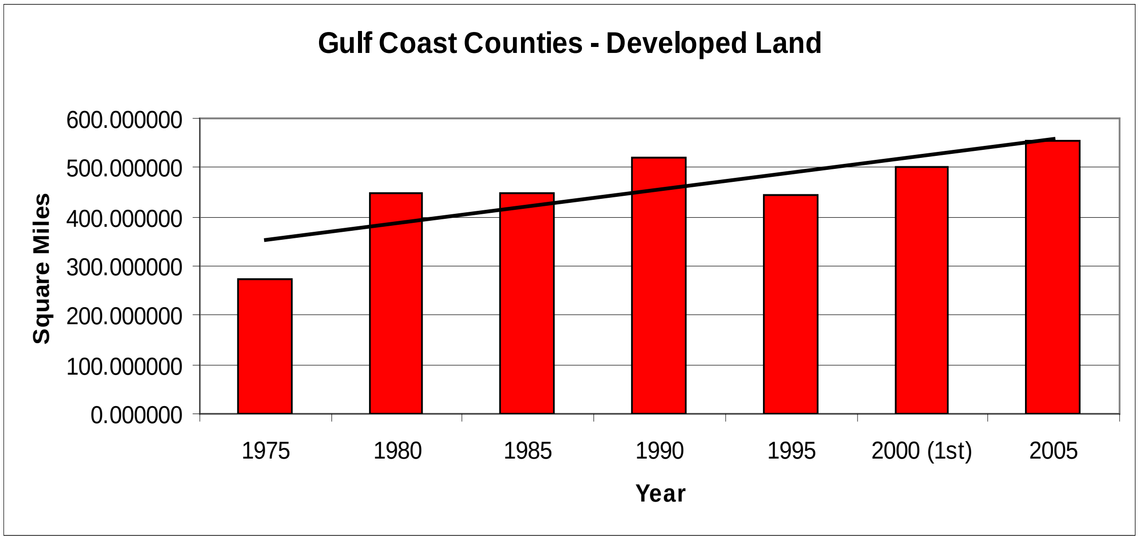

Figure 4.50: Area of developed land cover in the Gulf Coast Counties (1975 to 2005)

Figure 4.50 shows the area of developed land cover class in all Gulf Coast Counties combined during the period from 1975 to 2005. A general trend of increase in the developed land cover was observed along the Gulf Coast. The greatest gain in developed land cover occurred from 1975 to 1980 (175 mi^2). From 1990 to 1995, developed land cover decreased by 79 mi^2 only to increase by 114 mi^2 in 2005.

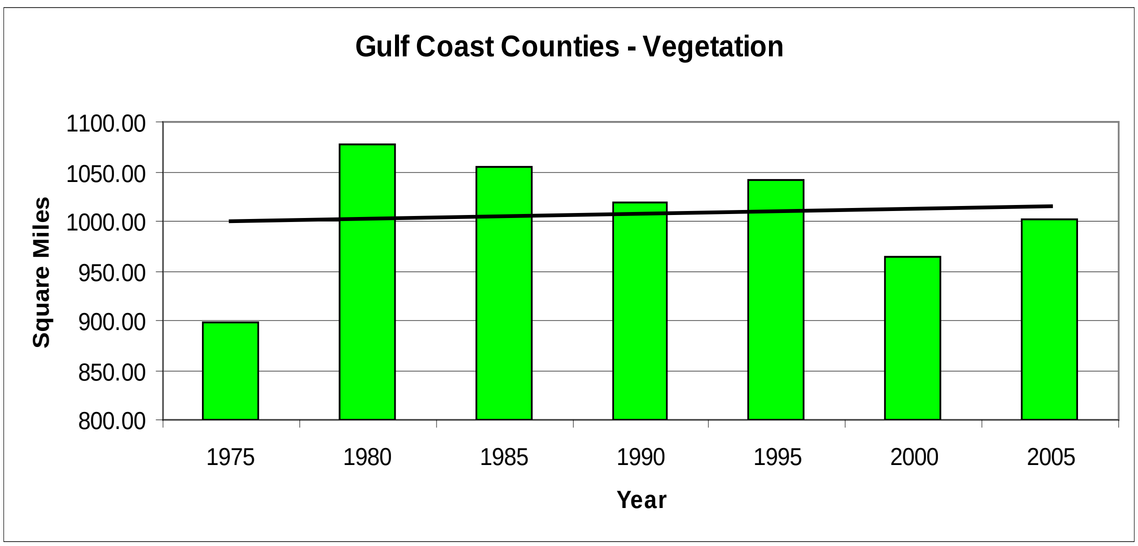

Figure 4.51: Area of vegetation land cover in the Gulf Coast Counties (1975 to 2005)

