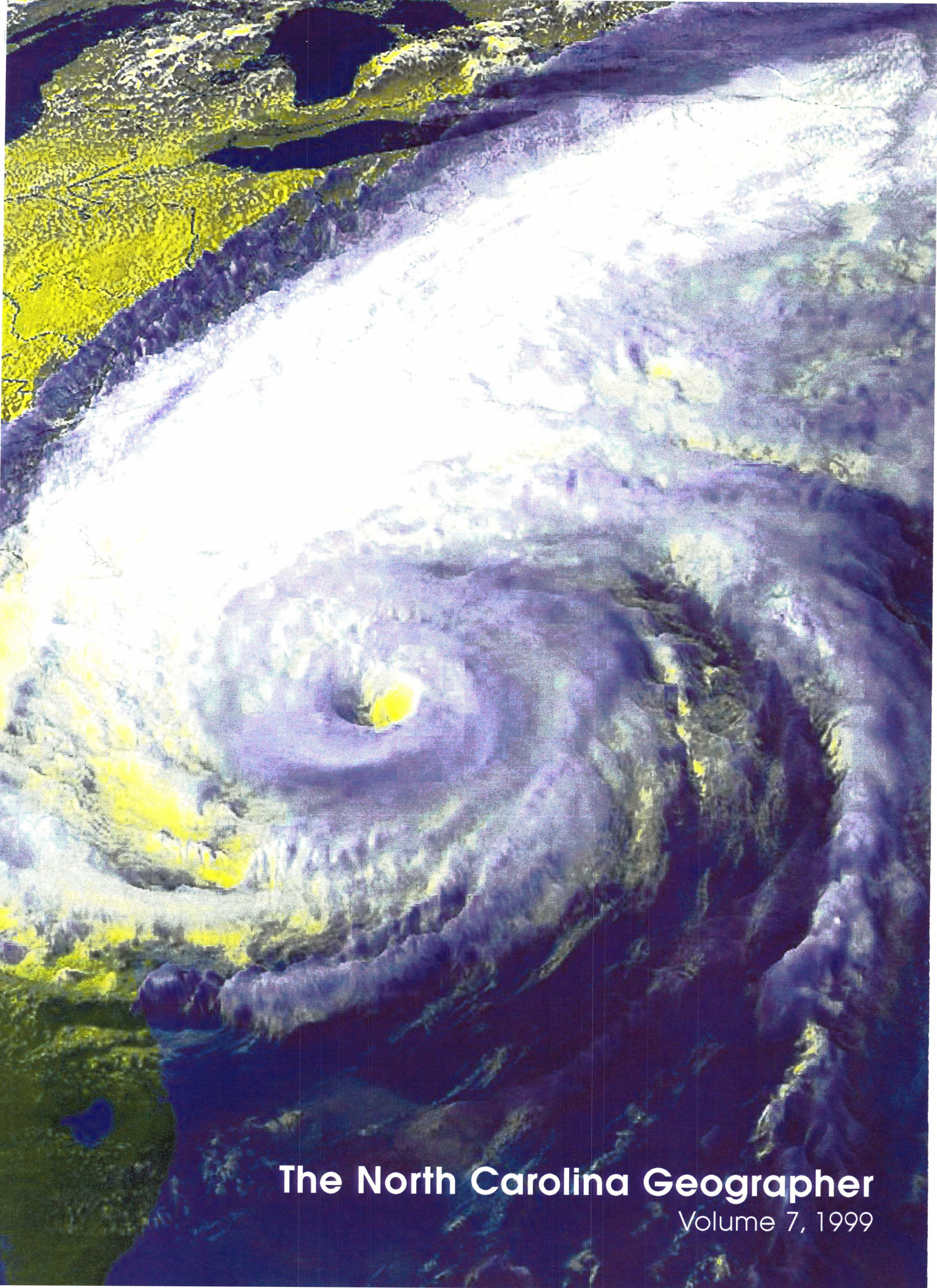

The North Carolina Geographer

Volume 7, 1999

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About the Cover
Composite image of Hurricane Floyd as the storm approached the North Carolina coast on September 15, 1999 at 3:15 pm. It was generated using GOES-8 data. Hal Pierce/Fritz Hasler, Laboratory for Atmosperes, NASA Goddard Space Flight Center.

THE UNIVERSITY OF NORTH CAROLINA

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CHAPEL HILL

Department of Geography

Is proud and pleased to support the continued publication of The North Carolina Geographer

The North Carolina Geographer
Volume 7, 1999

Contents

Editor's Remarks

On the morning of Thursday, 16th of September 1999, Hurricane Floyd finally came onshore near Wilmington, North Carolina, and proceeded to travel quickly over the eastern portion of the state. Despite predictions a few days earlier that this would be the "storm of the century," the winds had by this time lessened considerably, and Floyd was ranked as a Category 2 hurricane. As the storm advanced over the region many felt relieved as only scattered reports of minor property damage, and downed trees and power lines, came in. Yet, as Thursday evening and Friday morning news reports were to make clear, massive flooding of the many tributaries leading to the Tar, Roanoke, and Neuse Rivers had begun the day prior to the hurricane's landing, and the water was continuing to rise rapidly well beyond the 100 year floodplains. By the time President Clinton arrived in Tarboro, NC, on Monday, 20th September, it had become clear that in economic terms alone this was the greatest natural disaster to hit North Carolina in recorded history.

In this year's issue of *The North Carolina Geographer* the causes, progress, and impacts of Hurricane Floyd have begun to be recorded in Paul Gares' working report on the physical geography of the disaster in which he lays out the rainfall patterns associated with both Hurricane Dennis and Floyd and the rise of the floodwaters across the region. Karen Mulcahy's Statistical Analysis of the State is also devoted to the subject of Floyd as she describes some of the difficulties entailed in determining the spatial extent of the resultant flooding. As the year progresses we hope that other researchers will provide articles and reports on the impacts of Floyd on North Carolina for the 2000 issue.

Dennis Edgell continues the focus on physical geography with his analysis of the degree to which El Niño has impacted climatic variation in southeastern North Carolina. His study correlates the Southern Oscillation Index (SOI), which is a climatological variable that assesses the El Niño situation in the Pacific, with temperature and precipitation values in North Carolina. Contrary to the public's expectations, he argues, El Niño is not a major explanatory variable.

Also in this year's issue Gil Robbins provides a first-hand account of the development of a comprehensive Geographic Information System (GIS) for Beaufort County. As Gil points out, GIS's have become a valuable tool utilized by local governments, particularly in the area of property tax assessment and the maintenance of the modern cadastre. And yet the variety of these governments, their resources, and their abilities to attract qualified system operators, have given rise to wide disparities in system capabilities across the state and country. His case study illuminates many of the technological and social problems encountered by local governments as they strive to computerize a host of databases and allow for a user-friendly decision support tool.

Karen Cappiella and Michael Slattery provide a case study of the spatial and temporal variability of nitrogen, phosphorus and sediment within a small coastal plain agricultural catchment located near the Pitt County community of Littlefield. The authors then comment on the causes of this flux across the study basin, such as fertilizer application, crop harvesting and seasonal hydrological changes.

Emily Selby has provided a case study of the crab processing industry of Eastern Carolina. In the early 1990s, she argues, the industry faced a labor crisis prompted by the inability of the crab houses to recruit local workers. An alternative labor pool was subsequently established, consisting of Mexican migrant women brought into the

US under the H2-B temporary worker program. In her assessment of the Luther Lewis and Son crab house of Davis, North Carolina, Emily focuses on the work experiences of both groups of workers and draws some interesting parallels in regard to their marginalization from the economic mainstream.

In closing my account of this year's issue of *The North Carolina Geographer* I would like to take the opportunity to introduce the co-editors of next year's issue. Jeff Popke is a human geographer at East Carolina University whose work primarily focuses on the political and economic transition in post-apartheid South Africa. Patrick Pease is a physical geographer at East Carolina University, and has addressed sediment erosion and transportation in aeolian and fluvial environments. Both Jeff and Patrick were invaluable in overseeing the final production stage of this issue, and I am sure they will put together an excellent millennium issue. As always, contributions are welcome!

Climatology and Hydrology of Eastern North Carolina and Their Effects on Creating the Flood of the Century

Paul A. Gares
Department of Geography, East Carolina University

Hurricane Floyd crossed eastern North Carolina on September 15 and 16, 1999, causing the largest disaster in the State's history. The majority of the damage was caused by flooding associated with heavy rainfall rather than by high winds or coastal erosion. The rainfall produced a flood that exceeded the predictions for the 100 year event, catching most of the residents of the region by surprise. The general perception was that the region had seen hurricanes of that magnitude before and that they had not produced such extreme floods. This particular flood occurred because hurricane Floyd arrived less than two weeks after hurricane Dennis, which dropped up to 10 inches of rain on the region, saturating the soil and raising river levels to the bankfull stage. When hurricane Floyd dropped an additional 8-16 inches, the likelihood of a severe flood was enhanced. There are a number of physical features of eastern North Carolina that contributed to making this flood so severe. These include: the shape of the drainage systems; the topography of the coastal plain; the characteristics of the soils; and the land-use on the coastal plain. These factors combine with precipitation to produce hydrologic conditions that are highly variable, as these factors vary in time and space. When these factors come together in certain unique ways, extreme events, such as the flood associated with hurricane Floyd, occur.

Introduction

On September 16, 1999, hurricane Floyd made landfall on the coast of North Carolina in the vicinity of Wrightsville Beach. Residents of coastal areas along the southeast coast of the United States had been following the progress of this hurricane for several days as it moved through the Caribbean, across the Bahamas and along the Florida coast. As with all hurricanes, the National Weather Service predicted landfall over a rather broad section of coast, this time ranging from Charleston, South Carolina to Morehead City, North Carolina. Of great concern early on was the speed of the winds, which were reaching 150 mph, making Floyd a category 5 storm. As Floyd moved north, however, the wind speeds diminished, so that by the time it crossed the coast maximum winds were around 100 mph. To the residents of eastern North Carolina, the storm had become more of a nuisance, not even measuring up to the force of hurricanes Bertha and Fran which had followed nearly the same path in 1996. What people did not realize was that this storm was going to create widespread havoc throughout the region.

By the morning of September 17, 1999, hurricane Floyd had already moved far enough north that rainfall had ceased in the southern part of the state. The sun appeared during the early afternoon across all but the northern-most part of the region. The heavy rains overnight had caused localized flooding along small creeks, but these waters quickly passed through the system. Residents began hearing warnings of possible flooding along the major rivers that afternoon, and indeed water levels began to rise that evening. When people awoke on Saturday, September 18th, residents of the floodplains of the Tar, Neuse and Cape Fear Rivers found water lapping at their doors. Widespread evacuations began, and people looked on incredulously as water rose in their living rooms destroying treasured possessions. There was a general sense of amazement that such a disaster had developed from this rather innocuous storm. Yes, rainfall had been significant, but people recalled other storms that produced as much rainfall and no flooding. It turns out that a rather unique set of circumstances combined to create this flood.

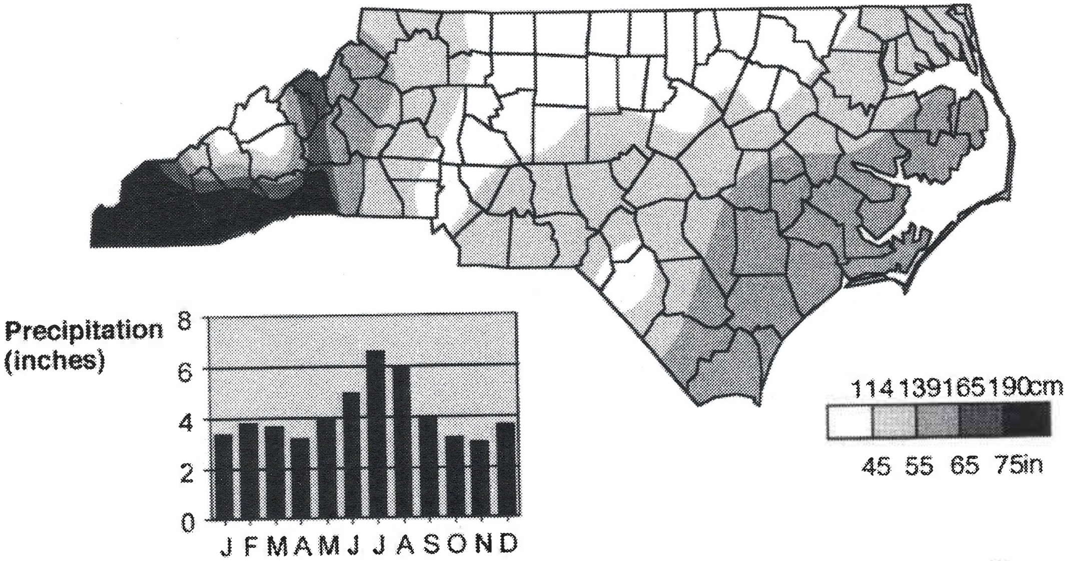

Figure 1. North Carolina annual rainfall and monthly distribution of rainfall for the Coastal Plain.

The purpose of this paper is to examine the climatic and hydrologic conditions of Eastern North Carolina with the purpose of explaining how this flood occurred. In order to accomplish this, a review of factors that affect flooding in this region will be undertaken and then rainfall and river stage data will be provided to characterize the magnitude of the event. There are five factors that affect river flow in general and flooding in particular:

1. The amount of precipitation and its intensity;

2. The shape of the drainage basin;

3. The topographic characteristics of the drainage basin;

4. The characteristics of the soils within the drainage basin; and

5. The land use characteristics of the region.

Each of these factors will be discussed within the context of eastern North Carolina.

Eastern North Carolina

Eastern North Carolina coincides with the region called the coastal plain. It consists of a flat, relatively featureless plain that slopes gently from the Piedmont to the ocean, losing about 200 feet in elevation over its 75-100 mile width. The flat appearance of the plain would suggest that runoff and surface erosion are minimal, but recent research by Phillips *et al.* (1993; 1999) and Slattery *et al.* (1997) suggests that this is not true.

Rainfall across Eastern North Carolina ranges from 45-65 inches per year (Figure 1), with the higher amounts concentrated along the coast, mainly in the southern two-thirds of the region. Rainfall is highly seasonal, with maximum amounts of 5-7 inches during June, July, August and September. There are four precipitation mechanisms responsible for the rain: 1. Cold fronts that cross the state from west to east and that dominate from fall to spring; 2. Thunderstorms produced by convective systems that develop during the hot, muggy summer months; 3. Coastal rain associated with northeaster storms that develop off the Cape Hatteras coastline; and 4. Tropical storm systems that track north from the Caribbean, often developing into hurricanes. Hurricanes are most likely to affect the region in late summer and early fall. This is a period of the year when monthly rainfall drops from about 4.5 inches in September to about 3 inches in November.

Four large river systems flow across the coastal plain (Figure 2). The drainage basins are elongated in a northwest-southeast direction, with the main trunks of the rivers running mainly along the southern margins of the watersheds. The location of the rivers with respect to their floodplains is significant because higher ground is generally located on the southern side of the rivers whereas broad, flat floodplains lie to the north. This configuration explains the fact that the most extensive flooding occurred north of the rivers, with sections of Tarboro, Greenville, Goldsboro and Kinston among other local communities being completely inundated.

There is a general perception that the soils of the coastal plain are predominantly sandy with silt/clay soils located in marshy or low-lying areas. The particle size characteristics of soils are an important component of the hydrologic system because they determine to a certain extent the amount of precipitation that can infiltrate into the soil, and therefore the amount of water that runs off across the surface. The infiltration/run-off relationship determines the rate at which the river discharge increases following the beginning of rainfall, and the length of time over which increased discharge occurs. A soil survey of Pitt County (Soil Conservation Service, 1974), located approximately in the middle of the coastal plain, reveals that about 63% of the land has soils characterized as poorly- or extremely poorly-drained, and the remaining 37% are equally divided between moderately well- and well-drained. Infiltration experiments conducted on two fields in southern Pitt County reveal the degree to which the particle size characteristics affect infiltration. The first field consisted primarily of soils of the Wagram series, characterized as well-drained loamy sand soils with an A horizon approximately two feet in depth. The second field consisted of Lenoir Series soils described as poorly drained loams with

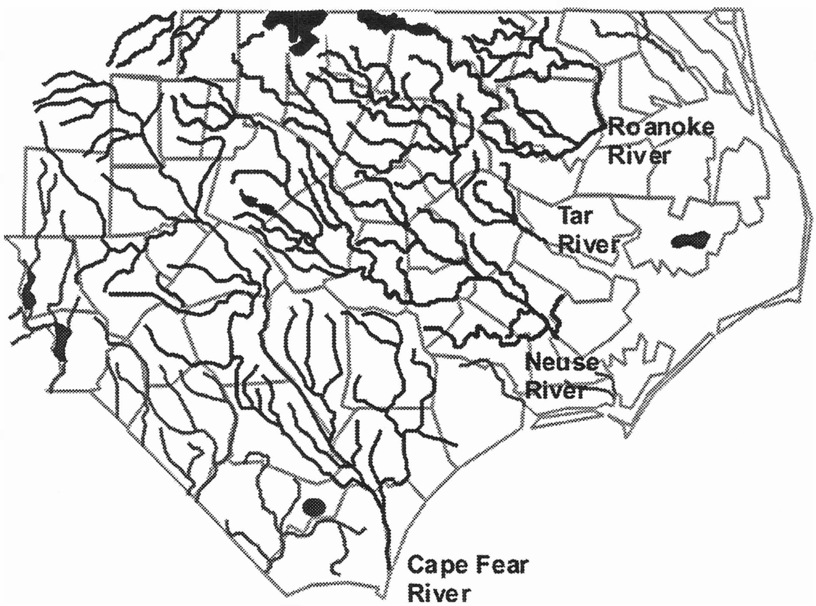

Figure 2. Drainage systems of the Coastal Plain of North Carolina.

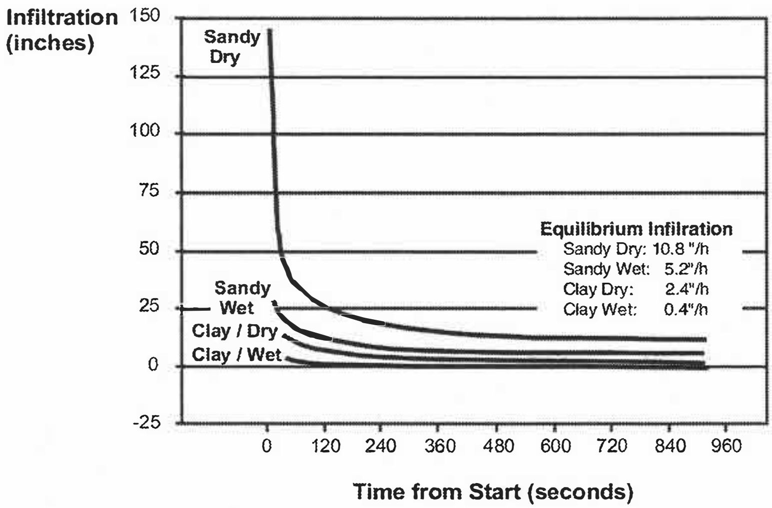

Figure 3. Infiltration on two Coastal Plain agricultural fields.

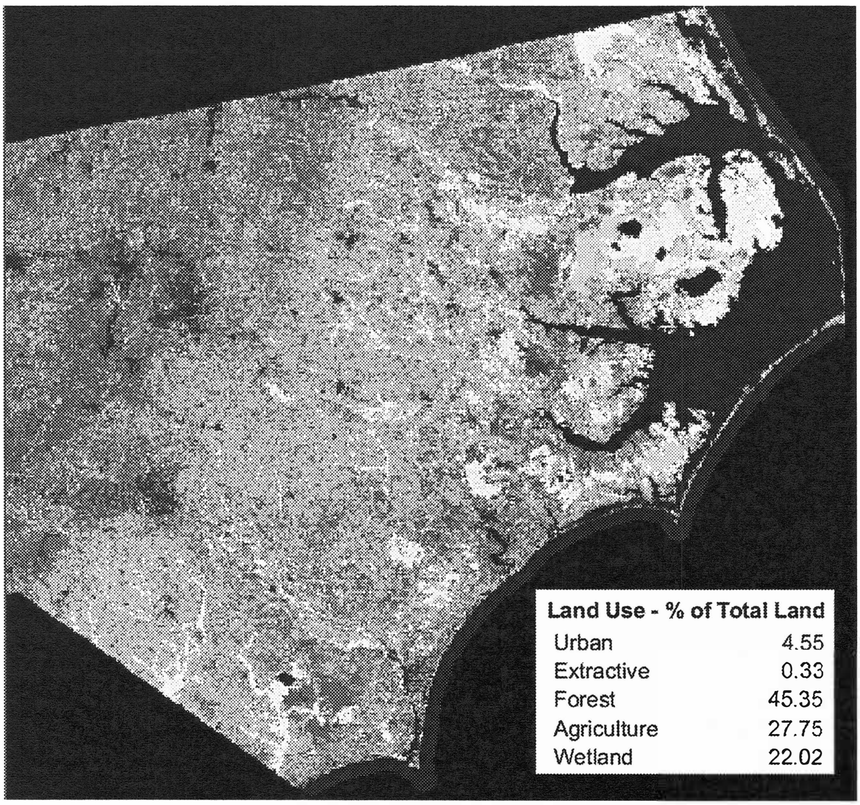

Figure 4. Land use in Eastern North Carolina. White represents agricultural land; light grey is wetland; medium grey is forest; dark grey is urban; nearly black is water.

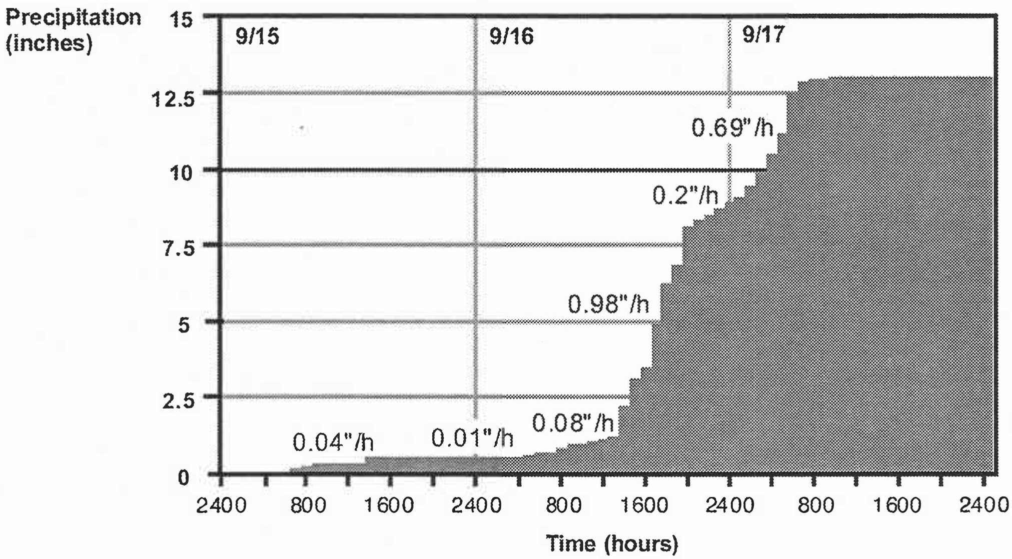

Figure 5. Precipitation recorded at Kinston, NC, September 14-16, 1999. Also shown are rainfall intensities for selected periods during the storm.

a shallow A horizon at about 8 inches depth. The infiltration data (Figure 3) reveal sharp differences between the soils. The first set of infiltration runs took place in late April, 1996 after a long period without rain. Gravimetirc soil moisture on the Wagram field was 0.7% and on the Lenoir field 6.4%. The second infiltration run was done in September, 1996, after hurricane Fran. Gravimetric soil moisture was 31% on the Wagram field, but not measured on the Lenoir field. On the dry fields, the initial infiltration rate is very high on the Wagram field, but it falls off to an equilibrium value of 10.8 inches/hour after 15 minutes of running time. Infiltration is lower on the Lenoir field, starting at 25 in/hr and achieving equilibrium at 2.4 in/hr. Under wet conditions, the infiltration rates are very low - 5.2 in/hr on the Wagram field and 0.4 in/hr on the Lenoir field. Given these observations, we could expect infiltration rates of 5-10 in/hr on about 18% of Pitt County, and rates of 0.5-2.5 on about 63% of the County. It seems safe to conclude that the 18% defined as moderately well-drained would have infiltration rates in the 2.5-5 in/hr range.

