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TILLAGE EFFECTS ON NEAR-SURFACE SOIL WATER DYNAMICS

by R.C. Schwartz

Improved soil water conservation with no tillage practices is principally a result of reduced evaporation, greater infiltration rates, and efficient storage of soil water brought about by the presence of surface residue. However, even when differences in residue cover are insignificant among tillage treatments, improved crop emergence and early growth can be realized (Fig. 1). This suggests that other factors in addition to residue cover are contributing towards improved soil water status.

Tillage modifies the soil physical properties near the surface that influence evaporation rates and how water is redistributed within the profile during and after precipitation. Exposure of moist soil to the atmosphere by tillage can initially accelerate evaporative losses over a few days (Unger and Cassel, 1991). A persistence of greater average soil water contents near the surface is usually exhibitted under no tillage as compared with recently tilled soils (Smika, 1976; Zhai et al., 1990). However some studies suggest that surface residues only slow the evaporation rate and do not influence the near-surface soil water contents in the long-term (~30 d) as compared with bare soil (Army et al., 1961). Because previous studies have typically been confounded by the presence of different residue amounts, evaporation differences among tillage treatments do not necessarily reflect differences in hydraulic properties. Moreover, evaporative fluxes in response to tillage are also influenced by initial water contents, soil, tillage implement, and surface meteorological conditions. This study evaluated near-surface soil water dynamics during fallow on recently sweep-tilled (ST) as compared with untilled (UT) areas to better examine tillage effects on evaporation in the absence of residue.

Field plots were established in a fallow field under stubble-mulch tillage management on a Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustolls). Plots were kept weed free and devoid of residue throughout the study period. In September 2004, the entire field was tilled using a para-plow to a depth of 0.3 m. Subsequently, thermocouples and 200-mm trifilar TDR probes were installed horizontally in 12 sub-plots at soil depths of 0.05, 0.1, 0.15, 0.2, and 0.3 m accessed through small (0.25 × 0.35 × 0.35 m) excavated pits. Waveforms were obtained using a cable tester (Tektronic, Inc., Beaverton, OR, model 1502C)[1] and processed by a computer running the TACQ program (Evett, 2000a, 2000b). Field water contents were estimated using a square root of apparent permitivity calibration with temperature compensation based on packed laboratory columns of Ap (0-0.15 m) and Bt (0.15-0.30 m) Pullman clay loam horizons.

Plots consisted of four parallel strips with alternating tillage treatments that were imposed in the spring of 2005. On 7 April, 20 May, and 21 July, 2005, tillage strip-plots were tilled to a depth of 0.07 to 0.1 m using a plow with two 0.9–m sweeps. Prior to tillage, TDR probes and thermocouples at 0.05 and 0.1 m depth were excavated and removed on the tillage subplots. Probes and thermocouples were reinstalled in the same location a few hours after tillage. Soil water contents were also monitored using a neutron moisture gage (Campbell Pacific Nuclear International, model 503DR, Martinez, CA) at three locations in each of the four plots to a depth of 2.3 m at weekly intervals. Ambient air temperature, relative humidity, wind velocity, net radiation (REBS Q7.1) at 1 m above tilled and untilled plots, and global irradiance (Licor 200 pyronometer at 2 m) were also monitored during the study. Soil water depletion was estimated by calculating the change in soil water content with time. Soil water drainage at 60 cm was estimated using a modified plane of zero flux method.

Mean soil water contents (n = 6) of untilled plots were greater than tilled plots at 0.05 and 0.1 m except during and immediately after precipitation events. Significant (P<0.05) differences in water contents were restricted to soil depths ≤ 0.15 m and were most pronounced at 0.1 m (Fig. 2). By DOY 290, water content at the 0.1 m depth averaged 0.09 m^3 m^{-3} greater on untilled plots as compared with tilled plots.

