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Burton C. English
Iowa State University

David R. Krog
Iowa State University

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Abstract

In a recent study, Pope, Bhide, and Heady [10] found that conservation tillage, when combined with contour farming, was the most economical means of reducing erosion on most Iowa soils. They continued by indicating that on some of the more erosive soils, less intensive crop rotations, strip cropping, or terracing may be required if soil loss is to be reduced to tolerable levels. However, the soils where terracing may be a viable alternative and a measure of the costs associated with the adoption of this soil-conserving method were not completely analyzed. As a result, a companion study aimed at determining the break-even costs of installing terracing on Iowa's soils has been conducted.

The general purpose of this study is to determine, from a farmer's perspective, the economic profitability of terracing in Iowa compared to other means of controlling soil erosion.

Disciplines

Agricultural and Resource Economics | Agricultural Economics | Economics

TERRACING ECONOMICS ON IOWA SOILS

by

Burton C. English
and
David R. Krog

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Terracing Economics on Iowa Soils

In a recent study, Pope, Bhide, and Heady [10] found that conservation tillage, when combined with contour farming, was the most economical means of reducing erosion on most Iowa soils. They continued by indicating that on some of the more erosive soils, less intensive crop rotations, strip cropping, or terracing may be required if soil loss is to be reduced to tolerable levels. However, the soils where terracing may be a viable alternative and a measure of the costs associated with the adoption of this soil-conserving method were not completely analyzed. As a result, a companion study aimed at determining the break-even costs of installing terracing on Iowa's soils has been conducted.

Objectives and Analytical Description

The general purpose of this study is to determine, from a farmer's perspective, the economic profitability of terracing in Iowa compared to other means of controlling soil erosion. Specific objectives are:

(1) To determine the break-even costs of installing terracing on selected Iowa soils.

(2) To determine on which soils and under what economic conditions terraces are an economical soil-saving practice for a farmer.

(3) To compare the economics of terracing to that of other conservation practices such as reduced tillage practices,

less intense crop rotations, contouring, and strip cropping.

The break-even terracing installation cost is defined as the maximum amount that a profit-maximizing farmer would be willing to pay to install terraces on a given soil before selecting an alternative, nonterracing means of controlling soil erosion. Nonterracing alternatives include practices such as reduced tillage, less intensive crop rotations, contouring, strip cropping, or some combination of these practices. Break-even terracing costs are determined for 187 individual soils under various farm situations defined by different constraints on soil loss and crop management systems.

This is a short-run analysis. The farmer is assumed to have a single year planning horizon. No attention is paid to the impact soil loss has on soil productivity because it is assumed to have no influence on short-run profits.[1] Because terracing contributes nothing to the farmer in the way of short-run cost reductions or short-run revenue increases, terracing will not be a profitable alternative for the short-run profit maximizing farmer unless constraints on soil loss are desired or enforced. Therefore, this analysis assumes that the farmer faces self-imposed and/or government-imposed limits on soil loss.

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[1] It must be noted that crop damage resulting from severe erosive conditions such as those under gully or rill erosion is not considered here.

Break-even terracing installation costs are determined by comparing profits on the most profitable non-terracing management system available to profits on the most profitable terracing system available. In Figure 1, net returns for each management system are plotted against respective soil losses for hypothetical soil X. Plots are made for both nonterracing and terracing management systems. Terraces at this point are assumed to cost nothing to install and maintain, but they are assumed to take land out of production. The profit-maximizing farmer will select the system that maximizes profits on Soil X. Without any restrictions on soil loss, the farmer will clearly choose management system A_N in Figure 1. Terracing is not a profitable practice on Soil X in the short run. The most profitable terracing system, even with terracing installation and maintenance costs set at zero, is $\partial_N - \partial_T$ dollars less profitable than the most profitable nonterracing system. The difference is a result of land taken out of production by terraces.

Now suppose that maintaining Soil X's soil loss below some maximum level is a desirable goal. This maximum level is desirable because it is the level of soil loss which can occur while Soil X still maintains its productivity potential (the effects of technological progress not considered). This maximum level is referred to as the T-value level of soil loss.

Restricting soil loss to T-value reduces the number of possible management system alternatives on Soil X. Systems available for selection are only those on which average annual soil losses are at or below the T-value level (systems with points to the left of the vertical dashed lines in Figure 1). Under this situation, the most profitable terracing system, B_T, has a higher per acre net return than the most profitable nonterracing system, B_N. The difference in net returns is $\beta_T-\beta_N$.

