A COMPARISON OF UNIVERSAL SOIL LOSS EQUATION RESULTS USING A REMOTE SENSING/GIS TECHNIQUE TO RESULTS OBTAINED USING A FIELD SURVEY TECHNIQUE

THESIS

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Digital satellite remote sensing and Geographic Information Systems (GIS) have been used in conjunction with the Universal Soil Loss Equation (USLE) to model soil erosion potential within watersheds. This study compared erosion estimates calculated by the remote sensing method to results obtained in the field by soil conservationists using conventional methods. Five data layers were used for the USLE for both field and remote sensing methods. The results demonstrated that similar erosion estimates could be produced by the two methods provided that the data layers were obtained from identical sources. The study concluded that the remote sensing method could be used for surveying large areas for erosion estimation.

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CHAPTER I

INTRODUCTION

Soil erosion is part of the natural process of changing mountains into fluvial plains and deltas; a process which has continued for millions of years. The introduction of human activity, particularly agriculture, into the natural cycle of generation and removal of soil has accelerated the erosional process. Often this occurs to the point of total soil depletion of crop and range lands. Accelerated erosion can result in diminished crop yields and declining fish populations due to buried spawning habitat. This was most evident in the United States during the 1930's when careless farming techniques coupled with extreme drought created the great 'Dust Bowl' of the plains, the product of which was dust-filled air and mud-filled rivers. As a result, numerous methods of monitoring erosional losses have been developed over the past fifty years. One of the better known techniques is the Universal Soil Loss Equation (USLE), a model widely used by the United States Department of Agriculture - Soil Conservation Service (U.S.D.A.-S.C.S.) to estimate potential soil loss due to sheet and rill erosion.

Remote sensing using satellite based multispectral sensors is a fairly recent innovation having started in the early 1970's with the launch of the Landsat satellite series. This event, coupled with the development of relatively inexpensive computers, has created a new field of study of the earth: digital remote sensing. The great strength of satellite remote sensing is that large areas of land can be monitored for the relatively low cost of a digital satellite image and computer processing time. Not long after the launch of the Landsat program, soil scientists and remote sensing researchers began to devise methods of applying this new found tool in an attempt to expedite estimation of erosion potential for large land areas.

Over the past decade numerous studies have been conducted which have used satellite remotely sensed land use analyses with the USLE (henceforth designated the RUSLE for Remote Universal Soil Loss Equation) for the purpose of estimating sheet and rill soil erosion potential. The Center for Remote Sensing and Landuse Analyses (CRSLA) at the University of North Texas has contributed to these studies, having produced four research reports in which soil erosion estimations for over 4 million acres have been calculated (Atkinson et al., 1988, Alan Plummer, 1988, and Atkinson et al., 1989). Estimates calculated by CRSLA using the RUSLE have been reported in tons/acre/year of potential soil loss due to sheet and rill erosion. The results have been effective in showing comparative erosion rates within the watersheds as well as between the watersheds studied, but have not been compared to actual erosion rates as recorded in the field.

One method to compare soil loss estimated by the RUSLE to actual loss is to establish a long term research project in which soil removal is determined by using calibrated steel rods driven into the ground in the study areas. Soil levels can be measured over a given period of time and the quantity of erosion determined by multiplying the depth of soil lost by the area of the test plot. Another method is to trap rainfall runoff from a test plot and measure the amount of soil lost from the plot. Both techniques have been used in the calibration stage of erosion models. The purpose of this thesis was to test a third approach to monitor erosional losses within large areas over time.

The USLE has been extensively tested (and is still in use) by the U.S.D.A.-S.C.S. for over thirty years. Potential erosion loss estimates calculated by soil scientists of the S.C.S. are used in all aspects of land management from cropland soil loss control to estimates of sedimentation in reservoirs and lakes. Although there are plans to implement a revised erosion model, the Water Erosion Potential Plan, USLE estimates remain the backbone of soil loss planning for the U.S. to date. For this reason, this study compared erosion estimates calculated by S.C.S. field researchers within a test watershed in north central Texas and estimates generated using the RUSLE. Although the calculations made by the S.C.S. personnel were "estimates" of erosion potential based on the USLE, the fact that the model has been extensively tested and in use for the past 30 years legitimizes these estimates for use in soil conservation planning and for calibrating the RUSLE.

The purpose of this research then was to compare erosion results presented in a S.C.S. study (U.S.D.A.-S.C.S., 1986) to erosion potential estimates generated in the laboratory using satellite remote sensing and the USLE. The basic hypothesis set forth was that the RUSLE was able to identify the same areas designated by the S.C.S. as having high erosion potential within the Caddo Creek watershed. Also, the RUSLE was able to produce quantitative estimates of soil loss comparable to S.C.S. estimates.

The Caddo Creek Watershed was identified on two Landsat satellite images recorded in spring and early summer of 1988. Land uses within the watershed were determined using computer analyses of satellite images using Earth Resources Data Analysis System (ERDAS) software. The land use classifications were used as one factor of the RUSLE and were combined with five additional factors derived from published sources. The six factors include: rainfall, soil erodibility, slope length, slope gradient, cropping management, and erosion control practices. A combination of the six factors was accomplished using a Geographic Information System (GIS).

A map of a section of the Caddo Creek watershed was produced using the RUSLE showing areas of different rates of potential soil loss recorded in tons/acre/year. This map was then compared to the same watershed section map made by multiplying factors used by the S.C.S. in hand calculated field measurements. Quantitative soil loss estimates in seven locations were compared. The results of the map overlay and quantitative comparison demonstrated the ability of the RUSLE to produce soil loss estimates comparable to those made by S.C.S. field techniques.

Following this introduction is a review of literature pertaining to the background of this study. The remote sensing and GIS methodology used in the laboratory to develop soil erosion estimates and means by which they are compared to S.C.S. results are examined. The final chapters of this paper present the results of the study, a discussion of the results and a summary of the study.

CHAPTER II

REVIEW OF LITERATURE

Erosion

The removal and transport of soil particles by water from one location to another generally falls into two broad categories: slope or channel erosion. Although this categorization is more one of convenience, it aptly describes the two main erosional processes within a watershed. Slope erosion includes the displacement of soil by splash and saltation, sheet displacement by overland water flow, and rill erosion. Rills are described as small channels of rapidly moving water. They are distinguished from true channels in that rills temporarily exist, either reverting seasonally to a smoothed surface or growing to true channel size (Chorley, 1969). Channel erosion entails the transport of material dislodged from stream beds and walls as well as the movement of material washed into the channel from the slopes.

A typical conceptual slope erosion model can be expressed as: $E = f(C, T, R, V, S, H,)$

where
E = soil erosion
C = climate
T = topography
R = rock type
V = vegetation
S = soil character
H = human interference
(Toy, 1977)

These factors can be grouped under the general headings: climate characteristics, surface characteristics and human modifications. In this grouping, the human factor is considered as a separate category in that man is able to change erosional loss through alterations of some surface and perhaps climatic factors.

Slope erosion starts with the splash of rain drops on soil causing the break down of soil aggregates. Tiny soil particles fly into the air, move down slope and hit other particles; a process known as saltation. The magnitude of the effect is due to the physical force contained in the raindrop. This physical force is a result of drop size and velocity. The effect is most noticeable in soils that have little to no vegetative cover and loose particles. Drop size can vary considerably, being as large as 5 or 6 mm. Low intensity rainfalls of long duration are generally comprised of small diameter drops whereas high intensity rainfalls often have drops of much larger size. Terminal velocity of a falling object is dependent upon the size and shape of the object. The terminal velocity of a rain drop increases as the size of the drop increases. A drop 5 mm. in size has a terminal velocity of approximately 9 meters per second (20 mph) (Hudson, 1971).

Mass and velocity of raindrops contribute directly to the magnitude of splash effect upon erodible soil. Equally important is the effect of rainfall intensity on sheet and rill erosion. In sheet erosion, detachment capability is proportional to rainfall energy. Transport capacity is directly related to the amount and velocity of runoff (Wischmeier and Smith, 1978).

According to Wischmeier, the kinetic energy per unit of rain varies as the square of the terminal velocity of the drops, and terminal velocities increase with drop size. The erosivity index (EI) reflects how particle detachment is combined with transport capacity. An isoerodent map, showing points of equal rainfall erosivity for the conterminous United States, shows the Caddo Creek watershed area having an EI of approximately 300, with values in the U.S. ranging from less than 20 to 550 (Wischmeier and Smith, 1978). About 60% of the average annual EI for the Caddo Creek area falls between the end of April and the end of September (Wischmeier and Smith, 1978). This is produced by numerous heavy storms during the late spring and throughout the summer months.

Erosion Effects

The effects of erosion can be viewed from several perspectives depending upon the area of discipline. In agriculture, the major problem of erosion is the loss of productive capacity of the soil resource; a loss which produces monetary loss to farmers and higher prices to the consumer due to reduced food and fiber production. The effects in the field include limited crop selection, suppressed yields, and reduced farming operation efficiency (U.S.D.A.-S.C.S., 1986). Preliminary erosion estimates from the 1982 National Resource Inventory (NRI) put the national average for sheet and rill erosion on cultivated cropland at 4.8 tons/acre/year. The NRI estimated that erosion on 44% of all croplands in the U.S. exceeds the soil loss tolerance T. T is the maximum average annual soil loss, allowing for natural soil regeneration, that will permit a high level of production, economically and indefinitely, on a specific soil (Lee, 1984).

Hudson (1971) suggests that one of the less obvious effects of erosion is a decrease in sunlight penetration in turbid water bodies resulting in reduced photosynthesis in aquatic plants. Deposition of erosion within rivers can cause such problems as the blanketing of fish spawning grounds or blocking estuarian outlets. Reservoir sedimentation is of particular interest to farmers, municipal water utilities, and industry. Reservoirs are often constructed at great cost and although filling by sediment is inevitable, it proves to be extremely expensive when accelerated sedimentation prematurely decreases reservoir capacity. The monetary cost of reservoir sedimentation has been estimated to range from $310 million to $1.6 billion per year in this country (Crowder, 1987).

Finally, erosion impacts drinking water quality both in particulate matter and taste and odor. Since the passage of the Federal Water Pollution Control Act of 1972 and the 1977 Soil and Water Conservation Act, more attention has been directed to off-farm impacts of cropland erosion. Numerous studies have been documented on the effects of erosion on water supply reservoirs involving suspended solids, nutrients and agricultural pesticides (Forster, Bardos and Southgate, 1987). Phosphorus, adsorbed to sediment particles, migrates from fertilizers applied in the field to reservoirs where it accelerates eutrophication and unwanted algal blooms. Agricultural pesticides often travel in the same manner. In the least, increased suspended solids in drinking water supplies task hydraulic machinery and increase the cost of removal by coagulation. Hudson (1971) summed up the problem of erosion pollution by suggesting that sediment was certainly the greatest pollutant in terms of volume and that soil conservation practices on cropland could reduce soil erosion by more than 90%.

Erosion Estimation Models

Soil conservation research began in the latter part of the 19th century with a German scientist by the name of Ewald Wollny (Meyer, 1984). He conducted numerous experiments on the effects that steepness of slope, plant cover, soil type, and direction of exposure had on runoff and erosion. His studies were apparently overlooked in the U.S. until the mid 1930's. Erosion studies in the U.S. began in 1912 on rangelands in the Manti National Park, Utah, by a team of researchers directed by A. W. Sampson. It was not until the 1920's that Hugh Hammond Bennett, a soil surveyor working for the U.S.D.A. Bureau of Soils, became concerned with the ever increasing loss of soil as a national problem. He is known as the "father of soil conservation" in this country (Meyer, 1984). As the first chief of the Soil Conservation Service, Bennett supervised the establishment of 10 experiment stations from Washington to North Carolina for the purpose of evaluating runoff and erosion.

During the 1930's and the 1940's such men as R. E. Horton, G. W. Musgrave (Horton, 1933; Musgrave, 1935) and others conducted fundamental research on runoff and erosion; but it was H. L. Cook (Cook, 1936) who began identifying the major variables involved in erosion. He listed three factors: 1) the susceptibility of the soil to erosion; 2) the potential erosivity of rainfall and runoff, including the influence of slope degree and length; and 3) the effect vegetative cover had on protecting the soil. Additional factors were added to the initial three and the Musgrave Equation was born in 1946. This equation included factors for rainfall, flow characteristics of surface runoff as affected by slope and length, soil characteristics, and vegetative cover effects.

Although there were some modifications to this early soil loss equation, it was part of one of several procedures used by S.C.S. geologists until 1972 to estimate sediment yield. Additional research on erosion resulted in the development of the USLE by the U.S.D.A. Agricultural Research Service (A.R.S.) in cooperation with the S.C.S.. It was introduced in a series of workshops between 1959 and 1962 and in September 1972 it replaced the Musgrave Equation for computing sheet and rill erosion in project areas (U.S.D.A.-S.C.S., 1984). Meyer (1984) credits Dwight Smith and Walt Wischmeier ('the "fathers" of the USLE') with the final form of the equation.

The USLE Equation

The USLE is "an erosion model designed to predict longtime average soil losses in runoff from specific field areas in specified cropping and management systems" (Wischmeier and Smith, 1978). The equation calculates average annual soil loss by combining six factors:

$$A = R * K * L * S * C * P$$

where: A = the computed annual soil loss (sheet and rill erosion) in tons per acre.

R = the rainfall factor: the number of erosion index units in a normal year's rain.

K = the soil erodibility factor: the erosion rate per erosion index unit for a specific soil in cultivated continuous fallow on a 9% slope 72.6 ft. long.

L = the slope length factor: the ratio of the soil loss from the field slope length to that from a 72.6 ft. length on the same soil type and gradient.

S = the slope gradient factor: the ratio of the soil loss from the field gradient to that from a 9% slope on the same soil type and slope length.

C = the cropping management factor: the ratio of the soil loss from a field with specified cropping and management to that from a fallow condition from which the K factor is evaluated.

P = the erosion control practice: the ratio of the soil loss with contouring, contour stripcropping, or contour-irrigated furrows to that with straight row farming, upslope and downslope.

(U.S.D.A.-S.C.S., 1984)

The R and K factors are fairly well established for the conterminous United States and have had few adjustments to them. The L and S factors, normally combined as LS in Handbook No. 537 (Wischmeier and Smith, 1978), has undergone much examination over the years as has the C factor. New LS factors have been determined for irregular (concave, convex, or compound) slopes (Wilson, 1986; Castro and Zobeck, 1986), a condition normally found in the field. But for the purpose of this study, LS will be considered to be a flat surface with varying slope for each unit area of study. For this study a unit area is analogous to a "pixel" which will be described later. The C factor was initially determined for cropland, hayland, pasture, rangelands, and woodland but new estimates have been added for construction sites (Wischmeier and Smith, 1978), various forest conditions (Dissmeyer and Foster, 1981), and landscaped slopes such as found in urban areas (DeTar, Ross and Cunningham, 1980).

