Using an “off-the-shelf" Center Pivot to Water Corn, Cotton and Soybeans on Mixed Soils Using a Concept of Precision Irrigation"

Joe Henggeler[1]

ABSTRACT

A test was conducted for two years on corn, cotton and soybeans to determine the ideal irrigation deficit/frequency for that crop. The field had two distinct soil types (SAND) and (SILT) as delineated by using a Veris 3100 EM machine. The various portions of both soil type were calculated for each compass degree; on average the pivot soil type was 26% sandy. Yields were separated by soil type. For each crop, yield data versus irrigation deficit treatments were used to develop net return curves based on the application amounts. For each crop three protocols were established to evaluate the economic impact of irrigating the entire field (1) using the ideal deficit irrigation for sand, (2) the ideal deficit for silty soils, and (3) concept of using a "precision irrigation," whereby that section of the field was irrigated using the deficit that gave highest net returns. This concept entails that added rotations are made with the pivot. Results were modeled.

Results showed that cotton tended to respond better to precision irrigation. This is because the net return-irrigation deficit curves were more distinct between the sandy and silty soils for cotton. In the cases of corn and soybeans, the ideal deficit for the two soil types were close enough together that precision irrigation increased net returns only little.

INTRODUCTION

Most center pivot companies offer an upgraded panel box that is capable of allowing the grower to irrigate portions of the circle, while traveling dry over other portions of the pivot circle. This special feature in panel boxes is sometimes provided free by the irrigation company has a sales incentive. Even when purchased, the cost of the panel up-grade is not prohibitive (approximately $3,000 to $5,000 more), especially when seen in light of acres involved and life of the system. Utilization of these types of control panels is examined in this paper as a means of precision irrigation.

Crop water use varies throughout the season. Irrigators can manage this change in water use over time by:

1. keeping the irrigation interval the same, but changing application amount
2. keeping the application amount the same, but changing interval
3. or a combination of one and two.

The over-whelming majority of irrigators using center pivots in the Midwest and mid-South, follow the second practice and apply a single application amount throughout the season. This amount is termed the irrigation deficit. The ideal irrigation deficit for a crop in a particular climate is a function of soil type.

[1] Extension Agricultural Engineer (henggelerj@missouri.edu) , Biological Engineering Department and Commercial Agriculatural Program, University of Missouri, Portageville, MO.

Empirical studies have been conducted to determine these ideal deficit amounts. Sometimes management concerns can over-ride the desire to apply the ideal deficit amount. This is the case of application amounts that cause run-off or get pivots stuck, or for flood irrigators, deficit amounts whose intervals are so long that the soil may crack first. However, there is --barring these other circumstances—generally an ideal application amount for a crop and soil type.

In fields with a homogenous soil type, precision irrigation becomes a mute point and is not required. However, if two or more distinct soil type exist under a pivot, precision irrigation may be beneficial. In this study *precision irrigation* is limited to only those management capabilities found in an up-graded pivot control panel. Distribution of water down the pivot lateral is always fixed. What can only occur is that as the pivot rotates it can be either "on" or "off" in terms of applying water. The precision irrigation management scheme thus involves dividing the field into certain arcs comprised mostly of Soil A that receive one application deficit/frequency scheme, with the remaining arcs (Soil B) receiving a second deficit/frequency scheme. Conceptually speaking, it is as if there are two separate fields being watered indepedently. One minor negative consequence is that this procedure leads to more hours of operation per year on a pivot, since the total number of circles made will be the sum of those required for watering Soil A plus those required for watering Soil B.

The smallest management zone in the controllers is an arc of one degree, thus for a normal 135-acre pivot the smallest zone of management would be an arc of 0.38 acres. However, a 5-degree span is probably as detailed as one can be in hand-discerning soil maps, thus the practical minimal size is 2 acres. Additionally, current control panels limit the numbers of line code in their control programs. For example, Zimmatic's controller, in its simplest form, allows only 16 lines of instruction, allowing at the most only eight zones (there must be separate "start" and "stop" lines for each zone). The panel does allow for multiple programs to be stored, so assuming two deficit/frequency schemes are used, then the pivot circle could be broken into 16 arcs, for an average management zone size of about 8 acres. The irrigator would use a Program A and a Program B which are kept in memory.