Figure 4.51 shows the area of vegetation land cover class in all Gulf Coast Counties combined during the period from 1975 to 2005. The trend line included in this figure shows a slight increase in vegetation land cover over this thirty year period; however, if 1975 were not included because of bad data present in two of three thematic maps, the general trend would most likely be a slight decrease in vegetation land cover from 1980 to 2005. The greatest decline in vegetation land cover appears to be from 1995 to 2000 (76 mi^2 of vegetation lost).

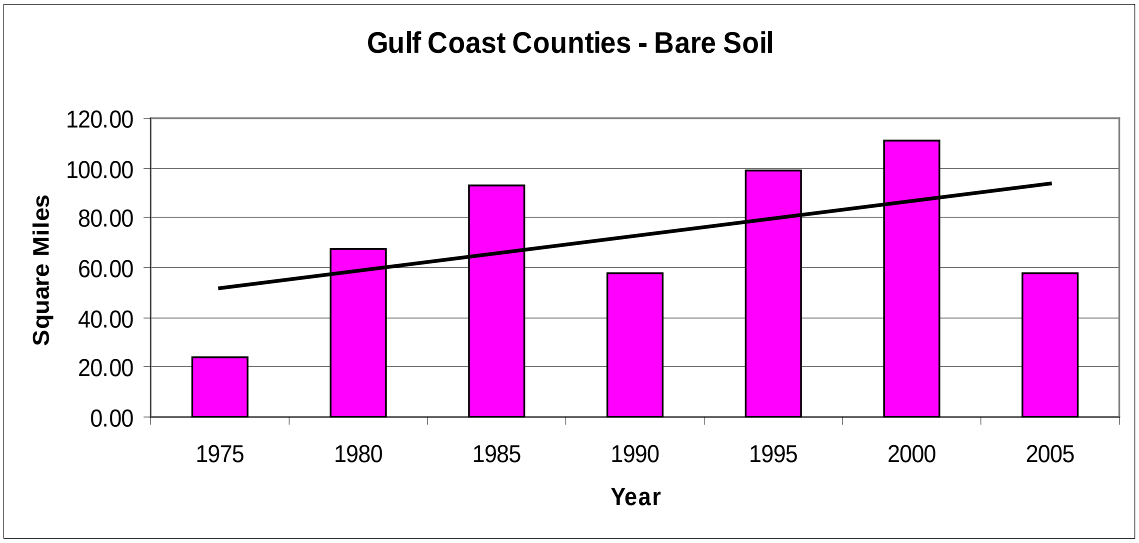

Figure 4.52: Area of bare soil land cover in the Gulf Coast Counties (1975 to 2005)

Figure 4.52 shows the area of bare soil land cover class in all Gulf Coast Counties combined during the period from 1975 to 2005. The general trend over this thirty year time period shows an increase in bare soil land cover; however there are two periods of decline in bare soil land cover, one is from 1985 to 1990 during which bare soil declined by 35 mi^2, and the second period is from 2000 to 2005 during which a decline of 54 mi^2 in bare soil occurred.

5. Discussion

This chapter is divided into two sections, the first focuses basic trends (growth/decline) and correlation analysis of several socioeconomic characteristics with changes in land cover detailed in the results section. The second section focuses on the limitations of this study.

5.1 Socioeconomic Factors

The purpose of this section is to answer the question, are there trends in land-use patterns from the 1970s to 2005 that are reflected in the socioeconomic characteristics of the selected Mississippi Coastal Counties? In general, all three socioeconomic factors increased in all three counties through the decades of this study, with the exception of Jackson County from 1985 to 1990, when both employment and housing fell. These increases generally were reflected in increases in developed land, with a few exceptions noted below. Bare soil generally increased but also with some notable fluctuations.

