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Decreases in Yadkin River Basin Sedimentation: Statistical and Geographic Time-Trend Analyses, 1951 to 1990

by

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ABSTRACT

In large river basins, the rate at which land-use changes affect sedimentation and water quality is not easily tested. This study's objective was to evaluate changes in land use, soil erosion, and sedimentation in the Yadkin River basin of western North Carolina from the 1950s to the 1980s. This river system offers an unusual opportunity to evaluate the temporal interaction of land use change and sedimentation at the river-basin scale. Above the U.S. Geological Survey's sampling station at Yadkin College (Station 02116500), the river drains a 5896-km^2 basin of the Blue Ridge and Piedmont. Land under cultivation in this river basin has declined to about 30% of that in 1920. The U.S. Geological Survey's daily sediment sampling from 1951 to 1990 is one of the world's longest duration sediment records; the data indicate that although the river continues to transport enormous amounts of sediment, averaging 1.39 Mg ha^{-1} yr^{-1}, the river transports about 30% less suspended sediment than it did in the early 1950s. Similarly, gross soil erosion from the rural areas of the basin has decreased substantially during this period, from 14.4 to 11.9 Mg $ha^{-1}yr^{-1}$, according to a geographic information system (GIS) analysis which included the Universal Soil Loss Equation. Although basin-wide erosion continues at relatively high rates, recent decreases in erosion are most pronounced on cultivated agricultural lands, due to decreases in area under cultivation and to improved soil management in the form of best management practices. Management control over new sources of sediment, especially from urban and suburban development and road construction activities, is considered critical for continued improvement of the water quality of the Yadkin River.

Key Words: Soil erosion, suspended sediment, Yadkin River, water quality, trend detection, water resources, soil resources, watershed management, GIS, stratified random sampling, land use-land cover, Universal Soil Loss Equation, best management practices.

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SUMMARY AND CONCLUSIONS

In large river basins, the rate at which changes in land management practices may decrease sedimentation and improve water quality is neither well documented nor easily tested. For this reason, the U.S. Geological Survey's (U.S.G.S.) 40-year daily sediment sampling program of the Yadkin River at Yadkin College in North Carolina is a major achievement in environmental monitoring. Above Yadkin College (U.S.G.S. Station 02116500), the river drains a 5896 km^2 Blue Ridge and Piedmont basin. In this basin, cultivated land area has decreased rapidly during the twentieth century, yet the river continues to transport massive amounts of sediment, averaging 139 Mg km^{-2} yr^{-1} over the 40-year record (1951-1990). The first of the two main objectives of this research was to evaluate temporal trends in suspended sediment concentrations and transport over the 40-yr record. The second objective was to place temporal sediment dynamics within the context of basin land use and land cover change by estimating changes in gross soil erosion from the early 1950s to the late 1980s. This was accomplished through the use of a geographic information system (GIS) database, created from available digital data and aerial photography from the 1950s and 1980s, and designed around a stratified random sample of the basin.

From 1951 to 1990, the transport of suspended sediment has been enormous, with a 40-year mean of 819,000 Mg/yr or about 1.39 Mg $ha^{-1}yr^{-1}$. Annual transport ranged from 0.17 to 2.63 Mg $ha^{-1}yr^{-1}$ with a coefficient of variation of 47%. About 79% of annual variation in sediment transport is attributable to variation in annual river discharge. After removing variation in sediment transport attributable to variations in river discharge, however, sediment transport is estimated to be slowly decreasing, at a rate of about 1.15 Mg km^{-2} yr^{-1}, with a 90% confidence interval around this mean decrease of $\pm$ 0.37 Mg km^{-2} yr^{-1}. Based on three trend detection techniques that remove variation in transport due to hydrology, the river is transporting about 30% less sediment that it was in the early 1950s. Although seasonal Kendall and Sen analyses indicated that decreases in sediment transport have been greatest in June to August, months with the highest rainfall erosivity, no significant differences in the rate of decrease were detected between months of the year. Sediment transport significantly decreased in all months over the record.

Three land use-land cover datasets of different spatial resolution, are used to describe the substantial changes in the landscape in the southern Piedmont and the Yadkin River basin during the twentieth century. U.S. Department of Agriculture Forest Service Inventory data indicate that between 1937 and 1990 rowcrop area has decreased from about 45% to 18% in the North Carolina Piedmont, whereas urban and residential area has increased from 5 to 18%. At the county level, U.S. Department of Commerce Agricultural Census data indicate that rowcrop area is currently about one-third of what it was in 1920 in the Yadkin basin. A remotely sensed land use-land cover database, specific to the Yadkin River basin, estimates that the area currently in rowcrops is about half of what it was in the 1950s (679 to 330 km^2), while residential and urban areas have grown by 80% (391 to 704 km^2). This latter database was derived by aerial photography interpretation of 185 1-km^2 sample areas, distributed throughout the basin by a stratified random sample. Changes in pastureland and forestland have also occurred, although at a smaller scale between the 1950s and the late 1980s.

Basin gross soil erosion rates from agricultural, forested, and cleared/transitional areas were estimated from the 185 1-km^2 stratified random samples for the 1950s and 1980s. A geographic information system (GIS) based model of the Universal Soil Loss Erosion (USLE) was used for the calculations. For the 185 1-km^2 sample areas, USLE factors for rainfall erosivity, soil erodibility, slope characteristics, and land cover were combined using IDRISI, a raster based GIS. In simulations where rainfall erosivity is held constant, soil erosion decreased over the four decades, with the basin-wide average decreasing from 14.4 to 11.9 Mg ha^{-1} yr^{-1} (6.4 to 5.3 tons $acre^{-1}$ yr^{-1}), primarily due to the reduction of cultivated area. Simulations based on major improvements in soil management of croplands indicates dramatic reductions in erosion rates in the early 1990s. The recent improved agriculture management is estimated to have reduced basin erosion rates to 8.4 Mg ha^{-1} yr^{-1} (3.7 tons $acre^{-1}$ yr^{-1}).

Results from the separate analyses indicate that water quality of the Yadkin River is improving in regard to suspended sediment, although at a slower rate than might be expected considering the decreases in rural sediment sources and improved agriculture management. Overall, the basin's land use, erosion, and sediment dynamics emphasize that watershed management must be implemented with great expertise if it is to control the soil-erosion problem on the river basin scale. Establishing management control over new sediment sources is important for continued improvement of water quality of the Yadkin River.

RECOMMENDATIONS

We recommend the following actions to help continue the improvement of soil and land management and water quality in the Yadkin River basin.

First, the four-decade U.S. Geological Survey's daily sediment sampling program of the Yadkin River should be better recognized as a major achievement of environmental monitoring. Planning should be conducted to ensure a continuity of financial support for this monitoring. A collaborative effort of local, state, and national interests would probably be the best way to continue sediment monitoring. Since the Yadkin River may well have the longest duration daily record of suspended sediment of any river in the world, it deserves financial support from many groups, even in times of budgetary scrutiny.

Second, this record provides a remarkable and unique opportunity for researchers and managers to work together in better managing erodible lands and sediment-dominated river systems. Future research should be directed at estimating the impacts of urban, suburban, and construction activities on sedimentation, estimating floodplain and channel storage potential for previously eroded sediment, and additional monitoring of suspended sediment at existing USGS gauging stations in several tributary watersheds. Also, erosion and sediment improvements resulting from the recent and substantial improvements in soil management of cultivated lands should be closely monitored.

Third, North Carolina is currently engaged in an ambitious and significant water quality planning effort for 17 major river basins in the state. If this state-wide water quality planning is to affect water quality improvement, it depends not only on technical data such as that evaluated in this report but also on effective interaction with local residents and institutions in the basins. Notable is vital Yadkin River Basin Commission which deserves special praise for facilitating better land and water management within the basin. We recommend that the Division of Environmental Management (DEM) work closely with the Yadkin River Basin Commission to facilitate more effective water quality planning, management, and improvement. The DEM Water Quality plan for the Yadkin River will be the last of the agency's 17 plans, and there appears to be ample time for the D.E.M. and basin residents to work together in developing effective strategies for long-term water quality improvement.

INTRODUCTION

Sedimentation is one of the world's primary water pollution problems, mainly because it is so readily accelerated by human activities such as forest clearing, farming, surface mining, road construction, and the growth of suburban and urban communities. The movement of sediment through a river system is difficult to predict (Walling 1983; Richter et al. 1985), because sediment results from soil and channel erosion that has occurred hours to centuries in the past. Sedimentation is difficult to control, because sources of sediment typically result from a large number of activities and disturbances to soils and stream channels within a river basin.

In the highly erodible Piedmont of eastern North America, clearing of forests and agricultural land-use have greatly accelerated soil erosion and river sedimentation since the 18th century (Meade and Trimble 1974). Trimble (1974) estimated gross soil erosion across the southern Piedmont to be equivalent to the volume of a 17-cm depth of soil across the entire Piedmont region from Virginia to Alabama. Although the actual magnitude of this soil erosion loss is subject to debate (Daniels 1987), there is no debate that many Piedmont soils are severely eroded from past agricultural use. As a result, many Piedmont watersheds have large volumes of sediment deposits that are periodically transported downstream. Piedmont river systems are transporting greater than 10-fold more sediment than they were prior to European colonization (Meade et al. 1990).

During the mid to late 20th century, however, soil erosion from cultivated lands has been decreasing in the Piedmont, as a result of row cropped land being abandoned and converted by farmers to less erosive uses (Trimble 1974), and because soil management has improved on Piedmont farms that remain under cultivation (Sojka et al., 1984). These agricultural changes are widely suggested to have caused rapid decreases in river sediment transport (Albert and Spector 1947; Maki and Hafley 1972; Trimble 1974; Harned and Meyer 1983; Patterson and Cooney 1986). Nonetheless, other sediment studies of the Piedmont and other regions suggest a more complex and long-term river basin response to land use-land cover change (Gilbert 1917; Meade and Trimble 1974; Meade et al. 1990; Simmons 1993). Moreover, much of the Piedmont is now entering a post-agricultural era as potentially erosive urban and suburban development and highway construction become increasingly common across the region. The response of large river systems to such shifts in land use-land cover are neither well documented nor easily tested experimentally.

The objective of this study was to evaluate 40-year time trends in sediment transport by the Yadkin River in North Carolina (Fig. 1) during a period in which this river basin was rapidly shifting from being dominated by agricultural uses to one with a mixture of land uses, including additional areas of low erosivity forest and pasture, and high erosivity urban and suburban development. The research tested the hypothesis that transport of river sediment has decreased over the past 40 years. Parametric and nonparametric statistical methods were used to evaluate sediment trends, and a combination of annual and monthly sediment statistics were assembled from the 14,516 daily sediment observations made by the U. S. Geological Survey from 1951 to 1990. Geographic information system (GIS) analyses were used to estimate changes in land use-land cover and gross erosion to evaluate shifting patterns in sediment source areas.

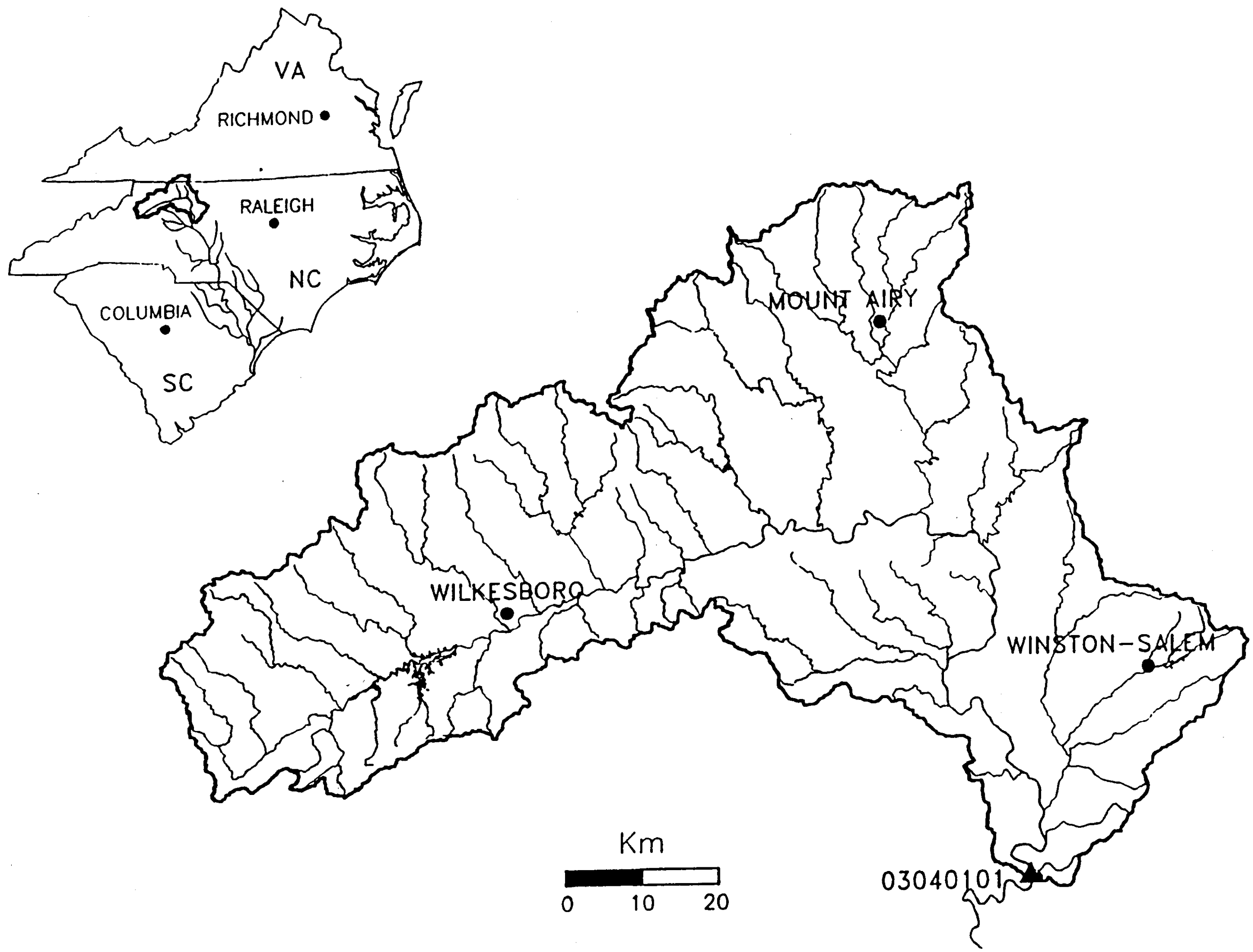


Figure 1. Map of Yadkin River basin above Yadkin College, North Carolina (U.S. Geological Survey Station 02116500).

The time-trend analyses of the Yadkin's 40-year record of sediment transport has been placed in the context of about 120 years of land use-land cover information for the 5896 km^2 basin, using data from 20 agricultural censuses of the U. S. Department of Commerce (U.S.D.C.) (Bureau of the Census 1987) and six U. S. Forest Service (U.S.F.S.) forest inventories (Brown 1991). To estimate changes in gross erosion between the 1950s and the 1980s, several GIS databases were constructed to simulate and combine basin rainfall, topography, soil erosivity, and land use-land cover in 1955, 1975, and 1988.

METHODS

US Geological Station 02116500 - The Yadkin River Basin above Yadkin College, NC

The Yadkin River basin above Yadkin College, North Carolina is 5896 km^2 in area, mainly draining the western Piedmont of North Carolina, but also the Blue Ridge escarpment of the Appalachian Mountains in both western North Carolina and Virginia (Fig. 1).

The suspended sediment record of the Yadkin River at Yadkin College, North Carolina is unusually valuable because it is one of the longest-duration daily suspended-sediment records in the world. The sediment record is also unusual because it spans a time over which land use has changed dramatically. The response of sedimentation in large river systems to shifts in land use is not well documented. Moreover, the river is largely free-flowing above the sampling station and not greatly affected by major dams and reservoirs. Piedmont rivers are commonly dammed, which traps sediment and reduces its concentration independently of changes in land use. The record and settings of the Yadkin River thus offer a unique opportunity to study the interactions of land use change and sedimentation in a large watershed.

The Yadkin College, North Carolina Station 02116500 has been sampled for suspended sediment at least daily from January 1951 to the present. Streamflow at Yadkin College has been continuously recorded since July 1928, and flow instrumentation has been located within about 30 m of its present location. Concentrations of suspended sediment are estimated by depth-integrated stream collections. Sample quality has been ensured by sampling during many floods as frequently as every two hours during periods of rapidly changing flow. Daily sediment transport is estimated with the sub-divided day method for estimating flow-weighted daily sediment concentrations and sediment transport. Sediment samples have been taken from multiple verticals across the river's cross section throughout the record to locate the optimal vertical for the daily sample. The station has operated as part of the U.S. Geological Survey's NASQAN network.

The Yadkin River above the sediment sampling site at Yadkin College has one significant dam, the W. Kerr Scott Dam, that was established in 1962 west of Wilkesboro, N. C. in the headwaters of the river system. We consider that this structure has had relatively minor effects on sediment transport at the sampling site, mainly because the dam affects runoff from about 15% of the basin (Fig. 2). Moreover, the subcatchment above the dam has remained heavily forested over the sediment record. Periodic sediment samples in the river and tributaries above and below the dam support the perspective that the dam has had a relatively small effect on sediment transport at Yadkin College (Simmons 1993).

On the other hand, immediately downstream of the Yadkin College sampling station are a series of large dams and reservoirs that effectively trap sediment. Using a U.S.G.S. data set accumulated from the 1970s and 1980s, sediment transport at the Fall Line in the greater Yadkin-Pee Dee River (at Rockingham, North Carolina) was estimated to be about 30% of that at Yadkin College, despite the basin being more than three-fold larger in area (Fig. 3).

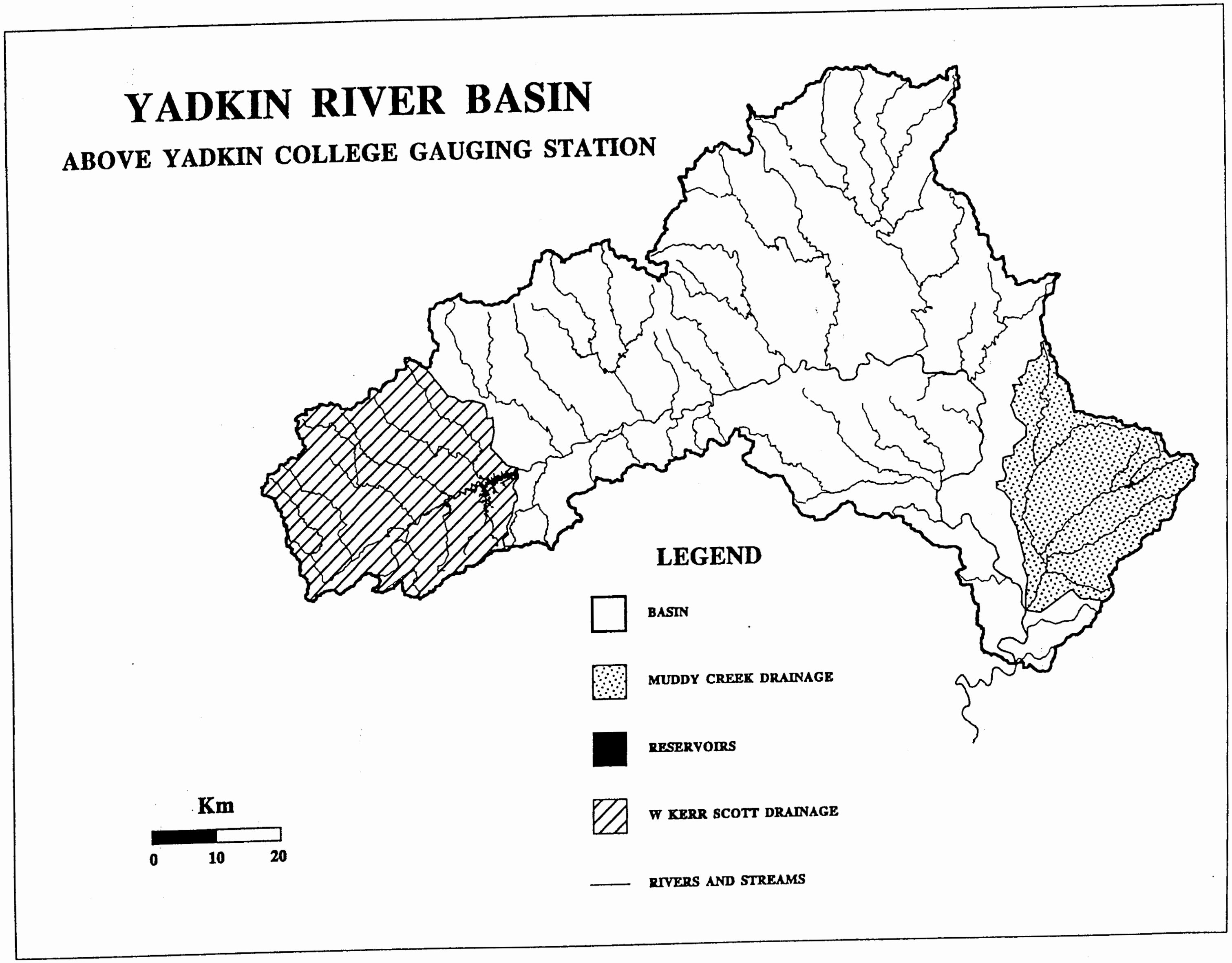


Figure 2. Map of Yadkin River basin illustrating subcatchments of Muddy Creek (containing Winston-Salem) and W. K. Scott Dam.

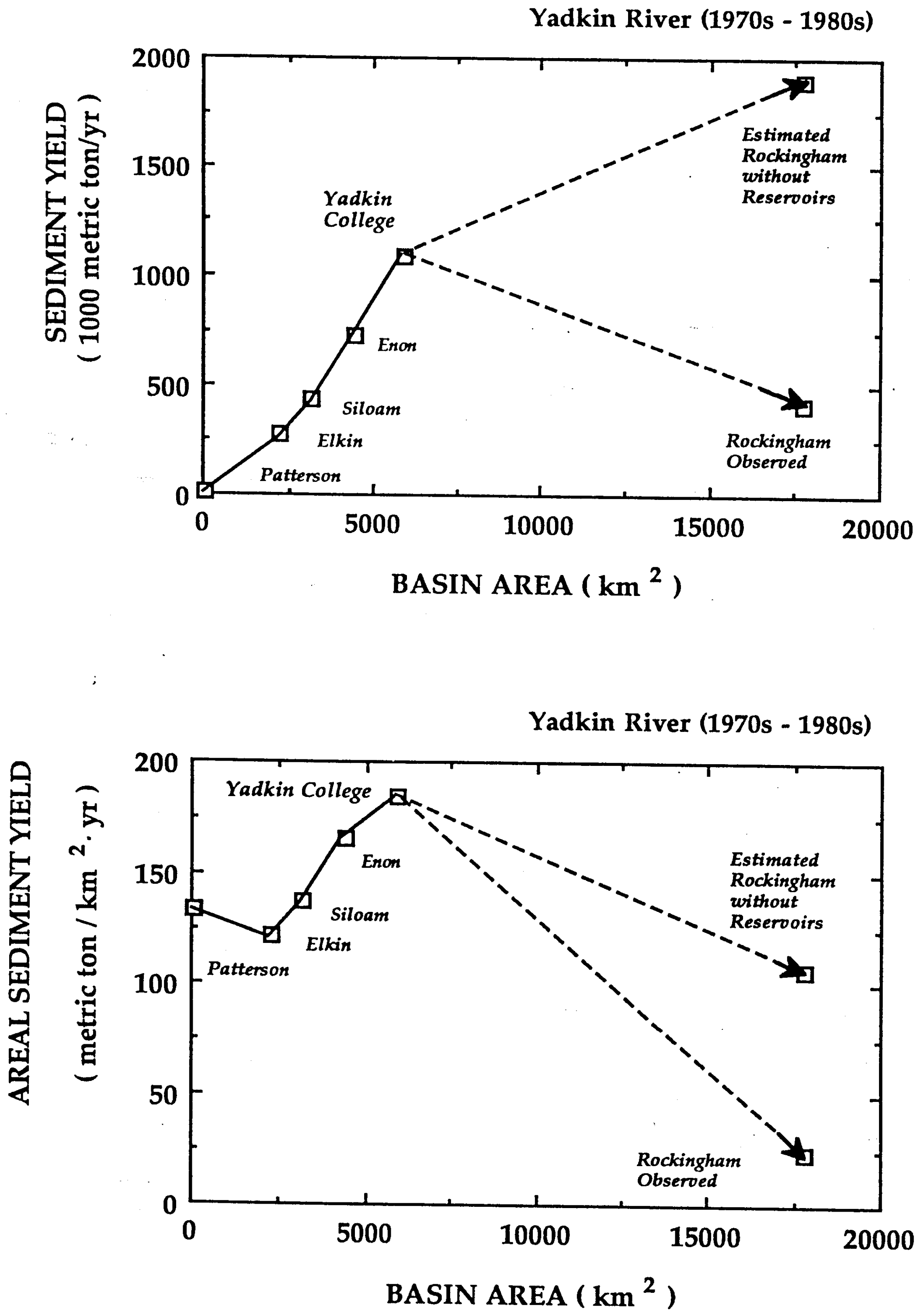


Figure 3. Sediment transport at different sampling stations on the Yadkin/Great Pee Dee River, illustrating the effects of dams and reservoirs below Yadkin College.

19th and 20th Century Changes in Land Use of Yadkin River Basin

U.S.D.A. Forest Service Inventories: 1937-1990.

General land use data for the North Carolina Piedmont as a whole was obtained from six U.S. Department of Agriculture Forest Service Inventories of the 1930s to 1990 (Brown 1991; Johnson 1991). These data are useful for estimating land use changes over multi-county areas. Although the data are collected specifically to inventory changes in growth and dynamics of the nation's forest, the inventory's non-forest land use data are useful as well. Four general land covers were evaluated in this analysis: row crops, pasture, forest, and urban-suburban.

U.S.D.C. Agricultural Censuses: 1870-1987.

Twenty U.S. Department of Commerce Agricultural Censuses were used to estimate land use change from 1870 to 1987 in the four major counties in the Yadkin River basin: Forsyth, Surry, Wilkes, and Yadkin. County borders varied little over this period. These four counties occupy 77% of the basin above the sediment sampling station at Yadkin College. Although data were collected from the 20 censuses on several aspects of farming, major emphasis was placed on cropland area of four major crops: corn, tobacco, wheat, and soybeans.

GIS Database Development: 1955, 1975, and 1988

Data used to create the GIS coverages for the basin were obtained in digital format from the U.S.G.S., the N.R.C.S., the North Carolina Department of Transportation (N.C.D.O.T.), and the North Carolina Center for Geographic Information and Analysis (N.C.C.G.I.A.), or were digitized in house by the researchers. Base coverages created for this project are listed in Table 1. At the 1:24,000 scale, all data were used at or converted to a UTM zone 17 reference system and projection using NAD27 datum and the Clarke 1866 ellipsoid. The 1:250,000 data were used with a Latitude/Longitude reference system and projection. Coverages for the gross erosion analysis derived from these base coverages are discussed in the gross erosion methods section.

A general database for 1975 was created from the 1:100,000 and 1:250,000 coverages and provides complete basin coverage. Detailed databases for 1955 and 1988 were created from the 1:24,000 coverages. The detailed coverages are limited to 185 sample areas selected by stratified random sample, although the road, basin boundary, and DEM-based 1:24,000 coverages are available for the whole basin. Only the hydrologic data do not exist at both the 1:24,000 and 1:250,000 scales. The U.S.G.S. is in the process of completing a 1:24,000 hydrologic coverage for the entire United States, but at this time most of the Yadkin River basin has not been completed at this scale.

Three GIS programs were used during the course of this project, Atlas GIS, IDRISI, and ARC/INFO. Atlas GIS and IDRISI are both PC-based programs. ARC/INFO was used primarily for data manipulation and import/export routines. The majority of the land use-land cover change analysis was conducted using Atlas GIS, whereas IDRISI was used for statistical analyses, the stratified random sampling process, and the gross erosion analysis.

Table 1. Base coverages created for GIS analyses.

COVERAGES	1:24,000	1:100,000	1:250,000
Digital Elevation Models (DEMs)	X		X
Slope	X		X
Aspect	X		X
Hydrology		X	
Watershed Boundary	X		X
General Soils			X
Roads	X	X	
Detailed Soils	X		
Land use-land cover	X		X

Stratified Random Sampling Procedure

The 1:250,000 scale database was used to create a stratified image based on elevation, slope, and proximity to rivers and streams. At 1:250,000, the cell size is approximately 76 by 92 meters (Fels 1993). Elevation and slope characteristics were chosen to characterize strata because of their correlation to land use and land cover. Data within these individual layers were grouped into general ranges and combined to form one composite image. All reclassing and sampling processes were done in a raster format using IDRISI.

Elevations within the watershed ranged from 203 to 1250 meters and slopes from 0 to 115% at the 1:250,000 scale. Frequency analyses were conducted to help define the strata and illustrate the distribution patterns of slope and elevation. Three zones of elevation were created as strata for the sampling operation: 200 to 400 m, 401 to 500 m, and 501 to 1250 m, generally representing Piedmont, transitional, and Blue Ridge regions. Slopes were combined into groups comparable to slope classes used by the Natural Resources Conservation Service: 0-15% (A, B, and C class slopes), 16-25% (C and D slopes), and 26-115% (E, F, and G slopes).