The strengths and reliability of the USLE have been examined by data collected to build the model. Statistical analysis of 10,000 plot-years of runoff and soil loss data from 49 Federal and State research projects prompted Wischmeier and Smith (1978) to state:

> Soil losses computed by the USLE are best available estimates, not absolutes. They will generally be most accurate for medium-textured soils, slope lengths of less than 400 ft., gradients of 3 to 18 percent, and consistent cropping and management systems that have been represented in the erosion plot studies. The farther these limits are exceeded, the greater the probability of significant extrapolation error.

The S.C.S. handbook (U.S.D.A., 1984) suggests that although soil loss, as opposed to sediment yield, computed by the equation represents nothing that can be located or measured in the field, it is a valuable tool for comparing the soil loss from different areas of the effects of different land treatments on a given area. According to Hauser (1984), although the USLE has been introduced in evidence in several soil conservation court cases there has been no reported case in the United States concerning evidentiary problems presented by the model.

It is significant to note that the USLE is used as the basis for numerous other erosion and runoff models such as ANSWER, CREAMS, SWRRB, EPIC, and AGNPS (Binger, Murphree and Mutchler, 1989). The rapid acceptance of the USLE into conservation planning has lead to the overextension of applicability in many cases; in effect, the misuse of the model. Wischmeier addressed this subject by issuing a recommended guide to the use of the equation. One of the uses the equation is designed for is to provide local soil loss data for S.C.S. technicians and others to use when discussing erosion control needs and conservation plans with farmers and contractors. Misuse is the application of the equation to situations for which the factor values cannot be determined from existing data with acceptable accuracy. Sources of error in factor values include: superficiality in selecting factor values; evaluation of the factors on a broad base such as a single C value for all cropland; extrapolation of factor values beyond the range of data; and defining slope length incorrectly (Wischmeier, 1976).

When asked in an interview if the USLE could be combined with interpretations from aerial photos to make large-area erosion predictions, Wischmeier responded that he thought that was an inappropriate application. His reasoning was that the model was designed to predict erosion from field size plots in which the factors were combined at each site. The only way the equation could apply was if the watershed was divided into subareas from which values of the six factors could be properly identified (JSWC, 1984). This concept is key to this thesis in that the grid network used in raster Geographic Information Systems allows for a multitude of subareas to be constructed, all of which can be assigned site specific factors.

Remote Sensing and GIS

For the purposes of this thesis the term remote sensing pertains only to digital processing of images recorded by a satellite based system. The process of satellite remote sensing involves recording reflected and generated electromagnetic radiation by sensors calibrated to receive specific sections of frequencies in the visible, near and mid infrared, and reflected infrared portions of the spectrum. Voltage variations related to reflections from physical variations on the ground are recorded as analog electrical signals. Analog to digital data conversion is performed within the sensor system and the information is transferred to ground receiving stations.

The data is partially processed and then stored on magnetic computer compatible tape.

Variables that can be recorded directly by the satellite sensor include such fundamental biological and biophysical features as planimetric location, object color, vegetation chlorophyll absorption, vegetation biomass, vegetation and soil moisture content, and temperature (Jensen, 1986). Images used in the CRSLA laboratory normally include recordings from the LANDSAT Thematic Mapper (TM), LANDSAT Multispectral Scanner (MSS), or SPOT satellite sensing systems. An important consideration in using these three satellite systems is the resolution of each: resolution being the ability of an optical system to distinguish between signals that are spatially near or spectrally similar (Swain and Davis, 1978). Four types of resolution important to monitoring biophysical parameters include spectral, spatial, temporal, and radiometric resolution (Jensen, 1986). Each system has different resolutions. This difference, coupled with monetary considerations and project requirements, determines the choice of system used.

A Geographic Information Systems (GIS) is basically database management software in which each piece of information recorded is referenced to a geographic location. Once a GIS database has been constructed from information layers such as soil type, vegetative cover, or stream network, it can be queried for combinations of information such as: "what is the quantity of corn growing on sandy/loam soil within 1/4 mile of a stream?". Typically, for erosion loss studies conducted using digitally processed remote sensing data, a GIS is used both to store the numerous data layers involved and to perform analyses on the data layers.

Watershed Management with Remote Sensing and GIS

The use of remote sensing with the USLE to monitor soil loss is not a novel idea. Earlier modeling used a combination of aerial photographs and the equation. The strength of this approach is due to the fact that sequential photographs have been taken over a long period of time, allowing for a visual record of the net effect of soil management. In a study conducted in New Brunswick, Canada (Stephens, Daigle and Chilar, 1982), researchers used photographs taken between 1945 and 1980. Areas of crop type were calculated using an electronic planimeter, and slopes were determined using a stereoscopic viewer. This information, representing C and LS, was entered into the USLE for the years 1945 and 1980 and estimates were made for soil loss under to the two sets of conditions.

The study showed that although crop rotation had not changed significantly for the time period, cropping technique had; changing C from 0.1 in 1945 to 0.4 in 1980. Also, slope length had changed in some areas over the 35 year period, affecting LS. The conclusion of the study was that aerial photography could be used to determine the nature, location, and timing of soil management changes. Stephens et al. (1985), in a continuation of his 1982 study, found that correlation coefficients for USLE soil loss values estimated with aerial photography and field estimated losses ranged from 0.85 to 0.94. He also found that the remote sensing method was two to four times faster than the field method and provided a permanent visual record of land use.

In another study color infrared photographs were used in conjunction with the USLE and a computerized land information system to identify problem erosion areas in a watershed in Johnson County, Texas (Morgan and Nalepa, 1982). A grid network was overlaid onto the color photographs and C and P factors were determined using a zoom transferscope and an interpretive key. Information for the six factors were stored in a GIS and USLE factor maps were computer generated. Results of the computer USLE were compared to results from a field study to determine accuracy. The average field losses of 2.6 tons/acre/year agreed closely with the average photo method of 2.4 tons/acre/year.

With the wide scale introduction of computers, satellite remote sensing and GIS became the next obvious choice in soil loss research. As early as 1978 Morgan suggested using satellite images for estimating soil losses (Morgan et al., 1978). In 1984 a study was presented in which the utility of Landsat Thematic Mapper data and U.S.G.S. Digital Elevation Model data for predicting soil loss was discussed (Gesch and Naugle, 1984). Several USLE models were set up in which factors C, K, L, and S were determined from different sources. The C factor was obtained from either Landsat MSS or TM images. The K factor, obtained from county soil surveys, was either the weighted average for soils associations or the actual value from soil series maps. The LS factor was determined from either county soil surveys or from DEM tapes.

Several combinations of the factors were run through the model and estimations of soil loss were compared using the Statistical Analysis System (SAS). The study concluded that the use of C factors derived from the two images resulted in significantly different erosion estimates. Also, the use of county soil surveys produced significantly different results from those obtained using DEM data (Gesch and Naugle, 1984).

For Dane County, Wisconsin, the Land Information and Computer Graphics Facility of the University of Wisconsin, Madison, developed a soil erosion data base for conservation planning (Ventura et al., 1988). The USLE was used with the K and LS factors obtained from county soil surveys, and the C factor from a 1984 Landsat TM image. The information was entered into a GIS and a computer map produced showing the estimated annual soil loss in tons per acre for each quarter section of the county. The conclusion of the study was that, although there were inherent spatial problems in using the USLE in this method, the comprehensive coverage and consistent analysis produced unbiased estimates when compared to field surveys produced by numerous field personnel. The results could be used for overall county planning, but that planning on the farm scale should be done after site specific estimates were conducted.

The above method was used at the VirGis Laboratory in the Agricultural Engineering Department of Virginia Polytechnic Institute and State University, Blacksburg, Virginia, in a program to address water quality issues and nonpoint source pollution to the Chesapeake Bay (Hession and Stanholtz, 1988; Stanholtz et al., 1988). Although the project was designed to calculate potential sediment loading to waterbodies, the conclusion was that the GIS approach was very flexible and the results of the approach showed excellent agreement with manually calculated results.

Current Research

Four studies have been conducted at the Center for Remote Sensing and Landuse Analyses laboratory at the University of North Texas within the past three years (Atkinson et al., 1988; Alan Plummer, 1988; and Atkinson et al., 1989). These studies have focused on erosion potential from large watersheds, all of them in excess of 100 square miles, and have predicted sediment and nutrient loading to receiving waterbodies. Erosion potential within the watersheds was estimated using the RUSLE. Land use classification for the C factor was determined by computer analysis of satellite images obtained from Landsat MSS and TM systems and from the French SPOT satellite. U.S.G.S. DEM data were entered into the GIS for the L and S factors. The results were reported in tons/acre/year of potential soil loss. The strength of these studies was the ability of the GIS to show relative erosion rates within the watersheds and, in the case of two studies where a total of nine watersheds were examined, a comparison of nonpoint source pollution potential for each watershed was possible. These studies showed the potential use of the RUSLE for large scale soil conservation planning but also the need to test the RUSLE to actual field surveys.

CHAPTER III

STUDY AREA

One of the more difficult aspects of this thesis was obtaining actual field data for a watershed. Since the RUSLE was to be compared to standard field estimates it was deemed necessary to use a watershed that had been surveyed by S.C.S. personnel. Such surveys are considered to be an 'industry standard' for agricultural conservation management but they are seldom conducted on a whole watershed. Data obtained were, however, from a project conducted by the Upper Sabine and Collin County Soil and Water Conservation Districts with assistance from the U.S.D.A. S.C.S. in Temple, Texas. The purposes of the S.C.S. study were to assure the capability of sustained long-term agricultural production and to reduce soil erosion in the Caddo Creek watershed (U.S.D.A.-S.C.S., 1986).

The Caddo Creek watershed is located on the western edge of Lake Tawakoni in south western Hunt and south eastern Collin Counties, Texas (Figure 1). The major tributaries of Caddo Creek are East Caddo, West Caddo, and Brushy Creeks. The creek flows southeast into a west arm of Lake Tawakoni. Total watershed area is 134,400 acres (210.0 square miles).

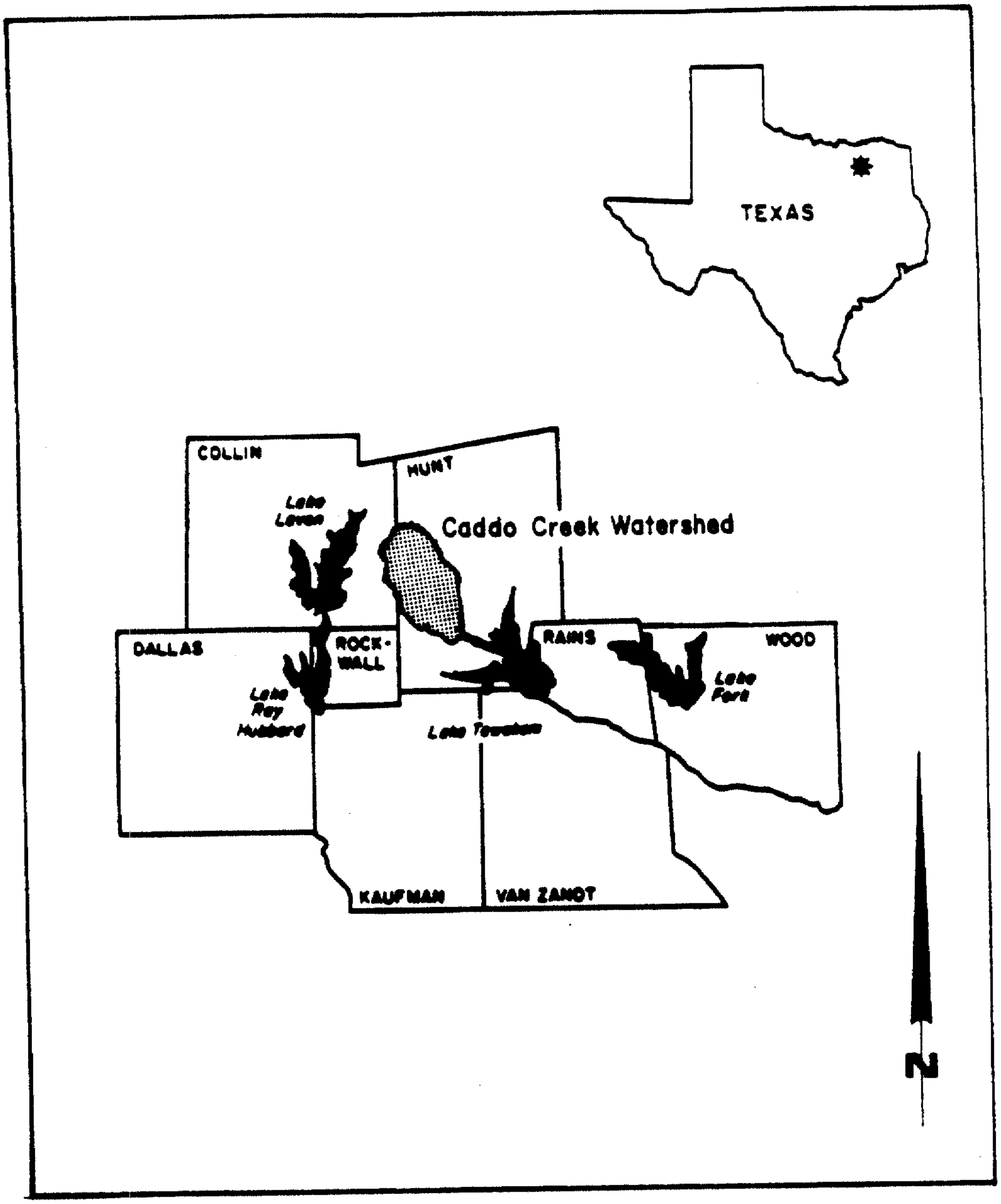


Figure 1

Location of Caddo Creek Watershed
Study Area (U.S.D.A.-S.C.S., 1986)

The watershed is in the Texas Blackland Prairie Major Land Resource Area. The area is nearly level to rolling, with well dissected prairies and moderate to rapid surface drainage. Native vegetation is tall bunchgrass with pecan, oak, and elm trees along the stream banks. Approximately 55% of the watershed is comprised of Houstan Black-Leson soil association and is classified as prime farmland. More than 55% of the 74,000 acres designated as prime farmland land was cropland in 1986.

The S.C.S. designated four broad land use classifications for the area: cropland, pastureland, rangelands, and other. According to S.C.S. definitions, cropland consists of areas which are plowed for agricultural purposes. Pasture is land seeded for fodder such as bermuda or sudan grasses. Rangelands is considered natural prairie with a mixture of shrubland and forest. Land use in the watershed is about 55% cropland, 30% pastureland, 8% rangelands, and 7% other (urban, built-up areas, water, roads, highways, etc.) (U.S.D.A.-S.C.S.,1986).

In 1980 the population of Hunt County was 55,248 and Collin County was 144,490 but the only town within the watershed is Caddo Mills (1,060). For this reason, 'urban' was not considered as a separate land use classification for the RUSLE in this study.

To perform the survey on the watershed, S.C.S. conservationists used helicopter flights to visually assess the extent of the erosion problems. Conservation project areas were identified and grouped according to their soil type, slope, and treatment needs. Potential soil losses for the area were calculated using the USLE. In addition, estimations were made for ephemeral and perennial gully erosion.