Land use in Eastern North Carolina is dominated by agriculture (Figure 4). Land classified as agricultural makes up about 28% of the image shown in Figure 4. The primary crops grown in the region are tobacco, cotton, corn and soy. The planting schedule can be important to hydrological processes as fields are left bare for certain parts of the year. Tobacco is generally planted in early spring and harvested by mid-summer, whereas cotton and soy are planted in late spring or early summer and harvested in mid to late fall. Fields are generally left bare over the winter, although in recent years there has been an increase in the number of fields planted with a cover crop such as rye.

Hurricane Floyd

On September 7th, 1999, a tropical depression was identified by the National Weather Service, located some 950 miles east of the Leeward Islands. By early on September 8th, the storm had gained sufficient strength to be classified as a tropical storm, and it became hurricane Floyd on September 10th, when the eye of the storm was located some

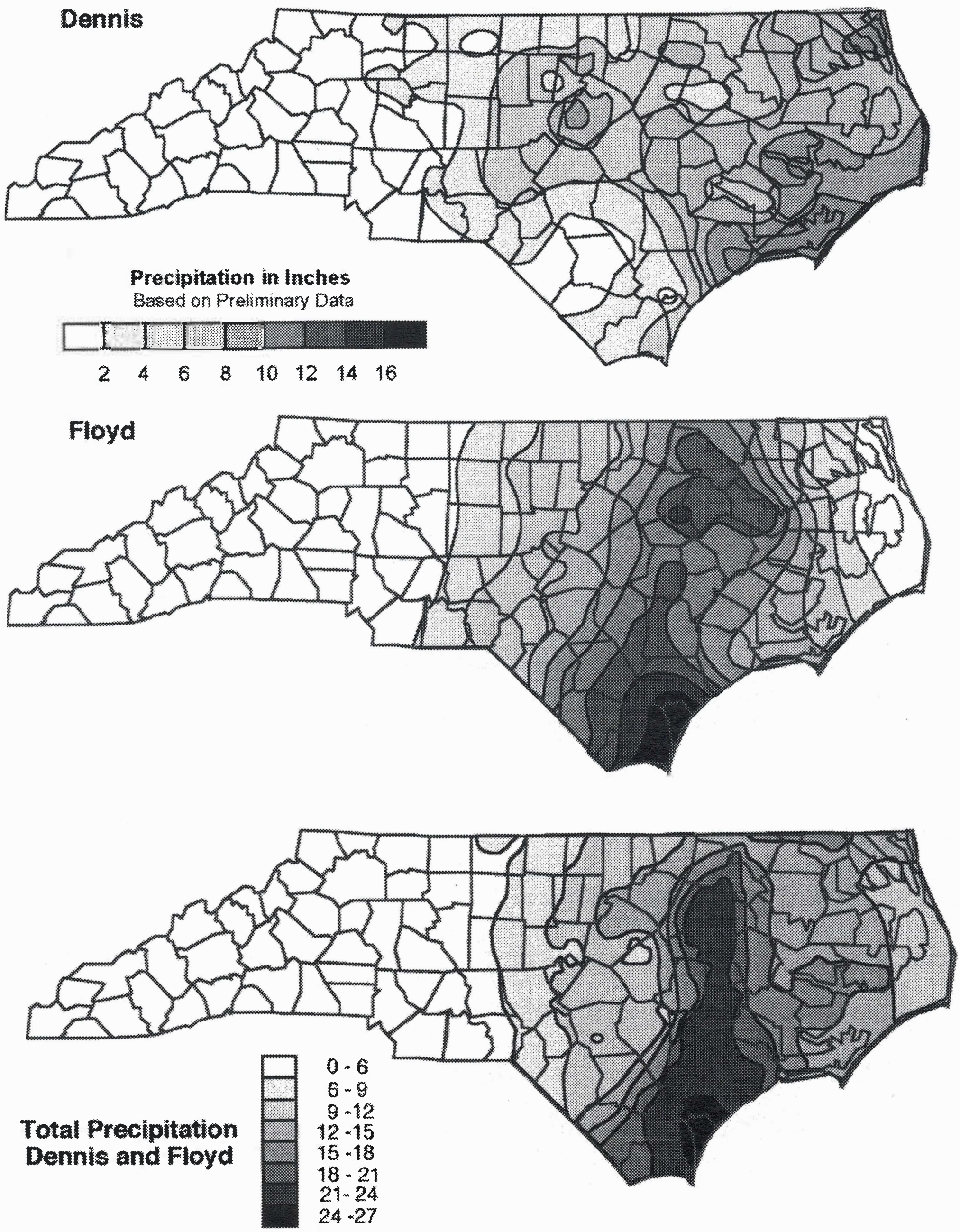

Figure 6. Distribution of rainfall during Hurricanes Dennis and Floyd. Also shown is total precipitation from the two events. (Note: Data for Dennis and Floyd are preliminary data, obtained from the State Climatic Office of North Carolina; precipitation total data are from the National Climate Data Center)

190 miles east of Barbuda. At that point, Floyd was moving in an east-northeast direction at 10 mph. On September 14th, Floyd crossed the Bahamas, moving at a speed of 14 mph toward the coast of Florida. Maximum sustained winds were 150 mph, making it a very strong category 4 storm on the Saffir-Simpson scale. Experts observed that Floyd had developed into a very large storm in which hurricane force winds (>74 mph) extended 125 miles out from the eye. The cloud cover associated with Floyd extended about 750 miles in a north-south direction, and 650 in an east-west direction. By contrast, comparable measurements made for hurricane Andrew when it was in approximately the same location, some 350 miles east of Miami, reveals a more compact storm, some 250-280 miles wide.

As Floyd progressed through the eastern Caribbean, forecasters believed that the storm would turn to the north. However, Floyd confounded the experts by continuing on a westward course, and evacuations were carried out along the entire coast of Florida. Late in the evening of September 14th, Floyd finally began the long-awaited turn to the north. At this time, the outer bands of the hurricane began to cross the North Carolina coastline, coming into contact with a strong cold front that was moving across the southeast. The stalled cold front produced 0.5 to 1.0 inches of rain across eastern North Carolina on September 14th, and into the early morning of September 15th (Figure 5). At 5 am on September 15th, the eye of the storm was centered 100 miles east of Cape Canaveral, moving forward at 14 mph, with maximum sustained winds of 140 mph. By 1pm, the eye was located about 150 miles east of Jacksonville. Maximum sustained wind speed had diminished to 125 mph, hurricane force winds (>74mph) still extended out to 140 miles from the eye, and tropical storm force winds (>39mph) extended out 230 miles. At this time, Floyd was about 250 miles south of Wilmington, NC. The heavier rain bands were beginning to move across the North Carolina coastal plain, producing heavy precipitation during the afternoon of September 15th (Figure 5). Tropical storm winds began to be felt along the NC shoreline from Wilmington to Morehead City.

By 5pm on September 15th, the storm center had moved to within 215 miles of Wilmington. The storm's forward speed had increased to 17 mph, while the maximums sustained winds had dropped to 115 mph. The hurricane force winds still extended 140 miles out from the eye. By 11 pm that night, the storm center was 100 miles south of Wilmington. Hurricane Floyd finally made landfall at 3 am on September 16th, at Cape Fear. Maximum sustained winds at that time were 110 mph. The National Weather Service continued to call for 6 to 12 inches of rain along the hurricane path, as it had been doing for the previous 24 hours. The hurricane was moving faster as it passed over the coast, advancing northward at 20 mph. At 7 am, the center was approximately over New Bern, moving at 24 mph. Maximum sustained winds had dropped to 100 mph. By 11 am, the storm was passing over Virginia Beach, moving offshore again. Maximum winds speeds were 80 mph.

The primary impact of Floyd was the rainfall associated with the storm. Whereas the National Weather Service had been predicting 6 to 12 inches of rain, preliminary data indicate that 10 to 18 inches of rain actually fell over much of eastern North Carolina (Figure 6). This amount of rainfall is unusual for this region, representing 15-25% of the annual total, and exceeding the average monthly rainfall for September by 6-12 inches. However, the region has experienced heavy rain before, having had recent experiences with hurricanes Bertha, Fran, and Gloria. Inhabitants of eastern North Carolina were, therefore, surprised when many small creeks in the region suddenly grew, overflowing their banks and flooding extensive areas adjacent to the streams. Residents woke up on Friday September 17th to find that the main stems of the region's rivers were predicted to reach flood stage during the course of the day and that the rivers would continue to rise for several days. Stage data for the Tar River at Greenville typify the rivers' conditions throughout the region (Figure 7). At this point, discharge data are not yet available from the USGS, but the agency estimates that the discharge will rank the flood in the 200 year recurrence interval range. This is significantly different from the 500 year level that many have cited, but this estimate is based on the stage data which have inherent inaccuracies.

The Hurricane Floyd Flood

All information about Hurricane Floyd suggests that this storm should have produced moderate flooding. Instead, Floyd created the worst disaster in the history of the state of North Carolina. Indeed, some estimates indicate that 50,000 homes were affected by the flood waters and that total losses will exceed $6 billion. The question on many people's mind is: what made Floyd such a devastating storm?

The answer to the question is found in the topics reviewed above. The primary factor was the fact that not two weeks prior to Floyd's arrival, hurricane Dennis moved over the Outer Banks and then stalled offshore. The result was several days of rain throughout the region, with rainfall totals reaching 8-12 inches (Figure 5). In fact, this amount of rain was sufficient to raise the rivers to bankfull stage. The rivers had only just begun to recede when Floyd arrived. The precipitation totals for the two storms are depicted in Figure 5. The map shows that much of eastern North Carolina received at least 13 inches of rain, with some places receiving over 20 inches. It is useful to consider the rainfall in terms of the infiltration data presented in Figure 3 and in terms of the nature of the soils that predominate in eastern North Carolina. Given that poorly drained soils make up the majority of the soils of the region, and given the infiltration rates of these soils, we can assume that rainfall intensities greater than about 0.5 inches per hour will result in nearly all the rain running off the land. These intensities occurred several times during the passage of Floyd. Using Pitt County as an example, about 270,000 acres are poorly drained. If we assume no infiltration on this land, and we estimate that 12 inches of rain fell during Floyd, there would be 11.8 billion cubic feet of water to dispose of. Given that the Tar River drainage system comprises about seven counties, if we assume that comparable amounts of water were

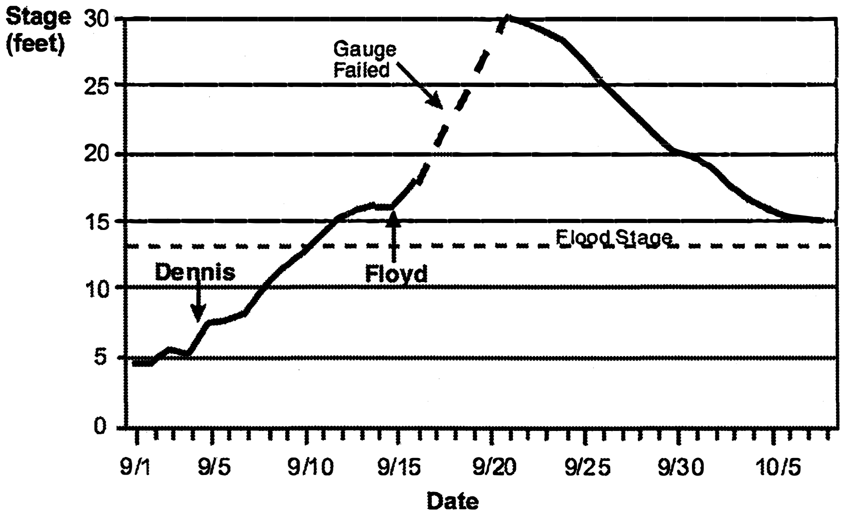

Figure 7. River stage data for the Tar River at Greenville, September, 1999 (data from USGS Regional Office, Raleigh, NC).

generated in each county, there would be nearly 100 billion cubic feet of water to move through the system.

The runoff situation in Eastern North Carolina is modified by the land use characteristics of the region. The heavy agricultural usage means that the vegetation cover is modified at certain periods of the year when the harvest occurs. The tobacco harvest typically occurs in late July through August. The result was that when Dennis and Floyd moved through eastern North Carolina many fields were covered only with crop residues. The absence of this vegetation can be expected to increase the intensity of rainfall impact on the surface and to increase run off.

From a hydrological standpoint, it could be argued that the flood associated with Floyd could have been worse had the storm track and river basin orientations not been perpendicular to each other. There is evidence that discharge is intensified when a storm tracks along the axis of a drainage basin, but it is attenuated when the storm passes across the basin perpendicular to its axis. This was the case during Floyd. Although there was considerable rain at the upper ends of the coastal plain drainage basins, it took several days for the peak flow to move downstream. This at least allowed evacuations to occur with some time to spare.

Conclusions

We have learned many lessons from this particular storm. It is clear that we do not completely understand all the interactions involved in environmental events - at least while they are occurring. If we did, we would have seen that the environmental factors that existed in eastern North Carolina prior to the storm were likely to lead to a catastrophic situation. The flood associated with Floyd was the product of a set of conditions that were relatively unique. The most important of these factors was the heavy rainfall that occurred just 10 days earlier when hurricane Dennis passed across the region. The rainfall associated with Dennis was spread across several days and increased soil moisture. The wet soils then inhibited infiltration when the rainfall from Floyd fell. The high percentage of poorly-draining soils in the region combined with pre-existing moisture conditions to limit infiltration. This and the intense rainfall that occurred during the storm led to high run off. The relatively rapid rise of the Tar River suggests that surface or sub-surface run-off was quite significant in this storm. All these conditions are also influenced by the absence of vegetation on the tobacco fields. The biggest problem for inhabitants of the coastal plain, and for the managers of the occupied areas, is that it is virtually impossible to quantify the combinations of these factors to produce reliable probability-of-occurrence data. Thus, the link between the operation of the physical system and the management of human systems will be very difficult to establish with a high degree of certainty.

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Association of the El Niño-Southern Oscillation Index and Monthly Temperature and Precipitation Records in Southeastern North Carolina

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The 1997-98 winter was an important El Niño season, received much media attention, and was blamed for many climatic aberrations worldwide. Although El Niño and the Southern Oscillation have been correlated with climate patterns in the circum-Pacific regions, there is a question as to what degree El Niño influenced climate as far away as southeastern North Carolina. The Southern Oscillation Index (SOI) is a climatological variable that assesses the El Niño situation in the Pacific. Correlation analysis is utilized to find a statistical link between the SOI and monthly averages of temperature, and monthly totals of precipitation. Lag correlations and other associations are also sought. Analysis showed that the magnitude of monthly SOI values does not directly correlate with the magnitude of monthly averages of temperature or monthly precipitation totals in southeastern North Carolina. Significant lag correlations indicate that subtler links may exist, but the SOI alone has little power for prediction of the climatic pattern in the region. Climate records indicate that not all El Niño/La Niña events are the same, nor do they exert the same influence on southeastern North Carolina. The public is advised not to perceive the "El Nino effect" as a catch-all explanation of all weather events. This paper illustrates that there is a need for more studies on global atmospheric circulation systems and their links to inter-regional climate patterns that affect southeastern North Carolina.

Introduction

Environmental education emphasizes that the entire world is linked ecologically. Climatic phenomena in one region may influence conditions in other regions, even at great distances. The winter and spring of 1997-98 were strong "El Niño" seasons and received much media attention, both nationally and locally. Unusually warm water of the eastern Pacific ocean, particularly off the west coast of South America, produced significant drought in the East Asia-Western Pacific Rim, and abnormally high precipitation, flooding, mudslides, etc. in the Americas. El Niño caused or was blamed for a number of synergistic environmental problems (Parris, 1998). Winter temperatures and precipitation totals were both above normal in the southern coastal plain of North Carolina (State Climate Office of NC, 1998). The local public enjoyed the mild winter (Jacobs, 1998), but perceived the high frequency of days with rain as a significant nuisance (Nilsen, 1998).

A global-scale atmospheric pressure reversal is monitored in the tropics and is linked to El Niño. The Southern Oscillation Index (SOI) is the difference between the sea level pressure measured in Tahiti and that measured in Darwin, Australia. When barometric pressure is higher than usual in the western Pacific, pressure is lower than usual in the eastern Pacific. This global-scale pressure swing is known as the "Southern Oscillation." The term "El Niño-Southern Oscillation" (ENSO) was coined by climatologists, however "El Niño" is just the name of the warm phase of fluctuation between warmer-than-usual and colder-than-usual ocean temperatures in the Eastern Pacific. Surface pressure at Darwin and Tahiti are strongly "negatively correlated." That is, when one is higher than normal, the other is lower than normal. Large negative values of the SOI indicate an El Niño phase (Allan, *et al.*, 1991). El Niño's cold, drought-associated, reverse counterpart is termed

"La Niña." Historically, an El Niño event irregularly recurs every three to seven years. Some evidence suggests that El Niño events are becoming increasingly common, and may explain weather aberrations worldwide.

The SOI is a simple, convenient, but also an important and accurate measure of the El Niño phenomena. It is the association of this measure with local climate records that are examined in this paper. Although the SOI has been statistically linked to greater precipitation along the Pacific Rim, the ENSO link to eastern regions of the U.S. has been studied less. An improved understanding of ENSO has economic value, particularly for U.S. agriculture (Solow, *et al.*, 1998). The occurrence of too much rain associated with El Niño may delay planting or waterlog crops, and La Niña associated drought could also affect crops. Successful prediction of El Niño-La Niña climate oscillations may result in long-term forecasts beneficial to US crop production (Keppenne,1995).

Many other factors directly influence weather patterns in southeastern North Carolina, but this study strives to find if indeed there is an SOI connection to the local climate. Conflicting opinions exist as to whether southeastern North Carolina experiences a cooler than normal winter (Clement, 1998) or a milder winter during an El Niño (Jacobs, 1998). The rule of thumb—if indeed there are any "rules"—is that during a typical El Niño year, southeastern North Carolina experiences a mild but wet winter, followed by a cool and wet spring, possibly followed by a drought-like summer as La Niña conditions prevail (NCDC, 1998). Highly variable day-to-day winter temperatures and extreme cold may also characterize a "typical" El Niño episode even when the average temperature for the entire season is "above normal." The lay public is aware that something unusual occurs during an El Niño year, but has a poor understanding of the phenomena. This paper attempts to find qualitative and quantitative links between the ENSO and records of temperature and precipitation in southeastern North Carolina.

Methods

Southern Oscillation Index Data

SOI is the difference between standardized air pressure (point data) at Darwin, Australia (12° South latitude, 131° East longitude) and standardized air pressure in Papeete, Tahiti, French Polynesia (17° South latitude). SOI calculations followed Allan *et al.* (1991). Monthly averages of raw SOI data were obtained from the National Oceanic and Atmospheric Association's (NOAA) Climate Prediction Center (CPC) web page.

The units of the SOI are dimensionless. The years 1951-1980 are the base period for the climatological "normal" of SOI, thus index values are reported above or below this average. Negative values of the SOI represent El Niño conditions. The lower (more negative) the SOI is, the more extreme the El Niño event. Positive SOI values indicate a La Niña episode. Although monthly SOI data exist back to 1882, data compiled before 1933 include significant gaps and are of questionable accuracy. These data are monthly means, January through December, for January 1933 through June 1998. The northern hemisphere winter season 1997-98 (December 1997, January 1998 and February 1998) will hence be referred to as the winter of year 1998.

Arguably, even the SOI may be misleading. Note that the SOI is an *index* and not a direct measure of warm El Niño waters. A better measure of El Niño is sea surface temperatures (SST) measured from moored ocean buoys and satellite remote sensors. However, buoy data and other direct observations exist for a much shorter time series than the SOI. A long time series is needed to examine the statistical link between El Niño and the North Carolina climate record.

Southeastern North Carolina Data

Temperature and precipitation data are divisional averages of several weather stations. Records from forty-two weather stations, past and present, across thirteen counties in North Carolina's Southern Coastal Plain region (Figure

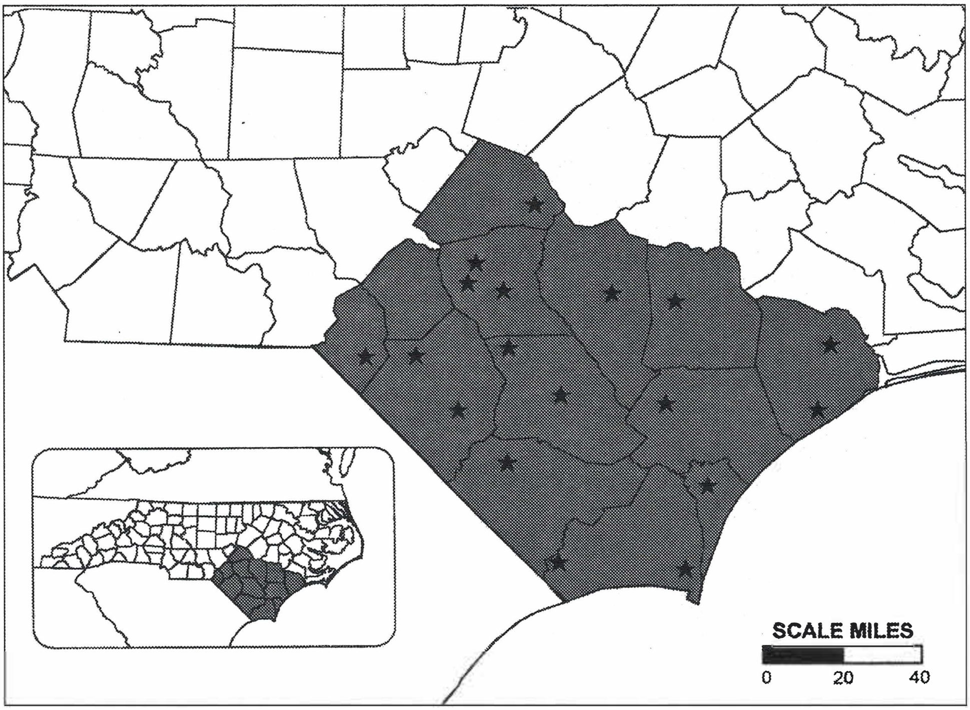

Figure 1. Location of North Carolina's Southern Coastal Plain Climate Division and Current Weather Observation Stations.

1) were compiled by NOAA's National Climatic Data Center (NCDC), to find climate division averages of monthly temperature and monthly precipitation total. Currently there are nineteen active stations (Figure 1) that comprise a divisional average. These raw data were obtained via FTP at the NCDC web page. The monthly divisional averages are useful because they smooth out spatial and short term irregularities in precipitation and temperature anomalies; however, important information about extremes and intra-regional variability may be lost. Average Monthly Temperature (AMT) and Monthly Precipitation Total (MPT) data were acquired to match the available period of the SOI, 1933 to 1998. Climatological "normal" values of AMT and MPT are 30 year averages (1961-1990) of these respective variables. Although metric units (degrees Celsius and centimeters, etc.) are standard in climatology, the NCDC collects and publishes data in English units (degrees Fahrenheit and inches). English units are disseminated by the NCDC for public use, thus English units will be used for reporting here.

Qualitative Methods

Tabular comparisons are made for the most important El Niño/La Niña months. SOI values are compared against the AMT and MPT deviation from their normals. January is chosen as a representative winter month when El Niño is often well developed, and June is chosen as a representative summer month when La Nina conditions prevail. The SOI, AMT, and MPT data time series for recent years are plotted and visually compared.

Quantitative Methods

Simple descriptive statistics are calculated for the monthly SOI, AMT, and MPT values. Pearson correlation coefficients and

Table 1. Comparison of Monthly SOI Values for Two Extreme El Niño Winters

1982-83 Southern Oscillation Index

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
-3.2	-4.0	-3.3	-3.6	-5.1	-4.6	-6.9	-7.6	-5.6	-2.2	0.7	-0.5

1982-83 Divisional average monthly temperature deviation from 1961-1990 normal (°F)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
-0.1	+0.8	-1.9	-1.9	+1.8	+5.7	-0.8	-1.0	+0.4	-4.0	-0.8	-1.1

1982-83 Divisional monthly precipitation total's deviation from 1961-1990 normal (in.)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
-0.51	-2.61	-0.42	+0.92	-0.92	+1.59	-0.14	+3.55	+4.49	+0.92	-2.29	-0.26

1997-98 Southern Oscillation Index

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
-1.7	-3.4	-2.6	-3.1	-2.3	-2.1	-5.4	-4.4	-5.6	-3.2	-0.2	1.0

1997-98 Divisional average monthly temperature deviation from 1961-1990 normal (°F)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
+1.3	-1.2	0.0	+0.2	-3.1	-0.1	+5.5	+3.7	+0.6	+1.7	+4.2	+5.0

1997-98 Divisional monthly precipitation total's deviation from 1961-1990 normal (in.)

Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
+0.01	-3.77	+1.83	0.25	+2.07	+1.16	+2.95	+4.48	+2.35	+2.57	-0.01	-1.63

regression analyses are completed to determine a quantitative linear relationship between SOI and AMT and between SOI and MPT. The correlation between a given month's SOI, and the following month's SOI is tested. Similarly, the lag correlations for AMT and MPT are also tested. The correlation between SOI in any given month and AMT and MPT for following months (lag correlation) is also investigated. The possible linear change in all values of SOI, AMT and MPT over time is also tested. All significance tests are made at the 95% confidence level. Null hypothesis of no significant correlation is at $p < 0.05$. The Shapiro-Wilk test is used to test for the normality of all variables. SAS is utilized for the calculation of descriptive statistics, correlation analyses and significance tests (SAS Institute, 1996).

Results

Qualitative Comparisons

The winters of 1983 and 1998 were the two most memorable El Niño events in the period of analysis. SOIs for the 1982-83 months November through March were in the lowest 5% (Table 1). Total winter temperatures were milder than normal, but that was a result of the abnormally warm December. A cool spring followed. Winter and spring precipitation totals were both above normal. SOIs for November through March of 1997-98 were also very low, and within the lowest 10% of all values. Although the coastal plain experienced a mild winter, spring was warmer than usual. Winter and spring months were abnormally wet, with a high frequency of number of days with rain, even though total accumulations were not greatly above the climatological normal (US Dept. Of Commerce, 1998). Drought conditions began in late spring 1998, and continued through early summer (Helm, 1998).

It is useful to examine the 1980s and 1990s in detail, as this period contained very active ENSO cycles. There is some evidence of a cyclic trend in the SOI data since 1980 (Figure 2-A), but low values recur on uneven intervals from three to seven years. The AMT data were obviously cyclic because of seasonal

Table 2. Comparison of Lowest Ten Southern Oscillation Index* Values for January and January Average Monthly Temperature and Monthly Precipitation Total in Southeastern North Carolina

RANK	YEAR	SOI	AMT	Deg. from Normal(°F)	MPT	Inches From Normal (In.)
1	1983	-6.9	41.6	(-0.8)	3.91	(-0.14)
2	1992	-5.6	45.0	(+2.6)	4.14	(+0.09)
3	1998	-5.4	47.9	(+5.5)	7.00	(+2.95)
4	1958	-3.8	38.8	(-3.6)	4.54	(+0.49)
5	1969	-3.2	40.7	(-0.8)	3.55	(-1.50)
6	1966	-2.8	39.8	(-2.6)	6.32	(+2.27)
7	1970	-2.3	37.3	(-5.1)	2.63	(-1.42)
8	1952	-2.0	50.7	(+8.3)	2.28	(-1.77)
9	1959	-2.0	43.4	(+1.0)	1.96	(-2.09)
10	1993	-2.0	47.3	(+4.9)	6.16	(+2.11)

* Large negative values indicate “El Niño” conditions.

Table 3. Comparison of Greatest Ten Southern Oscillation Index* Values for June and June Average Monthly Temperature and Monthly Precipitation Total in Southeastern North Carolina

RANK (In.)	YEAR	SOI	AMT	Deg. from Normal(°F)	MPT	Inches From Normal
1	1950	+2.0	76.7	(+1.4)	5.17	(+0.09)
2	1975	+1.8	76.1	(+0.8)	3.99	(-1.09)
3	1955	+1.7	72.3	(-3.0)	4.32	(-0.76)
4	1981	+1.7	79.6	(+4.3)	4.26	(-0.82)
5	1996	+1.6	76.3	(+1.0)	3.47	(-0.71)
6	1968	+1.4	76.0	(+0.7)	3.47	(-1.61)
7	1956	+1.3	76.3	(+1.0)	4.80	(-0.28)
8	1938	+1.3	74.4	(-0.9)	5.61	(+0.53)
9	1973	+1.3	76.1	(+0.8)	6.98	(+1.90)
10	1970	+1.2	75.4	(+0.1)	3.19	(-1.89)

* Large positive values indicate “La Nina” conditions.

temperatures, but there was an overall trend for milder winter temperatures toward the end of the 1990s (Figure 2-B). MPT is also somewhat cyclic, because of the summer precipitation maximum (Figure 2-C), but this does not visually match up with the SOI. The spikes in the MPT graph are explained by the summer convectional thunderstorms and occasional tropical storms characteristic of the climate of southeastern North Carolina.

The ten lowest January SOI values in the climate record are compared with the AMT and the MPT for each respective year that low SOI occurred (Table 2). The most extreme El Niño events do not necessarily dictate either a mild or a colder January. Average monthly temperatures in southeastern NC may be significantly above or below normal when the SOI of the Pacific is strongly negative. January 1952, 1959, 1992, 1993 and 1998 had strong SOIs, and AMTs for January in those years were above normal, yet January 1958, 1966, 1969, 1970, and 1983 also had strong SOIs when the AMT was below normal. Additionally, five years had MPTs above normal (1958, 1966, 1992, 1993, and 1998) and five years were below normal (1952, 1959, 1969, 1970, and 1983). A similar comparison of "La Niña" conditions found the ten highest SOI values for June had little relationship to AMT and MPT in June (Table 3). Seven of the ten largest La Niña episodes for June were characterized by below normal precipitation, and eight out of ten had warmer than normal temperatures. Thus, even when the most extreme El Niño/La Niña conditions exist, as measured by the SOI, monthly average temperatures or precipitation totals are not necessarily extremely high or low.

Correlation and Regression (Quantitative Analysis)

Monthly SOI values were found to be significantly correlated ($p < 0.05$) with SOI values of succeeding months (thus were autocorrelated). The value of any given month's SOI is strongly influenced by the magnitude of the preceding month's SOI. This "lag correlation" varied from a lag correlation of two months for February SOI to a lag correlation of ten months for March SOI.

However, the SOI for any given month was not correlated with the respective AMT or MPT of most months. Of the twelve monthly SOI's, none had a significant correlation with the AMT for its respective month. Furthermore, only two of the twelve monthly SOIs had a significant correlation with the respective month's MPT. The March SOI was significantly negatively correlated with precipitation in March. Low March SOI values were correlated with higher monthly precipitation totals ($p < 0.05$). The SOIs for September were significantly correlated with September precipitation. Higher September SOI values corresponded to higher precipitation totals in southeastern North Carolina. This contradicts the expected La Niña condition. If one considers a long time series, there is very little correlation overall between the Darwin-Tahiti pressure swing and temperature and precipitation patterns in southeastern North Carolina.

It should be expected that monthly precipitation totals would correlate with the magnitude of the SOI more than averages of monthly temperature. For example, a monthly average temperature of a winter month may include an unusual warm spell, but may also include a cold wave of a few days which would tend to balance out the "average" temperature. In such cases, ENSO influence may direct a west-to-east flow from a warm Pacific toward southeastern North Carolina. Localized and regional circulations of the atmosphere, influenced by other pressure systems, may act to balance out this warming. The presence of continental-scale pressure systems may create a northwest-to-southeast oriented jet stream, and cold fronts move into the southeast even during an El Niño year. Precipitation sums (MPT) are probably more directly associated with a warm Pacific and "typical" ENSO flow. The usual undulation of the jet stream flattens, and the weather flow across the

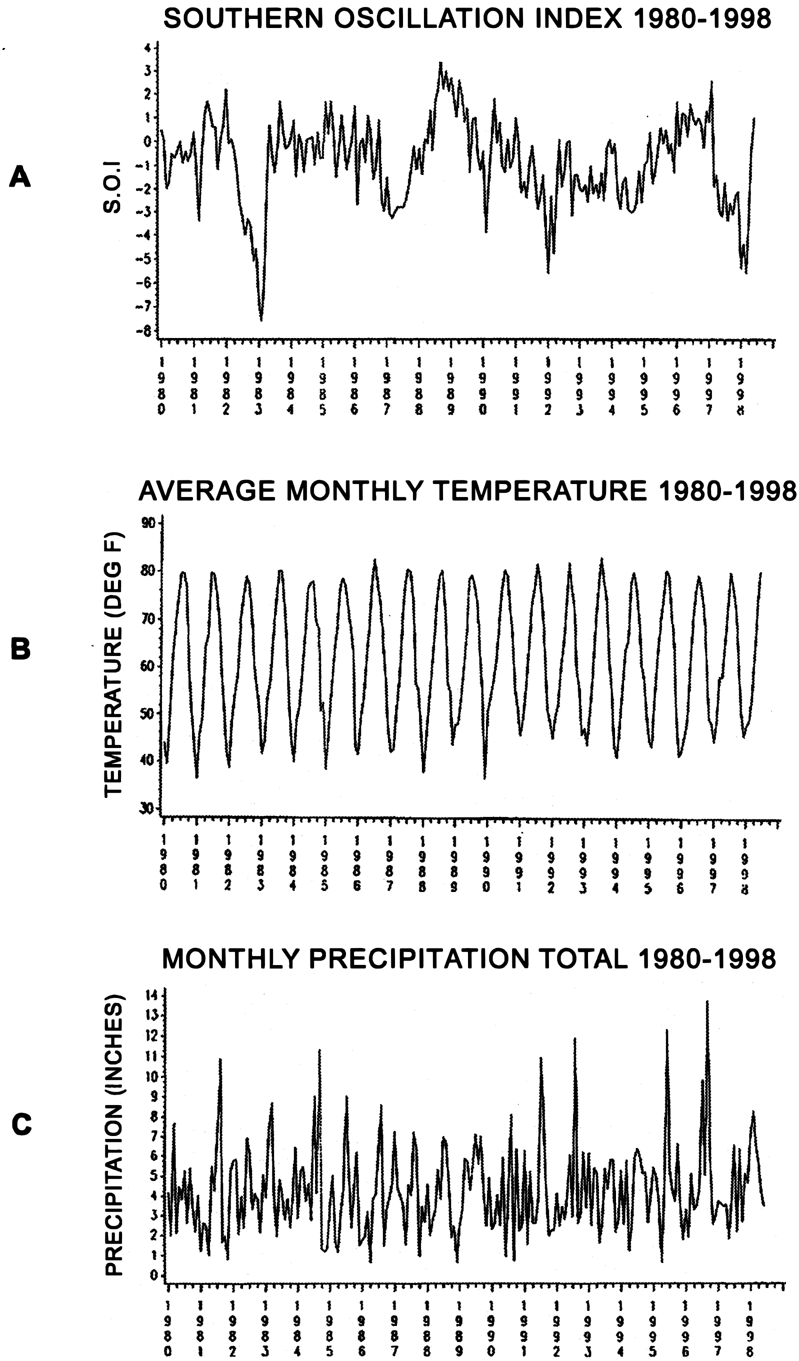

Figure 2. Time series graphs of the Southern Oscillation Index, Average Monthly Temperature and Monthly Precipitation Total in southeastern North Carolina, January 1980 to June 1998.

Table 4. Significant Lag Correlations and Pearson Correlation Coefficients of monthly SOI with AMT and MPT

Southern Oscillation Index Month:	Significant Correlation (+ or -) with Average Monthly Temperature or Monthly Precipitation Total in Southeastern NC
January SOI	- 29.1% February Precipitation - 38.7% March Precipitation - 28.2% July Temperature - 26.6% September Temperature - 29.5% November Temperature
February SOI	- 32.6% March Precipitation + 26.2% July Precipitation - 30.9% July Temperature - 29.9% August Temperature
March SOI	- 25.6% March Precipitation + 38.0% July Precipitation - 30.9% July Temperature
April SOI	+ 24.2% May Precipitation + 29.3% July Precipitation - 43.5% July Temperature + 27.2% October Temperature
May SOI	No significant correlations
June SOI	No significant correlations
July SOI	+ 35.1% September Precipitation + 40.8% February (of the following winter's) Temperature
August SOI	- 29.0% November Precipitation - 30.1% January (of the following winter's) Precipitation + 30.0 February (of the following winter's) Temperature - 25.6 March (of the following spring's) Precip.
September SOI	+ 24.0 September Precipitation + 30.6 February (of the following winter's) Temperature
October SOI	- 26.5% January (of the following winter's) Precipitation + 38.0% February (of the following winter's) Temperature + 24.1% May (of the following spring's) Precip.
November SOI	- 25.9% January (of the following winter's) Precipitation + 26.4% February (of the following winter's) Temperature + 27.3% May (of the following spring's) Precip.
December SOI	+ 31.1% (of the following) April's Temperature

Linear correlation is significant at greater than + 24.0% or less than -24% at 95% confidence.

southeast US becomes zonal (west-to-east). Low-pressure systems that originate from the Gulf track along the jet stream, producing increased precipitation in North Carolina (NC State Climate Office, 1999).

Although SOI was not correlated with any other month's AMT or MPT, other "lag correlations" were found. Because of a lag effect, SOI values in some months were significantly correlated with AMT or MPT in following months. For example, a low SOI for January was correlated with higher precipitation totals in February and March (Table 4). This follows the expected El Niño pattern that predicts a wet winter and spring. Lag correlations, although weak, may have predictive power, and the knowledge of an early season SOI could be useful for planning. For example, linear regression equations could be developed to predict March precipitation values from January's SOI (Figure 3). If March precipitation depends on the January SOI, then the significant regression equation can be given as:

$$\text{March MPT} = 10.43844 - 0.799103 \cdot \text{January SOI}$$

Significant lag correlations indicate that subtle links exist between the ENSO and North Carolina weather, and the causes of these links could be studied further. As more directly observed data of El Niño currents, continental-scale pressure systems, and local weather extremes are collected, these subtle links could be explored further.

There was a significant linear decline in the magnitude of the March and April SOI over time. Furthermore, January MPT and November MPT were also significantly correlated with time. There has been a significant linear increase for these values since 1933, but the significance of these linear relationships could be partly the result of short time series. Linear regression tests revealed no other significant relationships over time for any other monthly values of AMT, MPT, or SOI.

Conclusions

Although the El Niño/Southern Oscillation is not the usual direct cause of weather patterns in North Carolina, El Niño is sometimes associated with greater precipitation totals. The magnitude of the SOI-El Niño does not directly correspond to the magnitude of average temperatures and precipitation totals in southeastern North Carolina for any given month. The SOI alone has little predictive power for climatic patterns in the region. Thus, there is no guarantee that an El Niño year will always bring a warm wet winter, and the onset of La Niña does not necessarily signal a summer drought in southeastern North Carolina. (The current mild winter of 1998-99 is a good example. Temperatures and precipitation in January 1999 have both been above normal in southeastern North Carolina (NC State Climate Office, 1999). Winter 1999 has been an exceptionally mild winter yet 1999 is not an El Niño year!)

El Niño is not the only global atmospheric circulation system which influences regional weather patterns. The North Atlantic Oscillation, the Atlantic's SST and the status of the subpolar low pressure system all have an influence on weather patterns in the eastern US (Hurrell, 1995), but these phenomena have received much less media attention. "Catch-all" explanatory phrases for these phenomena do not exist as they do for El Niño. It is misleading to state that a certain weather event in southeastern North Carolina is "caused by El Niño" alone. Such oversimplifications have been perpetuated by the media. The El Niño relationship to any observed weather event is complicated by a number of factors, such as the state of the global or regional atmospheric circulation at the onset of El Niño. Furthermore, the characteristics of all "El Niño events" are not the same. It is difficult to obtain an uninterrupted sequence of causality for each El Niño occurrence that will match climate records. Likely, not every future El Niño event will have the same effect on southeastern North Carolina weather.

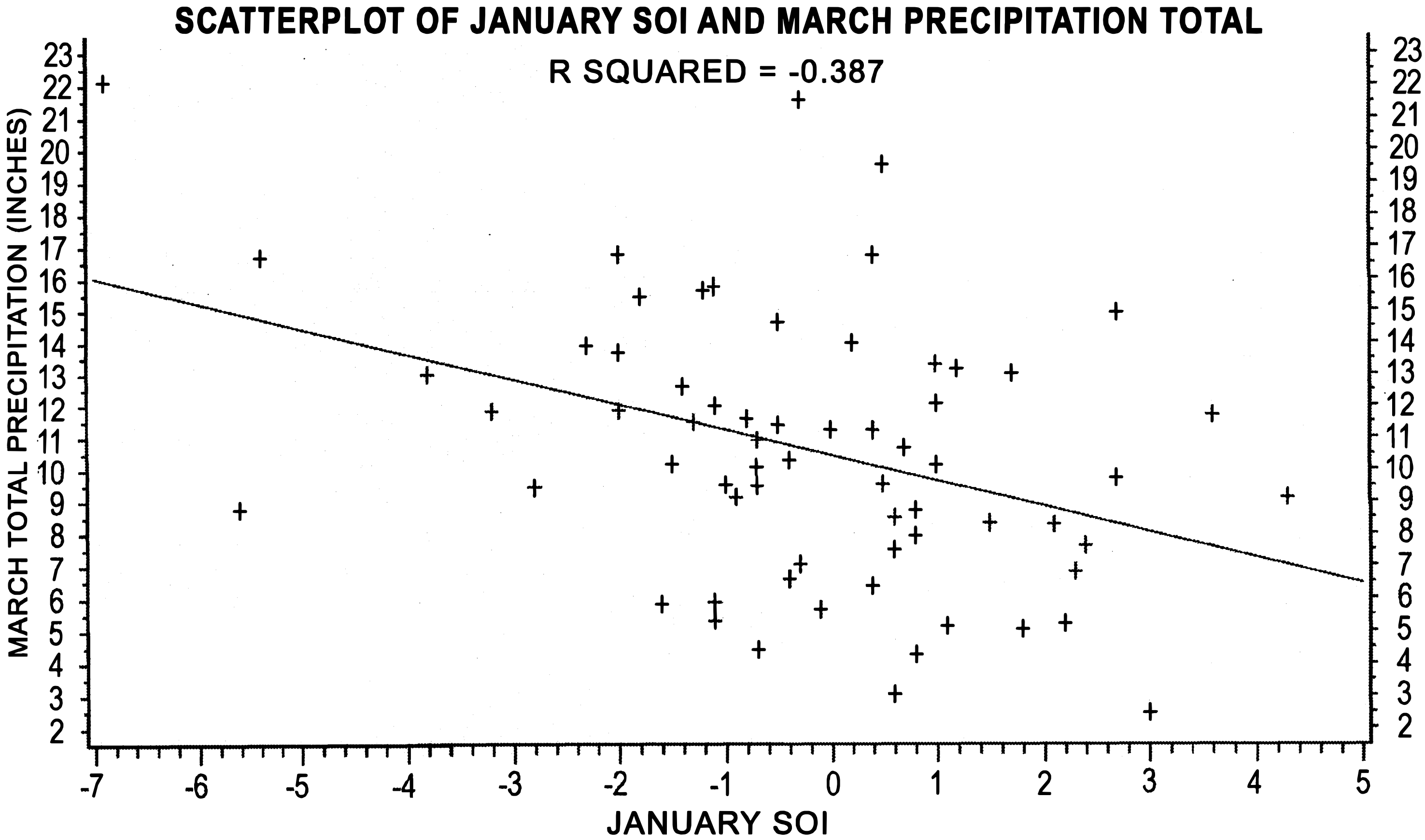

Figure 3. Scatterplot of January SOI and MPT for March. Correlation for these variables is significant ($p < 0.05$).

Unfortunately, the public may perceive what is "usual" or "expected" during an El Niño season to be what occurred in 1997-98 because of the sheer volume of media coverage that year. The climate record indicates that southeastern North Carolina has a good possibility of experiencing "opposite extremes" in the next El Niño/La Niña episode. Although the lay public may only relate to climate in the context of extremes the public is advised not to be misled by hysteria perpetuated by the media. Increasingly, the public demands to know more precise weather information, including a predictable pattern to regional climates. The climate system is complex however, and simple, all-encompassing explanations to atmospheric behavior are difficult to make and disseminate. Long term records may not match short term observations.

Although a direct link does not exist between SOI and a predictable weather pattern in southeastern North Carolina, this paper illustrates that there is a need for more studies on global atmospheric circulation systems and their links to inter-regional climate patterns.

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Implementation and Evolution of a Multipurpose GIS in a Rural County: The Case of Beaufort County, North Carolina

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The North Carolina present use value system, the 1994 property revaluation, and value defense/contest all created a need for a modern land records management system in Beaufort County, North Carolina. The existing manual system was inadequate to answer an increasing number of questions, and so the county began to explore the possible implementation of a geographic information system (GIS). Though its development was often arduous, the resulting GIS system found many uses as a decision support tool outside the confines of taxation, fueling additional system growth. Growth and technological evolution present a challenge not to be taken lightly. However, through vigilance, opportunism, and a keen sense of industry direction the future continues to look bright for the Beaufort County GIS.

Introduction

Geographic Information Systems (GIS) have become a valuable tool utilized by local governments, particularly in the area of property tax assessment and the maintenance of the modern cadastre. However, the variety of these governments, their resources, and their abilities to attract qualified system operators have given rise to wide disparities in system capabilities across the state and country. In my professional career, which has spanned 10 years (four with Westinghouse Landmark GIS and six with Beaufort County Land Records) I have gained a first-hand look at the development, planning, and deployment of one such system. The case study that follows details the development and evolution of a GIS in a rural county, from its inception as a land records management system to its current status as a multipurpose decision support tool. Special emphasis will be given to the stages of development, and problems encountered at those stages.

Study Area

Beaufort County is located in the lower coastal plain of North Carolina (Figure 1). It covers approximately 827 square miles of land and another 132 square miles of water. The county is bisected east to west by the Pamlico River and borders the Pungo River along its northeastern border. The population in 1990 was approximately 42,283. The only major city in the county is Washington, with a population of 9,160. Other smaller towns include Chocowinity (population 624), Bath (population 154), Belhaven (population 2,269), Aurora (population 654), Washington Park (population 486), and Pantego (population 171) (Beaufort County Government, 1997).[1]

The economy of Beaufort County is based primarily on agriculture and industry but also relies on a significant retail trade segment. Lesser economic activities include commercial fishing and recreation. County records indicate that in June of 1998 there were approximately 38,000 individual real property holdings within its tax jurisdiction. The total county budget for 1998 was approximately 32 million dollars on a tax base of approximately 2.00048 billion dollars.

Recognition of Need and Initial Planning

Demonstrated Need for a GIS

In the early 1970s the State of North Carolina created the present use value system through legislation (See North Carolina General Statutes 105-277.1A through 105-277.7). This system allows private land owners to defer a tax that is based on the difference in value between the "market value" (that which would be transferred in

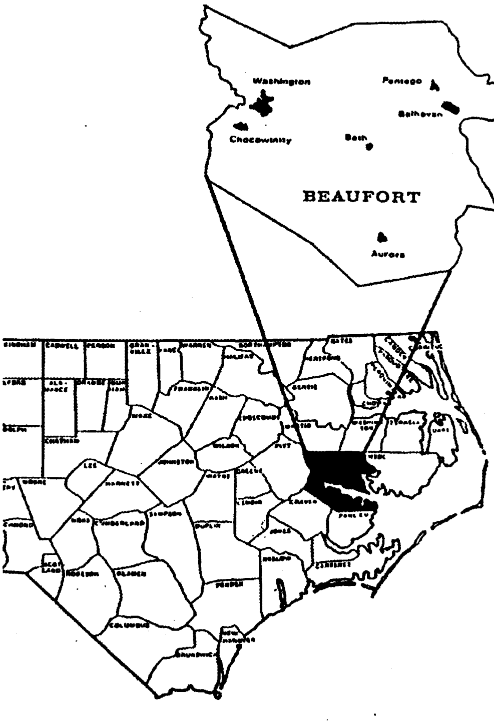

Figure 1. Beaufort County

an arms length transaction between a willing buyer and a willing seller) and its value under its present use (based on its ability toproduce agricultural, horticultural or silviculture commodities). Should an individual sell all or a portion of this property while included in this program, the taxes on the deferred amount would become due on the current year and the prior three years on that portion that was conveyed out of the program. The available manual methods of mapping and tax record management made it very difficult to calculate these taxes. This is because each land class (cultivated and forested) and each soil type (46 types reduced to six classes) has a different productivity rating resulting in a different value. Therefore the program required the identification of each class segment from the split tract be calculated for value and the result subtracted from the associated parent segment. The difference between this value and the market value would then be subject to the roll back. With the advent of soil mapping, and their link to the productivity brackets, there could be many segments. Each would then be calculated individually on a calculator for tax and interest and summed. The capability of GIS to automate all or parts of this process was a driving factor supporting its development.

