MANAGING COTTON WHEN WATER IS LIMITED

J. C. Henggeler
Commercial Agricultural Program
University of Missouri
Portageville, MO
W. L. Multer and B. L. Unruh
Texas Agricultural Extension Service
Texas A&M University
Ft. Stockton, TX

Abstract

Information from fifteen years of on-farm research done in a semi-arid area of Texas with limited ground water resources was used to make irrigation recommendations for growing cotton when water is limited. The data supports the concept of large pre-irrigation amounts and skip row farming (when water is very limited). Care must be taken in using yield versus water studies as the stepping point to making farm decisions. The data from such tests must be put into farm budgets based on actual conditions of the farm to see where the most profitable position regarding patterns used and amount of land farmed actually lies.

Introduction

This publication is a concept paper for managing cotton production when water resources are limited. Regional guidelines involving irrigation management strategies when farming cotton with limited water resources (the combination of both rainfall and pumping water supplies), are being developed for the St. Lawrence, TX region based on evaluating a decade and a half of on-farm irrigation studies carried out by the Texas Agricultural Extension Service (Extension). The St. Lawrence area, comprised of Glasscock, Reagan, and Upton Counties in Texas, consists of approximately 150,000 acres of tillable farmland. The average rainfall in this area is about 15 inches per year. The underlying aquifer is rechargeable, but at an inadequate rate, therefore, much of the water demand required for the 100,000 plus acres of cotton is not met. After WW II when the area was first farmed, 6- and 8-inch wells were common. Currently, the average discharge for wells is 30 gallons per minute (gpm). Pumping depth is 250-450 feet. Some farms have well flow rates that are actually less than a single furrow stream flow rates on their farm. Wells are net-worked together to optimize management. On a unit land basis, the underground water resource is approximately 1.5 gpm/acre, or, on a per-day basis, 0.08 inches per day (ipd). Peak consumptive use of cotton is 0.35 ipd, almost five times greater than the gross amount of underground water available to farmers. It is obvious under these conditions that soil moisture storage is of great importance. The typical soil is a silty clay loam underlain by a caliche soil at two to four feet depth. Normally six to eight inches of available moisture can be stored in the soils.

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Many cotton farmers have used skip row patterns as a way to deal with the water-short conditions of west Texas. Two-and-one, four-and-one, and eight-and-one are common skip patterns under irrigation. When dryland farming is attempted, wider patterns may be used such as one-and-one or two-and-two. Farmers cannot generally farm every-row under dryland; it is especially difficult to do so for more than one year running since the soil moisture profile becomes too depleted. Many different patterns have been tried by farmers that incorporate other row widths, packed/unpacked rows, etc. One method that has been accepted by many is to bring in the water furrow row pair, which in turn widens out the row width of the blank rows. This is done to provide shade for the water furrow.

Farmers generally apply a pre-plant irrigation and approximately 1 ½ summer waterings. Water is applied by every-other furrow. The estimated amount applied each year is about 6 to 8 inches. There is little center pivot irrigation in the area. Several LEPA systems have been tried with varying degrees of success. Sub-surface drip irrigation (SDI) has done excellent in some cases, while just average or poor in others. When it is done properly, it appears to be an excellent method of irrigation. Henggeler (1997) looked at historic ASCS records back 16 years on a single farm that had converted to SDI and concluded that net returns to all SDI costs were around 450%. Approximately 5% of the irrigated cotton land is now under SDI, and perhaps 20% of the farmers have experimented with it. Water conservation measures abound in the region, making St. Lawrence a state leader in *water use efficiency*. There is a near total use of either furrow dikers or contour rows (and in many cases, both); there are probably more surge flow valves on a per acre basis then any other place in the world; the row lengths are very short (approximately 700 feet); there is no dirt, or even concrete ditch, all water being delivered with underground pipe; as soon as it is possible to enter a field after a rain or an irrigation, farmers light sweep-cultivate the field to throw up a protective dry mulch to decrease the soil evaporation rate.

