

## **RESIDUAL SOIL WATER IN WESTERN KANSAS AFTER CORN HARVEST**

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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). This paper will focus only on the irrigated corn fields.

## PROCEDURES

A three year study (Fall 2010 through Fall 2012) was conducted 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.

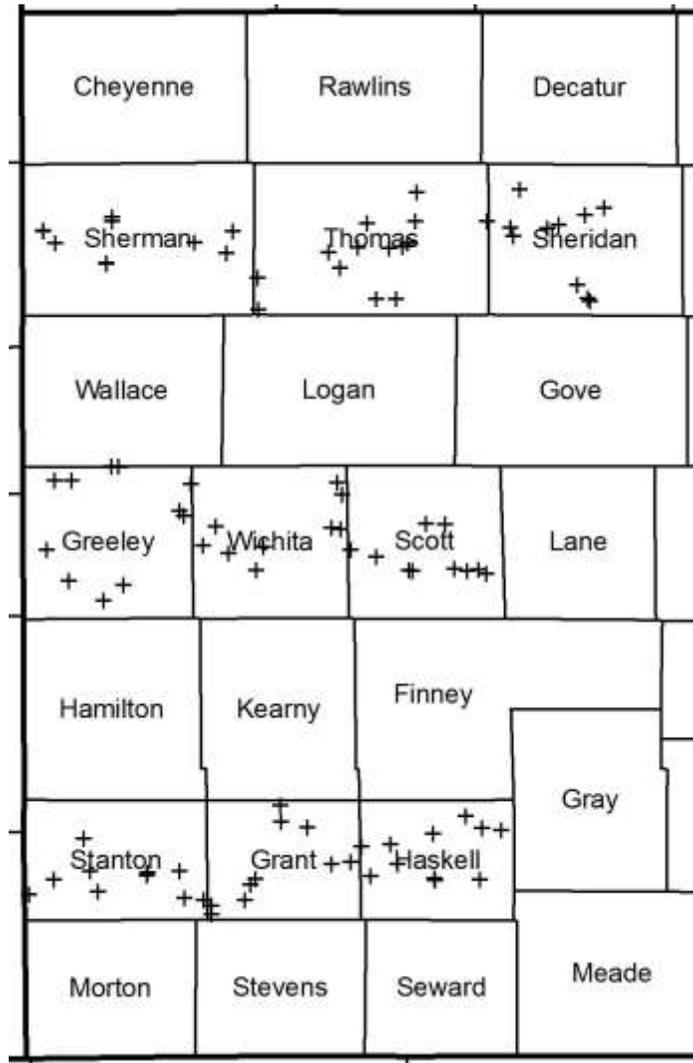


Figure 1. Geographical distribution of soil water measurements in producer fields in western Kansas, 2010. Each symbol represents a GPS-referenced producer field.

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. As time progressed into the third year, fewer fields were available for fall sampling due to extreme drought in western Kansas because producers had changed plans mid-summer often relegating their crop for ensilage production and replanting to winter wheat.

In 2012, corn grain yields were obtained from 26 irrigated fields by hand harvesting a representative sample in the vicinity of the soil water sampling tubes (within 50 ft.) to observe how fall PASW was correlated with yield.

## **RESULTS AND DISCUSSION**

The analysis is still 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. Exceptional drought conditions were generally the case for all of western Kansas in 2012.

### **Soil Water as Affected by Location**

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. However, these dormant season irrigation amounts were relatively small, just being used to facilitate easier tillage.

#### **Fall 2010 results**

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/8 ft in SW) and with an average value of 10.30 inches/8ft would approximate a profile at 60% of field capacity, which would suggest overall adequate irrigation management (Table 1). However, there was a large amount of field to field variation. The maximum PASW for the irrigated corn fields averaged nearly 16.4 inches/8ft 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.

#### **Fall 2011 results**

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 2 and 1, respectively). However, 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.

