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University of Tennessee Agricultural Experiment Station

William N. Blisard

Luther Keller

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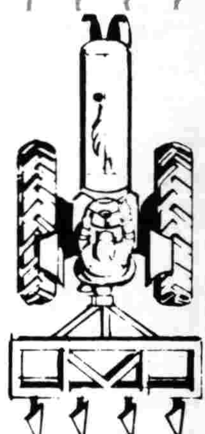

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TABLE OF CONTENTS

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Objectives and Procedures of the Study

I. INTRODUCTION

Each year soil is eroded from the earth's surface and is deposited downslope on land and in streams. The amount of sediment removed by rain in the United States is believed to be at least four billion tons annually, with about one billion tons of this reaching major streams. Thirty percent of the erosion can be attributed to geological erosion and about 50 percent to the erosion of agricultural land (12).

In recent years public awareness of the nonagricultural consequences of sediment pollution has intensified. A major result of the increased public interest in soil and water problems was the passage of the 1972 Federal Water Pollution Control Act. Section 208 of this act established the goal that "the discharge of pollutants into the navigable waters be eliminated by 1985." The plan for implementing this act in Tennessee was developed by the Division of Water Quality Control of the Department of Health (Agriculture—Water Quality Management Plan, November 1978) (5). The Tennessee plan relies upon voluntary farmer participation, emphasizes the use of Best Management Practices (BMPs) and utilizes soil loss tolerance as the best criteria for establishing goals for the reduction of water pollution from sediment.

II. PROBLEM OF STUDY

Terraces can be an effective means of combating soil erosion, but they are often expensive to install and maintain. However, federal subsidies are available to reduce the net cost to the farmer for structures that meet certain prescribed conditions. Cost sharing rates of 50 percent are common, and as much as 75 percent cost sharing is available

under some special programs. Permitting soil erosion to proceed unchecked may also be quite costly. Private costs to the farmer may take the form of reduction of potential yields, reduction in the field efficiency of machinery, the loss of fertilizer nutrients that have been added to the soil and losses in land value for agricultural and other purposes. The economic justification of a terrace system is a cost-benefit type question—a comparison in present value terms of the cost of building and maintaining terraces with the potential gains of preserving soil productivity. The planning horizon of the farmer, the costs of building and maintaining land-formed structures and the effect of particular levels of soil loss on yields, returns and production costs over time are important determinants of whether such structures are economical.

III. STUDY OBJECTIVES

This study was conducted to evaluate the cost and potential benefits of different types of terraces and their associated structures on a per acre basis for a 12-county area in West Tennessee. The specific objectives were to:

1. Determine the cost of constructing gradient, parallel and combination gradient-parallel terraces and their associated structures in a 12-county area in West Tennessee.
2. Determine, using cost-benefit analysis, the yield decline of corn and soybeans necessary to justify the costs of building various types of terraces and associated structures for selected planning periods, prices of corn and soybeans and interest rates.
3. Discuss the policy implications of terrace systems as a soil conservation alternative.

IV. PROCEDURES

Primary data were collected relative to the estimated and actual costs of constructing terraces and related structures over a wide range of situations on a selected group of West Tennessee farms in early 1981. These data were obtained from a questionnaire completed by the District Conservationist of the Soil Conservation Service (SCS) in each of the 12 counties of the study area (3).

For the cost-benefit analysis the assumption was made that the use of conventional straight row tillage would likely result in yield declines over time and that the installation of terraces would stabilize yields at current levels. Thus, to justify terraces, projected yields over some time period would have to decline by some specific amount for the present value of the lost revenue to equal or exceed the costs of the terraces. This analysis assumed that the yield decline would be a linear function of time. The effect of adding terraces and associated structures on the

cost of production and net returns was examined using budgets prepared for corn and soybeans, the two most common row crops grown in the area. Yields assumed in constructing the various budgets were adapted from *Yield Estimates for the Major Crops Grown on the Soils of West Tennessee* (4) and were dependent upon soil type, slope and the existing level of erosion.

Policy implications were examined on the basis of the cost-benefit analysis and budgetary comparisons. Particular attention was given to the various types of structures as well as the subsidies necessary to justify terraces for a particular projected yield decline.

V. THE STUDY AREA

The study included what is commonly referred to as the Loess Soils Region of West Tennessee and included the following 12 counties: Crockett, Dyer, Fayette, Gibson, Hardeman, Haywood, Lauderdale, Madison, Obion, Shelby, Tipton and Weakley, The soils of this area are primarily loess in origin, range from poorly drained to well drained, are low to moderate in fertility and are easy to till and erode.

This West Tennessee region is plagued by problems of excessive soil erosion, sedimentation of bottomlands and flooding and drainage problems associated with the sedimentation. Furthermore, relatively high prices for soybeans over the last few years have motivated landowners to convert land previously used for forest, grass and idle uses into row crop production some of which may be only marginally suited for such use.

Costs of Construction of Terraces and Associated Structures

I. OBTAINING THE SURVEY INFORMATION

Current information about the costs of terraces or the factors which influence these costs was not readily available. Thus, an important primary objective of this study was to obtain cost estimates and descriptive characteristics of a wide variety of terrace types and associated structures recently built on farms in West Tennesseee.

Survey information was obtained for a specific water management system. A water management system was defined as a set of land-formed structures which control the water runoff on a particular area of a farm. If a farm had terraces in three fields, each of which separately controlled and disposed of the runoff, then these were identified as three separate systems. Both technical and cost data were obtained about terraces, grassed waterways, pipe outlets and debris basins. The survey form and instructions for completing the questionnaire are shown in the Appendix.

Copies of the soil conservation survey were distributed to 12 SCS offices in January, 1981, along with a cover letter explaining the purpose of the survey and the type of information requested. Sixty surveys were returned. Fifty-eight included data for complete terrace systems and two were component structures that were being added to an existing system.

II. DESCRIPTION OF THE SURVEY

For each system, general information was obtained about the acreage of the terraced area, the date the terraces were built and the proportion of various types and slopes of soils on which terraces were built. The information obtained about each terrace system included spacing, dimensions of the front and back slopes, number of feet built, amont of land leveling required before construction, the estimated costs and the equipment assumed for the estimates, the actual costs and the actual equipment used in construction and, finally, the proportion of the construction performed by the farmer. Similar information was obtained on waterways, tile outlets and debris basins. The dimensions of the grassed waterways and debris basins were obtained in acre terms. Data for tile outlets were obtained on pipe diameter and the number of feet used.

III. COSTS OF CONSTRUCTING VARIOUS TYPES OF TERRACE SYSTEMS

Costs of construction of the 58 terrace systems are summarized in Table 1. The average cost per acre for the 23 gradient terrace systems was $133 while the cost per acre of the 25 parallel terrace systems averaged $339. The average cost of 10 systems involving a combination of gradient and parallel terraces was approximately $242 per acre.

Table 1. Variations in Cost of 58 Terrace Systems, West Tennessee, 1980

	Gradient	Parallel	Gradiient-Parallel Combinations
Total number of systems	23	25	10
Average cost per acre terraced	$133	$339	$242
Average cost with terraces only (number)	$ 56 (9)[a]	—	—
Average cost with terraces and tile (number)	—	$354 (7)[a]	—
Average cost with terraces,tile and debris basins (number)	$261 (8)[a]	$412 (15)[a]	—
Range per acre	$ 37-435	$ 87-978	$75-680

[a]Numbers in parentheses indicated the number of systems in each subcategory of gradient and parallel terrace systems.

Within a given terrace type the range of construction costs was quite great. For gradient terraces, the cost per acre ran from a low of $37 to a high of $435 (Table 1). Some parallel terrace systems cost as little as $87 per acre while the most expensive cost $978 per acre. The cost of the gradient-parallel type of terrace ranged from a low of $75 to a high of $680 per acre (Table 1).

Cost-Benefit Analysis

I. INTRODUCTION

The Decision to Conserve or Not

Terraces and other land-formed structures are just one method of controlling soil erosion. Many alternatives exist for dealing with the problem and a rational decision maker will carefully weigh the costs and consequences of each in light of his own goals and aspirations. The decision may be made strictly on an economic basis, but often decisions are influenced by a variety of goals. From an economic standpoint, the alternative chosen should achieve the desired goal at minimum cost and have the potential for paying for itself over the life span of the investment or the planning horizon of the decision maker, whichever is shorter.

The Cost-Benefit Approach

For cost-benefit calculations, the level of strategic variables must be chosen with care. Particularly, consistent standards should be used in the selection of price levels, discount rates, project costs and the determination of the economic life of the project. To be most useful, benefits and costs should be calculated in terms of the price levels expected at the time when the benefits and costs occur (1). Current prices or an average of the price levels for the last few years are most commonly used as proxies for expected prices. Project costs are usually calculated at current levels. More than one cost level may be utilized to determine the sensitivity of the results.

