Development and Implementation of an Environmental Training Program for Manure and Compost Haulers/Applicators in the Texas High Plains

TSSWCB Project 09-04
Final Report

Prepared By:

Texas A&M AgriLife Research & Extension: Brent W. Auvermann, Paul DeLaune, Kevin Heflin, and Texas Cattle Feeders Association: Ben Weinheimer.

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List of acronyms and abbreviations

AgriLife Research	Texas A&M AgriLife Research and Extension Center at Vernon
AgriLife Extension	Texas A&M AgriLife Research and Extension Center at Amarillo
BMP	Best management practice
BST Library	Bacterial Source Tracking Library
CAFO	Concentrated animal feeding operation
CCA	Certified crop advisor
CEA	County Extension Agent
CEU	Continuing Education Unit
CWA	Clean Water Act
E. coli	Escherichia coli
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESSL	AgriLife Vernon Environmental Soil Science Laboratory
FOTG	Field Office Technical Guide
GPS	Global positioning system
K	Potassium
LPELC	Livestock & Poultry Environmental Learning Center
N	Nitrogen
NRCS	U.S. Department of Agriculture-Natural Resources Conservation Service
P	Phosphorus
PM	Project manager
QAPP	Quality Assurance Project Plan
RSS	Real Simple Syndication
SWCD	Soil and water conservation district
TCEQ	Texas Commission on Environmental Quality
TCFA	Texas Cattle Feeders Association
TKN	Total
TP	Total Phosphorus
TSSWCB	Texas State Soil and Water Conservation Board
WTAMU	West Texas A&M University

EXECUTIVE SUMMARY

The primary goal of this project was to develop and demonstrate best management practices (BMPs) for land application of cattle manure and compost. This project also monitored surface runoff from constructed sub-watersheds receiving different application rates of manure or compost. Trends in soil nutrient status downgradient of land application areas were monitored as an indicator of transport of manure derived contaminants. The demonstration sites were located in the Texas High Plains in 5 distinct sub-watersheds located in three different counties.

In the 2000 and 2002 Texas 303(d) lists, two watersheds in the Texas High Plains were identified as impaired based on elevated bacteria levels in the creeks (Sweetwater Creek and Buck Creek) and were included again on the 2008 Texas 303(d) List. Buck Creek was monitored through Texas State Soil Water Conservation Board (TSSWCB) project 06-11 *Watershed Protection Plan Development for Buck Creek*. These two watersheds served as pilot watersheds for the "beta-testing" portion of the environmental training curriculum developed through this project. A targeted educational program to assist manure and compost applicators increased their understanding of appropriate BMPs that complement any watershed protection plan measures that may develop.

The project was divided into 9 different tasks and subtasks which included: (1) Project Administration; (2) Quality Assurance; (3) Environmental Knowledge Assessment; (4) Project Advisory Group; (5) Manure Spreader Calibration Kits; (6) Curriculum Development; (7) Demonstration and Program Delivery; (8) Technical Assistance; and (9) BMP Effectiveness Monitoring.

INTRODUCTION

The land application of manure/compost is a viable organic nutrient option for crop production across the Texas High Plains. Within 150 mile radius of Amarillo, 5.8 million head of beef cattle are fed in feedyards; this is about 30% of the nation's fed cattle production. The cattle feeding industry has served as an important economic driver in this region since the 1960s. Manure has been primarily used as a nutrient and soil amendment on cropland. Primary crops in the region include corn, wheat, cotton, alfalfa, peanuts, grain sorghum and hay.

The movement of manure/compost to cropland is typically a three-way relationship consisting of a crop producer, a feedyard source of manure/compost and a third-party custom hauler/ applicator. Over the past five decades, custom manure and compost companies have become an important component in the operation of feedyards and farms that provide or purchase manure or compost. Application rates are determined by the crops to be grown, residual nutrients, and the soil-test recommendations of crop advisors and soil testing laboratories at land grant universities or private firms. Manure and compost companies generally have a fixed rate for loading and spreading (i.e., $3.50 per ton) and a hauling charge (i.e., $0.25 per ton per mile). The cost of manure/compost to the crop producer serves as an important self-limiting tool to reduce the risk of over-applying nutrients.

Manure and compost companies have strived over the years to provide a service to both feedyards and crop producers in the most cost-effective manner possible. Unfortunately, little attention has been given to environmental impacts by this important segment of the cattle feeding industry. This project, through training and demonstrations, established a program to provide for long-term implementation of beneficial management practices (BMPs) to be used during the land application of manure or compost. An environmental training program, which used printed materials, videos, and web-based materials (in both English and Spanish) that heighted the environmental awareness of custom manure and compost owners and their employees, was developed. In addition, crop producers benefited by participating in the workshops, field days and seminars, which gave producers a greater assurance that using manure or compost in their nutrient management programs has agronomic benefits and can be applied in a manner that is protective of the environment.

While the land under the control of the feedyard is typically covered under the facility's CAFO permit, manure may be applied to that land by a custom manure/compost hauler. This manure must be applied in accordance to the feedyards nutrient management plan and the pollution prevention plan as defined by the feedyard's permit.

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This project was the first of its kind, in the Texas High Plains region, that targeted a diverse group of stakeholders and was specific to the independent business relationship (feedyards, manure/ compost haulers, CCAs, and crop producers) as well as the cropping systems that are implemented. Texas Cattle Feeders Association (TCFA) and Texas A&M AgriLife Research and Extension were uniquely situated to facilitate the development and implementation of this environmental training curriculum. TCFA represents the cattle feeding industry in Texas, Oklahoma and New Mexico and has nearly 200 Feedyard Members with a total membership around 5,000. As a result, this environmental training program has the potential to expand to Oklahoma and New Mexico.

The primary goal of this project was to organize a diverse stakeholder group that participates in the development of BMPs for land application of manure and compost. This project also monitored stormwater surface runoff from constructed sub-watersheds receiving different application rates of manure or compost. Trends in soil nutrient status downgradient of land application areas were monitored as an indicator of transport of manure derived contaminants. The demonstration sites were located in the Texas High Plains in 5 distinct sub-watersheds located in three different counties as shown in Figure 1 and Table 1.

