LAND USE AND SEDIMENTATION IN THE BASIN OF TUTTLE CREEK RESERVOIR

by

CHEN LI

B.S., Qinghua University, Beijing, 1983

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1988

Approved by:

Stephen L. Stover

Major Professor

ACKNOWLEDGMENTS

The author gratefully acknowledges the untiring assistance, comments, and guidance of his major professor, Dr. Stephen Stover. His guidance was invaluable, and his suggestions always came at a time that provided renewed stimulation and creative thinking.

To the rest of the faculty and graduate students in the Geography Department, the author also expresses his appreciation for additional suggestions and encouragement, and help on my English.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1 Introduction

Sedimentation is one of the important parameters of water quality and an indication of soil degrading. Sedimentation is a result of the processes of erosion, transport, and deposition of either weathered rock or soil. It is a part of the normal cycle that shapes the fluvially eroded landscapes of the earth. Rates of sedimentation are dependent on such variables as rock or soil type, topographic relief, climate, plant cover, and land use. Human activities which influence land-use have a marked effect on all processes in the cycle (Rausch 1984).

I. PURPOSE OF THE STUDY

The focus of this study is to determine to what extent human activity contributes to sedimentation beyond the natural erosional process in a region. This study attempts to find out the relative effect of the natural processes and compare it to human activities that contribute to the sedimentation in an area tributary to the Tuttle Creek Reservoir.

II. JUSTIFICATION

Humans are putting a great effort into erosion control, but at the same time their effect on the environment is still contributing significantly to sediment yield (Goldman 1986). The question is how much sedimentation is caused by natural occurrences from the physical cycle of the energy and materials exchange, as opposed to that accelerated by human economic and cultural activity? The answers to these questions should show us a clear picture of how much energy humans should put into controlling current sedimentation and how much unavoidable sedimentation they should consider acceptable. Actually, the unavoidable sedimentation should include two parts: that caused by natural processes and that caused by necessary human economic activity.

Specific and detailed study is essential for us to understand the mechanism of sedimentation. General information about the two aspects of sedimentation, natural processes and human acceleration of these processes, is required for us to manage the control effort.

III. METHOD OF APPROACH

A model of sedimentation based on land use or land cover patterns was prepared so that the relative influence of natural processes as compared to human activity could be shown. The model was based on statistical analysis of sediment loads in streams in various watersheds with differing proportions of land use or cover types. Current land use types primarily include cropping, grazing, forestry, recreation and residence (Li 1987).

IV. BACKGROUND OF STUDY SITE

Tuttle Creek Reservoir is located in the Big Blue River valley, a sub-basin of the Kansas River drainage system, in parts of Riley, Pottawatomie, and Marshall Counties, Kansas (Fig. 1). The dam which impounds the reservoir's water is located on the Blue River about six miles north of Manhattan. Creation of Tuttle Creek Reservoir was brought about during the time when the national government was implementing a general plan for flood control on the Mississippi River. Purposes of the reservoir include flood control, low-flow supplementation for the Kansas and the Big Blue Rivers, navigation supplementation for the Missouri River, water quality control, recreation, and fish and wildlife conservation (Department of the Army 1976).

The climate of the Tuttle Creek Basin is sub-humid.

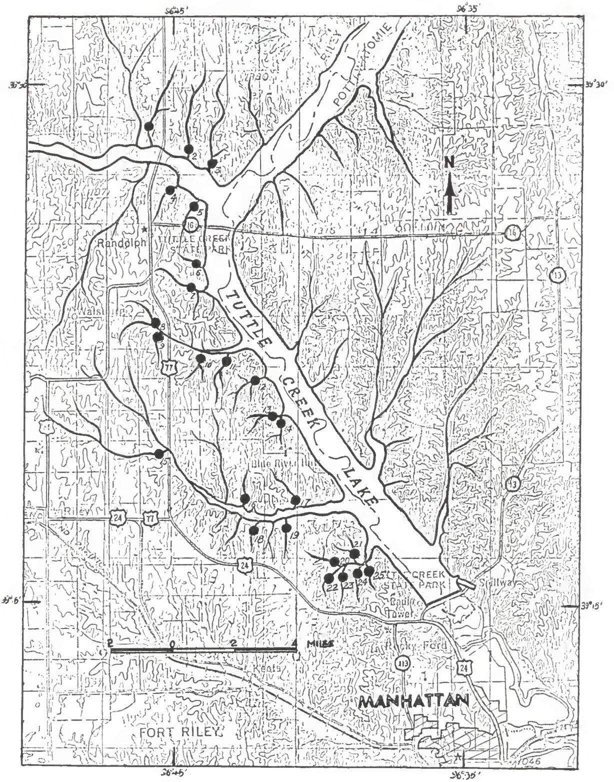

Fig. 1 Location of Study Area

The climate history includes periods of heavy rainfall during some years and severe drought in others without a fixed cyclical pattern. Average annual rainfall for the basin just above the dam is around thirty-three inches with June being the wettest month, with an average rainfall of four inches. Average annual snowfall for the basin is twenty-two inches (Department of the Army 1982).

The topography of the basin consists of stream channels with gently rolling uplands. Soils of the area are silty clay loams derived from loess, shale and limestone residuum (United States Department of Agriculture, Soil Conservation Service 1975).

The proposed study area in the basin comprises tributary watersheds that lie along the west side of the reservoir ten miles up stream from the dam. Data will be collected from twenty-five watersheds in this area. The sites were numbered in Fig. 1 from 1 to 25.

V. ORGANIZATION OF THE THESIS

Of the four following chapters, Chapter Two will have a brief review of the literature pertaining to Tuttle Creek Lake and related sedimentation and land use. Chapter Three will be a discussion of the methods used in classification of land use and related land cover, and data collection and analysis. The resulting analysis will be in Chapter Four, while Chapter Five will include a summary of the study, conclusions to be drawn from it, and suggestions for further research.

Chapter 2 Literature Review

I. LAND USE STUDIES

The geography of land use is a broad and general term which describes the spatial study of how land is used. It is the employment of land within spatial limits. Land use geography can vary widely in its content, generally including urban geography and agricultural geography, with many sub-divisions, such as recreational, transportation and industrial land use research.

Land-use-related research presented in the journal, Geographical Review, can be generally categorized into three main groups: historical, agricultural and urban. There is still geographical land use research, which could fit into more than one of these groups or classed into a miscellaneous group.

Trends of land use study have been reflected through the changing methods of studying land use geography. There has been a general shift associated with the shift in focus of study from a descriptive representation of land use patterns, through cartographic techniques and statistical description to a more sophisticated treatment of statistical data associated with increasing technology as well as the increasingly analytical and inquisitive nature of land use geography.

II. SEDIMENTATION STUDIES

Many studies have been done on sedimentation, but these have been done primarily from the hydrological perspective. That is, they deal mainly with the measurement and modelling of sedimentation as dependent on different single factors that affect its yield, such as soil, climate, slope and surface cover (Strahler 1983, 253-256).

One example of a recent sedimentation study, by G. J. Burch (1987, 19-42), showed the effects of clearing on the hydrology of small upland catchments in the central highlands of Victoria, Australia. It was evaluated on two experimental catchments: one vegetated by natural remnant eucalyptus forest and the other completely cleared of forest and maintained in grassland for over eighty years. The soil water status and soil hydraulic properties and infiltration were monitored over a period of three years, using different specific instruments.

Another sedimentation research project related to land use was conducted by Nani G. Bhowmik and M. Demissie (1984). They studied the Momence wetland in the central

United States. Studies on two major tributaries of the river basin--one draining a wetland system and the other draining a similar watershed with a slightly different geological setting--were utilized to determine the influence of wetlands on the flow and sediment load of the river.

There are several articles discussing the effects of forest on hydrology. M. O'R. Sternberg (1986) claims that on the basis of relatively short-term gauge observations and the perceptions of riverbank dwellers, that height and duration of Amazon floods are increasing. The paper discusses these assertions and the processes that might lead to the predicted trends. Two such processes are an increase in peak discharge and a decrease in channel cross-section. Both could be triggered or reinforced by human-induced changes in the environment. By altering the hydrologic relations of plant, soil and water, deforestation in the headwaters can enhance runoff. It can also increase the sediment load, which, if the carrying capacity of the river is exceeded, may be deposited in and aggrade the channel.

M. Hornung and M. D. Newson, 1986, indicated that afforestation in the British uplands can lead to changes in the hydrology, sediment load and chemistry of streams. These changes may affect water resource management costs, stream biota and the health of fisheries. Some of the changes can be related to specific phases of the forest management cycle, e.g., site preparation, fertilization and felling; modifications in management practice can limit their impact.

