Wetting Front Newsletter




Soil and Water Management Research News

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In This Issue


Lysimeters Measuring Crop Water Use Around the World 3


What are the Long-Term Effects of Profile Modifying Deep Plowing on Soil Properties and Crop Yield 8

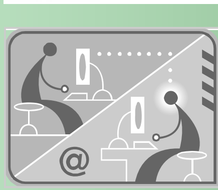

New Project Manager for the Ogallala Aquifer Program 14


Station Celebrates 70 Years 15

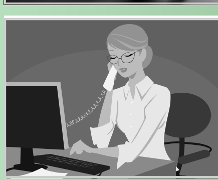

Personnel News 16


Meetings & Presentations 19


Publications 22

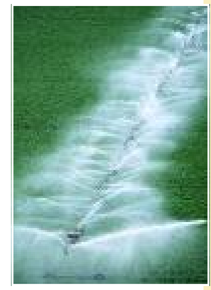

Technology Transfer News 23


Research Staff 24


Newsletter Contact 24







Lysimeters Measuring Crop Water Use Around the World

By Steve Evett

Personnel of the SWMRU have been involved in weighing lysimetry for crop water use measurements since the completion of the four large weighing lysimeters at Bushland in 1988 led by Dr. Terry Howell, Research Agricultural Engineer and Unit Research Leader. Crop water use (also known as evapotranspiration, ET) has been studied for all major crops in the Southern High Plains on those lysimeters, which has resulted in the scientific basis for the Texas High Plains Evapotranspiration (TXHPET) network. The TXHPET network provides crop water use estimates on a daily basis to over 400 producers across the Texan Panhandle, covering some 2 million irrigated acres. Since 1988, 48 smaller weighing lysimeters have been installed in the Soil-Plant-Environment Research (SPER) facility that is operated by Dr. Judy Tolk, Research Plant Physiologist. The SPER facility lysimeters comprise four soils that are important to Southern High Plains agriculture, allowing Dr. Tolk to investigate the important soil effects on crop water use under full and deficit irrigation practices. The SPER soils are from Garden City, Kansas; and from Big Spring, Bushland and Dalhart, Texas. Dr. Tolk's research has shown important differences, caused by soil properties, in the ability of several crops to uptake water and to translate water uptake into yield.

The 53rd weighing lysimeter at Bushland was built in 1993-1994 in order to study reference grass evapotranspiration as part of a three-year Egypt-USA joint research project on crop water use. At the same time, two weighing lysimeters, designed by SWMRU personnel, were installed at a research station in Ismailia, Egypt near the Suez Canal to study crop water use under drip and sprinkler irrigation on the deep desert sands there. Water for irrigation at Ismailia comes from the Aswan dam via a large canal system crossing the desert. The Egyptian Soil Water and Environment Research Institute (SWERI) partnered again with the SWMRU in the later 1990s for a second three-year project that consolidated the progress made earlier and which saw the installation of a unique soil water content monitoring

(Continued from page 3)

system utilizing time domain reflectometry probes installed to 3-m depth. Currently, Dr. Taha El-Maghraby of SWERI is visiting the SWMRU for six months to strengthen skills in weighing lysimeter and soil water measurement system operations for continued use of the Ismailia lysimeters. His contact here is Dr. Steve Evett, Research Soil Scientist.

As a result of the expertise gained from these lysimeter design processes, installations and operations, SWMRU have been invited often to consult on weighing lysimeter designs. Dr. Arland Schneider (since retired) consulted on lysimeter designs in Saudi Arabia and at the USDA-ARS Laboratory at Parlier, California. Dr. Terry Howell advised and consulted on lysimeter designs in Brazil, Tennessee, Arizona, Nebraska, and Louisiana. And, Dr. Judy Tolk advised the USDA-ARS Laboratory at Temple, Texas on design of lysimeters similar to those she manages in the SPER facility. Drs. Evett and Howell consulted with Dr. Peter Wierenga on the lysimeters installed at the University of Arizona in Tucson ; and Dr. Evett advised Dr. Michael Young of the Desert Research Institute in Nevada on the design of the weighing lysimeter research facility at Boulder City, NV. . And, Drs. Howell and Evett have provided advice to the State of Colorado for the lysimeters just installed at Rocky Ford for reference alfalfa water use measurements and other crop water use measurements in the Arkansas River Valley. Also, Agronomist Don Dusek (since retired), joined Drs. Howell, Evett, and Schneider in advising Texas AgriLife Research personnel on the design, installation and operation of the weighing lysimeters at Uvalde, Texas, used for horticultural and other row crop water use determinations in support of irrigation scheduling advice to the Winter Garden farming community.

More recently, Dr. Evett designed a weighing lysimeter (Fig. 1) for the Dayr Alla research station in the Jordan Valley, Jordan in collaboration with a three-person team from the National Centre for Agricultural Research and Extension (NCARE). The Jordanian team included Drs. Mohammed Jitan and Naem Mazahrih and Engineer Mahmoud Sawalha (Fig. 2). The lysimeter provides knowledge of crop water use in the agriculturally important Jordan Valley, often described as the world's largest green house since this rift valley is located more than 200 m below sea level. Due to the desert climate, more than 95% of irrigated land is drip irrigated and about 30% of the irrigated land is covered by plastic houses, which further conserve water and increase yield per unit of water applied. Horticultural and fruit crops from the valley are sold to markets around the Middle East and in Europe, where prices are high in the winter when production in the valley peaks.

The Dayr Alla lysimeter is a keystone of the Middle Eastern Regional Irrigation Management Information Systems (MERIMIS) project organized by Dr. Ibrahim Shaqir, Acting Director of the ARS Office of International Research Programs. This quadrilateral effort involves scientists, agricultural engineers and extension personnel from Israel, Jordan, the Palestinian Authority and the USDA-ARS. Their goal is to provide irrigation scheduling information to farmers in the region, and to improve crop yields per unit of water used. Crop water use measured at Dayr Alla, and by soil water balance in allied experiments using the neutron moisture meter, will be used to determine crop coefficients that are currently unknown for this environment. These coefficients will be used with reference ET values derived from weather station data from the 11- station MERIMIS network to provide crop water use estimates to drive accurate irrigation scheduling that saves water and improves yields and harvest quality.

The Dayr Alla lysimeter measures 2.4 m by 3.0 m at the surface and is 2.5-m deep (Fig. 3). The mass changes due to water use are measured with a lever arm type scale with a 1:100 mechanical advantage, resulting in a precision of 0.06 mm equivalent water depth. The lysimeter was commissioned in May 2008 after careful calibration and has since measured water use of a sweet corn crop (Fig. 4). Measurements show that the lysimeter and associated weather instrumentation are working as expected and are able to detect half-hourly changes in weather (needed for reference ET calculations) and associated ET rate responses (Fig. 5) (Evett et al., submitted to Transactions of the ASABE).

Also in 2008, Dr. Evett was invited by Dr. Xuzhang Xue of the Chinese National Engineering Research Center for Information Technology in Agriculture (NERCITA) to design a large weighing lysimeter and a facility comprising 24 smaller lysimeters for installation at the NERCITA research station outside of Beijing. In October, Dr. Evett traveled for ten days in China to collaborate on final lysimeter designs and to give five talks at government agencies and universities. After a lull due to the 2008 Olympics, construction on the lysimeters is now proceeding (Fig. 6). Weighing lysimeters avoid uncertainties in the soil water balance due to un-measurable horizontal and vertical water movement in the soil, which lead to uncertainties in subsequent crop water use calculations. As a result, weighing lysimeters are arguably the most accurate means of determining crop water use under a host of irrigation application methods, tillage and cropping systems, and in many different environments. The USDA-ARS SWMRU at Bushland is grateful for the many fruitful collaborations on crop water use determination, now extending to five continents. We look forward to many more such efforts.

Authors are Steven R. Evett, Terry A. Howell, Arland D. Schneider (retired), Donald D. Dusek (retired), Judy A. Tolk and Taha El-Maghraby (visiting scientist), USDA-ARS Conservation and Production Research Laboratory, Soil and Water Management Research Unit, Bushland, Texas USA..

Return To Index Page

Research Station in Dayr Alla, Jordan

Figure 1. Surface drip irrigation system installed in field and on weighing lysimeter at Dayr Alla, Jordan.

Figure 2. The Jordan lysimeter team inside the lysimeter after the datalogger (background) was installed and the first readings of lysimeter mass and microclimate were made. From left to right: Dr. Mohamed Jitan, Agricultural Engineer; Mahmoud Sawalha, Mechanical Engineer; and Dr. Naem Mazahreh, Soil Scientist. All are with the National Centre for Agricultural Research and Extension.

