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The Impacts of Furrow Diking, Terracing, and Contour Cultivation on Water Conservation in Texas Agriculture

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INTRODUCTION

Water is generally the most limiting factor in crop production in the state of Texas. It is an indispensable and fragile resource that must be managed carefully in order to insure its availability in years to come (Gerard, et al., 1980). Ground water is a non-renewable resource in many parts of the state where underlying aquifers are being depleted more rapidly than they can be recharged (TWDB, 1988). Thus, it is imperative that we properly maintain and manage our water resources.

Average water use in Texas exceeds the renewable supply by approximately 10 percent (Devin et al., 1986). Because agriculture accounts for about two-thirds of all water consumption in the state, a concentrated effort in proper water management techniques should be focused in this sector. Only about 60 to70% of surface irrigation water is efficiently utilized by crops, the rest being lost through inefficient irrigation practices and equipment (TWDB, 1988). More efficient irrigation methods in the agricultural sector alone could reduce annual statewide water use by about two million acre-feet (one acre foot = 325,851 gallons) without hindering crop production (TWDB, 1988). Reducing water usage for field crops now should help to ensure its availability for future crops.

Lowering the cost of production while maintaining or increasing yields results in an overall net gain for the farmer. One key way of lowering the cost of production is by lowering irrigation costs. Some of the costs to consider in an irrigation program are cost of the irrigation system, power unit, pump, fuel (gasoline, diesel, natural gas) or electrical power source, pumping rate and efficiency, power unit efficiency, and pumping depth. A large amount of time and energy is expended in the extraction of irrigation water (one acre inch of water is 27,154 gallons in volume and weighs 226,500 pounds) and costs vary according to a number of variables such as type of irrigation system, irrigation efficiency, and distance the water must be transported. Implementing water conservation practices can reduce equipment operation time, and substantially lower operation costs (Devin et al., 1986).

Evaporation and runoff losses significantly reduce water use efficiency. This is primarily true with furrow irrigation. Runoff water is not absorbed by the soil or used by the plant, therefore pumping costs are not recovered through increased crop yields. Excessive irrigation leads to water loss through runoff and deep percolation beyond the root zone (Bouwer, 1988). Evaporation losses are primarily associated with sprinkler irrigation systems.

Irrigation runoff not only decreases water use efficiency, but also contributes to soil erosion and nutrient loss. Erosion contributes to soil and plant nutrient loss, sedimentation, changes in soil texture, and degradation of soil structure (Troeh et al., 1991). Research has shown that soil water loss and erosion can be reduced through the use of conservation tillage (Waddell and Weil, 1996; Hill et al., 1985).

Three conservation practices can be implemented to reduce potential water loss from rainfall and irrigation: furrow diking, terracing, and contour tillage. Furrow diking, or basin tillage, is the practice of creating small earthen dams in the furrows between the crop rows. Terraces consist of ridges and channels constructed across the slope of the field. Contour tillage involves cultivating along the natural contours of the field as opposed to cultivating up and down the hill. When terracing and contour tillage are used in conjunction, they form a very good barrier against water runoff and soil erosion (Troeh et al., 1991).

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Ill. 1. Furrow diked rows adjacent to non-furrow diked rows

FURROW DIKING

Furrow diking is the practice of trapping water from rainfall or sprinkler irrigation in order to prevent water loss through runoff. Water is trapped in small basins in the furrow and allowed to infiltrate, thereby increasing moisture storage for crop production (Ill. 1). Dikes or dams are constructed mechanically with a diking implement, which can be used in conjunction with other equipment by attaching it to the back of the primary implement. This combination of operations eliminates the need to make two trips across the field for the purpose of constructing dikes. The three main types of diking equipment are wheel-type, paddle-type, and hydraulic type (Harris and Krishna, 1989) (Ill. 2-4). While furrow diking is not a new concept, it is a very effective one, and should be considered in water shortage areas with intense storms.

