TIMBER HARVEST AND SITE PREPARATION IMPACTS ON EROSION AND SEDIMENT AND NUTRIENTS YIELDS FROM FORESTED WATERSHEDS IN CLAYTON OKLAHOMA

By

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CLAYTON OKLAHOMA

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CHAPTER I

INTRODUCTION

Throughout history the forest has provided the human race with many essential needs. The vital commodities have included food, fuel, materials for shelter and tools, and more recently, the raw materials for many industrial products, such as paper and chemicals. Rapid population growth and the industrial revolution of 17th century resulted in scarcity of forest resources in some parts of world. Because the possibilities for expansion of the forest land base are quite limited in most countries, the increasing demands for timber generally have been met by some type of intensified forest land management. The primary objective of most management schemes has been increased production of lumber, pulp and various wood products. In addition, forests are increasingly relied upon to provide other amenities, such as recreation, quality of environment and protection of watersheds.

The intensification of forestry often involves a decrease in rotation length and the adoption of clear cutting and mechanical site preparations. All these operations create conditions conducive to soil erosion and nutrient removal, which can have adverse effects on site productivity and biological quality of water downstream. Dissolved nutrients, sediment and particulate matter may create accelerated eutrophication downstream. Eutrophication decreases the aesthetic value of water bodies, degrades water quality, increases the cost for use as water supply and decreases the life span of reservoirs. In the state of Oklahoma, there exists a great deal of concern about the negative effects of timber harvesting and site preparation on water quality and the productive potential of forest lands.

Some work on sediment export and stormflow as a result of silvicultural activities has been conducted and reported by Miller (1984), Miller, Beasley and Lawson (1988) and Heh (1982). On undisturbed nutrient status Lawrence (1985) conducted a study in southeastern of Oklahoma, but none of the work has been reported on nutrient dynamics of disturbed ecosystems. This study will provide information regarding the effects of harvesting and site preparation on sediment and nutrient status. The specific objectives of the study were to determine the effects of timber harvest and site preparation on:

1. Annual nitrate-nitrogen loads.
2. Annual total-phosphorus loads.
3. Annual sediment loads.

CHAPTER II

REVIEW OF LITERATURE

A unique characteristic of most forest ecosystems is the development of a distinct forest floor resulting from the periodic return through litterfall of leaves, branches, bark and fruit and sometimes entire trees.

Forests, with a heavy ground cover of organic litter are the most effective system for protecting soil from erosion and maintaining the soil's productive potential. When forest vegetation and ground cover is disturbed, the soil is exposed to the environment. As a result surface soil hardly resists the erosive power of the environment (Pritchett, 1979).

A number of studies, designed to evaluate the impacts of various combinations of silvicultural activities on the soil and water have been reported.

Erosion and Sediment Yield

The process of soil erosion consists of three phases: (1) detachment of soil particles; (2) transportation of soil particles; and (3) deposition of soil particles (Anderson, Hoover and Rienhart, 1976; Hewlett, 1982). Factors affecting erosional processes are soil characteristics, such as soil texture, structure, rainfall intensity and duration, percolation and infiltration rate, topography and vegetative cover (Brady, 1974; Pritchett and Fisher, 1987).

Forest cover strongly influences the rate of soil erosion and influxes of erosional products into streams (Anderson, Hoover and Reinhart, 1976). A review of literature on sediment production from undisturbed forest in the southern U.S has indicated a range of sediment yields from trace level to 0.32 tons per acre per year (Yoho, 1980).

Many investigators have reported that forest harvest and related operations have the potential to degrade the water quality (USDA, 1977). However, its very difficult to separate the effects of these activities one from another. Fredriksen (1970) conducted a study on a clearcut watershed over a period of three years that used a skyline logging system. Sediment concentrations were modestly increased during logging.

Logging and site preparation operations increase the potential for sediment production by disturbing the forest vegetative cover and mineral soil. The exposed mineral soil under the impact of high intensity rain and low infiltration rates increases the potential of surface runoff (Edward and Larson, 1964). Removal of vegetation and litter also reduces the resistance of flowing water, with the result the flowing water gains more velocity and, in return, the carrying capacity of flowing water increases (Douglas, 1975).

In southwestern Arkansas, the effects of mechanical and chemical site preparation were compared to no treatment on nine experimental watersheds having 50% loblly pine and 50% mixed hardwood cover types (Beasley, Granillo and Zillmer 1986). Mean annual sediment losses on the mechanically prepared site was significantly higher than those from either the chemically prepared or undisturbed watersheds (Table 1) during the first post-treatment year. Beasley and Granillo (1985) treated 3 watersheds in the Gulf coastal plain of southeastern Arkansas in a variety of ways; 1) clearcutting followed by shearing, windrowing, burning and replanting; 2) selective harvesting; and 3) undisturbed. They reported that losses from the clearcut watershed averaged 265 and 63 kg/ha for the first and second postreatment year but in third year the treatment effect was not statistically significant.

Blackburn, Dehaven and Knight (1982) monitored nine small watersheds in East Texas to determine sediment losses following; 1. clearcutting, shearing, windrowing and burning; 2. clearcutting, roller chopping and burning and 3. undisturbed. They reported that sediment losses were significantly greater from the sheared watersheds (2201 kg/ha) than from chopped watersheds (13 kg/ha) or the control watersheds (3 kg/ha).

