Research of Current and Potential Subsurface Irrigation Methods for United States Department of Agriculture (USDA) Federal Crop Insurance Corporation (FCIC) Program

Final Research Report

Solicitation: RFQ1396983
July 24, 2020

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Overview

Introduction

AgriLogic Consulting, LLC (hereafter referred to as AgriLogic) has written the following report to address the objectives detailed in the United States Department of Agriculture (USDA) Risk Management Agency (RMA) Solicitation RFQ 1396983 - *Research of Current and Potential Limited and Subsurface Irrigation Methods for USDA Crop Insurance Program*.

Per the requirement of the Food, Conservation, and Energy Act of 2018 (2018 Farm Bill):

> ***The contractor shall research the feasibility of creating a separate irrigation practice for SDI including the establishment of a separate transitional yield within a county that is reflective of the average gain in productivity and yield associated with the installation of a subsurface drip irrigation system.***

During the solicitation process, a follow up question regarding the scope (area) and crops to be included in the report was asked. The contracting officer's response clarified that the scope was for cotton. Additional discussions with USDA further narrowed the scope of work to the eight counties surrounding Lubbock, Texas. Therefore, all subsequent research and analyses found in this report focuses on areas where irrigated cotton overlaps with ground water restrictions and where efficiencies of sub surface drip irrigation (SDI) are being studied by academic research personnel and utilized by producers in the Texas High Plains.

AgriLogic has worked with industry experts, producers, and state officials during the contract period to develop a comprehensive recommendation regarding the potential and perceived need for a separate practice (and potentially separate cotton T-yields) for the SDI production practice in the High Plains.

Background

For this report AgriLogic Consulting focused on the feasibility of creating a separate irrigation practice in the Texas High Plains where the SDI practice has been most widely adopted for cotton production. However, recommendations made in this study could also be applicable in similar areas where cotton is being grown with SDI in western Oklahoma and western Kansas. First, it is important to define the Texas High Plains as the area from roughly Midland, TX to the top of the Texas Panhandle as illustrated in Figure 1.

The Ogallala Aquifer is the largest in the United States (U.S.) and one of the largest in the world. It underlies eight states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming) and spans 111.8 million acres. From wheat and cows to corn and cotton, the regional economy depends almost exclusively on agriculture dependent on Ogallala groundwater. However, according to the Fourth National Climate Assessment, producers are extracting water faster than it is being replenished, which means that parts of the Ogallala Aquifer should be considered a nonrenewable resource. (California Agriculture, 2016)

The characteristics of the aquifer vary greatly in different parts of the region. The Ogallala Aquifer in Nebraska is deeper in its saturated thickness and recharges more readily than other areas such as western Kansas and Texas. According to the Texas Water Resource Institute at Texas A&M University, Texas and Kansas together have used close to 40 percent of the total water in the Ogallala Aquifer, as compared to Nebraska which has only used 1 percent (TWRI, 2018). The steep decline in parts of Texas has caused concern for some time as demonstrated in Figure 2, which shows a reduction in water levels of over 150 feet in many areas of the Texas High Plains between 1950 and 2015.

Figure 1. Texas High Plains

According to the United States Geological Society (Stanton et al., 2011), Texas has exhausted nearly 30 percent of its water allocation from the aquifer. On average, the aquifer in Texas is dropping at a rate of almost one foot per year. The most significant decline in the Ogallala in the Texas High Plains has been in the southern part of this region. The Texas Water Development Board (TWDB) provided funding for Texas Tech University to perform long-term research on the best ways to improve irrigation management and to evaluate the decline in the aquifer in an area covering 97,000 acres in Hale and Floyd counties. The study estimated the volume of water in storage was 1,748,630 acre-feet in January 2003 and declined to 1,329,740 acre-feet by January

2014. The rate of decline averaged 3.3 percent per year and the most significant drop was not surprisingly during the catastrophic drought of 2011; in fact, there were many anecdotal reports of the evapotranspiration rates off irrigated crops in specific days and areas surpassing the amount of water that could be added by the irrigation systems as a result of the severe conditions during that year.

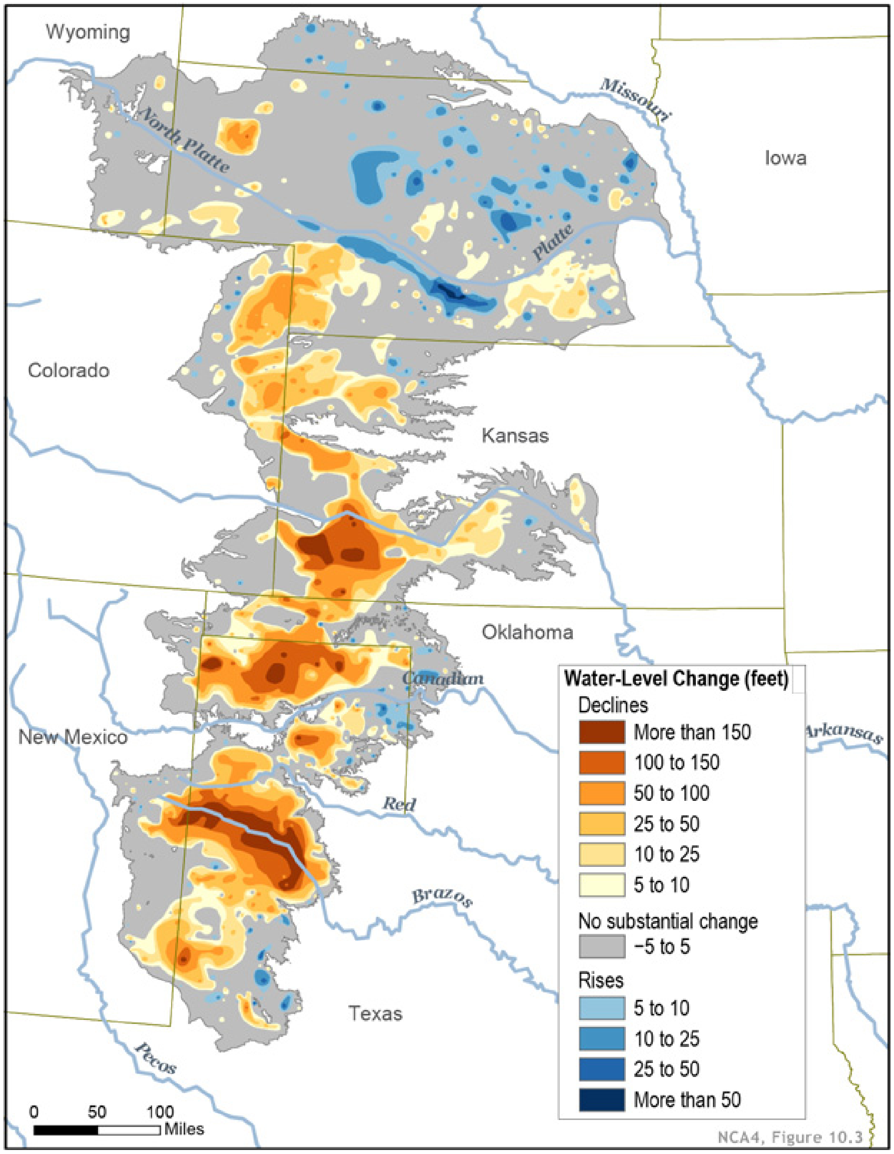

Figure 2. Water-level Changes in the Ogallala Aquifer, 1950-2015

Source: United States Geological Survey, 2020

The Texas Field Office of the USDA National Agricultural Statistics Service (NASS) provides data for two crop reporting districts (CRDs) that are most relevant to this study, the Northern High Plains - District 11 (red) and Southern High Plains – District 12 (blue) as illustrated in Figure 3.

Cotton is king in the Texas High Plains. NASS reports there were 7 million planted acres of cotton resulting in 6.4 million bales of production in 2019. Of that total, the Texas High Plains accounts for 63% of the planted acres and 51% of the total production, making this area the dominant cotton-producing area in the state. The Southern High Plains reported 2.3 million bales from 3.1 million planted acres while the Northern High Plains produced 940,000 bales on 1.3 million acres.

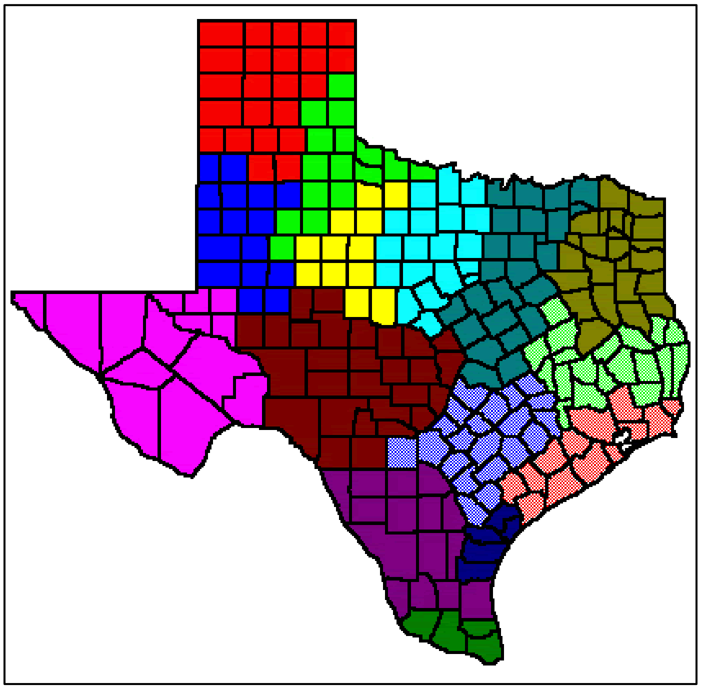

Figure 3. TASS Crop Reporting Districts (CRDs)
Source: USDA NASS, Texas Field Office, 2020

While the Southern High Plains region remains, the primary cotton producing region in Texas, there has also been a notable increase in cotton production in recent years in the Northern High Plains. The migration of cotton north has been a result of improved cotton varieties for the northern areas and ongoing water restrictions which have caused producers in these areas to seek more drought tolerant crop alternatives. Dr. Jourdan Bell, Texas A&M agronomist in Amarillo, observed that in the last five years cotton acreage in the 22 northernmost counties of the Texas High Plains has almost tripled. In 2013, producers in this area planted 300,000 acres of cotton which increased to 850,000 acres by 2018. Of that 550,000-acre increase, 350,000 acres have been north of Amarillo. Producers applied supplemental irrigation to less than a third of the cotton acres in 2013, and by 2018 nearly half of the acreage was being irrigated. Sixty percent of the farms south of Lubbock remain in dryland production.

