Precipitation Storage Efficiency During Fallow in Wheat-Fallow Systems

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ABSTRACT

Wheat-fallow production systems arose in order to stabilize widely ranging wheat yields that resulted from highly variable precipitation in the Great Plains. Historically, precipitation storage efficiency (PSE) over the fallow period increased over time as inversion tillage systems used for weed control were replaced first with less drastic tillage and later with no-till systems that employed herbicides for weed control. Previously published values of average fallow precipitation storage efficiency (PSE) for Great Plains wheat (*Triticum aestivum* L.)-fallow production systems have ranged widely (10-53%). The objectives of this study were to compare PSE in conventionally tilled (CT) and no-till (NT) wheat-fallow systems over 10 seasons at Akron, CO against previously published values of fallow PSE and to identify meteorological conditions that may be influencing PSE. Soil water measurements were made at four times during each fallow period: following wheat harvest, and about 1 October, 1 May, and 1 October to divide the fallow season into three periods (first summer, fall-winter-spring, second summer). Precipitation was measured in the plot area and other meteorological conditions were measured at a nearby weather station about 350 m from the plot area. Fallow PSE averaged 20% (range 8-34%) for CT and 35% (range 20-51%) for NT, much lower than previously reported for NT at Akron. PSE was not different between the two systems during the second summer fallow period. The largest PSE difference between the two systems was seen during the fall-winter-spring period (32 vs. 81%). Fallow soil water increased an average of 111 mm under CT and 188 mm under NT. PSE during the three fallow periods was related to tillage, precipitation, air temperature, and wind speed, but sometimes counter-intuitively. A simple linear regression using inputs of tillage system, percentage of fallow precipitation events with amounts between 5 and 15 mm, and percentage of fallow precipitation events with amounts greater than 25 mm can be used to accurately estimate PSE and fallow period water storage in this region.

Introduction

- Fallow systems have been used in the Great Plains to stabilize crop yields against highly variable precipitation.
- Precipitation storage efficiency during fallow has increased as tillage during fallow has become less aggressive and less frequent because of herbicide use.
- Greb (1979) anticipated fallow PSE to increase to ~40% because of herbicide use and reduced tillage, and Smika (1983, 1990) actually reported no-till fallow PSE ~50% at Akron, CO.
- Others have not been able to obtain these high PSE values.

Objectives

- Compare PSE in conventionally tilled (CT) and no-till (NT) wheat-fallow systems over 10 seasons at Akron, CO against previously published values.
- Identify meteorological conditions that may be influencing PSE.

Materials and Methods

- Location: Akron, CO
- Years: 1996-2006 (10 fallow seasons)
- Plot size: 9.1 m by 30.5m in NT and CT W-F plots from Alternative Crop Rotation Experiment; three replications
- Fallow weed control in NT was accomplished with 4 to 7 herbicide applications during the fallow period, while control in CT was accomplished with 4 to 8 tillage operations primarily with a V-sweep undercutter, occasionally with a rod weeder or disk
- Soil water measured at four times during fallow (see next bullet) by time-domain reflectometry in the 0-30 cm layer and with a neutron probe in the 30-60, 60-90, 90-120, 120-150, and 150-180 cm layers
- Soil water was measured at wheat harvest (early July), end of the first summer fallow period (about Oct 1), end of the fall-winter-spring period (about May 1), and end of the second summer period (wheat planting, about last week of Sep)
- Precipitation was measured in the plot area; other meteorological parameters were measured by an automated weather station about 300 m from the plot area
- PSE was calculated as 100*(change in soil water)/(interval precipitation)
- A variety of meteorological quantities were calculated for the various fallow periods and regressed against PSE to determine useful relationships using Best Subset Regression

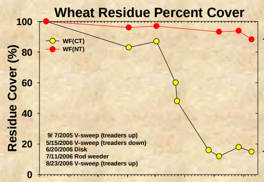

Fig. 1

← Percent cover with no-till declines gradually as residue ages.