METHODS AND MATERIALS

Yield curves for corn, soybean, and cotton based on irrigation deficit/frequency were developed from two years of experimental research on a single field composed of two broad soil types. Irrigation frequencies, or deficits, range from 0.75 inch per application to 3.00 inch per application for soybean and cotton. The frequency range for corn ranged from 0.50 inches to 2.50 inches per application. For each crop there were five deficit/frequency treatments. All treatments on the individual crops received approximately the same amount of irrigation.

The tests were conducted on a three-tower center pivot located at the University of Missouri Delta Center Research Center near Portageville, Missouri. This area is located near the New Madrid fault, the epicenter of a very large earthquake that occurred in the early part of the 19th Century. Said to be the largest earthquake in recorded history, this event churned up pockets of sand within existing alluvial fields creating "sand boils". The research pivot was located on such a field.

A Veris 3100 EM machine was used to differentiate the soil types (Fig. 1). The fingerprint of the EM survey corresponds to the aerial photographs of the field (Fig. 2). Experimental results indicated that the largest demarcation in terms of yield response was based on soil texture as being either a sandy or non-sandy,

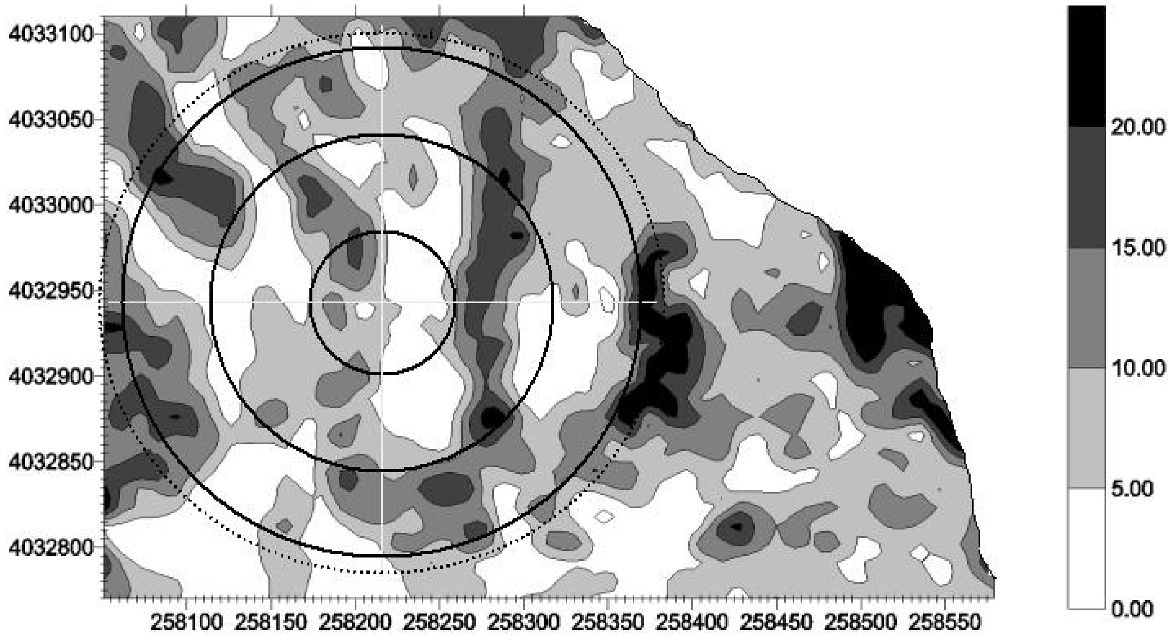


Fig. 1 Results of mapping apparent soil electrical conductivity (EC_a) with a Veris 3100 machine using the deep setting. Areas in the 0 to 5 EC_a range were grouped as one management group (SAND) and areas with values greater then 5 comprised the other group (SILT). The outline of the three pivot towers and overhang can be seen.