In 1994 the upward revaluation of real property within Beaufort County aggravated the condition described above. Until the 1994 cycle, assessed values based on present use were often at or above those of the assessed fair market values. For most owners the present use deferral system offered little or no benefit. For this reason most owners that were eligible did not participate. In the most recent cycle however, present use values were significantly lower than the fair market values, sending Beaufort County taxpayers flocking to the Assessor's office to enroll in the system. Furthermore, many did not understand the 'roll back' characteristics of the program. The additional workloads associated with both the present-use program itself and the associated rolled back taxes inundated the tax office.

Rising land values themselves created a need for the planned GIS. When taxpayers saw the increases in their property values, many scheduled meetings with the tax office (and still do) to discuss the increases. GIS has become a valuable tool by which property value assessments can be defended. Just as important, as taxpayers became more savvy and inquisitive, the system would become a tool by which they could gather information to contest their assessments.

The State of North Carolina has recognized the need for improved land records management procedures. In 1977 the North Carolina Legislature established the North Carolina Land Records Management Program (LRMP) to provide technical and financial

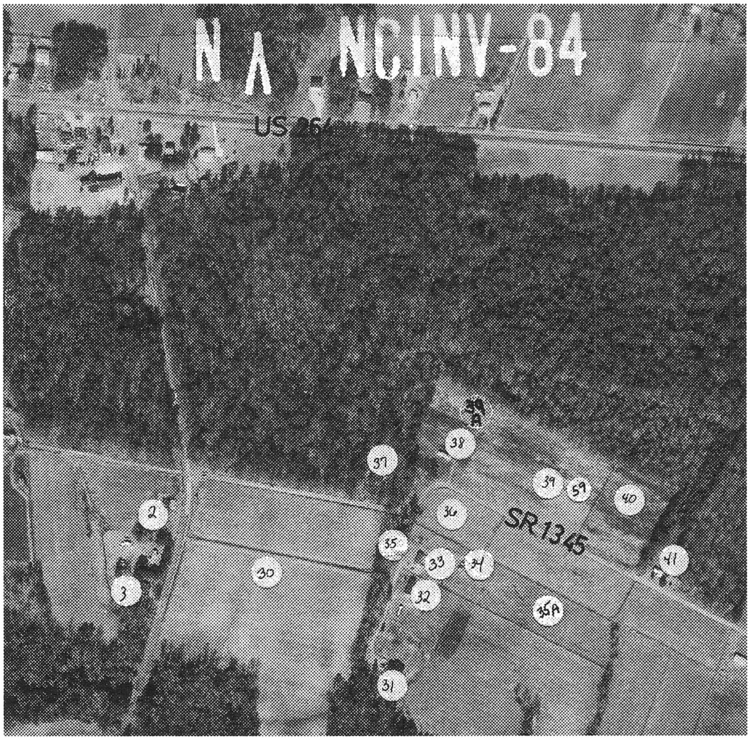

Figure 2. Note the paper dots affixed to the photo. These depicted the general location of listed properties within the county, but offered little additional information.

assistance to local governments to modernize their land records systems. In 1987 LRMP released its Technical Specifications For Base, Cadastral And Digital Mapping (Land Records Management Program, 1987) to aid in the maintenance of cadastral data (now moving to a digital format) for tax assessment purposes. This text still stands as the guide for the development of the cadastral database in North Carolina. Most, if not all, local governments that contract for the creation of digital graphic representations of their real property cadastre use this document as the base specification on which the data set will be created. According to a survey by the North Carolina GICC (Geographic Information Coordinating Council) over 60% of North Carolina counties have completed cadastral mapping. Forty-three of those were mapped to the specifications described above.

Pre-GIS Land Records Management System in Beaufort County

Some of the techniques used in past years to assess real property have themselves contributed to problems within the cadastre that could be addressed using GIS. Until recently, Beaufort County required taxpayers to list their properties yearly. Only 50 to 60% of the county's real property had an associated document (a deed, will or other instrument) reference by which the property came into the hands of the person doing the listing. This left many of the listings subject to the understanding or descriptions of the owner, including essential property valuation information such as the size and location of the property. In turn, this led to many low acreage listings, high acreage listings, unlisted property, and duplicate listed property. Furthermore, the existing mapping system consisted to a large extent of 'dot maps'. These were 1" to 660' scale glossy aerial photos, generally purchased from timber companies, with white paper stick-on dots affixed at the approximate location of the property (Figure 2). In most cases, no property lines were delimited on the photos. These maps offered little additional information, such as size or configuration, (information critical to a proper assessment) but were the standard (and only) spatial tool of the old system. Keep in mind that in these pre-GIS days the present use value was not a pressing issue because the market values remained lower, thereby minimizing the effect of less than adequate mapping.

During this period, ownership tracking was done by way of index cards that were associated with numbers applied to the paper dots on the maps described above. When a deed or other transfer instrument was recorded, a copy was made and sent to the Tax Assessor who instructed his/her staff to update both the digital tabular record (in the assessment database) and the index card. These cards were also available to the public for researching property characteristics.

It became evident that the existing system was inadequate to address daily issues faced within the assessment process. The labor-intensive nature of its maintenance had become prohibitive. Furthermore, the revaluation set to go into effect in 1994 was looming in the not too distant future. Until this time, the Tax Assessor, perhaps out of concerns centered on the upcoming revaluation, or fear of the massive change in the way of doing business, had refused to consider modernizing assessment methodologies.

As discussions began concerning the contracting of the aforementioned revaluation, the topic of the poor state of the existing record continually came up. The cost of revaluation would be significantly higher without good mapping. Under the provision that the County undertake up-to-date mapping, one contractor produced an attractive bid. This would prove to be a long-term benefit at short-term costs. The County, by request of the Tax Administrator, would use the lower revaluation cost to defray some of the costs associated with mapping the County using modern techniques. The Board of County Commissioners agreed to the project. Bids were let and a vendor chosen. As it happens, I was an assistant department supervisor for this vendor. The plan was simple: have the mapping done by 1992, and allow the revaluation contractor access to it thereafter. Any additional planning was limited to specifications proposed by the vendor and agreed to by the County's designated representative. The only exception was the laying off of the County into the scale grid, which will be discussed later in this text.

Initial Implementation

Platform Selection

Probably the most critical decision that had to be made by the County in 1990/91 was which platform (hardware and software) they were going to build their system around. There were a number of software choices available including ESRI's Arc-Info, Genesis, Intergraph, Map-Info, Strings, and even Auto-Cad. The mapping contractor could deliver its output as the County wished. But, the system had to cross a few hurdles. Most systems of that period were DOS-based PC platforms or launched from heavier mid-range computers and run on workstations. Those options that resided on the midrange systems were cost prohibitive to the County and were excluded. The company that supplied the tax assessment software was pushing their package 'Strings' (INFOCEL, Raleigh, NC, originally Geobased and later to become EDS). This package was cost effective and performed admirably in demonstrations. Furthermore, the level of expertise required by operators to become productive was far less than that of other systems reviewed.

The system would be required to generate the most accurate depiction of the real property cadastre as the documentation, and human hands, would allow (in other words, system precision had to be greater than personal accuracy). The system would also require a routine that would allow for a topologic soils/land-use overlay analysis that would facilitate present use valuations as described above.

Strings was the system that Beaufort County chose. Though I was not a part of this decision, I have not regretted it. Our primary concern was centered on the ease of editing. In the DOS era its menu and mouse driven editor proved to be quick, reliable, and easy to train. Though some of the other features (including plotting, system integration, and global editing) were more complex, I could manage them, allowing the technicians to focus on map maintenance.

Creating a Database

Beaufort County had no digital graphic data on hand at the time of project inception. The entire graphic cadastral data set therefore had to be created. Digital tabular data (textual descriptive data such as ownership, references, values, and type codes) had been maintained for a number of years, first on a Prime midrange computer system using a PASCO tax package and later on a Hewlett Packard 9000 using INFOCEL. These data would be the base on which all else was built.

Though I was privy to the planning elements described above, my personal involvement in system development began as an employee of Westinghouse Landmark (the database development contractor). The contract for the database development of the

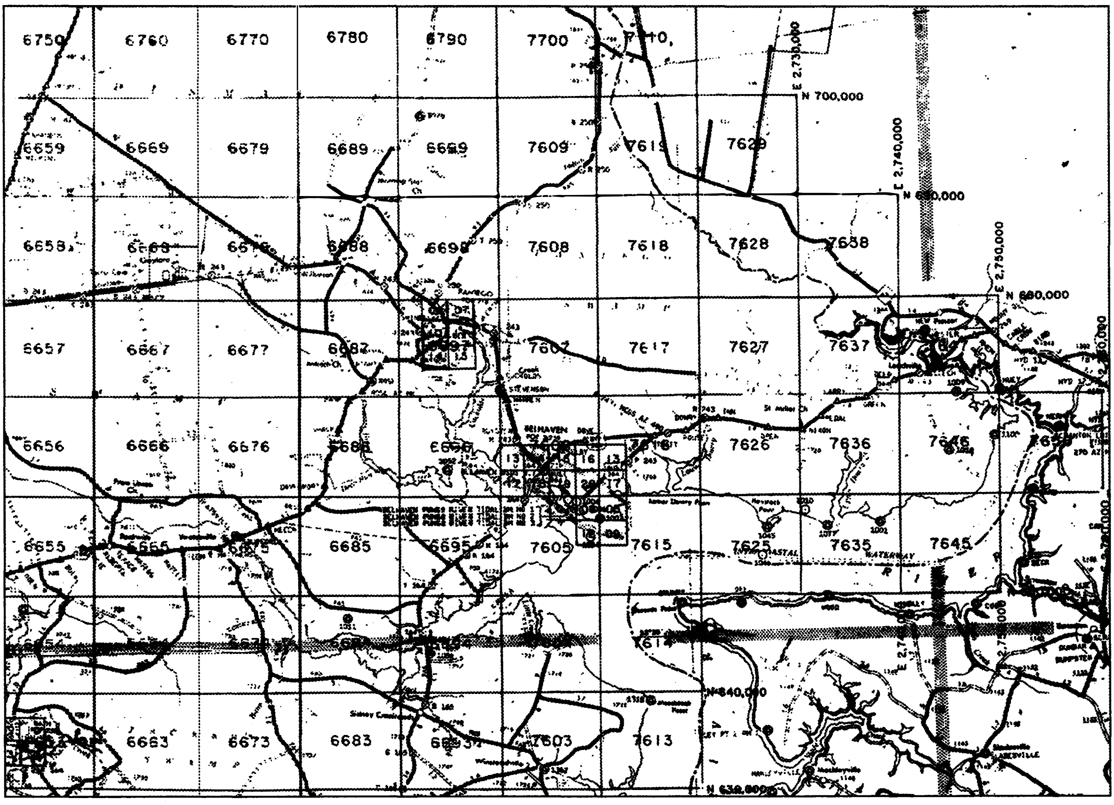

Figure 3. This is a portion of the grid depicting northeastern Beaufort County. Note the larger scale sections in the denser populated areas of the Town of Belhaven and the Town of Pantego.

graphic cadastral set consisted of five separate phases. The first phase centered on necessary map scales. A rough description of the process is as follows. Because aerial photography must be flown at different altitudes, it was incumbent upon County officials to establish the desired scales for different portions of the county depending on parcel densities. Though larger scales could have been chosen, they decided on 1:1200, 1:2400, and 1:4800 (in the industry, more commonly called 1" to 100', 1" to 200', and 1" to 400' respectively, for simplicity in application). Naturally, the larger scales were applied to the local municipalities and the smaller scales for rural areas. A grid showing the primary (small scale) panels was provided and larger scales drawn in where necessary. The resulting grid (Figure 3) was provided to the photographic unit where flight lines were drawn. Note that these flight lines included an 80% overlap to allow for stereo rectification processes. The pilots would then fly the lines in February or March (after leaf fall but before leaf out) and the resulting photography would be processed. This left a very small window during which photo capture could be attempted. Beaufort County was flown over a two-year period with the southern half flown in March of 1990 and the northern half in March of 1991. Following capture, the Photogrammetry department would process the film into bonded positives that were provided to the Stereo department for digital rectification. In this phase a DEM (digital elevation model) would typically be produced for counties with varied topography. In Beaufort County's case however, low elevation ranges would allow for simpler techniques. The elevation model would be based on USGS quads. Using the OR-1 machine (a German machine designed to manipulate photography) this model would be used to program the focus of a series of lenses to re-expose another run of film and rectify it. Photogrammetry would take the resulting negative and create the final othopositive and send it to CAD (computer aided drafting) to receive it's final markings such as easting, northing, scale, date of capture etc. The resulting orthophotography is critical in the accurate capture of cadastral data.

The second phase involved the gathering of initial data. A team was organized that orchestrated the gathering and binding of data that would be used in the compilation phase. This information included all existing property record cards (PRCs), any deeds called for in these records attached by staple thereto, any existing property maps (photocopied) held by the County, and the most current few years of maps or plats (photocopied). If a deed had an adequate metes and bounds description, a plot was produced using an automated drafting package. This plot would also be attached to the work packet for that particular property. Microfilm from the North Carolina State Archives of the entire Beaufort County deed record was purchased for the purpose of research during the compilation stage. PRCs were marked with identifying numbers on the tax maps. These existing tax maps were gridded to correspond to the orthophoto grid and PRCs placed in files for each photo, based on these grid lines and the property location markings on the maps (generally white paper dots with a number affixed) (Figure 2). This information was then boxed and shipped to the Compilation department (the office to which I was attached, located in Greenville, North Carolina).

The third phase was compilation. This is the phase where the gathered documentation is applied to a working copy of the orthophotography. A draftsman is given the file of information described in phase 2 and has the responsibility of interpreting those data and drafting them onto the worksheet. This is generally done by initially reviewing the file and separating the "good" information from the "bad" information. That information that is well supported or concise is the first that is applied. Through a building-block type process the entire worksheet is "mapped" using the orthophotgraphy to "ground truth" the mapper's findings. When deed descriptions were poor, other techniques were applied.

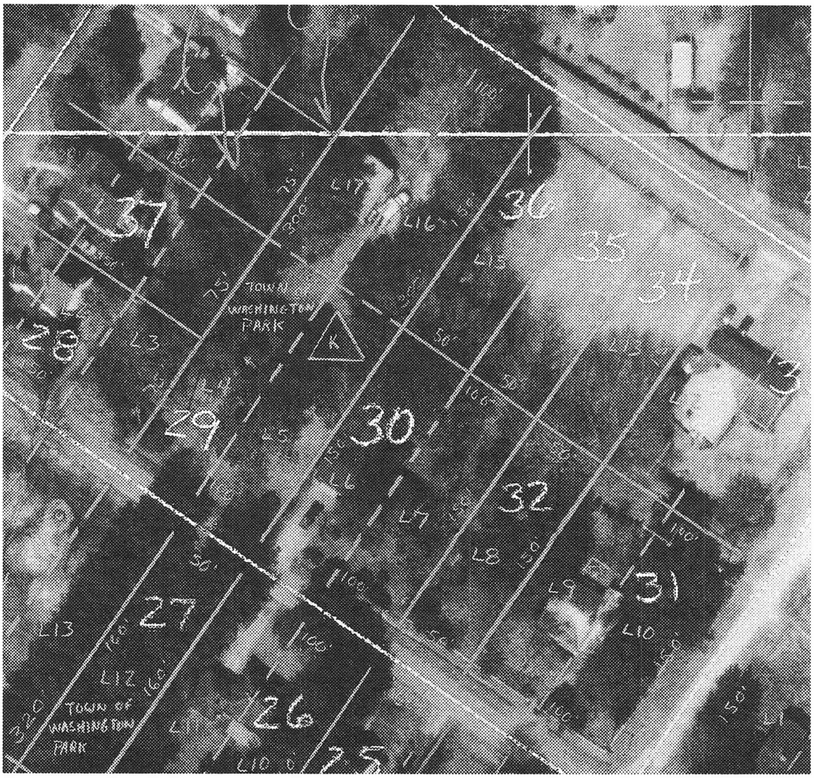

Figure 4. This figure depicts the manual drafting of linework from deeds, maps and other source information. It was later captured digitally.

Often a line of shrubs, distances to an intersection, or method of ground maintenance are elements that support or contradict placement of the property. Sometimes extensive research would be required to track down precedential information to assist in mapping. Descriptions from ancestral properties could yield insight critical to proper placement. When no deed was present (Beaufort County's records were about 50% to 60% referenced at project inception, now about 95%+) extensive research was applied as well as field trips and owner contacts to locate a deed or clear up a placement issue. When a scaled plot was attached to the work packet it could be slid under the ortho (orthophoto) and adjusted for goodness of fit and drafted where best suited based on acquired information. Eventually the puzzle would be filled in. At the time of compilation Beaufort County had about 33,000 individual properties, which were hand drafted in this fashion. After mapping a mapping code was attached to the PRC. Each code represented a mapping method: (1) was by deed or plat; (2) was by surrounding property information; (3) was field review and personal contact; and (4) was other information such as photo interpretation. Approximately 98% of the parcels were locatable and subsequently mapped. This is not to say that all of these properties were perfectly placed or accurately drafted. A lot of effort would be spent "cleaning up". As additional information (deeds, plats, or personal contacts) was provided, many properties would be "adjusted" to be more precise. If a change from the existing tax record was required to adhere to State specifications, a change order was created and sent to the County for approval. This documented the change and the associated reasoning for the change. If the County did not respond, the change was considered accepted as is.

Upon completion of this phase, the resulting worksheets (Figure 4) would go to the Digitizing department for data capture. Because "Strings" (our chosen GIS platform) had a particularly (for the time) robust editing element, the contractor used the same package for its data capture. This was convenient because it precluded the necessity of converting the data to another format after capture. The digitizing team took each of the worksheets provided by Compilation and captured it digitally. Also, for each sheet a "grid" (legend) was created to facilitate independent reproduction of the digital product at a later date. Using standards set forth in the 1987 Specifications for Base, Cadastral, and Digital Mapping provided through the State of North Carolina's Land Records Management Program, capture was completed. The product was returned to Compilation for quality control.

After the maps were checked by the compilation team and approved, a blueprint was made of the product and sent to the County for quality control and subsequent approval. Upon acceptance, the final phase of database creation was complete.

Initial Problems Encountered

After the County's acceptance of the mapping product, and about the time I became the land records supervisor for Beaufort County, we found that the County had failed to apply the "change orders" previously described. Therefore the tabular database of the Tax Assessor's office did not correctly correspond to that which was delivered by the mapping contractor. When a mapping project is completed an electronic file is created. In it such things as the document by which the property was mapped, any associated documents (plats, special proceedings, etc.), calculated acreage, and the associated PIN (parcel identification number) are provided. A piece of code is written that merges this information into the database. If the database is correctly updated the merge is essentially seamless and the resulting information appends to the correct parcels. However, with several thousand parcel splits and merges having taken place, and the merge of the two sets allowed to go through, a large number of inconsistencies became apparent. In the case of splits only one of the resulting parcels would 'hit', leaving one or more in the contractors data set without an associated parcel, and leaving a reduced acreage for the one that did. In the case of a merge, the resultant parcel in the contractors data set would hit with a high acreage and leave an associated 'no hit' in the Assessor's data set.

To further aggravate that condition, the insistence by the revaluation contractor that the new mapping be used in their contract prior to reconciliation of inconsistencies would result in values that were erroneously applied. Indeed, despite repeated complaints through my office, the maps were taken immediately upon delivery from the contractor, bluelined, and sent to the field for use. Often the appraisers were adjusting properties based upon the mapping that had not been reconciled between the data sets, in effect creating double listings of many properties. Often "no hits" (those properties on the maps that had no record in the tabular record) would be brought to Land Records and we would immediately be required to reconcile them. Though this corrected that problem (often requiring the rework of two or more parcels and reappraising them) it would impede efforts to electronically reconcile the two sets.

If the change orders had been correctly applied, reconciliation would have been (to

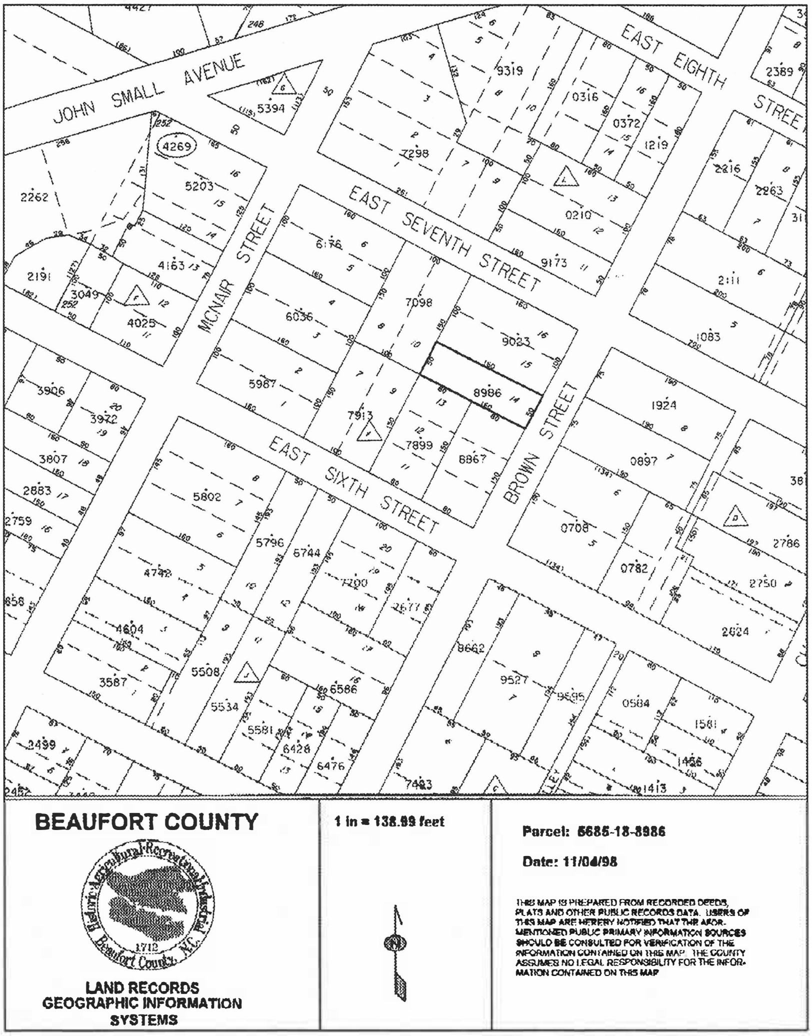

Figure 5. This is a "page plot" of a parcel of land from the Beaufort County Public Access System.

a large extent) limited to acreage, name, and PIN inconsistencies. Now however, we had to develop techniques to locate "no hit" PINs and subsequently work them backwards to a database match and apply the adjustments manually. Because this process could not be completed by the time that initial values were mailed to the citizens of our county, a large number of confused and concerned citizens turned to our office for answers. We conducted approximately 4,000 personal contacts during which we both corrected mapping errors and facilitated reconciliation, in an effort to alleviate taxpayer complaints where warranted. While this was not the preferred method for reconciliation, the process was effective, and the project was completed in this manner.

At this point the GIS was fully functional, but operating at a one to two year lag to the recordation of transfer documents, because the Assessor's transfer operations were this far behind. The Land Records Department assumed these responsibilities and began a concerted effort to bring the tabular record up to date. From the perspective of our systems, this would also had both positive and negative aspects. Nonetheless, a seamless county-wide graphic cadastre and associated land-use and soils coverages was now in place.

Evolution From a Land Records Management System to a Multipurpose GIS

Because other departments, for decision support purposes, required reports and other information, and because our systems were heavily automated, other department heads began to come to us to create their reports. We understood the operating systems (DOS, UNIX, and Windows) as well as the primary tax software and our own GIS. This rendered us as the '*de facto* data processing department' for several County departments. At first this was primarily associated with the Tax Administration (Collections, Assessing, and Land Records) but it would eventually include a number of other departments. Land Records' growing internal need for connectivity, and the County's lack of resources, would put Land Records in the unusual position of building our own network through a series of smaller contracts.

Network Development

In 1996 the State of North Carolina's need for more space in our County Courthouse would drive us into new facilities. This move would have both up and down sides. On the down side, it would move us away from the Office of the Register of Deeds. This department houses all of the vital information for research on property transactions. On the upside, however, it gave us the opportunity to upgrade our local area networking (LAN) capabilities and expand our operational base. That is to say, increase the hardware to which we could supply connectivity to the system and better distribute the work as well as the results.