Areas within 400 meters of a water body were designated as erosion sensitive, flood plain areas. In areas of steep topography, the flood plain was limited to the cells representing streams or other water bodies. This was accomplished by creating buffer zone with a 400 meter radius around the 1:100,000 stream network using IDRISI's *Cost* module. Slopes greater than 3% acted as an absolute barrier to the buffering operation and were excluded from the buffer zone. This had the effect of including only alluvial plains and terraces in the hydrologic buffer while preventing large flood plains from being created in the mountains. While this may still overestimate mountain flood plains in some areas due to the cell size, the hydrologic buffer represents a best estimate based on the resolution of the data.

Slope, elevation, and stream buffer strata were uniquely coded and combined to produce 18 strata (three slope classes, three elevation classes, and two buffer classes), with each cell representing an elevation, slope, and buffer attribute. Strata codes, descriptions, and distributions are provided in Table 2.

The IDRISI module *Sample* was used to generate random sample points distributed proportionately to the land area within each stratum. A total of 185 sample points, each representing one cell, were generated and the point data were imported into Atlas GIS. From the point data, 1-km^2 sample areas were created as boxes around each sample point. Each sample box was then reassigned to a strata based on the median value of the pixels within the 1-km^2 sample area. A comparison of the median to center point strata values showed that most sample areas were assigned to the strata of their center point. The majority of the samples that changed strata were reassigned based on the buffer attribute (e.g., changing from inside the buffer to outside the buffer) , with the elevation and slope attributes remaining the same.

Digital Elevation Models (DEM's) - 1:24,000 and 1:250,000

At the 1:250,000 scale, the watershed falls within the extents of four one-degree by one-degree DEMs. These raster images contain elevation data and have a resolution of three arc seconds, which corresponds to a raster cell size of approximately 76 meters on the x-axis (east-west) and 92 meters on the y-axis (north-south) at this latitude (Fels 1993). The program IDRISI was used to join the images into a single coverage.

At the 1:24,000 scale, 65 DEMs were needed to provide a complete coverage for the basin. Resolution for these images is 30 meters on a side. Individual DEMs were manually joined in IDRISI to form a single coverage.

Slope and Aspect Coverages - 1:24,000 and 1:250,000

Using the joined DEM files, the IDRISI module *Surface* was used to create slope and aspect coverages. *Surface* determines slope by calculating the maximum slope around each pixel from the local points in X and Y. Only the neighboring cells above, below, and to either side are accounted for in this procedure, called a "rook's case" procedure. Slope coverages were generated as percent slope, expressing the relative change in elevation for any distance traveled in X/Y. Aspect is the direction of the maximum slope of a cell from 0 to 360 degrees (Eastman 1992).

Hydrology - 1:100,000

The hydrology coverage was created by importing nineteen 15-minute Digital Line Graphs (DLGs) into the program Atlas GIS. The data were downloaded from a U.S.G.S. CD-ROM and are based on data files created in the mid-1980s. These files were merged and edited to correct for missing or misplaced segments. Individual segments were then selected, unioned, and named when possible to form complete stream networks. This coverage was then exported to IDRISI and converted for use with the raster images.

Table 2. Frequency distributions of the 30 m^2 cells within the 18 strata for the stratified random sampling process within the Yadkin River basin. Strata are based on physical factors (elevation, percent slope, and proximity to water) according to 1:250,000 U.S.G.S.-DEM and 1:100,000 U.S.G.S.-DLG data. Strata are coded by elevation, slope class, and whether the cells are inside or outside the floodplain.

ELEVATION: P = 200-400m; T = 401-500m; M = 501-1250 m.

SLOPE: ABC = 0-15%; CD = 16-25%; EFG = 26-115%.

FLOOD PLAIN: Outside = outside the hydrologic buffer; Inside = within the hydrologic buffer.

STRATA AND DESCRIPTIONS		# Cells	Freq.	Area (km^2)
1	P-ABC-OUTSIDE	352854	0.4139	2445.16
2	T-ABC-OUTSIDE	76879	0.0902	530.53
3	M-ABC-OUTSIDE	48284	0.0566	333.45
4	P-CD-OUTSIDE	9098	0.0107	62.87
5	T-CD-OUTSIDE	21449	0.0252	148.21
6	M-CD-OUTSIDE	47639	0.0559	329.00
7	P-EFG-OUTSIDE	569	0.0007	3.93
8	T-EFG-OUTSIDE	8322	0.0098	57.53
9	M-EFG-OUTSIDE	41493	0.0487	286.51
10	P-ABC-INSIDE	214031	0.2510	1478.88
11	T-ABC-INSIDE	20342	0.0239	140.31
12	M-ABC-INSIDE	6398	0.0075	44.18
13	P-CD-INSIDE	512	0.0006	3.54
14	T-CD-INSIDE	976	0.0011	6.75
15	M-CD-INSIDE	2668	0.0031	16.35
16	P-EFG-INSIDE	27	0.0000	0.19
17	T-EFG-INSIDE	176	0.0002	1.22
18	M-EFG-INSIDE	1160	0.0014	8.00
TOTAL		852577		5896.61

Watershed Boundary - 1:24,000 and 1:250,000

The Yadkin River watershed above the gauging station at Yadkin College was defined using 65 7.5-minute U.S.G.S. topographic maps (1:24,000 scale). Portions of the watershed within each topographic map were then digitized using Atlas GIS. The vector file was then exported to IDRISI, where it was converted into a raster image. The raster image was used as a mask to clip out areas of the elevation, slope and aspect coverages within the watershed. As defined by the digitized coverage in Atlas GIS, the total area of the Yadkin River basin above Yadkin College, NC is 5895 km^2. As an IDRISI coverage, the basin contains 852,577 cells with a calculated area of 5897 km^2 at the 1:250,000 scale and 6,550,559 cells with a calculated area of 5896 km^2 at the 1:24,000 scale.

Roads - 1:24,000 and 1:100,000

Road networks were digitally obtained from two sources. The 1:100,000 network was imported along with the hydrology DLG files and then joined in Atlas GIS. The basin layer was then used to clip out the road network within the watershed. This information was used with the 1:250,000 database. The 1:24,000 road network is a 1990 database provided by the N. C. Department of Transportation as an ARC/INFO coverage. It was made up of tiles corresponding to the 7.5-minute DEMs within the North Carolina portion of the basin. This accounted for all but three of the 185 sample areas used for the 1:24,000 database. Using ARC/INFO, a 500-meter buffer was created around the basin and used to clip out the basin road network. The buffer ensured that all roads near the watershed boundaries were included in the final coverage.

General Soils - 1:250,000

The North Carolina portion of the N.R.C.S. database, STATSGO, was obtained from the N. C. Center for Geographic Information and Analysis. This statewide coverage provides information on soil associations as well as some detailed soil statistics (primarily percent series composition within each association).

Detailed (1:24,000) Soils

Several counties within the basin have recent soil surveys, and several surveys are either in progress or awaiting publication. None of this information, however, is available in a digital format. Using published soil surveys and advance copies of field mapping sheets, most of the soil mapping units within the 185 sample areas were digitized. Only those sites in Patrick County, Virginia, and a small area in Surry County, North Carolina, were not digitized because soil survey mapping has not been completed. These areas instead rely on information from the 1:250,000 STATSGO database. Where it was necessary to use advance copies of the field mapping sheets, a zoom transfer scope was used to trace soil polygons onto U.S.G.S. topographic maps to provide geographic referencing. Details on the use of the zoom transfer scope are included with the methods for the 1:24,000 land use-land cover database.

Land use-land cover - 1:250,000

General land use and land cover data were obtained from the U. S. Geological Survey in both vector and raster formats (Table 3). Only the vector files were used, however, because the cell size of the raster CTG format files (200 by 200 meters) was much more general than the 1:250,000 DEM cell size of 72 by 92 meters. The vector files were imported and joined in ARC/INFO and exported for use in IDRISI. The 1975 LULC database serves both as the 1970's land use database for 185 specific sample sites and as the basis for the complete basin-wide land use coverage.

Land use-land cover - 1:24,000

The 1:24,000 land use-land cover databases for 1955 and 1988 were created by digitizing interpreted land cover information from aerial photography for the 185 1-km^2 sample areas selected by stratified random sample. The sampling procedures were necessary because of the absence of digital data for the 1950s and the large size of the basin. Details of the sampling method are explained in the stratified random sampling section.

Stereoscopic aerial photography covering the sample point areas was purchased from the U.S. Agriculture Stabilization and Conservation Service (A.S.C.S.) for the years 1955 (1:20,000) and 1988 (1:40,000). A panning stereoscope was used to delineate and classify land use into one of 17 categories (Table 4). A zoom transfer scope was then employed to adjust the scale of the photography to 1:24,000 and trace the areas delineated on the photography onto U.S.G.S. orthophoto quadsheets, which were used as basemaps in the project.

Photo interpretation and work on the zoom transfer scope was done at the Computer Graphics Center at North Carolina State University. The zoom transfer scope allows the operator to trace an area from a source map to a base map after adjusting for variable scale in aerial photography and compensating for the tilt of aircraft. U.S.G.S. orthophoto quadsheets are recent (1983-1984), rectified aerial photographs for an area defined by a topographic quadsheet. Because the photographs are tied to a quadsheet, they are easily referenced, thus minimizing digitizing error. As basemaps, orthophoto quad sheets proved to be valuable tools, for in addition to roads and streams, landscape features from past land use, such as abandoned fields or previously logged areas, were often detectable because of forest regrowth patterns. These patterns were most helpful for tracing 1955 land uses.

The 1988 1:24,000 land use-land cover data were field-checked for accuracy. All sample sites were visited to verify photo interpretations or checked against enlarged county A.S.C.S. photos. Areas inaccessible or difficult to locate were photo checked only. All county A.S.C.S. offices in the watershed had enlarged photography for the late 1980s, and A.S.C.S. notations on the photos were valuable verification aides. Field checks were made for approximately 70 of the 185 sample areas. Several A.S.C.S. offices also have archived large-scale photos dating back to the 1950s, and a few of the 1955 sample areas were checked against these photos. This proved to be an extremely time intensive process, however, and most of the 1955 data remains unverified.

The 1:24,000 land use-land cover data have also been adjusted for shifting or additional road areas in the 1950s and 1980s. Roads, stored as line features, were buffered to specific widths depending on the type of road to provide estimates of road area. These buffers were integrated into the land use-land cover databases. It was felt that this process was more accurate than transferring road boundaries from aerial photography to the orthophoto quadsheets and then digitizing them into the database. The 1955 road database is a modified version of the 1988 roads database, based on the presence or absence of a given road in the aerial photography. Buffering widths were based on modified N.C.D.O.T. estimates for the general road classes found on U.S.G.S. topomaps (Appendix A).

Table 3. Abridged U.S. Geological Survey land use and land cover (LULC) classification system for the 1975 Yadkin River basin LULC database.

LEVEL 1		LEVEL 2	
1	Urban or Built-up Land	11	Residential
		12	Commercial and Services
		13	Industrial
		14	Transportation, Communications, and Utilities
		15	Industrial and Commercial complexes
		17	Other Urban or Built-up Land
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Vineyards, and Nurseries
		23	Confined Feeding Operations
		24	Other Agricultural Land
4	Forest Land	41	Deciduous Forest Land
		42	Evergreen Forest Land
		43	Mixed Forest Land
5	Water	51	Streams and Canals
		52	Lakes
		53	Reservoirs
7	Barren Land	75	Strip Mines, Quarries, and Gravel Pits
		76	Transitional Areas

Table 4. Detailed (1:24,000) land use-land cover codes for 1955 and 1988 land use-land cover (LULC) coverages.

CODE	DESCRIPTIONS
AG	Rowcrops: Corn, tobacco, and other intensely cultivated crops
AGH	Mixed rowcrops/covercrops: Hay, small grains, or mixed cropping; contour strips
H	Covercrops: Hay or small grains
HP	Covercrop/pasture: Mowed pasture or hay fields
P	Pasture: Established pasture or grassed areas
CP	Cleared/pasture: Transitional grassed areas with trees and city parks
C	Cleared: Areas cleared or recently cleared of vegetative cover
O	Orchards
FL	Feed-lots: Confined animal feeding or holding areas
WP	Woodland pasture: Wooded areas near farms with evidence of foraging
W	Woodland: Wooded areas near farms or built-up areas; disturbed forested areas
F	Forest: Relatively undisturbed areas of forest; national and state parks
R	Rural development: Areas of low density housing or farmsteads
U	Urban development: Areas of medium to high density housing or development
I	Industrial: Urban commercial areas with little or no residential area
WATER	Streams, rivers, ponds, lakes, and reservoirs
RD	Major, multi-lane highways and interstates, turn-outs, county roads and city roads.

Gross Soil Erosion Analysis of Rural Basin Areas

The gross soil erosion analysis was conducted to provide a theoretical estimate of spatial changes in sediment sources and volume over time. The researchers used the Universal Soil Loss Equation (USLE) as the basis for their model because of its widespread use, general acceptance, and compatibility to available digital data. While somewhat simplified, the researchers believe that at the scales used in this project, the USLE is a useful tool for estimating relative erosion rates. The goal of this research is not to estimate precise amounts of soil erosion on a field by field basis, but to estimate general temporal trends in both erosion and sediment sources at a river-basin scale. As an empirical model, the components of the USLE are quantifiable and many are well verified. The North Carolina state office of the N.R.C.S. has recently published *The Universal Soil Loss Equation with Factor Values for North Carolina* (U.S.D.A. 1993). This handbook is an extremely detailed compilation of USLE factor parameters, specific to North Carolina, for a wide variety of cover types, tillage methods, and physiographic provinces.

The gross erosion analysis focused on forest, agricultural, and cleared, transitional areas of the basin. The cover or C factors for these land covers were taken from the N.C. USLE handbook (U.S.D.A. 1993) and were discussed with persons familiar with the equation. Urban C factors are not readily available and are not provided in the N.C. USLE handbook. For the Yadkin River basin, this strategy of focusing on rural areas accounts for 93% of the land cover in the 1975 database and provides a method for evaluating gross soil erosion response to changes in rural land uses over a four-decade period. The results help indirectly evaluate the influence of urban development and road construction on the sediment load.

The USLE takes the following form:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

where the product, A, is gross erosion from sheet and rill erosion in eroded soil mass per unit area ($Mg \cdot ha^{-1}$); R is a measure of rainfall intensity ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot y^{-1}$); K is a soil erodibility factor ($Mg \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$); LS is a combined length and steepness of slope factor (dimensionless); C is a vegetative cover factor (dimensionless); and P is a conservation practice adjustment (dimensionless). The conversion of USLE factors from English to metric units is well documented in Foster et al (1981). To use this equation, one or more raster coverages were created for each factor. The GIS program IDRISI was used to create these coverages by reassigning factor values to existing coverages in the GIS database, and then multiplying the layers to create a composite USLE coverage. This calculation was performed at two scales. At the 1:250,000 scale, gross soil erosion estimates were made for 1975 with complete basin coverage. For the early 1950s and the late 1980s, USLE estimates are made from the 185 1-km^2 sample areas, the locations of which were selected by the stratified random sample described above. With these procedures, soil erosion estimates were made for individual land uses, individual strata, and the entire basin.

The R factor was estimated in several ways. An area-weighted R value of 3591 (211 in English units) was calculated from long-term county R factors (U.S.D.A. 1993). A detailed, seasonally variable R factor was derived from the methods outlined by Richardson et al. (1983), based on daily precipitation records for eight 15-minute rainfall stations (1951-1990) were converted to a daily erosion index values and summed by water year to produce annual R factors. The *Thiessen* module of IDRISI was used to create Thiessen polygons for the rainfall stations and the R factors assigned to the appropriate station area.

The general form of the EI equation used (Richardson et al. 1983) is:

$$EI = aP^{b} + \epsilon$$

where EI is the calculated erosion index variable ($Mj \cdot mm \cdot ha^{-1} \cdot h^{-1}$), P is the daily (storm) rainfall (mm), ϵ is the random component, and a and b are model parameters. Daily calculations were summed by year for annual values. In the model of Richardson et al. (1983), model parameters a and b were taken as: a = 0.2 (cool season - Oct.to Mar.), a = 0.5 (warm season - Apr.to Sept.), and b = 1.65. According to Richardson et al. (1983), higher value for a in the warm season reflects the rainfall intensity differences between summer convective thunderstorms and winter frontal storm systems. This seasonal procedure estimated the long-term R factor to be 3625 (213) for the basin with our 40 year data, compared to the area weighted basin estimate of 3591 (211) derived from the N.C. USLE handbook (U.S.D.A. 1993).

To test the responsiveness of the model to variable R factors over time, a third R factor coverage was created by assigning long-term county R factors to the areas of the counties within the basin (U.S.D.A. 1993). This allowed the R factor to vary spatially, but not temporally. Model runs using the county R coverage were compared with the results obtained by assigning the constant value of 3591 (211) to the basin.

The K factors for the general soil coverage were calculated based on the distribution of the soils making up a given soil association in the STATSGO database. Individual soil K factors were taken in the USLE handbook (U.S.D.A., 1993) and used to estimate area-weighted average K factors for soil associations. To convert to metric units, the K factors were multiplied by 0.1317. These K factors were then assigned to the soil association areas for a general K factor coverage. For the detailed soil polygons of the 185 sample areas, metric K factors were assigned directly to the polygons based on values from the USLE handbook, N.R.C.S. county soil surveys, or data contained in the advance soil survey maps.

Detailed soil information was available for 160 of the 185 sample areas. For 21 of the remaining 25 sample areas, general soil K values were assigned, based on 1:250,000 scale soil association data. For the four samples in Patrick County, Virginia, however, no information was available. For these last areas, the average K value for a given sample's strata was assigned to that sample, providing a "complete" detailed soil K coverage.

The LS factors were estimated by 1 percent slope were based on the equation of Wischmeier and Smith (1978):

$$(\tau/72.6)^{m} \cdot (65.41 \cdot \sin^{2}\theta + 4.56 \cdot \sin\theta + 0.065)$$

where τ = slope length in feet
m = 0.2 for gradients < 1%
= 0.3 for gradients 1-3%
= 0.4 for gradients 3.5-4.5%
= 0.5 for gradients $\geq$ 5%
θ = angle of slope in degrees (inverse tangent of percent slope)

In IDRISI, the 1:24,000 percent slope coverage was converted from real numbers to integers and the LS factors assigned to the modified slope coverage to create the LS coverage. For the 185 sample areas, slopes ranged from 0 to 122.4 percent and the length was held constant at 98.4 feet, corresponding to the pixel size of 30 meters.

The C factors for the various land use-land cover classes were assigned after consultation with several N.R.C.S. district conservationists based in the watershed counties. These professionals provided county estimates of dominant cropping, rotation and tillage practices for various crops. Based on this information and crop distributions from the agricultural census, C factors were derived from the North Carolina USLE handbook (U.S.D.A. 1993). A list of the C factors assigned to the land use-land cover databases can be found in Appendix B.

In all simulations, P was set to 1 due to a lack of verifiable data for the 1955 database. While some BMPs, such as contour planting, are easily detected in the photographs, others are virtually impossible to detect. It was decided that by holding P constant, a consistent estimate of gross erosion could be generated.

The C-factors were adjusted for current management practices (BMPs) conditions, for the 1988 to 1990 period to estimate the potential impact of conservation planning. The C factor estimates for this simulation were provided by county N.R.C.S. personnel.

Statistical Analyses of Yadkin River Suspended Sediment

Due to recent implamentation of BMPs on most row crop lands in the basin, a final estimate was made to evaluate the effects of N.R.C.S.-guided farm management planning. Analyses included arithmetic means, discharge-weighted means, medians, and frequency analyses. Analyses on transformed and untransformed data using daily, monthly, and annual compilations of discharge, sediment concentration, and sediment transport. Transformations were used to obtain distributions that were normal or close to normal because daily discharge, sediment concentration, and sediment transport data are skewed (skewness factors exceed 3.5 for daily data).

Time-Trend Analyses of Yadkin River Suspended Sediment

A variety of approaches were used to evaluate time trends of sediment concentration and transport over the 40-yr record. A combination of parametric and nonparametric methods were employed depending on the characteristics of the data. A variety of statistical methods have been recently developed to test trends in water quality data (Sen 1968; Kendall 1975; Lettenmaier 1976; Hirsch et al. 1982; Hirsch and Slack 1984; van Belle and Hughes 1984; Gilbert 1987; Berryman et al 1988).

A strong structural feature of the sediment data is the hydrologic dependence of sediment concentration and transport. In many of our approaches to trend detection, a hydrologically based regression was used to predict sediment concentration or transport, and the slope of the time-ordered residuals was examined with a variety of non-parametric procedures.

These statistical methods include the following: non-parametric Mann-Kendall tests of no trend were used to test residuals that had low serial correlation; generally these were annual data (Kendall 1975; Hirsch and Slack 1984; Gilbert 1987). Non-parametric seasonal Kendall tests were used for data with skewed distributions, seasonality, and serial dependence; generally these were monthly and daily data (Hirsch and Slack 1984; Gilbert 1987). Confidence intervals (e.g., 90%) of monotonic trends in sediment transport were estimated following procedures outlined in Gilbert (1987).

In addition, a daily time-series of precipitation data was assembled primarily using eight Type A rainfall stations with data recorded on a 15-minute basis (Fig. 4). In addition to the eight time-series of daily precipitation, a basinwide daily precipitation time-series was created by weighting and lagging rainfall at individual stations on the basis of correlations of rainfall with discharge at Yadkin College. Lags and weights were developed for each rainfall station to maximize predictive ability of the basinwide adjusted rainfall time series.

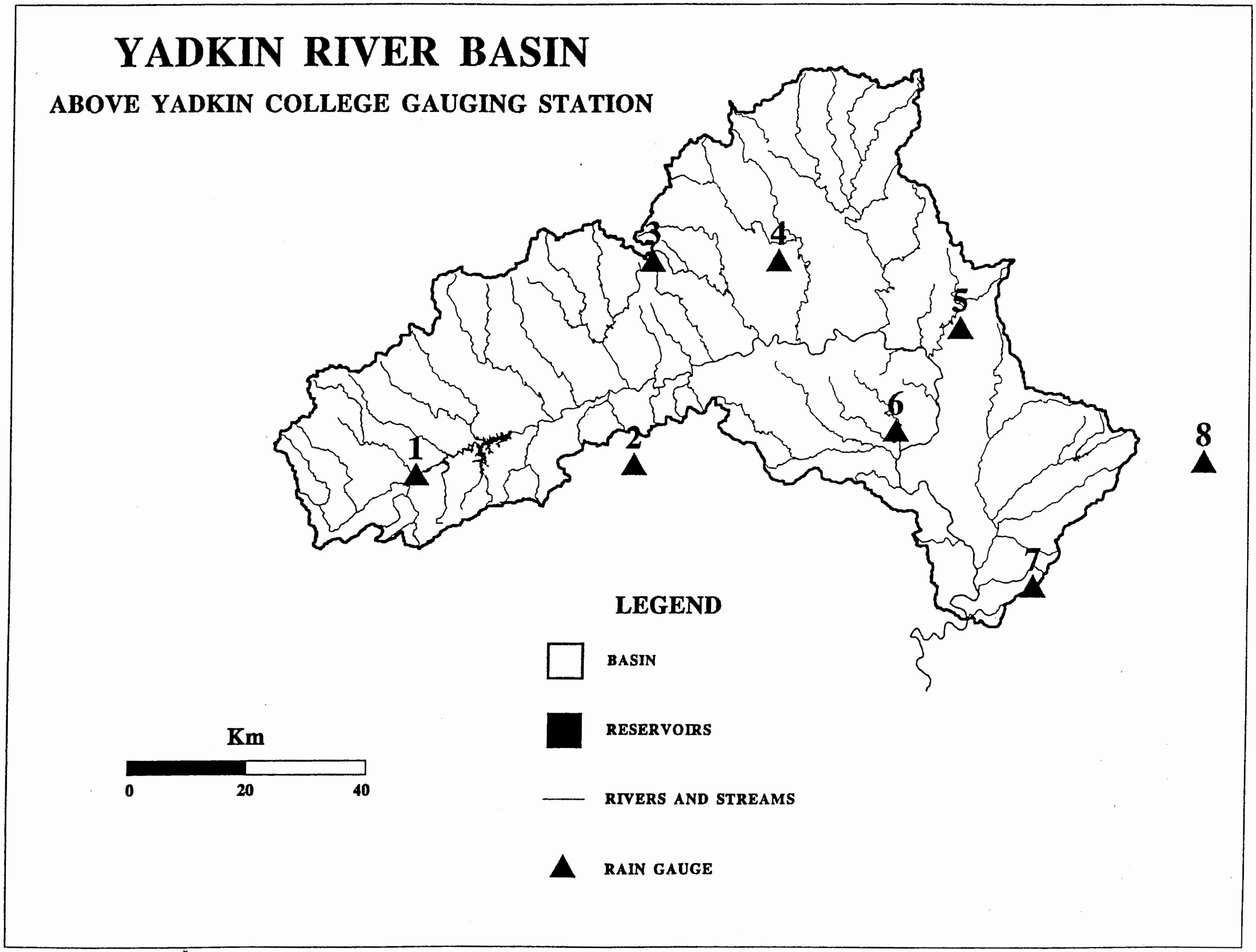


Figure 4. Map of Yadkin River basin illustrating location of eight high quality precipitation gauging stations from which was derived a 40-yr daily time-series of precipitation.

RESULTS AND DISCUSSION

Changing Land Use in the Yadkin River Basin

U.S.D.A. Forest Service Inventories: 1937-1987.

The land use of the southern Piedmont is in the midst of changing from a primarily agricultural landscape to one that is dominated by a mix of uses, which increasingly include urban and suburban areas as well as highways. Figure 5 illustrates changes in land uses over recent decades in the North Carolina Piedmont (Brown 1991). Most notable changes are the decreases in rowcrop land since the 1930s, from about 45 to about 18% of the land area of the North Carolina Piedmont. The increase in urban and residential uses is also notable, from about 5 to 18% over five decades. Smaller increases are observed in pasture and in forest land since the late 1930s.

U.S. Department of Commerce Agricultural Census: 1870-1987.

The U.S.D.C. Agricultural Census was used to examine more specific agricultural land uses in the Yadkin River basin. The census has agricultural data arranged by county and thus it was fortuitous that the political borders of the basin's four major counties, Forsyth, Yadkin, Wilkes, and Surry, closely match the hydrologic-basin boundaries. The four counties occupy 77% of the basin above the Yadkin College sampling station.

The overwhelming trend since about 1920 has been a reduction in area under cultivation. By the late 1980s, the area cropped to corn, tobacco, wheat, and soybeans was about 30% of what it was in 1920 (Fig. 6). A more detailed examination of the decreasing extent of crops and hay is illustrated in Figure 7, which suggests that the most rapid rate of decline of non-hay crops was between 1945 and 1950 and that although cultivated land area has decreased throughout the century, recent patterns may suggest that agricultural decreases of the 1990s will not be as drastic as in previous decades. Additional details from the Agricultural Census are contained in Table 5, which summarizes decreases in number of farms, total farmland area, total cropland area, harvested cropland, and specific area of several crops from 1925 to 1987 for the four county area. Details on a county basis are in Appendix C. These trends in the Yadkin basin are similar in magnitude and rate to the agricultural changes experienced in the Piedmont as a whole.

Since 1870, corn has remained the dominant rowcrop as measured by area harvested. Until about 1900, rowcrops in the basin were mainly corn and wheat (Fig. 6). Dating from the very late 19th century, tobacco has increased in area, and became the second most extensive rowcrop in about 1940. Soybeans have been planted on an increasing area since about 1960.