Considering agricultural land use, the study performed by A. Mumeka on the Kafue River of Zambia, 1986, showed that there was an increase in streamflow as a result of deforestation and subsistence agriculture. Hydrological observations were carried out on four small catchments under natural conditions and under agricultural use with accompanying deforestation. Simple linear regression analysis of both monthly and annual runoff from both the treated and undisturbed catchments were employed in the study.

III. MAIN WORKS DONE IN THE TUTTLE CREEK RESERVOIR AREA

Most studies in Tuttle Creek Reservoir area after the dam was built were mainly concentrated on management and on utility policy (Department of the Army Kansas City District, Corps of Engineers, Feb. 1976). A concern for biologists and biogeographers is turbidity, a common limnological feature of reservoirs, known for reducing phytoplankton and limiting primary production in the reservoirs. A study by Dufford (Dufford, 1970) was initiated to determine the agents correlative with turbidity in Tuttle Creek Reservoir, and to develop a predictive model for turbidity level.

A geographer, Gattorna, David (1969) in his thesis, dealt with water and land use. The study analyzed the reservoir's impact upon the land use in the area immediately surrounding the water.

In addition, there were studies done in this area on the discovery of cultural resources by archaeologist Miller (1982).

There has been no quantitative study about the influence of land use or land cover on the sedimentation in Tuttle Creek Reservoir Basin. The present study was designed to use a simple method to decide the land use influence on sedimentation by means of studying the sedimentation quantitatively.

Chapter 3 Statistical Approaches to the Study

There are many ways to find out how much sedimentation is produced by different land use patterns. One method is to measure sedimentation rates directly for a specific type of land use while eliminating the effects of all other land use types. This is a practical method for simulated tests in a laboratory. In an actual situation, different land uses are mixed within a small area adjacent to one another so that it is difficult to measure the specific sedimentation of land under one kind of utilization without other areas' influence. In order to get a general picture about the relationship between sedimentation and land use when the study area contains mixed land uses, the area is divided into smaller units of observation and regression analysis is employed. This technique will be used to compare the relative effect of natural processes and human activity on the level of sedimentation in an area adjacent to Tuttle Creek Reservoir.

I. MODEL ESTABLISHMENT

Regression analysis is a statistical method to discover interrelationships among several independent variables with a dependent variable (Taylor, 1977). It is impossible to get a true representation of the relationship among the variables in actual situations because the relationship between any two factors may be complex and confused by other random factors. The regression analysis is based on a large data set of more than two variables and reveals a general model of the relationship between variables. In this study of sedimentation and land use, the dependent variable will be the concentration of suspended sediment. Each unit of observation is the watershed of a small tributary (Fig. 1). The percentages of area devoted to each land use type within each of twenty-five watersheds are independent variables while the concentration of suspended sediment is a dependent variable. The form of the model is

$$Y = c + A_1 \times X_1 + A_2 \times X_2 + \ldots A_i \times X_i + \ldots A_n \times X_n .$$

where

Y -- dependent variable of suspended sediment concentration;

c -- a constant;

A_i-- regression coefficient of X_i, $i=1, 2, \ldots n$;

X_i-- independent variable of percentage of area, $i=1,2,\ldots n$.

The regression coefficient A_i indicates the slope of the relationship between Y and each X_i controlling for the effects of the other variables, and the correlation coefficients between Y and X_i indicate the strength of the relationship. These two parameters are the major indicators that delineate the influence of certain land uses or covers on sedimentation.

Sedimentation rates are dependent on such variables as rock or soil type, topographic slope and relief, climate, plant cover, and land use. A complete model of sedimentation should include all of these factors. Because of the similarity of the combined physical features of the watershed in this small study area, the influence from physical factors, such as climate, soil and topography, will be considered as constant. The regression model assumes that change in sedimentation is only dependent on the variables of different proportions of land use or cover. Concentration of suspended sediment is a unit of density, so it is not related to the area of the respective watersheds, but it is related to the percentage of land use or land cover type in each watershed. The independent variables of the land use pattern will be a percentage -- the area devoted to each type of land use or land cover in a watershed divided by the total area of that watershed.

Suppose

C_s -- the concentration of suspended sediment;

F -- the percentage of forest cover;

S -- the percentage of sparse woodland;

G -- the percentage of grassland (rangeland);

C -- the percentage of cropland;

R -- the percentage of residential land,

then, the regression model will be in the form of

$$C_s = c + A_f x F + A_s x S + A_g x G + A_c x C + A_r x R +- e$$

where

c is a constant;

A_f, A_s, A_g, A_c, A_r are regression coefficients;

e is the product of residual effects.

II. LAND USE CLASSIFICATION

Twenty-five watersheds with a total area of 38.74 square miles spreading within an area of one hundred square miles were selected as cases for this study. The choice of these twenty-five watersheds was based on the following principles: 1. typicality: the better watershed samples should be a mixture of different kinds of land use or cover; 2. randomness of site: the watershed samples should be spread randomly in the study area so they can serve as a good representation of the whole study area; 3. accessibility: it should be possible to collect mid-stream water samples near the lower end of each watershed; 4.

location: each involved stream should be reasonably close to a road or trail.

Selection of watersheds was aided by the use of a topographic map of 1:24,000 scale. Land use classification was based on airphoto interpretation and on field survey. The currently available airphoto of the study area was found in the U.S. Soil Conservation Service Office (SCS) of Riley County. It was in the form of a black and white print, 17" by 17", at a scale of 1:10,000, and dated 1984. The land use or cover map of the sample watersheds based on the field trip record and the airphoto was drawn in the SCS office. Some unknown land use conditions were surveyed later in the field. Tools used in the field survey included: (1) topographic maps at scales of 1:250,000 and 1:24,000, (2) compass and binoculars, (3) notebooks, (4) a copy of the bulletin, Soil Survey of Riley County and Part of Geary County, and (5) a vehicle. The field trip route was chosen on the topographic map by marking the points of the mouths of each watershed and having fewer stop points to view the watershed in the uplands as well as lowlands. The following were recorded on the field trip: (1) land cover, (2) land slope, (3) soil characteristics, (4) gully development, (5) residential conditions.

The categories finally chosen included both land use and land cover types: forest, sparse woods, grass (for

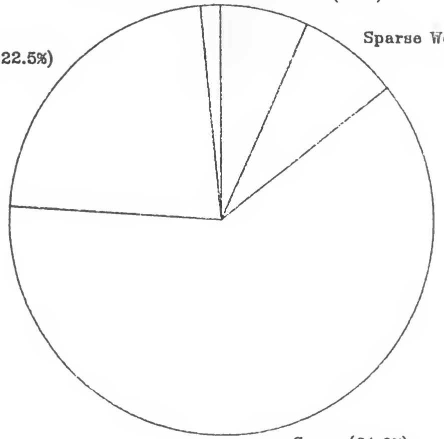

Fig.2

Proportion of Principal Types of

Land Use or Land Cover in the Study Area grazing), crops and residential. The categories resulted from laboratory study of maps and aerial photographs and from field study. The area of watersheds and the area devoted to each of these categories within watersheds were measured by microcomputer using the software Sigma Scan Measurement.

The studied watersheds range in area from 0.8 square miles to 3.8 square miles, and altitude varied from 1080 feet to 1370 feet above sea level. The hills were generally mesa-like with flat tops and steep slopes. The hydrographic net was dendritic in pattern. Shale and limestone made up the base rock. The percentages of land use or land cover types are as shown in Fig 2.

Following is a detailed description of each category of land use or land cover.

FOREST LAND

Forest land is characterized by thick tree growth, thirty trees per ten square meters, with thick grass growing in a layer of vegetation residues. No soil was bare. No disturbance was evident.

The study area as a whole was 6.76% forested. Individual watersheds within the study area had forest cover ranging from 0% to 24%. Most of the forest area was distributed on hillsides with slopes of seven to eighteen

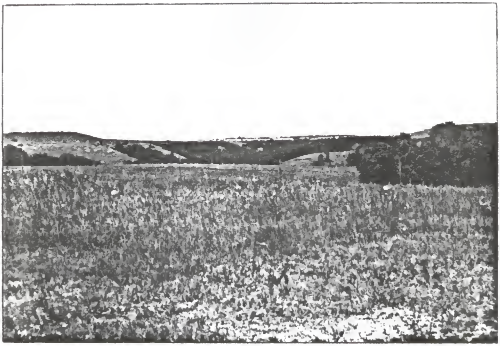

Fig. 3 Forest and Range Land

degrees. Soils mainly included Benfield-Florence (Bf) (Soil Conservation Service 1975). No erosion was noticed where the gullies were intensively covered by forest (Fig. 3).