Sediment losses due to clearcut/rip and clearcut treatments and no treatment were measured on 3 small watershed in southeastern Oklahoma (Heh, 1982). Average sediment yields from the clear-cut and ripped watershed was 496 kg/ha, 809 kg/ha from the clear-cut and 35 kg/ha from undisturbed (control) watershed. Hewlett (1978) monitored two watersheds in Georgia to measure the effects of forest harvesting and regeneration on water quality. The intent was to find out the extent to which hydrological and mineral cycles are altered by normal forest practices. He reported that total mass export was 900 kg/ha/yr including road and channel damage. Due to silvicultural practices alone sediment loss was 84 kg/ha/yr.

Sediment losses due to clearcut harvest and site preparation that included crushing the residual material, burning, and contour ripping on three pair of small watersheds were measured in the Ouachita mountains of southeastern Oklahoma (Miller, 1984). First year sediment losses following treatment averaged 282 and 36 Kg/ha from the treated and untreated watersheds respectively. Treatment differences were significant the second and third , but not the fourth, year following treatment. Douglass, Cox and Augspurger[2] (1985) conducted a study in the South Carolina piedmont over a period of three years following clearcutting. Clearcut to control sediment yields were 151:20, 23:3, and 49:9 kg/ha the first, second and third year following harvest, respectively.

The loss of sediment decreases with the establishment of vegetation (Table 1). The vegetative cover affects it in two ways. First, by reducing the impact of rain drops, the plants protects the soil against splash erosion, which is a significant factor in the detachment of soil particles. Second, plants and organic residue on the soil surface impede the velocity of overland flow and increase the infiltration rate of soil (Beasley and Granillo, 1986, Miller, 1984, Miller, Beasley and Lawson 1988).

Balci, Ozyuvaci and Ozhan (1985) conducted a study over 2 small watersheds near Istanbul Turkey in order to see the effects of forestry operations and conversions of natural hardwood to fast growing conifers upon water quality. They reported that annual suspended sediment loads were 60-80 kg/ha following 1st year of treatment.

TABLE I

SEDIMENT YIELD FROM WATERSHEDS IN ARKANSAS AND OKLAHOMA FROM DIFFERENT SILVICULTURAL TREATMENTS.

Treatment	Years following treatments					Source
	*	1	2	3	4	
	-----------------Kg/ha--------------					
	DeGray Creek, AR.					
Control	46	106	219	68		1
Clearcut&						
Mechanical	93	800	1505	398		
Chemical	64	376	257	134		
	Terre Noir Creek, AR.					
Control	2	1	2	2		
Clearcut&						
Mechanical	1	4	4	128		
Chemical	2	1	3	2		
	Cedar Mountain and Alum Creek, AR.					
Control		12	15	68		2
Selection		26	36	84		
Clearcut chop &						
Burn		237	90	177		
	Alum Creek, AR.					
Control	16					3
Shelterwood	12	35	6	13		
Clearcut	16	131	7	14		
	Battiest, OK.					
Control		43	8	5	24	4
Clearcut, crush &						
Burn, rip		282	35	15	43	

*-Pretreatment values are listed under year *.
1-Beasley, Granillo, and Zillmer, 1986.
2-Miller, Beasley and Lawson, 1988.
3-Lawson, 1985
4-Miller, 1984.
Source: Wheeler et al., 1991. A Final report to The U.S. Forest Service Ouachita National Forest.

Nitrate-Nitrogen Yield

Silvicultural activities like harvesting and site preparation accelerate the decomposition of forest litter and organic matter by exposing it to sun light and other environmental factors. This decomposed material leaches out into the streams and increases the nutrient concentration in stream water. Small increases in nutrient losses after clear cutting have been reported in the Douglas fir region (Brown et al. 1978, Feller, 1977, and Fredriksen et al. 1975), the Bitteroot National forest of Montana (Verry 1972), and the Fernow experimental forest in west Virginia (Aubertin and Patric, 1974). In these studies, the average increase of nitrate-N concentration in streamflow was 1 mg/l.

Brown et al. (1973) monitored three watersheds in the Oregon Coast Range two years prior to and two years after logging. One watershed, Flynn Creek served as control. Deer Creek was patch clearcut. No change in concentration of nutrients was observed after logging. Needle Branch was clearcut and burned. Maximum NO_3-N concentrations increased from 0.70 to 2.10 mg/l following harvesting. NO_3-N concentration returned to prelogging level by the sixth year after logging. The total yield of NO_3-N increased from 4.94 to 15.66 kg/ha the first year after treatment.

Hornbeck et al. (1986) in the Hubbard Brook Experimental Forest in Newhampshire monitored nutrient ion budgets following clearcuting. They reported that NO_3-N input over the 10 year study period was 52.9 kg/ha and estimated that the output in the absence of cutting was 45.2 kg/ha. As a result of strip cutting, outputs for the 10 years following harvest were increased by 27.3 kg/ha, or about 50 %. Block cutting increased NO_3-N outputs by 57.8 kg/ha or 128 %. The largest increases occured in first and 2nd year following cutting.

Hewlett (1978) monitored two watersheds in Georgia following clear felling, roller chopping twice and machine planting. He reported that forest operations did not significantly affect base line concentrations of nitrate, but because water yield was increased, a short term increase of 0.04 kg/ha was measured. All levels of export appeared to normalize after three years.

In East Texas Blackburn, Dehaven, and Knight (1982) compared treatments of; 1) clearcutting, shearing, windrowing and burning; 2) clearcutting, roller chopping and burning; 3) no treatment on NO_3-N yields from 9 small watersheds. They reported that total nitrogen losses were nearly 20 times greater from the sheared (2.14 kg/ha) than from undisturbed (0.12 kg/ha) watershed. Yields were three times greater from the chopped watershed (0.76 kg/ha) than the undisturbed watersheds.

