IDENTIFICATION OF CRITICAL SOURCE AREAS OF SEDIMENT POLLUTION: SOUTH FORK NEW RIVER

A Thesis

by

Glenn Graham Hyman

Submitted to the Graduate School

Appalachian State University

in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 1990

Department of Geography and Planning

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APPROVED BY:

Michael W. Mayfield
Chairperson, Thesis Committee

Garry Cooper
Member, Thesis Committee

Neal G. Lineback
Member, Thesis Committee

Neal G. Lineback
Chairperson, Department of Geography and Planning

Joyce V. Lawrence
Dean of Graduate Studies and Research

ABSTRACT

IDENTIFICATION OF CRITICAL SOURCE AREAS OF

SEDIMENT POLLUTION: SOUTH FORK NEW RIVER

Glenn Graham Hyman, B. A., University of North Carolina

M. A., Appalachian State University

Thesis Chairperson: Michael W. Mayfield

Human disturbance of the landscape can cause unacceptable levels of soil erosion. Soil erosion reduces soil fertility and agricultural production potential. Off-site impacts include damage of wildlife habitats in streams and siltation of dams, stream channels, and lakes. Soil erosion is a global problem which is multiplied by the tremendous population growth rate and its associated pressures on land resources.

Soil erosion potential was modeled in the South Fork of the New River watershed using remote sensing and geographic information systems (GIS). The Universal Soil Loss Equation was simulated in a raster based GIS for the 205 square mile basin. Data layers representing each factor in the model were created, georeferenced and registered to each other. USGS Digital Elevation Models provided the slope data. 7.5

minute topographic maps were used to estimate the length of slope factor. Landsat Thematic Mapper data provided the land cover component. The Soil Conservation Service provided the soil erodibility and rainfall data. The model was performed showing potential soil loss in tons/acre/year. Hypothetical changes showed potential soil erosion hazards from human disturbance of the land cover.

ACKNOWLEDGEMENTS

I wish to express my appreciation to my thesis committee, Neal Lineback, Garry Cooper, and Michael Mayfield. I would also like to thank Watauga County soil conservationist Al Childers for providing data and comments. A very special thanks is extended to my fellow graduate students in the Department of Geography and Planning. Finally, I am very grateful to my parents for their support and encouragement.

Note

The maps shown in this thesis were designed to give the reader a general understanding of the study area. Persons interested in maps showing greater detail and displaying finer resolution should contact Appalachian State University's Department of Geography and Planning.

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CHAPTER I

Introduction

The identification of critical source areas of sediment pollution is an initial step towards controlling soil erosion and sediment pollution. The drainage basin of the South Fork of the New River was chosen in this thesis to examine soil loss and the origin of sediments.

As a component of the National Wild and Scenic River system, the South Fork of the New River contains scenic resources that must be protected. This area's unique mountain environment and associated agricultural practices are quite different from lowland regions. Steep slopes and abundant rainfall within the basin enhance erosional processes. Christmas tree farming, second home development, and industrial growth also increases soil losses and attendant chemical pollution.

The spatial extent of soil loss potential indicates where current and future sediment pollution problems exist. Although the amount of soil loss does not translate directly into levels of sediment entering streams, the identification of critical source areas can be used as a starting point for more detailed monitoring of stream turbidity and sedimentation.

Due to the characteristics of soil erosion models, time and money constraints, and availability of data, field-sized areas or small watersheds are most often used in soil loss studies. Because soil erosion problems are greatest on farmlands, relatively little research has focused on nonagricultural areas.

Geographic information systems (GIS) and remote sensing technologies make large area soil erosion modeling feasible. The use of satellite image data in a GIS format to model and monitor biophysical processes has several advantages compared to more conventional methods (Jensen 1983). Perhaps the greatest advantage is the synoptic coverage of satellite imagery, allowing scientists to make large area investigations. Another benefit of satellite imagery in digital form is its compatibility with geographic information systems. The combination of these technologies allows users to incorporate information from several sources into a georeferenced database.

Conventional methods of investigating the physical and cultural environment require much time and money and are sometimes impossible for scientists and engineers to conduct with their limited resources. Thus, the use of remote sensing in a GIS format for resource management investigations and environmental modeling has great potential. Another advantage of this method is that it is well-suited to modeling potential impacts of proposed or hypothetical agricultural or residential projects.

The purpose of this study was to identify critical source areas of sediment pollution in the South Fork of the New River watershed and to model the effects of hypothetical changes in land use on soil loss. This problem was investigated by simulating the Universal Soil Loss Equation (USLE) in a raster-based GIS. The combination of satellite image data, digital elevation models (DEM), meteorological data, and soil survey data permitted soil erosion modeling and will allow the assessment of impacts of proposed changes in land use.

Geographic Setting

The watershed of the South Fork of the New River, located in Watauga and Ashe counties of North Carolina, lies within the Blue Ridge physiographic province. It is bounded by the Blue Ridge front on the southeast and the Tennessee Valley Divide on the west (Fig. 1). The towns of Boone and Blowing Rock are the largest urban areas within the watershed and are located near the headwaters of the South Fork of the New River. A small part of West Jefferson lies within the watershed. The Blue Ridge Parkway follows the southeastern boundary of the watershed. This natural region is characterized by some of highest mountains in the Appalachian Highlands and the massive Blue Ridge Front overlooking the Piedmont to the east (Hunt 1974).

The South Fork of the New River drains 205 square miles of land in Watauga and Ashe counties of North

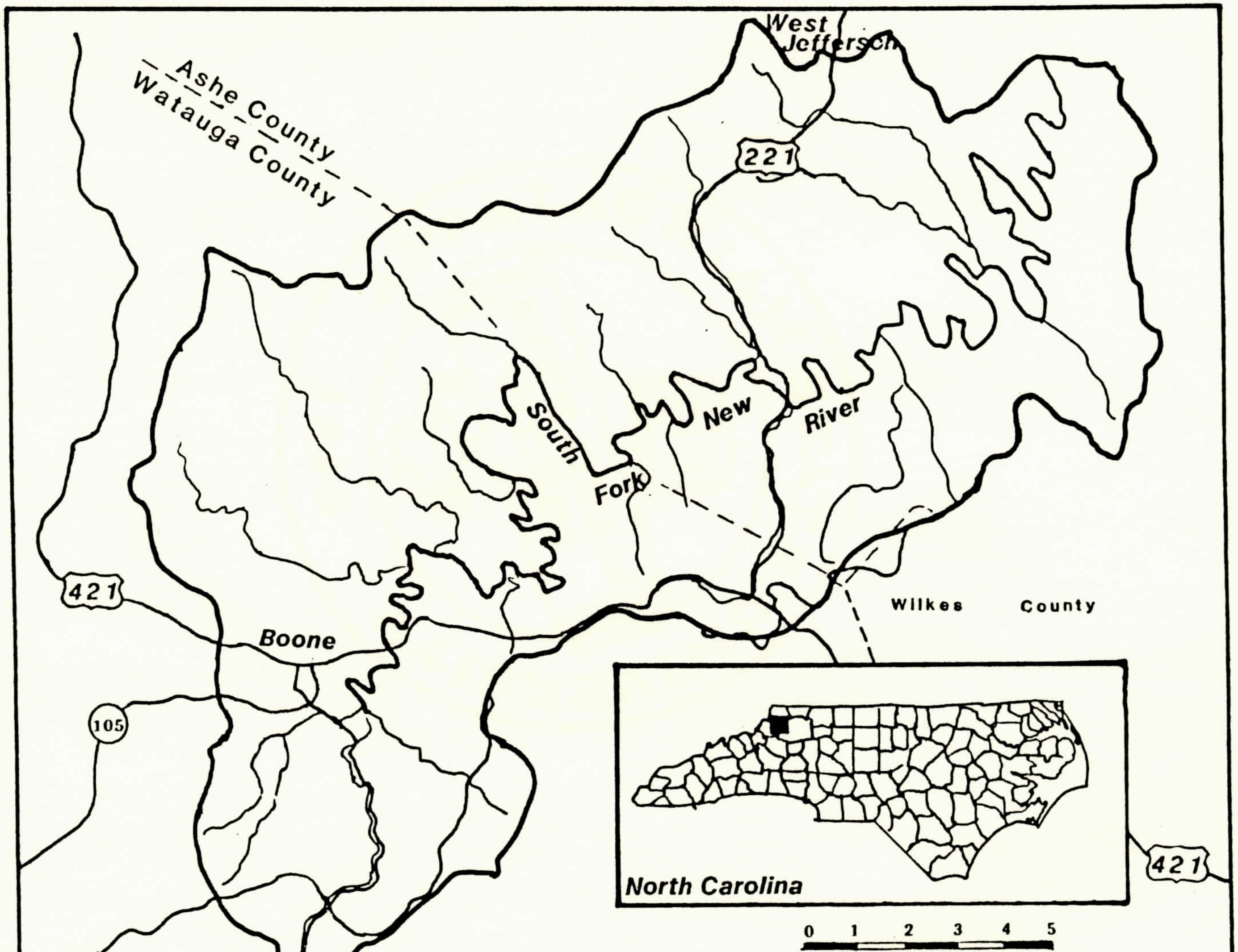


Figure 1. The Study Area

Carolina. Elevations range from 5,370 feet atop Rich Mountain to 2,657 feet above sea level at the South Fork's outlet at Index. The river joins the North Fork to form the New River, which flows northward into the Kanawha River in West Virginia. The Kanawha River joins the Ohio River which eventually joins the Mississippi River before reaching the Gulf of Mexico.

The climate of the area is characterized by relatively even monthly precipitation levels throughout the year, cool winters and mild summers. Average annual temperatures range from the upper 40's (F^o) at higher elevations to the lower 50's (F^o) in the valleys (NOAA 1988). Discharge records of the South Fork New River reveal highest levels of runoff in the spring and lowest levels in the fall (USGS 1990). Summer temperatures are relatively mild and warm in the valleys and pleasant at higher elevations. Winter temperatures are generally cool and can be considerably lower at higher elevations. Snow in winter is common but usually does not stay on the ground for long periods of time.

Methodology and Analysis

There exists a need to identify critical soil erosion source areas in the drainage basin of the South Fork. The purpose of this project was to build a database which includes variables needed for soil erosion modeling and to use these data to identify critical source areas for sediment pollution (Fig. 2). Remote sensing and geographic information systems technology were used jointly to allow large area studies with relatively low expense and time costs.

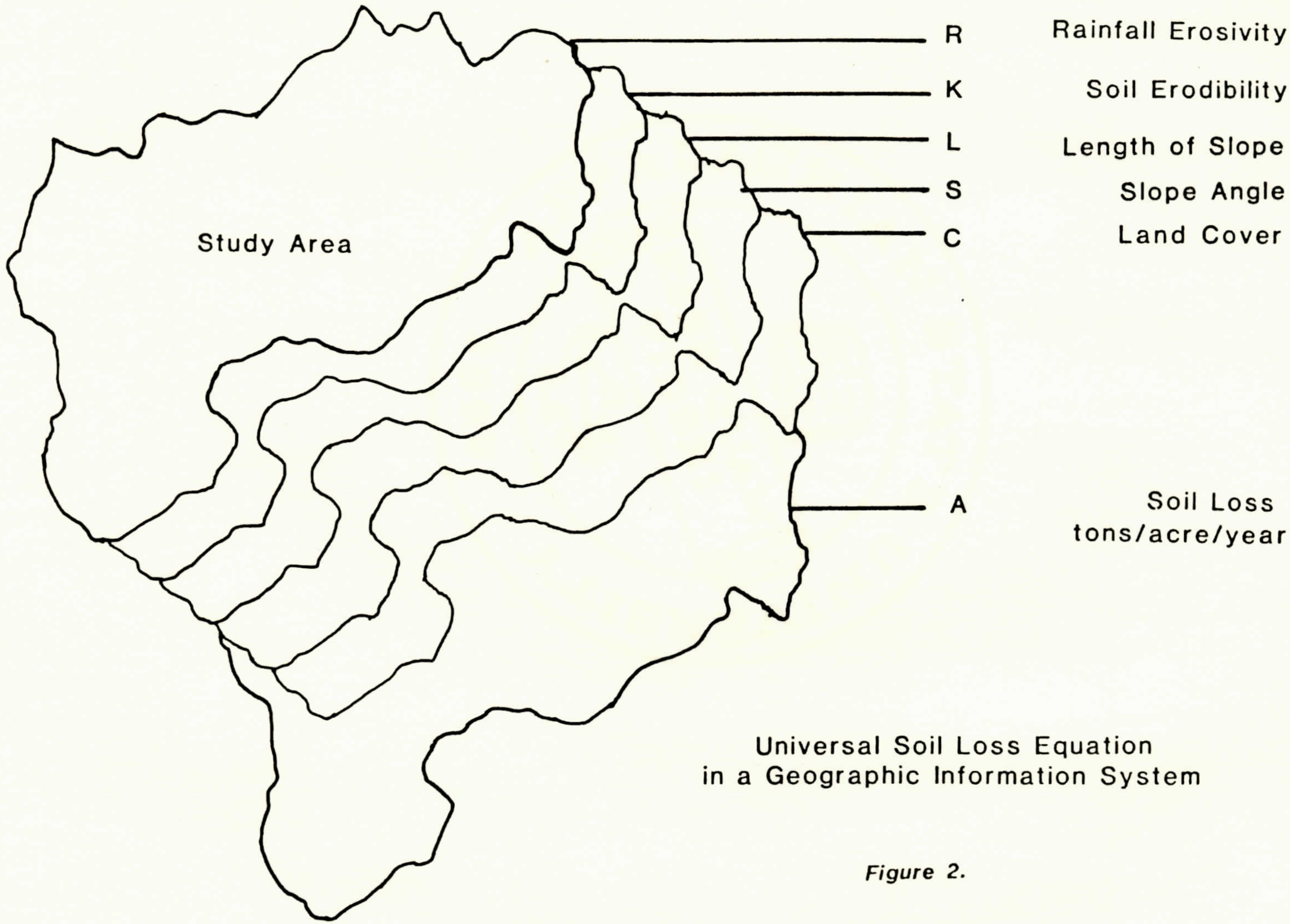
A database was generated with the factors of the USLE as basic variables in a GIS to make soil erosion modeling possible. The Earth Resources Data Analysis System (ERDAS) was used to integrate satellite image data, digital elevation models, soil survey information, rainfall data, and topographic information in a GIS format and to simulate the Universal Soil Loss Equation (ERDAS 1990).