Furrow diking has become a widely used technique, primarily in the semiarid High and Rolling Plains of Texas. These soils characteristically have poor structural qualities, leading to loss of water and soil from runoff even during periods of moderate amounts of rainfall (TWRI, 1984). Growers have found that furrow diking, conserves soil and critical soil moisture while boosting yields. Estimates of statewide furrow diking acreage is shown by district in Table 1.

Furrow diking can improve crop production in areas that are susceptible to drought. This is important since any part of the state may be stricken by drought at some time during the growing season. In non-irrigated areas, dikes should be present prior to expectation of significant rainfall. For the Rolling and High Plains, dikes should be installed prior to the growing season since this is when the region receives the majority of its annual rainfall. March is the optimum time for installing dikes in this area. For maximum moisture retention, growers in areas of the state that receive most of their rainfall in the late fall and early spring months should install dikes as soon after harvest as possible. Producers in South Texas should install dikes no later than August or September. In areas where excessive rainfall may delay planting, dikes should be installed after planting (Colburn and Alexander, 1986). Deeper dikes may need to be installed on finer textured soils due to the slower infiltration rates as compared to coarser soils (McFarland et al., 1991).

Diking can be used on dryland or irrigated cropland and is particularly efficient when used in conjunction with LEPA (low energy precision application) irrigation systems. Diking may also be utilized with alternate rows furrow irrigation. Three important rules to follow when constructing dikes are: (1) the basin should not be isolated from the soil bed, (2) a slightly convex bed should lead runoff to the basin, (3) and the top of the dike should be higher than the row shoulders to prevent runoff from one basin to another (Morin and Benyami, 1988). Diking will not disrupt ordinary field operations, as dikes can be plowed out and reinstalled while performing other tillage operations. It should be noted that in areas receiving adequate rainfall to grow crops, diking need not be used and can even cause yield reductions (Williams et al., 1988).

The main advantage of furrow diking is increased yields through increased stored soil moisture. Several tests have been conducted on the profitability of diking in cotton, grain sorghum, and other Texas crops.

Table 1. Appropriate number of acres where furrow diking is being used in Texas in 1998.

Geographical Area	Extension District	Number of Acres Furrow Diked
High Plains	Dist. 1 and 2	[1]1,230,000 - 1,640,000
Rolling Plains	Dist. 3	[2]50,000
Far West	Dist. 6	[3]268,000
West Central	Dist. 7	[4]115 - 120,000
Southwest	Dist. 10	[5]30,000
Coastal Bend	Dist. 11	[6]50 - 100
South	Dist. 12	[7]Less than 500

1. Dr. Leon New and Dr. Randall Boman, personal communication, 1998
2. Dr. Todd Baughmann, personal communication, 1998
3. Dr. Brian Unruh, personal communication, 1998
4. Dr. Billy Warrick, personal communication, 1998
5. Dr. Charles Stichler, personal communication, 1998
6. Dr. Steve Livingsotn, personal communication, 1998
7. Dr. Jason Johnson, personal communication, 1998

Ill 2. Hydraulic diker

Ill 3. Wheel type diker

Ill 4. Paddle wheel diker

Studies conducted throughout the state indicate that significant yield increases can be realized when diking is employed. For each additional inch of water stored in the soil, cotton lint increases 30 pounds per acre, grain sorghum yields increase 350 pounds per acre (Colburn and Alexander, 1986), and wheat yields increase by two and one-half bushels per acre (TWRI, 1984). Test results have shown from 16% to 147% increases in grain sorghum yields and 16 to 32% gains in cotton yields (Harris and Krishna, 1989). If widely practiced, it is estimated that diking would increase the total value of crop yields in the High Plains area by $87 million (TWRI, 1984).