Disturbances of the forest floor and burning bring changes in soil physical properties that reduces the resistence of flowing water, with the result surface flow increases. Douglass, Coax, and Augspurger (1985) monitored 6 watersheds in South Carolina piedmont over a period of three years following clearcutting and low intensity prescribed burning. They reported a loss of NO_3-N of o.o68, 0.025 and 0.024 kg/ha, respectively.

Feller and Kimmins (1984) monitored water chemistry on a clearcut and clearcut and burn watersheds in British Columbia two years prior to treatment and 9 years after treatment. They reported a maximum loss of 7 kg/ha of NO_3-N from clearcut, 2.4 kg/ha from clearcut and burn and 0.3 kg/ha from uncut (control) watersheds in the first year of treatment.

In a similar experiment in the Coweeta experimental forest of North Carolina, Swank (1988) conducted a study to measure the effects of clearcutting, logging and site preparation on stream chemistry. He reported that increases in NO_3-N on treated watersheds began in early Fall, about 9 months after the initiation of cutting. Increase in concentration remained low (50-75 ug/l) into the following summer and then peaked (100-150 ug/l) during the second winter after the treatment. The NO_3-N increases declined toward the base line value but were still elevated the fifth year after cutting.

Balci, Ozyuvaci and Ozhan (1988) monitored 2 small watersheds near Istanbual Turkey to measure the effects of forest operation and conversion of natural hardwood into fast growing conifers upon water quality. They reported that losses of NO_3-N were 3-4 kg/ha following first year of treatment.

Total-Phosphorous Yield

Phosphorous exists primarily in either insoluble or very poorly soluble inorganic forms. Erosion and the flushing of human wastes to the ocean are the major sources for the movement of terrestrial phosphorous to the ocean and reservoirs.

Hewlett (1978) monitored two watersheds in Georgia following forest harvesting and site preparation and reported that forest operations did not significantly affect baseline concentration of total phosphorus in streamwater. Because water yield was increased, a short term increase (0.49 kg/ha/yr) occurred in the export of Phosphorus. All levels of export appeared to normalize after three years.

Blackburn, Dehaven and Knight (1982) monitored nine small watersheds in Texas following clear cutting and site preparation. They reported that the maximum total phosphorus loss was 0.20 kg/ha from the sheared watersheds, and was significantly greater than that from chopped or control watersheds.

Douglass and Augspurger (1985) conducted a study in the South Carolina over a period of three years following forest harvesting and burning. They reported that nutrient concentrations varied among watershed locations because of soil depth, but were generally unaffected by forest harvest and site preparation.

Balci, Ozyuvaci and Ozhan (1986) monitored 2 adjacent watersheds near Istanbual Turkey to measure the affects of forest operations and conversion of hardwood into fast growing conifers upon water quality and quantity. They reported 0.4 kg/ha export of phosphorous following first year of treatment.

Blackburn and Wood (1990) monitored 9 small watersheds in East Texas following forest harvesting and site preparation. They reported a maximum loss of 333 g/ha from the sheared watersheds, 39 g/ha from the chopped watersheds and 15 g/ha from uncut watershed following first year of treatment.

Feller and Kimmins (1984) monitored water chemistry on clearcut, clearcut and burn and uncut (control) watersheds in British Columbia. They reported that all PO_4-P fluxes were less than 0.1 kg/ha/yr and not significantly different from pretreatment values.

CHAPTER III

MATERIALS AND METHODS

Study Area

The study was conducted on the Clayton Lake Research watersheds. It consisted of two forested watersheds WS-I and WS-III. The watersheds are located at latitude 34^{o} 41′ 45", longitude 95^{o} 20′ 00", approximatly 13 km southeast of Clayton, Oklahoma (figure 1). The size of WS-1 is 7.7 ha and WS-III 7.9 ha. The drainage patteren for the watersheds is generally composed of two or three main channels with dendritically branching tributries. Other information on general watershed characteristics is included in Table II.

Climate

The climate of the study area is humid temperate. Mean annual rainfall is 119.5 cm and mean annual temperature is 17.2^{o} C (Bain and Waterson, 1979). Temperature extremes are $+40^{o}$ C in the Summer and -7.8^{o} C in Winter.

Spring and Summer rainstorms are usually frontal-convective, producing rainfall, of high intensity and short duration. These storms results from prevailing winds from south or southeast. Winter precipitation is generally from cyclonic system generally orignating off the Pacific Coast

