AN ECONOMIC ANALYSIS OF LEVEL BENCH SYSTEMS FOR FORAGE PRODUCTION IN NORTH DAKOTA

CONSERVATION RESEARCH REPORT NO. 14

ECONOMIC RESEARCH SERVICE

AND

AGRICULTURAL RESEARCH SERVICE
U. S. DEPARTMENT OF AGRICULTURE

IN COOPERATION WITH
NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

PREFACE

This report presents partial results of research studies on the economics of agricultural water management. The studies were conducted jointly by the Natural Resource Economics Division, Economic Research Service, and the Soil and Water Conservation Division, Agricultural Research Service, USDA; South Dakota State University; and North Dakota State University. The studies stem from recognition of important, newly developing technologies for agricultural water management in the Northern Great Plains.

The research summarized in this report was planned, conducted, and guided by a number of individuals. The basic experiments, set up to explore the soil and water relationship on level benches and the resulting effects on crop production, were conducted at the Great Plains Research Center, ARS, Mandan, N. Dak. The physical results of some of these experiments have been reported elsewhere (items 9 and 10 in the bibliography). Contributions from North Dakota State University were made by Daniel J. McLellan, formerly Associate Professor of Agricultural Engineering, who gave valuable assistance in working out the estimates of construction costs; by Gary D. Lynne, Assistant in Agricultural Economics, who assisted with the regression analysis; and by Fred R. Taylor, Chairman of the Agricultural Economics Department, and Dale O. Anderson, Director of the North Dakota Water Resources Institute, who provided assistance in this and related studies. Officials of the Soil Conservation Service in both North Dakota and South Dakota provided helpful suggestions and valuable information. Supervision for the Economic Research Service was provided by George A. Pavelis of the Water Resources Branch, NRED, ERS.

Washington, D.C. 20250 March 1970

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SUMMARY

The use of level benches can more than double alfalfa production, increase bromegrass yield by almost 75 percent, and increase wheat yields by 5 or 6 bushels per acre over the yields produced on natural slopes. The increased yields are largely the result of the benches' ability to hold snow and snowmelt water. Benches, though similar to terraces, are much wider, level overall, and diked at the ends and front.

Not enough benches are in actual farm use to provide cost and return data. Limited tests and experience elsewhere show that cost of bench construction is mainly affected by width of bench and complexity of slope. The cost per acre for construction may range from $25 for the narrowest benches on the gentlest slopes to $353 for 70-foot benches on 10-percent slopes.

Operating costs would be higher on a level bench system than on a natural slope, because each bench and its contributing area (an unterraced area above the bench), if there was one, would be treated as a single field for harvesting and other operations. However, data on the increase in costs are fragmentary and some of the values were estimated.

For alfalfa production, gross returns for level bench systems increase as the slope decreases, because less land is occupied by dikes and backslopes. The resulting net returns decrease uniformly as the slope increases. On the more gentle slopes--1 or 2 percent--the width of bench has little effect on net returns. On the steeper slopes, the wider the bench the lower the net returns. In fact, negative net returns would be encountered with wide benches on slopes. On 1- and 2-percent slopes, the net returns for benches without contributing areas range from about $900 to $1,300 per 100 acres, while for benches with 1:1 contributing areas, the returns range from $590 to $769.

While detailed estimates of costs and returns were made only for alfalfa, results for both bromegrass and pasture grasses should be similar. Wheat, on the other hand, would probably not be much more profitable on benches than on natural slopes, and very few farmers could be induced to convert wheatland to level benches for alfalfa production.

In the Dakotas, stripcropping is fairly widely adopted. Contour farming is also practiced, but on a more modest scale. In both cases these are the easiest and least expensive conservation and erosion control practices. Terracing is seldom practiced in South Dakota and rarely in North Dakota.

AN ECONOMIC ANALYSIS OF LEVEL BENCH SYSTEMS FOR FORAGE PRODUCTION IN NORTH DAKOTA

by Wallace McMartin,[1] Howard J. Haas,[2] and Wayne O. Willis,[2]

INTRODUCTION

Level bench systems have more than doubled the yields of forage produced on slopes in the Northern Great Plains. Benches of this type were first introduced in the United States for study by the Agricultural Research Service (ARS) in 1955, but they have been used for centuries in other countries (23).[3] Benches differ from conventional terraces in that the channels are much wider, are level in all directions, and are diked at the ends and at the front (downslope side) to give them more water storage capacity than conventional terraces (fig. 1). Some level bench systems are built with an unterraced area above each bench. This is called the "contributing area" because it is intended to contribute runoff water to the bench. Level benches are built primarily for water conservation, and they serve the same purpose as conventional terraces in controlling soil erosion.

In the Northern Great Plains, research on level benches has been done at Mandan, N. Dak. (9, 10), at Sidney, Mont. (1), and at Newell, S. Dak.[4] In the Central and Southern Great Plains, work has been done in Nebraska (2), Colorado (18), Kansas (6), and Texas (11) but the results are somewhat different, partly because of differences in climate and partly because the benches in these areas are constructed primarily for conservation of runoff from summer rainfall. In the Northern Plains, the principal benefit of benches is realized from trapping snow and holding the snowmelt in place until the water infiltrates. A few farmers in various sections of the Northern Great Plains have used standard and parallel terraces. Both types are normally built mainly for erosion control, though they serve to a limited extent as a means of water conservation. Level benches for irrigation have been used extensively in western Nebraska (7) and have been studied experimentally in South Dakota. They have also been used for erosion control in Iowa (14).

Some of the results of the research conducted under this arrangement are already available. A study of irrigation practices was completed and published as a North Dakota experiment station bulletin (17). Another study showing the value of water for forage production was completed and the results were submitted to North Dakota State University as a master's thesis (16). Other studies relating to water management are nearing completion at South Dakota State University. Further research is in varying stages of completion at several locations.

This study analyzes the economic aspects of level benches. First, estimates were made

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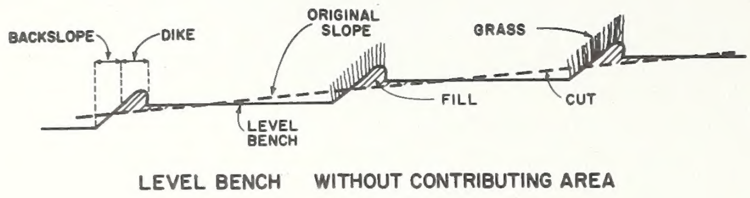
[3] Underscored numbers in parentheses refer to items in the Bibliography, p. 17.

[4] Unpublished data, 1966-68, Newell Irrigation and Dryland Field Station, ARS, USDA, Newell, S. Dak.



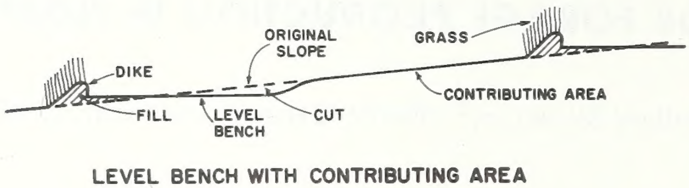


Figure 1.--Diagrammatic profile of level bench systems with and without contributing areas.

of their profitability for the individual farmer, compared with conventional farming methods for land with similar soil and topography. Factors affecting the adoption of benches by farmers were examined, and estimates were developed of the potential land area on which benches would be economically feasible and otherwise desirable in a representative North Dakota county.

The study results represent only an approximation of the pertinent economic relationships. Most of the data used are based on experimental trials or hypothetical situations, because there are very few examples of the practice having been adopted by farmers on a field scale. The analysis can be refined as more experimental data are collected and more farmers adopt the practice.

EXPERIMENTAL LOCATION AND DESCRIPTION

Climate

Water conservation in the Northern Great Plains is always important--and sometimes critical--in determining the level of crop production. At Mandan, N. Dak., the long-term average precipitation is almost 16 inches. About 70 percent of the annual total occurs in the 5 growing-season months, April through August, and about 20 percent occurs as snow. Winters are long and cold. Summers are short and relatively cool, though periods of very high temperature are not unusual; such periods are often accompanied by very dry and windy conditions.