II. PROCEDURE FOR COST-BENEFIT ANALYSIS

Costs are incurred both in the construction and maintenance of terraces and associated structures used in an erosion control system. A yearly maintenance cost will be incurred for the terrace system in order to retain the ridge height and slope of the terrace and to assure the proper functioning of the system in controlling water movement. Both parallel and gradient terraces can be adequately maintained with a two-way plow (2, p. 166).

Cost of Maintaining Terrace System

Estimated per acre costs of annual maintenance of both parallel and gradient terraces are shown in Table 2. The gradient terrace systems were assumed to include 214 feet of terraces per acre, each 29.5 feet

wide. Using machinery cost and performance data from the *Farm Planning Manual* (10), the estimated annual maintenance cost for gradient terraces was $1.15 per acre. Parallel terraces were assumed to be 33.5 feet wide and to include 230 feet of terraces per acre. The annual maintenance cost of parallel terraces was estimated to be $1.41 per acre. Maintenance cost estimates were based on one additional plowing of the terraced area. Assumed dimensions of each terrace type were based upon averages obtained from the soil conservation structures survey.

Table 2. Estimated Annual Maintenance Costs for Terraces, Per Acre

	Unit	Gradient Terraces	Parallel Terraces
Terrace area	acre	.145	.177
Cost per acre[a]			
Tractor	$	.70	.85
Plow	$	.23	.28
Labor	$	.22	.28
Total	$	1.15	1.41

[a] Machine costs taken from *Farm Planning Manual* (10) and were $13.70 per hour for tractor and $4.49 per hour for plow. Labor was valued at $3.50 per hour.

Terrace costs. The primary systems identified and their average installation cost per acre were: 1) gradient terraces with no support structures, $56 per acre; 2) gradient terraces with tile and debris basins, $261 per acre; 3) parallel terraces with tile, $354 per acre; and 4) parallel terraces with tile and debris basins, $412 per acre.

A relatively wide gap existed in the price range between the two gradient terraces. A review of the survey indicated that three terrace systems with tile outlets had been built at an average cost of $121 per acre. This system was included in the cost-benefit analysis making a total of five separate types of terrace systems ranging in cost from $56 to $412 per acre. Since the results of the cost-benefit analysis used in this study hinge only on the cost and not the type of terrace constructed, these five cost points could be interpreted as applying to any system with a cost at or near these particular levels.

Crops grown. The cost-benefit analysis was made for two major cash crops grown in the area—corn and soybeans. In the 12-county study area, reported 1979 acreage was 1,537,000 of soybeans and 158,000 of corn.

Price levels. Two product price levels were used in this study for each crop. The base price for corn and soybeans was assumed to be $2.90 and $7.25 per bushel, respectively.[1] Since product prices are quite

[1] These values are used in the 1981 *Farm Planning Manual* (10) and are judged to reflect average or normal prices expected to prevail over the next five years.

volatile and impact on the results of the cost-benefit analysis in a significant way, an alternative product price was considered for each crop. The analysis was also completed using prices of corn and soybeans of $2.40 and $6.00 per bushel, respectively (approximately 17 percent lower than the base price).

Discount rate. The appropriate discount factor for this study was considered to be approximated by the market rate of interest. Interest rates have been quite volatile recently and have varied over a wide range. The average interest rates charged by the Production Credit Association in the United States from 1975 to 1979 have ranged from about 7.9 percent to 10.7 percent. Interest rates charged by local Production Credit Associations in mid 1981 were 14 percent. For this analysis the interest rates (discount factors) chosen were 10 and 14 percent.

Planning spans. The results of the cost-benefit analysis depend upon the expected life of the project or, as an alternative perspective, the planning horizon of the decision maker. In general, with yearly maintenance, terrace systems can be expected to last at least 20 years before having to be rebuilt. However because a considerable proportion of corn and soybeans are produced on rented land, and due to the wide variations among farmers in risk preference and ability to withstand risk, it seemed appropriate to do the cost-benefit analysis over a range of planning horizons. Planning periods considered were 5, 10, 15 and 20 years.

Calculation of Yield Decline Necessary to Justify Cost

A terrace system cannot be economically justified from the farmer's point of view unless the present discounted value (PDV) of the expected reduction in yields are at least as great or greater than the PDV of the construction and maintenance costs of the terrace system over some specified planning span. In the analysis, yields were assumed to stabilize at present levels with the addition of terraces. By assuming a straight line relationship between soil loss over time and yield declines, the present value discount formula can be modified and solved for the break-even yield decline necessary to justify the cost of any given terrace system. This modified formula is:

$$X = \frac{PDV}{CP\,[(1 + i)^{-1} + 2\,(1 + i)^{-2} + \ldots\, n\,(1 + i)^{-n}]}$$

where:

X = total yield decline necessary for the discounted present value of cost to equal the discounted present value of benefits

PDV = present discounted value of the terrace system including annual maintenance over a specified planning period

CP = crop price

i = appropriate discount factor

n = number of years in planning horizon

III. COST-BENEFIT ANALYSIS FOR TERRACE SYSTEMS USED IN CORN PRODUCTION

The discounted present value for the five representative terrace systems are shown in Table 3 for each of the four planning spans and using a discount rate of 10 and 14 percent. For example, assuming a discount rate of 10 percent, gradient terraces with an initial cost of $56 per acre and a per acre annual maintenance cost of $1.15 would have a PDV of $60.84 over a five-year planning span and $66.27 over a 20-year horizon. Present discounted values would be somewhat lower at a 14 percent discount rate.

Table 3. Present Value of Cost and Maintenance Per Acre of Different Types of Terrace Systems with Variations in Discount Rates and Planning Horizons

Terrace Type	Planning Horizon (years) 5	10	15	20
	------discounted present value ($)------			
Gradient terraces with no support structures (initial cost $56.48)				
10% discount	60.84	63.55	65.23	66.27
14% discount	60.43	62.48	63.54	64.10
Gradient terraces with tile only (initial cost $120.90)				
10% discount	125.26	127.97	129.65	130.69
14% discount	124.85	126.90	127.96	128.52
Gradient terraces with tile and debris basins (initial cost $260.80)				
10% discount	265.16	267.87	269.55	270.59
14% discount	264.75	266.80	267.86	268.42
Parallel terraces with tile only (initial cost $354.39)				
10% discount	359.74	363.05	365.12	366.39
14% discount	359.23	361.74	363.05	363.73
Parallel terraces with tile and debris basins (initial cost $411.72)				
10% discount	417.07	420.38	422.45	423.72
14% discount	416.56	419.07	420.38	421.06

It should be noted that a direct relationship exists between the PDV cost of a terrace system and the necessary break-even yield decline needed to justify the system in each planning horizon. If the PDV cost of

the terrace system were doubled, the break-even yield decline would also double. In the tables for both corn and soybeans, the break-even yield decline is shown not only for the five terrace systems, but it is also expressed in terms of the yield decline needed for every $100 spent on a terrace system.

Corn $2.90 Per Bushel, Discount Rate 10 Percent

For comparative purposes, the base situation for corn was considered to be the 20-year planning horizon, $2.90 per bushel corn price, and the discount rate of 10 percent (Table 4). Over this time span, every $100 of terrace system required a potential yield decline of .54 of a bushel per year if the PDV of the yield loss were to equal the PDV of the terrace and maintenance costs. Over a 20-year period, this would result in a total yield reduction of 10.8 bushels of corn per acre.

Table 4. Yield Declines Per Acre Necessary to Justify Terraces for Corn Production with 10 Percent Discount Rate and Corn Price of $2.90 Per Bushel

Terrace Type	Planning Horizon (years) 5	10	15	20
	----------yield declines per acre---------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	1.97	.76	.47	.36
Planning span	9.85	7.60	7.05	7.20
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	4.06	1.52	.94	.71
Planning span	20.30	15.20	14.10	14.20
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	8.58	3.18	1.95	1.46
Planning span	42.90	31.80	29.25	29.20
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	11.65	4.31	2.64	1.98
Planning span	58.25	43.10	39.60	39.60
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	13.50	4.99	3.05	2.29
Planning span	67.50	49.90	45.75	45.80
Yield decline for $100 of terrace system				
Annually	3.23	1.19	.72	.54
Planning span	16.25	11.90	10.80	10.80

The least expensive system, a gradient terrace with no support structures, had a PDV of $66.27 over the 20-year period (Table 3) and required a potential yield decline of .36 of a bushel per year to justify that cost.

In comparison, a parallel system with tile outlets and debris basins required an annual yield decline of 2.29 bushels to justify a PDV of $423.72. To be economically justified over the 20-year planning span, the gradient system would require a yield loss of 7.2 bushels, while the parallel system would require a yield reduction of 45.8 bushels.