Such extensive agricultural changes have substantially decreased gross soil erosion on extensive areas of agricultural land in the Yadkin as well as other Piedmont basins (Maki and Hafley 1972; Meade and Trimble 1974; Trimble 1974; Harned and Meyer 1983; Simmons 1993; Weaver 1994). We postulate, however, that the sources of sediment in the Yadkin River are not simply decreasing but are rather shifting from being largely a result of agricultural activities to being a result of a variety of human activities, increasingly associated with urban and suburban

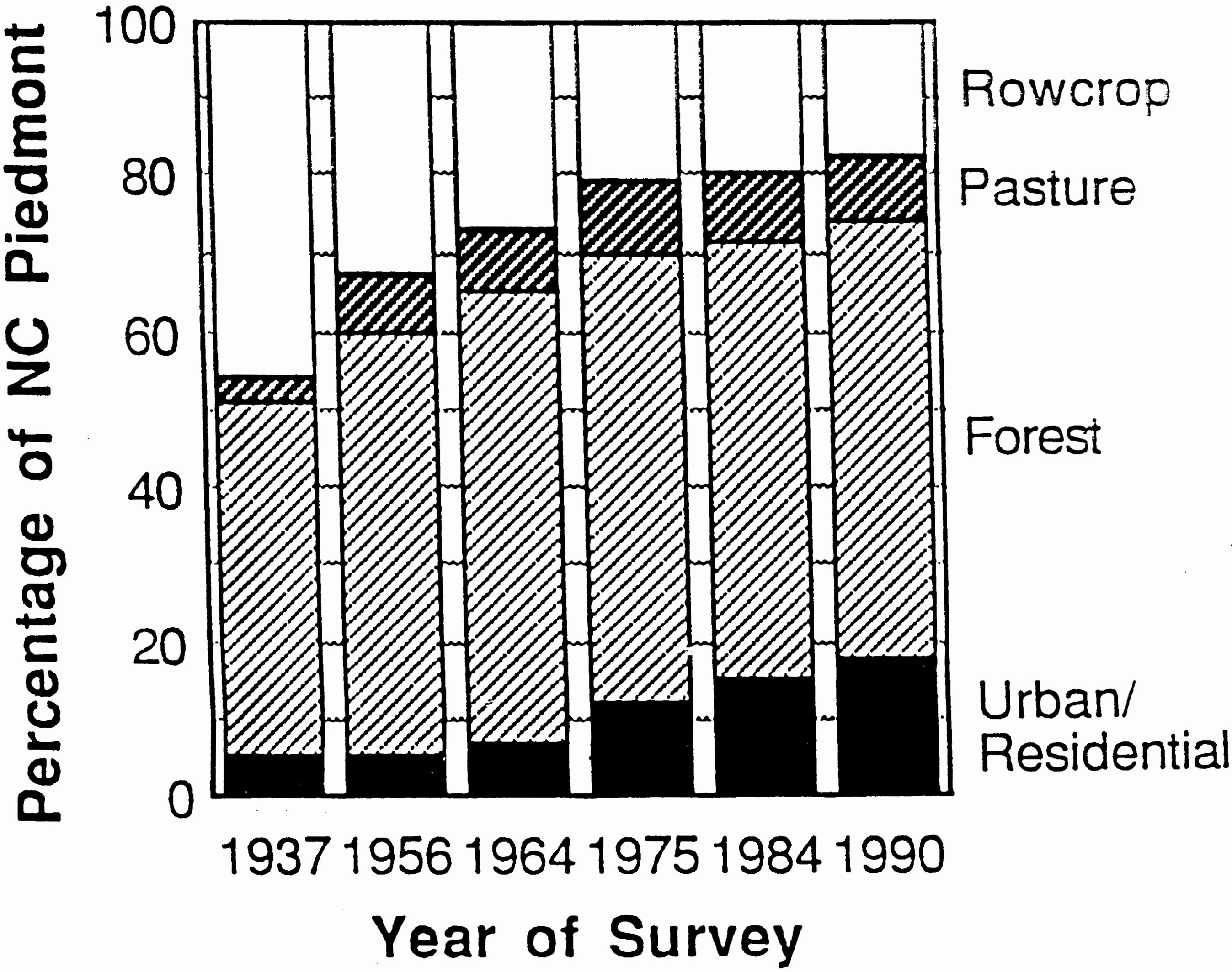


Figure 5. General land uses (1937-1990) of the North Carolina Piedmont, based on six forest inventories of the U.S. Department of Agriculture Forest Service (Brown, 1991).

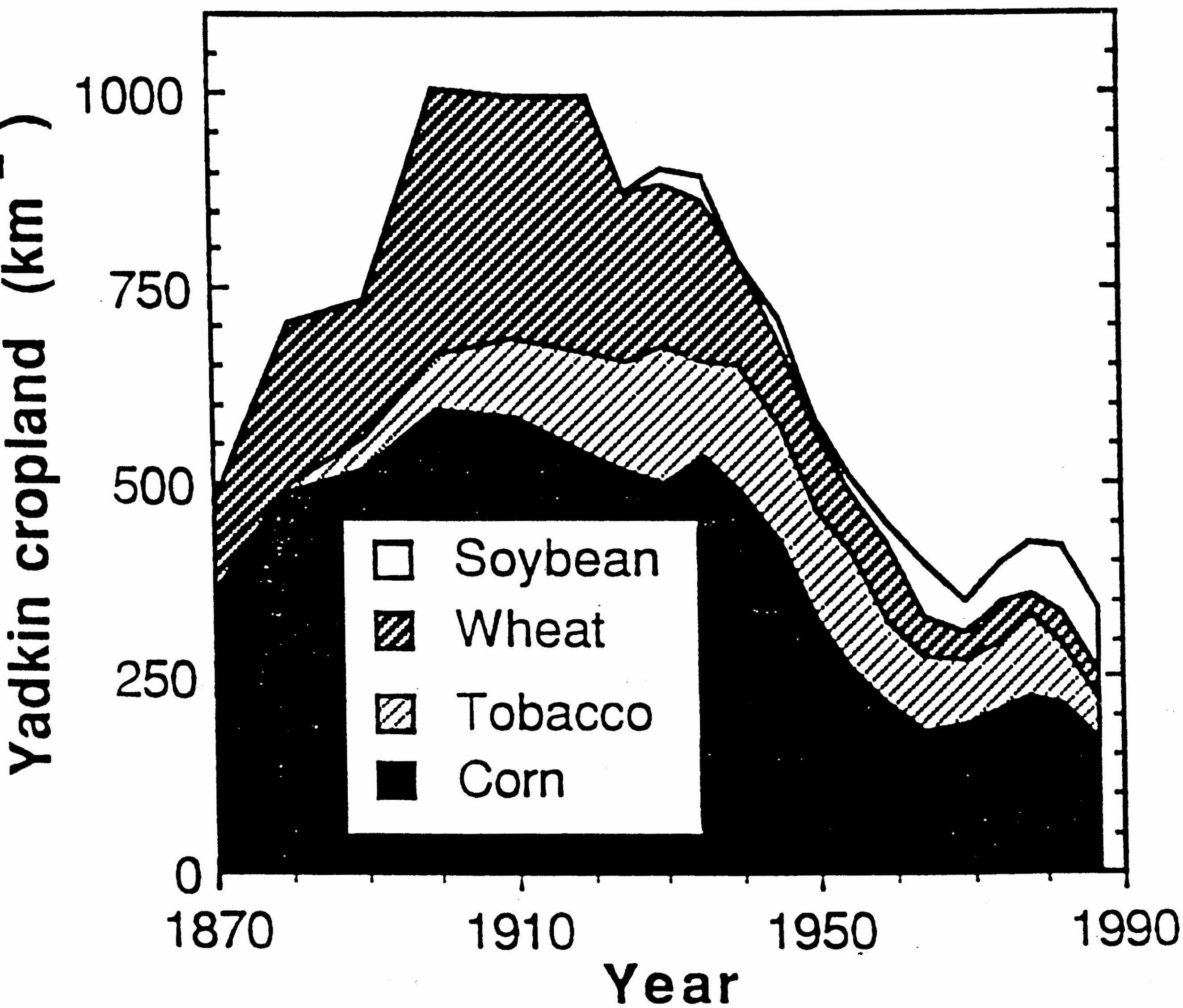


Figure 6. Time trends of land use in the U.S.A.'s southern Piedmont for major crops of the Yadkin River basin (1870-1987), based on 20 U.S. Department of Commerce Census of Agriculture inventories (Bureau of the Census, 1987).

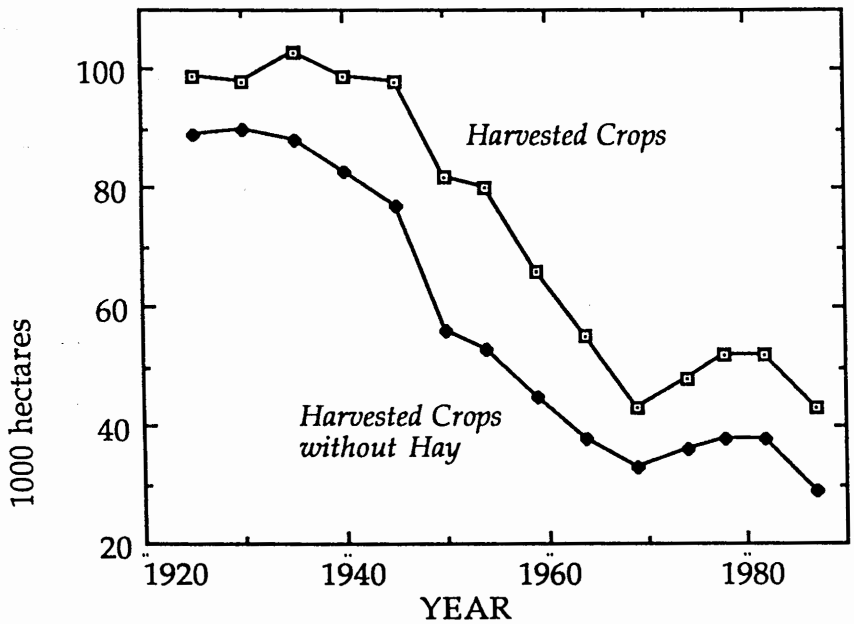


Figure 7. Decline in harvested cropland with and without hay in the four major counties of the Yadkin basin (Bureau of the Census, 1987).

development (e.g., Wolman 1967). The Yadkin basin, like the Piedmont as a whole (Fig. 5), is increasingly affected by urban and suburban developments and highway construction. Such developments have been particularly pronounced in the Muddy Creek subcatchment of the Yadkin basin, a subcatchment of about 13% of the total river basin area but which also is home to more than half of the human population of the Yadkin River basin, mainly in rapidly growing communities surrounding Winston-Salem, N. C. (Fig. 8). Population density data illustrate the growth of Forsyth County in relation to the other still rural counties of the basin (Fig. 9).

Despite these generalizations across the basin, the Agricultural Census also illustrates pronounced within-basin variation in land use (Table 5, Appendix C). In the late 1980s, rowcrops plus hay occupy nearly 19% of Yadkin County's total area, for example, but only about 5% of Forsyth and Wilkes Counties (Table 6). Similarly, in 1987, nearly 12.7% of Yadkin County remains in corn, tobacco, wheat, or soybean, whereas only 2 to 2.4% of Forsyth and Wilkes Counties are covered with such row crops.

These latter statistics suggest that agricultural sources of eroded soil and sediment remain the highest in the basin in Yadkin County. Given the decline in rowcrops and growth of urban and suburban activities in Forsyth County, sources of eroded soil and sediment have probably shifted away from agriculture to being mainly related to construction activities.

GIS Analysis of Basinwide Land Use-Land Cover (LULC).

Before the detailed land use-land cover (LULC) estimates were used in the gross erosion calculations, the GIS results were compared with U.S.D.C. estimates of land use within the four primary counties of the basin. For a general analysis, all data were aggregated into categories to the Level I LULC classification system outlined in Table 3 (U.S.G.S. 1990). For the detailed 1955 and 1988 GIS databases (see Table 4): "Urban" = R, U, I, and RD; "Agriculture" = AG, AGH, H, HP, P, O, and FL; "Forest" = WP, W, and F; "Water" = WATER; and "Other" = C and CP. The agriculture class for the U.S.D.C. data is the sum of harvested cropland, other cropland, cropland pastured, and other pastureland (Appendix C). A 1975 sample of 185 1-km^2 sample areas was also generated from the 1:250,000 LULC database. Results are presented in Table 7.

The two 1975 databases provide similar estimates of land use-land cover, suggesting that results obtained from the 185 1-km^2 plots (a 3.1% sample of the basin) reasonably approximate basin land cover. The results of both the GIS and Agricultural Census data show decreasing trends in the area in agriculture, although at somewhat different rates. The generalized GIS results for agriculture uses indicates a 4% decline between 1955 and 1988, compared to the 9% decline seen in the Agriculture Census data between 1954 and 1987. The difference between the 1987 and 1988 values, where the GIS database appears to overestimate the amount of agriculture, may in part be due to the classification of transitional land as pasture in the GIS database. Estimates for agriculture from the 1975 U.S.G.S. LULC are considerably higher than the 1974 four-county Agricultural Census estimate, most likely due to the scale of the data. LULC distributions by strata are provided in Table 8.

Table 5. Summary of four-county land use statistics for the Yadkin River basin (Bureau of the Census, 1987).

Attribute	Unit	1987	1982	1978	1974	1969	1964	1959	1954	1950	1945	1940	1935	1930	1925
Farms	Number	4298	5130	5571	5975	7714	9081	10726	14460	16019	15418	16258	16828	15577	15920
Farmland Area	1000 ha	164	182	191	197	241	280	307	351	387	390	411	431	410	428
Farmland/County Land	%	31.2	34.4	36.1	37.1	45.4	52.4	57.5	65.8	72.4	73.1	77.0	85.2	81.0	84.6
Mean Farm Area	ha	38.2	35.4	34.4	33.0	31.2	30.8	28.6	24.3	24.1	25.6	25.3	25.6	26.3	26.9
Total Cropland Area	1000 ha	85.3	90.5	93.0	90.4	98.9	94.9	101.8	116.6	130.3	142.0	165.2	161.4	153.4	138.3
Harvested Cropland	1000 ha	46.1	51.6	52.2	47.6	43.4	54.7	65.8	79.8	81.7	98.1	99.1	102.9	98.3	98.6
Grazing Cropland	1000 ha	-	27.6	27.2	29.9	30.0	14.6	8.9	12.1	13.1	13.8	30.1	24.2	21.7	24.2
Harvested/Farm Area	%	28.1	28.4	27.3	24.2	18.0	19.6	21.4	22.7	21.1	23.9	24.1	23.9	24.0	23.0
Specific Harvested Crops															
Corn	1000 ha	9.02	15.46	19.21	17.98	16.35	15.24	18.56	22.26	27.24	36.02	41.52	45.49	42.45	43.63
Tobacco	1000 ha	4.54	6.60	9.00	7.22	6.85	8.16	9.07	13.09	12.27	12.95	13.88	10.20	14.93	12.10
Soybean	1000 ha	6.75	7.59	5.80	4.36	3.62	6.06	1.95	1.84	1.29	2.55	-	2.35	1.78	-
Hay	1000 ha	16.89	13.70	14.25	12.09	10.22	16.23	21.00	27.15	25.21	22.66	15.82	14.49	7.85	9.59
Harv'd Crops w/o hay	1000 ha	29.24	37.86	37.99	35.51	33.20	38.49	44.80	52.70	56.54	76.50	83.33	88.42	90.41	89.03

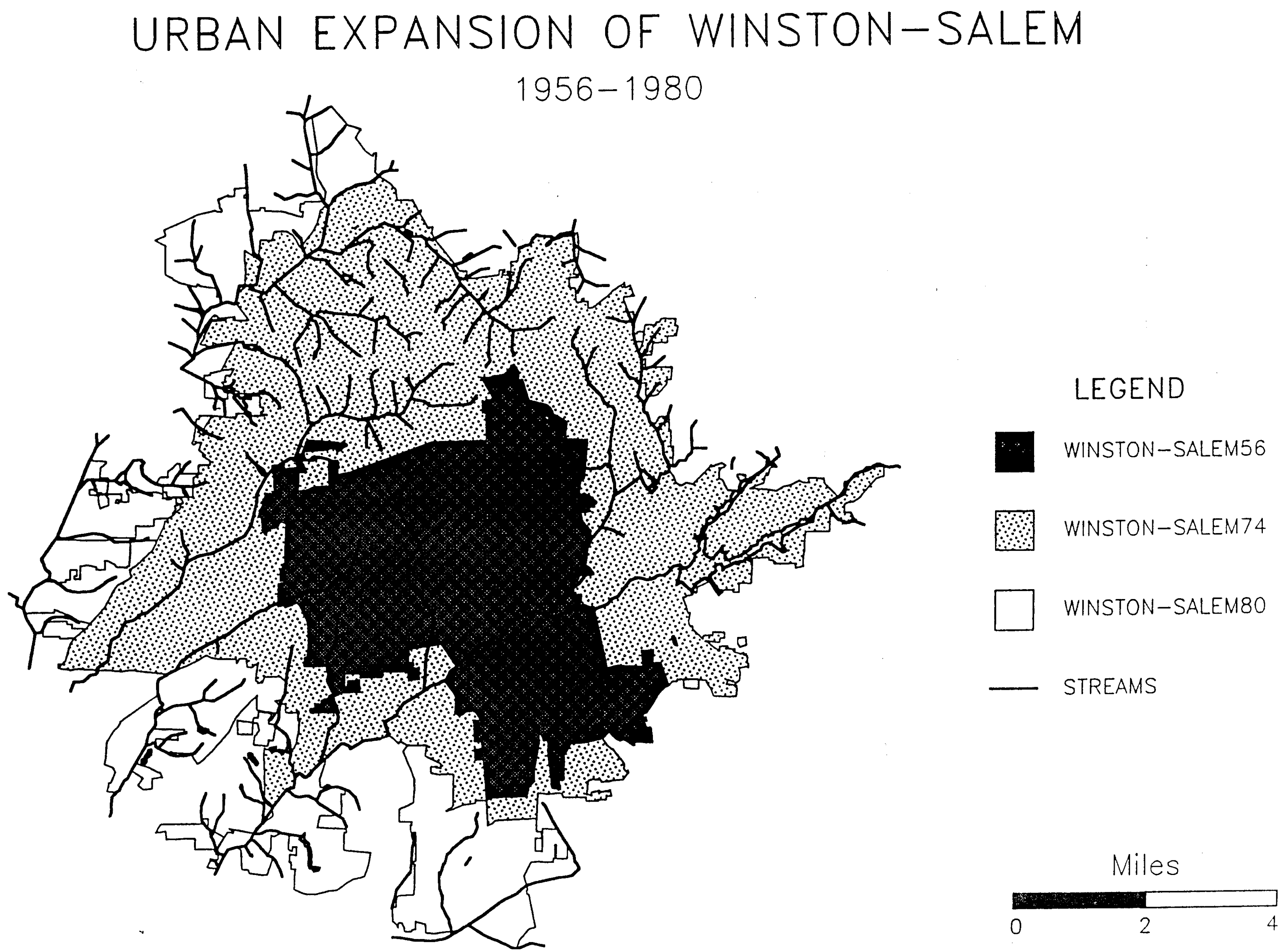


Figure 8. Urban expansion of the city of Winston-Salem between 1956 and 1980.

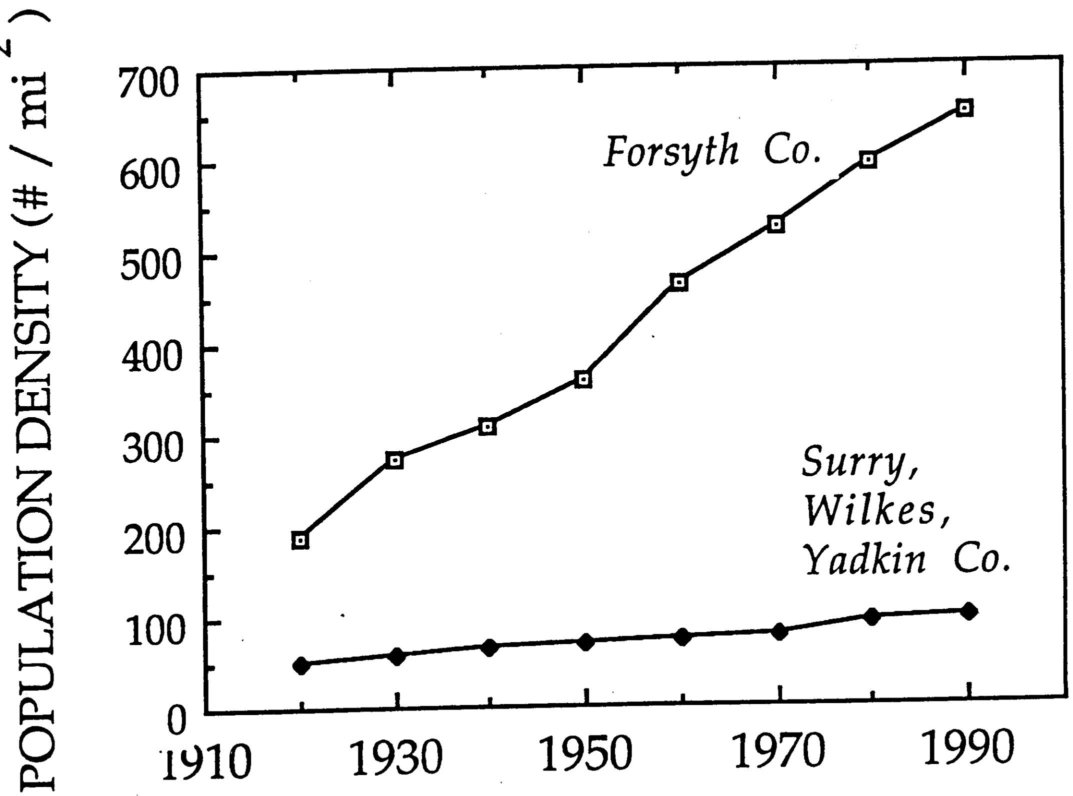


Figure 9. Human population density of the four major counties of the Yadkin basin.

Table 6. Harvested cropland with and without hay in four counties of the Yadkin River basin (Bureau of the Census, 1987).

County	Area		Proportion	
	Harvested Cropland	Harvested Cropland without Hay*	Harvested Cropland	Harvested Cropland without Hay
	(1,000 ha)		(%)	
Forsyth	6.0	3.0	5.4	2.4
Surry	14.3	9.5	10.2	6.1
Wilkes	9.5	4.3	4.9	2.0
Yadkin	16.3	12.3	18.8	12.7
Total	46.1	29.1	8.7	4.9

* w/o Hay, corn, Wheat, Tob, and Soy beans

Table 7. Distribution of general land use for the 185 sample areas in 1955, 1975, and 1988, and a comparison with the total basin coverage estimates of land use in 1975. 1955 and 1988 estimates based on aerial photography. 1975 data are from 1:250,000 U.S.G.S. Land Use/Land Cover (LULC) data. Combined cropland and pasture areas from the 1987 U.S.D.C. Agriculture Census and the 1987 N.R.C.S. Natural Resource Inventory (NRI) data for Forsyth, Surry, Wilkes, and Yadkin counties are provided for comparison.

	GIS Stratified Sample						Total Basin	
Land Use	1955		1975		1988		1975	
Class	km^2	%	km^2	%	km^2	%	km^2	%
Urban	12.3	6.63	15.7	8.68	22.1	11.94	461.4	7.82
Agriculture	50.5	27.28	51.8	28.63	43.5	23.27	1798.0	30.50
Forest	110.3	59.60	112.6	62.24	109.5	59.20	3596.0	60.99
Water	0.6	0.30	0.5	0.28	1.0	0.56	21.2	0.36
Other	11.5	6.22	0.3	0.16	9.3	5.04	19.4	0.33
Total	185.0		181.0		185.0		5896.0	

U.S.D.C.	U.S.D.C. Agriculture Census						N.R.C.S. NRI	
Ag Census/	1954		1974		1987		1987	
N.R.C.S. NRI	km^2	%	km^2	%	km^2	%	km^2	%
Agriculture	1469	27.50	905	17.05	958	18.12	1692	31.85

An analysis of the detailed agricultural land use distributions from the 1955 and 1988 GIS databases (Tables 9 and 10) shows that the area of cultivated cropland is decreasing at a much faster rate than pastureland. Between 1955 and 1988, combined rowcrop and covercrop areas (AG, AGH, and H) decreased 39% (1222 to 749 km^2), while pastured areas (HP and P) increased by 64% (355 to 584 km^2). U.S.D.C. records support the cultivated cropland findings, showing that between 1954 and 1987, non-pastured cropland decreased by 43% (1045 to 598 km^2), but that total pastureland actually decreased by 31% (719 to 495 km^2). Tables of U.S.D.C. Agriculture Census data are provided in Appendix C. Differences in the pastureland estimates are most likely due to misclassification of transitional land as pasture. Pastureland in mountainous counties but not included in the four-county estimate may also affect the accuracy of the four-county basin estimate. During site visits to the watershed, the researchers observed many mountainside pastures in Stokes, Surry, Wilkes, Caldwell, and Watauga counties.

Table 8. Breakdown of U.S.G.S. land use/land cover classifications by strata (1975 1:250,000 LULC data). Areas are presented in km^2. For explainations of the codes for the strata and U.S.G.S. LULC classes, refer to Tables 2 and 3, respectively.

	USGS LAND USE/LAND COVER CLASSES																		
STRATA	11	12	13	14	15	17	21	22	23	24	41	42	43	51	52	53	75	76	TOTAL
1	226.5	21.9	8.8	25.9	0.6	13.1	927.2	0.8	10.5	0.0	334.9	119.3	738.6	2.7	0.4	1.5	2.1	5.6	2440.4
2	11.8	0.7	0.0	1.6	0.0	0.0	135.2	7.7	2.4	0.0	247.5	22.6	100.5	0.0	0.0	0.2	0.0	1.7	531.7
3	0.9	0.1	0.0	0.0	0.0	0.3	24.2	2.8	0.0	0.0	252.5	4.6	47.5	0.0	0.0	0.0	0.0	0.9	333.9
4	1.2	0.2	0.0	0.1	0.0	0.1	9.5	0.1	0.4	0.0	16.5	3.5	31.1	0.0	0.0	0.0	0.1	0.1	62.9
5	0.2	0.0	0.0	0.0	0.0	0.0	8.1	0.9	0.2	0.0	101.2	3.2	34.3	0.0	0.0	0.1	0.0	0.2	148.4
6	0.5	0.2	0.0	0.0	0.0	0.0	6.7	2.1	0.0	0.0	276.8	3.4	38.7	0.0	0.0	0.0	0.0	1.0	329.5
7	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	2.1	0.0	1.4	0.0	0.0	0.0	0.0	0.0	4.0
8	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.1	0.0	0.0	43.6	0.5	11.7	0.0	0.0	0.0	0.0	0.0	57.6
9	0.2	0.1	0.0	0.0	0.0	0.0	3.5	1.0	0.0	0.0	254.1	2.2	24.6	0.0	0.0	0.0	0.0	1.3	287.0
10	101.7	11.6	4.5	16.4	0.8	9.6	589.6	0.1	3.6	0.1	216.5	77.8	426.3	8.5	0.9	6.7	0.4	5.2	1480.3
11	0.8	0.1	0.0	0.2	0.0	0.0	50.1	2.9	0.2	0.0	61.6	7.7	16.7	0.0	0.0	0.1	0.0	0.4	140.7
12	0.1	0.0	0.0	0.0	0.0	0.0	4.1	0.5	0.0	0.0	31.3	0.6	7.6	0.0	0.0	0.0	0.0	0.0	44.2
13	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.8	0.2	1.9	0.0	0.0	0.0	0.0	0.0	3.5
14	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	5.0	0.1	1.2	0.0	0.0	0.0	0.0	0.0	6.8
15	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	13.7	0.2	2.0	0.0	0.0	0.0	0.0	0.1	16.4
16	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.2
18	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	6.9	0.2	0.6	0.0	0.0	0.0	0.0	0.1	8.0
TOTAL	343.9	34.9	13.3	44.2	1.4	23.1	1761.5	19.1	17.3	0.1	1866.1	246.1	1485.0	11.2	1.3	8.6	2.6	16.6	5896.7

Table 9. 1955 land use-land cover (LULC) by strata for 185 1-km^2 sample areas. Area units are presented in km^2. Refer to Tables 2 and 4 for LULC and strata codes, respectively.

	STRATA									BASIN	
LULC	**1**	**2**	**3**	**5**	**6**	**8**	**9**	**10**	**11**	**TOTAL**	**%**
AG	13.891	2.623	0.119	0.034	0.053	0.000	0.029	4.570	0.000	21.32	11.5
AGH	4.467	0.438	0.143	0.000	0.042	0.000	0.013	1.793	0.001	6.90	3.7
H	6.000	1.450	0.251	0.023	0.076	0.080	0.071	1.952	0.242	10.14	5.5
HP	0.613	0.415	0.354	0.099	0.000	0.000	0.120	0.118	0.028	1.75	0.9
P	4.115	2.610	0.723	0.000	0.285	0.007	0.353	1.190	0.121	9.40	5.1
O	0.088	0.364	0.008	0.045	0.364	0.000	0.000	0.000	0.005	0.87	0.5
FL	0.007	0.050	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.08	0.0
WP	0.576	0.081	0.000	0.000	0.210	0.000	0.000	0.172	0.005	1.04	0.6
W	35.371	4.420	0.440	0.000	0.000	0.000	0.000	12.770	0.710	53.71	29.0
F	9.820	10.500	10.570	1.760	9.560	0.910	10.970	0.590	0.820	55.50	30.0
CP	4.349	0.855	0.459	0.005	0.203	0.000	0.198	1.998	0.010	8.08	4.4
R	1.502	0.450	0.032	0.001	0.024	0.000	0.012	0.269	0.027	2.32	1.2
U	2.335	0.170	0.000	0.000	0.000	0.000	0.000	0.740	0.000	3.24	1.8
I	0.741	0.012	0.000	0.000	0.000	0.000	0.000	0.092	0.000	0.84	0.4
RD	3.381	0.899	0.267	0.024	0.102	0.002	0.168	0.991	0.028	5.86	3.2
C	1.424	0.603	0.647	0.004	0.112	0.005	0.039	0.599	0.000	3.43	1.8
WATER	0.343	0.019	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.56	0.3
TOTAL	89.022	25.958	14.014	1.995	11.031	1.003	11.996	28.040	1.997	185.04	99.9

Table 10. 1988 land use-land cover (LULC) by strata for 185 1-km^2 sample areas. Area units are presented in km^2. Refer to Tables 2 and 4 for LULC and strata codes, respectively.