Return To Previous Page

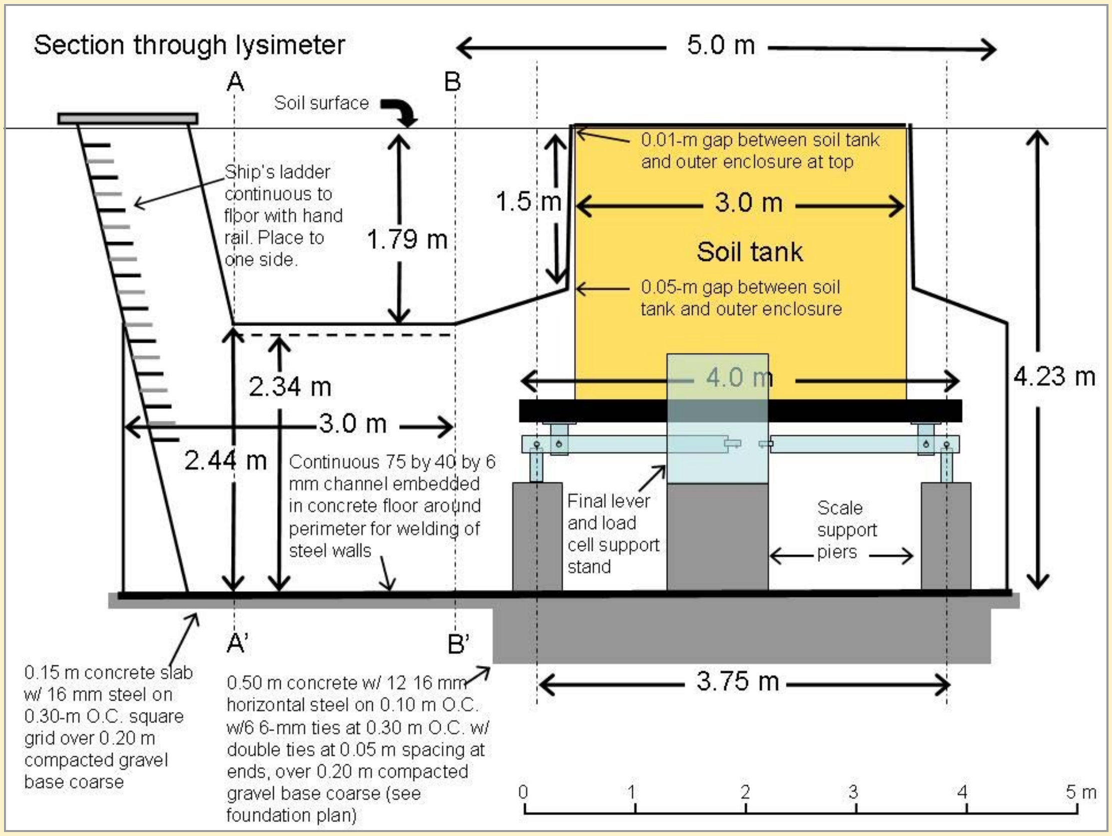


Figure 3. Cross section through the Dayr Alla, Jordan, lysimeter showing soil tank, outer enclosure, access way to entrance tunnel, and hatch. Not all items shown are in the same plane. The foundation and slab, steel channel in slab, scale support piers, scale, final lever and load cell support stand, main girder, and soil tank are not in the plane of the cross section but are shown for completeness. Roof support columns and horizontal and vertical reinforcing I-beams are not shown. The scale mechanism is shown in blue, the soil tank in yellow.

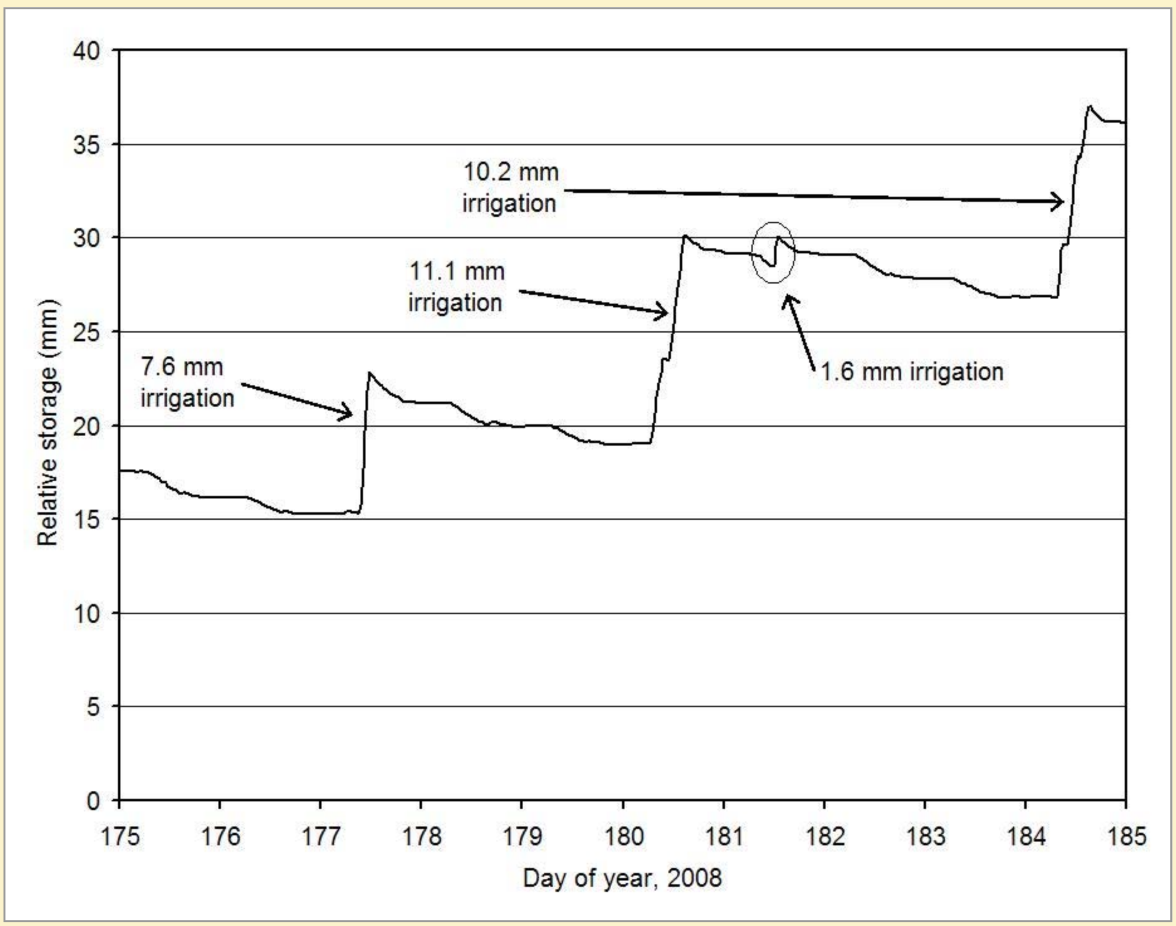


Figure 4. Lysimeter response to five irrigation events early in the season in terms of the relative storage in mm of water at Dayr Alla, Jordan. Storage decreases during the day and remains relatively static at night.

Return To Previous Page

Figure 5. **The weighing lysimeter with a sweet corn crop near harvest. The micrometeorological equipment is on a mast (center left); and one edge of the lysimeter surface appears centered between corn rows (lower right).**

Figure 6. **Dr. Xuzhang Xue with soil tanks for the large weighing lysimeter (behind him) and the smaller weighing lysimeters (he is touching one) to be installed at the research station of the National Engineering Research Center for Information Technology in Agriculture, Beijing, China.**

Return To Previous Page

Long-Term Research and the Deep-Plowing Experiment

R.Louis Baumhardt

What constitutes "long-term" research may be as apparent as collectable art; although many are quick to identify the plots in Rothamsted-UK, started in 1843, as the gold standard of long-term research. When researchers conduct experiments in reference to a hypothesis that determines treatment application, the test duration usually lapses after a few "climatically representative" years. Mr. O. Reggie Jones initiated his deep plowing experiment in September of 1971 to test the hypothesis that deep plowing a Pullman soil to break-up dense subsoil layers would increase dryland crop yield through increased rooting that expands the amount of soil explored for water. Any question of treatment durability or the sustainability of a management practice constituted an additional hypothesis. Nevertheless, sustained benefits of deep plowing depend on processes of soil consolidation and redevelopment of the dense subsoil layers, and these processes could span a growing season or, possibly, decades.

The summer of 1971 was also my first time to work at the Bushland Research Center as a student, armed with a nearly new driving permit. I helped collect soil and plant samples, and I quizzed practically everyone about the assortment of nearby experiments. These included on-going groundwater recharge experiments using excavated basins and efforts to quantify soil profile modification and deep plowing effects on the growth and yield of irrigated crops. One recurrent concern about some of these tillage practices was that the effects may be short lived.

