KW

Burwell

1792

Corn
Terraces
loess
water yields
Soil loss
nitrogen
Phosphorus
runoff

evel terraces with stabilized backslopes on loessial cropland in the Missouri Valley: a cost-effectiveness study

R. G. SPOMER, W. D. SHRADER, P. E. ROSENBERRY, and E. L. MILLER

ABSTRACT—High corn yields can be maintained on terraced and unterraced fields on deep loessial soils, even though construction and erosion remove a large percentage of the surface soils. Yields have been slightly higher from unterraced fields, but a terrace drainage system and gradual intraterrace benching would increase yields from terraced fields through better moisture distribution. Water yield averaged 7 inches a year from both fields; however, the yield was primarily base flow from the terraced field and surface runoff from the unterraced field. Soil loss averaged less than 1 ton per acre per year from the terraced field and 25 tons from the unterraced field. Preliminary results indicate that about 90 percent of the nitrogen and phosphorus moving off cropland is transported by soil in runoff.

ABOUT 7 million acres of soil are developed on deep, freely permeable loess in the Missouri River Basin. These soils are highly productive, but sloping croplands are subject to severe erosion.

The loessial soils and climate make feasible the use of level, parallel terraces in the area. Increased size of machinery and rising labor costs discourage the use of broad-base, graded- or level-terrace systems with numerous point rows. Parallel, level terraces with grassed backslopes alleviate many problems associated with the broad-base terraces and are therefore an effective conservation practice.

Physical Aspects of Watersheds

A study of corn production on a grassed-backslope, level-terraced watershed and on unterraced watersheds was begun near Council Bluffs, Iowa, in 1964 (Table 1). Soils on these watersheds are of the Monona-Ida-Napier series (silt loams of loessial origin). Loess overlies glacial till and ranges in depth from 80 feet on ridge tops to less than 15 feet in valleys. Topography varies from narrow valleys and ridges with 2 to 4 percent slopes to sidehills with 10 to 16 percent slopes. Saxton and Spomer (*1*) described the watersheds more completely.

Terraces and Soils

Parallel alignment of terraces was possible in some areas but impossible in others because of extreme topographic undulations (Figure 1).

A typical parallel, grassed-backslope terrace system requires high fills through drainageways and other depressions to permit uniform terrace spacing and to eliminate point rows (Figure 2). Terrace backslopes are steep (2:1) and seeded to grass. The backslope, about 10 percent of the area, cannot be cultivated.

Maximum cuts and fills for terrace construction on study watershed 4 were about 6 feet. Much of the watershed surface was disturbed during construction. Calcareous loess, the soil parent material, was exposed over large areas, resulting in crop production problems on scalped areas. Fortunately, all parts of the soil profile—surface, subsoil, and parent material—consist of friable silt loam. All soil horizons are relatively easy to till, are freely permeable, and have a high water-holding capacity. But these soils are not immediately equally productive under all conditions. Originally, there were wide differences in productivity.

Ridge tops and gentle slopes on the watersheds are Monona silt loam, which, when not eroded, has a dark-brown, friable silt loam surface about 10 inches thick and a brown subsoil.

Soils on steeper slopes and narrower ridges are calcareous throughout—Ida silt loam, a light, yellowish brown, calcareous, uniform silt loam from the surface downward.

Soil material eroded from higher elevations has accumulated on lower slopes and in swales. This colluvial soil, Napier silt loam, commonly has about 24 inches of dark-brown, friable silt loam surface.

Terrace construction increased the areas of Ida-like soils and thickened surface deposits over some colluvial areas.

The ground was wet when terraces were constructed. This resulted in compaction of soil in terrace channels that persisted until 1969. Subsoiling of terrace channels in 1969 and repeated freezing and thawing have reduced the compaction. Construction of terraces when soil moisture was near optimum for tillage would have prevented the soil compaction problem. Infiltration rates would have remained high, and crop damage by flooding would have been minimized.

Fertilizer Needs and Application

Ida soils are usually very low in plant-available N and P. Calcareous loess exposed during terrace construction is similar to Ida silt loam. In addition to extreme N and P deficiencies, these truncated areas are frequently deficient in plant-available zinc.

After terrace construction, the entire area was fertilized annually with 110 to 150 pounds of N per acre and 37 pounds of P (80 pounds of P_2O_5). All truncated areas received 10 pounds per acre of Zn as zinc sulfate. Even with this fertilizer application rate, there were nutrient shortages and imbalances on some areas in the first few years after terrace construction.