The Universal Soil Loss Equation (USLE) is an empirically based model that estimates soil loss (Wischmeier 1978). The USLE is simply stated as:

$$A = RKLSCP$$

where R is the rainfall erosivity factor, K is the soil erodibility factor, L is the length of slope factor, S is the slope factor, C is the land cover factor and P is the management practice factor.

The area of the South Fork watershed was extracted using a technique that created a polygon boundary of the study area. This boundary information was applied to each data set in order to "cut out" the area of interest. Each



Universal Soil Loss Equation
in a Geographic Information System

Figure 2.

cell of each information layer in the raster array was co-registered to the corresponding cells of separate data layers. A 30 by 30 meter raster cell size was chosen to match the spatial resolution of the Digital Elevation Model and satellite imagery.

The integration of the data into a geographic information systems format allowed the modeling process to begin. Each factor of the USLE was stored in the spatially georeferenced system, making the processing of the equation possible.

Current erosion rates in the South Fork watershed are relatively low due to the abundance of vegetative cover. Forest canopies protect the soil from the impact of raindrop erosion. There is some significant hazard in areas of pasture and cropland. The lack of large agricultural plots greatly reduces the potential for widespread erosion hazards within the study area. The relatively rapid growth of the population of this area is beginning to exert pressure on the South Fork watershed. Future construction and land use change could greatly increase sediment yield from the watershed.

The database was used to assess hypothetical changes in land use within the study area. Land cover (C) factors of the USLE were changed to predict the soil erosion from proposed changes in land use. Some agricultural uses on steeper slopes and highly erodible soils adversely affect soil erosion as to make cultivation unproductive. Simulations of changes in the study area were used to assess the effects of these changes upon soil erosion. A soil erosion index map was produced which integrates the physical properties of soil erosion.

Environmental resource management and investigations require data that can be efficiently stored and retrieved. Geographic information systems technology enables users to create a database in which these conditions can be met. Synoptic coverage of satellite imagery combined with GIS creates opportunities for large area investigations. These two technologies used in combination make a wide range of environmental studies possible. In addition to the integration of several different data structures, the technology allows large area investigations at relatively low cost. The ability to update the data base as new images become available is a significant advantage.

This project identifies critical source areas of sediment pollution within the South Fork of the New River drainage basin. The effects of hypothetical land use changes are demonstrated and the utility of remote sensing and geographic information systems for environmental resource modeling is assessed.

WORKS CITED

ERDAS Version 7.4 Earth Resources Data Analysis System, Inc., Atlanta, G. A.

Hunt, Charles B. 1974. Natural Regions of the United States and Canada. San Francisco: W. H. Freeman and Company.

Jensen, John R. 1983. Biophysical Remote Sensing. Annals of the Association of American Geographers. Vol. 73. pp. 111-132.

National Oceanic and Atmospheric Administration. 1988. Climatological Data Annual Summary: North Carolina 1988. Asheville: National Climatic Data Center.

U. S. Geological Survey. 1990. Water Resources Data North Carolina: Water Year 1989. Raleigh, N. C.: U. S. Geological Survey, Water Resources Division. NTIS, USGS/WRD/HD-90/250.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting Rainfall Erosion Losses - A Guide to Conservation Planning. Washington D. C.: U. S. Department of Agriculture. Agricultural Handbook No. 537.

Chapter II

Background

Soil erosion is a worldwide environmental problem. The impacts of soil erosion can be classified into two broad categories (Goldman, Jackson, and Burzyntsky 1986). Environmental impacts are those effects that harm ecosystems. Economic impacts are those that affect soil productivity or arise from damages caused by soil pollution. The economic impacts are relatively easy to quantify and can be controlled with less difficulty. Environmental impacts affect wildlife and often go unnoticed until it is too late to easily reverse them.

The obvious economic impact of soil erosion is in decreased productivity of agricultural lands. It has been projected that soil erosion may reduce worldwide agricultural productivity by as much as 30 percent by the year 2000 (Pimental et al. 1987). According to estimates based on typical prices of topsoil, $1.6 billion of soil is lost from construction sites alone each year (Goldman et al. 1986). There are also costs involved in dredging reservoirs, streams, and lakes filled with sediment. Holmes suggested that erosion control measures take into account the off-site damage of soil erosion including higher water treatment costs, dredging for navigation, and impacts on water related recreation (Holmes 1988).

Environmental impacts of soil erosion are difficult to measure and often do not attract our attention. Clark documented the danger to aquatic wildlife from increased turbidity, chemical and biological pollution associated with sedimentation of streams (Clark 1987). Turbidity reduces the amount of light available for photosynthesis for submerged aquatic vegetation. Sediments can disturb fish spawning grounds and interfere with feeding. The loss of topsoil decreases fertility and may prohibit the reestablishment of vegetation. The activities of humans on the earth has greatly increased soil erosion. Natural environments strain under the pressure of lost soil and increased sedimentation.

The development of equations to predict soil loss began in the 1940's using slope gradients and lengths as determining factors in soil loss (Wischmeier and Smith 1978). These early studies were improved by taking into account rainfall, land cover, and inherent erodibility of the soil. Unfortunately, the earlier predictive models did not effectively predict soil erosion outside the Midwestern United States.

The Universal Soil Loss Equation was developed in the late 1950's and early 1960's, culminating in the publication of Agricultural Handbook No. 282, "Predicting Rainfall Erosion From Cropland East of the Rocky Mountains" (Wischmeier and Smith 1965). The USLE is an empirical model based on 10,000 plot years of research in the eastern half of the United States. Numerous studies were conducted to correlate observed soil losses with the principle factors affecting soil erosion. Rainfall simulators were used to provide additional information used in determining USLE factor values.

The equation integrates the principle factors affecting sheet and rill erosion - rainfall erosivity, soil erodibility, length of slope, slope gradient, land cover, and conservation management practice:

$$A = RKLSCP$$

R = rainfall erosivity
K = soil erodibility
L = length of slope
S = slope gradient
C = land cover
P = conservation management practice

The rainfall erosivity factor, R, has been found to be a useful indicator of the ability of rainfall to detach and transport soil particles. The factor is a measure of rainfall's energy measured in tons per acre multiplied by its 30-minute intensity measure in inches per hour. The amount of rain is not in itself a useful indicator of its ability to erode soil. Soil erosion rates are tremendously increased by high intensity storms. Raindrop sizes are larger and have greater terminal velocities increasing the ability of raindrops' impacts to detach soil particles.

The soil erodibility factor, K, accounts for the cohesiveness of soil particles and is measured in units of R. Soil texture is the principle property which determines soil erodibility. Generally, soils with high silt content are the most erodible. Clay soils tend to be more cohesive and sandy soils are more difficult to transport (Goldman, Jackson, and Burszyntsky 1986). Organic matter tends to hold soil particles together, reducing their susceptibility to erosion. Structure and permeability affect a soil's vulnerability to raindrop impact and runoff. The USDA Soil Conservation Service determines soil erodibility for soils at the series level of classification. This information is useful to farmers, engineers, and others interested in natural processes related to soils.

The topographic factor, LS, measures the influence of slope gradient and the length of slope. These are dimensionless coefficients that are combined when used with USLE nomographs to measure the effects of topography on soil erosion. Steeper slope gradients increase runoff velocity and the gravity effects of soil particles dislodged by raindrop impact. Long slope lengths are able to accumulate greater volumes of runoff. Williams and Berndt found that "...it is much more important to accurately estimate slope gradient than length in applying the USLE" (Williams and Berndt 1977). According to their research, slope length estimate errors are reduced by 50 percent when calculating the equation. This reduction is necessary because variations in slope length have relatively little effect on erosion while slope variations have greater effects.

The cover factor, C, accounts for the vegetation cover's ability to intercept raindrops falling on soil and to reduce the erosive effects of runoff. Vegetation canopies reduce the erosive power of rain by intercepting falling raindrops. Litter of decaying vegetation blocks raindrops from striking bare soil. Vegetative covers protect bare soil from sheet and rill erosion. Cover factors have been determined for a wide variety of covers. Much more data are available for agricultural land covers and specific crop types since agricultural land presents the greatest soil erosion hazards. Most states provide technical guides that list land cover factor values for the USLE (USDA 1990).

The management practice factor, P, is a measure of erosion control practices such as strip cropping, terracing and contour plowing. This factor is often used in variations of the equation that will solve for P. The management practice is determined by identifying a specific technique that will decrease soil erosion to the point where the amount of soil loss is acceptable. Studies of soil erosion potential usually hold this factor constant.

The USLE was originally designed to predict average annual soil loss. It can be used for short time durations by using fractions of the rainfall factor. The equation was originally intended for agricultural applications and has since been expanded for forestry, rangeland, and urban uses. It is commonly used to estimate soil loss from construction sites and in areas subject to logging operations. The most common use is for soil conservation planning to guide farmers in their efforts to reduce erosion and maintain soil fertility. RKLS, known as the erosion index, is calculated and used with a soil loss tolerance value T. These values are the number of tons/acre/year of soil loss that can be tolerated while continuing to maintain suitable soil productivity levels. Equations have been developed with these factor values that enable the analyst to solve for C and P. The natural factors of soil loss and the assigned tolerance levels serve as a guide for what land covers and management practices can be used to mitigate high levels of soil loss. This method has proven successful in determining the optimal erosion control measures for a particular site (Goldman, Jackson, and Burszyntsky 1986).

The USLE has been modified to predict sediment yield from watersheds (Fogel, Heckman, and Duckstein 1977). The modified USLE uses a sediment delivery ratio to estimate the amount of sediment leaving a drainage basin. The USLE does not estimate the amount of sediment entering streams. Soil particles that are detached and transported often end up in natural catchments at the foot of slopes.

The principle developer of the equation has pointed out some limitations of its use (Wischmeier 1976). The equation is designed for general planning purposes for a variety of regions. Precise estimates of soil loss may require calibration of certain factors to more closely simulate local conditions. This process increases the difficulty applying the equation for practical purposes. Average topographic factors should not be estimated for large complex watersheds. These basins should be subdivided to into smaller subwatersheds.

Geographic Information Systems used in conjunction with remote sensing has spawned a wealth of research that was not possible as little as 10 years ago. Estes suggests that the combination of these technologies may be necessary to reach the full potential of both methodologies (Estes 1982). This technology allows researchers to study much larger areas and handle greater volumes of data. The temporal resolution of satellite imagery and aerial photography enable frequent survey updates.

Remote sensing has become an increasingly useful tool for resource management. The technology is beginning to move outside research domains and into practical surveys and studies for resource management. Johannsen and Barney reviewed practical applications for satellite remote sensing for resource management (Johannsen and Barney

1981). They examined the potential of remote sensing for land use and cover surveys, hydrologic modeling, distinguishing vegetation types, and locating mineral deposits. They also pointed out the need for technology transfer among users of remote sensing and GIS.

In conjunction with the increasing use of remote sensing, geographic information systems have become very popular for inventory and modeling over space. Walsh identified the potential of GIS for natural resource management and compliance with state and federal water pollution regulations (Walsh 1985). The use of GIS with the federal government's Land Evaluation and Site Assessment System demonstrates its potential to evaluate the potential of land for agricultural production (Williams 1985). Ventura, Niemann, and Moyer surveyed the costs and needs of creating a multipurpose GIS for rural resource planning. They suggest that, for many applications, GIS for resource management is highly beneficial. Users, however, must understand technical problems and limitations of GIS (Ventura, Niemann, and Moyer 1988).

Remotely sensed data have much potential and utility for soil erosion modeling (Pelletier 1985). Morgan et al. used color infrared and color high altitude photography to derive C and P factors of the USLE in Dane County, Wisconsin (Morgan et al. 1978). The other factors were obtained from soil surveys and topographic maps and manually encoded on grid overlays. Their results correlated well with field measurements. An advantage of high altitude photographs is their ability to distinguish cropping practice patterns as well as certain crop types. Stephens and Cihlar examined the potential of satellite remote sensing to derive land cover variables in soil erosion models (Stephens and Cihlar 1981). They evaluated the Landsat multispectral scanner (MSS) and thematic mapper (TM) and the French SPOT system to determine optimal data sources. The Spot system proved to be the most accurate classifier.