My professional appointment with the USDA-Agricultural Research Service at Bushland began in September of 1997. Agency leaders stressed that research conducted by ARS scientists should

What are the LONG-TERM EFFECTS OF PROFILE MODIFYING DEEP PLOWING ON SOIL PROPERTIES AND CROP YIELD

By R. Louis Baumhardt, Bridget Scanlon**, O. Reggie Jones****

Precipitation on the semiarid Southern Great Plains, during an average year, provides approximately 25 percent of the potential evapotranspiration (ET) for crop water use. Dryland cropping systems rely on stored soil water to supplement precipitation during dry years. The Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) is the dominant soil found on of the Southern Great Plains region, occupying 1.5 million ha (Unger and Pringle, 1981), and features a very slowly permeable subsoil layer from 0.15 to 0.7 m depth. This layer may impede infiltration of rain for crop use and delay internal drainage of ponded water. Eck and Taylor (1969) proposed a one-time deep, > 0.4 m, plowing modification of the soil profile to eliminate the dense subsoil to increase infiltration of rain and irrigation. Several studies at Bushland evaluating the effects of soil profile modification have consistently reported decreased bulk density (BD) and increased infiltration for a period of up to 26 years (Eck and Taylor, 1969; Eck, 1986; Eck and Winter, 1992; Unger, 1993). Another benefit of disrupting dense subsoil layers with deep plowing was decreased penetration resistance (PR) and, consequently, an expanded volume of soil explored by roots of irrigated crops. There is little information documenting the longevity of deep plowing effects on soil physical properties or growth and yield of dryland crops.

Another consequence of increased infiltration in deep plowed soil profiles is the potential for increased internal drainage leading to ground water recharge. Aronovici et al. (1972) ponded water using 0.4 ha basins excavated into the caliche layers beneath the Pullman soil and observed its progress down to and through the caprock strata overlying the Ogallala formation. The estimated recharge rates in these basins approached 0.4 m d^{-1}; however, the limited area of recharge basins restricts potential groundwater recharge. Deep plowing gently sloping Pullman soil in leveled bench terraces constructed around playa lakes may expand potential groundwater recharge using the

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emphasize regionally important topics of "high-risk" or requiring "long-term" study. From my perspective, practically any Bushland landmark identifying an old experiment could be a long-term study. Some of the research assets I now manage were originally established by V.L. Hauser in the 1950's and had been the site for Reggie Jones' deep plowing experiment. I also received a collection of unreported data from these studies along with "historical" observations from Reggie. One of those emphasized the rapid drainage on his old deep-plow plots. I suppose it was luck, but I saw this difference in drainage following a large rain and revised Reggie's original hypothesis that deep plowing to break-up dense subsoil layers would have a sustained effect to increase infiltration and drainage for a Pullman soil.

The folders from the deep-plow experiment contained growth, water use, and yield data for crops grown since the summer of 1972. These were combined with more recent paired crop observations. Soil measurements taken at the onset of the study were repeated after about 30 years with the goal of documenting any sustained "long-term" tillage benefit. In that report, it was concluded that the 1971 moldboard plowing of a Pullman soil to 27 in. (0.7 m) decreased subsoil penetration resistance and bulk density and increased infiltration. The intermittent yield increase with deep plowing was attributed to improved drainage (just like Reggie observed) that reduced flood injury to seedling sorghum. Proof of increased drainage due to deep plowing came from a cooperating scientist, Bridget Scanlon, who analyzed soil chloride concentrations with depth. Drainage through a Pullman with normal sweep tillage for weed control resulted in a chloride concentration bulge at about 10 ft (2.8 m). In contrast, the chloride bulge had moved to a depth of about 40 ft (12.0 m) because of increased drainage with deep plowing. From long-term results, we conclude that deep plowing increased sorghum grain yield through improved infiltration and drainage of rain.

normal runoff from contributing watersheds. To quantify subsurface water movement and evaluate potential groundwater recharge Scanlon et al. (2007) analyzed the distribution of native chloride concentrations with depth as a tracer to determine ion displacement. This method can be used to verify the long-term impact of deep plowing to modify the soil profile on the infiltration and internal drainage processes for possible groundwater recharge.

In addition to characterizing the effects of profile modification and deep plowing on soil physical properties, several studies reported consistently greater yields under full or limited irrigation (Eck and Taylor, 1969; Schneider and Mathers, 1970; Eck, 1986; Eck and Winter, 1992). Dryland crop production systems, however, were not evaluated. We hypothesize that profile modifying deep plowing to eliminate dense subsoil layers will have a sustained effect on soil properties and crop yields under dryland conditions. Our objectives were to quantify the long-term effects of deep plowing soil with a flow restricting subsoil layer on selected physical properties including infiltration, BD, and PR, and long-term crop yield.

Fig. 1. Moldboard plow used to till conservation benches to 0.70 -m depth without inverting the soil. Plow was pulled by a D-8 Caterpillar tractor.

METHODS

The long-term (1972-2005) effects of soil profile modification using deep plowing on crop yield and selected soil physical properties were evaluated at Bushland, TX as described by Baumhardt et al. (2008). Briefly, a pair of contour-farmed level conservation bench terraces (24 m by 410 m or larger) were either untreated (control) or deep plowed to 0.7 m in September of 1971. The 1.0-m single blade moldboard was adjusted to retain topsoil in the top part of the profile (Fig. 1). Afterwards, stubblemulch tillage was performed at a 0.10 m depth as needed for weed control. Wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.)

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Moench] were uniformly cropped on the runoff contributing terrace watersheds using the wheat-sorghum-fallow (WSF) rotation. The level benches were planted to various annual crops, but grain sorghum, seeded at 8 seed m^{-2} during early to mid-June in single 0.75-m rows permitted the greatest number of paired yield comparisons during the study (i.e., 15 growing seasons). We used herbicides for seasonal weed control and applied N fertilizer as needed for sorghum crops on benches. Sorghum grain yields were determined by combine harvesting triplicate plot areas.

Soil BD for both deep plowed and control terraces was measured at 3 to 4 locations ~ 100-m apart to ~ 1 m depths in 1975 and 2002. In 1975, infiltration was estimated from periodic measurements of ponding depth beginning 10 hours after a 56 mm natural rainfall and continued for up to 50 h. In 2002, we timed ponded infiltration of four applications of well water added to 1.0 by 1.5 -m framed areas in 25 or 50 mm increments (total depth of 100 and 200 mm) with ~ 72 h delay between each application to permit drainage. Soil PR was determined with depth in 2002 according to Allen and Musick (1997) using triplicate measurements taken within each of the infiltration frames after allowing them to drain for one week. This decreased the variable effect of the initial soil water content on PR. The approach to evaluate impacts of deep *Cl*− plowing on subsurface water movement was the measurement and analysis of deep profiles (Scanlon et al., 2007). That is, continuous soil cores were obtained from December 2006 to August 2008 using a direct-push drill rig (Model 6620DT, Geoprobe, Salina, KS) to depths up to ~25 m. The core samples were encased in 1.2 m plastic sample sleeves for storage and were sectioned in the laboratory for analyses of various ions, water content, and soil *Cl*− concentration. Our analyses compared the control and deep plow effects on soil properties and crop yield using a t-test procedure for two sample populations assuming unequal variances (SAS Inst., 1988). In this way, plowing treatment effects on the observed BD and PR were compared by depth interval, while infiltration was compared, incrementally, by water application depth. Seasonal measurements of yield were analyzed according to a t-test procedure of plowing treatment effects paired for the common years of observation.

RESULTS

Soil Properties

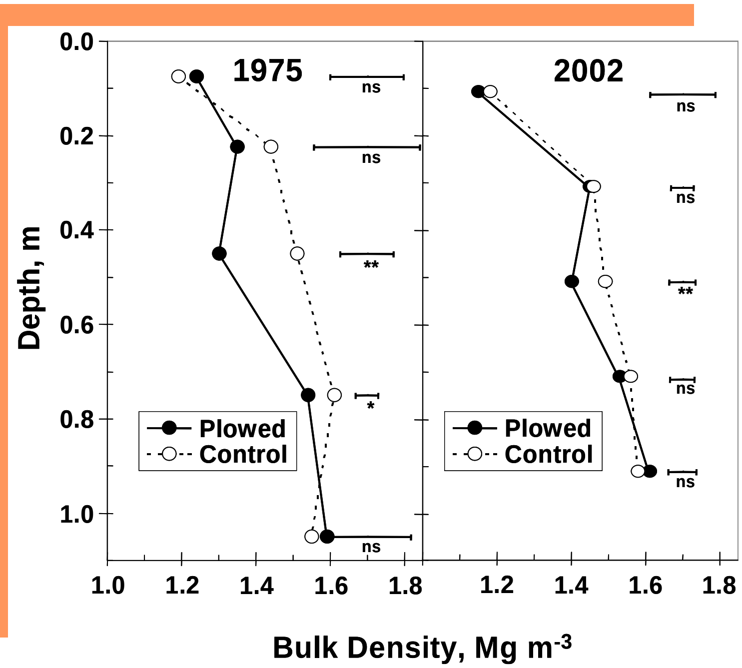

Fig. 2. Deep plowing effects on mean soil bulk density determined with soil depth for after 4 years (n = 3) and 31 years (n = 8). Error bars represent the least significant difference (* p = 0.05, ** p = 0.01).