R. G. Spomer is an agricultural engineer with the Agricultural Research Service, U. S. Department of Agriculture, Council Bluffs, Iowa 51501; W. D. Shrader is a professor of agronomy at Iowa State University, Ames, Iowa 50010; P. E. Rosenberry is an agricultural economist with the Economic Research Service, USDA; and E. L. Miller, at the time of this study, was a research associate in the ISU Department of Agronomy. This article is a contribution from ARS and ERS in cooperation with the Agronomy Department of the Iowa Agriculture and Home Economics Experiment Station. Published as Journal Paper No. J-7221 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project 1853.

Reprinted from the Journal of Soil and Water Conservation
May-June 1973, Volume 28, Number 3

Figure 1. Terrace system on watershed 4 in September 1970.

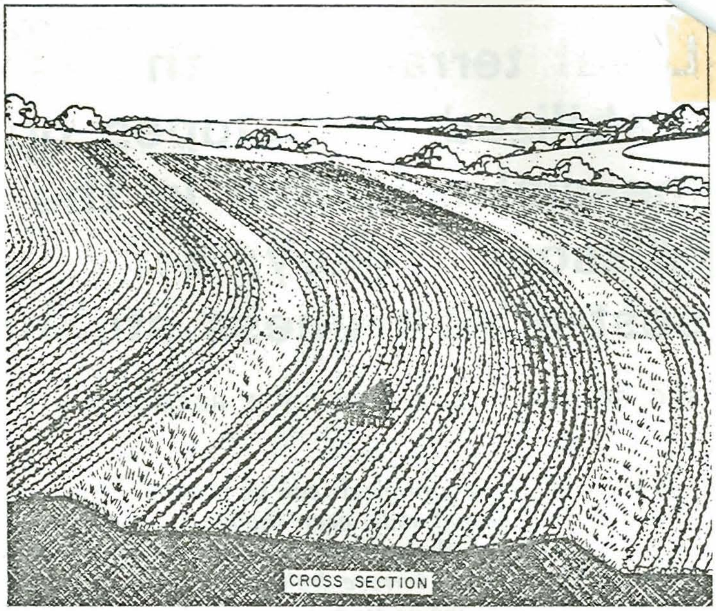

Figure 2. Typical level, parallel terraces with grassed backslopes.

Starting in 1969, as part of another study, 400-200-60 fertilizer was applied annually to terraced watershed 4 and unterraced watershed 1. Soil fertility, as a result, should be high.

All fields are spring-plowed and disked annually so the fertilizer is mixed through the plow layer.

Terrace Performance

During the first 2 years of operation, terraces on watershed 4 were subjected to two rainstorms that have a chance of occurring, on the average, only once in 10 to 15 years. Although many breaks occurred in the terraces during these storms, the terrace system was 90 to 95 percent effective in reducing flood flow and sediment discharge. A 4-inch rainstorm on June 26, 1966, did not damage the terraces, nor did a 30-day, 18-inch total rainfall early in the 1967 growing season.

Miller (2) indicated that in 1968 and 1969 more moisture was available to corn in terrace channels than in the intervals between terraces. Corn yields were positively correlated with moisture. In other years, however, excessive moisture in terrace channels depressed yields.

Shrader and Murdock (4) reported corn production of 12 bushels more per acre for each additional inch of soil moisture in the root zone. In the area of the watersheds, corn suffers from lack of moisture in most years. Yet little water infiltrated by the terrace system was available to corn because interterrace intervals were relatively steep and runoff into the terrace channels was rapid. Water ponded in low areas of channels and percolated downward so that interterrace intervals were no better supplied with moisture than were unterraced fields. Thus, only a small percentage of the field received added soil water. A level-benched area or an area with contour ridges between terraces would better distribute infiltrating water and should increase corn yields.

Measuring Crop Yields

An intensive, intrafield sampling program from small areas within the watersheds began in 1968. This program permitted yield comparisons among different soil conditions and among corn-growing portions of terraced and unterraced watersheds.

Although yields were relatively high for all soil conditions, 3-year average yields were lower from truncated or eroded areas (Table 2). Stands were slightly higher on undisturbed soil and in depositional areas, and stand variability seemed to account for most yield differences. This variability evidently resulted from greater difficulty in preparing seedbeds on the raw loess compared with surface soils. Yields were commonly higher on Napier soil.

Annual corn yields were about equal on terraced and unterraced watersheds, based on small-area samples (Table 3).