We were allowed to work with the architect and the wiring contractors to specify 10/100 MBPS certified category 5 wiring pulled through the walls to a patch panel in the computer room. This would allow us to provide voice and data access to any point in the building by 'patching them in'. Also, and more importantly, it would facilitate a change in our networking protocol to TCP/IP and allow installation of an NT server on which to house our graphics. The old configuration was a pier to pier network that was inefficient. I can remember having to call across the room to tell someone that I was sending something, or going to get something, from their desktop, in order to preclude a data collision that would 'lock up' the system. Our increasing network traffic was making that an ever more frequent occurrence. It would also provide (through the new protocol) enhanced access to the midrange computer on which the Tax Assessor's database was housed and allow our desktops to exchange information with it more freely. In the past the connectivity to that system was restricted to a serial interface on the desktop (PC), or the operation of a CRT (cathode ray tube) simultaneously with our desktops. We still find that there is benefit in both cost and flexibility in the use of serial interfaces. This is mostly where technicians require visual access to both systems simultaneously (they operate a CRT and a PC side by side). In most applications though, the single click switching between applications on a single desktop PC is more desirable.

One of the greatest benefits of this configuration was our ability to 'pipe' information to remote parts of the building. This allowed us to utilize older machines as public access terminals elsewhere and use the system as a traffic control tool. On the other hand, it also allowed us to give other departments access to visual tools, and opened the door to additional system growth.

New Applications

As stated above, the ability to 'pipe' data throughout the building was a great plus. It allowed us to consider public access from a different perspective. When the system was in its infancy, public access required the full attention of one of the technicians who understood both the mid-range system and the GIS. Assisting a taxpayer in getting information on their property would take as much as thirty minutes of valuable time. Abilities to reproduce graphic depictions were limited as well. The end result was much time spent to produce a gaudy raster image of their property. Nonetheless, citizens found these capabilities and related services important. In short order we were being inundated with requests for information. With the change in infrastructure we could now view public access as a means of traffic control.

Our GIS vendor had been working on some new viewing tools. The original DOS tool, PMS (parcel management system) was outdated, and, name not withstanding, a new system was required. The result was a software product called 'Breeze'. With a few modifications to its reproduction capabilities, we built a public access system which allowed the viewing of all layers, maps, and individual properties (Figure 5). The personal interface was easily mastered and the system was quickly accepted by the primary users (attorneys, realtors, loggers, appraisers, etc.). We continue to support onetime users over the counter because the time to train the user would match the time to simply produce the property plot.

After implementing the system we began to send the same outputs (in conjunction with other supporting documentation) to the Tax Assessor to depict any changes that Land Records might have made to a particular property. Soon the appraisers decided that the benefit of an accurate map in the field was immeasurable. They sent lists down to us for reproduction. In short order we were overwhelmed again by these additional requests. Once again our attention to infrastructure in the Seaboard Building paid off. We simply placed an additional PC in the Assessor's office, loaded it with the necessary software, and trained the appraisers on its use. For most properties visited in the field, the appraiser will have a plot of the property in hand for notes and reference.

The utility of these outputs created additional demand from the Environmental Health Department, who wanted to use them to map the location of proposed septic fields, and Building Inspections, who required them to accurately locate proposed structures or improvements for permitting purposes. A machine was networked into these offices to facilitate their requests.

The primary mandate of the Land Records Office remains the support of the Tax Assessor and maintenance of the split and transfer processes associated therewith. However, the wealth of information that is generated through that process is in great demand. Our ability to fashion means by which this information could be delivered in various useful formats placed us in the position of acting as the County's information exchange.

Beaufort County had undertaken a project to convert its addressing to the E-911 format. A contractor was hired to create the system based on the centerline file that we had saved from the database generation processes for the cadastre. The idea was to base the address assignments on a 5.28 foot increment (allowing for 1000 possible addresses per mile), which would allow for quick field conversion of address to distance over ground. This information would be integrated with our centerline file and used to create an incident mapper that would be placed in the dispatch center at the Sheriff's Department. It became apparent that different segments of the industry viewed graphics from very different perspectives. When we began testing the incident mapper, we found that many addresses were coming out on the wrong end of a street segment and on the opposite side of the road. We quickly determined that the digitized direction of the roads was not in sync with the direction of addressing. The contractor did not appear to be aware of the requirement for this. In the end we had a piece of code written that would allow us to flip individual line segments to make them correctly correlate to the appropriate address directions. It is imperative when undertaking development of applications while dealing with more than one contractor that you apply a holistic approach and are aware of the technical requirements of the entire application, as well as attend to the inevitable evolution of those requirements as they relate to multiple tasks. As you become aware of new requirements you must pass them on to all contractors involved in various activities so that they may respond. Furthermore, you must periodically check the contractor deliverables to make sure that those technical requirements are being met.

Likewise, the address maintenance systems provided by the contractor were inadequate to do the job. In conjunction with the Planning Department we determined that "SAM" (Street Address Manager), a system developed by Digital Mapping Technology, Inc. (DMT, Raleigh, NC), was going to be our best choice as a replacement. It used the same data format as our GIS and would allow the use of our other map layers to assist address placement. This program, used by our County Planner, is utilized in conjunction with other data sets to enhance his address assignment accuracy and capability.

The same contractor that developed the centerline file for E-911 also was contracted by the Beaufort County Board of Elections to produce a series of digital map files. These maps included congressional districts, senatorial districts, precincts, and school districts, which would be used with the fire and rescue districts maps for E-911. Aware of the previous problems associated with prior deliverables, we engaged in extensive quality oversight on behalf of both Planning and the Board of Elections. We found that adjacent polygons (closed areas representing a feature, in this case districts) were actually mapped with a 50-foot gap between them. If an address may be assigned every 5.28 feet and the gap between districts is 50 feet there is a potential loss of 9 addresses at every point where a road crosses a district line. If an address falls in this 'no mans land' who do we dispatch? These problems were caught and we required that the contractor address them. These maps, even after capture, had to be brought into our office for remastering and conversion for use in our GIS.

The damage caused by hurricanes Bertha and Fran in 1995 created a new set of demands on our office. An excessively wet period created a boom in mosquito reproduction that had health officials very concerned. A plan was developed to spray certain populated areas to control the explosion in population growth of the pesky bugs and provide some relief for the local population. The problem was that they knew the general targets but did not know the size and therefore did not know the area to which the insecticide would be applied. This information was critical to quantity determinations. They came to us with their problem. We inquired of the areas to be sprayed, the anticipated flight lines (the insecticide was to be applied by helicopter), and the width of spray dispersion at a standard spraying speeds. With this information we calculated the area to be covered without threatening waterways and mapped them for use by the Health Department. Luckily, the rains went away and by the time the spray teams could be organized and approval secured (some local residents were naturally concerned over developments, and the thought of spraying poisons so broadly across the landscape), the spraying never happened.

Another effect of the hurricanes was the destruction or damage to real property along county waterways. The Federal Emergency Management Administration (FEMA) offered grants to local jurisdictions for hazard mitigation purposes. This money was to be used to raise houses to the 100-year flood level. A number of residents applied for grant assistance. Among the criteria for raising the homes was location and elevation. FEMA and the planners contracted to administer the grants asked us to create a map that would show the dispersion of the properties as well as accurately depict their locations. One base map showing county-wide dispersion was created as well as a series of inserts to depict the actual location of the properties in relation to roads and waterways.

Each structure was then surveyed to the nearest benchmark to determine its elevation. This process is ongoing.

A change in building codes to create a '110 mile-per-hour wind-zone' was another result of government hazard-mitigation steps. New structures built within one mile of the river at any point that was more than one mile wide at a forty-five degree angle must be built with materials and components to withstand wind forces sustained in excess of 110 miles per hour. In this case, we utilized a corridor tool to create a buffer around the rivers at points that met the base criteria. This layer was placed in the GIS viewing catalog and shaded to allow the inspectors to call up a parcel based on its Tax ID or NCPIN (based on NC State Plane Coordinate System). They could then apply the windzone layer and know immediately whether the parcel fell in or out of the zone.

The City of Washington came to us for the creation of their official city zoning map. We instructed them on preparation of source information and created a map, which included an index map and sixteen individual panels showing parcels, hydrology, zoning, historic district, city limit and extra-territorial jurisdiction.

They also needed assistance with determinations as to property owners within areas of the county that were to be annexed. In these cases we used Point-In-Polygon (PIP) analyses to acquire PINs (parcel identification numbers) and then shipped them up to the midrange system where we created a standard query engine that downloads specified data fields back to the PC in an ASCII (American Standard Code for Information Interchange) format. These data were then imported into a DBMS (database management system) for manipulation and output. The city was provided with electronic listings of property owners, values, deed references, addresses, and other information specified by them.

Local fire departments came to us wanting to know their constituencies for fund-raisers etc. We PIP'd the fire districts over the parcel layers and used the same strategy as above to create an electronic reference of names and addresses within their respective jurisdictions. Even the public got on the bandwagon with requests like "I need to know all of the land owners that front on Gum Swamp so we can have the beaver dams blown and the creek snagged".

It appeared that all roads lead to Land Records. Our unique perspective and broad reach have made us a valuable resource to attorneys, Realtors, surveyors, loggers, farmers, and the list goes on. At the same time other government agencies view us as a starting point. Now they can efficiently associate a point on the ground with an increasing variety of information and begin their problem solving responsibilities with a tremendous head start over only a few years ago.

Though the system has been generally successful, there have been problems associated with hardware and software evolution, year 2000 issues (mostly on the database side), and system robustness. All systems do not evolve at the same pace, forcing us to slow our approach to technology advancements including networking and primary system upgrading (Beaufort County Government, 1997).

Rapid system and budgetary growth, as well as increased capability, also proved to be formidable problems. Educational requirements grew with the technology, and manpower needs increased with demands. Our capabilities exposed us to issues that were often unexpected as we sought to fulfill requests from various users.[2]

Future Trends and Developments

In an environment in which technology evolves so swiftly, it is important to recognize developments as they occur. Systems can be rendered nearly useless in short periods of time. An example could be seen in our original network configuration. Increased flows of graphic information bogged down the peer-to peer system to the extent that we would have to call across the room to announce traffic on the system. Now a new technology would add a tremendous amount of traffic to that system essentially incapacitating it. I speak of digital ortho-imagery. These files can consume 25 to 30 megabytes of data each, and must be rapidly accessed and displayed by the seeking desktop unit. The only alternative would be to hold a large number of copies and load each desktop with hard disk space, or CDROM (compact disc read only memory) and RAM (random access memory) capabilities to handle the increased volume. Nonetheless, the utility of this graphic layer makes it highly desirable. It facilitates 'heads up' digitizing (allows the technician to draft on the desktop alone without the aid of digitizing tables and orthophoto mylars). They provide a tremendous visual aid to users of cadastral and other data. They also provide for easy output in numerous sizes and formats. More and more local governments in North Carolina are moving toward this type of photography in lieu of the hardcopy orthophoto on mylar. Planning is now underway for digital capture of Beaufort County in its entirety.

In conjunction with the above image capabilities, there is a move toward reproduction over highspeed networks on top-end plotters. Some of these configurations can produce raster images at speeds of 1" to 2" per second. Now complex (multiple layers) images can be produced quickly and at high resolutions from a desktop, increasing the value of the cadastre as it relates to decision support.

High-speed networks as described above (10/100 megabit certified) will also enhance system integration. The improved traffic handling capabilities of network protocols (TCPIP and others) is allowing us to consider new and exciting ways to deliver geographic information for decision support. We are presently working to bring the appraisal offices 'online' with a desktop tool that will allow them access to both tabular and graphic data (rasterized structural photos, ortho-imagery, maps, and tax data) simultaneously. This should reduce out of office work times, as well as produce more accurate valuation decisions as they pertain to real estate.

The World Wide Web is introducing public access options into the GIS field. Already, there are companies that will (for a fee) house your graphic and tabular tax data and the appropriate engines for query purposes. Though locally there is some discord between those that see this as exporting local business and those who see is as expanding a market, this alternative is seeing some interest in government circles, particularly as a marketing tool for industrial development. In a matter of time it will probably cover most areas of public information.

WAN (wide area network) connectivity is another area where high-speed networks have benefited local governments. The ability to link Local Area Networks (LAN) into a broader network structure has enabled information to be passed among local agencies, not only for administrative purposes (finance, payroll, etc.), but also to deliver decision support information to other parts of the government in a closed environment. We are now planning (and will soon be implementing) just such a network which will allow several additional agencies access to the web, administration, and our graphic data.

Conclusion

I have watched the Beaufort County Land Records GIS evolve from a single 386 DX2 PC to a vital integrated network of over 25 PC's and 26 CRTs that provide information to the Tax Assessor, the public, and a spectrum of other agencies. Still others are attaching to our network to reach the Internet or to develop other connectivity needs for such things as finance or payroll. The evolution of the technology, while exhilarating, has sometimes been so fast paced as to threaten the system itself. Learning and relearning operating systems, network operations, GIS operations, etc. has been a challenge in itself. The goal of providing a geographic perspective to often mundane objects and seeing the results is quite exciting. Watching the world's desire to use these outputs grow at such an extraordinary pace is imposing. The challenge of managing a modern GIS in the government environment requires vigilance, opportunism, and a keen sense of industry direction. With these qualities we hope to propel the Beaufort County GIS into the 21st century.

References

Beaufort County Government (1997) *Beaufort County, NC 1997 Land Use Plan,* Washington, North Carolina, table 3 County Population, page I-19.

Land Records Management Program (1987) *Technical Specifications for Base, Cadastral, and Digital Mapping,* Division of Land Resources, North Carolina Department of Environment, Health, and Natural Resources, Raleigh, North Carolina.

Endnotes

1. Our departmental long-range plan included a sustained effort to enhance integration to the tax package, in an effort to consolidate information on the desktop for use by the appraisers. The tax package is a voluminous program that creates and maintains county assessment and collections information. It is used to create abstracts, bills, and receipts, as well as act as a pool for critical assessment information such as land types, structural types, etc. We felt it important to maximize the amount of information available to appraisers at minimal effort. This decision support, we felt, would pay dividends in the long run in quality of output and value defense capabilities. Unfortunately, this effort had to be set aside as it became evident that the vendor that supported the tax package would be preparing to discontinue that support. The package (an old pick/basic system) had not been maintained nor evolved with technology for too long. Now it was unclear as to whether any effort would be made prior to the year 2000 to enhance it. It was even questionable whether the package would be made 2000 compliant at all. In an era of fiscal restraint, it was not feasible to spend that amount of money on the short-term gain of integration versus pursuing the long-term gain of conversion to a new and more robust package written in modern code. The offer of 'hooks' (points of interface written into the code to allow other packages, such as GIS, or raster imaging to operate hand in hand with the application) laid in specifically for that purpose made the move even more practical. We took the latter option despite disappointment at the pace of integration advancement. We also had some problems with PC operating system evolution. 'Pedit' (the 'Strings' editor) was a DOS-based application. The rapid evolution of viewers and other peripheral programming toward the Microsoft NT operating system has prompted many vendors to suggest these as the 'preferred' platform on which to run their systems. This included our GIS vendor. The only problem was that a 32-bit version of the editor was not yet available. We purchased two units with NT-Workstation on them and immediately found that we could not run our 'legacy' (old applications that still do what we need, but use old technology to accomplish it) applications on them. We had to reformat the hard drives and load DOS then upgrade the OS (operating system) to Windows 95 to allow enough DOS capability and still allow us to run the new applications. The new 32-bit editor is in beta testing and should be released in the near future. As more and more desktop units were deployed (and requests still come in for others) training operators, even for simple and repetitive tasks became an issue. Our staff levels could not sustain much more. Likewise, as the network grew, it became apparent that the old peer-to-peer network model on which the original network was designed could not sustain the traffic. As stated above, we used the move to our present location to switch to a client/server model and Ethernet connectivity.

2. The rapid growth of our system, from a one PC office to a vital network of information, has brought with it its own set of problems. Increased traffic flows associated with information-seekers is very distracting to employees who are torn between serving the public by whom we are employed and maintaining already excessive work loads. Likewise, the proliferation of project

requests from other agencies, departments, as well as the public with limited manpower with which to perform the associated tasks, leads to resource allocation issues. Greater capability exposes your office to a broader user base and thereby to a broader political spectrum, which will sometimes approach you for answers for which you have no authority to address. While delivering information for decision support, we operate independently of the decision making process. For example, we were once working with Craven County GIS to correlate the location of our mutual county line and correct the associated tax records. At the same time, there was a dispute over the potential location of an intensive livestock operation near the county line in Craven County. We were accused of moving the county line to facilitate its acceptance. I had to respond to this complaint with a detailed synopsis of the reconciliation project and its basis in fact. In this case our line had not been moved at all. Craven County was adjusting theirs to match. Neither office had any contact with higher authorities concerning the placement of the operation. In another example, the Tax Assessor had inadvertently billed a significant number of incomplete valuations. A new subdivision had been divided and lot values had not been placed on the individual lots. Rather, the original value (according to procedure) still remained. Once again we were called on to explain the failure of the system (though value is the exclusive domain of the Assessor). Now all values are rolled back to zero until new values are assigned. We wrote a piece of code to identify these parcels prior to billing to assist the Assessor in tracking them. As the systems budget grows, that budget naturally becomes a greater target for cuts in times of fiscal constraint. Under these conditions it is important to position yourself technologically for future advancements everywhere that it is practical, with an eye on market (in terms of technology) and evolution (it is easier to sustain what is in place than it is to add additional services). It is equally important I think, to design your systems and deploy them using modular concepts to facilitate severability in times of fiscal constraint and minimize performance impediments should you loose some assets or resources. And, make sure that there is uniform support for specific applications design prior to accepting the challenge. This leads to a measure of security and assures sustained support for the cost of code maintenance and evolution.

Spatial and Temporal Patterns of Sediment and Nutrient Flux in a Coastal Plain Agricultural Basin, Littlefield, North Carolina

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This paper reports the results of a 6-month field study conducted in a small coastal plain watershed in eastern North Carolina. The objective was to identify spatial and temporal patterns of nitrogen, phosphorus, and sediment flux under a range of flow conditions in the basin. Although the pollutant concentrations and exports found in this study were, overall, relatively low, a number of problem areas were identified including: (i) cultivated fields, that contributed disproportionately large amounts of nitrate-plus-nitrate to the total basin export due to the leaching of unused nitrogen-based fertilizer, and (ii) devegetated ditch banks, where TSS concentrations were found to be almost three times greater than areas draining crop or pasture.

Introduction

The North Carolina Division of Environmental Management manages pollution in North Carolina waters through the use of a basinwide water quality plan. Every five years, new data are compiled for each basin, and the result is a report consisting of a general basin description, causes and sources of water pollution, water quality status, existing regulations, and management implications. According to the most recent report on the Neuse River basin, which encompasses both the piedmont and coastal plain regions of North Carolina, the major pollutants are nitrogen, phosphorus, and sediment (NCDEM, 1997).

Nutrient pollution is a potential problem in coastal plain waters because of the large percentage of land in agricultural use, which adds high levels of nitrogen and phosphorus to the fields in the form of fertilizers and animal wastes. In fact, the use of inorganic nitrogen fertilizer in North Carolina increased by 400% between 1945 and 1983 (Jacobs and Gilliam, 1983) and, in 1987, fertilizer accounted for 45% of the total nitrogen yield from the Lower Neuse (EPA, 1987 online report, see http://www.epa.gov/surf2/hucs/03020202/canindicators/canindex.html). Furthermore, the clearing and plowing of land for agriculture increases its susceptibility to erosion of sediment, which often contains nutrients in their particulate form, specifically sediment-bound phosphorus. Recent studies have also shown that the surface waters of the North Carolina coastal plain are highly susceptible to sediment pollution because a significant amount of erosion is occurring in this area (e.g., Phillips *et al.,* 1993; Phillips, 1997; Slattery *et al.,* 1998; Phillips *et al.,* 1999). The problem, however, is that little is actually known about erosion processes in the region or about the transport, storage, and ultimate fate of the eroded soil. There is also a dearth of information on nutrient export from headwater basins in the region, as evidenced by the recent addition of so-called "candidate indicators" in the EPA's Index of Watershed Indicators.

This paper reports the results of a field study conducted in a small coastal plain watershed in eastern North Carolina. Our objective was to identify spatial and temporal patterns of nitrogen, phosphorus, and sediment flux under a range of flow conditions in the basin, and to then interpret these patterns based on factors such as land use, seasonal hydrological conditions, and runoff mechanisms. Two specific research questions were addressed, as follows:

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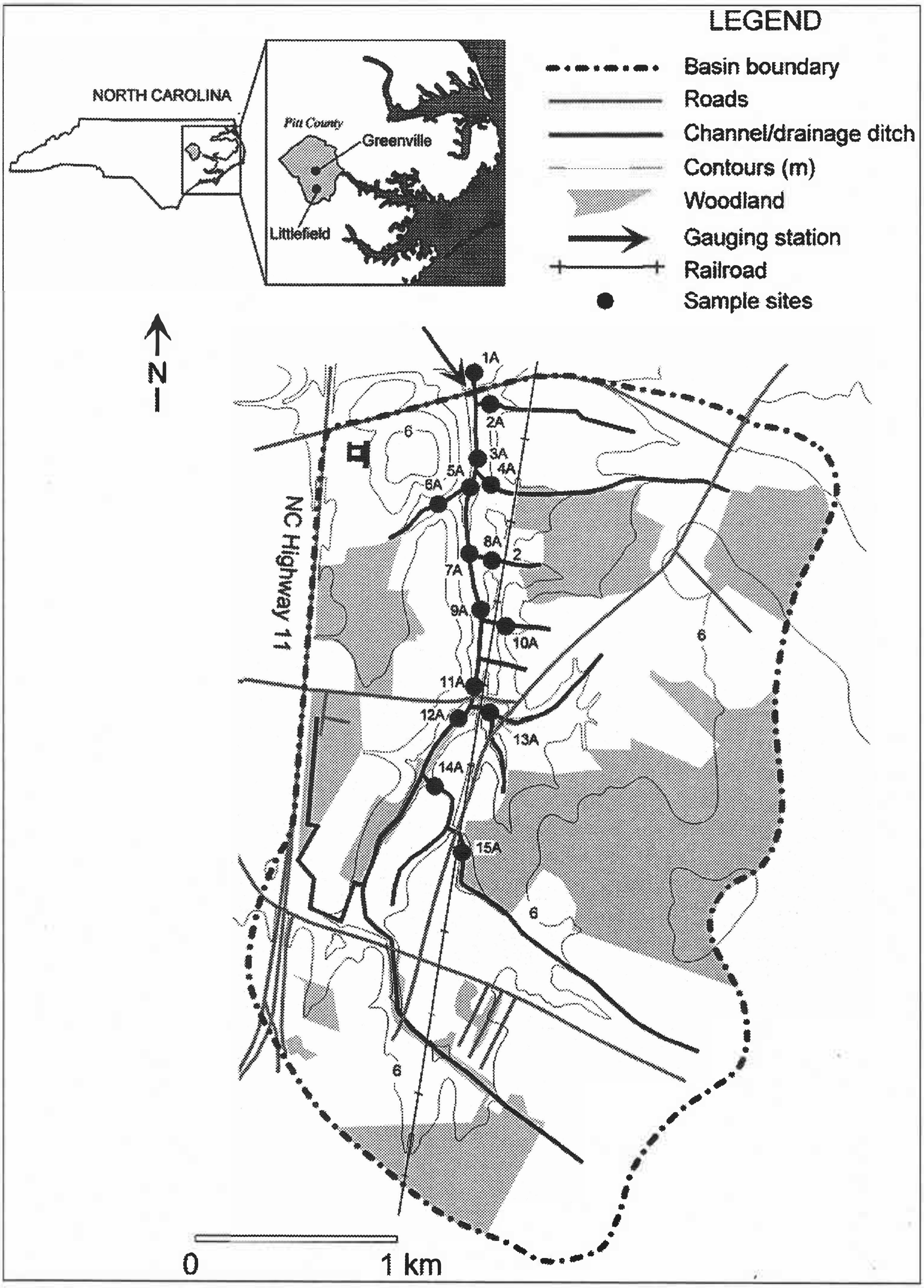

Figure 1. The study basin in Littlefield, North Carolina, showing the main channel and ditches with sampling locations. The ditch at 10A was almost always dry; 8A also dried out on occasion. The site at 14A became inaccessible after the 1st month of sampling.

1. What, if any, spatial patterns are apparent with regard to nitrogen, phosphorus, and sediment flux across the study basin, and what factors affect these patterns (for example, do certain portions of the basin contribute disproportionate amounts of sediment, nitrogen, or phosphorus to the total basin export)?

2. What, if any, temporal patterns are apparent with regard to nitrogen, phosphorus, and sediment flux throughout the study period, and what factors affect these patterns (for example, do pollutant levels fluctuate after fertilizer application, after crop harvest, or with seasonal hydrological changes)?