As planning spans were shortened, break-even yield declines rose sharply. For a five-year horizon, an annual yield reduction of 3.23 bushels would be required for every $100 of terrace expenditure. A gradient system with no support structures would then require a yearly yield loss of 1.97 bushels or a total reduction of 9.85 bushels over five years. In comparison, a parallel system with both tile and debris basins would require a decline of 13.5 bushels annually or a total yield reduction of 67.5 bushels over the five-year time span.

Corn $2.90 Per Bushel, Discount Rate 14 Percent

Yield declines necessary to justify particular types of terraces are shown in Table 5 for a corn price of $2.90 and a discount rate of 14 per-

Table 5. Yield Decline Per Acre Necessary to Justify Terraces for Corn Production with 14 Percent Discount Rate and Corn Price of $2.90 Per Bushel

	Planning Horizon (years)			
Terrace Type	**5**	**10**	**15**	**20**
	---------yield declines per acre--------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	2.22	.93	.63	.51
Planning span	11.10	9.40	9.50	10.20
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	4.58	1.89	1.26	1.02
Planning span	22.90	18.90	18.90	20.40
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	9.71	3.96	2.64	2.13
Planning span	48.55	39.60	39.60	42.60
Parallel terraces with tile only (Initial cost $354.39) break-even yield decline				
Annually	13.17	5.37	3.58	2.88
Planning span	65.85	53.70	53.70	57.60
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	15.27	6.23	4.14	3.333
Planning span	76.35	62.30	62.10	66.60
Yield decline for $100 of terrace system				
Annually	3.67	1.49	.99	.79
Planning span	18.35	14.90	14.85	15.80

cent. Within the 20-year time frame, an expected yield decline of .79 of a bushel was required for every $100 of terrace system. This represented a 46 percent increase in the required yield decline as compared to the situation with the 10 percent discount rate (see Table 4). A gradient system with no support structures would require a yearly decline of .51 of a bushel to justify a PDV of $64.10 (Table 4) or a net yield reduction of 10.2 bushels over a 20-year period. This can be compared to the required reduction of 7.2 bushels for the base solution. A parallel system with both tile and debris basins would have a PDV of $421.06 and would require an annual yield decline of 3.33 bushels for a total reduction of 66.6 bushels over the 20-year period, up substantially from the required decline of 45.8 bushels when a discount rate of 10 percent was used.

If the planning span were five years, an annual yield decline of 3.67 bushels would be needed to justify $100 of terrace expenditure. A gradient terrace with no support structures would then need a total decline of 11.10 bushels while a parallel system with tile and debris basins would require a yield decline of 76.35 bushels over the same time period. If the planning span were either 10 or 15 years, a net loss of 9.40 and 9.50 bushels, respectively, would be needed to justify the least expensive gradient system. For the same two planning spans, a parallel system with tile and debris basins would require an approximate reduction of 62 bushels.

As the discount rate is increased, the amount of expenditure for terraces that can be justified decreases for a given yield decline. For a span of 10 to 20 years, gradient terraces with no support structures could be justified for a projected yield decline of 10 percent, but none of the representative terraces would be feasible for a five-year horizon. The effect of the higher discount rate was to decrease the PDV of each terrace system, increase the yield decline needed to justify a particular system and, if viewed in a different sense, increase the length of the planning span needed for the PDV of returns to equal the PDV of costs.

Corn $2.40 Per Bushel, Discount Rate 14 Percent

Similar analysis was done with a corn price of $2.40 per bushel and a discount rate of 14 percent (Table 6). The effect of the decreased corn price with the discount rate held constant at 14 percent can be seen by comparing Tables 5 and 6.

Assuming a 20-year planning span, a corn price of $2.40 per bushel and a discount rate of 14 percent, every $100 of terrace system cost would require a yield decline of .96 of a bushel per year. A gradient terrace system with no support structures would require an annual reduction of .61 of a bushel per acre, while a parallel system with both tile and debris basins would require a reduction of 4.03 bushels each year to be justified. Over the 20-year period, the total break-even yield decline

would be 12.2 and 80.6 bushels per acre for the gradient and parallel systems, respectively.

Table 6. Yield Declines Per Acre Necessary to Justify Terraces for Corn Production with 14 Percent Discount Rate and Corn Price of $2.40 Per Bushel

Terrace Type	Planning Horizon (years) 5	10	15	20
	----------yield declines per acre---------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	2.68	1.12	.76	.61
Planning span	13.40	11.20	11.40	12.20
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	5.57	2.28	1.52	1.23
Planning span	27.65	22.80	22.80	24.60
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	11.73	4.79	3.19	2.57
Planning span	58.65	47.90	47.85	51.40
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	15.91	6.49	4.32	3.48
Planning span	79.55	64.90	64.80	69.60
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	18.45	7.52	5.00	4.03
Planning span	92.25	75.20	75.00	80.60
Yield decline for $100 of terrace system				
Annually	4.43	1.80	1.19	.96
Planning span	22.15	18.00	17.85	19.20

If the planning span were shortened, the potential yield decline needed to justify terrace costs would be higher. For a 15-year planning span, every $100 of terrace expenditure would require a reduction of 1.19 of a bushel each year. The annual yield reduction necessary for each $100 expenditure would be 1.80 bushels for a 10-year horizon and 4.43 bushels for a five-year time frame. Over the five-year planning horizon, the least expensive gradient terrace system would require a total decline of 13.40 bushels. But to justify the parallel system with tile and debris basins, a total reduction of 92.25 bushels would have to occur.

Corn $2.40 Per Bushel, Discount Rate 10 Percent

Results are shown in Table 7 for a corn price of $2.40 and a discount rate of 10 percent. The effect of the interest rate changes with the corn price held constant at $2.40 per bushel can be seen by comparing the results shown in Tables 6 and 7. The effect of corn price changes with the interest rate held constant at 10 percent can be determined by comparing the results shown in Tables 4 and 7.

Table 7. Yield Declines Per Acre Necessary to Justify Terraces for Corn Production with 10 Percent Discount Rate and Corn Price of $2.40 Per Bushel

Terrace Type	Planning Horizon (years) 5	10	15	20
	----------yield declines per acre---------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	2.38	.91	.57	.43
Planning span	11.90	9.10	15.57	8.60
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	4.90	1.84	1.13	.85
Planning span	24.50	18.40	16.95	17.00
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	10.37	3.84	2.35	1.76
Planning span	51.85	38.40	35.25	35.20
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	14.07	5.21	3.19	2.39
Planning span	70.35	52.10	47.85	47.80
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	16.31	6.03	3.69	2.76
Planning span	81.55	60.30	55.35	55.20
Yield decline for $100 of terrace system				
Annually	3.91	1.44	.87	.65
Planning span	19.55	14.40	13.05	13.00

Using a corn price of $2.40 and a discount rate of 10 percent over a 20-year planning span, an annual yield reduction of .65 of a bushel would be required to justify every $100 of terrace system costs. This would be 20 percent more than the .54 of a bushel decline required in the base solution (corn price $2.90 and discount rate 10 percent). A gradient system without support structures would then require an annual yield reduction of .43 of a bushel or a total yield decline of 8.6 bushels over the 20-year planning span. In comparison, the most expensive

parallel system would be justified only if the annual yield loss was 2.76 bushels per acre or greater, or a decline of 55.20 bushels over the 20-year horizon.

If the planning span were five years, a potential annual decline of 3.91 bushels would be needed to justify every $100 of terrace cost. A gradient terrace system without support structures would then require a total decline of 11.9 bushels while a parallel system with tile and debris basins would need a reduction of 81.55 bushels over a five-year period. For the two intermediate planning spans of 10 and 15 years, the least expensive gradient system would need total losses of 9.10 and 8.55 bushels, respectively. For the most expensive system, the corresponding declines necessary to justify the outlay would be 60.30 and 55.35 bushels.

IV. COST-BENEFIT ANALYSIS FOR TERRACE SYSTEMS USED IN SOYBEAN PRODUCTION

The results of the cost-benefit analysis for soybean production are discussed below. As in the earlier section for corn production, analysis was first done for a base situation (soybean price of $7.25 per bushel and a discount rate of 10 percent). In subsequent analysis, break-even yield declines were recalculated after successive changes in one variable at a time. The five terrace systems of Table 3 were retained for these comparisons as were the two interest rates and the four planning spans. The two price levels for soybeans were assumed to be $6.00 and $7.25 per bushel.

Soybeans $7.25 Per Bushel, Discount Rate 10 Percent

For the base analysis, the price of soybeans was assumed to be $7.25 per bushel and the discount rate was assumed to be 10 percent. Results of this analysis are shown in Table 8. Given the 20-year planning span, a soybean yield decline of .21 of a bushel per year would be necessary to offset every $100 of terrace system cost. A gradient terrace system with no support structures had a PDV of $66.27 (Table 3) and required a yield reduction of .14 of a bushel each year to justify that cost. This can be compared to a parallel system with tile outlets and debris basins which had a PDV of $423.72 and required a per year yield decline of .91 of a bushel. Over the 20-year planning span, the gradient system required a total loss of 2.8 bushels while a reduction of 18.2 bushels would have to occur to justify the parallel system.