Assessment of the watershed showed a weighted average annual erosion rate for the watershed for all land uses and erosion type to be approximately 12.0 tons per acre. Areas exceeding this rate totalled 15,990 acres (approximately 12%) and were considered to be the target areas for primary attention and treatment (Table 1). This acreage was comprised of 273 treatment areas with a weighted average erosion rate of 16 tons per year. It was determined by S.C.S. interviews that farmers who worked about 55% (8,800 acres) of the problem cropland would be willing to participate in a conservation project. The 117 conservation project areas were used for the RUSLE study and are shown in Figure 2.

Of the 117 project areas, only 34 areas had erosional losses calculated by hand (henceforth referred to as 34PROJ). Data for each of the six USLE factors for separate fields in the 34 areas were recorded on work-sheets (Table 2) and estimations of soils loss calculated.

Table 1

Soil Conservation Service Erosion Estimates for Caddo Creek Watershed (U.S.D.A.-S.C.S., 1986)

Watershed Resource Information

Size of Watershed:	Watershed area	-	134,400 acres
	Total problem area	-	15,990 acres
	Project treatment area	-	8,800 acres (based on 55% participation rate)

Landuse	acres	percentage of total
Cropland	73,900	54.99
Pastureland	40,300	29.99
Rangeland	10,800	8.03
Other	9,400	6.99

Cropland Erosion Rates and Acres Affected

Erosion Type	Range (ton/acre)	Weighted Ave. (ton/acre)	Area Affected (acres)
Perennial Gully Erosion	15-244	100	90
Ephemeral Gully Erosion	6-254	118	410
Sheet-Rill Erosion	5-25	11	15,300
Weighted Average - Total Acres		16	15,990

(U.S.D.A.-S.C.S., 1986)

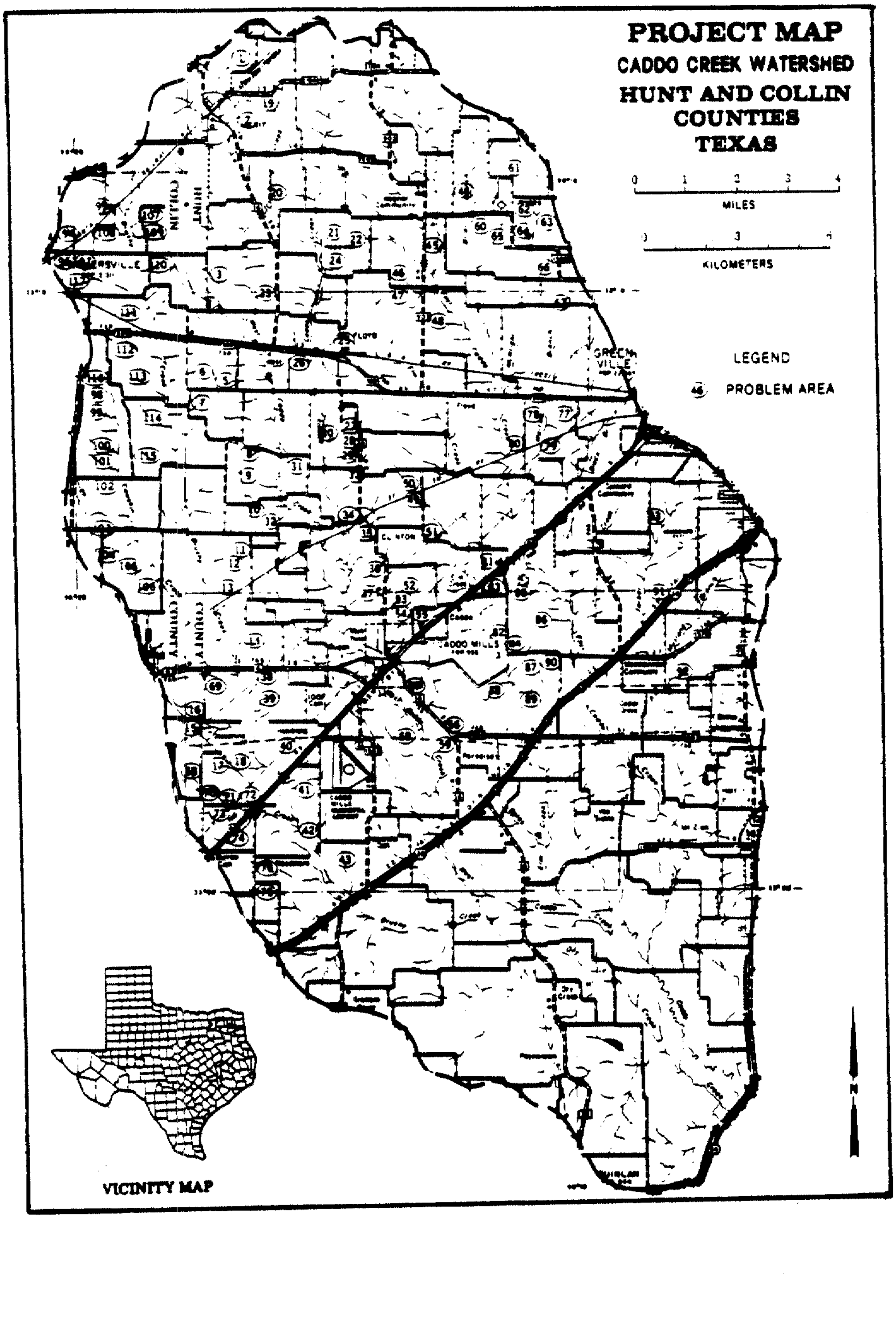


Figure 2

Soil Conservation Service Project Sites Map
(U.S.D.A.-S.C.S., 1986)

Table 2

A Sample of a Soil Conservation Service Field Work-sheet for Caddo Creek Watershed Study (U.S.D.A.-S.C.S., 1986)

Watershed ______ Sq.Mi ____ Acres ______ Field Office ______

Land Resource Area ______ County ______

* Future without a Project
\# Future with a Project DB

Field Number & Soil	Land Use			Conservation Treatment			Acres	Erosion Phase			'K' Factor			Slope %	Slope Length			Slope Factor			'C' Factor			'P' Factor			'R' Factor	Av. Annual Erosion-tons			Erosion Rate tons/ac/yr		
	Pres.	*Fut.	#Fut.	Pres.	*Fut.	#Fut.		Pres	*Fut	#Fut	Pres	*Fut	#Fut		Pres	*Fut	#Fut	Pres	*Fut	#Fut	Pres	*Fut	#Fut	Pres	*Fut	#Fut		Pres	*Fut	#Fut	Pres	*Fut	#Fut
20																																	
1-17	C	C	C	2,3	2,3	2,3	32					0.32		2	125	125	125	0.22	0.22	0.22	0.35	0.35	0.35	0.60	0.60	0.60	320				7.88		
2-17	P	P	P	11	11	11,8	10							2	200	200	200	0.25	0.25	0.25	0.042	0.042	0.042	1.0	1.0	1.0					1.08		
3-17	C	C	C	2,3	2,3	2,3	41							2	125	125	125	0.22	0.22	0.22	0.35	0.35	0.35	0.60	0.60	0.60					7.88		
4-17	C	C	C	2,3	2,3	2,3	77							2	125	125	125	0.22	0.22	0.22	0.35	0.35	0.35	0.60	0.60	0.60					7.87		
5-17	R C	P	C	–	–	2,3	} 31							2	200	200	125	0.25	0.25	0.22	0.15	0.20	0.35	1.0	1.0	0.60					3.84		
5-13	R C	P	C	–	–	2,3								4	300	300	125	0.62	0.62	0.44	0.40	0.45	0.35	1.0	1.0	0.50					15.4		
6-13	P	P	P	11	11	11,8	31							4	300	300	300	0.62	0.62	0.62	0.15	0.20	[illegible]	1.0	[illegible]	[illegible]					9.52		
7-17	C	C	C	–	–	2,3	} 18							2	200	200	125	0.25	0.25	0.22	0.40	0.45	0.35	1.0	1.0	0.60					10.24		
7-13	C	C	C	–	–	2,3								4	300	300	125	0.62	0.62	0.44	0.40	0.45	0.35	1.0	1.0	0.50					[illegible]		
8-13	C	C	C	6	6	6	26							4	300	300	300	0.62	0.62	0.62	0.40	0.45	0.35	1.0	1.0	1.0					[illegible]		
9-17	C	C	C	2,3	2,3	2,3	95					↓		2	125	125	125	0.22	0.22	0.22	0.35	0.35	0.35	0.60	0.60	0.60	↓				7.85		
							421																										
225																																	
1	Acreage in pond dr. area			# 224								0.32															300						
2-HoB	C	C	C	–	–	2,3	51							2	200	200	125	0.25	0.25	0.22	.4			1.0	1.0	0.6					9.6		
3-HoB	C	C	C	–	–	2,3	27							2			125			0.22	.4			1.0	1.0	0.6					9.6		
4-HoB	Grass Strip	→	WW	–	–	2	25							2			200			0.25				1.0	1.0	1.0							
5-HoB	C	C	C	–	–	2,3	36							2			125	↓	↓	0.22	.4			1.0	1.0	0.6					9.6		
6-HoB2	P	P	P	–	–	8,11	25							3			200	0.35	0.35	0.35	.15			1.0	1.0	1.0					5.09		
7-HoB2	C	P	C	–	–	2,3	14							3			125	0.35	0.35	0.31	.4			1.0	1.0	0.5					13.44		
8-HoB	C	C	C	–	–	2,3	23							2			125	0.25	0.25	0.22	.4			1.0	1.0	0.6					9.6		
9-HoB2	Gully	Gully	WW	–	–	2,7	8							3			200	0.35	0.35	0.35				1.0	1.0	1.0							
10-HoB	C	C	C	–	–	2,3	90					↓		2	↓	↓	125	0.25	0.25	0.22	.4			1.0	1.0	0.6	↓				9.6		
							299																										

For the remaining 83 projects areas, calculations were made on a portable computer by conservationists in the helicopter. The conservationist in the front seat would estimate field size and would relay the information to the computer operator in the rear seat. This information, along with soil type and corresponding K and LS factors were entered into the computer and soil erosion rates recorded.

It must be noted that land use percentages for the watershed were only estimates and that detailed land use mapping was not conducted by the S.C.S. Also, detailed soil loss estimates were not made for the whole watershed but only for those areas of cropland which were identified by experienced S.C.S. conservationists as being problem areas (U.S.D.A.-S.C.S., 1990, personal conversations). Estimates for total erosion for the watershed were not therefore based on detailed calculations but on estimates of soil loss by land use type coupled with actual soil loss estimates from the 273 treatment areas. This approach to calculating erosion rates in the watershed dictated the methods for examining the RUSLE, as will be explained.

CHAPTER IV

METHODS AND MATERIALS

Data Sources

Satellite data for this research consisted of Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) images located at Path 28 Row 37 on the Landsat coverage index. The TM image was acquired in April of 1988. It contained 7 bands of data which included: three visible wavelength bands, three near and mid infrared bands, and one thermal infrared band. All 7 bands were used for analysis. The MSS image was acquired in June of 1988 and contained 4 bands of data: two visible and two infrared. The MSS image had been used in a previous CRSLA erosion study (Atkinson et al., 1988) so it was chosen for use with the test watershed. Also, it became apparent from the date of the TM image that land use classification for crops from TM alone might be difficult due to absence of substantial plant growth at that time of the year.

None-the-less, the TM image was used because it has a much higher spatial resolution than MSS; 30m x 30m compared to 80m x 80m. For this reason MSS data were combined with TM data to produce a new dataset which contained information with optimal time (MSS) and high spatial resolution (TM). This procedure will be discussed later. Land use classification was conducted on each of the separate images as well as the 'Combined' image.

Two topographic data sources were chosen for comparison purposes: United States Geological Survey Digital Elevation Model (DEM) data and Digital Terrain Tapes (DTT) data produced by the Defense Mapping Agency Topographic Center. The unit of coverage for both DEM and DTT data is a 1° x 1° block of latitude and longitude. In this study, 1° x 1° coverage represented the eastern half of the USGS 1:250,000 Sherman sheet.

DEM data consist of a regular array of elevations projected on the geographic (latitude and longitude) system and are ordered as profiles ascending northward from the origin in the southwest corner of the map. Spacing of the elevations along and between each profile is 3 arc-seconds. Three arc seconds represent approximately 90m in the north-south axis and a variable dimension (approximately 90m at the equator and 60m at 50° latitude) in the east-west axis due to convergence of the meridians. Elevations are recorded in meters. The 1:250,000 DEM are considered to be a Level 3 classification in that they have been edited and modified to insure positional consistency with planimetric data categories such as hydrography and transportation (USGS, 1985).

DTT data (U.S. Dept. of the Interior, Geological Survey, undated) are obtained and recorded as a grid of elevation values for every 0.01 inch on each map (approximately 200 ft. on the ground). Elevations are recorded in feet. Elevation points are obtained from traced contour lines on standard 1:250,000 topographic maps. Undefined points on the grid are found by either linear or planar interpolation. A sequence of computer accuracy checks are performed and the elevations of grid points not intersected by contour lines are interpolated. Accuracy of the DTT data is no better than the accuracy of the stable-base 1:250,000 scale map sheets from which they were digitized. A matrix of the two data types was conducted and the comparison is presented in the Results chapter.

The Caddo Creek watershed covers all or parts of eight 7.5 minute USGS topographic maps. These include: Greenville S.W., Greenville N.W., Greenville S.E., Farmersville, Caddo Mills, Royce City, Quinlan, and Tawakoni sheets. The stream network of the watershed was digitized from the quad sheets into a GIS file for use in testing the topographic data. In addition, 30 ft. contour intervals ranging from 440 ft. to 710 ft. were digitized. The outline of the watershed was established by interpolation of the quad sheets. This boundary was then digitized into a separate file.

U.S.D.A.-S.C.S. Soil Surveys for Collin and Hunt Counties (U.S.D.A.-S.C.S., 1969; U.S.D.A.-S.C.S., 1981) were used for determining the values of soil erodibility (K). Soil association maps for the two counties were digitized into one file and K values for the associations were assigned to them. Soil series maps for the 34PROJ areas were also digitized and appropriate K values assigned to them. In addition, four complete soil series maps of the area (Hunt County sheets 25, 26, 30 and 31; henceforth referred to as CADMIL for simplicity) were digitized into a separate file. This file was established in order to compare the K values of soil series maps with those of soil associations maps.

One problem which arose when joining the two county soil association maps was that the soil associations did not properly match across the county boundary. The National Soils Handbook (U.S.D.A., 1983) states that "general soil maps of adjoining soil survey areas should be consistent" but "this may not be practical for maps more than ten years old". The Hunt County map was issued in 1981 whereas the Collin County map was issued in 1969. This discrepancy was alleviated when the soil associations were assigned K values.

