Geometric Shaping and Contouring of Land as Related to Potential for Surface-Water Storage

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It is almost impossible to provide a crop canopy on erodible soils of the Corn Belt from the time of planting until after the second cultivation, or about 60 days after planting. It is during this time that about 75 to 90 percent of the annual erosion and 60 to 75 percent of the annual runoff occurs. Some type of surface configuration applied to the land surface during this period that would provide surface-water storage and reduce runoff and erosion would be particularly beneficial.

Any ridge or depression, referred to as a geometric shape in this paper, will affect runoff rates and quantities. The practice of bedding (7)* for improving surface drainage on nearly level land with poor internal drainage is an example of using geometric shapes to increase surface runoff. However, if beds such as those shown in Fig. 1 (7) were placed on the contour, they could store a sizeable amount of surface water and thus reduce the quantity of rainfall runoff. Field terraces, another form of geometric shapes, are used to reduce the length of overland flow and reduce erosion (1), (2), (4), and can be profitable if properly designed (3). Even though runoff rate is not the only factor affecting soil loss, it is a major one (2), (6). If a conservation practice to reduce runoff could be developed for use in conjunction with terraces by using beds on the contour, perhaps terrace spacing could be increased and thus reduce the cost of applying conservation practices. These beds could be made during the normal plowing operation with little additional cost.

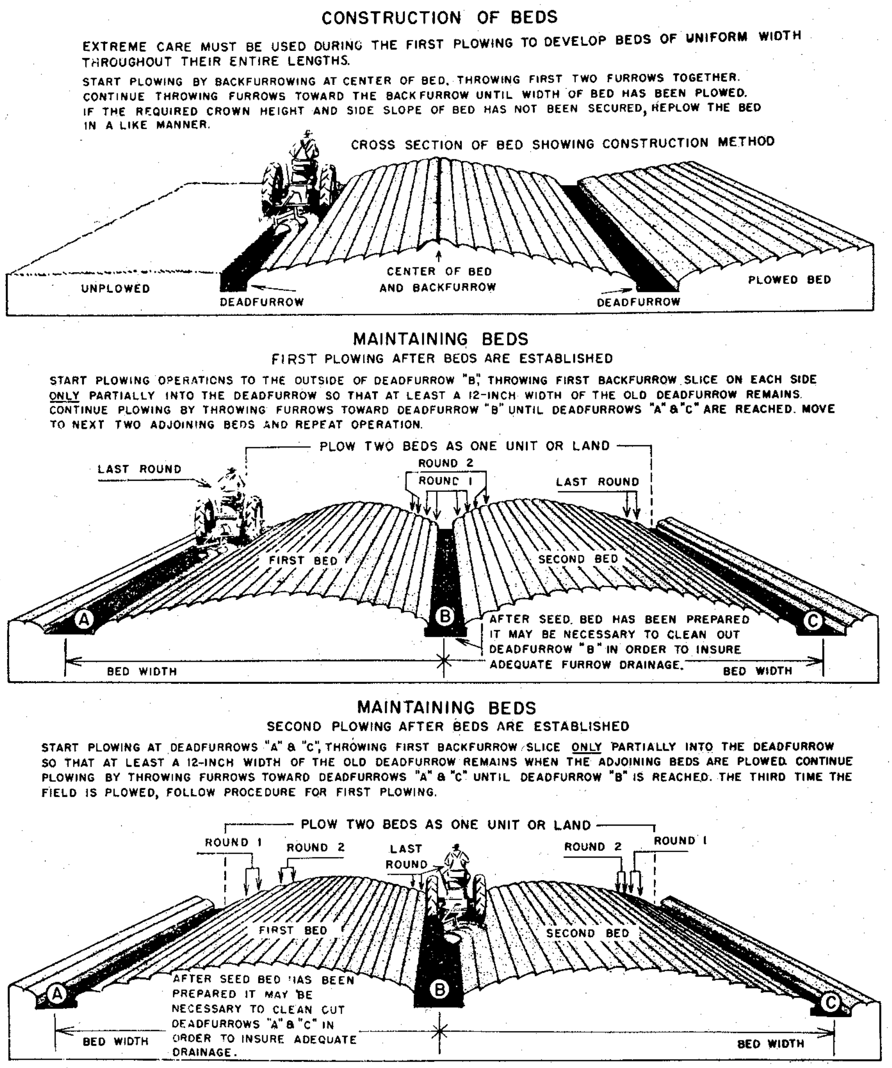

FIG. 1 Constructing and maintaining bedding system for surface drainage (7). These same beds placed on the contour provide surface-water storage and may reduce runoff and erosion.