The amount of irrigated cotton planted annually in the last twenty years varies for a number of reasons, a principal one being restrictions based on government programs. Another factor in the mid- 1980s was the liquidation of stock in a denim mill that many local farmers were associated with; this infusion of capital spurred the purchase of local range land, which was cleared, installed with deep wells, and farmed. Since the aquifer has only a finite amount of water available each year, the actual amount of land farmed per year has a bearing on how much pumped water will be applied per acre that season. Figure 1 shows the harvested irrigated and dryland acres for the St. Lawrence region from 1980 to 1995. Figure 2 shows the average ASCS (now called Farm Service Agency) yield for irrigated and dryland for the same period, as well as, the gross useable rainfall (rain received from October to December the preceding year plus that received January to August the current year). Figure 3 shows *rainfall use efficiency* (RUE), the amount of lint produced per acre for each inch of gross useable rainfall. This figure indicates that RUE increases as more land is farmed, which is equivalent to saying that RUE increases as the water resource is stretched.

The Crux of the Problem

When water resources are short, two divergent strategies are possible. The first is to plant the full land resource and anticipate that the yield level will be less then maximum. The second is to plant only portions of the land resource, such that the unit land yield levels increase due to being able to allocate higher amounts of irrigation water; should sufficient land area be left out, yields become totally non-water-limited. Within this last scenario is a second level of options exist. The out-land can be either (1) complete non-farmed blocks, or (2) skip-rows, or (3) a combination of both. Figure 4 shows the decision tree for the cotton farmer with deficit water resources, including benefits and liabilities for various strategies.

It is very difficult to decide which strategy is the economic optimum one. Also it is very likely that the best scenario for one year may not be the best the next year. For example, if there is more than normal in-season rainfall, planting "fence row to fence row" would probably be the best strategy; in a drought year a skip-row may be the best. However, based on the land-water ratio resource possessed by the cotton farmer and long-term weather averages, there is a "best" farmed acreage level for him to be at. Determining what this should be involves the factors of: the farm's land/irrigation water ratio, the region's Heat Units and rainfall, and his economic situation (especially fixed costs). In the past research showing yield versus water data (sometimes accompanied with economic analysis) has "muddied the water", since the "per acre" basis rarely translates into a "per farm" basis when a limited resource is scenario exists.

On-Farm Water Use Studies Conducted

Since the early 1980s local cotton water studies have been conducted under the supervision of local county Extension personnel and agricultural engineering and agronomy specialists from the Extension service on various cotton producers' farms in the St. Lawrence area. The studies completed to date include:

STUDY	FOCUS OF STUDY	LENGTH (Years)
A	Water Amount-Yield Function Study	5
B	Drip-Irrigated Water -x- Nitrogen Study	3
C	Pre-Irrigation Amount Study	2
D	Irrigation Timing Study	2
E	Row pattern (40-inch rows) -x- Water Study	4

Currently a comprehensive study of Row Pattern (40-, 30-, 15-inch rows) -x- Water Amount is underway. Data from the 1997 year have been collected, but will not be discussed in-depth in this paper, other than to illustrate the concept that results on a "per acre" basis can be wildly divergent from the results when taken to the "total farm" level.

A yield function for two-and-one, skip-row cotton versus water is seen in Figure 5; this was developed from Study A. The yield is in terms of the planted acre. The corresponding *irrigation use efficiency* (IUE) curve (not shown) indicated that IUE always exceeded 100 lbs/acre-inch of water, but that at levels less then 5 inches (five inches of water is based on the planted-acre; the land-acre amount was 3 1/3 inch) several hundred lbs of lint per pumped acre-inch were possible. Results of this study indicated:

> √ *the total amount of irrigation is the most significant aspect basically, it does not matter whether it is applied as pre-plant, first summer irrigation, or second summer irrigation, although there was some trend showing that, the amount being equal, two summers was better than a single summer irrigation.*

Study B was used to develop a yield function based on both water and nitrogen. The results on the nitrogen aspect (rates from 50 to 200 lbs/Acre) were inconsistent over the three years of the study. However, the water aspect of this study (0.5 to 6.0 gpm/Acre) showed itself to be highly correlated to final yield. One item of interest in the study was:

> √ *even smallest water amount (only about 1 ½ inches during the season could be applied) had the potential to produce 500 or 600 lbs of cotton year-in-and-year if the off-season is used to judiciously store up pre-irrigation.*

Study C on pre-irrigation illustrated how important it was to fill up the root-zone with pre-season water when supplies are short. Increased pre-irrigation amounts almost always increased yield. The timing study (Study D) indicated that timing of the one or two summer irrigations did have an impact, but that as a practical matter a farmer could not manage to "hit" the entire planted acreage at the critical times. Stagger-planting to allow this to happen, was found to be self-defeating in that the timing benefit was loss to reduced yield due to shortened seasons.