	STRATA									BASIN	
LULC	**1**	**2**	**3**	**5**	**6**	**8**	**9**	**10**	**11**	**TOTAL**	**%**
AG	6.551	1.529	0.006	0.000	0.002	0.000	0.000	2.190	0.075	10.35	5.6
AGH	6.228	0.954	0.000	0.000	0.015	0.065	0.039	2.217	0.000	9.52	5.1
H	1.941	0.915	0.057	0.002	0.000	0.000	0.045	0.657	0.017	3.64	2.0
HP	3.339	0.657	0.397	0.071	0.000	0.000	0.002	0.853	0.000	5.32	2.9
P	7.047	2.382	0.799	0.000	0.172	0.000	0.313	2.110	0.183	13.01	7.0
O	0.140	0.376	0.007	0.000	0.200	0.000	0.000	0.028	0.110	0.86	0.5
FL	0.251	0.108	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.36	0.2
WP	0.370	0.177	0.000	0.000	0.000	0.000	0.000	0.093	0.000	0.64	0.3
W	40.103	9.070	0.072	0.000	0.000	0.000	0.000	13.320	0.590	63.16	34.1
F	3.660	6.700	11.450	1.790	9.650	0.320	10.590	0.690	0.870	45.72	24.7
CP	1.670	0.205	0.371	0.000	0.038	0.000	0.080	0.507	0.074	2.94	1.6
R	3.246	0.584	0.095	0.010	0.034	0.000	0.033	0.680	0.017	4.70	2.5
U	6.220	0.424	0.000	0.000	0.000	0.000	0.000	1.767	0.000	8.41	4.5
I	1.610	0.000	0.000	0.000	0.000	0.000	0.000	0.439	0.000	2.05	1.1
RD	4.126	0.938	0.290	0.024	0.118	0.002	0.177	1.222	0.028	6.92	3.7
C	2.075	0.920	0.455	0.109	0.772	0.610	0.723	0.676	0.035	6.38	3.4
WATER	0.456	0.043	0.003	0.000	0.001	0.000	0.004	0.535	0.000	1.04	0.6
TOTAL	89.032	25.983	14.003	2.007	11.003	0.997	12.004	27.983	1.999	185.02	99.8

Gross Soil Erosion Rates from Rural Basin Areas

1:250,000 Estimated Gross Erosion Rates

Two basinwide theoretical estimates of gross erosion rates were made using USLE factors derived from the 1:250,000 coverages. In the first analysis, the basin R (metric unit based with English R given in parentheses) was held constant at 3591 (211), the area-weighted basin average, whereas in the second analysis R varied by county. Both simulations provided similar results, suggesting relatively little model differences using a spatially variable R factor. This was an unexpected result, since the mountain regions of the watershed receive approximately 10 cm more rainfall per year. Figure 10 illustrates the variation of the county R values from the USLE handbook (U.S.D.A. 1993) and the 40-year average R values estimated from daily rainfall to the eight precipitation gauges. Among the four major counties in the watershed (Forsyth, Wilkes, Yadkin, and Surry), there is little variation, and the four-county average 3574 (210) appears to dominate the county model.

Results from the 1:250,000 simulation with R= 3591 (211) are presented in Tables 11 and 12. Of the 18 strata classes (Table 11), only four had annual gross soil erosion rates or above the 11.2 $Mg{\cdot}ha^{-1}{\cdot}y^{-1}$ (5 $tons{\cdot}ac^{-1}{\cdot}y^{-1}$), the N.R.C.S upper limit of tolerable erosion loss. Fourteen strata were within one standard deviation of the 11.2 Mg benchmark. Of the four strata with high erosion rates, all were located in the Piedmont with slopes greater than 15%. Breaking down the erosion rates by land use-land cover shows that only two of the included 1:250,000 U.S.G.S. LULC classes exceeded 11.2 $Mg{\cdot}ha^{-1}{\cdot}y^{-1}$. This is not surprising, considering cropland and pasture are reported as a single land class and the small scale of the database as a whole. Most agricultural or disturbed land classes were within one standard deviation of the 11.2 $Mg{\cdot}ha^{-1}{\cdot}y^{-1}$ target. Estimated rates from all the forest classes were significantly below 11.2 $Mg{\cdot}ha^{-1}{\cdot}y^{-1}$.

1:24,000 Estimated Gross Erosion Rates - 1950's and 1980's

To test both temporal and spatial variation, estimated gross erosion rates using the area weighted R factor 3591 (211) were compared to estimated gross erosion rates from models using the annual R factors estimated from the observed daily precipitation. Annual models spanning five years in the 1950s (1953-1957) and five years in the 1980s (1986-1990) were created. It was assumed that the land use-land cover databases for 1955 and 1988 represented that throughout a these five-year periods, allowing only the R factor to vary. Figure 11 shows the annual distributions of R for each of the eight precipitation station records. Estimated annual R factors from the daily precipitation ranged from 1328 (78) to 11471 (674). The eight station 40-year average was 3625 (213) and the individual station 40-year averages ranged from 3081 (181) at Greensboro to 4817 (283) at Roaring Gap, indicating a good fit with the county R values. The results also support the findings of Wischmeier and Smith (1978), in that annual R factors were generally lower at the Piedmont stations and higher in the mountain areas, although deviations from this rule exist.

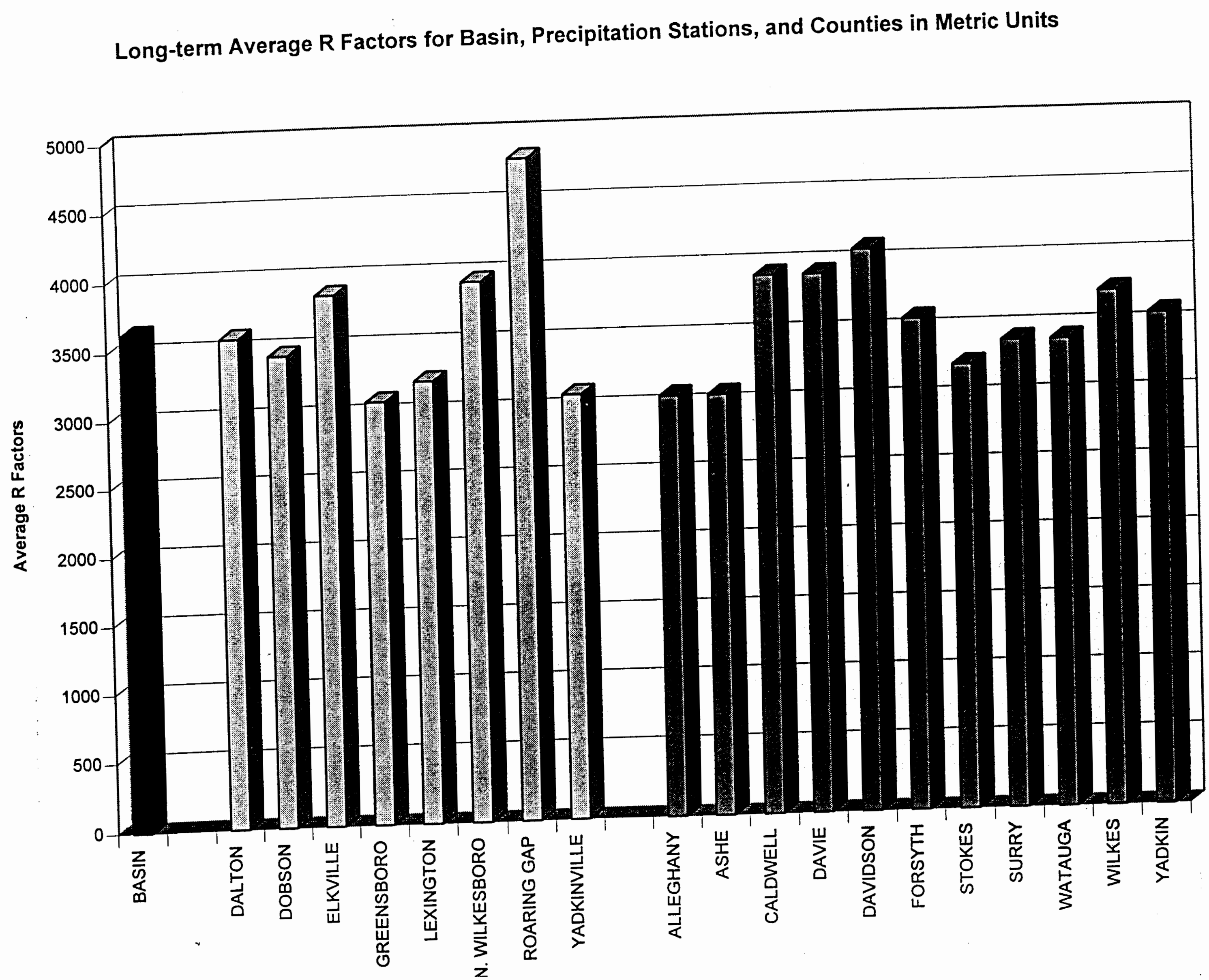


Figure 10. Average R factors (MJ.mm.ha-1 h-1 y-1) for the Yadkin River basin, eight precipitation stations (U.S.D.A. 1993), and eleven counties (Richardson et al. 1983).

Table 11. Estimated average soil erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) and USLE factor statistics by strata from the 1975 basin-wide coverage. P in the USLE was set to 1.00 and R was held constant at 3591 (211), the area-weighted average R value of all counties making up the basin. Refer to Table 2 for strata codes. All statistics were generated using the *Extract* module in IDRISI and are in metric units.

STRATA	AVG A	STD A	AVG K	STD K	AVG LS	STD LS	AVG C	STD C
1	4.19	7.06	0.0326	0.0034	0.6044	0.5558	0.0723	0.0783
2	3.90	8.05	0.0314	0.0031	1.0505	0.7521	0.0451	0.0690
3	1.84	6.05	0.0301	0.0043	1.4043	0.8290	0.0150	0.0416
4	11.21	23.94	0.0310	0.0028	3.6414	0.7823	0.0278	0.0575
5	5.31	16.54	0.0318	0.0039	4.1150	0.9680	0.0118	0.0361
6	2.94	10.29	0.0297	0.0043	4.3413	0.9915	0.0066	0.0231
7	15.65	42.55	0.0310	0.0032	8.1004	1.9201	0.0171	0.4500
8	6.61	22.96	0.0318	0.0043	9.1315	3.2786	0.0069	0.0248
9	5.83	21.70	0.0291	0.0040	10.9508	5.1270	0.0052	0.0183
10	1.52	2.85	0.0328	0.0037	0.1895	0.2418	0.0746	0.0784
11	1.79	4.55	0.0318	0.0033	0.3714	0.5465	0.0607	0.0749
12	1.03	4.19	0.0295	0.0042	0.8307	0.8525	0.0182	0.0461
13	10.63	23.34	0.0308	0.0029	3.6742	0.7715	0.0263	0.0559
14	6.14	17.49	0.0308	0.0042	3.9890	0.9328	0.0148	0.0415
15	2.80	9.86	0.0286	0.0038	4.1456	0.9453	0.0066	0.0231
16	59.17	80.02	0.0327	0.0036	7.9792	1.1013	0.0572	0.0748
17	7.22	23.36	0.0298	0.0041	8.3840	2.2103	0.0090	0.0308
18	6.57	22.02	0.0282	0.0034	10.7278	4.9169	0.0064	0.0222
BASIN	3.43	9.37	0.0318	0.0041	1.6257	2.9864	0.0552	0.0739

Table 12. Estimated average soil erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) and USLE factor statistics by U.S.G.S. LULC class from the 1975 basin-wide coverage. P in the USLE was set to 1.00 and R was held constant at 3591 (211), the area-weighted average R value of all counties making up the basin. Refer to Table 3 for U.S.G.S. LULC codes. All statistics were generated using the *Extract* module in IDRISI and are in metric units.

LULC	AVG A	STD A	AVG K	AVG LS	STD LS	C
11	0.00	0.00	0.0303	0.3684	0.5211	0.000
12	0.00	0.00	0.0295	0.3804	0.6933	0.000
13	0.00	0.00	0.0281	0.3216	0.3477	0.000
14	0.00	0.00	0.0310	0.3821	0.4158	0.000
15	0.00	0.00	0.0290	0.4614	0.6108	0.000
17	8.41	15.04	0.0300	0.3860	0.7135	0.200
21	8.86	14.33	0.0328	0.4820	0.8126	0.220
22	13.72	19.42	0.0307	2.0597	2.9336	0.060
23	0.00	0.00	0.0309	0.7559	0.9324	0.000
24	3.23	1.12	0.0356	0.1582	0.0551	0.015
41	0.94	1.21	0.0309	3.2506	4.2260	0.003
42	0.25	0.45	0.0322	0.7958	1.4828	0.003
43	0.34	0.58	0.0319	1.0864	1.8618	0.003
51	0.00	0.00	0.0309	0.2802	0.2759	0.000
52	0.00	0.00	0.0356	0.4869	0.3775	0.000
53	0.00	0.00	0.0302	0.5307	0.7730	0.000
75	0.00	0.00	0.0327	0.7676	0.8360	0.000
76	14.82	28.56	0.0316	1.7149	3.3010	0.080

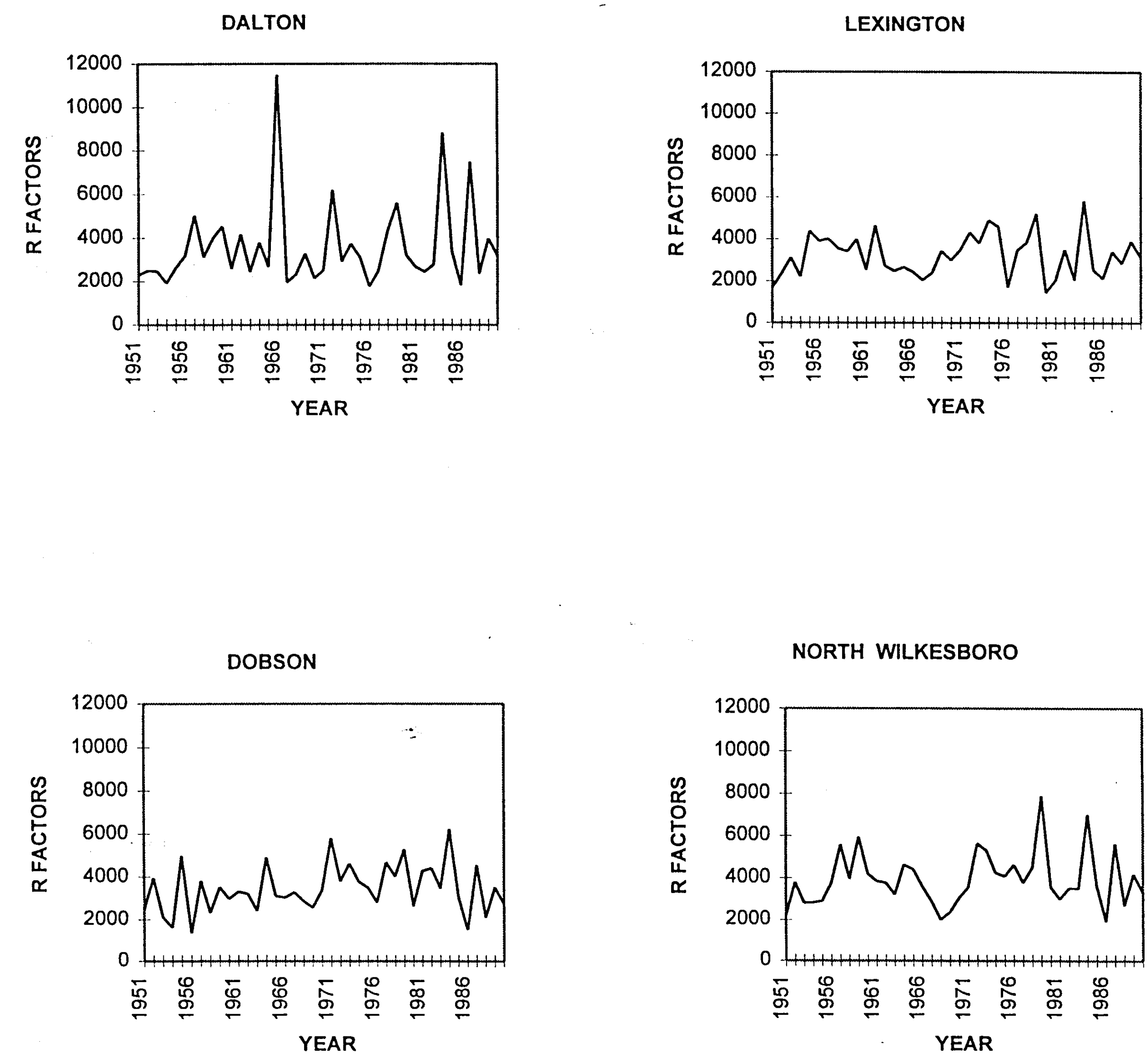
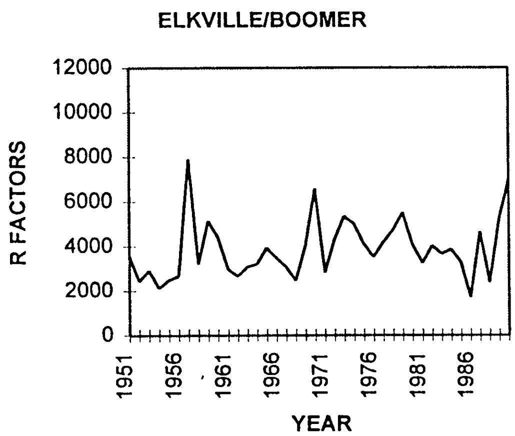


Figure 11. Annual R factors (MJ·mm·ha^{-1}·h^{-1}·y^{-1}) for eight precipitation stations (1951-1990).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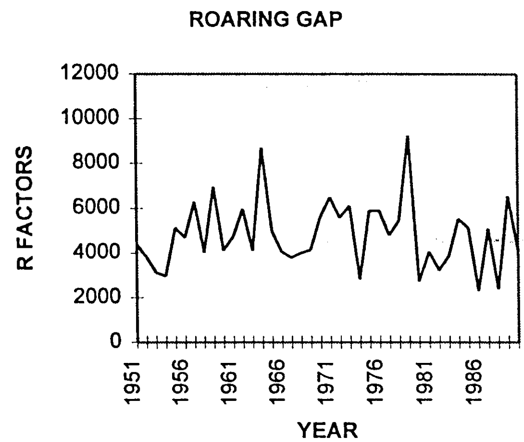
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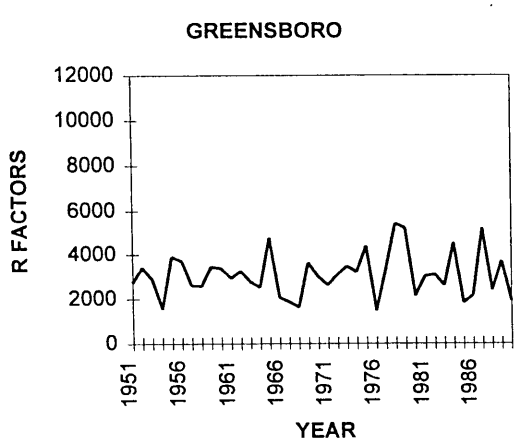
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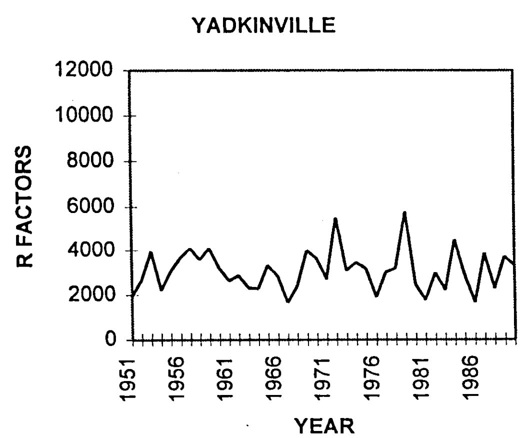
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Tables 13 to 16 illustrate the estimated annual average erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by land use-land cover, strata, and for the basin as a whole in the years 1953-57 and 1986-90. Both periods contain wet and drought years, relative to the 40-year precipitation records. Estimates based on average annual precipitation are provided by simulations with R set at 3591 (211). These latter simulations provide a method for directly comparing effects of land-use changes between the two time periods.

Between the 1950s and 1980s, simulated gross soil erosion rates from cultivated lands (AG, AGH, and H) remained virtually unchanged (see estimates under columns R= 3591 (211), Tables 13 and 14), even though cultivated land area has decreased by an estimated 39% during this period. Distributions of the USLE factors K, LS, and C also show little change between these periods (Appendix D). These results imply that changes in the basinwide estimates of total gross soil erosion are primarily the result of the smaller agricultural landbase, and not the result of changes in the physical agricultural landscape. This view is supported by a stratified analysis of the data, which indicates that the highest erosion rates for both the 1950s and 1980s are associated with strata 1, 2, 3, and 10, strata that are associated with cultivation although they have relatively low slope (Tables 15 and 16). In 1955 and 1988, more than 98% of the basin's cultivated land was located within these strata.

Evidence of the variability and major influence of precipitation's erosivity is demonstrated by the shifting gross erosion values among the strata from year to year (e.g. 1953 vs. 1957) and by the annual basinwide estimates. Overall, basinwide estimates of annual average erosion rates exceed 11.2 $Mg \cdot ha^{-1} \cdot yr^{-1}$ in all but three of the simulation years. All three of the low erosion rate years were dry years.

If the changes in the estimated gross erosion rates from rural areas between 1955 and 1988 are compared, results indicate that the average gross erosion rate from the basin has decreased by 17% between 1955 and 1988, from 14.4 to 11.9 $Mg \cdot ha^{-1} \cdot y^{-1}$. These simulations were made with a constant R factor of 3591 (or 211). The primary factor in reducing the aggregate erosion rate across the basin was the contraction of the acreage of row crops.

Since the late 1980s, however, BMPs have been implimented on nearly all farms across the basin and as a result the C factors and gross erosion rates have rapidly diminished. Tables 17 and 18 contain the results of a simulation which lowered the average C factor on agricultural land from 0.463 to 0.124 for the years 1988-1990. This new value for C, derived from discussions with N.R.C.S. personnel, is applicable to current cropping conditions and accounts for improvements from conservation tillage and other BMPs now mandated by the federal farm legislation. Although full implementation of the plans had not been achieved during the period of study, many farm management plans had been initiated by the late 1980s. Results indicate a potentially dramatic 73% reduction in gross erosion rates from rowcropped lands, from about 75 to 20 $Mg \cdot ha^{-1} \cdot y^{-1}$ (Table 17). With R held constant at 3591 and Best Management Practices (BMPs) simulated in these three years, the estimated basinwide gross erosion rate decreased by nearly 42%, from 14.4 to 8.4 $Mg \cdot ha^{-1} \cdot y^{-1}$ (see **BASIN** estimates under R=3591 column, Tables 15 and 17).

Table 13. Average simulated gross erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by land use-land cover class from 185 sample areas (1953-57). R factors used in the annual USLE calculations were derived from annual precipitation records. C factor distributions were based on 1955 land use-land cover database. The column R=3591 represents erosion rates using average annual rainfall erosivity. N refers to the number of 30 x 30 m pixels used in the simulations.

LULC	N	1953	1954	1955	1956	1957	R=3591
AG	23779	60.24	42.56	81.99	61.08	94.08	75.25
AGH	7629	18.69	14.08	28.52	18.34	33.07	26.07
H	11295	13.61	9.89	17.68	14.24	23.14	16.62
HP	1943	11.34	9.88	16.31	13.51	25.68	15.19
P	10478	4.32	3.48	6.54	4.61	8.49	5.65
CP	8951	12.77	9.79	18.83	12.93	23.58	16.82
C	3787	46.12	34.87	55.83	46.46	102.64	58.82
WP	1174	4.01	2.94	4.29	4.08	8.85	4.87
W	59498	0.89	0.67	1.24	0.91	1.53	1.16
F	61834	0.25	0.20	0.32	0.27	0.59	0.32
O	973	18.67	16.06	27.16	18.54	38.64	26.40
BASIN	191341	11.38	8.25	15.53	11.56	19.16	14.42

Table 14. Average simulated gross erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by land use-land cover class from 185 sample areas (1986-90). R factors used in the annual USLE calculations were derived from annual precipitation records. C factor distributions were based on 1988 land use-land cover database. The column R=3591 represents erosion rates using average annual rainfall erosivity. N refers to the number of 30 x 30 m pixels used in the simulations.

LULC	N	1986	1987	1988	1989	1990	R=3591
AG	11566	35.92	95.12	47.85	82.83	66.56	74.83
AGH	10560	12.00	32.88	16.26	26.99	22.64	25.36
H	4050	8.13	22.07	10.28	20.33	16.77	15.95
HP	5881	5.09	13.77	6.76	11.91	10.07	10.43
P	14390	2.32	6.22	2.98	5.84	4.96	4.61
CP	3287	10.99	27.43	13.73	27.83	23.00	20.75
C	7062	44.37	121.30	57.68	122.26	127.81	87.91
WP	712	1.34	3.55	1.60	3.23	2.30	2.40
W	70140	0.61	1.72	0.81	1.45	1.23	1.25
F	51016	0.18	0.46	0.22	0.51	0.52	0.35
O	964	10.44	28.33	13.76	25.31	21.24	20.39
BASIN	179628	5.85	15.74	7.71	14.41	12.92	11.92

Table 15. Average simulated gross erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by strata from 185 sample areas (1953-57). R factors used in the annual USLE calculations were derived from annual precipitation records. C factor distributions were based on 1955 land use-land cover database. The column R=3591 represents erosion rates using average annual rainfall erosivity. N refers to the number of 30 x 30 m pixels used in the simulations.

STRATA	N	1953	1954	1955	1956	1957	R=3591
1	89568	14.21	9.87	18.72	14.34	21.11	17.56
2	27061	10.88	9.00	18.80	11.03	22.54	15.19
3	15273	7.83	6.10	8.84	7.94	19.51	9.79
5	2214	4.62	3.38	3.92	4.21	12.54	5.70
6	12149	2.71	2.04	3.74	2.32	6.43	3.74
8	1096	2.17	1.59	1.84	1.98	5.90	2.68
9	13170	2.29	1.85	3.93	2.20	4.84	3.22
10	28445	14.27	10.25	18.80	15.14	23.40	17.90
11	2143	3.71	2.71	3.14	3.38	10.06	4.58
BASIN	191119	11.38	8.25	15.53	11.56	19.16	14.42

Table 16. Average simulated gross erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by strata from 185 sample areas (1986-90). R factors used in the annual USLE calculations were derived from annual precipitation records. C factor distributions were based on 1988 land use-land cover database. The column R=3591 represents erosion rates using average annual rainfall erosivity. N refers to the number of 30 x 30 m pixels used in the simulations.

STRATA	N	1986	1987	1988	1989	1990	R=3591
1	81124	6.12	16.98	8.29	13.71	11.28	12.80
2	26498	6.35	16.86	7.99	16.83	14.43	12.72
3	15176	3.17	7.31	3.49	9.06	6.80	5.28
5	2200	2.96	7.96	4.07	8.96	11.89	6.18
6	12114	4.31	10.81	5.18	11.90	9.95	8.10
8	1095	47.49	127.90	65.36	143.89	190.91	98.99
9	13159	5.40	14.31	7.24	16.17	20.11	11.02
10	25846	5.70	15.21	7.58	12.90	10.32	11.69
11	2162	3.74	10.07	5.14	11.33	15.03	7.81
BASIN	179374	5.85	15.74	7.71	14.41	12.92	11.92

Table 17. Influence of C factors on estimated gross soil erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) from rowcrops (category AG in the 1:24,000 database). The lower C factor represents present conditions with conservation plans enacted. Erosion rate estimates based on 185 1-km^2 sample areas (1988-90).

AG	1988	1989	1990	R=3591
C = 0.463	47.85	82.85	66.56	74.83
C = 0.124	12.81	22.18	17.83	20.04
BASIN	5.45	10.51	9.78	8.39

Table 18. C factor sensitivity on estimated gross soil erosion rates ($Mg \cdot ha^{-1} \cdot y^{-1}$) by strata. The lower C factor represents present conditions with conservation plans enacted. Erosion rate estimates based on 185 1-km^2 sample areas (1988-1990).

STRATA	1988	1989	1990
1	5.23	8.71	7.15
2	5.30	11.15	10.23
3	3.47	9.01	6.74
5	4.07	8.96	11.89
6	5.18	11.89	9.94
8	65.36	143.89	190.91
9	7.24	16.17	20.11
10	4.44	7.57	6.10
11	3.94	8.68	11.52
BASIN	5.45	10.51	9.78

Statistical Analysis of Yadkin River Suspended Sediment

Averaged over the 40 years of sampling, the Yadkin River transports massive amounts of sediment: annually about 819,000 Mg of suspended sediment averaged over the 40 years. Per unit of basin area, annual transport of suspended sediment amounts to 1.39 Mg ha^{-1}, high rates for a river basin with the Yadkin's area (Milliman and Meade 1983). Between 1951 and 1990, the daily median concentration was 70.0 mg/L, the daily arithmetic mean was 150.6 mg/L, and the daily volume-weighted suspended-sediment concentrations averaged 297.7 mg/L.

