ADOPTION OF ADVANCED IRRIGATION TECHNOLOGY: LEPA VS. DRIP IN THE TEXAS HIGH PLAINS

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Abstract

Economic budgeting is used to compare the levels of expected net revenues to management and risk above variable and fixed costs of twelve irrigation system-irrigation application strategies. Overall, it was found that even when irrigation under Subsurface Drip Irrigation (SDI) was found to result in higher cotton lint yields, the economics of its adoption would not be necessarily as profitable as adopting Low Energy Precision Application (LEPA) irrigation.

Introduction

Irrigated agriculture has played a critical role in the growth and development of the agricultural sector in the U.S. Irrigated cropland accounts for about 12 percent of the total agricultural cropland acreage, but accounts for more than 30 percent of total output value (Segarra and Feng, 1992). Since the introduction of irrigated agriculture in the U.S., irrigated cropland acreage has increased significantly. In 1900, less than one percent of the agricultural cropland acreage was irrigated. In 1949, irrigated acreage accounted for 25 million acres, and increased to approximately 50 million acres by 1978. A decline in irrigated acreage has been experienced since that time. Recent information indicates that national irrigated acreage is at approximately 45 million acres (National Research Council, 1989).

In the Texas High Plains, irrigation started to expand after World War II. In 1949, there were about 3.1 million irrigated acres in the Texas High Plains. By 1974, this figure had reached 8.6 million acres. By 1992, however, it had decreased to approximately 6.9 million acres. Currently, this accounts for almost 15 percent of the total irrigated acreage in the U.S. This decline in irrigated acreage in the Texas High Plains came as a result of the overdraft of the Ogallala Aquifer, withdrawal of water is greater than recharge, and the increase in pumping costs associated with this overdraft (Feng, 1992).

Irrigated agriculture in the U.S. critically depends on ground water sources. About two-thirds of the total irrigated acreage in the U.S. utilizes ground water as the source of water. In the U.S., fourteen million acres of cropland are irrigated in areas where ground water aquifers are declining. Of these fourteen million acres, Texas accounts for about 4 million acres (National Research Council, 1989). The majority of these acres in Texas are located in the Texas High Plains, where the main source of water for irrigation is the Ogallala Aquifer. The Ogallala Aquifer is located in the Great Plains and extends from the Texas High Plains and eastern New Mexico, northward through the panhandle area of Oklahoma, into western Kansas and eastern Colorado, to central Nebraska. The saturated thickness of the Ogallala Aquifer, which represents the interval between the water table of the aquifer and the base of the aquifer, ranges from 0 to 300 feet. In many areas of the Ogallala Aquifer, mainly in the southern areas which includes the Texas High Plains, the saturated thickness has been significantly reduced as a result of continued overdraft (Texas Water Commission, 1989).

The dramatic expansion of irrigated agriculture in the Texas High Plains has led to the significant depletion of the pre-development water resources available in the southern portion of the Ogallala Aquifer. As withdrawal rates exceed recharge rates, the decline of the ground water table is expected to continue over time. Sources of recharge in the Texas High Plains portion of the Ogallala Aquifer are limited. It is estimated that the aquifer receives as recharge 0.2 inches of water per year from precipitation. However, artificial recharge and irrigation return water has caused ground water table levels to rise in some areas (Texas Water Commission, 1989). It is estimated that in the Texas High Plains area the weighted average water table declined about 10 feet from pre-development to 1980, and about 1.5 feet from 1980 to 1994 (Dugan and Sharp, 1994). Continued water withdrawal from the aquifer at current rates will cause the eventual depletion of this finite resource.

The seriousness of this problem comes from the fact that the Texas High Plains economy critically depends on irrigated agricultural production which uses ground water. Texas agricultural cash receipts for 1996 were approximately $13 billion, of which 41 percent were from crop production (Texas Agricultural Statistics, 1996). Thus, the 1996 estimated cash receipts from field crops production for the state were $5.3 billion with an estimated total economic impact of $18 billion. The value of crop production of the four major commodities (cotton, sorghum, corn, and wheat) in the Texas High Plains was $1.9 billion with an estimated total economic impact of $6.5 billion. Irrigated cropland production value of the four major commodities in the Texas High Plains in 1996 was estimated to be $1.6 billion with an estimated total economic impact of $5.1 billion.