Fig. 2. Aerial view of same field showing location of where the pivot waters.

corresponding to apparent electrical conductivity (EC_a) values of 0-5 and 5-25, respectively, and designated SAND and SILT, respectively. The three crops were grown during the 2001 and 2002 growing season. A third of the pivot area was dedicated to each crop. Sections were rotated between years. Crops were planted in concentric circles in 30-inches rows.

The 1/3 portion of the field dedicated to a single crop was sub-divided into 15 equal sections (5 treatments by 3 reps) having an arc of approximately eight degrees. The control panel was used to apply the correct amount of water to the appropriate plot. The computer program, ***Arkansas Scheduler***, was used to time the irrigations. Harvest was accomplished by cutting alleyways between experimental units. A harvesting pass gathered two-row yield samples on the 15 experimental units. Approximately five separate passes were made at different radial distances down the lateral. The large number of yield samples collected was to ensure that ample yield samples would be available for both soil types. Corn and soybean samples were measured for moisture and yields converted to standard moisture levels (15% and 13%, respectively). Harvested seed cotton was ginned to determine lint yield.

Later, a soil map with the treatment boundaries and harvested rows drawn in was used to determine if the particular samples came from a SAND portion of the field or a SILT portion of the field. Plots that contained both soil types were not used. Yield results from two years for each deficit/frequency treatment were average for use.

Enterprise budgets develop by a local agricultural economist from the University of Missouri Outreach and Extension Service were used to calculate net returns for each deficit used. Total input costs were based on yield received and typical equipment charges. Irrigation costs were based on the gross amount of inches applied at $1/acre-inch) and a set charge of $30 per irrigation. A second-degree polynomial equation relating net economic return versus deficit was developed for each crop and soil type. The derivative of these equations were solved for zero to obtain the deficit that produced the highest net return, except in the case of cotton on sandy soil which had a very linear net return-deficit function.

Final economic analysis was made be comparing net return estimates under three main scenarios:

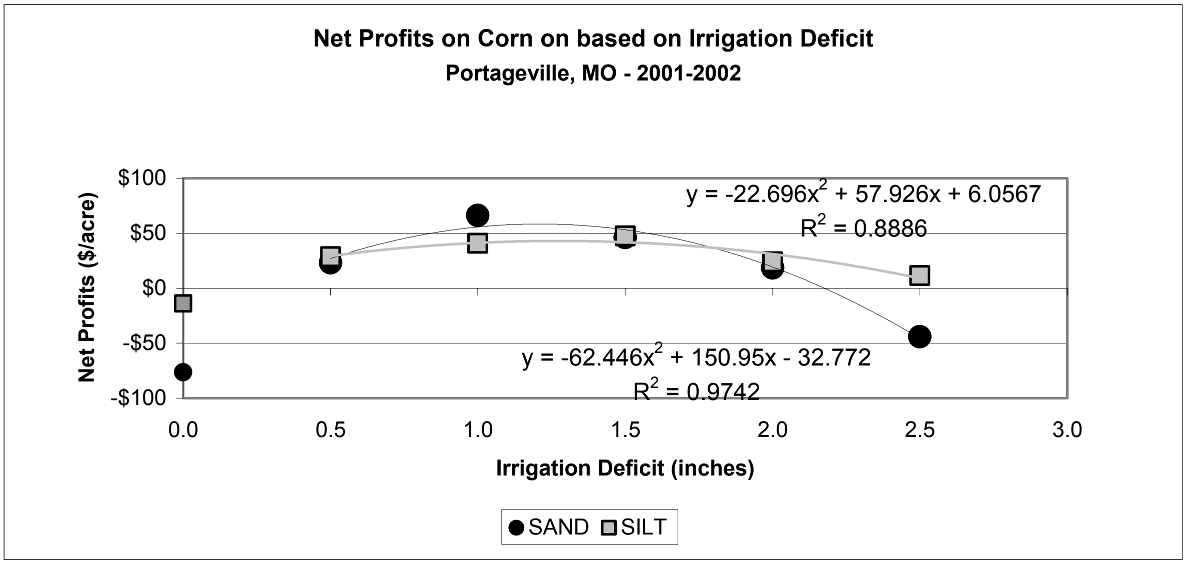
1) The pivot was operated normally using the ideal deficit/frequency for SAND throughout
2) The pivot was operated normally using the ideal deficit/frequency for SILT throughout
3) The pivot was operated in a precision irrigation mode, in which, for each 5-degree arc, the deficit/frequency that produced the most net return was used on that arc