Following are precipitation data from Mandan for 1962-68, with long-term averages for comparison:

Year	April-August	Annual
	Inches	Inches
1962	12.34	14.95
1963	15.51	18.28
1964	12.10	14.82
1965	19.12	23.34
1966	12.10	15.77
1967	6.79	13.52
1968	14.15	17.92
Averages		
1962-68	13.16	16.94
1915-68	11.25	15.88

Description of Experiments

A series of trials has been underway for several years at the Northern Great Plains Research Center at Mandan to test level bench systems for the production of corn (grain and silage), wheat, alfalfa, and bromegrass. Three sets of trials are analyzed in this report. One, called the "cropland study," compared production from a wheat and corn rotation on benches with and without contributing areas, and on natural slopes. The land sloped downward toward the east, with a gradient ranging from 1 to 5 percent. The soils were Bainville loam and silt loam, Grail silt loam, Grail-Moline silty clay loam, and Regent silty clay loam. There were four benches--two 50 feet wide and two 70 feet wide. Soil water determinations at seeding and harvesttimes were made at 1-foot increments to a depth of 6 feet. Data for this experiment are available for 4 years, 1962-65 (9).

A second experiment, called the "grassland study," compared alfalfa and bromegrass hay production from 50-foot-wide benches with and without contributing areas, and from natural slopes. The land sloped downward toward the west, with a 5-percent gradient. The soil was classified as Grail silty clay loam. Soil water determinations were made at 1-foot increments to a depth of 6 feet in early spring, at about monthly intervals during the growing season, and in late fall about the time the soil normally freezes. Data are available for 4 years, 1963-66 (9).

In both studies, the contributing areas were equal in size to their respective benches.

A third set of experiments, called the "contributing area study," investigated the effectiveness of contributing areas of various sizes in supplying runoff water to level benches. The land sloped downward towards the north, with a gradient ranging from 5 to 10 percent. The soil was classified as Morton silt loam and Regent silty clay loam. All the benches were 30 feet wide and were used for producing alfalfa hay. One group of benches collected water from a bromegrass-covered contributing area of 10.4 acres, with possible contributing-area-to-bench ratios ranging from 19:1 to 85:1. A second group of benches had narrow bromegrass-covered contributing areas with ratios of 3:1, 2:1, 1:1, and 0:1 (no contributing area). Soil water readings were taken at 1-foot increments to a depth of 8 feet just before and just after snowmelt, after each harvest, and in late fall about the time the soil normally freezes. Data on runoff, soil water, and alfalfa production are available for 5 years, 1964-68.

EXPERIMENTAL RESULTS

The three sets of experiments demonstrated the bench systems' ability to trap snow and snowmelt water for the benefit of growing crops. In the spring, the benches in the cropland, grassland, and contributing area studies averaged about 3, 1, and 7 inches more water than the unterraced slopes. For snow collection, the contributing area study was located the most favorably and had the best growth of grass on the dikes. Benches with a contributing area generally contained slightly more water in the spring than others.

Runoff from the bromegrass-covered watershed in the contributing area study was measured during snowmelt and during each rain. Total runoff from snowmelt and rainfall was as follows:

	Runoff inches	
Year	Snowmelt	Rainfall
1964	[1] 0.020	0.071
1965	[1] .050	.168
1966	.147	.038
1967	.462	.001
1968	.023	.002

[1] Estimated values.

Snow Control

The above data show that water collection from runoff alone would not be important in most years if the contributing area was covered with grass. Observation of the benches in the wintertime indicates that two of their chief advantages are their ability to trap snow and to hold the snowmelt water. Under normal conditions, snowstorms in the Northern Great Plains are accompanied by high winds and a considerable amount of drifting. Characteristically, a field that is plowed or fallowed will be blown clear of snow in the wintertime. A stubble field will trap some snow, to a depth of slightly less than the height of the stubble. The snow cover on pasture is usually slight, depending somewhat on how much and how uniformly it was grazed during the fall. The level bench systems at Mandan, however, trapped large quantities of snow, particularly from storms in which the wind blew at right angles to the benches (fig. 2). This points up a distinct advantage of the level bench system. Frozen soil can absorb very little water. If the soil on sloping ground is frozen when the snow melts, the water runs off and is lost. On level benches, however, snowmelt water is held in place by the dikes even if the soil is frozen when the snow melts (fig. 3). As soon as the ground begins to thaw out, the water begins to soak into the soil.

Alternative means of trapping drifting snow have been tried. "Shelterbelt" plantings, consisting of one or more rows of trees, will trap large quantities of snow, and one or more rows of tall-growing annual crops, such as corn or sorghum, have sometimes been used effectively. Even though each tree row will catch a large amount of snow, the rows are not usually spaced to give a uniform depth of snowcover for an entire field. In general, snowdrift control is effective for distances from the tree row of some 12 to 14 times the height of the trees in ordinary windbreaks (22). Snowdrifts are deep on the leeward side of the tree row, but there is little snow cover on the rest of the field (8). During spring thaw, the snow may melt rather rapidly; drainage channels will be formed along the snowdrift to carry the water away, and small gullies may result. The damage might be reduced if the tree rows were planted across the slope instead of up and down, but such plantings are not always practical.

Crop Yields

Yield data for both the cropland study and the grassland study for a period of 4 years show a decided variation between crops

Figure 2.--Snow deposit on a level bench.

Figure 3.--Snowmelt water on a level bench.

(table 1).[5] Generally yields of grain corn have not been increased by using level benches. In both 1964 and 1965, for example, the nonbenched slopes produced more corn than the benches, though the 4-year average yield was about the same on the benches as on the slope.[6] For corn silage, the results were similar, with an average yield of 8.02 tons per acre from plots on the slope, 7.83 tons from the bench without a contributing area, and 7.52 tons from the bench with a contributing area.

The pattern of yields from the plots seeded to spring wheat were more nearly as expected. The average yield from the untreated slope was 29.0 bushels per acre, compared with 35.0 and 34.3 bushels, respectively, from benches with and without contributing areas. This represents an increase in yield of 6.0 bushels for the benches with a contributing area and 5.3 bushels without a contributing area.

In the grassland study, yield comparisons were made for both alfalfa and bromegrass. The average yield of alfalfa from the benches without a contributing area was about 1 ton per acre higher than from the slope, though there was little difference between the yields from benches with and without contributing areas. The bromegrass yield differential was 0.63 ton for benches without a contributing area and 0.70 ton with a contributing area.

In the contributing area study, data are presented for 4 of the 5 years.[7] Water storage and yield on benches with 3:1, 2:1, and 1:1 contributing area-to-bench ratios were not related to ratio size, but appeared to be influenced more by favorable location for snow collection. The data from these benches were therefore averaged to give the figures shown

[5] In this section, the data on yield per acre for level benches refer to the leveled portion only. In later sections, appropriate allowance is made for the fact that the dike and backslope are not harvested and therefore do not contribute directly to crop production. Tables are grouped at the end of the report.

[6] An early frost reduced yields substantially in 1964, and the damage was heavier on the benches and the contributing areas than on the nonbenched slope.

[7] The results for 1967 are omitted because runoff from the large watershed was diverted to two of the benches without contributing areas in that year.

in the table for a bench with a contributing area. The data for a bench without a contributing area are also averages of three benches. Yield of alfalfa from the benches ranged from 2.59 to 4.46 tons per acre. The 4-year average yield from the benches was more than twice that from the nonbenched slope, or a gain of 2.2 tons per acre. The benches with contributing areas outyielded the benches without by only 0.12 ton.