Several studies in the 1980's used geographic information systems and remote sensing in combination to model soil erosion. Spanner, Strahler, and Estes used the Image Based Information System developed at the NASA Jet Propulsion Laboratory to solve the USLE for the Santa Paula 7.5 minute quadrangle in California (Spanner, Strahler, and Estes 1983). This study showed the utility of a raster based GIS to incorporate satellite data and other data already in raster formats. The USGS digital elevation models (DEM) are particularly well suited to this task. The Virginia Division of Soil and Water Conservation made soil erosion and sediment yield estimates for the Chesapeake Bay drainage basin in Virginia using GIS and Landsat multispectral imagery (Hession and Shanholtz 1988). Based on their analysis, money was allocated to areas with greatest pollution hazards.

Geographic information systems and remote sensing enable biophysical modeling over large areas. Environmental modeling research is largely based on site analysis and evaluation. The new technologies permit dramatic changes in scale for environmental modeling. The USLE, for example, was developed as a guide for site planning to control erosion. With GIS and remote sensing, it is possible to use the USLE to evaluate soil erosion at the watershed scale.

Works Cited

Clark, Edwin H. 1987. Soil Erosion: Offsite Environmental Effects. In Agricultural Soil Loss, Eds. John M. Harlin and Gigi M. Berardi. 59-91. Boulder: Westview Press.

Estes, J. E. 1982. Remote Sensing and Geographic Information Systems Coming of Age in the Eighties. In Remote Sensing: An Input to Geographic Information Systems in the 1980's. Falls Church, VA: American Society of Photogrammetry, 23-40.

Fogel, M. M., L. H. Heckman, Jr., and L. Duckstein. 1977. A Stochastic Sediment Yield Model Using the Modified Universal Soil Loss Equation. In Soil Erosion: Prediction and Control: Proceedings of National Conference on Soil Erosion in West Lafayette, Indiana, May 24-26,1976, by the Soil Conservation Society of America. Ankeny: Soil Conservation Society of America, 1977, 226-234.

Goldman, Steven J., Katherine Jackson, and Taras A. Bursztynsky. 1986. Erosion and Sediment Control Handbook. New York: Mcgraw Hill, Inc.

Hession, W. Cully, and W. D. Shanholtz. 1988. A Geographic Information System for Targeting Nonpoint-source Agricultural Pollution. Journal of Soil and Water Conservation. May-June 1988.

Holmes, Thomas P. 1988. The Offsite Impact of Soil Erosion on the Water Treatment Industry. Land Economics. 64 (November) 356-366.

Johannsen, Chris J. and Terry W. Barney. Remote Sensing Applications for Resource Management. Journal of Soil and Water Conservation. May-June 1981.

Morgan, Ken M., Gerhard B. Lee, Ralph Keifer, T. C. Daniel, Gary D. Bubenzer, and John Murdock. 1978. Prediction of Soil Loss on Cropland with Remote Sensing. Journal of Soil and Water Conservation. November-December 1978: 291-293.

Pelletier, R. E. 1985. Evaluating Nonpoint Source Pollution Using Remotely Sensed Data in Soil Erosion Models. Journal of Soil and Water Conservation. July-August: 1985

Pimental, D. et al. World Agriculture and Soil Erosion. Bioscience. April 1987: 277-283.

Spanner, M.A., Alan Strahler, and John E. Estes. 1983. Soil Loss Prediction in a Geographic Information System Format. In Proceedings of the Seventeenth International Symposium on Remote Sensing of Environment, May 9-13,1983, by Environmental Research Institute. Ann Arbor: Environmental Research Institute.

Stephens, Peter R. and Josef Cihlar. 1981. The Potential of Remote Sensing to Monitor Soil Erosion on Cropland. In Proceedings of the Fifteenth International Symposium on Remote Sensing of Environment, May, 1981, by Environmental Research Institute. Ann Arbor: Environmental Research Institute.

U. S. Department of Agriculture. Soil Conservation Service. 1990. The Universal Soil Loss Equation with Factor Values for North Carolina. [Raleigh, N. C.]: U. S. Department of Agriculture. Soil Conservation Service.

Ventura, S. J., B. J. Niemann Jr., and D. D. Moyer. 1988. A Multipurpose Land Information System for Rural Resource Planning. Journal of Soil and Water Conservation. May-June 1988: 226-229.

Walsh, Stephen J. 1985. Geographic Information Systems for Resource Management. Journal of Soil and Water Conservation. March-April 1985: 202-205.

Williams, J. R. and H. D. Berndt. 1977. Determining the Universal Soil Loss Equation's Length-Slope Factor Watersheds. In Soil Erosion: Prediction and Control. Ankeny: Soil Conservation Society of America.

Williams, T. H. Lee. 1985. Implementing LESA on a Geographic Information System - A Case Study. Photogrammetric Engineering and Remote Sensing. 51 (12) 1923-1933.

Wischmeier, W. H., and D. D. Smith. 1965. Predicting Rainfall-erosion from Cropland East of the Rocky Mountains. Washington D. C.: U. S. Department of Agriculture. Agricultural Handbook No. 282.

Wischmeier, W. H. 1976. Use and Misuse of the Universal Soil Loss Equation. Journal of Soil and Water Conservation. 31 (January): 5-9.

Chapter III

Methodology

The identification of critical source areas of sediment pollution using remote sensing and geographic information systems requires the acquisition of model data, data processing and management, model application, and map generation delineating the spatial extent of soil erosion. This process was accomplished using the Universal Soil Loss Equation to estimate soil loss potential. The data for each factor of the equation were acquired, georeferenced, and spatially registered to all other data layers in order to simulate the model.

This project was accomplished using Earth Resources Data Analysis Systems (ERDAS) software (ERDAS 1990). The system was designed to process remotely sensed digital image data and perform geographic information systems analysis. ERDAS is a raster based GIS and one of the more popular digital image processing systems.

A necessary first step for this project was to define and delineate the study area. Index, NC was chosen as the watershed outlet for this study. The United States Geological Survey maintains a gaging station at this point on the South Fork. The watershed was then delineated by sketching the basin divides on the Boone 1:100,000 USGS metric topographic map. Some portions of the divides, such

USLE Factor	Data Source
R= rainfall erosivity	SCS Factor Values Guide
K= soil erodibility factor	County Soil Surveys
S= slope gradient factor	USGS DEM
L= length of slope factor	USGS 7.5 minute topo sheets
C= land cover	1988 Thematic Mapper Image
P= management practice	constant

Table 1. USLE Factors and Data Sources

as the Tennessee Valley Divide, were already delineated. The portions of the divide that were not marked on the map were drawn by analyzing contours to determine the direction of runoff.

The study area boundary was converted to digital form by registering the map to the Universal Transverse Mercator coordinate system and digitizing the map boundary using the DIGPOL program and a tablet digitizer. This program stores the coordinates of the watershed boundary in a polygon file. For each data layer used in this project the study area is "cut out" in a cookie cutter fashion, using the ERDAS program CUTTER. The compatibility of the data layers for pixel to pixel registration is assured because each file is exactly the same size and all are georeferenced to

UTM coordinates.

The R factor of the USLE was derived from technical guides for model use in North Carolina (USDA 1990). This value is a measure of rainfall's energy multiplied by its maximum 30-minute intensity and has been found to be a useful indicator of the ability of rain to dislodge soil particles and transport them. The Soil Conservation Service has assigned a value of 200 for Watauga County and 180 for Ashe county. These are values SCS personnel use when making USLE predictions in the field. The rainfall factor for each county was added to the attribute data files for digitized soil maps of Watauga and Ashe counties, thus assuring that each raster cell in this data layer stored the appropriate rainfall factor.

The S factor of the USLE was derived from USGS Digital Elevation Models (USGS 1987). These data, purchased from the National Cartographic Information Center, are referenced to standard USGS 1:24,000 topographic maps on a UTM coordinate system and stored on computer compatible tape. The study area includes all or part of ten quadrangles. Each DEM quadrangle was loaded from computer compatible tape to the ERDAS system using LOADDEM. As purchased the data is stored such that north is facing to the right on the display device. The program, ROTATE, positions the image so that north faces the top of the display screen. Because the data are already geometrically rectified, the program FIXHED was used to assign UTM coordinates to each pixel for each quadrangle. The STITCH program was performed to mosaic the ten quadrangles together in their proper georeferenced position.

The SLOPE program transforms the DEM to a slope gradient map. This program calculates percent slope by comparing neighboring pixel elevations to the pixel of interest. Planes are drawn in mathematical space tangent to the sampled pixels and their gradient calculated. Errors were identified at the quadrangle borders that were corrected using GISEDIT. This program was used to delete lines with error and assign their pixel values to similar neighboring values. The study area was extracted using CUTTER. S factors were assigned by the equation:

$$\text{Slope coefficient} = (.43 + .3S + .043S^2)/6.617$$

where S is percent slope, for slopes less than nine percent and:

$$\text{Slope coefficient} = (S/9)^{1.3}$$

for slopes greater than nine percent (Wischmeier 1978).

The soil erodibility factor, K, was derived from Soil Conservation Service soil surveys of Watauga and Ashe counties (SCS 1944, 1984). County-wide soil association maps were digitized and assigned the average values of soil erodibility for all soil types within the association. Soil series maps were not used due to the extremely poor quality of the Watauga County soil data.

The length of slope factor accounts for the erosive power of runoff to dislodge and transport soil particles. To obtain average values for this factor the basin was divided into 26 subwatersheds. USGS Digital Line Graph data were used to delineate general watershed boundaries. These boundaries were used to locate the correct boundary on USGS 1:24,000 quad sheets by determining direction of runoff.

Lengths of three contours throughout each subwatershed were measured and summed (Williams and Berndt 1977). Along each contour the number of extreme points was counted and summed. Extreme points are points where contours point towards the basin divide. These points mark drainage channels and thus, the effective end of the slope length. Length of contours divided by the number of extreme points estimates average slope lengths if the direction of runoff is perpendicular to the channel. Since overland flow is rarely perpendicular to the channel, this method is modified to account for varying direction of runoff.

The length of slope factor was estimated for subwatersheds within the study area using the following equation:

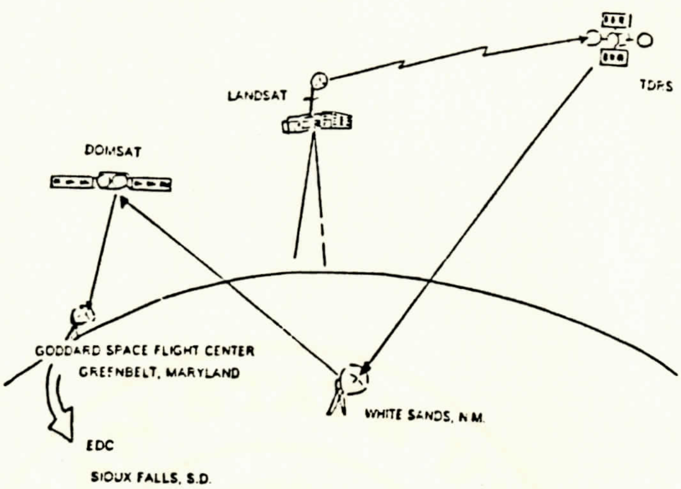
$$\text{slope length} = \frac{LB * LC}{2EP * \ LC^2 - LB^2}$$

where LC is the length of contours within the subwatershed, LB is a base line that accounts for variation in directions of runoff and EP is the number of extreme points. It was necessary to subdivide the basin to derive average L factors due to greater inaccuracies occurring for these average values in complex watersheds (Wischmeier 1976). Subwatershed boundaries were digitized and each one was assigned its estimated average slope length. These values were converted to the L coefficient using the equation

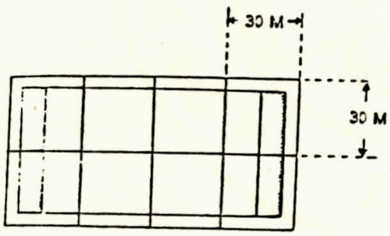
$$L = (1/72.6)^{.3}$$

where L is the length of slope coefficient, l is the average slope length in feet (Wischmeier and Smith 1978).

