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OPTIMUM DESIGN CAPACITIES FOR SUBSURFACE DRIP IRRIGATED COTTON

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Abstract

A common practice in areas with limited water supplies is to irrigate more uniformly and to spread a small amount of water over bigger areas. The main dilemma under these water-limited conditions is to decide between two irrigation strategies. The first is to design for a smaller flow rate and irrigate more land resource, or the second is to reduce the irrigated area and apply the flow rate that is closer to the higher potential yield. The objectives of the study were 1. To determine the optimum design capacity for cotton irrigated with a subsurface irrigation system in the Saint Lawrence area of Texas. 2. Determine the effect of different row spacing and patterns on the optimum capacity. Crop production functions for different cotton row spacings (ultranarrow, 30, and 40 in) and two planting row patterns (1 planted and 1 skipped, and 2 planted and 1 skipped) were obtained from literature and then used to conduct an economic analysis to obtain the optimum water allocations for West Texas. The crop production function obtained for this study showed a linear yield response as water allocations increased. When fixed and variable costs were included in the net return function, returns above breakeven were achieved when seasonal water allocations greater than 1.9 GPM/ac or with 23.3 inches per acre per season (including rainfall, preseason irrigation and in-season irrigation) was considered. The ultranarrow (UNR) produced the highest net returns followed by the 30 and 40 in row spacings respectively.

Introduction

West Texas agricultural production depends on limited groundwater supplies and on erratic and limited rainfall. Agricultural competitiveness depends on management and optimization of the water allocated to the crop. To become more profitable farmers have adopted irrigation systems such as subsurface drip irrigation (SDI) that allow them to irrigate more uniformly and to spread a small amount of water over bigger areas. In the Southwest part of Texas water capacities of 1.3 GPM/acre are common. Some agricultural producers try to stretch this amount of water by using different practices, but the dilemma of which capacity to use per unit area have not been defined. There are two divergent design strategies. The first is to design for a smaller flow rate and irrigate more land resource. The second is to reduce the irrigated area and apply the flow rate that is closer to the higher potential yield. By allocating more water in less area, yields become totally non-water limited. Some researchers affirm that the optimal strategy is to design the system to supply an irrigation depth close to the depth required to produce maximum yield regardless of the efficiency of the system. (Barret and Skorgoboe, 1980). Other recommend to determine the breakeven point between irrigation and dryland be obtained first, then design the system so it can apply a depth greater that the breakeven depth if dryland is unprofitable. If dryland is profitable the system should applied a uniform depth over the entire field (Stewart and Hagan, 1973). In the semi-arid areas it is difficult to determine if dryland is profitable because rainfall is highly variable from one year to the other. Another complexity to the problem is the inclusion of different agronomic practices such as the use of different row patterns and spacing. Choosing the right capacity and the right agronomic practice is crucial to optimize the entire farm operation when water is limited. Several studies like the ones of Yaron and Bresler (1983), Barret and Skorgoboe (1980) and Martin et al (1982) have proposed general methodologies to optimize the irrigation depth for different crops. These authors have developed the net return function first and then they determined the optimum irrigation depth either for water or land limiting conditions. A common problem in doing that is to determine precisely the fixed and variable cost from one farm to the other, which may vary year after year. When the farmer faces the decision to install a SDI system, he needs to know a priori how much water he need to allocate per unit area a priori. Then during management he needs to do re-adjust the water allocation per unit area depending on the price of his commodities like cotton and water. He also needs to know how much area he needs to farm for breakeven and when he is loosing money.

Objectives

The objectives of this study were 1. To determine the optimum design capacity for cotton irrigated with a subsurface irrigation system in the Saint Lawrence area of Texas. 2. Determine the effect of different row spacing and patterns on the optimum capacity.