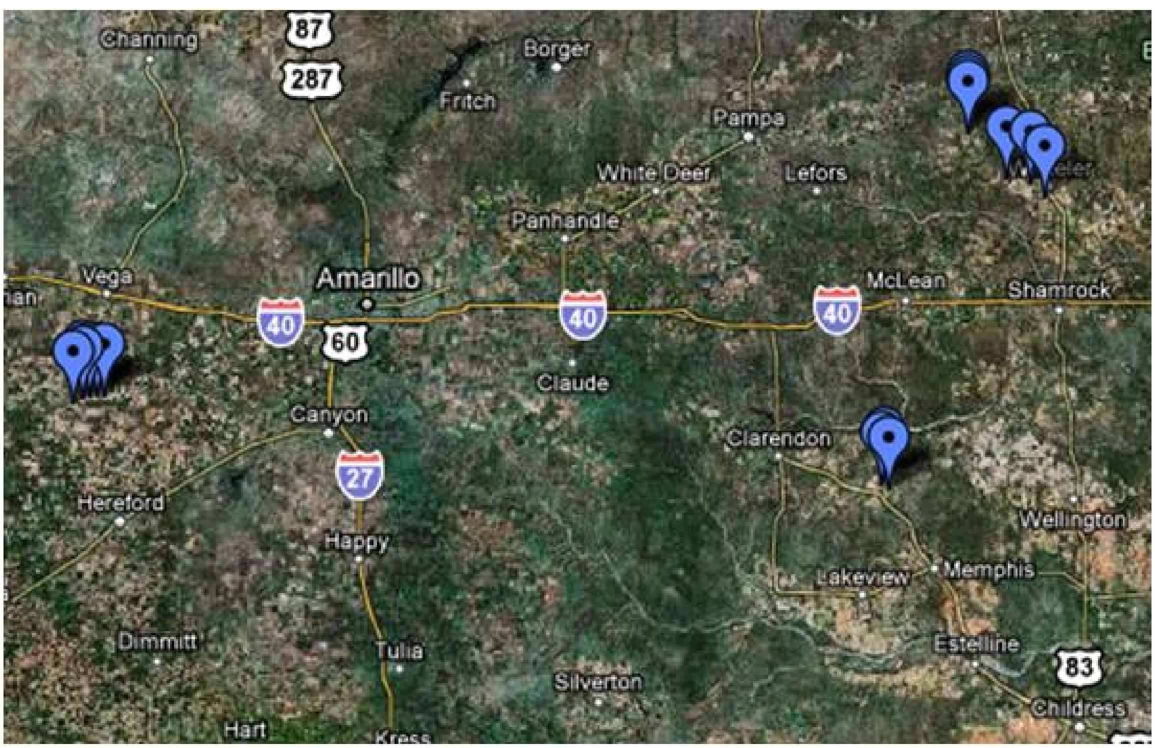


Figure 1. Demonstration site locations for the project area located in the Texas High Plains region.

MATERIALS AND METHODS

GENERAL INFORMATION

The primary focus of this project was to develop and implement an education, training, and demonstration program to improve the understanding of environmental protection principles by manure/compost haulers, equipment operators, CCAs, and crop producers. The project focused on areas that are generally described as the Texas High Plains (the Amarillo and Lubbock regions of Texas). The demonstration sites are situated within the Red River Basin, and were specifically located in the Buck Creek, Silver Creek, Sweetwater Creek, and the Palo Duro Creek watersheds. To help disseminate the project information a website was created and maintained by Texas A&M AgriLife Research & Extension. Project information was updated regularly at http://manurespreading.tamu.edu.

The project was divided into 9 different tasks and subtasks which included: (1) Project Administration; (2) Quality Assurance; (3) Environmental Knowledge Assessment; (4) Project Advisory Group; (5) Manure Spreader Calibration Kits; (6) Curriculum Development; (7) Demonstration and Program Delivery; (8) Technical Assistance; and (9) BMP Effectiveness Monitoring.

PROJECT ADMINISTRATION

The United States Environmental Protection Agency (EPA) provided funding through a federal Clean Water Act §319 Nonpoint Source Grant from the TSSWCB.

The TSSWCB provided project oversight and funding at the state level. The TSSWCB was responsible for ensuring that the project delivered data of known quality, quantity, and type on schedule to achieve project objectives. The TSSWCB was also responsible for technical oversight of activities involved in generating analytical data by the Texas A&M AgriLife Research-Vernon (AgriLife Research) laboratory and was responsible for general facilitation of audits and reporting of corrective actions.

The Texas Cattle Feeders Association (TCFA) provides the primary point of contact between the TSSWCB and the project contractors. The TCFA tracked and reviewed deliverables to ensure that tasks in the workplan were completed as specified.

Texas A&M AgriLife Extension Service Amarillo (AgriLife Extension) was responsible for day-to-day project coordination, including soil and manure sampling, manure-spreader calibration activities, and field demonstrations; and preparation, review, delivery of quarterly progress reports, and for maintaining and updating a project website with assistance from the TSSWCB. Texas A&M AgriLife Extension was responsible for ensuring tasks and other requirements in the contract are executed on time as defined by the grant workplan; assessing the quality of work by participants; submitting accurate and timely deliverables and costs to the TSSWCB; and coordinating attendance at conference calls, meetings, and related project activities. AgriLife Extension was also responsible for ensuring applicable tasks and other requirements in the contract are executed on time and with the QA/QC requirements in the system as defined by the contract workplan and in the Quality Assurance Project Plan (QAPP). Other responsibilities included, verifying that data are of known and acceptable quality, ensuring adequate training and supervision of all activities involved in generating analytical data, news releases, public presentations, publications, and ensuring accuracy of data disseminated concerning ongoing activities in the Buck Creek, Sweetwater Creek, and Palo Duro Creek watersheds.

Texas A&M AgriLife Research-Vernon (AgriLife Research) was responsible for collection of stormwater runoff samples and data analysis. AgriLife Research was responsible for coordinating and supervising runoff sampling activities, and ensuring that field personnel have adequate training, equipment, and thorough knowledge of standard operating procedures specific to the analysis or task performed. Other responsibilities included: ensuring applicable tasks and other requirements in the contract to be executed on time and with the QA/QC requirements in the system as defined by the contract workplan and in the QAPP. AgriLife Research was also responsible for verifying that data are of known and acceptable quality, facilitation of audits and the implementation, documentation, verification, and reporting of corrective actions. AgriLife Research was also responsible for conducting analysis of runoff and well water samples collected.

Servi-Tech Laboratories performed all data analysis not performed by AgriLife Research. The Servi-Tech laboratory ensured complete compliance with QA objectives as defined by the contract and as stated in the QAPP.

QUALITY ASSURANCE

AgriLife Extension/AgriLife Research developed a QAPP for project activities consistent with EPA Requirements for Quality Assurance Project Plans (QA/R-5) and the TSSWCB Environmental Data Quality Management Plan. All monitoring procedures and methods prescribed in the QAPP were consistent with the guidelines detailed in the Texas Commission On Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue (RG-415), and Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data.