Records of field-harvested yields (calculated by dividing total yield by total acreage in the watershed) are

Table 1. Description of research watersheds, Treynor, Iowa.

Watershed Number	*Size (a)*	*Cropping*	*Land Treatment*
1	74.5	Continuous corn	Field contoured (unterraced)
2	82.8	Continuous corn	Field contoured (unterraced)
4	150[a]	Continuous corn	Level terraced

[a] Corn yields are from 147.5 acres; 2.5 acres is not farmed with the watershed.

Table 2. Small-area corn yields and plant density as affected by soil conditions on a terraced watershed, Treynor, Iowa.

	Yield (bu/a)			*Averages*	
Soil Conditions	*1968*	*1969*	*1970*	*Yield (bu/a)*	*Stand (plants/a)*
Undisturbed Monona silt loam	106	147	120	124	16,100
Truncated or eroded area (Ida-like)	108	134	108	117	14,800
Depositional areas (Napier-like)	129	154	120	134	16,000

available from 1964 to 1970 (Figure 3). Yields have been consistently higher on unterraced watersheds, but that difference has decreased in recent years. Average yield difference for the past 3 years was 8 bushels per acre. More important, yields have increased rapidly on all watersheds on soil areas that, to a large extent, formerly had low corn yields. For the past 3 years, yields have averaged 100 bushels per acre or more.

Lower field-harvested yields from the terraced watershed resulted from the loss of land in terrace backslopes and ponded areas in terrace channels.

It seems reasonable to expect that yields from areas actually in corn should be about equal on the terraced and unterraced fields. Where terracing and farm operations reduce the slope of interterrace areas, increased infiltration will result, which should increase yields most years in southwest Iowa (4).

Watershed Hydrology

Annual water yield (surface runoff and base flow) from 1964 to 1970 on level-terraced watershed 4 did not differ significantly from water yields on unterraced watersheds 1 and 2. Much more of the water yield from the terraced watershed occurred as base flow, however (Figure 4).

Peak runoff rates on unterraced watersheds 1 and 2 were similar. The regression of peak runoff rate between level-terraced watershed 4 and unterraced watershed 1 approximately describes the linear equation

$$Q_4 = 0.05\ Q_1$$

where Q_4 is the peak runoff rate on watershed 4 and Q_1 is the peak runoff rate on watershed 1. Therefore, terracing fields similar to those at the Treynor site will, on the average, reduce the peak runoff rate 95 percent. This represents a tremendous potential for reducing downstream flooding.

Soil Erosion

Sheet erosion from terraced watershed 4 averaged 1 ton per acre annually during the 7-year period, 1964-1970, which included years af above- and below-normal rainfall (Table 4). Erosion on unterraced watersheds 1 and 2 averaged 25 tons per acre per year.

During the record 6-inch rainstorm on June 20, 1967, soil loss from sheet erosion on watersheds 1 and 2 averaged 35 tons per acre. Four inches of rain fell on watershed 4, causing a soil loss of 3 tons per acre. Gully erosion exceeded 300 tons each from watersheds 1 and 2 during this storm; however, the gully on watershed 4 filled slightly.

Terrace Costs and Benefits

Of primary economic concern to a farmer is the effect terracing will have on his current income or, more specifically, on his cash return and the cost of producing a crop. Long-term benefits and costs to a farmer and society are more difficult to evaluate. The issue here concerns the economic decision of an individual farmer and not the decisions of farmers in general.

Construction and Maintenance

Terrace construction on watershed 4 in 1964 cost $38.95 per acre (38,305 lineal feet at 15 cents per foot). In 1964 and 1965, $23.15 per acre was spent repairing the terraces. This second cost should not be considered normal maintenance but should be added to the intial cost for the following reasons: (a) lack of experience in building this type of terrace, (b) unfavorable soil conditions during construction, (c) above-normal rainfall after construction, and (d) the fact that maintenance costs since then have been negligible. Exclusion of the repair cost would not materially affect the economic analyses, however.

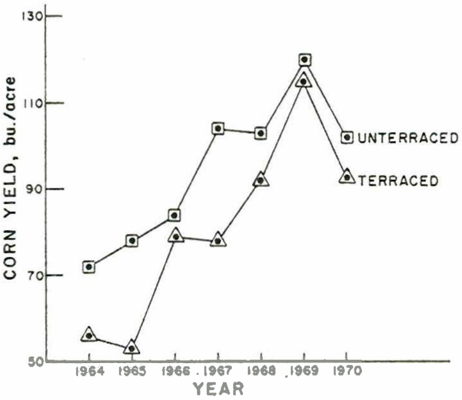

Figure 3. Comparison of corn yields on terraced and unterraced watersheds, Treynor, Iowa, 1964-1970.