Study Site and Methods

The research site is a small coastal plain agricultural watershed located near the Pitt County, North Carolina community of Littlefield (Figure 1). The basin has an area of approximately 776 hectares, and includes the headwaters of Swift Creek, a major tributary of the Neuse River. Approximately half the site is mixed pine and hardwood forest, while the remainder is primarily agricultural land, planted in tobacco and cotton, with a significant portion under pasture. A network of subsurface tile drains and surface ditches artificially drains the fields. The main ditch experiences year-round base flow. The topography in the basin is gentle, as is characteristic of the Coastal Plain. Maximum relief is 7m with typical slope gradients on the order of 0.001 to 0.004. The climate is humid subtropical.

The basin is located on the Pleistocene-aged Wicomico marine terrace. The soils are Ultisols belonging to two general groups. One may be called the Norfolk group, after the Norfolk series, a Typic Kandiudult. In addition to the Norfolk series, soils at the site in this group include the Wagram series, an Arenic Kandiudult which differs from the Norfolk only in the thickness of the surficial horizons, and the Lynchburg and Goldsboro series, which are somewhat poorly and moderately well-drained members, respectively, of the same drainage catena as the well-drained Norfolk. The second group consists of finer-grained Ultisols mainly along stream terraces, of which the most common are the Pantego and Bayboro series (both Umbric Paleaquults).

A gauging station was established at the basin outlet in May 1997. Flow was monitored with a Sigma 900MAX portable water sampler fitted with an integral flow meter to measure water level and discharge. The sampler was programmed to take 500 ml water and sediment samples every 15 minutes during storm conditions. An external "tipping bucket" rain gauge fitted to the water sampler recorded the timing of each 0.1 inches of rain. An Endico/YSI 6000UPG Multiprobe also provided a continuous and detailed record of stream turbidity in relation to changing discharge at the outlet. Four storms were monitored in detail: September 12; September 24-25; November 7; and November 12-14. Runoff samples were collected from field slopes during a fifth storm on September 28. Manual water samples were also collected at 13 sites across the basin during both low flow and storm flow conditions from May to November of 1997. All samples (n = 402) were returned to the laboratory and analyzed for six forms of pollutant: dissolved kjeldahl nitrogen (DKN), total dissolved phosphorus (TDP), nitrate-plus-nitrite, particulate nitrogen (PN), particulate phosphorus (PP), and total suspended solids (TSS), all according to standard methods. Because base flow samples were almost always visually clear, TSS was only conducted on the storm samples.

Results and Discussion

Spatial patterning

The first of the two research questions was initially addressed by graphing the average pollutant concentrations at each sampling location during both storm flow and low flow conditions (Figure 2). Subsequent statistical tests were performed on the data based on the classification of each sampling location as either crop, pasture or forest, its primary land use. These included one-way analysis of variance and Kruskal-Wallis tests, to

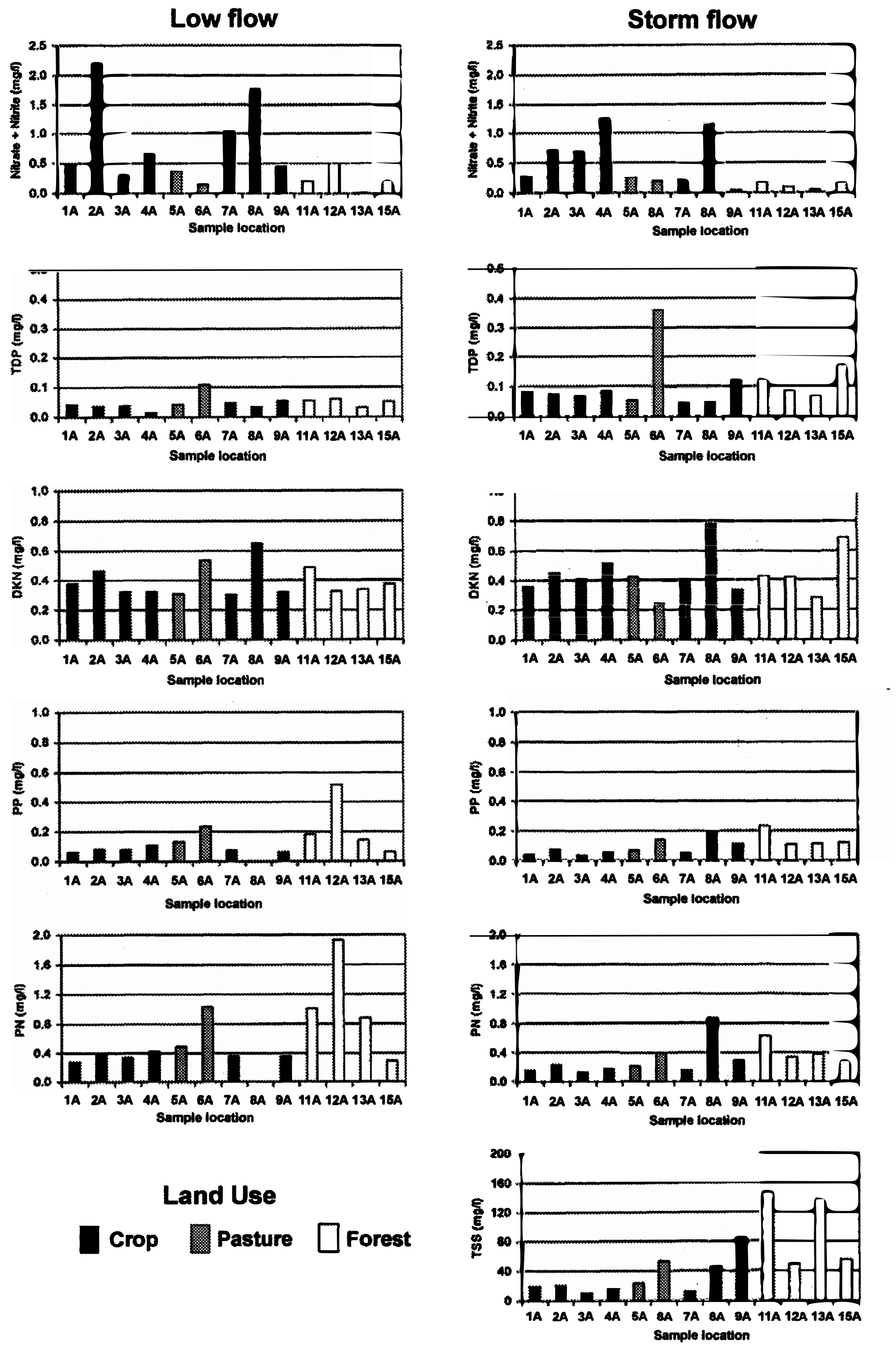

Figure 2. Average pollutant concentrations at each sampling location during both storm flow and low flow conditions in relation to land use.

determine whether the means of the three land use groups were significantly different, and the post hoc Scheffe test, used to determine, specifically, which land use groups had significantly different pollutant concentrations. These results are summarized in Table 1.

The average pollutant concentration data show that the cultivated fields contributed a relatively large proportion of nitrate-plus-nitrite to the total basin export due to the leaching of unused nitrogen-based fertilizer from fields. Mean concentrations during low flow and storm flow were 0.877 and 0.665 mg/l, respectively, both significantly higher than either the pasture or forest sample means. This suggests that nitrification occurs readily in these soils, because nitrate must be converted from the ammonia form found in fertilizer. Phosphorus concentrations at the site draining the pasture (6A) were consistently high due to leaching and/or runoff of phosphorus in livestock waste. The forested portion of the basin contributed disproportionately large amounts of PN and PP to the total basin export, specifically under low flow conditions, where mean concentrations were at least double those found in samples draining cropland (Table 1). Somewhat surprisingly, TSS values were also significantly elevated in the forested area, with mean concentrations almost three times those found under crop or pasture. This was the result of the erosion of highly unstable, devegetated ditch banks just upstream from site 13A which then drained directly into the main collector ditch at site 11A. TSS values were also significantly higher at site 9A in the main channel and at site 8A, a tributary ditch draining tobacco and cotton fields. The main channel site at 9A was just downstream of the ditch site at 10A (see Figure 1) which had become clogged with several tons of sediment eroded off the adjacent field via an extensive network of rills. Although some of this sediment made it out of the ditch system and into the main channel, elevating TSS values there, it is clear that dense vegetation in and around the cropland ditches contributed to the trapping of sediment, making them in effect long-term stores of material. Thus, on-site rates of erosion on these fields are most likely much higher than downstream yields suggest. In fact, runoff samples collected from field slopes adjacent to the ditches at 10A and 11A during the September 28 storm showed TSS concentrations *at least* an order of magnitude greater than those sampled at the basin outlet. Similar findings have been reported by others working in basins in this region (see Slattery *et al.*, 1998).

Temporal patterning

The pollutant concentration data for all

Table 1. Mean pollutant concentrations for all sites during low flow and storm flow conditions.

Low Flow

	NO3 + NO2 (mg/l)	TDP (mg/l)	DKN (mg/l)	PP (mg/l)	PN (mg/l)
Crop	0.877	0.039	0.379	0.077	0.345
Pasture	0.315	0.061	0.373	0.163	0.651
Forest	0.241	0.048	0.374	0.215	0.987

Storm Flow

	NO3 + NO2 (mg/l)	TDP (mg/l)	DKN (mg/l)	PP (mg/l)	PN (mg/l)	TSS (mg/l)
Crop	0.665	0.084	0.457	0.121	0.342	51.095
Pasture	0.248	0.131	0.381	0.086	0.254	31.345
Forest	0.139	0.123	0.486	0.153	0.421	91.016

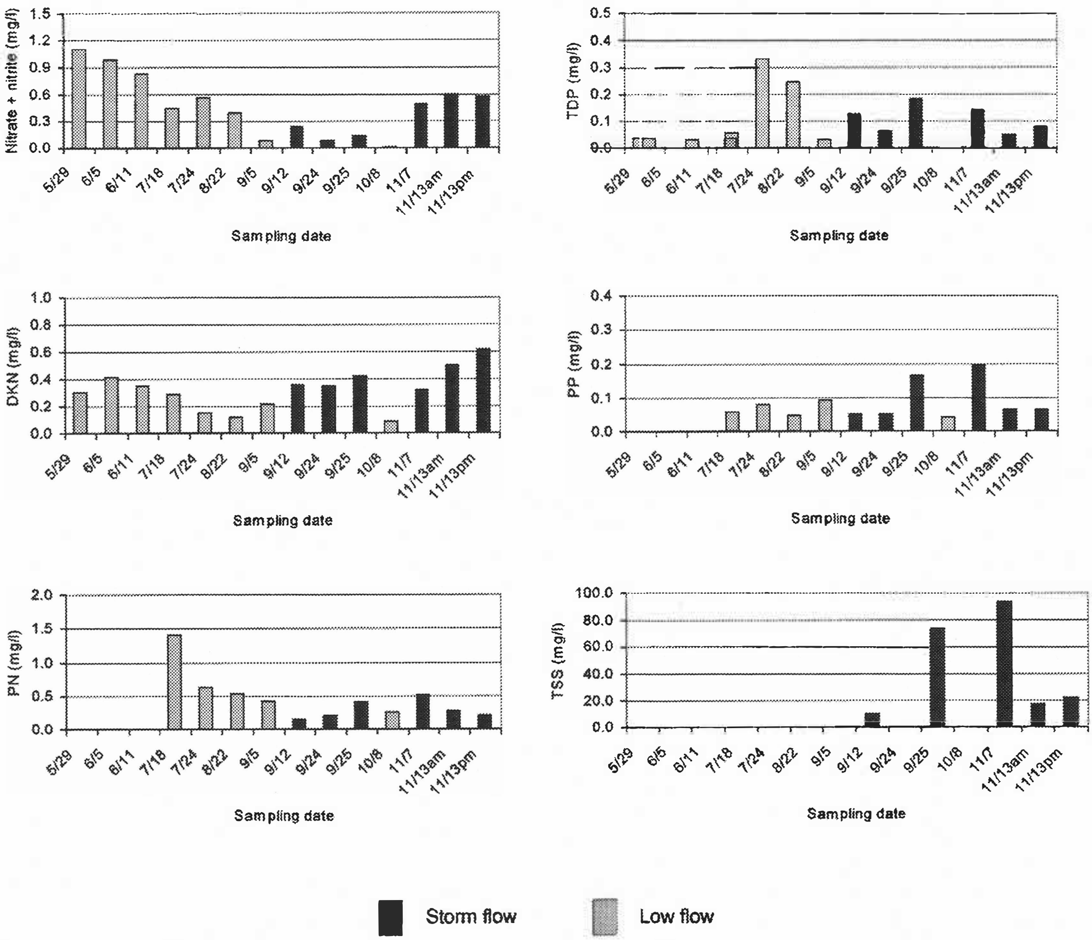

Figure 3. The pollutant concentration data for all sites averaged for each sampling date during the study period.

sites were averaged for each sampling date and then graphed to show temporal variation during the study period (Figure 3). Under low flow conditions, nitrate-plus-nitrite, DKN and PN all show a clear declining trend during the summer period, reaching their lowest values during the early fall (i.e., October 8). TDP showed little temporal variation with the exception of elevated concentrations on July 24 and August 22. Similarly, PP concentrations were also relatively uniform during the sampling period. During storm conditions, however, pollutant concentrations became elevated, specifically for nitrate-plus-nitrite, DKN, TDP and PP. Because TSS concentrations were measured only during storm events, the only discernible pattern in Figure 3 is that levels were highest during the November 7 storm, when runoff was greatest.

The data shown in Figure 3 were examined more closely with regard to the timing and rates of fertilizer application, crop harvest, precipitation, and discharge. While spatial averaging of the data was useful in detecting general temporal trends, pollutant flux still had to be examined at *each* sampling point over time due to the distinct spatial aspects of fertilizer application and crop harvesting, and also because subtle

Table 2. Mean pollutant concentrations during low flow and storm flow conditions at the basin outlet.

	NO3 + NO2 (mg/l)	TDP (mg/l)	DKN (mg/l)	PP (mg/l)	PN (mg/l)
Low Flow	0.506	0.042	0.379	0.065	0.273
Storm Flow	0.661	0.085	0.456	0.125	0.348

temporal patterns became masked at the more general scale.

Fertilizer application took place in April on the cotton, corn, and tobacco fields, and again in June on the cotton fields. The fertilizer used contained different proportions of nitrogen, phosphorus, and potash (a combination of potassium and oxygen) for each crop. The steady decrease in nitrogen-based pollutants over the summer period, specifically nitrate-plus-nitrite, therefore fits well with the expected leaching of fertilizer which tends to occur fairly soon after application. The cotton was harvested in mid to late November while corn was harvested in late October. The tobacco was harvested in stages beginning in mid July and was completed by September. The difficulty here was determining whether the fall and early winter increase in nutrient concentrations was the result of increased flow or the crop harvest itself. Certainly, nitrogen is most readily lost through leaching to drainage waters and streams during periods of heavy rain. But it is also well known that when crops mature and are harvested, much soluble nitrogen remains in the soil, mainly in the form of nitrates. If the nitrogen is not captured by a cover crop planted at harvest time, as was the case at Littlefield, the nitrogen is subject to leaching during the spring and winter months. The most likely scenario here is that both effects are manifest in the data.

Mean pollutant concentrations were then computed for each pollutant for all samples taken at the basin outlet under both low flow and storm flow conditions (Table 2). An independent sample t-test was subsequently performed on the data to determine whether the base flow and storm flow concentrations were significantly different. While the storm flow pollutant concentrations all appear to be consistently higher than the base flow concentrations, onlyTDP and PP were found to be statistically significantly different.

The storm data were subjected to more detailed hydrograph and chemograph analysis, including analysis of storm hysteresis loops for each pollutant. While the results of this analysis are presented in detail elsewhere (Slattery and Cappiella, in prep.), two points are worth noting here. First, we found that, generally, PP, PN, and TSS were directly related to discharge during storms, while nitrate-plus-nitrite was inversely related to discharge (TDP and DKN showed no clear relationship with discharge). And second, the two September storms were generally characterized by positive hysteresis (i.e., pollutant-discharge lead), while the November storms generally showed negative hysteresis (i.e., pollutant-discharge lag). The flushing out of sediment and particulates stored in the stream channel was the cause of positive hysteresis in the TSS, PP, and PN relationship during the September 24-25 storm. On November 7, TSS, PP, and PN concentrations showed negative hysteresis with discharge, which suggests that the source of these pollutants is the severely eroded upper basin ditch banks, which were shown earlier to contribute a disproportionately high amount of these pollutants to the total basin export. Negative hysteresis shown by nitrate-plus-nitrite concentrations on November 12-14 indicated that a large proportion of this pollutant was transported in subsurface flow. This was confirmed by field runoff data collected on several slopes. These data showed that the concentrations of all pollutants, with the exception of nitrate-plus-nitrite, decreased with the movement of storm water from the field slopes to the basin outlet. In particular, the TSS, PP, and PN concentrations found at the outlet are at least an order of magnitude lower than those found on the slopes. This indicates that a significant amount of deposition occurs in the fields and along the stream channel. TDP and DKN concentrations were higher in the field runoff than at the outlet due to the transformation of ammonia to nitrate and the sedimentation of phosphorus in the stream channel, as well as the uptake of orthophosphate and ammonia by aquatic plants. Nitrate-plus-nitrite exports at the outlet were significantly greater than what was found in the field runoff, suggesting that much of this compound is transported by subsurface flow.

Conclusions

The goals of the NCDEM for the Neuse River basin are to reduce total nitrogen and total phosphorus concentrations by 30% and 50%, respectively, through the implementation of Best Management Practices, which also reduce erosion of sediment. The pollutant concentrations and exports found in this study are, *overall*, relatively low and may not contribute significantly to pollutant levels in the Neuse River. However, possible problem areas identified in this study include the leaching of nitrate from croplands, and the erosion of certain portions of the study basin. The latter problem may not ultimately affect water quality in the Neuse River because the majority of the sediment does not leave the study site; however, it does have implications for soil fertility, agricultural costs, and water quality within the study area. Possible solutions for this problem include stabilization of the ditches in the upper basin with vegetative buffers, and use of Best Management Practices on croplands to prevent rill formation and soil erosion. Specific ways to reduce leaching of nitrate from croplands include: using time release fertilizers, nitrification inhibitors, and no-till methods, as well as by denitrifying standing pools of collected runoff from fields.

The results of this study may be applicable to the coastal plain in general, or to catchments with similar soil types, drainage, topography, and basin areas. More studies of this type are needed to further increase our understanding about how non-point source pollutants are processed in their movement from fields to the basin outlet in order to reduce sediment and nutrient pollution in the Neuse River basin.

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The Transformation of Labor Geographies in the Crab Processing Industry of Eastern North Carolina

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Transitions in regional economies and social structures arise out of the complex interaction of global processes and local events. The manifestations of these regional transformations include the restructuring of local industries and their labor forces, as well as the reworking of social ideologies. This paper investigates one such transformation, focusing upon labor restructuring in the crab processing industry of eastern North Carolina. In the early 1990s the crab processing industry faced a labor crisis based on the inability of the industry to continue to recruit workers from local labor sources. An alternative labor force was found in Mexican migrant women who were brought into the industry under the H2-B temporary worker program. This change in the labor pool of a once quite localized industry is shown in this study to be a reflection of broader transformations in the regional economic base, social ideologies, and the internationalization of the industry itself.

Introduction

The crab processing industry and the region of eastern North Carolina have a long history together, beginning in the early 1900s in the wake of the declining fin fishery. Before that time, both shrimp and crabs were considered by-catch and were thrown away or used as fertilizer (Stick, 1958). Crab processing did not always take place in buildings designed for that purpose. Most of the crab processing began as a cottage industry performed in private homes, usually by members of fishermen's families. Crab processing was later performed in plants that process other seafood as well, as most seafood is processed similarly and it requires little restructuring to shift from one type to another. The Chesapeake Bay crab operation began earlier and remained larger, but by 1995 the North Carolina fishery ranked third in Blue Crab production. In 1994, the state's crab catch exceeded its fish catch for the second year of the previous five (Griffith 1994).

In the early 1990s, however, a crisis began to emerge in the crab-processing industry. The major problem that faced the processing plants was not acquiring seafood or the set up of the processing houses, but as stated by one crab house manager, it is "...labor...finding it and keeping it" (Griffith, 1993). Despite recruiting attempts, local workers could no longer be found to perform the processing jobs, and as the older women aged and retired, younger members of the community would not step in to fill the gaps created. The processing jobs are typically tedious and smelly, requiring long hours at low wages. Local white women who had family ties to fishermen or black women from nearby minority neighborhoods have historically held the processing jobs. There were several impetuses for this change, one being that the increase in the prominence of tourism as a local industry provided the local women with more desirable employment alternatives. Another was that the younger women were being encouraged to get more education, thereby increasing job prospects. The establishment of Carteret Community College in Morehead City in 1963 and its subsequent development of a well respected nursing program in the 1980s contributed to this process. (Lewis, 1996; Chadwick, 1996).

In order for the industry to survive, an alternative labor force had to be found. Crab house managers began to bring in Mexican women, under the H-2B temporary worker program, as a means of filling in these gaps. This seemingly simple change in the labor pool has brought together two distinct groups of workers with very different cultural experiences, and is indicative of the increasing internationalization of the industry itself: local linkages between people and the workplace, community and industry, are being dissolved, and at the same time international linkages are becoming more firmly established.

Methodology

In order to assess this transformation, I examined the mechanisms by which local linkages have been undermined, and replaced with what may be called "global" connections, using two lines of inquiry. The first is extensive, and involves a broad-scale examination of the development and current status of the crab-processing industry and its workers in eastern North Carolina. Griffith's (1993) study of low wage labor in the US, a section of which focuses upon seafood processing workers in NC, and Mosher's (1993) thesis study on the crab pickers of eastern NC, provided empirical data on the women who work in this industry. I also used survey methods, calling managers across the region, in order to ascertain the state of the industry. The second line of inquiry is an intensive one, and involved an in-depth examination of the attitudes and beliefs of the workers themselves. Interviews allow for a greater understanding of the motivating factors behind an individual's participation in the industry. Further, it provides a means by which individual and social ideologies are internalized, and acted upon, by people.

This research is structured around the following questions: Given the historical background of labor in the industry, and looking beyond simply other job alternatives, what precipitated the industry's labor crisis in eastern North Carolina? Why did it become necessary to bring in migrant labor? What happened in terms of changes in attitudes and/or opportunities that made it more beneficial for younger locals to work outside of this industry and not take these jobs? Why were Mexican women a viable alternative labor source for this type of work?

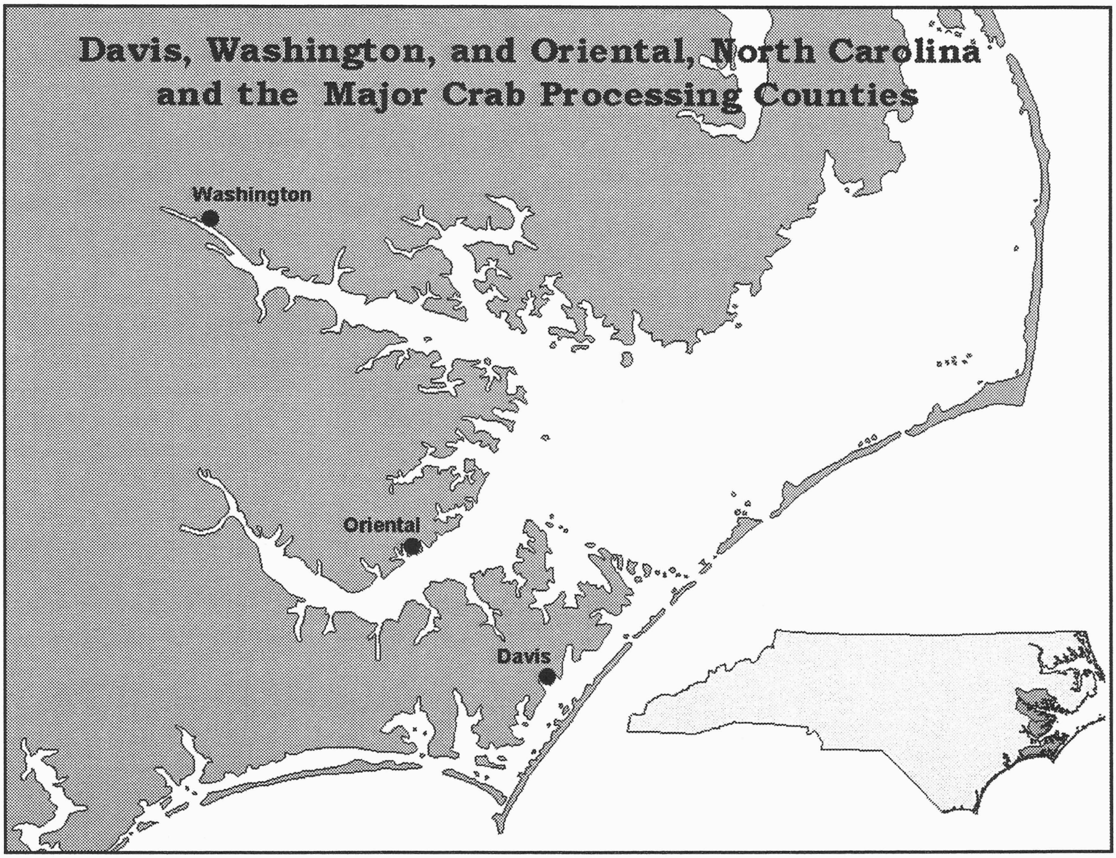
In order to understand the transformation of the crab processing industry, then, there is a need to examine specific events and people in light of their embeddedness within local social relations. In doing so, I focus on two groups. The first is the local women who previously dominated this labor pool. The interview questions presented to them sought to establish how they view this job and why locals are no longer willing to be employed within this industry. What other options have opened up at the local level for this group? The second group consists of Mexican migrant women, who form the new labor pool.[1] Why is it that Mexican migrants were willing to move into this labor niche? In other words, what specific socio-economic factors made this opportunity viable and desirable for the migrant workers?

