8-1978

The effects of degree of erosion and slope characteristics on soybean yields on Memphis, Grenada, Lexington, and Loring soils

Harry Paul Denton

To the Graduate Council:

I am submitting herewith a thesis written by Harry Paul Denton entitled "The effects of degree of erosion and slope characteristics on soybean yields on Memphis, Grenada, Lexington, and Loring soils." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Frank F. Bell, Major Professor

We have read this thesis and recommend its acceptance:

George Buntlet. M. E. Springer, L. N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Frank F. Bell

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We have read this thesis and recommend its acceptance:

George J. Buntley

M. E. Springer

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THE EFFECTS OF DEGREE OF EROSION AND SLOPE CHARACTERISTICS ON SOYBEAN YIELDS ON MEMPHIS, GRENADA, LEXINGTON, AND LORING SOILS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Harry Paul Denton

August 1978

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to:

Dr. Frank Bell, for his guidance and encouragement throughout this study, and the author's entire graduate program, as his major professor;

Dr. George Buntley, Dr. M. E. Springer, and Professor L. N. Skold for their assistance as members of the author's graduate committee;

Dr. Lloyd Seatz, the Plant and Soil Science Department, and the University of Tennessee Agricultural Experiment Station for providing the author with a graduate research assistantship, and for providing financial and other support for this study;

Dr. William Sanders, for his aid in conducting the statistical analysis of the data collected in this study;

Numerous Soil Conservation Service personnel, including Billy Headden, State Resource Conservationist, Warren P. Corbett, Resource Conservationist, Robert Fisher and Ray Bryant, Area Conservationists, William Brown, Aaron Clement, and Charles Moore, Area Soil Scientists, Donald Clements, Jimmy Spencer, Wendell Perry, Billy Cude, Douglas Summers, Earl West, Joe Boswell, Doyle Tucker, Charles Lites, James McAdams, Lee Graham, Richard Kirby, Charles Leslie, Paul Aydelott, Willie Moore, Thomas Jones, Dale Ferguson, and Thurston Dorsett, District Conservationists, and others who aided in selection and harvesting of the samples, without whose aid this study would not have been possible;

John Connell, Dr. Bobby Duck, Tom McCutchen, Joe Overton, Marshall Smith, and other Experimental Station personnel in West Tennessee, for their aid in selection, harvesting, and threshing of samples;

His fellow graduate students, particularly Charles Finley, John Zinn, and John Holowid, for their friendship and assistance throughout this study;

His wife Glenda, for her patience, understanding, and encouragement during this study;

His parents, for their encouragement and support throughout his college career.

ABSTRACT

Soil erosion is a very serious problem in upland soybean fields in West Tennessee. This study was undertaken for the purpose of determining the effects of degree of erosion and slope characteristics on soybean yields on four West Tennessee soil series - Memphis, Grenada, Lexington, and Loring.

In 1976 and 1977, yield samples were taken from areas of various soil mapping units of each soil series in soybean fields on West Tennessee farms and experiment stations. Soil mapping units sampled varied in slope from 2% to 12%, and in degree of erosion from slight to severe. The yield data collected were analyzed by use of a least squares analysis of variance. Least squares mean yields were obtained for each soil mapping unit sampled within each soil series. Erosion and slope effects on yields were determined by comparisons of pairs of least squares mean soil mapping unit yields.

Results in 1976 showed no effect of degree of erosion on yield on any soil series. A trend toward reduced yields as slope gradient increased was evident on all soils. Results in 1977 showed significant yield reductions on all soils due to the combined effects of degree of erosion and slope gradient. On Grenada soils, the reduction in yields was due largely to degree of erosion, while on the other soils it was equally due to slope gradient and erosion.

A combined analysis of both years' data showed no differences in

yield due to degree of erosion and slope gradient on Memphis soils. On the other three soils, yields were reduced significantly by a combination of severe erosion and increased slope gradient. Neither increased slope gradient alone, nor severe erosion alone caused a significant yield reduction. Yields on Lexington and Memphis soils did not differ significantly from year to year, but yields on Grenada and Loring soils declined significantly from 1976 to 1977.

The differences in the effects of degree of erosion and slope gradient between 1976 and 1977 were probably a result of lower 1977 growing season rainfall. The drier conditions in 1977 resulted in lower yields on steeper, more eroded sites due to their lower moisture supplying capacity. The greater variability in yields on the Grenada and Loring soils was due to the fragipans in their subsoils, which restricted rooting and led to more moisture stress in a drier year. The overall lack of reduction in yield on Memphis soils was due to their deep, silty subsoils, which were able to supply more water to the soybeans than the less favorable subsoils of the other three soils.

Shape of slope, either convex, concave, or smooth, had no significant effect on yields on any soil in either year when included in a model with field and soil mapping unit. The inclusion of linear and quadratic effects of pH and available potassium in the model had a significant effect on yields on Memphis soils in 1977. Adjustment of soil mapping unit yields for pH and available potassium eliminated significant differences between yields. The inclusion of linear and quadratic effects of pH in the model had a significant effect on yields on Grenada soils in 1977. Adjustment of soil mapping unit yields for pH increased the differences caused by slope gradient and degree of erosion.

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CHAPTER I

INTRODUCTION

Soybeans are the leading row crop in Tennessee, in terms of both acreage and value of production (Tennessee Crop Reporting Service, 1977). Acreage of soybeans has increased greatly in Tennessee in recent years, largely in response to favorable prices. In 1961, there were 463,000 acres of soybeans harvested for beans in Tennessee. By 1966, this had increased to 871,000 (Tennessee Crop Reporting Service, 1967) and by 1976 to 1,800,000 acres (Tennessee Crop Reporting Service, 1977).

Much of this increase in acreage has taken place in western Tennessee. In many cases, Class IIIe, IVe, or VIe land which was formerly in pasture or idle has been switched to continuous soybean production. This has led to a very serious erosion problem.

In dealing with this erosion problem, and for general planning purposes, it is necessary to estimate the yields of crops when grown on these eroding soils. Reliable soybean yield data on the important soils of the area are needed. Therefore, this study was instituted to determine the yields of soybeans on four of the major upland soil series of West Tennessee as affected by slope gradient and degree of erosion. Soil series used were Memphis, Loring, Grenada, and Lexington.

CHAPTER II

LITERATURE REVIEW

Slope gradient and degree of erosion of the soil have long been recognized as factors affecting crop yields. Since 1930 there have been a number of field studies evaluating the effect of slope gradient and degree of erosion on crop yields. Utz et al. (1938) reported on a number of field experiments on a variety of soils in different regions of the United States in which yields on uneroded soils were compared with yields on the same soils eroded to various degrees. In all cases, yields were lower on the eroded soils. Crops used in these studies included cotton, corn, oats, and wheat. Murray et al. (1939) reported the results of a two-year study of corn and oat yields on a number of soils in Iowa. Yield was shown to be highly dependent on depth of topsoil, when the depth of the topsoil was eight inches or less. Slope gradient was found to have little effect on yield when depth of topsoil was constant.

Uhland (1940) reported that on a Shelby loam (fine-loamy, mixed, mesic Typic Arguidolls) in Missouri, corn yields were about 50 bushels per acre with 13 inches of topsoil, and about 18 bushels per acre with 3 inches of topsoil. On a Marshall silt loam (fine-silty, mixed, mesic Typic Hapludolls) in Iowa, Uhland found that the yield of corn declined from 77 bushels per acre with 18 inches of topsoil to 37 bushels per acre with 3 inches of topsoil. In both cases, yields tended to decline more rapidly as topsoil depth decreased. The decline in yield was attributed largely to a lower nitrogen supply due to the reduction in organic matter in the soil as topsoil depth decreased. Uhland also reported that, in a two-year study in Indiana, yields of corn declined 2.1 bushels per acre per inch of topsoil, as topsoil depth decreased from 13 inches to 6.5 inches. As topsoil depth decreased from 6.5 inches to 1.5 inches, yields declined 4.8 bushels per acre per inch of topsoil. This indicated that the effects of additional erosion became more severe as the degree of erosion increased.

Latham (1940) grew cotton in South Carolina on plots consisting of material from the A, B, and C horizons of a Cecil sandy laom (clayey, kaolinitic, thermic Typic Hapludults) for three years. He found that yields of seed cotton on the A horizon material were three times as great as yields on the B horizon material, and 11 times as great as yields on the C horizon material, when grown using low rates of mixed fertilizer. In a one-year experiment in which manure was added to the plots, yields on the A horizon material were 1.6 times as great as on the B horizon material, and two times as great as yields on the C horizon material. This showed that improved fertility, plus other beneficial effects of organic matter, could make up for some of the differences in productivity between the various materials.

Thomas et al. (1943) reported on the effect of erosion on dryland wheat yields on soils in eastern Oregon. They found that wheat yields declined 0.9 bushels per acre per inch of decrease in topsoil depth under a 22 inch annual rainfall regime, and 0.8 bushels per acre per inch of decrease in topsoil depth under a 12 inch annual rainfall regime. They attributed the decrease in yield to both lower fertility and lower moisture supplying capacity. Their data indicated that the yield decrease was more severe when depth of topsoil was less than 8 to 10 inches.

Smith et al. (1945) reported the results of long-term yield trials on normal and desurfaced Shelby soils. Yields of corn and oats averaged about half as great on the desurfaced plots as on the normal soil plots.

Alderfer and Fleming (1948) studied the soil factors influencing yields of grapes on Chenango gravelly sandy loam soils (loamy-skeletal, mixed, mesic Typic Dystrochrepts) in Pennsylvania. They found grape yields to be highly correlated with available water-holding capacity of the soil, which was in turn highly dependent on degree of erosion because of the unfavorable gravelly texture of the subsoil. They concluded that degree of erosion was a critical factor in grape production on this soil.

Adama (1949) compared yields of cotton, corn, oats, and vetch grown in rotation on uneroded Cecil soils with yields of the same crops grown on severely eroded Cecil soils. Cotton yields were 38% lower on the severely eroded plots, corn yields 40% lower, oat yields 34% lower, and vetch yields 22% lower. Parks et al. (1969) studied the effects of slope gradient and other factors on corn yields on a number of Piedmont upland soils in South Carolina and Georgia, including many sites on Cecil soils. They concluded that when the sites had been in fescue sod the previous year, slope gradient had no effect on corn yields.

Several studies have been conducted to determine the effects of various management practices on yield reductions due to erosion. Hays et al. (1948) in Wisconsin compared yields of corn, small grain, and grasslegume hay grown in a five-year rotation under good management on moderately eroded areas of Fayette silt loam (fine-silty, mixed, mesic Typic Hapludalfs) to yields of the same crops under the same management when grown on severely eroded areas of the same soil. Fayette soils are formed in deep loess and are similar in many respects to Memphis soils, which are in a closely related family. The area used for the study was on a 16% slope. The study was conducted for a period of eight years. Early in the study, the severely eroded areas were much lower in grain yields, but after five years the yields on the severely eroded areas had increased until they equaled the yields on the moderately eroded areas. The initial low yields of the severely eroded areas were attributed to lower initial fertility than that of the moderately eroded areas. Addition of phosphorus and potassium fertilizer, together with the nitrogen fixed by the legumes in the hay crops, restored the fertility of the severely eroded areas after five years. Because of the silty texture of the subsoil of Fayette silt loam, there was probably little difference in moisture supply between the severely eroded and moderately eroded areas, so most of the yield differences were due to fertility which could be added under good management.

Bactell et al. (1956) reported a study of long-term crop yields on two Ohio soils, Canfield (fine-loamy, mixed, mesic Aquic Fragiudalfs) and Celina (fine, mixed, mesic Aquic Hapludalfs). Crop yields on areas with normal topsoil depth were compared with yields on areas from which six inches of surface soil had been removed to expose the subsoil material, and on areas which had been covered with six additional inches of topsoil. On the Canfield soil, yields were initially higher on the filled area than on the area with normal topsoil depth, and much lower on the area from which six inches had been removed. After 12 years in rotation of grain crops and meadow under low to moderate fertilization, yields on the area of exposed subsoil had improved, but were not equal to yields on the normal and filled areas. In a second phase of the experiment covering three years, fertilization, especially with nitrogen, was greatly increased. Under heavy fertilization, yields on the subsoil area almost equaled those on the normal and filled areas. On the Celina soil, yields in the rotation remained much lower on the subsoil area than on the normal and filled areas, and improved little over the years. The Celina subsoil was more clayey than that of the Canfield soil, and the authors attributed the continued lower yield on the Celina subsoil to the poor tilth and droughty conditions caused by the clayey texture of the subsoil, as well as to lower fertility. Their conclusion was that under good management eroded areas could be as productive as uneroded if the subsoil material had a physical character suitable for plant growth, but not if the subsoil material had poor physical properties.

Engelstad et al. (1961) studied the effects of nitrogen fertilization and surface soil thickness on corn yields on Marshall (fine-silty, mixed, mesic Typic Hapludolls) and Monona (fine-silty, mixed, mesic Typic Hapludolls) soils in farmers' fields in Iowa. They found that in 1957 the addition of enough nitrogen could completely substitute for topsoil lost to erosion in corn production on these soils. In 1958, however, addition of nitrogen did not make up for the difference in yields due to loss of topsoil. Corn yields without nitrogen fertilization were positively related to the depth of topsoil, becoming much lower as topsoil depth decreased. Their conclusion was that nitrogen could substitute for topsoil in corn production in some years on these soils, but not in others, and that the difference was probably due to differences in weather between years. Both Marshall and Monona soils have silty, permeable subsoils, and erosion of topsoil would not greatly reduce their available water-holding capacity. In a related study, Engelstad and Shrader (1961) compared the effect of nitrogen fertilization on corn yields on a Marshall silt loam from which the surface had been removed and on a normal Marshall silt loam. They found that yields were much lower on the desurfaced area without nitrogen fertilization, but that the addition of nitrogen fertilizer completely eliminated any differences in yields between the two areas in 1958 and 1959. They concluded that the addition of nitrogen could substitute for lost topsoil, and overcome the effect of erosion on yields, on Marshall soils.