Additional statistical details of the 40-yr daily record are found in Table 19. A characteristic of these 14,516 daily data are their skewness, which is, however, controlled by log

Table 19. Statistical summary of 40-yr daily data of suspended sediment at the Yadkin College, North Carolina sampling station in the Yadkin River (1951-1990).

Attribute	Log Transformation	Daily Discharge (m3/s)	Suspended Sediment Concentration (mg/L)	Suspended Sediment Yield (Mg/d)
Sample size	-	14516	14516	14516
Arithmetic mean	No	84.68	150.6	2244.5
Mean Nat. Log	Yes	4.200	4.340	6.090
Standard deviation	No	87.210	223.23	7373.1
Standard error	No	0.7200	1.850	61.20
Coeff. of variation, %	No	103.0	148.2	328.5
Coeff. of variation, %	Yes	15.04	26.2	27.2
Minimum	-	9.34	1	2.72
Lower quartile	-	44.46	35	136.1
Median	-	62.86	70	367.4
Upper quartile	-	92.60	160	1188.4
Upper 10%	-	145.00	379	4599.0
Upper 1%	-	470.10	1100	37830
Maximum	-	1868.92	2970	165,110
Skewness	No	5.99	3.64	7.87
Skewness	Yes	0.70	0.24	0.50
Kurtosis	No	58.86	19.07	84.30
Kurtosis	Yes	1.57	-0.21	0.10

Table 20. Statistical summary of daily discharge at Yadkin College, North Carolina in the Yadkin River arranged by decade.

Attribute	Log Transformation	River Discharge (m3/s) 1950s	1960s	1970s	1980s
Sample size	-	3559	3652	3653	3652
Arithmetic mean	No	78.76	76.70	103.89	79.21
Median		57.20	59.18	77.87	56.07
Mean of daily natural logs	Yes	4.070	4.150	4.440	4.130
Standard deviation	No	86.36	75.33	102.02	79.92
Coeff. of variation, %	No	109.7	98.2	98.2	100.9
Coeff. of variation, %	Yes	17.4	13.2	12.6	15.3
Minimum	-	9.34	19.88	25.32	9.91
Lower quartile	-	36.25	44.17	58.62	41.48
Upper quartile	-	87.78	81.84	106.47	91.18
Upper 10%	-	136.80	120.90	175.80	143.30
Upper 1%	-	523.90	396.40	532.40	368.10
Maximum	-	911.80	1350.71	1868.91	1554.59
Skewness	No	4.59	7.18	5.98	6.39
Skewness	Yes	0.55	1.15	1.22	0.70
Kurtosis	No	27.91	81.88	57.35	70.93
Kurtosis	Yes	0.95	2.70	1.22	1.12

Table 21. Statistical summary of daily suspended sediment concentration at Yadkin College, North Carolina in the Yadkin River arranged by decade.

Attributes	Log Transformation	Sediment Concentration (mg/L) 1950s	1960s	1970s	1980s
Sample size	-	3559	3652	3653	3652
Arithmetic mean	No	181.11	133.52	174.43	114.14
Mean of Nat. Log	Yes	4.41	4.31	4.60	4.04
Standard deviation	No	268.70	193.42	222.78	193.91
Coeff. of variation, %	No	148.4	144.9	127.7	169.9
Coeff. of variation, %	Yes	29.1	24.0	22.6	27.4
Minimum	-	1	4	7	2
Lower quartile	-	35	38	46	26
Median	-	80	68	91	48
Upper quartile	-	203	135	203	112
Upper 10%	-	486	312	433	277
Upper 1%	-	1260	1000	1100	955
Maximum	-	2970	2100	2210	2480
Skewness	No	3.30	3.78	2.88	4.89
Skewness	Yes	0.020	0.35	0.27	0.52
Kurtosis	No	15.75	19.21	10.62	35.01
Kurtosis	Yes	-0.35	0.07	-0.44	-0.03

Table 22. Statistical summary of daily sediment transport or yield at Yadkin College, North Carolina in the Yadkin River arranged by decade.

Attributes	Log Transformation	Sediment Yield (Mg/d) 1950s	1960s	1970s	1980s
Sample size	-	3559	3652	3653	3652
Arithmetic mean	No	2459.9	1699.1	3036.2	1788.0
Mean Nat. Log	Yes	6.043	6.011	6.594	5.729
Standard deviation	No	7333.9	5859.9	9017.8	6844.7
Coeff. of variation, %	No	298.1	344.9	297.0	382.8
Coeff. of variation, %	Yes	30.8	24.3	23.2	28.7
Minimum	-	2.72	14.51	31.75	8.26
Lower quartile	-	116.1	147.9	233.1	92.5
Median	-	385.56	337.5	594.2	215.9
Upper quartile	-	1388.0	850.5	1905.1	841.0
Upper 10%	-	5361.5	3048.1	6232.4	3302.2
Upper 1%	-	39009	28214	46811	31025.7
Maximum	-	97,976	114,305	165,108	125,192
Skewness	No	6.22	9.03	7.23	9.13
Skewness	Yes	0.23	0.73	0.78	0.78
Kurtosis	No	48.36	110.81	72.49	105.71
Kurtosis	Yes	-0.25	0.64	0.07	0.27

transformation. The skewness factor for untransformed sediment concentrations is 3.64, for discharge is 5.99, and for sediment transport or yield 7.87. A similar presentation of the data for each of the four decades is given in Tables 20, 21, and 22 for discharge, sediment concentration, and sediment transport, respectively.

This skewed nature to these data are illustrated by the fact that within a given year, about 71% of the annual sediment transport was produced in 36 to 37 high-flow days per year (10% of the time), and about 26% of annual transport occurred in 3 to 4 days per year (1% of the time). These frequencies are displayed for each year in Figure 12.

Sediment transport by the river is not only massive but like most rivers is also highly variable from year to year (Fig. 12 and 13). Among the 40 years, annual transport of suspended sediment ranged from 0.17 to 2.63 Mg $ha^{-1}yr^{-1}$ (coefficient of variation of 47%), a variation strongly associated with annual in river discharge (Fig. 13). No monotonic trend is evident in the 40-yr data set illustrated in Figure 13. A linear regression between annual discharge and sediment transport indicated that about 79% of the variation in sediment transport was associated with variation in discharge (Fig. 14).

A detailed set of annual statistics is provided in Table 23. The low skewness factor of 0.03 for the annual sediment transport (or yield) is notable. A similarly arranged sets of statistics for monthly data sets are summarized for volume-weighted monthly concentrations in Table 24, arithmetic monthly mean concentrations in Table 25, mean monthly discharges in Table 26, and mean monthly sediment transport in Table 27.

Frequency diagrams of each of the four decades are included in Figure 15 for discharge, sediment concentration, and sediment transport or yield. The daily data were subdivided into four decades with nearly equal numbers of observations for the 1950s, 60s, 70s, and 80s. The frequency diagrams illustrate the dynamic character to sediment transport and its response to variations on decadal time scales. Each of the 12 lines in the three panels of Figure 15 contains 3650 daily observations.

Time-Trend Analyses of Yadkin River Suspended Sediment

Because there is no apparent monotonic trend of sediment transport through time (Figs. 13 and 16), and because sediment and hydrologic transport are so closely related (Figs. 13 and 14), we estimated time trends in sediment transport after removing effects attributable to hydrologic variation. Regression equations were fit to sediment-hydrologic data (e.g., Fig. 14), and time-ordered residuals were examined as a function of sampling date since 1951 (e.g., Fig. 17). The trends in the time-ordered residuals of annual sediment regressions (Fig. 17, $n = 40$ years) were tested with the Mann-Kendall test, a nonparametric test of zero slope of the annual regression residuals (Kendall 1975; Gilbert 1987). Relatively low serial correlation of the annual data indicated that this Mann-Kendall test was appropriate for this test (Hirsch and Slack 1984). Based on these annual residuals, sediment transport is decreasing at about 6900 Mg yr^{-1}(Fig. 17). The Sen-slope estimate (Sen 1968) indicated that sediment transport was decreasing significantly, by about 7789 Mg/year between 1951 to 1990, equivalent to 0.013 Mg $ha^{-1}yr^{-1}$.

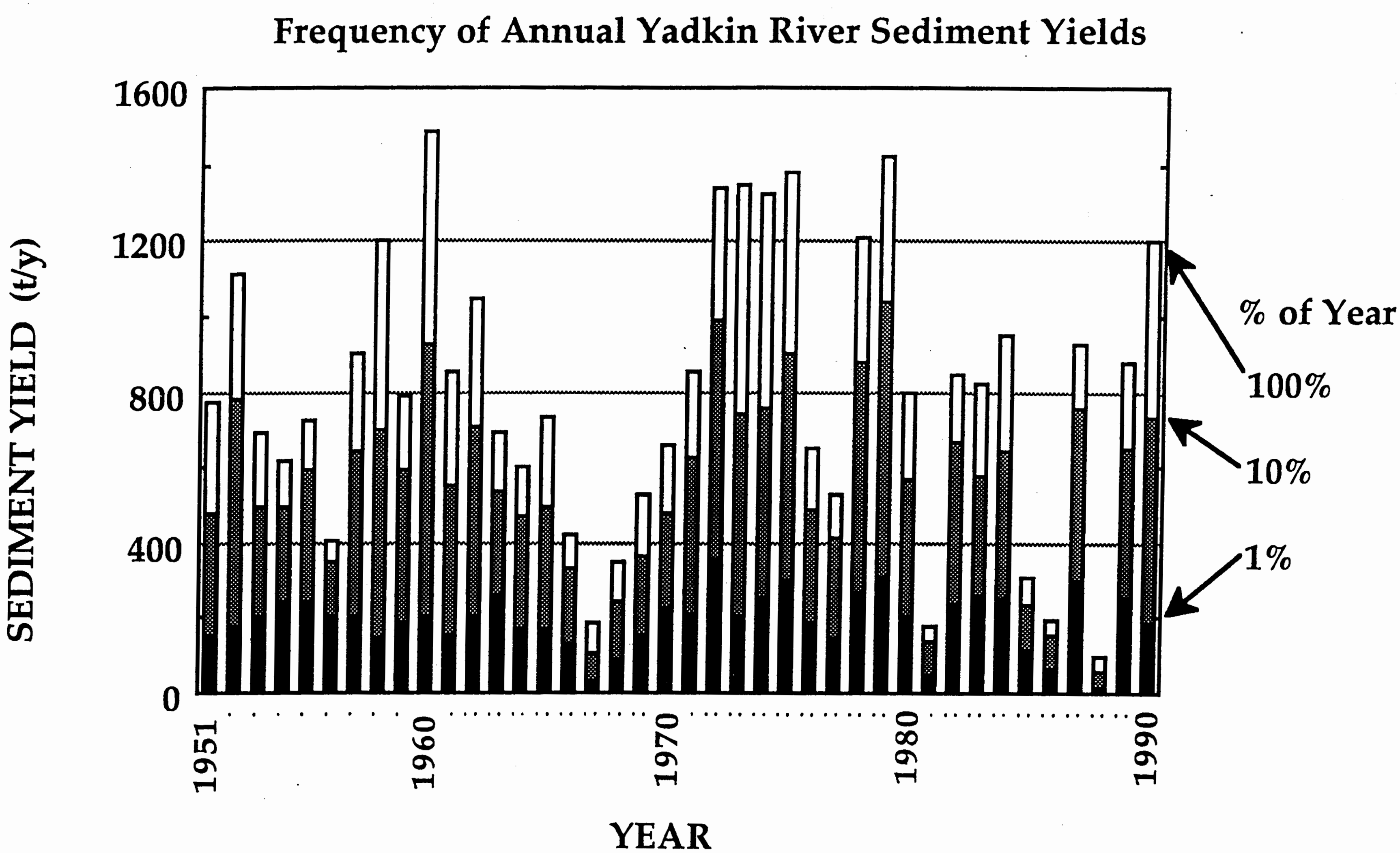


Figure 12. Frequency analysis of Yadkin River sediment transport or yields illustrated by year 1951-1990. Black bars represent the volume of sediment transported during the top 3 to 4 events (1%) of a year and grey bars represent the volume of sediment transported during the top 36 to 37 events (10%) of a year. Cumulative, annual totals (100%) are represented by all three sections.

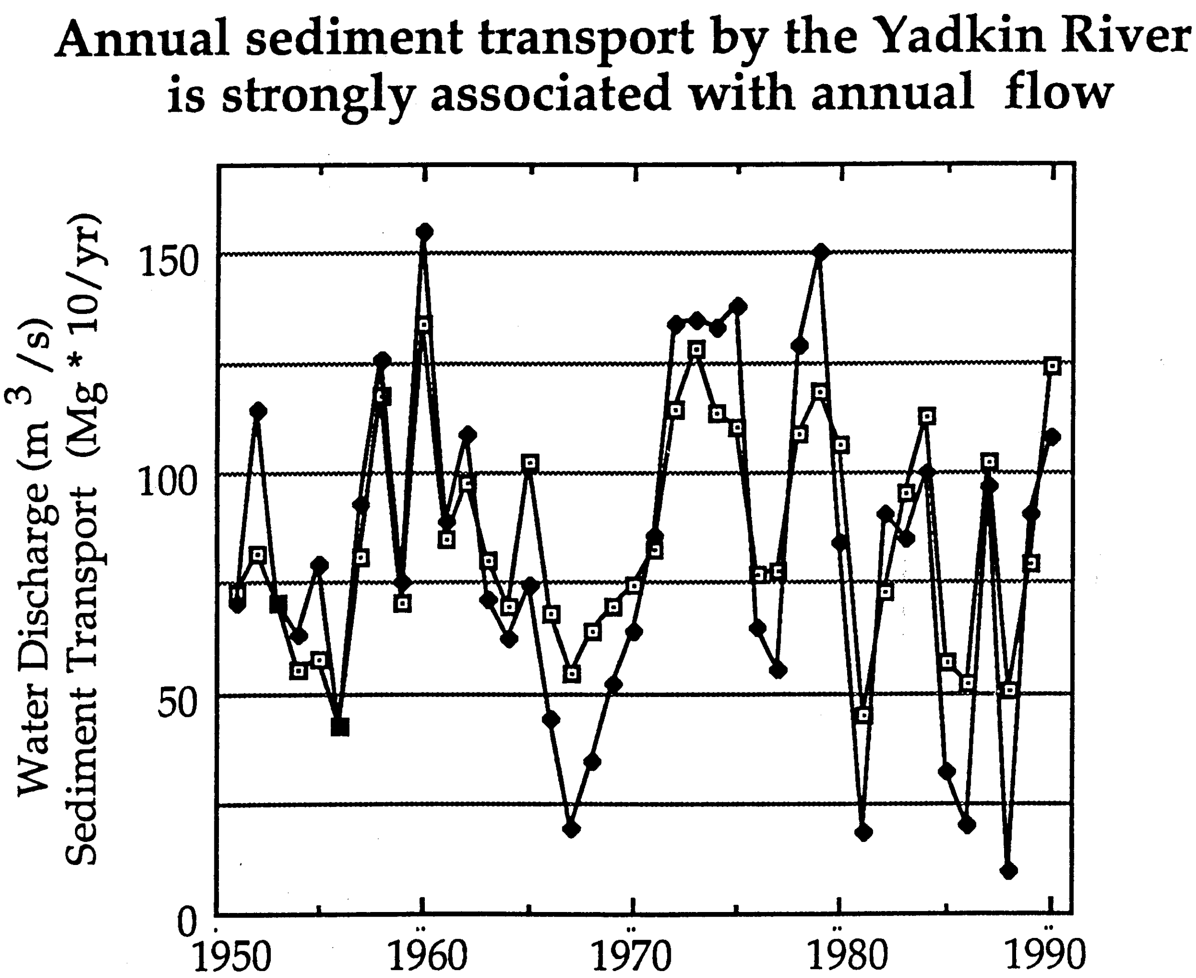


Figure 13. The association of annual suspended sediment transport and discharge in the Yadkin River. Sediment transport is illustrated by filled diamonds and discharge by open squares.

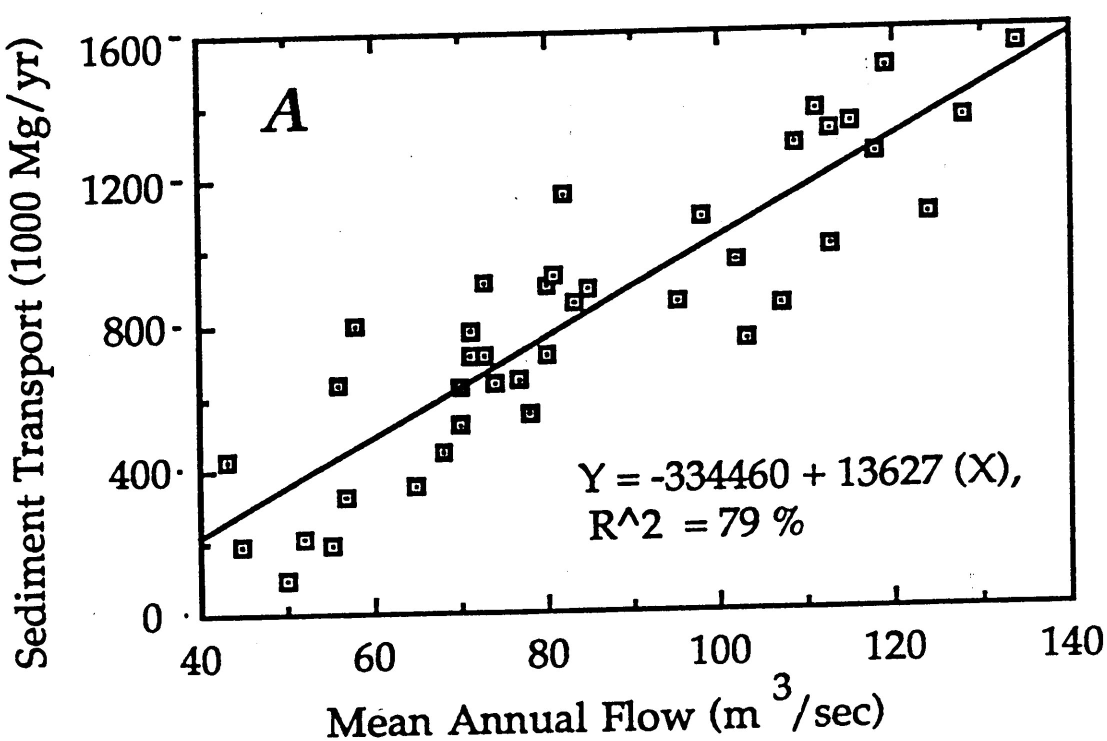


Figure 14. Linear regression of annual discharge and sediment transport in the Yadkin River.

Table 23. Statistical summary of annual sediment and discharge data at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

Attributes	Vol-Wt Mean Conc. (mg/L)	Arit. Mean Conc. (mg/L)	Mean Nat. Log Conc. (mg/L)	Mean Ann. Discharge (m3/s)	Mean Nat. Log Ann. Discharge (m3/s)	Annual Sediment Yield (Mg/y)
Sample size	40	40	40	40	40	40
Arithmetic mean	285.50	150.97	82.64	84.60	69.53	819,023.30
Standard deviation	86.72	48.97	31.96	24.95	20.49	382,012.94
Coeff. of variation, %	30.4	32.4	38.7	29.5	29.5	46.6
Minimum	60.88	49.88	34.04	42.93	31.63	98,542
Lower quartile	238.86	118.56	61.63	69.03	55.53	590,063
Median	303.26	152.86	78.55	80.00	63.66	818,378
Upper quartile	351.25	184.63	101.19	107.82	88.24	1,086,938
Upper 10%	373.00	219.30	127.30	118.50	98.47	1,346,650
Upper 1%	430.00	240.90	156.70	134.20	110.01	1,551,030
Maximum	429.99	240.87	156.74	134.23	110.01	1,551,033
Skewness	-0.81	-0.08	0.66	0.26	0.34	0.03
Kurtosis	0.16	-0.58	0.00	-0.98	-0.76	-0.66

Table 24. Statistical summary of monthly volume-weighted mean suspended sediment concentration at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

	Vol-Wt Mean Monthly concentration (mg/L)											
Attribute	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sample size	39	39	39	40	40	40	40	40	40	40	40	40
Arithmetic mean	191.85	129.13	185.64	195.97	276.60	266.06	243.92	272.73	316.78	263.21	267.76	224.33
Standard deviation	193.09	113.35	154.64	165.31	166.79	161.15	163.48	166.24	225.42	145.68	206.63	217.66
Coeff. of variation, %	100.6	87.8	83.3	84.4	60.3	60.6	67.0	61.0	71.2	55.4	77.2	97.0
Minimum	14.70	13.05	6.67	4.72	26.72	26.12	26.70	46.78	39.37	37.56	35.13	25.77
Lower quartile	39.27	33.14	51.70	65.65	116.53	138.98	97.58	152.47	134.46	164.68	99.11	54.91
Median	139.92	90.42	176.42	172.44	282.10	247.41	220.06	200.94	252.87	265.79	214.76	129.47
Upper quartile	254.36	160.99	268.11	270.44	407.95	375.14	369.30	368.47	434.49	314.04	414.82	394.26
Upper 10%	494.40	331.00	468.80	382.80	496.40	521.40	493.20	519.60	686.60	437.30	536.90	571.80
Upper 1%	750.40	391.40	573.10	738.50	632.70	663.90	651.40	668.70	891.00	756.20	877.90	759.70
Maximum	750.44	391.43	573.06	738.54	632.67	663.89	651.41	668.71	891.04	756.15	877.94	759.65
Skewness	1.48	1.13	0.90	1.35	0.06	0.62	0.50	0.74	0.94	1.07	1.10	1.02
Kurtosis	1.56	0.23	0.03	2.28	-0.94	-0.23	-0.60	-0.21	0.03	2.25	0.85	-0.29

Table 25. Statistical summary of monthly arithmetic mean suspended sediment concentration at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

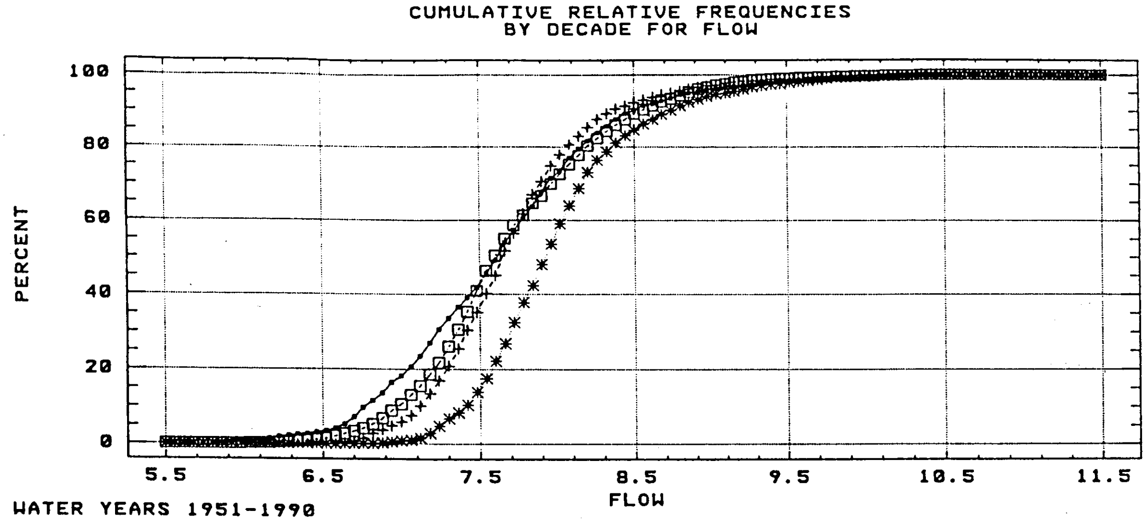
	Arithmetic Mean Monthly Concentration (mg/L)											
Attribute	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sample size	39	39	39	40	40	40	40	40	40	40	40	40
Arithmetic mean	95.87	78.44	103.32	119.59	161.91	171.74	163.51	183.86	222.70	190.63	185.99	126.10
Standard deviation	71.62	58.02	74.11	86.30	97.87	96.31	94.51	93.15	148.12	89.27	121.25	99.58
Coeff. of variation, %	74.7	74.0	71.7	72.2	60.4	56.1	57.8	50.7	66.5	46.8	65.2	79.0
Minimum	14.26	12.83	6.68	4.77	23.14	25.29	27.00	41.32	38.90	36.35	33.39	28.50
Lower quartile	35.68	29.90	41.61	42.27	88.52	106.45	86.75	110.92	116.35	121.03	84.18	45.18
Median	86.68	62.37	100.32	101.42	156.93	148.10	168.57	167.61	152.98	190.50	170.00	99.85
Upper quartile	136.10	107.73	147.03	166.31	201.75	225.15	226.02	236.19	296.17	245.32	256.23	169.55
Upper 10%	199.90	183.20	209.50	225.90	297.60	316.50	294.40	311.90	447.00	317.80	357.50	298.00
Upper 1%	299.60	217.60	336.10	352.00	405.60	414.20	364.80	424.40	598.80	385.90	565.60	393.50
Maximum	299.65	217.57	336.10	352.03	405.62	414.23	364.77	424.35	598.83	385.90	565.58	393.47
Skewness	1.24	1.03	0.95	0.85	0.78	0.72	0.33	0.66	1.05	0.34	1.02	1.10
Kurtosis	1.32	0.06	1.12	0.46	0.52	0.00	-0.88	-0.01	0.43	-0.34	0.97	0.20

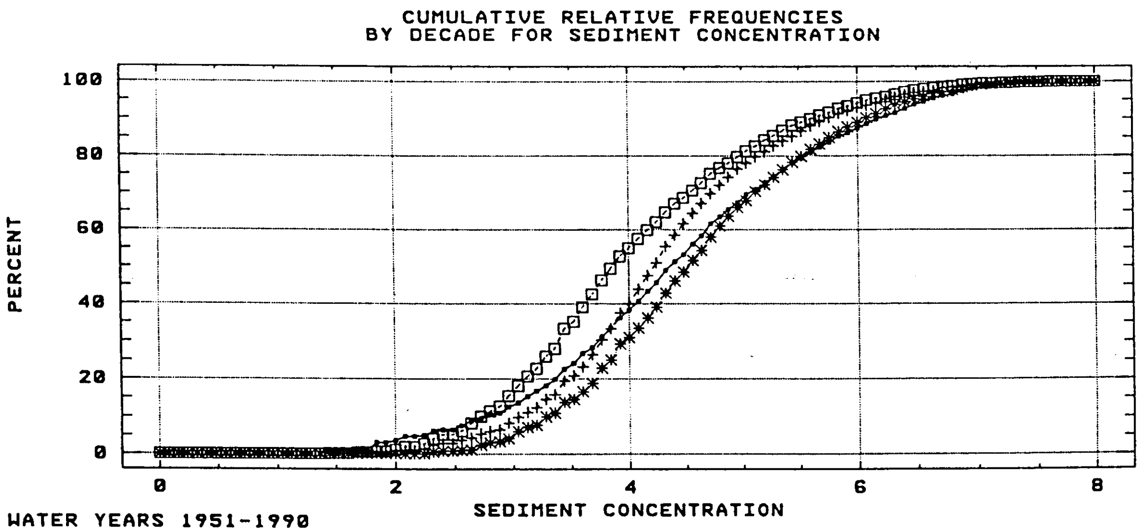
Table 26. Statistical summary of monthly discharge at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

	Monthly Discharge (m3/s)											
Attribute	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sample size	40	40	40	40	40	40	40	40	40	40	40	40
Arithmetic mean	66.48	66.47	81.40	88.64	117.36	123.76	118.50	92.32	80.22	62.34	62.32	57.05
Standard deviation	46.33	33.66	32.68	38.15	50.08	58.37	57.42	37.76	38.40	25.71	34.70	34.25
Coeff. of variation, %	69.7	50.6	40.2	43.0	42.7	47.2	48.5	40.9	47.9	41.2	55.7	60.0
Minimum	22.66	26.74	25.77	25.24	59.94	52.30	47.16	44.60	25.58	21.23	16.35	13.21
Lower quartile	39.11	44.53	51.41	61.17	77.34	77.92	73.78	62.25	51.39	42.14	38.59	37.23
Median	51.16	54.15	79.20	80.66	103.27	103.01	106.47	85.04	74.08	62.13	53.99	47.22
Upper quartile	69.56	79.96	100.57	111.88	142.93	167.04	142.10	120.97	98.82	78.58	81.69	66.14
Upper 10%	155.30	115.30	132.40	138.70	178.60	201.10	203.10	153.60	123.80	96.90	95.30	98.80
Upper 1%	203.00	169.80	163.80	214.60	291.00	311.50	261.40	177.60	219.60	130.90	204.00	203.70
Maximum	203.00	169.76	163.79	214.64	291.00	311.49	261.37	177.76	219.61	130.89	204.03	203.71
Skewness	1.67	1.46	0.52	1.07	1.36	1.11	0.91	0.71	1.29	0.59	1.87	2.32
Kurtosis	1.86	1.77	-0.19	1.75	2.35	1.29	0.15	-0.63	3.00	0.08	5.93	7.66

Table 27. Statistical summary of monthly suspended sediment transport or yield at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

	Monthly Sediment Yield (Mg/mo)											
Attribute	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Sample size	39	39	39	40	40	40	40	40	40	40	40	40
Average	48,030	30,941	51,768	62,688	90,950	113,177	99,052	78,780	83,224	50,442	56,347	52,471
Standard deviation	65,466	42,507	56,375	78,663	84,930	113,174	96,485	70,899	93,347	41,178	63,321	71,131
Coeff. of variation, %	136.3	137.4	108.9	125.5	93.4	100.0	97.4	90.0	112.2	81.6	112.4	135.6
Minimum	1,095	907	461	324	4,499	3,707	3,469	5,294	3,234	3,361	2,194	1,471
Lower quartile	4,602	4,442	7,427	11,726	20,412	37,007	19,058	25,125	22,066	20,081	9,439	6,435
Median	18,326	13,731	33,280	31,103	60,000	75,070	68,746	42,060	36,609	39,590	25,218	16,647
Upper quartile	69,869	33,676	83,278	88,353	148,409	160,780	137,985	133,374	119,966	63,493	102,320	73,636
Upper 10%	147,850	101,880	138,930	154,310	198,780	263,550	270,620	166,030	223,070	118,360	135,870	169,270
Upper 1%	252,010	171,850	251,720	380,640	372,390	528,780	335,860	284,800	363,120	170,660	300,970	301,800
Maximum	252,006	171,849	251,718	380,641	372,390	528,776	335,858	284,802	363,122	170,661	300,973	301,798
Skewness	1.70	2.09	1.65	2.38	1.32	1.83	1.11	1.23	1.77	1.30	1.84	1.84
Kurtosis	2.12	3.94	3.07	6.73	1.75	3.91	0.30	1.01	2.64	1.26	4.33	3.10





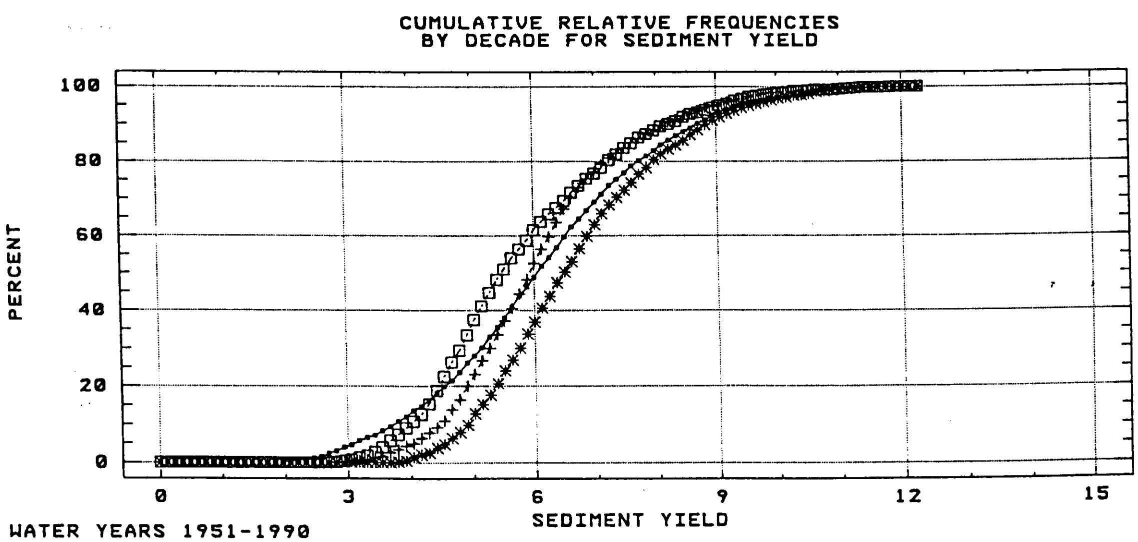


Figure 15. Cumulative frequency distributions of discharge or flow (ln cfs), sediment concentration (ln mg/L), and sediment transport or yield (ln Mg/d). Symbols for each decade: • for 1950s; + for 1960s; ∗ for 1970s; and for 1980s.