The value of $\beta_T-\beta_N$ is referred to here as D_x, the difference between the most profitable terracing and nonterracing systems' short-run net returns on Soil X when soil loss is contrained to T-values. D_x is equal to the annual cost which the farmer can afford to pay for terracing in order to be indifferent between choosing the terracing system or the nonterracing system.

The annual difference, D_x, includes the annualized break-even terracing installation cost and the annual maintenance cost. This relationship is expressed as:

$$D_x = R_x + 0.0375 \cdot R_x \tag{1a}$$

$$= 1.0375 \cdot R_x \tag{1b}$$

where R_x is the annualized break-even cost for terracing on Soil X, and where the annual maintenance costs are assumed to be 3.75 percent of annualized installation costs [12]. Solving for R_x, we get:

$$R_x = D_x/1.0375 \tag{2}$$

The break-even terracing installation cost is obtained by determining the discounted present value of R_x for the life of the terrace.

Mathematically,

$$I_x = \int_o^n R_x e^{-rt} dt \tag{3a}$$

$$= \int_o^n (D_x/1.0375) e^{-rt} dt \tag{3b}$$

$$= (D_x/1.0375) \int_o^n e^{-rt} dt \tag{3c}$$

$$= \frac{D_x}{(1.0375)(r)} (1 - e^{-rn}) \tag{3d}$$

where I_x = the break-even terracing installation cost for Soil X (\$/acre),

t = the time period in years ($t = 1,\ldots,n$),

n = the years of life of the terrace,

r = the discount rate,

e = a constant equal to 2.718, and

D_x = as previously defined.

Crop Management Systems

Each crop management system requires numerous pieces of information. Each system consists of a crop rotation, a tillage system, and a supporting practice. Alternatives for each are shown in Figure 2. For each management system, average costs, returns, input requirements, and outputs (including soil loss) are determined. Estimated costs for terracing installation and maintenance are not included since break-even terracing costs are the unknowns to be determined in the analysis. Further documentation of management systems can be found in Krog, English, Schatzer, and Heady [1984].

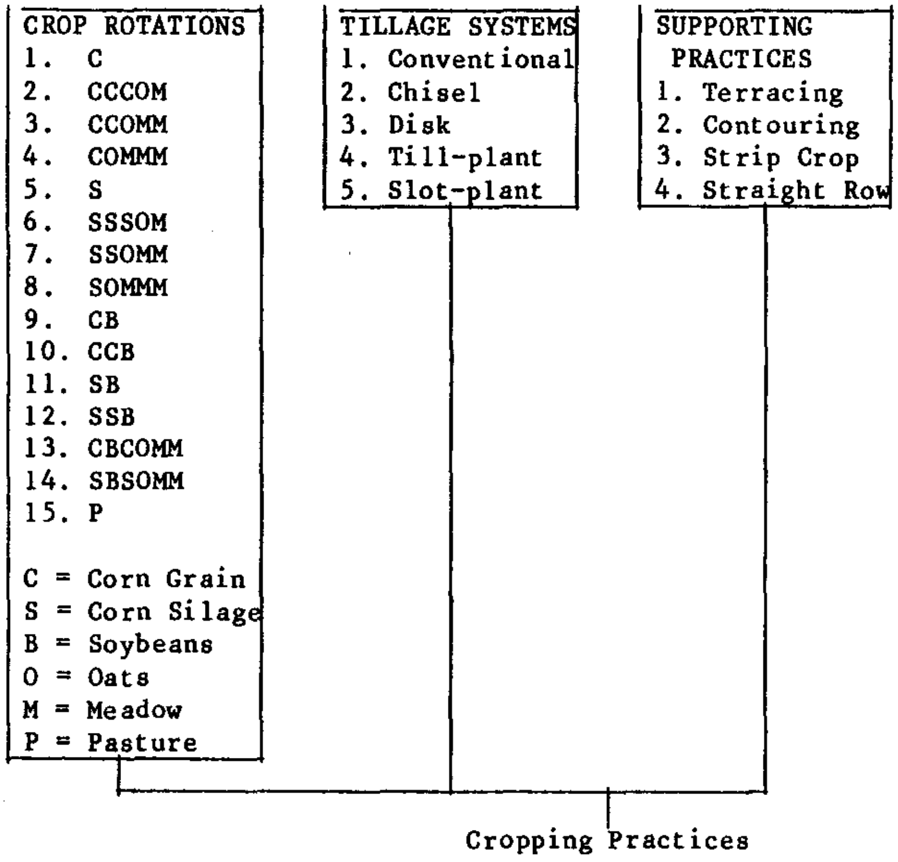

Figure 2. Alternative crop rotations, tillage, systems, and supporting practices.