SDI Adoption and Water Efficiency Comparisons

Our first objective was to develop an in-depth understanding of 1) the extent that SDI irrigation is being utilized in the Texas High Plains on cotton, and 2) the benefits of SDI in terms of yield and water use efficiency. This task was carried out by:

1) Reviewing published literature from credible sources on SDI;
2) Consulting with extension offices/universities that have researched SDI;
3) Collecting all available data from commercial agricultural scale field-level trials comparing yields of SDI to other common irrigation methods in the region;
4) Conducting listening sessions with producers, water officials and industry experts.

The objective in evaluating the feasibility of a separate irrigation practice for SDI is to enable growers to obtain a more representative guarantee for their acreage when they transition from an alternative irrigation practice to SDI. The critical questions that must be addressed are:

1) Is cotton yield performance for SDI statistically different enough from other commonly used irrigation methods in the region to merit segregation of the alternative irrigation production practices? This could lead to the potential of establishing alternative T-yields for the irrigation practices.
2) Is there significantly different risk presented by the SDI irrigation method compared to other commonly used methods (e.g. Low Energy Precision Application (LEPA)) in the region? This could lead to the establishment of different premium rates for the production practice.
3) Do irrigated cotton T-yields in the Texas High Plains appropriately represent actual producer performance, who are using advanced irrigation methods?

The first two questions address whether there is a need to establish a separate SDI production practice in the crop insurance programs for cotton. The final question addresses if there is just a need for a more rigorous update of yield expectations for irrigated yields for the areas in question.

SDI Adoption in the High Plains

The decline in the Ogallala aquifer has motivated scientists and irrigation engineers to develop new types of irrigation with improved efficiency compared to furrow irrigation, a type of flood irrigation. Furrow irrigation was the dominant type of irrigation in the Texas High Plains until 1994, with only an approximate 60% water application efficiency, at which time center pivot sprinkler irrigation overtook flood irrigation in utilization (Evett, et al, 2014; Amosson, et al, 2011). The center pivot was recognized in a 1976 Scientific American article which called the center pivot irrigation "perhaps the most significant mechanical innovation in agriculture since the replacement of draft animals by the tractor" (California Agriculture, 2016). That is quite a statement, but there is no doubt that center pivot irrigation had an enormous impact on agriculture in the Texas High Plains. The early center pivots were an improvement over furrow irrigation in many respects, but their use can also result in significant loss to evaporation, especially with the early high pressure high-elevation nozzle styles. The next step in center pivot development was the introduction of the mid-elevation spray application (MESA) center pivots, which improved application efficiency to 78% while the low-elevation spray application (LESA[1]) continued the improvement to a mean 88% efficiency (Amosson, et al, 2011). Bill Lyle, a Texas A&M University agricultural engineer, is credited with pioneering the next major irrigation revolution by developing the low energy precision application (LEPA) system. It was so named because it used lower pressure and less energy than the traditional center pivot systems. LEPA type systems have continued to improve since that time, partly by lowering the droplines to reduce evaporation that has resulted in a 95% water application efficiency (Amosson, et al, 2011). Currently, approximately 80 percent of the producers in the Texas High Plains use center pivot systems with LEPA being one of the more advanced systems (Porter, 2020). LEPA is well suited to the high plains region with large fields that allow the use of extended pivots which reduces producer cost on a per acre basis (Porter, 2020). However, it is not an ideal application method for all situations as soil type, producer's equipment capabilities (e.g. precision planting equipment, furrow diking, and application equipment to farm in a circular pattern, etc.), that lead a mixtures of systems being more preferable in different applications (Sides, 2020).

The next innovation in water application efficiency for specific applications is SDI with a mean water application efficiency of approximately 97%. SDI is only marginally more efficient compared to LEPA and other newer pivot type systems; moreover, it requires a significantly greater investment to install. SDI also requires a higher level of management to utilize its full capabilities. SDI is currently on approximately 18%[2] of irrigated acreage in the Texas High Plains region, which is a relatively minor percentage of the irrigated cotton acres in the region currently, but its adoption rate has been steadily rising. SDI started catching on in commercial agriculture in the 1980s, and initially on high-value fruit, vegetable and orchard crops. Cotton was one of the first large scale row crops to begin to make extensive use of SDI. SDI is gaining in popularity, especially in areas with limited irrigation well capacities and where water application efficiency is paramount, a common problem particularly in the southern part of the High Plains. SDI also works well on small or irregularly shaped fields not well suited for pivots where a relatively small percentage of it can be cost effectively irrigated.

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[1] A subset of the LESA classification which is very popular in the Texas High Plains is the low pressure in canopy (LPIC) system that was noted by the USDA Natural Resource Conservation Service (NRCS) as being one of the most popular systems they fund through the EQIP program. It is estimated by Keith Sides, the NRCS Texas State Irrigation Engineer that there is an even split between traditional LESA and LPIC systems in the classification given their worked with Texas producers (Sides, 2020). The water use efficiency is estimated as being the same for the LESA and LPIC systems by the Texas Water Development Board hence suggesting the LPIC is a sub-classification of the LESA category (TWDC, 2013).

[2] The 18% SDI assumption is the average of the SDI acreage reported by Sosebee and Dr. Porter of 600,000 acres times 85% (an average of the 90% estimate from Sosebee and the 80% estimate from Porter) in the high plains divided by the 2,912,500 irrigated acreage reported by USDA NASS for the Texas High Plains in 2018 for cotton, corn, and sorghum irrigated acreage combined.

One of the impediments of SDI adoption is the cost to install the system, particularly for cotton in tight market conditions as the industry is currently experiencing. According to an article in the American Society of Farm Managers and Ranch Appraisers, a LEPA system cost approximately $600 per acre for a quarter mile machine, while a typical SDI system costs approximately $1,200 per acre for the equipment not counting the cost of the well or pump (Guerrero, et al, 2016; DuBois, 2020). (The LEPA per acre cost advantage over SDI increases as the field size increases.) The study concludes that savings in pumping costs by themselves are not enough to off-set the increase in the investment cost of SDI compared to LEPA. However, when the potential for yield increases as well as reduced pumping costs are factored into the analysis, the total benefits may be enough over time to justify the additional cost of SDI.

It is estimated that between 500,000 to 700,000 acres in Texas are irrigated with SDI, and approximately 85%[3] of those acres, which equates to approximately 510,000 acres assuming the mean of this range, are in the High Plains (Sosebee, 2020). There are significant differences in cotton production and irrigation practices between the Southern and Northern High Plains. For the Southern High Plains, cotton is generally planted continuously year after year without rotating to other crops, in part because cotton uses less water than some other crops including corn. Another reason the producers in this area do continuous cotton is because of the sizable investment they have in the equipment necessary to be a competitive cotton producer. Conversion of some or even all of a producer's acreage to dryland production is also common in this area. The availability of an adequate amount of water is generally more important in determining potential yields than the type of irrigation system used to produce the cotton.

According to Dr. Jourdan Bell, the northern area has a shorter growing season that is being addressed by new cotton varieties. Producers are also becoming more concerned about their water situation and since cotton requires less water than corn, a rotation between the two is becoming more common. Dr. Bell noted that corn in this region requires about 24 to 30 inches of total water (irrigation and rainfall) while cotton only uses 12 to 24 inches in a typical year to make a crop. As noted earlier, SDI is not as common in this area as it is further south. SDI does have benefits over LEPA and other alternatives in certain areas but there are certainly challenges that the practice presents as well with a special emphasis on seed germination and emergence in dry years at planting. It is much more challenging to "water the crop up" with SDI, if the soil moisture is inadequate for germination without irrigation. This is particularly the case on soil types with high concentrations of sand.

It must be concluded then that many producers are finding that SDI has enough benefits to justify the higher initial investment. In summary, there is no question that SDI is a proven irrigation practice for cotton production in this region and it should be expected that the adoption of SDI will continue to increase over time.

[3] Dr. Porter suggested 80% of SDI was in the Texas High Plains but she deferred to Sosebee to have the most accurate information as they are the principle manufacturer of the technology (Porter, 2020).