(Continued on page 2)

Table of Contents

(Continued from page 1)

Tillage increased depth of infiltrated rainfall by 28 mm for the four major precipitation events in August 2006 [DOY 219 (18 mm); DOY 224-227 (45 mm); DOY 231-233 (28 mm); DOY 239 (13 mm)]. After rainfall, declines in soil water content with time were greatest with tilled compared to untilled plots (Fig. 2). Although tillage increased infiltration of rainfall, these soil water gains were offset by higher evaporation rates over the long term. From April through October 2005, tillage decreased mean soil water storage at 0.0 to 0.3 m by 12 mm on DOY 217, by 7 mm on DOY 287 and by 15 mm on DOY 305 as compared with untilled plots. After extended periods without rainfall (>30 d) in September, the rates of drying were nearly equivalent (0.475 and 0.477 mm d^{-1}) between tillage treatments despite significantly greater water contents near the surface in untilled plots. Drainage out of the surface 0.6 m profile during this same time period was estimated to be 0.1 mm d^{-1}.

Large decreases in measured soil water content at 0.05 and 0.1 m depth were evident within several hours after tillage. A portion of the water content reductions were ascribed to an abrupt decrease in bulk density upon tillage. Accounting for changes in bulk density, average soil water depletion during the first four hours after tillage ranged from 1 to 6 mm and decreased with increasing number of tillage operations (Table 1).

Maximum daily net radiation of the tilled surface after DOY 203 ranged from 4 to 19% greater than the untilled surface and these differences diminished with time after tillage. Decreasing differences between net radiation on untilled and tilled surfaces reflect the gradual reconsolidation and crusting of the tilled plots. A lower net radiation on untilled plots is likely a result of greater albedo on these more reflective and sealed surfaces.

From this study we conclude that greater water contents at 0.05 and 0.1 m persisted throughout the summer in untilled plots despite greater rainfall infiltration under sweep tillage. Increased soil water depletion with tillage was likely due to a change in soil hydraulic properties accompanied by enhanced vapor flow near the surface and greater absorption of radiation by a tilled surface with reduced albedo. In absolute terms, the difference in soil water depletion (~10 mm) between tillage treatments is small with respect to seasonal evapotranspiration in dryland sorghum (~300 mm). However, greater soil water contents near the surface in conjunction with slower drying rates after precipitation afford improved moisture conditions and a longer window of opportunity for dryland crop establishment. Favorable soil water status near the surface under no tillage can promote rapid crop establishment and root proliferation early in the growing season and lead to increased water use efficiency (Moroke et al., 2005).

(Continued on page 3)

Technology Transfer News

28th Annual Southern Conservation Systems Conference

Approximately 100 participates attended the 28th Annual Southern Conservation Systems Conference held on 26th, 27th, and 28th of June, 2006, in Amarillo, Texas. The conference was hosted by the USDA-ARS Conservation and Production Research Laboratory and chaired by Dr. R. Louis Baumhardt. Conference participants included agricultural operators and consultants, university and USDA extension personnel, research scientists, and others interesed in soil and crop management practices. In this years theme, "Improving conservation technologies to compete for global resources and markets", we highlighted the connection between all types of conservation systems and the farmer's bottom line profit. Conference proceedings can be downloaded at http:// www.cprl.ars.usda.gov/SCSC.htm

Tour - Wheat Field Day; Bushland, TX - May 25, 2006 to discuss "No-till residue management systems"

Tour - Southern Conservation Systems Conference; Amarillo, TX -June 28, 2006 to discuss "Residue management and deficit irrigation"

On 17-18 July 2006, Victor Alchanatis and Yafit Cohen of the Volcani Institute, Israel visited the irrigation automation team at Bushland to plan and conduct cooperative research on irrigation automation, canopy temperature sensing and plant water potential.

On 25-28 July 2006, Bill Kustas, Martha Anderson, Nurit Agam, and FuQin Li of the USDA-ARS Hydrology Laboratory, Beltsville, Maryland, visited the ET team at Bushland to plan cooperative research on remote sensing and energy balance modeling.

Tour – Randall County Field Tour; Bushland, TX. – Sept. 26, 2006 "Residue management of wheat for use with deficit irrigated cotton and corn"

On 11 October 2006, Robert Lascano, Professor of Soil Physics with Texas A&M University, presented the seminar "Explicit and Recursive Calculation of Evapotranspiration" at the Bushland laboratory.