The land cover analysis showed an overall increase in developed land and bare soil from 1975 to 2005 in Hancock County, mirroring the general upward trend in socioeconomic indicators. The greatest increase in developed land cover was from 1990 to 2000. The census data in Figure 5.1 show that the Hancock County population more than doubled from 1970 to 2000. The population rose steadily from 1970 to 1990 and then increased more dramatically to 2000. Figure 5.2 shows the number of jobs also more than doubled in from 1980 to 2000 with a total of 5, 910 more jobs. The number of housing units nearly doubled from over 12,000 in 1980 to 21,000 in 2000 as shown in Figure 5.3.

In Harrison County, the area of developed land increased from 1975 to 1990 while bare soil decreased. Developed land then actually decreased from 1990 to 2000 while bare soil increased. An overall increase in population, employment, and housing units (Figures 5.1, 5.2, and 5.3) was observed in Harrison County. Although there were slight fluctuations in population and employment, the number of housing units built from 1980 to 2005 rose steadily every decade by about 10,000 housing units. An increase, in population and employment occurred from 1970 to 1980. This increase matches up with an increase in developed land and decrease in bare soil. A second dramatic increase in these socioeconomic factors occurred from 1990 to 2000, 14% in population and 18% in 1990 employment. The decline of developed area that occurred during this decade is difficult to reconcile with the increases in all three socioeconomic factors.

In Jackson County, developed area increased from 1975 to 1990 then decreased from 1990 to 2000. The pre-1990 increase matches increases in the three socioeconomic factors during this period. However, the 1990-2000 interval saw continued net increases in socioeconomic variables despite temporary rises and falls in employment and housing; this is difficult to reconcile with the loss in developed land over this decade. Bare soil decreased from 1975 to 1990 and then increased from 1990 to 2000. The population increased from 1970 to 1980 by about 34%. The population decreased by about 2% from 1980 to 1990 while employment increased by about 8%. Similar to Hancock and Harrison Counties, housing units increased from 1980 to 2005; over 12,000 housing units were built during this time period. The decline of developed area from 1990 to 2000 is difficult to explain with the increases in the number of housing units in this same time period. However, this may be due to misclassification of some areas of developed land as bare soil due to the closeness of their brightness values.