Following is a summary of the alfalfa yield results for each of the two studies, and an average for the two:

	Grassland study	Contributing area study	Average	Gain, bench over slope
	Tons per acre			
Slope	0.90	1.58	1.24	---
Bench without C.A.	1.94	3.74	2.84	1.60
Bench with C.A.	2.08	3.86	2.97	1.73

ENGINEERING ASPECTS

Several engineering aspects affect the problem of laying out a level bench system, and each influences costs and returns. To conserve water efficiently, the benches must be level in all directions, and they should be uniform in width to permit efficient farming operations. These two requirements complicate the layout job, especially on irregular slopes. In general, the cost of the bench is presumed to depend on the amount of earthmoving to be accomplished, which in turn depends on the degree of slope and bench width. The relative complexity of the slope will likewise affect the cost.

Slope, Bench Width, and Depth of Cut

On a given slope, the wider the bench and the steeper the slope, the deeper will be the cut necessary to construct the benches, and the deeper the cut, the more earthmoving will be required per acre. For a given width of bench, the steeper the slope, the deeper the cut, and hence the more earth to be moved. Several widths of bench on several ranges in slope were analyzed for comparison.

To improve efficiency in harvesting operations, the width of bench should be a multiple of the width of the harvesting machinery to be used. Two types of hay-harvesting machines considered were a 7-foot mower and a 14-foot self-propelled swather. With either of these machines, the width of bench should be a multiple of 14 feet. For analysis, five multiples of 14 were selected: 14, 28, 42, 56, and 70 feet. If different widths of harvesting machines were used, appropriate modification should be made in the bench widths.

For each of the five widths of bench, costs were calculated for 10 degrees of slope (i.e., 1 percent through 10 percent at intervals of 1 percent). To simplify the analysis, the slope was assumed to be perfectly uniform, though no such slope is likely to be found in actual practice.

In developing comparative cost data, the first step was to calculate the maximum depth of cut for each slope and each bench width. To build a 14-foot bench on a 1-percent slope would require a cut of 0.9 inch, while a 70-foot bench on the same slope would require a cut of 4.4 inches (table 2).[8] On a 10-percent slope, a cut of over 3 1/2 feet would be required for a 70-foot bench, but an 8.9-inch cut would be enough for a 14-foot bench. Where the soil is cut below the A horizon (topsoil), enough topsoil should be reserved to return at least 2 inches of it to the exposed subsoil areas (3).

[8] The calculations in tables 2 and 3 are based on unpublished data furnished by Dan McLellan, formerly Associate Professor, Agricultural Engineering, North Dakota State University, Fargo. A "balance factor" of 1.3 cubic yards of cut for each cubic yard of fill was assumed.

The quantity of earth to be moved in building the terraces and the dikes is approximately proportionate to the maximum cut. Relatively little earth needs to be moved to build narrow benches on gentle slopes. For example, with a 1-percent slope and a 14-foot bench, removal of only 32 cubic yards per acre is required; on the same slope, a 70-foot bench would require removal of 160 cubic yards (table 3). On a 10-percent slope, a 14-foot bench would require 320 cubic yards, while a 70-foot bench would require 1,603 cubic yards.

Width of Dike

To control water, each bench must have a dike at its outer (front) edge, and one on each end. Experimental results at Mandan show that the best results in snow control are achieved if the dikes are seeded permanently to bromegrass and not harvested. Consequently, the area occupied by the dikes and the backslope at the front edge of each bench is excluded from the productive area. To provide access to the benches for harvesting machinery, the end dikes should be built with gentle slopes and seeded to alfalfa.

In a field laid out with continuous benches, the area occupied by dikes is a function of the number of benches, and the area occupied by the backslope below the dike is a function of the depth of cut, which in turn is a function of the slope. To calculate the productive area lost to dikes and backslopes, it was assumed that each dike would be 2.5 feet wide at the base and the backslope ratio of horizontal to vertical distance would be 1.5:1. Thus for 14-foot benches without contributing areas, dikes and backslopes would occupy 15.2 percent of the area on a 1-percent slope and 25.2 percent on a 10-percent slope (table 4). For 70-foot benches, dikes would occupy 4.9 percent of the area on a 1-percent slope and 16.3 percent of the area on a 10-percent slope. If benches are built with contributing areas, the proportion of land occupied by dikes is reduced by a little less than half.

Turning and Odd-Shaped Areas

Since the dikes separating the benches are built with a steep backslope, it is not practical to drive across them with most farm machinery. Each bench thus tends to become a separate field for all tillage and harvest operations. In designing a system of benches, access to each bench must be provided. Probably the most practical way to assure easy access would be to leave space for turning along both sides of the field, as illustrated in the diagrams of hypothetical fields (figs. 4 and 5). For each 100-acre field, 4.0 acres were assumed to be occupied by turning areas.

To achieve the most satisfactory pattern of travel in harvest operations, it would be ideal if the benches were rectangular and parallel to one another. Such benches could be built only on a field that was exactly uniform in gradient and direction of slope, but areas of such uniformity are seldom found. Changes in the direction or degree of slope will invariably occur, resulting in adjustments in alinement. When such adjustments are made, small irregular or odd-shaped areas will remain, unless a substantial amount of earth is moved. Such areas are difficult to work with either tillage or harvesting machines because much extra turning is required. For this analysis, it was assumed that these would be harvested, and that the yields of hay would be the same as on natural slopes.

The number and size of odd-shaped areas would probably increase as complexity of the slope increased. Also, it is probable that the steeper the slope the more difficult it would be to maintain parallel alinement, so the amount of odd area likely increases somewhat as the slope increases. Actually, there is no way to estimate these areas except on a case-by-case basis, using the actual topography of a particular field. To illustrate the probable effects of this hypothesis, it was arbitrarily assumed that for benches without contributing areas the area occupied by odd areas would increase 0.5 acre per 100 acres for each percentage increase in slope. For benches with contributing areas (1:1 ratio), the increase in land used for odd-shaped areas was assumed to increase by 0.3 acre per 100 acres for each percentage increase in slope. In each situation, a standard deduction of 3 acres per 100 was made for roads, lanes, and fences.

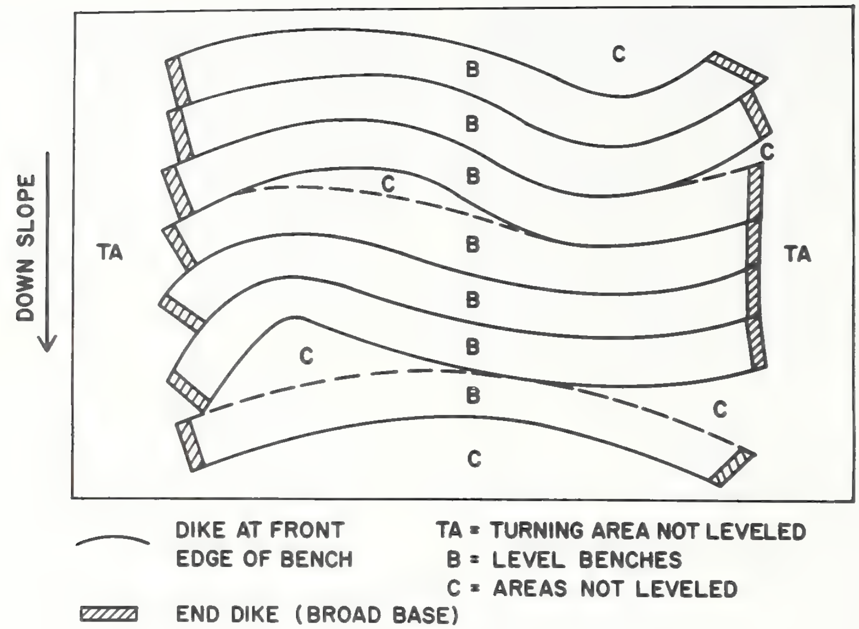


Figure 4.--Layout of level bench system without contributing area.