On 21 November 2006, Steve Evett conducted a field tour for the West Texas A&M University class number 7325, Soil-Plant-Water Relations. The tour involved discussion of irrigation research, use of the large weighing lysimeters at Bushland for determination of crop water use and crop coefficients for irrigation scheduling, and weather measurements for estimation of reference evapotranspiration and field crop water use.

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(Continued from page 2)

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[1]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-ARS.

Table 1. Soil water depletion of the 0.0 to 0.1 m soil layer over a four-hour period after subsequent tillage passes.

Tillage Operation	DOY	θ_i †	Measured Depletion‡	Corrected Depletion‡
		$m^3\ m^{-3}$	-- mm --	--mm --
1st	97	0.153	8.1	6.1
2nd	140	0.079	2.3	2.2
3rd	202	0.051	1.1	1.0

†θ_i – initial water contents averaged over the 0.0 to 0.1 m depth increment.
‡ Measured depletion is the depletion of stored soil water after tillage whereas corrected depletion is the depletion that takes into account changes in soil bulk density.

Greater soil water contents near the surface in conjunction with slower drying rates after precipitation afford improved moisture conditions and a longer window of opportunity for dryland crop establishment under NT.

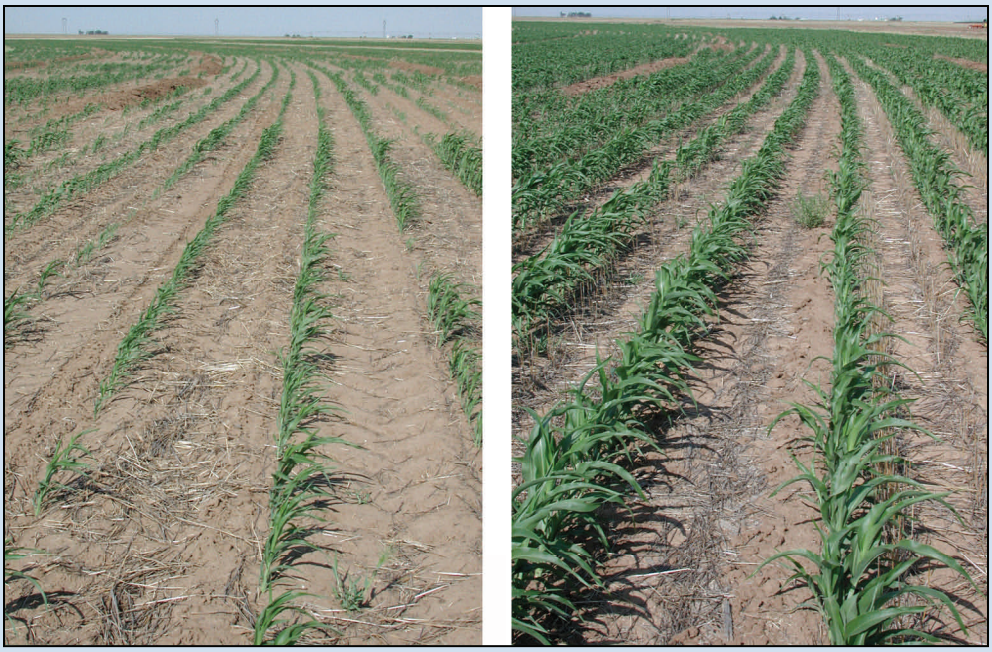

Fig. 1 Grain sorghum establishment after an extremely dry 11-mo. fallow (184 mm) on stubble-mulch (sweep) tillage (left) and no-tillage (right) plots, 15 July 2002. Sorghum was seeded on 11 June a few days after a one-inch rainfall. Note the low level of residue cover in both plots.