ENVIRONMENTAL KNOWLEDGE ASSESSMENT

The project was designed to develop an environmental training curriculum, in both English and Spanish, tailored to the current business relationship that exists between feedyard, manure/ compost companies and crop producers. The curriculum outlined key concepts for environmental management and water quality protection. A survey was developed and administered at the initiation of the project to assess the current level of environmental knowledge of custom manure/compost haulers and the extent of training provided to equipment operators. Also, a project advisory group was organized, consisting of CAFO operators, manure and compost haulers, livestock industry organizations (i.e., Texas Farm Bureau, Texas Association of Dairymen, Texas and Southwestern Cattle Raisers Association), commodity organizations (i.e., Corn Producers Association of Texas, Plains Cotton Growers, Texas Grain Sorghum Producers Board), AgriLife Extension, TSSWCB, SWCDs, Texas Department of Agriculture, U.S. Department of Agriculture-Natural Resources Conservation Service (NRCS), CCAs and crop producers, stakeholders of the pilot watersheds (Buck Creek and Sweetwater Creek) and demonstration site cooperators, to design and develop the environmental training curriculum and prioritize the selection of project demonstration sites.

PROJECT ADVISORY GROUP

TCFA met with AgriLife Extension specialists and Extension agents in Potter, Lubbock and Wilbarger counties and NRCS personnel to brief them on the objectives of the project, to solicit nominations for the advisory group and to identify potential demonstration sites and farmer collaborators. The advisory group consisted of CAFO operators, manure and compost haulers, livestock industry organizations (i.e., Texas Farm Bureau (TFB), Texas Association of Dairymen (TAD), Texas and Southwestern Cattle Raisers Association (TSCRA), commodity organizations (i.e., Corn Producers Association of Texas, Plains Cotton Growers, Texas Grain Sorghum Producers Board), AgriLife Extension, TSSWCB, SWCDs, Texas Department of Agriculture (TDA), NRCS, Certified Crop Advisors (CCAs) and crop producers, stakeholders of the pilot watersheds (Buck Creek and Sweetwater Creek) and demonstration site cooperators. The project advisory group reviewed project objectives; and provided input on project activities; and provided input into development of an environmental training curriculum for manure/compost haulers, program delivery, and CEU processes.

MANURE SPREADER CALIBRATION KITS

TCFA identified options for field calibration of manure/compost spreader trucks. Options included single-pass calibration using calibration kits developed by project personnel as described in Subtask 5.2 of the work plan, and/or calibration using a whole-truck method (scale weights and area to which manure/compost has been applied). TCFA assembled 30 manure/compost spreader truck calibration kits. These kits were distributed to each manure/compost hauling company in Texas High Plains at no charge during public events such as field days and site specific demonstrations. Texas A&M AgriLife Extension Service evaluated the field-scale techniques for whole-truck calibration and single pass calibration during field days, at demonstration plots, and by private consultation with independent manure/compost haulers.

CURRICULUM DEVELOPMENT

TCFA/AgriLife Extension produced educational materials to provide concise and accurate descriptions of manure calibration equipment options. These educational materials will be deployed at a national scale through the Livestock and Poultry Environmental Learning Center and the Extension Community of Practice (www.extension.org). AgriLife Extension also provided a template for field-level feedback from manure and compost haulers to assess implementation of single-pass and whole-truck methods.

DEMONSTRATION AND PROGRAM DELIVERY

Demonstration sites based on the recommendations of the advisory group were selected on the basis of crop types, soil types, manure vs. compost, application rates, location of water wells, ability to sample down-gradient soils and records of previous manure/compost applications. These demonstration sites were used to train custom manure hauler owners, equipment operators, certified crop advisors, and crop producers on the principles of environmental management for land application of manure. TCFA also organized, in conjunction with all project partners, seven seminars/workshops across the Texas High Plains for program delivery and provided project results to state livestock organizations in Oklahoma, New Mexico, Kansas, Colorado and Nebraska.

TECHNICAL ASSISTANCE

Project members used group workshops, field days, and hands-on demonstration of BMPs and ensured availability of education materials through the project website. Custom manure haulers, and landowners were notified of the availability of on-site technical assistance and field training for owners and operators, and were encouraged to implement NRCS conservation practices through the Environmental Quality Incentives Program (EQIP). TCFA, with assistance from local SWCDs, NRCS, and the TSSWCB promoted the availability of technical assistance and encouraged adoption and implementation of NRCS conservation practices described in the NRCS Field Office Technical Guide (FOTG) to mitigate the environmental impact of manure/compost applications.

BMP EFFECTIVENESS MONITORING

TCFA, AgriLife Extension , and AgriLife Research established control and treatment plots at a farm on Palo Duro Creek in Deaf Smith County. Treatments included application of manure and/or compost at single-year vs. multi-year agronomic rates. At the Deaf Smith County demonstration, AgriLife Research installed automatic water samplers to collect runoff from the control and treatment plots. These runoff water samples were analyzed for nutrients and bacteria by the AgriLife Research Laboratory at Vernon.

TCFA collected soil samples annually from control and treatment plots using GPS grid soil sampling. Samples were collected at the 0-6 inch depth and 6-24 inch depth across the grid. Composite samples were submitted to a commercial soil testing laboratory for macronutrient, micronutrient, pH and organic matter. In a similar manner, soil samples will be collected at two distances down-gradient of the plots. Distances were determined by site-specific topographic features of the site locations. TCFA also collected representative manure and/or compost samples prior to all planned land application events. Samples were analyzed by a commercial testing laboratory for macronutrients, micronutrients, and moisture content. Split samples of the manure and compost samples were provided to AgriLife Research for inclusion in the Texas Bacterial Source Tracking (BST) Library. In addition to soil and manure sampling, TCFA collected water samples from all water wells located within the boundaries of the control and treatment plots as well as any water wells (where access was first granted) within 500 feet down-gradient of the plot locations. These water samples were analyzed for bacteria and nutrients.

The following diagrams and site descriptions show each field that was sampled, its soil characteristics, topography, the area that contributed to runoff, direction of runoff, and the downgradient soil sampling area. Soil sampling sites with were geo-referenced to the maps shown in Figures. 2-11.

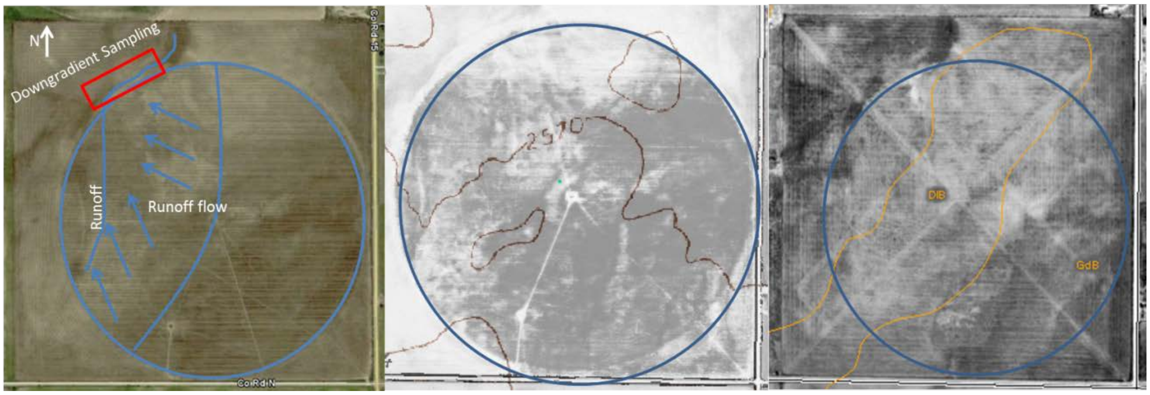


Figure 2. Demonstration site, downgradient soil sampling location, topographic features, and soil map for WC-1. Downgradient soil sampling was from a channel that starts in the field and exits the crop circle. Topography prevented downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