Diking requires little additional equipment or effort. The estimated cost of furrow diking equipment is $150 to $300 per row and can be purchased or fabricated by the producer. Research has shown that the total annual cost of diking is about $1 per acre and can pay for itself in just one year with the increased yields from only 75 acres of cotton (TWRI, 1984) (Harris and Krishna, 1989). The versatility of furrow diking allows it to be used in most cropping systems throughout the state.

TERRACING

The main purpose of terracing is to prevent runoff of rainfall on sloping land, thereby limiting soil erosion and increasing water infiltration by collecting and storing runoff water (Ill. 5). Several types of terrace systems may be used depending upon the grower's situation. Some are designed specifically for the purpose of soil conservation, while others are more specialized for water conservation.

Two main types of terrace alignment systems are used in today's agriculture. Contour terraces are constructed following the natural topographical layout of the land. Construction of contour terraces minimizes the amount of soil moved, but creates odd shaped fields that result in several "point rows" that are difficult to harvest and maintain. Parallel terraces are constructed parallel to one another and operations, and may be either straight (where the topography will permit) or gently curving. One of the most attractive features of a parallel system is that it eliminates point rows, thereby increasing operation efficiency (Dickey et al., 1997).

Terraces can be further sub-divided depending upon how they are constructed. Bench terraces, which are used widely overseas on very steep slopes, are the oldest type of terraces. These stair-step type terraces are costly and are not used in commercial agriculture in the United States (Troeh et al., 1991). Graded terraces intercept runoff and any discharge is via a protected outlet or grassed waterway. Water can be diverted to a temporary storage basin or discharged off the farm. Two types of graded terraces are used in modern production agriculture. These are broadbase and narrowbase or grass ridge terraces. While graded terraces are an efficient tool for decreasing soil loss, they do not conserve water. The runoff collected by these terraces is transported to a grassed waterway or an underground outlet. Terraces that are designed to conserve runoff must trap the water in order for it to infiltrate into the soil (Troeh et al., 1991).

Ill. 5. Contour terraces

Terraces used for water conservation purposes are the level ridge-type and conservation-bench type terraces. Care should be taken not to confuse the latter with traditional bench terraces. True to its namesake, the level ridge terrace must have a level channel in order to allow water to pond and subsequently infiltrate. There are three general subdivisions of level ridge-type terraces: the ridge and channel, the steep backslope, and the flat channel terraces. (Troeh et al.,1991)

Conservation-bench terraces are constructed at the bottom of each contributing area. The bench structure has a flat front surface and a sloped back surface. Studies indicate that in years with favorable amounts of rainfall, conservation-bench terraces have nearly doubled yields while reducing erosion. However, in areas of high humidity or in wet years, yields may be reduced due to excessive ponding of surface water (Troeh et al., 1991).

While terracing has many advantages (such as improving crop yield, reducing soil loss through erosion, reducing water loss, and helping seeds, seedlings, and crops be less susceptible to runoff damage), it may not always be practical to implement given the producer's situation (Troeh et al., 1991). For instance, terraces cannot be used on extremely sandy, stony, or shallow soils with an impermeable subsoil. Any type of terrace will, to some degree, obstruct field operations, and take some land out of production (Wheaton and Monke, 1997). On slopes of greater than 8 to 12%, terracing becomes too costly for mechanized agriculture (Troeh et al., 1991). Some of the other major advantages and disadvantages associated with each type of terrace are listed below.

Terrace Layout

Contour terracing
The main advantage of a contour terrace layout structure is that it is cost effective to construct and is more practical where multiple slope variation exists. However, contour terraces may be more costly over time due to limitations in farmability due to odd shaped fields and point rows (Dickey et al., 1997).

Parallel terracing
Parallel terracing allows the farmer to conduct field operations parallel to the terrace borders. They eliminate point rows and improve the overall ease of farming (Wheaton and Monke, 1997). The main drawback to this type of system is the high cost associated with the construction of parallel terraces (Dickey et al., 1997). Because of the extra cutting and filling associated with construction, parallel terraces should only be constructed where soils have deep root zones (Troeh et al., 1991).