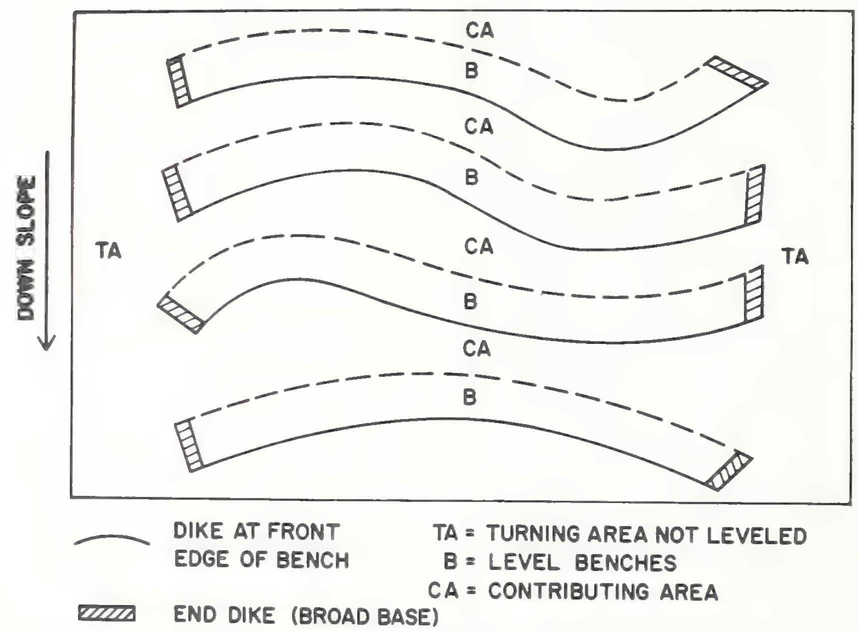


Figure 5.--Layout of level bench system with contributing area.

Construction Costs

The principal factor affecting the costs of construction is the total amount of earth to be moved. The cost of moving a cubic yard of earth will vary considerably from one bench construction job to another, and there seems to be no standard set of coefficients for computing costs for varying quantities of earth moved (12, 13). Inquiries were made of several persons familiar with earthmoving techniques--including contractors, irrigation and drainage engineers, and Soil Conservation Service engineers--and the cost estimates reported tended to center around a median value of 23 cents per cubic yard for quantities in the most common range of 350 to 499 cubic yards per acre. Most agreed that the cost per cubic yard would probably vary inversely with the total quantity moved per acre. From fragmentary data, the following sliding scale of cost was developed to illustrate the relationship between the quantity of earth moved and unit costs:

Cubic yards of earth	Cost per cubic yard
Under 150	$0.27
150 - 249	.25
250 - 349	.24
350 - 449	.23
450 and over	.22

These estimates are based on the assumption that the contractor would use a carryall. For building 14-foot benches, however, a road grader could be used, probably at less cost. On benches of 28 feet and wider, the use of a road grader probably would not be practical. The data for 14-foot benches in table 3 are probably overestimated for steep slopes, and underestimated for gentle slopes. To partially compensate for this possibility, a lower limit of $25 per acre was arbitrarily assumed.

At the rates assumed, the cost per acre for building 14-foot benches on a 1-percent slope would be $25 per acre, and would increase to $40 per acre for 70-foot benches (table 5). On a 10-percent slope, the cost per acre would be $76.80 for 14-foot benches and would increase to $352.66 per acre for 70-foot benches.

The cost data shown in table 5 do not include any allowance for the work necessary to survey and stake the field. There is no convenient way to estimate such costs accurately except on a case-by-case basis, using topographic maps of the fields on which the benches are to be constructed.[9] No allowance was made for stockpiling and returning topsoil to exposed subsoil areas where deep cuts are made. The cost of this operation will vary, depending on the depth of the A horizon, the depth of cut, and the kind of equipment available.

ECONOMIC ASPECTS

For this analysis, a field of 100 acres was assumed to be the basic land resource. Thus, the land use figures can be used as acres or percentages, whichever is more convenient.

Alfalfa Production

Harvested Area

The harvested area of the 100-acre field was computed by deducting the acreage in roads, lanes, fences, dikes, and backslopes as explained earlier. The harvested area was then divided into two parts: (1) The area actually in benches, and (2) the area in natural slopes, including contributing areas, turning areas, and odd-shaped areas. For example, for 14-foot benches without contributing areas, the net area in benches would be 63 acres on a 10-percent slope and 76 acres on a 1-percent slope. For 14-foot benches with contributing areas, the net area in benches would be 38 acres on a 10-percent slope and 42 acres on a 1-percent slope.

Yields

In computing alfalfa production, the acreage in each part of the harvested area was multiplied by its respective average yield; that is, 1.2 tons per acre for natural slopes, 3.0 tons for benches with contributing areas, and 2.8 tons for benches without contributing areas. For an entire field with a given bench width the total alfalfa production would decrease with each increase in slope. For example, a 100-acre field with 14-foot benches

[9] The layout and staking of the benches might possibly be performed by engineers and technicians from the local Soil Conservation District at no expense to the farmer.

on a 1-percent slope without contributing areas would produce 219 tons (table 6). The same size benches on a 10-percent slope would produce 187 tons. With contributing areas, a field of 14-foot benches on a 1-percent slope would produce 181 tons of alfalfa, compared with 167 tons on a 10-percent slope. A 100-acre field on a natural slope with no benches would produce 116 tons.

The data in table 6 show that for any given slope, the wider the bench, the higher the production of alfalfa, because with wider benches there are fewer dikes and therefore the area available for harvest is greater. The yield per acre on the harvested portion of each bench is assumed to be the same regardless of its width. This assumption may not be entirely valid, because a field with narrow benches would have more dikes with grass barriers to trap snow. Thus, the narrow benches might have higher yields per acre than the wide ones.

Where benches are built with contributing areas, yield for the whole field is less than on those without contributing areas. The yield per acre is higher on benches with than without a contributing area, but the natural slopes produce substantially less than either kind of bench. If the ratio of contributing area to bench is 1:1, then for every acre of bench there is an acre of contributing area, and the effective average yield for the whole field is substantially reduced.

Fixed Costs

For amortizing the construction costs, an average bench life of 30 years was arbitrarily selected, though a longer life seems possible. To convert construction costs to annual equivalents, the "capital recovery factor" method was used, with an assumed interest rate of 7 percent. An annual charge of $935 per 100 acres was assumed, to cover the investment in land, machinery, and equipment.[10]

[10] The assumed charges for land and machinery and the operating costs were developed from data presented by Rice, Billy B., and Paul, Rodney R., Crop Costs and Returns, N. Dak. Agr. Ext. Cir. FM-5-67, Fargo, 1967.

To simplify the analysis, no allowance was made for income losses connected with the original construction of the benches. Under normal circumstances, a full year of crop production might be lost in building the benches and establishing a stand of alfalfa. Even if the benches were constructed in the fall after harvest, it probably would not be possible to get a stand of alfalfa ready for hay production in the following year.

Operating Costs

Operating costs include costs for seed, machinery, and labor for harvesting, including the added costs associated with harvesting small areas. An alfalfa stand will last for an estimated 7 years at a seeding cost of $14 per acre. This cost includes an allowance to compensate for the reduction in income which would probably occur during the year when the stand is being reseeded. For purposes of estimating harvesting cost, it was assumed that cuttings would average 1 1/2 per year on natural slopes. There would be 2 1/2 cuttings per year on the benches because of increased water supply. Harvesting costs other than labor were assumed to be $7 per acre on benches and $4 per acre on natural slopes. Labor was valued at $1.50 per hour, resulting in a cost of $10 per acre on the benches and $6 on natural slopes.

Adjustments were made for extra turning and waste motion due to short fields and odd areas. While the necessity for making such adjustments is well recognized, it is difficult to obtain specific data to serve as cost guidelines (20). It was assumed that the adjustments would be in direct proportion to the number of benches constructed on an average field of 100 acres, with benches built at right angles to the longest (1/2 mile) side of the field.

The use of bromegrass or some other permanent grass protects the dikes against erosion, and from damage caused by harvesting equipment. The benches and the dikes would therefore be unusually stable, and there would be little need for repair work once the stands of alfalfa and bromegrass were established.