Materials and Methods

The study consisted on simulating different cost and net returns as water allocations varied. To conduct the economic simulation some crop production functions that described the yield response to different water allocations under selected agronomic practices were obtained from a previous study for the St. Lawrence areas of Texas (Enciso et. al. 2002). These production functions reflected three years of study and they were determined for three row spacings (30 in, 40 in, and UNR; in which cotton rows were spaced every 15 in), and two planting-row-patterns for the 40 in row-spacing (1-and-1, and 2-and-1), see Fig 1 and 2 respectively. The crop production functions were used to calculate the yield response to water on a spreadsheet and these water levels were associated to its variable and fixed costs as shown in Tables 1 and 2 for the 40-in row spacing. For this simulation, a limited land resource of 300 acres with a water allocation of 1.3 GPM was considered representative of the area. Farmers in this area generally multiply their water resource by starting irrigation earlier. For example if they have a seasonal allocation of 1.3 GPM per acre, they can multiply it to 2.6 GPM per acre by starting to irrigate on February. Farmers generally start irrigating after they plant (generally in May) and stop irrigating on September. Due to the extreme water limited conditions of the area they are forced to irrigate continuously. They never stop pumping water unless a big rainfall is received (more than 4 in), which is a rare event. The crop productions functions used in this study considered pre-irrigation. The fixed cost of the machinery was annualized by considering the useful life of the equipment shown in Table 3.

Results

The crop production function selected for this study showed a linear yield response as water allocations increased (Fig. 1.). In this figure it can be observed that lint yield increased with narrower spacings. Higher yields were observed with UNR spacing followed by 30 and 40-inch row spacings respectively. When the net return function was generated just considering the variable cost, all the options appear profitable (See Fig. 3). However, when fixed and variable costs were included in the net return function, returns above breakeven were achieved when seasonal water allocations greater than 1.9 GPM/ac or with 23.3 inches per acre per season (including rainfall, pre-season irrigation, and in-season irrigation) was considered. The UNR produced the highest net returns followed by the 30 and 40 in row spacings respectively. (See Fig. 4). The crop production functions for the 2-and-1 and 1-and-1 planting patterns did not consider the whole range of water allocations, and they cannot be used to extrapolate to higher water allocations. Figure 4 shows that for lower allocations the 40 inch 2-and-1 pattern produced higher return than the other options due to lower input costs, and installation cost of the drip tape. Fig 4 also show higher net returns for the UNR and 30 in row spacing due to higher water use efficiencies.

Conclusions

A water allocation above 1.9 GPM per acre was necessary to produce cotton above breakeven with subsurface drip irrigation in the Saint Lawrence area of Texas. This water allocation is equivalent to applying 23.3 in of water (this includes rainfall, pre-season irrigation, and in-season irrigation). To generate a complete water optimization it is necessary to obtain more points especially at the wet part of the crop production function.

Acknowledgements

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Literature Review

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Table 1. Irrigated cotton production budget for the 30 inches row Spacing.

% of area		100	75.0	60.0	50.0	33.3
Area (ac)		300	225.0	180.0	150.0	100.0
Seed	47.01	14102	10576	8461	7051	4701
Fertilizer ($/in)		7828	6536	5762	5245	4384
Pre-Harvest Chemicals	33.07	9921	7441	5953	4961	3307
Crop Insurance	18.00	5400	4050	3240	2700	1800
Fuel	7.37	2211	1658	1327	1106	737
Interest on Operating Cap.	6%	2026	1696	1498	1367	1147
Repairs	4.70	1410	1058	846	705	470
Labor	19.13	5739	4304	3443	2869	1913
Ginning Expense		10531	10854	11048	11177	11392
Harvest costs(labor, fuel, chemical)	22.00	6600	4950	3960	3300	2200
Irrigation Costs ($)	$7.97(ac-in)	20916	20916	20916	20916	20916
TOTAL VARIABLE($/ac)	151.34	86684	74040	66454	61396	52967
Total Variable cost per irrigated acre		289	329	369	409	530
Interest cost per irrigated acre		6.75	7.54	8.3	9.11	11.47
Fert cost per irrigated Acre		26.10	29.05	32.01	34.97	43.84
Ginning cost per irrigated acre		35.10	48.24	61.38	74.51	113.92

Table 2. Fixed cost for the 30 in row spacing.

Irrigated Area	300.0	225.0	150.0	100.0	90.0
Annual Depreciation on Machinery ($)	4768	4768	4768	4768	4768
Annual Depreciation on Fixed Irrig. Eq. ($15000)	1050	1050	1050	1050	1050
SDI Pipe, Tape, Manifold, etc (575/ac)	230012	172509	115006	76670	69003
Depreciation on SDI (10yr life, SV=0)	23001	17250	11500	7667	6900
Fixed cost Irrigated Land ($)$50/ac	15000	11250	7500	5000	4500
Fixed cost dryland ($) $15/ac	0.00	1125	2250	3000	3150
TOTAL FIXED COST $/300ac)	43819	35444	27069	21485	20369
TOTAL FIXED COST ($/ac)	146.06	118.15	90.23	71.62	67.90

Table 3. Equipment inventories assuming that the total area farmed is 1500 acres.