Overton and Bell (1974) studied corn yields from production fields on the West Tennessee Experiment Station for the 15-year period 1957-1972 to determine the productivity of various West Tennessee soils for corn under a high level of management. Soils studied included Memphis, Loring, and Grenada, as well as a number of other series. They found corn yields under a high level of management to be affected by both slope gradient and degree of erosion. They estimated average yields across all erosion classes to be 94 bushels per acre on 0-2% slopes, 91 bushels per acre on 2-5% slopes, and 84 bushels per acre on 5-12% slopes. Across all slope classes, they estimated average yields to be 105 bushels per acre on uneroded areas, 98 bushels per acre on eroded areas, and 71 bushels per acre on severely eroded areas of these soils. Their study indicated that management practices, including a high level of fertilization, could not overcome the effects of erosion and slope gradient on corn yields on these soils.

Langdale et al. (1978) reported the results of a three-year experiment in which corn yields were related by regression analysis with depth to the top of the B2t horizon of a Cecil soil in Georgia. Depth to the B2t horizon was found to be highly significant in explaining variation in corn yields. As depth increased, corn yields increased. On the severely eroded areas, corn yields were found to be 41% lower than on the uneroded areas. The authors pointed out that this was approximately the same yield reduction reported by Adams (1949) on Cecil soils. They concluded that even though overall corn yields had increased greatly on the Piedmont from 1949 to 1977, the yield reduction due to erosion was about the same under modern management as in 1949.

When land is leveled for purposes of irrigation, mechanization, or conservation, topsoil is often removed and subsoil exposed, leading to productivity problems similar to those which occur when subsoil material is exposed by erosion. A number of greenhouse experiments using subsoil material from leveled soils in the Midwest and Plains states have shown that subsoil material is generally as productive as topsoil when the proper nutrients are added and water is not limiting (Rost, 1939; Ruess and Campbell, 1950; Eck and Ford, 1962). Field studies under irrigation in the same regions of the country have been in general agreement with this conclusion (Whitney et al., 1950; Carlson et al., 1961; Heilman and Thomas, 1961; Eck et al., 1965; Olson, 1977). Under conditions of limited moisture, however, Eck (1969) found that on a Pullman silty clay loam (fine, mixed, thermic Torrertic Paleustolls) addition of fertilizer did not competely restore the productivity of cut areas for grain sorghum, although it did raise their yields. The continuing lower yields on the cut areas were attributed to the lower available water-holding capacity of the clayey subsoil of the Pullman soil, as compared to the more silty topsoil. For the same reason, plots on areas which had been covered with topsoil fill material during the leveling operation yielded higher than normal, uncut areas. The thickened topsoil resulted in a still higher available water-holding capacity.

Data on the effects of degree of erosion and slope gradient on soybean yields are more limited than is the case with other field crops, especially corn. This is probably due to the more recent emergence of soybeans as a major crop in the United States. Some studies have been made in recent years in Tennessee. Buntley (1972) reported on the soybean production potential of a number of major Tennessee soils. The yield data used came from high management plots in soybean fields located on key soils in 1971. Memphis, Grenada, and Loring were among the soils included. Little difference was found among upland soils, probably because of high rainfall in 1971. Yields were found to be affected by slope, with 0-2% slopes averaging 52.6 bushels per acre, 2-5% slopes averaging 48.5 bushels per acre, and 5-12% slopes averaging 43.7 bushels per acre. These differences may be partly due to erosion, since all the 5-12% slope areas were eroded, while all the 0-2% and 2-5% slope areas were slightly eroded.

Simpson (1974) studied soybean yields on Dewey soils (clayey, kaolinitic, thermic Typic Paleudults) in Blount County, Tennessee, in 1973. His study showed average yields on B1 (2-5% slopes, slightly eroded) mapping units to be 25 bushels per acre, while yields on C3 (5-12% slopes, severely eroded) mapping units were 19.6 bushels per acre. There was no significant difference among soil mapping units in fertility, so the difference in yield was attributed to a lower moisture supplying capacity on the C3 sites. This was due to the combined effects of increased slope gradient and severe erosion.

Rhoton (1975) continued Simpson's study in 1974. He obtained average yields of 25.8 bushels per acre on Dewey B1 areas and 17.7 bushels per acre on Dewey C3 areas. The results were similar to those of Simpson, and the effect was again attributed to the lower moisture supplying capacity of the C3 areas.

In summary, a review of the pertinent literature shows that under low levels of fertilization, erosion or removal of topsoil often results in lower yields, due to a decrease in the supply of nutrients to the plant and lower moisture supplying capacity on soils with clayey or coarse-textured subsoils. Under programs of high fertilization and improved management, productivity of some eroded soils can be as high as uneroded soils. If the subsoil material is favorable for root development and has an available water-holding capacity as great as that of the lost topsoil, or if the soil is under irrigation so that water is not a limiting factor, the highly fertilized eroded soils can be very productive. If, on the other hand, the subsoil is clayey or coarse-textured, and lower in available water-holding capacity than the eroded topsoil, added fertility will not restore the productivity of the soil completely under natural rainfall or limited irrigation in most cases. Poor tilth of exposed subsoil material may also lower yields. Studies of the effect of slope gradient on yields have been inconclusive, with some showing little or no effect when erosion was constant, while others have shown yield reductions with increased slope. Few data are available on the effects of slope gradient and erosion on soybean yields. The data which are available from Tennessee indicate that increasing slope gradient lowers soybean yields on many soils, and that increasing slope gradient and severe erosion, in combination, lower yields on soils with clayey subsoils.

CHAPTER III

METHODS AND PROCEDURES

I. AREA AND SOILS

The purpose of this study was to determine the effects of degree of erosion and slope characteristics on soybean yields on Memphis, Grenada, Loring, and Lexington soils. Hereafter, the words erosion and slope will refer to degree of erosion and slope gradient, respectively. It was conducted for two years, 1976 and 1977. Sites used for the study were in soybean fields on private farms in 17 West Tennessee counties, and in soybean fields on experiment station farms at Ames Planatation, and at the University of Tennessee, Martin.

Memphis soils are fine-silty, mixed, thermic Typic Hapludalfs. They are well-drained upland soils which have developed in loess 4 to 70 feet thick. Typically, if not eroded, they have brown silt loam surface horizons, dark brown silt loam or silty clay loam upper subsoils, and dark brown silt loam lower subsoils. The loess is underlain by Coastal Plains sediments at depths of 4 to 70 feet (Brown et al., 1965; Brown et al., 1973; Buntley et al., 1977; Flowers et al., 1964). In the western section of West Tennessee, in the area just east of the loess bluffs bordering the Mississippi River floodplain, they are the predominant upland soils. This area includes most of the western halves of Shelby, Tipton, and Obion counties, and the central sections of Lauderdale and Dyer counties. In this area Memphis soils are on narrow, gently sloping and sloping ridgetops and on steep side slopes. Slopes range from 0 to 50%. Memphis soils are also found throughout the western and central sections of West Tennessee in areas where the loess thickness exceeds four feet. In these areas Memphis soils are usually on the higher, more rolling parts of the landscape, on and near the ridgetops. They are usually associated with Loring and Grenada soils, which are on the sideslopes and on the lower lying areas of the landscape. Sites on Memphis soils used in this study were located on farms in Obion, Dyer, Lauderdale, Tipton, Shelby, Madison, and Gibson counties, and on Ames Plantation in Fayette and Hardeman counties.

Grenada soils are fine-silty, mixed, thermic Glossic Fragiudalfs. They are moderately well-drained upland soils which have developed in loess greater than four feet in thickness. They have a dense, brittle fragipan, which begins at a depth of about two feet in slightly eroded profiles. This fragipan restricts the movement of air, water, and roots. Typically, uneroded Grenada soils have dark grayish-brown silt loam surface horizons and silt loam or silty clay loam upper subsoil horizons, overlying a distinctly lighter-colored A'2 horizon which tongues into a dense, brittle silt loam fragipan in the lower subsoil (Brown et al., 1965; Brown et al., 1973; Flowers et al., 1969; Buntley et al., 1977). Grenada soils are the most prevalent upland soil in the central section of West Tennessee. They are on level to sloping areas of the landscape in areas of loess greater than four feet thick. Often they are associated with Loring and Memphis soils, which occupy the higher, more rolling areas of the landscape. Sites on Grenada soils used in this study were on farms in Obion, Weakley, Gibson, Crockett, Haywood, and Fayette counties in both 1976 and

1977, and in Tipton and Lauderdale counties in 1976. Sites were also included on experiment station fields at Martin in Weakley County and at Ames Plantation in Fayette County.

Loring soils are fine-silty, mixed, thermic Typic Fragiudalfs. They are moderately well-drained upland soils developed in loess greater than four feet in depth. Loring soils have a fragipan of varying degree of development in their lower subsoil. The fragipan varies from weakly developed to strongly developed. When not eroded, Loring soils typically have brown silt loam surface horizons, brown silt loam or silty clay loam upper subsoils, and a fragipan in the lower subsoil. Depth to the fragipan is commonly 30 to 36 inches. Loring soils differ from Grenada soils in being generally deeper to the fragipan, in having a more weakly developed fragipan, and in lacking a light-colored A'2 horizon immediately above the fragipan (Brown et al., 1965; Brown et al., 1973; Buntley et al., 1977; Flowers et al., 1964). Loring soils are in the western and central sections of West Tennessee in areas covered with more than four feet of loess. They are on nearly level to strongly sloping areas of the landscape. Slopes range from 0 to 20%. Loring soils used in this study were on farms in Gibson County in 1976 and in Gibson and Carroll counties in 1977, and in experiment station fields at Martin in Weakley County and at Ames Plantation in Fayette and Hardeman counties in both years.

Lexington soils are fine-silty, mixed, thermic Typic Paleudalfs. They are well-drained upland soils developed in loess two to four feet thick overlying sandy Coastal Plains sediments. When not eroded, they have brown silt loam surface horizons and reddish-brown silty clay loam or silt loam upper subsoil horizons, which overlie loam or sandy loam lower subsoils formed in Coastal Plains sediments. The lower subsoils become increasingly sandy with depth (Flowers et al., 1960; Brown et al., 1978). To meet the criteria for the Lexington series under the present classification system, the Coastal Plains material must be at least 20 inches below the surface. Many areas on strongly sloping, severely eroded slopes which originally were mapped as Lexington soils will not meet this criteria. However, in this study all of the soils used were deeper than 20 inches to the sandy layer except one in Henry County and one in Carroll County in 1976. Lexington soils are found on nearly level to sloping areas in the eastern and east-central sections of West Tennessee where the loess is generally thinner than four feet. Slopes generally range from 2 to 15%, though they may occasionally range up to 30%. Lexington soils used in this study were on farms in Henry, Carroll, Henderson, Chester, and McNairy counties in both years, and in Hardeman County in 1976.

These four soils were chosen for a number of reasons. They are among the most extensive upland soils of West Tennessee in acreage. They are very important agriculturally in the areas in which they occur. All four can be highly productive under good management, and they are extensively used for cropland. Under present management they are often used for continuous soybean soybean culture, even on steeper slopes. Because of their silty nature and their present management, they are highly susceptible to erosion. This makes them good choices for a study of erosion effects on yields. Also, these four series present a wide range of profile characteristics. Because of this, they can provide a test for erosion and slope effects on yield over a wide range of soils.

II. SELECTION OF SITES

Sites used in this study were selected from soybean fields on cooperators' farms and from production fields on experiment stations in West Tennessee. Fields selected contained areas of Memphis, Grenada, Lexington, or Loring soils which contained at least two or more soil mapping units differing in slope or erosion or both. Originally, it was planned to concentrate on Memphis, Grenada, and Lexington soils, and to use Loring soils only when they were in the same field with one of the others. Although this was not strictly adhered to, it did result in fewer Loring samples.

Slope classes used in the study were 2-5%, 5-8%, and 8-12%, hereafter referred to as B, C, and D slopes, respectively. Erosion classes used were slightly eroded, moderately eroded, and severely eroded, hereafter referred to as 1, 2, and 3 erosion, respectively. All possible combinations of these slope and erosion classes gave nine soil mapping units to be sampled within each soil series. These were B1 (2-5% slopes, slightly eroded), B2 (2-5% slopes, moderately eroded), B3 (2-5% slopes, severely eroded), C1 (5-8% slopes, slightly eroded), C2 (5-8% slopes, moderately eroded), C3 (5-8% slopes, severely eroded), D1 (8-12% slopes, slightly eroded), D2 (8-12% slopes, moderately eroded), and D3 (8-12% slopes, severely eroded).

It was very difficult to find C1, C2, D1, or D2 soil mapping unit sites in cultivated fields in West Tennessee, because most slopes steeper than 5% had undergone severe erosion due to intensive row cropping. No cultivated D1 sites of any of the four soils were found. Only a few D2, C1, and C2 areas were used in the study, and only on Memphis soils in 1976 were sites of all three of these mapping units used. Consequently, most of the areas sampled were B1, B2, B3, C3, and D3 mapping units. This sampling distribution allowed a test of the effect of erosion within B slopes on yields, and a test of the effect of slope within severe erosion on yields. The number of sites of each soil mapping unit sampled within each soil, by year, is given in Table 1. These figures do not include a few sites that were selected, but from which no samples were taken due to early harvest by the farmer.

The sites to be sampled in the soybean fields were selected in June after the soybeans had emerged. This was done to remove the possibility of lower yields on some sites due to poor stands. The Soil Conservation Service District Conservationists in the 17 counties chose 2 to 4 fields on private farms in each of their counties as prospective experimental sites. They based their choices on soil maps of the fields and the management ability of the farm operators. The District Conservationists were asked to choose only those farms which were operated by superior managers, in order to reduce, as much as possible, variation in yields due to management. Each field was then inspected by the Soil Conservation Service Area Soil Scientist, who selected the areas of the various soil mapping units present in the field from which yield samples were to be taken. From 2 to 5 soil mapping unit sites were selected in each field. Whenever areas of two or more soil mapping units of one of the four soils could be located in a field, the field was chosen for sampling. As many different mapping

TABLE 1. Number of soil mapping units sampled by year and soil series

Year	Soil Series	Soil Mapping Unit							
		B1	B2	B3	C1	C2	C3	D2	D3
1976	Memphis	7	9	3	1	2	6	1	2
1976	Grenada	9	10	4	-	3	7	-	3
1976	Lexington	5	3	4	-	-	4	1	4
1976	Loring	2	3	-	-	3	1	-	1
1977	Memphis	6	9	8	-	1	10	-	5
1977	Grenada	10	14	7	-	1	11	-	6
1977	Lexington	4	5	5	-	1	7	-	3
1977	Loring	4	3	1	-	2	1	-	1

units as could be located in the field were selected as sites for sampling. Sites in fields on Ames Plantation and on one farm adjoining the Milan Field Station in Gibson County were selected by Dr. George Buntley and Dr. Frank Bell of the University of Tennessee Plant and Soil Science Department in 1976, and by the author in 1977. Sites on the Martin Experiment Station were chosen by the Area Soil Scientist.