Theoretical Background

The answers to such questions are found in the transformation of local social relations that were traditionally structured around ideologies, which included capitalism and patriarchy. I take capitalism to be a structure that encompasses economic activity engaged in for profit, one in which the owners of the means of production exploit workers for their labor power, and which often incorporates the particularities of place and space in its temporal manifestations. Patriarchy is the dominance of men in social structures generally, and particularly, the systematic subjugation of women by men.

Both of these structures are manifest at the empirical level, in the realm of practices, ideas and beliefs, and work together at local levels of action and interaction. Patriarchal ideologies often shape women's work experiences, and influence the manifestations of capitalism in that construction of some jobs as "women's work" serves capital

1. In order to interview the Mexican workers, I enlisted the help of the translator that the crab house itself uses (Rachael Raymond). This translator's assistance was invaluable because she knew the crab house's staff and the migrants, and both trusted her.



Map 1.

concerns. Female labor can be labeled as "unskilled", and therefore compensated by lower pay, effectively re-establishing the woman's inferior status. In addition, any labor that can be associated with home and family, such as working with food, is deemed "natural" for women and therefore compensation. In this way, does not require special skills or high monetary any job that can use women's labor can be minimally compensated, thereby increasing profits (Foord and Gregson, 1986; Massey and McDowell, 1984).

Griffith (1987) argues that low wage labor, even in advanced capitalism, is governed by non-market labor forces, placing it further outside regulatory controls. Non-market labor processes, which include coercion by the deployment of established ideologies and myths about gender and racial divisions of labor, rely on kinship and informal social relations. For example, the industry may accentuate sexual or racial distinctions among workers in order to reinforce myths that certain groups of people are predisposed or better suited to assume certain positions in the international division of labor. Griffith notes that in the seafood processing industry, employers must utilize such myths concerning sexuality, ethnicity, and nationality, to assure supply of, and exert control over, labor. These myths consist of socially and culturally dictated norms concerning gender roles, the accepted definition of "women's work", and racial biases concerning status in the work force.

Study Area

The crab houses focused upon in this investigation are located in Carteret, Pamlico, and Beaufort counties (see Map 1). These counties were chosen because they have the highest concentration of crab processing plants in North Carolina. One crab house was chosen from each county, Luther Lewis and Son in Davis, Carteret County; Washington Crab Co. in Washington, Beaufort County; and Garland Fulcher seafood in Oriental, Pamlico County. I selected Luther Lewis and Son (Figure 1) for in-depth investigation because of its close proximity to my own home in Morehead City.

The village of Davis is located about forty miles east of Beaufort, NC, which is the nearest commercial center. Primary economic activities have been the traditional means of subsistence. The older women pickers were all born and raised in the local area, and there are no ethnic black neighborhoods nearby from which to draw workers. One of the local pickers is the owner's mother, Lue Lewis. Besides Lue there are only two local pickers left at this crab house, Leontine and Rosie, both in their 70s. About six years ago, the Lewis crab house started bringing in Mexican Migrant workers to meet their labor needs, and these workers now comprise the majority of the workforce.

Crab House Setup

All seafood processing plants are set up in similar ways, regardless of the type of seafood they process. Most are family owned and operated, with family members occupying virtually every rung of the occupational ladder. The work force tends to be divided into management, office personnel, pickers (who number from 15 to 20 generally), and 'floor help' (men doing miscellaneous jobs around the plant). There are large vats and cookers in one part of the plant for cooking the

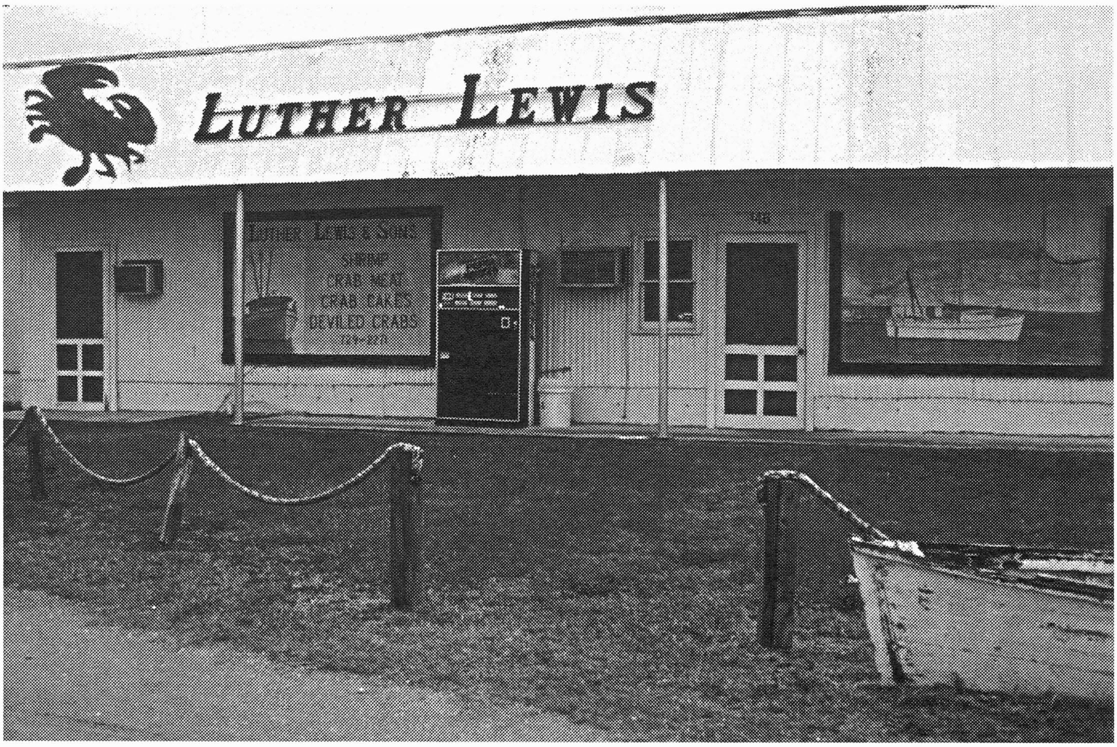


Figure 1. Frontage of Luther Lewis and Son Crab House.

Figure 2. Mexican and Local Pickers at Luther Lewis and Son, Davis, NC.

seafood, and long tables of various heights, for sitting and standing, where the meat is removed from the shells by the pickers, clad in hairnets and aprons. Mounds of raw shrimp, scallops or oysters, or cooked crabs, recently cooled, are placed in the center of the table, and as the meat is removed it is placed in plastic tubs for weighing (Figure 2).

The differing conditions under which the local and migrants workers were hired manifests itself in differing processing set ups for the two groups inside the crab house. The contrasting set ups can be related to contrasting conditions under which the women work. The Mexican workers are constrained by the provisions of their visas and often work under strict supervision, as well as submit to controlled living conditions enforced by their employers. In Mexico it is customary to stand and work diligently, and the migrants practice the same work techniques in the US. In contrast, the local workers have a history with the crab house and the community, and often enjoy kinship ties to owners and managers. As a result, local women work under much more liberal and relaxed circumstances. They are seated at tables while cleaning crab, chatting and giving the observer the impression of friends seated around a kitchen table. In contrast, the migrant workers are standing and working in silence, giving the impression of a robotic assembly line. One crab house manager divulged that longer legs had to be welded to their crab picking tables in order to accommodate the different technique of the migrant workers.

The pickers are all paid at a "piece rate", meaning by the pound of crabmeat produced. The piece rate varies between crab houses, but at Luther Lewis and Son the workers are paid $2.00 per pound. Approximately 10 to 15 pounds of whole crabs must be picked to obtain one pound of picked meat. Minimum wage is currently $5.35 an hour or about $43 for an eight hour day. Using these figures, the picker must produce at least 21 pounds of finished crab meat to make minimum wage. That means between 210 and 315 crabs a day, or between 25 and 40 crabs an hour, or a crab every two minutes! If the worker does not pick enough crabs to make minimum wage, the crab house by law must make up the difference. It can be determined then, that an increase in minimum wage under the piece rate system does not benefit workers, but forces them to work harder. The crab house may be forced to use fewer workers or fire some because the crab plant can not make up worker wages and maintain profitability.

Traditional Labor Force

The community of Davis is rural in nature and employment was previously dominated by agricultural or fishery pursuits. Kinship ties and social networks were prominent in determining employment options. The local job market is gendered, as there were few job opportunities available to women outside of caring for children or the elderly, housework, agricultural labor, or working in the seafood houses. Men were expected to support the family so they were privileged in terms of education and job opportunities. None of the local pickers interviewed had finished high school, completing formal education only through the 7th or 8th grade (Chadwick, 1997; Lewis, 1996).

Lue Lewis refers to the relationship between pickers and management at the crab house as "...one big family". The other two pickers, Leontine and Rosie, are old friends of the Lewis family. The women concur in their assessment of the "down East" area where they grew up. Lue says "..it wasn't good but we didn't know it" (Lewis, 1997). Leontine says "...we were poor but we didn't know it...everybody was that way...all alike...we had all we could eat.." (Chadwick, 1996). Both women describe their processing jobs in similar terms. Lue states "...its the greatest...like a quilting party...like a spelling bee...not like an average job...we're able to talk and carry on, stop and take a break when we want...". Leontine agrees "..its the best job I ever had...".

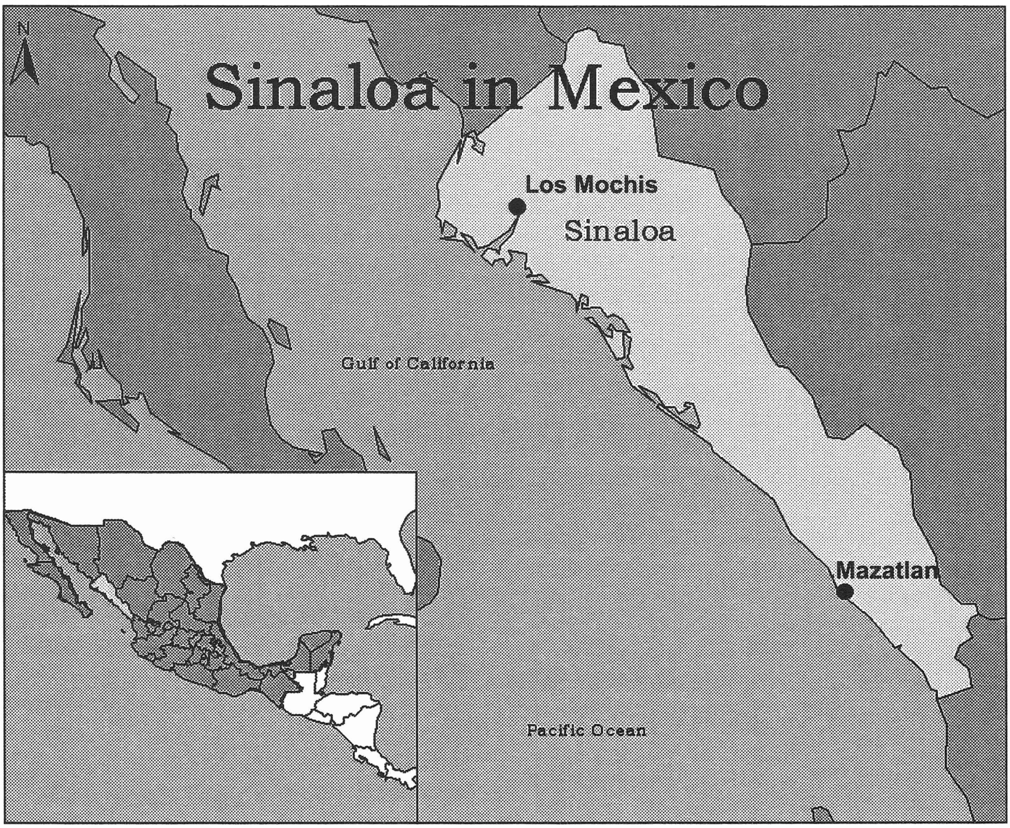
This association of the job with the ideologies of family and housework tends to place the work outside the realm of strictly economic pursuits and into that of housework and a "woman's place". The relaxed atmosphere further equates the workplace with the home, kitchen, and private "female" spaces. This has traditionally justified minimal compensation because capital identifies the work as "natural" and supplemental to the woman's primary role as housewife and/or mother. The relational ties between worker and owner/manager also blur the lines between employer and employee, wage labor and family labor. These ties were previously considered a benefit, since the close ties allowed the workers flexibility in work schedules and a certain bargaining posture to use in negotiations of wages and conditions. These ties kept abuse at a minimum, because social repercussions would surely ensue. There are no such ties for the migrants in the US, but they work together to ensure fair treatment in the workplace and optimum utilization of social services. Now legal action serves the purpose once provided by social and community ties.

Mexican Migrant Workers

Many parallels can be drawn between the older local workers and the Mexican migrants that now make up most of the work force. One is the similarities between the two geographical areas from which the workers came; the "down East" region and its companion region of Mexico. Except for one, all the Mexican pickers at L.L. and Son came from the same small village in the state of Sinaloa, called Gabriella Leva Solarno, near Los Mochis (Map 2). The Migrant pickers were recruited in Sinaloa by the staff of the crab house there in which they work after the season in North Carolina is over. It is called the "Fish Export of the Pacific", and acts as an informal labor contractor for the US crab houses. Seafood processors found out about the possibility of using migrant workers by word of mouth from employers in other local industries, such as poultry processing. The process of securing these workers required paperwork on both sides of the border and compliance with state and federal stipulations, such as sponsor requirements (Johnson, 1997; Griffith, 1993).

The migrant workers relate that the procedure for processing seafood and the type of crab used (the blue crab) are the same. The only difference is the unit of measure, as Mexico uses the Metric system, and the pay rate, because the workers get paid more in the US for crab picking due to our minimum wage legislation. The Mexican pickers also concur that the two villages, Davis and Gabriella, are "... the same ... small, little town[s] ...". They agree that in their home village there are "...no jobs...only ... agriculture and seafood ... everybody does everything ... all the same ..."(Ramona and Patricia, 1997). Kinship networks are also used extensively in Mexico to recruit labor for the industry. All the migrant workers at the Lewis House, except one, were related in some way as extended family. The Mexican workers family ties between themselves and in Mexico serve as an equally important labor control mechanism. Relational networks serve to facilitate the creation of impromptu labor unions.

The Mexican women were subject to similar gender discrimination in their home job market. Mexican men are privileged in terms of education and employment opportunities. None of the Mexican pickers from Sinaloa



Map 2.

had finished High School, and most had only completed through the 4th or 5th grade. The one Mexican picker that had finished High School was from Mexico City, and she was only picking crabs as a temporary means of supporting herself because she left her previous job. She left the crab house the next year to work full time in a local motel.

The primary concern of the Mexican workers is their families, and all stated that they endured the long journey and the separation from loved ones so that they could provide more money to secure a better future for their children. They stated that they would work anywhere "... wherever it is better" (Ramona and Patricia, 1997), in order to do this. All the migrant workers stated that they attended Catholic Mass and that the church was an important part of their lives. The Mexican workers recruitment via kinship ties serves the same purpose as that used in the local labor force, by making the lines between paid labor and home labor less distinct. Patriarchy and gender discriminations serve again to restrict women to the lowest strata of the labor hierarchy, in which monetary compensation is the least.

Summary and Conclusions

The current labor crisis in the seafood processing industry can be explained in terms of the dismantling of previously localized linkages between worker, community and industry. As internationalization of the industry increases, and diversification of other economic sectors in the region develops, the historically close connection between economic pursuit and community life has been altered. There has been a generational shift in expectations as to acceptable and appropriate employment for women which was encouraged by advances in education and opportunities for the local women. The rise of the tourist industry and the employment alternatives that accompanied it have provided local women with job alternatives that do not involve the more disagreeable factors found in seafood processing, such as the smell and monotony.

It can be seen that gender and cultural ideologies tended to shape women's expectations in both of the labor forces—the older local and the new migrant. The past local labor pool and present labor pool are both characterized by little formal education, which corresponds to the limited employment alternatives available outside of the processing plants. The deteriorated condition of Mexico's economy, and the inequality and injustice that shape its society, have influenced the migrant women's job choices and expectations. The social reality of both past and present groups is that of working class, with few expectations of upward mobility. This may partially explain the success of the relational networks in structuring job opportunities.

This is neither a unique situation nor industry action. Capital can and does maintain its global nature today because of its ability to access and utilize diverse groups and areas to meet its needs. It is unique, however, for this particular industry in this particular area to now be accessing such a distant labor source. What was once a local industry has become globalized, not just in terms of labor, but also in terms of competition from foreign sources of crabmeat.

What are implications of this transformation for the broader rural "down East" region? As a result of the importation of these new migrant workers, there is now the establishment of new international communities, or enclaves. The Mexican migrants have their own dynamic relationship with other groups in the area, but are culturally and historically distinct. There is also a changing portrayal of this local industry—it is no longer part of a community, no longer blurring family and business ties, but is now increasingly seen as a separate, distinct economic concern for profit. This change in the traditional connection between the industry owners and the labor force can be felt by merely watching the difference in how the two groups work in the crab house. The older local women sit at the table and laugh or chat together, evidently enjoying the work they are doing. Conversely, the Mexican women stand at the picking tables and work in silence, with no indication of similar enjoyment or relaxation. To the Mexican women, it is a job and no more, there is no personal connection between themselves and the local community, no continuity between their family history and the local history. They are glad to do the work, but owe nothing to the industry beyond labor participation.

Because of these transformations, the manipulation of relational ties in the local area can no longer be relied upon to maintain the labor pool from local sources. It is true that the survival of the industry has been secured by the introduction of this new source of labor, but the industry that survives now is not the same entity as that which the local women became a part of twenty or thirty years ago. It is now more of a capital concern than a community concern, and the linkages between community and industry have been altered forevermore.

Acknowledgment
Thank you to Karen Mulcahy for supplying and assisting with the preparation of the figures used in this article.

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N. Lewis, manager of Luther Lewis and Son, October, 1996.

L. Lewis, picker at Luther Lewis and Son, December, 1997.

L. Chadwick, picker for Luther Lewis and Son, October, 1996.

Patricia, Mexican migrant worker at Luther Lewis and Son, November, 1997.

Ramona, Mexican migrant worker at Luther Lewis and Son, November, 1997.

Statistical Review
A Brief Commentary: Floyd's Frustrations

Karen Mulcahy
Department of Geography, East Carolina University

Floyd. That one syllable sums up a multitude of activities and events associated with heavy rainfall in an already saturated eastern Carolina. For researchers, planners and a host of others, Hurricane Floyd has proven frustrating due to a lack of detailed information about the specific impacts of the storm. Even with swarms of satellites in the sky and hard drives crammed with data, two of our most basic questions about Floyd's floods remain unanswered: How bad was the flooding? How far and how deep were the waters?

As a relative newcomer to North Carolina, I had assumed that it would be easy to access the necessary digital spatial data to answer these and other questions about the flood. Like everyone else involved in this crisis, I set about trying to understand what had happened to the region. Little did I know that the Flood Insurance Rate Maps (FIRMs), from the Federal Emergency Management Agency (FEMA) were discordant with the post-flood needs of eastern Carolina.

The FEMA Q3 digital spatial database is the non-legally binding, digital version of the FIRMs. Pitt County Q3 data is shown in Figure 1. Given the expanse of 100 and 500-year flood zones, Pitt County was clearly in for a major flooding event when Floyd suanted up through eastern North Carolina. Both the Tar River basin, stretching northwest to east in the northern half of the county, and the Neuse

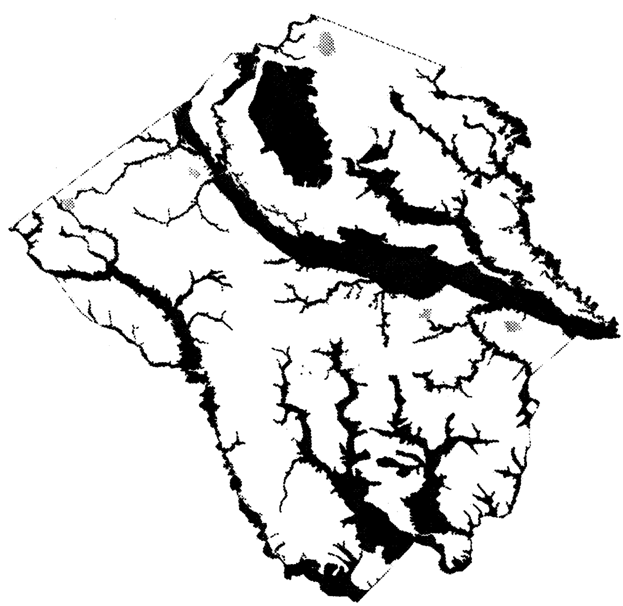


Figure 1. FEMA Q3 map.

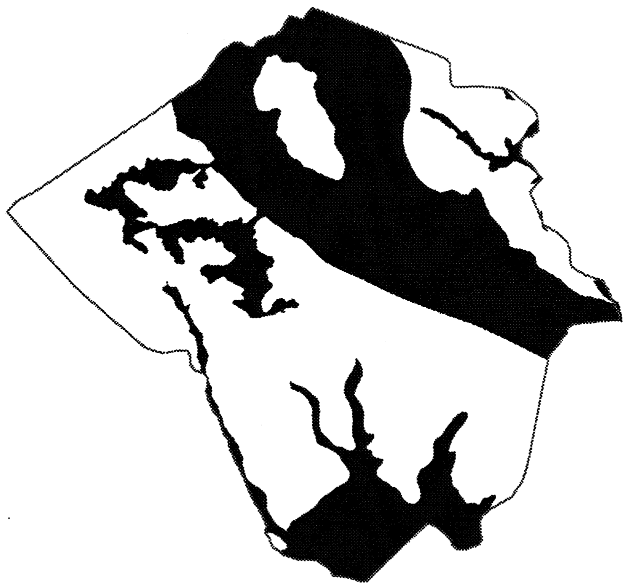


Figure 2. Preliminary draft of actual flood extent derived from satellite imagery.

river basin, covering the southern half of the county, received heavy rainfall. There is a very basic problem with using this mapped data: it is inaccurate. In many places it dramatically underestimated flooding, and in other areas it overestimated the flooding.

Although the map was inadequate for efficient emergency planning, it was used in Pitt County as the basis for a revised estimate of the extent of the flooding, and for direction of relief operations. In the days after the hurricane, Ralph Forbes of the Pitt County MIS department estimated that the flood waters sloshing at the front door of his home were at least a quarter mile from the nearest delineated flood zone. For lack of a better view of the flooding, the Pitt County MIS department used the GIS spatial operation of buffering to extend the flooding extent of the Q3 data a quarter of a mile. Although we know that such an arbitrary spatial operation would not produce accurate flood extent information, it proved a better fit in many areas.

So where exactly was the flood if not where predicted? Our next view came from Draft flood extent data based on 5 Radarsat images, from 9/23 and 9/25 (http://radarsat.space.gc.ca). These data were provided by FEMA from the Radarsat images and interpreted by a private firm. As seen in Figure 2, the extent of flooding looks extreme and is probably the source of estimates of 50% of Pitt County being flooded. This view of the flooding is very different from the designated zones in Figure 1. In fact, the area in the northern section of the county, which is zoned as 100 year flood in Figure 1, shows no flooding in Figure 2. Either an area predicted to flood did not, or more likely, there was too much vegetation present to permit proper interpretation of the flooded area; the radar sensor could not see the flood for the trees. The amount of detail here is also quite different. The radar data set shows a much smaller-scale representation. One can conjecture about issues of satellite resolution and raster-to-vector conversion issues, but the basic questions remain: where exactly, and how deep, were the waters?

