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ASSESSMENT OF PLANT AVAILABLE SOIL WATER ON PRODUCER FIELDS IN WESTERN KANSAS

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INTRODUCTION

Water shortage is the primary factor limiting crop production in the USA's west-central Great Plains, and agricultural sustainability depends on efficient use of water resources. Precipitation is limited and sporadic with mean annual precipitation ranging from 16 to 20 inches across the region, which is only 60-80% of the seasonal water use for corn. Yields of dryland crops are limited and variable and some producers have used irrigation to mitigate these effects. Continued declines within the Ogallala Aquifer will result in a further shift from fully irrigated to deficit or limited irrigation or even dryland production in some areas. As this occurs, producers will desire to maintain crop production levels as great as possible while balancing crop production risks imposed by constraints on water available for production. Efficient utilization of plant available soil water (PASW) reserves is important for both dryland and irrigated summer crop production systems.

In western Kansas, dryland grain sorghum yield was linearly related to PASW at emergence and sorghum yields increased 501 lbs/acre for each additional inch of PASW (Stone and Schlegel, 2006). When the experimental effects of tillage were considered, grain sorghum yield response to water supply (PASW at planting plus cropping season precipitation) was greater with no-tillage than with conventional tillage (417 vs. 292 lbs/acre-inch). With conventional tillage at

Bushland, Texas, grain sorghum yield increased 385 lbs/acre-inch of PASW at planting (Jones and Hauser, 1974). Evaporative demands increase from north to south (i.e., decreasing latitude) in the Great Plains and this can reduce overall yield response to water (Musick et al., 1994; Nielsen et al., 2002). Precipitation increases from west to east in the Great Plains and in Kansas the average increase is approximately 1 inch for each 18 miles (Flora, 1948). Research is needed to characterize the amounts of PASW available to producers in the spring before planting of summer crops. The research results can be used to develop better cropping recommendations for producers based on their geographical location within western Kansas when used with information about their anticipated summer precipitation.

Preseason irrigation (also referred to as preplant, dormant-season, off-season, or winter irrigation) is a common practice in central and southern sections of the western Great Plains on the deep soils with large water-holding capacity that are prevalent. The residual soil water left in irrigated corn fields has a strong effect on the amount of preseason irrigation and precipitation that can be stored during the dormant period (Lamm and Rogers, 1985). Although preseason irrigation is common, research has shown it is often an inefficient water management practice (Stone et al., 1987; Lamm and Rogers 1985; Musick and Lamm, 1990). Measured water losses from marginal preseason irrigation capacities during the 30-45 day period prior to planting in a Texas study were extremely high, ranging from 45 to 70% (Bordovsky and Porter, 2003). While several reasons are given by producers for the use of preseason irrigation, Musick et al. (1971) stated its primary purpose is to replenish soil water stored in the plant root zone.

From an analysis of soil water data from producer fields with silt loam soils near Colby, Kansas, Rogers and Lamm (1994) concluded that irrigation above the amount required to bring soil water to 50% PASW water would have a high probability of being lost or wasted. They found in a three-year study (1989-1991) of 82 different fields that on average producers were leaving residual PASW in the top 5 ft of the soil profile at 70% of field capacity. Since that time, groundwater levels have continued to decline and more irrigation systems have marginal capacity. Research is needed to both assess the current amounts of residual PASW producers are leaving in the field after irrigated corn harvest and how much PASW is replenished during the period before spring planting of the next corn crop.

The primary objectives of this project were to characterize the fall residual profile PASW after irrigated corn production and the PASW in dryland wheat stubble following the winter period and prior to dryland summer crop production in producer fields in three distinct regions of western Kansas [southwest (SW), west central (WC) and northwest (NW)]. Secondary objectives were to characterize aspects of the overwinter precipitation storage for the two crop residues (i.e., irrigated corn and dryland wheat).

PROCEDURES

The ongoing study was initiated in the fall of 2010 on the deep silt loam soils in western Kansas. Fifteen fields from each of the three regions (SW, WC and NW) were sought for each crop residue type (dryland wheat and irrigated corn) for sampling of PASW. In general five fields of each residue type were selected in each county (Figure 1). In a few cases, additional fields (generally 1 or 2) were selected when it was deemed useful in gaining a better geographical distribution. Another selection criterion for the irrigated corn fields was irrigation system capacity. Attempts were made to find one or two fields in each county with capacities equivalent to less than 400, 400 to 600, and over 600 gpm for a 125 acre field.