SPARSE WOODLAND

Sparse woodland is grassland with individual trees scattered across it. Except for some grazing, sparse woodlands were free of human activity. It was an intermediate zone between forest land and range land or

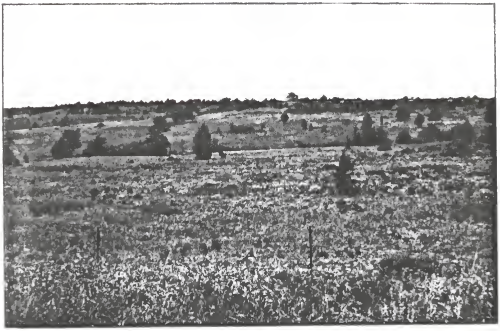

Fig.4 Sparse Woodland

crop land, with slopes about six to fifteen degrees. Some of the watersheds were lacking this type of land cover. Total area in this kind of cover was three square miles, 7.73 % of the combined area of all the watersheds in the study. The average area of land with sparse woods in each watershed was 0.25 square miles, 12.27 %. Soil on this land was mainly Clime-Sogn (Cs) and Benfield-Florence (Bf) (Soil Conservation Service, 1975). Stones reaching ten inches in diameter were scattered around (Fig. 4).

RANGE LAND

Both uplands and lowlands having a general slope of three to seven degrees might be used as range. There was a large area of this type of land use, a total of 24.1 square miles, which constituted 62.22 % of the total study area.

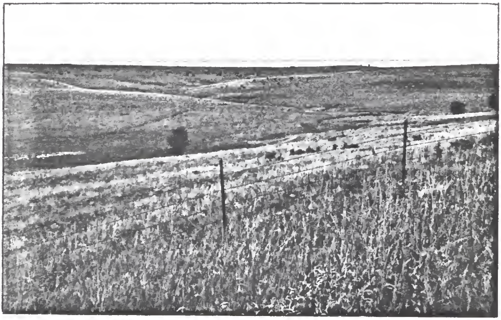

Fig. 5 Range Land

This land use type ranged from 36 % to 94 % of the area of the studied watersheds. The soil on the uplands was shallow, with a significant amount of gravel in it. Soil types were most often Dwight-Irwin (Dr, Dw), Wymore silty clay loam (Wn, Wo) and Clime-Sogn (Cs). Soil on the lowlands for the most part consisted of Alluvial land (Ad), Reading silt loam (Re) and Tully silty clay loam (Tu) (Soil Conservation Service, 1975). Few trees were found associated with this land use type, due to the shallow soil on the upland and the widespread practice of grass burning. A few small trees were noticed dead from grass burning (Fig. 3 and Fig. 5).

CROP LAND

Crop lands lay on the flat beds of the valleys with a gentle slope of less than four degrees. The land was

Fig. 6 Crop Land

usually planted with corn, wheat or sorghum. Total area in this land use category was 8.8 square miles, 22.76 % of the total study area, an average of 0.46 square miles or 25.6 % of the area of each watershed. The surface material

Fig. 7 Crop Land and Residential Land

included Reading silt loam (Rd) and Wymore silty clay loam (Wn and Wo) (Soil Conservation Service, 1975). Most of the crop land was bare of cover waiting for planting (Fig. 6 and Fig. 7).

RESIDENTIAL LAND

There were 90 households found on flat or slightly sloping sites in the study area with a total area of 0.6

square miles. Most of them were scattered farmhouses not in a residential community. The average area used by an individual household as a residential site was about 0.007

Fig. 8 Residential Land

square miles, with garden, implement storage area and drive-ways being considered. They occupied a small proportion of the studied area, about 1.55 % . The condition of the buildings and surroundings varied considerably; some were well maintained and others were not. Most of the driveways and roads were light duty (Fig. 7 and Fig. 8).

There were also small areas of recreational land found near the mouths of streams entering the reservoir. These were classified into the Sparse Woods category because they comprised such a small part of the study area and because they were similar to the sparsewood type of land cover.

Forest land will be assumed to be the land in its natural condition because of the relatively permanent vegetation cover; that is, human activity has had limited effect on it.

III. LAND USE AREA ANALYSIS

Land use mapping was done on a copy of a topographic map, scale 1:24,000, mainly by studying the 17" x 17" airphoto, scale 1:10,000. Some questionable areas were checked on the field survey. Each area of different land use or land cover was measured on a microcomputer by the software Sigma Measurement. The slope of certain areas was determined from the topographic map by calculating relief over distance.

Most of the land use types in the study area were easily recognized on the air photos and classified into the different land use categories of forest, sparse woods, range, crop, and residential land use. Forest land was distinguished by its dense crown of trees in a dark tone and rough texture. The range land was of a fairly smooth texture and a grey tone spreading into a larger area. Crop land, most of it in fields of regular shape, appeaared dark in tone. It was characterized by the tracks of plowing . Residential sites were typically light-toned and recognized by the houses associated with them. Usually there were shadows indicating the rectangular shape of the structures.

The percentage of each land use or land cover type was computed for each watershed. It should be noted that the suspended sediment concentration in a stream does not depend on the area of the watershed involved but on the ratios of the mixture of land use types, when the area of each watershed falls into a certain size range. Concentration of suspended sediment is determined by the water volume and solid materials in the water, so the same mixture of land use and land cover should produce the same value of concentration of suspended sediment, even if the areas differ in size.

IV. WATER SAMPLE DATA COLLECTION AND ANALYSIS

Suspended sediment is a good indicator of sedimentation, and concentration is a major property of suspended sediment. For these reasons concentration was chosen as the subject for the sedimentation and land use analysis.

Concentration of suspended sediment is a measurement variable of solid material in the studied water. The common unit for expressing suspended sediment concentration is milligrams (mg.), and it is computed as one thousand times the ratio of the dry weight of sediment in grams to the volume of water- sediment mixture in cubic centimeters: (Guy, 1969).

$$\text{Concentration (mg/l)} = \frac{\text{weight of sediment (milligrams)}}{\text{1,000 x volume of water-sediment mixture (cubic cm)}}$$

Water samples were collected on May 21, 1988 between 11am and 2pm. There had been a long dry spell before the four cm rain of that day. It rained for ten hours before it stopped about 2pm (from TV 13 forecast). There was a thunder storm which lasted thirty minutes before water sample collection was begun. Since there was a long period of rain before the collection, all run-offs in the watersheds were at an even condition to produce sediment. The three-hour period of sample-collecting took place close to the end of the rain; thus it is considered that the various samples were taken under equal conditions.

In each watershed water samples were taken from near the mouth of the stream, each of which was from one to two meters in width and twenty to thirty cm in depth with a flow speed of 0.5 m/second. Normally these stream channels are dry, having water only during and after rainfall. Tools used for sampling were a long stick with a cup fastened on the end and jars for storing the samples.

In order to make the sediment sample accurate, water samples were taken from two locations: middle of the stream, and one side of the stream. The volume of each water sample was about 1.5 liters. The concentration of suspended sediment was obtained by the evaporation method, which consists of allowing the sediment to settle to the bottom of the sample bottle, decanting the superincumbent liquid, washing the sediment into an evaporation beaker and drying it in an oven. The volume of sediment and water mixture is measured by scaled cup and the sediment weighed by electric scale.

The concentration was determined by the formula

$$c = \text{weight} / \text{volume} .$$

Chapter 4 Analysis of the Results

The sample size is twenty five. The original data are

Table 1. Suspended Sediment Concentration and Land Use / Land Cover

SITE No.	C_s (mg/l)	AREA (sq.mile)	F (%)	S (%)	G (%)	C (%)	R (%)
1	72	2.91	4.77	0.48	65.89	27.65	1.20
2	78	3.08	2.53	7.21	57.14	31.97	1.33
3	71	2.84	9.22	1.28	55.72	31.46	2.32
4	71	2.47	0.00	0.00	63.32	29.10	7.58
5	64	1.49	0.00	23.12	55.70	18.23	2.95
6	62	0.70	10.82	0.00	81.93	7.25	0.00
7	61	1.32	6.12	0.00	87.37	3.85	2.64
8	87	3.14	3.69	0.00	47.17	46.88	2.26
9	85	1.02	7.05	0.00	35.91	57.05	0.00
10	71	2.32	9.84	12.73	49.50	26.67	1.25
11	66	1.22	21.83	18.32	47.75	10.55	1.55
12	61	0.81	12.05	27.45	60.12	0.00	0.37
13	59	1.45	15.99	16.88	61.68	5.10	0.34
14	66	0.94	24.05	3.71	59.43	10.70	2.12
15	80	3.87	0.00	17.66	48.02	33.75	0.57
16	64	1.86	3.12	8.02	82.88	5.98	0.00
17	77	0.95	2.10	0.00	68.00	29.91	0.00
18	71	1.39	5.52	37.59	39.38	16.93	0.57
19	52	1.00	23.77	0.00	66.10	10.13	0.00
20	60	0.86	13.24	0.00	86.76	0.00	0.00
21	65	0.23	8.70	0.00	91.30	0.00	0.00
22	63	0.86	3.24	0.00	92.64	3.51	0.58
23	71	0.76	6.44	0.00	91.99	0.00	1.57
24	76	0.88	5.59	0.00	94.41	0.00	0.00
25	62	0.75	11.94	0.00	88.06	0.00	0.00

listed in Table 1. There

C_s -- Suspended sediment concentration;

F -- Forest land;

G -- Grass land;

C -- Crop land;

R -- Residential land.