Crop yields are not adjusted across tillage systems. Farmers are assumed to have a high level of management ability. No consistent evidence exists that, given proper management, the different tillage systems would show significantly different crop yields [10]. It is realized that crop yields could be lower in the first year or two when the farmer begins using a new tillage system. This is, of course, because the farmer is unfamiliar with the new practices in the initial stages of use. Possible changes in yields due to the tillage system changes, however, are not accounted for when determining crop yields for this study.

Maximum soil loss is defined according to soil tolerance values (T-values). T-values are maximum levels of soil loss that can occur while still maintaining current productivity levels. T-values are determined by factors such as soil depth and other soil characteristics that affect root development, plant nutrient losses, seeding losses, organic matter reduction, and sediment problems [18]. T-value levels of soil loss may not always be adequate or appropriate objectives on some soils. For this reason, three maximum soil loss constraints are chosen for the analysis. The three levels are 2T (twice T-value), T (T-value), and .5T (one-half T-value), corresponding to Farm Situations A1, A2, and A3.

Results

Break-even terracing installation costs vary considerably across soils and across the three situations ranging from a low of

-$143/acre on the Clarion, 138D1 soil under the 2T soil loss constraint to a high of $1,398/acre on the Tama, 120D1 soil under the .5T soil loss constraint. In general, break-even costs are rather low across the selected soils. On most soils, nonterracing alternatives exist that are more profitable in controlling soil erosion than the best (most profitable) terracing alternatives, even when terraces cost nothing to install and maintain. Of the 187 selected soils, only 30 percent had positive break-even costs under Situation A1, 38 percent under Situation A2, and 48 percent under Situation A3. Most positive break-even costs are less than $200 per acre under 2T and T situations while most positive break-even costs are greater than $200 under the .5T situation.

On which soils then are terraces likely to have the highest value relative to nonterracing practices? Table 1 shows the number of soils with positive break-even costs for the four possible slope classes. The B-sloped soils are shown to be poor candidates for terracing, even with extremely low soil loss constraints. The till-plant system is the most profitable tillage system on most soils and its impact on reducing soil erosion is enough to keep soil losses to desired levels on many B- sloped soils. On some B-sloped soils, the slot-plant system is required, but it costs only slightly more than till-planting. Terracing's contribution to decreasing soil loss relative to reduced tillage on B-sloped soils is not enough to offset reductions in net returns caused by land taken out of production by terraces.

On the steeper sloped soils, till- and slot-plant tillage systems do not provide all the control needed to keep soil loss to desired levels. Less intense crop rotations and occasionally strip cropping are needed on many soils if terraces are not used. With terraces, however, the farmer may be able to grow a more intense, yet higher valued, crop rotation while still maintaining the soil loss objective. In this case, the terraces usually have a short-run value, and break-even costs are positive. On some soils, terracing along with reduced tillage is not enough to control soil loss, and less intense crop rotations may also be needed. The value of the terrace is less if a less intense crop rotation is needed along with the terrace.

On some of the steepest soils, no nonterracing systems are available to control soil loss to desired levels. If the farmer wants to grow a crop on these soils while still maintaining soil loss objectives, he must install terraces. The value of terraces on these soils is then derived from the farmer's ability to grow a crop using terraces rather than leave the land idle. The highest break-even costs in these cases are generally found on the most productive of the potentially very erosive soils.

Four Marshall soils (9B2, 9C2, 9D2, and 9E2) are used to illustrate the range of break-even costs across soils and across the three farm situations. Table 2 shows that till-planting and slot-planting on the B-sloped Marshall soil are adequate for controlling soil loss to desired levels. Terraces have little value on this soil as indicated by the negative break-even costs. As the Marshall soil becomes more steep, less intense crop rotations may be required if terraces are not installed. For example, under T-value soil loss constraints (Situation A2), the C-sloped soil requires a CBCOMM rotation in the nonterracing system. With terraces, however, the farmer can grow the corn-soybean rotation. The value to the farmer over the life of the terrace for growing the higher valued crop rotation is $205 per acre (the break-even cost). If actual terracing installation costs are less than $205 per acre, the farmer should install terraces and grow the corn-soybean rotation on this soil. If actual installation costs are greater than $205 per acre, the farmer should use the nonterracing alternative. Break-even costs are shown to be the highest on the steep, D- and E-sloped Marshall soils under .5T soil loss constraints where terraces must be installed if land is not to be idled.