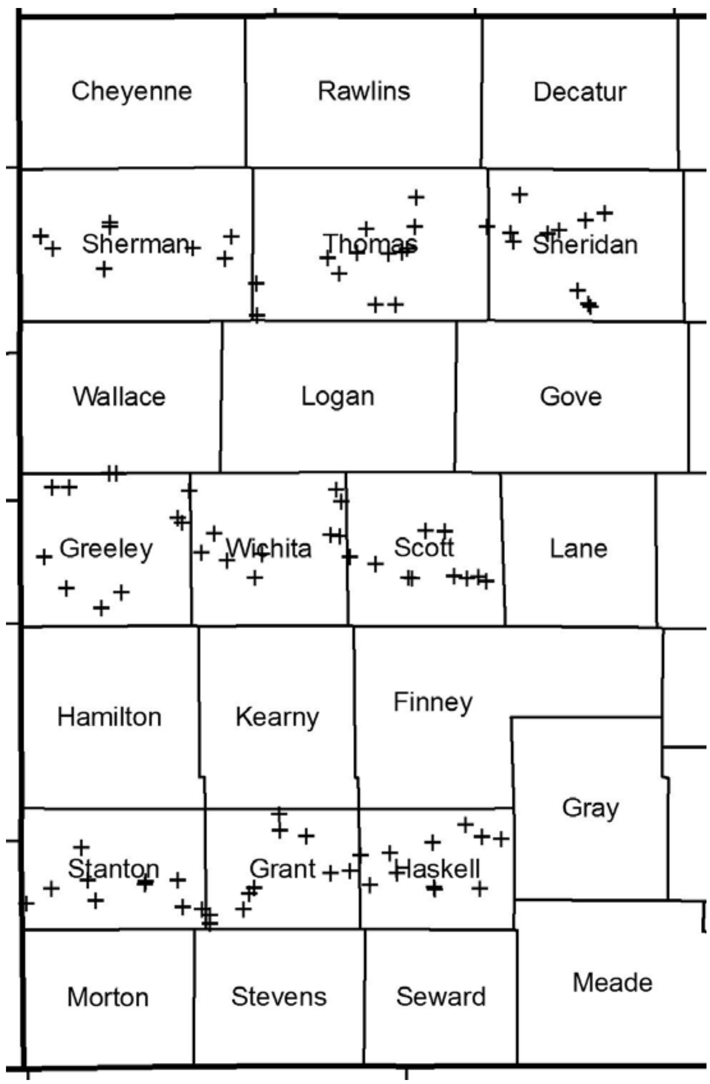

Figure 1. Geographical distribution of soil water measurements in producer fields in western Kansas, 2010. Each symbol represents a GPS-referenced producer field.

Although a broad geographical representation was a primary desire (Figure 1), an attempt was made to select producers using good management practices and for which realistic weather conditions could be obtained from public sources. Fields in NW Kansas were selected in Sheridan, Thomas and Sherman counties (east to west counties). Fields in WC Kansas were selected in Scott, Wichita and Greeley counties (east to west counties). There was increased difficulty finding producers with continuous (year-after-year) irrigated corn fields in WC Kansas, particularly in Wichita and Greeley Counties. The Ogallala aquifer in this region of Kansas is more marginal and severely depleted, so producers appear to be using more crop rotation to utilize residual soil water better, thus conserving more aquifer water for future years. Fields in SW Kansas were selected in Haskell, Grant and Stanton counties (east to west counties). There were 96 total fields in 2010 fall sampling and 91 fields in 2011.

The GPS-referenced neutron access tubes (3 per field) were installed in an equilateral triangular-shaped pattern (50-foot sides). Initial volumetric soil water content was determined in these fields after installation of tubes and again in late spring prior to summer crop initiation in one-foot increments to a depth of 8 feet. Published soil type and soil characteristics were used to estimate PASW within the profile. The data from the three sampling points was examined for uniformity between readings and to remove any anomalies. A few tubes were lost due to damage by producer field operations between the fall and spring measurement periods. Less than 1% of the data was lost due to measurement anomalies or damaged tubes.

RESULTS AND DISCUSSION

The study is ongoing and some of the more complex interrelationships of producer practices with residual soil water have not been quantified or evaluated yet. Although it should be noted that the results may vary widely from what may be occurring on your or other fields located within these counties, the soil water results may still be indicative of some of the irrigation capacities and practices, climatic, soil, and cropping conditions of these three distinct regions of western Kansas.