Net Returns

Gross returns were calculated by multiplying the tons of alfalfa produced (table 6) by an assumed price of $17 per ton.[11] Net returns were obtained by subtracting total costs from gross returns. Details of the calculations for 42-foot benches on 4-percent slopes are shown in table 7. Net returns are $468 per 100 acres for benches with contributing areas and $699 for benches without, indicating that the use of contributing areas does not increase net returns for the slope and bench width illustrated in this table. However, alfalfa production on benches--either with or without contributing areas--is substantially more profitable than on natural slopes, where there is a net loss of $120 per 100 acres.

Net returns were calculated for five bench widths and 10 different slopes, for systems both with and without contributing areas. The highest net returns were found on the gentlest slopes, and for each width of bench the net returns decreased as the slope increased (table 8). On slopes of 1 percent, the 42-foot benches had the highest net returns, while on 2-, 3-, and 4-percent slopes the 28-foot benches showed the highest returns. On all slopes of 5 percent or more, the returns decrease as the bench width increases. On the steepest slopes the returns are negative on the widest benches, largely because of higher construction costs.

For benches on a 1-percent slope with contributing areas, the net return is lowest on the 14-foot width and highest on the 42-foot width. On 2-, 3-, and 4-percent slopes returns are highest on the 28-foot benches. On slopes of 5 percent and over, the net returns decrease as the bench width increases. The relationship between bench width and net returns is much the same for benches with contributing areas as it is for benches without.

Slope appears to have more effect than width of bench on net returns. For every bench width, either with or without a contributing area, the net returns decrease as the slope increases. The level of net returns is generally higher for benches without contributing areas than for those with contributing areas--except for some of the widest benches on the steepest slopes. Variations in width of bench and in percentage of slope have less effect on net returns for benches with contributing areas than for those without. Because the investment is smaller for situations with contributing areas, the net losses are not as high as is the case without contributing areas.

The data on net returns are useful as a guide in deciding whether to build a level bench system on a particular field, and if so, what width of bench. For example, if the field has a slope of only 1 percent, a 42-foot bench appears to be most profitable, though net returns are almost as large on 28-, 56-, and 70-foot benches, and the latter two have an advantage because they are easier to farm. Benches without contributing areas seem to have a convincing advantage over benches with contributing areas. For slopes of more than 4 percent, 14-foot benches seem to be most profitable. With a 10-percent slope, only the narrowest benches have favorable net returns.

Relationships of Available Water and Alfalfa Yields

As mentioned earlier, soil water readings were taken at intervals during each growing season. While it is not part of the purpose of this report to analyze in detail the soil water data, it is relevant to show the economic importance of conserving as much precipitation as possible. At Mandan, and in areas with similar climate, the amount of available water is one of the major factors influencing crop yields and profits; therefore, it was the principal variable in this set of level bench experiments. There were differences between benches in the water-holding capacity of the soil, but water readings were corrected for this difference by calculating the soil water available to plants. The lowest water value for each 1-foot increment of soil throughout the study period was selected as the minimum point of exhaustion for alfalfa (3). Any water in

[11] This is the expected long-term price currently used in North Dakota by various State and Federal agencies for river basin planning.

excess of this amount was considered available to the alfalfa plants.

For each year, 1964 through 1968, the total amount of water available for plant growth was calculated for each plot in the experiment. The starting point was the available water in the soil after spring snowmelt. To this was added the precipitation recorded at the site for the remainder of the growing season for each year. Water from contributing areas was added to their respective benches. Runoff (if any) from natural slopes was subtracted from the water available for plots on slopes. The relationship of total water available to alfalfa yields indicates that 73 percent of the variation in yield is associated with variation in the amount of water available (fig. 6).[12] The economic value of the alfalfa, indicated in the right-hand scale, was obtained by applying a price of $17 per ton. Alfalfa production and its economic value evidently increases rapidly as total water increases, particularly at the lower water levels. The value of each additional inch of water, calculated from the regression formula is as follows:

If the water available is:	Then the alfalfa resulting from one more inch of water would be:	And the added (or marginal) product would be worth:
Inches	Tons per acre	Dollars
10	0.287	4.88
12	.263	4.47
14	.239	4.06
15	.229	3.86
16	.215	3.66
18	.191	3.25
20	.167	2.84
22	.143	2.43
24	.119	2.02
26	.095	1.62
28	.071	1.21
30	.047	.80
32	.023	.39
34	0	0

The average water available for the natural slopes in the years included in the study was about 14 inches. At this level, an additional inch of water would produce 0.239 tons of additional alfalfa, which would be worth $4.06. The additional returns for a second inch would be $3.86, and for a third inch, $3.66, or $11.58 for three additional inches.

Table 7 shows that producing 100 acres of alfalfa on a 4-percent slope with 42-foot benches and no contributing areas would cost $3,231, while on a natural slope the cost would be $2,099. The level bench system would therefore cost $1,132 more than on the natural slope, or the equivalent of $11.32 per acre. To recover the additional cost, it would be necessary to produce additional alfalfa worth at least $11.32. In the previous paragraph, it was shown that three additional inches of water would result in alfalfa production worth $11.58, or slightly more than enough to cover the additional costs. Thus, this particular system of benches would appear to be profitable for alfalfa production if it could be depended upon to trap and store the equivalent of

[12] Results of the regression analysis, significant at the 0.001 probability level, were:

$$Y = -2.05131 + 0.40764W - 0.00601W^2$$

$$R^2 = 0.7290$$

where Y = alfalfa yield

W = water available.

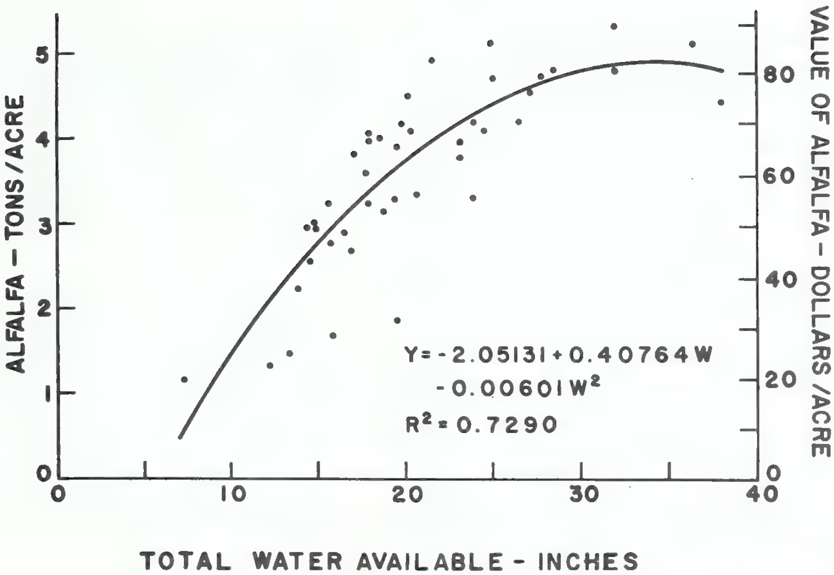


Figure 6.--Relationship of alfalfa production and value to total water available.

3 inches of water in addition to the water normally available on a nonbenched slope. As mentioned earlier, benches located favorably in relation to wind direction averaged about 7 inches more soil water in the spring than a nonbenched slope.

Other Crops

So far in this analysis, alfalfa has been the only crop considered. A few rough calculations, plus some careful reasoning, suggest that benches might be profitable for other crops, particularly grass, and to a lesser extent for wheat. No yield increases for corn have been demonstrated in the experimental work.

Grass

The increase in grass production was less than for alfalfa, but if grazed, costs would be reduced considerably. There is, however, the added cost of nitrogen fertilizer, which is necessary for most efficient grass production. Investment cost would be less because narrow benches could be used throughout, and there would be no harvesting costs. There is a question, however, as to whether animals grazing on the benches might make paths over the dikes and eventually break them down at irregular intervals. A new experiment has been set up to test the use of benches on pastureland, and to determine whether maintenance problems are likely to develop.