← Percent cover with conventional till declines rapidly as tillage buries residue, stirs the soil, and promotes degradation and loss.

Table 1. Fallow period precipitation and precipitation storage eficiency (PSE) for conventional till (CT) and no-till (NT) wheat fallow systems at Akron, CO.

	----Fallow Period----											
	First Summer			Fall-Winter-Spring			Second Summer			Entire Fallow		
	Precip	PSE		Precip	PSE		Precip	PSE		Precip	PSE	
Year		CT	NT		CT	NT		CT	NT		CT	NT
	(mm)	(%)	(%)	(mm)	(%)	(%)	(mm)	(%)	(%)	(mm)	(%)	(%)
1996-1997	213	2.8	13.7 NS	41	-3.1	81.0*	264	14.6	15.2 NS	518	8.3	19.8*
1997-1998	116	2.8	21.0*	131	35.9	68.9 NS	212	8.2	18.0 NS	459	14.7	33.1 NS
1998-1999	165	30.4	43.7 NS	140	28.6	60.4†	377	37.8	42.8 NS	682	34.1	46.6*
1999-2000	260	55.4	58.2 NS	101	48.0	95.7 NS	222	-1.9	-9.1 NS	583	32.3	39.0*
2000-2001	159	27.3	28.4 NS	154	56.7	128.0†	310	11.0	-13.0†	623	26.5	32.4 NS
2001-2002	174	12.3	39.7*	50	33.7	76.5 NS	183	7.3	28.5 NS	407	12.7	39.2*
2002-2003	129	3.9	28.2*	213	33.3	76.9**	244	-1.8	-15.2†	586	12.2	27.8**
2003-2004	56	27.4	27.1 NS	83	87.5	124.9**	277	9.4	32.9**	416	27.5	50.5**
2004-2005	92	18.9	34.0 NS	157	1.7	59.1**	309	17.3	5.8 NS	558	13.2	25.4 NS
2005-2006	220	45.9	56.8 NS	109	-7.1	38.0*	225	4.0	14.6 NS	554	18.5	35.9†
Average	158	27.7	35.1**	118	31.5	80.9**	262	10.6	12.0 NS	539	20.0	35.0**

First Summer runs from wheat harvest (about 10 July) to about 30 September

Fall-Winter-Spring runs from about 1 October to about 30 April

Second Summer runs from about 1 May to wheat planting (about 20 September)

NS, †, *, ** = difference between PSE due to tillage treatment within a fallow period are not significant, significant at p=0.10, significant at p=0.05, or significant at p-0.01, respectively

Results

Table 1. PUE ranged widely from year to year within each of the three periods and for the entire fallow period

First Summer: PUE averaged 22.7% (range 2.8 to 55.4%) for CT; averaged 35.1% (range 13.7 to 58.2%) for NT

Fall-Winter-Spring: PUE averaged 31.5% (range -7.1 to 87.5%) for CT; averaged 80.9% (range 38.0 to 128.0%) for NT

Second Summer: PUE averaged 10.6% (range -1.9% to 37.8%) for CT; averaged 12.0% (range -15.2 to 42.8%) for NT

Entire 14-month fallow: PUE averaged 20.0% (range 8.3 to 34.1%) for CT; averaged 35% (range 19.8 to 50.5%) for NT

These values are lower than anticipated by Greb (1979) and reported by Smika (1983; 1990), but support the conclusion reached by Peterson and Westfall (2004) that improving PSE in wheat-fallow systems beyond 35% may not be possible.