The data were analyzed in the computer program, Statistics Analysis System (SAS). The following aspects were executed in computer: 1) correlation coefficients of the land use or land cover pattern; 2) correlation coefficient between suspended sediment concentration and the land use or land cover pattern; 3) regression model of suspended sediment concentration as dependent variable and percentage of area of forest land as independent variables; 4) regression model of suspended sediment concentration as dependent variable and percentage of area of each of all five kinds of land use or land cover (forest land, sparse woods land, range land, crop land and residential land) as independent variables. 5) the best fit model for dependent variable of suspended sediment concentration by the independent variables among percentage of area of five kinds of land use or land cover.

I. RELATIONSHIPS BETWEEN AREA OF DIFFERENT TYPES OF LAND

Correlation coefficients can be used to measure and determine the strength of a relationship between two variables. Values of correlation coefficients vary from -1.0 to +1.0, with extreme values representing either a perfect positive or negative relationship between the two variables. A value of 0.0 indicates the absence of a statistically significant relationship. The plus sign means there is a positive relationship between variables and the minus sign means there is a negative or inverse relationship between variables. For example, when the value of one variable increases while the other variable also increases then the relation is positive. However, if one increases while the other decreases, the relationship is negative.

Table 2 displays correlation coefficients between the proportion of area of five classified land uses within each watershed, three statistically significant values shown here: -0.741 between Crop and Range, -0.536 between Range and Sparse Wood, -0.368 between Crop and Forest.

The first column of the table shows the obviously stronger relationship of forest land use is with crop land by the value of -0.368 at a significance level of 0.05. It implies that a reduction of forest area was partially the result of bringing more area under cultivation.

The correlation coefficient between crop land and range land is the highest absolute value in the table, -0.741 at a significance level of 0.05. The strong negative relationship indicates that a certain amount of area in a watershed was shared between crop land and range land; that is, more land used for crop will mean less for range.

Table 2. Correlation Coefficients of Land Use / Cover

	F	S	G	C	R
F	1.00				
S	0.002	1.000			
G	-0.036	**-0.536**	1.000		
C	**-0.368**	-0.048	**-0.741**	1.000	
R	-0.253	-0.055	-0.196	0.265	1.000

The negative relationship between sparse woodland and range land, in the value -0.536 of correlation coefficient, can be explained by the fact that some range land results from sparse woodland when trees were removed from the sparse woodland.

At a significance level of 0.05, the hypothesis that the other correlation coefficients are different from zero is rejected. That is, they tend to be independent from each other among the areas of land use pattern beyond the relationships between forest land and crop land, crop land

and range land, and sparse woodland and range land.

II. RELATIONSHIPS BETWEEN SUSPENDED SEDIMENT CONCENTRATION AND LAND USE / LAND COVER

The relationships are clearly shown by the correlation coefficient values between concentration of suspended sediment and the percentage of area in different land use or land cover within a watershed (Table 3).

A general study of the signs in front of the values in the table of correlation coefficients shows that the concentration of suspended sediment was negatively associated with the percentage of land in forest, sparse woods and range land, and was positively associated with the percentage of

Table 3. Correlation Coefficients of Suspended Sediment Concentration and Land Use / Cover Ratio

	F	S	G	C	R
C_s	-0.540	-0.073	-0.455	0.783	0.121

land in crops and residential use. Further study shows that the correlation coefficients between the concentration of suspended sediment and sparse woodland, and residential land are not significantly different from zero at the significance level of 0.05. Therefore, sparsewood land and residential land are not indicators of suspended sediment concentration.

The correlation coefficient value between suspended sediment concentration and percentage of area in forest is -0.540. The correlation coefficient value between suspended sediment concentration and percentage of area in range land is -0.454. A higher percentage of area of forest land and a higher percentage of range land results in a lower production of sediment. There is a stronger relationship between suspended sediment concentration and the percentage of area in crop land, with a correlation coefficient value of 0.783. More area under cultivation means higher sedimentation. The suspended sediment concentration also bears a positive, but insignificant relationship to residential land, with a correlation coefficient of only 0.121.

III. LEAST SQUARES ANALYSIS OF FOREST LAND AS AN INDEPENDENT VARIABLE

When forest land was considered to be the only independent variable for concentration of suspended sediment, it implied that the other land use or land cover patterns -- sparse woods, range, crop and residential --

which were assumed to be affected by human activity, were considered to be one category -- human-activity-affected land. So the model of sediment with one independent variable, percentage of land in forest, will indicate the sediment effect influenced by two aspects: natural process and acceleration caused by human activity. The correlation coefficient of percentage of area in forest land and percentage of area in human activity affected land is 1.000, because the sum of them is a constant 10 %.

The least square regression model of concentration of suspended sediment which depends on the percentage of area in forest will be in the following form:

$$C_s = c_f + A_f \times F$$

where the

C_s --concentration of suspended sediment in mg/l

F -- percentage of area of forest land

c_f --constant in mg/l

A_f -- regression coefficient of F in mg/(l x %),

also will be in the form:

$$C_s = c_f + A_f \times (100\% - H)$$

$$= (c_f + A_f) - A_f \times H$$

$$= c_h + A_h \times H$$

with $c_h = c_f + A_f$

$A_h = -A_f$,

when the independent variable F was changed to H -- the

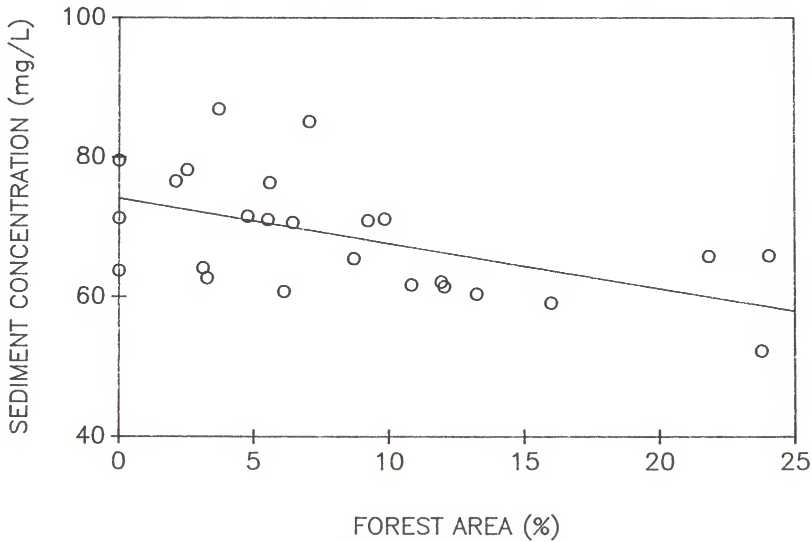

Fig. 9 Relationship of Forest Area and Sediment

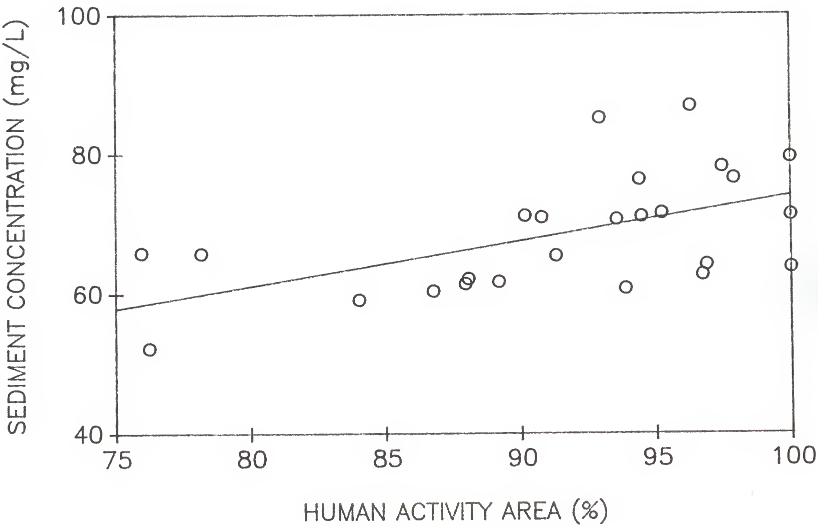

Fig. 10 Relationship of Human Activity Area and Sediment

percentage of the area affected by human activity in a watershed, was in the above formula

where the

c_h -- constant, equals to (cf + Af),

A_h -- regression coefficient of H.