(Continued on page 4)

(Continued from page 3)

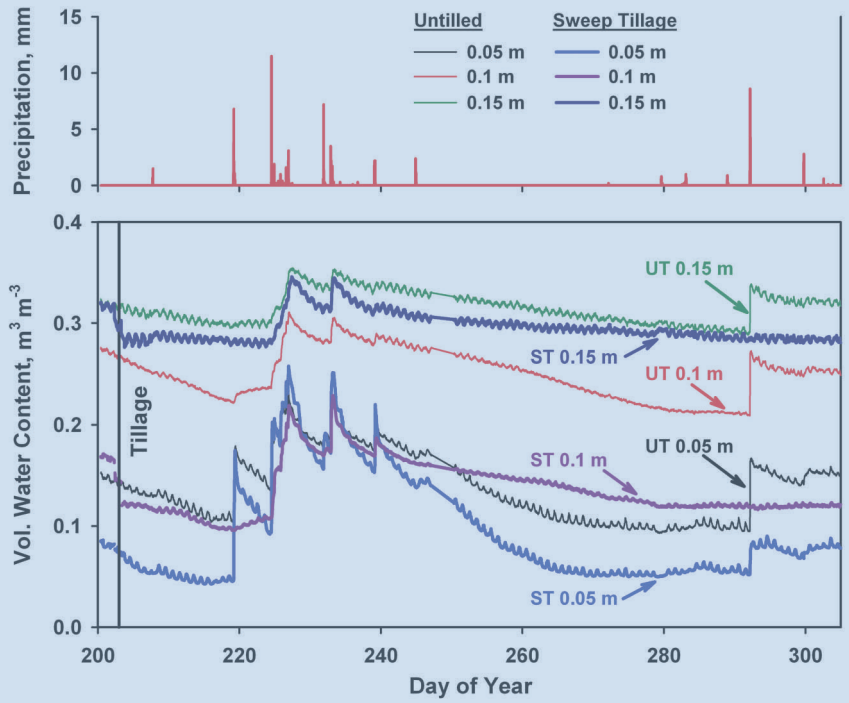

Fig. 2. Mean volumetric water contents at three depths for untilled (UT) and sweep tillage (ST) plots in 2005 and corresponding half-hourly precipitation depths. Vertical line indicates time of tillage.

Meetings & Presentations

Louis Baumhardt presented "Modeling to Evaluate Irrigation and Crop Management Strategies for Maximizing Grain Sorghum Yield and Water Use Efficiency" at the Biological Systems Simulation Group; Fort Collins, CO. April 11, 2006.

Paul Colaizzi attended the 2006 ASCE-EWRI World Water and Environmental Resources Congress, May 21-25, Omaha, NE

Louis Baumhardt presented "Tillage and Grazing Effects on Soil Physical Properties and Crop Yield", Steve Evett presented "Controlling Water Use Efficiency with Irrigation Automation: Cases from Drip along with Center Pivot Irrigation of Corn and Soybean" and Judy Tolk moderated Session IV of the Technical Sessions plus presented a poster "Water Use Efficiencies of Grain Sorghum Grown in Three USA Southern Great Plains Soils" at the Southern Conservation Systems Conference; Amarillo, TX, June 26-28, 2006. Paul Colaizzi attended the Conference as well.

Terry Howell attended the WERA-202 Committee Meeting, Fargo, ND, June 27-28, 2006.

Paul Colaizzi, Prasanna Gowda and Terry Howell attended the 2006 ASABE Annual International Meeting, sponsored by the American Society of Agricultural and Biological Engineers, July 9-12, Portland, OR.

Robert Schwartz presented "Estimation of Soil Water Content and Evapotranspiration of Dryland Crops Using Neutron Moisture Meter" and "Monitoring Tillage Effects on Soil Water Dynamics Using Automated Time-Domain Reflectometry" and Steve Evett presented "Soil Water Content Sampling in Time and Space: A Comparison of Methods" at the World Congress of Soil Science, July 9-14, 2006, Philadelphia, PA.

Terry Howell attended the TAES North Plains Field Station Field Day, Etter, TX, on August 9, 2006.