SDI vs. Center Pivot Irrigation System Performance

Benefits of SDI are described in scientific literature, but it is also useful to learn about producers' perspectives of SDI and the anecdotal evidence associated with their observations. The following section highlights several stories from farmers about their experiences with SDI:

- *Jamey Duesterhaus, Lamb County - Farms 1,900 acres of mostly minimum-till cotton. 260 of the 500 irrigated acres of cotton are on SDI. He likes that he can directly spoon feed the root zone with nitrogen and zinc and have less evaporation. In 2015 he produced 2,340 pounds per acre on a 60-acre field. (Cotton Farming, 2016)*
- *Jeffrey Kitten, Lubbock - Kitten says the biggest factor in his excellent yields are because of the way SDI allows him to apply fertilizer. This improved method of feeding nutrients to cotton makes it possible to generate some phenomenal yields. In 2013 their drip fields produced more than 4 bales per acre (each bale is 500 pounds) and some even made 5 bales. (Wolfshohl, 2014)*
- *Glenn Schur and son Layton, Hale County - Installed 60 acres of SDI on some of their best land but it had "weak water." In 2018 he planted at the beginning of May and replanted at the end of May and the cotton yielded about 3 bales per acre. (Huguley, 2019)*

A 2016 article in MyFarmLife.com summed up the comparison of SDI and LEPA and raises the question of whether SDI saves water in field crops. The answer, it turns out, is complicated. Ricky James, a producer in the Plainview area, said water scarcity is the biggest issue. He stated that they must "work at it to get water out of the wells compared to times past when water was under pressure and it flowed more freely". He stated that today the water situation is very different, "The water is just not as clean as before and can cause emitters to become clogged." Also mentioned in the article was a field trial on Eddie Teeter's farm 65 miles north of Lubbock that was designed by Rick Kellison, project manager for the Texas Alliance for Water Conservation at Texas Tech University. The experiment involved six different fields with three on SDI and the other three on LEPA with bubblers (a feature in some of the newer pivots). The conclusion of this test was that SDI did not save much water, but Teeter was able to water more acres with about the same amount of water.

In addition to the above examples, a review of the literature on SDI summarizes some of the benefits of SDI compared to LEPA which are:

- Potential for higher yields
- Works well with lower capacity wells (system can be designed with multiple zones to accommodate low well capacity)
- Less water lost to evaporation and runoff
- More uniform application of water over entire field
- Ability to place water and the fertilizer directly into the root zone and do so frequently
- Fewer weed seeds germinate because the soil is dry
- Other farming operations can take place concurrently because the irrigation system is underground

- Corners of the field can be irrigated
- Not difficult to install in irregularly shaped fields

SDI systems have many benefits, but also have some issues. Potential problems include clogging of emitters, rodent damage, and obtaining seed germination if there is limited rainfall at planting time. The ability to overcome germination challenges depend partly on soil type. There are likely to be more problems getting a good stand with coarse soils (i.e. higher sand content) because they have less water holding capacity and as a result less of a tendency to wick moisture up to the seed bed. Mitigation steps include changing the spacing and depth of the driplines (i.e. 40 inches apart instead of 80 inches) as well as installing the driplines shallower (e.g. 10 inches deep rather than 14 inches). SDI systems are also not portable like pivot systems; as a result, landlords are sometimes less likely to support the installation of SDI.

Dr. Freddie Lamm of Kansas State University, a recognized authority on drip irrigation, observed the most critical thing to remember about SDI or any system is the importance of proper management. When the management of the system is lacking, new irrigation efficiency can be just as inefficient as it is with older technology. Proper management of the SDI system is key as well as for it to be installed in the proper application (e.g. soil type is certainly a consideration) for it to offer any improvement over the older technology. (Texas H20, 2018)

Greg Sokora, NRCS Zone Engineer for the Texas Panhandle, provides a good summary of the potential advantages of SDI by stating that, if properly managed, SDI irrigation on cotton can provide a yield advantage over other types of irrigation systems due to the crop response to daily irrigation and micro-nutrient application. (Terry, undated)

Table 1 provides a general comparison between furrow, SDI and several versions of center pivot irrigation systems. As can be observed from the data, the application efficiency of SDI is approximately 2% higher than that of LEPA and significantly higher than that of the other irrigation systems listed, which further confirms that SDI does result in greater water use efficiency overall when compared to center pivot systems.

Table 1. Basic Assumptions for Five Irrigation Distribution Systems (Amosson, et al, 2011)

Irrigation system	Operating Pressure (psi)[1]	Application Efficiency (%)	Efficiency Index	Acres Irrigated
Furrow	10	60	1.47	160
Mid-elevation spray application (MESA)	25	78	1.13	125
Low elevation spray application (LESA)	15	88	1.00	125
Low energy precision application (LEPA)	15	95	0.93	125
Subsurface drip irrigation (SDI)	15	97	0.91	160
1psi = pounds of pressure per square inch of water				

Source: Texas A&M System AgriLife Extension, Economics of Irrigation Systems, B_6113, October 2011

TX Cotton Yields with Alternative Irrigation Systems (SDI, LEPA, etc.)

Mean Yield of Cotton on SDI vs. Other Common Irrigation Systems

In addressing the principle question, “Is cotton yield performance for SDI statistically different enough from other commonly used irrigation methods in the region to merit establishment of a separate irrigation production practice?” several studies that have been conducted in the region were considered.

The first study reviewed was conducted by the Texas Alliance for Water Conservation (TAWC), which collected data for cotton yields and irrigation efficiencies in Floyd and Hale counties. The data was collected on the primary irrigation systems utilized in the region from multiple farm fields between 2005 and 2013. The results are presented in Table 2 (TAWC, 2015). The cumulative results across all years of the study suggests cotton yields from the SDI systems were 16% higher than LEPA and approximately 29% higher than other types of center pivot irrigation systems used in the region. The total water consumed was higher on SDI in this study than the other alternative methods. Total water (both precipitation and irrigation) consumption must be the metric of comparison as that is what it took to make the crop. However, the water use efficiency was certainly improved with the SDI method over alternative methods.

Table 2. Cotton Yields and Water Efficiency by Irrigation Technology, 2005-2013 (TAWC, 2015)[4]

Irrigation Technology	**Number of site-years**	**Irrigation applied** (in)	**Total Water** (in)	**Lint Yield** (lbs./ac)	**Irrigation Efficiency** (lbs./ac-in)	**Total Water Efficiency** (lbs./ac-in)
Subsurface drip irrigation (SDI)	32	15.9	24.5	1,642	125	69
Low energy precision application (LEPA)	37	15.4	23.7	1,415	109	61
Spray (MESA & LESA)	79	12.8	20.1	1,268	122	66
Furrow	27	14.4	23.1	1,059	96	47

Source: Texas Alliance for Water Conservation, Texas Tech, An Integrated Approach to Water Conservation for Agriculture in the Texas Southern High Plains, April 20, 2015

The TAWC study was expanded in 2015 to cover six additional counties in the Texas High Plains and is still ongoing. With the inclusion of the expanded counties, the current comparison of irrigated cotton yields under the SDI and the array of center pivot irrigated practices (i.e. MESA, LESA, LEPA) does not demonstrate as dominant of a position for the SDI relative to the other more advanced center pivot alternatives. The probability distribution of annual observations were estimated from a data set obtained from TAWC from the 2005 to 2018 period and is presented in Figure 4. The mean yield advantage of the SDI over the center pivot irrigated alternatives has decreased to only approximately 4% as compared to the more than 16% yield advantage suggested by earlier studies. The distribution of those annual observations both above and below the mean SDI Yield Relative to the Center Pivot yield in the same year is demonstrated in Figure 4. The results are not consistently above the alternative methods as demonstrated by the distribution of actual observations.

[4] This table presents the exact numbers as reported in Table 5 of the TAWC 2015 Final Report for Phase 1 of their project. In evaluating the information, it was not possible to arrive at the exact values the study reported in the "Irrigation Efficiency" and "Total Water Efficiency" columns yet the relationship between the SDI and other irrigation alternatives remained consistent. Therefore, the values were reported as published in the original document as there was potentially information that they had in their raw data which had not been fully conveyed in the summary format that was published. Despite the discrepancies identified, it did not modify our conclusions.

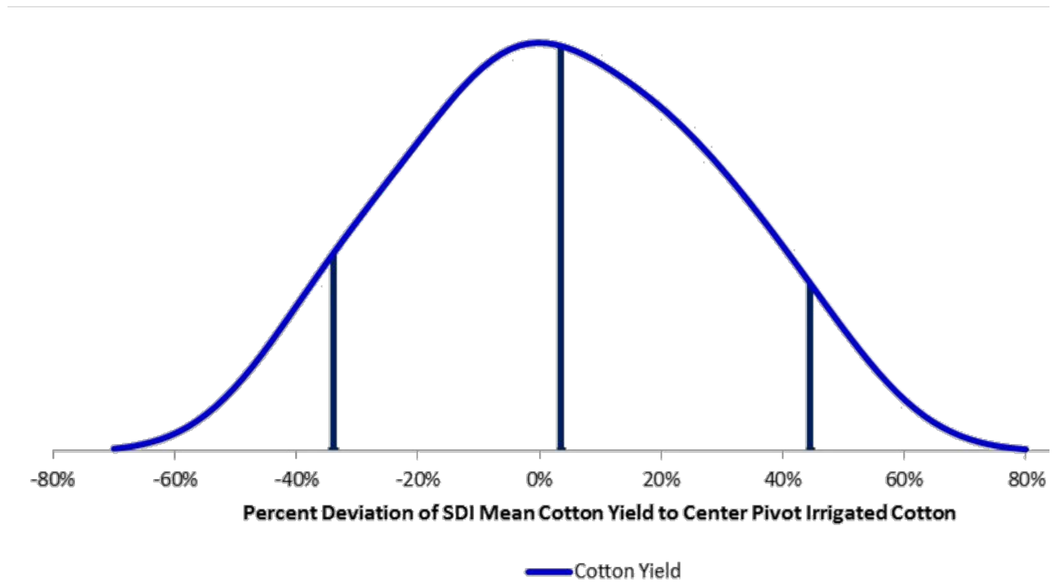
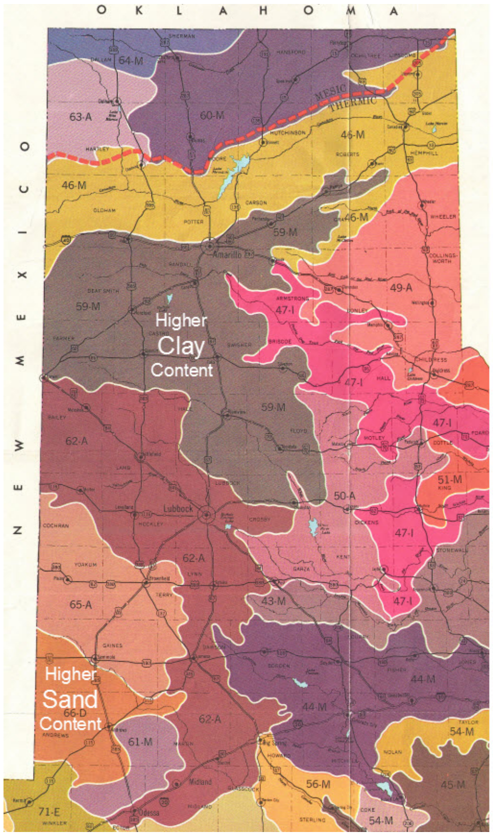