If the planning span were shortened, the break-even yield decline needed to justify each terrace system would rise. For an expected life of five years, a potential yield decline of 1.3 bushels per year would be needed for every $100 of terrace expenditure. Within the five-year time span, the gradient terrace system without support structures could be justified for fields which were expected to sustain a total loss of 3.95

bushels. However, to justify the parallel system with tile and debris basins, a yield decline of 27 bushels over the five-year period would be necessary.

Table 8. Yield Declines Per Acre Necessary to Justify Terraces for Soybean Production with 10 Percent Discount Rate and Soybean Price of $7.25 Per Bushel

Terrace Type	Planning Horizon (years) 5	10	15	20
	---------yield declines per acres--------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	.79	.30	.19	.14
Planning span	3.95	3.00	2.85	2.80
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	1.62	.61	.37	.28
Planning span	8.10	6.10	5.55	5.60
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	3.43	1.27	.79	.58
Planning span	17.15	12.70	11.85	11.60
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	4.66	1.73	1.05	.79
Planning span	23.30	17.30	15.75	15.80
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	5.40	2.00	1.22	.91
Planning span	27.00	20.00	18.30	18.20
Yield decline for $100 of terrace system				
Annually	1.30	.47	.29	.21
Planning span	6.50	4.70	4.35	4.20

Soybeans $7.25 Per Bushel, Discount Rate 14 Percent

Results of the analysis are shown in Table 9 for a discount rate of 14 percent and a soybean price of $7.25. In this case, every $100 of terrace expenditure would require a yield decline of .32 of a bushel in order to be jusitified over a 20-year period. This represented a 50 percent increase over the .21 of a bushel required in the base solution (when the discount rate was 10 percent). To justify a gradient terrace system with a PDV of $64.90, a yearly loss of .21 of a bushel, or a total reduction of 4.2 bushels over the life of the system would be needed. Compared to this, a parallel system with tile and debris basins would require an annual decline of 1.34 bushels for a net loss of 26.8 bushels over the 20-year period.

Table 9. Yield Declines Per Acre Necessary to Justify Terraces for Soybean Production with 14 Percent Discount Rate and Soybean Price of $7.25 Per Bushel

	Planning Horizon (years)			
Terrace Type	5	10	15	20
	----------yield declines per acre---------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	.89	.37	.26	.21
Planning span	4.45	3.70	3.90	4.20
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	1.87	.76	.51	.41
Planning span	9.35	7.60	7.65	8.20
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	3.89	1.59	1.06	.86
Planning span	19.45	15.90	15.90	17.20
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	5.28	2.16	1.44	1.16
Planning span	26.40	21.60	21.60	23.20
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	6.12	2.50	1.67	1.34
Planning span	30.60	25.00	25.05	26.80
Yield decline for $100 of terrace system				
Annually	1.46	.58	.40	.32
Planning span	7.30	5.80	6.00	6.40

A reduction in the planning span altered the required break-even yield decline. For a five-year horizon, yields would have to decline by 1.46 bushels each year to justify $100 of terrace cost. Therefore, for the least expensive gradient system, a total yield decline of 4.45 bushels would be required while for a parallel system with tile and debris basins, a reduction of 30.6 bushels would be required to justify the terracing cost. However, if the time frame were 15 years, anticipated yield declines of .40 of a bushel would be needed to justify every $100 of terrace expenditure. In this case, the gradient system would require a total loss of 3.9 bushels as compared to a decline of 25.05 bushels needed to justify the parallel system. Total losses of 3.7 and 25 bushels were required for the gradient and parallel systems, respectivley, over a 10-year horizon.

Soybeans $6.00 Per Bushel, Discount Rate 14 Percent

For the results shown in Table 10, the price per bushel of soybeans was decreased to $6.00, but the discount rate remained at 14 percent. Thus, the effect of a decrease in soybean price with a discount rate held constant at 14 percent can be determined by comparisons of Tables 9 and 10.

Table 10. Yield Declines Per Acre Necessary to Justify Terraces for Soybean Production with 14 Percent Discount Rate and Soybean Price of $6.00 Per Bushel

	Planning Horizon (years)			
Terrace Type	**5**	**10**	**15**	**20**
	---------yield declines per acre--------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	1.07	.45	.30	.25
Planning span	5.35	4.50	4.50	5.00
Gradient terraces with tile only (initial cost $120.90) break-even yield decline				
Annually	2.21	.91	.61	.49
Planning span	11.00	9.10	9.15	9.80
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	4.69	1.92	1.28	1.03
Planning span	23.45	19.20	19.20	20.60
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	6.37	2.60	1.73	1.39
Planning span	31.85	26.00	25.95	27.80
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	7.38	3.01	2.00	1.61
Planning span	36.90	30.10	30.00	32.20
Yield decline for $100 of terrace system				
Annually	1.77	.72	.48	.38
Planning span	8.85	7.20	7.20	7.60

If a farmer had a 20-year planning span, a yield decline of .38 of a bushel would be necessary to justify every $100 of terrace expenditure. Given the 20-year planning span, a price of $6.00 per bushel and a 14 percent discount rate, a gradient system without support structures would not be justified unless the projected yield declined by 5.00 bushels or more over the planning span. A parallel system with tile and debris basins would not be justified unless the yield declined by 32.2 bushels or more per acre.

The annual yield decline needed to justify each $100 of terracing cost would be .48 of a bushel for the 15-year planning span, .72 of a bushel for the 10-year period and 1.77 bushels for the five-year horizon. Over a five-year period, the least expensive gradient terrace system could be justified if the total yield decline were 5.35 bushels. For the most expensive parallel terrace system, a reduction of 36.90 bushels would be needed over the five years to justify the expenditure.

Soybeans $6.00 Per Bushel, Discount Rate 10 Percent

Analysis of break-even yield declines necessary to justify terraces

is shown in Table 11 for a soybean price of $6.00 and a discount rate of 10 percent. Over a 20-year planning span, gradient terraces without support structures could be justified if yields declined a total of 3.40 bushels. A parallel system with tile and debris basins could be justified if the anticipated yield decline were 22.0 bushels. These relationships can also be expressed as an annual yield reduction of .26 of a bushel of soybeans for every $100 of terrace expenditure.

Table 11. Yield Declines Per Acre Necessary to Justify Terraces for Soybean Production with 10 Percent Discount Rate and Soybean Price of $6.00 Per Bushel

	Planning Horizon (years)			
Terrace Type	5	10	15	20
	----------yield declines per acre---------- (bushels)			
Gradient terraces with no support structures (initial cost $56.48) break-even yield decline				
Annually	.95	.36	.23	.17
Planning span	4.75	3.60	3.45	3.40
Gradient terraces with tile only (initial cost $120.00) break-even yield decline				
Annually	1.96	.73	45	.34
Planning span	9.80	7.30	6.75	6.80
Gradient terraces with tile and debris basins (initial cost $260.80) break-even yield decline				
Annually	4.15	1.54	.94	.71
Planning span	20.75	15.40	14.10	14.20
Parallel terraces with tile only (initial cost $354.39) break-even yield decline				
Annually	5.63	2.08	1.27	96
Planning span	28.15	20.80	19.05	19.20
Parallel terraces with tile and debris basins (initial cost $411.72) break-even yield decline				
Annually	6.53	2.41	1.47	1.10
Planning span	32.65	24.10	22.05	22.00
Yield decline for $100 of terrace system				
Annually	1.56	.57	.35	.26
Planning span	7.80	5.70	5.25	5.20

If the planning span were 15 years, every $100 of terrace structure would require an annual yield decline of .35 of a bushel, while a parallel system with tile and debris basins would require a yield reduction of 22.05 bushels. If the horizon were 10 years, every $100 of terrace cost would require a .57 of a bushel decline. For a five-year period, the necessary yield decline to justify the $100 cost would be 1.56 bushels. For the five-year planning span, the least expensive gradient terrace would require a total reduction of 4.75 bushels. This can be compared to a reduction of 32.65 bushels needed to justify a parallel system with tile outlets and debris basins.

Soil Loss and Policy Considerations

I. INTRODUCTION

In general, this study has demonstrated that terraces appear to be an expensive method of keeping soil in place. Analyses in earlier sections have evaluated the costs of soil conservation only from the individual farm operator's point of view. However, the public costs of erosion damage can be quite large, and the benefits of constructing terraces cannot be fully determined without considering these costs as well.

The cost of terrace structures may be too expensive for the individual farmer to justify simply on the basis of private benefits. Since the failure to conserve soil also involves a public cost, subsidies of conservation practices have been and may continue to be utilized to provide an inducement for private investment. The public subsidy is supposedly offset by public benefits realized from a reduction in damage caused by the offsite deposition of sediment.

It should be noted that information for making decisions about the justification of public subsidies for reducing soil erosion is quite limited. Estimates of offsite damage are often quite crude and subject to wide error. Also, techniques for relating onsite soil movement to the amount of sediment actually entering streams are not well developed.