The surface-water storage capacity, the area behind a ridge or in a depression of a geometric shape where water will accumulate, can be calculated by using equation [1]

$$S = \frac{V}{H} \qquad [1]$$

where

S = surface water storage
V = volume of storage per unit of length
H = horizontal spacing from ridge to ridge

$S \alpha \frac{V}{H}$, therefore, if a system can be provided where H decreases more rapidly than V, the surface-water storage will be greatly increased.

Fig. 2 illustrates the storage capacity of three bed widths on 4 percent slope where it is assumed that the backfurrow is 6 in. above and the deadfurrow 6 in. below the original ground surface. The surface water storage increases as the horizontal distance decreases, and the width of bed at which the front slope becomes level decreases as the slope of the land increases.

The objective of this study was to determine the various geometric shapings of land obtained when bedding, conventional tillage, and listing are used on the contour and their effect on surface-water storage, crop yield, erosion control, and terrace spacing. Six

Paper No. 68-209 was presented at the Annual Meeting of the American Society of Agricultural Engineers at Logan, Utah, June 1968, on a program arranged by the Soil and Water Division.

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Author's Note: This paper is approved as a contribution from the Corn Belt Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Agricultural Engineering Department, South Dakota State University.

* Numbers in parentheses refer to the appended references.

This article is reprinted from the Transactions of the ASAE (Vol. 12, No. 3, pp. 322, 323, 324, 325 and 328, 1969)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

different geometric shapes were studied in this investigation. The water-holding capacities of these geometric shapes were then related to their ability to reduce runoff and soil erosion.

Experimental Procedure

A field study on slightly eroded soils at three locations – Eastern South Dakota Soil and Water Research Farm (Madison, S.D.) on a 4-percent Kranzburg loam, Southeast South Dakota Experiment Farm (Centerville, S.D.) on a 1-percent slope Kranzburg-like silt loam, and Northeast South Dakota Experiment Farm (Garden City, S.D.) on a 3½ percent slope Poinsett silty clay loam – was completed using normal cultural practices and commercially available farm equipment. Recommended hybrid corn was planted in 40-inch rows and thinned to 14,000 plants per acre. Recommended amounts of fertilizer were applied at planting and as a later side dressing. The following treatments were tested:

1 Conventional contouring was used as the check treatment. The plots were spring-plowed with a 16-in., two-bottom plow and then were disked with a tandem disk. Corn was surface planted and cultivated with conventional two-row equipment.

2 The contour listing treatment was listed in the spring and the ridges were disked. The planting operations were performed so that the row was placed in the middle of the ridge formed in the previous operation. A lister planter was used to place the seeds in the bottom of the lister furrow. During the first lister cultivation, the soil was thrown toward the ridge in the middle between the rows, and during the second cultivation, the soil was moved toward the row with disk hillers on the lister cultivator.

