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WATER AND ENERGY REQUIREMENTS FOR SUBSURFACE AND CENTER-PIVOT IRRIGATION

by

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SUMMARY: Water and energy required for a CaRD (Controlled and Reversible Drainage) system where water was supplied through a system of ditches and drain tubes was compared with that required for a high-pressure center-pivot system where water was pumped directly from a deep well. Both systems are located in Orangeburg County, S.C.

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INTRODUCTION

Water and energy are major factors affecting today's agriculture. Rainfall in the southern Coastal Plains is erratic, ranging from 70 to 194 cm annually and from 3 to 35 cm in July. The water-holding capacity of the sandy loam soils ranges from 2 to 5 cm per 30 cm of soil. This is about enough water to supply crop needs for 5 to 10 days. However because the natural water table is within 2 m of the surface, some soils need drainage during wet periods (Doty 1980). These are some of the factors affecting water-associated management decisions

Energy costs have soared over the past few years. The agricultural producer must closely manage all inputs including energy to effectively retrieve their costs at market time.

With these two factors at the forefront, we would like to discuss a study comparing water and energy requirements of a subsurface (CaRDS Controlled and Reversible Drainage System) and a center-pivot irrigation system.

Experimental Site and Procedure:

The experiment is located in Orangeburg County, South Carolina. The CaRD system is located approximately 8 km southeast of Orangeburg on U.S. 21 on lands of Mr. Henry Young. The center-pivot system is located on the lands of Mr. Lewis Shuler, approximately 1.6 km south of the intersection of U.S. 301 and I-26. These sites were chosen because of these similarities and their proximity to each other, 8 km apart (Fig. 1).

Subsurface Irrigation System:

Mr. Young's farm is located near the edge of a natural cypress pond. The pond is capable of storing approximately 20-25 cm of water over an structure to record all stages of movement of water for either drainage or irrigation. Recorders are strategically located throughout the area of the field to monitor water table levels throughout the system. They are placed 30 cm away from the tile lines and one-half the distance between tile lines at three locations approximately 100 m from the lateral ditch. Two locations are on the 30-m spaced tile. The third location is on the 60-m spaced tile. Several recorders are also located near the edge of the cypress pond and out into the field to monitor possible water loss from the system into the pond or seepage from the pond into the field.

Water supplied to the CaRD system was pumped over the control structure by a gasoline-powered pump. A 10-cm water meter was installed in the line to record the amount of water pumped into the system daily. Gasoline usage was also recorded daily. Electric energy useage by the pump on the main supply well was also recorded.

The CaRD system was not fully operational until late summer 1979. The well for Mr. Young's operation was not installed until late August 1979. The complete installation was finished only a short time before the cropping season was over. Operation of the system for approximately two weeks however allowed us to check out the system and equipment. Complete data were obtained during the 1980 season.

<u>Center-Pivot Irrigation System:</u>

The center-pivot system covers approximately 45 ha. A water meter was installed in the supply line to record the amount of water applied by the system. Readings were taken on the electric energy meter to determine electrical energy used for moving the system. Water to the system was supplied by a well 300-m deep. The well is gravel packed area of 40-60 ha. A drainage ditch was cut through the pond in past years and water is now held in the pond by a flashboard riser control structure located at the edge of the field. Water released from the pond can be used to irrigate early in the season.

Supplemental water is supplied by a gravel-packed well. The well is 71 cm in diameter with gravel pack up to the casing of 41 cm. Depth of the well is 150 m with 76 m of screen in the Pee Dee stratum. Pumping capabilities are approximately 450-475 m^3 per hour.

The water is pumped into a surface ditch which connects with the main ditch serving the entire farm (Fig. 2). A control structure in the main ditch located near the well holds the water level in the ditch as needed until it is pumped by a series of lift stations into the areas requiring water for irrigation. This ditch also serves as the main drainage ditch for the farm. The uniformity of elevation of the farm is such that only three lift stations are needed to service the largest portion of the farm.