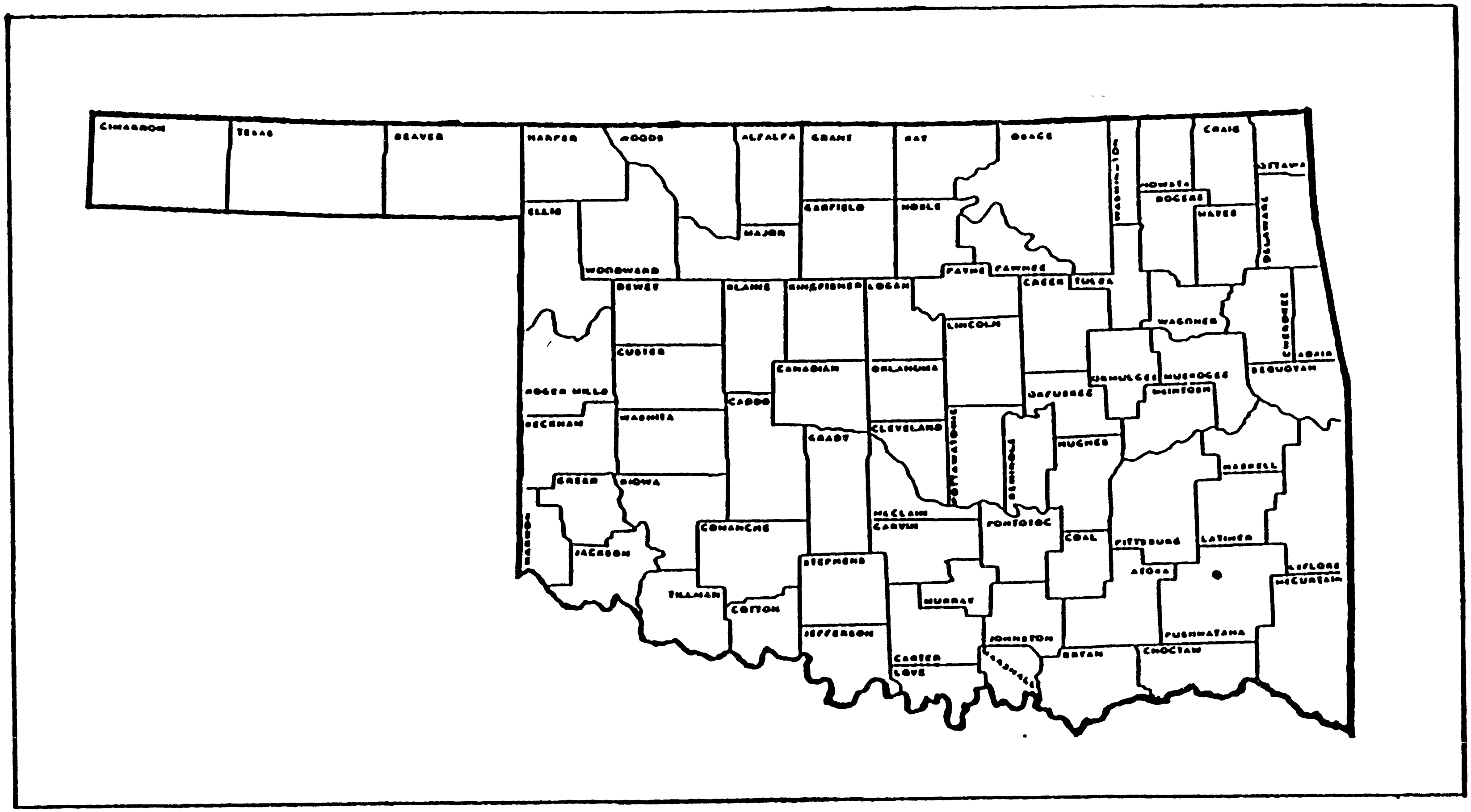

Figure 1. Location of Clayton Lake Watershed Research in Oklahoma

and moving west to east into the area. Most of the precipitation occurs as rain with about 42% of the annual precipitation falling between March to June.

Vegetation and Soils

The vegetation and soils are indicative of the climatic conditions of the region. Scattered old and sapling stands of shortleaf pine (Pinus echinata) mixed with hard wood is common. Predominant hardwoods included Oak-hickory (Quercus, Carya) associations, and elms (Ulmus).

The primary soil type of the study area is the Carnasaw series (Bain and Waterson, 1979). This soil (clayey, mixed, thermic, Hapludult) is charcterized as moderately deep. The soil is well drained with moderate permeablity (1.52-5.08 cm/hr) in the A horizon and low permeablity (0.51-1.52 cm/hr) in the B horizon. The soil parent material is weathered shale and sandstone. Pirum and Stapp soils are found frequently and have less clay in the control section. The depth of the A horizon of Carnasaw soils is 0-18 cm and is a stony, sandy loam. The B horizon depth is 18-90 cm. The texture is predominantly clay (Bain and Waterson, 1979).

Hydrology

Streamflow in the study area is ephemeral and occurs generally in response to high intensity convective storms, although cyclonic storms of long duration will also produce streamflow. The response of the watersheds to precipitation is rapid, producing hydrographs with a steep rising limbs, short crest segments, steep falling limb and delayed flow of variable length. This type of hydrologic response is characteristic of watersheds with shallow soils, little bank storage, and little ground storage.

Treatments

It a is paired watershed study consisting of two watersheds WS-I and WS-III. Watershed-I (WS-I) was the treated watershed and Watershed-III (WS-III) was maintained as a control. Watershed-1 was clearcut in Septmber of 1983. Site preparation consisted of drumchopping and knocking over of hardwoods in July 1984, slash burning in August 1984, and ripping on the contour at a spacing of 2.5 meters in January 1985. The watershed was planted with loblolly pine in March 1985.

Instrumentation and Sampling

Streamflow was measured in calibrated 1.2 meter H flumes. Approach section were 2.5 meter long and constructed of concrete. Approach cutoff walls were extended into bedrock.

ISCO (Instrument Specialties Company) model 1680 pumping samplers with 28 sample capability were installed with fixed level intakes 1 meter upstream from the flume inlets. Floats with mercury switches were used to activate the pumps during runoff events. Discrete or individual samples were time sequenced at 15 to 30 minute intervals.

Rainfall was measured with weighing-bucket recording gages. One gage was located on each watershed. Standard 4-inch collection gages were also used as a backup and check against recording equipment operation.

Sediment and Nutrient Analysis

Suspended sediment was determined by vacuum filtering each sample through 0.45 pm filters, oven drying the filtrate at 110^{o} C and weighing.

Nitrate-Nitrogen analyzed by the Cadmium reduction method (APHA, 1976). Total-P was determined by persulfate digestion followed by analysis using the ascorbic acid colormetric method (APHA, 1976).