Terrace Structure

Graded terraces
Graded terraces smooth the overall field and also increase land slope, but channels may reduce plant population and crop yield if the channel stays wet. Graded terraces should not be used where water conservation is the main objective (Troeh et al., 1991).

Level terraces
The main advantage for this type of structure is water conservation potential. Level terraces have no outlet so water must infiltrate. They work well in arid or semi-arid regions, and are most practical in areas where the slopes are less than 4%. Level terraces may also contribute to groundwater recharge. They do require additional maintenance and are more expensive than certain other types to construct (Dickey et al., 1997).

Steep backslope terraces
Steep backslope terraces reduce the gradient between terraces, and are relatively easy to farm. With this type of structure, soil is pushed up from the backside of the terrace, thus forming the steep backslope. They can also be used on land too steep to farm with broad-based terraces. The steep backslopes do decrease the amount of tillable surface area, thereby reducing production acreage. These steep slopes may also contribute to field accidents, increased insect populations, and habitat for rodents (Troeh et al., 1991).

Conservation-bench terraces
Conservation-bench terraces are well adapted to high value forage crops and also improves the reliability of grain production. Grain sorghum works particularly well because of its ability to withstand drought and flooding. Bench terraces require a deep fertile soil with a large available water holding capacity. High value crops should be grown on the bench and the terrace ridge should be planted to grass cover. Good leveling precision is required to distribute water uniformly over the bench. Outlets should be installed to prevent damage from heavy rainfall. Conservation-bench terraces work well when designed to follow the contour, but are sometimes adapted to a parallel layout (Hauser and Jones, 1988).

When to Terrace

When determining the need for a terracing system on the farm, a producer should ask a few key questions. Will a terrace system work on the farm? What additional labor and capital are required? What will be the benefits both economically and environmentally?

Terracing will not work on extremely sandy soils or soils with shallow topsoil. They are best suited to long, uniform slopes that are not too steep. To determine proper spacing, a field surveyor's services may be required. With contour terraces large farm equipment may become impractical to use, due to the small, oddly shaped fields. The operator may decide to build the terraces with present equipment or hire a contractor. Regardless of who installs the terraces, all topsoil should be removed prior to construction and replaced evenly over the field after completion, even though this does increase construction costs. Terraces are not economically feasible over short time frames. If improved yields through proper water and land management is the producer's goal, then terracing should be economically and environmentally desirable (Powell and Kok, 1994).

Effective terrace systems must be maintained. One of the main concerns is the avoidance of overtopping, which can occur during periods of heavy rainfall. Overtopping occurs when excessive amounts of rainfall overflow the terrace. Excessive sedimentation, erosion, farm machinery, animals, or land settling degrade terrace systems. Terraced fields require a regular maintenance schedule. Maintenance intervals will vary according to terrace type, soil texture, rainfall amounts, steepness of the slope, and intensity of tillage operations. Terraces should be checked at least annually, although sandier soils or steep fields should be checked on a more frequent basis. Height of terraces is a good benchmark for determining needed maintenance. Graded terraces should have a minimum height of 12 inches, while level terraces should have a minimum height of 18 inches. Narrow or low terrace ridges can be reinforced or built up with farm machinery by moving additional soil to the ridge through plowing or other tillage to raise and widen the terrace ridge. Buildup of sediment can lead to excessive amounts of water being held for too long in the terrace channel. Plowing out the channel works well in these situations and is recommended on steeper slopes to maintain adequate channel capacity. In level terraces, the terrace bottom must be level to ensure even distribution of water. (Powell and Kok, 1994).

Farm machinery such as a blade, scraper, front-end loader, moldboard plow, or disk can be used to manage terraces (Wheaton and Monke, 1997). Care should be taken to maintain terrace outlets and grassed waterways. The adoption of contour farming operations can reduce the need for maintenance by up to 50%. Other practices which aid in maintenance are residue management, conservation tillage, and crop rotation. The goal of terrace maintenance is to move soil from the channel to the ridge, thereby improving the overall structure of the terrace (Powell and Kok, 1994).