Measurements were made on a 26-ha field. This field has 10-cm black corregated plastic tile lines installed on a grade of 0.1% toward the ditch. Tile lines enter the lateral ditch from either side. All tile line outlets were located on the same elevation and are therefore serviced from a single lift station located at the end of the lateral ditch

Tile lines are perpendicular to the lateral ditch and are spaced 30 m apart except for three lines on the upper end of the field. These lines are spaced 60 m apart

A flashboard riser is used to control the water level in the lateral ditch. Stage recorders are located on each side of the control with 150 m of screen. It is 71 cm in diameter with gravel pack up to the casing of 41 cm. It is capable of pumping 3000 gpm. Pumping is done by a diesel engine. Fuel usage for the system was calculated to determine pumping energy expense.

Weather stations were set up on each location to provide rainfall and irrigation data. Recording rain gages were used to record rainfall. Screened evaporation pans were used to determine evaporation rates (Campbell and Phene 1976).

Corn was grown on both locations during the 1980 crop year. Fertilization, cultivation, and chemical weed control were decisions of each farmer. Planting dates for both farms were nearly the same, April 11-15, 1980. Current up-to-date farming practices were used in both systems

Corn yields in the CaRD system were obtained by taking samples from sections of row adjacent to or between recorders located in the irrigated field. Check yields were obtained in adjacent nonirrigated fields. Yields were taken from random plots under the center-pivot system and in adjacent nonirrigated areas.

Each irrigation system was operated by the farmer. Decisions for applying water were left to their own discretion.

RESULTS AND DISCUSSION

Subsurface System:

Mr. Young kept the water level near the top of the lateral ditch to maintain as much head on the tile lines as possible. This situation produced nearly 75-90 cm of head above the tile outlets. The water level in the field was held 60 cm below the soil surface throughout the growing season.

During most of the season, the irrigated corn appeared to have ample moisture to produce higher yields. Late in the season, corn in the nonirrigated areas showed signs of stress. A flight over the field and adjacent areas clearly showed the irrigated areas

Mr. Young applied 21 cm of water to his 26 hectare field using 332.5 gal. of gasoline, costing $385 (Table 2)

Some loss of water through cracks in the boards in the control structure were not subtracted from the total amount pumped. These losses were very small and considered to be insignificant

Other losses such as seepage into or out of the system are now being calculated from data taken from the stage recorders located along the edge of the field.

Corn on Mr. Young's farm yielded from 8.7-12.1 t/ha, irrigated, with an average of 10.42 t/ha. Nonirrigated corn yields ranged from 6.2-9.5 t/ha with an average of 6.86 t/ha. The average increase due to subsurface irrigation was 3.56 t/ha (Table 3).

Center-Pivot System:

Mr. Shuler's center-pivot system covers an area of 45 ha. The system makes only 3/4 of a circle. Corn was also grown under this system. Modern cultural practices were used. Fertilization rates, chemical weed control, and cultivation were determined by Mr. Shuler.

The center-pivot system supplied 16.7 cm of water (Table 1) using 650 kwh/ha of electricity to move the system in addition to the diesel fuel used to pump the water (Table 2). Calculation of diesel use for this system was complex. A large center-pivot system is also supplied from the same deep well, diesel-powered pump. Table 2 shows operation of the small system run alone. Information from North Dakota research indicated a fuel rate of $9.50/ha in a 1968 publication (2). Since energy costs have increased 5-6 times since then, our fuel cost of $79.96/ha are in the range of expected fuel costs (McMartin and Bergan 1968). The diesel engine and pump for the well were designed for use with the larger system in an adjacent field. A considerable savings results when both systems are operated together.

Corn yields for the center-pivot irrigated area ranged from 9.4-10.3 t/ha and averaged 10.98 t/ha. Nonirrigated yields 7.1-9.2 t/ha and averaged 7.83 t/ha (Table 3).

The nonirrigated corn showed signs of stress several times during the year. Irrigated corn showed stress from dry weather only a few time during periods of extreme drought.

The cost of irrigation per ton (Table 4) of corn produced was $7.36/ton of corn for the center-pivot system compared to $2.04/ton for the subsurface (CaRD) system. The cost/ton for yield increases due irrigation was $25.57/t for the center-pivot system compared to $5.97/t for the CaRD system. The efficiency of corn produced/cm of water applied is shown in Table 5. This shows that the center-pivot system soils were more efficient in producing corn. These results are for one year of data, and may not be conclusive. However, one would expect a center-pivot system to be efficient in supplying water.

Weather data taken from both locations is being analyzed now Rainfall from April until August harvest time was 41.3 cm on the CaRD system and 38.9 cm on the center-pivot system. This was a difference 2.4 cm more for the CaRD system. The total rainfall difference for the growing season was apparently not significant.