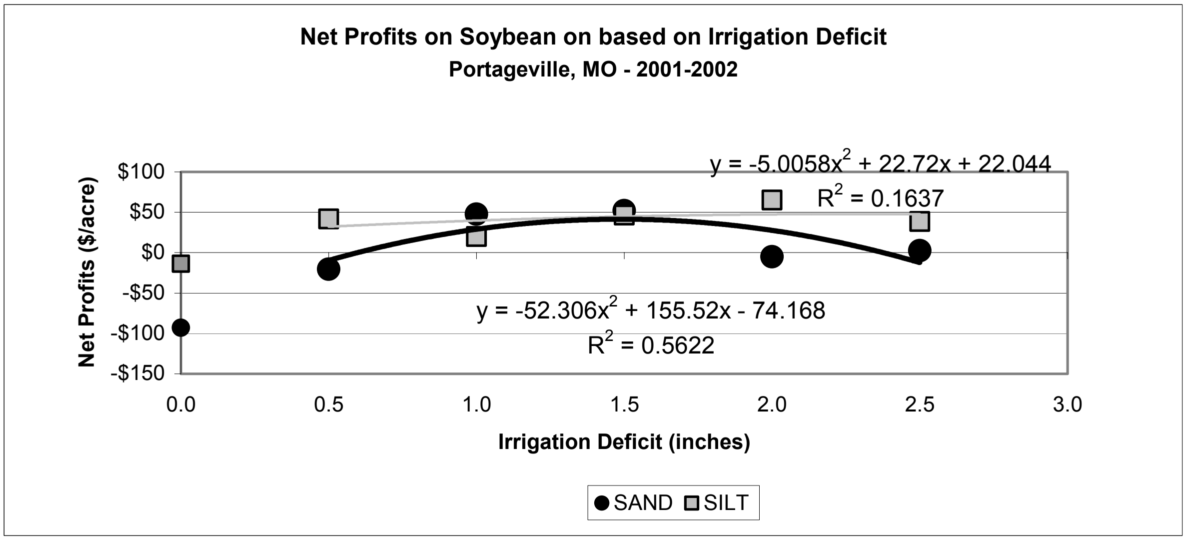
RESULTS

The average yield for two years for the three crops based on the irrigation deficit is seen in Table 1. Figure 3 show the net return versus irrigation deficit curves for the three crops and two soil types.

Table 1. Average yields for corn, soybeans and cotton (bu/acre for corn and soybeans, lbs of lint for cotton) for five different irrigation deficits, Portageville, MO, 2001-2002.

	Corn					**Soybeans**					**Cotton**				
	------- inches per application -------					------- inches per application -------					------- inches per application -------				
	0.50	**1.00**	**1.50**	**2.00**	**2.50**	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**
SAND	203.8	223.9	212.8	199.5	168.2	47.1	59.5	60.2	49.6	50.7	1369	1237	1275	1216	1118
SILT	206.4	211.9	213.5	202.2	194.7	58.5	54.5	59.2	62.3	57.2	1151	1115	1296	1177	1147