The runoff volume associated with each sample was multiplied by the concentration of sediment, NO_3-N and total-P for each storm. Then all storms were summed up to get the annual load of sediment, NO3-N and total-P.

Data Analysis

To do a reliable analysis, a certain period of pre -treatment is necessary to establish the relationship between treated and control level outputs. Watershed I was clearcut in 1983. As a result, only one year of pre-treatment data was available. So using simple comparative techniques treatment effects will be determined.

TABLE II

WATERSHED CHARACTERISTICS[1]

Parameter	Unit of Measurement	Watershed-I	Watershed-III
Area	Hectare	7.86	7.71
Elevation	Meters		
Maximum		418	378
Minimum		348	274
Aspect		NW	SW
Slope (avg.)	Percent	14	21
Crown Cover[2]	Percent	90	88
Surface cond.	Percent		
Litter		86	76
Rock		3	6
Tree		6	6
Erosion		1	1
Stream channel		4	11
Drainage Density	Km/Km^2	24.8	22.2

1 Data were collected from sample points at 20 meter intervals on a random grid (from Vowell [1980]) and a boundary survey completed 1983.

2 Percent crown cover was estimated from aerial photographs. Table is adapted from Rochelle, B.P. (1984).

CHAPTER IV

RESULTS AND DISCUSSION

Sediment Yield

In the clearcut, ripped and revegitated watershed (WS-1) the sediment yield in (water year 1983) the pre-treatment year was 58 kg/ha. The treatment was applied in September of 1983. The sediment yield from water year 1984-88 was 66, 1954, 373, 137 and 140 kg/ha, respectively (Table IV).

The sediment yield in the forested control watershed (WS-III) responded with slight variation in response to differing rainfalls. In the pre-treatment period (water year 1983) the amount of sediment generated was 52 kg/ha, which is approximatly equal to the amount measured from the treated watershed. The sediment yields for water years 1984-88 were 39, 176, 192, 53 and 76 kg/ha (Table IV).

The reasons for the different responses of sediment yield in different years may relate to timing of different forestry operations and weather conditions. In the treated watershed (WS-I), in water year 1984 the sediment yield increased from 58 kg/ha (pretreatment level of water year 1983) to 66 kg/ha. This small increase in sediment yield is

TABLE III

AVERAGE ANNUAL PRECIPITATION AND RUNOFF
IN CLAYTON RESEARCH WATERSHEDS
WATER YEAR (81-88)

	WS-III		WS-I	
Water year	Precipitation	Flow	Precipitation	Flow
	---------------	cm	---------------	
81	118	33	115	28
82	114	30	103	29
83	119	30	116	20
84	127	21	120	30
85	184	78	166	95
86	162	58	156	55
87	121	24	134	40
88	118	37	114	39

TABLE IV

ANNUAL SEDIMENT AND NUTRIENTS YIELDS FROM FORESTED CONTROL (WS-III) AND CLEARCUT AND RIPPED WATERSHED (WS-I) IN CLAYTON RESEARCH WATERSHEDS

Water	NO_3-N		Total-P		Sediment	
	(kg/ha)					
year	Treated	control	Treated	Control	Treated	Control
1983	0.02	0.02	0.06	0.06	58	52
1984	1.34	0.01	0.11	0.05	66	39
1985	7.40	0.05	1.21	0.20	1954	176
1986	1.04	0.09	0.35	0.13	373	192
1987	0.18	0.02	0.13	0.04	137	53
1988	0.96	0.02	0.09	0.06	140	76

due to forest harvesting. In water year 1985 there was a remarkable increase in sediment yield. It increased from 66 kg/ha in water year 1984 to 1954 kg/ha. This substantial increase in sediment yield was due to the continuation of forestry operations, exposure of the soil to the environment and an increase in precipitation. This was the only year in the study period in which the site was without vegetative cover, severly changed surface condition, less resistance against flow and lower infiltration capacity. All these factors contributed to an increase in sediment yield.

Following water year 1985 there was a declining trend in sediment yield. In water year 1986 the sediment yield from the treated watershed was 373 and in 1988 it was 140 kg/ha. The sediment yield of water year 1988 was three times more than the sediment yield of pre-treatment year. This decline in sediment yield is due to stabilization of the soil, by the establishment and growth of vegetative cover over the site.

On the forested control watershed there was a slight increase in sediment yield (Figure 2). This increase in sediment yield is due to variation in precipitation (Table III).

The ratio of sediment yield generated from the treated watershed (WS-I) to the control watershed (WS-III) in water years 1984-88 was 1.6:1, 11:1, 2:1, 2.5:1, and 1.8:1, respectively (Figure 2).