Policy Implications

The goal of soil and water conservation policy should be to bring about acceptable levels of soil erosion and water quality at the least possible cost to both farmers and the rest of society. Policy measures should also be equitable in distributing the costs of erosion control among farmers and the rest of society. Various conservation policy alternatives exist including educational and technical assistance programs, incentive payments such as through cost-sharing and other subsidy programs, disincentive income penalties, land use altering or easement programs, and direct regulations on the use of certain farming practices.

Indications from this study are that educational, technical assistance, and research programs dealing with reduced tillage should be expanded. Reduced tillage is shown to be effective in reducing soil erosion and also improves profits for those farmers with enough expertise to include it in the farming operation. From our analysis, reduced tillage practices, in particular the till-plant tillage system, is included in nearly all of the most profitable management systems when farmers are willing and able to use these practices. Reduced tillage also seems to complement the effects of terracing in reducing soil loss. Reduced tillage, therefore, seems to be the first step in efforts to control erosion. Invest- ments in promoting its adoption could yield high returns for both farmers and the rest of society. Reduced tillage on many of the steeper, potentially more erosive soils does not go far enough in reducing soil erosion to acceptable levels. Additional soil-conserving practices are needed. Policy measures are required to decrease soil loss beyond the points that are profitable for the farmer. In the past, one means has been to provide cost-sharing funds for installing terraces.

This study indicates that on many Iowa soils a substantial amount of the actual terracing installation cost will need to be paid by outside-the-farm sources before a farmer will install terraces rather than use a nonterracing means for erosion control. In fact, on many soils, the farmer will require compensation in excess of installation costs because of the land taken out of production by terraces. The cost-share payment or subsidy required by the farmer in order to install terraces can be determined by subtracting the break-even cost from actual installation costs. Actual installation costs and break-even costs for some soils are shown in Table 3. Whether the rest of society chooses to make these cost-share payments depends upon the value placed upon the additional beneficial effects which terracing has on reducing sediment delivery into streams and other waterways. The farmer will have to choose to use other conservation practices if adequate payments for terracing are not provided.

Whether terraces or some other means of control are used, reaching acceptable levels of soil loss on some soils will be costly and are unlikely to be borne solely by the farmer or land owner. Costs for controlling soil erosion are likely to be higher when terraces are used, but the additional cost may be worthwhile if terraces prevent sediment from entering waterways. The job of the policymaker becomes one of formulating policy which distributes these costs in an equitable fashion to those who receive the benefits of increased soil productivity and improved water quality.

Results of the study, first of all, lend further support to the idea that adoption of reduced tillage practices should be the first step in efforts to combat soil erosion. These practices help to significantly reduce soil loss while also improving farm profits. In addition, reduced tillage complements the effects of terracing in reducing soil loss and, in general, increases the value of terraces. The number one priority of conservation policy, then, should be to encourage, support, and assist in the widespread adoption of reduced tillage practices, especially those similar to the till-plant and slot-plant tillage practices included in this analysis.

Study Limitations

A complex problem such as the economics of soil and water conservation practices can only be analyzed in a manageable way using certain simplifying assumptions and procedures. Limitations, therefore, arise as complex problems are made simple. Interpretation of results must always be made in light of these inevitable limitations.

This analysis is conducted on an individual soil basis. Ignored are field-specific interactions among soils that may affect the use of certain cropping practices. For example, when terraces are installed, rarely will they be located on one soil only. Terraces are usually designed for individual fields and not individual soils. Also, the analysis does not consider farm-specific complications such as constraints on capital availability. Capital constraints could be a limiting factor for constructing terraces on some farms [2]. In order to account for field- and farm-specific interactions and complications, an analysis could be made using linear programming models. Of course, it would be more difficult to generalize results obtained under specific farm situations.