Equipment	**Purchase Price**	**Salvage Value**	**Annual cost**	**Useful life (years)**	**% used in this crop**	**midlife value**	**Machinery operation**	**Repair cost**	**Machinery depreciation.**
Harvest	100,000	40,000	5,000	7	100%	70000	46.67	3.33	5.71
Pickups	47,000	10,000	2,000	5	76%	28500	14.44	1.01	3.75
180 hp tractor	87,000	40,000	2,750	10	75%	63500	31.75	1.38	2.35
150 hp tractor	67,800	35,000	1,769	10	75%	51400	25.70	0.88	1.64
Shredder	5,500	0	500	7	100%	2750	1.83	0.33	0.52
Chisel	5,000	500	250	10	50%	2750	0.92	0.08	0.15
planter	7,920	3,000	500	7	50%	5460	1.82	0.17	0.23
Row cultivator	7,500	1,500	250	7	50%	4500	1.50	0.08	0.29
3pt sprayer	650	0	100	7	50%	325	0.11	0.03	0.03
module builder	8,000	2,500	400	7	100%	5250	3.50	0.27	0.52
8 row lister	13,000	6,500	250	10	75%	9750	4.88	0.13	0.33
boll buggy	10,000	4,500	500	10	100%	7250	4.83	0.33	0.37
						251435	137.9	4.70	15.89

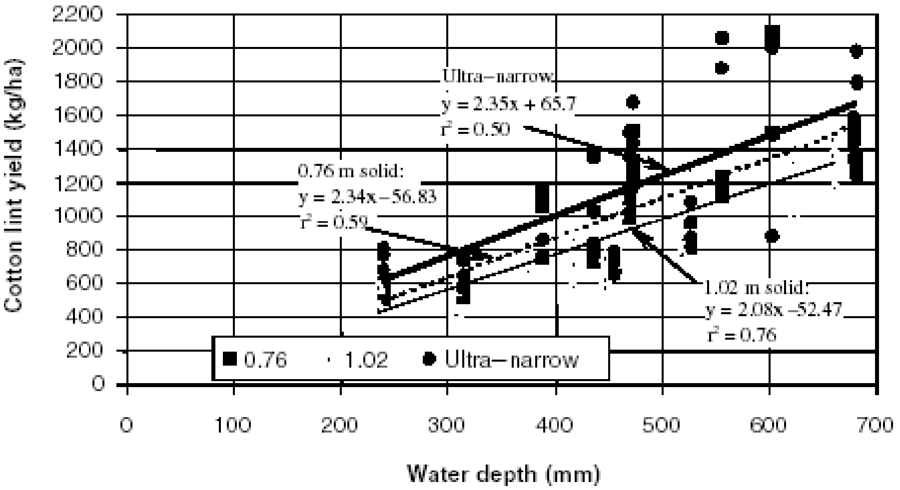

Figure 1. Relation between average cotton lint yields and total water applied for UNR, 30 in, and 40 in row spacing in 1997-1999.

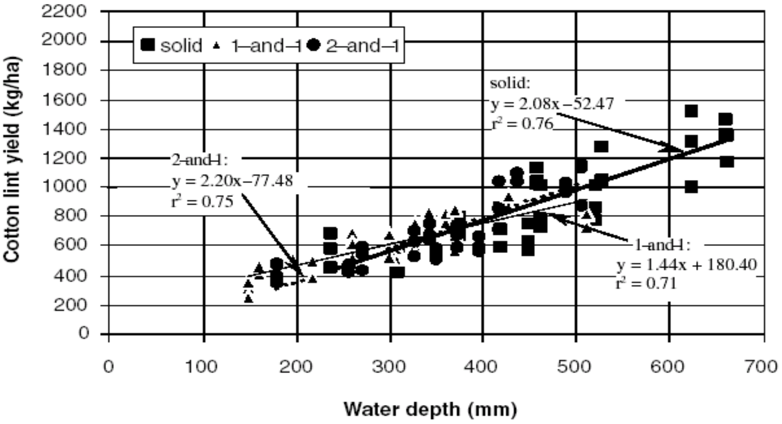

Figure 2. Relation between average cotton lint yield and total water applied for different planting patterns for the 40-in row spacing in 1997-1999.