The effects of the 1971 deep plowing on soil BD was evaluated twice during this experiment at four and 31 years after profile modification. Soil bulk density was expected to be higher in control plots than where deep plowed; however, density measured in 1975 averaged a similar 1.4 and 1.46 Mg m^{-3} for the control and tilled profiles, respectively. After 31 years, in 2002, the profile density remained relatively unchanged; averaging ~ 1.43 Mg m^{-3} for deep plowed plots compared with the not significantly different 1.45 Mg m^{-3} for control plots A more revealing view of the profile modifying plowing effects on soil BD measured in 1975 and again in 2002 is plotted with depth for the deep plow and control plots (Fig. 2). In both 1975 and 2002, soil bulk density in deep plowed plots was significantly lower than control plots at 0.45 m and 0.50 m depths; the midpoint of the dense subsoil layer. In 1975 but not 2002, the soil bulk density in deep plowed plots was significantly lower at 0.75 m or the approximate limit of the plow depth. No treatment effect was expected, or measured, below the 0.7 m plow depth in 1975 or 2002.

We measured PR to further assess long-term deep plowing effects on compacted subsoil layers in 2002, but no corresponding 1975 PR data are available for comparison. Overall, deep tillage decreased mean soil profile PR to 1.09 MPa compared with 1.22 MPa for control plots. Our measured PR (Fig. 3) was similar for the control and deep plow treatments above the dense subsoil layers

(Continued on page 11)

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beginning at the 0.3 m depth. Penetration resistance below 0.3 m, however, was consistently lower in the deep plowed compared with control plots and significantly lower with deep plowing at 0.38 m and 0.53 m (Fig. 3). Deep plowing had a sustained impact to reduce the PR through the dense subsoil. In the absence of this subsoil layer after tillage root proliferation could increase and expand the volume of soil explored by crop roots. Using the core break method we observed deeper rooting in deep plowed plots.

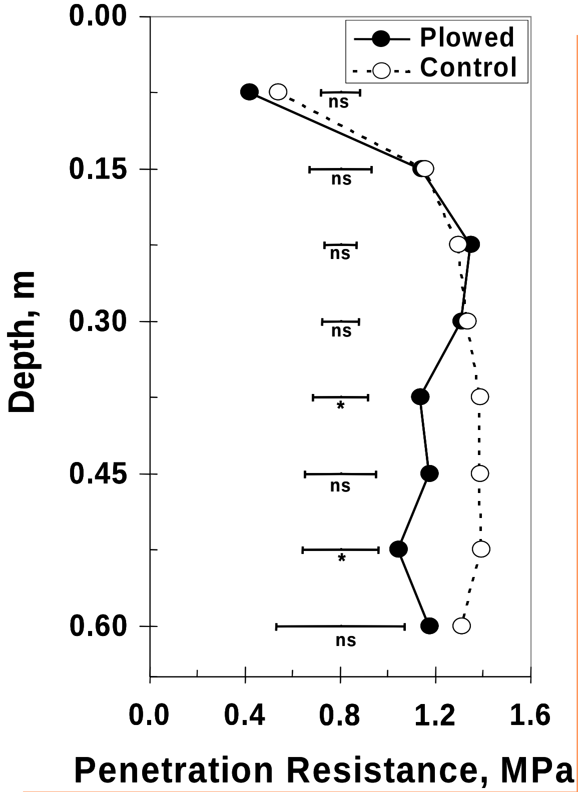

Fig. 3. Long-term effects of deep plowing on mean soil penetration resistance determined with depth (n = 8) after 31 years. Error bars are the least significant difference (* p = 0.05).

The effect of deep plowing on ponded infiltration was evaluated twice at four and 31 years after profile modification. Measured infiltration of rain in 1975 was 8 mm h^{-1} with deep tillage or a 6-fold increase over the control. In 2002, a second comparison of deep plowing effects on ponded infiltration was conducted using multiple 25 and 50 – mm water applications. These applications mimic typical overhead irrigations with 72 hours between applications that totaled 100 and 200 mm. Measured total time required for the observed incremental cumulative infiltration is shown in Fig. 4. Time for infiltration of 25, 50, and 75 – mm of water did not vary with tillage probably because the estimated wetting front position was above most of the 0.2-0.8 m deep flow-restricting subsoil layer. Beginning with the 100 mm water application, the subsoil impeded water movement in the control plots and significantly increased observed time of infiltration over the deep plowed soil. Compared with control plots, the impact of deep plowing further increased the difference in infiltration as the water application depth increased. Overall, ponded infiltration into the deep tilled plots required 30% less time than in the untreated control plots (r^2=0.94). These data show that deep moldboard plowing disturbed the subsoil and increased pore space and size, which eliminated a flow restricting subsoil layer and increased infiltration due to improved drainage for > 30 years.

Crop Yield

We hypothesized that deep plowing the dense 0.2-0.6 m subsoil layer in the Pullman clay loam increased the volume of soil explored by crop roots and, consequently, the available soil water and yield of dryland crops. Annual sorghum grain yield (Fig. 5) revealed no large yield increase during the years immediately after

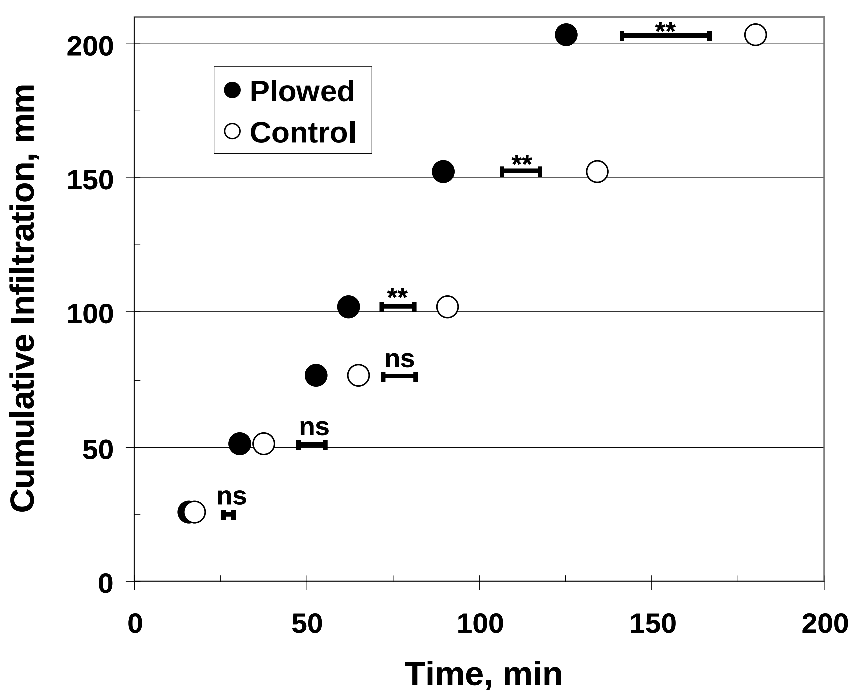

Fig. 4. Long-term deep plowing effects on mean cumulative infiltration (n = 4) with increasing time. Error bars represent the least significant difference (** p = 0.01).

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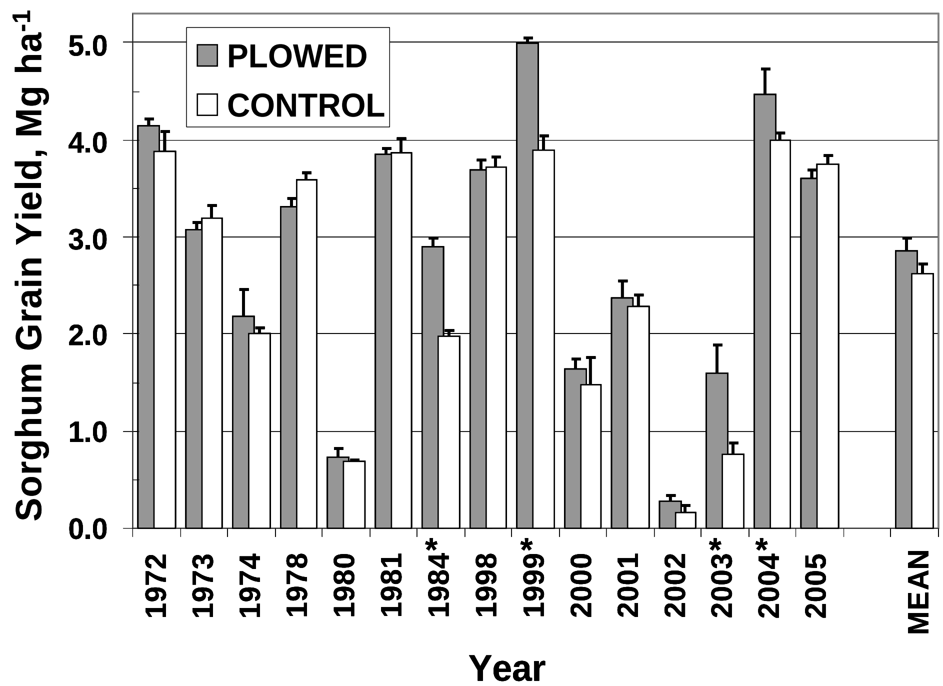

Fig. 5. Mean sorghum grain yield (n = 3) with standard error bars for paired tillage treatments plotted by year. Asterisks denote those years with early post planting precipitation > 60 mm that may have resulted in temporary flooding and crop injury.