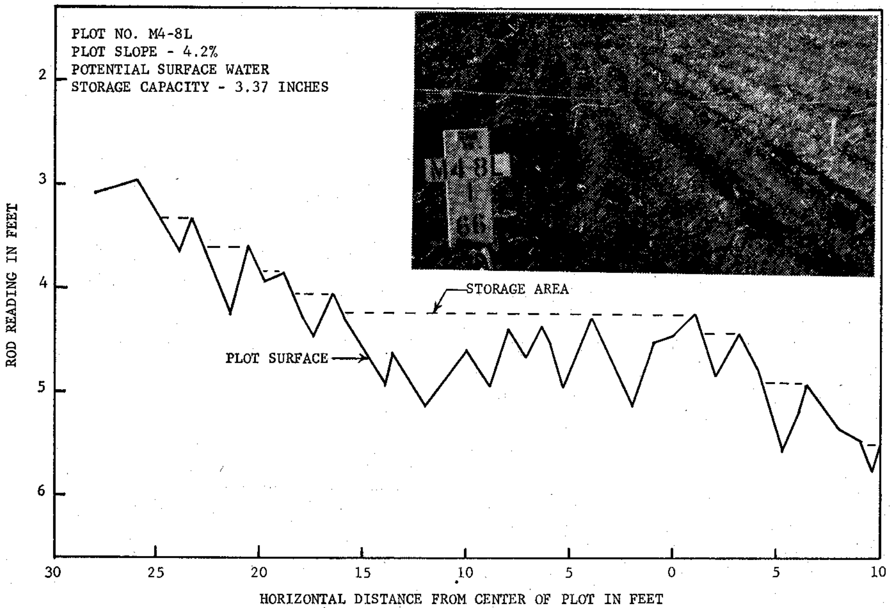

FIG. 3 Geometric shape of contoured 8-row bedding with lister planting after planting.

3 The contoured 4-row bedding with lister planting treatment was bedded in the spring following the instructions in Fig. 1. Only one plowing operation was performed. The 13.3-ft-wide beds provided space for four 40-in. rows. The contour line was the center of the bed as shown in Fig. 1. A seedbed was prepared by disking, being careful to keep the ridges intact. The lister planter and cultivator were used for the subsequent operations. The second year the beds were prepared as shown in Fig. 1 for the first plowing after beds were established.

4 The contoured 8-row bedding with lister planting treatment was the same as treatment 3, except that the beds were 26.7 ft wide with 8 rows on each.

5 The contoured 4-row bedding with conventional planting treatment was the same as treatment 3, except that conventional 2-row equipment was used for planting and cultivating.

6 The contoured 8-row bedding with conventional planting treatment was the same as treatment 3, except that the beds were 26.7 ft wide with 8 rows on each and the planting and cultivating operations were accomplished with conventional equipment.

The experimental design was a randomized design with two replications at each location, a total of 36 plots, each being 50 ft long on the contour and 8 rows or 26.7 ft wide. Surface-water storage capacity and geometric shapes were measured after each cultural operation (5). The geometric shapes were then applied to different slopes and the surface-water storage capacity extrapolated for other slopes. The surface-water storage capacity afforded by the geometric shapes on different slopes and for the expected rainfall amounts were used to determine the need for terraces and terrace spacing.

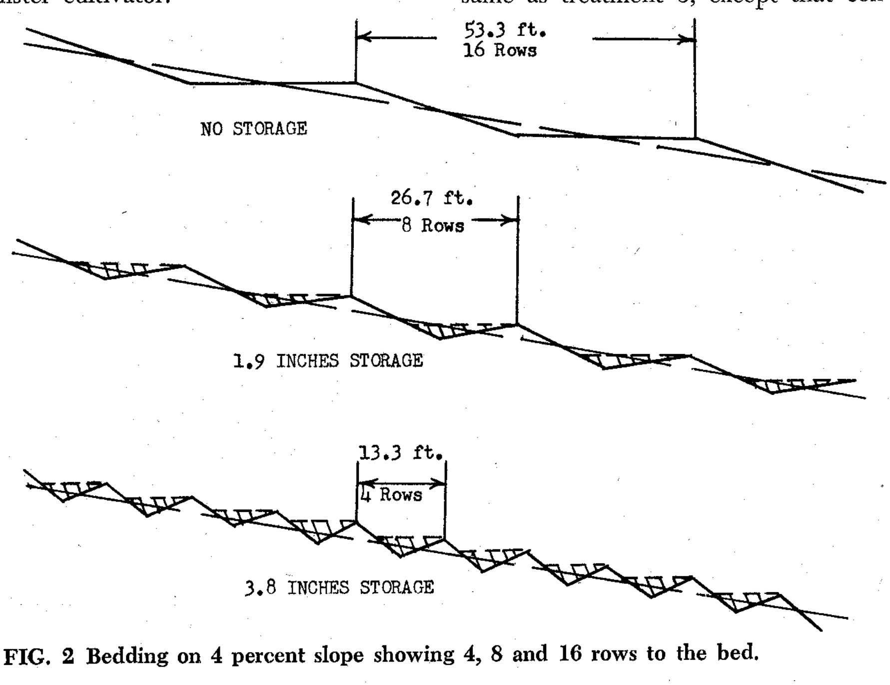

FIG. 2 Bedding on 4 percent slope showing 4, 8 and 16 rows to the bed.