In selecting and verifying the identify of the various soil mapping units within each soil series, slope of the prospective site was determined by use of a hand-held Abney level. Erosion class was determined according to criteria set up as guidelines at the beginning of the study. For Memphis and Lexington soils, erosion class was based on texture and color of the plow layer. If the plow layer contained less than 12% clay and the color was 10YR in hue, then the erosion class was slightly eroded. If the plow layer contained more than 12% clay and the hue was 10YR, the erosion class was moderately eroded. If the hue was 7.5YR in the plow layer, the erosion class was severely eroded. The clay content and color were based on the judgment of the individual selecting the sites, and were not verified by textural analysis or use of a color book. For Grenada soils, erosion class was based on depth to the light colored A'2 horizon overlying the fragipan. If the depth to the A'2 horizon was 20 inches or more, the site was considered to be slightly eroded. If the depth to the A'2 horizon was between 12 inches and 20 inches, the site was considered to be moderately eroded. If the depth to the A'2 horizon was less than 12 inches, the site was considered to be severely eroded. For Loring soils, erosion class was based on the depth to the fragipan. If the depth to the fragipan was 28 inches or more, the site was considered to be slightly eroded. If the depth to the fragipan was 20 inches to 28 inches, the site was considered to be moderately eroded. If the depth to the fragipan was 20 inches or less, the site was considered to be severely eroded. For Grenada and Loring soils the depth to either the A'2 horizon or fragipan was determined on the site to be sampled when the sites were selected.

III. COLLECTION OF DATA

At the time the sites were selected, three row sections ten feet in length within each soil mapping unit area selected were marked with flags for eventual harvest. The row sections to be harvested were selected by first marking one ten-foot section, then skipping two rows to the right or left and marking another, and then skipping two more rows and marking another. Where size and shape of the mapping unit and row orientation permitted, the row sections marked were spaced diagonally to one another, rather than directly to the right or the left. Harvesting of the selected row sections was carried out by the local Soil Conservation Service District Conservationists in the fields on cooperators' farms, and by Experiment Station personnel in experiment station fields. Each row section was harvested separately, giving three yield samples from each mapping unit site. In a few cases, all three row sections were placed together at harvest due to misunderstanding on the part of the harvesters, giving only one yield sample for these sites. Harvested samples were threshed at the West Tennessee Experiment Station at Jackson under the supervision of Mr. Joe Overton and at the U.T. Martin Experiment Station under the supervision of Dr. Bobby Duck in 1976. All 1977 samples were threshed at Martin. All yields were adjusted to 13% moisture content and then converted from pounds to bushels per acre, based on the row widths as determined at harvest.

Management practices used in each field were determined and recorded by the local District Conservationists or by Experiment Station personnel using the information sheet shown in Appendix A. Information obtained included planting date, soybean variety, harvest date, fertilization and liming rates, use of molybdenum, and herbicides used. Where available, information on past land use was obtained. Summaries of some of the management practices used are contained in Appendix B. Soil samples were taken from the plow layer near each row section selected. These samples were analyzed by the University of Tennessee Soil Testing Laboratory for pH, available phosphorous and available potassium. Any conservation practices being used on the sites were recorded. Shape of slope, either concave, convex, or smooth, was recorded at each site. The slope gradient at each site was measured and recorded. Depths to the A'2 horizon, fragipan, and Coastal Plains material were determined on Grenada, Loring, and Lexington soils, respectively.

IV. STATISTICAL ANALYSIS

The experimental design used for this study was an incomplete block, in which fields were blocks, soil mapping units were the main effects, and row sections were subsamples within the soil mapping units. Because the soil mapping units within a given soil did not occur together within fields the same number of times, a least squares analysis of variance was deemed appropriate. Field and soil mapping unit effects were estimated for each soil within the separate years. The model used contained field, soil mapping unit, and the interaction of soil mapping units and fields as classes of effects. Because the variation due to the interaction of soil mapping units and fields was large relative to the variation due to subsamples within soil mapping units, the interaction was considered to be the proper error term in testing main effects. Because of this, computations were made using the mean of the subsamples rather than the individual subsample yields. Alpha risk for all tests was set at 0.10.

Effects were estimated for each soil across both years using a model containing years, fields nested within years, soil mapping unit, the interaction of soil mapping unit and year, and the interaction of fields and soil mapping units nested within years as classes of effects. The effect due to the interaction of soil mapping units and years was tested for significance using the interaction of fields and soil mapping units nested within years as the error term. Main effects were tested by a pooled error term containing the effects of both interactions. Alpha risk for all tests of significance of effects was set at the 0.10 level.

Tests of erosion and slope effects were made by predetermined comparisons of pairs of least squares mean yields of soil mapping units within the respective soil series. The least squares mean yields were mean yields of the soil mapping units adjusted for the other effects in the models. Differences between the yields were tested by t-test, using the same error terms used in testing the main effects.

Five comparisons of mean yields were used for all soils. These were B1 and B3, B3 and D3, B2 and C3, B2 and B3, and B1 and D3. The comparison of B1 and B3 mean yields was chosen to test the effect of erosion on yields with slope held constant. The comparison of B3 and D3 mean yields was chosen to test the effect of slope on yields with erosion held constant. B2 and C3 mean yields were compared because they represent two of the most common mapping units of these soils found in cultivated fields in West Tennessee, and because they test the combined effect of increased slope and increased erosion on yields. The B2 and B3 comparison of yields was chosen to test the effect of further erosion on a soil which was already moderately eroded. The B1 and D3 comparison was chosen to test the combined effect of erosion and slope on yields. In addition to these five, other comparisons were added in a few cases when more degrees of freedom for soil mapping unit were available.

Partial effects due to shape of slope, either concave, convex, or smooth, and fertility were determined for each soil within the individual years, with the field and soil mapping unit effects in the models. Shape of slope was included in the models as a class effect. Available phosphorous (P), available potassium (K) and pH were included in the models as continuous variables. Fertility variables were tested first for their linear effects alone. Then pH and K were tested for both linear and quadratic effects (pH^2 and K^2). The partial effects of slope shape and fertility variables were tested for significance using the F-test. The error term was the field by soil mapping unit interaction. Alpha risk was set at the 0.10 level. If the partial effects were significant, the least squares mean yields of the soil mapping units were examined to see what effect adjustment for slope shape or fertility variables had on their comparisons.

CHAPTER IV

RESULTS AND DISCUSSION

I. RESULTS FROM 1976

The average soybean yield in 1976 across all soils, fields, and soil mapping units was 30.7 bushels per acre. This was a relatively high average yield when compared with state and county averages, indicating that the fields chosen probably had better than average management. There was considerable variation in yields across all soils, fields, and soil mapping units. The highest yield recorded in 1976 was 51.1 bushels per acre on a Memphis C3 site at Ames Plantation. The lowest yield recorded was 9.5 bushels per acre on a Memphis D2 in Dyer County.

Yields from sites on Memphis soils are shown in Table 2. The average yield of all sites on Memphis soils in 1976 was 33.3 bushels per acre. The high and low yields on Memphis soils were 51.1 bushels per acre on a C3 site at Ames Plantation and 9.5 bushels per acre on a D2 site in Dyer County. Yields varied considerably from field to field. This would be expected, due to differences from field to field in management and weather.

Average yields and least squares mean yields for each soil mapping unit sampled on Memphis soils in 1976 are shown in Table 3. The least squares means are adjusted for differences between fields, and are shown along with their standard errors. When adjusted for differences between

TABLE 2. Soybean yields on Memphis soils by field in 1976

Field	Soil Mapping Unit							
	B1	B2	B3	C1	C2	C3	D2	D3
	Bu/A							
<u>Dyer Co.</u>								
Field 1	-	18.2	-	-	-	32.6	-	-
Field 2	-	32.3	-	-	-	-	9.5	-
<u>Gibson Co.</u>								
Field 1	38.1	35.0	-	-	-	-	-	-
<u>Lauderdale Co.</u>								
Field 1	-	-	-	29.6	-	30.3	-	-
<u>Madison Co.</u>								
Field 1	-	39.7	-	-	-	42.9	-	-
Field 2	-	20.4	-	-	27.7	-	-	-
<u>Obion Co.</u>								
Field 1	-	45.7	-	-	43.0	-	-	-
<u>Shelby Co.</u>								
Field 1	32.3	34.8	35.8	-	-	33.8	-	-

TABLE 2 (continued)

Field	Soil Mapping Unit							
	B1	B2	B3	C1	C2	C3	D2	D3
	Bu/A							
Tipton Co.								
Field 1	25.7	-	34.2	-	-	-	-	-
Field 2	20.7	15.7	-	-	-	19.6	-	-
Field 3	-	-	27.8	-	-	-	-	20.1
Ames Plantation								
Field 1	50.1	-	-	-	-	-	-	44.7
Field 3	46.6	46.7	-	-	-	-	-	-
Field 5	47.8	-	-	-	-	51.1	-	-

TABLE 3. Average and least squares mean soybean yields on Memphis soils in 1976

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		--------------	Bu/A --------------	
B1	7	37.3	34.4	1.5
B2	9	32.1	32.5	1.4
B3	3	32.6	38.9	2.6
C1	1	29.6	36.9	4.9
C2	2	35.3	34.7	3.4
C3	6	35.1	37.6	1.7
D2	1	9.5	9.6	4.8
D3	2	32.4	30.2	3.5

*Adjusted for differences between fields.

fields, the highest mean yield was that of the B3 mapping units, at 38.9 bushels per acre, while the lowest mean yield was found to be on the D2 mapping units at 9.6 bushels per acre. The D2 estimate was based on only one site, and was not a good measure of yields on Memphis D2 sites as a whole. Estimates for B3, C1, C2, D2, and D3 soil mapping units were all based on few samples, which explains their high standard errors relative to the other soil mapping units sampled.

Results of the comparisons between least squares means are given in Table 4. The comparison between B1 and B3 mean yields showed B3 yields to be 4.5 bushels per acre higher than B1 yields. The difference was not significant at the 0.10 level of probability, indicating that erosion had no effect on yields on Memphis soils on B slopes in 1976. The B3 mean yield was based on only three samples, and the fact that it was higher than the B1 yield was probably due to random chance. The comparison between the mean yields of B3 and D3 mapping units showed a yield advantage of 8.7 bushels per acre for the B3 sites. This difference was significant at the 0.10 level of probability. This indicated that an increase in slope on severely eroded sites resulted in reduced yields on Memphis soils in 1976. The comparison between B2 and C3 mean yields showed C3 yields to be 5.1 bushels per acre higher, significant at the 0.10 level of probability. The comparison between B2 and B3 mean yields showed the B3 yields to be 6.4 bushels per acre higher, also significant at the 0.10 level of probability. Taken together, these two comparisons suggest that increasing erosion and slope actually increased yields over those obtained on B2 sites. On the other hand, the comparison between B1 and D3 mean

TABLE 4. Comparisons of least squares mean yields on Memphis soil mapping units in 1976

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	-4.5#	0.144 n.s.
B3 - D3	8.7	0.039 **
B2 - C3	-5.1	0.045 **
B2 - B3	-6.4	0.072 *
B1 - D3	4.2	0.277 n.s.
C2 - C3	-2.9	0.502 n.s.
B1 - B2	1.9	0.390 n.s.

*Significant at the 0.10 level of probability.

**Significant at the 0.05 level of probability.

#Negative sign indicates a higher mean yield for the second soil mapping unit in the comparison.

n.s. - Not significant at the 0.10 level of probability.

yields showed no significant difference due to the combination of increased slope and severe erosion. The other two comparisons, C2 versus C3 and B1 versus B2, showed small, insignificant differences.

The results of the mean comparisons of Memphis soil mapping units were contradictory. Some showed no effect due to slope or erosion, others showed significantly higher yields on steeper, more eroded sites, while still another showed a significant reduction in yield due to increased slope with erosion held constant. The main source of these contradictory results was the low mean yield on B2 sites relative to B3 and C3 sites. Because of the number of samples of B2 and C3 yields available and the statistical significance of the results, it does not seem likely that the lower B2 yield was due to random chance alone. Part of the explanation may be found in the nature of the Memphis subsoil. As Typic Hapludalfs, Memphis soils have B2t horizons with a higher clay content than the A horizons. However, these B2t horizons are relatively thin, and are underlain by silty material which is higher in available water-holding capacity than the more clayey B2t material. When the sites were chosen, the erosion class was based on texture and color of the plow layer on Memphis soils. Moderately eroded sites were those in which the plow layer was a mixture of original A horizon material and material from the underlying B horizon, while on severely eroded sites the plow layer consisted largely, or entirely, of B horizon material. Because the B horizon had a higher clay content than the A horizon, it was expected that the loss of the A horizon material would result in a lower available water-holding capacity for the rooting zone, and therefore lower yields. However, in many areas of Memphis soils in West Tennessee, past erosion has been so severe that most of the B horizon has been removed along with the A horizon. Although these soils no longer belong in the Memphis series in many cases, they are often mapped as taxadjuncts to Memphis. In these cases, the rooting zones extend into the silty material underneath the B2t horizon, and the available water-holding capacity of the soil profile may actually be higher than that of moderately eroded sites where the rooting zones are in the more clayey B2t horizons. This possibility was not considered when the sites were selected in 1976, and some of the B3 and C3 samples may have been taken from such very severely eroded sites. This may account for some of the higher yields on severely eroded sites than on moderately eroded sites, but it needs further investigation before anything definite can be stated.

Overall, 1976 results indicated that erosion did not decrease yields on Memphis soils, but that a trend toward decreased yields with increasing slope on severely eroded areas did exist. However, the slope effect was based on estimates made with few samples, and was contradicted by some of the other results.

Yield data for Grenada sites in 1976 are shown in Table 5. The average yield of all sites on Grenada soils was 27.5 bushels per acre. The highest yield was 49.5 bushels per acre on a B1 site at Ames Plantation, and the lowest yield was 10.9 bushels per acre on a D3 site in Fayette County. Yields varied widely from field to field, and there were differences in the relative yields of the soil mapping units from field to field.