Weather Conditions

Weather conditions in nearly all of western Kansas were excessively dry from early August 2010 through mid-April of 2011. The western portion of WC and NW Kansas began to get more normal precipitation in late April 2011 and ended the cropping season with normal amounts of precipitation or greater. However, SW Kansas remained under severe drought conditions through the summer and much of the fall. For example, Grant County received less than 30% of normal annual precipitation for the period September 1, 2010 through September 1, 2011. In SW Kansas, dryland summer crops resulted in almost total failure and even many of the irrigated crops were severely stressed. The western edge of WC Kansas (Greeley County) and for nearly all of NW Kansas experienced near-to above-normal precipitation for most of the summer period. A particularly wet weather multi-day period in early October 2011 that tracked across some counties in WC Kansas and the eastern half of NW Kansas with those areas receiving between 2 and 4 inches of precipitation. Because of the multi-day nature of this precipitation, much of the water infiltrated into the soil profile.

Soil Water as Affected by Location and Residue Type

In general, sprinkler irrigated corn fields had greater PASW than the dryland wheat fields (Tables 1 – 3) as might be anticipated. Additionally, it should be noted that in many cases in SW Kansas, some fall dormant season irrigation (both 2010 and 2011) had been practiced prior to the soil water measurements to facilitate easier strip tillage operations.

Fall 2010 results

In 2010, NW Kansas had slightly more PASW (7.39 inches) in wheat fields (Table 1) than in the other two regions (WC, 5.43 inches and SW, 6.57 inches, respectively). The coefficient of variation (CV) of PASW in wheat fields was least in NW Kansas and greatest in SW Kansas, probably reflecting the higher evaporative demand and worse drought conditions affecting SW Kansas.

The irrigated corn fields residual PASW averaged 160% that of the dryland wheat fields (Table 1) and also had less variability (CV of 0.30 and 0.43 for corn and wheat, respectively). The average PASW in irrigated corn fields for the three regions only varied about 1 inch (range of 9.99 in NW to 10.90 inches in SW) and with an average value of 10.30 inches would approximate a profile at 60% of field capacity, which would suggest overall adequate irrigation management. However, there was a large amount of field to field variation. The maximum PASW for the irrigated corn fields averaged nearly 16.4 inches which would be very wet unless there was considerable late season precipitation or fall dormant season irrigation. At the other end of the spectrum, the minimum average PASW was approximately 4.3 inches, which would be only about 25% of field capacity.

Spring 2011 results

There was on average slight losses or very small accumulations in the dryland wheat residue fields by late spring 2011 (Table 2), with the exception of NW Kansas which saw an average increase of 2.05 inches of PASW. This reflects some appreciable late April 2011 precipitation events in NW Kansas that the other regions had missed or had lesser amounts.

In contrast, NW Kansas had only minimal increase in PASW in the irrigated corn fields while PASW in the WC and SW Kansas fields increased approximately 2 inches (Table 2). This reflects that many of the WC and SW Kansas fields had received additional dormant season irrigation to better cope with the drought before spring planting. The maximum PASW for the sprinkler irrigated corn fields averaged 12.15, 20.06, and 18.65 inches for NW, WC and SW Kansas, respectively. These values in WC and SW Kansas would be considered extremely wet (i.e., above field capacity) and would be subject to high deep percolation rates. Close examination of the individual field data revealed that these high maximum values in the spring 2011 also were very high on the same fields in the fall of 2010, suggesting that these irrigators should cut back on late and/or dormant season irrigation. In contrast, the minimum values of PASW in the spring of 2011, on the producer fields averaged only 5.51 inches in the 8 ft profile (approximately 30% of field capacity). These producers with such low values of PASW might have greatly benefited had they used more dormant season irrigation, particularly in such a dry summer.

The irrigated corn fields had approximately 160% of the PASW of the wheat fields, similar to the results from the fall of 2010 and again with less variability in PASW.

<u>Fall 2011 results</u>
In fall of 2011, because of the continuing drought in SW Kansas, it was anticipated that producer fields would be much drier than in 2010 (Tables 3 and 1, respectively). Although this turned out to be true for SW Kansas for dryland wheat fields (nearly 1.5 inches drier), overall the irrigated corn fields were wetter (approximately 11% wetter) in 2011, with only SW Kansas having slightly drier irrigated fields in fall 2011 (approximately 7% drier). The wetter summer period in portions of WC Kansas (Greeley County) and NW Kansas no doubt had some effects on the amounts of residual PASW.

The October 2011 multi-day wet period resulted in some very wet wheat residue fields in Thomas and Sheridan Counties in northwest Kansas (Table 3).