However, estimates can be made regarding how much expenditure for a terrace system could be justified by the potential yield decline from a farmer's point of view for various crops, prices and planning spans. By comparing this information with the estimated cost per ton of soil loss reduction, it would be possible to indicate the most cost effective targeting of public conservation expenditures and to determine the amount of public subsidy needed in a given situation to justify the construction of a terrace system for an individual farmer.

The purpose of this section is to determine the costs of retaining a ton of soil with various terrace systems on Memphis and Grenada soils utilized in corn and soybean production. In particular, the difference in costs between the two cash crops and the two soil series will be noted. In addition, the role of public subsidies for terrace construction will be evaluated. The amount of subsidy which would be required to justify the various terrace systems for the individual farmer will be determined for specified rates of yield decline over time.

II. SOIL LOSS

The amount of soil erosion over time for a particular soil, crop and set of production practices can be estimated using the Universal Soil Loss Equation (USLE). This equation considers the effect of all the major factors known to influence rainfall and provides estimates of the amount of soil moved from its present location but which may be

deposited at the bottom of a slope in a given field, in a bottomland area on another part of a farm or carried in suspension to the waters of nearby streams.

The coefficients needed for estimating average annual soil loss from water erosion were obtained from *Predicting Soil Losses in Tennessee Under Different Management Systems* (7) and from personal communications from Jent and Bell. An "R" value of 256 was used as the average for the 12 counties in the study area. Soil loss calculations were made for both Memphis and Grenada soil series. The "K" factors used for the soil loss estimates were .37 for Memphis and .43 for Grenada. When no terraces were used, slopes were assumed to be 200 feet in length. For the slope factor the midpoints of the two slope ranges, 2 to 5 percent and 5 to 8 percent, were utilized. The "LS" factor used for the 3.5 percent slope was .441 while the "LS" factor used for the 6.5 percent slope was 1.066.

When terraces were added to a field, the slope length was considered to be the horizontal distance between terraces. Results from the terracing survey reported in earlier sections indicated that terrace spacing averaged about 125 feet for gradient terraces and approximately 150 feet for parallel terraces. For gradient terraces the "LS" factor used was .371 for a 3.5 percent slope and .837 for a 6.5 percent slope. For parallel terrace systems the "LS" factors used were .398 and a 3.5 percent slope and .921 on a 6.5 percent slope.

The "C" values were adapted from unpublished data from Jent and Bell which will be published as an update to *Predicting Soil Losses in Tennessee Under Different Management Systems* (7). All analysis in the following sections was based on "C" factors appropriate for the average production levels (less than 100 bushels per acre for corn and less than 40 bushels per acre for soybeans). Without terraces, production of corn and soybeans were assumed to be with conventional, straight-row cultivation with crop residue left and without a winter cover crop. The "C" factors used in this case were .235 for corn and .372 for soybeans.

If straight-row farming is assumed, then the "P" factor is equal to one. However, terraces are usually used in conjunction with contour plowing. The "P" factor for terracing should then equal the contouring practice factor which is .50. As noted earlier, the influence of the terraces themselves on soil erosion in the USLE is expressed in the "LS" factor which would be based upon the horizontal spacing of the terraces.

III. SOIL LOSS CALCULATIONS

Estimated soil erosion losses for corn and soybean production are shown in Table 12 for Memphis soils. In each case, estimates were made with and without terraces for two slope ranges (2 to 5 percent and 5 to 8 percent). Separate estimates were made for gradient and parallel terrace systems. Soil losses shown represent the estimated total amount

Table 12. Estimated Soil Erosion Loss for Corn and Soybeans Grown on Memphis Soils

Land Slope	Terrace Type	Tons Soil Loss/ Acre/Year[a] Corn	Soybeans
2-5 percent	none	9.3	15.5
	gradient	4.1	6.5
	parallel	4.4	7.0
5-8 percent	none	23.7	37.6
	gradient	9.3	14.8
	parallel	10.3	16.2

[a]Estimates were made on the basis of "C" factors derived by Buntley and Bell (3) for average productivity. Average productivity refers to situations where expected yields per acre are 75-100 bushels for corn and less than 40 bushels for soybeans.

of soil that moves including the amount that would be deposited in the terrace channel.

Continuous corn grown without terraces on a 2 to 5 percent slope, Memphis soil, would be expected to result in 9.3 tons of soil loss per year (Table 12). The addition of a gradient terrace on this slope range would reduce soil loss by 56 percent to 4.1 tons. Because of the wider spacing, parallel terraces would be somewhat less effective in reducing erosion and would result in an estimated soil loss of 4.4 tons—an approximate reduction of 53 percent as compared to the no terrace system.

Erosion problems are more serious on steeper slopes, and terraces would have a greater potential for the reduction of erosion. For corn produced on a Memphis soil with 5 to 8 percent slopes, estimated soil loss per acre per year was 23.7 tons without terraces, 9.3 tons with gradient terraces and 10.3 tons with parallel terraces.

Soybeans provide less of a protective canopy and soil losses would be greater than for corn production. On a 2 to 5 percent slope, 15.5 tons of soil loss would be expected without terraces; for the 5 to 8 percent slope range the expected soil loss would be 37.6 tons. The addition of a terrace system would reduce the amount of soil loss by approximately the same percentages as those for continuous corn production. Gradient terraces would reduce the soil losses to 6.5 tons on 2 to 5 percent slopes and 14.8 tons on 5 to 8 percent slopes. The reduction from the addition of parallel terraces would be somewhat less.

Similar soil loss comparisons are shown in Table 13 for Grenada soils. Continuous corn grown on Grenada soils would be expected to result in 11.4 tons of soil loss on a 2 to 5 percent slope and 27.6 tons on the 5 to 8 percent slope. A gradient terrace would reduce these losses to 4.8 tons and 10.8 tons, respectively, for the two slopes. Parallel terraces would be slightly less effective because of their wider spacing.

As on Memphis soils, estimated erosion levels were greater for soybeans than for corn. On the 2 to 5 percent slope expected soil loss was

Table 13. Estimated Soil Erosion Loss for Corn and Soybeans Grown on Grenada Soils

Land Slope	Terrace Type	Tons Soil Loss/ Acre/Year[a] Corn	Soybeans
2-5 percent	none	11.4	18.1
	gradient	4.8	7.6
	parallel	5.2	8.2
5-8 percent	none	27.6	43.7
	gradient	10.8	17.1
	parallel	11.9	18.9

[a]Estimates were made on the basis of "C" factors derived by Buntley and Bell (3) for average productivity. Average productivity refers to situations where expected yields per acre are 75-100 bushels for corn and less than 40 bushels for soybeans.

18.1 tons without a terrace system. A gradient terrace could reduce the erosion loss of 7.6 tons while a parallel terrace could reduce the loss to 8.2 tons. Expected soil losses were quite high on the steeper sloped Grenada. Estimated soil erosion was 43.7 tons per year for the 5 to 8 percent slope. Total soil movement could be reduced to 17.1 tons if a gradient terrace were added and 18.9 tons if parallel terraces were used.

IV. THE COST OF EROSION REDUCTION PER TON OF SOIL

From an individual farmer's standpoint, soil conservation is usually viewed in terms of the effect on the cost of production and net returns over the appropriate planning span. But public expenditure to stimulate or encourage soil conservation can best be judged in terms of its cost effectiveness, i.e., achieving the greatest reduction in soil erosion or stream pollution for a given expenditure, or achieving a given reduction in soil erosion losses for the lowest possible cost. In this sense, it is appropriate to evaluate conservation measures in terms of the cost per ton of soil erosion reduction.

Estimates of the cost of reducing soil erosion per ton are shown in the next four tables for each of the terrace systems used on Memphis and Grenada soils to produce corn or soybeans. A 20-year planning span was assumed in all cases. The PDV of the five terrace systems was taken from Table 3. For each slope range the amount of soil that would be "saved" over the 20-year planning horizon by terracing was determined from the estimated soil loss values shown in Tables 12 and 13. The PDV of each terrace system was then divided by the tons of soil erosion reduction over the 20-year period to determine the PDV of retaining one ton of soil. Note also that the amount of soil erosion reduction was independent of the terrace system, i.e., all gradient terraces were assumed to save the same amount of soil as were all parallel terraces. Therefore, as the cost of an erosion control system rose, so did the cost of soil erosion reduction.

Table 14. Estimated Cost Per Ton of Soil Loss Reduction for Various Type Terraces on Memphis Soil Used for Corn Production[a]

Type of Terrace	Present Value of Terrace Cost	Reduction in Soil Loss (tons)		Cost Per Ton of Soil Retained (dollars)	
		2-5% Slope	5-8% Slope	2-5% Slope	5-8% Slope
Gradient terrace with no support structures	$ 66.27	113.8	288.2	$ .58	$ .23
Gradient terrace with tile only	130.67	113.8	288.2	1.15	.45
Gradient terrace with tile and debris basins	270.59	113.8	288.2	2.38	.94
Parallel terrace with tile only	366.39	107.8	269.6	3.40	1.36
Parallel terrace with tile and debris basins	423.72	107.8	269.6	3.93	1.57

[a]Estimates were made using a 20-year planning horizon and a 10 percent discount factor.