Results and Discussion

Potential Surface Water Storage Capacity

The geometric shape of the 8-row bedding with lister planting after planting at the Eastern South Dakota Soil and Water Research Farm (Madison) is shown in Fig. 3. The amount of potential surface-water storage is shown below the dashed line. The maximum potential surface-water storage was obtained on the geometric shapes after planting. Most of the treatments had the minimum potential surface-water storage at harvest. Measured shapes of all treatments are given by Doty (5).

The two-year average potential surface-water storage capacity for conventional contouring, contour listing and 8-row bedding treatments for five different cropping periods are indicated in Fig. 4. For the two-year average, 4-row bedding was practically the same as the 8-row bedding; however, during the first year the 4-row bedding showed a slight advantage (5). The potential surface water-storage capacity for the bedding and listing treatments is greatest in the period between plowing and second cultivation, which coincides with the period of greatest potential runoff. The natural runoff plots located at the same station indicate that about 80 percent of the erosion and 60 percent of the runoff occurs between planting and 60 days after planting. Since little can be done to speed the forming of a crop "canopy" during this period, any runoff reduction is important. The listing, 4-row and 8-row bedding treatments provided the needed surface geometry to reduce runoff during this critical period. The bedding treatments with conventional planting had ample storage throughout the year.

Crop Yield

A good incentive for accepting any conservation practice is an increase in crop yields. Table 1 shows the yields for the six geometric shapes for 1966-67. At the Madison location where the growing season rainfall of 12 in. in 1966 and 13 in. in 1967 was poorly distributed, yields were increased during both years by the bedding and listing treatments. Even though the rainfall during both years came as high-intensity rainfall, the listing and bedding systems had the storage capacities to hold this rainfall and allow it to infiltrate into the soil.

Rainfall at the Northeast Experiment Farm (Garden City) was more evenly distributed and no high-intensity rainfall occurred over the two-year growing season, 14 in. in 1966 and 9 in. in 1967. Little increase in yield occurred under these conditions. The storage capacity of the conventional contouring was large enough to hold the rainfall.

TABLE 1. CORN YIELD IN BUSHELS PER ACRE FROM SIX GEOMETRIC SHAPES AT THREE LOCATIONS IN EASTERN SOUTH DAKOTA

		Treatment					
Location	Year	Conventional contouring	Contour listing	Contoured 8-row bedding, conventional	Contoured 8-row bedding, listing	Contoured 4-row bedding, conventional	Contoured 4-row bedding, listing
Madison	66	24.4	40.1	35.6	30.3	22.0	47.8
	67	32.4	41.9	52.0	58.2	25.5	52.4
	Ave.	28.4	41.0	43.8	44.2	23.8	50.1
Garden City	66	84.6	93.3	76.6	85.7	73.6	83.4
	67	55.1	55.3	56.3	54.3	51.6	54.5
	Ave.	69.8	74.3	66.5	70.0	62.6	69.0
Centerville	66	135.0	123.6	129.4	114.3	124.6	129.1
	67	103.1	95.7	90.0	81.2	94.6	80.9
	Ave.	119.0	109.6	109.7	97.8	109.6	105.0

The Southeast Experiment Farm (Centerville) received above-average rainfall, 22 in. in 1966 and 16 in. in 1967. In 1967, the Centerville location was extremely wet during June and July; the corn at the bottom of the deadfurrow was killed by excess water stored between the beds. Water was observed standing between the beds for 3 to 5 days. Under these conditions yield decreased somewhat on the listing and bedding treatments. At locations where large amounts of rainfall occur each year, the beds should be placed on a nonerodible grade to allow for some surface drainage.