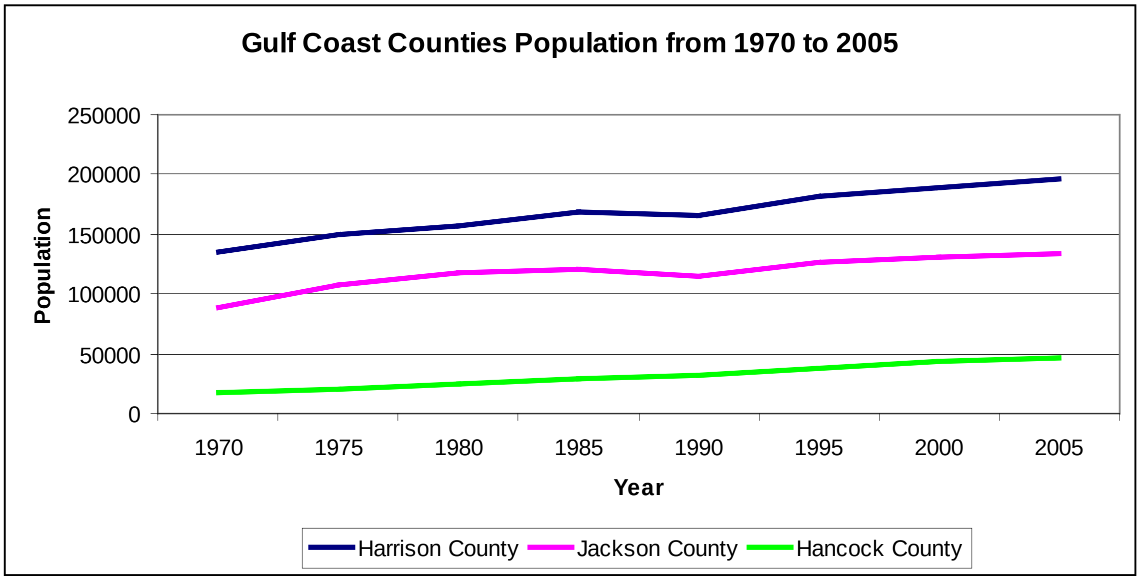

Figure 5.1: Gulf coast counties population from 1970 to 2005

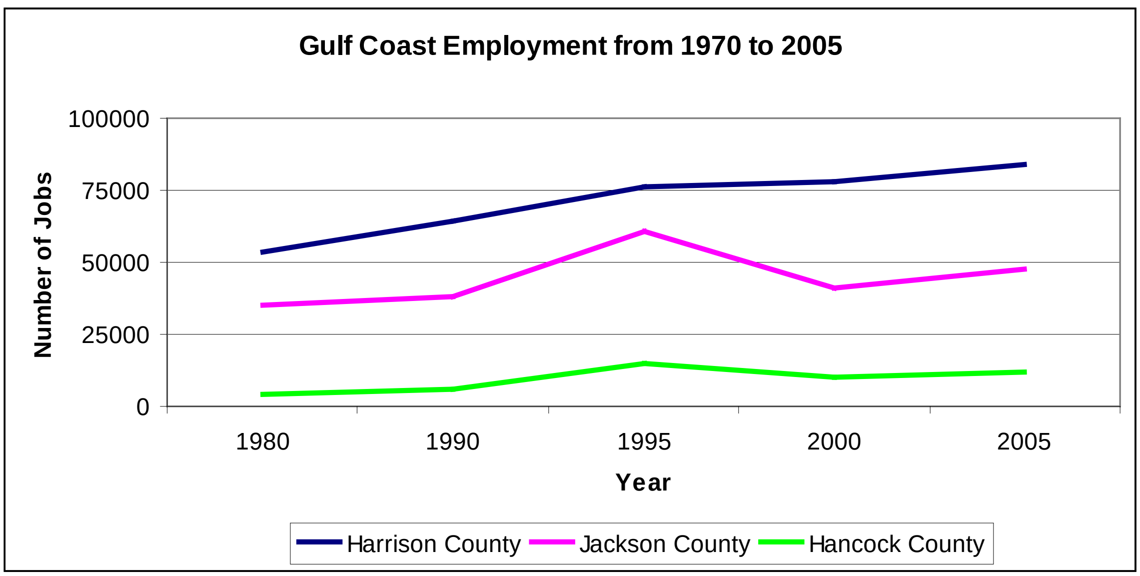

Figure 5.2: Gulf coast counties employment from 1980 to 2000

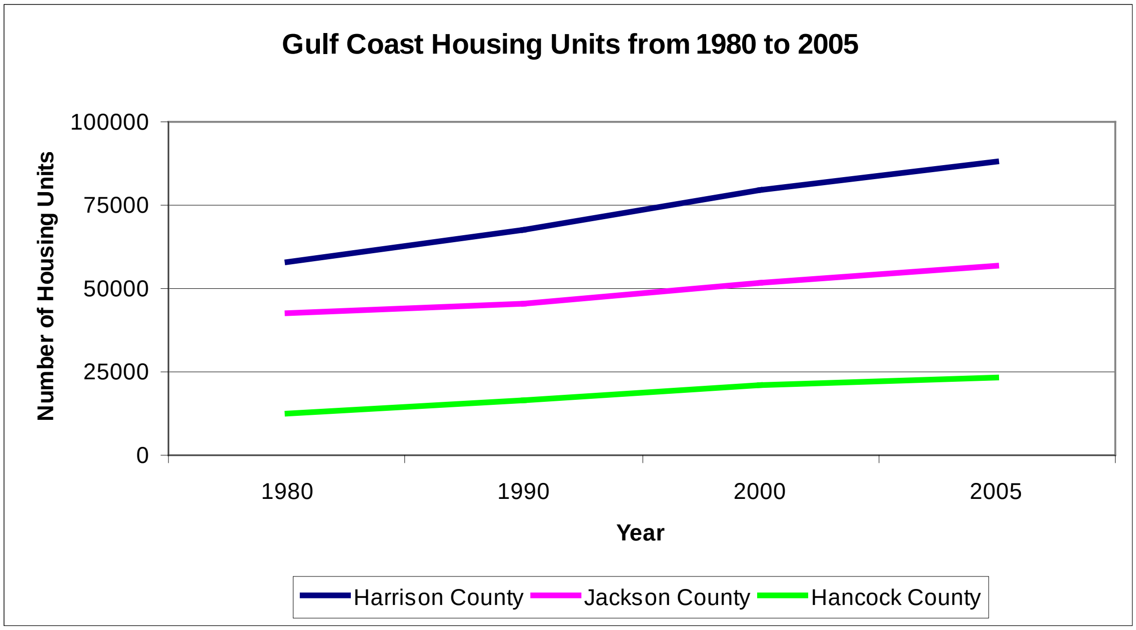

Figure 5.3: Gulf coast counties housing units from 1980 to 2005

Table 5.1 shows correlation coefficient of each LULC type with population, employment and housing unit data. These results are not statistically significant because the number of data points is very small. Associations between developed land and socioeconomic factors are generally less evident at the shorter time intervals used in this portion of the analysis than in the analysis of ≥ 10 year intervals presented above. Only a few land cover types and socioeconomic factors showed a strong positive relationship (values near or above 0.8) in Hancock County. These strong positive relationships were between developed land and population, and developed land and housing units. A strong negative correlation was found in Hancock County between vegetation and housing units. The socioeconomic factors did not have any strong relationships with the LULC classes in either Harrison or Jackson counties. Weak positive relationships (> 0.6) were found in Harrison County between developed land and population, marsh and population, and marsh and housing units. Weak negative relationships were found between housing units and vegetation. A weak positive relationship was found in Jackson County between bare soil and population.

Table 5.1: Gulf Coast County Socioeconomic Factors and Area of each LULC Class Correlation Coefficients

County	**Class**	**Correlation**		