Figure 4. Probability Distribution Function (PDF) of SDI Annual Mean Cotton Yield Relative to Center Pivot Irrigated Cotton (2005 to 2018) Based on TAWC Observations

In evaluating this information, it is beneficial to understand the distribution of the irrigation methods represented by the data, particularly the center pivot category that SDI is compared to in Figure 4. The irrigated acreage represented by the TAWC study as of 2018 comprises approximately 2% furrow, 19% MESA, 43% LESA, 22% LEPA and 13% SDI. This distribution is not an ideal representation of the Texas High Plains but is generally representative of the principle areas of focus. A rough estimate of the pivot irrigated acreage in the Texas High Plains overall is approximately 80% (Porter, 2020); therefore, the distribution presented by this study is not that dissimilar from the overall expectations.

The concentration of different irrigation systems varies across the Texas High Plains. In the northern portion of the Texas panhandle, north of Amarillo, the North Plains Groundwater Conservation District (NPGCD) contains very little SDI. The estimates from the Master Irrigator NPGCD program from 2016 to 2019 includes approximately 263,000 acres of irrigation which were considered a good cross section of the farmers in the region with MESA systems representing 9%, LESA 58%, LEPA 32%, furrow 0.1%, and SDI 1.3% of the irrigated acreage (Amosson, 2020). Hence SDI was a very minor player in the northern portion of the Texas Panhandle. As you examine the southern portions of the plains where soils have a higher sand content, such as in Gaines, Terry and Yoakum Counties, the SDI production practice has experienced limited success. Western Peanut Growers funded a research farm in the mid 1990's for a period of five years that was run by Texas A&M and Texas Tech University researchers. The conclusion was the inability to push adequate amounts of water to the root zone in soils with high sand contents and that SDI was not workable on peanuts; further only limited success was experienced with cotton at the time. As a result, the MESA and LESA systems still comprise most of the irrigated acreage in the region with the remainder being LEPA systems. In examining a soil map of the high plains, the areas where SDI has been most successful are those where the soils have a lower concentration of sand and a higher concentration of clay.



NEARLY LEVEL SOILS OF THE HIGH PLAINS

MOLLISOLS, ALFISOLS, ENTISOLS, ARIDISOLS

Map Symbols for Soil Associations		Approximate Acreage
	Mostly soils with loamy surface layers and clayey subsoils; some soils with indurated to powdery lime within 20 inches of the surface:	
	Paleustolls[a], Calciustolls[b]	
59-M	Pullman[a]-Olton[a]-Mansker[a]	6,000,000
60-M	Sherm[a]-Gruver[a]-Sunray[a]	2,650,000
61-M	Kimbrough[b]-Slaughter[a]	550,000
	Soils mostly loamy throughout with lime accumulation in the subsoil, some with clayey subsoils:	
	Paleustalfs[a], Paleustolls[b]	
62-A	Amarillo[a]-Acuff[b]-Mansker[b]	5,200,000
63-A	Dallam[a]-Sunray[b]-Dumas[b]	1,000,000
64-M	Sunray[b]-Conlen[b]-Gruver[b]	600,000
	Soils with sandy surface layers and loamy subsoils; and soils sandy throughout:	
	Paleustalfs[a], Ustipsamments[b]	
65-A	Patricia[a]-Brownfield[a]-Tivoli[b]	2,000,000
	Usually dry soils with sandy surface layers and loamy subsoils; and usually dry soils sandy throughout:	
	Haplargids[a], Torripsamments[b]	
66-D	Triomas[a]-Jalmar[a]-Penwell[b]	1,400,000
	Total	19,400,000

Figure 5. Excerpt of Texas High Plains from Texas Agricultural Experiment Station, Texas A&M University, General Soil Map of Texas 1973 (Godfrey, et al, 1973)

One such area is the region surrounding Plainview, Texas stretching down toward Lubbock. One of the most extensive scientifically rigorous studies on the performance of SDI relative to some of the more advanced center pivot systems has been conducted at the Helms Research Farm, located in Halfway, TX. The lead scientist for this study was Dr. Jim Bordovsky, agricultural engineer with Texas A&M AgriLife Research. The research objective was to compare yields and irrigation quantities from farm scale cotton production irrigated by SDI and LEPA. Helms Research Farm has many advantages to perform this type of research in that it provides a controlled environment and offers side by side comparisons of the two technologies. Data was collected from 2002 to 2012 (Bordovsky, et al, 2009; Bordovsky, et al, 2013). Results are shown in Table 3.

SDI yields averaged 1,281 pounds per acre, approximately 25% higher than the 1,023 pounds per acre produced on the LEPA system. The higher yield performance on SDI is not surprising given the farm is comprised of deep clay loam and silty clay loam soils (Bordovsky, et al, 2013). In the report Dr. Bordovsky observes that from various experiments, SDI yields ranged from zero to 2,400 pounds per acre. LEPA yields ranged from 200 to 2,000 pounds per acre. The wide range illustrates the variability of cotton yields in the High Plains particularly with the alternative production systems.

Table 3. Helms Farm Report – Cotton Yield and Irrigation Delivered by SDI and LEPA, 2002-2012

	Subsurface drip irrigation (SDI)			Low energy precision application (LEPA)		
Year	**Area (acres)**	**Total Irrigation (ac-in/ac)**	**Yield**	**Area (acres)**	**Total Irrigation (ac-in/ac)**	**Yield**
2002	71	18.47	1,127	84	15.71	1,209
2003	71	14.95	1,086	103	12.86	1,084
2004	71	14	1,500	103	10.00	1,100
2005	53.6	10.86	1,041	60	3.05	828
2006	71	17.33	1,566	100	16.73	1,537
2007	55.3	8.95	1,642	104	8.06	1,232
2008	71.3	18.13	1,335	93	15.13	909
2009	67.1	16.6	1,386	93	12.80	1,013
2010	Not Available[5]					
2011	83.0	22.14	1,016	68	16.00	467
2012	75.76	19.81	1,114	75	15.20	850
Average		**16.12**	**1,281**		**12.55**	**1,023**

Source: Bordovsky & Nesmith, 2009; Bordovsky, et al, 2013

The research study presented the irrigation water applied relative to the crop year under the alternative methods. When that information is plotted in a raw format as demonstrated in Figure 6 with lint yields on the vertical axis and irrigation water on the horizontal axis, the relationship is not properly characterized. One must consider the precipitation that the field received during the season to understand yield performance under the alternative irrigation practices. For this analysis the precipitation during the March to October time period from the NOAA NCDC CONUS

[5] The data for 2010 was not published by the research farm. An inquiry as to why the data was missing and the researcher's response was something had occurred beyond the evaluation parameters in the study design for the year that caused them to not include the data in their reports (Bordovsky, 2020). This could have been an event like a hailstorm that negated the quality of the data for the crop year.

gridded dataset was utilized (NCDC, 2020). The results of that analysis are presented in Figure 7. The clear consistent advantage for SDI over LEPA is demonstrated in the figure from a total water applied perspective.

However, to take the analysis a step further you must consider what moisture is available to the crop. It is common with natural precipitation events for there to be considerable runoff when the amount exceeds a given threshold. To account for the infiltration rate of precipitation events into the soil profile a capping mechanism for the daily precipitation observations was established. This enabled an estimate of the precipitation that could be utilized by the crop for each event. To conduct the analysis, an infiltration factor of 7.5 mm per hour for clay and 25 mm per hour for sand was utilized in conjunction with the clay and sand compositions of the soil in the area. The duration of precipitation events and its interaction with the daily infiltration rates was assumed to be 1 hour for this evaluation. The result of the analysis is presented in Figure 8. The expected relationship between total available moisture to the crop and yield is demonstrated in the figure with the advantage of SDI being highlighted as years in which lower levels of precipitation are experienced after seed emergence which produces a more consistent yield expectation. This was particularly the case for a year like 2011.

Ultimately, the yield differential between the two systems is contingent on the percentage of water delivered by irrigation relative to available rainfall and soil moisture. The improved water use efficiency for SDI is optimal when irrigation represents in excess of 50% of total water availability after the crop has emerged from the soil. This is most notable in 2011 when irrigation made up between 58% to 65% of the total water availability (on a daily capped basis accounting for infiltration rates of approximately 76% and 70% respectively) for SDI and LEPA respectively, as depicted in Figure 9, and when evapotranspiration (ET) rates were extreme during the growing season.