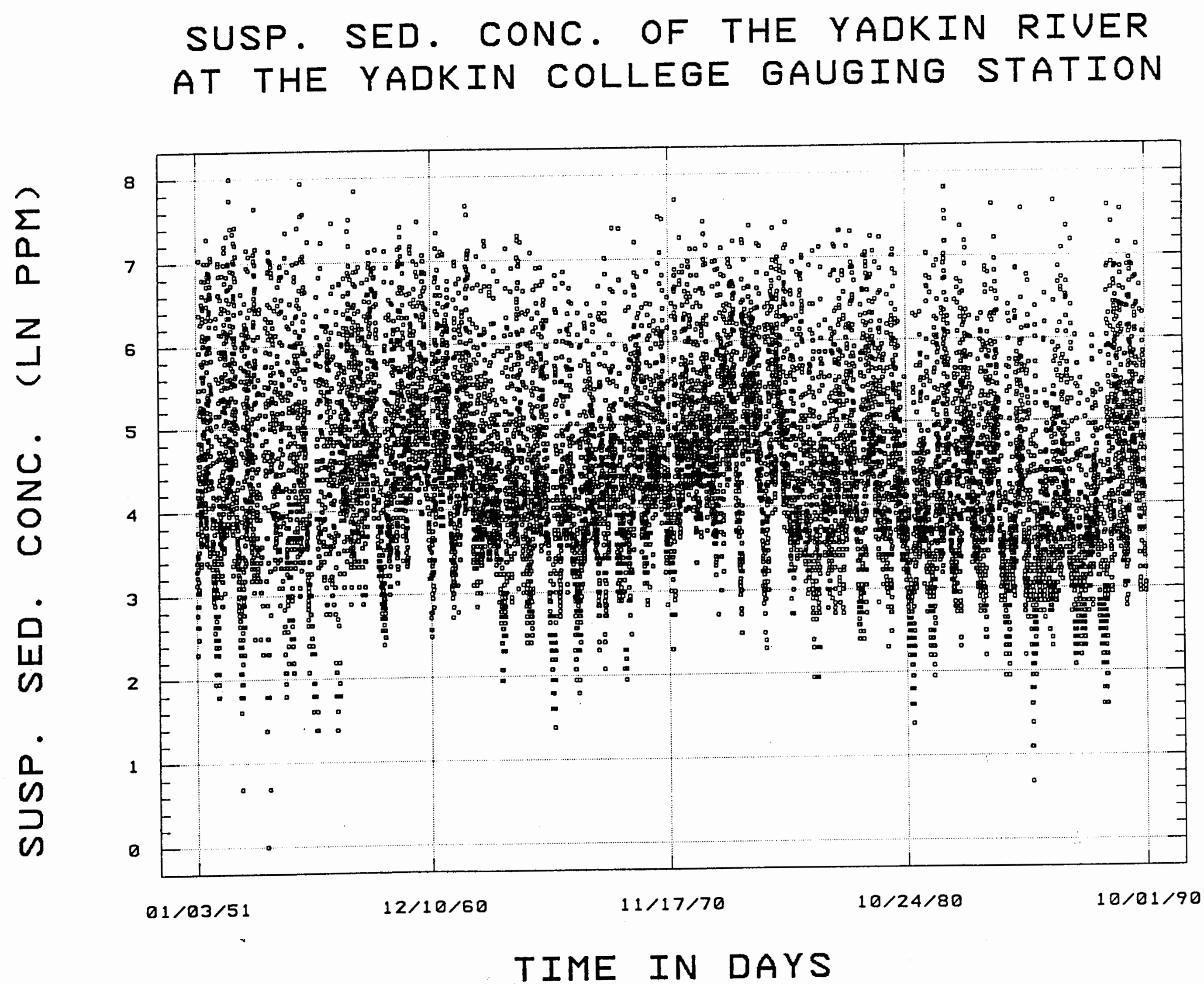


Figure 16. Time-series of daily sediment concentrations (n = 14,516) of the Yadkin River at Yadkin College, North Carolina (U.S.G.S. 02116500).

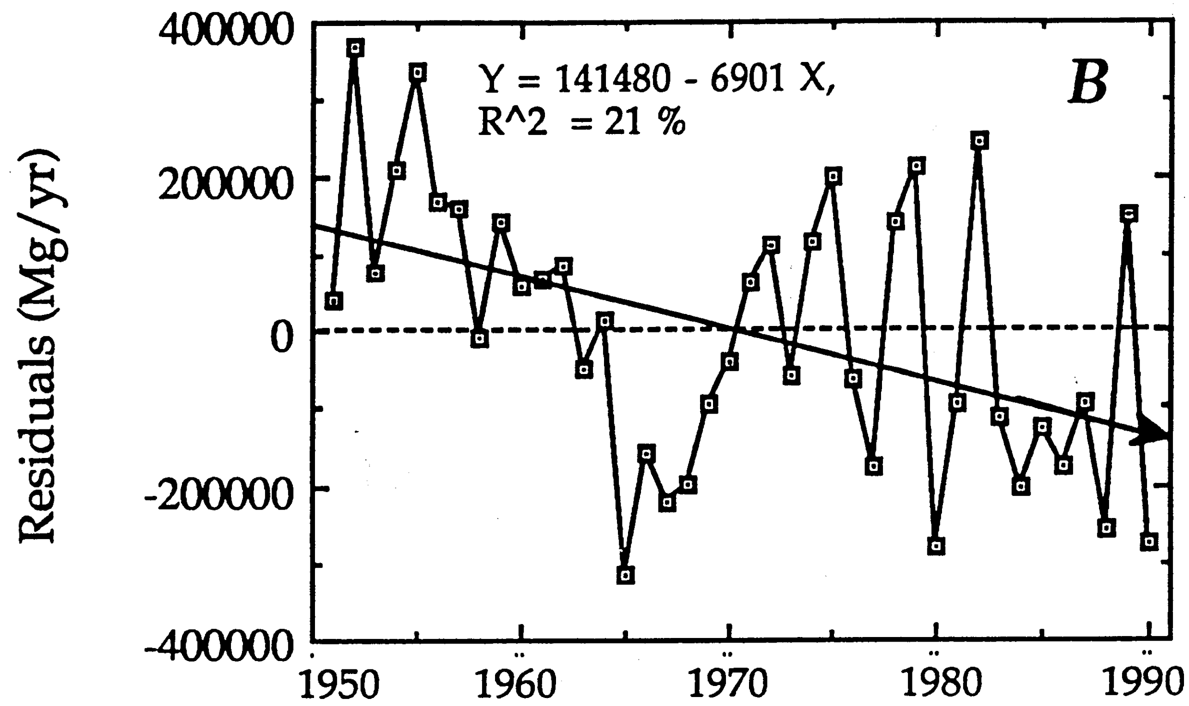


Figure 17. Time-ordered residuals of linear regression illustrated in Figure 14 illustrating significant improvement of 6901 Mg/yr less sediment being transported by the Yadkin River since 1951.

The trends in time-ordered residuals of monthly sediment regressions (n = 477 months of sediment and discharge data) were tested with the non-parametric seasonal Kendall test, a test suitable for data with skewed distributions, seasonality, and serial dependence (Hirsch and Slack 1984), characteristics that were pronounced in the monthly data. The seasonal Kendall test indicated significantly negative trends of sediment transport and log-transformed sediment concentrations. Figure 18 illustrates the time-ordered residuals of sediment concentration trends through the 40-year record. The seasonal Kendall and Sen slope estimators of monthly sediment transport indicated that sediment transport was decreasing at about 0.0115 Mg ha^{-1} over the 477-month record. A 90% confidence interval ($C.I._{0.9}$) on the true negative slope was estimated to be between -0.0078 and -0.0153 Mg $ha^{-1}yr^{-1}$ (Gilbert 1987). These decreases in sediment transport are equivalent to about 0.46 Mg·ha^{-1} over the full 40 years with a $C.I._{0.9}$ of ±0.148 Mg $ha^{-1}yr^{-1}$.

Daily concentration data were also evaluated for trends over the 40-yr period, and several regression models that were constructed had remarkably high predictive capabilities of log-transformed concentration (Table 28). Time-ordered residuals of the simplest of these models (with but two independent variables) are plotted in Figure 19. Like the annual and monthly analyses, the residuals of the daily regressions illustrate a decreasing monotonic slope of sediment concentration over time.

The monthly data of discharge and sediment transport demonstrated that the river system functions very differently in summer and winter seasons (Fig. 20). Yet, the Yadkin produces a pronounced counter-clockwise pattern between seasonal discharge and sediment concentration. Up to twice as much sediment per unit discharge is produced during the months of May through October compared to the months of November through April (Fig. 20). We attribute the Yadkin's sediment-discharge hysteresis (Fig. 20) mainly to the seasonality of rainfall erosivity (Fig. 21) and overland runoff (Wischmeier and Smith 1965), and to the generally large availability of transportable sediment within the basin. Many rivers exhibit a clock-wise loop of monthly discharge and sediment concentration, a pattern usually explained by a depletion of transportable sediment during months of high flow (Nordin and Beverage 1965; Wood 1977; Whitfield and Schreier 1981). In the Yadkin, there appears to be little depletion of transportable sediment at high flows. In the western Carolina Piedmont, more than half of the annual erosivity of rainfall occurs between June and August (Wischmeier and Smith 1965), when summer convective storms generate large volumes of overland runoff that move erodible soil rapidly through the river system. As a result, intensity of rainfall and of overland runoff greatly elevates sediment concentrations per unit of river discharge during summer months (Fig. 20).

Based on the pronounced hysteresis of sediment concentration and river discharge (Fig. 20) and the basin's rapid land use changes, we hypothesized that the 20th century decreases in cultivated land had decreased the fraction of river sediment that was derived from erosion of cultivated fields during summer months when precipitation intensity and erosivity of overland runoff are greatest. To evaluate whether sediment was decreasing homogeneously in all months of the year, a Chi-square test was used following procedures similar to those outlined by van Belle and

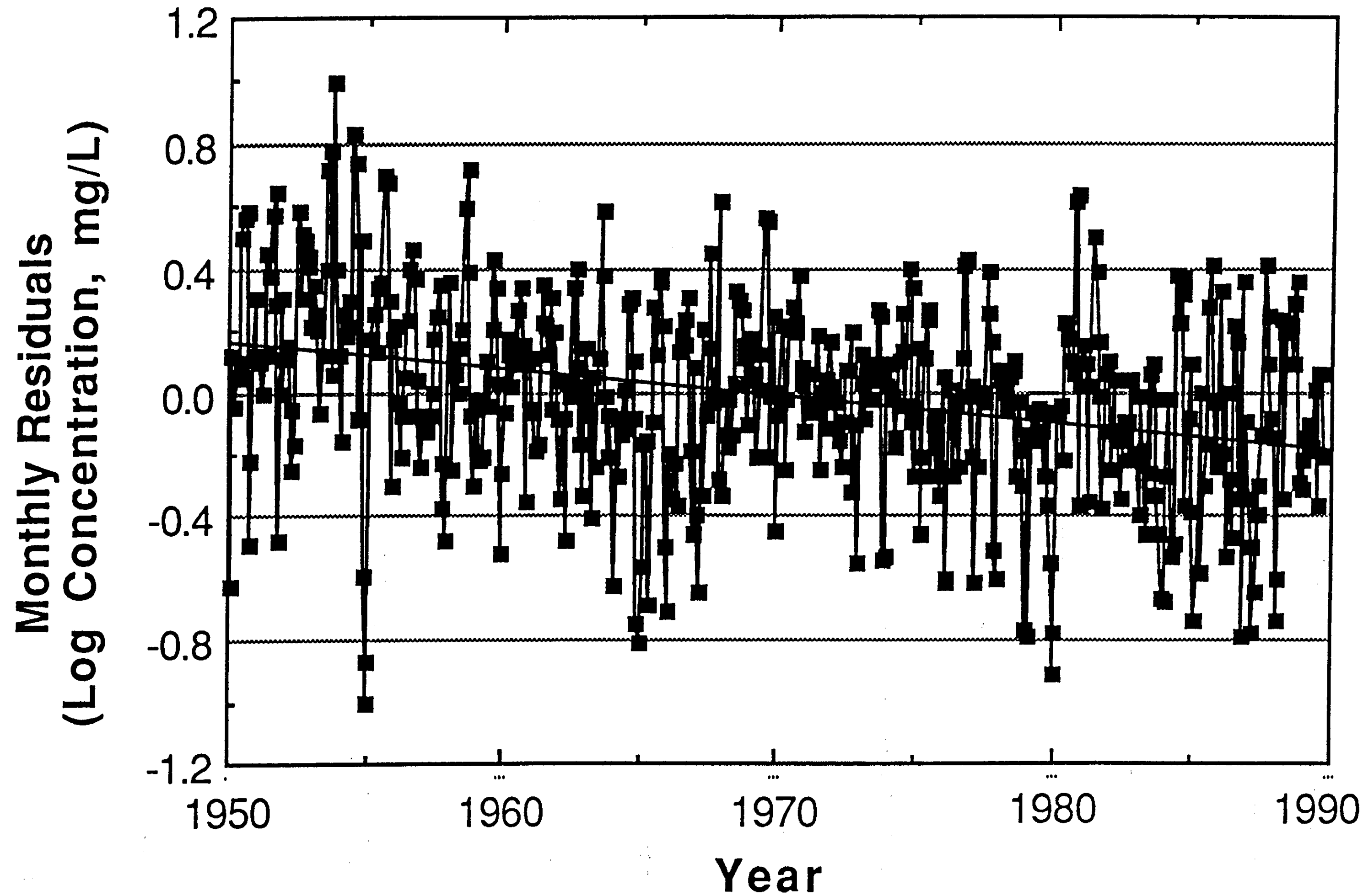


Figure 18. Time-ordered residuals of linear regression of log-transformed volume-weighted mean monthly concentration (log mg/l) and discharge (log cms) illustrating a significant decreasing trend in sediment concentration in the Yadkin River since 1951.

Table 28. Descriptive statistics of regression models constructed to estimate daily log transformed suspended sediment concentration at Yadkin College, North Carolina in the Yadkin River, 1951 to 1990.

Dependent Variables	R^2 %	Durbin-Watson Statistic	Std Error
*Model 1** 1-day lag Ln(SSConc) Adjusted Precipitation	85.0	2.03	0.44
Model 2 1-day lag Ln(SSConc) Ln(Flow) Mean Precipitation	82.0	1.84	0.48
Model 3 1-day lag Ln(SSConc) 1-day lag Ln(Flow) Ln(Flow) Adjusted Precipitation	89.0	2.10	0.39

* Preferred due to simplicity of expression

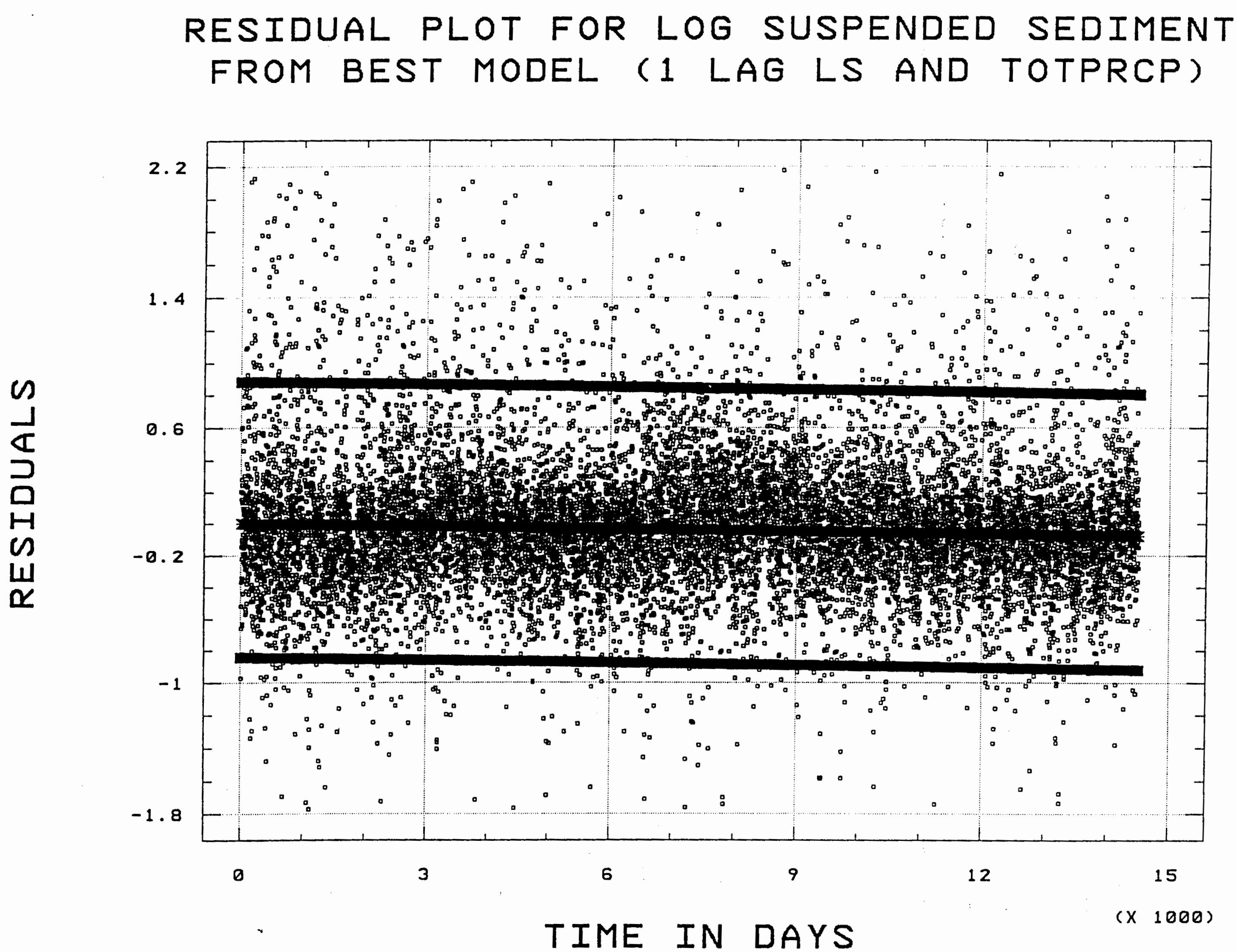


Figure 19. Time-ordered residuals of linear regression of log-transformed daily sediment concentration (ln mg/l) and daily discharge (ln cfs) illustrating a significant decreasing trend in sediment concentration in the Yadkin River since 1951.

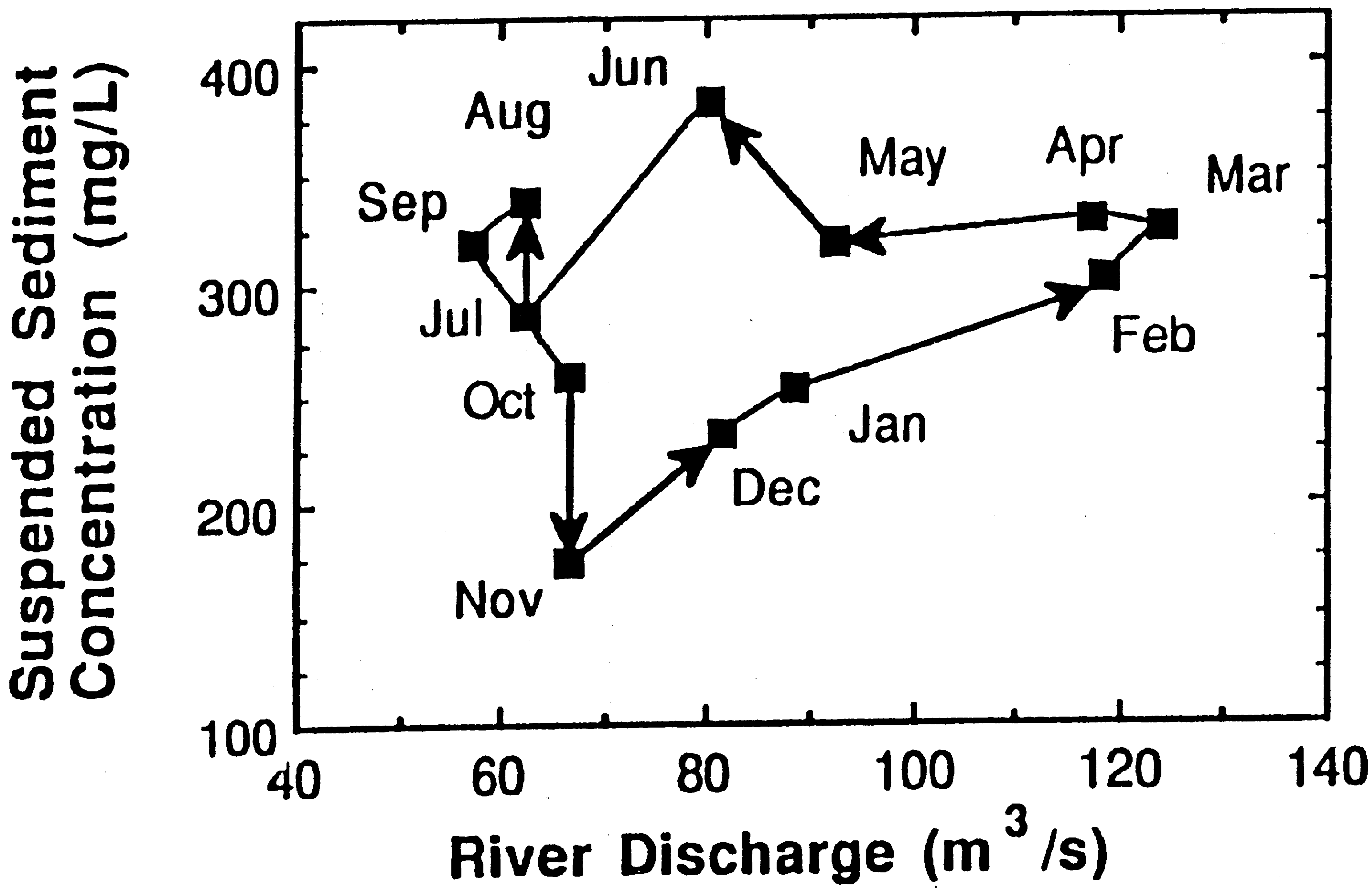


Figure 20. Monthly sediment concentration dynamics of the Yadkin River, North Carolina in which volume-weighted concentrations of monthly suspended sediment are illustrated as a function of mean monthly discharge.

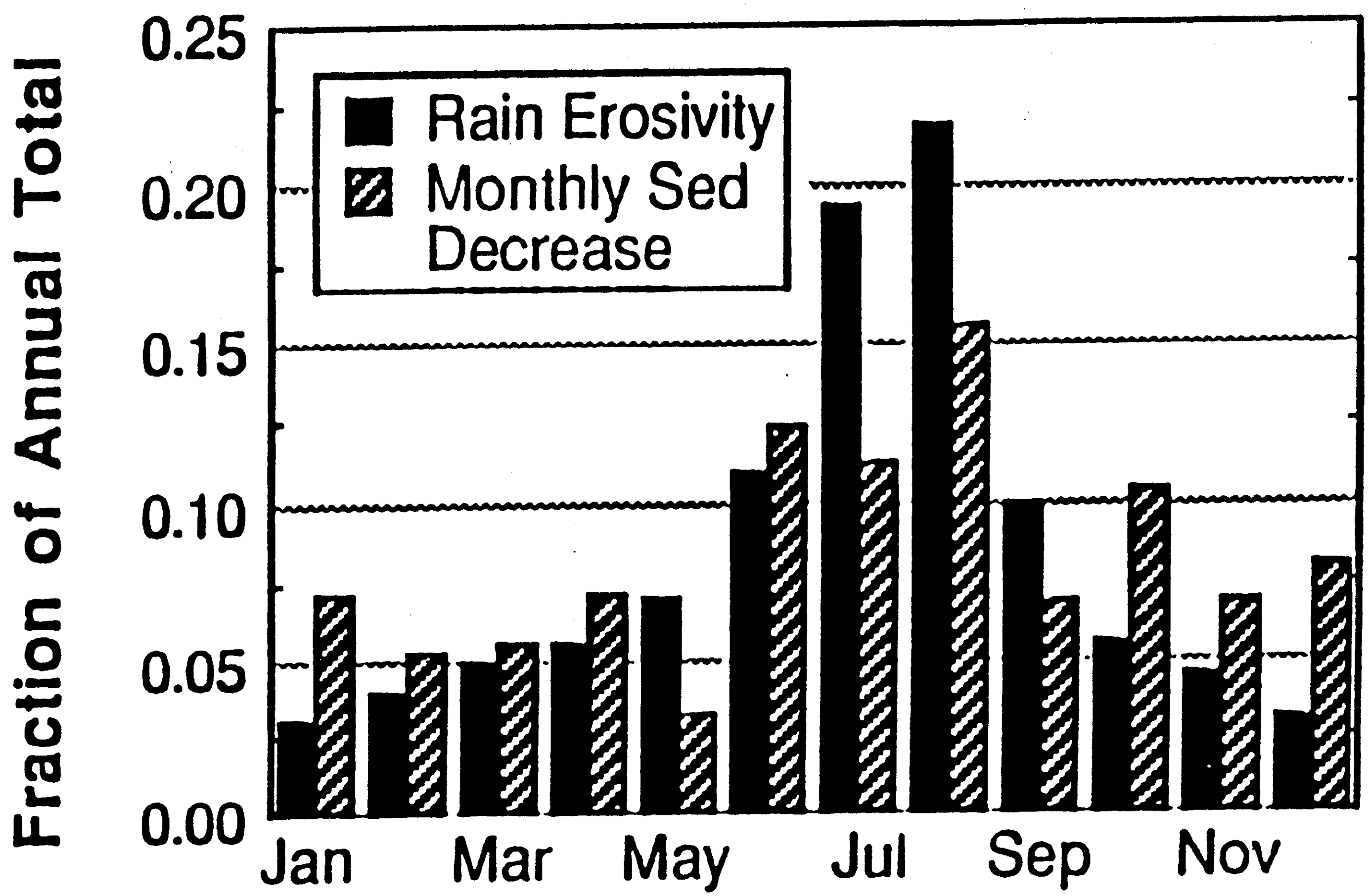


Figure 21. Monthly sediment concentration dynamics of the Yadkin River, North Carolina in which monthly rainfall erosivity is compared with monthly sediment concentration decreases over the 40-yr estimated according to the Van Belle and Hughes (1984) Chi-square test of monthly homogeneity.