Memphis Soils

The cost of retaining a ton of soil utilizing each of the five terrace systems on Memphis soil to produce corn is shown in Table 14. On a 2 to 5 percent slope, it was estimated that any gradient terrace would reduce soil losses by 113.8 tons over a 20-year planning horizon. If a gradient terrace with no support structures were built, it would then cost $.58 in PDV terms to retain a ton of soil. Parallel terraces, slightly less efficient due to their wider spacings, were calculated to save 107.8 tons of soil over the planning span. Under these circumstances, if a parallel terrace with tile outlets and debris basins were built, it would cost $3.93 per ton of soil erosion reduction.

On the 5 to 8 percent slopes, the cost of reducing soil erosion per ton declines due to the larger volume of soil retained. It was estimated that any gradient terrace would keep 288.2 tons of soil from eroding, and that any parallel system would retain 269.6 tons of soil. In this case, the gradient system without support structures could retain soil at a cost of $.23 per ton while the cost for the parallel system with tile and debris basins would be $1.57 per ton of soil saved.

The costs of reducing soil erosion per ton for each of the five terrace systems utilized in soybean production on Memphis soil are shown in Table 15. Any gradient terrace on a 2 to 5 percent slope was estimated to save 180 tons of soil over a 20-year planning span. It would cost $.37 per ton of soil retained if a gradient terrace with no support structures were built. The same system on a 5 to 8 percent slope would save approximately 456.2 tons of soil for a per ton cost of $.15.

On a 2 to 5 percent slope, any parallel terrace was estimated to retain 170.6 tons of soil. The parallel terrace with tile outlets and debris basins could be utilized to retain soil at a cost of $2.48 a ton. However, that cost would fall to $.99 per ton if the same system were built on a 5 to 8 percent slope, and an estimated 426.8 tons of soil were saved over a 20-year period.

Grenada Soils

A similar analysis was done for corn and soybean production on Grenada soil and the results are shown in Tables 16 and 17. The addition of terraces results in greater reduction in erosion on Grenada soils than on Memphis soils for either corn or soybeans. Thus, because the cost of structures were assumed to be the same, the cost per ton of soil retained is lower on Grenada than for Memphis soil used for either corn or soybeans. For corn, estimated cost per ton of soil saved on Grenada soils ranged from $.20 per ton for gradient terraces with no support structures on 5 to 8 percent slopes to $3.38 per ton when parallel terraces with tile and debris basins were used on 2 to 5 percent slopes.

The costs per ton of soil erosion reduction for soybean production are shown in Table 17. Cost per ton of soil retained were lower than

Table 15. Estimated Cost Per Ton of Soil Loss Reduction for Various Type Terraces on Memphis Soil Used for Soybean Production[a]

Type of Terrace	Present Value of Terrace Cost	Reduction in Soil Loss (tons)		Cost Per Ton of Soil Retained (dollars)	
		2-5% Slope	5-8% Slope	2-5% Slope	5-8% Slope
Gradient terrace with no support structures	$ 66.27	180.0	456.2	$ .37	$.15
Gradient terrace with tile only	130.67	180.0	456.2	.73	.29
Gradient terrace with tile and debris basins	270.59	180.0	456.2	1.50	.59
Parallel terrace with tile only	366.39	170.6	426.6	2.15	.86
Parallel terrace with tile and debris basins	423.72	170.6	426.6	2.48	.99

[a]Estimates were made using a 20-year planning horizon and a 10 percent discount factor.

Table 16. Estimated Cost Per Ton of Soil Loss Reduction for Various Type Terraces on Grenada Soil Used for Corn Production[a]

Type of Terrace	Present Value of Terrace Cost	Reduction in Soil Loss (tons)		Cost Per Ton of Soil Retained (dollars)	
		2-5% Slope	5-8% Slope	2-5% Slope	5-8% Slope
Gradient terrace with no support structures	$ 66.27	132.2	335.0	$ .50	$ .20
Gradient terrace with tile only	130.67	132.2	335.0	.99	.39
Gradient terrace with tile and debris basins	270.59	132.2	335.0	2.05	.81
Parallel terrace with tile only	366.39	125.2	313.4	2.93	1.17
Parallel terrace with tile and debris basins	423.72	125.2	313.4	3.38	1.35

[a]Estimates were made using a 20-year planning horizon and a 10 percent discount rate.

Table 17. Estimated Cost Per Ton of Soil Loss Reduction for Various Type Terraces on Grenada Soil Used for Soybean Production[a]

Type of Terrace	Present Value of Terrace Cost	Reduction in Soil Loss (tons)		Cost Per Ton of Soil Retained (dollars)	
		2-5% Slope	5-8% Slope	2-5% Slope	5-8% Slope
Gradient terrace with no support structures	$ 66.27	209.2	530.2	$ .32	$.13
Gradient terrace with tile only	130.67	209.2	530.2	.63	.25
Gradient terrace with tile and debris basins	270.59	209.2	530.2	1.29	.51
Parallel terrace with tile only	366.39	198.2	495.8	1.85	.73
Parallel terrace with tile and debris basins	423.72	198.2	495.8	2.14	.85

[a]Estimates were made using a 20-year planning horizon and a 10 percent discount rate.

for the other situations due to the erodability of the Grenada soil and to the higher risk for erosion from land used for soybean production. Any gradient terrace system with no support structures was estimated to retain this amount of soil at a cost of $.32 per ton. If the same system were built on a 5 to 8 percent slope, an expected 530.2 tons of soil would be retained at a cost of $.13 per ton. On a 2 to 5 percent slope, any parallel terrace was estimated to retain 198.2 tons of soil. It would then cost $2.14 to retain a ton of soil if the parallel terrace with tile outlets and debris basins were built. However, the same system was calculated to retain 495.8 tons of soil on 5 to 8 percent slopes at a cost of $.85 a ton.

Data on the estimated cost per ton of soil erosion reduction should be interpreted with some caution since soil loss estimates are subject to error, and comparisons were made only between terrace systems and straight-row tillage. Obviously, numerous alternatives for erosion control can be used. Also, the cost of each type of terrace system was assumed to be the same for each soil type and slope.

In any given situation, the least expensive way to save a ton of soil would be to build the least expensive system possible that would achieve the desired result. In some cases, the cost might be $50 per acre while in others the cost may be $400 per acre depending on soil type, slope, land leveling required, availability of natural water outlets and other factors.

V. THE QUESTION OF SUBSIDIES

Concern about the public costs of sedimentation and the most cost effective ways of reducing soil erosion losses leads to the question of subsidies for terrace construction. In most cases, those farmers who seek the assistance of the Soil Conservation Service in planning and laying out a terrace system are eligible for a 50 percent cost-share program if local fund allocations are adequate. Under some special watershed programs this share may be as high as 75 percent. Continued public subsidies seem likely if terraces are seen as a viable method of keeping soil in place and if the farmers cannot justify the total construction costs in terms of their effect on net farm returns.

The estimated subsidies required for a farmer to justify various types of terrace structures are shown in Tables 18 and 19 for corn and soybean production. For the comparisons, it was assumed that the initial yield was 105 bushels for corn and 36 bushels for soybeans. Prices used were $2.90 per bushel for corn and $7.25 per bushel for soybeans. The discount factor used was 10 percent, and the planning span was assumed to be 20 years.

Comparisons were made for various yield declines from the base yield over the planning span ranging from 2.5 to 15 percent for corn and 3 to 18 percent for soybeans. These rates of yield decline were translated into an annual decline in bushel terms, which were then coverted into

Table 18. Subsidies Needed to Justify Terraces Used in Corn Production

Projected Yield Decline: Percent Decline Over 20 Years	Projected Yield Decline: Annual[a] Decline in Bushels	Present[b] Discounted Value	Percent Subsidy Needed to Justify[c] a Terrace with a PDV of: $66	$137	$271	$366	$424
2.5%	.13	$ 24	64%	82%	91%	93%	94%
5.0%	.26	$ 48	27%	65%	82%	87%	88%
7.5%	.39	$ 72	0%	47%	73%	80%	83%
10.0%	.53	$ 98	0%	28%	64%	73%	77%
12.5%	.67	$125	0%	9%	54%	66%	71%
15.0%	.79	$146	0%	0%	46%	60%	65%

[a]Assumes an initial yield of 105 bushels of corn.

[b]Based on a crop price of $2.90 per bushel and a discount rate of 10 percent.

[c]The present value of terrace cost shown is for the five terrace systems identified in earlier sections but could be representative of any terrace system with costs shown.