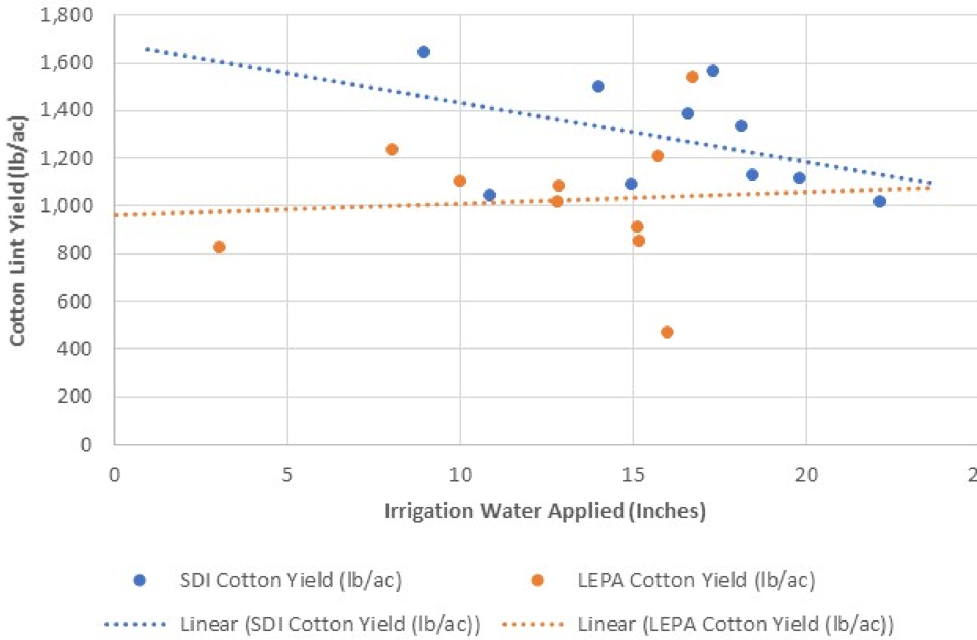


Figure 6. Inches of Irrigation Water Applied and Resulting Yields, SDI vs. LEPA

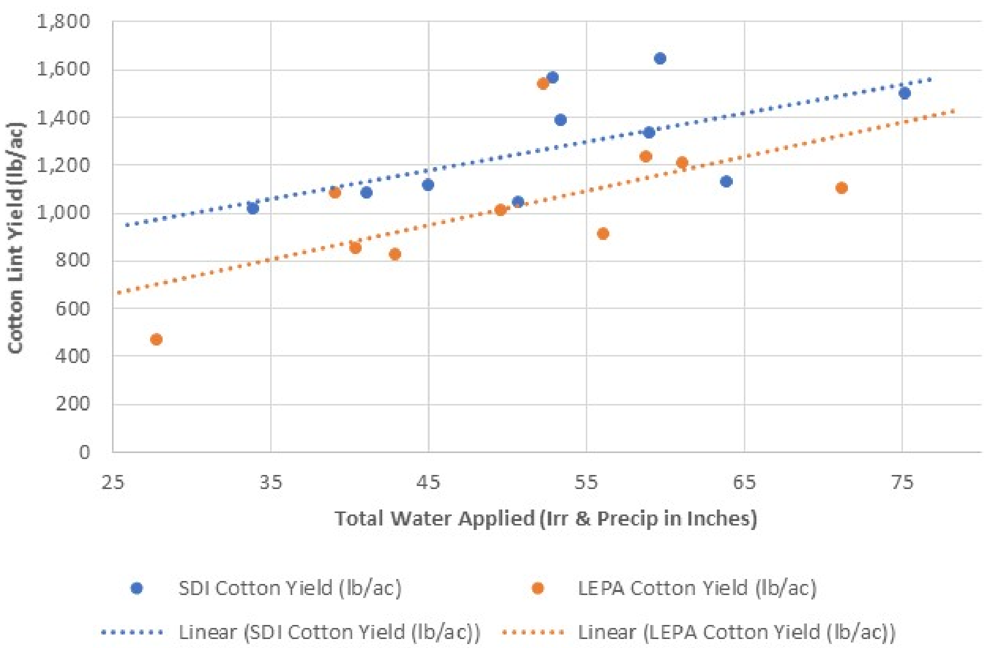


Figure 7. Total Water Applied (Irrigation & Precipitation of March – October) SDI vs. LEPA Cotton Yields

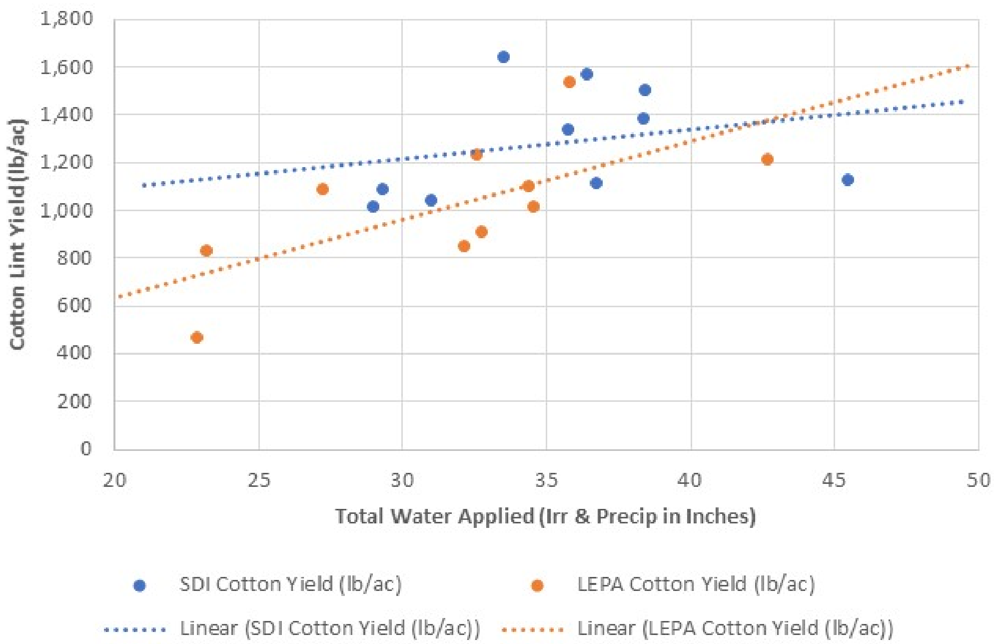


Figure 8. Total Water Applied (Irrigation & Precipitation of March – October with Mean Storm Duration Assumed of 1 hr. for Infiltration Purposes) SDI vs. LEPA Cotton Yields

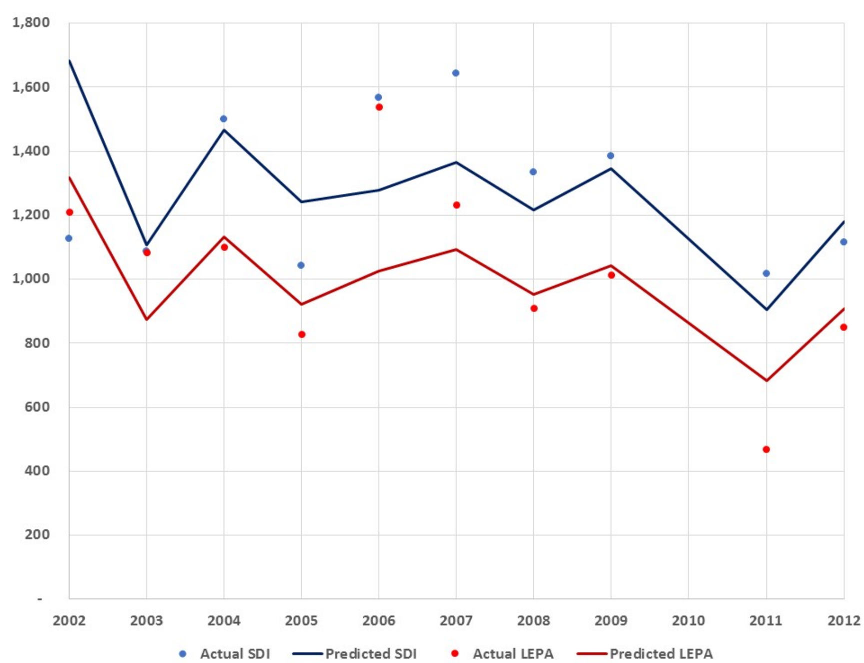


Figure 9. Actual and Predicted Yields – SDI vs. LEPA 2002 - 2012

The conclusion of the analysis is the SDI systems do provide advantages over other types of irrigation in specific situations including those areas where soil contents have a higher concentration of clay and in years where ET rates are high. SDI also has an advantage where well capacities are low and if the field is small or has an irregular shape. However, it does not offer a distinct advantage in all applications as demonstrated by the TAWC study which considered a broader view of soil compositions, variations in management intensity by producers, and other factors common to commercial scale operations. This is particularly the case in years where there is inadequate moisture to germinate the seeds for establishing the crop and in those areas with soils comprised of higher compositions of sand.

When the broader range of applications are considered (particularly when SDI is compared to LEPA) the water application efficiency is not significantly greater (for SDI of 97% versus 95% for LEPA) (Amosson, et al., 2011). When SDI is considered relative to other types of commonly used irrigation such as MESA and LESA that comprise most of the irrigated acreage in the Texas High Plains, SDI does offer a significant advantage in several applications with 78% water application efficiency for MESA and 88% for LESA. The water application efficiency between alternative center pivot systems is further complicated when you consider that some LEPA machines have bubble emitters that can be adjusted to function as sprinkler emitter, thereby operating more as a LESA system for getting seed emergence at planting (Brown, 2020). This blurs the lines between some systems, leading to the current structure of crop insurance practices in the region that classifies all irrigated cotton into one practice irrespective of the system utilized.