Average and least squares mean yields for the soil mapping units

TABLE 5. Soybean yields on Grenada soils by field in 1976

Field	B1	B2	B3	C2	C3	D3
	Soil Mapping Unit					
	Bu/A					
Crockett Co.						
Field 1	-	-	30.7	-	13.5	-
Field 2	-	40.2	-	-	25.1	-
Field 3	25.1	-	-	-	-	16.1
Fayette Co.						
Field 1	16.0	-	-	-	-	10.9
Field 2	-	-	42.7	-	-	31.5
Gibson Co.						
Field 1	44.6	28.0	-	-	-	-
Field 2	20.9	15.3	-	-	-	-
Haywood Co.						
Field 1	17.8	14.6	11.4	-	-	-
Field 2	20.8	-	-	17.4	14.4	-
Field 3	-	23.2	-	-	10.8	-
Lauderdale Co.						
Field 1	-	-	42.2	-	20.3	-
Obion Co.						
Field 2	-	33.3	-	-	43.1	-
Tipton Co.						
Field 3	22.0	-	-	-	22.2	-
Weakley Co.						
Field 1	-	47.0	-	46.3	-	-
Ames Plantation						
Field 3	49.5	-	-	-	-	-
Field 4	31.5	33.7	-	-	-	-
Field 5	-	40.3	-	-	-	-
Martin						
Field 2	-	35.1	-	39.1	-	-

sampled on Grenada soils are given in Table 6. The highest least squares mean yield was that of the B3 sites, at 36.2 bushels per acre. The lowest mean yield was 23.0 bushels per acre on the C3 sites. Fewer samples of B3, C2, and D3 yields were taken than of the other soil mapping units, leading to higher standard errors for those three soil mapping units.

Results of the comparisons of least squares mean yields of the soil mapping units are shown in Table 7. Mean yields of the B3 sites were 3.5 bushels per acre higher than those of the B1 sites, but this difference was not significant at the 0.10 level of probability. The comparison of B3 and D3 mean yields showed the B3 yields to be 9.9 bushels per acre higher. However, because of small sample numbers, both the B3 and D3 least squares means had large standard errors, and the 9.9 bushel per acre difference was not significant at the 0.10 level of probability. B2 mean yields were 5.5 bushels per acre higher than C3 mean yields, but the difference was not significant at the 0.10 level of probability. B2 mean yields were found to be 7.7 bushels per acre lower than B3 yields. The difference was not significant at the 0.10 level of probability, and was therefore apparently due to random chance in sampling. Mean yields of D3 sites were 6.4 bushels per acre lower than those of B1 sites but this difference was not significant at the 0.10 level.

Although some of the differences between the pairs of means were large, none were statistically significant. This was because of the variability in the relative yields of the soil mapping units within fields, and because of small sample numbers of some of the soil mapping units. Based on the comparisons of the B slope soil mapping units, there was no

TABLE 6. Average and least squares mean soybean yields on Grenada soils in 1976

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		Bu/A		
B1	9	27.3	32.7	2.4
B2	10	30.7	28.5	2.3
B3	4	31.8	36.2	4.0
C2	3	34.3	29.1	4.5
C3	7	21.0	23.0	2.8
D3	3	19.5	26.3	4.9

*Adjusted for differences between fields.

TABLE 7. Comparisons of least squares mean yields on Grenada soil mapping units in 1976

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	-3.5#	0.476 n.s.
B3 - D3	9.9	0.114 n.s.
B2 - C3	5.5	0.166 n.s.
B2 - B3	-7.7	0.140 n.s.
B1 - D3	6.4	0.239 n.s.

#Negative sign indicates a higher mean yield for the second soil mapping unit in the comparison.

n.s. - Not significant at the 0.10 level of probability.

difference in yield due to erosion on the Grenada soils on B slopes. There did appear to be a trend toward lower yields as slope increased, but the comparison testing the effect of slope on severely eroded sites was not quite significant at the 0.10 level of probability. This was largely due to the low number of samples from B3 and D3 sites. Tests of the combined effects of increased slope and erosion showed no significant differences in yield.

Yields from sites on Lexington soils in 1976 are shown in Table 8. The average yield of all Lexington sites was 30.1 bushels per acre. The highest yield was 46.0 bushels per acre on a C3 site in Hardeman County, and the lowest was 12.3 bushels per acre on a B1 site in Henry County. Of the sites originally selected, samples from eight sites in Henderson County were lost due to a fire after harvest, and three others in Chester County were lost when the farmer harvested the field before they could be sampled. Because of this, there were fewer samples from Lexington soils than from Memphis or Grenada soils.

The average and least squares mean yields of the Lexington soil mapping units are shown in Table 9. The highest least squares mean yield was on the B2 sites, and the lowest was on the D3 sites, at 33.0 and 26.4 bushels per acre, respectively. The least squares mean yields of the soil mapping units showed an overall trend toward reduced yields due to both increased slope and increased erosion. However, none of the comparisons of means, shown in Table 10, were significant at the 0.10 level of probability. All the differences between pairs of means showed lower yields due to increased slope and erosion, but the differences were too small for

TABLE 8. Soybean yields on Lexington soils by field in 1976

Field	B1	B2	B3	C3	D2	D3
	Soil Mapping Unit					
	Bu/A					
Carroll Co.						
Field 1	-	-	23.4	-	-	19.5
Field 2	-	23.6	-	-	19.8	-
Chester Co.						
Field 1	34.8	-	34.5	31.7	-	-
Hardeman Co.						
Field 1	-	49.5	39.1	-	-	-
Field 2	-	-	45.8	46.0	-	-
Henry Co.						
Field 1	31.6	-	-	-	-	32.9
Field 2	12.3	-	-	17.3	-	-
McNairy Co.						
Field 1	27.9	20.0	-	-	-	14.7
Field 2	41.7	-	-	36.9	-	32.3

TABLE 9. Average and least squares mean soybean yields on Lexington soils in 1976

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		---------- Bu/A	----------	----------
B1	5	29.7	32.3	2.3
B2	3	31.0	33.0	3.4
B3	4	35.4	29.3	2.6
C3	4	33.0	30.6	2.7
D2	1	19.9	29.3	6.7
D3	4	24.9	26.4	2.6

*Adjusted for differences between fields.

TABLE 10. Comparisons of least squares mean yields on Lexington soil mapping units in 1976

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	3.0	0.433 n.s.
B3 - D3	2.9	o.464 n.s.
B2 - C3	2.4	0.557 n.s.
B2 - B3	3.7	0.426 n.s.
B1 - D3	4.8	0.102 n.s.

n.s. - Not significant at the 0.10 level of probability.

statistical significance at the 0.10 level of probability. The comparison between the B1 and D3 means was very close to significance, and would have been significant at the 0.11 level of probability. This indicated that there probably were reductions in yield due to slope and erosion on Lexington soils in 1976, but the reductions in yield were small.

Yield of sites on Loring soils are given in Table 11. The average yield of all sites on Loring soils was 35.1 bushels per acre, highest of the four soils studied in 1976. There were only ten Loring sites sampled in 1976, and seven of those were in experiment station fields at Ames Plantation and at Martin. This probably accounted for the high yield. Because of the small number of samples, no analysis of the Loring results was made. In order to make use of the data from the Loring sites, a combined analysis was made of the Loring and Grenada data. This was done because both Loring and Grenada soils are moderately well-drained fragipan soils, and would be expected to be affected by slope and erosion in much the same manner.

Average and least squares mean yields of the soil mapping units with the Loring and Grenada data combined are given in Table 12. The highest mean yield was 38.2 bushels per acre on the B3 sites, while the lowest was 26.0 bushels per acre on the C3 sites. Results of the comparisons between means are shown in Table 13. There was a significant difference between B3 and D3 mean yields, with B3 yields being 10.8 bushels per acre higher. B3 mean yields were 8.1 bushels per acre higher than B2 mean yields. This was also significant at the 0.10 level of probability. None of the other three comparisons showed a significant difference in yields.

TABLE 11. Soybean yields on Loring soils by field in 1976

Field	B1	B2	C2	C3	D3
	Soil Mapping Unit				
	---------- Bu/A ----------				
Gibson Co.					
Field 1	-	-	39.5	-	-
Field 2	-	21.2	-	20.3	-
Ames Plantation					
Field 2	50.1	-	-	-	-
Field 3	40.1	-	-	-	-
Field 4	-	35.1	41.3	-	-
Martin					
Field 1	-	36.9	36.1	-	32.9

TABLE 12. Average and least squares mean soybean yields on Grenada and Loring soils in 1976

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		-----------	Bu/A	-----------
B1	11	30.5	33.2	2.1
B2	13	31.1	30.1	1.9
B3	4	31.8	38.2	3.7
C2	6	36.6	32.6	2.9
C3	8	21.2	26.0	2.4
D3	4	22.9	27.4	3.6

*Adjusted for differences between fields.

TABLE 13. Comparisons of least squares mean yields on Grenada and Loring soil mapping units in 1976

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	- 5.0#	0.274 n.s.
B3 - D3	10.8	0.043 **
B2 - C3	4.1	0.191 n.s.
B2 - B3	- 8.1	0.078 *
B1 - D3	5.8	0.177 n.s.

*Significant at the 0.05 level of probability.

**Significant at the 0.10 level of probability.

#Negative sign indicates a higher mean yield for the second soil mapping unit in the comparison.

n.s. - Not significant at the 0.10 level of probability.

The comparisons indicated that increased slope reduced yields significantly on Loring and Grenada soils in 1976 when erosion was held constant. However, this result was contradicted by the comparisons testing the combined effects of both increased slope and erosion, neither of which was significant. The large difference between B3 and D3 slopes was based on fewer samples than any of the other comparisons, and therefore the size of the difference is somewhat suspect, especially when compared with a difference of only 5.8 bushels per acre between B1 and D3 sites. There is no logical explanation of why the B3 yields were significantly higher than the B2 yields. All the B3 sites had less soil material above the fragipan, and were lower in available water-holding capacity. Even in a year of good rainfall there would be no reason for yields on the severely eroded sites to be higher. It is doubtful that this difference would have occurred had there been more B3 samples taken in fields where B2 or B1 samples were also taken. Probably the best interpretation of the results on Grenada and Loring soils is that no difference in yields was shown due to erosion in 1976, but there was a trend toward reduced yields on steeper slopes.

Overall, in 1976 there was no significant reduction in yield on any soil due to erosion when slope was held constant. On the Memphis soils and on the Grenada and Loring soils yields on severely eroded B slopes were significantly higher than on moderately eroded B slopes. This can not be adequately explained at present, especially on Grenada and Loring soils. On Lexington soils there did appear to be a trend toward reduced yields as erosion increased, but it was not significant statistically. The lack of yield reductions due to erosion was surprising on the Grenada and Loring soils, with fragipans in their lower subsoils, and on the Lexington soils, with sandy lower subsoils. It was not as surprising on the Memphis soils with their deep, silty subsoils. The lack of response to erosion may be due to favorable rainfall over most of West Tennessee in 1976. Monthly rainfall totals for the 1976 growing season at three representative West Tennessee stations and for West Tennessee as a whole are given in Table 14. The figures show greater than normal rainfall for the period May through July for two of the three stations and for West Tennessee as a whole, and then below normal rainfall for August and September. Buntley et al. (1973) found that rainfall during flowering and pod filling was very important in determining yields of soybeans. For most of the soybeans in this study, those stages would have been in late July and August. Although rainfall in August was below normal, the high rainfall in the May through July period may have stored enough water in even the droughty soils to allow the soybeans to go through most of the flowering and pod filling stages without undergoing severe moisture stress.

On all the soils, there was a trend toward reduced yield as slope increased, although the effect of slope alone was not large enough to be significant on Lexington soils. This result was in general agreement with the findings of Buntley (1972), who reported differences due to slope on soybean yields in a year of high rainfall in 1971. This probably reflects the effect of a lower moisture supply due to runoff on the steeper slopes.

TABLE 14. Growing season monthly rainfall at three representative stations and for West Tennessee overall in 1976

Month	Jackson		Martin		Milan		West Tennessee	
	Rainfall	Difference From Normal	Rainfall	Difference From Normal	Rainfall	Difference From Normal	Rainfall	Difference From Normal
	Inches							
Apr.	1.57	-3.54	1.98	-2.59	2.26	-2.70	2.01	-2.93
May	7.62	3.55	4.93	.66	6.92	2.39	5.56	1.17
June	3.17	- .46	5.81	1.32	5.13	.82	5.61	1.81
July	2.25	-1.84	5.27	.97	4.52	.65	4.32	.45
Aug.	.88	-2.13	1.88	-1.13	3.82	.20	1.67	-1.51
Sept.	3.56	.34	1.98	-1.52	2.03	1.59	2.75	- .64

Source: National Oceanic and Atmospheric Administration. Environmental Data Service. Climatological Data - Annual Summary for Tennessee. 1976. 81(13):4.

II. RESULTS FROM 1977

The overall average soybean yield of all sites in 1977 was 27.6 bushels per acre, 3.1 bushels per acre lower than in 1976. There was a wider range of yields in 1977. The highest yield was 65.7 bushels per acre on a Memphis B2 site in Obion County. The lowest yield was 5.6 bushels per acre on a Lexington D3 site in McNairy County. The lower overall yield and the higher variability in yields in 1977 may be due to rainfall differences between the two years. Table 15 gives monthly growing season rainfall totals for three representative West Tennessee stations and for West Tennessee as a whole in 1977. Rainfall for West Tennessee was below normal during the April through July period, and above normal for August and September. In 1976 rainfall was above normal during the May through July period, and below normal in August and September. The dry weather in the early and middle portions of the growing season in 1977 may have caused less vegetative growth, and may have led to moisture stress in the early parts of the flowering and pod filling stages for some of the soybean fields in the study. This could have caused the lower overall yields. In addition, it was observed in the fields in 1977 that there was severe moisture deficiency in many local areas of West Tennessee. This probably reduced yields in some fields and led to the greater variability in yields in 1977.