Discussion of Annual Differences in Corn Residual PASW

Although record or near-record drought conditions existed in southwest Kansas for the entire period from the middle of the summer of 2010 through the fall of 2011, there were only minimal differences in fall irrigated corn PASW for the 31 fields that were available for PASW measurements in both years (Figure 2). Part of the rationale might be that drought conditions were similar between the two years. However, the irrigated corn residual soil water is still relatively high on the average for SW Kansas (approximately 60% of field capacity). So, the presence of severe drought may not be a good indicator of the amounts of residual soil water left after irrigated corn harvest. Sometimes, crop damage is caused by system capacity (gpm/acre) at the critical stages, rather than what irrigation amounts can be applied during the total season. Insect damage such as spider mites is exacerbated by high canopy temperatures and drought. Producers recognizing the drought and crop damage may continue to irrigate hoping to mitigate further crop damage and this sometimes increases profile PASW as the damaged crop is no longer transpiring typical amounts of water. One caveat, in some cases the PASW results are probably reflecting the effects of some fall dormant season irrigation that occurred before the PASW sampling. However, in most cases the fall irrigation amounts were not large.

Table 1. Plant available soil water (inches/8ft) in producer fields in western Kansas in fall 2010 (October through December).

Residue Type	County and number of fields	Average	Maximum	Minimum	CV*
Northwest Kansas, Sheridan, Thomas and Sherman Counties					
Dryland Wheat	Sheridan (5)	7.64	11.40	4.49	0.33
	Thomas (7)	8.58	11.08	6.16	0.19
	Sherman (5)	5.48	8.26	3.86	0.31
	All 3 Ctys (17)	7.39	11.40	3.86	0.30
Irrigated Corn	Sheridan (5)	10.50	11.10	8.57	0.06
	Thomas (7)	10.79	15.55	6.76	0.22
	Sherman (5)	8.35	11.64	6.56	0.24
	All 3 Ctys (17)	9.99	15.55	6.56	0.24
Irrigated to Dryland Ratio	Sheridan	1.37	0.97	1.91	0.19
	Thomas	1.26	1.40	1.10	1.12
	Sherman	1.52	1.41	1.70	0.77
	All 3 Ctys	1.35	1.36	1.70	0.79
West Central Kansas, Scott, Wichita and Greeley Counties					
Dryland Wheat	Scott (5)	5.11	8.97	2.48	0.50
	Wichita (6)	5.10	9.31	3.03	0.48
	Greeley (5)	6.13	11.08	2.07	0.53
	All 3 Ctys (16)	5.43	11.08	2.07	0.48
Irrigated Corn	Scott (5)	11.98	16.57	8.20	0.27
	Wichita (5)	9.31	11.78	6.54	0.20
	Greeley (5)	8.78	10.63	3.96	0.32
	All 3 Ctys (15)	10.02	16.57	3.96	0.29
Irrigated to Dryland Ratio	Scott	2.34	1.85	3.31	0.54
	Wichita	1.83	1.27	2.16	0.42
	Greeley	1.43	0.96	1.91	0.60
	All 3 Ctys	1.85	1.50	1.91	0.60
Southwest Kansas, Haskell, Grant and Stanton Counties					
Dryland Wheat	Haskell (5)	5.39	10.19	1.50	0.72
	Grant (5)	3.43	6.08	1.70	0.50
	Stanton (5)	10.88	14.41	7.39	0.29
	All 3 Ctys (15)	6.57	14.41	1.50	0.66
Irrigated Corn	Haskell (6)	9.82	17.06	2.37	0.61
	Grant (5)	9.06	13.86	6.28	0.37
	Stanton (5)	13.83	16.71	11.50	0.14
	All 3 Ctys (16)	10.84	17.06	2.37	0.41
Irrigated to Dryland Ratio	Haskell	1.82	1.67	1.58	0.84
	Grant	2.64	2.28	3.69	0.74
	Stanton	1.27	1.16	1.56	0.47
	All 3 Ctys	1.65	1.18	1.58	0.62

** Coefficient of variation is defined as the standard deviation of PASW divided by the mean PASW.*

Table 2. Plant available soil water (inches/8ft) in producer fields in western Kansas in spring 2011 (March through May).