Wheat

With wheat, the maximum gain in production from benches was 6 bushels per acre for the benched area. When the reduction in acreage for dikes is taken into account, the gain in yield is reduced substantially, even on the gentlest slopes. Large machinery is more commonly used for wheat than for alfalfa, so it would be especially advantageous to consider benches 56 or 70 feet wide.

Results of preliminary calculations show that for wheat the additional returns from the construction of benches without contributing areas exceeded the increased fixed costs on 1-percent slopes but not on 2-percent slopes (table 9). For benches on 1- and 2-percent slopes with contributing areas, there were increased net returns on all benches except the 70-foot width with 2-percent slope. For both types of benches, operating costs would increase more for wheat than for alfalfa because cultural operations require more "times over." With wheat, heavy tillage machinery would be used on the benches, so maintenance of the end dikes might be more costly.

With a reduced gross income and increased costs, it seems doubtful that the production of wheat on benches could be profitable, except possibly under the most favorable circumstances. There is a possibility, however, that further experiments with cultural treatments or varieties may show yield increases of more than 6 bushels per acre, or there may be improvements in operating efficiency which could make the practice profitable.

FACTORS INFLUENCING THE ADOPTION OF LEVEL BENCHES

The foregoing analysis shows that using level benches for alfalfa production is potentially profitable to a farmer, providing he has a market for the hay or he needs it for livestock feed. This seems true for any farmer who has land similar to that on which experiments have been conducted. However, there are very few instances of farmers having adopted benches either in North Dakota or in any adjoining State.

Terracing, Contour Farming, and Stripcropping

Terracing, contour farming, and stripcropping are conservation practices somewhat similar to level benches insofar as their appeal to farmers is concerned. The three practices represent three levels of intensity in conservation farming and three levels of cost. A system of stripcropping can be installed with little or no capital expenditure, and the operating costs are but little more than they would be for large rectangular fields. The use of large-scale machinery is just as practical on stripcropping as on any other field layout. The potential returns from stripcropping are limited, as the principal benefit is protection against wind erosion. Stripcropping, as such, has little effect on water conservation, and little or none on water erosion control.

Contour farming is an intermediate practice. The installation cost may range from negligible to a substantial amount, depending on the kind of terrain and irregularity of slope. The contours need to be accurately staked with surveying instruments, and the cultivation pattern has to be carefully established. Operating costs are higher than they would be for rectangular fields because there are likely to be a number of odd-shaped areas which require excessive turning.

Terracing is the most intensive of the three conservation practices, involving large expenditures for installation and significant increases in operating costs. Level benches are similar to terraces in this respect, and in addition have some operating problems not common to other types of terraces.

A brief examination of the geographic distribution of these practices may indicate the rate of adoption that might be expected for level benches. For terracing, financial assistance in the form of cost-sharing payments have been available to farmers under both the Agricultural Conservation Program (ACP) of ASCS and the Great Plains Conservation Program (GPCP) of SCS. Despite this, there have been relatively few terraces installed in North Dakota. In the past 4 years, the total area served by terraces installed under the ACP was 429 acres (table 10). In contrast, there were 965,000 acres served by terraces in Kansas and 527,000 acres in Nebraska in the same period.

Some terraces have been constructed in North Dakota under the GPCP, but the total amount is small compared with other States. Back and Kasal[13] assert that the combined cost-sharing expenditure for standard terraces, diversion terraces, and sod waterways in 1958-66 was about $220,000 in North Dakota, compared with $1.6 million in Kansas, $1.8 million in Nebraska, and $2.8 million in Texas.

For contour farming and stripcropping, more complete data are available from the U.S. Census of Agriculture (21). In North Dakota in 1964, there were 192,000 acres of

[13] Back, W. B., and Kasal, James, unpublished research information relating to a study of the Great Plains Conservation Program.

grain or row crops planted on the contour, which was 0.7 percent of the total cropland in the State (table 11). Contour farming occupied 2 percent of the land in Minnesota, 1.2 percent in South Dakota, and 0.5 percent in Montana. Among the States adjoining the Dakotas, those leading in contour farming were Iowa with 8.8 percent, and Nebraska with 7.4 percent.

The practice of stripcropping was much more prevalent in North Dakota than contour farming; 11.8 percent of the cropland was stripcropped. In Montana, more than a third of the cropland was stripcropped. In Minnesota, 2.6 percent was stripcropped; in Iowa, only 1.5 percent.

Possible Limiting Factors

There seems to be no apparent explanation for the fact that terracing and contour farming play an important part in the agriculture of some neighboring States but not in North Dakota. Level benches may prove to be a more intensive land-use practice than terraces, but they offer some advantages not found in either contour farming or conventional terracing. Despite such advantages, it seems prudent to speculate on some of the factors which could limit or delay the adoption of level benches.

Climate

Climate does not appear to be a limiting factor in the adoption of level bench systems in North Dakota because alfalfa will probably respond to additional moisture supplies anywhere in the State. In North Dakota, where the growing season ranges from 120 to 140 days, irrigated alfalfa needs about 24 inches of water annually (4). The probability of getting more than 14 inches from precipitation in any 120-day period during the growing season is less than 20 percent in all parts of the State except the extreme southeastern corner, and is less than 10 percent in all but the east-central and south-central parts (19). This leaves a water deficit of 10 inches or more in the major portion of the State in all but 1 or 2 years in 10. It therefore follows that in at least 80 percent of the years of record, an alfalfa crop probably would have given a measurable response to additional water.

Soil and Topography

Soil and topographic conditions would limit the use of level benches for crop production in nearly every area of the State. Earlier it was shown that benches 70 feet wide would be profitable for alfalfa only on slopes of 5 percent or less, and 56-foot benches on slopes of less than 6 percent, and then only if the surface is unusually smooth and even. On fields that are nearly level, there would probably be no need for benches. Thus, the most advantageous location for level benches would be on fields with smooth, even slopes between 1 and 6 percent.

Soil texture would also limit the use of benches. Coarse-textured soils, such as gravel or sand, would not benefit because they lack water-holding capacity. In some cases, fine-textured soils, such as clays, might not be suited to alfalfa production because they are likely to be poorly drained, a problem which might be aggravated rather than improved by the construction of benches.

The depth of the soil limits the amount of cut and fill that can be made without seriously reducing crop yields. On most soils, the maximum cut should not go deeper than the A horizon, so shallow soils might not be suitable.[14]

To clearly identify the areas that could benefit from the use of benches, it would probably be necessary to use a land classification system specifically designed for this purpose. Such a system might be developed from the data contained in a detailed soil survey, particularly if some supplementary data on topography were available. Modern detailed soils surveys are available for only a few counties in North Dakota. One good example is Stark County, in the west-central part of the State (15). From the data in the survey for

[14] A new experiment was started in 1969 to determine the combined effects of a level bench system and deep tillage on some solonetzic soils in western North Dakota.

Stark County, the following tabulation of land suitable for level benches was developed for illustration:

	1,000 acres	Percent
Possibly suitable[1]	315	37.3
Doubtful suitability[2]	150	17.8
Probably unsuitable[3]	379	44.9
Total	844	100.0

[1] Slopes of 9 percent or less, soils at least 18 inches deep, occurring in SCS Capability Class II and its subunits, or in Capability Units IIIe-3, IIIe-3M, IIIe-4, IIIe-6, or IIIes-4.

[2] Mixed soils or those of questionable suitability because they do not fall into either of the categories shown in footnotes 1 or 3.

[3] Slopes of more than 9 percent, shallow soils (12 inches or less to rock, gravel, or claypan), stony surface, presence of gumbo, slick spots, coarse soils (gravel or sand), fine soils (clay), poor drainage, or subject to flooding. All soils in SCS Capability Classes V, VI, VII, and VIII, and some of those in Class IV, are in this group.

The above tabulation does not take into account the degree of regularity or the evenness of the slope, mainly because there are no topographic data available in sufficient detail. General observations of the terrain in Stark County suggest that there are many areas where the slopes are too complex to be adaptable to level bench systems. Detailed consideration of smoothness of slope would probably serve to change much of the area shown as "possibly suitable" to "unsuitable."