This analysis uses only one set of costs and relative prices. Price relationships can and do change over time because of demand and supply shifts of inputs and outputs. The sensitivity of the results to various changes in relative prices can be determined but goes beyond the scope of this study.

Coefficients used in the Universal Soil Loss Equation (USLE) assume average weather and soil conditions. In addition, coefficients which account for the effects of reduced- and no-tillage practices on soil loss are based upon a limited amount of data. More accurate estimates of USLE coefficients can possibly be obtained after further research efforts have been made.

The value of terracing is evaluated only from the farmers' perspective. That is, only the effects of terracing on reducing soil movement as estimated by the USLE are considered. Further work needs to be done on estimating the value of terraces when account is taken for terraces' additional influence on reducing sediment delivery into waterways. Estimating the value of improved water quality is very difficult and is not done in this study.

This analysis has been conducted from a short-run perspective. Soil loss constraints used in the farm situations indirectly recognize the long-run value of conserving topsoil, but no direct account is taken of soil erosion's long-run impacts on potential soil productivity and farm profits. As better data comes available, an extensive long-run study could be conducted.

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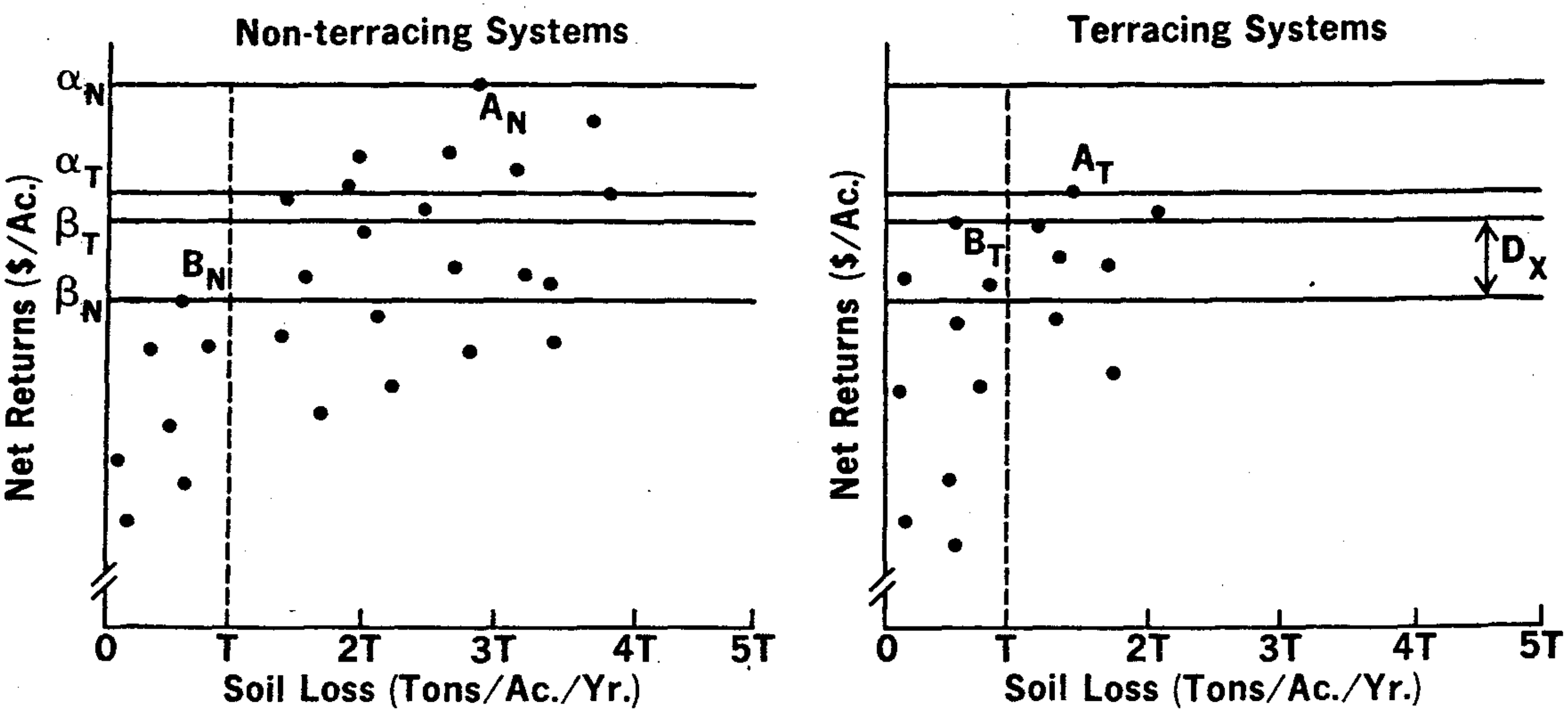

Figure 1. Net returns plotted against soil loss for nonterracing and terracing crop management systems used on Soil X.