Table 19. Subsidies Needed to Justify Terraces Used for Soybean Production

Projected Yield Decline			Percent Subsidy Needed to Justify[c] a Terrace with a PDV of:				
Percent Decline Over 20 years	Annual[a] Decline in Bushels	Present[b] Discounted Value	$66	$137	$271	$366	$424
3%	.05	$ 23	65%	83%	91%	94%	95%
6%	.11	$ 51	23%	63%	81%	86%	88%
9%	.16	$ 74	0%	46%	73%	80%	83%
12%	.22	$102	0%	25%	62%	72%	76%
15%	.27	$125	0%	8%	54%	66%	70%
18%	.32	$148	0%	0%	45%	60%	65%

[a]Assumes an initial yield of 36 bushels of soybeans.

[b]Based on a crop price of $7.25 per bushel and a discount rate of 10 percent.

[c]The present value of terrace cost shown is for the five terrace systems identified in earlier sections but could be representative of any terrace system with costs shown.

a PDV that the farmer could afford to pay for a terrace system. Thus, for any of the five terrace systems utilized in this study, the percentage subsidy needed to justify a particular system for an individual farmer was calculated.

For example, suppose a farmer grew corn and had an estimated yield of 105 bushels per acre, and the expected yield decline was 10 percent over the 20-year planning span (Table 18). The per acre yield reduction would be approximately .53 of a bushel each year. Thus, in PDV terms, the break-even price a farmer could afford to pay for a terrace system that would maintain the current yield level would be $98 per acre. If a gradient terrace with no support structures could be built on the land in question at a PDV of $66, no subsidy would be required. It would be in the farmer's own interest to build and maintain a terrace system.

Suppose, however, that the least expensive system which could be built and maintained had a PDV of $424. The farmer could still afford to pay the $98 which the projected annual yield decline would justify, but he would now need a subsidy of 77 percent of $326 to build the terrace system. If a terrace could be built and maintained for a PDV of $271, a subsidy of $173 or 64 percent of the total cost would be necessary to make the addition of the terrace system a break-even situation from the farmer's standpoint. By comparing the cost per ton of soil retained and the amount of subsidy required, public funds could be targeted to those farms where the cost per ton of soil retained was lowest and/or the amount of subsidy required was least.

From the farmer's standpoint, the percent subsidy required to build a terrace system at a given cost will decline with increases in the expected impact of erosion on yield. From the public standpoint, cost effectiveness of public funds to subsidize terrace construction will depend on the cost per ton of soil retained, the cost and effectiveness of alternative public means for achieving a reduction in soil erosion losses, the relationship between soil erosion losses and stream pollution and other factors. Unfortunately, knowledge is not in place to accurately estimate the public cost as a result of sediment damage or the expected yield decline as a result of given levels of soil erosion loss.

Summary, Conclusions, Cautions

I. SUMMARY

Terraces are considered a viable method for combating soil loss at the farm level. However, they can be expensive to build and maintain even when federal subsidies are available to reduce net cost. A basic premise of this study was that soil erosion would result in reduced yields and that the reduction would be a linear function of time. From the farmer's standpoint, terraces could be economically justified if the

cost of a terrace system in PDV terms were equal to or less than the PDV of lost yields over the farmer's appropriate planning span.

The objectives of this study were to determine the cost of building and maintaining various types of terrace systems in 12 counties of West Tennessee; to determine by cost-benefit analysis the break-even yield decline necessary to justify different terrace systems utilized in corn and soybean production under different situations of crop price; and to examine policy implications suggested by the cost-benefit study.

A survey was used to collect estimated and actual costs of constructing terraces and related structures on a selected group of West Tennessee farms in early 1981. Questionnaires were completed by the district conservationists in 12 counties located in the Loess Soil Region of West Tennessee. Break-even yield declines for different terrace systems were calculated by means of a modified present discount formula that took into account a potential linear yield decline. Policy implications were based upon the results obtained from the break-even yield decline analysis and the reduction in soil erosion that could be expected from installation of terrace systems for different crop and soil situations.

The two main types of terraces utilized in the West Tennessee area were gradient and parallel terraces. In some cases both terrace types were combined into one system. The initial cost of a terrace system was influenced by the number and types of additional support structures needed and the amount of land leveling required.

Costs of 58 terrace systems installed varied widely among farms. The initial cost of gradient terrace systems ranged from $37 to $435 per acre and averaged $133 per acre. The per acre costs for parallel terrace systems ranged from $87 to $987 and averaged $339 per acre. Systems including a combination of gradient and parallel terraces ranged in cost from $75 to $680 per acre and averaged $242 per acre.

As stated above, the economic justification of a terrace system was evaluated in terms of the amount of yield decline necessary for the PDV of terrace construction and maintenance cost to equal the PDV of the yield decline. A linear relationship between soil loss and yield declines over time was assumed. Alternative planning spans of 5, 10, 15 and 20 years were considered. In addition, two crop prices for both corn and soybeans, two discount rates and five terrace systems were used to calculate the projected yield declines necessary to justify a terrace system.

For the base situation for corn, a price of $2.90 per bushel and a discount rate of 10 percent was assumed. In this case, a gradient terrace with a PDV of $66 would require a yearly yield decline of .36 of a bushel to justify that cost over a 20-year period. This can be compared to the annual decline of 2.29 bushels which would be required to justify a parallel terrace with tile outlets and debris basins with a PDV of $424.

As the planning span was shortened, the required yield decline necessary to justify the terrace systems rose.

If a discount factor of 14 percent and a corn price of $2.90 per bushel were assumed, the gradient terrace with no support structures would have a PDV of $64 and would require a yearly yield decline of .51 of a bushel to be justified. The parallel terrace system with tile outlets and debris basins would have a PDV of $421 and require a reduction of 3.33 bushels each year to justify that cost over a 20-year planning span. With a corn price of $2.40 per bushel and a discount rate of 10 percent, the least expensive gradient terrace system with no support structures would require an annual yield decline of .43 of a bushel over a 20-year period. In comparison, the most expensive parallel terrace system with tile and debris basins would need a yearly yield decline of 2.76 bushels to be justified.

For the base situation for soybeans, a crop price of $7.25 per bushel and a discount factor of 10 percent was assumed. A gradient terrace with no support structures would have a PDV of $66 and would require a yearly yield decline of .14 of a bushel per year to be justified if the planning span were 20 years. A parallel terrace system with tile and debris basins would have a PDV of $424 and would require an annual yield decline of 2.4 bushels over the 20-year horizon.

Like the corn analysis, the required yield decline rose when the discount rate rose relative to crop price, or when the crop price fell relative to the discount factor. When the crop price was assumed to be $6.00 per bushel and the discount rate 10 percent, the gradient terraces without support structures were found to require a yearly yield decline of .17 of a bushel. The parallel terrace with tile and debris basins would require an annual reduction of 1.10 bushels over a 20-year planning span. In all cases, the necessary yield decline to justify the cost of the terrace system rose as the planning spans were shortened.

Some policy implications related to soil erosion losses were also evaluated. Soil erosion loss was calculated for both corn and soybean production on 2 to 5 percent and 5 to 8 percent slopes and on both Memphis and Grenada soil types. The cost of retaining a ton of soil was determined by using the PDV of the five terrace systems utilized in this study. As expected, based on the estimates, the lowest costs for retaining a ton of soil would be achieved on a 5 to 8 percent slope Grenada soil used for continuous soybean production.

Over a 20-year period gradient terraces were estimated to save 530.2 tons of soil on a 5 to 8 percent slope Grenada soil used for soybean production. If a gradient terrace could be built for a PDV cost of $66 per acre, it would retain that amount of soil at a cost of $.13 per ton. However, if a parallel terrace with tile outlets and debris basins were built with a PDV of $424 per acre, an estimated 495.8 tons of soil would be retained at a cost of $.85 a ton. The difference in the amount of soil

retained over the 20-year planning span was due to the different horizontal spacings of the two terrace types.

Public subsidies necessary to induce farmers to construct particular types of terrace systems were determined for various projected yield declines resulting from soil erosion. Estimates were made for both corn and soybeans for the five basic terrace systems identified in the study and for projected yield declines over a 20-year period of 2.5 to 15 percent for corn and 3 to 18 percent for soybeans. Initial yields were assumed to be 105 bushels per acre for corn and 36 bushels per acre for soybeans. Crop prices used were $2.90 per bushel for corn and $7.25 per bushel for soybeans. The subsidy required was the difference between the estimated cost of terracing that could be justified from a farmer's standpoint and the total cost of the terrace system.