CONTOUR CULTIVATION

In contour cultivation, the row orientation follows the contour of the slope. Contour farming is an effective tool in combating erosion. With row crops, surface water movement is slowed to non-erosive velocities by the row ridges. Each ridge acts as a mini-terrace, allowing small to moderate amounts of water to infiltrate instead of running off.

Contour tillage should be practiced on gently sloping land where water conservation is a major concern. If attempted on too steep or too long of a slope, contouring may actually contribute to gully erosion if excessive rainfall overtops the row ridges. A guideline for slope length in relation to land slope is presented in Table 1 (Troeh et al., 1991).

Contour cultivtion is designed to catch light to moderate amounts of rainfall. It works well when combined with other conservation strategies such as furrow diking. Furrow dikes improve the storage capacity for each furrow, further reducing erosion and subsequently

Ill. 6. Contour cultivation with level terraces

water and soil loss. When these two practices are initiated along with level terracing, they create an excellent system for saving water and fighting erosion. Combining contouring with strip or no till systems can also be very effective for the farmer to reduce erosion (Felsot et al., 1990).

Contour cultivation significantly reduces soil loss from erosion compared to farming up and down the slope. Contoured fields withstand higher rainfall amounts than fields plowed up and down the slope before runoff occurs (McIsaac et al., 1991). The result is more efficient rainfall management and higher plant available soil moisture. Contouring also promotes soil productivity due to organic matter and fertilizer retention and crop yields should increase. It also improves plant stands by reducing the number of seeds that may be lost to sedimentation and erosion (Troeh et al., 1991). Contour cultivation also can reduce pesticide losses from the field by reducing runoff.

Table 2. Contour cultivation land slope and slope length guidelines.

Land slope (%)	Maximum slope length (ft)
1 - 2	400
3 - 5	300
6 - 8	200
9 - 12	120
13 -1 6	80
17 - 20	60
21 - 25	50

The main objective of contour cultivation is to increase yields through conservation of precious soil water. Contour ridges increase soil water retention, vastly improves the amount of levels of plant available water and increases crop yields by as much as 29% (Troeh, et al., 1991). Contour strip rainfall harvesting has also been shown to increase rooting depth and soil water storage. This is due to an increase in water harvesting as compared to methods where no water conservation tactic is used (Zaongo et al., 1988).

Contour cultivation is inexpensive to implement, costing the grower little more than a few extra hours of operating time. Rainfall that is used efficiently is water that does not have to be supplied through irrigation and helps conserve the water of underground aquifers.

While the benefits of contour tillage are numerous, it may have drawbacks. It causes some inconvenience due to point rows and may take more time. Overtopping can also be problem. Contour farming does not work well on the lower parts of long slopes. Field borders have to be redefined to follow the contour.

SUMMARY

The benefits of a good water conservation program are multi-fold. Water conservation and soil conservation often go hand in hand. By decreasing water loss from the landscape, soil sedimentation is reduced, soil moisture is increased, less soil nutrients are lost, and the physical structure of the soil is maintained. The positive economic impact results from improved yields and less irrigation.

Each of the aforementioned techniques is a form of water harvesting. Water harvesting is simply saving rainfall or irrigation by preventing runoff. Combining these operations with other practices such as cover cropping, conservation tillage, and residue management helps improve water retention and soil moisture storage conditions. Water conservation is not only important from an economic standpoint, but with the growing shortage of water in Texas, it is a major environmental concern. Although it may require some extra effort and time, a good water conservation program is needed to maintain our agricultural and water resources throughout the state.

REFERENCES CITED

Bouwer, H. 1988. Water conservation for drought management. Water use data for water resources management. Proc. Amer. Water Res. Assoc., Bethesda, MD. pp 499-505.