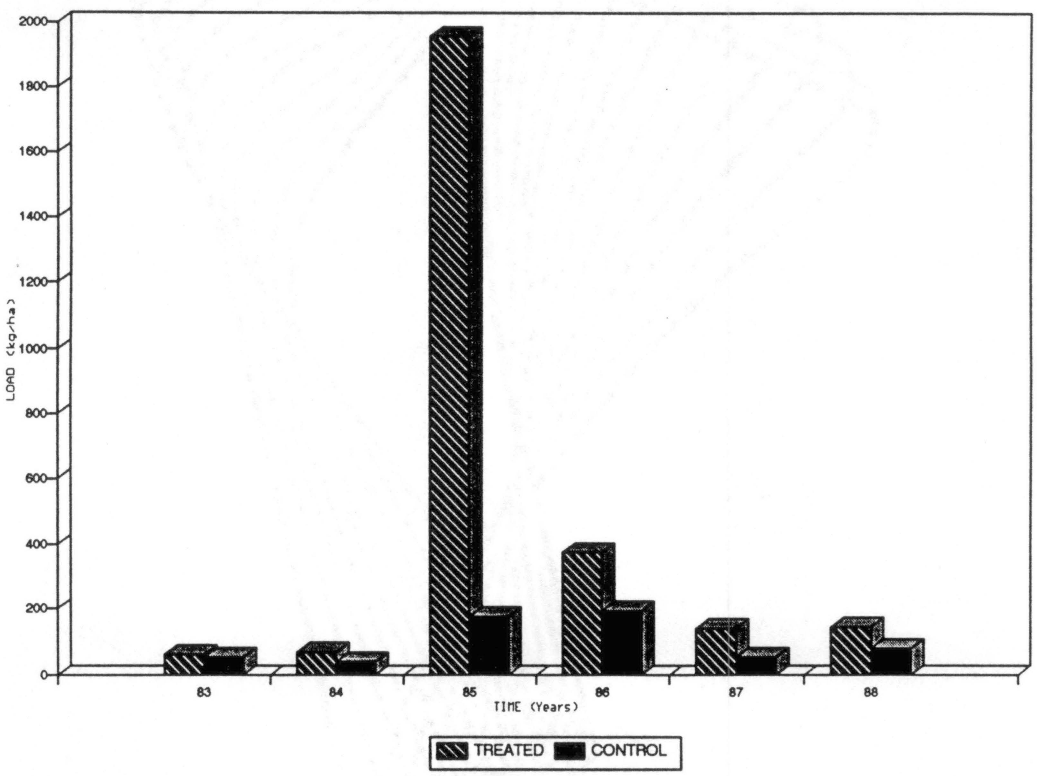

Figure 2. Annual sediment yield losses from the forested control watershed-III and clearcut, ripped and burned watershed-I in Clayton Research watersheds.

Comparable studies in the Ouachita Mountain in Arkansas indicate similar trends in per year sediment loss following clearcutting and site preparation

In DeGray Creek, AR. Beasley et al. (1986) reported that clear cutting and mechanical site preparation generated, 800, 1505 and 398 kg/ha of sediment yield the 1st, 2nd, and 3rd year following treatment, respectively. In Battiest, Oklahoma Miller (1984) reported a loss of 282, 35, 15, and 43 kg/ha of sediment yield the 1st, 2nd, 3rd, and 4th year following clearcutting, crushing, burning and ripping. In East Texas Blackburn et al. (1982) reported a maximum loss of 2201 kg/ha the 1st year following clearcutting, shearing, windrowing, and burning.

Battiest study was similar to Clayton study in harvesting technique and soils. Normal October-November rainfall of that area is 9.7 and 8.5 cm. In water year 1985 in October-November the rainfall was 45.5 cm and 12 cm (NOAA, 1989). This storm in the Clayton study area was received before ripping of the site, but after slash burning. This variation in amount of rainfall in October and November (water year 1985), slash burned and unripped site generated a greater sediment yield on the Clayton study area.

Sediment losses in this study were 66, 1954, 373, 137, and 140 kg/ha the 1st, 2nd, 3rd 4th and 5th year following treatments, respectively. The sediment yields are slightly higher than that of Beasley et al. (1986) and Miller (1984) but are slightly less than the sediment yields reported by Blackburn et al.(1982).

Nitrate-Nitrogen Yield

Nitrate-nitrogen export in streamwater following forest harvesting, site preparation and planting with loblolly pine from the treated watershed (WS-I) ranged from 0.95 to 7.40 kg/ha/yr over a five year period of this study. The pretreatment NO_3-N load in water year 1983, was 0.02 kg/ha. Following clearcutting and burning in water years, 1984 and 1985 the NO_3-N load was 1.34 and 7.40 kg/ha, respectively. Following this period there was a declining NO_3-N load. From water year 1986 to 1988 the NO_3-N load was 1.04, 0.18, and 0.96 kg/ha/yr (Table IV).

In water year 1984 when only the forest was cut and burned in August of 1984 WS-I yielded 1.34 kg/ha of NO_3-N. The pre-harvest baseline was 0.02 kg/ha. The removal of the trees from the watershed stopped the uptake of nutrients from the soil. Nitrate is poorly retained by the soil, and as a result it leached into streamwater, raising the level of NO_3-N.

In water year 1985 the NO_3-N load (7.04 kg/ha) was at the peak level of the study period. This substantial increase in NO_3-N yield is related to the severity of the site preparation. In August of 1984 the crushed slash was burned. The slash burning process increased the process of