In conclusion, when you consider SDI versus center pivot style systems in a broad range of commercial scale applications, which is more reflective of potential insureds than a purely research trial would be, the mean advantage across the board for SDI is not evident. It is instead driven more by the specific circumstances of soil types and management practices than the irrigation method.

COTTON YIELD VARIABILITY WITH SDI VS. OTHER COMMON IRRIGATION SYSTEMS

To address the second question, as to SDI's impact on cotton yield variability that would translate into the premium rate appropriate for characterizing the risk of extending crop insurance coverage to the crop, the yield data from the TAWC and Helms farm studies were once again considered. The mean yield for the SDI production practice was calculated and the percent deviation of each annual yield observation from the mean was determined. The process was repeated for the center pivot data series comprised of MESA, LESA, and LEPA systems. The results of those calculations are presented as a probability distribution functions (PDF) of cotton yields from the TAWC study from 2005 to 2018 in Figure 10 and from the Helms Farm study from 2002 to 2012 in Figure 11.

The figures suggest that the distributions of yields are recognizably different between SDI and other irrigated production practices. The left tail of the distributions (i.e. 85% and less) is of the most interest from rating perspective suggesting that the corresponding premium rates for the irrigation practice would diverge from the other common irrigation methods. It is suspected that a significant portion of this could be attributed to farmers learning how to effectively manage the SDI practice in the TAWC data as it is not a controlled research study but, instead more reflective of commercial operations. Despite those limitations the similarity to the pdfs estimated for the Helms Farm which was a controlled research study suggests that the relationship is likely valid and representative of actual expectations.

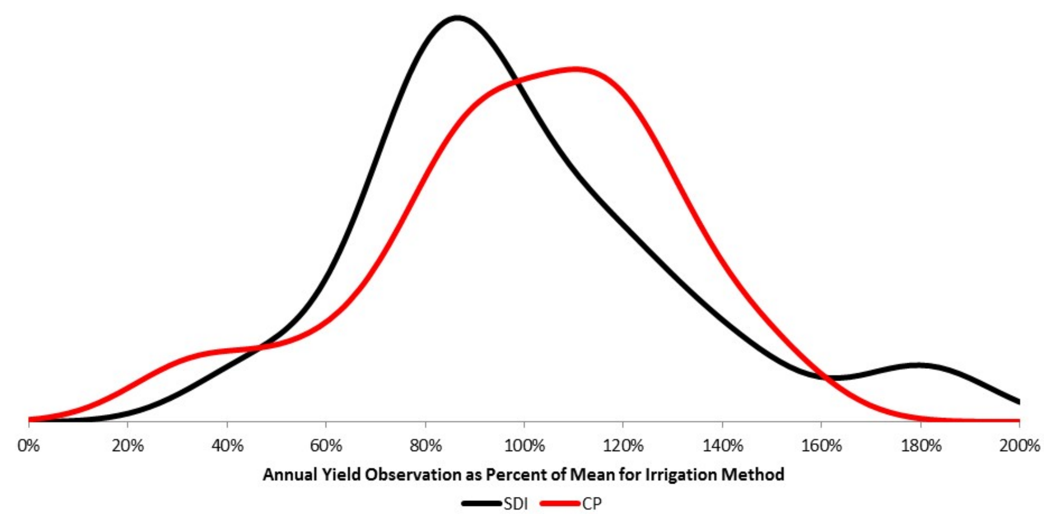


Figure 10. Probability Distribution Function (PDF) of Cotton Yields from the Mean Irrigation System Observed Yields TAWC from 2005-2018 for SDI and Center Pivot Systems

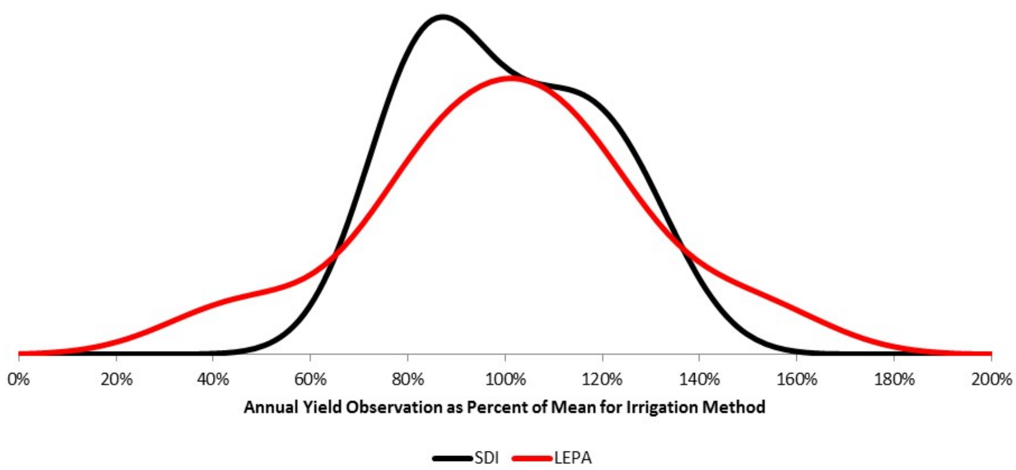


Figure 11. Probability Distribution Function (PDF) of Cotton Yields from the Mean Irrigation System Observed Yields Helms Farm from 2002-2012 for SDI and Center Pivot Systems

The understanding of the distribution characteristics of SDI versus other irrigation practices is different yet there are likely an array of distributional characteristics included in the other irrigation practices with furrow, MESA, LESA, and LEPA, which comprise the current population of irrigated insurance experience in each county. With this consideration the continuous rating methodology can likely be fine-tuned over time to account fluctuations in distributional characteristics for SDI along with the other irrigated production practices.

USDA RMA T-Yields vs. County Average NASS and RMA Annual Data

There were comments received during our evaluation that irrigated T-Yields in some counties were not entirely representative of actual expectations in the locations. Therefore, an evaluation of the irrigated T-yields on cotton in the Texas High Plains was conducted. The objective of the analysis was to determine if the T-yields were generally representative of irrigated cotton producer yields for the practice and if those farmers who were utilizing advanced irrigation methods were properly represented.

T-yields may be necessary to fill in the gaps when a producer is seeking insurance but does not yet have the minimum required four years of yield history to establish an initial yield guarantee. For example, if a producer is growing irrigated cotton for the first time in a county, he would have multiple options[6] with the most common being the use of T-yields. T-yields can be used to establish an initial yield guarantee for the first four years until he accumulates enough of his own

[6] The T-yields may not apply if the insured is farming the insured acreage on a share basis with another insured who has yield history for the production practice in the county or could use the yield history established by the person who farmed the land previously if they had participated in the management and physical activities of the operation.

experience for the crop and production practice in the county. T-yields are used to complete four years of data in the following manner:

- No actual record available, use 65% of T-yield for all 4 years
- One year of actual record, use 80% of T-yield for remaining 3 years
- Two years of records, use 90% of T-yield for remaining 2 years
- Three years of records, use 100% of T-yield for one missing year

If the insured qualifies as a new producer, he can use 100% of the T-yields for the years without actual yields.

In the Northern High Plains, most producers have predominately grown corn on their irrigated acreage historically but recently have begun to rotate cotton into their operations. This is due to the more limited water availability which has incentivized them to consider more drought tolerant crops. As a result, better cotton varieties have been developed for the region and infrastructure has begun to be established making cotton a feasible alternative for more producers. One such example of the infrastructure in development is the Adobe Walls Gin in Spearman, Texas. It is now recognized as the largest gin in the country and is expected to process approximately 400,000 bales annually (Boyd, 2019).

An evaluation of the T-yields was conducted on a county and practice-specific basis. The aggregate view of that information is presented in Figure 12 and Figure 13 for the Southern and Northern High Plains, respectively. The columns represent the annual USDA NASS yield observations, while the blue line series represents the mean USDA RMA T-yield for the region and year. The 10-year moving average yield, with a lag year to account for the information that would be available when the T-yield is published annually, was calculated both for NASS (represented by the yellow line series) and the RMA[7] annual actual yield observation data sets. The result of that analysis suggests that for the overall irrigated production practice the T-yields do tend to lag the NASS observations. However, since the NASS observations are the function of a voluntary survey and not necessarily verifiable records in all instances, the internal RMA data series driven by yield reports aggregated from verifiable insured data is likely a more representative measure of actual conditions. The T-yield in the last three years appears to be appropriate for the overall production practice in both the Northern and Southern High Plains. There was a period from 2010 to 2015 that the RMA T-yields appeared to lag actual expectations, yet that appears to have largely been rectified by 2016 in both regions. The appearance of a discrepancy during this period is likely attributed to NASS not reporting an irrigated practice-specific yield observation for 2011 due to the severe drought conditions. That shock to the system, if included, would temper the yield expectations and lead to RMA holding the T-yields constant for the period.

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[7] The USDA RMA actual annual yield observations are reported through their Area Plan Historical Yield report annually (RMA2, 2020).

The T-yields in the Northern High Plains are reasonable for the overall production practice for the 2016 to 2018 period but prior to that the T-yields consistently lagged the mean yield observations for the majority of years, as demonstrated by Figure 13. The significant departure of the NASS reported and RMA calculated actual average yields (demonstrated as the green and yellow series in the figures) from the T-yield is likely attributed to RMA not considering that enough information had been accumulated for many of the Northern High Plains' counties to allow the T-yields to be principally established from the county's own information which was often much higher than the T-yield. This is in the consideration of the credibility requirements on the counties' information was limited until adequate insurance experience was accumulated.