It is obvious that the absolute values of Af and Ah are equal.

The calculated results for the model

$$C_s = c_f + A_f \times F$$

are

c_f = 74.63, with a standard error of 2.30,

A_f = -65.05, with a standard error of 21.11.

So the formula will be

$$C_s \text{ (mg/l)} = 74.63 - 65.05 \times F \text{ (\%)}$$

or

$$C_s \text{ (mg/l)} = 9.58 + 65.05 \times H \text{ (\%)}$$

with R-square value equaling 0.29. R square reflects the percentage variation of C_s that can be explained by the independent variable F or H. So this formula explains 29 % of change of C_s by F or H.

The scattergram of original data and the regression line of C_s and F are plotted in Fig. 9, and the scattered points of original data and the regression line of CS and H are plotted in Fig. 10. The two plots show a linear pattern of the points in the main range of data except for

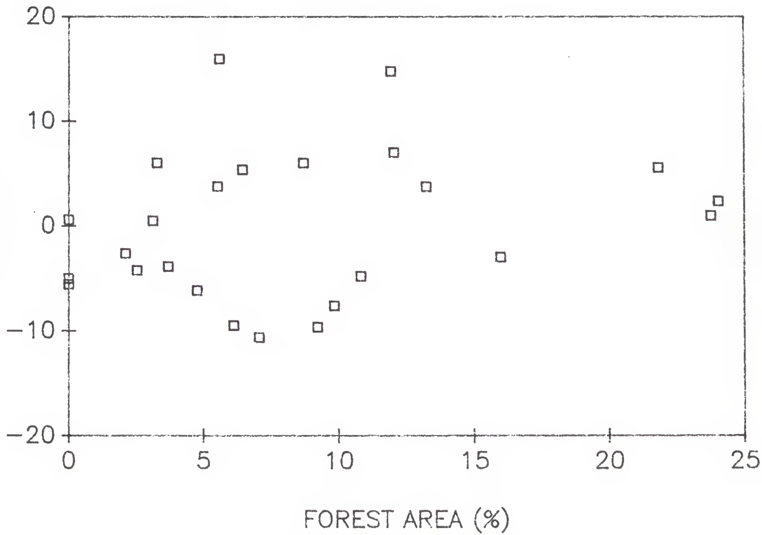

Fig. 11 Residual by Forest Area ($C_s = c_f + A_f F$)

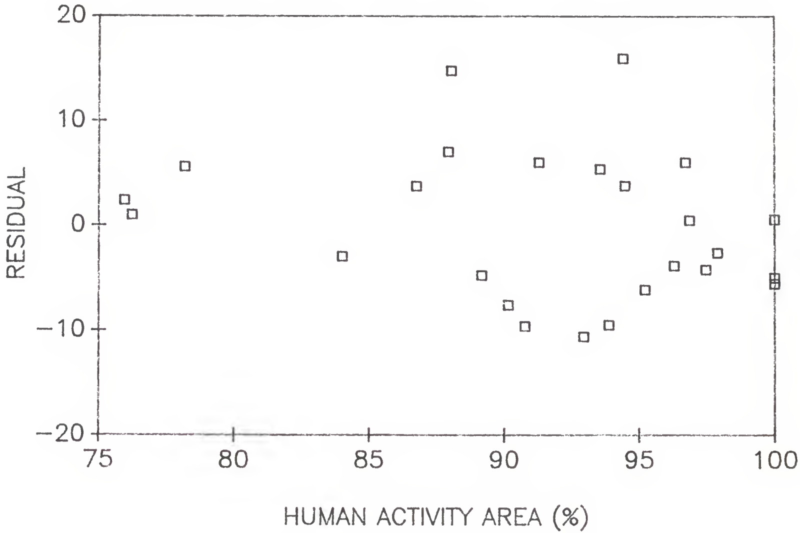

Fig. 12 Residual by Human Activity Area ($C_s = c_f + A_f F$)

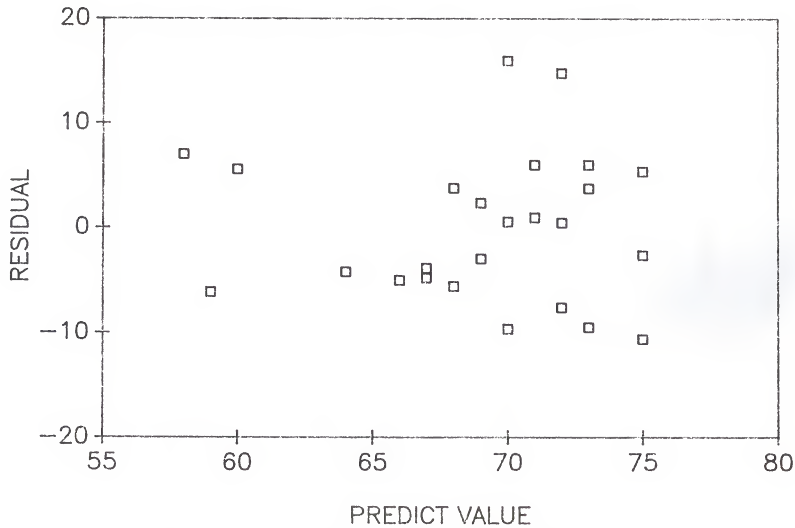

Fig. 13 Residual by Predicted Value of Sediment Concentration ($C_s = c_f + A_f F$)

large values of F or small values of H, where the slope becomes more gentle, and for small values of F or large values of H, where the slope becomes more steep. In any event the linear regression line might fit because the residual distributions of F, H and predicted value of C_s are random (Fig. 11, Fig. 12, Fig. 13).

Extreme values may be assigned to F or H. Under these conditions (100 % of F or 0 % of H) the watershed fell into the category of forest land and no human activity had affected the watershed. Conversely, under conditions where F is assumed to be 0 % or H is assumed to be 100 %, no part of a watershed was in the category of forest land or the entire area of watershed was affected by human activity with a mixture of sparse woods, range, crop and residential land. This results in

$$C_s \text{ (minimum)} = 10 \text{ milligram / liter} ,$$

with a standard error of 19

when

$$F = 100 \% ;$$

that is, if the surface of a watershed were entirely covered by forest, the mean value of concentration of suspended sediment production would be 10 milligrams;

$$C_s \text{ (maximum)} = 75 \text{ milligram / liter} ,$$

with a standard error of 2

when

$$H = 100\ \%\ ,$$

that is, if all the land in a watershed were affected by human activity, the mean value of concentration of suspended sediment production would be 75 milligrams / liter. In this region, in the current land mixture pattern, the rate of sediment production under human activity was seven times more than under natural condition.

The actual mean values of concentration of suspended sediment in the above two extreme cases should be not less than the predicted values of 10 mg/l and 75 mg/l. This can be explained both by statistics and by the actual situation. As mentioned before, in Fig. 7 and Fig. 8, slope becomes less steep for large values of F or small values of H, while the slope becomes more steep for small values of F or large values of H. Thus the linear regression line lies below the sample points around the extreme values of F or H. In turn, this will make the predicted values be smaller in the two extreme cases where F equals to 0 % or 100 % .

The important finding about sedimentation in the study area is that the mean suspended sediment concentration under natural conditions was not less than 10 (milligrams / liter). The least mean suspended sediment concentration which can be reached when human influence is involved could not be less than 10 (milligrams / liter).

The question of the extent to which human activity contributes to sedimentation beyond the natural erosional process can be estimated by the following formula

$$C_s \text{ (accelerated)} = C_s \text{ (actual)} - C_s \text{ (minimum)}$$

where the

C_s (accelerated) -- suspended sediment concentration accelerated by human activity

C_s (actual) -- suspended sediment concentration actually measured

C_s (minimum) -- suspended sediment concentration caused by natural occurrences, 10 mg/l here.

Also the rate of sedimentation accelerated by human activity, R (accelerated), can be calculated by the following formula

$$R \text{ (accelerated)} = C_s \text{ (accelerated)} / C_s \text{ (minimum)}.$$

In the study area with a mean value of suspended sediment concentration of 69 (m/l) the rate of sedimentation accelerated by human activity will be

$$R = (69 - 10) / 10$$
$$= 590 \%$$

with a standard error of 100% at a significance level of 0.05. That is, human activity in the study area increased sedimentation about 490% to 690% by a mean value of 590%.

The human accelerated rate of sedimentation in each

Table 4. Accelerated Rate of Sedimentation by Human Activity (Mean Value)

SITE No.	RATE (%)	SITE No.	RATE (%)	SITE No.	RATE (%)	SITE No.	RATE (%)
1	620	8	770	15	700	22	530
2	680	9	750	16	540	23	610
3	610	10	610	17	670	24	660
4	610	11	560	18	610	25	600
5	540	12	510	19	520		
6	520	13	490	20	500		
7	510	14	560	21	550		

sample watershed is listed in Table 4.