Yields of sites on Memphis soils in 1977 are given in Table 16. The average yield on Memphis soils in 1977 was 33.9 bushels per acre. This was 0.6 bushels per acre higher than in 1976. The highest yield on Memphis soils was 65.7 bushels per acre on a B2 site in Obion County. This was

TABLE 15. Growing season monthly rainfall at three representative stations and for West Tennessee overall in 1977

Month	Jackson		Martin		Milan		West Tennessee	
	Rainfall	Difference From Normal	Rainfall	Difference From Normal	Rainfall	Difference From Normal	Rainfall	Difference From Normal
	Inches							
Apr.	4.67	- .44	6.57	2.00	4.28	- .68	4.76	- .18
May	2.54	-1.53	4.23	- .04	2.94	-1.59	2.61	-1.78
June	3.54	- .09	3.69	- .80	3.74	- .57	3.35	- .45
July	3.40	- .69	3.61	- .69	3.23	- .64	3.01	- .86
Aug.	2.96	- .05	6.53	3.52	5.15	1.53	3.81	.63
Sept.	10.82	7.60	8.85	5.35	9.63	6.01	8.65	5.26

Source: National Oceanic and Atmospheric Administration. Environmental Data Service. Climatological Data - Annual Summary for Tennessee. 1977. 82(13):4.

TABLE 16. Soybean yields on Memphis soils by field in 1977

Field	Soil Mapping Unit					
	B1	B2	B3	C2	C3	D3
	Bu/A					
Dyer Co.						
Field 1	-	22.2	-	-	27.6	31.6
Field 2	-	-	42.1	-	40.3	36.2
Gibson Co.						
Field 1	23.8	20.0	-	-	-	-
Lauderdale Co.						
Field 2	-	-	31.0	-	32.5	25.9
Field 3	-	41.9	25.7	-	25.8	29.6
Madison Co.						
Field 1	-	56.8	40.9	-	49.6	-
Field 3	-	36.1	32.3	-	14.4	-
Obion Co.						
Field 3	-	65.7	56.5	-	56.2	52.1
Shelby Co.						
Field 1	31.6	34.4	37.0	-	39.3	-
Tipton Co.						
Field 1	10.9	15.1	20.3	-	12.7	-
Ames Plantation						
Field 3	36.6	35.8	-	-	-	-
Field 5	42.2	-	-	-	24.3	-
Field 6	37.8	-	-	26.1	-	-

the highest yield obtained on any soil in the two years of the study. The lowest yield on Memphis soils in 1977 was 10.9 bushels per acre on a B1 site in Tipton County. The wide difference between these yields shows the degree of variability which existed in yields in 1977.

Average yields and least squares mean yields for the soil mapping units sampled on Memphis soils in 1977 are shown in Table 17. When adjusted for differences between fields, the highest least squares mean yield was 37.3 bushels per acre on the B2 sites. The lowest was 24.1 bushels per acre on the C2 sites, but this was based on only one sample. The next lowest yield was on the D3 sites, with 30.6 bushels per acre. Overall, the mean yields of the soil mapping units followed the expected pattern, declining as slope and erosion increased, but the yield reductions were small.

Results of the comparisons of the least squares mean yields of the Memphis soil mapping units are shown in Table 18. The only comparison showing a significant difference between two mean yields was the comparison of B2 and C3 yields. This comparison showed the C3 yields to be 6.3 bushels per acre lower than the B2 yields, due to the combined effects of increased slope and erosion. The comparison of B1 and D3 mean yields showed a decrease of 5.1 bushels per acre, but this decrease was not significant at the 0.10 level of probability. The other three comparisons showed small decreases in yield due to either increased slope or increased erosion, but none of these decreases were large enough to be significant. The comparisons indicate that neither the effect of increased slope nor the effect of increased erosion significantly reduced yields when the other was held

TABLE 17. Average and least squares mean soybean yields on Memphis soils in 1977

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		-------------	Bu/A	-------------
B1	6	30.5	35.7	3.0
B2	9	36.4	37.3	2.2
B3	8	35.7	33.4	2.5
C2	1	26.1	24.1	9.0
C3	10	32.3	31.0	2.2
D3	5	35.1	30.6	3.3

*Adjusted for differences between fields.

TABLE 18. Comparisons of least squares mean yields on Memphis soil mapping units in 1977

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	2.3	0.589 n.s.
B3 - D3	2.8	0.472 n.s.
B2 - C3	6.3	0.051 *
B2 - B3	3.9	0.237 n.s.
B1 - D3	5.1	0.312 n.s.

*Significant at the 0.10 level of probability.

n.s. - Not significant at the 0.10 level of probability.

constant. However, the combined effects of increased slope and erosion did result in significantly lower yields on C3 sites than on B2 sites. Although the difference between B1 yields and D3 yields was not significant, the comparison did show a fairly large decrease in yields due to slope and erosion. Apparently the combined effects of the two factors did cause significant reductions in yields on Memphis soils in 1977.

Some of the 1977 results on Memphis soils were quite different from the 1976 results. Yields on B3 and C3 sites were lower, while yields on the B1 and B2 sites were higher than in 1976. The relative yields of the soil mapping units were much different from 1976, when both the B3 and C3 yields were significantly higher than the B2 yields. Part of the reason for the lower B3 yields, relative to the B2 yields, may be that more samples were taken from B3 sites in 1977, giving a better estimate of yields. Another reason for the lower yields on the B3 and C3 sites may be that care was taken in 1977 not to choose sites from which most of the B horizon had been removed by very severe erosion, to expose the silty material underneath. Inclusion of such sites was cited earlier as a possible reason for the higher yields on B3 and C3 sites in 1976. Another reason for the lower B3 and C3 yields was the drier weather in 1977. This may have led to a lower moisture supply for the soybeans on the severely eroded areas.

Yields of sites on Grenada soils in 1977 are given in Table 19. The average yield of all Grenada sites was 21.8 bushels per acre in 1977, 5.7 bushels per acre lower than in 1976. This reduction in average yield was probably partly due to drier weather, and partly due to the inclusion

TABLE 19. Soybean yields on Grenada soils by field in 1977

Field	Soil Mapping Unit					
	B1	B2	B3	C2	C3	D3
	Bu/A					
<u>Crockett Co.</u>						
Field 1	-	-	7.0	-	12.2	-
Field 2	-	13.4	7.3	-	10.0	-
Field 3	34.0	16.3	-	-	10.5	7.7
<u>Fayette Co.</u>						
Field 1	25.7	-	-	-	19.2	26.6
Field 2	-	37.0	26.6	-	-	20.6
<u>Gibson Co.</u>						
Field 1	17.8	14.8	-	-	-	-
Field 3	12.3	7.7	-	-	17.8	21.5
Field 4	20.8	16.2	-	-	14.2	-
<u>Haywood Co.</u>						
Field 1	17.9	20.7	8.2	-	22.3	-
Field 2	18.0	11.5	4.2	-	23.7	-
<u>Obion Co.</u>						
Field 4	-	46.6	56.5	-	17.9	-
<u>Weakley Co.</u>						
Field 2	-	41.1	19.1	-	41.4	23.7
Field 3	48.2	42.4	-	-	39.5	19.2
<u>Ames Plantation</u>						
Field 3	38.8	-	-	-	-	-
Field 4	22.6	19.2	-	-	-	-
Field 5	-	36.8	-	-	-	-
<u>Martin</u>						
Field 2	17.8	14.8	-	-	-	-

of relatively more B3, C3, and D3 sites. The highest yield on Grenada soils in 1977 was 56.5 bushels per acre on a B3 site in Obion County, and the lowest yields were 7.7 bushels per acre on a B2 site in Gibson County and on a D3 site in Crockett County. There were large differences in yields from field to field on Grenada soils in 1977, reflecting differences in local rainfall and in management.

Average and least squares mean yields of Grenada mapping units in 1977 are shown in Table 20. The highest least squares mean yield was 28.3 bushels per acre on the B1 sites. The lowest was 12.4 bushels per acre on the C2 sites, but this was based on only one sample. The next lowest yield was 16.4 bushels per acre on the D3 sites. The least squares means indicated a sizeable reduction in yield due to erosion. This was confirmed by the results of the comparisons of least squares means, shown in Table 21. The comparison of B1 and B3 mean yields showed a significant decrease in yield of 9.9 bushels per acre due to severe erosion on B slopes. The comparison of B2 and B3 means showed a 6.6 bushel per acre yield advantage for moderately eroded sites over severely eroded ones, but this difference was not significant at the 0.10 level of probability. The comparison of B2 and C3 means showed no significant difference in yields due to slope on severely eroded areas. The comparison of B2 and C3 mean yields gave no significant difference. The C3 yield was somewhat higher than the yields of the other severely eroded mapping units, and this was the cause of the small difference in the B2 and C3 comparison. The comparison of the B1 and D3 mean yields showed a significant 11.9 bushel per acre yield advantage for the B1 sites. Based on the other comparisons, it appears that most of the difference in yield between the B1 and D3 sites was due to the severe erosion of the D3 sites,

TABLE 20. Average and least squares mean soybean yields on Grenada soils in 1977

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		Bu/A		
B1	10	25.6	28.3	3.2
B2	14	24.1	25.0	2.5
B3	7	18.3	18.4	3.9
C2	1	12.5	12.4	12.7
C3	11	19.5	22.1	3.0
D3	6	19.4	16.4	4.2

*Adjusted for differences between fields.

TABLE 21. Comparisons of least squares mean yields on Grenada soil mapping units in 1977

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	9.9	0.074 *
B3 - D3	2.0	0.720 n.s.
B2 - C3	2.9	0.471 n.s.
B2 - B3	6.6	0.172 n.s.
B1 - D3	11.9	0.030 **

*Significant at the 0.10 level of probability.

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

and not increased slope. Overall, the comparisons of the least squares means showed a significant decrease in yield on Grenada soils due to erosion, but not due to slope. This decrease in yield was probably due to the lower moisture storage capacity of the severely eroded areas. The decreased depth to the fragipan on these areas made the rooting zones shallow, and probably led to moisture stress.

The results on Grenada soils were different in 1976 and 1977. In 1977, a year of lower than normal rainfall, erosion had a significant effect on yield and slope had little effect, while in 1976, a year of above normal rainfall, erosion had no effect on yields, but there seemed to be a trend toward reduced yields on steeper slopes. This was probably related to the rainfall in the two years. In a year of high rainfall, moisture storage capacity would not be as important as in a dry year, but slope would be more important because of runoff water. In a dry year, erosion would be more important because of its effect on moisture storage capacity. This may explain the differences in yields on the Grenada mapping units in 1976 and 1977. Yields were lower on all Grenada soil mapping units in 1977, with the drop in yields being most severe on the severely eroded mapping units. Least squares mean yields dropped 4.4 and 3.5 bushels per acre on the B1 and B2 sites from 1976 to 1977. Mean yields dropped 17.8, 0.9, and 9.9 bushels per acre on the B3, C3, and D3 sites. These figures indicated that yields on Grenada soils would be quite variable from season to season according to rainfall, and that the most variable yields would be on the severely eroded areas

Yields of the sites on Lexington soils in 1977 are given in Table 22. The average yield of all sites in 1977 was 29.3 bushels per acre, about 0.8 bushels per acre less than in 1976. The highest yield in 1977

TABLE 22. Soybean yields on Lexington soils by field in 1977

Field	Soil Mapping Unit					
	B1	B2	B3	C2	C3	D3
	Bu/A					
Carroll Co.						
Field 1	-	29.9	-	-	21.1	-
Chester Co.						
Field 1	36.2	-	35.3	-	20.2	-
Henderson Co.						
Field 1	31.9	-	25.7	-	26.8	-
Field 2	-	36.7	17.8	-	21.6	-
Henry Co.						
Field 3	-	44.3	-	42.5	-	43.7
Field 4	-	34.8	29.6	-	30.9	-
McNairy Co.						
Field 1	27.4	11.2	23.8	-	15.7	5.6
Field 2	40.7	-	-	-	40.8	37.7

on Lexington soils was 44.3 bushels per acre on a B2 site in Henry County, and the lowest yield was 5.6 bushels per acre on a D3 site in McNairy County. Yields varied from field to field, but they did not appear to vary as much as on Grenada soils.

Average and least squares mean yields of Lexington mapping units are given in Table 23. The highest least squares mean yield was 35.9 bushels per acre on B1 sites, and the lowest was 25.1 bushels per acre on D3 sites. The least squares means overall showed a definite trend toward lower yields as erosion and slope increased.

Results of the comparisons of the least squares mean yields of Lexington mapping units are shown in Table 24. The comparison of B1 and B3 yields showed a 5.3 bushel per acre decrease in yield due to the effect of severe erosion on B slopes. The comparison of B3 and D3 mean yields showed a 5.5 bushel per acre yield advantage for the B3 slopes, indicating that increasing slope decreased yields on severely eroded areas. However, neither of these differences was significant at the 0.10 probability level. The comparison of B2 and C3 yields showed a 5.1 bushel per acre lower yield on C3 sites, but this also was not significant. The comparison of B1 and D3 mean yields showed a significant yield advantage of 10.8 bushels per acre on the B1 sites.

The comparisons showed that in 1977 yields on Lexington soils were reduced 10.8 bushels per acre by a combination of severe erosion and steeper slope. Based on the differences shown in the other comparisons, it appeared that this difference was equally due to the effects of slope and erosion. Other comparisons showed reductions in yield due to the

TABLE 23. Average and least squares mean soybean yields on Lexington soils in 1977

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		-------------	Bu/A	-------------
B1	4	34.1	35.9	3.6
B2	5	31.4	32.6	3.1
B3	5	26.4	30.6	3.1
C2	1	42.5	27.4	7.9
C3	7	25.3	27.5	2.5
D3	3	29.0	25.1	4.2

*Adjusted for differences between fields.

TABLE 24. Comparisons of least squares mean yields on Lexington soil mapping units in 1977

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	5.3	0.271 n.s.
B3 - D3	5.5	0.336 n.s.
B2 - C3	5.1	0.226 n.s.
B2 - B3	2.0	0.657 n.s.
B1 - D3	10.8	0.071 *

*Significant at the 0.10 level of probability.

n.s. - Not significant at the 0.10 level of probability.

effects of slope and erosion, both separately and combined, but the reductions were not large enough for significance at the 0.10 level of probability. The lower yield on the D3 slopes was probably due to the lower available water-holding capacity and higher runoff of rainwater. Had more samples been taken, it is possible that some of the other differences due to slope and erosion might have been significant. The low sample numbers led to high standard errors.

Yields of the Lexington soil mapping units did not vary very much between years. Yields on the B1 and B3 sites were 3.6 and 1.3 bushels per acre higher, respectively, while yields on the B2, C3, and D3 sites were 0.4, 3.1, and 1.3 bushels per acre lower than in 1976. This indicated that yields on the Lexington soils did not vary as much from year to year due to weather fluctuations as yields on Grenada soils. The overall trend toward reduced yields on steeper, more eroded sites was present in both years, but was more pronounced in 1977. This could be due to drier weather, but the small differences in yields between the soil mapping units from 1976 to 1977 make it seem possible it could be due to sampling differences.