On 13 September 2006, Dr. Evett visited Dr. Lee Heng and Dr. Dirk Raes at the Water Resources office of the Land and Water Development Division of FAO in Rome. Purpose of the visit was to initiate collaboration on the revision of FAO 33, Yield Response to Water. The revision involves the development of a computer model, AquaCrop, that is expected to encapsulate the knowledge of crop water use, yield, and water use efficiency that has been accumulated since the publication of FAO Irrigation and Drainage Paper 33 in 1979. Dr. Raes is the lead modeler; and Dr. Heng is testing the model during development against high quality datasets for irrigated crops around the world. We are sharing datasets for full- and deficit-irrigated crops grown on the large weighing lysimeters at the USDA-ARS Conservation & Production Research Laboratory, Bushland, Texas. These datasets include direct measurements of crop water use and are some of the most accurate datasets available. Datasets for multiple cropping seasons of cotton, maize, sorghum, soybean and winter wheat will be shared. Researchers at the Bushland Laboratory will collaborate with FAO to ensure the correct use and interpretation of the data.

On 14-16 September 2006, Dr. Evett attended the 3rd Workshop and Annual Meeting of the project "Deficit Irrigation for Mediterranean Agricultural Systems" at CIHEAM – Mediterranean Agricultural Institute, Bari, Italy. Purpose of the visit was to explain the AquaCrop model to project participants from the Mediterranean countries and to elicit their cooperation in providing datasets for model testing. Dr. Evett proposed a symposium for the 2007 International Meeting of the Agronomy Society of America in Division A3, Agronomic Modeling and Climatology, for which he will be chair. The symposium will highlight progress in the development and testing of AquaCrop.

Steve Evett traveled to Uzbekistan on 18-26 September 2006, to work with Dr. Nazirbay Ibragimov, Head of the Soil Fertility Deparment, Uzbekistan National Cotton Growing Research Institute (UNCGRI); with Dr. Bakhtiyor Kamilov, Head of Coordination and Planning Department, Uzbek Science Production Center, Ministry of Agriculture and Water Resources; and with other project team members. Purposes of the work were to i) complete final project reports for project number P116, Science and Technology Center Ukraine (STCU), entitled "Improving Irriga-

(Continued on page 5)

(Continued from page 4)

tion Water Use Efficiency and Water Quality in Uzbekistan", ii) drafting of two manuscripts for submission to peer-reviewed scientific journals, iii) preparation of datasets for testing of the FAO AquaCrop model for cotton and maize in Uzbekistan, and iv) writing of a pre-proposal for a new project entitled "Effects of Agricultural Practices on Evaporation, Transpiration, Yield and Water Quality" that has since been submitted to USDA-OIRP. Titles of the draft papers are "Neutron moisture meter calibration and use in six soils of Uzbekistan" and "Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation".

Terry Howell and Paul Colaizzi attended the TAMU Meeting with Drs. Vijay Singh and Gary Riskowski on October 3, 2006.

Terry Howell attended the 2006 Texas Section ASABE, October 10-12, 2006, in Brenham, TX.

Paul Colaizzi and Prasanna Gowda attended the USCID Water Management Conference: Ground Water and Surface Water Under Stress: Competition, Interaction, Solutions, October, 25-28 in Boise, ID. Paul Colaizzi presented "Reducing Ogallala Withdrawals by Changing Cropping and Irrigation Practices in the Texas High Plains," and Prasanna Gowda presented "Assessing Climatic Suitability for Cotton Production in the Ogallala Aquifer Region."

Terry Howell attended the W-1128 CSREES Committee Meeting, San Antonio, TX, on November 1-3, 2006.

Paul Colaizzi, Susan O'Shaughnessy and Terry Howell attended the Irrigation Association 27th Annual International Irrigation Show in San Antonio, TX, on November 5-7, 2006. Terry Howell and Susan O'Shaughnessy set up and organized the ARS booth with help from Jim Fouss (ARS-Baton Rouge, LA) and John Repogle (ARS-Maricopa, AZ). Paul Colaizzi presented "Near-surface Soil Water and Temperature for SDI, LEPA, and Spray Irrigation."