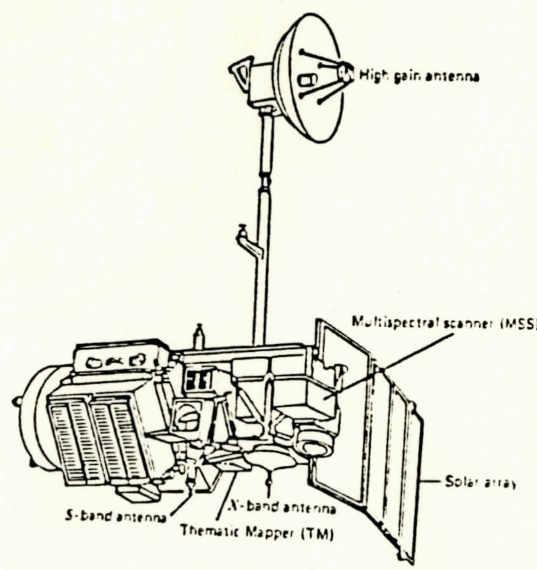
The cover factor C, was derived from a classified Landsat Thematic Mapper satellite image obtained on 27 August 1988 (Figure 3). The Thematic Mapper records 7 bands of electromagnetic radiation ranging from .45 to 2.35 microns on the electromagnetic spectrum (Table 2). Picture elements, called pixels, represent 30 by 30 meter areas on the ground (spatial resolution) for bands 1 through 5 and band 7. Band 6 measures data at a spatial resolution of 120 by 120 meters. TM radiometric resolution enables the system



Data Flow
Source: Campbell, 1987



Ground Resolution
Source: Campbell, 1987



Landsat 5
Source: Lillesand and Kiefer 1987

Figure 3. Thematic Mapper Characteristics

Landsat TM Band Number	Spectral response on electromagnetic spectrum
1	.45-.53
2	.52-.60
3	.63-.69
4	.76-.90
5	1.55-1.75
7	2.08-2.35
6	10.4-12.5

Table 2. TM 7 band spectral resolution

to record 8-bit data or 256 brightness levels.

Preprocessing of the raw TM data requires that the image be rectified to account for distortions of irregular topography and the curvature of the earth surface. The ERDAS program GCP was used to select 33 points within the study area to serve as ground control points. These points were input into the COORD2 program to calculate a transformation matrix that assigns each pixel to the Universal Transverse Mercator coordinate system. Since it is virtually impossible to transform the image data to its exact location on a coordinate system, some error is tolerated. COORD2 calculates this error using root mean square (RMS) distances in pixels. An RMS error of 1.0 pixels was chosen for the error tolerance. In order to reach this tolerance 12 ground control points were eliminated from the transformation matrix. RECTIFY used the transformation matrix to assign each pixel of the raw data to a position on the UTM grid in a process referred to as "rubber sheeting." The nearest neighbor technique for intensity interpolation was employed. CUTTER was used to extract the study area from the larger file.

The TM image was classified using unsupervised and supervised methods. An unsupervised classification was performed in which the computer identified pixel brightness values in seven-dimensional spectral space and grouped them according to their similarity. The program generated 20 classes with statistics for each one. Three hard copy image maps of subsets of the study area were printed on a color ink jet printer to assist in the identification of training sites for the supervised classification. The hard copy image maps were taken into the field to assign information to each spectral class (ground truthing). Large contiguous areas of a common class were identified and delineated on USGS 7.5 minute maps. These areas became the training sites for the supervised classification.

The supervised classification was performed using the USGS Level I classification system (Anderson et al. 1976). Water, agricultural land, pasture, forest land, urban and built-up land were chosen as the areas of interest. Ten training sites for each class were identified throughout the study area and delineated using DIGSCRN. Statistics for training sites were produced with SIGEXT and evaluated with ELLIPSE to determine the separability between signatures to be used in the supervised classification. ELLIPSE creates scatterplots of the training pixel values for two band combinations allowing the analyst to select signatures with the greatest separability.

The image was classified using a combination of parallelepiped and minimum distance to means decision rules in the program MAXCLAS. The algorithm calculates parallelepipeds in seven-dimensional spectral space based on the training statistics. A parallelepiped for each class of interest is constructed with boundaries two standard deviations from the training statistic mean. Pixel brightness values were classified according to the parallelepipeds that lay within. Those pixels that did not fall in a parallelepiped's spectral space in a first pass over the data were classified by the minimum distance to means decision rule. This rule assigns the pixel to the class whose training statistic mean is the minimum distance in spectral space.

Attribute files store USLE factor values in a relational database which allows the user to relate these factors to digital maps of each data layer. DSCEDIT enables creation and manipulation of these files. INQUIRE enables the analyst to determine coordinate position, file values, attribute values, and other information for each pixel location in multiple data layers. This program enables the analyst to check for registration accuracy and accuracy of the model.

The Universal Soil Loss Equation was calculated for 30 by 30 meter grid cells for the South Fork watershed. The model was written and performed in the GISMO program. Factor values in attribute files were multiplied by each other to estimate potential soil loss for each grid cell in the study area.

Works Cited

Anderson, J. R. et al. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Professional Paper No. 964. U. S. Geological Survey. Washington, D. C.

Campbell, James B. 1987. Introduction to Remote Sensing. New York: The Guilford Press.

ERDAS Version 7.4. Earth Resources Data Analysis System, Inc., Atlanta, Georgia.

Lillesand, Thomas M. and Ralph W. Kiefer. Remote Sensing and Image Interpretation. New York: John Wiley and Sons.

U. S. Department of Agriculture. 1990. The Universal Soil Loss Equation with Factor Values for North Carolina. Raleigh: Soil Conservation Service.

U. S. Department of Agriculture. 1984. Soil Survey of Ashe County, North Carolina. Raleigh: Soil Conservation Service.

U. S. Department of Agriculture. 1944. Soil Survey of Watauga County. Raleigh: Soil Conservation Service.

U. S. Department of the Interior. U. S. Geological Survey. 1987. Digital Elevation Models: A User's Guide. [Reston, V.A.]: U. S. Department of the Interior, U. S. Geological Survey.

Williams, J. R., and H. D. Berndt. 1977. Determining the Universal Soil Loss Equation's Length-Slope Factor for Watersheds. In Soil Erosion: Prediction and Control. Ankeny: Soil Conservation Society of America.

Wischmeier, W. H. 1976. The Use and Misuse of the Universal Soil Loss Equation. Journal of Soil and Water Conservation 31(1) 5-9.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting Rainfall Erosion Losses - A Guide to Conservation Planning. Washington D. C.: U. S. Department of Agriculture. Agricultural Handbook No. 537.

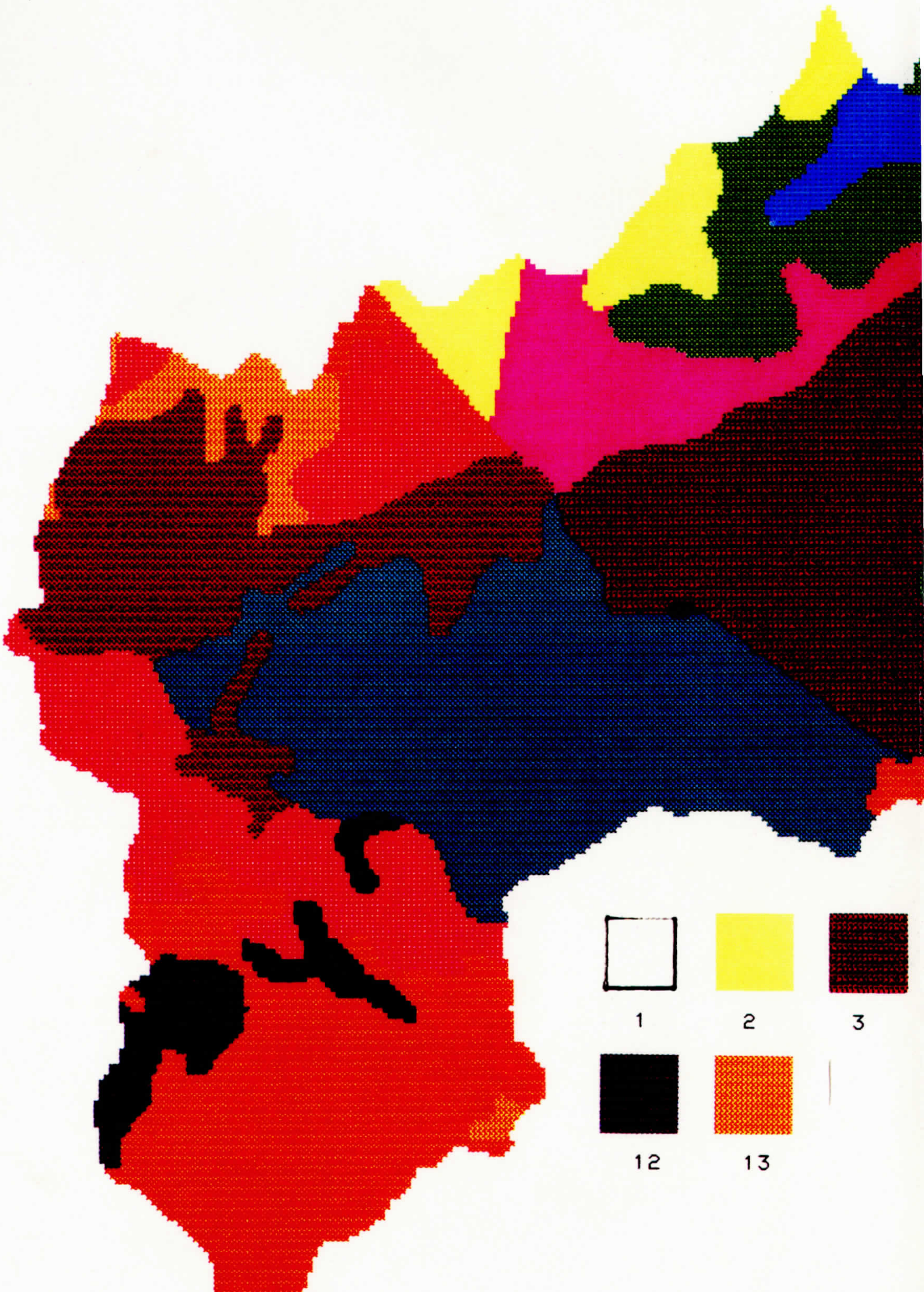
Chapter IV

Analysis

Analysis of Factors of the Soil Loss Equation

The relative abundance of rainfall in northwestern North Carolina affects soil erosion in two ways. First, greater rainfall intensity generally erodes more soil if all other factors remain constant. The Soil Conservation Service assigned R factors of 200 and 180 for Watauga and Ashe counties respectively (USDA 1990). These values are lower than most of the Southeast, roughly equivalent to values found in the Midwest, and much higher than R factors for the western part of the United States. Secondly, abundant rainfall results in higher vegetation density levels. The dense vegetation provides canopies and ground litter to intercept raindrops, as well as root networks which help to hold soils in place. The effect of abundant vegetation is accounted for in the land cover factor of the soil loss equation.

The soils of the South Fork watershed can generally be said to be loamy (Figure 4, Table 3). This is reflected in the soil erodibility factor, K. In the watershed, K factors range from 0.02 to 0.69. Soils with high percentages of very fine sand and silt are the most susceptible to erosion (Goldman, Jackson and Burzyntsky 1986). Loamy soils have K factors ranging from 0.2 to 0.35. Soils in the South Fork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igure 4. South Fork Soil Associations

Soil Associations	% area	Square miles	K
Porters-Tusquitee-Spivey	3.45	7.05	.21
Watauga-Fannin-Chandler	26.48	54.16	.21
Evard-Ashe	5.64	11.52	.16
Clifton-Evard-Fannin	11.73	23.98	.19
Braddock-Toxaway	1.89	3.86	.21
Congaree-Chewacla-State	.98	2.01	.25
Ashe-Perkinsville-Tate	11.62	23.76	.23
Chandler-Watauga-Tate	16.62	33.99	.21
Porters-Halewood-Tusquitee	8.88	18.16	.20
Clifton-Porters-Tusquitee	9.07	18.54	.21
Ramsey-Matney-Tate	1.68	3.43	.26
Stony Colluvium	1.96	4.00	.26

Table 3.
South Fork Watershed Soil Associations

watershed have K factors ranging from 0.19 to 0.26. Watauga-Fannin-Chandler association soils make up over 26 percent of the watershed and have an assigned K value of .21. This indicates that these soils are moderately susceptible to soil erosion if all other factors are equal. Soil erodibility factors throughout the watershed reflect the generally loamy nature of these soils. A limitation of the soil erodibility data is the fact that the data are over 40 years old. The reliability of these data will improve as better soil surveys are completed.

The length of slope factor, L, was estimated for 26 subwatersheds in the study area (Figure 5). A standard 72.6 foot slope length has an L factor equal to 1. The longer slope lengths in this area increase runoff which accordingly erodes more soil by sheet erosion. Estimated average values for this factor are not as accurate as surveying every slope segment in the study area, but such field measurements are beyond the scope of this project. Some studies hold this value constant at 1 to negate the influence of the length of slope factor (Vold, Sondheim, and Nagpal 1985). Since most slope lengths in the study area are greater than 72.6 feet in length, it is necessary to account for this factor in the USLE (Table 4).

Slope factors for the watershed have a considerable effect on soil erosion. The mountainous terrain of the Blue Ridge physiographic province limits certain activities.