Potential Surface-Water Storage Index

The potential surface-water storage index (5) (hereafter referred to only as "index") is a method of measuring the relative storage capacity of each treatment for the entire year. The index takes into account the amount of available storage and the percent of mean annual precipitation during each period. The mean rainfall for the past 25 years was used to calculate the index. The index for each period was found by multiplying the potential surface-water storage capacity for the period by the percent of the total mean rainfall that occurred within the period. The index for the year is the sum of the indexes of the cropping periods. The index can be used to compare the relative value of the six individual treatments as depicted in Fig. 5.

Although the index indicates that the 4-row bedding treatment is best, the 8-row bedding which is nearly as good is more adaptable to large-size modern farm equipment.

The bedding treatment will cost very little to include in the farm plan. With the instructions as given in Fig. 1, the plow lands are large enough so that turning time would not add to the cost of plowing. When small grains are to be grown, the bed width can be adjusted to a width to suit the combine operation. Fig. 4 shows the 8-row bedding treatment had 2 inches of surface water storage on 5 percent slope land when the beds were plowed and disked in the spring. Most of this storage would carry through until harvest.

The index for contour listing indicates that its holds twice as much water as conventional contouring and also furnishes the following advantages: (**a**) no seedbed preparation before planting, (**b**) weeds are more easily controlled, and (**c**) yields are usually comparable (5), (8). Contour listing is the simplest of the six treatments to apply.

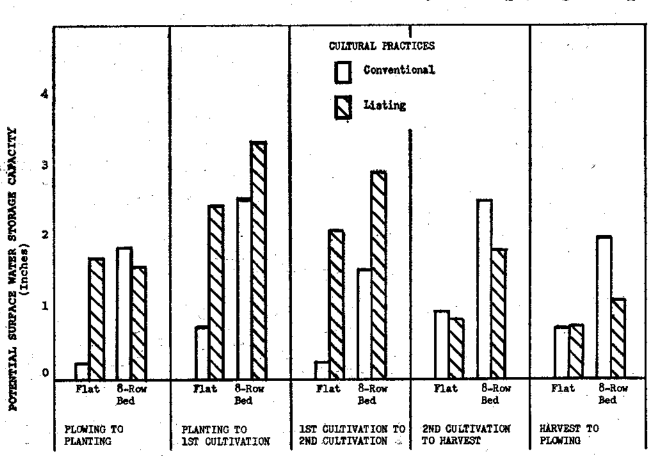

FIG. 4 Potential surface-water storage in inches of conventional contouring, contour listing and 8-row bedding with a conventional and listing cultural practices at the Madison location for five cropping periods during the year.

Effect of Slope on Potential Surface-Water Storage Capacity

The effect of slope on the efficiency of each geometric shape was determined by plotting data on semilog paper and calculating the best fit curve by the least-squares method (10). The predicted relationship for conventional contouring and contour listing is shown in Fig. 6. The 4-row and 8-row bedding treatments are shown in Figs. 7 and 8, respectively. At 5 percent slope, contour listing has an index as great as conventional contouring has at 2 percent (Fig. 6). Even though the

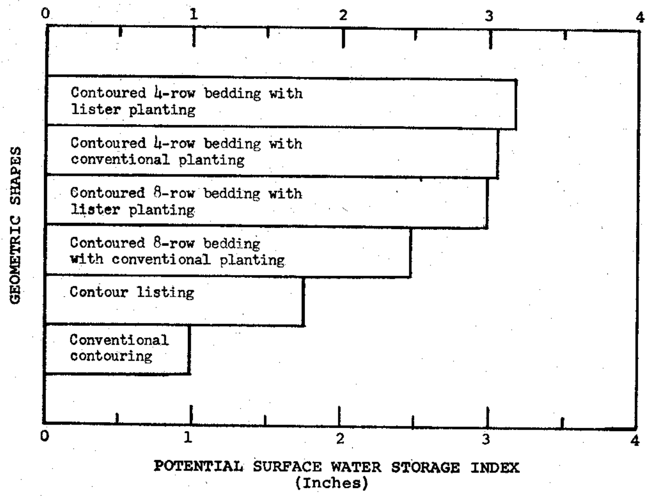

FIG. 5 Comparison of potential surface-water storage index for six geometric shapes. A two-year average over three locations and two replications per location.