#### **Fall 2012 results**

The drought continued in western Kansas in 2012 and actually was more severe in NW and WC Kansas than in the southwest though it was only marginally better. It should be noted that SW Kansas was still experiencing precipitation

shortfalls that had been very severe in 2011. On average, NW Kansas irrigated corn fields were the driest with a range of 5.95 to 16.86 inches/8 ft and an average of 10.16 inches/8 ft which would approximate a profile at 60% of field capacity, similar to 2010 values (Table 3). The average irrigated corn field PASW in SW Kansas was 12.12 inches/8 ft or approximately 70% of field capacity. These difference may reflect the increased severity of the drought in NW Kansas or some early fall rains that occurred near harvest in SW Kansas

### **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.

There were a total of 21 irrigated corn fields in the region that were available for fall soil water sampling in all three years. Generally, there was considerable similarity in the fall PASW for a particular field (Figure 3.) with an overall difference for the 21 fields averaging 3.1 inches. The similarity suggests that fall PASW for irrigated corn is much stronger related to the irrigation management conducted on a particular field than it is to weather conditions. That management may either be reflecting the preference of the irrigator or the irrigation system capacity or a combination of both aspects.

### **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 results averaged over 2010 through 2012 (Figure 4.). 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.

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*
<b>Northwest Kansas, Sheridan, Thomas and Sherman Counties</b>					
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
<b>West Central Kansas, Scott, Wichita and Greeley Counties</b>					
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
<b>Southwest Kansas, Haskell, Grant and Stanton Counties</b>					
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

\* 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 fall 2011 (September through December).

Residue Type	County and number of fields	Average	Maximum	Minimum	CV*
<b>Northwest Kansas, Sheridan, Thomas and Sherman Counties</b>					
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
<b>West Central Kansas, Scott, Wichita and Greeley Counties</b>					
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
<b>Southwest Kansas, Haskell, Grant and Stanton Counties</b>					
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

\* 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 2012 (October 19 through 26).

Residue Type	County and number of fields	Average	Maximum	Minimum	CV*
<b>Northwest Kansas, Sheridan, Thomas and Sherman Counties</b>					
Irrigated Corn	Sheridan (6)	11.06	16.46	7.37	0.33
	Thomas (6)	10.29	16.56	7.18	0.33
	Sherman (3)	8.11	11.97	4.40	0.47
	All 3 Ctys (15)	10.16	16.56	4.40	0.34
<b>West Central Kansas, Scott, Wichita and Greeley Counties</b>					
Irrigated Corn	Scott (3)	12.55	16.06	10.02	0.25
	Wichita (3)	10.19	10.84	9.50	0.07
	Greeley (3)	7.92	10.86	5.94	0.33
	All 3 Ctys (9)	10.22	16.06	5.94	0.28
<b>Southwest Kansas, Haskell, Grant and Stanton Counties</b>					
Irrigated Corn	Haskell (4)	12.32	19.45	5.11	0.54
	Grant (3)	13.06	19.10	5.14	0.55
	Stanton (2)	10.33	12.44	8.22	0.29
	All 3 Ctys (9)	12.12	19.45	5.11	0.46