plowing (1972-1974) when crop rooting would benefit the most. Also, we observed no gradual decline in yield differences between deep plowed and control plots due to soil consolidation as a result of periodic tillage and traffic on the plots. Dryland sorghum grain yield measured during 15 growing seasons from 1972-2005 averaged 2.86 Mg ha^{-1} after deep plowing compared with the significantly lower 2.61 Mg ha^{-1} average for the control plots. The 15 year cumulative sorghum grain yield with deep plowing was ~ 3.75 Mg ha^{-1} more than the control; however, conspicuously large yield increases over control treatments were observed with deep plowing in 1984 (0.92 Mg ha^{-1}), 1999 (1.11 Mg ha^{-1}), 2003 (0.84 Mg ha^{-1}), and 2004 (0.47 Mg ha^{-1}). The cumulative yield increase with deep plowing for those four years accounted for ~ 90% of the yield difference during the 15 year study. We reviewed the precipitation during these four years and determined that early growing season precipitation for brief, < 5 days, periods varied from 60 to 100 mm and was sufficient to flood the unplowed terrace benches (Fig. 6). Our ponded infiltration measurements show that deep plowing has a sustained effect to increase infiltration and improve profile drainage. Consequently, the potential for flooding injury to growing crops in 1984 1999, 2003, and 2004 was prevented in deep plowed plots. Eck et al. (1977) noted a similar benefit for irrigated alfalfa (*Medicago sativa* L.) grown on soil profiles similarly modified to 0.9 m in 1964.

Fig. 6. Temporary flooding of bench terrace without deep plowing, this often injured seedlings and occasionally depressed yield.

Drainage and Ion Displacement Profiles

Natural ecosystems in semiarid regions are generally characterized by near surface *Cl−* accumulations where drainage and recharge is limited (Scanlon et al., 2008). However, increased drainage below the root zone will displace the *Cl−* bulge downward through the profile. The *Cl−* profile sampled beneath native rangeland at

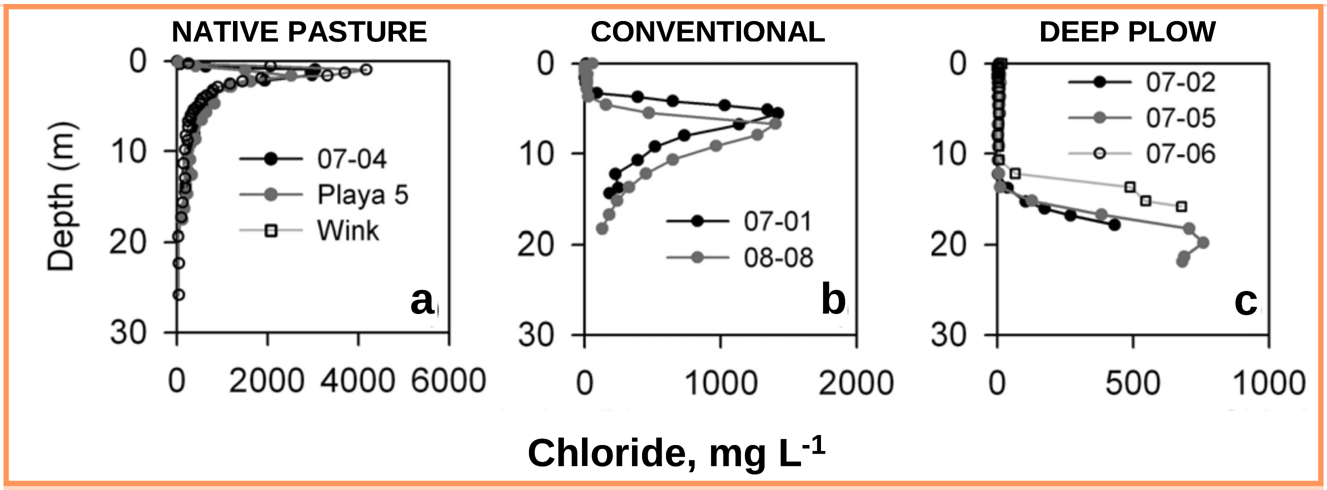

Fig. 7. Chloride concentrations in soil profiles for native pasture "07-04" (a), deep plowed bench terraces (b), and conventional tillage bench terraces (c).

Bushland exhibit a bulge-shaped peak at ~ 1.0 m depth and a concentration of 3042 mg L^{-1} (Fig. 7a). The near surface high *Cl*− concentrations were attributed to concentration by evaporation of atmospherically deposited *Cl*− from precipitation and dry fallout and indicate that no recharge has occurred in this setting during the Holocene. The *Cl*− profile for the conventionally tilled bench terrace system was displaced to 2.8 m depth (Fig. 7b), which translates to a surface water flux of 9 mm yr^{-1}. In contrast, displacement of *Cl*− bulges to depths of 10.7, 12.3, and 13.7 m (Fig. 7c) were observed in the deep-plowed bench terrace. These data indicate that deep plowing disrupted the flow-limiting subsurface layer, leading to increased drainage below the root zone as suggested during the interpretation of sorghum yield data. The difference in *Cl*− displacement for the deep plowed and conventionally tilled bench terraces during the 35-yr experiment averaged ~ 0.26 m yr^{-1} with corresponding water drainage averaging ~ 72 mm yr^{-1} with deep plowing. Minimum estimates of drainage beneath the deep plowed areas averaged 8 times higher than that beneath the conventionally tilled profile. Deep plowing that eliminated flood injury of crops following intense precipitation may also have the potential to increase recharge of groundwater resources.

SUMMARY

The extensive Pullman clay loam found in this region features a dense and very slowly permeable subsoil layer that limits infiltration and root growth. We evaluated the effects of deep plowing the dense subsoil, which reduced subsoil PR and BD while increasing ponded infiltration and crop yield. These profile modification benefits were sustained > 30-year; thus, indicating that the dense subsoil layer did not completely redevelop. The decreased BD and PR with deep plowing promoted root growth and expanded the volume of soil explored for water by dryland sorghum. However, the 10% increase in mean grain sorghum yield on deep plowed plots was largely (~ 90%) attributed to overcoming infrequent soil surface flooding. Compared with conventional tillage, the estimated drainage through the Pullman soil increased 8 fold to 72 mm yr^{-1} with deep plowing and may lead to successful recharge of groundwater resources. For a Pullman soil, deep plowing may be an economical soil modification because of the sustained soil and yield benefits that extends the time to recoup the 1971 installation cost of $160 ha^{-1}.

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Return To Index Page

New Project Manager for Ogallala Aquifer Program

I am looking forward to serving the needs of agriculture and communities of the Southern High Plains as I begin my new assignment as Research Agronomist/ Manager of the Ogallala Aquifer Program at the Conservation & Production Research Lab in Bushland, Texas.

I started my career in agricultural research 32 years ago this fall while an undergraduate at the University of Delaware. Agriculture in Delaware in the 1970's was undergoing significant changes in the 1970's. The poultry industry on the Delmarva Peninsula had finally grown enough to create market opportunities for corn and soybean growers, thus encouraging the wide spread use of overhead irrigation systems. The yield barrier for corn increased overnight from 50 bu/ac to 150 to 200 bu/ac. Farmers were eager for information to support such higher yields. The second major development that was occurring was the adoption of no-till, especially for dryland soybeans and corn. My undergraduate and M.S. research related to soil fertility issues that were merging with increasing yield potentials.

Towards the end of my stay in Delaware, I became very interested in the physiology of plant roots. Areas of focus for my Ph.D. research at the University of Kentucky and the early part of my career with ARS/ USDA were the processes that roots use to accumulate nutrients from the soil. My career with ARS started in 1986 at the Eastern Regional Research Lab, just outside of Philadelphia, Pennsylvania.

In 1998, I became Research Leader/Lab Director of the Small Farms Research Center in Booneville, Arkansas. At Booneville I was responsible for leading and supporting a diverse research program that addressed production and environmental issues related to beef production and specialty crop production. I also was responsible for coordinating two large projects with four universities.

During the summer of 2007, I was the Acting Laboratory Director (LD) of ARS' Cropping Systems Research Laboratory in Lubbock Texas. It was during my stint as Acting LD that I became aware of the Ogallala Aquifer Project. I felt that Manager of the Ogallala Aquifer Program was the perfect position to use my knowledge of many different types of agriculture production systems and the administrative tools used to coordinate a multi-institutional project. I am glad that circumstances fell into place for me to become the Manager in September 2008. I look forward to becoming more familiar with agriculture and communities of the Southern High Plains. I can be contacted at 806-356-5769 or david.brauer@ars.usda.gov if you have questions or comments related to the Ogallala Aquifer Program.

Return To Index Page

Conservation & Production Research Laboratory Celebrates 70 Years

In 1934, when skies over the nation's capitol were first darkened by dust, Congress started enacting legislation for wind erosion research in the Texas Panhandle. By 1936, federal funding was in place and land was purchased. A local committee composed of H. H. Finnell, Denny Hill, and Dr. Horace Grub from the USDA Soil Conservation Service and assisted by U. S. Rep. Marvin Jones; Art Bralley, Potter County Extension agent; and Dr. C. J. Whitfield, Soil Conservation Service, Dalhart, was formed to handle the details of setting up the new facility.