R values for the study were obtained from a report for the Texas Department of Water Resources (Greiner, 1979). Although R values for past CRSLA studies were assigned according to isoerodent contours obtained from a map by Wischmeier and Smith (1978), for this study each county was assigned one R value (Figure 3). Two sources were initially used for preparing the RUSLE factors: "Predicting Rainfall Erosion Losses", Wischmeier and Smith (1978) and "Predicting Soil Loss Using the USLE", (U.S.D.A.-S.C.S., 1980). This was thought to insure that the model was constructed in as similar a manner as that used by S.C.S. personnel. It was only after discussing the project with a Hunt County S.C.S. conservationist that field techniques for calculating erosion losses were determined. This conversation prompted the use of soils series maps as a third method for determining slope value in addition to the use of DEM/DTT data. This will be discussed further in the section on model construction.

Satellite Image Analysis

The first step in the analysis was to spatially rectify the images. Ground Control Points (GCPs) were obtained from throughout the study area using such obvious locations as road and stream intersections. A transformation matrix was created from the GCPs using a Root Mean Square (RMS) error of 0.25. The Nearest Neighbor option for intensity interpolation was used. All images were originally rectified to 30m x 30m cells. These 30m x

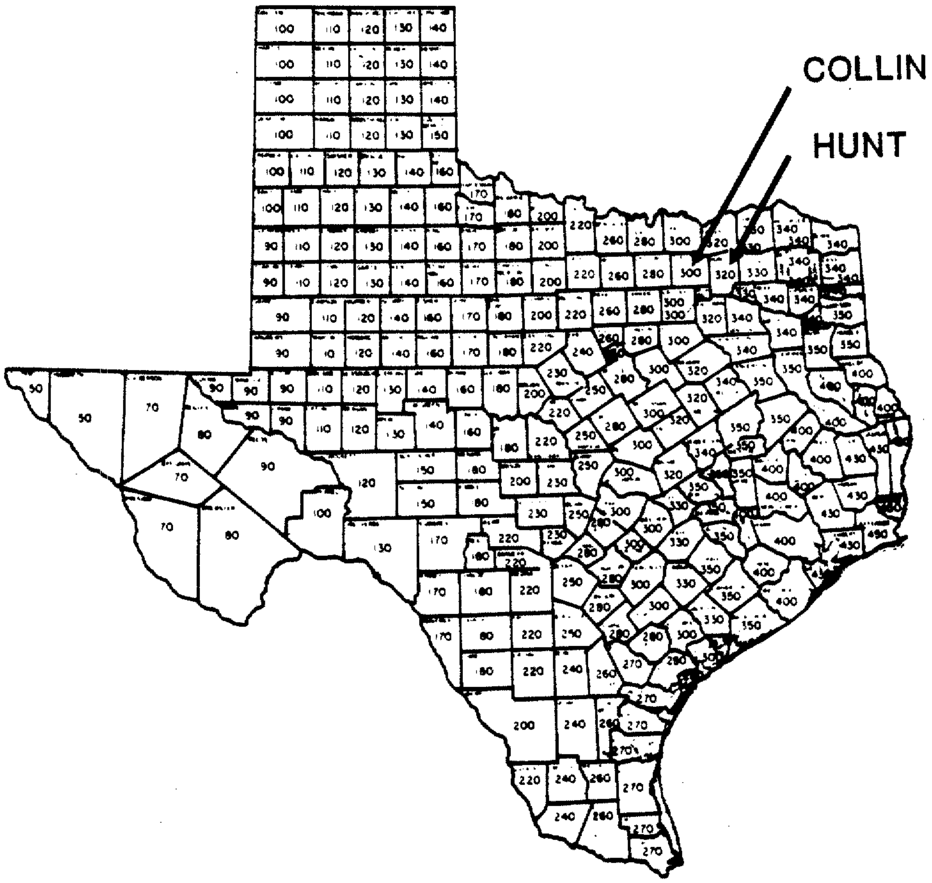


Figure 3.

'R' Values for Counties of Texas (Greiner, 1979)

30m grids represent the smallest area for which data were collected by the satellite. This smallest area is the instantaneous field of view (IFOV) of the scanning system and is often referred to as a 'pixel' (picture element). A pixel is the smallest square that can be displayed on a color computer monitor. The color monitor used in this study could display 512 x 512 pixels or 262,144 grids of 30m TM image.

The next step in the analysis was chosen both to reduce the data size and to combine the qualities of the TM and MSS images as mentioned previously. An ERDAS software Principal Component Analysis (PCA) program was performed on both the TM and MSS images. The results of this procedure were two new images; one with seven bands and the other with four. One of the characteristics of ERDAS PCA is that the first three bands of the image produced by the analysis may contain as much as 99% of the information in the original 4-band or 7-band image (ERDAS, 1986). So, the 'PCA' images produced were subset to two 3-band images in order to reduce data size. In order to benefit from both the MSS and TM images, the two 3-band 'PCA' images were combined into a new 6-band image. PCA was then re-applied to this new image and the resulting 6-band image was again subset to three bands (Figure 4). This new image was called 'Combined'. The visual results of the combination were different than the original MSS and TM images.

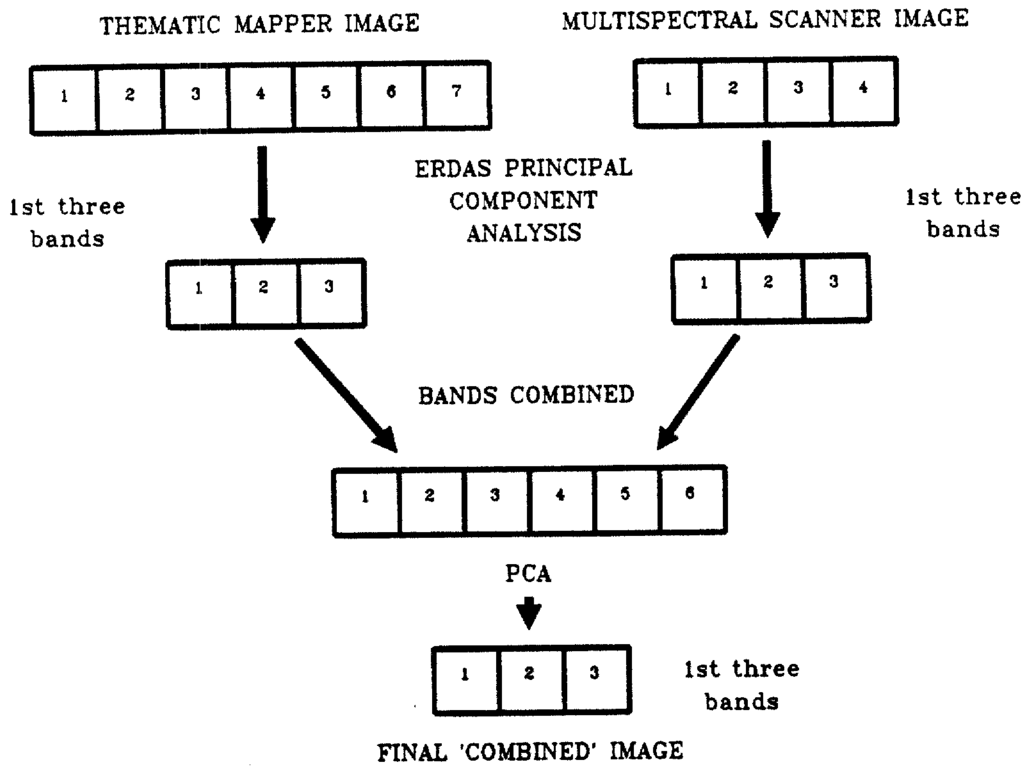


Figure 4

ERDAS Principal Component Analysis (PCA) used to Produce a 'Combined' Image

Land use classification of the images was conducted in two steps. Field training signatures were chosen within the TM, MSS and Combined images. To produce training sites it was necessary to become familiar with the land uses in the study area. A 'window survey' was conducted by driving through sections of the watershed while making note of the land uses on quad sheets. In addition, a second method of identifying field signatures was used. Aerial color slides of Hunt County taken from an altitude of 8,000 ft were obtained from the Hunt County U.S.D.A. Agricultural Stabilization and Conservation Service. The slides were photographed in the summer of 1988 and therefore recorded the same land uses as that of the MSS image. Land use areas from the 'window survey' and from the slides were located in the images (Plate 1) on the computer monitor and field signatures were developed for four land uses : water, forest, pasture, and cropland.

The ERDAS program STATCL was performed on the MSS, TM, and Combined images and unsupervised signatures were obtained. These signatures were appended to the field signatures. A maximum likelihood classifier program was conducted using the appended signatures file. The results of the classifier were three GIS files containing up to as many as 50 classes. The GIS files were then recoded to 5 classes: cropland, pasture, rangelands/forest, water, and other.

Plate 1

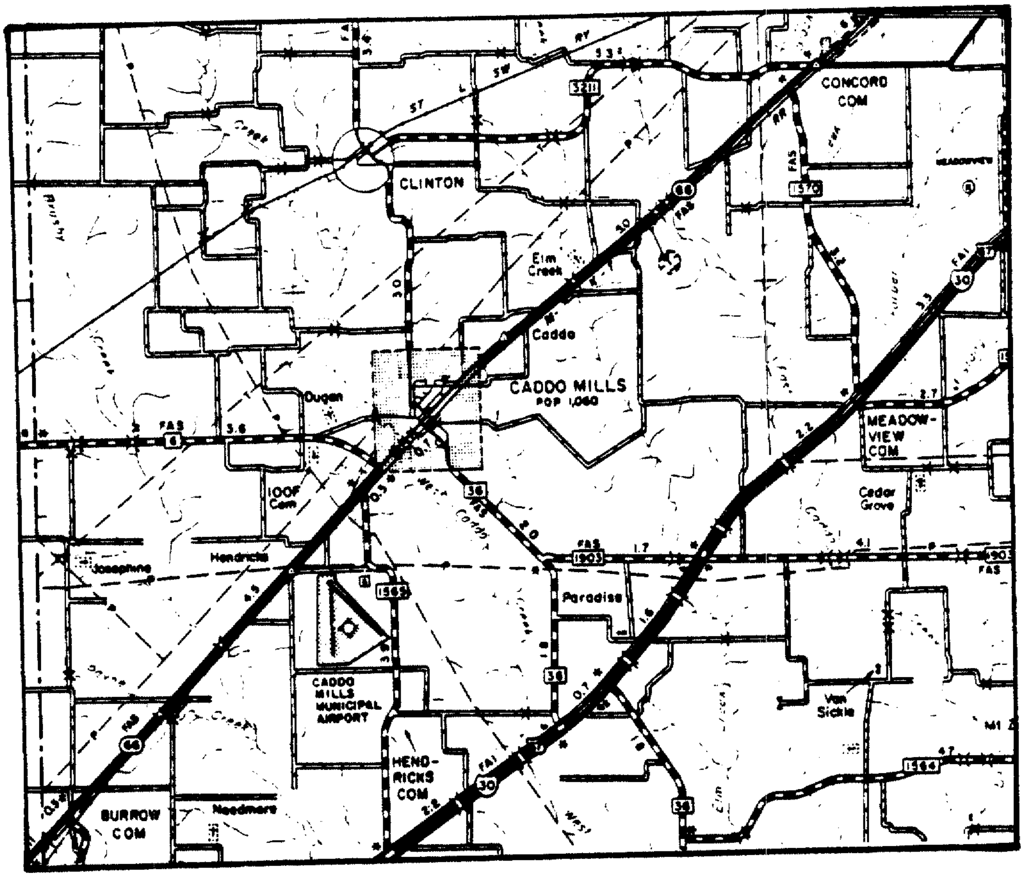
Aerial Image of Land Use Within Watershed
(U.S.D.A.-A.S.C.S, 1986)

Model Construction

The next step in the study was to develop the USLE model from all the data obtained. For each of the six USLE factors a data layer was produced within the GIS. All of the layers consisted of data files of the same size in rows and columns. This size was produced by using the outline of the watershed as a mask to cut the same watershed shape out of all the data layers.

Three sizes were used for the study. The first size was the whole watershed (WTRSHD), approximately 127,000 acres in area. The second size (CADMIL) was a much smaller area, approximately 49,000 acres, surrounding the town of Caddo Mills (Figure 5). This size was determined by digitizing four soil series maps air photo maps (25, 26, 30, and 31) from the Hunt County Soil Survey. The third size (34PROJ) was taken from 34 areas within the watershed for which detailed hand calculated erosion estimates were made by S.C.S. personnel. The size of the project areas ranged from 40 to 400 acres. The RUSLE was developed for all three areas.

The R layer was obtained by assigning an R factor of 300 to Collin County and 320 to Hunt County (Greiner, 1979). Two separate K layers were developed for use. The first layer was obtained in the same manner used by Atkinson et al. (1988) in which the K values for the soil



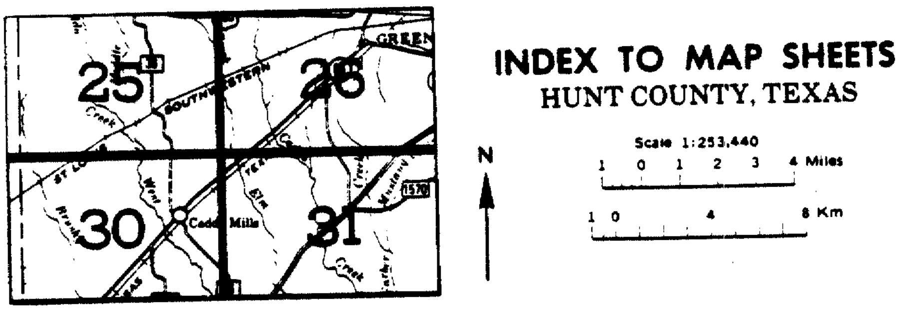


Figure 5

CADMIL Study Area from soil series maps
25, 26, 30, and 31 (U.S.D.A.-S.C.S., 1981)

associations of the two counties were used. The second method used K values taken from soil-series maps in the smaller study area (CADMIL) and in the 34 project areas (34PROJ).

Slopes values were obtained in two different manners. In the first method, slopes for the whole watershed were obtained by processing the DTT data using an ERDAS program called SLOPE. This program compared the elevation of one pixel (one 60m x 60m cell) to elevations in surrounding cells and determined the degree or percentage of slope between them. For this study percent slope was used.

The second method duplicated the technique used by the S.C.S. This method uses the average slope associated with a soil series (U.S.D.A.-S.C.S., 1990, personal conversations). For example; slopes for Houstan Black series soils range from 1 to 3 percent (U.S.D.A.-S.C.S., 1981) and therefore the slope value assigned was 2% for all Houstan series soils. Soils series maps for the 34PROJ areas were digitized and slope values corresponding to the series were assigned to the file.

Choice of length of slope was rather limited for the RUSLE. In standard S.C.S. USLE calculations "slope length begins at the point where runoff begins. It ends where the slope decreases, deposition begins, or where runoff enters a well defined channel that may be part of a drainage network or a constructed channel such as a terrace or diversion" (U.S.D.A.-S.C.S., 1980). This was not possible using satellite images so length was confined to the image resolution. Initially two slope lengths were chosen; 60m (approximately 100 ft.) and 80m (approximately 250 ft.) corresponding to the spatial resolution of TM and MSS images.