1
2
3
12
13
14
23
24
25

1 Winkler Creek
2 Middle Fork
3 Camp Creek
4 Call Creek
5 Boone
6 Happy Valley
7 Old Field Creek
8 Lake Ashe
9 Howard Creek
10 Elk Creek
11 Idlewild Road
12 Pine Swamp Creek
13 Cranberry Creek
14 Laron Creek
15 Bethel Church
16 Oval
17 Multon Creek
18 Grassy Creek
19 Beaver Creek
20 Bear Creek
21 Obids Creek
22 Gap Creek
23 Swampy
24 Riverview Church
25 Round Knob
26 Index

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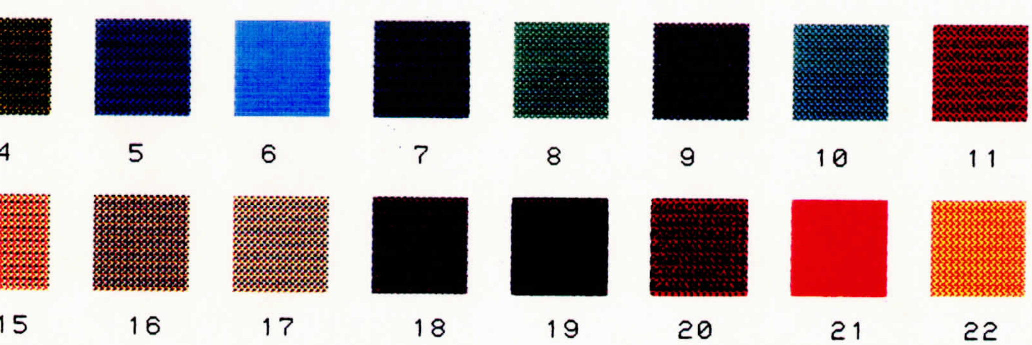

Figure 5 South Fork Subwatersheds

Subwatershed	LC	LB	EP	length	L
Winkler Cr	152203	97717	166	384	1.64
Middle Fk	313239	232564	272	638	1.91
Camp Creek	304164	267655	400	704	1.97
Call Creek	260242	215778	344	561	1.84
Boone	149218	124729	171	664	1.94
Happy Valley	171493	139318	250	478	1.76
Old Field Cr	143744	117426	194	525	1.81
Lake Ashe	139066	114886	180	566	1.85
Howard Creek	178981	178981	250	611	1.89
Elk Creek	193217	193217	299	560	1.84
Idlewild Rd	89471	74961	139	494	1.77
Pine Swamp	231076	201229	284	721	1.99
Cranberry Cr	252454	211735	339	573	1.85
Laron Creek	207488	175271	270	606	1.88
Bethel Ch	131672	106307	295	305	1.53
Oval	103184	87345	182	451	1.72
Multon Cr	74340	68145	122	629	1.97
Grassy Cr	147380	125097	217	545	1.83
Beaver Cr	133927	113757	203	531	1.81
Bear Creek	144496	109235	203	411	1.68
Obids Creek	203115	162528	300	452	1.73
Gap Creek	136596	111348	188	511	1.79
Swampy	62616	52247	88	538	1.82
Riverview	106623	93357	170	568	1.85
Round Knob	107528	90033	135	610	1.89
Index	71341	59054	110	478	1.76

Table 4.
Average watershed slope length
calculation measurements

The terrain constraints also put great pressure on the valleys, and to a lesser extent the ridgetops. Agricultural activities are severely limited due to steeply sloping land. Large mechanized farm operations would not be economical because there are insufficient large, contiguous tracts with gentle slopes. The distribution of slope gradients throughout the watershed is centered around a mode of between 16 and 20 percent (Figure 6 and Table 5). Most slope gradients fall between 6 and 30 percent. With only 6.75 percent of the watershed having slope angles of 5

percent slope	square miles	percent of watershed
0 - 5 %	13.85	6.75%
6 - 10 %	26.24	12.79%
11 - 15 %	32.76	15.97%
16 - 20 %	33.77	16.46%
21 - 25 %	31.98	15.59%
26 - 30 %	25.85	12.60%
31 - 35 %	18.29	8.92%
36 - 40 %	10.45	5.10%
41 - 45 %	5.41	2.64%
> 45 %	6.52	3.18%

Slope Gradient Distributions Throughout Study Area
Table 5.

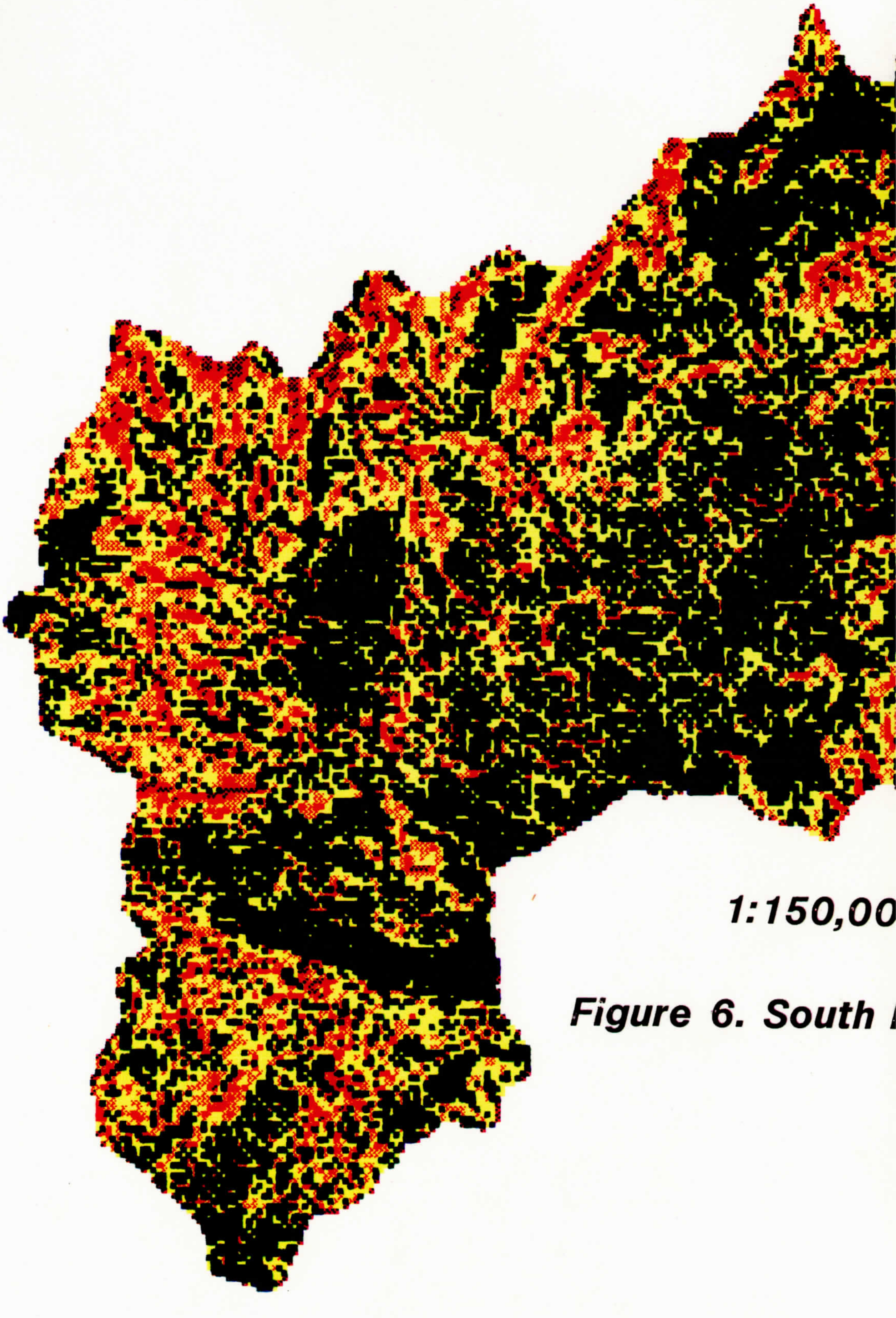

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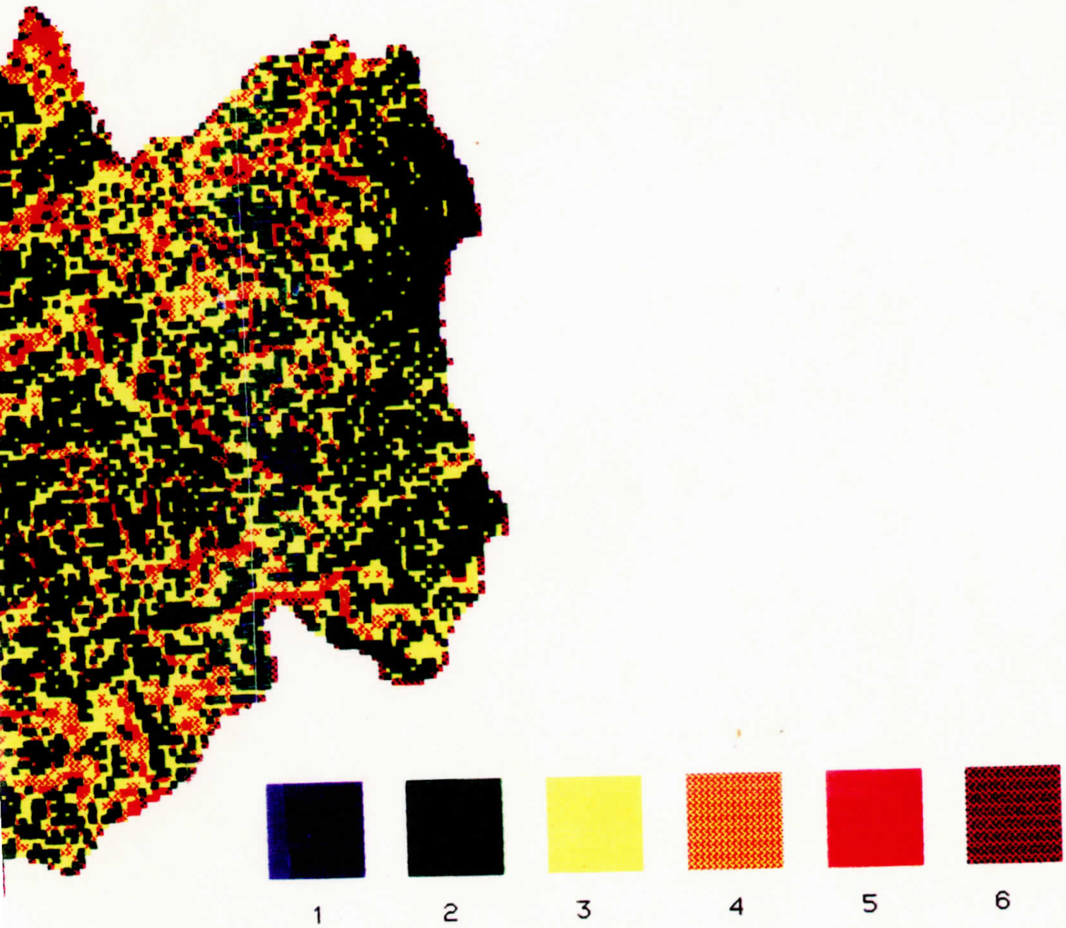
Figure 6. South



1	0-5%	Slope
2	6-10%	Slope
3	11-15%	Slope
4	16-20%	Slope
5	21-25%	Slope
6	>26%	Slope

rk Slope

percent or less, the competition for gently sloping areas is intense. The town of Boone occupies a large amount of the gently sloping land. Land adjacent to the New River is not necessarily gently sloping. In fact, there are cliffs overlooking parts of the river that are the steepest slopes in the study area.

The steep slopes of the watershed, and all the limitations these imply, are borne out in the land cover classification (Figure 7). Less than 2 percent of the study area was classified as urban and built-up land (Table 6). Most of the watershed is forested and is less susceptible to erosion. Forest canopies intercept raindrops and provide a litter that reduces the effects of rainsplash and runoff. Pasture for cattle grazing does not represent any widespread erosion hazards. Most erosion from pasture occurs near feed lots and on cattle trails. Any specific site in an urban area may have erosion problems, but generally over a short period of time. Construction sites pose the greatest danger for soil erosion hazard, especially in the urbanized portions of the watershed.