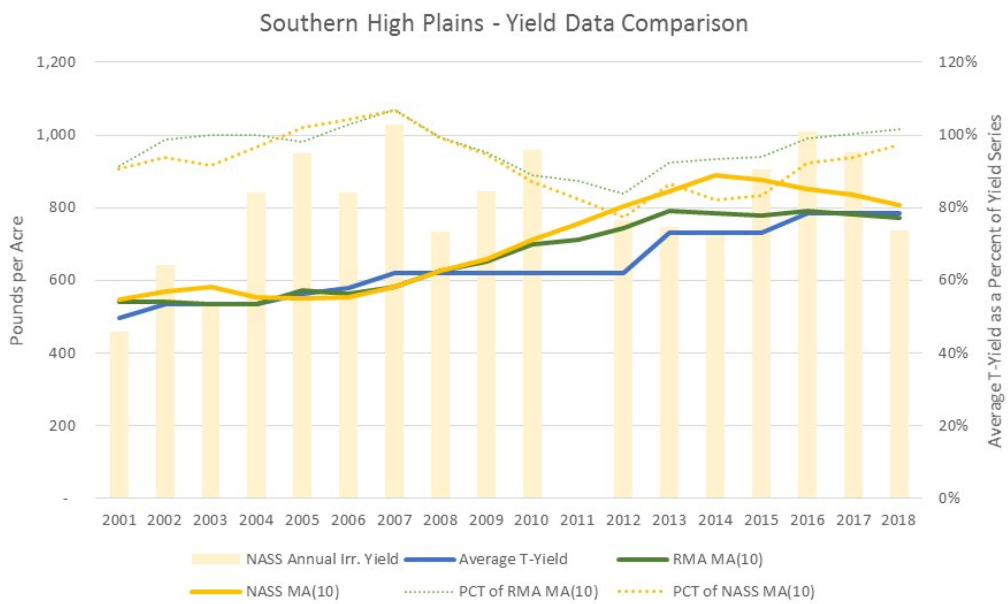

Figure 12. USDA RMA T-yields vs. NASS and RMA 10-Yr Moving Average County Yields, Southern High Plains 2001-2018

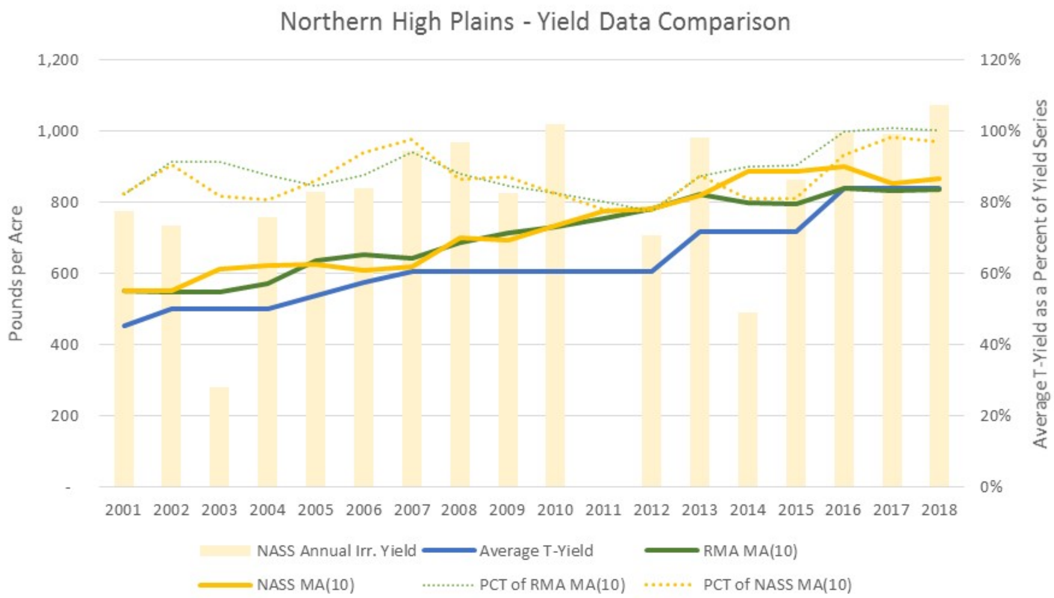

Figure 13. USDA RMA T-yields vs. NASS and RMA 10-Yr Moving Average County Yields, Northern High Plains 2001-2018

T-yields in Hale County, which is located in the southern portion of the Northern High Plains track very closely to the RMA 10-year moving average yield as depicted in Figure 14. However, the T-yields in Ochiltree County in the northern portion of the Northern High Plains where cotton production was more intermittent, took longer to catch up with the RMA 10-year moving average yield as demonstrated in Figure 15. Until 2016, the T-yield was less than 58% of the actual county average yield, where RMA had a county yield reported 13 out of the 15 years in which 8 of the years the observed yield was almost double the T-yield. This significant delay in the T-yield aligning with expectations for the county is likely due to a lack of credible metrics for recognizing county-specific yield performance coupled with a conservative approach to T-yield establishment for an area largely new to cotton production. Most likely, areas like Ochiltree County is where the call for T-yield reviews may have originated.

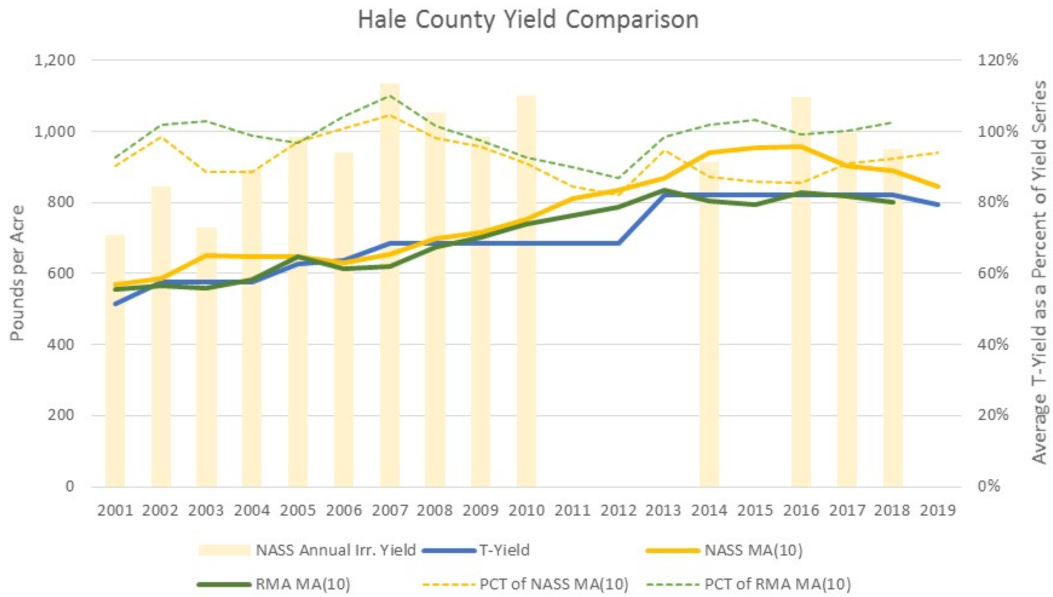

Figure 14. USDA RMA T-yields vs. NASS and RMA 10-Yr Moving Average County Yields, Hale County, TX 2001-2018

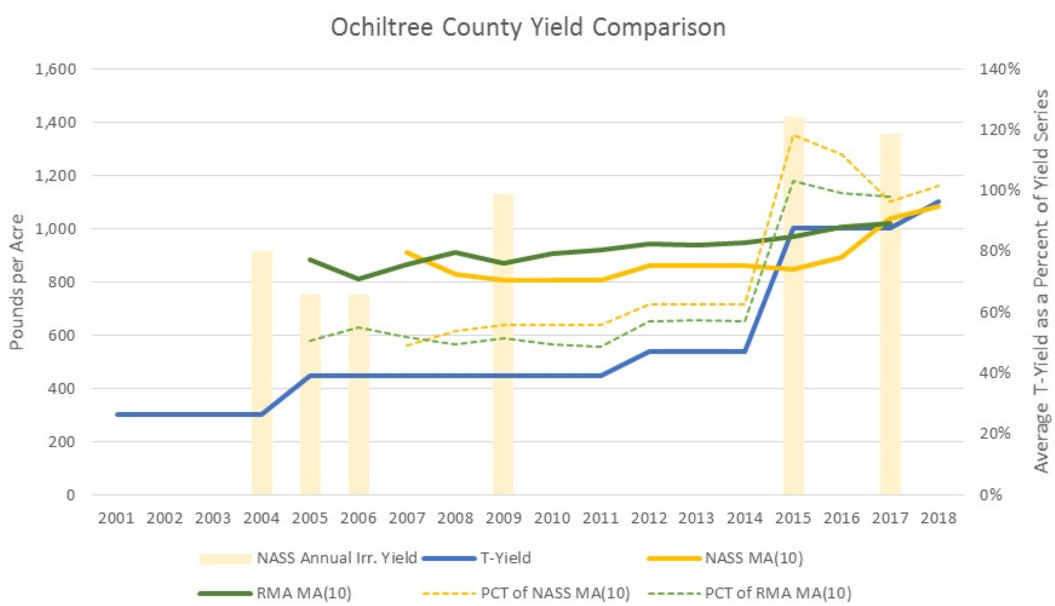

Figure 15. USDA RMA T-yields vs. NASS and RMA 10-Yr Moving Average County Yields, Ochiltree County, TX 2001-2018

To confirm the theory on the lag observed in some areas, current T-yield review parameters were sought to be understood. The cotton specialist in the Oklahoma City RMA Regional Office (RO) was contacted, to better understand the current procedures used and the status of irrigated cotton yields in the High Plains. Based on our discussion, T-yields for irrigated cotton in the Texas High Plains were updated for 2018. The RO representative indicated that since cotton has been produced for a few years in most all the counties in the High Plains, he was able to find credible data by the time they made it to the 2018 T-yield updates. If such data was not available for a given county, yields from a neighboring county were used. The representative also reported that RMA is on a three-year cycle to update cotton T-yields in the High Plains, and such timely updates will keep them in line with improvements in yields due to new varieties and other developments.