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

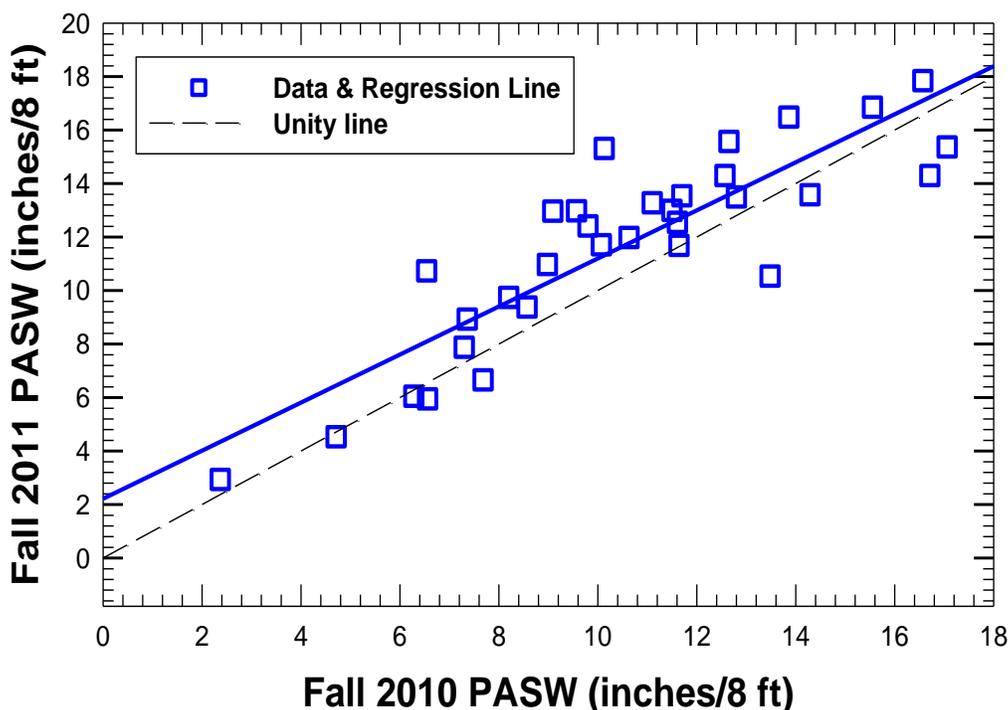


Figure 2. Similarity of plant available soil water (PASW) in the 8 ft soil profile in irrigated corn fields after harvest for the fall periods in 2010 and 2011 in western Kansas producer fields. These data represent 31 fields that producers made available for PASW measurements in both years.

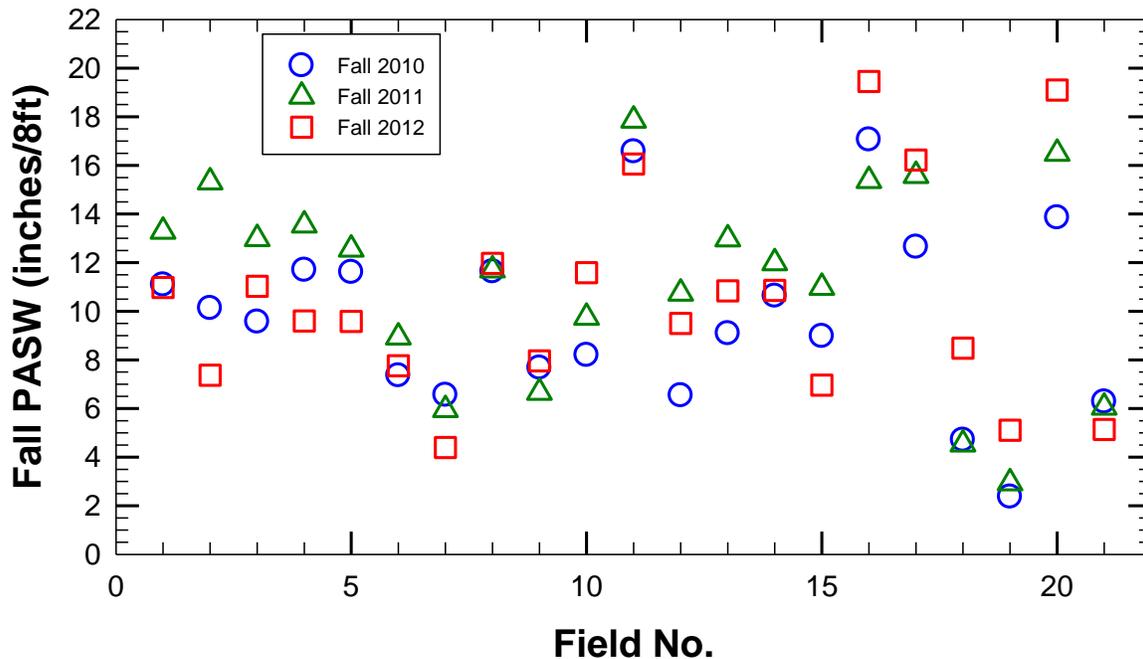


Figure 3. Similarity of plant available soil water (PASW) in the 8 ft soil profile in irrigated corn fields after harvest for all three fall periods 2010 through 2012 in western Kansas producer fields. These data represent 21 fields that producers made available for PASW measurements in all three years.