The row pattern study (Study E) looked at various row patterns and summer irrigation levels of 0 to 3 summer waterings. All blocks were pre-watered. The study was done on 40-inch centers. Economic analysis was done to include the added cost for skip rows due to sprayed blank row. This study indicated several items:

√ *on average 2-and-1 skip-row cotton made 90% the lint of every-row on a land acre basis, but with 2/3rds the irrigation. The result was that skip-row was generally more profitable.*

As a continuation of this last effort, a more rigorous study was designed that incorporates four water levels and eleven different row spacings/patterns (Every-row, two-and-one, one-and-one, four-and-one, eight-and-one [all of these for both 30- and 40-inch centers], and UNR). The results will be that eleven separate yield versus water functions will be developed that can be incorporated into a cotton production budgets with three dimensions: z) over-all farm profit, y) farmable acres on that farm, and x) irrigation water resource available on that farm. Figure 6 shows some of the tentative yield results. However, as stated before, such data is only the first step; it must be "plugged in" to crop budgets and examined. Using a the agronomic data from Fig. 6 and assuming a farm of 1,000 acres and a water resource of 1,000 GPM on the farm Figure 7 was constructed. This represents the net return to the entire farm based on four separate row patterns (Every, 4-and-1, 2-and-1, and 1-and-1) when different numbers of acres are farmed. The yield study (Fig. 6) would indicate that the irrigation system used should have 4.0 GPM/Acre capacity (meaning only 250 acres would be farmed); it also would seem to indicate that Every row should be used. The economic analysis (Fig. 7) indicates almost opposite: stretching the water resource out to only 1.0 GPM/Acre is used but all 1,000 acres could be famed is more profitable. Also, Every row is the least profitable of all patterns.

References

Henggeler, J. 1997. Irrigation economics of drip-irrigated cotton under deficit irrigation. Proceedings Irrigation Association Technical Conference. 125-132.

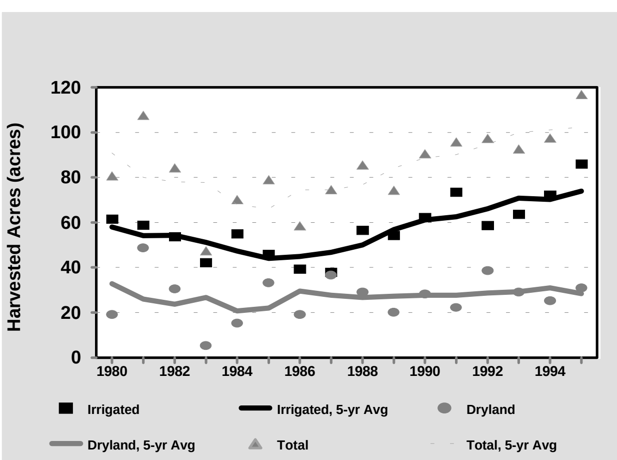

Figure 1. Irrigated, dryland & total cotton acreage for Glasscock, Reagan, and Upton Counties, TX; 5-year running average lines indicated.

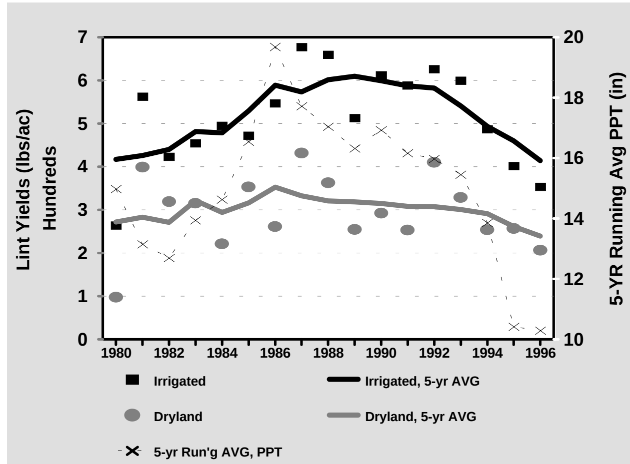

Figure 2. RUE for irrigated and dryland cotton and average rainfall amount for Glasscock, Reagan, and Upton Counties, TX; 5-year running average lines included.