Residue Type	**County and number of fields**	**Average**	**Maximum**	**Minimum**	**CV***
Northwest Kansas, Sheridan, Thomas and Sherman Counties					
Dryland Wheat	Sheridan (5)	9.66	12.55	7.78	0.19
	Thomas (7)	9.67	11.47	7.34	0.13
	Sherman (4)	8.77	10.80	7.07	0.20
	All 3 Ctys (16)	9.44	12.55	7.07	0.16
Irrigated Corn	Sheridan (5)	11.21	12.15	10.67	0.05
	Thomas (7)	11.02	15.69	8.23	0.22
	Sherman (5)	8.74	11.84	6.37	0.24
	All 3 Ctys (17)	10.41	15.69	6.37	0.21
Irrigated to Dryland Ratio	Sheridan	1.16	0.97	1.37	0.26
	Thomas	1.14	1.37	1.12	1.69
	Sherman	1.00	1.10	0.90	1.21
	All 3 Ctys	1.10	1.25	0.90	1.28
West Central Kansas, Scott, Wichita and Greeley Counties					
Dryland Wheat	Scott (5)	6.26	10.92	3.74	0.46
	Wichita (5)	5.06	7.22	3.63	0.30
	Greeley (5)	6.44	11.36	2.43	0.50
	All 3 Ctys (15)	5.92	11.36	2.43	0.43
Irrigated Corn	Scott (5)	14.51	20.06	9.70	0.27
	Wichita (5)	11.12	13.87	7.51	0.23
	Greeley (5)	10.60	13.60	4.47	0.34
	All 3 Ctys (15)	12.08	20.06	4.47	0.30
Irrigated to Dryland Ratio	Scott	2.32	1.84	2.59	0.58
	Wichita	2.20	1.92	2.07	0.78
	Greeley	1.65	1.20	1.84	0.67
	All 3 Ctys	2.04	1.77	1.84	0.70
Southwest Kansas, Haskell, Grant and Stanton Counties					
Dryland Wheat	Haskell (5)	6.25	11.03	2.09	0.64
	Grant (5)	4.02	6.91	2.28	0.45
	Stanton (5)	8.76	11.93	5.28	0.34
	All 3 Ctys (15)	6.34	11.93	2.09	0.54
Irrigated Corn	Haskell (5)	12.10	18.65	5.70	0.43
	Grant (5)	11.50	15.74	7.05	0.30
	Stanton (5)	13.64	16.13	10.24	0.18
	All 3 Ctys (15)	12.39	18.65	5.70	0.31
Irrigated to Dryland Ratio	Haskell	1.94	1.69	2.73	0.67
	Grant	2.86	2.28	3.10	0.67
	Stanton	1.56	1.35	1.94	0.53
	All 3 Ctys	1.95	1.56	2.73	0.56

** Coefficient of variation is defined as the standard deviation of PASW divided by the mean PASW.*

Table 3. Plant available soil water (inches/8ft) in producer fields in western Kansas in fall 2011 (September through December).

Residue Type	County and number of fields	Average	Maximum	Minimum	CV*
Northwest Kansas, Sheridan, Thomas and Sherman Counties					
Dryland Wheat	Sheridan (5)	13.95	17.81	7.03	0.29
	Thomas (5)	7.11	9.14	6.19	0.16
	Sherman (5)	6.85	8.70	3.76	0.31
	All 3 Ctys (15)	9.30	17.81	3.76	0.46
Irrigated Corn	Sheridan (6)	13.77	15.60	10.45	0.14
	Thomas (5)	13.07	16.86	8.94	0.22
	Sherman (5)	8.31	11.69	5.95	0.28
	All 3 Ctys (15)	11.85	16.86	5.95	0.28
Irrigated to Dryland Ratio	Sheridan	0.99	0.88	1.49	0.49
	Thomas	1.84	1.84	1.44	1.32
	Sherman	1.21	1.34	1.58	0.89
	All 3 Ctys	1.27	0.95	1.58	0.61
West Central Kansas, Scott, Wichita and Greeley Counties					
Dryland Wheat	Scott (5)	8.08	10.96	5.44	0.25
	Wichita (5)	8.36	10.05	6.46	0.20
	Greeley (5)	8.57	10.76	6.63	0.18
	All 3 Ctys (15)	8.34	10.96	5.44	0.20
Irrigated Corn	Scott (5)	13.00	17.85	9.75	0.23
	Wichita (5)	12.59	14.21	10.74	0.11
	Greeley (5)	11.73	12.25	10.98	0.04
	All 3 Ctys (15)	12.46	17.85	9.75	0.16
Irrigated to Dryland Ratio	Scott	1.61	1.63	1.79	0.90
	Wichita	1.50	1.41	1.66	0.57
	Greeley	1.37	1.14	1.66	0.22
	All 3 Ctys	1.49	1.63	1.79	0.80
Southwest Kansas, Haskell, Grant and Stanton Counties					
Dryland Wheat	Haskell (5)	5.98	10.30	2.73	0.46
	Grant (5)	3.26	6.74	0.16	0.90
	Stanton (5)	5.57	8.16	4.63	0.26
	All 3 Ctys (15)	4.94	10.30	0.16	0.52
Irrigated Corn	Haskell (5)	10.40	15.58	2.94	0.59
	Grant (5)	8.76	16.49	3.13	0.66
	Stanton (5)	11.11	14.30	8.65	0.20
	All 3 Ctys (15)	10.15	16.49	2.94	0.46
Irrigated to Dryland Ratio	Haskell	1.74	1.51	1.08	1.30
	Grant	2.69	2.45	19.02	0.74
	Stanton	2.00	1.75	1.87	0.76
	All 3 Ctys	2.06	1.60	17.84	0.88