After consulting with Hunt County conservationists (U.S.D.A.-S.C.S., 1990, personal conversations), the 80m length was dropped in favor of the 60m slope length. S.C.S. personnel used 200 ft. in most estimates for cropland in Hunt County. Although some calculations were based on lengths ranging from 100 ft. to 500 ft., the average length was 200 ft. Original DEM/DTT data were rectified to 60m x 60m pixels before the program SLOPE was used to determine slope values. In addition, files for C, K, and R values were rectified to 60m so that all files were the same size. The LS values were then obtained from a table of LS factors provided by Hunt County conservationists (Table 3).

Of the six factors used for the USLE there are two factors which appeared to have subjective values: L and S. For the 34PROJ areas of the watershed study the S.C.S. used an average of 200 ft. and so 60m was chosen as the grid size for the RUSLE. The slope was obtained from DEM/DTT data for the RUSLE whereas it was taken as the average of the slopes associated with soil series in the S.C.S. study.

Table 3

Length/Slope (LS) Values Used in the USLE
(U.S.D.S.-S.C.S., 1990)

"LS" TOPOGRAPHIC FACTORS

Percent Slope	Slope Length in Feet								
	10	50	100	150	200	300	400	500	600
0.50	0.06	0.08	0.10	0.10	0.11	0.12	0.13	0.13	0.14
0.80	0.07	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16
1.00	0.07	0.11	0.13	0.15	0.16	0.18	0.20	0.21	0.22
2.00	0.10	0.16	0.20	0.23	0.25	0.28	0.31	0.33	0.34
3.00	0.14	0.23	0.29	0.33	0.36	0.40	0.44	0.47	0.49
4.00	0.16	0.30	0.40	0.47	0.53	0.62	0.70	0.76	0.82
5.00	0.17	0.38	0.54	0.66	0.76	0.93	1.07	1.20	1.31
6.00	0.21	0.48	0.67	0.82	0.95	1.17	1.35	1.50	1.65
7.00	0.26	0.58	0.83	1.02	1.18	1.45	1.67	1.86	2.04
8.00	0.31	0.70	0.99	1.21	1.41	1.72	1.98	2.22	2.43
10.00	0.43	0.97	1.37	1.68	1.94	2.37	2.74	3.06	3.36
12.00	0.57	1.28	1.80	2.21	2.55	3.13	3.61	4.04	4.42
14.00	0.73	1.62	2.30	2.81	3.25	3.98	4.59	5.13	5.62
16.00	0.90	2.01	2.84	3.48	4.01	4.92	5.68	6.35	6.95
18.00	1.09	2.43	3.43	4.21	4.86	5.95	6.87	7.68	8.41
20.00	1.29	2.88	4.08	5.00	5.77	7.07	8.16	9.12	

In order to test the accuracy of the values assigned in both studies actual slopes were recorded in the field using a transit and stadia rod.

Eight of the 34PROJ sites were chosen from the CADMIL area for comparison. The sites were located on a $7^1/_2$ minute quad sheets using the location of the S.C.S. project map as a guide. At each of the sites the transit was set up in a mid-slope location which visually represented the general slope and aspect of the area. Elevations and distances were obtained and recorded. The slope for the sites were then calculated and compared to the slopes used for calculations by the S.C.S. and for the RUSLE.

The C factor was obtained from one source; the Caddo Watershed Project. The predominant cropping rotation for the study area was wheat-cotton-milo or wheat-milo (U.S.D.A.-A.S.C.S., 1989, personal conversations). The average C value for this rotation was 0.4. The other average C values of interest to this study were 0.13 for rangelands and 0.15 for pasture (U.S.D.A.-S.C.S., 1986). A C value of 0.0 was assigned to water and to the 'Other' classification.

The P value used in the model was 1.0 for all areas within the watershed. P values normally range from 1.0 for up and down hill cropping to 0.37 for contour stripcropping (U.S.D.A.-S.C.S., 1980). Although contour farming techniques can often be identified in aerial photography, they can seldom be seen in satellites images and for this reason the value of 1.0 was used. The use of the maximum value for P meant that erosion estimates were most likely higher than actual field values. Some P values, such as 0.6 for terraced slopes (Table 2), were used by S.C.S. personnel when estimating erosion losses for the project areas.

Once all the RUSLE data layers were created, matrices of information layers were generated by the GIS. This involved sequential steps of combining layers. First the R factor file was merged with the K factor file to create a rainfall/soil file. Next the rainfall/soil file was merged with the LS file to create a rainfall/soil/slope file. The final step merged the rainfall/soil/slope file with the C file to produce a file of estimated erosional loss.

Erosional losses were calculated for each pixel of cropland, pasture, and rangelands. This process was repeated for the various uses of K and LS values as outlined above. The final output were maps of the watershed which showed areas of varying erosional rate. In all, nine different combinations (Method 1 - Method 9) of the data base components for erosion calculations for three study sizes were generated. These combinations are shown in Table 4.

In order to compare the results of the RUSLE to S.C.S. estimates, several techniques were used. The first

Table 4

Nine Methods of Factor Combinations for Determining Erosion Rates within Study Area

METHOD	STUDY AREA	R	K	L	S	C	P
1	WTRSHD	300/320	ASSOC.	30M	DTT	COMBINED	1.0
2	WTRSHD	300/320	ASSOC.	60M	DTT	COMBINED	1.0
3	WTRSHD	300/320	ASSOC.	80M	DTT	COMBINED	1.0
4	CADMIL	300/320	ASSOC.	60M	DTT	COMBINED	1.0
5	CADMIL	300/320	SERIES	60M	DTT	COMBINED	1.0
6	34PROJ	300/320	ASSOC.	60M	DTT	COMBINED	1.0
7	34PROJ	300/320	SERIES	60M	DTT	COMBINED	1.0
8	34PROJ	300/320	SERIES	60M	SER.	COMBINED	1.0
9	34PROJ	300/320	SERIES	60M	SER.	COMBINED	1.0

WTRSHD = watershed area
CADMIL = Caddo Mills area
34PROJ = area for 34 project sites
ASSOC. = soil association map
SERIES = soil series map
30M = 30 meters (approx. 100ft.) for slope length
DTT = Digitial Terrain Tape data
SER. = soil series map
COMBINED = Satellite image produced using ERDAS PCA program.

involved an overlay of the RUSLE erosion map and the S.C.S. project erosion map displayed in Figure 2. A visual comparison was made to determine if those areas estimated by the S.C.S. to have erosion greater than 5 ton/acre/year coincided with high erosion areas calculated by the RUSLE. This overlay technique was used for method 2.

A second technique used to compare methods for the CADMIL area involved a series of matrices of the erosion results from methods 4, 5, and 6. These matrices compared the results produced using soil association and soil series K values and the results from DTT slope values and soil series slope values.

The third method to compare results involved using the hand calculations made for the 34PROJ area. A mask file containing the project areas was created and this was used to 'cut out' project area sizes from the erosion maps generated in methods 4, 5, and 6. The project areas in the mask file were a minimum of 56 acres in size. The masked project areas became methods 7, 8, and 9 for comparison purposes. Erosion rates in 16 project areas from methods 7, 8, and 9 were compared to each other and to results recorded in the field.

A statistical comparison of the results of RUSLE methods and the results of the S.C.S. hand calculations could not be made because the exact location of each field studied by the S.C.S. could not be found on the RUSLE output. Only the approximate center of the project area could be located using the map shown in Figure 2. To locate each field would have required more time and resources than available to the project. Also, although Hunt County Conservationists were extremely helpful in providing data and information they were committed to too many tasks of their own to be able to spend additional time in the field on this study. For this reason, a visual comparison was made of the results of the masked areas for methods 6 - 8.

CHAPTER V

RESEARCH RESULTS

Land Use Classification

The first results of the study were not soil erosion estimates but rather were land use classifications for the three satellite images used. Land use classes within the MSS, TM and 'Combined' images were determined by identifying cropland, rangeland and pastureland in aerial photo slides obtained from the A.S.C.S. (U.S.D.A.-A.S.C.S., 1990). Classifications generated by the unsupervised classification program were assigned a land use category of cropland, pastureland, rangeland, or other. Land use acreage for Caddo Creek Watershed for each of the three images is shown in Table 5. The land use 'other' included roads and areas that were not readily identifiable and therefore could not be associated with any of the three main classes.

The 'Combined' image was chosen to represent the C factor for the study (Plate 2). The reason for this decision was that the image, through the combination of ERDAS PCA output from both the MSS and TM images, contained more information than either of the images individually. The TM image showed greater detail than the MSS, due to 30m

Table 5

Land Use Percentages for Watershed Area Using
TM, MSS and 'Combined' Images

Land Use	MSS	TM	'Combined'	SCS Study
Cropland	45.28%	46.66%	48.28%	54.99%
Pastureland	43.39%	35.32%	38.70%	29.99%
Rangeland	6.95%	11.79%	7.40%	8.03%
Other	4.38%	6.23%	5.62%	6.99%

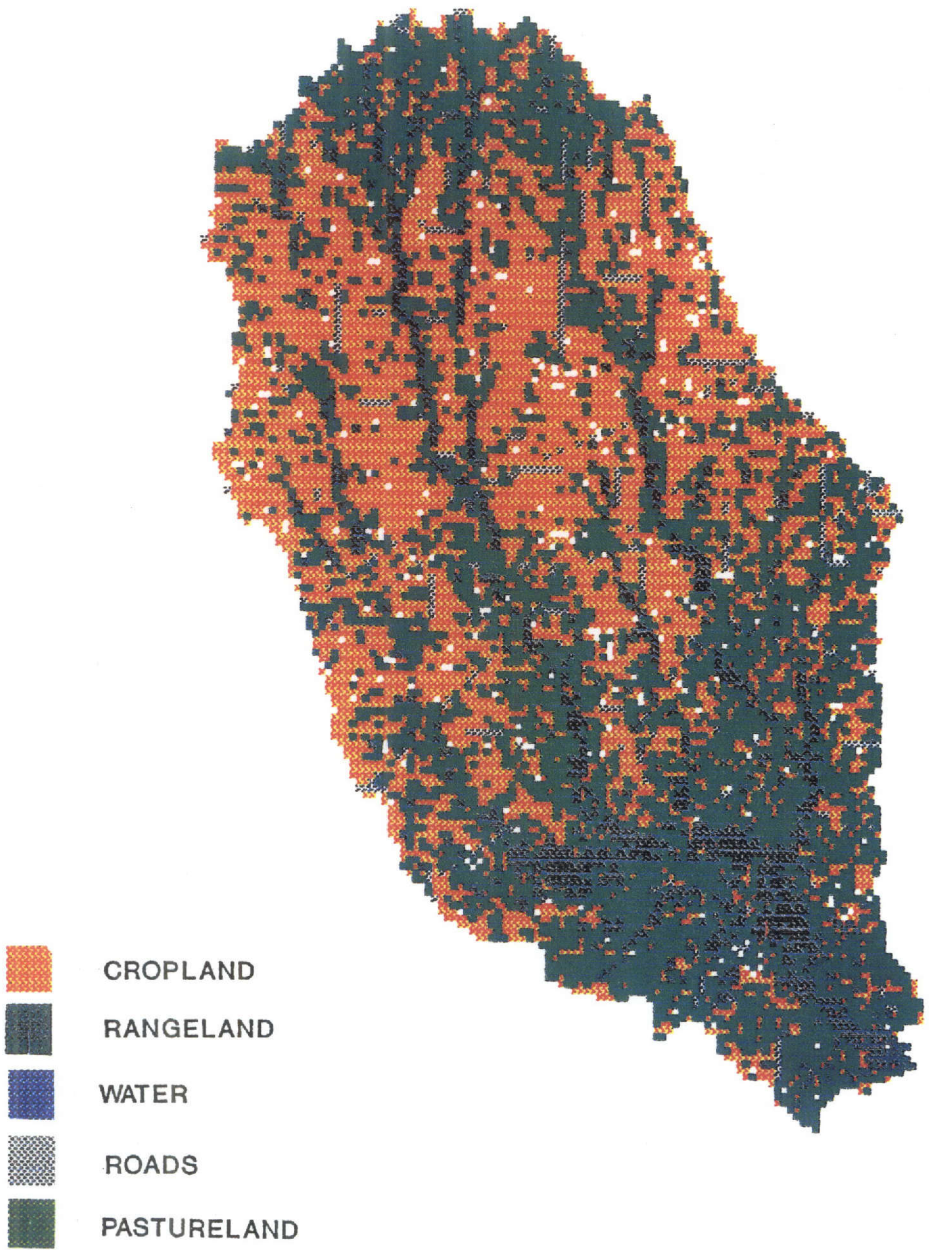


Plate 2

Land Use Classifications for the 'Combined' Image spatial resolution, but the MSS data were recorded in June, rather than April for TM. The ERDAS PCA analysis combined the first three bands from the output of each image and contained unique information from the two images to form a new image. To add to the decision, the Caddo Creek Watershed Report had stated that the acreage of cropland within the watershed was approximately 55% of the total area. The 'Combined' image contained 48% cropland which was closest to that in the report.

A detailed random ground truthing of the watershed was not attempted. Window surveys of the areas were conducted on two occasions. In addition, a map 2 ft. x 3 ft. (approximately 1:43,200 scale) showing land use classifications was presented to the Hunt County Conservationist directly responsible for the Caddo Creek Watershed Project. He examined the map, looking particularly at areas that he was developing conservation programs for, and stated that, by and large, the map adequately represented land uses within the watershed (U.S.D.A.-S.C.S., personal conversation, 1990). In his opinion there were places that were misclassified but that the map correctly showed that the majority of cropland was located between State Highway 380 in the North and U.S. Interstate 30 to the south. The detail of the map was such that he was able to identify stands of trees, with which he was familiar, along fence rows and within fields.

DEM versus DTT Data

Another comparison made was for DEM and DTT data. A matrix of slope values was constructed with DEM values along the X axis and DTT values along the Y axis (Figure 6). All pixels with the same value fell upon the diagonal of the matrix. The percentage agreement among the two data sets was approximately 71 percent demonstrating that although the two elevation images appeared very similar visually, the manner in which the two data sets were created provided for considerable difference, particularly in the areas with greater than 4 % slope. The results of this comparison will be discussed in the following chapter.

Erosion Calculations

A series of erosion calculations were gathered from the nine different methods listed in Table 4. The nine methods combined different values for the six factors of the USLE. Erosion loss estimates were totaled for each method and compared in the following results. Erosion rates were divided into 8 categories:

1-2 ton/acre/yr
3-4 "
5-6 "
7-8 "
9-10 "
11-12 "
13-14 "
Greater or equal to 15 ton/acre/year.

'LS' VALUES FOR DTT DATA

'LS' VALUES FOR DEM DATA		.13	.16	.25	.35	.53	.76	.95	1.18	1.41
		1	2	3	4	5	6	7	8	9
.13	1	55.4	11.2	0.7	0.1	0.06	0.02	0.02	0.0	0.0
.16	2	11.9	14.1	2.1	0.3	0.05	0.03	0.0	0.0	0.0
.25	3	0.5	1.4	1.1	0.2	0.08	0.02	0.01	0.0	0.0
.35	4	0.09	0.09	0.12	0.10	0.07	0.01	0.01	0.0	0.0
.53	5	0.02	0.04	0.02	0.01	0.03	0.02	0.01	0.0	0.0
.76	6	0.01	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0
.95	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.18	8	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.41	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

70.71 %

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Figure 6

Matrix of Percentages of LS Values for DEM and DTT Data

Methods 1, 2, and 3.