### **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 (data not shown) 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.

### **Corn Grain Yield as affected by Fall PASW**

Corn yields were related yields were related to fall PASW (Figure 5.), increasing sharply up until approximately a PASW of 8 inches/8 ft. (45% of Field Capacity) and then plateauing at approximately 10 inches/8 ft. (60% of Field Capacity). This suggests that many of the irrigators have determined from experience that they cannot severely deplete soil water reserves without encountering corn grain yield reductions.

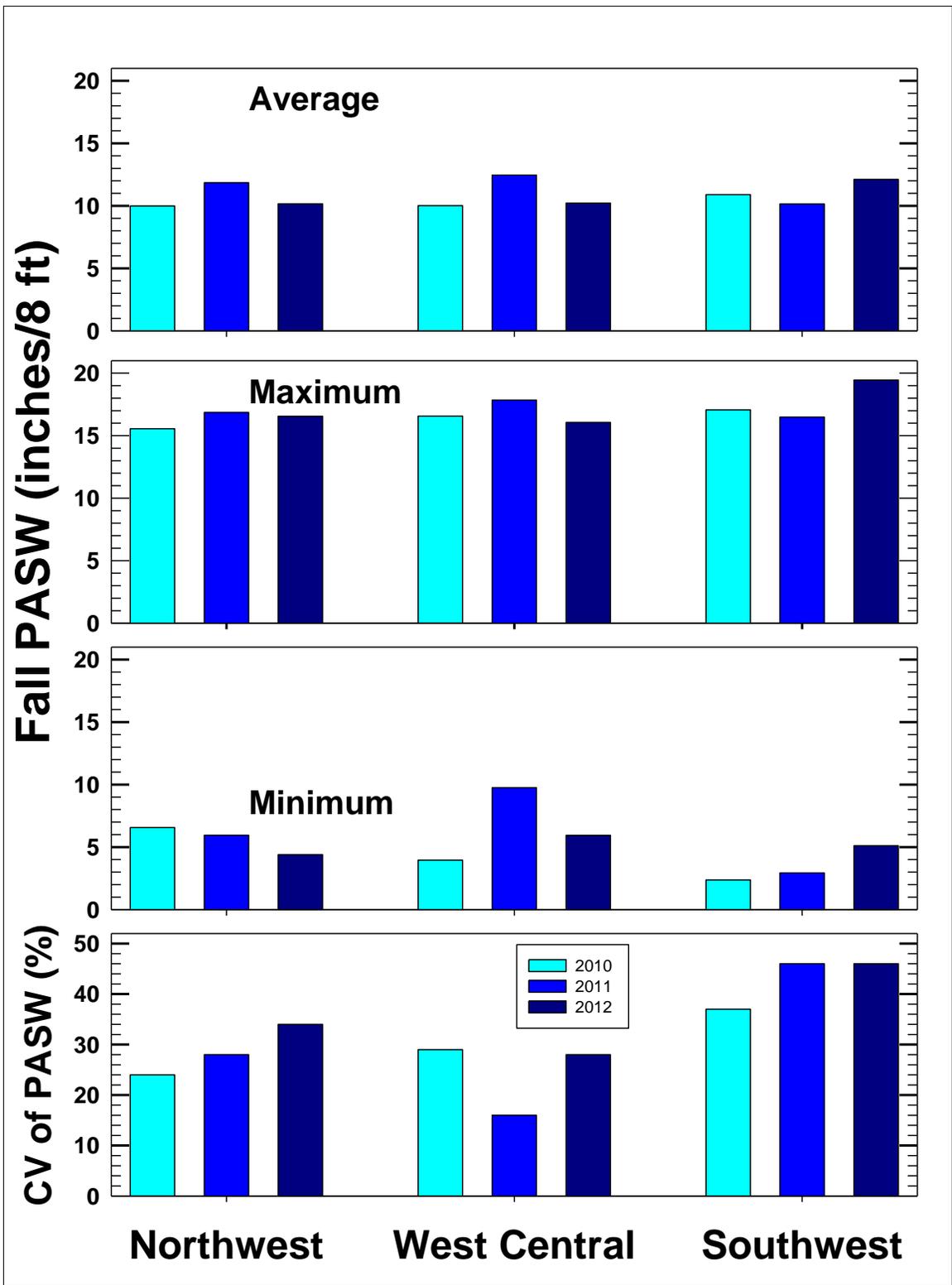