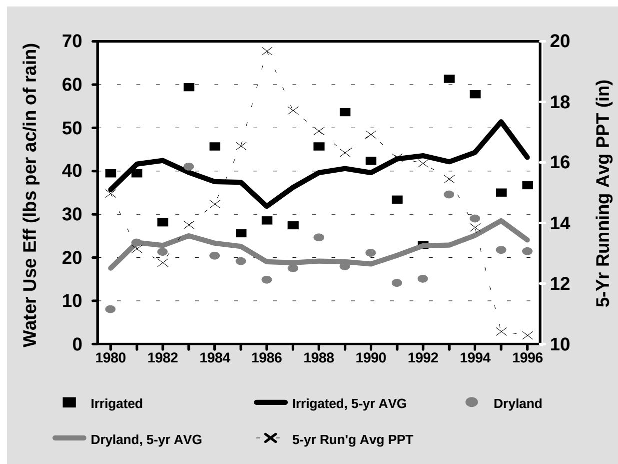

Figure 3. RUE for irrigated and dryland cotton and average rainfall amount for Glasscock, Reagan, and Upton Counties, TX; 5-year running average lines included.

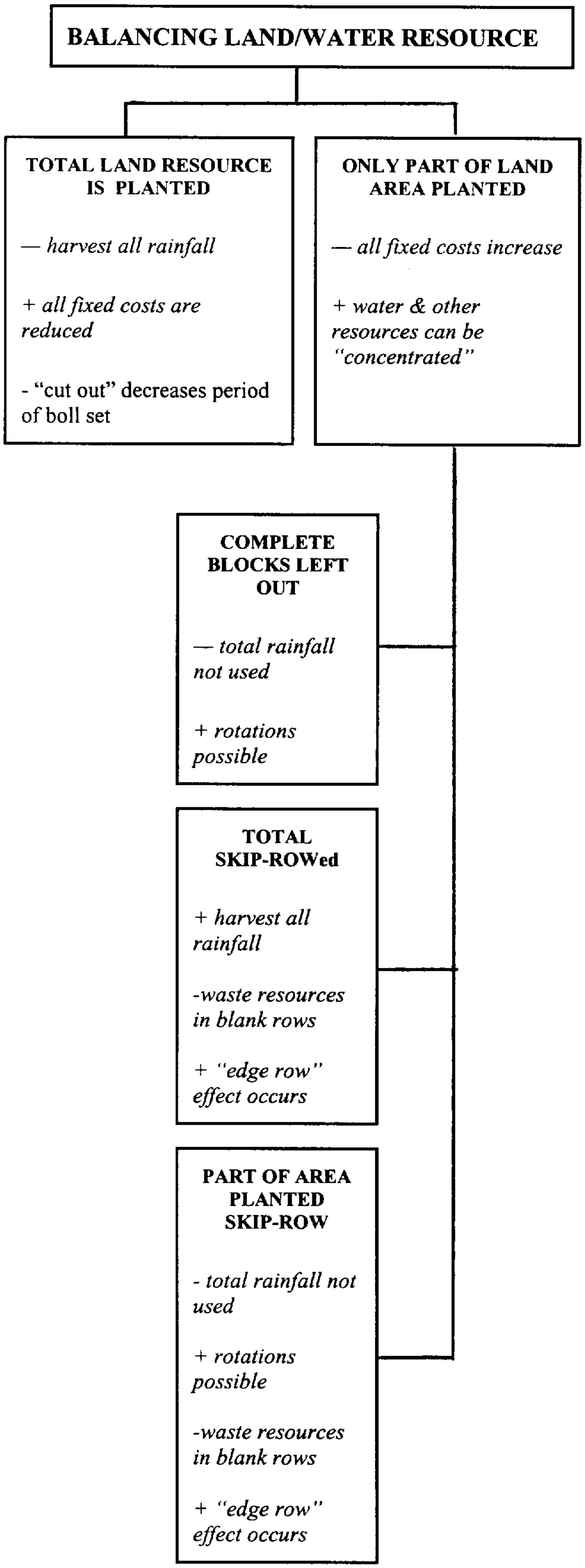

Figure. 4. Diagram of possible land/water management strategies and their benefits (+) and liabilities (-). Government program considerations not involved.