		Population	**Employment**	**Housing Units**
Hancock	Developed	*0.9350*	0.7105	*0.9024*
	Marsh	-0.6943	-0.5834	-0.5976
	Vegetation	-0.1869	-0.7300	*-0.8271*
	Bare Soil	0.3484	0.6298	0.1518
Harrison	Developed	0.6285	0.1816	0.4781
	Marsh	0.6662	0.6234	0.6691
	Vegetation	-0.1798	-0.5596	-0.6529
	Bare Soil	0.5150	0.1737	0.0596

Table 5.1 continued

County	Class	Correlation		
		Population	Employment	Housing Units
Jackson	Developed	0.2515	-0.4879	-0.0162
	Marsh	0.0993	-0.4193	-0.4083
	Vegetation	0.0628	0.3945	0.1712
	Bare Soil	0.6559	0.0434	0.4960
All	Developed	0.5508	0.1830	0.6169
	Marsh	0.2249	-0.0721	0.4883
	Vegetation	-0.1691	-0.2771	*-0.8119*
	Bare Soil	0.6557	0.3477	0.6558

In lieu of an accuracy assessment, analysis was conducted on the amount of each land cover type varied within the same year. As mentioned in the Results Chapter, two images from 2000 were analyzed for each county. The first image used in the classification for Hancock County was acquired on April 19, 2000 while the second image was acquired on Oct 11, 2000. The first image used in the classification for Harrison and Jackson Counties was acquired on January 6, 2000 while the second image was acquired on Oct 4, 2000. Figures 5.3 through 5.5 show the results of the difference between each image for each Gulf Coast County. In Hancock County, developed land cover (20 mi^2) was found to have the most difference between the two images followed by vegetation, water, marsh and lastly bare soil (0.005 mi^2). Visually, the amount of land cover differences between to the classification maps (Figure 4.6 and 4.7) is not noticeable when comparing the two images side by side.