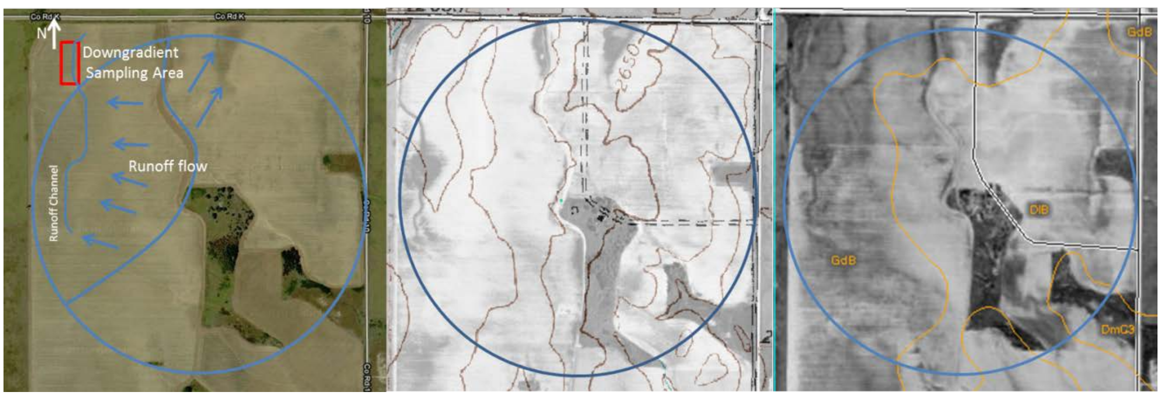


Figure 3. Demonstration site, downgradient soil sampling location, topographic features, and soil map for WC-2. Downgradient soil sampling was from a channel that starts in the field and exits the crop circle. Topography prevented downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

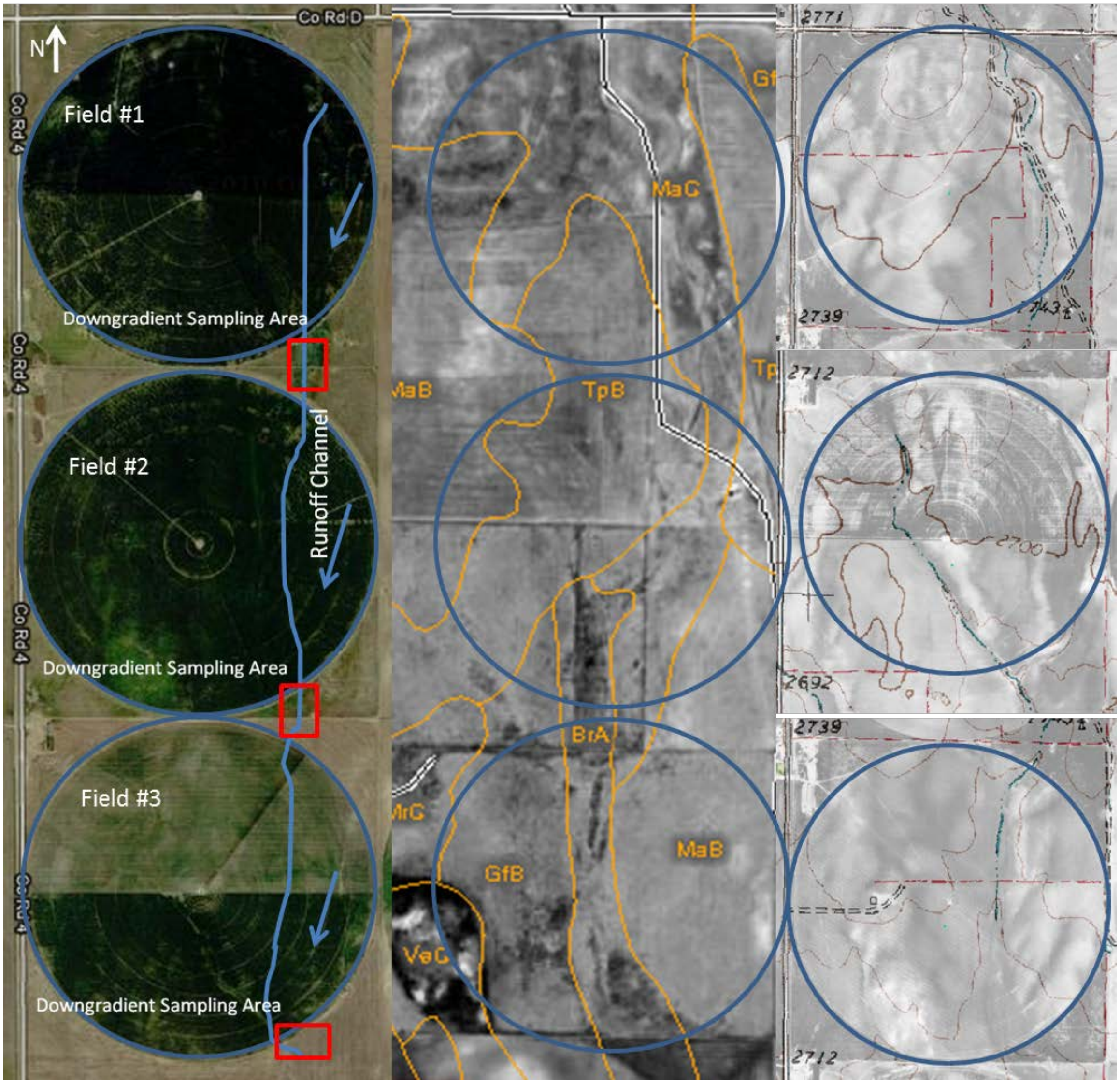


Figure 4. Demonstration site, downgradient soil sampling locations, topographic features, and soil map for WC-3, WC-4, and WC-5. Downgradient sampling locations were located within the same channel to evaluate the net as well as the cumulative contributions of runoff from each field to the watershed. To the best of our knowledge and belief, all contributing runoff originated within the crop circle. The runoff channel originates in field 1 and flowed through fields two and three.