Alternate Uses for Land Resources

It was shown in an earlier section that alfalfa can be produced at a profit on level benches under experimental conditions.

As farmers become familiar with the practice, some of them might consider shifting land from some other use to level benches. Before making such a decision, the farmer should consider which of the two alternatives would be most advantageous to him, rather than just that one was profitable. In North Dakota, wheat-on-fallow would be the most likely alternate practice used for such a comparison. The comparative position of alfalfa relative to wheat may depend a great deal on the status of the Federal wheat program at the time. Farmers know that wheat acreage allotments are important farm assets, and under 1969 circumstances, most of them would probably be reluctant to reduce wheat acreages and increase alfalfa. By affecting the relative profitability of the alternate use for the land resource, changes in the wheat program would affect the rate at which farmers adopt level benches.

Government Conservation Programs

Government programs which provide direct assistance to farmers for installing certain conservation practices are likely to affect the adoption of level benches, though the impact of a program on the adoption of a particular practice is not known in detail. Payments for standard terraces have been made under both the GPCP of SCS and the ACP of ASCS for several years, but level bench systems were added to both programs for the first time in 1969. As a result, a few benches were installed this year, but it remains to be seen whether cost-sharing assistance will provide the incentive necessary to promote wide adoption of level benches.

Other Factors

Some nonfinancial factors are likely to affect the rate of adoption of level benches. On most farms, it would be necessary to break a slope up into many small fields to build an effective system of benches. Farmers object to small fields, particularly in the Northern Great Plains where they are accustomed to using large machinery. In the analysis, a token attempt was made to account for this objectionable aspect of the practice, but there is some question that the assumed extra cost was enough to represent actual conditions.

To use level bench systems, many farmers would need to change their land-use pattern from wheat to alfalfa, a shift which would be attractive only to those in a position to market hay advantageously, either in cash or through livestock.

Another factor is the natural reluctance to make an investment for which the results are relatively remote or uncertain. It may be difficult to convince people that benching actually produces as much additional hay as the experiments at Mandan indicate. A farmer may let uncertainty make a negative decision for him.

Research Needs

There has been limited active interest in North Dakota in level bench systems, probably because they are new to the area and because information is not widespread on either their performance or profitability. More research is needed to add validity to various aspects of the analysis attempted herein, because at several points it was necessary to make assumptions based on fragmentary data or on logic alone with no supporting data.

In addition, there are a number of physical relationships for which more research may be desirable. Studies are underway to examine more thoroughly the effect of the direction of prevailing winds and the direction which the slopes face. It is likely that narrow benches are more effective than wide ones for trapping drifting snow. This relationship should be explored. Field-sized trials should be conducted to determine the most practical travel patterns for tillage and harvest machinery, to investigate the relationship between bench size and operating efficiency, to establish optimum width of benches for various crops and machine sizes, and to furnish additional data on expected increases in yield. More accurate methods of estimating construction costs are needed, as well as data on maintenance costs and depreciation rates for bench systems. Another problem area needing study concerns the rate of adoption of level benches and closely related soil and water conservation practices. Research directed along these lines would do much to provide more detailed information on the physical, economic, and other relationships the farmer needs to consider in deciding which practices to select for soil and water conservation and management.

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Table 1.--Crop yields per acre on level benches: Summary of 3 sets of experiments, 1962-68

Item	1962	1963	1964	1965	Mean, 1962-65
Cropland study					
Corn grain			Bushels		
Slope	42.0	29.6	24.0	62.9	39.6
Bench without C.A.	43.2	43.9	20.4	54.1	40.4
Bench with C.A.	40.9	39.4	23.8	51.7	39.0
Corn silage			Tons		
Slope	7.62	6.84	5.74	11.86	8.02
Bench without C.A.	7.81	7.61	6.06	9.84	7.83
Bench with C.A.	7.21	7.40	6.20	9.27	7.52
Wheat			Bushels		
Slope	44.1	7.3	23.7	40.8	29.0
Bench without C.A.	48.2	10.3	36.5	42.2	34.3
Bench with C.A.	48.2	11.1	38.2	42.3	35.0
Grassland study	1963	1964	1965	1966	Mean, 1963-66
Alfalfa			Tons		
Slope	0.60	0.77	1.18	1.05	0.90
Bench without C.A.	1.70	1.84	2.17	2.07	1.94
Bench with C.A.	1.88	1.80	2.44	2.22	2.08
Bromegrass					
Slope	1.02	0.84	0.98	0.93	0.94
Bench without C.A.	1.49	1.56	1.93	1.31	1.57
Bench with C.A.	1.76	1.62	1.78	1.40	1.64
Contributing area study	1964	1965	1966	1968	Mean, 1964-68
Alfalfa			Tons		
Slope	1.32	1.84	1.49	1.68	1.58
Bench without C.A.	2.59	4.19	3.84	4.36	3.74
Bench with C.A.	2.75	4.16	4.08	4.46	3.86

C.A. = contributing area.

Table 2.--Maximum depth of cut for benches, by slope and bench width

Percentage of slope[1]	Depth of cut when width of bench in feet is--				
	14	28	42	56	70
	Inches	Inches	Inches	Inches	Inches
1	0.9	1.8	2.7	3.6	4.4
2	1.8	3.6	5.3	7.1	8.9
3	2.7	5.3	8.0	10.7	13.4
4	3.6	7.1	10.7	14.2	17.8
5	4.5	8.9	13.4	17.8	22.3
6	5.3	10.7	16.0	21.4	26.7
7	6.2	12.5	18.7	24.9	31.2
8	7.1	14.2	21.4	28.5	35.6
9	8.0	16.0	24.0	32.1	40.1
10	8.9	17.8	26.7	35.6	44.5

[1] For this calculation the slope is assumed to be uniform throughout.

Table 3.--Quantities of earth to be moved in construction of benches of varying widths, by slope

Percentage of slope[1]	Amount of earth moved when width of bench in feet is--				
	14	28	42	56	70
	Cubic yards per acre[2]				
1	32	64	96	128	160
2	64	128	192	256	321
3	96	192	289	385	481
4	128	256	385	513	641
5	160	320	481	641	802
6	192	385	577	769	962
7	224	449	673	898	1,122
8	256	513	769	1,026	1,282
9	288	577	866	1,154	1,443
10	320	641	962	1,282	1,603

[1] For this calculation the slope is assumed to be uniform throughout.
[2] Cut volume. The ratio of cut to fill is assumed to be 1.3:1.

Table 4.--Land area occupied by dikes and backslopes (Percentage of total area in a field)

Percentage of slope[1]	Proportion of dikes and backslopes when width of bench in feet is--				
	14	28	42	56	70
	Percent	Percent	Percent	Percent	Percent
	Benches without contributing area:				
1	16.2	9.5	7.0	5.7	4.9
2	17.4	10.8	8.4	7.1	6.3
3	18.4	12.1	9.7	8.5	7.7
4	19.5	13.2	11.0	9.8	9.0
5	20.5	14.4	12.2	11.0	10.3
6	21.6	15.6	13.4	12.3	11.6
7	22.5	16.7	14.6	13.5	12.8
8	23.4	17.8	15.7	14.6	14.0
9	24.4	18.9	16.8	15.8	15.2
10	25.2	19.9	18.0	16.9	16.3
	Benches with 1:1 contributing area:				
1	8.8	5.0	3.6	2.9	2.5
2	9.5	5.7	4.4	3.7	3.3
3	10.1	6.4	5.1	4.4	4.0
4	10.8	7.1	5.8	5.1	4.7
5	11.4	7.8	6.5	5.8	5.5
6	12.1	8.5	7.2	6.5	6.2
7	12.7	9.1	7.9	7.2	6.9
8	13.2	9.8	8.5	7.9	7.5
9	13.9	10.4	9.2	8.6	8.2
10	14.4	11.0	9.9	9.2	8.9

[1] The slope is assumed to be uniform throughout the field.