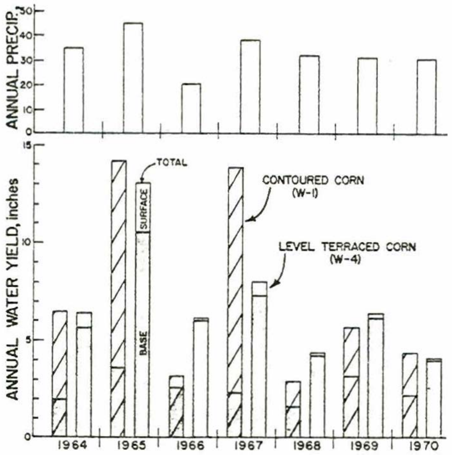

Figure 4. Annual water yield and precipitation on terraced and unterraced watersheds near Treynor, Iowa.

Beginning in 1963, watersheds 1 and 2 were contour-farmed. Grassed waterways were established at a cost of $698.00, which included land-fills, leveling, and seeding. Cost per acre was $4.43.

The difference in construction and maintenance costs on the terraced and unterraced watersheds was $57.67 per acre. In 1964 a farmer could have applied for cost-sharing payments from the Agricultural Stabilization and Conservation Service of 10 cents per foot of terrace constructed or $27.22 per acre of watershed. This would have reduced the difference in construction and maintenance costs to $30.45 per acre. If this difference were capitalized into land investment and a charge assessed for capital at an interest rate of 7 percent, the annual interest cost to a farmer for the additional investment in terraces would be $2.13 per acre.

Maintenance costs on the terraced watershed after repairs in 1965 totaled $25.50 (1966 to 1970) or 3 cents a year per acre of watershed. In contrast, maintenance costs for waterways on the unterraced watersheds totaled $486.50 for the 1966-1970 period or 37 cents a year per acre of watershed. This period represents a valid time base for comparison because waterways had deteriorated to the point of needing extensive repairs in 1970. Waterways seem to require major renovation about every 3 years if they are to function properly.

Terrace Farmability

Terraces can transform rough fields with short rows into smooth fields with longer rows to permit efficient operation of large machinery. The farmable land slope on the terraced watershed decreased an average of 4 percent where the original topography varied between 8 and 14 percent. This slope decrease would increase average machine-operating speed 18 percent (3). Assuming the cost of tractor operation is $3.00 per acre per year, this saving amounted to 54 cents per acre on the terraced watershed.

Farmers understandably dislike conservation measures that complicate field operations, but they will seriously consider measures that improve farmability. A good example is the acceptance of tile drainage, which removes standing water and permits earlier field operation in the terrace channels. The cost of additional tiling to drain the terrace channels at the Treynor site would be $2,000 (5,000 feet of tile at 40 cents per foot). If 50 percent of the installation cost were shared by the Agricultural Stabilization and Conservation Service, the increased investment by the farmer would be $6.79 per acre of watershed, plus 7 percent interest, or $7.25 per acre per year.

Costs and Benefits

A comparison of onsite costs and benefits of producing corn on the terraced and unterraced fields showed that the farmer fared $15.25 per acre better on the unterraced field (Table 5). Considering onsite benefits only, there is no indication that terracing will greatly benefit the farmer in the near future.

Costs of terracing vary widely among fields, as does the rate of deterioration of unterraced fields. Difference between yields on the terraced and unterraced fields has diminished (Figure 3). As this trend continues and as unterraced fields deteriorate, yields from terraced fields will compare more favorably. The initial period of unfavorable returns may be short because of increased soil moisture and, in turn, greater yields from terraced fields.

We lack the information to estimate offsite effects of this terrace system, but they are significant. Traditionally, the physical consequences and damage from sediment (for example, filling of reservoirs, channels, ditches, and other structures and abrasion of turbines and pumping equipment) have received prime consideration. But runoff that transports soil particles also transports plant residue, manure particles, dissolved solids, pesticides, nutrients, and other chemicals that have an adverse effect on the environment. Preliminary results from a study of plant nutrient movement on the Treynor watersheds show that 90 percent of the N and P lost from cropland is carried by sediment in surface runoff.

Table 3. Small-area corn yields from terraced and unterraced watersheds, Treynor, Iowa.