Hughes (1984) and Gilbert (1987). The results indicated that negative trends in sediment over the 40 years were present in all 12 months of the year, and that decreases in sediment transport were most pronounced during June through August, compared with the other nine months of the year (Fig. 21). On the other hand, significantly different rates of decrease were not detected among months, based on this Chi-square test. The volume of transportable sediment in storage may simply be large enough that the river continues to respond with relatively high concentrations to intense summer storms.

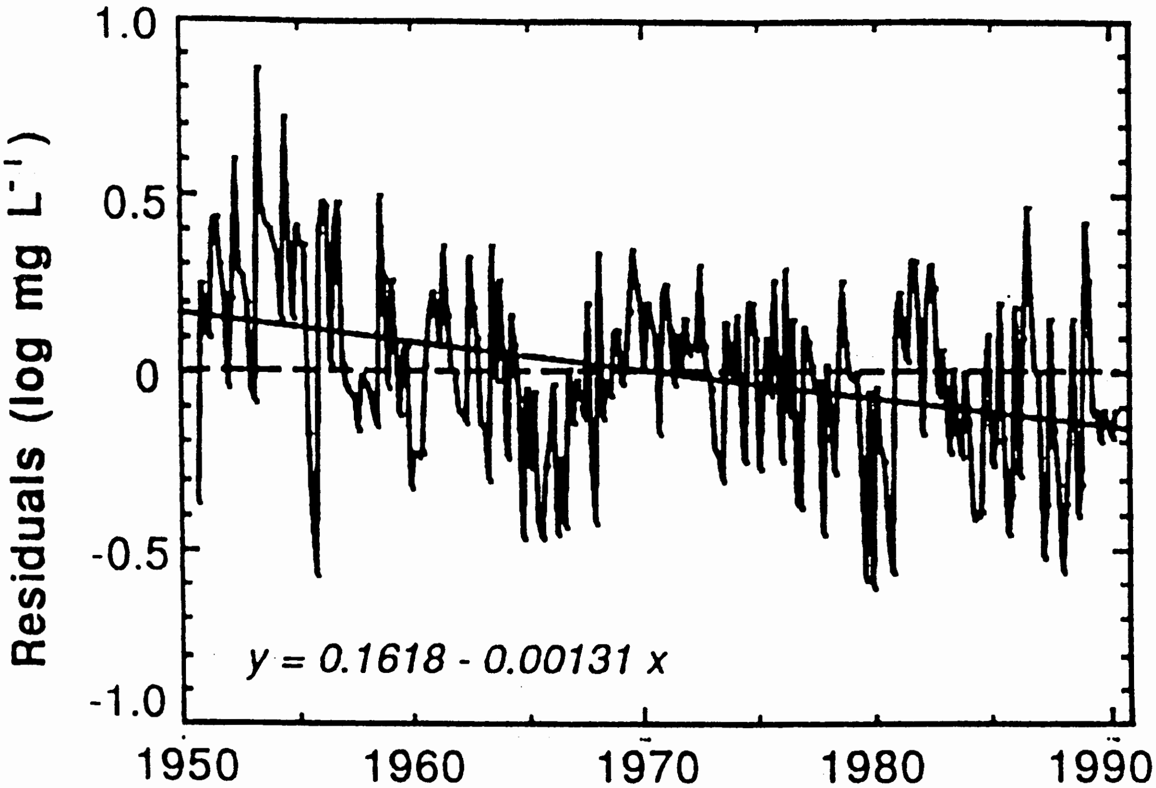
To further evaluate whether sediment was decreasing homogeneously in summer and winter seasons, the data were split by season, and time-ordered residuals were evaluated in the two seasons of the year. Figure 22 illustrates the significant negative trend that is found in both summer and winter seasons, indicating improvements in water quality throughout the year.

Changes in Land Use-Land Cover and Gross Soil Erosion and the Implications to Water Quality Management

This detailed four-decade analysis demonstrates that improvements in Yadkin River water quality are occurring, albeit at a relatively slow pace. The estimated reduction in sediment transport of about 0.0115 Mg $ha^{-1}y^{-1}$ is equivalent to an annual reduction of 0.83% of the mean annual transport of 1.39 Mg $ha^{-1}y^{-1}$. The Yadkin is annually transporting about 30% less suspended sediment than it was in 1951 at the beginning of the sediment sampling program. Nonetheless, based on the estimate of Meade et al. (1990) that the region's rivers are currently transporting on the order of 10-fold more sediment than they were prior to forest clearing and agricultural expansion in the 18th century, the river will require many decades before its water quality will appreciably improve from its present sediment-enriched state.

Sediment delivery ratios (the quotient of sediment transport and gross erosion) were estimated for the 1950s and the 1980s, with and without recent agricultural BMPs. These are summarized in Table 29 and Figure 23. Although variable from year to year, such analyses suggested that 6.8 to 14.1% of the rural erosion had been delivered and transported in the river system; in the 1980s, such annual percentages ranged from 2.5 to 16.4%.

The spatial and temporal analyses conducted in this report suggests that watershed management can play a significant role in controlling the rate at which the water quality of this large river improves. The shrinking agricultural landbase had a significant impact on gross erosion in the basin, but as of the late 1980s, erosion from cultivated fields was still higher than nominally acceptable rates. Recent conservation planning and BMP implementation, as shown in the results of this study, are apparently greatly reducing soil losses from agricultural lands. The Yadkin, however, is no longer a predominately agricultural basin, and as land use has changed, so have the sources of sediment. As the basin is increasingly impacted by urban development and construction activities, watershed management needs to be implemented with great expertise if it is to effectively control the soil erosion problem at the river-basin scale. The relatively slow recovery of the Yadkin River system indicates that controlling new sediment sources is critical to the continued improvement of river water quality.



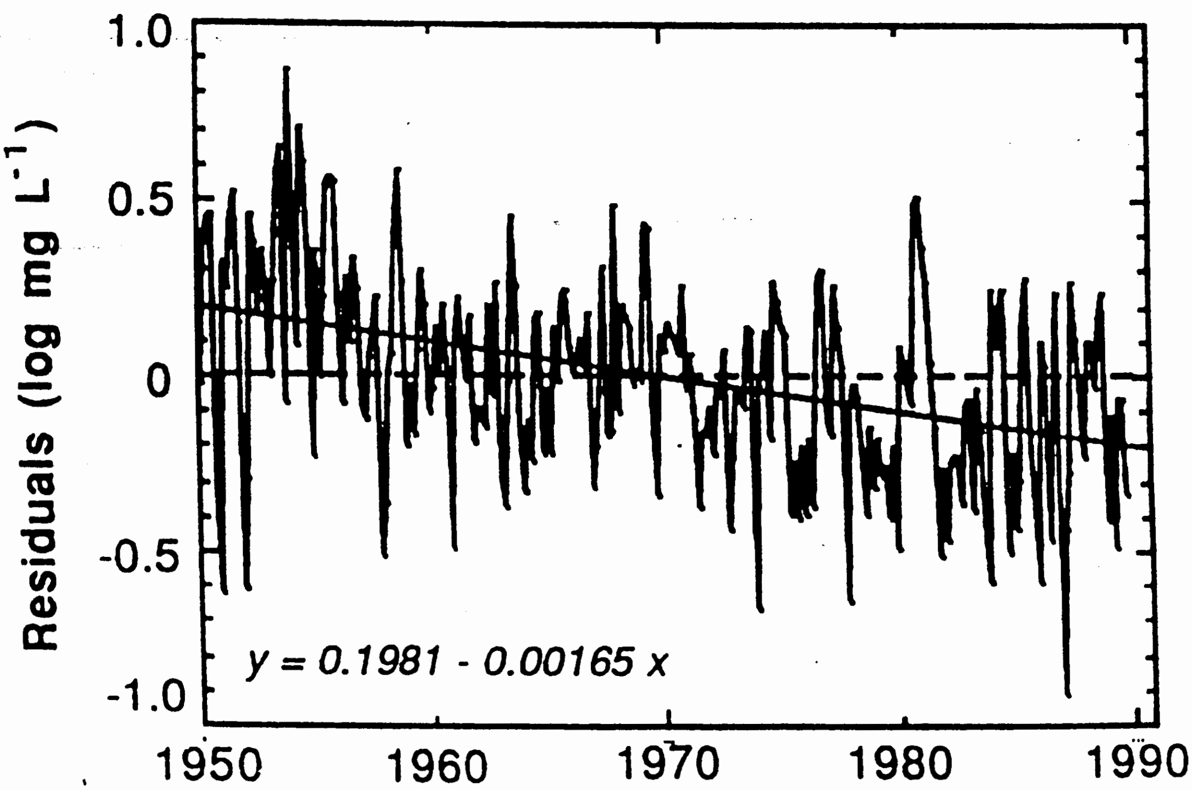
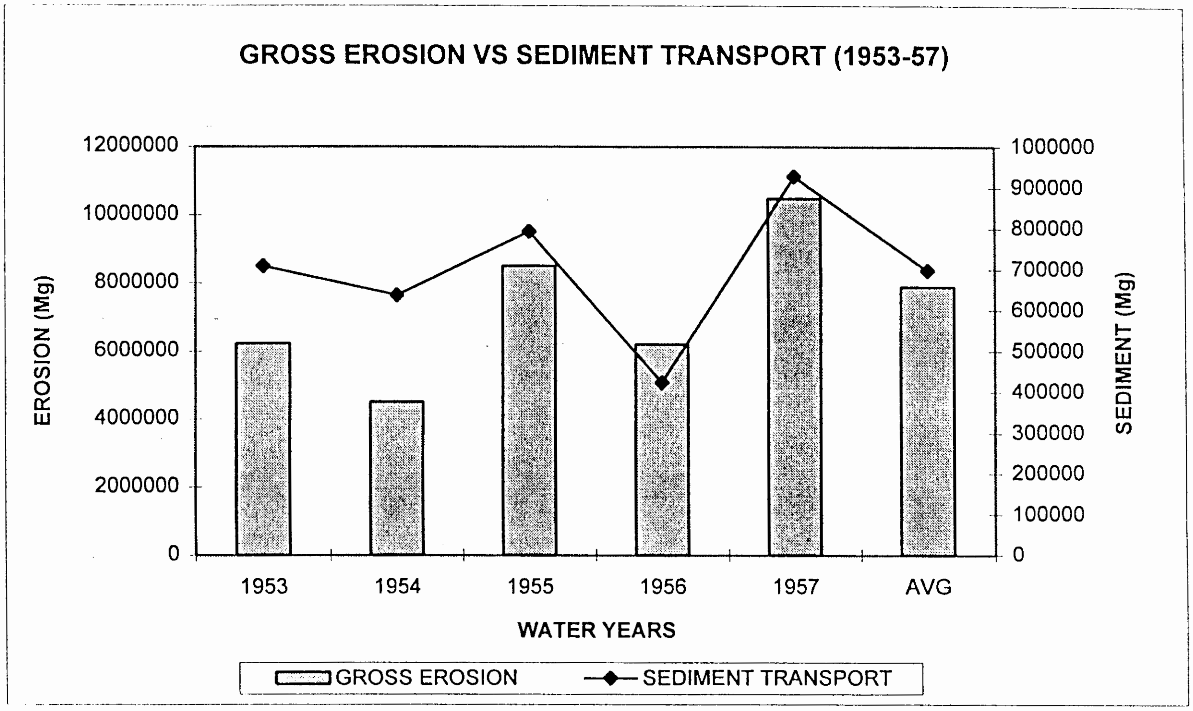


Figure 22. Time-ordered residuals of regression of log-transformed monthly sediment concentration and monthly discharge for dormant and growing seasons illustrating a significant decreasing trend since 1951 in sediment concentrations in both seasons in the Yadkin River.

Table 29. Annual basinwide estimates of gross erosion from rural sources (Mg/ha), sediment transport (Mg/ha), rural sediment delivery ratios (transport/gross erosion), precipitation (cm), average R ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot y^{-1}$), and area weighted average R ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot y^{-1}$) for simulation years 1953-1957 and 1986-1990.

ESTIMATES (1950s)	**1953**	**1954**	**1955**	**1956**	**1957**	**AVG**
Gross Erosion (Mg)	6235896	4516596	8506918	6199741	10494819	7895476
Sediment Transport (Mg)	708694	636012	792630	423059	927443	697567
Sediment Delivery Ratio	0.114	0.141	.093	0.068	0.088	0.088
Total Precipitation	110	89	110	92	135	107
Annual Average R	2919	2176	3678	3361	4908	3409
Area Weighted Average R	2887	2132	3405	3311	5250	3397

ESTIMATES (1980s)	**1986**	**1987**	**1988**	**1989**	**1990**	**AVG**
Gross Erosion (Mg)	3009947	8100745	3964963	7416507	6650685	6131749
Sediment Transport (Mg)	203688	969825	98544	904118	1087931	652821
Sediment Delivery Ratio	0.068	0.120	0.025	0.122	0.164	0.106
Total Precipitation	87	140	90	134	121	114
Annual Average R	1901	4969	2428	4331	3574	3441
Area Weighted Average R	1879	5376	2370	4471	3872	3594



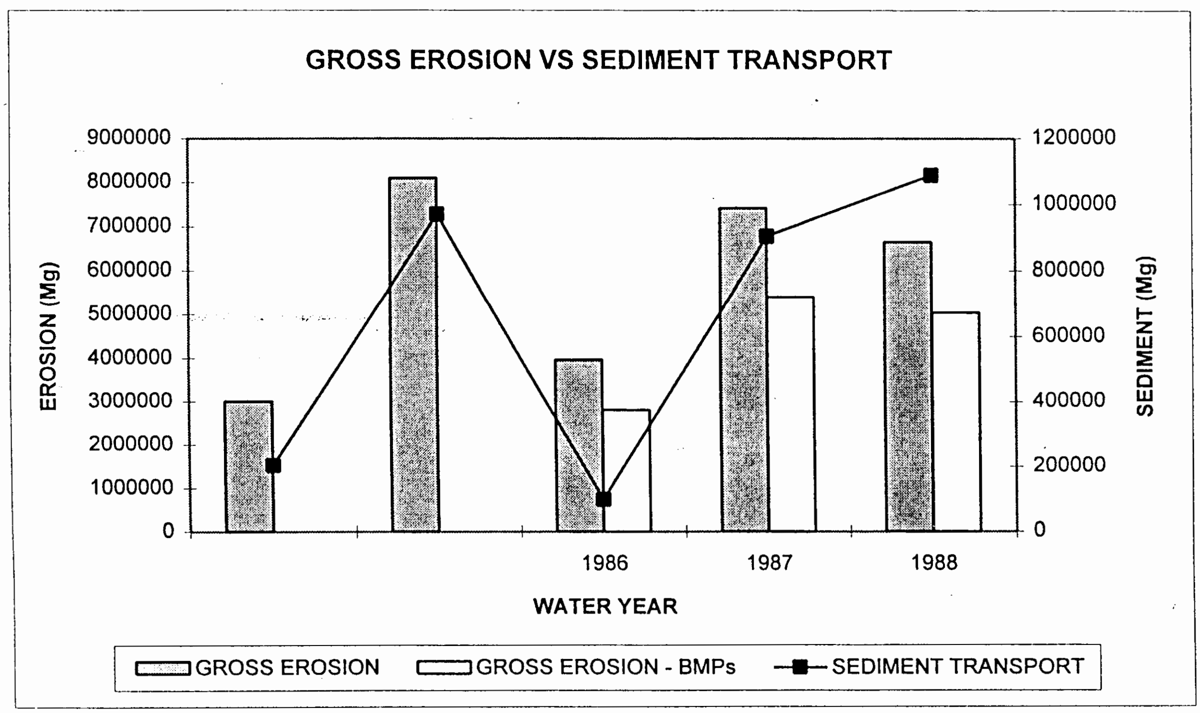


Figure 23. Gross erosion estimates from rural areas (Mg) compared to sediment transport (Mg) in the Yadkin River for 1953-1957 (top) and 1986-1990 (bottom). Reductions in gross erosion due to agricultural best management practices in the late 1980s are illustrated by second bar in 1988, 1989, and 1990.

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GLOSSARY

Abbreviations (units of measurement)

cfs	cubic feet per second
cms	cubic meters per second
ha	hectares (10^4 m^2)
km^2	square kilometers
l	liter
Mg	Megagram, metric ton (10^6 grams)
$Mg \cdot ha^{-1} \cdot y^{-1}$	Megagrams per hectare per year
$Mg \cdot km^{-2} \cdot y^{-1}$	Megagrams per square kilometer per year
mg/l	milligrams per liter
MJ	Megajoule
ppm	parts per million
$t \cdot ha^{-1}$	metric ton per hectare

APPENDICES

Appendix A

Road Buffer Widths

CLASS	DESCRIPTION	DISTANCE
Heavy Duty Roads	Interstate, four lane highways	300 feet
Medium Duty Roads	State Highways, county roads	100 feet
Light Duty Roads	County and city roads	80 feet
Unimproved Roads	Unpaved rural roads	40 feet
Trails	Logging and jeep trails	20 feet

Appendix B

C Factor Values Used in USLE Model of Rural Areas from
The Universal Soil Loss Equation with Factor Values for North Carolina

LULC CODE	DESCRIPTION	WEIGHT	AREA (acres)	C FACTOR
AG	Rowcrop (Pre-1991)			0.463
	Corn	0.492	30250	
	Tobacco	0.646	13768	
	Soybeans	0.428	17726	
	Wheat	0.100	7706	
AG	Rowcrop (Post-1991)			0.124
AGH	Con-till row/cover RdL MT corn/SG (line 104)			0.150
C	Cleared/Disturbed			0.200
CP	Cleared-Pasture (Table 9, p.64) 50% cover, avg drop of thrufall 6.5'; 50% ground cover			0.08
F	Forestland			0.0005
H	Covercrop			0.100
P	Pasture (permanent) 50% cover, grass cover 70% cover contacts ground			0.024
HP	Hay/Pasture (mean of H and P)			0.062
O	Orchard (line 166, p. 57) Undist. cover 3 yr., 25% tree cover			0.060
W	Woodland (Dissmeyer and Foster (1984)			0.005
WP	Woodland pasture (avg. W and P)			0.015

Appendix C

U.S.D.C. Agriculture Census Data by County and Four County Totals

FOUR COUNTY STATISTICS	1945	1950	1954	1959*	1964	1969	1974	1978	1982	1987
# OF FARMS	15418	16019	14460	10726	9081	7714	5975	5571	5131	4298
FOUR COUNTY AREA (ha)	533808	533808	533808	533808	533808	530312	530312	530312	528309	528309
PERCENT IN FARMLAND	73.11	72.45	65.77	57.53	52.37	45.43	37.14	36.11	34.36	31.15
TOTAL FARMLAND (ha)	390260	386723	351075	307078	279582	240924	196971	191497	181529	164576
AVG. FARM SIZE (ha)	25.31	24.14	24.28	28.63	30.79	31.23	32.97	34.37	35.38	38.29
CROPLAND TOTAL (ha)	142064	130272	116527	101788	94910	98961	90413	93047	90500	85363
CROPLAND HARVESTED	98154	81797	79838	65825	54697	43399	47587	52240	51544	46149
CROPLAND PASTURED	13759	13054	12134	8896	14605	29991	29854	27176	27563	25652
OTHER CROPLAND	30149	35421	24556	27067	25608	25571	12972	13632	11393	13562
WOODLAND TOTAL (ha)	204711	206307	188641	159152	141758	100124	71093	73132	65438	55243
WOODLAND PASTURED	21723	27528	29410	19092	18422	14440	11142	16145	13937	13400
OODLAND NOT PASTURED	182988	178779	159231	140060	123336	85684	59951	56987	51501	41843
OTHERLAND TOTAL (ha)	43487	50144	45907	46139	43766	41839	35450	25306	25589	23970
OTHER PASTURE	25087	29192	30291	29230	28383	0	0	0	0	0
OTHERLAND	18400	20953	15617	16909	15382	0	0	0	0	0
PASTURELAND TOTAL (ha)	60569	69774	71834	57217	61410	44431	40995	52964	51749	49444
CROP BREAKDOWN (ha)										
CORN TOTAL	36032	27243	22261	18563	15242	16351	17976	19212	18366	14421
SORGHUM TOTAL	23	36	450	701	393	199	428	482	2	129
SMALL GRAINS TOTAL	14081	16120	15103	15741	8177	5240	6249	3764	4429	4552
SOYBEAN TOTAL	2547	1287	1843	1951	6062	3616	4357	5803	7593	6754
COWPEAS TOTAL	1446	491	283	283	65	0	0	0	0	0
HAY TOTAL	22645	25322	27151	21004	16669	10225	12086	14254	13700	16893
FIELD SEED TOTAL	1498	1833	1416	891	255	0	0	0	0	0
IRISH POTATO	1191	583	168	149	49	187	242	101	102	9
SWEET POTATO	883	142	53	51	21	0	32	11	18	3
COTTON	191	107	102	45	22	2	0	2	0	0
TOBACCO	12958	12267	13091	9070	8157	6855	7223	8998	6604	4539
VEGETABLES TOTAL	567	229	172	198	123	265	108	189	384	251
ORCHARDS TOTAL	3210	2142	1608	1082	809	764	895	803	579	716

FORSYTH	1945	1950	1954	1959*	1964	1969	1974	1978	1982	1987
# OF FARMS	3370	3294	2927	2031	1622	1488	1072	929	893	735
COUNTY AREA (ha)	109818	109818	109818	109818	109818	108393	108393	108393	106834	106834
PERCENT IN FARMLAND	71.33	67.26	58.76	47.94	41.12	34.67	27.61	24.65	22.61	20.88
TOTAL FARMLAND (ha)	78333	73862	64534	52641	45161	37577	29931	26723	24151	22312
AVG. FARM SIZE (ha)	23.24	22.42	22.05	25.92	27.84	25.25	27.92	28.77	27.05	30.36
CROPLAND TOTAL (ha)	35921	32814	27541	23979	19803	17614	14528	14469	12245	11929
CROPLAND HARVESTED	26187	20051	18840	14401	10524	7161	6908	7708	6558	6005
CROPLAND PASTURED	2960	3146	2375	2304	3614	4679	5509	4431	3540	3913
OTHER CROPLAND	6775	9616	6326	7274	5665	5774	2111	2330	2147	2011
WOODLAND TOTAL (ha)	33055	31773	28352	20495	18401	13308	9716	8796	7633	6971
WOODLAND PASTURED	3887	4699	5065	4179	3490	2662	1943	1924	2173	1836
OODLAND NOT PASTURED	29168	27074	23287	16316	14911	10646	7773	6872	5459	5136
OTHERLAND TOTAL (ha)	9357	9276	8641	8168	6919	6655	5687	3446	4274	3412
OTHER PASTURE	3608	4335	5349	4840	3987	0	0	0	0	0
OTHERLAND	5748	4941	3292	3328	2932	0	0	0	0	0
PASTURELAND TOTAL (ha)	10454	12180	12789	11323	11090	7340	7452	7456	7200	7049
CROP BREAKDOWN (ha)										
CORN TOTAL	7321	5293	4536	3679	2747	1914	2029	1962	1623	1191
SORGHUM TOTAL	7	9	220	216	165	49	68	98	0	53
SMALL GRAINS TOTAL	6067	6717	5305	4411	2223	1355	1208	773	774	737
SOYBEAN TOTAL	284	261	322	418	638	422	550	629	866	498
COWPEAS TOTAL	247	138	71	48	10	0	0	0	0	0
HAY TOTAL	8467	7369	7437	4953	3240	2074	2251	2844	2159	3026
FIELD SEED TOTAL	598	745	597	355	85	0	0	0	0	0
IRISH POTATO	221	53	36	29	6	38	23	8	12	2
SWEET POTATO	244	46	35	20	9	0	4	3	6	0
COTTON	69	50	43	19	9	0	0	0	0	0
TOBACCO	2686	2283	2304	1556	1362	1209	1018	1518	1105	686
VEGETABLES TOTAL	382	114	56	100	47	72	38	55	46	49
ORCHARDS TOTAL	325	156	192	71	47	21	11	23	0	28

SURRY	1945	1950	1954	1959*	1964	1969	1974	1978	1982	1987
# OF FARMS	3711	4306	4297	3397	2928	2539	1958	1839	1605	1314
COUNTY AREA (ha)	139085	139085	139085	139085	139085	138826	138826	138826	139691	139691
PERCENT IN FARMLAND	71.74	76.72	76.74	70.41	64.34	58.59	46.59	45.50	42.00	38.59
TOTAL FARMLAND (ha)	99775	106700	106728	97925	89486	81345	64679	63173	58667	53913
AVG. FARM SIZE (ha)	26.89	24.78	24.84	28.83	30.56	32.04	33.03	34.35	36.55	41.03
CROPLAND TOTAL (ha)	34738	36094	34200	29873	29944	31637	28550	29652	29172	27371
CROPLAND HARVESTED	23251	22964	23525	19441	16057	11600	14378	16626	15624	14296
CROPLAND PASTURED	4180	3867	3605	2391	4964	10303	9360	8293	8561	8413
OTHER CROPLAND	7305	9263	7070	8041	8923	9735	4813	4733	4987	4662
WOODLAND TOTAL (ha)	54892	56817	58679	52690	45595	35203	23844	24513	21399	18983
WOODLAND PASTURED	4641	5174	8885	4849	4469	3520	2384	5714	4000	4596
OODLAND NOT PASTURED	50251	51642	49794	47841	41126	31682	21460	18799	17399	14387
OTHERLAND TOTAL (ha)	10146	13790	13849	15362	13921	14505	12285	9007	8095	7559
OTHER PASTURE	5743	8065	8939	9520	9210	0	0	0	0	0
OTHERLAND	4403	5724	4911	5842	4711	0	0	0	0	0
PASTURELAND TOTAL (ha)	14564	17106	21429	16760	18643	13824	11744	17848	15465	16531
CROP BREAKDOWN (ha)										
CORN TOTAL	9737	8515	7538	6624	4884	4147	5707	6788	5945	4352
SORGHUM TOTAL	2	1	25	94	42	47	131	76	0	0
SMALL GRAINS TOTAL	2172	2555	1896	2466	1383	1143	1251	721	692	1003
SOYBEAN TOTAL	284	141	191	275	1224	393	528	1153	2066	2167
COWPEAS TOTAL	188	21	20	23	8	0	0	0	0	0
HAY TOTAL	4299	6255	7362	5936	4727	2646	3455	3733	3904	4742
FIELD SEED TOTAL	89	121	125	54	4	0	0	0	0	0
IRISH POTATO	283	67	45	32	11	83	51	30	26	4
SWEET POTATO	191	25	8	12	4	0	21	1	5	2
COTTON	0	0	0	0	0	0	0	0	0	0
TOBACCO	5281	5532	5911	4019	3712	3136	3447	4320	3110	2288
VEGETABLES TOTAL	62	41	34	23	17	103	59	50	140	91
ORCHARDS TOTAL	866	408	333	138	49	42	71	65	52	42