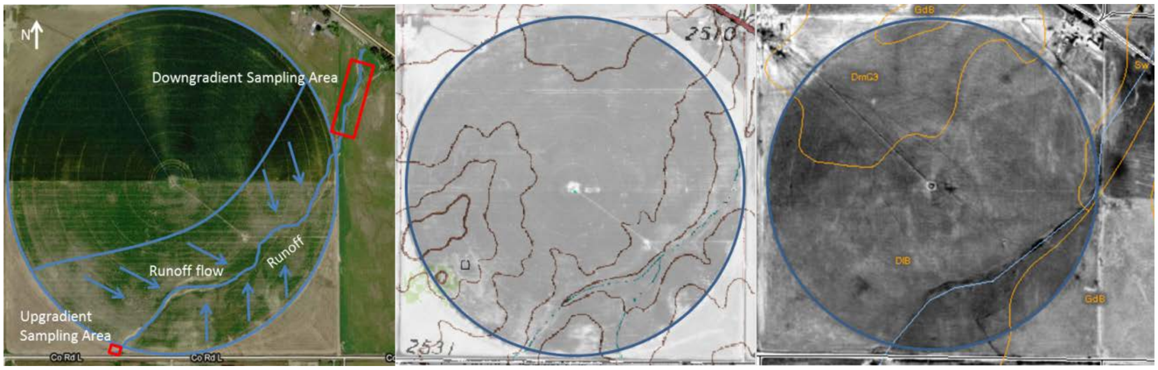


Figure 5. Demonstration site, downgradient/upgradient soil sampling locations, topographic features, and soil map for WC-6. Up gradient soil samples were collected to determine background concentrations.

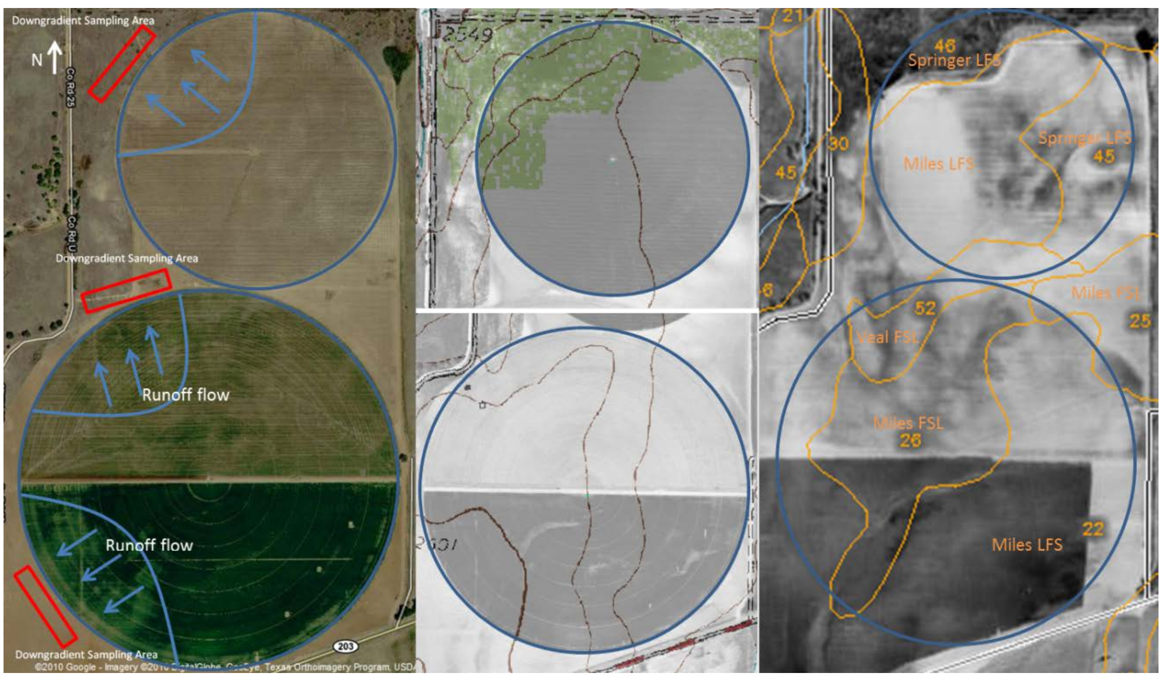


Figure 6. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DC-1 and DC-2. To the best of our knowledge and belief, all contributing runoff originated within the crop circle. Topography prevented downgradient sampling areas from being influenced by adjacent watersheds from each field.

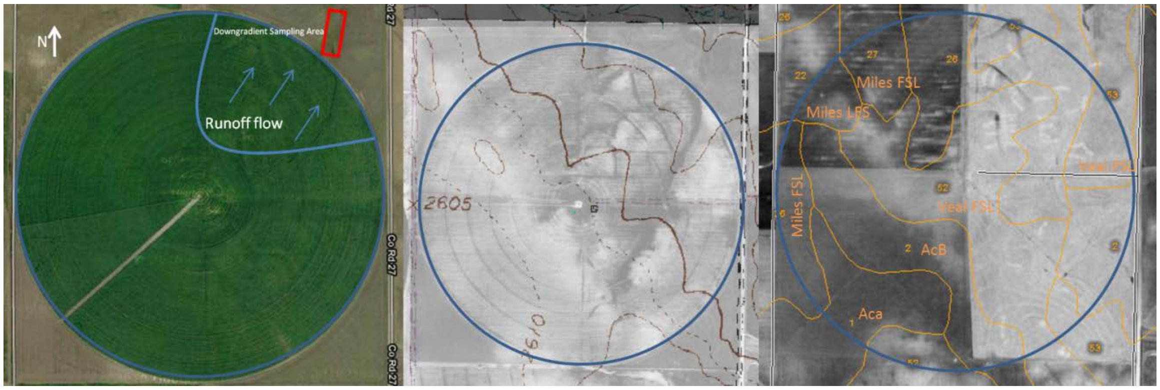


Figure 7. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DC-3. Downgradient soil samples were from a channel that starts in the field and exits the crop circle. Topography prevented downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

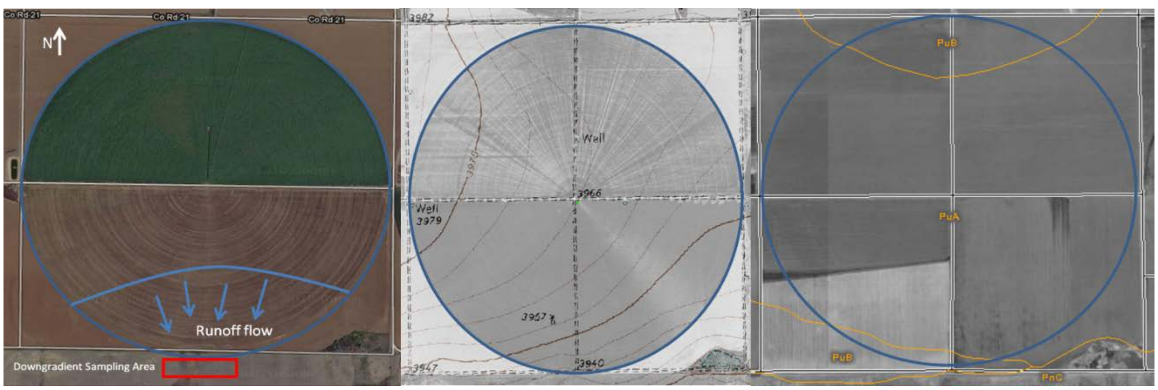


Figure 8. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DSC-1. Downgradient soil samples were taken from a channel that starts in the field and exits the crop circle. Topography prevents downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