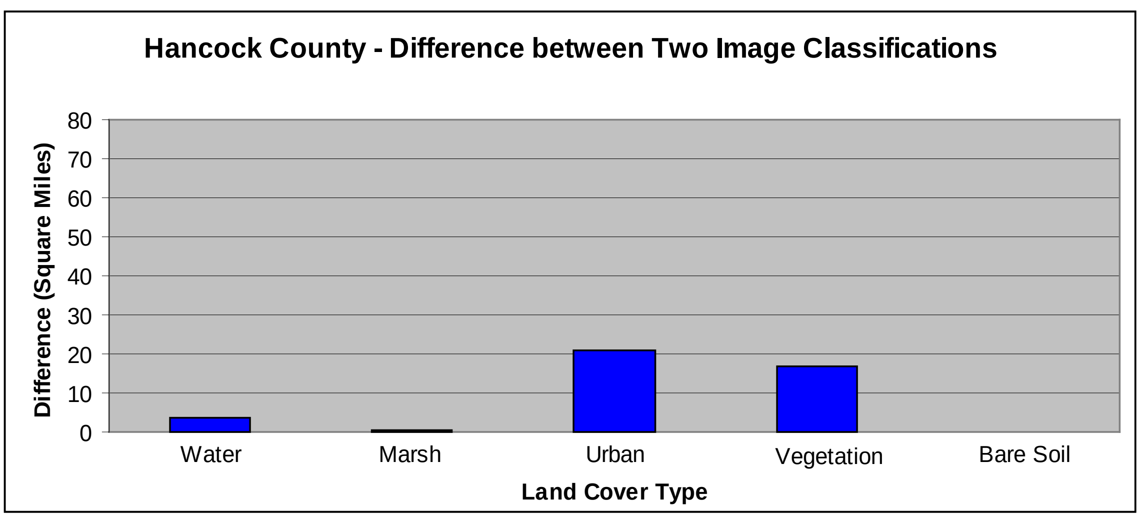

Figure 5.4: Difference in the amount of each land cover type of two classified 2000 images covering Hancock County

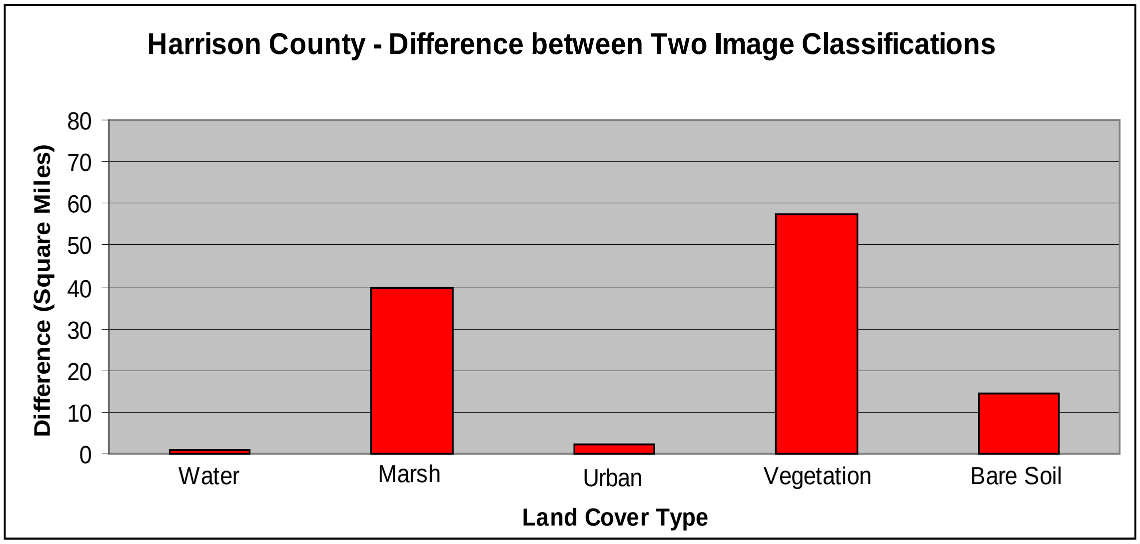

Figure 5.5: Difference in the amount of each land cover type of two classified 2000 images covering Harrison County