Yields of sites on Loring soils in 1977 are presented in Table 25. The average yield of all Loring sites in 1977 was 25.9 bushels per acre. This was a decrease of 9.2 bushels per acre from 1976. This decrease was probably due to drier weather in 1977. The highest yield on Loring soils was 31.5 bushels per acre on a B1 site on Ames Plantation, and the lowest was 18.9 bushels per acre on a B2 site in Carroll County. There was less variation from field to field on Loring soils than on the

TABLE 25. Soybean yields on Loring soils by field in 1977

	Soil Mapping Unit					
Field	B1	B2	B3	C2	C3	D3
	---------- Bu/A ----------					
Carroll Co.						
Field 3	22.5	18.9	-	-	-	-
Gibson Co.						
Field 1	-	-	-	20.6	-	-
Ames Plantation						
Field 3	29.3	-	-	-	-	-
Field 4	30.2	26.5	-	-	23.9	-
Field 6	31.5	-	31.3	-	-	-
Martin						
Field 1	-	28.8	-	25.0	-	22.5

other three soils, probably because of fewer fields and because most of the sites were in experiment station fields.

As with the 1976 data, no separate analysis of the Loring yields was made because there were so few samples, but an analysis of the combined Loring and Grenada yields was made. The average and least squares mean yields of the mapping units are shown in Table 26. The least squares means are almost the same as in the analysis of Grenada alone, as would be expected with 49 Grenada sites and 12 Loring sites in the analysis. The yields of the B3 sites and C2 sites were increased 1.4 and 4.7 bushels per acre, respectively, but all the other least squares means were changed less than 1.0 bushel per acre. The comparisons of least squares mean yields of the soil mapping units are shown in Table 27. The difference in yield between B1 and B3 sites was 1.5 bushels per acre less than with Grenada alone, but the difference was still significant. The difference between B1 and D3 mean yields was slightly less, at 11.3 bushels per acre, but still significant. The results indicated that on the two fragipan soils, Loring and Grenada, erosion sharply reduced yields, while slope had little effect. As with Grenada alone, the least squares mean yields were lower for all soil mapping units in 1977 than in 1976, with the yield reductions being greatest on the severely eroded sites.

In summary, there were significant reductions in yield due to the combination of increased slope and erosion on all soils in the study in 1977. The reductions in yield were greatest on Grenada soils, on Lexington soils, and on Grenada and Loring soils combined. In all three cases, yields on B1 sites were approximately ten bushels per acre higher than on D3 sites. On Memphis soils, the differences were less, with 6.3 bushels

TABLE 26. Average and least squares mean soybean yields on Grenada and Loring soils in 1977

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		----------------	Bu/A ----------------	
B1	14	26.4	28.2	2.6
B2	17	24.9	25.3	2.2
B3	8	20.0	19.8	3.4
C2	3	19.4	17.1	7.2
C3	12	21.1	22.9	2.7
D3	7	20.3	16.9	3.5

*Adjusted for differences between fields.

TABLE 27. Comparisons of least squares mean yields on Grenada and Loring soil mapping units in 1977

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	8.4	0.062 *
B3 - D3	2.9	0.557 n.s.
B2 - C3	2.4	0.478 n.s.
B2 - B3	5.5	0.178 n.s.
B1 - D3	11.3	0.015 **

*Significant at the 0.10 level of probability.

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

per acre higher yields on B2 sites than on C3 sites, and 5.1 bushels per acre higher yields on B1 sites than on D3 sites. The latter difference was not statistically significant, but the difference between B2 and C3 yields was significant at the 0.10 level. On Grenada soils, the difference in yield was largely due to the effects of erosion, with slope having little effect. On Memphis and Lexington soils, the differences appeared to be due to a combination of slope and erosion effects. The greater yield reductions on Grenada and Lexington soils than on Memphis soils were probably due to the fact that erosion reduces the available water-holding capacity of Grenada soils and of Lexington soils more than that of Memphis soils. This is because of the fragipan in the lower subsoil of Grenada soils and the sandy Coastal Plains material in the lower subsoil of Lexington soils. Memphis soils have deep, silty subsoils with no unfavorable layers, and removal of topsoil does not greatly reduce their available water-holding capacity. Thus, in a year of lower than normal rainfall, it was not surprising that yields were reduced less on the Memphis soils.

The results in 1977 and 1976 were somewhat different. In 1976 there was no significant effect due to erosion alone on any soil, and only on Lexington soils was there even a trend toward yield reductions on severely eroded sites. On Memphis, Grenada, and Loring sites, yields actually tended to be higher on severely eroded sites, although small sample numbers and problems in site selection on Memphis soils may have contributed to this. There was a trend toward lower yields on steeper slopes in 1976, but it was not clear. In 1977, on the other hand, there were significant yield reductions due to slope and erosion combined on all soils, and on Grenada soils there was a significant reduction in yields due to erosion alone. These differences in response were probably related to the differences between the weather in the two years.

Overall yields varied more between the years on Grenada and Loring soils than on Lexington and Memphis soils. Both Grenada and Loring had large reductions in overall average yield in 1977, while the overall average yields on Memphis and Lexington soils were almost the same as in 1976. There was also greater variation in the yields of individual soil mapping units on Grenada soils, with severely eroded sites showing greater yield decreases in 1977 than the less eroded sites. This indicated that yields on Memphis and Lexington soils are likely to show less variation from year to year due to weather differences than are yields on Grenada and Loring soils. This is probably due to the effect of the fragipans of Grenada and Loring soils, which limit the depth of the rooting zone and thus lower the available water-holding capacity of these soils. This makes them more prone to moisture deficiency in years of low rainfall. Lexington soils are lower in moisture storage capacity than the Memphis soils, due to their sandy lower subsoils. However, the texture of the sandy Coastal Plains material is variable, often containing considerable amounts of silt and clay, and it is permeable to roots. It can therefore supply some moisture to plants, unlike the fragipans of Grenada soils and of Loring soils which restrict rooting. This extra rooting depth increases the moisture available to plants on Lexington soils, and makes them less prone to moisture deficiency. It should be pointed out, however, that the Lexington sites used in this study, with two exceptions, had at least 20 inches of silty loess-derived soil material above the more sandy Coastal Plains material. Many soils mapped as Lexington on C and D slopes do not have this much silty material, and are more likely to be deficient in moisture in dry seasons.

III. RESULTS OF ANALYSIS OF BOTH YEARS' DATA COMBINED

To test the average effects of erosion and slope on soybean yields on these soils across a wider range of management and weather conditions, a combined analysis of the 1976 and 1977 data was performed for each soil. The overall average yield of all sites in the two years of the study was 29.0 bushels per acre. This is a high yield when compared to state and county averages for Tennessee, and reflects the better than average management level used in most of the fields. The average yield of all sites on Memphis soils for both years was 33.6 bushels per acre, the highest of the four soils studied. Average and least squares mean yields for Memphis soils for both years are presented in Table 28. The comparisons of the mean yields are shown in Table 29. None of the comparisons were significant at the 0.10 level of probability. The results of the mean comparisons indicate that there were no significant effects of slope and erosion, either separately or combined, on soybean yields on Memphis soils in the study as a whole. The interaction between years and soil mapping units was almost significant at the 0.10 level on this soil. This indicates that the mapping unit effects were different in each year, and that the effects of the soil mapping units on yield in the two-year analysis are

TABLE 28. Average and least squares mean soybean yields on Memphis soils with 1976 and 1977 data combined

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		----------	Bu/A	----------
B1	13	34.2	35.1	1.9
B2	18	34.2	35.0	1.5
B3	11	34.9	34.9	2.1
C1	1	29.6	32.5	8.3
C2	3	32.3	32.6	4.6
C3	16	33.3	33.2	1.7
D2	1	9.5	12.1	8.2
D3	7	34.3	30.8	2.7

*Adjusted for differences between fields and years.

TABLE 29. Comparisons of least squares mean yields on Memphis soil mapping units with 1976 and 1977 data combined

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	0.2	0.951 n.s.
B3 - D3	4.1	0.197 n.s.
B2 - C3	1.8	0.430 n.s.
B2 - B3	0.1	0.968 n.s.
B1 - D3	4.3	0.222 n.s.
B1 - B2	0.1	0.977 n.s.
C2 - C3	-0.6#	0.919 n.s.

#Negative sign indicates a higher mean yield for the second soil mapping unit in the comparison.

n.s. - Not significant at the 0.10 level of probability.

at least partially confounded with the effects of the differences between years. Because of this, more emphasis should be placed on the individual years' results than on the results of the two-year analysis on this soil.

The average yield of all sites on Grenada soils in the study was 24.3 bushels per acre, lowest of the four soils studied. Average and least squares means for the mapping units sampled on Grenada soils are presented in Table 30. A trend toward yield reductions as slope and degree of erosion increased was evident from the least squares means. The results of the comparisons of the least squares means are shown in Table 31. The comparison of B1 and D3 means showed D3 yields to be 10.9 bushels per acre lower, significant at the 0.10 level. None of the other comparisons were significant at the 0.10 level of probability. The comparison of B1 and B3 yields showed a 5.5 bushel per acre lower yield due to severe erosion on B slopes, and the comparison of B3 and D3 yields showed a 5.4 bushel per acre lower yield on the D slopes. Neither of these differences, however, was large enough for significance. The results of these comparisons indicate that on the average in 1976 and 1977 soybean yields on Grenada soils were significantly reduced by a combination of severe erosion and increase in slope. Neither the effect of severe erosion alone nor of increased slope alone was shown to significantly reduce yields. Based on the differences between means shown in the other comparisons, the lower yields on D3 sites compared to B1 sites were equally due to the effects of slope and severe erosion. The interaction between years and soil mapping units was not significant on this soil.

Average and least squares mean yields of Lexington mapping units

TABLE 30. Average and least squares mean soybean yields on Grenada soils with 1976 and 1977 data combined

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		------------- Bu/A	-------------	-------------
B1	19	26.4	30.3	2.2
B2	24	26.9	27.6	1.9
B3	11	23.5	24.8	3.0
C2	4	28.8	25.1	5.5
C3	18	20.0	23.3	2.2
D3	9	19.4	19.4	3.2

*Adjusted for differences between fields and years.

TABLE 31. Comparisons of least squares mean yields on Grenada soil mapping units with 1976 and 1977 data combined

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	5.5	0.165 n.s.
B3 - D3	5.4	0.224 n.s.
B2 - C3	4.3	0.157 n.s.
B2 - B3	2.8	0.446 n.s.
B1 - D3	10.9	0.007 **

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

for 1976 and 1977 combined are shown in Table 32. The average yield of all Lexington sites was 29.7 bushels per acre. The least squares mean yields of the mapping units showed a trend toward lower yields as slope and degree of erosion increased. The existence of this trend was confirmed by the results of the mean comparisons, shown in Table 33. The comparison of B1 and D3 yields showed a significant decrease in yield due to the combination of increased slope and increased erosion. The results of the other comparisons showed that neither slope nor erosion alone had a significant effect on yields. These results indicated that yields were significantly reduced on Lexington soils in the study as a whole by a combination of increasing slope and increasing erosion. The yield difference between B1 and D3 sites was 7.7 bushels per acre. The reduction was equally due to the effects of erosion and slope, based on the differences between mean yields shown by the other comparisons. Neither the effect of increasing slope alone nor of severe erosion alone resulted in a significant yield decrease. The interaction between years and soil mapping units was not significant on this soil.

Average and least squares mean yields of Loring soil mapping units for the study as a whole are in Table 34. Results of the comparisons of mean yields are in Table 35. The average yield of all Loring sites in the study was 30.0 bushels per acre. Yields of D3 sites were 7.5 bushels per acre lower than yields of B1 sites, a significant difference at the 0.10 level of probability. None of the other comparisons showed significant differences in yields at this probability level. The difference of 7.3 bushels per acre between B3 and D3 yields would seem to indicate

TABLE 32. Average and least squares mean soybean yields on Lexington soils with 1976 and 1977 data combined

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		----------------	Bu/A	----------------
B1	9	31.6	33.7	2.1
B2	8	31.3	33.1	2.2
B3	9	30.2	29.9	2.0
C2	1	42.5	28.0	6.7
C3	11	28.1	28.4	1.8
D2	1	19.9	29.3	7.7
D3	7	26.6	26.0	2.4

*Adjusted for differences between fields and years.

TABLE 33. Comparisons of least squares mean yields on Lexington soil mapping units with 1976 and 1977 data combined

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	3.8	0.199 n.s.
B3 - D3	3.9	0.245 n.s.
B2 - C3	4.7	0.134 n.s.
B2 - B3	3.2	0.305 n.s.
B1 - D3	7.7	0.016 **
B1 - B2	0.6	0.844 n.s.

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

TABLE 34. Average and least squares mean soybean yields on Loring soils with 1976 and 1977 data combined

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		----------	Bu/A	----------
B1	6	40.0	34.0	1.5
B2	6	27.9	30.2	1.3
B3	1	31.3	33.8	3.5
C2	5	31.9	30.7	1.8
C3	2	22.1	28.3	2.2
D3	2	27.7	26.5	2.3

*Adjusted for differences between fields and years.

TABLE 35. Comparisons of least squares mean yields on Loring soil mapping units with 1976 and 1977 data combined

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	0.2	0.954 n.s.
B3 - D3	7.3	0.170 n.s.
B2 - C3	1.9	0.451 n.s.
B2 - B3	-3.6#	0.404 n.s.
B1 - D3	7.5	0.064 *

*Significant at the 0.10 level of probability.

#Negative sign indicates a lower yield on the second soil mapping unit in the comparison.

n.s. - Not significant at the 0.10 level of probability.

that most of the difference between B1 and D3 yields was due to increased slope. However, the B3 mean yield was based on only one sample, and does not provide a good estimate of overall yields on Loring B3 sites. The data available do not really indicate whether the difference in yield was due to slope, erosion, or a combination of the two. The interaction between years and soil mapping units was not significant on Loring soils.