The current state of ground water utilization in the Texas High Plains area is a reflection of the combined result of current economic, social and political factors. The main reason why ground water resources in the Texas High Plains are being used at a rate higher than the natural rate of

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recharge, is because of the revenues stemming from their current use being higher than the associated cost of extraction. However, water use in the Texas High Plains, given the critical dependence of the regional economy on this resource, is an inter-generational issue that must be evaluated in terms of the sustainability of agricultural activities in the long-run. For this reason, given the current state of economic, social and political factors, the sustainability of this resource needs to be better understood, given current and expected technological advances in agricultural production. In particular, advanced irrigation system technology can increase the efficiency of water utilization, and thus decrease the amount of water resources needed to produce a crop. Thus, the objective of this study was to determine the economics of adopting the Low Energy Precision Application (LEPA) versus Subsurface Drip Irrigation (SDI) for cotton production in the Texas High Plains.

Methods and Procedures

Several irrigation system alternatives are used to irrigate cotton in the Texas High Plains. However, LEPA and SDI are considered to be the two irrigation system alternatives that are most likely to contribute towards increasing water application efficiency, and thus potentially decrease the amount of water resources needed to produce a cotton crop. The LEPA irrigation concept was developed by the Texas Agricultural Experiment Station at Halfway, Texas between 1976 and 1978. The entire concept was designed to optimize total water availability (Bordovsky, et al., 1992).

SDI is a convenient and efficient way of supplying water directly to the soil along individual crop rows or surrounding individual plants. SDI offers desirable agronomic, agrotechnical, and economic advantages for the efficient use of water resources and labor. Also, SDI provides effective means for the delivery of very small amounts of water, which can save energy and has a great potential for minimizing the leaching of soluble chemicals. While the technical requirements of SDI are well known, only a few studies have compared its economic feasibility versus conventional irrigation system alternatives (Henggler, 1997; Hill and Keller, 1980; and Wilson, et al., 1984). Bosch, et al. (1992) used simulation to compare the relative profitability of microirrigation with both fixed and mobile center-pivot irrigation for a representative row-crop system in eastern Virginia. O' Brien, et al. (1997) conducted a relative profitability analysis of SDI and center pivot irrigation for corn production in western Kansas. In all of these studies, the authors identify those factors that would ultimately determine the economic feasibility of drip irrigation systems by agricultural producers.
In this particular study, the relative profitability of cotton production under LEPA and SDI were evaluated by using experimental data generated at the Texas Agricultural Experiment Station at Halfway, Texas from 1995 to 1998. These experiments were conducted on moderately permeable (0.1 in./hour) Olton loam (fine, mixed thermic *Aridic Paleustolls*) soil with slope of less than 0.2 percent. The LEPA treatments were irrigated on 1, 2, and 3-day intervals while the SDI treatments were irrigated daily. Irrigation quantities were restricted to delivery rates of 0.1, 0.2, and 0.3 in./day. The approach followed to evaluate the economics of LEPA versus SDI was to assume the development of a 120 acre representative irrigated farm in the Texas High Plains. Implicit in this formulation is that sufficient ground water resources (227, 453 and 679 gal./minute, respectively, for the 0.1, 0.2 and 0.3 in./day treatments) would be available for irrigation purposes in this farm. Given these assumptions, irrigated cotton budgets were generated. These budgets were composed of expected revenues, variable costs, and fixed costs. These components were then used to derive expected levels of net revenues to management and risk above variable and fixed costs.

The expected revenue calculations used the corresponding levels of yields for the 12 scenarios analyzed (3 SDI yield levels corresponding to daily water delivery rates of 0.1, 0.2, and 0.3 in./day; and 9 LEPA yield levels corresponding to 1, 2, and 3-day irrigation intervals X the three irrigation capacity limitations of 0.1, 0.2, and 0.3 in./day). Constant prices of $0.64/pound for cotton lint and $110/ton for cottonseed were used throughout the calculations to derive the levels of expected revenues (standard procedures were used to derive cottonseed yields from cotton lint yields).