The first noticeable difference was between methods 1, 2, and 3. These three methods used different values for slope length, maintaining the same values for the remaining five factors. Initially only 30m (approx. 100ft.) and 80m (approx. 250) lengths were chosen, using standard 30m and 80m spatial resolutions of TM and MSS data. But, upon speaking with a S.C.S. Conservationist, 60m (approx. 200ft.) was chosen as this was the typical length used in the Caddo Creek study. Erosion rates for the three methods are shown in Table 6.

Note that the erosion rate increases as the length of slope increases. This is to be expected since the L value increases with length (see Table 3). Also note that the total acreage increases as the grid size increases. This is an inherent function of the raster or grid based GIS. For example, if the boundary of the watershed falls within a grid, the area of the grid is added to the total area of the watershed. The watershed boundary may not include as many 80m grids as 30 m grids but since an 80m cell is approximately 1.6 acres in size compared to a 30m cell at approximately .22 acres in size, the total area for the 80m watershed is greater than the 30m watershed. In the case of the Caddo Creek watershed the difference is approximately 523 acres.

Table 6

Erosion Rates for 30m, 60m and 80m Slopes
(tons/acre/year)

Erosion Rate (t/a/y)	30m (acres)	60m (acres)	80m (acres)
1 - 2	58,976 (46.4%)	51,139 (40.1%)	51,752 (40.6%)
3 - 4	56,805 (44.7%)	46,243 (36.3%)	12,034 (9.4%)
5 - 6	3,848 (3.0%)	21,188 (16.6%)	55,420 (43.4%)
7 - 8	4,468 (3.5%)	3,200 (2.5%)	940 (0.7%)
9 - 10	1,338 (1.1%)	3,285 (2.6%)	5,062 (4.0%)
11 - 12	536 (0.4%)	721 (0.6%)	223 (0.2%)
13 - 14	113 (0.1%)	779 (0.6%)	1,403 (1.1%)
15 & >	998 (< 1%)	942 (< 1%)	771 (< 1%)
Total Acres	127,082 (100%)	127,497 (100%)	127,605 (100%)

Methods 4 and 5.

The next comparison made was between methods 4 and 5. In method 4, K values were weighted values assigned to the soil association map of Hunt County. Method 5 used K values obtained from soil series maps 25, 26, 30, and 31 of the Hunt County Soil Survey. The soil survey was much more detailed and, although the K values have the same range for both series and association, the values are not necessarily located in the same places. All other factors were held the same. The 'Combined' C value was used as was the 60m L value. Erosion rates from the CADMIL area were generated. The results can be seen in Table 7. The soil series results show higher soil erosion estimates. This is due to the fact that there was a higher proportion of .43 to .32 K values in the soil series than there was in the soil association. When the two K value maps were matrixed the results showed that 90.34 percent of the area had the same erosion estimates. The difference in erosion estimates for the two data sets were therefore produced from an area of approximately 4220 acres.

Methods 5 and 6.

Following the comparison of K values, the next stage of the study compared erosion estimates using different LS

Table 7

Erosion Rates using K Values from Soil Association
and Soil Series Maps (tons/year)

Erosion Class (tons/acre/year)	Series (tons)	Association (tons)
1 - 2	15,382.35	15,403.45
3 - 4	15,576.48	18,104.33
5 - 6	8,925.56	7,132.01
7 - 8	1,202.74	464.21
9 - 10	704.76	801.82
11 - 12	173.03	84.40
13 - 14	122.38	126.60
15 & >	113.94	84.40
TOTAL TONS/YEAR *	154,154.86	143,731.37

* Total tons are calculated by multiplying number of acres by the erosion class and adding results

values from methods 5 and 6 for the CADMIL area. In method 5 the slope values were obtained from the DTT data. Slope values for method 6 were obtained in the manner most often used in the Caddo Creek study where they were assigned the average slopes associated with soil types within the soil series maps. All other factors of the equation were held equal. The maps produced (Plates 3 and 4) show a great visual difference in the quantities of erosion as calculated by these different methods. Table 8 shows the quantitative results of the comparison.

Erosion estimations within method 6, the method similar to the S.C.S. technique, were much higher with a far larger area of erosion greater than 5 tons/acre/year than that estimated by the RUSLE. When the erosion maps for methods 5 and 6 were matrixed, a total of 8895 pixels representing 7916.96 acres (18.76%) fell upon the diagonal (Figure 7). A matrix of the slope values for the DEM data and the soil series maps produced an 11.83 percent similarity. The red color in Plate 5 represents the areas that had the same slope values for both data sources.

Since the two methods produced such differing results, slope values were compared to determine which of the two, method 5 or method 6, was more likely to be correct. This was accomplished by using slope values obtained in the field using the transit and stadia rod method. The comparisons was made for seven of the 34PROJ areas found

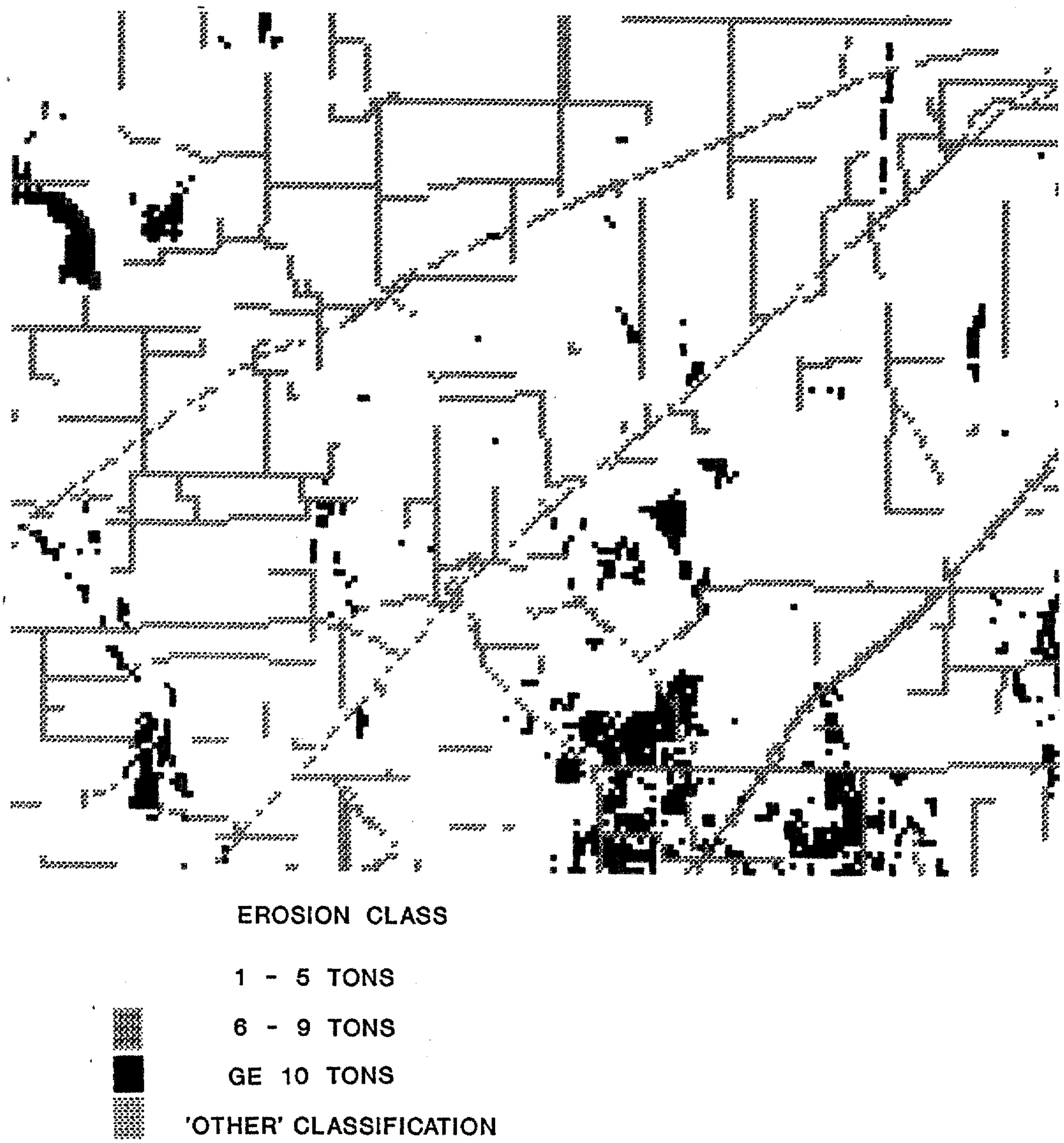

Plate 3

Erosion Classifications using Method 4 for CADMIL Area

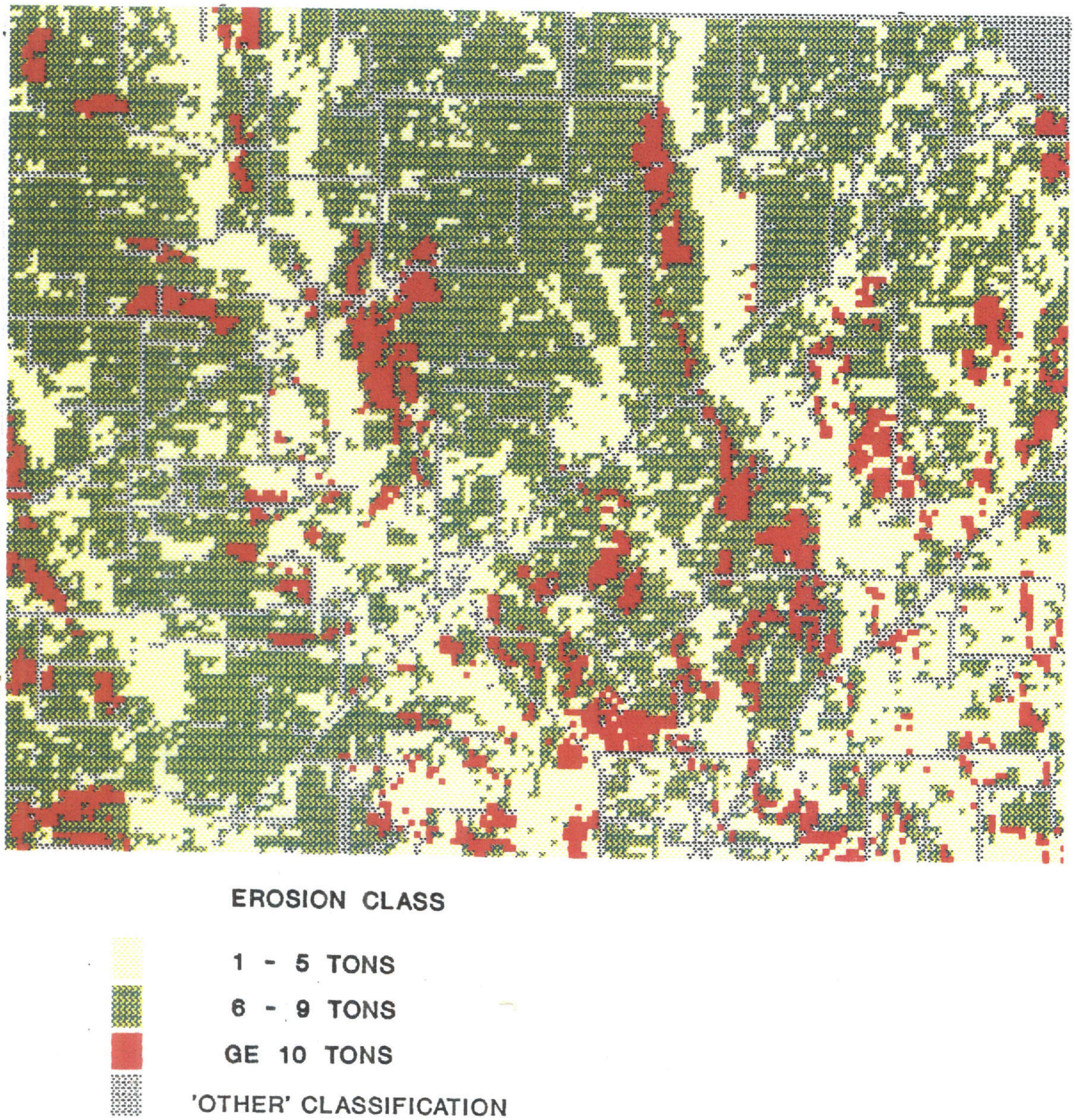

Plate 4

Erosion Classifications using Method 6 for CADMIL Area

Table 8

Erosion Rates using LS Values from DTT Data and Soil Series Maps for the CADMIL Area (tons/acre/year)

Erosion Class (ton/acre/year)		DTT Data (tons)	Soil Series (tons)
1 - 2		15,382.35	5,967.26
3 - 4		15,576.48	8,136.40
5 - 6		8,925.56	6,212.02
7 - 8		1,202.74	4,211.68
9 - 10		704.76	14,251.36
11 - 12		173.03	0.00
13 - 14		122.38	873.57
15 & >		113.94	2,548.96
TOTAL TONS/YEAR	*	154,154.86	297,091.82

* Total tons are calculated by multiplying number of acres by the erosion class and adding results

METHOD 6 EROSION CLASSES

METHOD 5 EROSION CLASSES	1	2	3	4	5	6	7	8
1	12.45	1.29	0.27	0.08	0.0	0.03	0.01	0.01
2	18.40	0.69	0.03	0.12	0.02	0.01	0.01	0.0
3	2.83	8.20	2.96	0.01	0.57	0.0	0.09	0.05
4	2.14	0.09	5.66	1.74	0.0	0.30	0.0	0.03
5	0.62	23.52	8.36	0.02	0.91	0.0	0.17	0.17
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	1.26	0.76	0.0	0.04	0.0	0.0
8	0.0	3.13	2.59	0.11	0.16	0.03	0.01	0.01

18.76 %

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Figure 7

Matrix of Erosion Rates for Methods 5 and 6
(shown as a percentage of total erosion)