Cropland represents significant soil erosion hazards. Almost 5 percent of the study area is used as cropland. Human disturbance of the vegetative cover on farmland results in the most widespread soil environmental impacts because such large areas have bare soil during early growth and after harvest. Large construction sites such as

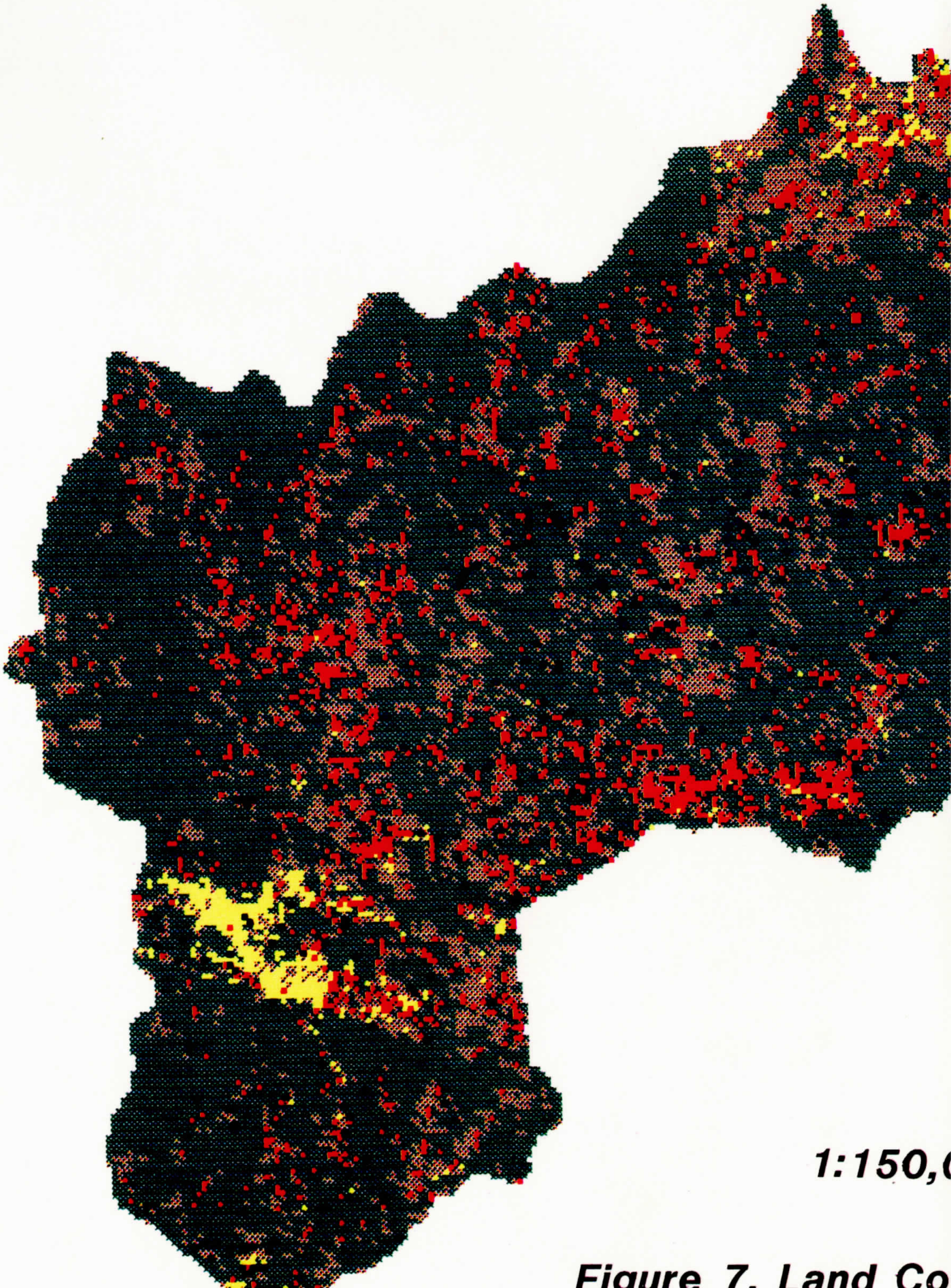


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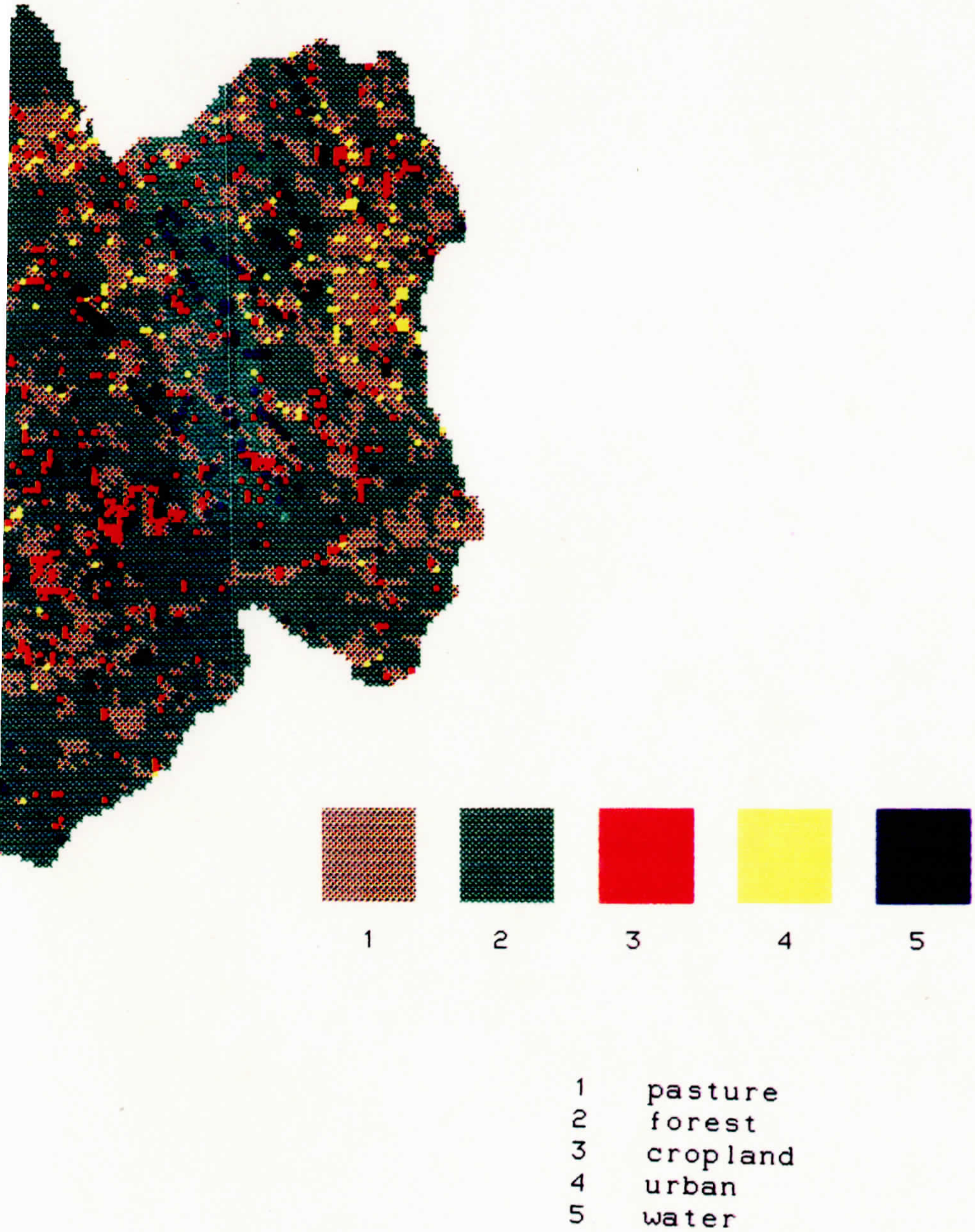
Figure 7. Land Co



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r Classification

land cover	sq. mi.	% of basin
cropland	13.25	6.46%
pasture	41.88	20.4%
forest	143.72	70.0%
water	2.27	1.1%
urban/built	4.13	2.01%

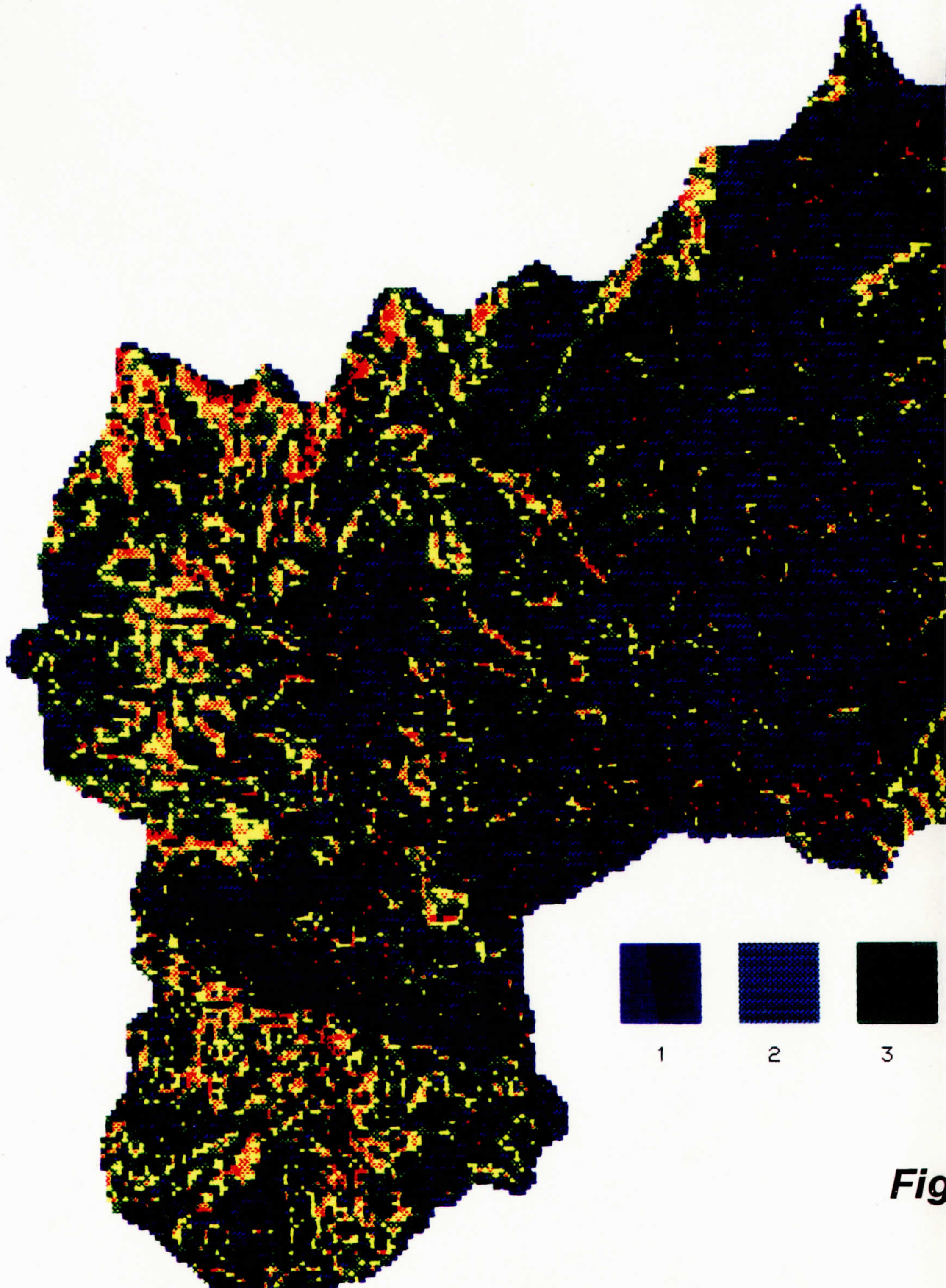
Table 6.
South Fork New River Land Cover

highway and road development are the second greatest significant hazard.

Analysis of Soil Erosion Potential

The Universal Soil Loss Equation was calculated for the South Fork watershed (Figure 8). Estimated potential soil loss for over 75 percent of the watershed is under 5 tons/acre/year (Table 7). The Soil Conservation Service uses the 5 tons/acre/year figure as the most soil loss that can be tolerated before serious threats to soil productivity occur.

Cover factors for cropland include crop types that do not leave large areas of bare soil. For example, hay crops have lower C factor values than other crops that leave larger portions of the surface in bare soil. Thus, cropland



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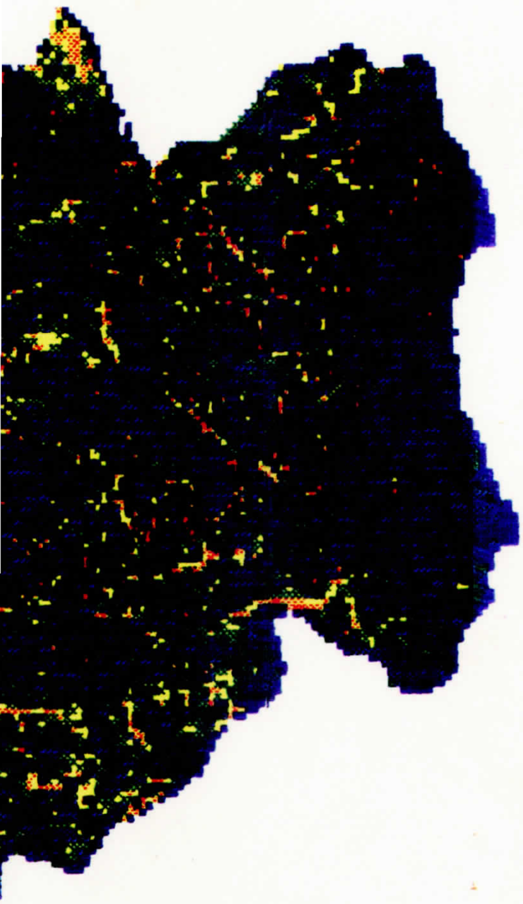

tons /acre/year

1	0-1
2	1-2
3	2-3
4	3-4
5	4-5
6	5-6
7	6-7
8	7-8
9	8-9
10	9-10
11	>10

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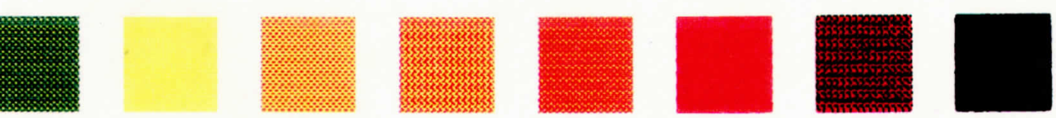


re 8. Estimated Soil Loss

values are likely to be higher than those that actually exist. The relative absence of large tracts of farmland in cultivation reduces the portion of soil loss and sedimentation resulting from agricultural activity.