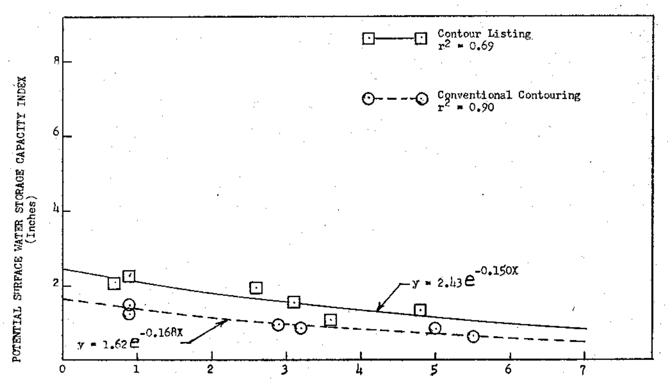

FIG. 6 Relation of potential surface-water storage index to percent slope for conventional contouring and contour listing.

TABLE 2. CROPPING PRACTICE FACTOR "P" FOR SIX GEOMETRIC SHAPES ON 4 PERCENT SLOPE LAND

Treatment	Cropping practice factor P
Conventional contouring	0.50
Contour listing	0.37
Contoured 8-row bedding	
with conventional planting	0.18
and with lister planting	0.11
Contoured 4-row bedding	
with conventional planting	0.04
with lister planting	0.09

4-row bedding treatments are impractical in many instances, their storage was considerable throughout the entire slope range of this study. On 4-row bedding, the lister planting treatment became less effective than the conventional contouring at slopes greater than 3 percent (Fig. 7). This was due to the fact that the back slope of the bed became so steep that it was almost impossible to keep the tractor on the bed.

The 8-row bedding treatments were not difficult to till until slopes reached the 5½ percent range. The contoured 8-row bedding was effective throughout the slope range of this experiment. The index was in excess of one inch at 7 percent slope for both the conventional and listing treatments on 8-row bedding (Fig. 8). Almost 100 percent of the index variation was explained by the percent slope on the contoured 8-row bedding with lister-planting treatment. This, together with the fact that the index is apparently in excess of one inch at 7 percent slope, indicates that this treatment may be very effective as a conservation practice.

Cropping-Practice Factor

The cropping-practice factor *P* as used in the "universal soil loss equation" (12), (9) is the ratio of the soil loss with the practice to the loss without the practice. The potential surface-water storage capacity indexes given in this paper can be converted to the *P* factor by a few mathematical calculations (5). The cropping practice factor *P* for the six geometric shapes on 4 percent slope land is shown in Table 2.

Effect of Geometric Shapes on Terrace Spacing

The "P" factor given in Table 2 and the additional potential surface-water storage index of the listing and bedding treatments over conventional contouring at 4 percent slope as shown in Figs. 5, 7, and 8 was used to calculate the terrace spacing shown in Table 3. The universal soil loss equation (12), (9) and the volume storage formula (11) were used. The method of calculation is given by Doty (5). Terrace spacing can be greatly increased by using contour listing or the bedding treatments, thus reducing the cost of construction.

TABLE 3. TERRACE SPACING ON 4 PERCENT SLOPE LAND USING THE SIX GEOMETRIC SHAPES

Treatment	Estimated horizontal terrace spacing by use of	
	Universal soil loss equation, ft	Volume storage formula, ft
Conventional contouring	160	130
Contour listing	291	174
Contoured 8-row bedding		
with conventional planting	1200	372
with lister planting	No terrace	650
Contoured 4-row bedding		
with conventional planting	No terrace	No terrace
with lister planting	No terrace	866

Conclusions

Listing and 8-row bedding provide surface configuration to increase water storage and reduce runoff during the period of greatest erosion hazard. Contoured 8-row bedding is the most versa-

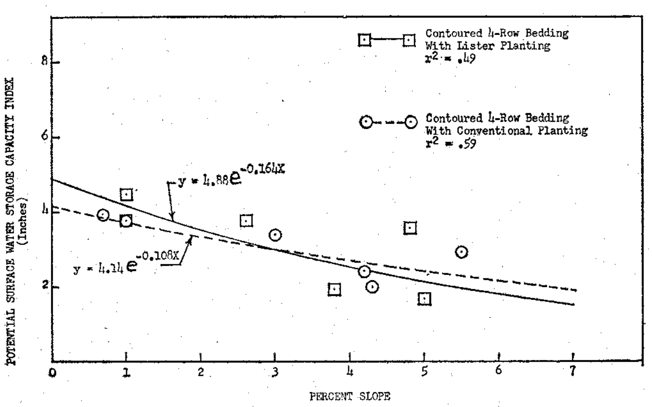

FIG. 7 Relationship of potential surface-water storage capacity index to percent slope for contoured four-row bedding.