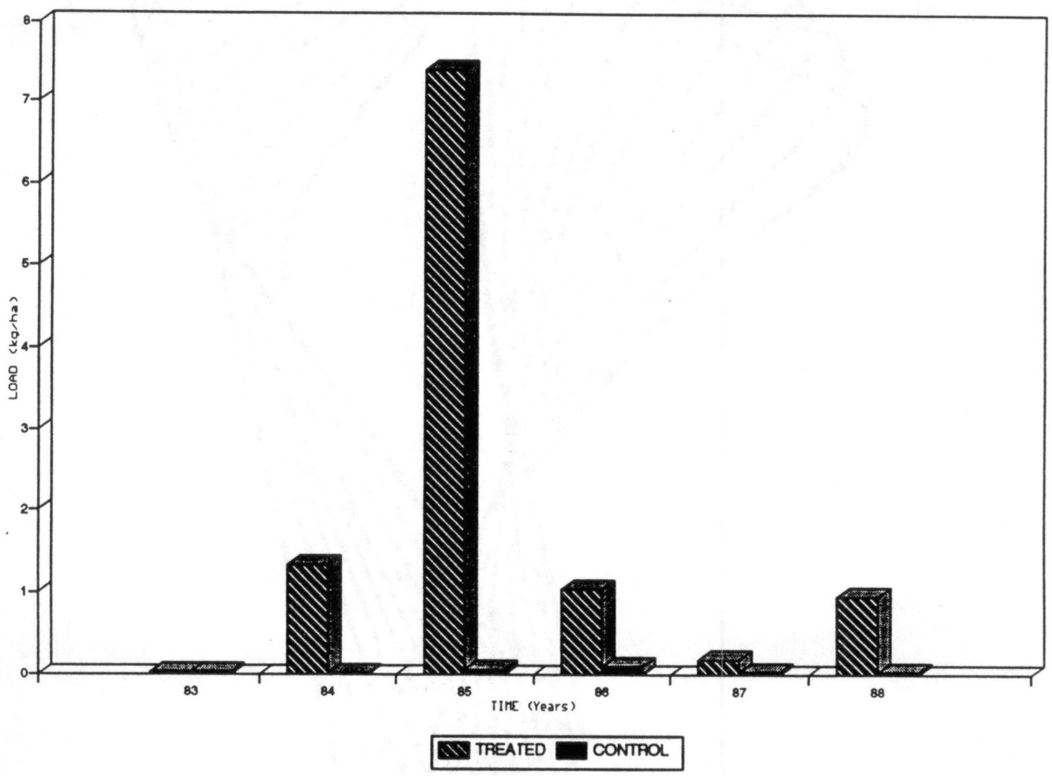

Figure 3. Annual Nitrate-nitrogen yield losses from the forested control watershed-III and clearcutt, ripped and burned watershed-1 in Clayton Research watersheds.

mineralization of organic matter, resulting in a substantial increase in the amount of NO^3-N in the stream water.

Following this severely disturbed period, there was a decrease in NO_3-N loads (Figure 3). This decrease is due to the establishment of vegetative cover. The vegetative cover protected the soil against erosion and trapped the available nutrients.

On the other hand, the yield of NO_3-N was relatively constant from the control watershed (Table IV, Figure 3), except for slight variations which was due to fluctuation in precipitation.

The ratio of NO_3-N loads between the treated watershed (WS-I) and the control watershed (WS-III) in water years 1984-88 was 135:1, 138:1, 12:1, 10:1, and 37:1 respectively.

Comparable studies in different parts of the U S indicate variations in per year NO_3-N losses following clearcutting and site preparation. Brown et al. (1973) monitored three watersheds in the Oregon Coast Range. They reported that the yield of NO_3-N increased from a pretreatment level of 4.94 to 15.66 kg/ha the first year after treatment.

In East Texas Blackburn et al. (1982) reported a loss of 2.14 kg/ha from clearcut, sheared and burned watersheds, 0.12 kg/ha from an uncut (control) and 0.76 kg/ha from clearcut, chopped and burned watersheds following first year of treatment. Feller and Kimmins (1984) monitored water

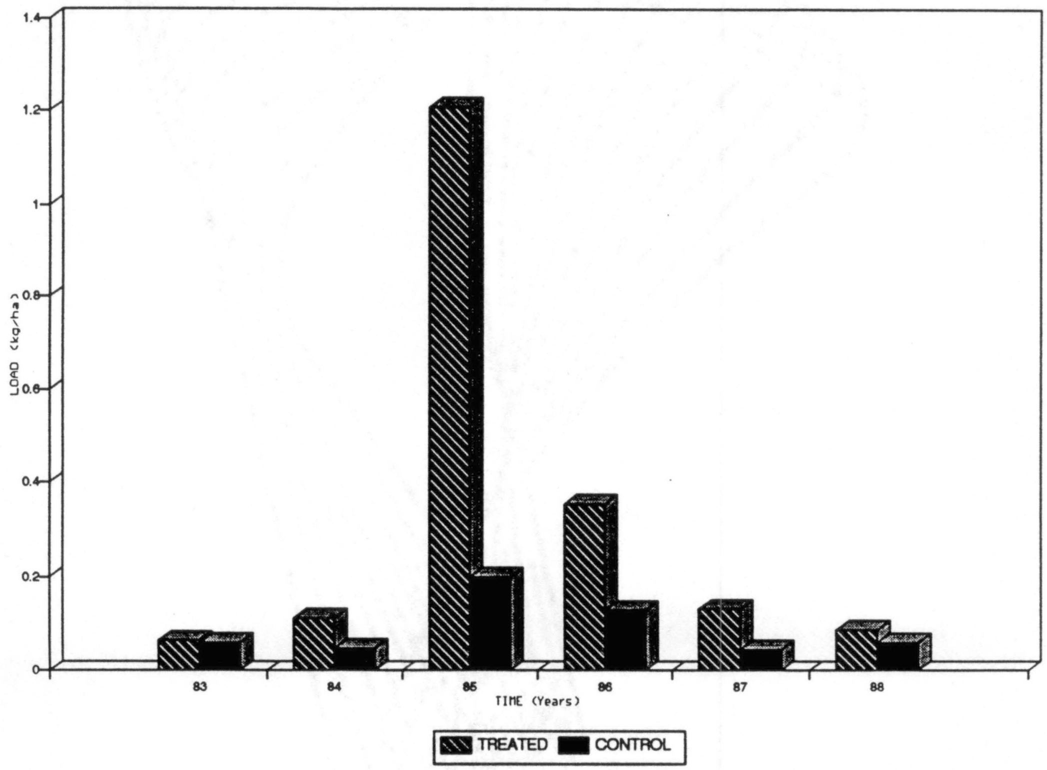

Figure 4. Annual Total-Phosphorus yield losses from the forested control watershed-III and clearcut, ripped and burned watershed-I in Clayton Research watersheds

chemistry on a clearcut and clearcut and burned watersheds in British Columbia two years prior to treatments and 9 years after treatment. They reported a maximum loss of 7 kg/ha of NO_3-N from clearcut, 2.4 kg/ha from clearcut and burn, and 0.3 kg/ha from uncut (control) watersheds in the first year of treatment.