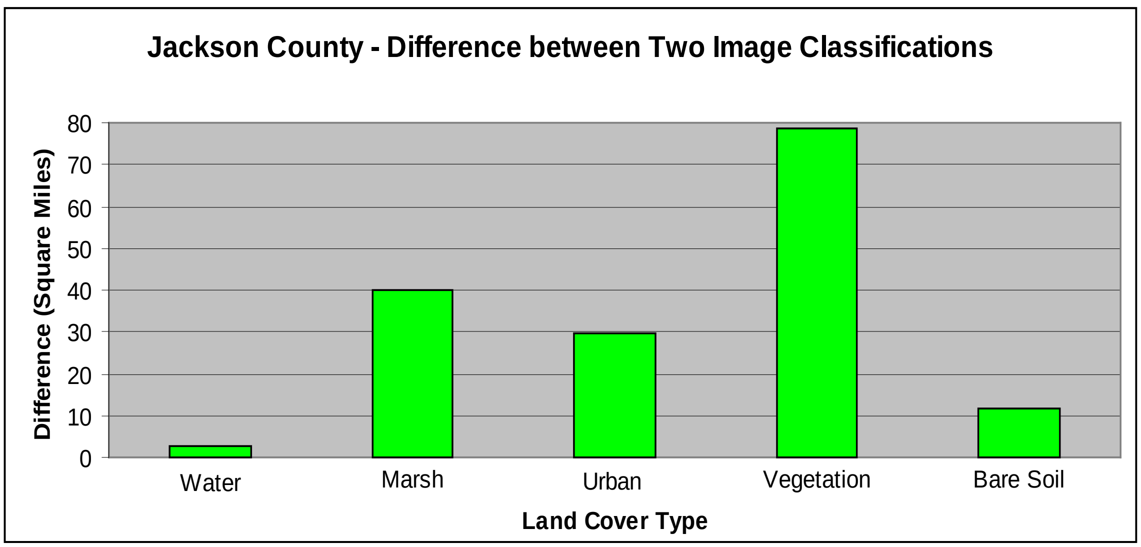

Figure 5.6: Difference in the amount of each land cover type of two classified 2000 images covering Jackson County

Vegetation and marsh land cover types were found to differ between the two images the most with 57 and 39 mi^2 respectively in Harrison County. Bare soil, developed land, and water all fell below the 15 mi^2 difference level. The difference in the amount of marsh in both classification maps (Figure 4.19 and 4.20) is noticeable unlike the difference in the vegetation and developed areas.

Vegetation varied the most in Jackson County with close to 80 mi^2 followed by marsh (39 mi^2), developed land (29 mi^2), bare soil (11 mi^2) and water (2 mi^2). The possible reason for the difference in marsh is also mentioned in the Results Section 4.3; one image was taken during a period of drought or low tide which caused a lower water level (classified as vegetation) in the marsh area located in the central part of Jackson County. The developed area in the northeast corner of the county was also shown to be different in both images; for instance, in the first

image, some areas were classified as developed areas while the in the second image, they were classified as vegetation.

These differences in the amount of each type of land cover within the same year put some perspective on the changes of each land cover type through the thirty year period. If just within one year, one land cover type could very as much as 80 mi^2 than an amount of change less than 80 mi^2 may be negligible. More analysis of more images within each year studied is necessary to determine if there is a trend in the amount a particular land cover type varies within a year. However, from the data provided, it appears that the land cover types in Jackson County vary more than Harrison and Hancock Counties.

5.2 Study Limitations

There were several limitations with this study that affected the results, such as lack of an accuracy assessment. The results of this study are not complete without an understanding as to the accuracy of the data. An error matrix of the classified data and a reference dataset is a common method to assess accuracy. A reference dataset for each LULC classification would have been difficult to acquire. Reference datasets for the older images from 1970 and 1980s would have most likely required manually digitizing older LULC maps or searching through historical county records relating to how the land was used before GIS datasets. One possible reference dataset that could have been used for the 1990 and 1995 LULC maps was the USGS NLCD datasets; however the classification systems were different therefore one classification would have to be modified to fit the other to make the comparison. Field data could have been used as a reference dataset if the study was extended to 2010.

A second issue deals with the unsupervised methodology used in this study LULC classification. A supervised LULC classification may have improved classification results; however this method often requires more time and resources than an unsupervised classification method. Supervised classifications often include field data to act as training data to more accurately classify the imagery into LULC classes. Field data may have improved the LULC of Harrison and Jackson counties; both counties had low correlation values with the socioeconomic data which could mean that the LULC classification was not correct. The author of this study was more familiar with Hancock County than Jackson and Harrison Counties therefore this first hand knowledge most likely helped the classification of Hancock County imagery. An unsupervised classification method was chosen for this study because it required minimal analyst input and was achievable with the limited time and resources available.

The imagery used for this study also had several issues to overcome, such as the cloud cover and spatial resolution. Most of the imagery acquired along the Gulf Coast Counties in the summer months contained cloud cover which inhibits LULC classification because the BV of the pixels were not representative of the land. The majority of the imagery used for this study was acquired when seasonally the vegetation BV (leafless trees and brown grass) are close to developed area and bare soil BV which could lead to misclassification of the imagery because the vegetation pixels may have been clustered with the developed land and bare soil spectral classes. One solution is to increase the number of spectral clusters the ISODATA algorithm produces which would perhaps separate the bare soil, vegetation, and developed land BV in the winter months. The number of spectral classes chosen for this study was thirty. If the number of spectral classes were increased, the analyst would have to spend more time manually assigning LULC classes to each spectral class because there would be more clusters to assign.