DeDe Jones, an extension specialist with Texas AgriLife Extension in Amarillo also reviewed the 2018 T-yields for appropriateness in selected counties and consulted with various other county agents. The general response she received was that the yields might be on the low side by about 10 percent, but they were generally in the correct range for the overall irrigated production practice. This confirms our assessment as well, since in most areas the yields since 2016 seem to be well aligned with typical irrigation production practices.

Since most of the irrigated acreage on the Texas High Plains is still comprised of MESA and LESA systems (e.g. ≈ 60%) whose water application efficiency is significantly less (and in turn the corresponding yield performance is also less) than LEPA or other higher efficiency systems such as SDI, the all irrigated acreage T-yield for the county as is currently published by RMA will lag that of the higher efficiency systems on theoretical basis. However, when the variance in performance is realized in commercial scale operations with a broad array of circumstances and management intensities, the difference in system performance becomes more varied as demonstrated in the TAWC study from 2005 to 2018. Hence, the differences are not as evident, and the additional administrative burden must be considered when evaluating the potential of segregating irrigated production practices into higher and lower efficiency characterizations.

CONCLUSION

As part of analyzing the possible justification for segregating SDI from other irrigation production practices, AgriLogic considered the potential benefits of offering a separate practice while also considering the limitation that it may present. The reasons for establishing a separate practice for SDI from the standard irrigation production practice are twofold: first is that a T-yield must align with the practice's general yield potential for the county (e.g. expected SDI yield, LESA yield, LEPA yield, etc.). If the yield expectations are significantly different, then they should be segregated. The second is if the risk of yield variability differs significantly between the alternative irrigated production practices. The case for establishing an alternative T-yield for SDI is largely to address the coverage for the first four years that an insured uses SDI irrigation in a specific location (after four years the insured's yield guarantee will be established off their own history). Given that the continuous rating methodology adjusts the insured's premium rate by comparing the mean yield performance relative to the county, the insured's insurable unit would be dynamically aligned with their performance over the four-year period anyway.

T-yields allow producers producing cotton for the first time to establish an initial insurance guarantee for coverage until their own actual yields are accumulated and this process tends to mitigate the impact of T-yields. Other uses of T-yield plugs are situations where yield substitutions or yield exclusions are used according to APH procedures. This function is implemented to help support the insured's APH when loss years are experienced. Because the concentration of cotton produced on SDI varies significantly across the Texas High Plains, the practice if segregated should only be done for a limited number of counties where the practice is a valid consideration (e.g. high clay contents in the soil profile). In other words, if the segregation of SDI acreage into a specific irrigation practice were implemented, it would only have merit in certain areas[8] since the practice's performance lags that of other methods (e.g. LEPA) in certain circumstances[9] as previously discussed.

SDI on cotton is a long-standing and accepted practice; its viability is not in question but instead it must be considered in the context for which the production practice is being established. This is not limited to soil characteristics but also to the insured's understanding of proper management of the system, the insured's diligence in executing its operation, and the consistency of that approach. These questions require that the insured prove their performance to earn that recognition to justify a higher yield guarantee. SDI does not consistently produce a significantly higher yield in all circumstances as previously discussed compared to a modern well-maintained LEPA and in some instances LESA systems. This conclusion is based on extensive

[8] Where the SDI practice has been adopted in meaningful volumes and has demonstrated significantly different performance from other irrigation methods. Otherwise the additional resources required to collect and maintain the additional level of detail would not be justified and a single irrigation practice should be used in the interest of simplicity of program administration.

[9] The SDI practice is actually inferior to MESA, LESA, and LEPA in areas such as Gaines County, TX where soils are comprised of high concentrations of sand that do not lead to successful implementations of the SDI method.

conversations with producers, cotton organization personnel and irrigation specialists. On properly managed operations with soil properties conducive to the practice, SDI does present advantages over other irrigation methods, however, the results are not always consistent. Therefore, other factors must also be considered prior to recommending the addition of a segregated irrigation practice, which include the insured support for the segregation and the additional administrative burden required on insureds, the insurance industry (i.e. AIPs), and the regulator (i.e. USDA) to administer the more complex program.

Meetings were conducted with producers in multiple locations throughout the High Plains to assess their interest in a separate practice for SDI irrigation. Overall, based on discussions, significant support for the segregation of SDI from other irrigated production practices was not identified at this time. The primary commodity association representing cotton producers in the High Plains, Plains Cotton Growers Inc., was consulted and they do not support a separate SDI practice for cotton, if it is to be implemented as a mandatory reporting requirement. The reasons for their position are:

1) An adequate supply of water including adequate well capacity is more important in determining yield potential for cotton than the irrigation system utilized;
2) There is an array of irrigation systems available which offer enhanced efficiency with each having advantages and disadvantages; and
3) It would not be worth the additional effort for most producers to collect and report separate yield information for a SDI as a separate irrigation practice.

The role water availability plays in assessing the production potential of a crop is vast, and there are unquestionable advantages to many of the higher efficiency systems. The question gets down to the economics of the situation for a specific insurable unit as to whether a high efficiency irrigation system makes sense. This has to do with the suitability of the soil properties and the management style of the producer which would better suggest what level of improved performance may be anticipated. The return of a higher efficiency system from an economic perspective must be considered as to the merit of making the investment.

Plains Cotton Growers' position that if you have enough water you can make a crop with whatever irrigation application method that is used is appreciated, but in the context of the insurance program where water availability is limited, the efficiency of that system can have an impact on the expected yield and the variability about that expectation (i.e. the risk and the associated premium rate appropriate for it). In this context, the water availability and system type must be considered simultaneously to fully evaluate potentially different outcomes. This would suggest for certain counties whose soils are principally comprised of higher clay contents such as Hale and Floyd Counties, a separate production practice for SDI could be established that would typically demonstrate a higher yield expectation. In a perfect world where collection of detailed practice-specific information did not require a significant effort by the insurance program participants, it would be ideal to capture the segregated irrigated practice-specific insurance experience for furrow, MESA, LESA, LEPA and SDI to better understand the risk associated with insuring each of the alternative methods. However, that is not feasible on a broad scale in considering the burden that would place on the industry particularly in many other counties where the difference is not significant. In actuality, other irrigation methods in certain circumstances are preferred over SDI due to their superior performance for the application.

These considerations coupled with a lack of broad producer support for the addition of a new SDI practice places more emphasis on the additional administrative burden to introduce the added level of detail. The additional administrative burden is not trivial particularly given the number of irrigation systems that the typical Texas High Plains irrigated producer must manage and track. This is particularly the case when multiple systems currently underly a single insurable unit even at the optional unit level.

When the increased efficiency of the LEPA system is considered relative to the furrow, MESA, or LESA systems, it is more like SDI regarding its yield potential than those other irrigation methods with which it is currently grouped. As a result, if a new production practice were considered it may be more appropriate to consider LEPA with SDI in an advanced irrigation production practice as opposed to just singling our SDI. The approach to managing a LEPA system is very similar to that for MESA or LESA systems for which farmers are already well acquainted. However, successful management of SDI systems require a significantly different understanding[10] and management approach. This could be a limiting factor for combining SDI with LEPA into a single high-efficiency practice; however, in most applications it is believed that SDI and LEPA systems' performance will be comparable for most insureds. In summary, there are already a broad range of irrigated production practice systems grouped together under a single classification (irrigated) in the insurance program; if SDI were segregated into its own irrigated practice, other high efficiency systems such as LEPA should be considered in that classification as well.

[10] In dry years, farmers must begin pre-watering 10 days or more in advance prior to planting to germinate the cotton seeds while they may have traditionally planted the crop and then watered the crop up in a matter of days given their ability to apply large amounts of water to the seed bed rapidly with center pivots.

RECOMMENDATIONS

In conclusion, given the additional administrative burden required, coupled with the lack of broad producer support for segregation of the production practices**, a separate production practice is not recommended to be established for SDI at this time.** While a separate production practice is not recommended for SDI, RMA may want to consider offering a pilot written agreement program allowing interested producers to establish a separate yield for cotton produced with SDI and possibly extending that opportunity for LEPA as well. Both irrigation practices for cotton in the Texas High Plains have demonstrated the ability in some circumstances to produce higher yields in comparison to other types of irrigation systems.

This task of this project focuses on the feasibility and evaluation of possible changes related to SDI and it did not direct the contractor to develop detailed policy provisions. However, if RMA decides to develop a pilot written agreement program for SDI on cotton, AgriLogic suggests the following elements be considered for the program:

- A producer's SDI actual cotton yield history would be the basis for establishing the relationship to the other irrigated yields for any new acreage on SDI. This feature could enable those desiring to transition acreage from less efficient irrigation practices to transfer their yield experience from the SDI acreage to the newly converted insurable unit (e.g. going from a MESA to an SDI system should demonstrate different yield expectations).
- A written agreement would be required because there is not a separate production practice for SDI. The function of the written agreement would be to allow the insured to translate their SDI irrigated experience to other acreage as it is converted to the new system.
- As determined by the RO the number of SDI records required (e.g. 2 years) of experience could be utilized to begin the translation of SDI experience to other acreage.
- The SDI rate and approved yield would be used for input into the continuous rating methodology to determine the applicable premium rate.

This pilot written agreement program would also enable RMA to capture valuable insurance experience for assessing future policy offerings in the area regarding the divergence of SDI premium rates from other irrigated production practices.

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