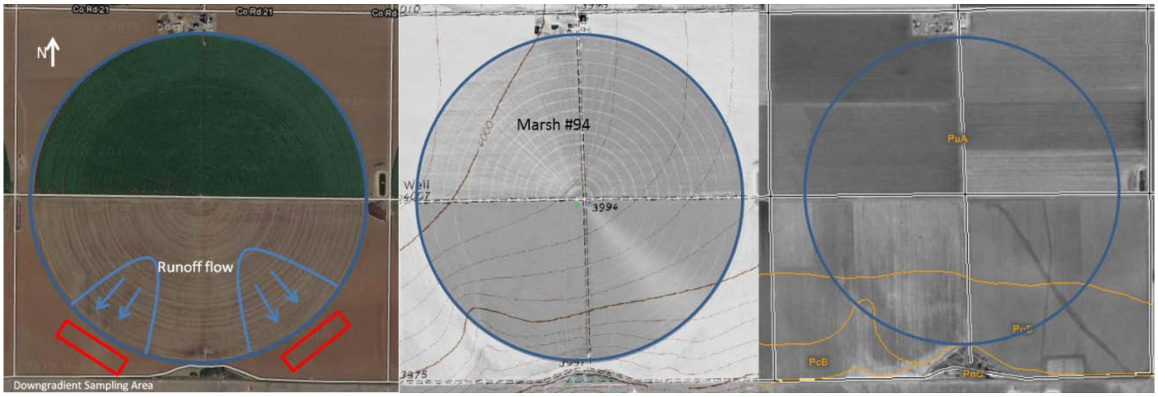


Figure 9. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DSC-2. Downgradient soil samples were taken from a two channels that start in the field and exits the crop circle. Topography prevents downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

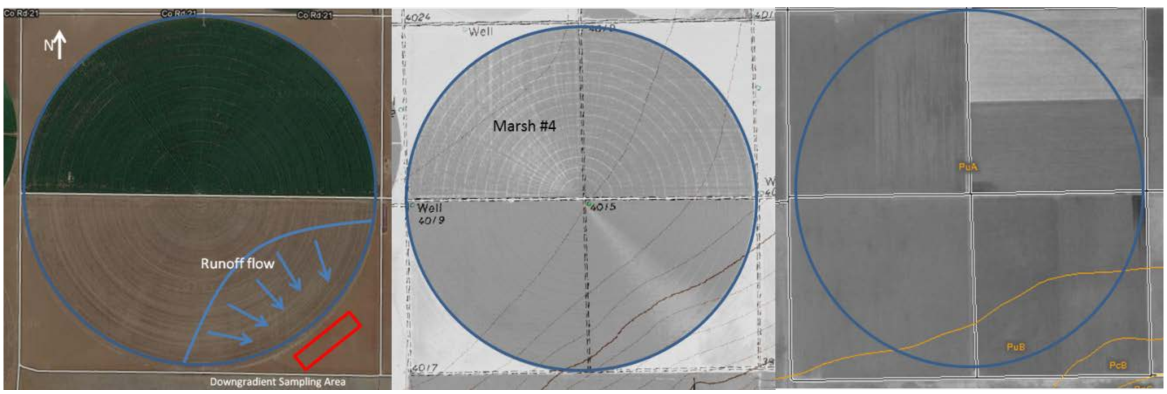


Figure 10. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DSC-3. Downgradient soil samples were taken from a channel that starts in the field and exits the crop circle. Topography prevents downgradient sampling areas from being influenced by adjacent portions of the circle. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

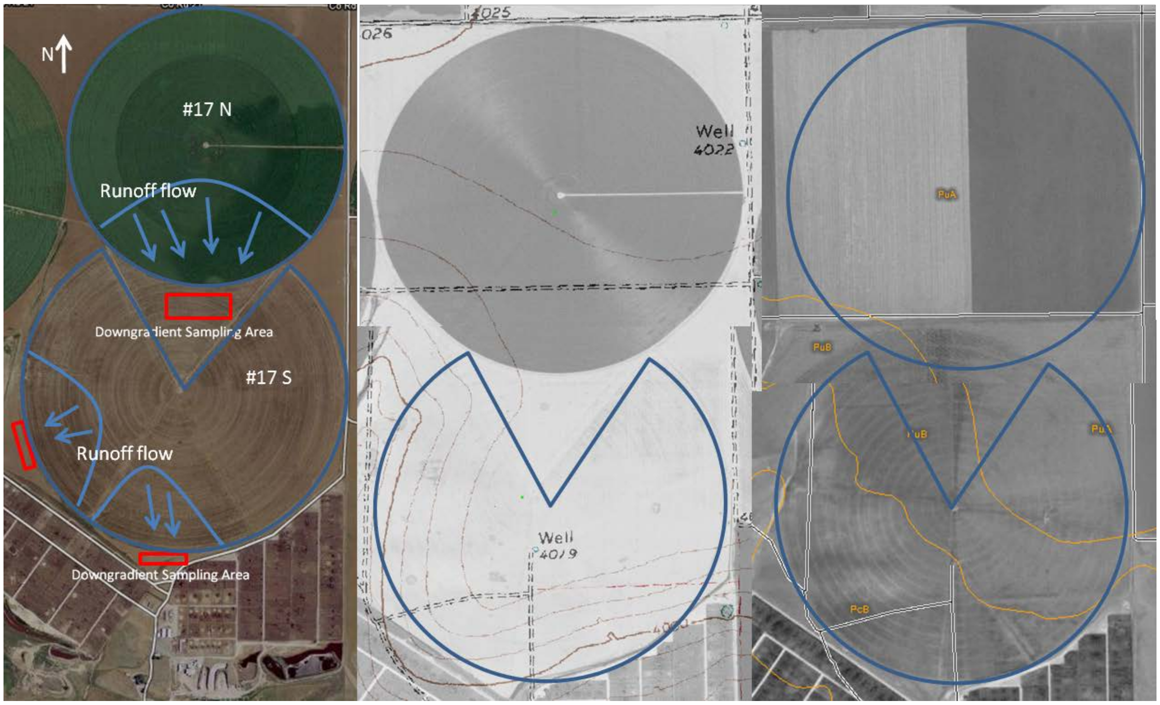


Figure 11. Demonstration site, downgradient soil sampling location, topographic features, and soil map for DSC-4 and DSC-5. Downgradient soil samples from 17N were from a channel that starts in the field and exits the crop circle. The downgradient soil sampling site for 17N is located in the circle 17S, but does not influence the sampling areas in 17S due to topography. Topography prevents downgradient sampling areas from being influenced by adjacent portions of the circle in 17S. Downgradient soil sampling in 17S were from channels that start in the field and exits the crop circle. Topography prevents downgradient sampling areas from being influenced by 17N. To the best of our knowledge and belief, all contributing runoff originated within the crop circle.