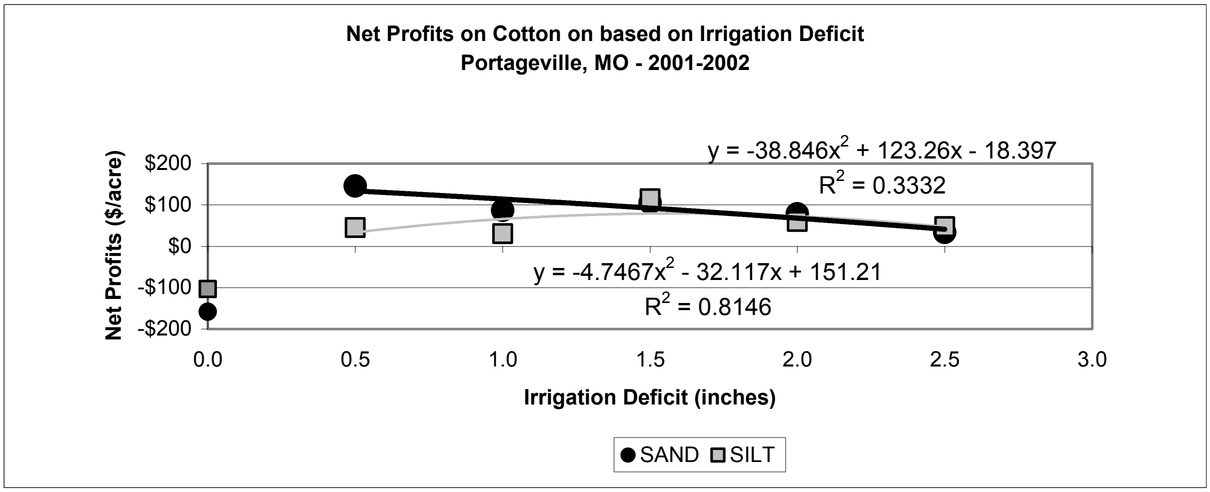


Figure 3. Net return versus irrigation deficit for SAND (left) and SILT (right) with corn (top), soybean (middle) and cotton (bottom).

The ideal irrigation deficit for the three crops and two soil types was determined by taking the first derivate of the net return versus deficit equations (these are seen imbedded in the graphics from Fig. 3). The one exception to this was the cotton-sand equation, whose linearity gave a false solution to the ideal deficit amount. In this case 0.50 inches was chosen from the shape of the curve. These ideal deficit values are seen in Table 2.

Table 2. Ideal irrigation application deficit for corn, soybeans, and cotton for sandy and silty soils

Soil Type	Corn	Soybeans	Cotton
	------------------ inches per application ------------------		
SAND	1.21	1.75	0.50
SILT	1.28	2.06	1.92

The proportion of SAND and SILT down the radial distance from the pivot point varied depending on direction from the pivot point. The percent of SAND varied from 0 to about 80%. Overall, the field was 31% sand. Figure 4 shows the graph of the SAND distribution around the full 360 degrees of the circle.