** Coefficient of variation is defined as the standard deviation of PASW divided by the mean PASW.*

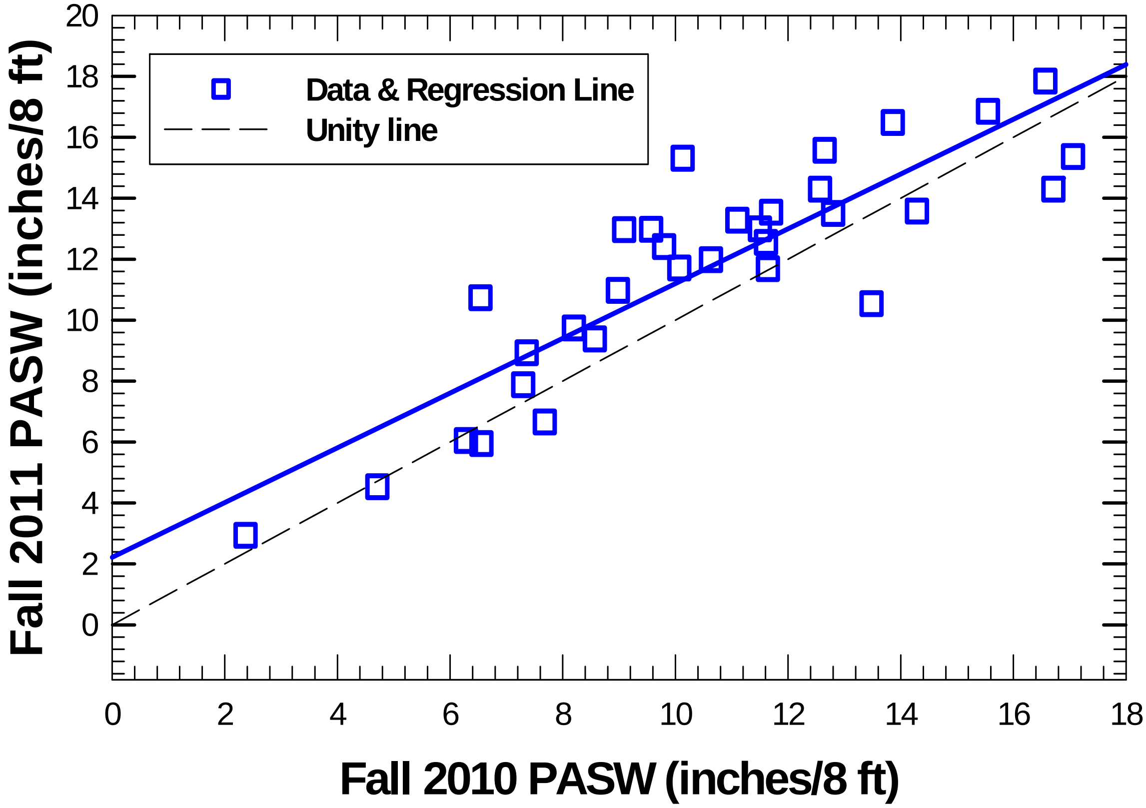

Figure 2. Similarity of plant available soil water (PASW) in the 8 ft soil profile in irrigated corn fields after harvest for the fall periods in 2010 and 2011 in western Kansas producer fields. These data represent 31 fields that producers made available for PASW measurements in both years.

Effect of Regional Characteristics on Corn Residual PASW

Although intuition might suggest that less saturated thickness of the Ogallala and more marginal irrigation system capacities (gpm/acre) would result in less residual PASW in the irrigated corn fields of WC Kansas, there was no strong evidence of that in the data from 2010 and 2011 (Figure 3). This might be because producers with lower capacity irrigation systems have adjusted to their limitation by using longer pumping periods. Their goal by pumping later into the crop season would be to minimize crop yield loss, but sometimes those later irrigation events also increase residual PASW.