Pictured left to right: Dr. John Sweeten, Resident Director, Texas AgriLife Research and Extension Center; Dr. Nolan Clark, current Laboratory Directory, Conservation & Production Research Laboratory; Dr. Bob Stewart, former Director, CPRL and current Director, Institute of Dryland Agriculture, WTAMU, Canyon, Texas.

Land west of Bushland in Potter and Randall Counties was chosen because it represented the fine-textured soils of the southern Great Plains and was severely eroded. The first experiments were conducted at the laboratory in 1938.

Administration Building 1938

Back then, the laboratory was called the Amarillo Experiment Station and staffed by Dr. Whitfield, Director; Hugh Poterfield, soil erosion; C.E. Van Doren, dryland production; and Dr. Dave Reid, small grains breeder. During World War II operations were reduced to a standstill. After the war, several new scientists were added to the staff and the research program was greatly expanded to include machinery, irrigation, entomology, fertility, and weed control.

Throughout its history as a joint state and federal location--Bushland scientists of USDA's Agricultural Research Service and Texas Agricultural Experiment Station, now Texas AgriLife Research have worked side by side in cooperative studies and research activities.

In 1959, an Amarillo Business Men's Committee worked to secure funds to expand the facilities at Bushland. A new office and laboratory building were completed in 1961. Subsequent expansions have included a plant and soil processing building and water laboratory. A 350-head research feedlot and a metabolism laboratory were later added for cattle feeding research. The Kenneth Porter wheat seed processing and greenhouse complex was added in recent years.

Several name changes have occurred since 1938. What began as the Amarillo Experiment Station became the Southwestern Great Plains Field Station in 1956, then Southwestern Great Plains Research Center in 1965. Finally in 1973, the lab's name became what it is today--the Conservation and Production Research Laboratory.

Return To Index Page

Personnel News

Irrigation Honors

Local researcher Terry Howell received two national awards recently at the American Society of Agricultural and Biological Engineers international meeting in Rhode Island. The Heermann Sprinkler Irrigation Award recognizes professionals in research, development, extension, education or industry who have made significant contributions to the improvement of efficient and effective sprinkler irrigation. The ASABE 2008 John Deere Gold Medal Award recognizes significant advances in the application of science and art to the soil.

Howell is the water management unit research leader and supervisory agricultural engineer at the U.S. Department of Agriculture-Agricultural Research Service Conservation and Production Research Laboratory at Bushland.

"It is difficult to determine how much groundwater Terry's work has saved over the last two decades, but it is enormous," said Thomas Marek, Texas AgriLife Research Engineer.

In Amarillo Globe News, July 20, 2008 by Staff writer, Kevin Welch.

Scientist Moves On

Dr. José L. Chávez has moved to Colorado State University. He is Assistant Professor of Irrigation Engineering in the Department Civil and Environmental Engineering. In his new position, José will have teaching, research, and extension responsibilities. His new work address is Colorado State University, Civil and Environmental Engineering Dept., 1372 Campus Delivery, Fort Collins, CO 80523. His new email address is Jose.Chavez@ColoState.edu.

The Soil and Water Management Research Unit and the Conservation and Production Research Laboratory wish José and his family the best in his new position and thank him for his dedicated work on remote sensing and evapotranspiration research at Bushland.

José is shown on our newest tractor for our research at Bushland.

Return To Index Page

Owls Maintain a Watchful Eye in the Tree Row

Pictured above is one of the two great horned owls that have decided the tree row (pictured right) makes a good place to supervise station activities

Visitors To The New Tree Rows

We are proud of our new tree rows, where the trees and shrubs are growing enthusiastically under the diligent care of ARS technician Jim Cresap. Jim was the one who prepared the sites and took the lead in the installation of the trees, along with Texas Forest Service Forester Brian Scott of Canyon. Brian is also proud of what the two have done. He brought Kevin Wilde, assistant park superintendent of the City of Amarillo Parks and Recreation Department, on September 16th to see the sites and examine the equipment (chisel, disk plow, rototiller, etc.) used to prepare the site in hopes the city would adopt the same practices for their tree installations. Brian also brought his new boss, Jim Rooni, the Texas Forest Service chief regional forester for central and west Texas, on November 18th. We expect Brian back this spring to help prune and shape the trees (he gets it done about 10 times faster than the rest of us).

Shrubs were planted at the Soil Plant Environment Research Facility to serve as a living snow fence.

Return To Index Page

Conservation and Production Research Laboratory employee, Don McRoberts, sorts recycled materials that are taken on a monthly basis to the recycling center.

Inside the local recycling center in Amarillo, Texas.

Steve Evett was elected Fellow of the Soil Science Society of America and awarded the honor at the Joint International Meetings of ASA-CSSA-SSSA-GSA in Houston, Texas, 4-9 October 2008.

Terry Howell was elected Fellow in the American Society of Civil Engineers for outstanding contributions to water resources engineering.

New Appointee: Paul Colazzi has been appointed as the new Location Radiation Protection Officer (LRPO) and Permit Holder for sealed source radiation devices (neutron probes) at Bushland. He recently took over from Dr. Steve Evett, but have served as an unofficial assistant for several years. He will be handling all aspects of safety and compliance for use of neutron probes stored at the USDA-ARS Conservation and Production Research Laboratory (CPRL), and will the main contact for any and all questions and concerns.

Update from previous newsletter: For family reasons, Steve Evett did not make the move to Kimberly, Idaho to work at the USDA-ARS Northwest Irrigation and Soils Research Laboratory located there. Steve apologizes for any confusion caused by his premature announcement of this move in the previous Wetting Front.

Return To Index Page

MEETINGS & PRESENTATIONS

Prasanna Gowda attended the ARS Congressional Briefing Conference that was held on June 2-5, 2008 in Capitol Hill, Washington D.C.

Terry Howell and Susan O'Shaughnessy attended the ASABE Meeting, June 29-July 2, 2008 in Providence, R.I. Susan O'Shaughnessy gave lecture presentation, "Integration Of Wireless Sensor Networks For Automatic Irrigation Scheduling Of A Center Pivot." Paul Colazzi attended ASABE Hydrology Group (SW-21), moderated two technical sessions at the Annual ASABE Meeting. Prasanna Gowda authored "Simplified surface energy balance approach for estimating actual evapotranspiration" co-authored by P. Colaizzi and T. Howell.

Terry Howell and SWMRU hosted with Texas AgriLife Research Amarillo (Thomas Marek) and Texas AgriLife Extension Service Lubbock (Dana Porter) the ASCE/EWRI Evapotranspiration in Irrigation and Hydrology committee meeting and the WERA202: Climatic Data Application in Irrigation Scheduling and Water Conservation committee meeting at Bushland, TX on July, 15-18, 2008.

José Chavez attended the American Society of Civil Engineering (ASCE) Environmental & Water Resources Institute (EWRI) Evapotranspiration in Irrigation and Hydrology committee meeting. The meeting was held at the USDA-ARS Conservation & Production Research Laboratory, Bushland, TX, July 15-16, 2008.

Paul Colazzi attended ASABE Hydrology Group (SW-21), moderate two technical sessions at Annual Meeting, June 29-July 2, 2008, Providence, RI.

Susan O'Shaughnessy attended the Southern Great Plains Dairy Consortium Workshop, August 14, 2008, Texas Tech University, Lubbock, Texas.

Steve Evett presented an invited talk entitled "Use of Water, Water Management, Water Reuse" at the National Research Council Workshop on 21st Century System Agriculture, August 5-6, 2008, Washington, D.C., organized by the Board on Agriculture and Natural Resources, National Academy of Sciences.

Steve Evett presented a talk entitled "Quantifying water use across the High Plains: An intensive observation campaign in 2008" to the South Amarillo Rotary Club on September 11, 2008.

Louis Baumhardt, José Chavez, Paul Colaizzi, Steve Evett, Prasanna Gowda, Terry Howell, Susan O'Shaughnessy, Robert Schwartz and Judy Tolk attended the Tri-Society Meeting in Houston, TX, October 5-9, 2008. Susan O'Shaughnessy gave poster presentation, "Estimating Crop Canopy Coverage of Cotton Plants Within the FOV of an Infrared Thermometer Using a Two Band Photodiode Sensor."

At the Tri-Society Meeting in Houston, TX, October 5-9, 2008 the following were presented:

Terry Howell and Prasanna Gowda co-authored "Comparison of estimated surface energy fluxes using METRIC and two-source algorithms for Advective Conditions."

Steve Evett, authored "Two- and one-layer implicit energy balance solutions compared with the one-layer explicit Penman-Monteith solution for evapotranspiration of alfalfa" Terry Howell and Judy Tolk co-authored.

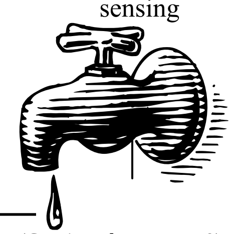
Steve Evett co-authored "Evapotranspiration: Measured with a lysimeter vs. calculated with a recursive method."