Table 1. Number and percent of soils with positive break-even costs for four slope phases under Situations A1, A2, and A3.

		Farm situations					
		A1		A2		A3	
Slope phase	Total number of soils	Number of soils	Per-cent	Number of soils	Per-cent	Number of soils	Per-cent
B	68	0	0	0	0	1	1
C	62	14	23	44	71	38	61
D	45	36	80	23	51	38	84
E	12	6	50	5	42	12	100
	187	56	30	71	38	89	48

Table 2. Most profitable terracing and nonterracing management systems[a], annual net return differences, and break-even terracing costs for four soils under Farm Situations A1, A2, and A3.

Soil		Farm situation		Most profitable terracing system			Most profitable nonterracing system				
Number i	SMU	Number j	Name	Crop rotation	Tillage system	Supporting practice	Crop rotation	Tillage system	Supporting practice	D_i^j[b]	I_i^j[cd]
12	9B2	1	A1	CB	Till-plant	Terracing	CB	Till-plant	Contouring	-6.62	-62
14	9C2	1	A1	CB	Till-plant	Terracing	CB	Slot-plant	Contouring	-7.25	-68
16	9D2	1	A1	CB	Slot-plant	Terracing	CBCOMM	Slot-plant	Contouring	12.00	112
18	9E2	1	A1	CB	Slot-plant	Terracing	COMMM	Slot-plant	Strip crop	10.80	101
12	9B2	2	A2	CB	Till-plant	Terracing	CB	Till-plant	Contouring	-6.66	-62
14	9C2	2	A2	CB	Till-plant	Terracing	CBCOMM	Slot-plant	Contouring	21.97	205
16	9D2	2	A2	CB	Slot-plant	Terracing	COMMM	Slot-plant	Strip crop	19.14	179
18	9E2	2	A2	COMMM	Slot-plant	Terracing	COMMM	Slot-plant	Strip crop	-10.13	-95
12	9B2	3	A3	CB	Slot-plant	Terracing	CB	Slot-plant	Contouring	-6.52	-61
14	9C2	3	A3	CB	Slot-plant	Terracing	COMMM	Slot-plant	Strip crop	31.24	292
16	9D2	3	A3	COMMM	Slot-plant	Terracing	*	*	*	94.43	883
18	9E2	3	A3	COMMM	Slot-plant	Terracing	*	*	*	63.95	598

[a] Asterisk indicates that no practices are available which keep soil losses to the desired level.

[b] Annual net return difference between the most profitable terracing and nonterracing management systems for soil i under farm situation j.

[c] Assumes a 10 percent discount rate and a terrace life of 35 years.

[d] Terracing break-even cost for soil i under farm situation j.

Table 3. Estimated actual installation cost and five break-even installation costs for selected soils.

						Break-even Installation Costs		
						Farm Situations		
Soil Number	SMU	Soil Series	County in Iowa	Terrace type[a]	Actual Installation Cost[b] ($/Ac.)	A1	A2	A3
						dollars per acre		
4	1D3	Ida	Ida	GBS	700	94	-19	418
6	1E3	Ida	Ida	GBS	900	-51	155	155
11	9B1	Marshall	Pottawattamie	GBS	250	-64	-64	-62
14	9C2	Marshall	Pottawattamie	GBS	275	-68	205	292
16	9D2	Marshall	Pottawattamie	GBS	275	112	179	883
21	10C2	Monona	Ida	GBS	650	-58	122	180
23	10D2	Monona	Ida	GBS	700	27	49	646
26	12C1	Napier	Ida	GBS	650	-68	153	231
29	24D2	Shelby	Pottawattamie	GBS	275	115	173	766
32	24E2	Shelby	Jasper	GBS	900	111	-47	383
49	76C2	Ladoga	Iowa	GBS	450	-74	234	334
50	76D2	Ladoga	Iowa	GBS	650	133	8	994

[a] Grassed backslope terrace

[b] Actual costs will vary across the state