The variable cost estimation took into account all of the variable inputs needed to produce irrigated cotton in the Texas High Plains (herbicide, fertilizer, crop insurance, seed, seed treatment, insecticides, fuel and lube, repairs, labor, harvest-aid chemicals, strip and module charges, and ginning). It is important to point out, that these costs varied slightly across scenarios due to the fact that strip and module charges and ginning costs vary according to lint yield levels. Also, given an interest on how variable costs would change due to different depths to the ground water table, four depths to the ground water table scenarios were analyzed (170, 200, 250 and 300 feet) in the variable cost calculations (standard procedures were followed to calculate these pumping costs). However, in this paper only two levels of depth to the ground water table, 200 and 300 feet, are reported.

In calculating the annual per acre level of fix costs, these were separated into three categories: machinery, land, and irrigation system. The machinery and land charges were assumed to be $48.41 and $40.00 per acre, respectively. The irrigation system cost was composed of two components: irrigation well cost and irrigation system cost. The irrigation well cost was assumed to be $33,000 for the 120 acre farm ($12,000 for drilling, casing and installation; $9,000 for the pump assembly; $4,000 for the bowl; $5,000 for the power unit; $2,000 for the meter loop and installation; and $1,000 for developing the well). With respect to the irrigation system costs, it was assumed that the cost and installation of the LEPA system would be $40,000 for the 120 acres, and two levels of cost for the SDI system were assumed, $600 and $800 per acre (Funck, 1998). The reason for using two fix cost levels for the SDI system, is based on the fact that the $800 figure would be close to the actual installation cost if a private company was to install the SDI system, and the $600 figure would be a close estimate of the cost of installing the SDI system privately (Funck, 1998). Both LEPA and SDI systems are supposed to last around 20 years, however, given the uncertainties associated with this assumption, three lengths of planning horizon were assumed in the calculations of the annual irrigation system cost, these were: 10, 15 and 20 years. Also, cotton production in the Texas High Plains is highly susceptible to adverse weather conditions, especially hail damage, thus a hail out possibility every five years scenario was also derived.

Results

Table 1, depicts the 1995 to 1998 with and without hail damage average cotton lint yield levels for the 12 scenarios analyzed (3 SDI yield levels for daily maximum irrigation capacities of 0.1, 0.2, and 0.3 in./day; and 9 LEPA yield levels for 1, 2, and 3-day irrigation intervals X the three irrigation capacities at 0.1, 0.2, and 0.3 in./day). Again, the cotton lint yields with hail damage assume a crop hail out every 5 years, i.e. the yields are 80 percent of the yields without hail damage. As depicted in Table 1, all the yield levels for SDI are higher than those under LEPA for the one day interval between irrigations. Also, under LEPA irrigation: (1) the highest level of yield under the 0.1 inch irrigation capacity per day took place under the two day interval (this was significantly higher than that for the 1 and 3 day intervals, Duncan p <or = 0.05); (2) the highest level of yield under the 0.2 inches irrigation capacity per day took place under the one day interval; and (3) the highest level of yield under the 0.3 inches irrigation capacity took place under the three day interval.

Tables 2 to 4, depict the expected levels of net revenues to management and risk above variable and fixed costs, assuming a $800 per acre cost for the SDI system adoption and no hail damage for 10, 15, and 20 years life span of the irrigation systems, respectively. As depicted in those tables, the most profitable alternative across the scenarios analyzed is to adopt LEPA under the three day interval irrigation strategy applying a maximum of 0.9 inches/application (0.3 inches/day X 3 day interval). When the loss of the cotton crop due to hail damage is assumed, similar results to those just depicted result. That is, the most profitable alternative across the scenarios analyzed is to adopt LEPA using the three day interval irrigation strategy applying water at the 0.3 inches/day capacity (Table 5 to 7). It is important to point out, however, that assuming the loss of one cotton crop every five years due to hail damage, the lowest irrigation capacity (0.1 inches per day) under all scenarios would result in negative net revenues.