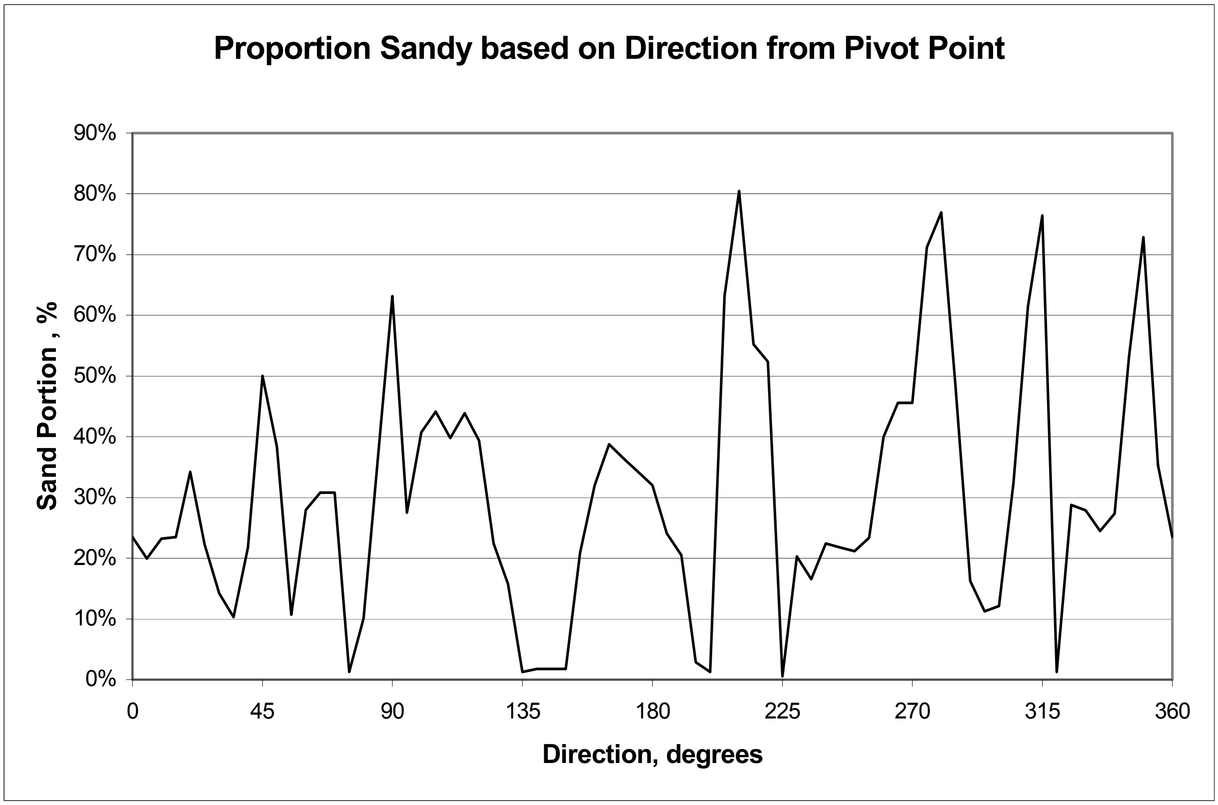


Fig. 4. The percentage of SAND in the pivot at various degrees of the compass.

The economic analysis was computed by assuming that the pivot could be operated for each crop in one of three ways:

1) Manage deficit/frequency by choosing a deficit that enhances yields and net returns for SAND soils
2) Manage deficit/frequency by choosing a deficit that enhances yields and net returns for SILT soils
3) Use a concept of precision irrigation where portions of the field would be managed based on which of the two deficit/frequency strategies provided highest net returns for that portion of the field.

Table 3 shows the results of the three strategies.

Table 3. Net returns from using the three possible irrigation management strategies on three separate crops.

Soil Type	Corn	Soybeans	Cotton
	------------------- $/acre -------------------		
SAND	$47.65	$46.19	$52.76
SILT	$47.62	$46.56	$82.25
Precision Irrigation	$47.67	$46.71	$84.68

CONCLUSIONS

Although the precision irrigation management strategy always produced the greatest amount of net profit, it must be pointed out that analysis did not include the added cost had the panel upgrade had to be purchased (around $2 to $3 per acre per year). In this case, only precision irrigation on cotton would be feasible. Assuming a $2.50 cost per acre per year for the upgrade, dollars would have been traded if the grower had been using the ideal deficit for silty soils (1.93 inches). However, if he had been using the ideal deficit for sandy soils (0.50 inches), then the precision irrigation strategy produced $29.42 per acre more net profit.

The driving factor in the economic feasibility of the panel up-grades as a means of precision irrigation is based on the difference in optimum net returns between the two soil types. In the case of corn and soybeans, the peak net return points for both soil types were very close to each other. In cotton, using the ideal deficit that produced the peak net return for the silty soils (1.92 inches per application) on the sandy soils caused a loss of $60.00 per acre on the sandy portions. Likewise, using the ideal deficit that produced the peak net return for sandy soils (0.50 inches per application) on the silty soils, likewise caused a net profit loss of about $60.00 per acre.

It is interesting to note that managing cotton by irrigating to the most vulnerable portion of the field (i.e., the sand), advice often given to producers, was not wise in this case.