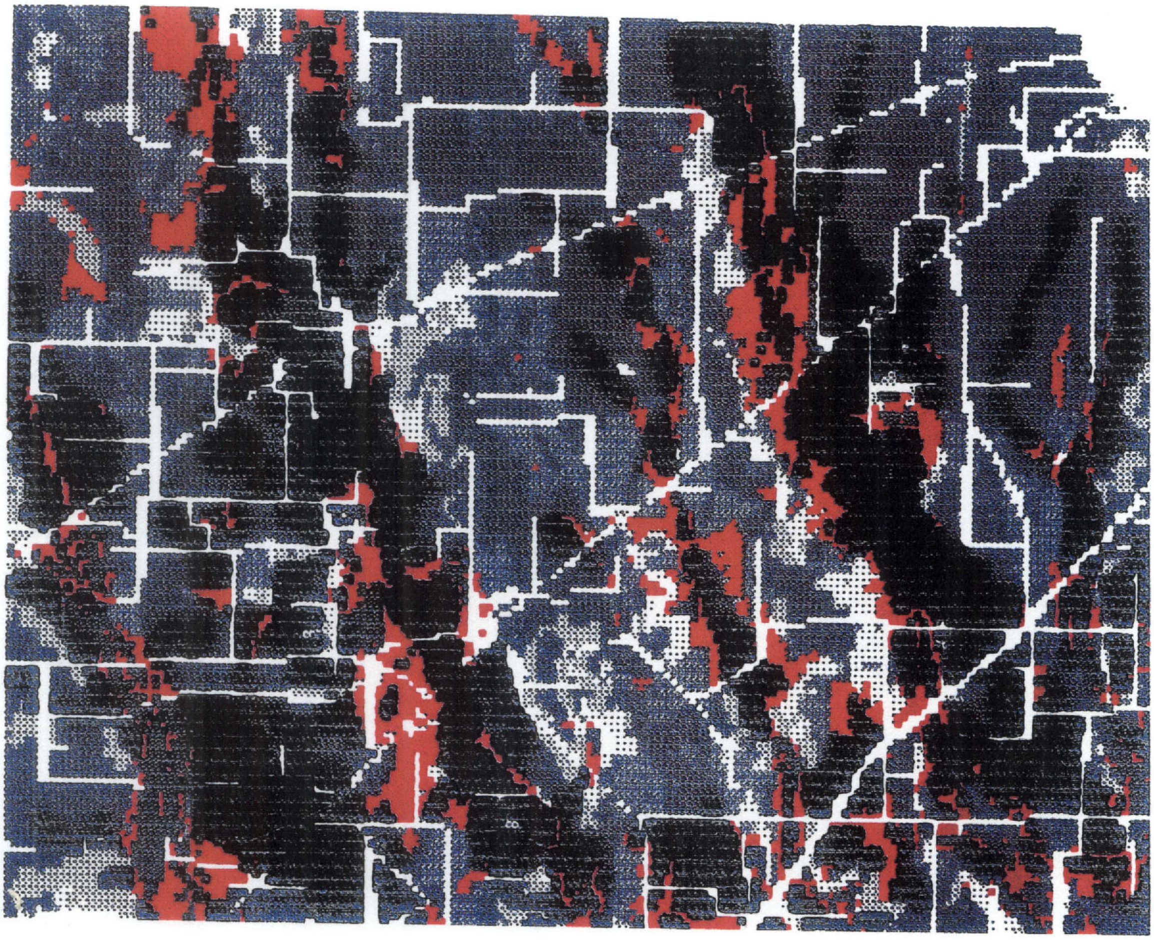

Plate 5

Red color represents areas with the same slope for Dtt data and soils series maps in CADMIL area.

within the CADMIL area. UTM coordinates of the field sites were determined from the Quad Sheets used and the approximate corresponding area within the CADMIL soil series slope map located.

Although the exact locations of the S.C.S. values are not possible, the acreage of each of the sites is large and generalizations were made concerning their slope values. A comparison of slopes for DTT data, soil series, S.C.S. recorded values and the transit records is shown in Table 9. As can be seen, the transit values are closer to the soils series and S.C.S. values than the DTT values.

Methods 7, 8, and 9.

The final section of the study compared erosion estimates from methods 7, 8, & 9. All three of these methods produced estimates for the 34PROJ areas for which S.C.S. hand calculations were made. Sixteen project sites within the CADMIL area were chosen for comparison. A mask file approximating the size of the individual project sites was produced. This mask was then used to cut out erosion estimates from the CADMIL areas. These areas were compared to each other and to the actual hand calculations performed by the S.C.S. The results are presented in Table 10. As can be seen, there is considerable difference in the results of the different methods. Estimations from methods

Table 9

Comparison of Slopes (in percentages) for DTT Data, Soil Series, Caddo Creek Study, and Transit Sources

PROJECT AREA	DTT	SOIL SERIES	CADDO CREEK S.C.S STUDY	TRANSIT METHOD
10	1%	2%	2 - 4%	2.66%
33	1%	2%	1 - 4%	2.52%
88	< 1 - 1%	2%	2 - 4%	2.10%
87	< 1%	2%	1 - 4%	3.6%
84	< 1 - 2%	4%	1 - 2%	0.95%
91	< 1%	2%	2 - 4%	1.6%
56	< 1%	2%	2%	0.05%

Table 10

Comparison of Erosion Estimates for Methods 7, 8, and 9 for Sixteen Project Sites in the CADMIL Area

PROJECT SITE	MTD. 7	MTD. 8	MTD. 9	FIELD ESTIMATES
	(values represent erosion range in ton/acre/year)			
8	1 - 5	1 - 5	1 - 9	3.84 - 10.24
9	1 - 9	1 - 9	1 - 9	7.88 - 25.40
10	1 - 9	1 - 9	1 - 21	1.08 - 25.40
33	1 - 5	1 - 5	1 - 21	2.0 - 10.24
14	1 - 4	1 - 4	1 - 9	7.53 - 11.06
79	1 - 4	1 - 4	1 - 9	10.24
81	1 - 5	1 - 5	1 - 9	3.84 - 10.24
83	1 - 5	1 - 5	1 - 9	10.24
86	1 - 5	1 - 5	1 - 21	9.01 - 25.40
82	1 - 9	1 - 9	1 - 9	9.01 - 10.24
84	1 - 9	1 - 9	1 - 21	10.24 - 11.06
87	1 - 9	1 - 9	1 - 21	2.28 - 21.71
88	1 - 5	1 - 5	1 - 21	9.52 - 10.24
89	1 - 5	1 - 5	1 - 21	2.28 - 10.24
56	1 - 5	1 - 5	1 - 13	13.76
91	1 - 4	1 - 4	1 - 21	2.56 - 10.24

7 and 8 are much lower than the results of method 9 and are much lower than the S.C.S. hand calculated results.

Plates 6 and 7 display the erosion classifications for the sixteen project sites in Table 10. It can be seen in Plate 6, representing the RUSLE in method 7, that there are only five project sites with erosion rates as high as 9 tons/acre/year. The other eleven sites have erosion rates less than or equal to 5 tons/acre/year. The comparison in Table 10 shows that this is also true for the estimates produced by method 8. Plate 7, representing the S.C.S. factors used in method 9, show that all sixteen project sites have erosion rates at least as great as 9 tons/acre/year and that eight sites have rates as high as 21 tons/acre/year. When these rates are compared in Table 10, it can be seen that the estimates produced in method 9 closely represent the estimates calculated by S.C.S. personnel in the field. Erosion rates for five sites were overestimated, two sites were underestimated, and ten sites were within at least 2 tons/acre/year.

CHAPTER V.

DISCUSSION

The original purpose of the study was to compare the results of erosion rates calculated using the RUSLE to rates calculated using a field survey technique. In the process of doing so, comparisons were made of results obtained from combining different data sources for the five factors used in the RUSLE. Ultimately the qualitative results of the RUSLE were compared to those erosion estimates calculated in the field by S.C.S. personnel for the Caddo Creek Watershed Study.

Land Use Classification

The first test of the data involved land use classification from the satellite image. Although a detailed ground truthing of the classification map was not conducted, the evaluation by a S.C.S. conservationist was considered acceptable for the scope of this project (U.S.D.A.-S.C.S., 1990). His conclusion was that the satellite classification adequately represented the land use of the watershed, particularly cropland, for he was able to visually identify many of his project sites from the lay out of roads, rangeland (tree-lined fence rows) and cropland patterns.

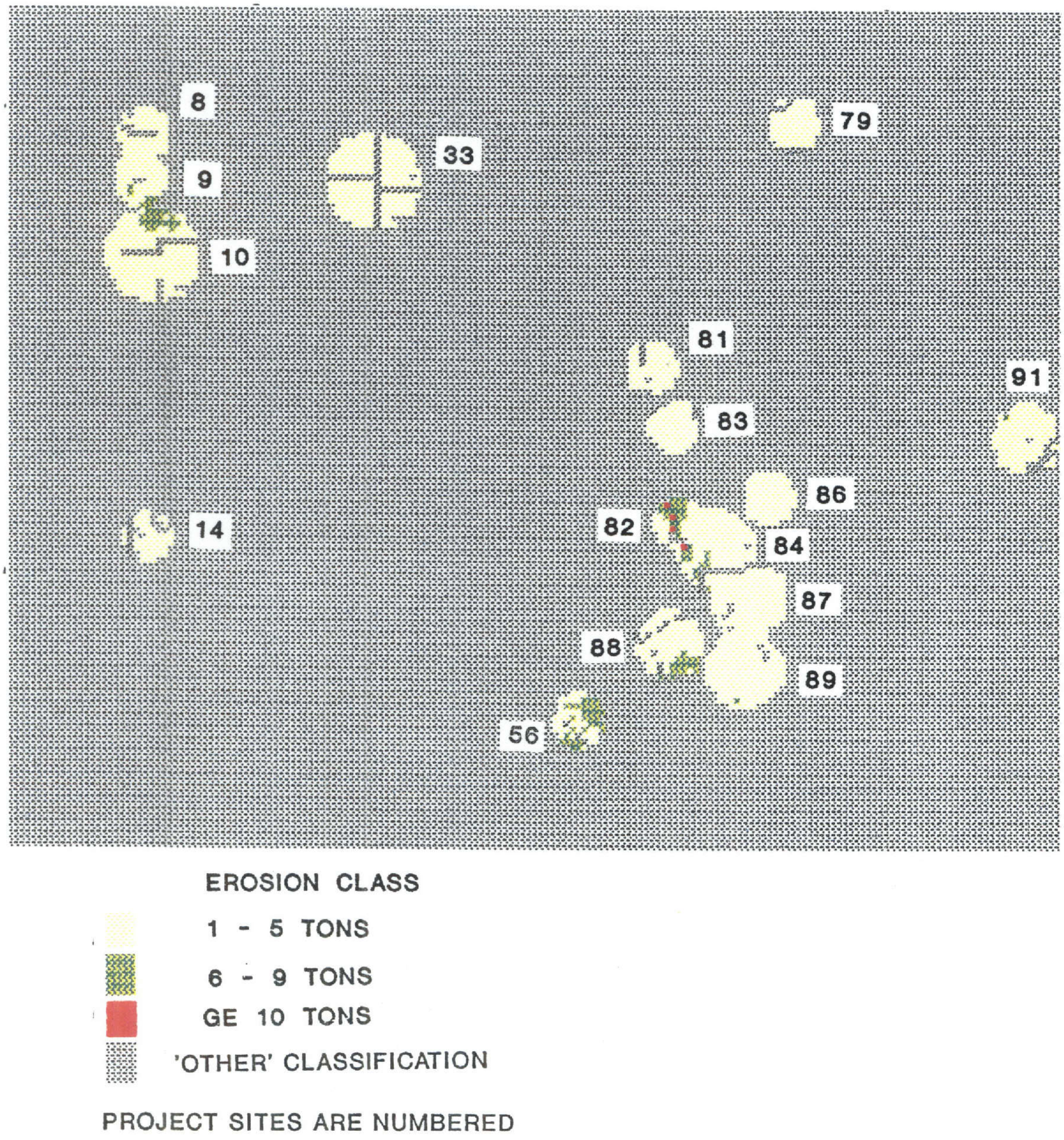

Plate 6

Erosion Classifications for Method 7 for Sixteen Project Sites in the CADMIL Area

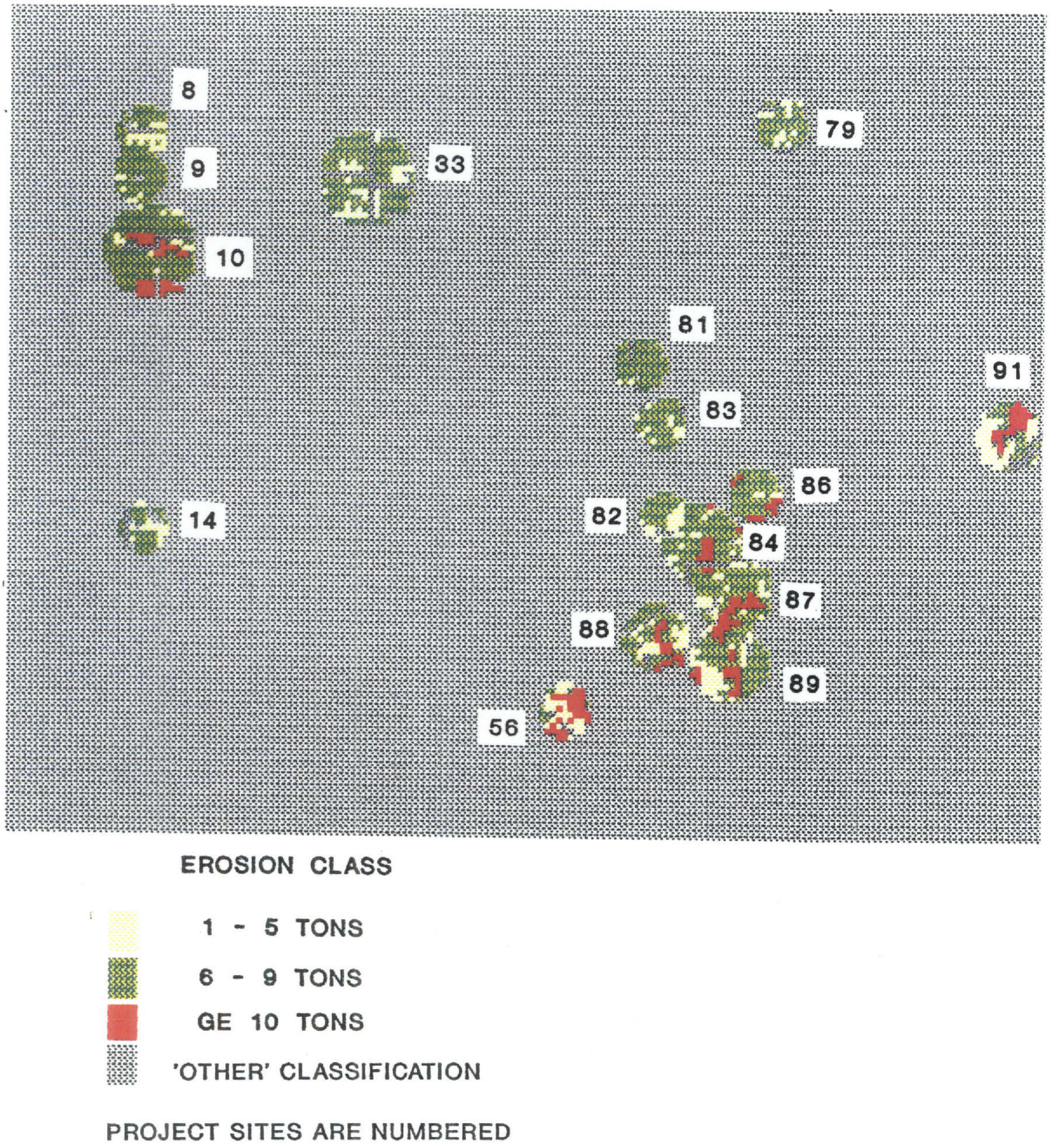

Plate 7

Erosion Classifications for Method 9 for Sixteen Project Sites in the CADMIL Area

Slope Length

By comparing the estimated erosion classes from three different grid or pixel sizes, 30m, 60m, and 80m, it was shown that erosion potential increased as the grid cell increased in size. This was not surprising in that the LS values for the same slope, for example 5% as seen in Table 3, increased as the length of the slope increased. After this comparison was complete the remainder of the study used a 60m slope.