As pointed out above, the $800 per acre of adopting SDI might be lowered if producers install their own SDI system. For this reason, the economics of SDI system adoption assuming a $600 per acre figure were calculated. Table 8, depicts the results obtained under this scenario. As shown in this table, the economics of SDI adoption significantly improve as compared to the $800 per acre SDI scenario. But, even under the $600 per acre cost for SDI scenario, the most profitable alternative across the scenarios analyzed is to adopt LEPA using the three day interval irrigation strategy applying irrigation water at the 0.3 inches/day irrigation capacity. Notice, however, that for the 15 and 20 year irrigation system life span, the second highest net revenue generating alternative (assuming $600 per acre cost for SDI adoption) would be under SDI using the one day interval irrigation strategy and applying 0.3 inches of irrigation water per day. That is, if the cost of SDI adoption is lowered from $800 to $600, and its economic life 15 to 20 years, then SDI becomes more competitive.

Summary and Conclusions

The current state of ground water utilization in the Texas High Plains area is a reflection of the combined result of current economic, social and political factors. The main reason why ground water resources in the Texas High Plains are being used at a rate higher than the natural rate of recharge, is because of the revenues stemming from their current use being higher than the associated cost of extraction. However, water use in the Texas High Plains, given the critical dependence of the regional economy on this resource, is an inter-generational issue that must be evaluated in terms of the sustainability of agricultural activities in the long-run. For this reason, given the current state of economic, social and political factors, the sustainability of this resource needs to be better understood, given current and expected technological advances in agricultural production. In particular, advanced irrigation system technology can increase the efficiency of water utilization, and thus decrease the amount of water resources needed to produce a crop. Thus, the objective of this study was to determine the economics of adopting LEPA versus SDI for cotton production in the Texas High Plains.

Economic budgeting was used to compare the levels of expected net revenues to management and risk of twelve irrigation system and irrigation application strategies. Overall, it was found that even when irrigation under SDI was found to result in higher cotton lint yields, the economics of its adoption would not necessarily be as profitable as adopting LEPA. The main reason for this result lies in the fact that the adoption of a LEPA system would cost much less, $333.33 per acre, than either of the two cost scenarios analyzed for the adoption of SDI, $600 and $800 per acre. In most of the cases analyzed, given the current cost of custom SDI adoption in the Texas High Plains, it would not be economically justifiable to adopt SDI when compared to LEPA. Under the 20 year irrigation system life scenario, it was found that even under the possibility of having the total loss of one cotton crop every five years, adoption of LEPA or SDI at the 0.2 and 0.3 inches of irrigation per day would always be expected to result in positive net revenues to management and risk, except for one case under the SDI $800per acre cost.

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Table 1. Irrigation system alternatives and yields (without and with hail damage).

Irr, Syst. & interval	Inches per day	Yield lbs./Ac (no hail)	Yield lbs./Ac (hail)
SDI 1	0.1	1108	886.4
	0.2	1195	956.0
	0.3	1215	972.0
LEPA 1	0.1	897	717.6
	0.2	1091	872.8
	0.3	1113	890.4
LEPA 2	0.1	978	782.4
	0.2	1077	861.6
	0.3	1101	880.8
LEPA 3	0.1	911	728.8
	0.2	1088	870.4
	0.3	1155	924.0

Table 2. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 10 years system life, and no hail damage).

		Lift in Feet	
Irr, Syst. & interval	Inches per day	200	300
		------($/Ac.)------	
SDI 1	0.1	62.35	47.59
	0.2	106.63	89.42
	0.3	116.90	99.16
LEPA 1	0.1	49.23	31.90
	0.2	160.36	143.13
	0.3	173.00	155.80
LEPA 2	0.1	94.02	76.01
	0.2	150.44	132.35
	0.3	165.01	147.30
LEPA 3	0.1	56.07	38.21
	0.2	157.27	139.43
	0.3	195.64	177.83

Table 3. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 15 years system life, and no hail damage).