Much can be said for both systems. The advantages and disadvantages of these systems are well known by the operators. Each farmer speaks highly of his system and feels that it fits his needs best. Currently, Mr. Young is putting tile under additional acreage with plans for a water table management system under his entire farm. Both systems are expensive and require a high amount of management.

CaRD systems and center-pivot systems have a place in irrigation in the Southeast. Each system is unique. Some advantages of the CaRD system are: 1) supplies drainage for the same cost, 2) system can be financed over a longer period of time, 3) does not have to be moved for field operations, 4) grass seeds will not germinate as readily on a dry surface, and 5) the water table can be regulated to suit varying conditions and weather patterns. Some advantages of the center-pivot system are: 1) may be used to apply fertilizer and some chemicals, 2) supplies water above ground to aid in seed germination, 3) status symbol, 4) manager can observe the water as it is applied to the crop to assure uniformity. Some disadvantages of the CaRD system are: 1) cannot apply water over the top to assist chemical incorporation and seed germination, 2) observation of uniform water applications is not possible, and 3) crop management practices for a high water table are not well known (Doty et al. 1975). Disadvantages of the center-pivot system are: 1) must be moved for field operations, and 2) requires some regular services and maintenance

Water and energy are both valuable resources without which the American farmer is limited. From available data it appears that the dual purpose CaRD system uses less energy, but requires more water than the center-pivot system. Further studies and research should give us much reliable information on both of these systems.

REFERENCES

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Table 1. Rainfall and Irrigation Applied
April through August 1980

	Rainfall	Irrigation	Total
	-----------------	cm	-----------------
Center Pivot System	38.9	16.7	55.6
Subsurface (CaRD) System	41.3	21.0	62.3

Table 2. Cost of Applying Irrigation Water to the Two Systems for One Crop Year.

	Center Pivot System			Subsurface (CaRD) System		
	Energy/ha	$/ha	$/ha-cm	Energy/ha	$/ha	$/ha-cm
Diesel Fuel (gallons)	79.96	79.96	4.79	-	-	-
Electricity (kw hrs)	14.4	.58	.03	160.8	6.43	.31
Gasoline (Gallons)	-	-	-	12.79	14.84	.71
	-	$80.54	$4.81	-	$21.27	$1.02

Table 3. Corn Yields at 15% Moisture - 1980

System	Range	Average	Increase
	t/ha		
Center Pivot System			
Irrigated	9.4 - 12.3	10.98	
Nonirrigated	7.1 - 9.2	7.83	3.15
Subsurface (CaRD) System			
Irrigated	8.7 - 12.1	10.42	
Nonirrigated	6.2 - 9.5	6.86	3.56

Table 4. Efficiencies (Cost per Ton) for Corn Produced by Irrigations Under Two Systems

System	Total	Increase
	--------$/ton--------	
Center Pivot	7.36	25.57
Subsurface (CaRDS)	2.04	5.97