Colburn, A.E., and U.U. Alexander. 1986. Furrow diking in Texas. TAES, B-1539. 7 p.

Devin, R.L., S.K. Johnson, J.M. Sweeten, W.E. Knoop, E.A. Colburn, J. Henggler, and T.G. Welch. 1986. Texas Water Commission. TAEX, CONS-5. 57p.

Dickey, E.T., T. Hamer, D. Hay, and P. Jasa. 1997. Terrace systems for Nebraska. Coop. Ext, C-5. Inst. Agric. Nat. Res., Lincoln, NE. 7 p.

Felsot, A.S., J.K. Mitchell, and A.L. Kenimer. 1990. Assessment of management practices for reducing pesticide runoff from sloping cropland in Illinois. J. Environ. Qual., 19:539-545.

Gerard, C.J., D.G. Bordovsky, and L.E. Clark. 1980. Water management studies in the Rolling Plains. TAES, B-1321. 19 p.

Harris, B.L., and J.H. Krishna. 1989. Furrow diking to conserve moisture. J. of Soil Water Cons. 44: 271-273.

Hauser, V.L., and O.R. Jones. 1988. Management of surface runoff for crop production: Challenges in dryland agriculture. Proc. Int. Conf. Dryland Agric., Amarillo/ Bushland, TX, August, 1988, pp. 261-263.

Hill, R.L., R. Horton, and R.M. Cruse. 1985. Tillage effects on soil water retention and pore size distribution of two mollisols. Soil Sci. Soc. Am. J. 49:1264-1270.

McFarland, M.L., F.M. Hons, and V.A. Saladino. 1991. Effects of furrow diking on corn grain yield and nitrogen accumulation. Agron. J. 83:382-386.

McIsaac, G.F., J.K. Mitchell, M.C. Hirschi, and L.K. Ewing. 1991. Conservation and contour tillage for corn in the Tama Silt Loam Soil: The hydrologic response. Soil Till. Res., 19:29-46.

Morin, Joseph , and Y. Benyam. 1988. Tillage selection based on runoff modeling: Challenges in dryland agriculture. Proc. Int. Conf. Dryland Agric. Amarillo/ Bushland, TX August, 1988, pp. 251-254.

Powell, G.M., and H. Kok. 1994. Maintaining terraces. Coop. Ext. Serv., C-709, Kansas State University, Manhattan, KS.

Troeh, F.R., J.A. Hobbs, and R.L. Donahue. 1991. Soil and Water Conservation. Prentice Hall, Englewood Cliffs, NJ. pp. 127-129, 235-239, 247-255, 349-351.

[TWDB] Texas Water Development Board. 1988. Conserving water in irrigated agriculture. Austin, TX. 16 p.

[TWRI] Texas Water Resources Institute. 1984. Storing soil moisture. Water Currents. 3: (3). College Station, TX. 8 p.

Waddell, J.T. and R.R. Weil. 1996. Water distribution in soil under ridge-till and no-till corn. Soil Sci. Soc. Am. J. 60: 230-237.

Wheaton, R.Z., and E.J. Monke. 1997. Terracing as a "best management practice" for controlling erosion and protecting water quality. Coop. Ext. Serv. AE-114, Purdue University, West Lafayette, IN.

Williams, J.R., G.L. Wistrand, V.W. Benson, and J.H. Krishna. 1988. A model for simulating furrow dike management and use: Challenges in dryland agric., Proc. Int. Conf. Dryland Agric., Amarillo/ Bushland, TX, August, 1988. pp.255-257.

Zaongo, C.G., C.W. Wendt, and L.R. Hossner. 1988. Contour strip rainfall harvesting for cereal grains production in the Sahel: Challenges in dryland agric., Proc. Int. Conf. Dryland Agric., Amarillo/ Bushland, TX, August, 1988. pp.242-244.

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