Higher resolution imagery may have improved the results of this study as well. The spatial resolution of Landsat imagery (30 m) also may have led to mixed pixel classification errors. Mixed pixels are an issue fore non-homogenous landscapes when the size of the pixel is large enough that it covers an area that has more than one land cover type. Mixed pixels can lead to classification errors since the more abundant brightness value wins out and the less abundant land cover is not represented. The scale of the classification system can account for this issue. The classification used for this study, vegetation, developed land, water and etc was appropriate for the spatial resolution of the Landsat Imagery. Higher resolution imagery requires larger storage space, more processing power (more pixels to classify) and more images are required to cover the three counties used in this study.

6.0 Conclusions

LULC analysis throughout the Mississippi Gulf Coast Counties over thirty years provides an interesting look at the temporal changes in the landscape. These results correlated with socioeconomic data show the affects of growth in population, jobs and housing units on the environment. Two Landsat path/row images were found to cover the Gulf Coast Counties. Sixteen images were used in this study, one image per year from 1975 to 2005. After running an ISODATA clustering algorithm, classification of these images into five types of land cover, developed land, vegetation, marsh, water, and bare soil, was completed. The land cover types were then compared by analyzing the area of each type and theirs changes over thirty years. The thematic maps of each county were created to show where the major areas of transition of the environment were located, i.e. from vegetation to developed land and marsh to vegetation in five year intervals.

A literature review of relevant LULC classification studies was conducted. These studies provided insight into various methods and the presentation of the results of classifying land cover in coastal settings. Various types of both supervised and unsupervised methods were described as well as accuracy assessments. Most LULC studies presented results in the form of thematic maps and tables of areas of each LULC type. It was interesting to note that most studies used a different LULC classification system.

Analysis of two sets of images acquired in different seasons of 2000 was conducted to get an idea of the differences of each land cover type within the same year. Each land cover type was found to vary from image to image, in varying degrees. This difference between the areas of each land cover type over this study period is most likely due to the seasonal variations of vegetation from spring to winter to fall. These differences helped put the amount of change of land cover type discussed in the Results Chapter within the thirty year period in perspective; for instance, if the area of vegetation can vary by 80 mi^2 within one year than a change less than that in five years is not significant.

Over the past thirty years, the population, employment and housing units in each of the selected coastal counties grew more than most counties in Mississippi. Although, no significant statistical conclusions were drawn from this study (too few data points); developed land and bare soil appeared to be positively correlated to the selected socioeconomic characteristics of Hancock County. Vegetation appeared to be negatively correlated to employment and housing units in Hancock County. These results and the thematic maps suggest that changes in areas of developed land, vegetation, and bare soil could relate to the increases in population, employment, and housing sector in the counties covered by the study. Several limitations were discussed such as an accuracy assessment, unsupervised classification, cloudy imagery and mixed pixels.

7.0 References

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Appendix A

The raw socioeconomic data is presented in Table A-1.

Table A-1: Gulf Coast Counties raw socioeconomic data

County	Class	2005	2000	1995	1990	1985	1980	1975	1970
Hancock	Population	46088	42967	37802	31760	29091	24537	20000	17387
	Employment	11610	10081	14900	5663	N/A	4171	N/A	N/A
	Housing Units	23551	21072	N/A	16561	N/A	12517	N/A	N/A
Harrison	Population	195756	189601	181553	165365	168762	157665	149300	134582
	Employment	83820	78193	76089	64104	N/A	53337	N/A	N/A
	Housing Units	88138	79636	N/A	67813	N/A	57954	N/A	N/A
Jackson	Population	134243	131420	126626	115243	120119	118015	107700	87975
	Employment	47500	40990	60691	38119	N/A	35162	N/A	N/A
	Housing Units	56732	51678	N/A	45542	N/A	42635	N/A	N/A

Vita

Ms. Amanda English was born in Daytona, Ohio. Since her father was in the Air Force, she moved around several times throughout her childhood into adolescence; however, today she considers Florida her home. She graduated from Florida Institute of Technology in 2003 with a Bachelor's degree in Environmental Science. After graduation, she moved to Mississippi to work for the Naval Oceanographic Office as a Physical Scientist in the Mine Warfare Department. After acceptance in the Department of Defense's Long Term Training Program, she began her graduate studies focusing on Remote Sensing and Coastal Sciences at the University of New Orleans in the fall of 2008. Dr. Mahtab Lodhi provided mentorship over her graduate studies in the Geography Department at UNO until graduation in Spring 2011.