When the percentage of area in forest, F, and the percentage of area affected by human action, H, is known, it is possible to determine the ratio of sediment contributed by forest land:

$$C_s(\text{minimum}) \times F / [C_s(\text{maximum}) \times H + C_s(\text{minimum}) \times F]$$

and the ratio of sediment affected by human activity:

$$C_s(\text{maximum}) \times H / [C_s(\text{maximum}) \times H + C_s(\text{minimum}) \times F].$$

The suspended sediment concentration contributed by forest land or by land affected by human activity can be calculated by multiplying the above ratio by actual C_s.

In the study area with a mean value 6.8 % of the area of forest land and a mean value 69 (m/l) of suspended

Table 5. Suspended Sediment Concentration: Forest Land and Human-Activity-Affected Land (Mean Value)

SITE No.	SEDIMENT (mg/l) By F	By H	SITE No.	SEDIMENT (mg/l) By F	By H
1	0.5	71.5	14	2.7	63.3
2	0.3	78.7	15	0.0	80.0
3	0.9	70.1	16	0.3	64.7
4	0.0	72.0	17	0.2	76.8
5	0.0	64.0	18	0.6	71.4
6	1.0	61.0	19	2.1	50.9
7	0.5	60.5	20	1.2	59.8
8	0.4	86.6	21	0.8	65.2
9	0.9	85.1	22	0.3	62.7
10	1.0	71.0	23	0.6	70.4
11	2.4	63.6	24	0.6	76.4
12	1.1	60.9	25	1.1	61.9
13	1.5	58.5			

sediment concentration, the mean suspended sediment concentration contributed by forest land is

$$69 \times (10 \times 6.8\ \% / [75 \times (1 - 6.8\ \%) + 10 \times 6.8\ \%])$$

$= 0.7$ (m/l) ,

by human activity affected land is

$69 - 0.7 = 68.3$ (m/l).

The result shows that the major part of the sediment results from human-affected land, which occupies a high percentage of the area.

The result of the mean suspended sediment concentration contributed by forest land and by man-affected land for each watershed is listed in Table 5.

IV. REGRESSION ANALYSIS OF ALL LAND USE PATTERNS AS INDEPENDENT VARIABLE

As noted in Section I of this chapter, it is possible to determine relationships between some of the five parameters of percentage of area devoted to the different types of land use or land cover, because the sum of the five parameters has a constant value of 100 %. Although the model of suspended sediment concentration depends on the percentage of area in each of the five different land uses, it will not be a good model to explain the variation or predict the value of suspended sediment concentration. The parameters of regression coefficients of different land use will show the contributions to the sediment from each of the five land use or cover categories, at least in quality.

The regression model of suspended sediment concentration defined by the five independent variables -- the percentage of area in forest, sparse woods, range, crop and residential land -- will be in the following form:

$$C_s = c + (A_f \times F) + (A_s \times S) + (A_g \times G) + (A_c \times C) + (A_r \times R)$$

where the

C_s -- concentration of suspended sediment in mg/l

F, S, G, C, R --

percentage of area in the five categories of land use

c -- constant in mg/l

A_f, A_s, A_g, A_c, A_r --

regression coefficient of the five categories of land use in mg/(l x %).

The solution of the equation for this model is

$$\begin{aligned} C_s \text{ (mg/l)} = -15240 &+ 15269 \times F\ (\%) \\ &+ 15309 \times S\ (\%) \\ &+ 15308 \times G\ (\%) \\ &+ 15344 \times C\ (\%) \\ &+ 15234 \times R\ (\%)\ . \end{aligned}$$

with the R-square value equalling 0.72. All the perimeters of constant and regression correlation coefficients have large standard errors (more than 20000); that means the model can not be used to predict the variable of suspended sediment concentration. But from the test of the hypothesis of equality between each of the correlation coefficients of the five independent variables, the differing influence on sediment in each of land use types can be found.

The null hypotheses H_{io} are that no difference exists between every pair of two land use categories, and the research hypotheses H_{i1} are that there is a difference, that is

H_{10}: $A_f = A_s$ vs. H_{11}: $Af <> A_s$

H_{20}: $A_f = A_g$ vs. H_{21}: $A_f <> A_g$

H_{30}: $A_f = A_c$ vs. H_{31}: $A_f <> A_c$

H_{40}: $A_f = A_r$ vs. H_{41}: $A_f <> A_r$

H_{50}: $A_s = A_g$ vs. H_{51}: $A_s <> A_g$

H_{60}: $A_s = A_c$ vs. H_{61}: $A_s <> A_c$

H_{70}: $A_s = A_r$ vs. H_{71}: $A_s <> A_r$

H_{80}: $A_g = A_c$ vs. H_{81}: $A_g <> A_c$

H_{90}: $A_g = A_r$ vs. H_{91}: $A_g <> A_r$

H_{00}: $A_c = A_r$ vs. H_{01}: $A_c <> A_r$

Under the significance level of 0.05, the null hypotheses of H_{40}, H_{50}, H_{70}, H_{90} and H_{00} failed to be rejected, while reserved hypotheses, H_{11}, H_{21}, H_{31}, H_{61} and H_{81} are accepted. This means that there are no significant differences between the pairs of Af and A_r, A_s and A_g, A_s and A_r, A_g and A_r, A_c and A_r. We can be 95 % confident that there are significant differences between the pairs of A_f and A_s, A_f and A_g, A_f and A_c, A_s and A_c, A_g and A_c.

A comparing of values of correlation coefficients for the five independent variables reveals that the concentration of suspended sediment produced by forest land was significantly smaller than that produced by sparse wood, range and crop land. The concentration of suspended sediment produced by crop land was significantly larger than that produced by forest, sparsewood and rangeland. The concentration of suspended sediment produced by sparsewood land as compared to range land is not significantly different. The regression coefficient of percentage of area in residential land was not significantly different from any of the others; this can be explained by the smaller correlation coefficient between the concentration of suspended sediment and the percentage of the area in residential land.

V. THE BEST FIT REGRESSION MODEL OF SEDIMENT CONCENTRATION

How well do the independent variables explain sediment concentration in a linear form? This can be explained by multiple regression, attempting to predict and explain the variation of a single dependent variable Y, from a number of independent variables X; and take the form of the equation:

$$Y = c + b_1 \times X_1 + b_2 \times X_2 + \ldots + bi \times X_i$$

Where c is constant

b_i is regression coefficients

X_i is independent variables

In this study, the Y is the suspended sediment concentration, and the X_i ($i = 1$ to 5) refers to the five kinds of land use or land cover that influence the sediment. X_6 refers to the area of each watershed. If the size of the sampled watershed influenced the sediment concentration, it would show in the regression formula. After the c and b_i are decided, we will determine the linear relationship between dependent variable and independent variables and also the strength of that relationship.

The stepwise regression technique of multiple correlation and regression analysis is employed to deal with this problem. Instead of calibrating a single regression equation using all independent variables, this approach starts with a bivariate equation and proceeds by adding one variable at a time until the complete equation is finally completed. The order in which variables X_i enter the regression sequence is not arbitrary but depends on their contribution to an explanation of the remaining variance in the dependent variable Y. Thus, for the bivariate equation, we start with the independent variable that has the highest correlation with the dependent variable. The second variable to be added is that which has the highest partial correlation coefficient, r, with the dependent variable when the initial independent variable is controlled for. This process is repeated by selecting the independent variable with the highest partial correlation coefficient, r, when the independent variables already considered are allowed for. Actually, the r square indicates the percentage variation of Y involved in the variable. And at the same time the multiple correlation coefficient, R (the strength of relationship between the dependent variable and the independent variables that entered), is shown. R square means the total explanation for the variation of Y by the entered X_1, X_2, ...X_i.

The following are the regression results calculated by computer on the SAS program.

Step 1, independent variable C entered: the equation is given by

$$CS = 62 + 41 \times C$$

with an R value of 0.783.

The total explanation of suspended sediment concentration by the percentage of area of crop land is 61.4 % now.

Step 2, independent variable F entered: the equation is given by

$$C_S = 66 - 35 \times F + 35 \times C$$

with an R value of 0.828.

The total explanation of suspended sediment concentration by adding the percentage of area of forest use land is increased to 68.7 % now.

Step 3, independent variable R entered: the equation is given by

$$C_S = 67 - (38 \times F) + (37 \times C) - (75 \times R)$$

with an R value of 0.840.

The total explanation of suspended sediment concentration by adding the percentage of area of forest land is increased to 70.6 %.