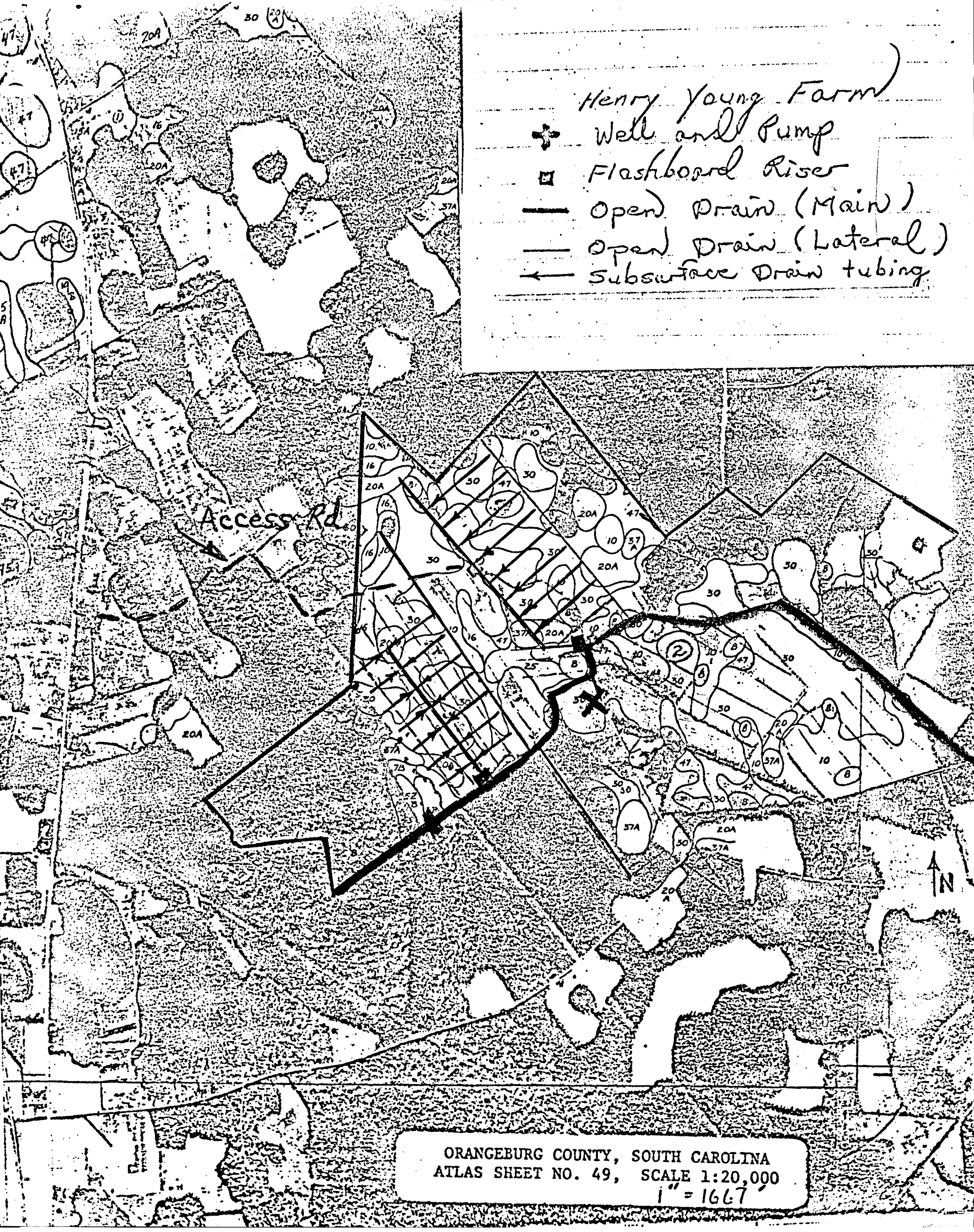
Table 5. System Efficiencies for Water Pumped for One Crop Year

System	Total Water	Irrigation Water
	---------------t/cm---------------	
Center Pivot		
Irrigated	.20	.19
Nonirrigated	.20	-
Subsurface (CaRD)		
Irrigated	.17	.17
Nonirrigated	.17	-

ROWESVILLE
POP. 388
BOWMAN
POP. 1,106
DORCHESTER
CARDS
PIVOT
To Cameron
To Columbia
To Rosinville
To Reevesville
Bethel Ch.
Forest Chapel
St. Johns Ch.
Pineville Ch.
Shiloh Ch.
Prospect Ch.
Cattle Creek Ch.
Gavintown Ch.
Mays Chapel
St. Stephens Ch.
Sardis Ch.
Zion Ch.
Mt. Tabor Ch.
Mack Branch Ch.
Andrew Chapel
White House Chapel
Cedar Grove Ch.
Olive Grove Ch.
Four Holes Ch.
Granger Ch.
Red Hill Ch.
Walnut Grove Ch.
Ebenezer Ch.
Antioch Ch.
Bethune Memorial Sch.
Bowman Community Center
Cattle Creek
Cow Castle
Sandy Run
Buck Branch
Patrick Branch
Wadboo Br.
Small Branch
Mill Branch
Four Hole Swamp
Indian Camp Br.
Middle Pen Cr.
Crum Branch

Figure 1

Figure 2



Henry Young Farm
Well and Pump
Flashboard Riser
Open Drain (Main)
Open Drain (Lateral)
Subsurface Drain tubing
Access Rd
N
ORANGEBURG COUNTY, SOUTH CAROLINA
ATLAS SHEET NO. 49, SCALE 1:20,000
1" = 1667'