Louis Baumhardt, Robert Schwartz and Terry Howell co-authored "Conservation Tillage and Deficit Irrigation Effects on Water Use and Yield of Cotton and Corn."

Louis Baumhardt and Prasanna Gowda co-authored "Crop Water Use in the Ogallala Aquifer Region."

José Chavez, Prasanna Gowda, Terry Howell and Paul Colaizzi co-authored, "ET mapping with METRIC algorithm using high resolution multispectral remote sensing imagery."

Susan O'Shaughnessy attended the Training: Extramural Agreements Training for Authorized Departmental Officers Designated Representatives, October 8,



(Continued on page 20)

Return To Index Page

(Continued from page 19)

2008.

Research Soil Scientist Steve Evett traveled to P.R. China on October 11, 2008, arriving in Beijing on October 12, 2008. He was invited by two agencies. The primary inviter was the National Engineering Research Center for Information Technology in Agriculture (NERCITA). Dr. Evett's primary host was Dr. Xuzhang Xue with whom he worked on the design of a large weighing lysimeter and 24 smaller weighing lysimeters for determination of crop water use, water use efficiency and fertilizer use efficiency. Dr. Evett was also invited by the Chinese Academy of Agricultural Sciences to give a presentation titled "Role of Irrigation and Irrigation Automation in Improving Crop Water Use Efficiency" at the International Symposium on Water in Agriculture and Forestry: Challenges, Technological Solutions and Innovations, October 20-23, 2008, Beijing, China.

Dr. Evett was invited to give four other presentations during his visit. On October 14, 2008, he presented Soil Water Determination: What's measurement – What's estimation – What works!" to the staff of NERCITA in Beijing, China. On October 15, 2008, he presented "Crop Water Use Measurement & Estimation in Support of Irrigation Management" to the Tianjin Municipal Meteorological Bureau, Sciences and Technology Department. On October 17, 2008, he presented "Theory and Design of Weighing Lysimeters" to staff at Xi'an University of Technology, Institute of Water Resources. On October 22, 2008, he presented "Irrigation Automation Progress" to the Precision Agriculture staff at NERCITA. Dr. Evett was also invited to attend the Second IFIP Conference on Computer and Computing Technologies in Agriculture, October 18-20, 2008.

Drs. Evett and Xue traveled to the NERCITA research station outside Beijing to work on site selection for the lysimeters; and they traveled to Xi'an, China to work on design finalization with the engineer who will organize and supervise construction. Dr. Evett returned to his duty station on October 22, 2008.

Susan O'Shaughnessy and Jourdan Bell attended and led classes for Women in Science Conference, Amarillo Independent School District, October 25, 2008, AACAL Center, Amarillo, TX.

Paul Colazzi presented "Radiometric surface temperature component model for row crops" at the Joint GSA-Tri-Societies Annual Meeting, October 4-7, 2008, Houston, TX.

At the Joint International Meetings of the ASA-CSSA-SSSA, GSA and GCAGS, Houston, TX, Oct. 4-9, 2008 the following were presented:

P. Colaizzi, S. Evett, P. Gowda and T. Howell co-authored "Surface energy flux estimation using diurnal surface temperature modeling at BEAREX08" authored by French, A, Hunsaker.

S. Evett, J. Tolk, P. Colaizzi, P. Gowda, J. Chávez, and K. Copeland co-authored "Energy balance of irrigated and dryland cotton in the Southern High Plains" authored by T. Howell.

S. Evett co-authored "Comparison between BIOTIC irrigation scheduling and a recursive ET method" authored by J. Mahan.

S. Evett, P. Colaizzi, T. Howell, and P. Gowda, co-authored "Estimating crop canopy coverage of cotton plants within the FOV of an infrared thermometer using a two band photodiode sensor" authored by S. O'Shaughnessy.

R. Schwartz, S. Evett, co-authored "Analysis of coaxial soil cell" authored by M. Pelletier.

S. O'Shaughnessy and S. Evett co-authored "Influence of cotton crop development and level of irrigation of microbial community structure" authored by W. Rice.

J. Tolk and S. Evett co-authored "A comparison between evapotranspiration measurements made by weighing lysimeter and neutron moisture meter for cotton grown in four soils."

S. O'shaughnessy, R. Schwartz, S. Evett, T. Howell, J. Chávez,, P. Gowda, and J. Tolk co-authored "Radiometric surface temperature components for row crops" authored by P. Colaizzi.

R. Schwartz and T. Howell co-authored "Conservation tillage and deficit irrigation effects on water use and yield of cotton and corn" authored by L. Baumhardt.

P. Gowda authored "Modeling surface energy fluxes over Texas High Plains using Two-Source Model" co-authored by T. Howell.

T. Howell, R. Baumhardt, and P. Colaizzi co-authored "Clump planting to reduce the tiller production and increase the yield in dryland corn" authored by M. Kapanigowda.

P. Gowda, T. Howell, P. Colaizzi, and K. Copeland co-authored "ET mapping with METRIC algorithm using airborne high resolution multispectral remote sensing imagery" authored by J. Chavez.

P. Gowda, and T. Howell co-authored "Monitoring ET over Texas High Plains using two source model and high resolution aster data" authored by O. Akasheh.

P. Gowda and T. Howell co-authored "Comparison of Estimated Surface Energy Fluxes Using METRIC and Two-Source Algorithms for Advective Conditions" authored by O. Akasheh.

J. Tolk and S. Evett co-authored "A Comparison Between Evapotranspiration Measurements Made by Weighing Lysimeter and Neutron Moisture Meter for Cotton Grown in Four Soils."

L. Baumhardt and P. Gowda co-authored "Crop Water Use in the Ogallala Aquifer Region".

P. Gowda authored "Finger Millet: An Alternative Forage Crop for Southern High Plains" with T. Howell as a co-author.

R. Schwartz and S. Evett co-authored "Analysis of Coaxial Soil Cell" authored by M. Pelletier.

R. Schwartz authored "Phosphorus Dynamics in Amended Soils during a Growing Season: I. Availability and Plant Uptake" with J. Bell as a co-author.

R. Schwartz and J. Bell co-authored "Phosphorus Dynamics in

(Continued on page 21)

Return To Index Page

(Continued from page 20)
Amended Soils during the Growing Season: II. Ligand Exchange and Mineralization", authored by T. Dao.

S. Evett co-authored "Evapotranspiration: Measured with a Lysimeter vs. Calculated with a Recursive Method" authored by R. Lascano.

S. Evett authored "Two- and One-layer Implicit Energy Balance Solutions Compared with the One-layer Explicit Penman-Monteith Solution for Evapotranspiration of Alfalfa" co-authored with T. Howell and J. Tolk.

P. Gowda co-authored "Evaluating the Influences of Climate Change and Land Use Change on River Discharge and Water Quality in Minnesota" authored by D. Julla.

P. Gowda co-authored "Integration of Hydrogeology and Soil Science for Sustainable Water Resources—Focus on Water Quantity" authored by B. Scanlon.

Evett, S.R. and Howell, T.A. co-authors of "Role of irrigation and irrigation automation in improving crop water use efficiency" at the 1st International Symposium on Water in Agriculture and Forestry: Challenges, Technological Solutions and Innovations. Chinese Academy of Agricultural Sciences, Beijing, China. October 21, 2008.

Susan O'Shaughnessy attended the New Scientist Training, October 28-30, 2008, College Station, TX.

Susan O'Shaughnessy attended Irrigation Association New Innovations, Conference & Show, November 2-4, 2008, Anaheim, CA, lecture presentation, "Soil Water Measurement and Thermal Indices for Center Pivot Scheduling."

Terry Howell attended the 2008 IA Meeting in Anaheim, CA on November 2-4, 2008 and moderated a session on "Water Management".

Steve Evett, Paul Colazzi, Susan O'Shaughnessy, Prasanna Gowda, José Chavez, and Terry Howell attended BEAREX08 post field campaign meeting, November 12-14, 2008, Irving, TX.

Steve Evett presented an invited talk on "International Water Management Perspectives" at the Water, Agriculture and the Environment Conference, Lethbridge, Alberta, Canada, November 27-28, 2008, sponsored by Alberta Agriculture and Rural Development, the Prairie Farm Rehabilitation Administration, the Water Research Institute and the Canadian National Committee on Irrigation and Drainage. The presentations may be viewed at http://www.demofarm.ca/Water_Ag_Env-conf08.htm.

At the The 17th William T. Pecora memorial remote sensing symposium – The future of Landsat imaging, American Society of Photogrammetry and Remote Sensing, November 16-20, Denver, CO the following were presented.

P. Gowda authored "Deriving hourly surface energy fluxes and evapotranspiration from Landsat Thematic Mapper data using METRIC" co-authored by T. Howell

G. Gowda and T. Howell co-authored "Comparing artificial neural network and least square regression techniques for LAI retrieval from remote sensing data" authored by S. G. Bajwa.