Average and least squares mean yields of Loring and Grenada sites combined for both years are shown in Table 36, and the comparisons of mean yields are shown in Table 37. The results were similar to the results of the two-year analysis of Grenada sites alone. The comparisons showed a 9.6 bushel per acre lower yield on D3 sites than on B1 sites, significant at the 0.10 level. Based on the differences shown in the other comparisons, this lower yield was equally due to the effects of increased slope and severe erosion. Neither slope nor erosion had a significant effect on yields when acting alone, but the combination of severe erosion and an increase from B to D slopes did reduce yields on Loring and Grenada soils.

The combined analysis of both years' data showed no differences in yields due to slope, erosion, or a combination of the two on Memphis soils. This result was in agreement with the findings of Hays et al. (1948) in Wisconsin and Engelstad and Shrader (1961) in Iowa. They found no differences in yields of crops due to erosion on deep, well-drained, silty soils similar to Memphis when fertility was not different. Apparently slopes of up to 12% and erosion did not reduce the moisture supplying capacity of Memphis soils enough to significantly reduce yields of soybeans when the results of both years were combined. Because of the significant interaction

TABLE 36. Average and least squares mean soybean yields on Grenada and Loring soils with 1976 and 1977 data combined

Mapping Unit	Number of Sites	Average Yield	Least Squares* Mean Yield	Standard Error
		-------------	Bu/A	--------------
B1	25	28.2	30.5	1.8
B2	30	27.6	28.1	1.5
B3	12	23.9	26.1	2.6
C2	9	30.9	27.4	3.4
C3	20	21.1	24.8	2.0
D3	11	21.2	20.9	2.7

*Adjusted for differences between fields and years.

TABLE 37. Comparisons of least squares mean yields on Grenada and Loring soil mapping units with 1976 and 1977 data combined

Mean Comparison	Difference	Probability of a Greater /t/
	Bu/A	
B1 - B3	4.4	0.184 n.s.
B3 - D3	5.2	0.163 n.s.
B2 - C3	3.3	0.179 n.s.
B2 - B3	2.0	0.527 n.s.
B1 - D3	9.6	0.004 **

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

between year and soil mapping unit, care must be used in interpreting these results. The effect of the soil mapping units varied between years, and no positive prediction of the effect in a given year can be made from these results.

Results were different on the other three soils. Yields on Grenada, Lexington, and Loring soils were shown to be significantly reduced by a combination of increased slope and severe erosion when both years' data were combined. The yield difference between B1 and D3 sites was 10.9 bushels per acre on Grenada soils, and between 7 and 8 bushels per acre on both Lexington and Loring soils. The subsoils of all three of these soils are less favorable for plant growth than are the subsoils of Memphis soils. Erosion therefore lowers the available water-holding capacity of these soils much more than it lowers that of the Memphis soils. Slope also has a greater effect, probably because runoff becomes more important as the available water-holding capacity of soils declines. The decline in yields of soybeans due to a combination of slope and erosion on soils with unfavorable subsoils was in agreement with the work of Simpson (1974) and Rhoton (1975). They found similar yield reductions on Dewey soils in East Tennessee. There was a trend toward lower yields on Grenada and Lexington soils due to the separate effects of slope and erosion in the combined analysis, but the yield reductions were not large enough to be statistically significant.

Overall yields for the two years were highest on Memphis soils and lowest on Grenada soils, with Lexington and Loring yields falling between the other two. These differences probably reflect differences in the inherent productivity of the four soil series.

IV. SLOPE SHAPE AND SOIL FERTILITY

The shape of slope, either convex, concave, or smooth, can affect yields due to its influence on runoff of water. Since differences in shape of slope might be responsible for some of the variability in the relative yields of some of the soil mapping units from field to field, an analysis was performed in which slope shape was entered into the model as a variable along with field and soil mapping unit. A separate analysis was performed for each of the three major soils studied in each year. No analysis was attempted on Loring due to few samples. The results of the analysis showed slope shape to have no significant effect on yields in any case at the 0.10 level of probability when included in a model with soil mapping unit. In one case, on Lexington soils in 1976, the effect would have been significant at the 0.11 level. In this case, the least squares mean yields were 28.9 bushels per acre on concave slopes and 22.6 bushels per acre on convex slopes. No smooth slopes were included. The effect on the least squares mean yields of the soil mapping units was small, and the differences in the selected mean comparisons were not changed significantly. In no other case was slope shape close to significance at the 0.10 level of probability. This indicated that this factor had little or no effect on the relative yields of the soil mapping units in either year.

Average values of pH, available phosphorous (P), and available potassium (K) for the plow layer of each soil mapping unit sampled within each soil and year are in Table 38. Along with lower available water-holding capacity, lower fertility due to the removal of fertile topsoil has often been cited as cause of lower yields on eroded soils. To test the effects of fertility in this study, analyses were performed for each of the three major soils in each year in which fertility variables were added to the models along with field and soil mapping unit variables. In each case, analyses were performed in which pH, available phosphorous, and available potassium were added separately to the models as linear variables. The fertility variables were tested individually in the models because of their high degree of intercorrelation. Results of these analyses showed no significant effect in any case of either of the three fertility variables on yields when included in a model with soil mapping unit. Apparently differences in fertility between the soil mapping units had no significant effect on their relative yields in either year on any soil, when the fertility variables were tested for a linear effect.

It is well known that yield response to fertility variables is often nonlinear. Therefore, analyses were also performed in which both linear and quadratic components for available potassium and pH were added to the models along with field and soil mapping unit. Results of these analyses showed no significant effect at the 0.10 level of probability on yields of any soil in 1976 due to pH. On Memphis soils, the linear component of available potassium (K) was not significant, but the quadratic component (K^2) was significant. When the linear component was removed from the model, the quadratic component was no longer significant at the 0.10 level. Neither the linear nor the quadratic effect of available

TABLE 38. Average pH, available P, and available K of plow layers of soil mapping units

Soil Mapping Unit	1976 pH	1976 P	1976 K	1977 pH	1977 P	1977 K
		Lbs/A			Lbs/A	
Memphis						
B1	6.4	25(M)*	285(H)	6.2	26(H)	268(H)
B2	6.1	34(H)	307(H)	6.1	47(H)	347(H)
B3	5.8	31(H)	267(H)	5.8	35(H)	256(H)
C1	5.2	50(H)	230(H)	-	-	-
C2	6.4	29(H)	370(H)	6.3	25(H)	300(H)
C3	5.4	31(H)	225(H)	5.4	28(H)	232(H)
D2	5.2	50(H)	140(M)	-	-	-
D3	5.4	18(M)	200(H)	5.3	42(H)	212(H)
Average	5.9	31(H)	272(H)	5.8	35(H)	268(H)
Grenada						
B1	5.9	19(M)	211(H)	5.8	18(M)	223(H)
B2	5.7	14(L)	206(H)	5.8	17(M)	214(H)
B3	5.8	27(H)	198(H)	5.5	15(L)	202(H)
C2	5.9	12(L)	187(M)	5.9	12(L)	140(M)
C3	5.0	17(M)	170(M)	5.5	18(M)	201(H)
D3	5.4	19(M)	215(H)	5.2	16(M)	204(H)
Average	5.6	18(M)	199(H)	5.6	17(M)	208(H)
Lexington						
B1	6.8	47(H)	276(H)	6.2	49(H)	312(H)
B2	6.2	16(M)	315(H)	6.2	26(H)	326(H)
B3	7.0	36(H)	285(H)	6.1	30(H)	374(H)
C2	-	-	-	5.4	5(L)	290(H)
C3	6.8	19(M)	287(H)	6.1	25(M)	290(H)
D2	5.3	2(L)	160(M)	-	-	-
D3	6.8	24(M)	288(H)	5.8	11(L)	267(H)
Average	6.7	29(H)	279(H)	6.1	28(H)	315(H)
Loring						
B1	6.3	15(L)	215(H)	6.2	15(L)	265(H)
B2	6.0	12(L)	200(H)	6.5	25(M)	227(H)
B3	-	-	-	7.3	18(M)	300(H)
C2	6.0	13(L)	229(H)	5.6	10(L)	220(H)
C3	5.1	8(L)	160(M)	6.3	14(L)	290(H)
D3	5.4	17(M)	160(M)	4.9	15(L)	160(M)
Average	5.9	13(L)	203(H)	6.2	17(M)	244(H)

*Letters following figures for P and K indicate the general soil test level. L = low, M = medium, and H = high.

potassium was significant on Lexington or Grenada soils when included in a model with soil mapping unit. Based on these results, differences in fertility had no effect on the relative yields of the soil mapping units of Grenada, Memphis, or Lexington soils in 1976.

Results of the analyses of the 1977 data were different. In 1977, the effects of the linear (pH) and quadratic (pH^2) components of pH on yield were significant on Memphis and Grenada soils. The linear (K) and quadratic (K^2) effects of available potassium on yields were also significant on Memphis soils, but not on Grenada soils.

The effects of adjustment for the linear and quadratic effects of pH on least squares mean yields on Memphis soil mapping units in 1977 are shown in Table 39. The effects of the adjustment for pH on the comparisons of mean yields are in Table 40. From these tables, it can be seen that adjustment for pH eliminated any significant differences in yields due to slope and erosion. The effects of adjustment for available potassium on the least squares mean yields of the soil mapping units and on the comparisons between mean yields are shown in Table 41 and Table 42, respectively. The results of adjustment for potassium were the same as the results of adjustment for pH. All the significant differences due to slope and erosion were eliminated. From the results of the analyses, it appears that most of the yield decrease shown on Memphis soils due to slope and erosion in 1977 was a result of lower fertility of some of the C3 and D3 sites.

Results of the adjustment of the least squares mean yields of Grenada soil mapping units in 1977 for pH are shown in Table 43. The effects of the adjustment for the linear (pH) and quadratic (pH^2) effects of pH were

TABLE 39. Effect of adjustment for pH on least squares mean yields on Memphis soils in 1977

Mapping Unit	Least Squares Mean Yield	
	Unadjusted for pH	Adjusted for pH
	Bu/A	
B1	35.7	33.4
B2	37.3	37.3
B3	33.4	33.8
C2	24.1	19.0
C3	31.0	32.8
D3	30.6	32.9

TABLE 40. Effect of adjustment for pH on comparisons of least squares mean yields on Memphis soil mapping units in 1977

Mean Comparison	Difference	
	Unadjusted for pH	Adjusted for pH
	Bu/A	
B1 - B3	2.3 n.s.	-0.4 n.s.
B3 - D3	2.8 n.s.	0.9 n.s.
B2 - C3	6.3 *	4.5 n.s.
B2 - B3	3.9 n.s.	3.5 n.s.
B1 - D3	5.1 n.s.	0.5 n.s.

*Significant at the 0.10 level of probability.

n.s. - Not significant at the 0.10 level of probability.

TABLE 41. Effect of adjustment for available K on least squares mean yields on Memphis soils in 1977

Mapping Unit	Least Squares Mean Yield	
	Unadjusted for K	Adjusted for K
	Bu/A	
B1	35.7	34.6
B2	37.3	33.8
B3	33.4	32.8
C2	24.1	23.0
C3	31.0	32.4
D3	30.6	34.0

TABLE 42. Effect of adjustment for available K on comparisons of least squares mean yields on Memphis soil mapping units in 1977

Mean Comparison	Difference	
	Unadjusted for K	Adjusted for K
	---------------- Bu/A	----------------
B1 - B3	2.3 n.s.	1.8 n.s.
B3 - D3	2.8 n.s.	-1.2 n.s.
B2 - C3	6.3 *	1.4 n.s.
B2 - B3	3.9 n.s.	1.0 n.s.
B1 - D3	5.1 n.s.	0.6 n.s.

*Significant at the 0.10 level of probability.

n.s. - Not significant at the 0.10 level of probability.

TABLE 43. Effect of adjustment for pH on least squares mean yields on Grenada soils in 1977

Mapping Unit	Least Squares Mean Yield	
	Unadjusted for pH	Adjusted for pH
	---------- Bu/A ----------	
B1	28.3	33.4
B2	25.0	24.8
B3	18.4	16.0
C2	12.4	13.7
C3	22.1	21.5
D3	16.4	12.6

much different on Grenada soils than on Memphis soils. Rather than eliminating differences in yield due to erosion, adjustment for pH increased the magnitude of the differences. The B1 least squares mean yield was 5.1 bushels per acre higher as a result of the adjustment, while the D3 yield was 3.8 bushels per acre lower. Results of the mean comparisons as affected by adjustment for pH are in Table 44. The estimated decrease in yield due to severe erosion on B slopes was increased from 9.9 bushels per acre to 17.4 bushels per acre by the adjustment for pH. The overall difference due to the combined effects of severe erosion and increased slope was increased from 11.9 bushels per acre to 20.8 bushels per acre. After adjustment for pH, the comparison of B2 and B3 mean yields showed a significantly lower yield on B3 sites. This indicated a significant reduction in yields when soils already moderately eroded were eroded further. The estimated yield decrease due to severe erosion was 8.8 bushels per acre. These results indicated that yield differences on Grenada soils in 1977 due to erosion were not a result of lower fertility of the eroded soils. Probably they were due to a lower water supply. In fact, the results indicated that yields on some of the B1 sites probably were held below their potential by low pH. Some of the B1 sites in the study were in fields which were not under a high level of management, and this probably led to a lower yield on the B1 sites before adjustment for pH differences.

Overall, the analyses of the effects of fertility variables on the yields of the soil mapping units of Lexington, Grenada, and Memphis soils showed different effects for each soil and each year. On Lexington soils,

TABLE 44. Effect of adjustment for pH on comparisons of least squares mean yields on Grenada soil mapping units in 1977

Mean Comparison	Difference	
	Unadjusted for pH	Adjusted for pH
	---------------- Bu/A ----------------	
B1 - B3	9.9 *	17.4 **
B3 - D3	2.0 n.s.	3.4 n.s.
B2 - C3	2.9 n.s.	3.3 n.s.
B2 - B3	6.6 n.s.	8.8 **
B1 - D3	11.9 **	20.8 **

*Significant at the 0.10 level of probability.

**Significant at the 0.05 level of probability.

n.s. - Not significant at the 0.10 level of probability.

there was no significant effect in either year. On Grenada soils, adjustment for the linear and quadratic effects of pH caused significantly larger differences in yield due to erosion in 1977, but not in 1976. On Memphis soils, adjustments for the linear and quadratic effects of pH and available potassium eliminated significant differences in yield due to slope and erosion combined in 1977. Their effects were not significant at the 0.10 level in 1976. These results indicate a possibility that most of the yield reductions due to slope and erosion on Memphis soils in 1977 were a result of lower fertility on the C3 and D3 sites. This could be overcome by better management. On the Grenada and Lexington soils, with their less favorable subsoils, most of the yield reductions appear to have been a result of lower available water-holding capacity on steeper, more eroded sites rather than fertility differences.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was conducted for the purpose of investigating the effects of degree of erosion and slope characteristics on soybean yields on four West Tennessee soils. Soils studied were Memphis, Grenada, Lexington, and Loring. The study covered two years, 1976 and 1977.