Total-Phosphorous Yield

Total-phosphorous yield, following forest harvesting and site preparation followed the same pattern of increase as did the sediment yield on the treated watershed (WS-I). The Total-P yield in the pre-treatment year on WS-I (water year 1983) is 0.06 kg/ha. Total-P yield from the treated watershed (WS-I) was 0.11, 1.20, 0.35, 0.13, and 0.09 kg/ha (Table IV) the 1st, 2nd, 3rd, 4th, and 5th year following harvesting and site preparation.

In water year 1984 on treated watershed following harvesting and burning there was 1.7 times increase in amount of total-P from pre-treatment yield level, while in water year 1985 there was an 18 times increase in the export of total-P (Figure 4). The smaller increase in yield of total-P in water year 1984 as compared to water year 1985 is related to the forestry operations. In water year 1985 following the treatments of harvesting, burning, soil ripping and excessive rainfall, there is substantial increase in total-P yield.

From water year 1986 to 1988 there was a declining trend in total-P yield. In water year 1988 total-P was at the lowest level (Table IV). The reasons for the decline in the export of total-P was the establishment of vegetative cover, stabilization of the soil and rehabilitation of soil micro and macro organisms.

The total-P export from the forested control (WS-III) fluctuated slightly (Figure 4) in response to changes in precipitation (Table IV).

On comparing the treated (WS-I) and the control watersheds (WS-III) it was found that in water year 1984 loss of total-P was two times more from the treated watershed than from the control watershed, while in water year 1985 the amount of total-P was 6 times more from the treated watershed than from the control watershed. In water year 1986 and 87 the ratio progressively decreased, but the ratio was still 1.5:1 (Figure 4).

Comparable studies in the U S and other countries indicate variations in total-P losses following clearcutting and site preparation. Blackburn et al. (1982) following the 1st year of treatment in east Texas reported a loss of 0.2 kg/ha, Balci et al. (1986) monitored 2 watersheds near Istanbul, Turkey for the five years. They reported an average loss of total-P of 0.4 kg/ha.

In this study the maximum total-P loss was 1.207 kg/ha the first year following site preparation. Total-P load decreased towards the pretreatment level in three years.

CHAPTER IV

SUMMARY AND CONCLUSION

Two small forested watersheds in the Clayton Research Area in southeastern Oklahoma were selected for study. The WS-I was treated watershed and WS-III was uncut (control) watershed. Watershed-I was clearcut in September of 1983. Site preparation consisted of drum chopping and knocking over of hardwoods in July of 1984, slash burning in August and ripping on contour at a 2.5 meter spacing in January of 1985. The watershed was planted with loblolly pine in March 1985. Data was collected from 1983-88. The data was collected one year prior to treatment and five years after treatment. The pretreatment sediment yield for water year 1983 was 58 kg/ha. The sediment yields following treatment from water years 1984-88 were 66, 1954, 373, 137, and 140 kg/ha, respectively.

The sediment yield from the forested control (uncut) watershed (WS-III) for the pretreatment water year 1983 was 52 kg/ha. The sediment yields for water years 1984-88 were 39, 176, 192, 53, and 76 kg/ha. The ratios of sediment yield generated from the treated watershed (WS-I) to the control watershed (WS-III) in water years 1984-88 were 1.6:1, 11:1, 2:1; 2.5:1 and 1.8:1, respectively.

The pretreatment NO_3-N yield for water year 1983 of WS-I treated watershed was 0.02 kg/ha. The NO_3-N yields from the treated watershed (WS-I) for water years 1984-88 were 1.34, 7.4, 1.04, 0.18, and 0.96 kg/ha, respectively. The Nitrate-nitrogen yields from the uncut (control) watershed-III for water years 1984-88 were 0.01, 0.05, 0.09, 0.02, and 0.9 kg/ha, respectively. The ratios of Nitrate-nitrogen yield generated from the treated watershed-I to control watershed-III in water years 1984-88 were 135:1, 138:1, 12:1, 10:1, and 37:1, respectively.

The pretreatment total-P yield for water year 1983 of watershed-I (WS-I) was 0.06 kg/ha. The total-P yields of watershed-I (WS-I) for water years 1984-88 were 0.11, 1.21, 0.35, 0.13 and 0.09 kg/ha, respectively. Total-P yields from the uncut watershed (WS-III) for water years 1984-88 were 0.05, 0.02, 0.13, 0.04, and 0.06 kg/ha, respectively. The ratios of total-P yield from the treated watershed-1 (WS-I) to the control watershed-III (WS-III) were 2:1, 6:1, 3:1, 3:1, and 1.5:1 kg/ha, respectively.

The variability in sediment and nutrients yields following the harvesting and site preparation is an indication of the treatment effects. The comparisons are based on identical periods for each watershed. Long term statistical predictions are not possible. However, inferences can be made about the treatment effects because this comparative method minimized the differences in geology, weathering and climatic conditions.

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