The two remaining independent variables, percentage of sparse woodland and percentage of range land, were not entered into the model because they did not meet the 0.5 significance level. Considering the previous study of residential land use, that R did not correlate with C_S, and its distribution to the variation of CS, only increasing 1.9 % by its entry, the variable of R is eliminated. Then the equation should be on the Step 2,

$$C_s = c - A_f \times F + A_c \times C$$

where

C_s -- concentration of suspended sediment in mg/l

F -- percentage of area of forest land

C -- percentage of area of crop land

c -- constant in mg/l

A_f -- regression coefficient of F in mg/(l x %).

A_c -- regression coefficient of C in mg/(l x %).

and

c = 66 mg/l, with a standard error of 2,

A_f = 35 mg/(l x %), with a standard error of 15,

A_c = 35 mg/(l x %), with a standard error of 7.

so the model is

$$C_s(\text{mg/l}) = 66(\text{mg/l}) + \\ - 35(\text{mg/(l} \times \%)) \times F + 35(\text{mg/(l} \times \%)) \times C$$

The relationships between sediment concentration and forest land and between sediment concentration and crop land are shown separately in Fig. 9 and Fig. 14.

That all three plots of residuals (suspended sediment concentration predicted values--C_s, percentage of area of forest land--F and percentage of area of crop land--C) (Fig. 15, 16, 17), show that the distribution of the residual of each variable is random; that is , the data are unbiased; the relationship between the dependence and each independence is linear. By the standard error +-1, there

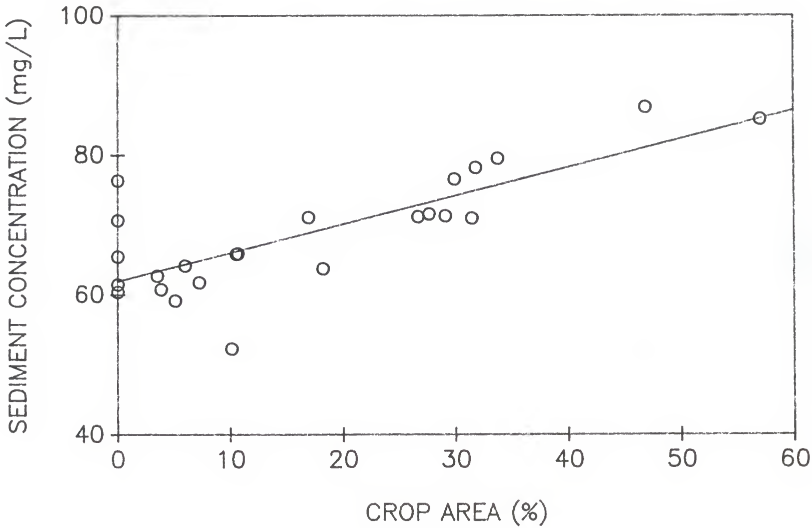

Fig. 14 Relationship of Crop Land Area and Sediment

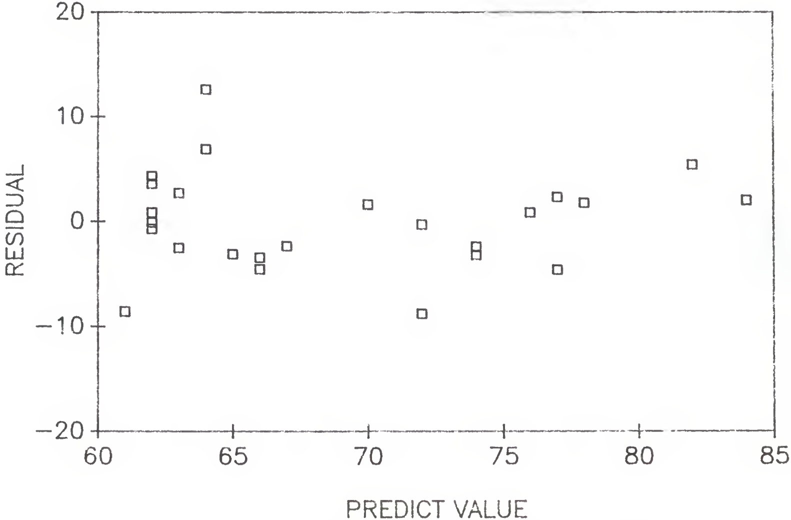

Fig. 15 Residual by Predicted Value of Sediment Concentration ($C_s = c + A_f F + A_c C$)

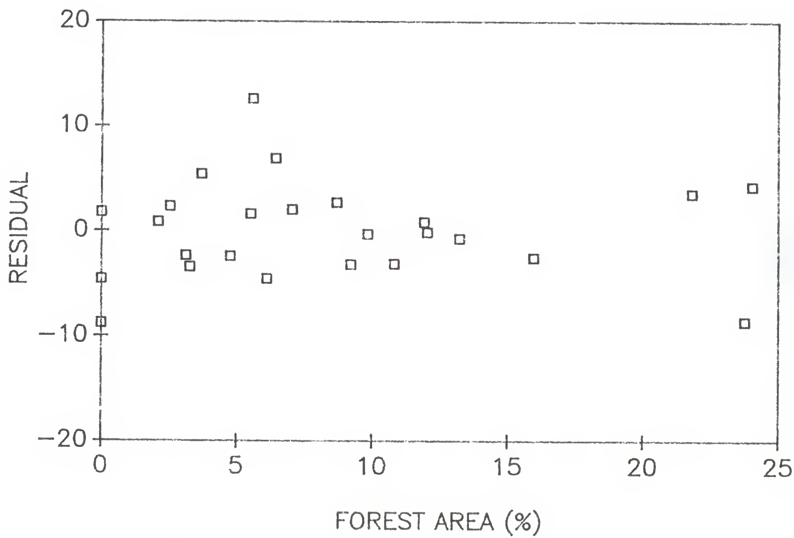

Fig. 16 Residual by Forest Area ($C_s = c + A_f F + A_c C$)

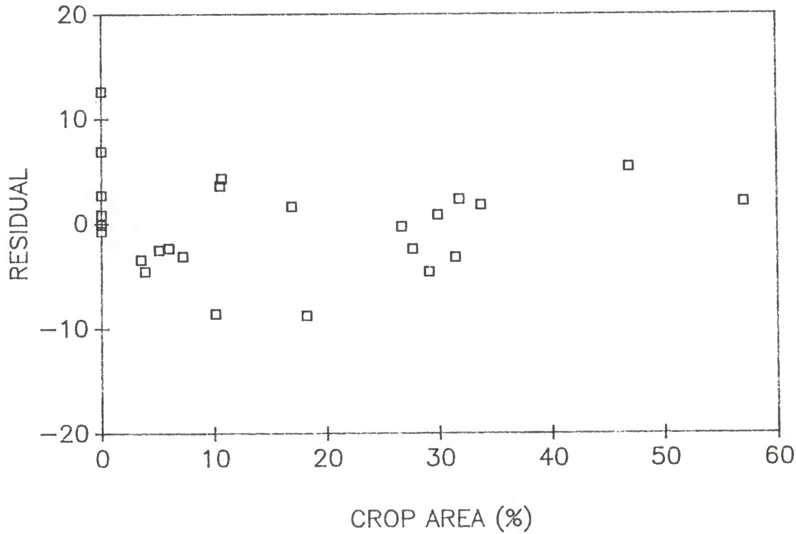

Fig. 17 Residual by Crop Land Area ($C_s = A_f F + A_c C$)

are two samples underpredicted, four samples overpredicted by the equation, and nineteen (i.e. 76%) of the samples that do fit the equation. With the R square value of 0.687, the two independent variables of percentage of area in forest land and percentage of area in crop land explain 68.7% of the suspended sediment concentration. It is evident that the equation is quite significant.

Chapter 5 Summary and Suggestions

This study, done in a small part of the Tuttle Creek Lake basin, can be considered as a simple test of a method that could be modified and used to study larger areas in a more complex condition.

I. SUMMARY OF THE STUDY

All the inferences achieved in Chapter Four are based on two assumptions: 1. Only land use or land cover types in five categories: forest land, sparse woods, range land, crop land and residential land, are considered as independent variables in the statistical analysis. Other phenomena, such as climate, soil and topography, are considered as constant. This makes the regression model only dependent on five land use or land cover types; other factors were assumed to be in the same conditions as constants in statistical analysis; 2. The percentages of area in the five land use or land cover types in each watershed were used as the unit of independent variables, the absolute size of each watershed was assumed to have no influence on the suspended sediment concentration.

The statistics in Chapter Four indicate that the models used for data analysis fit the study's purpose well in a general aspect; that is, the two basic assumptions can be believed to be tenable in this study area.

More work can be done to make the inferences more accurate, one is to check the two external values of C_s(min) and C_s(max) -- suspended sediment concentrations when all the land was in the forest (C_s(min)) and when all the land was affected by human activity (C_s(max)). This can be done by a simulations test in certain small areas for the C_s(min) and by measurement of more samples in some watersheds without forest cover for C_s(max).