If the expected yield decline of soybeans were 12 percent over a 20-year period, the yearly yield decline would be .22 of a bushel; in this case, a farmer could justify a terrace expenditure of $102 per acre. If a terrace system could be built for $66 per acre, no subsidy would be needed. However, if the least costly terrace system possible to maintain erosion to acceptable levels were $271 per acre, then a subsidy of 62 percent would be required to induce a profit-maximizing farmer to make the investment. However, if yields declined by only 6 percent over the planning span, the annual yield decline would be .11 of a bushel for which the farmer could justify an expenditure of $51 per acre. In this case, a farmer would need a subsidy of 23 percent to build a terrace with a PDV of $66, or a subsidy of 81 percent, if the least costly system possible had a PDV of $271 per acre. Results were similar for corn production.

II. CONCLUSIONS

From the farmer's standpoint, terraces are more likely to be justified by potential yield declines if built upon severely eroded slopes and with a planning span of at least 20 years. However, in addition to the potential yield decline, the feasibility of a terrace system would depend upon its initial cost and the long-term expectation of crop prices and discount rates. In general, the least costly the system which is built and the longer the planning span, the more likely it can be justified by the potential yield declines.

For all situations analyzed, estimated soil erosion levels, even with terrace systems, exceeded soil tolerance values except in the case of terrace systems on 2 to 5 percent slopes Memphis soil. Terraces can reduce soil loss significantly on steeper slopes particularly on Grenada soil, but closer spacing of the terraces would be necessary to reduce the total soil movement within the tolerance value. Terraces could be used in conjunction with other soil erosion conservation practices to achieve tolerance levels. For properly constructed and maintained terrace systems, the proportion of the soil actually leaving a field may be quite low.

Assuming that the public costs due to soil erosion are greater than or equal to the private costs of constructing and maintaining terraces, subsidies could be used to induce investments in water control structures. Public funds could be targeted in an efficient manner if the cost of retaining a ton of soil and the percent subsidy required were minimized for specific situations.

III. CAUTIONS

The results of this study should be interpreted with a due amount of caution. While the costs of terraces were calculated and several variables which influence costs were identified, the exact relationship between them could not be determined by this study. Furthermore, lack of empirical knowledge about yield declines due to soil erosion and the dollar amounts of offsite damages due to sediment resulted in multiple answers to specific questions throughout this study.

Several factors which could lead to a rational decision to construct terraces were also ignored in the preceding analyses. It is possible that farmers may construct terraces in order to improve field efficiency and thereby lower the costs of production. Savings in production costs would then offset terrace expenditures over time. Subsidies and income tax incentives would likewise provide a basis for constructing terraces. As mentioned before, government cost-share plans of 50 percent are available and run as high as 75 percent under some special programs. If a farmer used his own equipment in the construction of the terraces and also received a subsidy, then his marginal costs could be lower than the hourly rates at which he would be reimbursed. If a tax incentive on construction costs were also considered, then net terrace costs could be low enough to be offset by a rather modest potential yield decline.

Therefore, discretion should be used when deciding on the suitability of terrace systems in an economic sense, as each situation will reflect the unique needs of a particular farmer. When empirical data exist to answer the questions of offsite damages and onsite yield declines, then the methods of this study, or some modification of them, may be used to more precisely determine the economic justification of different terrace systems in different situations.

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APPENDIX

SOIL CONSERVATION STRUCTURES SURVEY
Agricultural Experiment Station
University of Tennessee

I

County ________________

D.C. ________________

1. Farm cooperator (or number) ________________ Water management system I.D. _____
2. Acres terraced ________________ Year terraced 1979 or 1980 (circle).
3. Predominant soil types:

   Memphis _____% Grenada _____% Lexington _____%

   Loring _____% Other _________ _________%
4. Slope: 0-2% _____% 2-5% _____% 5-8% _____% Greater than 8% _____%

II

A. Terraces Structures:

1. What type of terrace was constructed? (Check)

   Gradient_____ Parallel_____ Steep backslope_____ Other__________ _____
2. Spacing of terraces____ft. Dimensions: Frontslope____ft. Backslope____ft.
3. Terraces built____ft. Land Leveling (Check) None____Moderate____Extensive____
4. Estimated cost of terraces $_______ Equipment assumed for cost estimate_______

   ________________ Size ____________ Rate used ____________
5. Actual equipment used ________________ Actual cost $__________
6. Did farmer do the work _____ hire out _____ do part, hire part _____ (Check)
7. Describe work done by farmer ________________________________

B. Grass Waterways:

1. Number ____________ Acres ____________ Estimated cost $__________
2. Equipment assumed for cost estimate ________________________

   Size________________________ Rate used________________________
3. Actual equipment used ________________ Actual cost $__________
4. Did farmer do the work _____ hire out _____ do part, hire part _____ (Check)
5. Describe work done by farmer ________________________________

C. Tile Outlets:

1. Pipe Size ______________________(in.) No. feet ______________________
   Pipe Size ______________________(in.) No. feet ______________________
   Pipe Size ______________________(in.) No. feet ______________________
2. Estimated cost tile $ ____________ Estimated cost installation $ ____________
3. Equipment assumed for installation cost estimate __________________________
   ___________________________________ Size __________ Rate used __________
4. Actual equipment used ____
5. Actual cost (tile + installation) $____
6. Did farmer do the work _____ hire out _____ do part, hire part _____ (Check)
7. Describe work done by farmer ____

D. Debris Basins:

1. Number of Basins _____ Acres or capacity _____ Estimated cost $__________
2. Equipment assumed for cost estimate ____________________________________
   Size __________________________ Rate used __________________________
3. Actual equipment used __________________________ Actual cost $__________
4. Did farmer do the work _____ hire out _____ do part, hire part _____ (Check)
5. Describe work done by farmer ____

Additional Comments or Explanations:

____

____

____

____

____

____

____

____

(Continue on back if necessary.)

INSTRUCTIONS FOR COMPLETING SOIL CONSERVATION STRUCTURES SURVEY FORM

General Instructions: Please complete a separate questionnaire for each water management system **involving terraces.** A case farm may have only one separate system or several. We hope to obtain information not only about the terraces but also about associated structures necessary to control the water movement. If possible we would like to obtain separate cost estimates for each part of the water management system and also if available cost of actual construction. If cost (estimated or actual) cannot be broken down into component parts please indicate the total cost of the system. Space for explanations are provided on page 2 of the survey form.

SECTION I

Section I of the survey form was designed to provide descriptive and identification information about the area terraced. We may need the **farmer's name or I.D. number** in case it becomes necessary to contact you later for clarification. If more than one **water management system** was planned on a particular case farm, designate as I, II, III, etc. for later identification. **Acres terraced** refers to the approximate number of acres on which terraces were built—not acres in a given field or fields. Under **date terraced** circle whether completed in 1979 or 1980. **Predominant soil type** refers to soils for area actually terraced. Percentages can be approximated without actual map measurements. Indicate the % of the area terraced that would fall in the **slope** classifications indicated.

SECTION II

Section A asks for information about the **terraces** constructed.

1. Check type of terrace(s) constructed. If more than one type of terrace was built indicate approximate % of each.

2. Indicate average terrace spacing and front and back slope dimensions. If not all terraces were the same dimension, indicate with an explanatory note here or on page 2.

3. Indicate total feet of terraces built. If two types of terraces were built show number of feet of each. If land leveling was necessary before terrace construction, indicate the degree of leveling by checking one of three blanks (none, moderate, extensive).

4. If separate estimates were made of terraces construction, please indicate here. If estimates were made only for the complete water management system, please note. Also indicate the type and size of equipment assumed, and the charge rate (per hour or other basis) used for making the cost estimate.

5. If available we would also like to know the actual equipment used and actual cost of constructing the terraces. Again if this information is available only in terms of the complete job, please indicate the total cost and note that such cost is for the entire system.

6. and 7. Check whether construction was done by farmer, by contractor, or by both and indicate the type of work done by the farmer (if applicable).

Section B asks for information about the construction of **grass waterways,** if any.

1. Please indicate the number and area covered by any waterways built to handle water from the terraces described above. Also indicate estimated cost of waterways, if separate cost estimates are available.

2, 3, 4, and 5. These questions have the same general meaning as explained above for terraces.

Section C deals with **tile outlets,** if any, built to handle water from the terraces.

1. Space is provided to indicate the number of feet of tile of various dimensions that were installed. Add additional spaces if more than 3 different dimensions were used.

2. (on page 2). If possible provide separate estimates of cost of tile and installation.

3, 4, 5, and 6. These questions have the same general meaning as explained above for terraces.

Section D asks for information about **debris basins,** if any, constructed to handle water from the terraces.

1, Indicate the number, capacity and estimated cost of debris basins planned.

2, 3, 4, and 5. These questions have the same general meaning as above.

Section E. Because of the difficulty of constructing a survey form to fit each situation we have provided plenty of space for necessary explanations. If necessary write on the back of the form.

If additional information is needed about the completion of the form please call Luther H. Keller, University of Tennessee, Agricultural Economics Department, Knoxville, Tennessee—telephone 615—974-7231.

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AGRICULTURAL EXPERIMENT STATION
KNOXVILLE, TENNESSEE 37916

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