Urban areas within the watershed appear to be negligible contributors to sedimentation. The impervious surfaces of roads, parking lots, and other urban land covers serve as a barrier between erosive rains and bare soil. The urban development in the study area is generally located in the valleys and lowlands. The gently sloping gradients of these areas reduce the effects of rainfall erosion as well. Rapid runoff and the frequency of disturbance in urban areas offset some of the barriers to erosion.

Forested portions of the study area show low erosion levels. The upper limit of possible C factors was used for this land cover. Forest canopies intercept falling raindrops and create a thick ground litter that shields the soil from raindrops and runoff. These areas, however, are particularly susceptible to erosion if the forest cover is disturbed. One reason this land is in forest is that it is often not economical for other uses.

Pasture and idle land present no large scale erosion hazards. As mentioned earlier, hazards from these areas are related to the exposure of bare soils by animal traffic. During field work in the study area, few areas of bare soil

potential soil loss tons/acre/yr	square miles	percent of basin
< 1	36.75	17.9
1 - 2	40.44	19.7
2 - 3	35.83	17.5
3 - 4	24.91	12.1
4 - 5	14.97	7.3
5 - 6	8.49	4.1
6 - 7	4.64	2.3
7 - 8	2.92	1.3
8 - 9	1.96	.96
9 -10	1.85	.90
>10	32.24	16

Table 7.
Soil Loss Potential Classification

were seen in pasture covers. The abundance of rainfall ensures a lush vegetation cover in pasture areas. Grazing cattle reduce canopy height and the canopy's potential to intercept raindrops. Grass covers do, however, protect bare soil and hold soil together with their root systems. Perhaps a greater pollution hazard in pasture is runoff of animal wastes to streams.

The soil erosion potential map generated in this study shows estimated potential soil erosion for typical cover conditions. Areas under cultivation and pasture on steep slopes exhibit high soil erosion potential. Ridgetops and valley lowlands are less likely to be susceptible to rainfall erosion.

Modeling Proposed Disturbances of Landscape

Proposed human changes on the land and their effect on soil erosion can be modeled by changing factors of the USLE. For example, effective length of slope can be altered by constructing drainage channels and terracing of hillslopes. The length of slope factor, L, factors would be changed to account for the slope lengths associated with the change. Cut and fill development can also radically alter slope gradients.

The most likely changes, however, will be in the land cover of a particular area. Changing the C factor can represent the proposed change in land cover and its related effect on soil erosion. The following example shows factors for a current cover, for a proposed change, and the difference in estimated soil loss. The rainfall factor is the value used for Watauga County. The soil erodibility factor, K, is typical of a loamy textured soil in the New River basin. The length of slope factor represents a 385 foot slope length. The slope factor is for a 12 percent slope gradient. This example represents typical RKLS values for the study area with a forest land cover. Estimated soil loss is 1.07 tons/acre/year:

R = 200
K = .24
L = 1.65
S = 1.35
C = .01

A = (200)(.24)(1.65)(1.35)(.01)
A = 1.07

Changing the site from forest cover to cropland would result in an estimated soil loss of 32.08 tons/acre/year:

R = 200
K = .24
L = 1.65
S = 1.35
C = .3

A = (200)(.24)(1.65)(1.35)(.3)
A = 32.08

Cultivating this land would require management practices to reduce the effective slope and slope lengths. Terracing this land, and thereby changing effective slope length and slope gradient, would reduce the soil loss. For example, if the farmer terraced this slope into 72.6 feet slope lengths and reduced the slope gradient to 3 percent the equation would take this form:

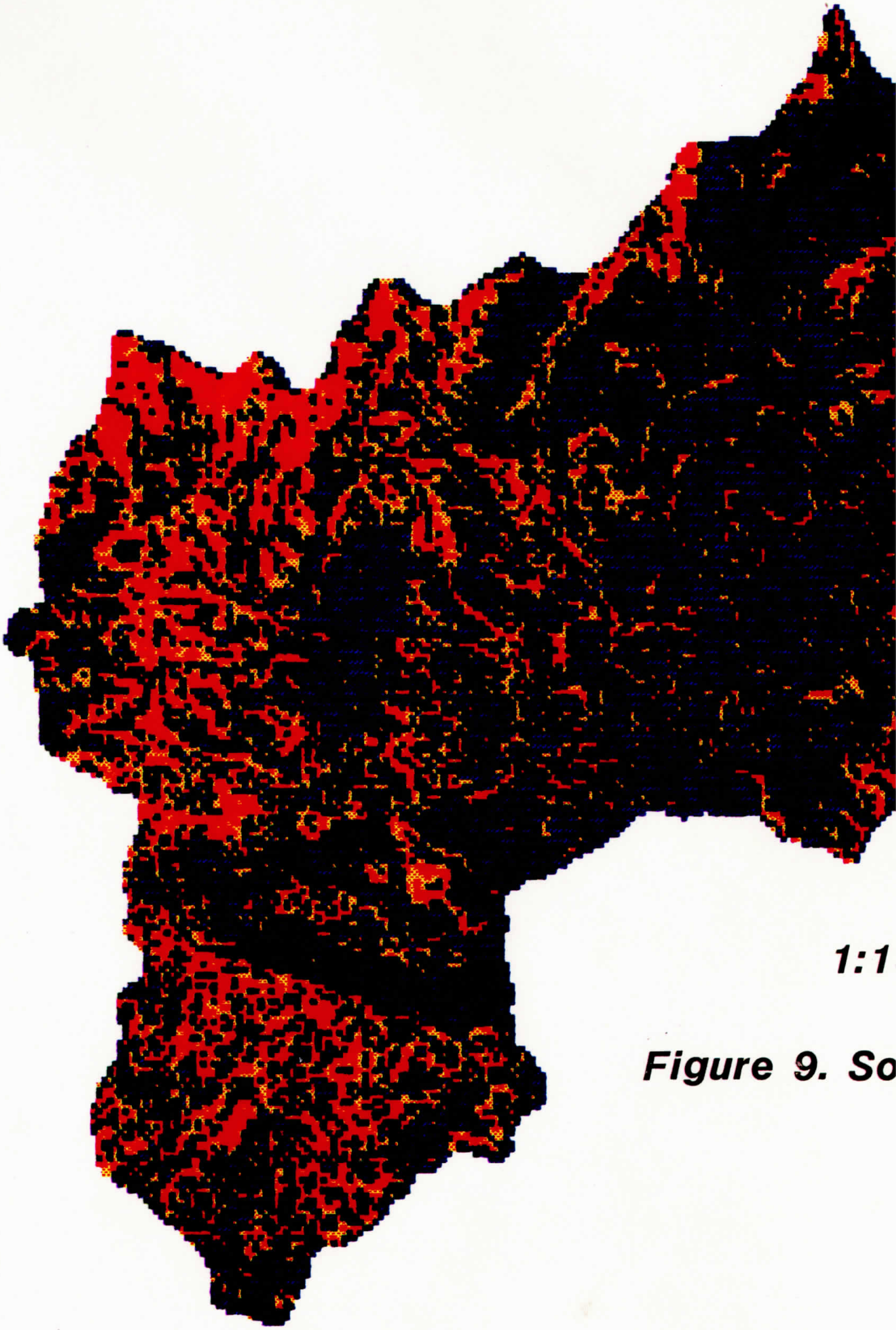
$$R = 200 \quad K = .24 \quad L = 1.0 \quad S = .23 \quad C = .3$$

$$A = (200)(.24)(1.0)(.23)(.3)$$
$$A = 3.31$$

These changes yield an estimated soil loss of 3.31 tons/acre/year which may be acceptable. The farmer could use other management practices to reduce soil loss even further.

The soil erosion index, determined by the product of RKLS, is often used for planning purposes. This equation integrates the physical factors of the USLE. Human impacts upon the landscape are not considered and are assumed to be maximal. Soil erosion indexes model the physical potential of an area or site to erode. Modeling of this nature is especially useful for large construction projects (Goldman et al. 1986). Results of soil erosion index analysis indicate areas particularly vulnerable to soil erosion. Builders can set up abatement structures to reduce sedimentation of the watershed.

A soil erosion index map was generated for the South Fork watershed (Figure 9). RKLS was calculated and classified on a scale from 1 to 500. Lower values represent areas where disturbances of the natural vegetation are less likely to cause substantial erosion damage. High values mark areas susceptible to erosion damage. As expected,



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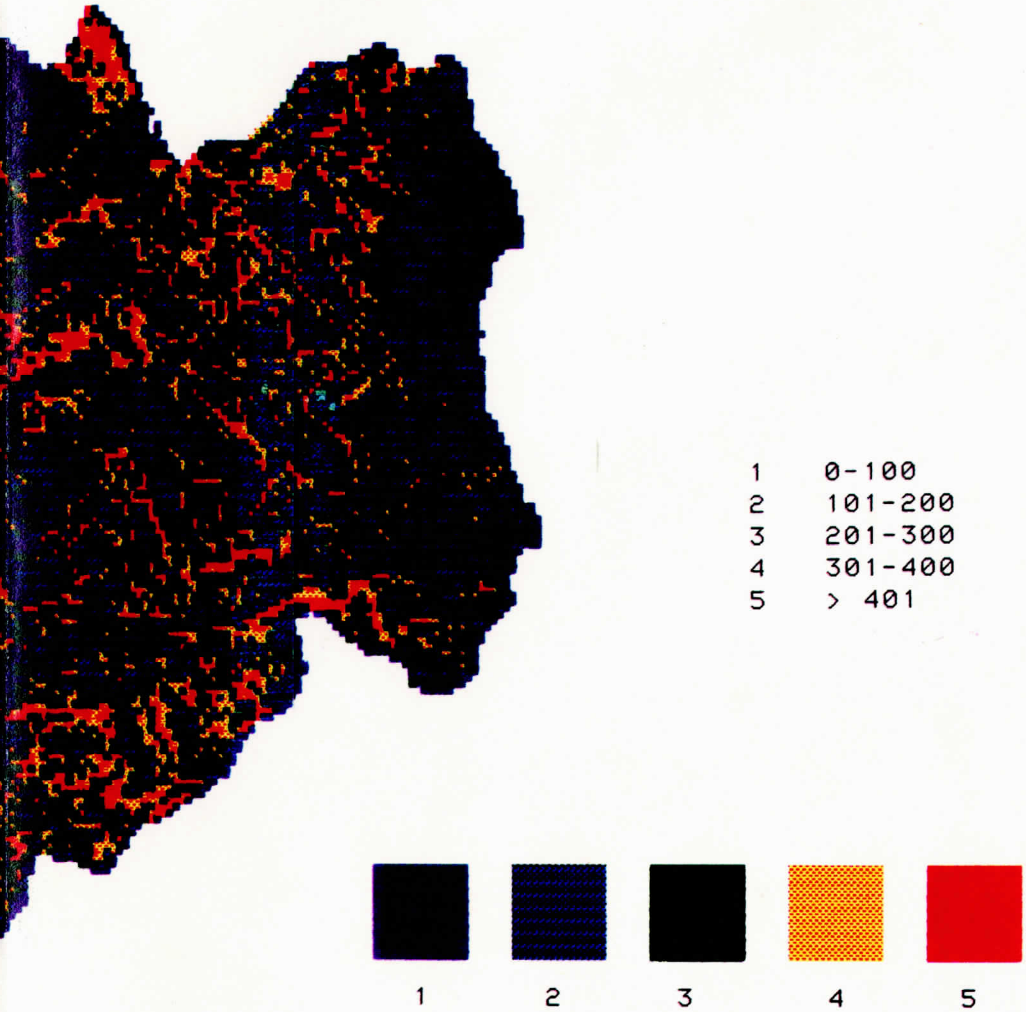

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Erosion Index

RKLS Index	Square Mi.	% of basin
0-100	49.98	24.35
101-200	54.97	26.78
201-300	43.97	21.42
301-400	27.03	13.17
401-500	29.30	14.28

Table 8. Soil Erosion Index
South Fork of the New River

the headwaters of the basin are generally high on the index. High erosion potentials were modeled south of Boone in the Winkler Creek, Middle Fork and East Fork subwatersheds, and on the northeast rim of the basin on the slopes of Snake and Rich mountains.

The examples shown demonstrate how proposed changes can be modeled to assess impacts that are likely to occur when a given disturbance is created. In the database created for this project, a proposed disturbance can be represented by editing file values of length of slope, slope, and land cover data layers respectively. For example, GISEDIT can be used to change an area on the land cover map to a new cover. In this way, the proposed disturbance is modeled to understand the likely impact on soil erosion and sedimentation.