Figure 4. Effect of western Kansas region on average, maximum and minimum measured plant available soil water (PASW) in the 8 ft soil profile in irrigated corn fields after harvest for the fall periods in 2010 and 2011.

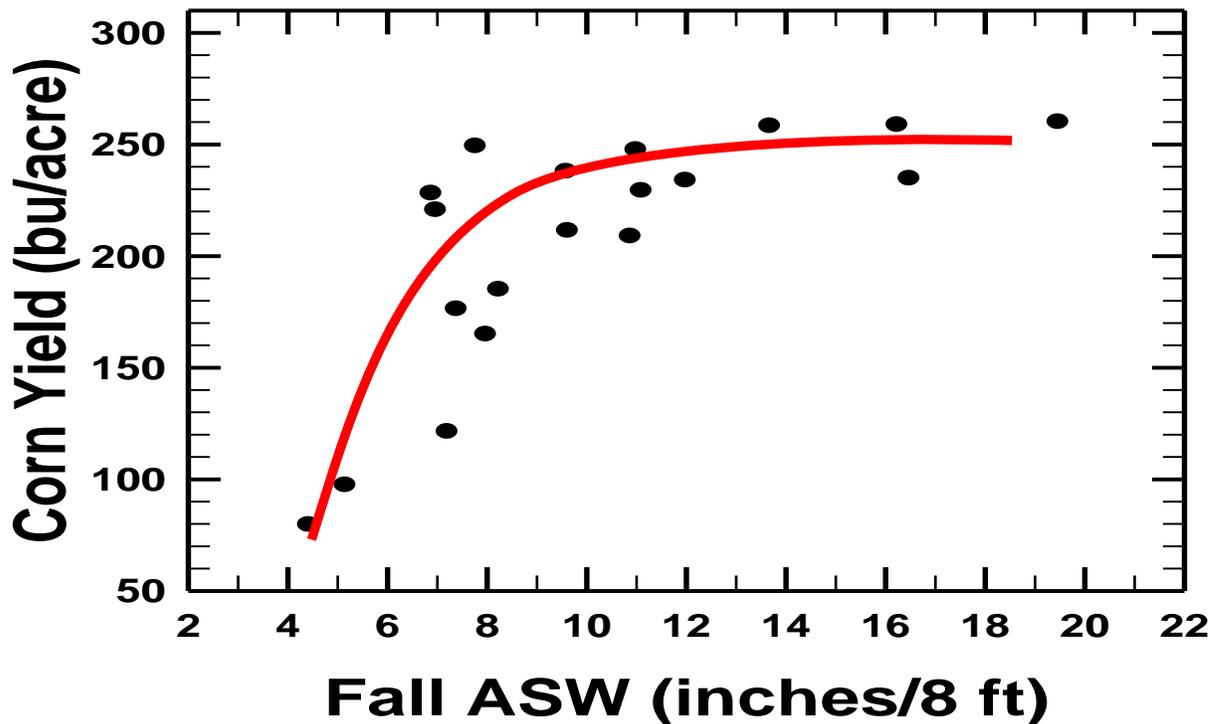


Figure 5. Corn yield as related to fall 2012 PASW in western Kansas irrigated fields.

### 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.

## ACKNOWLEDGEMENTS

This research was supported in part by the Ogallala Aquifer Program, a consortium between USDA Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

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