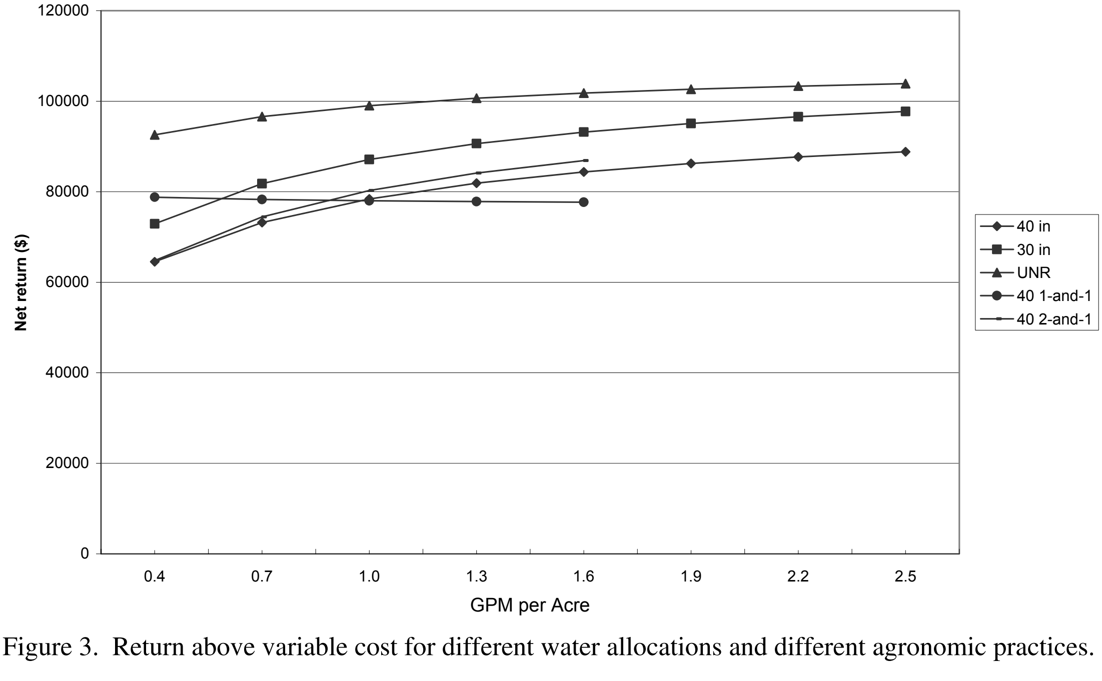

Figure 3. Return above variable cost for different water allocations and different agronomic practices.

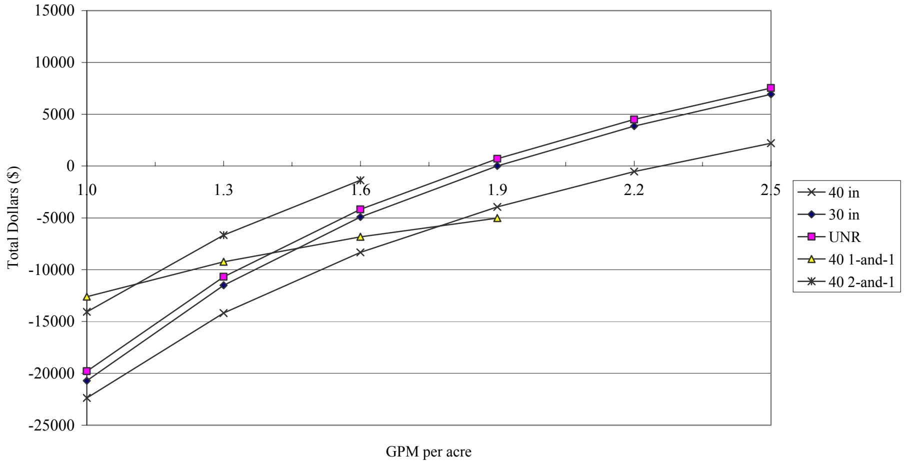

Figure 4. Net Return for different water allocations and different agronomic practices.