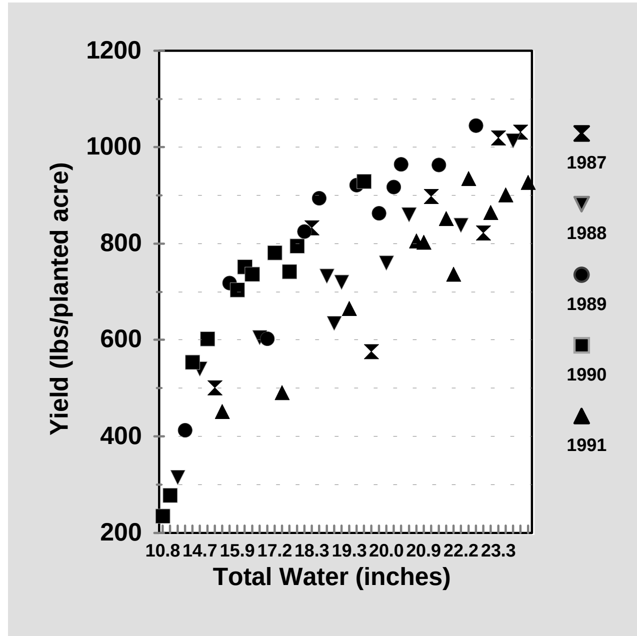

Figure 5. Yield response curve to skip-row cotton from all water sources.

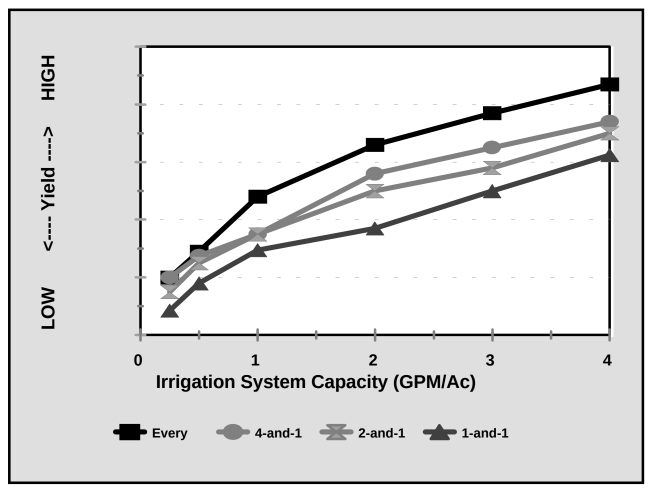

Figure 6. Yield response based on four patterns and irrigation system capacities.

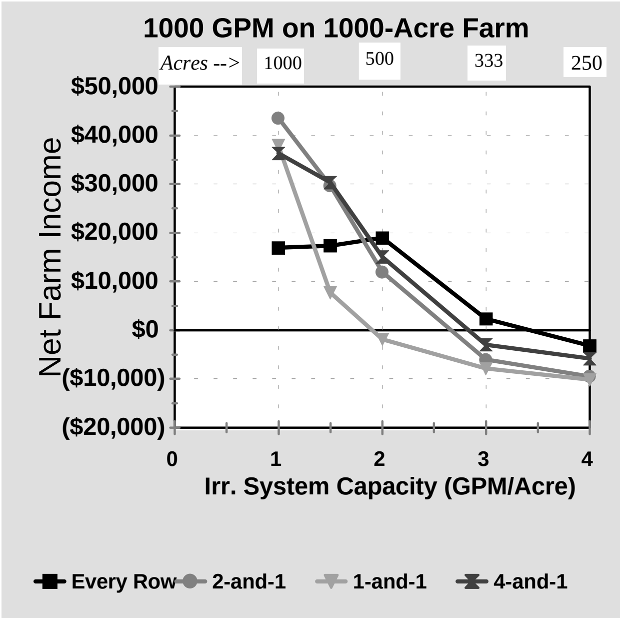

Figure 7. Net returns to a 1,000-acre farm with 1,000 GPM of water based on the agronomic data of Fig. 6.