Maybe the USGS Digital Elevation Models (DEMs) can help. By pasting them together and modeling the flooding, perhaps we can reevaluate the other digital data sets. Maybe not. The North Carolina Center for Geographic Information and Analysis (NC CGIA) does not distribute combined state or county coverages of this digital terrain data. The U.S. Geological Survey data are inadequate for modeling the mildly undulating surface "Down East." We are pasting the DEMs together anyway to investigate the situation further.

So, we continue to search for detailed information about the extent and depth of flooding brought on in the aftermath of Hurricane Floyd. This information is critical for moving people from the flood zones; improving or removing waste lagoons in the flood zones; updating FIRMs; understanding the influence of the built environment upon flooding intensity; screening for health related issues; and a wide range of other issues. Individual counties, cities and towns may have various information regarding flooding in their areas but how can it be utilized? Photos, surveys performed during the flood, anecdotal information, and data about condemned structures may all provide additional information. Whether this information will ever be combined, utilized, and archived for the entire region remains, however, an open question.

A Meteorologist's Thoughts on "The Flood of the Century"

Phillip Williams
Chief Meteorologist
WNCT Channel 9, Greenville, NC

Eastern North Carolina is prone to hurricane strikes and has a storied past with such monstrous storms. Why then did this years assault of storms cause "The Flood of the Century?" To answer this question we need to review the events that led up to the disaster.

The tropical storm season was predicted to flourish this year and it did. Hurricane Dennis approached North Carolina from the south in late August. Rain bands began to lash eastern North Carolina on August 30th. Even though the eye of Hurricane Dennis didn't cross the coastline, rain totals exceeded two and half inches. This seemed to be a blessing, as much of the area was 5 to 10 inches below normal rainfall for the year.

The steering current winds for Hurricane Dennis relaxed and left the storm adrift over the Atlantic east of North Carolina in early September. It is rare for a storm to leave North Carolina moving northeast and then to return, but "Dennis" made a second visit. On September 4th, Tropical Storm Dennis, after drifting southward for days, moved inland from the east-southeast.

Rainfall from this second Dennis assault totaled over 6 inches. The majority of this rain fell over the Neuse and Tar river basins. With rainfall of nearly a foot within 10 days, these rivers were projected to have minor flooding. As these rivers were nearing their projected crests another major hurricane, Floyd, was brewing over the southwestern Atlantic.

Hurricane Floyd was a major hurricane that moved toward eastern North Carolina from the south. As the hurricane neared, winds became easterly. This produced surface converging winds over eastern North Carolina and led to a steady heavy rain on September 14th. The rain continued on the 15th as the hurricane neared. The eye of Floyd made landfall in the early morning hours of the 16th. In three days, over 15 inches of rain fell on Greenville, NC. Flash flooding was widespread during the hurricane, but the worst was yet to come.

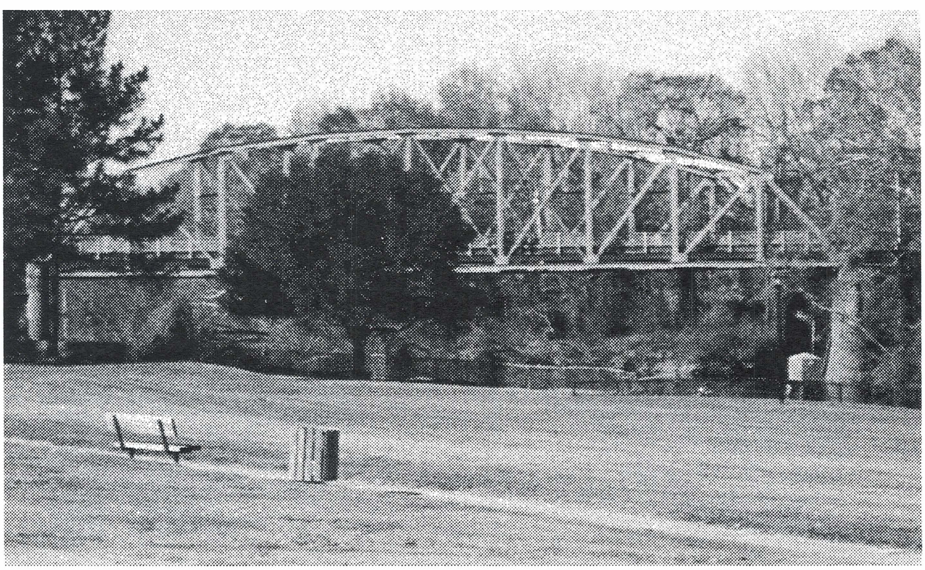
The Tar River reached record levels in Rocky Mount and Tarboro-so high that the gauges that measure the levels were completely submerged. As chief meteorologist for the local CBS affiliate, I took to the air to see the breadth of the flood. I saw the Pitt-Greenville airport submerged; cars and planes beneath the murky water. I saw rooftops, but few yards. I witnessed helicopter rescues from north Greenville. For the next week, my TV station was on-air constantly, giving information about what roads were closed and where to get free ice, water, and other necessities to survive. Thousands were suddenly homeless and many others were without power or clean drinking water.

I will never forget the sights I saw from the helicopter, or the emotional moments of seeing people talk about their personal losses. I will remember seeing the President of the United States visit the flood ravaged area and promise federal assistance. However, the most touching experience was when a little boy at a shelter told one of our reporters he had a message. He faced the camera and showed a crayon drawing that said, "Please help us. We need food and clothing." He was about 5 years old. My memories of the "Flood of the Century" will last my lifetime.

Images of Hurricane Floyd

Hurricane Floyd has, in some way, impacted everyone in North Carolina. The *North Carolina Geographer* is currently produced at East Carolina University in Greenville, North Carolina. Located along the banks of the Tar River, our community was hard-hit by the flooding. Homes and buisneses were destroyed, thousands were forced into community shelters, and the university was forced to close its doors for two weeks. The images on the following pages were collected by the editors from around the Greenville area to provide a personal sense of both the human and physical impacts of the large magnitude flooding following Hurricane Floyd.

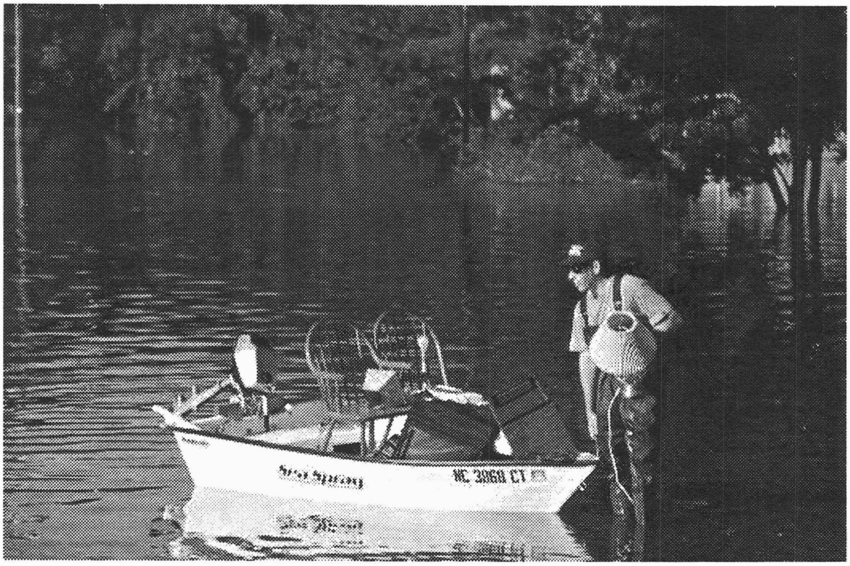
This photo was taken several days before the river crested at the Greenville Town Commons park on the banks of the Tar River. The water eventually rose to touch the bottom of the bridge (photo by Patrick Pease).



Photograph of the Greenville Town Commons on a normal day (photo by Jeff Popke).

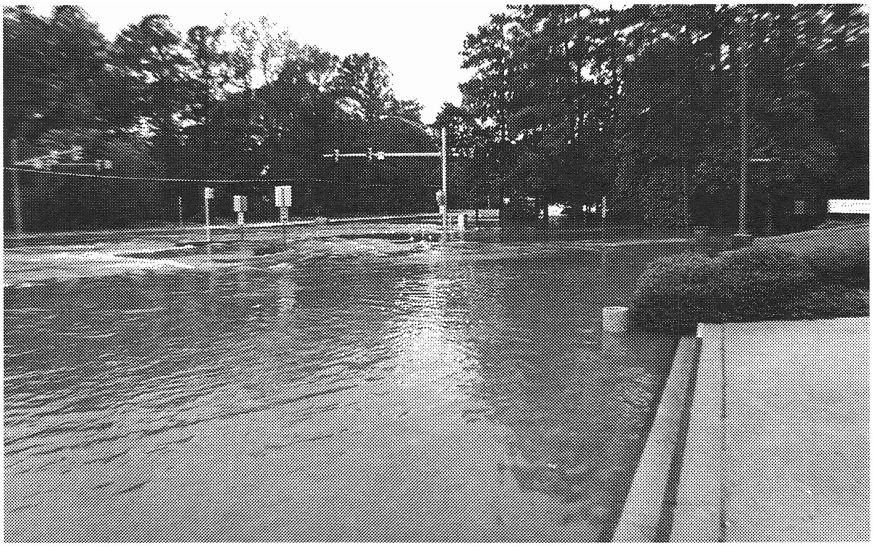
Greenville apartment complexes occupied primarily by East Carolina University students. The university estimated 2,500 students were impacted by the flood and a temporary trailer park has been set up to house over 900 students who are still homeless (photo by Greg Eans/The Daily Reflector/Greenville, NC).

Flood waters at the apartments shown in the photo above. Notice the students on their balconies looking over the destruction. On the right are two tobacco bails that floated in from a warehouse upstream (photo by Bill Edwards).

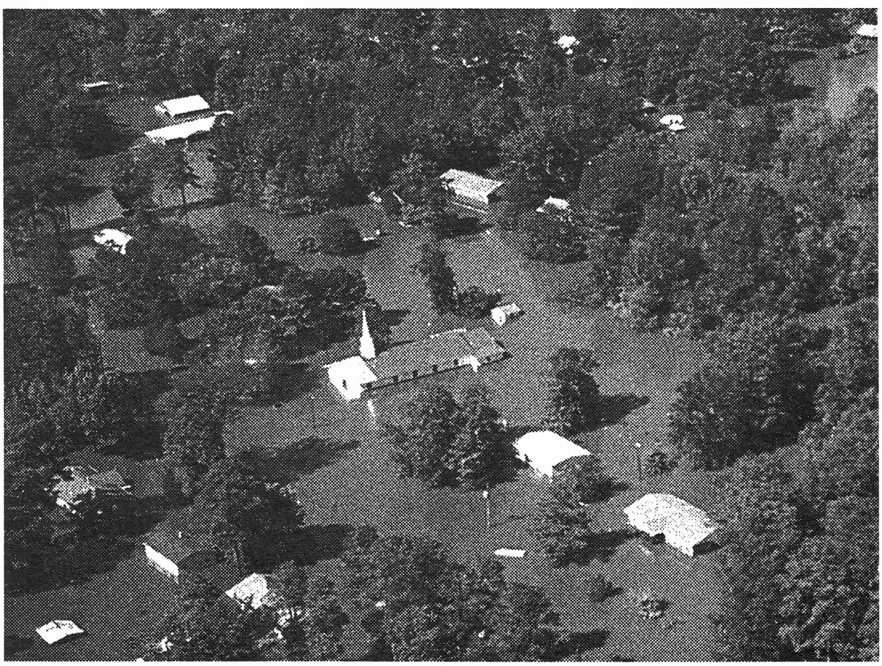


Many residents in the Greenville area tried to salvage belongings as the realization of the flood's magnitude begun to set in (photo by Kent Keeter).

Students attempt to salvage belongings from a second story 'apartment by boat. Most students living in flood prone areas were caught off-guard and did not feel they were well informed about how high the flood waters would rise (photo by Kent Keeter).



Water from the initial flash floods following Hurricane Floyd. This photo looks into the parking lot in front of the Geography Department at ECU. Notice the rapid flow of water around the street signs. (photo by Jean Luc Scemama).



The community of Belvoir, northwest of Greenville, showing homes and a church inundated by flood waters from the Tar River (photo by Greg Eans/The Daily Reflector/Greenville, NC).

Aerial view of the Greenville Airport. This photo looks south towards the overflowing channel of the Tar River (photo by Greg Eans/The Daily Reflector/ Greenville, NC).

Many streets were blocked by fallen trees in Greenville following Hurricane Floyd (photo byJean-Henri White/The Daily Reflector/Greenville, NC).

The torn out interior of flooded homes was a common site during the recovery effort (photo by Katherine Jones).

Approximately 6000 structures in Eastern North Carolina were condemned following the flooding of Hurricane Floyd (photo by Katherine Jones).

EAST CAROLINA UNIVERSITY

Department of Geography

PROGRAMS AND RESEARCH FACILITIES

Undergraduate tracks include the B.A. in Geography and the B.S. in Applied Geography. The former is a broadly-based geography program, drawing courses from human and physical geography, as well as techniques. The latter has a strong emphasis on spatial analysis, and requires an internship in a state agency or private firm.

At the graduate level the Department specializes in human geography, physical geography and spatial information technologies, and supports a variety of philosophical and methodological approaches within each of these areas. Students are encouraged to develop their research in conjunction with faculty, and to disseminate their findings via professional meetings and journals. Faculty expertise is clustered around the following:

Economic Geography: development policies, practices, and impacts; urban and rural restructuring; and geographic thought (political economy, feminist theory, critical geopolitics).

Cultural Geography: community development; tourist landscapes; cultural ecology; and field methods.

Coastal Plain Geomorphology: coastal geomorphology (aeolian processes and dune formation); drainage basin hydrology; fluvial geomorphology; soil geomorphology; and environmental management (natural hazards research, land and water use planning).

Spatial Information Technologies: geographic information systems (watershed/environmental modeling, topographic effects on digital data); remote sensing and image processing, computer cartography (global databases and map projections), and spatial quantitative methods.

Regional Specializations: Africa-East; Africa-South; Asia-South; Caribbean; Middle East; North Carolina; Western Europe.

Faculty are actively engaged in research in all four clusters, and have received multiple-year grants from, amongst others, the U.S. Department of Agriculture, the National Science Foundation, the New Jersey Sea Grant Program, N.A.S.A. and the U.S. Forest Service.

The department maintains both a fully equipped physical geography laboratory and a Unix-based Spatial Data Analysis Laboratory. The physical geography laboratory is designed for mechanical analyses of soil and sediment, but also includes state-of-the-art GPS, electronic surveying equipment, and instrumentation for monitoring hydrologic and aeolian processes and responses. The spatial laboratory consists of ten Sun workstations, a large format digitizer, and an Esize DesignJet plotter for teaching and research. Primary software includes Arc/Info, ArcView, and Imagine. A PC-based cartogrphy laboratory was recently established. Students also have access to a wide variety of university facilities including the Institute for Coastal and Marine Resources, the Regional Development Institute, International Programs, and the Y.H. Kim Social Sciences Computer Laboratory. The Kim laboratory provides access to PC-based software such as Adobe Illustrator, ArcView, Atlas*GIS, IDRISI, SAS, SPSS, and Surfer.

FOR CATALOG AND FURTHER INFORMATION WRITE TO:

Undergraduate Catalog: Director of Admissions, Office of Undergraduate Admissions, East Carolina University, Greenville, North Carolina 27858-4353. Tel.: (919) 328-6640. World Wide Web: http:/www.ecu.edu/geog
Graduate Catalog: Graduate School, East Carolina University, Greenville, North Carolina 27858-4353. Tel.: (919) 328-6012. Fax: (919) 328-6054.

APPALACHIAN STATE UNIVERSITY
Department of Geography and Planning
www.geo.appstate.edu

Degrees Offered: B.A. in Geography; B.S. in Geography (teaching or concentrations in general geography or geographic information systems); B.S. in Community and Regional Planning; M.A. in Geography with liberal arts option (thesis or applied).

Facilities: The Department maintains four computer laboratories for work in computer cartography, GIS, and image processing. These labs have both PC and SUN workstations which are networked to each other and to the campus mainframe cluster. Software includes ERDAS, ARC/INFO, ArcView, SPSS, Surfer, Atlas GIS, SAS, CorelDraw and Aldus Freehand.

Graduate Program: The Masters program in geography is designed to provide students with a relatively broad range of academic and professional options, preparing them for Ph.D. work in geography and planning, professional applications in GIS, or opportunities in teaching at all educational levels. Accordingly, concentrations are offered in liberal arts with thesis or in applied geography with internship in regional, urban, and environmental analysis and planning. In addition, the Department participates in a program leading to the Master of Arts degree in Social Science with preparation in geographic education.

For a catalog and further information, please contact:
Undergraduate Geography: Dr. Roger Winsor {winsorra@appstate.edu}
Undergraduate Planning: Dr. Garry Cooper {coopergv@appstate.edu}
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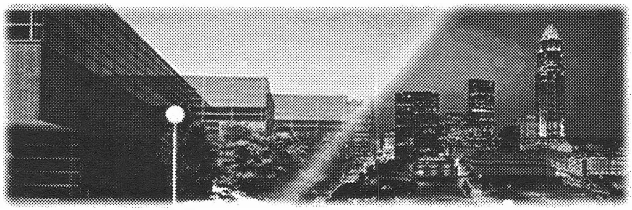
THE UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Master of Arts in Geography



The MA in Geography at UNC Charlotte emphasizes the application of skills, methods, and theory to problem solving in contemporary society. Students are offered a solid foundation in research methods, problem formulation, quantitative methods and computer and GIS skills. Many UNCC graduates have gone directly into jobs working as professional geographers using skills acquired in their MA program. Jobs include research and/or marketing specialists, location analysts, planners, transportation specialists and private consultants. About 15% of the more than 100 graduates have gone on to study in Ph.D. programs.

CHARACTERISTICS
- About 55-60 students and 23 faculty are in residence
- Class sizes are small; student and faculty are in close contact; community involved in class projects
- Funding is available on a competitive basis; about half of all full-time, current students have funding
- Excellent Spatial Analysis Laboratory with ARC/INFO GIS (workstation and PC) and ERDAS (workstation)
- The Department manages the Center for Transportation Studies which contains a research laboratory

PROGRAM CONCENTRATIONS

Community Planning Track

Students who choose the Community Planning track are awarded an M.A. in Geography and complete a formally structured multi-disciplinary core which includes course work in Geography, Architecture, Economics and Public Administration.

Environmental Analysis and Assessment

The environmental concentration draws upon the expertise of practitioners and professionals and a diverse earth science and geography faculty. There are three main courses of study: hydrologic processes; atmospheric studies; and an interdisciplinary focus which includes environmental assessment and planning.

Urban-Regional Analysis and Planning

Students in the urban-regional analysis and planning concentration normally become planners in public sector planning agencies. Course work concentration is in one of the following areas:

Planning Theory	Public Facility Siting	Regional Development
Urban Theory	Environmental Planning	Site Feasibility Analysis
Urban Planning	Impact Analysis	

Location Analysis

The Location Analysis concentration prepares students for jobs in location research with retail companies, real estate developers, consulting firms, commercial banks, and economic development agencies or for continued academic training in economic geography and location analysis. Course work is offered in:

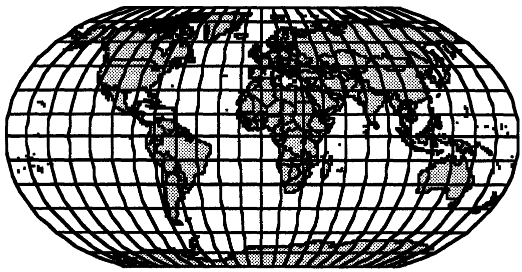
Retail Location	Trade Area Analysis	Facility Siting
Office and Industrial Location	Real Estate Development	Applied Population Analysis

Transportation Studies

Students in Transportation studies can pursue course work in transportation systems analysis, policy formulation, impact analysis, and planning. This concentration prepares students for jobs in the public sector as planners and in the private sector as analysts for transportation providers and private consulting firms.

THE INTERNSHIP As a program which emphasizes applied geography, the Internship is an especially important element and normally replaces the traditional thesis as the capstone project of a graduate program. Projects normally involve the students in the execution of a substative research task for private or public sector clients where the student is the primary investigator in a specific "real world" research task.

FOR FURTHER INFORMATION CONTACT: Dr. Gerald L. Ingalis, Graduate Coordinator
Department of Geography and Earth Sciences, UNCC, Charlotte, NC 28223 (704-547-4260)



GEOGRAPHY
AT
UNIVERSITY OF NORTH CAROLINA AT WILMINGTON

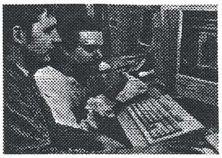
Geography at the University of North Carolina at Wilmington is housed in the Department of Earth Sciences. There are five full-time geography faculty. Research interests and specialties include: cultural-historical geography; material culture studies; environmental planning; and fluvial geomorphology. Equipment available for teaching and research includes modern PC-based cartographic and image-processing lab, and photographic and darkroom facilities. The university library contains a strong geography collection including all major journals, and is a repository for government documents and maps. About 40 majors are currently working towards a B.A. in geography.

Wilmington, North Carolina's premier port city, is located on the Cape Fear River and is only ten miles form the Atlantic shore. It is linked to the research Triangle area directly via Interstate 40. With a metropolitan area of over 130,000 residents, Wilmington is the economic and cultural hub of southeastern North Carolina. Climate is warm and humid during the summer, and exceptionally pleasant during the rest of the year, enhancing the variety of coastal recreational activities of the region.

For further information on our undergraduate program contact:

Dr. Frank Ainsley
Department of Earth Sciences
The University of North Carolina at Wilmington
Wilmington, NC 28403
TEL: (910) 962-3490
FAX: (910) 962-7077

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

UNDERGRADUATE PROGRAM: The geography major can choose a concentration in Urban Planning or Earth Science/ Environmental Studies. Currently, there are about 80 majors.

MASTERS IN APPLIED GEOGRAPHY: The program requires 30 hours in geography, including a thesis or internship, plus two courses in statistics or computer science.The program has nearly 30 students and offers several graduate assistantships

FACILITIES: The Geography Department houses a state-of-the-art research and teaching lab for GIS, computer cartography, digital image processing, and air photo interpretation. There are 20 networked pentium pro machines on an NT operating system, plus several printers, scanners and digitizing boards, as well as GPS equipment. Software used in the lab includes Arc/Info, ArcView, ERDAS, Surfer, Atlas GIS, MapInfo, ER Mapper,Adobe Illustrator,Adobe Photoshop and Corel Draw. There is also a climatology and SPSS computer lab, faculty/grad student research lab, geomorphology/geology lab, and a 100+ acre field camp to study geomorphology, meteorology, biogeography, and GPS mapping.

SPECIAL ACTIVITIES: Students can become involved in the department, University, and community while becoming better acquainted with other students, faculty, employers and community leaders. The department hosts lectures bi-monthly at Geography Club meetings and sponsors several campus-wide events. Students can join the campus chapter of Gamma Theta Upsilon, the international geography honor society, and participate on UNCG's Geography Bowl Team in state competition. Many students take the summer field course to the West.

For Undergraduate Information:
Call: 336-334-3911
E-mail: KGDebbag@UNCG.EDU

For Graduate Information:
Call: 336-334-3895 or 3918
E-mail: Hidore@UNCG.EDU or
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Guidelines for Authors

The *North Carolina Geographer* is an annual, peer-reviewed journal published by the North Carolina Geographical Society. The journal serves as an outlet for research related to the geographical phenomena of regional interest.

All manuscripts submitted to the North Carolina Geographer should be in acceptable form and ready for peer-review. Contributions should adhere to the following general guidelines.

- Send one original and two copies of manuscripts. Only original, unpublished material will be accepted.
- All manuscripts should be on 8 1/2 " x 11" paper. Type on only one side of the page. Type should be 10 or 12 point font and double spaced. One inch margins should be used on all sides.
- References are to be listed on separate pages, double spaced, and in alphabetical order by authors last name.
- Figures and tables should be submitted on separate pages with each copy of the manuscript. Authors names and page numbers should be written on the backs of all figure sheets.
- High quality, black and white photographs may be included.

Send manuscripts to:

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