One of the primary objectives was to evaluate implementation of manure/compost BMPs through collection of water runoff using automatic water samplers and water well samples. The water-sampling program was designed to characterize water quality in rainfall and irrigation runoff from constructed watersheds receiving various rates of manure and compost. The experimental design consisted of 4 treatment plots at the DSC-6 site, shown in Figure 12, via automated water samplers collecting runoff samples after each rainfall event. The plots were labeled 1-4 from east to west. The treatment for plot #1 consisted of a single application of manure at a rate of 20-25 tons/acre. The treatment for plot #2 was 4-5 tons/acre of composted cattle manure applied annually. Commercial fertilizer was applied annually to plot #3 by the producer at standard agronomic rates based upon whole-field, soil-test recommendations. The treatment for plot #4 was 10 tons/acre of cattle manure applied annually. AgriLife Research installed automatic water samplers to collect runoff water. Water samples were analyzed for nutrients and bacteria by the AgriLife Research laboratory at Vernon. All water samples collected by the automated water samples were handled as described in the QAPP. Berms surrounded each plot so as to isolate it from “run-on” from other adjacent sources as well as to direct the flow of water toward the water-sampling devices. Each plot had a separate sampling device, and efforts were made to ensure that the water sample was representative of the runoff. This included the topographic isolation previously mentioned as well as a protective cover to prevent contamination or dilution. Composite samples were then taken, labeled, filtered, preserved, and properly stored until analysis was completed.

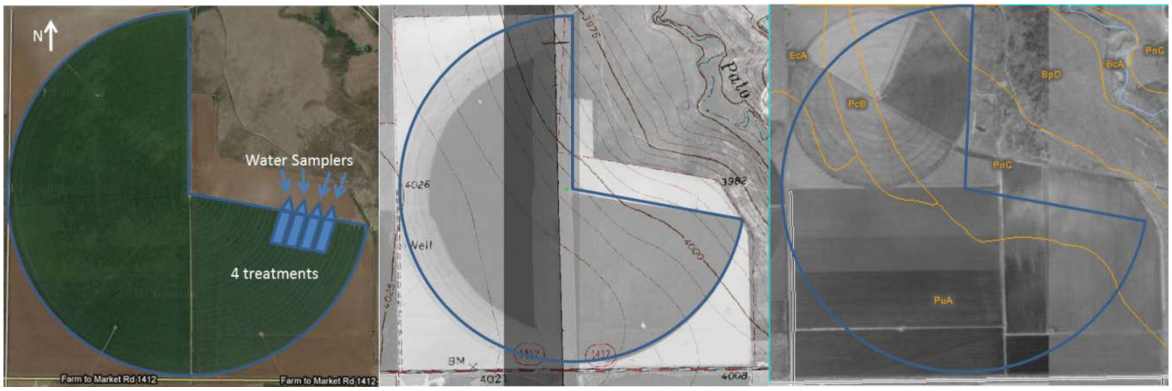


Figure 12. Demonstration site, water sampling location, topographic features, and soil map for site DSC-6.

RESULTS AND DISCUSSION

ENVIRONMENTAL KNOWLEDGE ASSESSMENT

Two survey instruments were prepared to assess the environmental knowledge of manure and compost haulers/applicators in the Texas High Plains. The first survey was to be an in-person interview with manure haulers to discern current practices and assess spreader-calibration activities. The second was directed to farmers and was intended to assess basic knowledge of soil and manure testing as it relates to water quality. Based on input received at the Jan. 5, 2011 Project Advisory Group meeting, an additional third survey was finalized in the 1st quarter of 2011 to include feedyards.

An on-line survey instrument for manure haulers and spreading contractors was deployed by AgriLife Extension at https://www.surveymonkey.com/s/Jan2011PAG. The on-line survey had no measurable success and it was determined that group meetings and or field days were the only way education outreach could be achieved. AgriLife Research & Extension, West Texas A&M University (WTAMU), and TCFA personnel participated in seven environmental management seminars. Survey questions were used at these seminars to assess the environmental knowledge of the participants. Survey questions were asked before and after each seminar. The anonymous responses were tabulated via Turning Point® interactive software.

Feedback from the manure/compost haulers during the seminars was used in lieu of conducting a post-survey to assess adoption and implementation of BMPs and employee training programs. Contact information for TCFA and AgriLife Extension was included on the last page of the spreader calibration kit instructions (in English and Spanish) and are included in the appendix. The project website was also listed were additional information could be found: http://manurespreading.tamu.edu.

PROJECT ADVISORY GROUP

County Extension Agents (CEAs) and NRCS personnel attended the June 16, 2010 project kickoff meeting in Amarillo and were briefed on the objectives of the project. Attendees provided guidance for preferred BMP emphasis. The CEAs facilitated watershed tours that were conducted in Deaf Smith (Tierra Blanca and Palo Duro Creeks; June 22), Collingsworth (Buck Creek; July 1), and Wheeler (Sweetwater Creek; June 14) Counties.

A field day and project advisory group meeting was held at the water quality demonstration site in Deaf Smith County on September 14, 2011. Attendees included certified crop advisors, crop producers, personnel from NRCS, WTAMU, Clarendon College, AgriLife Research and Extension, agricultural environmental firms, manure/compost applicators, and representatives from the beef industry. Project team members presented results on manure spreading calibration trials and kits, water well sampling, soil sampling, feedyard manure management surveys, and water quality demonstration results to date. The field day event ended with a compost and manure application event to demonstrate the various techniques used to calibrate manure and compost spreading equipment. Certified crop advisors and pesticide applicators received CEUs for attending the field day.

MANURE SPREADER CALIBRATION KITS

TCFA assembled 30 manure/compost spreader truck calibration kits and distributed one calibration kit to each manure/compost hauling company in Texas High Plains at no charge during public project events. The manure/compost calibration kits include two tarps with a 4:1 aspect ratio (28”x112”) for collecting and weighing manure/compost from spreader trucks in the field, a hand held digital scale, 2.5 pound weights to hold the tarps in place, and instructions for using the kits (in English and Spanish) which are included in appendix C.

CURRICULUM DEVELOPMENT

High definition video and pictures were taken at the field calibration event on October 18-22, 2010. Some of the pictures have been used in the slide sets presented at various project event and project advisory group meetings. Slide sets and video used at the educational seminars held in April and May 2013 are being converted for use in AgriLife Extension bulletins and posted to the project website. AgriLife Extension is currently in discussion to deploy educational materials at a national scale through the Livestock and Poultry Environmental Learning Center and the Animal Waste Management Community of Practice (http://www.extension.org/animal_waste_management).