The utility of GIS and remote sensing for soil erosion modeling in the South Fork watershed was demonstrated by this study. While relatively few concentrated hazards presently exist within the study area, the potential for soil erosion and sediment pollution problems is considerable. Sediment is currently coming primarily from construction sites and dispersed areas of agriculture. Modeling proposed disturbances of the soil cover is an effective method for gaining a general understanding of the impacts of land use change.

Works Cited

Goldman, Steven J., Katherine Jackson, and Taras A. Bursztynsky. 1986. Erosion and Sediment Control Handbook. New York: McGraw Hill, Inc.

U. S. Department of Agriculture. Soil Conservation Service. 1990. The Universal Soil Loss Equation with Factor Values for North Carolina. Raleigh. Soil Conservation Service.

Vold, T., M. W. Sondheim, and N. K. Nagpal. 1985. Computer Assisted Mapping of Soil Erosion Potential. Canadian Journal of Soil Science. 65 (August): 411-418.

Conclusions

Soil loss and sediment pollution in the South Fork of the New River is hazardous to agricultural productivity and water quality. Sediment pollution is a significant problem and soil erosion control should be pursued. It is unlikely, however, that there will be intense pressure to put substantially more land into agricultural uses. Christmas tree acreage may increase, and the effect of this land use needs to be monitored. Threats to water quality in the South Fork of the New River will most likely come from second home development, transportation infrastructure development, and industrial expansion of the area. A program to monitor and reduce soil loss and sedimentation of streams is necessary in order to assure water quality in the river, as well as protect the productivity of the soils.

Since the 1940's soil conservationists have made great strides in their efforts to reduce soil erosion and its associated soil productivity loss and off-site environmental impacts. The development of the Universal Soil Loss Equation marked an important event towards these efforts. Today, geographic information system and remote sensing technology make our ability to model and monitor soil erosion and sedimentation even more powerful. The combination of the USLE, a model which has proven to be a useful conservation guide, with the new technologies should make a significant impact on our efforts to reduce soil erosion and sediment pollution on a regional scale.

The temporal resolution of satellite remote sensors allows the monitoring of soil loss on a frequent basis. Rapid changes in land cover due to economic growth can increase sediment pollution of the South Fork of the New River basin significantly. Environmental planners need information to monitor this growth and its effect on the quality of soil and water. The land use and land cover of the study area will change over time and these data can be kept current with the purchase of recent satellite coverage.

The land cover component of the soil erosion model is easily updated because the temporal resolution of remotely sensed data allows frequent coverage. Research is needed using sensors with greater spatial resolutions such as the French SPOT system. The level of analysis can then be extended to larger scale coverage, thus increasing the detail of the model and increasing the accuracy of land cover classification. Trends in satellite remote sensing are toward better sensor resolution, especially spectral and spatial resolution. When improved systems become available soil erosion modeling with satellite remote sensing will be even more powerful.

The utility of geographic information systems is in its ability to store, retrieve, and manipulate large volumes of data. Studies such as the one presented here would be much more costly and time consuming using conventional methods. The method is particularly appealing for analysts desiring a synoptic view of a large area. The individual farmer will still get better results from making an on-site analysis of soil erosion. A developer of a large construction project may find the analysis useful to get estimates of needed erosion control measures. An environmental land use planner, however, seeking to protect water quality or soil productivity needs information at this scale to determine the scope of the problem and where conservation efforts should be focused.

GIS formats enable data to be updated as new surveys become available or whenever the integrity of data can be improved. For example, the length of slope data was estimated for subwatersheds. Other research has shown more accurate methods for calculating this factor. When, through technology transfer, methods such as this become available the update of the length of slope data can be easily accomplished. The Soil Conservation Service is currently working on the Watauga County soil survey and new data from this survey will be available within five years that will be more accurate due to better mapping and survey techniques developed since the original survey. The placement of new weather stations within the study area will improve the quality of rainfall data used for this project. Once a database is developed, its update is relatively easy to accomplish.

The seriousness of the problems of soil erosion and sedimentation is slowly becoming aware to public officials and the general public. The state of North Carolina has passed a watershed protection law that will require local governments to make efforts to reduce stream pollution. The methodology presented in this thesis, when applied to soil erosion and sedimentation modeling, could help local governments comply with new watershed protection regulations. Conducting quick and easy updates after the original survey is made is a significant advantage of this technique and an important consideration for monitoring watersheds.

This project has demonstrated the utility of geographic information systems and remote sensing to model soil loss potential in the South Fork watershed. Studies of this nature can give planners, developers, soil and water conservationists, and others useful information regarding the susceptibility of particular areas to soil erosion. By using the data to model proposed changes of land cover, topography, and land management practices, the effects of the changes can be predicted and steps can be taken to mitigate the negative aspects of disturbance of the land cover.

Bibliography

Anderson, J. R., et al. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data.Professional Paper No. 964. U. S. Geological Survey. Washington, D. C.

Brown, Lester. 1984. State of the World 1984. New York: W. W. Norton and Company, Inc.

Campbell, James B. 1987. Introduction to Remote Sensing. New York: The Guilford Press.

Campbell, William J. 1979. An Application of Landsat and Computer Technology To Potential Water Pollution From Soil Erosion. In Satellite Hydrology. American Water Resource Association.

Colwell, Robert N. et al. eds. 1983. Manual of Remote Sensing. Falls Church, V. A.: American Society of Photogrammetry.

Dissmeyer, George E. and George R. Foster. 1985. A Guide for Predicting Sheet and Rill Erosion on Forest Land. Atlanta: USDA, Forest Service SA-TP 11.

ERDAS Version 7.4. Earth Resources Data Analysis System, Inc., Atlanta, G. A.

Estes, J. E. 1982. Remote Sensing and Geographic Information Systems Coming of Age in the Eighties. In Remote Sensing: An Input to Geographic Information Systems in the 1980's. Falls Church, VA: American Society of Photogrammetry, 23-40.

Estes, John and Jeffrey Star. 1990. Geographic Information Systems: An Introduction. Englewood Cliffs, N. J.: Prentice Hall.

Fogel, M. M., L. H. Heckman, Jr., and L. Duckstein. 1977. A Stochastic Sediment Yield Model Using the Modified Universal Soil Loss Equation. In Soil Erosion: Prediction and Control: Proceedings of National Conference on Soil Erosion in West Lafayette, Indiana, May 24-26,1976, by the Soil Conservation Society of America. Ankeny: Soil Conservation Society of America, 1977, 226-234.

Goldman, Steven J., Katherine Jackson, and Taras A. Bursztynsky. 1986. Erosion and Sediment Control Handbook. New York: Mcgraw Hill, Inc.

Harlin, John M., and Gigi M. Berardi. eds. 1987. Agricultural Soil Loss: Processes, Policies, and Prospects. Boulder: Westview Press.

Hession, W. Cully, and W. O. Shanholtz. 1988. A Geographic Information System for Targeting Nonpoint-source Agricultural Pollution. Journal of Soil and Water Conservation. May-June 1988.

Hunt, Charles B. 1974. Natural Regions of the United States and Canada. San Francisco: W. H. Freeman and Company.

Holmes, Thomas P. 1988. The Offsite Impact of Soil Erosion on the Water Treatment Industry. Land Economics. 64 (November) 356-366.

Hooke, J. M. ed. 1988. Geomorphology in Environmental Planning. New York: John Wiley and Sons.

Jenson, John R. 1986. Introductory Digital Image Processing. Englewood Cliffs, N. J.: Prentice Hall.

Johnson, Leonard C. 1987. Soil Loss Tolerance: Fact or Myth. Journal of Soil and Water Conservation. May-June 1987: 155-160.

Lee, Linda K. and J, Jeffrey Goebel. 1986. Defining Erosion Potential on Cropland: A Comparison of the Land Capability Class-Subclass System with RKLS/T Categories. Journal of Soil Water Conservation. January-February 1986: 41-44.

Lillesand, Thomas M. and Ralph W. Kiefer. 1987. Remote Sensing and Image Interpretation. New York: John Wiley and Sons.

Morgan, Ken M., Gerhard B. Lee, Ralph W. Kiefer, T. C. Daniel, Gary D. Bubenzer, and John T. Murdock. 1978. Prediction of Soil Loss on Cropland with Remote Sensing. Journal of Soil and Water Conservation. November-December 1978: 291-293.

National Oceanic and Atmospheric Administration. 1988. Climatological Data Annual Summary: North Carolina 1988. Asheville: National Climatic Data Center.

Pelletier, R. E. 1985. Evaluating Nonpoint Source Pollution Using Remotely Sensed Data in Soil Erosion Models. Journal of Soil and Water Conservation. July-August: 1985.

Phillips, Kelly M., Ken Morgan, Leo Newland, and David G. Koger. 1986. Thematic Mapper Data: A New Land Planning Tool. Journal of Soil and Water Conservation. September-October: 1986.

Pimental, D. et al. World Agriculture and Soil Erosion. Bioscience. April 1987: 277-283.

Richards, K. S., R. R. Arnett, and S. Ellis. eds. 1985. Geomorphology and Soils. London: George Allen and Unwin.

Ripple, Bill J. and Steve B. Miller. 1982. Remote Sensing and Computer Modeling for Water Quality Planning in South Dakota. In Remote Sensing For Resource Management. Ankeny, Iowa: Soil Conservation Society of America.

Spanner, M.A., Alan Strahler, and John E. Estes. 1983. Soil Loss Prediction in a Geographic Information System Format. In Proceedings of the Seventeenth International Symposium on Remote Sensing of Environment, May 9-13,1983, by Environmental Research Institute. Ann Arbor: Environmental Research Institute.

State of North Carolina. 1988. Erosion and Sediment Control Planning and Design Manual. Raleigh: North Carolina Sedimentation Control Commision.

Stephens, Peter R. and Josef Cihlar. 1981. The Potential of Remote Sensing to Monitor Soil Erosion on Cropland. In Proceedings of the Fifteenth International Symposium on Remote Sensing of Environment, May, 1981, by Environmental Research Institute. Ann Arbor: Environmental Research Institute.

U. S. Department of Agriculture. Soil Conservation Service. 1990. The Universal Soil Loss Equation with Factor Values for North Carolina. [Raleigh, N. C.]: U. S. Department of Agriculture. Soil Conservation Service.

U. S. Department of Agriculture. Soil Conservation Service. 1984. Soil Survey of Ashe County, North Carolina. [Raleigh, N. C.]: U. S. Department of Agriculture. Soil Conservation Service.

U. S. Department of Agriculture. Soil Conservation Service. 1944. Soil Survey of Watauga County, North Carolina. [Raleigh, N. C.]: U. S. Department of Agriculture. Soil Conservation Service.

U. S. Department of the Interior. U. S. Geological Survey. 1987. Digital Elevation Models: A User's Guide. [Reston, V A.]: U. S. Department of the Interior. U. S. Geological Survey.

Ventura, S. J., B. J. Niemann Jr., and D. D. Moyer. 1988. A Multipurpose Land Information System for Rural Resource Planning. Journal of Soil and Water Conservation. May-June 1988: 226-229.

Walling, D. E. 1983. The Sediment Delivery Problem. Journal of Hydrology. 65 (1983) 209-237.

Walling, D. E. 1987. Rainfall, Runoff, and Erosion of the Land: A Global View. In Energetics of Physical Environment, Ed. K. J. Gregory, 89-119. New York: John Wiley and Sons.

Walsh, Stephen J. 1985. Geographic Information Systems for Resource Management. Journal of Soil and Water Conservation. March-April 1985: 202-205.

Wischmeier, W. H., and D. D. Smith. 1965. Predicting Rainfall-erosion from Cropland East of the Rocky Mountains. Washington D. C.: U. S. Department of Agriculture. Agricultural Handbook No. 282.

Wischmeier, W. H. 1976. Use and Misuse of the Universal Soil Loss Equation. Journal of Soil and Water Conservation. 31 (January): 5-9.

Wischmeier, W. H., and D. D. Smith. 1978. Predicting Rainfall Erosion Losses - A Guide To Conservation Planning. Washington D. C.: U. S. Department of Agriculture. Agricultural Handbook No. 537.

Williams, T. H. Lee. 1985. Implementing LESA on a Geographic Information System - A Case Study. Photogrammetric Engineering and Remote Sensing. 51 (12) 1923-1933.

VITA

Glenn Graham Hyman was born in Raleigh, North Carolina on October 17, 1962. He attended grade school in that city and graduated from Athens Drive Senior High School in June, 1981. The following September he entered Appalachian State University. After two years at Appalachian State, Mr. Hyman transferred to the University of North Carolina at Chapel Hill where he received a Bachelors degree in International Studies in December, 1985. Mr. Hyman entered the Graduate School at Appalachian State University in the Department of Geography and Planning under a graduate assistantship in August, 1988. He graduated with a Masters degree in Geography in August, 1990. Mr. Hyman accepted a graduate teaching assistantship at the University of Tennessee where he will pursue a doctoral degree in the Department of Geography.

The author's parents are Sue and Theodore Hyman both of Raleigh, N. C. He has two brothers, Hayes Hyman of Raleigh, N. C. and Wesley Hyman of San Diego, C. A. and one sister, Alyson Hyman of Washington, D. C.