Best 5-parameter Regression Model for Entire 14-month Fallow (see Fig. 1)

PSE = -14.21 + 14.97*Tillage +1.19*Snow3 + 32.0*VPD2 +11.98*WS1 – 1.24*Rad1 **R^2=0.89**

Tillage = 0 for CT, 1, for NT

Snow3 = amount of snow (cm, melted water) falling during Second Summer period

VPD = average vapor pressure deficit during Fall-Winter-Spring period

WS1 = average wind speed during First Summer period

Rad1 = average daily solar radiation (MJ/m^2/day) during First Summer

Best 4-parameter Regression Models for Each Fallow Period (see Fig. 2)

Period	Regression	
First Summer	PSE = 91.18 + 12.36*Tillage + 0.1933*Precipitation (mm) – 3.7626*Snow (mm) - 4.49*Temperature (C)	R^2=0.86
Fall-Winter-Spring	PSE = -12.78 + 49.40*Tillage + 27.11*Wind Speed (m/s) – 0.7532*Snow (mm) – 9.6362*Temperature (C)	R^2=0.74
Second Summer	PSE = -122.76 + 1.44*Tillage +0.1157*Precipitation (mm) +25.48*Wind Speed (m/s) + 3.8670 *VPD (kPa)	R^2=0.36

Tillage = 0 for CT, 1 for NT

Parameters are averaged (temperature, wind speed, VPD) or summed (precipitation, snow) within each specific fallow period

Best Regression Model for Entire 14-month Fallow Using Only Tillage and Precipitation Parameters (see Fig. 3)

PSE = -35.19 + 14.97*Tillage +2.070*(%Events5..15) + 1.505*(%Events>25) **R^2=0.87**

Tillage = 0 for CT, 1, for NT

%Events5..15 = percent of precipitation events with amounts between 5 and 15 mm

%Events>25 = percent of precipitation events with amounts greater than 25 mm

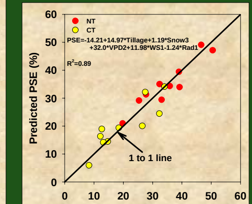

Fig. 2

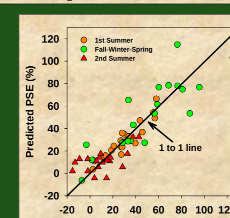

Fig. 3

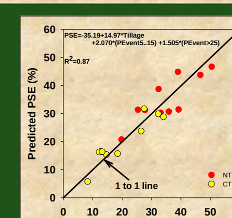

Fig. 4

Results

Fig. 2. PSE over the entire 14-month fallow period was well predicted over a range of 8 to 51% by a model that included tillage, amount of precipitation falling as snow during the second summer, vapor pressure deficit during the fall-winter-spring, and wind speed and solar radiation during the first summer.

Fig. 3. PSE during the first summer was well predicted over a range of 3 to 58% by a model that included tillage, precipitation, snow, and air temperature; PSE during the fall-winter-spring was predicted acceptably, but less precisely, over a range of -7 to 128% by a model that included tillage, wind speed, amount of precipitation falling as snow, and air temperature; PSE during the second summer was not predicted as well by tillage and meteorological parameters as during the other two fallow periods, but was significantly related to precipitation and wind speed (there was no tillage effect during this period).

Fig. 4. PSE over the entire 14-month fallow period was well predicted over a range of 8 to 51% by a model that included tillage, percent of precipitation falling in amounts between 5 and 15 mm, and percent of precipitation falling in amounts greater than 25 mm.

Conclusions

The average value of PSE > 50% reported for the 14-month fallow in W-F (NT) by Smika appears to be anomolous, although there are certain years when conditions can occasionally occur that will result in high PSE. A more reasonable PSE to expect under NT is 35%.

Using NT fallow management will result in an average 15 point increase in PSE for the 14-month fallow, but the tillage effect is not evident during the second summer period, even when very large differences exist in residue cover (Fig. 1). This finding suggests that reduced tillage systems that use herbicides for weed control during the first 10 months of fallow and then tillage during the last four months may be a valid alternative to a NT fallow management system for many farmers.

The most important meteorological parameters controlling PSE vary with time of year and it is not always easy or intuitive to understand how those parameters are controlling PSE.

A simple and effective model for predicting fallow period PSE over a range of 8 to 50% was identified that will allow farmers to estimate PSE and fallow period precipitation storage by simply tabulating precipitation amounts.

Testing of the model will be necessary to establish the validity of the relationship to other Great Plains locations.

References

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Acknowledgement

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