Year	*Terraced (bu/a)*	*Unterraced (bu/a)*
1968	113	118
1969	143	153
1970	118	118
Average	125	130

The magnitude of offsite benefits and costs becomes more difficult to evaluate when environmental considerations are introduced. Society's cost is greater when sediment is transported from the unterraced watersheds at 25 tons per acre per year compared with 1 ton per acre per year from terraced watersheds. If this sediment is removed from a ditch where the stream crosses a river bottom, as many streams that drain into the Missouri River do, the cost will be high. Private contractors currently are charging 20 cents per cubic yard to remove sediment from drainage ditches in the Missouri River floodplain. Dredging to remove sediment delivered to the Missouri River itself costs 35 to 40 cents a yard, according to the Army Corps of Engineers.[1] This cost is based on government-owned and operated equipment. Dredging by private contractors may cost $1.00 per cubic yard or more.

Additional offsite benefits of terraces accrue when flood damages to buildings, fences, roads, and personal property are reduced and human life and livestock are safeguarded.

Although it is difficult to evaluate quantitatively the economic benefits of terracing on hydrology, all results from this study favor terracing. A small, essentially constant flow of clear water is more attractive and far more valuable than a periodic flash flood of muddy water.

Despite terrace construction difficulties and unusual weather conditions, crop yields are now nearly the same on terraced and unterraced fields and probably would approach equity if surface tile inlets were installed in the terrace channels and tillage methods used to better distribute moisture.

The terraced field becomes smoother and easier to farm each year. On unterraced fields, finger gullies, often 3 feet deep, develop on the hillsides after heavy rains. These gullies must be filled each year and even then present hazards to machinery and operator and result in planting, cultivating, and harvesting inefficiencies. The hillsides become so "washboarded" that they are difficult to till.

---

[1] Personal communication with Clem Myers, Army Corps of Engineers, Kansas City, Mo.

Table 4. Annual soil loss from sheet erosion.

	Unterraced		
Year	*Watershed 1 (t/a)*	*Watershed 2 (t/a)*	*Terraced Watershed 4 (t/a)*
1964	25[a]	25[a]	(no record)
1965	44	36	<1
1966	7	9	<1
1967	99	75	3
1968	4	4	<1
1969	2	1	<1
1970	12	7	<1

[a] Estimate based on samples at weir site and observed gully erosion.

Table 5. Costs and benefits of producing corn on terraced and unterraced watersheds, 1964-1970, Treynor, Iowa.

	Conservation Practice (cost/a)		
Item	*Terrace*	*Contour*	*Difference*
Interest charge on capital invested	$ 2.44	$ 0.31	$ 2.13
Cost of maintenance	.03	.37	—.34
Cost of decreased machinery efficiency	—	.54	—.54
	$ 2.47	$ 1.22	$ 1.25
Average yield valued at $1.00 per bushel	$81.00	$95.00	$14.00
Total			$15.25

Terracing stopped gully growth completely in the main drainageway on the terraced watershed. On the unterraced watersheds, erosion on the main channel continues, resulting in loss of land and creating the danger of isolating much larger parcels of land than are actually voided by the gully.

Grassed waterways quickly became obsolete as sediment accumulated on the grass strip, causing runoff to concentrate along the edges of the grass and rills to develop parallel to the grass. This required reshaping of the waterways, which destroyed their sod cover and thus reduced their effectiveness and increased maintenance costs.

Summary and Conclusions

The terrace installation was one of the first parallel, grassed-backslope terrace systems installed and has certain deficiencies inherent in any new system. But the system will produce high yields of row crops with acceptable levels of erosion and surface runoff.

Soil and water waste is and probably will continue to be primarily a cost to society. Costs that can be tabulated with sufficient accuracy, plus offsite costs to society, indicate that sloping land used to produce corn should be terraced.

REFERENCES CITED

1. Saxton, K. E., and R. G. Spomer. 1968. *Effects of conservation on the hydrology of loessial watersheds.* Trans., Am. Soc. Agr. Eng. 11(6): 848, 849, 853.
2. Miller, E. L. 1970. *Effect of level terraces on soil moisture and distribution and utilization by corn.* M.S. thesis. Iowa State University, Ames.
3. Mitchell, J. K., and C. E. Beer. 1964. *The effect of land slope and terrace systems on machine efficiencies.* Trans., Am. Soc. Agr. Eng. 8: 235-237
4. Shrader, W. D., and Stanley Murdock. 1970. *Improve your subsoil moisture for higher yields.* Iowa Farm Sci. 25(2): 3-4. ☐