Effect of Field Type on Overwinter Change in PASW

Overwinter accumulation or loss of PASW could be affected by precipitation, initial PASW, residue type, and any applied dormant season irrigation, so the following results are being discussed in terms of field type, rather than just crop residue type. The corn fields on average accumulated approximately 2 inches of soil water overwinter when the fall 2010 PASW was very low and only about 1 inch of accumulation when the PASW was high (Figure 4). In contrast, the wheat fields accumulated only about 1 inch of soil water overwinter when the fall 2010 PASW was very low and tended to lose up to 2 to 3 inches of PASW when PASW was higher (Figure 4). These differences are probably due to dormant season irrigation slightly increasing PASW in the corn fields while the drought conditions were not favorable for much overwinter accumulation in the dryland wheat fields.

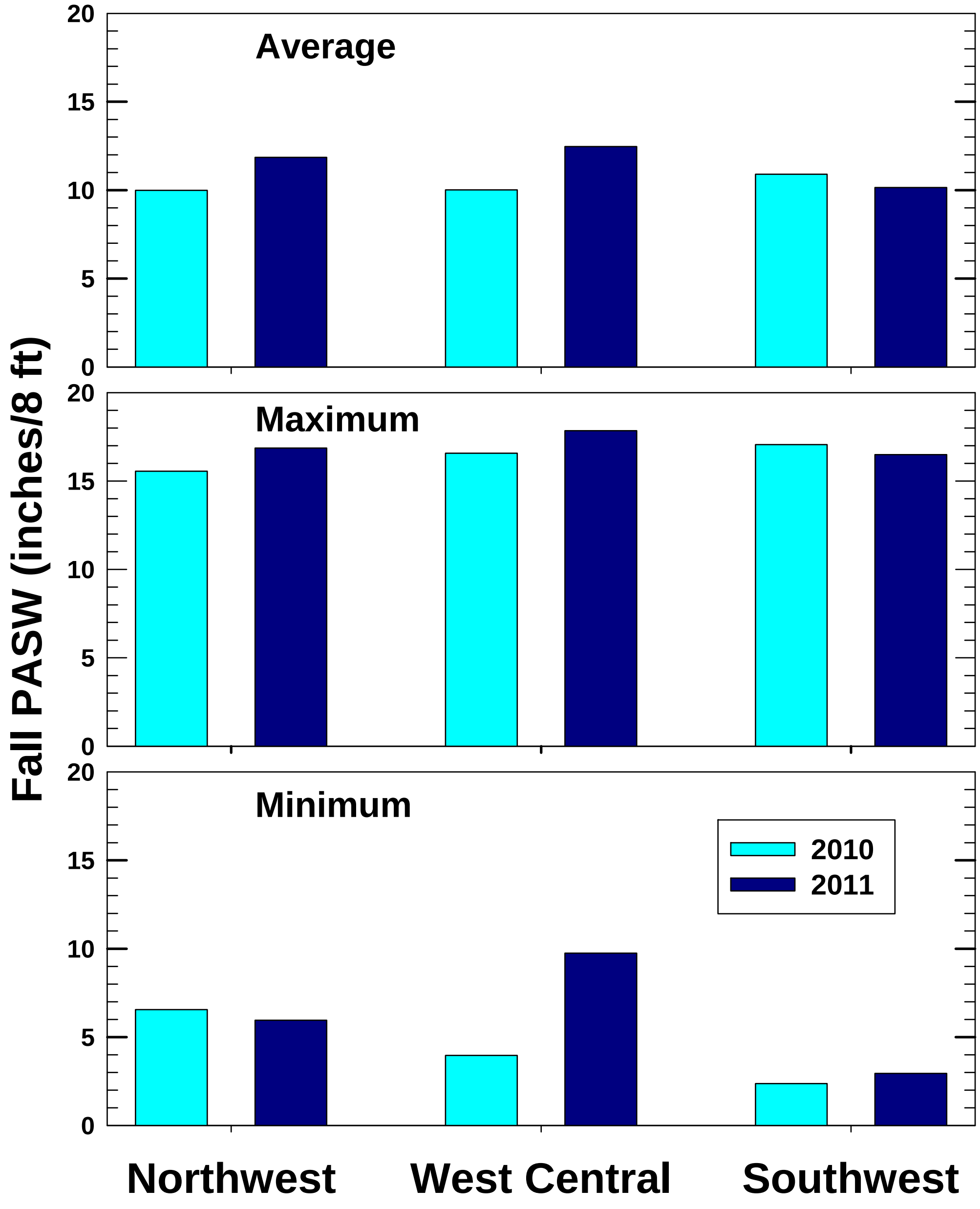

Figure 3. Effect of western Kansas region on average, maximum and minimum measured plant available soil water (PASW) in the 8 ft soil profile in irrigated corn fields after harvest for the fall periods in 2010 and 2011.