At the AGU Fall Meeting, December 15-19, San Francisco, CA the following were presented:

P. Gowda and T. Howell co-authored "Groundwater modeling of the Texas High Plains using MODFLOW" authored by J. Hernandez

P. Gowda, authored "Sensible heat flux measurements using a large aperture Scintillometer over irrigated cotton" co-authored by T. Howell.

P. Gowda and T.Howell co-authored "Groundwater modeling of the Texas High Plains using MODFLOW" authored by J. Hernandez.

P. Gowda and T. Howell co-authored "Estimation of leaf area index from Landsat imagery for Texas High Plains using support vector machines" authored by D. Misra.

P. Gowda and T. Howell co-authored "Estimating shortwave solar radiation using net radiation and meteorological measurements" authored by O. Akasheh.

P. Gowda co-authored "Atmospheric boundary layer evening transitions over West Texas" authored by A. Ruiz-Columbie.

Check it out:
Texas High Plains ET Network

⬇

http://txhighplainset.tamu.edu/

Return To Index Page

Publications

Alam, M., **Colaizzi, P.D**., Rogers, D.H., and Shaw, L.K. 2008. Irrigating cotton in a thermally-limited area. Proc. 2008 Irrigation Show and Conference, Nov. 2-4, 2008, Anaheim, California. (CD-ROM)

Balota, M., Payne, W.A., **Evett, S.R**. and Lazar, M.D. 2008. Morphological and physiological traits associated with canopy temperature depression in three closely-related wheat lines. Crop Sci. 48:1897-1910.

Chávez, J.L., **Howell, T.A., Gowda, P.H.,** Neale, C.M.U., and **Colaizzi, P.D.** 2008. Evaluating airborne remote sensing ET estimates using eddy covariance systems and a heat flux source area function. Proc. 2008 Irrigation Show and Conference, Nov. 2-4, 2008, Anaheim, California. (CD-ROM)

Chávez, J.L., Gowda, P.H., Howell, T.A., Neale, C.M.U., and **Copeland, K.S.** 2008. Estimating seasonal ET from multispectral airborne imagery: an evaluation of interpolation-extrapolation techniques. In: Proceedings of the 2008 Annual International ASABE Meeting. Paper No. 083637, Providence, RI, June 29- July 2, 2008. Published by ASABE, St. Joseph, MI.

Chávez, J.L., Howell T.A., Gowda P.H., Neale C.M.U., and **Colaizzi P.D.** 2008. Evaluating airborne remote sensing ET estimates using eddy covariance systems and a heat flux source area function. In: Proceedings of the 2008 Annual International Irrigation Show, Technical Session, Paper No. IA09-1013, Anaheim, CA, November 2-4, pp. 1-29, Published by the Irrigation Association, Falls Church, VA. (CD-ROM)

Colaizzi, P.D., Gowda, P.H., Marek, T.H., and Porter, D.O. 2008. Irrigation in the Texas High Plains: A brief history and potential reductions in demand. Irrig. and Drain. DOI: 10.1002/ird.418.

Colaizzi, P.D., Bliesner, R.D., and Hardy, L.A. 2008. A review of evolving critical priorities for irrigated agriculture. In: Proceedings of the Environmental and Water Resources Institute World Congress, May 12-16, 2008, Honolulu, HI. (CD -ROM)

Colaizzi, P.D., Gowda, P.H., Marek, T.H., and Porter, D.O. 2008. Irrigation in the Texas High Plains: A brief history and potential reductions in demand. Irrig. and Drain. DOI: 10.1002/ird.418.

Evett, S.R., Heng, L.K., Moutonnet, P., and Nguyen, M.L. (eds.). 2008. Field Estimation of Soil Water Content: A Practical Guide to Methods, Instrumentation, and Sensor Technology. 131 pp. IAEA-TCS-30. International Atomic Energy Agency, Vienna, Austria. ISSN 1018–5518. Available at http://www-pub.iaea.org/mtcd/publications/PubDetails.asp?pubId=7801

Gowda, P.H, J.L. Chavez, P.D. Colaizzi, S.R. Evett, T.A. Howell, and **J.A. Tolk.** 2008. ET mapping for agricultural water management: Present status and challenges. Irrigation Science, 26(3):223-237. DOI:10.1007/s00271-007-0088-6.

Gowda, P.H, Howell, T.A., Evett, S.R., Chavez, J.L., and New, L. 2008. Remote sensing of contrasting tillage practices in the Texas Panhandle. International Journal of Remote Sensing, 29(12):3477-3487. DOI: 10.1080/01431160701581810.

Gowda, P.H., Mulla, D.J. and D.B. Jaynes. 2008. Modeling impact of timing and amount of nitrogen fertilizer on water quality for an Iowan agricultural watershed. Agricultural Water Management, 95:616-624.

Gowda, P.H., Chavez, J.L., Howell, T.A., Marek, T.H. and New, L.L. 2008. Surface energy balance based evapotranspiration mapping in the Texas High Plains. Sensors, 8:5186-5201.

Howell, T.A. 2008. Addressing the world water crisis. American Society of Agricultural and Biological Engineers Resource Magazine 15(3):5-8.

Mazahrih, N.Th., Katbeh-Bader, N., **Evett, S.R.,** Ayars, J.E., and Trout, T.J. 2008. Field calibration accuracy and utility of four down-hole water content sensors. Vadose Zone J. 7: 992 -1000.

Nangia, V., **Gowda, P.H.,** Mulla, D.J., and Sands, G.R. 2008. Water quality modeling of fertilizer management impacts on nitrate losses in tile drains at the field scale. Journal of Environmental Quality, 37:296-307. doi:10.2134/jeq2007.0224.

O'Shaughnessy, S.A., Evett, S.R., Colaizzi, P.D., and **Howell, T.A.** 2008. Soil water measurement and thermal indices for center pivot irrigation scheduling. Proc. 2008 Irrigation Show and Conference, Nov. 2-4, 2008, Anaheim, California. (CD-ROM)

O'Shaughnessy, S.A., Evett, S.R., Colaizzi, P.D., and **Howell, T.A.** Soil water measurement and thermal indices for center pivot irrigation scheduling. Paper No. IA09-1000, In: Proc. Irrigation Association Show 2008, Anaheim, Calif., Nov 2-4, 2008, (CD-ROM),: pp. 1-17.

O'Shaughnessy, S.A., and **Evett, S.R.** 2008. Integration of Wireless Sensor Networks into Moving Irrigation Systems for Automatic Irrigation Scheduling. Paper No.: 083452. 2008 ASABE Annual International Meeting, Rhode Island Convention Center, Providence, Rhode Island, June 29 – July 2, 2008. American Society of Agricultural and Biological Engineers.

Peters, R.T., and **Evett, S.R.** 2008. Automation of a center pivot using the temperature-time-threshold method of irrigation scheduling. J. Irrig. Drain. Engr. 134(3):286-291.

Tolk, J.A., and **Howell, T.A.** 2008. Field Water Supply: Yield Relationships of Grain Sorghum Grown in Three USA Southern Great Plains Soils. Agricultural Water Management, DOI 10.1016/j,agwat.2008.05.09.

Return To Index Page

Paul Colaizzi was interviewed by Kevin Welch of the Amarillo Globe News on June 2, 2008 with Nolan Clark and Steve Evett. Article "Measuring Water: Project Aims to Reduce Use of Aquifer by Farms' Crops" appeared in the Business Section, page 6D, on June 10, 2008.

Steve Evett and Robert Schwartz were invited to visit the Xcel Energy Harrington Power Plant to give advice on deep soil profile water content measurement on June 18, 2008.

Steve Evett and Susan O'Shaughnessy were invited to discuss irrigation automation research by Valmont Industries on July 11, 2008.

Paul Colaizzi was interviewed by television Channel 7 KVII PRONEWS, Amarillo with Steve Evett and Bill Kustas. Segment aired on the 10 PM edition on July 16, 2008.

During the 2008 Western Extension and Research Administration (WERA) committee meeting, at the USDA-ARS, CPRL, Bushland, TX, José Chavez, Steve Evett, Judy Tolk, Paul Colaizzi, Susan O'Shaughnessy, Karen Copeland, and Prasanna Gowda participated in the field tour on July 16, 2008. José Chavez prepared a hand-out document on "Open Path Eddy Covariance System" and by showing/explaining the principles and operation of the eddy covariance energy balance stations installed in the east lysimeter field.

Paul Colaizzi assisted hosting Dr. Nurit Agam, visiting scientist from Israel, on microlysimeter installation for soil evaporation measurements (part of BEAREX08) during July 2008.

Paul Colaizzi and Brian Vick (Renewable Energy and Manure Management Research Unit) assisted and trained Dr. Raad Salih, Bourlag Fellow and agricultural engineer with the Iraq Ministry of Agriculture, Bagdad, Iraq, on the design and management of drip irrigation systems using solar-powered pumps for various crops grown by small producers in the Bagdad and Najaf areas of Iraq. The design and training was conducted from August 5-20, 2008 at Bushland and hosted by Drs. Nolan Clark and Terry Howell.

Paul Colaizzi hosted Drs. Jin Ye, Xuenong Wang, Southwest University, China, August 27, 2008.

Return To Index Page

Soil and Water Management Research Unit

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Return To Index Page