Results from 1976 showed no significant reduction in yield on any soil due to severe erosion on B (2-5%) slopes. There was a slight trend toward reduced yields due to erosion on Lexington soils, but the reduction was too small for significance at the 0.10 level. There was a trend on all soils toward reduced yields as slope increased on severely eroded sites. The effect of slope was significant on Memphis, Grenada, and Grenada and Loring soils combined, but was not large enough to be significant on Lexington soils. There was a reduction in yields on Lexington soils in 1976 due to the combined effects of severe erosion and an increase in slope. The lack of significant yield reductions due to erosion in 1976 was probably due to above normal rainfall in the early and middle parts of the growing season. The trend toward lower yields as slope gradient increased was probably due to increased runoff of water on the steeper slopes. Yields on B1 sites in 1976 were 34.4, 32.7, 32.3, and 33.2 bushels per acre on Memphis, Grenada, Lexington, and Grenada and Loring soils, respectively.

Results from 1977 showed significant reductions in soybean yields on all soils due to the combination of severe erosion and increased slope.

Yields on B1 (2-5% slopes, slightly eroded) sites were approximately ten bushels per acre higher on Grenada, Lexington, and Grenada and Loring soils combined than yields on D3 (8-12% slopes, severely eroded) sites. On Memphis soils the difference was 5.1 bushels per acre. Yields on B1 sites were 35.7, 28.3, 35.9, and 28.2 bushels per acre on Memphis, Grenada, Lexington, and Loring and Grenada soils, respectively. The smaller reduction on Memphis soils was because the available water-holding capacity is not reduced as much by erosion on Memphis soils as on the other three soils. On Grenada soils, the yield reduction was mainly due to the severe erosion of the D3 sites, while on Lexington and Memphis soils it was equally due to slope and erosion. Severe erosion on B slopes significantly reduced yields on Grenada soils. On Lexington and Memphis soils, neither slope alone nor erosion alone had a significant effect on yields.

The differences in results between 1976 and 1977 were apparently due to differences in growing season rainfall. Rainfall was below normal in the early and middle parts of the 1977 growing season. This made the available water-holding capacity of the soils more important, and led to lower yields on severely eroded sites. In 1976, rainfall was above normal during this part of the growing season. This reduced the importance of available water-holding capacity, because plants did not have to depend as much on stored water. This reduced the effect of erosion on yields.

Grenada and Loring yields varied more from 1976 to 1977 than did Memphis and Lexington yields. This was true both of overall yields and of yields of the individual mapping units. Yields of both Grenada and Loring soils declined significantly from 1976 to 1977, with the largest declines in yield coming on the steeper, more eroded mapping units. It appears that yields on Grenada and Loring soils can be expected to show greater variation from year to year due to weather differences than on Memphis and Lexington soils. This is a result of the fragipans in the subsoils of Grenada and Loring soils, which restrict rooting and make crops more susceptible to moisture stress in dry weather.

When both years' data were combined for analysis, there were no significant differences in yields due to slope and erosion on Memphis soils. On Grenada, Lexington, and Loring soils the combined effects of severe erosion and increased slope significantly reduced yields of soybeans over both years. The yield reductions appeared to be equally due to severe erosion and increased slope. The difference in yield between B1 and D3 sites was 10.9 bushels per acre on Grenada soils, 7.7 bushels per acre on Lexington soils, and 7.5 bushels per acre on Loring soils. Neither slope nor erosion alone had a significant effect on yields on any soil. Yields were 35.1, 30.3, 33.7, and 34.0 bushels per acre on B1 sites on Memphis, Grenada, Lexington, and Loring soils, respectively.

Slope, either concave, convex, or smooth, was found to have no significant effect on the yields of the mapping units on any soil in either year.

To determine if any of the differences in yields were a result of differences in fertility of the soil mapping units, analyses were performed in which the yields were adjusted for fertility variables. On Memphis soils in 1977, adjustment of yields for either pH or available potassium eliminated significant differences in yields due to slope and erosion.

The effects of the fertility variables were not significant on any of the soils in 1976, or on Lexington soils in 1977. A significant effect due to pH was shown on Grenada soils in 1977, but adjustment of the mapping unit yields for pH resulted in larger differences due to erosion, rather than eliminating them as with Memphis. Results of the analyses in which fertility variables were included indicate that yield differences on Memphis soils in 1977 due to slope and erosion may have been a result of lower fertility on the steeper, more eroded mapping units. On Grenada and Lexington soils, results indicate that fertility had little effect, and that the differences in yields in 1977 were largely due to the lower available water-holding capacity on the steeper, more eroded areas.

The differences in the effects of erosion and slope on the four soil series can be largely explained by differences in their profiles. Memphis soils, with their deep, silty subsoils, lose little of their available water-holding capacity as a result of erosion, and therefore show little effect of erosoin on yields on average if lost fertility is replaced. Lexington, Grenada, and Loring soils have less favorable subsoils. Erosion lowers their available water-holding capacity, and causes yields to decline. Slope is probably also more important on these soils. With their lower available water-holding capacity, loss of water during the growing season due to runoff is probably more important than on Memphis soils. These effects lead to lower yields on steeper, eroded areas of these soils in the average year.

The two years of this study did not include a very dry growing season. If the study had been conducted in a very dry year, results might have been different. Erosion effects would probably have been greater, even on the Memphis soils, than were shown in this study.

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LITERATURE CITED

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APPENDIXES

APPENDIX A

INFORMATION SHEET

For UT-SCS Soybean Yield Study

County ______________________________

Soil (Name, Slope, Erosion) ______________________________

Name of Farmer ______________________________

Address ______________________________

Community ______________________________

Acres in Field ______________________________

Soil Test Results pH__________ P__________ K__________

Variety of Beans ______________________________

Planting Date ______________________________

Harvest Date ______________________________

Fertilizer last applied - Amount ____________________ Year________

Lime last applied - Amount ____________________ Year________

Molybdenum applied ____________________ Year________

Name of Weed Control Chemicals Used ______________________________

Row Width ______________________________

Yield (to be completed later) ______________________________

Soil Loss (use slide rule for each plot) ________________ Tons/Acre______

<u>REMARKS</u> (No. years in beans, double cropping etc., infested with weeds, insect damage, terraces)

APPENDIX B

TABLE 45. Summary of management practices used in 1976

Field	Variety	Planting Date	Fertilizer Used P	Fertilizer Used K	Mo	Year Last Limed
			- Lbs/A -			
Carroll Co.						
Field 1	Essex	5-25	26	56	yes	1975
Field 2	Essex	6-22	10	20	yes	no record
Chester Co.						
Field 1	York	5-12	17	33	no	1976
Crockett Co.						
Field 1	Forrest	6-20	13	50	no	1969
Field 2	Forrest	6-20	13	50	no	1972
Field 3	Forrest	5-20	20	79	yes	1973
Dyer Co.						
Field 1	FFR 666	6-25	0	0	yes	1967
Field 2	FFR 666	6-25	0	0	yes	1967
Fayette Co.						
Field 1	Bragg	6-3	5	9	yes	1974
Field 2	Forrest	5-20	23	43	yes	1974
Gibson Co.						
Field 1	Forrest	6-11	0	0	yes	1970
Field 2	York	5-24	0	0	no	no record
Hardeman Co.						
Field 1	-	-	-	-	-	-
Field 2	-	-	-	-	-	-
Haywood Co.						
Field 1	Forrest	6-8	0	0	yes	no record
Field 2	Forrest	6-9	0	0	yes	no record
Field 3	Forrest	6-15	0	0	yes	no record
Henry Co.						
Field 1	York	5-15	20	50	yes	1973
Field 2	Bragg	6-20	14	46	yes	1976

TABLE 45 (continued)

Field	Variety	Planting Date	Fertilizer Used P	Fertilizer Used K	Mo	Year Last Limed
			- Lbs/A -			
Lauderdale Co.						
Field 1	Forrest	5-10	0	0	yes	1970
Madison Co.						
Field 1	York	6-5	17	33	yes	1976
Field 2	Forrest	5-15	22	46	yes	no record
McNairy Co.						
Field 1	York	5-23	26	66	no	1975
Field 2	York	5-22	22	42	no	1976
Obion Co.						
Field 1	York	5-18	0	0	no	1972
Field 2	Forrest	5-1	0	0	no	1975
Shelby Co.						
Field 1	Pickett	5-19	20	50	yes	1974
Tipton Co.						
Field 1	Ring-a-round #60	5-20	20	37	no	1975
Field 2	Pickett	6-7	0	0	no	no record
Field 3	Pickett	6-8	0	0	no	no record
Weakley Co.						
Field 1	Mitchell	6-11	3	5	yes	1973
Ames Plantation						
Field 1	Forrest	5-10	17	32	yes	no record
Field 2	Forrest	5-15	17	32	yes	no record
Field 3	Forrest	5-24	19	37	yes	1976
Field 4	Forrest	5-24	19	37	yes	1976
Field 5	Forrest	5-28	17	32	yes	no record
Martin						
Field 1	Forrest	6-11	17	33	no	1974
Field 2	Forrest	6-11	17	33	no	1974

TABLE 46. Summary of management practices used in 1977

Field	Variety	Planting Date	Fertilizer Used P	Fertilizer Used K	Mo	Year Last Limed
			- Lbs/A -			
Carroll Co.						
Field 1	Essex	5-16	24	45	no	1975
Field 3	Essex	6-5	29	75	yes	1975
Chester Co.						
Field 1	York	6-15	26	50	no	1976
Crockett Co.						
Field 1	Bragg	6-18	21	40	yes	1976
Field 2	Bragg	6-23	21	40	yes	1976
Field 3	Forrest	5-20	20	75	yes	1975
Dyer Co.						
Field 1	Pickett	5-13	0	50	yes	1967
Field 2	Pickett	5-14	0	50	yes	1967
Fayette Co.						
Field 1	Bragg	6-3	6	12	yes	1974
Field 2	Forrest	5-13	23	43	yes	1974
Gibson Co.						
Field 1	Forrest	6-2	26	50	yes	1970
Field 3	Forrest	5-27	17	33	yes	1976
Field 4	Forrest	6-27	13	25	yes	1976
Haywood Co.						
Field 1	Forrest	5-27	0	0	yes	no record
Field 2	Forrest	5-26	0	0	yes	no record
Henry Co.						
Field 3	Essex	5-12	3	5	no	1976
Field 4	Essex	5-25	-	-	no	1977
Henderson Co.						
Field 2	Forrest	5-17	10	20	no	1977
Field 3	Forrest	5-12	-	-	-	-

TABLE 46 (continued)

Field	Variety	Planting Date	Fertilizer Used P	K	Mo	Year Last Limed
			- Lbs/A -			
Lauderdale Co.						
Field 2	Forrest	6-1	17	33	yes	no record
Field 3	Forrest	6-3	14	27	no	1976
Madison Co.						
Field 1	York	5-16	26	50	yes	1976
Field 3	Pickett	5-20	17	50	yes	1975
McNairy Co.						
Field 1	York	5-23	26	66	no	1975
Field 2	York	5-22	22	42	no	1975
Obion Co.						
Field 3	Forrest	5-9	21	40	yes	1977
Field 4	Pickett	5-16	0	0	no	no record
Shelby Co.						
Field 1	Dare	5-5	22	62	yes	1974
Tipton Co.						
Field 2	Pickett	6-15	0	0	yes	1976
Weakley Co.						
Field 2	Mitchell	5-17	42	80	yes	1976
Field 3	Forrest	5-23	40	99	no	1976
Ames Plantation						
Field 3	Forrest	5-19	17	17	yes	1976
Field 4	Forrest	5-18	17	17	yes	1976
Field 5	Forrest	5-17	-	-	-	-
Field 6	Forrest	5-21	0	0	yes	1977

TABLE 47. Degrees of freedom (d.f.) and mean squares (m.s.) from analyses of variance in 1976

	Memphis		Grenada		Lexington		Loring and Grenada	
Source	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
SMU	7	56.8	5	91.7	5	17.8	5	83.1
Fields	13	241.2	17	241.0	8	262.8	20	259.3
SMU*FIELD	10	11.5	13	36.0	7	18.7	20	31.1

TABLE 48. Degrees of freedom (d.f.) and mean squares (m.s.) from analyses of variance in 1977

Source	Memphis		Grenada		Lexington		Loring and Grenada	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
SMU	5	52.7	5	130.1	5	55.9	5	123.2
Fields	12	431.4	16	276.4	7	259.9	20	230.9
SMU*Fields	21	38.6	27	81.7	12	40.5	35	67.9

TABLE 49. Degrees of freedom (d.f.) and mean squares (m.s.) from analyses of variance with 1976 and 1977 combined

	Memphis		Grenada		Lexington		Loring		Loring and Grenada	
Source	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
SMU	7	50.9	5	138.5	6	52.4	5	9.5	5	125.1
Year	1	5.5	1	578.3	1	11.0	1	485.1	1	1026.2
Fields (year)	25	332.5	33	258.2	15	261.5	10	86.1	40	245.1
Year*SMU	5	60.9	5	83.3	4	13.5	2	7.6	5	81.3
Field*SMU (year)	31	29.8	40	66.9	19	32.5	3	4.0	55	54.5
Pooled Year* SMU and Field* SMU (year)	36	34.1	45	68.7	23	29.2	5	5.5	60	56.7

VITA

Harry Paul Denton was born in Newport, Tennessee on April 10, 1954. He graduated from Cocke County High School in 1972, and entered Walters State Community College that fall. He received an Associate of Science degree in June 1974, and entered the University of Tennessee at Knoxville the following fall. He received his Bachelor of Science degree, with a major in Plant and Soil Science, in June 1976.

In June 1976, he began work toward a Master of Science degree in Plant and Soil Science at the University of Tennessee. While working toward this degree, he received a research assistantship from the department. He received this degree in August 1978.

He is married to Glenda Blackman Denton of New Market, Tennessee. He is the son of Mr. and Mrs. Harry C. Denton of Newport, Tennessee.