Originally, more watershed samples were expected to be taken and the resulting data be put into the regression models to make the regression analysis more powerful. The sample population should have been more than 30, not, as in this study, only 25. The number was reduced because of the water sample collection time during the raining period and by the limited availability of transportation.

The assumption of the same physical conditions beyond land cover in the study area was based on a realistic land study. The assumption of neglective influence by watershed size but rather by proportion of different land uses or land covers on suspended sediment concentration was made subjectively. It was tested during the procedure by regression analysis. The treatment analysis in regression can be employed to determine to what extent the size of a study area and size of each sample watershed will influence the suspended sediment concentration. This method can also be used in large area analysis of sedimentation influenced by land use pattern by putting other influencing factors beyond land use pattern into a different treatment group.

II. CONCLUSION

Based on the analysis set forth in the preceding chapter, several conclusions can be reached for this study area:

1. The suspended sediment concentration had a strong significant relationship
   - -- positively with the percentage of area of crop land;
   - -- negatively with the percentage of area of forest land and range land.
2. The least suspended sediment concentration would be
   - -- 10 milligrams per liter, if all the land were in forest;
   - -- 75 milligrams per liter, if all the land were affected by human activity.

In the study area, the sedimentation derived from land affected by human activity in the current mixture of land use was approximately seven times more than that from land under natural vegetation cover, the forest land. The human activity in this region increased suspended sediment concentration by 590 % .

3. Suspended sediment concentration from a given size of watershed is significantly

-- smaller, when produced by forest land than the other kinds of land use or cover;

-- larger, when produced by crop land than by any other kind of land use or cover.

4. The best fit multiple regression model for suspended sediment concentration in this study area is

-- C_s(mg/l) = 66(mg/l) +

- 35[mg/(l x %)] x F + 35[mg/(l x %)] x C

where

C_s -- suspended sediment concentration;

F -- percentage of area of forest land;

C -- percentage of area of crop land.

III. SUGGESTIONS FOR FURTHER RESEARCH

Where a large area of a large river basin is under study to determine the relative effect of natural processes as compared to human activity that contributed to sedimentation, there would be fewer similarities in physical conditions as well as land use pattern. As a result, factors in addition to land use pattern would influence the sedimentation.

The samples can mainly be determined according to the set of hydrometric stations along the river. Each of the sample regions is the area where the run-off empties into the river section between two of the hydrometric stations in sequence. If the sample population is not big enough, or the size of the sample is much larger than the general range of samples, or if some physical condition changes greatly in a section of the river between two hydrometric stations, sites for sediment collection can be inserted at the proper points between hydrometric stations to rearrange the samples.

In the regression analysis model more independent variables, such as the strength of precipitation, evaporation, temperature, soil characteristics and topography, should be considered beyond the land use pattern. These variables could then be sorted out by the method of Treatment Analysis of regression so that the influence of land use patterns on the sediment could be compared. In this way a better understanding of the relationship between sedimentation and land use could be achieved.

BIBLIOGRAPHY

Allen, John R.L., 1977. Physical Processes of Sedimentation. George Allen and Unwin Ltd, London

Berry, Michael Wayne, 1981. Modeling Reduced Water Yields into Webster Reservoir Due to Changing Land Use Practices. Kansas State University Master's Thesis

Bhavsar, P.D., 1984. Review of Remote Sensing Applications in Hydrology and Water Resources Management in India. Remote Sensing from Satellites, New York, pp. 193-200.

Bhowmik, Nani G. and Demissie, M., 1984. Momence Wetland: Influence on Sediment and Water. Sediments and Water Interactions, Edited by peter G. Sly, 1986, Springer-Verlag New York.

Burch, G. J., 1987. Comparative Hydrological Behaviour of Forest and Cleared Catchment in Southeastern Australia. Journal of Hydrology 90(1-2), 1987. pp.19-42.

Colwell, Robert N., 1983. Manual of Remote Sensing. The Sheridan Press, US, pp. 1531-1540.

Curran, P.J., 1987. Remote Sensing Methodologies and Geography. International Journal of Remote Sensing, Vol. 8, No. 9, 1987, pp. 1255-1275.

Department of the Army, Kansas City District, Corps of Engineers, 1972. Tuttle Creek Lake Water Quality.

Department of the Army, Kansas City District, Corps of Engineers, 1976. Final Environmental Statement Operation and Maintenance Tuttle Creek Lake, Kansas.

Department of the Army, Kansas City District, Corps of Engineers, 1979. Tuttle Creek Lake Sediment Ranges Location & Vicinity.

Department of the Army, Kansas City District, Corps of Engineers, 1982. Project Memorandum for Tuttle Creek Reservoir, p. 116.

Duckson, D.W. 1984. Water-Quality Monitoring and Specious data: the Example of Georges Creek, Maryland. Professional Geographer, Vol.36, No. 4, 1984, pp. 473-478.

Dufford, D. W., 1970. Analysis of The Causative Agents of Turbidity in a Great Plains Reservoir. Kansas State University Master's Thesis.

Gattorna, David Bart, 1969. Some Land Use Impacts in a Portion of the Immediate Area of Tuttle Creek Reservoir. master's Thesis, Kasnsas State University.

Goldman, Steven J., 1986. Erosion and Sediment Control Handbook. McGraw-Hill Book Company, New York.

Guy, Harold P., 1969. Laboratory Theory and Methods for Sediment Analysis. United States Government Printing Office, Washington.

Hornung, M. and Newson, M. D., 1985. Upland Afforestation: Influences on Stream Hydrology and Chemistry. Soil Use & Management, 2(2), 1986, pp. 61-65.

Johnson, Thomas C., 1984. Effects of Bottom Currents and Fish on Sedimentation in a Deep-Water, Lacustrine Environment. Geological Society of America Bulletin, Vol. 95, 1984, pp. 1425-1436.

Li, Chen, 1987. Land Use Analysis for Sedimentation Study. Geographic Field Research Techniques, Project in Curriculum "Field Trip Methods".

Miller, Patricia, 1982. An Intensive Cultural Resources Survey at Tuttle Creek Lake Pottowatomie and Riley Counties. Soil Systems, Inc. Earth Systems Division Overland Park, Kansas.

Mumeka, A., 1985. Effect of Deforestation and Subsistence Agriculture of Runoff of the Kafue River Headwaters, Zambia. Hydrological Sciences Journal, 31(4), 1986, pp. 543-554.

Nellis, M. Duane, 1985. Remote Sensing Techniques for Identifying Regional Agrohydrologic Parameters. Applied Geography Conferences, Vol. 8, 1985, pp. 117-124.

Rausch, D.L., 1984. Measuring and Prediction Soil Erosion. Erosion and Sediment Yield, University

Press, Cambridge, Great Britain, p. 1.

Rodda, John C., 1976. Facts of Hydrology, John Wiley and Sons, London.

Scarpace, F. L., 1980. Landsat Analysis of Lake Quality. Photogrammetric Engineering and Remote Sensing, Vol. 45, No. 5, 1980, pp. 623-633.

Schwartz, Joseph M., 1971. Sediment Characteristics and Distribution in Tuttle Creek Reservoir, Kansas. Transactions of the Kansas Academy of Science, Vol.74, No. 1, 1971, pp. 59-66.

Sternberg, M. O'R., 1986. Aggravation of floods in the Amazon River as a consequence of deforestation?. Geografiska Annaler, Series A, 69A(1), 1987, pp. 201-219.

Strahler, Arthur N., 1983. Modern Physical Geography. John Wiley and Sons, New York, pp. 253-256.

Taylor, Peter J., 1977. Quantitative Methods in Geography, Houghton Mifflin Company Boston.

Troendle, C. A., and King, R. M., 1985. The effect of partial and clear cutting on streamflow at Deadhorse Creek, Colorado. Journal of Hydrology, 90(1-2), 1987, pp. 145-157.

United States Department of Agriculture Soil Conservation Service, 1975. Soil Survey of Riley County and Part of Geary County, Kansas, Washington D.C..

LAND USE AND SEDIMENTATION IN THE BASIN OF TUTTLE CREEK RESERVOIR

by

CHEN LI

B.S., Qinghua University, Beijing, 1983

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1988

ABSTRACT

This study attempts to compare the relative effects of natural processes with those of human activities on the sedimentation of Tuttle Creek Reservoir, Kansas. Using the statistical analysis method, several models of sediment concentration based on different independent variables of land use or cover are analyzed. The results show that the suspended sediment concentration was increased by a mean value of 590 % by the human activity in this region. Also, the best fit multiple regression model for suspended sediment concentration was obtained, based on the independent variables of forest and cropland use.