LONG-TERM CONVENTIONAL AND NO – TILLAGE MANAGEMENT, CROP GROWTH AND FIELD HYDROLOGY

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INTRODUCTION

- In the semiarid southern High Plains much of the intensive crop production depends on irrigation from the Ogallala aquifer to supplement precipitation. Volatile fuel costs and the decreasing saturated thickness and irrigation well capacity of the Ogallala aquifer (Pittman et al., 2007) promotes greater reliance on less productive and inherently riskier dryland cropping systems.
- Dryland wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] are grown using a wheat-sorghum-fallow (WSF) crop rotation (Fig. 1). The WSF rotation consistently produces two crops in a three year cycle with mean grain yields of 3.1 Mg ha^{-1} for sorghum and 1.2 Mg ha^{-1} for wheat (Jones and Popham, 1997). Stubble-mulch (SM) and no-tillage (NT) retain residue that reduces evaporation to increase storage of precipitation as soil water for later crop use (Baumhardt and Jones, 2002).
- Precipitation in excess of the soil infiltration or storage capacity (less crop use) results in runoff or drainage below the root zone. In a study quantifying tillage effects on soil water drainage, Eck and Jones (1992) measured an accumulation of nitrate at ~ 4 m under NT or about 1.25 m deeper than with SM. They concluded that NT not only increased water conservation but also movement of nitrate to depths > 3 m. Conversion from range to irrigated crops in the Texas High Plains increased groundwater recharge based on chloride displacement (Scanlon et al., 2005). Dryland fallow with NT that increases water storage may also increase recharge.

Wheat-Sorghum-Fallow (WSF) Rotation

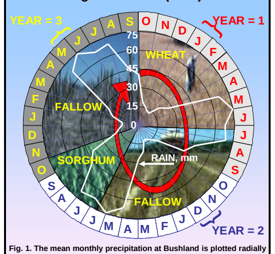

Fig. 1. The mean monthly precipitation at Bushland is plotted radially over the wheat-sorghum-fallow (WSF) rotation diagrammed as a 3-year cycle beginning with October wheat planting. Wheat harvest is 10-months later in July and the soil is fallowed until June of the second year (11 months). Then sorghum is grown using stored soil water and summer rainfall. After sorghum harvest in November of the third year the soil is fallowed for 10-months when wheat is planted and the cycle repeated.

OBJECTIVES

- Our objectives were to quantify the long-term effects of stubble-mulch tillage or no-tillage during a wheat-sorghum-fallow rotation on yield, runoff, soil water storage, and groundwater recharge through a Pullman clay loam.

MATERIALS AND METHODS

Agronomic

- The experiment was conducted using paired 1.8 to 4.1 ha contour-farmed graded terraces (0.5% slope) on a Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) cropped in the WSF (Fig.1) rotation at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX, USA (35° 11' N, 102° 5' W). Beginning in 1984, terraces were managed with either conventional SM tillage (3 - 4 operations) performed using a 5 m-wide sweep-plow at 0.1 m depth or NT using both contact and soil active herbicides depending on chemical residual and subsequent crop sensitivity (Baumhardt and Jones, 2002).

- Wheat was seeded in 0.2-m rows during October at approximately 45 kg ha^{-1} using a high clearance hoe opener grain drill for 2.0 x 10^6 plants ha^{-1}. A medium-early sorghum hybrid was planted in 0.76-m rows during mid-June at 24,000 seed ha^{-1} with unit planters. No supplemental N was added because this soil mineralizes approximately 50 kg ha^{-1} N during fallow (Eck and Jones, 1992), which is adequate to meet expected yields for dryland crops (Jones and Popham, 1997). No P or K fertilizers were applied because the Pullman clay mineralogy supplies sufficient K to meet crop demand (Johnson et al., 1983) and dryland crop response to broadcast applied P fertilizer is limited (Eck, 1969, 1988). Herbicides provided growing season weed control.

MATERIALS AND METHODS (cont.)

Measurements

- Soil water content was measured gravimetrically in 0.3-m increments to a 1.8-m depth after planting and harvest of each crop. Volumetric soil water, reported as plant-available soil water, was calculated from these gravimetric samples and previously measured soil density.
- Biomass and grain yield were determined from hand harvested samples. Wheat and sorghum grain yield was corrected to standard water contents of 12% and 13%, respectively.
- Runoff from terraces was measured with 0.9 and 1.2 m H-flumes and precipitation was measured using a standard gage.

Deep Soil Core Measurements

- Because infiltration into and drainage through the soil will, over-time, transport anions in the soil, we used the soil Cl concentration as a marker to determine drainage below the root zone.

- Using a Geoprobe[1] push drill (Model 6620DT, Salina, KS) we collected a series of 1.2 m long core samples contained within plastic sleeves to a depth of 10-20 m for subsequent analyses.
- Soil core analyses included: soil water content, matric potential, and the concentrations of Cl, sulfate, and nitrate as described by Scanlon et al. (2007).
- The Cl concentration peak displacement, relative to uncultivated rangeland vegetation, was used to define the depth of ion flushing and, subsequently, the drainage rate that should ultimately reach the aquifer (85 m below the surface).

Analysis

- Because the terraces were paired for tillage treatments, we analyzed the runoff, soil water content, and crop growth and grain yield data according to a paired t-test.