Irr, Syst. & interval	Inches per day	Lift in Feet 200	300
		------($/Ac.)------	
SDI 1	0.1	89.02	74.26
	0.2	133.30	116.09
	0.3	143.57	125.83
LEPA 1	0.1	60.34	43.01
	0.2	171.47	154.24
	0.3	184.11	166.91
LEPA 2	0.1	105.13	87.12
	0.2	161.55	143.46
	0.3	176.12	158.41
LEPA 3	0.1	67.18	49.32
	0.2	168.38	150.54
	0.3	206.75	188.94

Table 4. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 20 years system life, and no hail damage).

Irr, Syst. & interval/ day	Inches	Lift in Feet 200	300
		------($/Ac.)------	
SDI 1	0.1	102.35	87.59
	0.2	146.63	129.42
	0.3	156.90	139.16
LEPA 1	0.1	65.90	48.57
	0.2	177.03	159.80
	0.3	189.67	172.47
LEPA 2	0.1	110.69	92.68
	0.2	167.11	149.02
	0.3	181.68	163.97
LEPA 3	0.1	72.74	54.88
	0.2	173.94	156.10
	0.3	212.31	194.50

Table 5. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 10 years system life, and hail damage).

Irr, Syst. & interval	Inches per day	Lift in Feet 200	300
		------($/Ac.)------	
SDI 1	0.1	-64.32	-79.08
	0.2	-29.99	-47.20
	0.3	-22.00	-39.74
LEPA 1	0.1	-53.32	-70.65
	0.2	35.64	18.41
	0.3	45.77	28.57
LEPA 2	0.1	-17.79	-35.80
	0.2	27.31	9.22
	0.3	39.15	21.44
LEPA 3	0.1	-48.07	-65.93
	0.2	32.89	15.05
	0.3	63.60	45.79

Table 6. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 15 years system life, and hail damage).

Irr, Syst. & interval	Inches per day	Lift in Feet 200	300
		------($/Ac.)------	
SDI 1	0.1	-37.65	-52.41
	0.2	-3.32	-20.53
	0.3	4.67	-13.07
LEPA 1	0.1	-42.21	-59.54
	0.2	46.75	29.52
	0.3	56.88	39.68
LEPA 2	0.1	-6.68	-24.69
	0.2	38.42	20.33
	0.3	50.26	32.55
LEPA 3	0.1	-36.96	-54.82
	0.2	44.00	26.16
	0.3	74.71	56.90

Table 7. Per acre net revenues to management and risk above variable and fixed costs ($800 SDI cost, 20 years system life, and hail damage).

Irr, Syst. & interval	Inches per day	Lift in Feet 200	300
		------($/Ac.)------	
SDI 1	0.1	-24.32	-39.08
	0.2	10.01	-7.20
	0.3	18.00	0.26
LEPA 1	0.1	-36.65	-53.98
	0.2	52.31	35.08
	0.3	62.44	45.24
LEPA 2	0.1	-1.12	-19.13
	0.2	43.98	25.89
	0.3	55.82	38.11
LEPA 3	0.1	-31.40	-49.26
	0.2	49.56	31.72
	0.3	80.27	62.46

Table 8. Per acre net revenues to management and risk above variable and fixed costs ($600 SDI cost, 10, 15, and 20 years system life, with and without hail damage).

Irr, Syst. & interval	Inches per day	Lift in Feet 200	300
		------($/Ac.)------	
10 years, no hail damage			
SDI 1	0.1	110.87	96.11
	0.2	155.15	137.94
	0.3	165.42	147.68
15 years, no hail damage			
SDI 1	0.1	130.87	116.11
	0.2	175.15	157.94
	0.3	185.42	167.68
20 years, no hail damage			
SDI 1	0.1	140.87	126.11
	0.2	185.15	167.94
	0.3	195.42	177.68
10 years, hail damage			
SDI 1	0.1	-15.80	-30.56
	0.2	18.53	1.32
	0.3	26.52	8.78
15 years, hail damage			
SDI 1	0.1	4.20	-10.56
	0.2	38.53	21.32
	0.3	46.52	28.78
20 years, hail damage			
SDI 1	0.1	14.20	-0.56
	0.2	48.53	31.32
	0.3	56.52	38.7