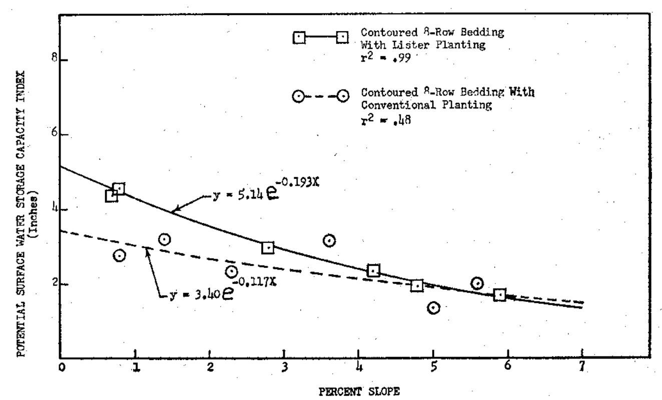

FIG. 8 Relationship of potential surface-water storage capacity index to percent slope for contoured eight-row bedding.

tile of the six geometric shapes studied. It should be valuable for small grains as well as for row crops. To afford the same control of runoff, terrace spacing may possibly be increased up to three times that of conventional contouring by use of the 8-row bedding system. Very accurate contouring, however, will be required to prevent breakover. Eight-row bedding treatments can be established with a minimum of expense, since the beds are made during the normal plowing operation. More storage capacity can be obtained if the beds are plowed the same way for two years before beginning the maintenance program.

References

1 Baver, L. D. Soil physics. Third edition. John Wiley and Sons, Inc., New York, 1956.

2 Carter, C. E., Doty, C. W. and Carroll, Barby R. Runoff and erosion characteristics of the brown loam soils. **Agricultural Engineering** 49:(5)296, May 1968.

3 Corley, T. E., Helms, J. O., Kummer, F. A., and Stokes, C. M. Preparing land for mechanization in the Southeast. **Agricultural Engineering** 38:(10)730-733, October 1957.

4 Cox, M. B., Daniel, H. A. and Elwell, H. M. Terraces on grassland. **Agricultural Engineering** 33:(5)294-296, 1952.

5 Doty, C. W. Potential surface water storage capacities of various contoured geometric shapes. Unpublished M.S. thesis, South Dakota State University, Brookings, S.D., 1968.

6 Doty, C. W. and Carter, C. E. Rates and particle-size distribution of soil erosion from unit source areas. **Transactions of the ASAE** 8:(3)309-311, 1965.

7 Soil Conservation Service. Engineering handbook for soil conservationists in the Corn Belt. U.S. Dept. Agr., Agr. Handbook No. 135, 11:31-59, 1958.

8 Sanford, J. O., Bruce, R. R., Doty, C. W., Myhre, D. L. and Crockett, S. P. Tillage practices for corn. Mississippi State Univ. Agr. Exp. Sta. Inf. Sheet 855, May 1964.

9 Smith, Dwight D. and Wischmeier, Walter H. Rainfall Erosion. Advances in agronomy Vol. 14, Academic Press, Inc., New York, N.Y., 1962.

10 Steen, Frederick H. and Ballou, Donald H. Analytic geometry. Second ed., Ginn and Co., Boston, 1946.

11 U.S. Department of Agriculture, Soil Conservation Service. South Dakota technical guide. Engineering standards and specifications for level terraces. SCS state office, Huron, S.D., May 7, 1962.

12 Wischmeier, W. H. A rainfall erosion index for a universal soil loss equation. Soil Sci. Soc. Amer. Proc. 23:246-249, 1959.