[1] The mention of trade names of commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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RESULTS AND DISCUSSION

Soil Water and Crop Growth

- Soil water is critical for dryland crop production. The 24 year mean available soil water at wheat planting totaled 195 mm for NT compared with the significantly lower 169 mm for SM tillage. Likewise, soil water at sorghum planting of 191 mm for NT was significantly greater than the 169 mm for SM. Soil water at planting combined with mean growing season precipitation of 278 mm for wheat and 254 mm for sorghum resulted in significant differences in water use for wheat that averaged 367 mm and 342 mm for NT and SM (respectively) and sorghum that averaged 325 mm for NT and 310 mm for SM.
- Peak leaf area index, LAI (m^2 m^{-2}), can reflect favorable growing conditions such as greater soil water at planting. Long-term average wheat LAI varied from 0.97 for NT to 0.91 for SM because of negligible sustained tillage effects over the entire growing season; however, sorghum LAI of 2.12 for NT was significantly greater than 1.91 for SM due to good early season growing conditions with NT. Favorable late growing season conditions can increase seed mass, but NT and SM tillage method resulted in no differences for either wheat, averaging 28 mg, or sorghum that averaged 18.7 mg.
- Wheat yield averaged 2.27 and 2.31 Mg ha^{-1} with NT and SM tillage, respectively. In contrast, mean sorghum yield of 3.38 Mg ha^{-1} with NT was significantly greater than the grain yield of 3.05 Mg ha^{-1} for SM tillage. The ratio of crop yield to water use, or water use efficiency (WUE), can identify superior management practices. For sorghum, NT achieved a 0.99 kg m^{-3} WUE that was significantly greater than 0.89 kg m^{-3} with SM. As observed for wheat growth factors and yield, the corresponding WUE of 0.62 kg m^{-3} and 0.66 kg m^{-3} with NT and SM (respectively) were not significantly different.

Hydrology – Runoff

- From 1984 to 2008, we measured small but significantly different runoff amounts during the 3-year WSF rotation that averaged 91 mm for NT compared with 59 mm for SM. The measured runoff from NT and SM plots did not differ during the wheat or sorghum cropping phases, but was greater for NT compared with SM during fallow phases. Measured runoff was greatest during the fallow after sorghum rotation phase and averaged 41 mm for NT compared with 21 mm for SM, or ~ 60% of the total difference in runoff due to tillage. This may have been due to nearly complete replenishment of soil water storage prior to repeating the rotation with wheat planting.

Soil Cl Concentration

- Chloride accumulation, from natural atmospheric deposition in precipitation, is shown in Fig. 2 for a nearby range site. The Cl concentration increases from the surface downward, peaking at 1-m depth or within the root zone, then quickly declines as the depth increases. This indicates rangeland vegetation consumed practically all of the precipitation and resulted in negligible water flux (drainage/recharge) through the Pullman clay loam profile.

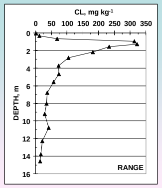

Fig. 2. Chloride concentration, mg kg^{-1}, with depth for native range.

RESULTS AND DISCUSSION (cont.)

Soil Cl Concentration

- The Cl concentration with depth is shown in Fig. 3 for SM and NT residue management for our 24-yr wheat-sorghum-fallow rotation experiment. Compared with rangeland, the cultivated soils had deeper Cl peaks. The concentration of Cl in the leached surface soil was negligible for the upper 2.2 m in NT plots (Fig. 3 L) and within the root zone at 0.95 m for SM plots (Fig. 3 R). The Cl concentrations then increased rapidly at depths of ~ 2 m that generally exceed the estimated crop rooting depth in the NT treatment. With NT, the Cl concentration increased for an additional 3 m to peak at 5 m. In contrast, the peak Cl concentration displacement with SM tillage was ~3.0 m before decreasing towards 25 mg kg^{-1} Cl concentration in the lower profile. The calculated annual soil water drainage in NT plots averaged 11.5 mm or almost double the 6.3 mm rate estimated for the region; however, the estimated time required to reach the 85 m deep water table is ~1400 years.

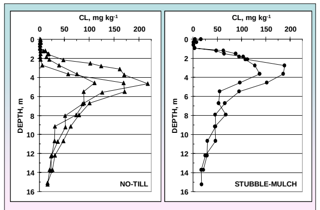

Fig. 3. Chloride concentration, mg kg^{-1}, with depth for dryland Wheat-Sorghum-Fallow rotation NT (3-cores) and SM (2-cores) tillage plots.

SUMMARY AND CONCLUSIONS

- For the period 1984-2008, we measured a consistent 25 mm increase in plant available soil water at planting for NT compared with SM tillage. This greater soil water content did not affect grain yield of wheat, but increased sorghum grain yield ~ 300 kg ha^{-1} for NT compared with SM .
- Although NT increased soil water storage during fallow and the grain yield of sorghum, mean runoff from the 3-year Wheat-Sorghum-Fallow rotation totaled 91mm for NT plots and 59 mm for SM tillage. The 32 mm difference was significant but only comprises 2% of the precipitation.
- We conclude that mean annual drainage rates through a NT managed Pullman clay loam soil was 11.5 mm or almost double the 6.3 mm regional drainage rate. The estimated time required for this increased downward water flux to reach the groundwater table, however, is a matter of centuries (~1400 years).

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