WILKES	1945	1950	1954	1959*	1964	1969	1974	1978	1982	1987
# OF FARMS	5348	5075	4088	2730	2354	1794	1317	1349	1332	1204
COUNTY AREA (ha)	198138	198138	198138	198138	198138	196066	196066	196066	194826	194826
PERCENT IN FARMLAND	68.59	65.12	54.75	45.18	41.71	32.74	26.42	27.17	26.58	23.27
TOTAL FARMLAND (ha)	135897	129023	108477	89523	82649	64188	51809	53270	51782	45331
AVG. FARM SIZE (ha)	25.41	25.42	26.54	32.79	35.11	35.78	39.34	39.49	38.88	37.65
CROPLAND TOTAL (ha)	35584	29590	24539	20564	18576	21091	19162	20052	20326	19026
CROPLAND HARVESTED	25098	18768	15982	13041	10677	8521	8037	9384	9659	9505
CROPLAND PASTURED	3591	2897	3248	3158	4358	9223	8641	8524	9278	7973
OTHER CROPLAND	6894	7926	5309	4365	3541	3347	2484	2144	1389	1548
WOODLAND TOTAL (ha)	83971	81546	70099	57455	52064	32962	23313	25606	23717	18703
WOODLAND PASTURED	11251	13229	11849	7062	7293	5274	3730	5424	4555	4087
OODLAND NOT PASTURED	72721	68316	58251	50394	44772	27688	19583	20182	19162	14616
OTHERLAND TOTAL (ha)	16342	17887	13839	11504	12195	10136	9320	7612	7739	7603
OTHER PASTURE	10915	12106	9911	7826	8517	0	0	0	0	0
OTHERLAND	5427	5781	3928	3677	3677	0	0	0	0	0
PASTURELAND TOTAL (ha)	25757	28232	25008	18046	20168	14497	12372	16824	17433	15233
CROP BREAKDOWN (ha)										
CORN TOTAL	11363	7892	5215	3709	2654	3052	2516	3016	2670	3042
SORGHUM TOTAL	11	14	27	79	51	14	51	27	2	0
SMALL GRAINS TOTAL	3866	3131	1888	2063	932	426	428	195	276	206
SOYBEAN TOTAL	1699	720	975	894	965	315	310	507	593	328
COWPEAS TOTAL	828	236	66	113	27	0	0	0	0	0
HAY TOTAL	4164	5454	5902	5014	5177	3709	3830	4712	4744	5227
FIELD SEED TOTAL	160	165	68	100	23	0	0	0	0	0
IRISH POTATO	511	188	69	61	16	41	31	7	32	2
SWEET POTATO	285	52	6	13	2	0	3	1	3	0
COTTON	67	31	35	22	9	0	0	0	0	0
TOBACCO	734	671	742	516	430	367	367	490	348	296
VEGETABLES TOTAL	70	33	25	49	22	14	4	19	18	20
ORCHARDS TOTAL	1799	1411	968	777	550	596	710	599	527	635

YADKIN	1945	1950	1954	1959*	1964	1969	1974	1978	1982	1987
# OF FARMS	2989	3344	3148	2568	2177	1893	1628	1454	1301	1045
COUNTY AREA (ha)	86766	86766	86766	86766	86766	87025	87025	87025	86958	86958
PERCENT IN FARMLAND	87.89	88.90	82.22	77.21	71.78	66.43	58.09	55.54	53.97	49.47
TOTAL FARMLAND (ha)	76256	77137	71335	66988	62285	57814	50551	48331	46929	43021
AVG. FARM SIZE (ha)	25.51	23.07	22.66	26.09	28.61	30.54	31.05	33.24	36.07	41.17
CROPLAND TOTAL (ha)	35821	31774	30247	27372	26588	28619	28173	28874	28756	27038
CROPLAND HARVESTED	23618	20014	21491	18942	17439	16117	18264	18522	19702	16344
CROPLAND PASTURED	3028	3144	2905	1042	1670	5787	6344	5927	6184	5354
OTHER CROPLAND	9175	8615	5851	7387	7478	6715	3565	4425	2870	5340
WOODLAND TOTAL (ha)	32792	36172	31510	28512	25697	18652	14220	14217	12690	10586
WOODLAND PASTURED	1945	4425	3611	3002	3170	2984	3084	3083	3209	2882
OODLAND NOT PASTURED	30848	31747	27899	25509	22527	15668	11136	11134	9481	7704
OTHERLAND TOTAL (ha)	7642	9191	9578	11105	10730	10544	8159	5240	5481	5397
OTHER PASTURE	4820	4686	6091	7043	6669	0	0	0	0	0
OTHERLAND	2822	4506	3486	4062	4062	0	0	0	0	0
PASTURELAND TOTAL (ha)	9793	12255	12608	11088	11509	8771	9427	10837	11650	10631
CROP BREAKDOWN (ha)										
CORN TOTAL	7612	5542	4972	4550	4957	7238	7724	7445	8128	5835
SORGHUM TOTAL	2	13	178	312	136	89	178	280	0	76
SMALL GRAINS TOTAL	1975	3717	6014	6800	3639	2317	3362	2075	2687	2605
SOYBEAN TOTAL	280	166	356	365	3234	2486	2968	3512	4068	3761
COWPEAS TOTAL	183	95	125	100	20	0	0	0	0	0
HAY TOTAL	5715	6244	6449	5100	3526	1795	2550	2965	2893	3898
FIELD SEED TOTAL	651	802	627	381	142	0	0	0	0	0
IRISH POTATO	176	276	17	27	16	25	136	56	32	2
SWEET POTATO	162	19	4	6	6	0	4	6	3	0
COTTON	56	26	23	4	4	2	0	2	0	0
TOBACCO	4257	3781	4134	2979	2653	2142	2391	2671	2040	1270
VEGETABLES TOTAL	53	41	57	25	37	76	8	65	180	90
ORCHARDS TOTAL	221	166	115	96	163	104	103	117	0	11

Appendix D

USLE factor values and factor statistics for the gross soil erosion estimates, 1955 and 1988.

USLE factor statistics (mean and standard deviation) for 1955 simulations by strata.

STRATA	AVG K	STD K	AVG LS	STD LS	AVG C55	STD C55
1	0.032	0.005	1.963	2.144	0.108	0.169
2	0.031	0.004	3.284	3.074	0.072	0.143
3	0.027	0.006	5.738	4.392	0.023	0.062
5	0.026	0.003	7.024	4.216	0.015	0.064
6	0.024	0.004	6.994	4.749	0.010	0.042
8	0.032	0.002	6.585	4.088	0.010	0.030
9	0.025	0.005	11.708	7.409	0.006	0.030
10	0.032	0.006	1.725	1.922	0.115	0.170
11	0.025	0.004	6.221	4.909	0.018	0.033
BASIN	0.030	0.006	3.541	4.368	0.081	0.151

USLE factor statistics (mean and standard deviation) for 1988 simulations by strata.

STRATA	AVG K	STD K	AVG LS	STD LS	AVG C88	STD C88
1	0.032	0.005	2.050	2.221	0.073	0.133
2	0.031	0.004	3.323	3.092	0.056	0.119
3	0.028	0.006	5.757	4.394	0.013	0.040
5	0.026	0.003	7.039	4.219	0.013	0.045
6	0.024	0.004	7.005	4.749	0.017	0.052
8	0.032	0.002	6.587	4.089	0.132	0.092
9	0.025	0.005	11.733	7.404	0.015	0.049
10	0.032	0.006	1.792	1.943	0.075	0.136
11	0.025	0.004	6.179	4.910	0.033	0.093
BASIN	0.030	0.006	3.697	4.454	0.057	0.118

R factor estimates by strata for simulations in the 1950s and 1980s.

STRATA	R53	R54	R55	R56	R57	R86	R87	R88	R89	R90
1	2876	2110	3744	3012	4646	1770	4919	2366	4034	3353
2	2740	2281	4153	2996	5991	1855	4800	2298	5089	4527
3	2927	2383	3574	3268	7029	1906	4783	2349	5532	5617
5	2910	2128	2468	2655	7897	1719	4629	2366	5208	6910
6	2740	2213	3898	2842	6297	1821	4714	2298	5089	4970
8	2910	2128	2468	2655	7897	1719	4629	2366	5208	6910
9	2859	2315	3761	3098	6672	1872	4766	2332	5344	5276
10	2893	2076	3898	3098	4561	1787	4851	2332	4119	3285
11	2910	2128	2468	2655	7897	1719	4629	2366	5208	6910
BASIN	2859	2179	3778	3030	5361	1804	4834	2349	4527	4068

C, K, and LS factor statistics by land use-land cover for 1955 and 1988 databases.

		1955				1988			
LULC	C	AVG K	STD K	AVG LS	STD LS	AVG K	STD K	AVG LS	STD LS
AG	0.463	0.033	0.005	1.383	1.376	0.033	0.006	1.379	1.157
AGH	0.150	0.033	0.005	1.489	1.280	0.033	0.004	1.408	1.197
H	0.100	0.032	0.006	1.463	1.347	0.032	0.006	1.399	1.231
HP	0.062	0.031	0.006	2.238	1.974	0.033	0.005	1.441	1.212
P	0.024	0.031	0.006	2.140	2.172	0.031	0.006	1.728	1.546
CP	0.080	0.031	0.006	1.931	1.887	0.033	0.006	2.313	3.374
C	0.200	0.030	0.006	2.954	3.312	0.030	0.006	4.398	4.283
WP	0.015	0.031	0.005	3.372	4.499	0.033	0.004	1.412	1.636
W	0.005	0.032	0.005	2.074	1.975	0.032	0.005	2.202	2.158
F	0.0005	0.027	0.005	6.948	5.809	0.026	0.005	7.780	5.832
O	0.060	0.026	0.005	4.847	3.462	0.028	0.005	3.508	2.784

R factor statistics by land use-land cover based on rainfall from eight weather stations (1953-57).

	R53		R54		R55		R56		R57	
LULC	AVG	STD	AVG	STD	AVG	STD	AVG	STD	AVG	STD
AG	2961	686	2093	410	3932	974	3115	1130	4442	1070
AGH	2587	572	1957	412	3898	1079	2604	1132	4510	1099
H	3030	647	2179	434	3812	1036	3251	1086	4868	1367
HP	2944	572	2332	516	3915	1162	3200	1241	5651	1544
P	2808	562	2247	543	4051	1123	3081	1294	5634	1482
CP	2791	625	2093	460	4000	1048	2876	1219	4766	1317
C	2842	505	2110	378	3625	1117	2961	1038	5532	1755
WP	3081	475	2213	306	3778	955	3438	854	5055	1573
W	2842	677	2093	442	3830	1038	2961	1147	4595	1069
F	2842	315	2315	468	3591	1263	3098	1128	6689	1438
O	2485	366	2179	572	3847	1081	2485	1144	4970	1305

R factor statistics by land use-land cover based on rainfall from eight weather stations (1986-90).

	R86		R87		R88		R89		R90	
LULC	AVG	STD	AVG	STD	AVG	STD	AVG	STD	AVG	STD
AG	1753	279	4561	1016	2315	223	4050	942	3234	693
AGH	1702	228	4629	1244	2315	228	3812	548	3166	710
H	1855	305	4885	1084	2332	145	4595	1248	3608	974
HP	1770	250	4680	1157	2349	223	4068	834	3472	1139
P	1855	306	4868	882	2349	211	4561	1190	3727	1297
CP	1872	289	4698	1104	2417	250	4442	1094	3710	1251
C	1838	266	5038	873	2366	175	4817	1042	4646	1765
WP	1991	262	4868	1312	2451	211	4527	1195	3302	616
W	1787	269	4919	1161	2349	228	4170	956	3421	1023
F	1855	279	4834	555	2332	90	5293	933	5514	1680
O	1838	277	4970	647	2417	250	4442	1026	3778	1382

Appendix E

N.R.C.S. Natural Resources Inventory - General Land Classes

Areas (acres/1000) of general land use-land cover from the 1982 N.R.C.S. National Resource Inventory (NRI) of the four primary counties of the Yadkin River basin.

DESCRIPTION	FORSYTH	SURRY	WILKES	YADKIN
CROPLAND-CULTIVATED	25.2	115.2	12.9	71.3
CROPLAND-NONCULT	17.5	11.5	13.9	8.9
FORESTLAND	114.4	147.8	354.6	78.7
PASTURELAND	24.5	38.6	55.4	37.6
RURAL	9.5	10.2	9.7	6.0
URBAN	63.5	14.1	17.2	7.9
LARGE HYDRO	0.9	0.1	1.5	0.0
SMALL HYDRO	5.1	2.3	3.2	2.6
OTHER	4.5	5.5	16.9	3.1
TOTALS	264.9	345.3	485.3	216.1

Areas (acres/1000) of general land use-land cover from the 1987 N.R.C.S. National Resource Inventory (NRI) of the four primary counties of the Yadkin River basin.

DESCRIPTION	FORSYTH	SURRY	WILKES	YADKIN
CROPLAND-CULTIVATED	22.4	82.1	14.8	63.6
CROPLAND-NONCULT	11.8	18.5	15.2	7.3
FORESTLAND	114.9	152.9	337.7	83.5
PASTURELAND	26.4	54.5	60.6	40.5
RURAL	9.5	10.3	9.7	6.1
URBAN	70.3	16.3	21.2	9.3
LARGE HYDRO	0.9	0.1	1.5	0.0
SMALL HYDRO	5.2	2.3	3.2	2.5
OTHER	3.5	8.3	21.4	3.3
TOTALS	264.9	345.3	485.3	216.1

Areas (acres/1000) of general land use-land cover from the 1992 N.R.C.S. National Resource Inventory (NRI) of the four primary counties of the Yadkin River basin.

DESCRIPTION	FORSYTH	SURRY	WILKES	YADKIN
CROPLAND-CULTIVATED	18.9	74.6	17.2	60.3
CROPLAND-NONCULT	10.6	12.3	12.5	10.5
FORESTLAND	107.3	154.0	333.1	78.7
PASTURELAND	24.8	62.2	58.8	41.1
RURAL	9.7	10.1	9.8	6.1
URBAN	82.5	21.4	23.8	11.5
LARGE HYDRO	0.9	0.1	1.5	0.0
SMALL HYDRO	5.2	2.3	3.2	2.6
OTHER	5.0	8.3	25.4	5.3
TOTALS	264.9	345.3	485.3	216.1

Appendix F

Stratified Random Sample Distributions

Distribution of the 18 strata for the stratified random sampling process within the Yadkin River basin. Strata are a combination of physical factors (elevation, percent slope, and proximity to water) based on 1:250,000 U.S.G.S. DEM and 1:100,000 USGS DLG data. **Elevation**: P=200-400m; T=401-500m; M=501-1250 m. **Slope**: AB=0-10%; CD=11-25%; EFG=26-115%. **Flood Plain"**: Outside=outside the hydrologic buffer; Inside=within the hydrologic buffer. Second half of the table shows the distribution of the cells used in the USLE model (urban and water cells masked out). Statistics presented in report tables are based on the second distribution.

STRATA		# OF CELLS	FREQUENCY	AREA (KM^2)	CELLS USED	FREQUENCY	AREA (KM^2)
1	**P-AB-OUTSIDE**	352854	0.4139	2445.16	309349	0.3949	2142.32
2	**T-AB-OUTSIDE**	76879	0.0902	530.53	74474	0.0951	513.94
3	**M-AB-OUTSIDE**	48284	0.0566	333.45	48133	0.0614	332.40
4	**P-CD-OUTSIDE**	9098	0.0107	62.87	8801	0.0112	60.81
5	**T-CD-OUTSIDE**	21449	0.0252	148.21	21380	0.0273	147.74
6	**M-CD-OUTSIDE**	47639	0.0559	329.00	47543	0.0607	328.34
7	**P-EFG-OUTSIDE**	569	0.0007	3.93	562	0.0007	3.89
8	**T-EFG-OUTSIDE**	8322	0.0098	57.53	8312	0.0106	57.46
9	**M-EFG-OUTSIDE**	41493	0.0487	286.51	41458	0.0529	286.27
10	**P-AB-INSIDE**	214031	0.2510	1478.88	191592	0.2446	1322.70
11	**T-AB-INSIDE**	20342	0.0239	140.31	20149	0.0257	138.98
12	**M-AB-INSIDE**	6398	0.0075	44.18	6385	0.0082	44.09
13	**P-CD-INSIDE**	512	0.0006	3.54	493	0.0006	3.41
14	**T-CD-INSIDE**	976	0.0011	6.75	974	0.0012	6.73
15	**M-CD-INSIDE**	2668	0.0031	16.35	2366	0.0030	16.34
16	**P-EFG-INSIDE**	27	0.0000	0.19	26	0.0000	0.18
17	**T-EFG-INSIDE**	176	0.0002	1.22	175	0.0002	1.21
18	**M-EFG-INSIDE**	1160	0.0014	8.00	1158	0.0015	7.99
BASIN TOTAL		852577		5896.61	783330		5414.80

Appendix G

1975 1:250,000 U.S.G.S. LULC Distributions

Distribution of general 1:250,000 scale land use/land cover classes (USGS LULC) within the Yadkin River basin. Second half of the table shows which LULC classes were used in the USLE model and their distributions.

USGS LULC CLASSES	# OF CELLS	FREQUENCY	AREA (KM^2)	USED CELLS	FREQUENCY	AREA (KM^2)
11 RESIDENTIAL	49710	0.0583	343.72	0	0.0000	0
12 COMMERCIAL	5046	0.0059	34.89	0	0.0000	0
13 INDUSTRIAL	1927	0.0023	13.32	0	0.0000	0
14 TRANSPORTATION	6388	0.0075	44.16	0	0.0000	0
15 INDUSTRIAL COMPLEX	213	0.0002	1.47	0	0.0000	0
17 OTHER URBAN	3351	0.0039	23.18	3351	0.0043	23.18
21 CROPLAND/PASTURE	254693	0.2987	1761.77	254693	0.3264	1761.77
22 ORCHARDS	2769	0.0032	19.08	2769	0.0035	19.08
23 CONFINED FEEDING	2523	0.0030	17.44	0	0.0000	0
24 OTHER AGRICULTURE	11	0.0000	0.08	11	0.0000	0.08
41 DECIDUOUS FOREST	269814	0.3165	1866.66	269814	0.3458	1866.66
42 EVERGREEN FOREST	35570	0.0417	245.70	35570	0.0456	245.70
43 MIXED FOREST	214720	0.2518	1483.71	214720	0.2752	1483.71
51 STREAMS	1615	0.0019	11.19	0	0.0000	0
52 LAKES	182	0.0002	1.26	0	0.0000	0
53 RESERVOIRS	1268	0.0015	8.77	0	0.0000	0
75 QUARRIES/MINING	377	0.0004	2.60	0	0.0000	0
76 TRANSITIONAL	2405	0.0028	16.61	2405	0.0031	16.61
BASIN TOTAL	852577		5895.61	780195		5416.79

Appendix H

1955 and 1988 Land Use-Land Cover Basin Estimates and Statistics

1955 total basin land use-land cover estimates (km^2) by strata. Strata land use-land cover estimates from the 185 1-km^2 sample areas were multiplied by 31.87 to arrive at basin estimates.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	442.708	83.602	3.789	1.090	1.702	0.000	0.915	145.660	0.000	679.466
AGH	142.369	13.950	4.565	0.000	1.348	0.000	0.398	57.144	0.025	219.801
H	191.222	46.196	7.993	0.717	2.419	2.550	2.265	62.197	7.722	323.280
HP	19.526	13.223	11.282	3.149	0.000	0.000	3.824	3.748	0.886	55.638
P	131.137	83.189	23.052	0.016	9.067	0.214	11.234	37.917	3.850	299.675
O	2.795	11.604	0.257	1.441	11.613	0.000	0.000	0.000	0.157	27.867
FL	0.239	1.606	0.000	0.000	0.000	0.000	0.781	0.000	0.000	2.625
WP	18.346	2.572	0.000	0.000	6.693	0.000	0.000	5.494	0.169	33.275
W	1127.283	140.865	14.023	0.000	0.000	0.000	0.000	406.981	22.628	1711.780
F	312.963	334.635	336.866	56.091	304.677	29.002	349.614	18.803	26.133	1768.785
CP	138.596	27.244	14.642	0.149	6.459	0.000	6.304	63.680	0.311	257.385
R	47.867	14.327	1.022	0.031	0.770	0.000	0.383	8.581	0.857	73.838
U	74.426	5.402	0.000	0.000	0.000	0.000	0.000	23.453	0.000	103.281
I	23.615	0.382	0.000	0.000	0.000	0.000	0.000	2.942	0.000	26.939
RD	107.745	28.649	8.518	0.775	3.257	0.052	5.364	31.583	0.892	186.835
C	45.386	19.224	20.628	0.135	3.560	0.158	1.236	19.091	0.000	109.417
WATER	10.923	0.596	0.000	0.000	0.000	0.000	0.000	6.375	0.000	17.895
TOTAL	2837.147	827.266	446.638	63.593	351.566	31.975	382.318	893.649	63.631	5897.782

Sample means (km^2) from the 185 1-km^2 sample areas for the 1955 land use-land cover estimates, by strata.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	0.156	0.101	0.008	0.017	0.005	0.000	0.002	0.163	0.000	0.115
AGH	0.050	0.017	0.010	0.000	0.004	0.000	0.001	0.064	0.000	0.037
H	0.067	0.056	0.018	0.011	0.007	0.080	0.006	0.070	0.121	0.055
HP	0.007	0.016	0.025	0.049	0.000	0.000	0.010	0.004	0.014	0.009
P	0.046	0.100	0.052	0.000	0.026	0.007	0.029	0.042	0.060	0.051
O	0.001	0.014	0.001	0.023	0.033	0.000	0.000	0.000	0.002	0.005
FL	0.000	0.002	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000
WP	0.006	0.003	0.000	0.000	0.019	0.000	0.000	0.006	0.003	0.006
W	0.397	0.170	0.031	0.000	0.000	0.000	0.000	0.456	0.355	0.290
F	0.110	0.404	0.755	0.880	0.869	0.910	0.914	0.021	0.410	0.300
CP	0.049	0.033	0.033	0.002	0.018	0.000	0.016	0.071	0.005	0.044
R	0.017	0.017	0.002	0.000	0.002	0.000	0.001	0.010	0.013	0.013
U	0.026	0.006	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.018
I	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.005
RD	0.038	0.035	0.019	0.012	0.009	0.002	0.014	0.035	0.014	0.032
C	0.016	0.023	0.046	0.002	0.010	0.005	0.003	0.021	0.000	0.019
WATER	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.003
SAMPLES	89	26	14	2	11	1	12	28	2	185

Sample variance (km^2) from the 185 1-km^2 sample areas for the 1955 land use-land cover estimates, by strata.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	0.023	0.018	0.001	0.001	0.000	0.000	0.000	0.020	0.000	0.020
AGH	0.009	0.002	0.001	0.000	0.000	0.000	0.000	0.012	0.000	0.007
H	0.008	0.005	0.002	0.000	0.000	0.000	0.000	0.006	0.020	0.006
HP	0.001	0.001	0.008	0.005	0.000	0.000	0.001	0.000	0.000	0.001
P	0.005	0.010	0.010	0.000	0.001	0.000	0.002	0.002	0.001	0.006
O	0.000	0.004	0.000	0.001	0.010	0.000	0.000	0.000	0.000	0.001
FL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WP	0.001	0.000	0.000	0.000	0.004	0.000	0.000	0.001	0.000	0.001
W	0.056	0.057	0.014	0.000	0.000	0.000	0.000	0.032	0.252	0.070
F	0.070	0.126	0.079	0.000	0.027	0.000	0.009	0.012	0.336	0.158
CP	0.003	0.001	0.003	0.000	0.002	0.000	0.001	0.007	0.000	0.003
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
U	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.004
I	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
RD	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
C	0.001	0.002	0.016	0.000	0.000	0.000	0.000	0.001	0.000	0.002
WATER	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SAMPLES	89	26	14	2	11	1	12	28	2	185

1955 land use-land cover 90% confidence intervals and standard errors

LULC	LOW	MEAN	HIGH	STANDARD ERROR
AG	0.096	0.115	0.134	0.010
AGH	0.026	0.037	0.049	0.006
H	0.044	0.055	0.066	0.006
HP	0.004	0.009	0.015	0.003
P	0.040	0.051	0.061	0.005
O	-0.000	0.005	0.010	0.002
FL	-0.000	0.000	0.001	0.000
WP	0.002	0.006	0.009	0.002
W	0.260	0.290	0.321	0.015
F	0.262	0.300	0.338	0.019
CP	0.035	0.044	0.052	0.004
R	0.011	0.013	0.015	0.001
U	0.014	0.018	0.021	0.002
I	-0.002	0.005	0.011	0.003
RD	0.028	0.032	0.036	0.002
C	0.012	0.019	0.025	0.003
WATER	0.001	0.003	0.005	0.001

1988 total basin land use-land cover estimates (km^2) by strata. Strata land use-land cover estimates from the 185 1-km^2 sample areas were multiplied by 31.87 to arrive at basin estimates.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	208.77	48.74	0.18	0.00	0.08	0.00	0.00	69.79	2.39	329.95
AGH	198.49	30.41	0.00	0.00	0.48	2.08	1.25	70.64	0.00	303.36
H	61.85	29.18	1.83	0.06	0.00	0.00	1.43	20.95	0.54	115.84
HP	106.43	20.93	12.67	2.27	0.00	0.00	0.07	27.18	0.00	169.54
P	224.59	75.92	25.47	0.00	5.47	0.00	9.96	67.24	5.84	414.50
O	4.47	12.00	0.23	0.00	6.37	0.00	0.00	0.88	3.51	27.46
FL	7.99	3.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.43
WP	11.80	5.65	0.00	0.00	0.00	0.00	0.00	2.96	0.00	20.42
W	1278.07	289.06	2.31	0.00	0.00	0.00	0.00	424.51	18.80	2012.75
F	116.64	213.53	364.91	57.05	307.55	10.20	337.50	21.99	27.73	1457.10
CP	53.21	6.52	11.81	0.00	1.21	0.00	2.53	16.16	2.37	93.81
R	103.45	18.60	3.03	0.33	1.09	0.00	1.05	21.68	0.53	149.75
U	198.22	13.52	0.00	0.00	0.00	0.00	0.00	56.31	0.00	268.06
I	51.31	0.00	0.00	0.00	0.00	0.00	0.00	13.98	0.00	65.29
RD	131.51	29.88	9.24	0.78	3.76	0.05	5.63	38.94	0.89	220.67
C	66.13	29.32	14.51	3.48	24.61	19.44	23.03	21.56	1.10	203.18
WATER	14.52	1.36	0.09	0.00	0.05	0.00	0.13	17.05	0.00	33.19
TOTAL	2837.44	828.07	446.27	63.96	350.66	31.77	382.58	891.82	63.71	5896.28

Sample means (km^2) from the 185 1-km^2 sample areas for the 1988 land use-land cover estimates, by strata.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	0.074	0.059	0.000	0.000	0.000	0.000	0.000	0.078	0.037	0.028
AGH	0.070	0.037	0.000	0.000	0.001	0.065	0.003	0.079	0.000	0.028
H	0.022	0.035	0.004	0.001	0.000	0.000	0.004	0.023	0.009	0.011
HP	0.038	0.025	0.028	0.036	0.000	0.000	0.000	0.030	0.000	0.017
P	0.079	0.092	0.057	0.000	0.016	0.000	0.026	0.075	0.092	0.049
O	0.002	0.014	0.001	0.000	0.018	0.000	0.000	0.001	0.055	0.010
FL	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
WP	0.004	0.007	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.002
W	0.451	0.349	0.005	0.000	0.000	0.000	0.000	0.476	0.295	0.175
F	0.041	0.258	0.818	0.895	0.877	0.320	0.883	0.025	0.435	0.506
CP	0.019	0.008	0.026	0.000	0.003	0.000	0.007	0.018	0.037	0.013
R	0.036	0.022	0.007	0.005	0.003	0.000	0.003	0.024	0.008	0.012
U	0.070	0.016	0.000	0.000	0.000	0.000	0.000	0.063	0.000	0.045
I	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.004
RD	0.046	0.036	0.021	0.012	0.011	0.002	0.015	0.044	0.014	0.022
C	0.023	0.035	0.033	0.055	0.070	0.610	0.060	0.024	0.017	0.103
WATER	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.003
SAMPLES	89	26	14	2	11	1	12	28	2	185

Sample variance (km^2) from the 185 1-km^2 sample areas for the 1988 land use-land cover estimates, by strata.

STRATA	2	3	4	6	7	9	10	11	12	TOTAL
AG	0.009	0.007	0.000	0.000	0.000	0.000	0.000	0.009	0.003	0.008
AGH	0.009	0.006	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.007
H	0.002	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.002
HP	0.006	0.003	0.009	0.003	0.000	0.000	0.000	0.002	0.000	0.004
P	0.007	0.009	0.007	0.000	0.001	0.000	0.001	0.005	0.003	0.007
O	0.000	0.003	0.000	0.000	0.004	0.000	0.000	0.000	0.006	0.001
FL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WP	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W	0.041	0.081	0.000	0.000	0.000	0.000	0.000	0.032	0.174	0.070
F	0.037	0.142	0.032	0.006	0.028	0.000	0.036	0.017	0.378	0.155
CP	0.001	0.000	0.008	0.000	0.000	0.000	0.000	0.001	0.002	0.001
R	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
U	0.025	0.003	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.015
I	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.004
RD	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
C	0.004	0.004	0.004	0.000	0.020	0.000	0.041	0.001	0.001	0.009
WATER	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
SAMPLES	89	26	14	2	11	1	12	28	2	185

1988 land use-land cover 90% confidence intervals and standard errors

LULC	LOW	MEAN	HIGH	STANDARD ERROR
AG	0.015	0.028	0.040	0.006
AGH	0.016	0.028	0.040	0.006
H	0.005	0.011	0.017	0.003
HP	0.008	0.017	0.027	0.005
P	0.037	0.049	0.060	0.006
O	0.006	0.010	0.014	0.002
FL	-0.000	0.001	0.002	0.001
WP	-0.001	0.002	0.004	0.001
W	0.146	0.175	0.204	0.014
F	0.473	0.506	0.539	0.017
CP	0.008	0.013	0.019	0.003
R	0.007	0.012	0.017	0.002
U	0.028	0.045	0.063	0.009
I	-0.005	0.004	0.013	0.004
RD	0.017	0.022	0.027	0.002
C	0.091	0.103	0.115	0.006
WATER	-0.000	0.003	0.006	0.002