Louis Baumhardt, Steve Evett, Prasanna Gowda, Judy Tolk and Terry Howell attended the ASA/CSSA/SSSA Annual Meeting, Indianapolis, IN on November 12-16, 2006. Judy Tolk presented a poster "Advection Influences on Evapotranspiration of Alfalfa in a Semiarid Climate" and presided over the session titled, "Climate and Weather Data Sources". Louis Baumhardt presented "Deep tillage Effects on Crop Productivity and Soil Properties 30 years After Treatment". Steve Evett presented the invited presentation "Soil Water Sensing for Plant Water Uptake" in the symposium titled "Understanding Plant Water Uptake". Steve also served as chair-elect of Division A-3, Agroclimatology and Agronomic Modeling and chaired the session titled "Climate Change and Agriculture".

Terry Howell presented a poster 'Evapotranspiration of Soybean in a Semi-Arid Environment." Steve Evett presented "Soil Water Sensing for Plant Water Uptake." Prasanna Gowda presented "a Geographic Profile of Manure Production and Antibiotic Use in the Ogallala Aquifer Region."

Paul Colaizzi attended the International Conference on Water in Arid and Semiarid Lands, International Center for Arid and Semiarid Land Studies (ICASALS, Texas Tech University), November 15-17, 2006, in Lubbock, TX.

Paul Colaizzi attended the Meeting with scientists at the USDA-ARS Hydrology and Remote Sensing Laboratory, Beltsville, MD, November 27-28, 2006, to review two-source energy balance modeling results and further developments.

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(Continued on page 6)

(Continued from page 5)

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(Continued on page 7)

New Scientist…..
By Susan O'Shaughnessy

Regardless of geographic location, water has become a significant topic of research. Whether the objective addresses quality, quantity, supply or management, sound research continues to have the ability to positively impact the constituent sectors of communities and their standard of living. I became part of the Soil and Water Management Research Unit here at Bushland in late July 2006, after completing my Ph.D. at the University of Arizona, Department of Agricultural and Biosystems Engineering. My research interests include: management of irrigation systems and water resources; ground based remote sensing and recycling of agro-based products.

On a broad scale, I am currently working to improve the water use efficiency of a center pivot irrigation system as an important measure to help sustain the Ogallala Aquifer. On a narrower scope, I am developing a prototype signal conditioner to interface between an infra-red thermocouple and a RF module in order to establish a wireless system of field sensors. The goal is to allow for a practical turn-key setup that builds on the current automated irrigation scheduling research developed by this research unit for a center pivot system. A second project is to implement ground-based remote spectral sensors and thermal imaging to provide real-time signaling of crop water stress. When used in conjunction with the proven time temperature threshold (TTT) method of irrigation scheduling, these additional 'stress' triggers will make for a more robust automated system.

My research work at the University of Arizona involved the improvement of management practices for the solar drying of biosolids for agricultural land application in arid and semi-arid regions. I deployed various sensors to measure key environmental parameters affecting pathogen inactivation and used control processing to prevent regrowth of pathogens using an automated cover and speed Class A production. The experimental field work that I did encompassed work in various locations in Arizona, Jordan and in southern Mexico. The objectives of the international work were to provide technology transfer to other scientists and encourage best management practices in producing an environmentally safe soil fertilizer from sewage waste residuals. In addition to pathogen studies, chemical analysis was performed to understand the degree of ammonia volatilization and N mineralization during the drying process.

Prior to obtaining my Ph.D., I worked in the private sector and with the U.S. Department of HUD on single-family housing construction matters ranging from energy efficiency to environmental issues.

Having spent the majority of my life in Arizona, I am well aware of the impact that an arid climate and drought have on crop production, water policy, conservation practices, and the resulting competition between economic sectors for water use and water rights. However, I also realize that water issues are unique to each community, and therefore, I expect to become familiar with the specific challenges and needs of the surrounding communities, farmers and cattle ranchers in the high plains area. My telephone number is (806) 356-5770 and my e-mail address is soshaughnessy@cprl.ars.usda.gov if you have questions or would like to give me any input.

(Continued from page 6)

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The *Wetting Front* publication is designed to foster technology transfer from our research to industry and to agricultural producers in the Southern High Plains and to improve communications with our stakeholders and partners.

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