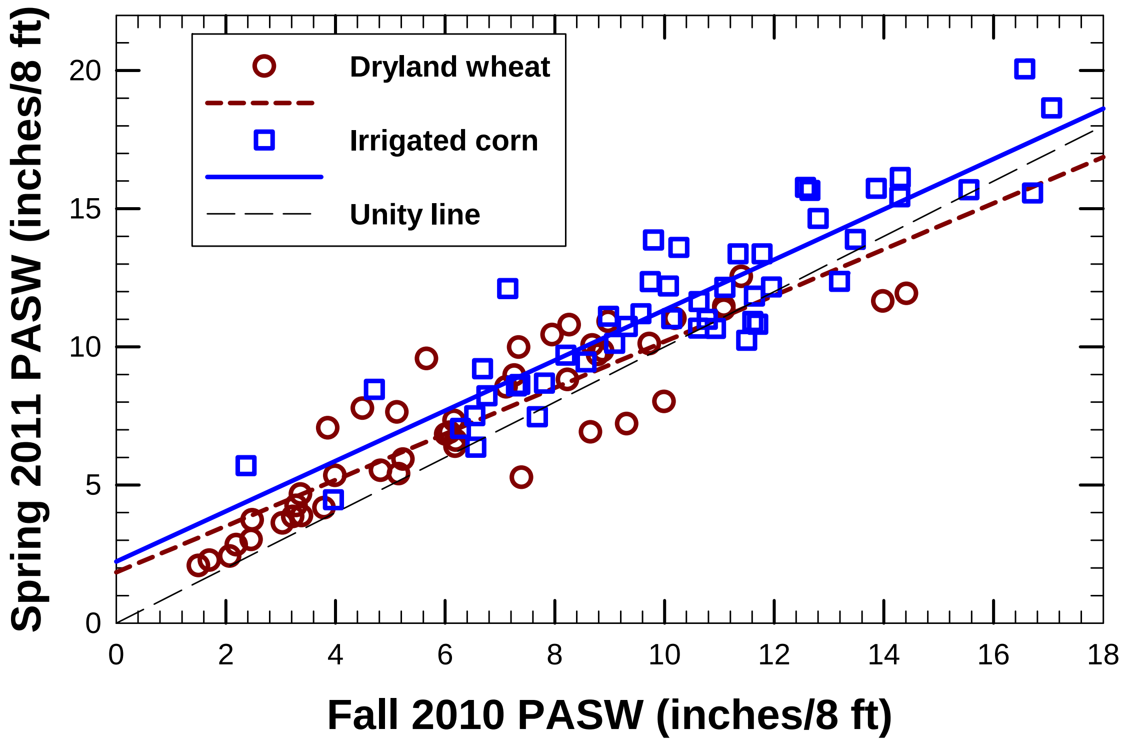

Figure 4. Effect of field type on accumulation of plant available soil water (PASW) in the 8 ft soil profile for the period fall 2010 through spring 2011 for producer fields in western Kansas.

Effect of System Capacity on Fall PASW in Irrigated Corn Fields

There were only small differences in PASW (less than 1 inch) as affected by low (less than 400 gpm/125 acres), medium (400 to 600 gpm/125 acres) or high (greater than 600 gpm/125 acres) irrigation system capacity (Figure 5) in 2011. Further analysis of the effect of capacity on fall PASW will be done by incorporating more precise information about system capacity and also from information to be provided by the producers about actual aspects of their irrigation cropping season and irrigation schedule.

SUMMARY

These results suggest a few very important aspects for irrigated crop production in western Kansas:

1. Irrigation not only increases the water available for crop production, but also reduces the variability in ASW in the field.

2. Average PASW may not be indicative of an individual field, so it is wise to check your each field after harvest.

3. Each year is different, so irrigating to average conditions is very risky and may be less profitable.

4. Science-based irrigation scheduling can help to better manage your water resources in-season and between seasons. Cost-sharing programs may be available to help individuals implement science-based irrigation scheduling.

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