K Values

The next conclusion of the study was that the erosion rates increased when K values from soil series maps were used instead of K values obtained from soil association maps for the same area. For the CADMIL area the difference in total erosion rate for the soil series map was 10,423 tons/year greater than for the soil association map. This difference represents an average of approximately 0.2 tons/acre/year over the CADMIL area but the majority of the difference is in erosion class values less than 6 tons/acre/year. There is only approximately 800 tons/year difference between the two soil maps in the erosion values greater than 6 tons showing that, for the CADMIL area, the additional work needed to digitize the soils series maps did not produce a large difference in estimates of high erosion.

The choice to use soil association or soil series K values is perhaps more a matter of the scale of the project and whether the RUSLE is to exactly duplicate the data sources the S.C.S. typically uses. For a small scale project in which soil series data could be easily input the K values can produce estimates more in the manner that the USLE can in that soil series K values are typically used by the S.C.S. (U.S.D.A.-S.C.S., 1990).

Total time required for data input for the two sources is very different. The Caddo Creek Watershed encompasses all or parts of 18 soil series maps. Digitizing a soil series map often requires between 3 to 7 hours, depending on map complexity, so input for the watershed area could take as much as 80 hours. This total is compared to the time required to digitize parts of two soil association maps for Hunt and Collin Counties. Less than 3 hours was required. To produce an overview of the area the soil association data was certainly far more expedient than the soil series data.

Slope Values

The next comparison of the study involved slope values obtained from DTT and DEM data. When values from the two sources were matrixed the difference was 29%. This difference can be attributed to the two methods by which the data are produced and by possible misregistration in the overlay of the two files. Although both sets are obtained from 1:250,000 scale maps using 50 ft. contour intervals, the interpolation procedure used two different grid intervals, 0.01 map inches versus 3 arc seconds latitude and longitude, for sampling distances. Also one is measured in feet whereas the other is in meters. This combination of differences can certainly contribute to differences within the slope values. No judgement was made in this study as to which of the data sets was more correct. DTT data had been used in past studies and was on file in the CRSLA laboratory and therefore was used for this watershed study.

So far none of the combinations of factors (C from 'Combined', R, K from soil series or association, and LS from DTT) in the RUSLE was able to reproduce erosion estimates similar to those calculated by the S.C.S. in field investigations. It was only after replacing the DTT LS values with those associated with the average slope of various soils obtained from the soil series map that similar values were calculated. This is the pivotal factor of the RUSLE.

When slope values from soil series maps and DTT data were compared to actual slopes obtained in the field using transit and stadia rod the soil series values were closer to actual values. This similarity is very hard to explain in that the soil series values were average values for the soil type, values often ranging from 1% to 5%. In most cases the difference between DTT data and soil series values was only 1%. But, that 1%, especially changing the value from 1% to 2%, often made a large difference in erosion estimates in that the LS factor changed from 0.16 to 0.25 for a 60m (200 ft) slope length. This contributed much more to the change in erosion rate than the difference in length of 30m to 60m grid size with corresponding LS values of 0.13 to 0.16 for 1% slope.

When erosion values produced by the RUSLE using the same factors as those used by the S.C.S. were compared to the erosion estimates calculated in the field, they were found to very similar; within 2 tons/acre/year for high erosion values. The factor combinations using DTT data, as used in past studies within the CRSLA laboratory, underestimated erosion loss when compared with results using the S.C.S. factors.

A very definite problem arises with this successful combination of factors. The average slope values associated with soil series maps do not represent actual slope conditions. Single value slopes do not necessarily coincide with soil types. A range of slopes is more likely and that is why soil types are assigned a range of slopes within the soil series maps. The effect of this average slope value can be overestimation of high erosion areas. Plate 4 presents a much larger 'problem' area than that presented in the Caddo Creek Study in the 55 actual project sites (16 of which were hand calculated) within the CADMIL area. When the 55 project sites are overlaid onto the erosion map for method 6 (Plate 8) it can be seen that there are many areas of red showing erosion greater than 10 tons/acre/year that are not identified as project areas. There are two possibilities for this. Either the S.C.S. personnel were taking some additional factors into account when assigning sites, which would explain the sites within the 1 - 9 t/a/y range, or the use of slope values from series maps does not adequately represent the area. The latter is more plausible.

Perhaps a more legitimate use of slope values from soil series for the RUSLE is to perform calculations using both maximum and minimum values for the soils. It is far from a legitimate representation of true slope conditions in that it does not model the natural transition of slopes but rather produces blocks of slope of the same value. A more viable means of producing slope values is needed.

The problem with the DTT data appears to be that when the ERDAS SLOPE program calculates slope, values are truncated to integer values rather than rounded off. For a slope value of 1.8% ERDAS produces a grid with slope of 1%

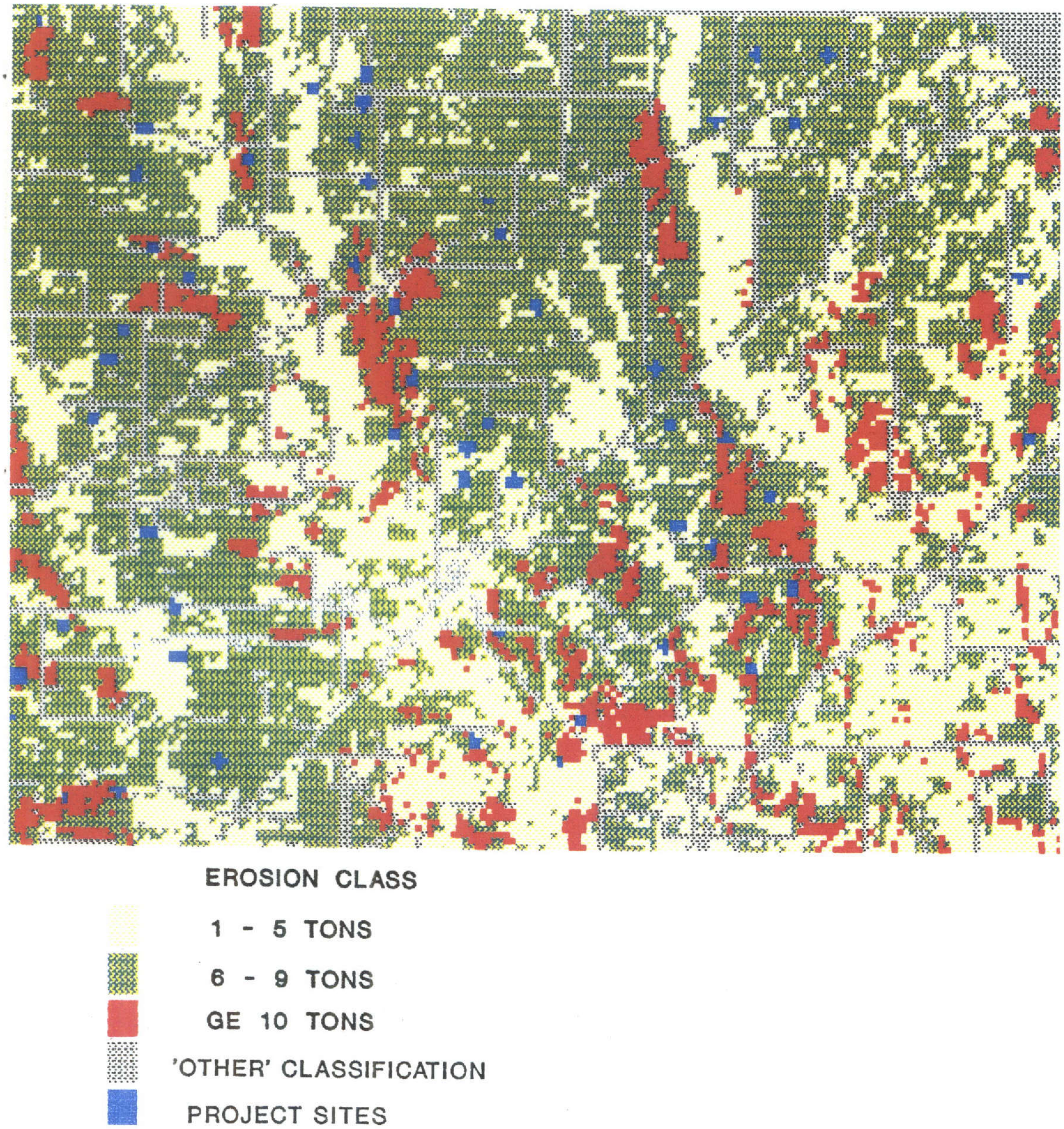

Plate 8

Caddo Creek Watershed Study Project Sites Overlaid on Erosion Estimates from Method 6 for CADMIL Area rather than 2%. A 2% LS value would be closer to the true value. As can be seen from the LS comparison above, the 1% makes for considerable difference in erosion potential. One possibility is to shift values up one percent. This would move 1% slope to 2% and would have the effect of increasing erosion estimates for the area. This would also shift slopes that are actually 1% to 2% which is not acceptable.

Alternate Slope Data

An alternative to using both DTT data and soil series maps is to use 1:24,000 quad sheets with the ARC/INFO GIS software. Within ARC/INFO is a package which takes point elevation data and produces an interpolated elevation surface in a grid format. Elevation points could be digitized in from a quad sheet using any technique allowing for a fairly equal distribution of points. Contour lines would be used for elevation reference. Since topo sheets have 10 ft. contour intervals they would produce higher resolution data than that obtained from DTT data at 50 ft. intervals. The elevation file would be converted into grid format, elevation interpolation conducted and then slope values calculated all within the TIN section of ARC/INFO. A strong feature of the slope program in ARC/INFO is that slope values are calculated with a floating decimal point of up to three places. These real number values allow for a more accurate assignation of LS values to the slope and eliminates the problem of truncated integer values as found in the ERDAS software.

Once the slope file had been produced and LS values assigned it could be exported into ERDAS and combined with the other factors for the RUSLE. The slope detail of the ARC/INFO file would be controlled by the number of points that were initially digitized. This program would produce a much more realistic representation of slope conditions and allow for more accurate erosion calculations.

Conclusion

In conclusion, the objective of this study was to determine whether or not satellite remote sensing applications in the USLE can produce erosion estimates equivalent to that produced in the field. The initial comparison was between the RUSLE, using K values from soil association maps and LS values obtained from DTT data, and actual estimations made in the field by S.C.S. personnel. The result of this comparison was that the RUSLE did not produce equivalent quantitative or locational results.

The next comparison was between the RUSLE, using K and LS values obtained from soil series maps, and field calculations. This comparison was much more successful with quantitative results generally within 2 tons/acre/year for project sites. The locational comparison was not as successful. Although many S.C.S. project sites were identified by the RUSLE method, there were many high erosion areas which were not identified as project sites.

By combining factors from the same data sources as those used in the S.C.S. study the outcome has to be the same as that from hand calculations with allowances for differences in slope lengths due to grid size. For this reason the conclusion of this study is that slope value is the critical factor within the RUSLE calculation and that by initially entering realistic slope data the RUSLE can produce both locational and quantitative results equivalent to those produced from field calculations. This is not to say that the RUSLE can replace field calculations. Although most factors can be mimicked, length of slope is site specific and effects the erosion outcome. Also, misclassification of the satellite image, such as identifying wheat as pastureland, would create an very large difference in erosion estimates.

The strength of the RUSLE then is as a screening tool. Whereas a helicopter was used to overfly the Caddo Creek Watershed so S.C.S. personnel could identify high erosion areas, the RUSLE could effectively screen the area before the conservationists go into the field. Most conservationists have a good sense of land use within their county and this knowledge, possibly coupled with crop reports generated by the Agriculture Stabilization and Conservation Service, would allow for rapid ground truthing of land use classification maps and verification of areas of high erosion.

CHAPTER VI

SUMMARY

The USLE has been used many times in conjunction with remote sensing to estimate potential soil loss within watersheds. In this study this process has been termed the RUSLE for remotely sensed USLE. The factors used in the equation remained the original six: R, K, L, S, C, and P. The hypothesis of this study was that the RUSLE was able to identify the same areas designated by the S.C.S. as having high erosion potential within the Caddo Creek watershed. Also, the RUSLE was hypothesized to be able to produce quantitative estimates of soil loss comparable to S.C.S. estimates.

A study was obtained from the U.S.D.A.-Soil Conservation Service which examined and calculated erosion estimates within the Caddo Creek watershed in North Central Texas. The purpose of the study was to implement conservation practices within areas determined to produce high erosion. In order to conduct the conservation project potential soil loss was calculated in the field using standard S.C.S. techniques and recorded on work-sheets.

For this thesis Thematic Mapper (TM) and Multispectral Scanner (MSS) images were obtained from Landsat satellite 4. These images were georectified and land uses classified by computer using ERDAS software. The resulting land use classification file was entered as one factor of six of the USLE in a GIS. The grid size chosen for the raster GIS files was 60m x 60m to approximate 200 ft. which was the average slope length for the 34 project sites recorded in the field for the Caddo Creek study.

Data input for the remaining RUSLE factors was made in several manners. Soil association and soil series obtained from Hunt and Collin County soil surveys were digitized into separate files and K and values assigned them. L and S factors were combined into LS and were assigned values according to either slope percentages obtained from DTT data using the ERDAS program 'Slope' or average slope values associated with soil series types as designated in the soil surveys.

Several combinations of data sources were used in the RUSLE and the results compared in order to determine which combination produced estimates comparable to those determined in the field by soil conservationists. In addition, slope values obtained from DTT data and soil series maps were compared to actual slope percentages recorded in the field using transit and stadia rod technique. This comparison showed that in seven sites examined the majority of the slope values from the soil series were closer to actual values than the slope percentages obtained from the DTT data.

The results of the study show that in the original use of the RUSLE in which LS values were obtained from DTT data that soil erosion estimates were not comparable with field estimates. When LS values were obtained from soil series maps the quantitative results were comparable within 16 conservation project sites in which field calculations were recorded. Although most project sites were located in areas shown to have high erosion by the RUSLE, there were numerous areas of estimated high erosion which were not identified as project sites by the S.C.S.

The conclusion of the study was that the RUSLE, with modifications for slope value input, was capable of identifying the same areas designated by the S.C.S. as having high erosion potential within the Caddo Creek watershed. Quantitative values for both the RUSLE and field calculations were often within 2 tons/acre/year for high erosion areas. The suggestion of this study is that the use of the RUSLE is an expedient method for initial screening of watersheds for identification of high erosion areas.

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