Table 5.--Estimated construction cost per acre for benches of varying widths, by slope[1]

Percentage of slope[2]	Cost when width of bench in feet is--				
	14	28	42	56	70
	Dollars	Dollars	Dollars	Dollars	Dollars
1	[3]25.00	[3]25.00	25.92	34.56	40.00
2	[3]25.00	34.56	48.00	61.44	77.04
3	25.92	48.00	69.36	88.55	105.82
4	34.56	61.44	88.55	112.86	141.02
5	40.00	76.80	105.82	141.02	176.44
6	48.00	88.55	126.94	169.18	211.64
7	56.00	103.27	148.06	197.56	246.84
8	61.44	112.86	169.18	225.72	282.04
9	69.12	126.94	190.52	253.88	317.46
10	76.80	141.02	211.64	282.04	352.66

[1] Calculated from quantities of earth moved (table 3) at the following rates per cubic yard (see text):

Cubic yards per acre	Cost per cubic yard
Under 150	$0.27
150 - 249	.25
250 - 349	.24
350 - 449	.23
450 and over	.22

[2] The slope is assumed to be uniform throughout the field.
[3] A lower limit of $25 per acre was assumed.

Table 6.--Estimated alfalfa production per 100 acres on level benches, by slope and width of bench

Percentage of slope[1]	Production per 100 acres when width of bench in feet is--				
	14	28	42	56	70
	Tons	Tons	Tons	Tons	Tons
	Benches without contributing area:				
1	219	238	245	248	251
2	215	233	240	244	246
3	211	229	236	239	241
4	207	225	231	235	237
5	204	221	227	230	232
6	200	217	223	226	228
7	197	213	219	222	224
8	193	209	215	218	220
9	190	205	211	214	215
10	187	202	207	210	212
	Benches with 1:1 contributing area:				
1	181	189	192	194	195
2	180	188	190	192	193
3	178	186	189	190	191
4	176	184	187	188	189
5	175	182	185	187	187
6	173	181	183	185	186
7	172	179	182	183	184
8	170	177	180	181	182
9	169	176	178	180	180
10	167	174	177	178	179

[1] The slope is assumed to be uniform throughout the field.

Table 7.--Cost and returns from alfalfa on natural slopes and level benches, per 100-acre field on 4-percent slope

Item	Unit	Natural slope	42-foot bench	
			With contributing area	Without contributing area
Land use:				
Roads and fences	Acres	3.0	3.0	3.0
Dikes	do.	0	5.8	11.0
Turning and odd-shaped areas	do.	0	5.2	6.0
Contributing area and natural slope	do.	97.0	43.0	0
Benches	do.	0	43.0	80.0
Total	do.	100.0	100.0	100.0
Alfalfa production:				
Turning and odd-shaped areas	Tons	0	6.2	7.2
Contributing area and natural slope	do.	116.4	51.6	0
Benches	do.	0	129.0	224.0
Total	do.	116.4	186.8	231.2
Gross returns	Dollars	1,979	3,176	3,930
Total investment, bench construction	do.	0	4,321	8,058
Annual costs:				
Amortization of bench construction	do.	0	348	649
Land and machinery cost	do.	935	935	935
Maintenance of stand (reseeding)	do.	194	182	172
Harvest cost	do.	388	494	584
Labor	do.	582	719	836
Added cost for small fields, etc.	do.	0	30	55
Total annual cost	do.	2,099	2,708	3,231
Net returns (gross returns minus total annual costs)	do.	-120	468	699
Average yield per acre (net)	Tons	1.16	1.87	2.31
Gain in yield per acre	do.	---	.71	1.15
Increase in cost per acre	Dollars	---	6.09	11.32
Gain in gross returns per acre	do.	---	11.97	19.51
Gain in net returns per acre	do.	---	5.88	8.19

Table 8.--Net returns per 100 acres from alfalfa on level benches of varying widths and slopes

Percentage of slope	Net returns when width of bench in feet is--				
	14	28	42	56	70
	Dollars	Dollars	Dollars	Dollars	Dollars
	Benches without contributing areas				
1	948	1,211	1,300	1,287	1,276
2	906	1,091	1,088	1,040	953
3	861	947	884	792	692
4	757	809	699	570	392
5	680	656	531	325	92
6	581	529	339	80	-205
7	490	385	147	-163	-492
8	418	279	-40	-400	-781
9	327	143	-226	-634	-1,067
10	241	9	-413	-866	-1,344
	Benches with 1:1 contributing area				
1	613	728	769	762	755
2	594	673	664	636	590
3	576	602	561	513	461
4	521	528	468	398	304
5	482	449	380	270	143
6	430	383	278	138	-15
7	382	308	173	6	-175
8	345	249	71	-127	-333
9	295	174	-35	-260	-495
10	248	100	-140	-391	-659

Table 9.--Cost and return per 100-acre field for spring wheat production on level benches

Item	Unit	Natural slope	On 1-percent slope		On 2-percent slope	
			56-foot bench	70-foot bench	56-foot bench	70-foot bench
Benches without contributing areas:						
Wheat production	Bushels	2,813	3,108	3,136	3,057	3,085
Increase over natural slope	do.	---	295	323	244	272
Gross returns from wheat	Dollars	4,782	5,284	5,331	5,197	5,245
Investment cost	do.	---	3,197	3,700	5,652	7,088
Increased gross returns	do.	---	502	549	415	463
Increased annual fixed cost	do.	---	258	298	455	571
Increased net returns (over fixed cost)	do.	---	244	251	-40	-108
Benches with contributing areas:						
Wheat production	Bushels	2,813	2,999	3,012	2,972	2,985
Increase over natural slope	do.	---	186	199	159	172
Gross returns from wheat	Dollars	4,782	5,098	5,120	5,052	5,075
Investment cost	do.	---	1,652	1,904	2,949	3,683
Increased gross returns	do.	---	316	338	270	293
Increased annual fixed cost	do.	---	133	153	238	297
Increased net returns (over fixed cost)	do.	---	183	185	32	-4

Table 10.--Terrace construction for which payment was made under the Agricultural Conservation Program in North Dakota, South Dakota, and other States[1]

State	1965	1966	1967	1968	4-year total
	Acres served				
North Dakota	194	15	120	100	429
South Dakota	13,250	17,781	14,972	7,287	53,290
Minnesota	1,890	2,366	4,973	3,544	12,773
Iowa	51,591	42,347	34,018	39,268	167,224
Nebraska	136,764	130,156	107,407	152,760	527,087
Kansas	272,454	275,483	205,175	211,847	964,959
Wyoming	688	1,057	1,607	873	4,225
Montana	---	425	1,200	215	1,840
All other states[2]	261,052	238,295	203,599	192,012	894,958
United States	737,883	707,925	573,071	607,906	2,626,785

[1] Data from Agricultural Conservation Program, 1965-67 Summary, Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture, Washington, D.C., 1968, and Agricultural Conservation Program Accomplishments, 1968, Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture, Washington, D.C., 1969.
[2] Most of this acreage is in Oklahoma, Texas, Missouri, Georgia, Alabama, and South Carolina.

Table 11.--Contour farming and stripcropping in North Dakota, South Dakota, and other States, 1964[1]

State	Total cropland	Contour farming		Stripcropping	
		Area contoured[2]	Percentage of total cropland	Area stripcropped[3]	Percentage of total cropland
	1,000 acres	1,000 acres	Percent	1,000 acres	Percent
North Dakota	27,446	192	0.7	3,228	11.8
South Dakota	18,707	232	1.2	780	4.2
Minnesota	22,243	454	2.0	582	2.6
Iowa	26,356	2,309	8.8	395	1.5
Nebraska	22,100	1,644	7.4	959	4.3
Kansas	29,421	3,336	11.3	707	2.4
Wyoming	2,766	14	0.5	378	13.7
Montana	15,388	78	0.5	5,638	36.6
All other States	269,805	13,306	4.9	4,016	1.5
United States	434,232	21,565	5.0	16,683	3.8

[1] Data from U.S. Census of Agriculture, 1964.
[2] Includes "grain and row crops grown on the contour."
[3] "Land in strip-cropping systems for erosion control."

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C. 20250

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