AgriLife Extension also provided a template for field-level feedback from manure and compost haulers to assess implementation of single-pass and whole-truck methods. None of the feedback forms has been returned to date verifying implementation of the single-pass and whole-truck calibration methods nor has feedback been received concerning the calibration kit design and implementation.

We requested and received a quote from Appiction, Inc., for commercial development of a smartphone app to support in-field calibration of manure spreaders. The estimated cost, $45,000, could not be justified by the relatively limited market potential for such an app. The request for a quote is covered by a Non-Disclosure Agreement between AgriLife Extension Service and Appiction, Inc. While this project did not develop a smartphone app, there was an app developed by the University of Nebraska that was tested and verified for the whole-truck calibration method. This app is currently available on iTunes and Android and was publicized via the project web site and county-level seminars and associated slide sets.

DEMONSTRATION AND PROGRAM DEVELOPMENT

County Extension Agents in several locations throughout the Texas High Plains identified landowners to serve as project collaborators/demonstration site participants. Demonstration sites were identified in Donley, Wheeler, and Deaf Smith Counties following tours conducted by CEAs.

The first field day event was located at the water quality demonstration site in Deaf Smith County. Attendees at the September 14, 2011 field day represented 50% of the commercial composters that compost 70% of the cattle manure in the region. Raw manure applicators that apply 40% of all the manure generated in the region also attended the event. In the aggregate these commercial composters and raw manure applicators are responsible for land applying manure generated by more than 2.5 million beef animals annually. Feedyard environmental managers representing 40% of all fed beef (1+ million fed animals) annually in this region also attended the field day. The two largest environmental agricultural engineering consulting firms in the Texas High Plains region attended the field day event. Other attendees to the field day event included area producers, certified crop advisors, college students, and a representative from Congressman Mac Thornberry's office (13th Congressional District of Texas).

TCFA project team members discussed the current state of the project and results from soil sampling events with cooperating producer/land owners. Project goals and results were also presented at an annual event hosted by TCFA and WTAMU called "Feedyard Camp" on June 24, 2013. A project synopsis was presented to the Property Rights and Environmental Management Committee at a National Cattlemen's Beef Association Annual Convention in Denver Colorado, August 2013.

AgriLife Research & Extension, WTAMU, and TCFA personnel participated in seven environmental management seminars. Educational materials in the form of printed slide sets were distributed at each of the meetings. Spreader truck calibration kits were also distributed to all manure/compost contractors that attended the seminars.

The proper use of the spreader truck calibration kits was demonstrated in the field by AgriLife Extension Service during September 2013. The owner of the contract hauling company and 4 of his employees participated in the event. Four trucks were calibrated and on site adjustments were made to achieve the targeted land application rate at 8-10 tons per acre. Thirteen different measurements were taken, and results of these measurements were shared with the contractor. Two of the three calibration methods (single-pass and whole-field) promoted through this project were used constructively to refine and justify post-hoc billing arrangements that did not match application rates.

TECHNICAL ASSISTANCE

Project members used group workshops, the project website, field days and hands-on demonstration of BMPs to ensure the availability of education materials. TCFA and AgriLife Extension notified custom manure haulers of the availability of on-site technical assistance and field training for owners and operators, and encouraged implementation of NRCS conservation practices by landowners through the EQIP. Twenty seven manure and compost haulers were identified and added to the contact list maintained by TCFA.

AgriLife Extension established a system of tracking and providing notifications on the availability of technical and financial assistance (i.e., mail, email, website subscription) to custom manure and compost haulers in the Texas High Plains region via an RSS (Really Simple Syndication) feed available on the project website. Additionally a link to the smart phone app developed by the University of Nebraska to assist in spreader truck calibration was added to the website to assist custom manure and compost haulers.

TCFA, with assistance from local SWCDs, NRCS and the TSSWCB Hale Center Regional Office, promoted the availability of technical assistance and encouraged adoption and implementation of BMPs. TCFA also promoted the availability of technical assistance and encouraged the development and implementation of TSSWCB-certified Water Quality Management Plans (WQMPs). These WQMPs include a site-specific plan developed through and approved by SWCDs which includes appropriate land treatment practices, production practices, management measures, and technologies that prevent and abate agricultural nonpoint source pollution. TCFA, with assistance from local SWCDs and NRCS, promoted the availability and use of cost-share funds through the EQIP State Resource Concern for AFO-CAFO Beef – Water Quality/Air Quality.

TCFA and AgriLife Extension explored options for future development of a certification program for manure and compost haulers based on the outcomes of the training and demonstration efforts of this project. Most custom haulers have grasped the concept of calibration and currently use the whole-field method to calibrate their equipment. Based on the conversations with these haulers it has been determined that a certification process is not needed at this time.

BMP EFFECTIVENESS MONITOR

TCFA, AgriLife Extension and Research established control and treatment plots in Sweetwater Creek, Buck Creek and Palo Duro Creek watersheds. Treatments included application of manure and/or compost at single-year vs. multi-year agronomic rates. At one of demonstration locations AgriLife Research installed automatic water samplers to collect runoff from the control and treatment plots. The crop yields by treatment were also collected at the water quality demonstration site. At all demonstration sites TCFA collected soil samples annually from control and treatment plots using GPS grid soil sampling. Samples were collected at the 0-6 inch depth and 6-24 inch depth across the grid. In a similar manner, soil samples were also collected at two distances down-gradient of the plots. Distances were determined by site-specific topographic features of the site locations. TCFA also collected representative manure and/or compost samples prior to all planned land application events. Manure and compost split samples were provided to AgriLife Research for the BST library. Water samples were collected by TCFA from all water wells located within the boundaries of the control and treatment plots as well as any water wells (where access is granted) within 500 feet down-gradient of the plot locations. Water samples were analyzed for bacteria and nutrients.

SOIL SAMPLING

Soil samples were collected by TCFA. Samples were collected using a hydraulic 1-inch auger probe that is mounted on the side of utility vehicle. TCFA used soil sampling GPS software developed by Site Specific Technology (SST). Prior to collecting samples in the field, TCFA staff mapped the field and down-gradient soil sampling locations using the aerial and topographic maps provided in the SST software. In the field, TCFA staff used a handheld GPS mapping unit. Fields and down-gradient areas were sampled in a consistent grid pattern from year to year. Individual sub-sample locations were recorded on the GPS unit and subsequently uploaded to the SST desktop computer software. Each of the sampled areas had a minimum of 10 sub-samples collected and combined to create a composite soil sample of the target area and sampling depth.

Soil samples were collected at the 0-6 inch and 6-24 depths at each sampling point. Sub-samples were composited in a clean bucket, thoroughly mixed and transferred to cloth soil bags provided by Servi-Tech Laboratories. Samples were primarily collected from October to January depending upon field conditions and crop rotations. Samples collected at each of the demonstration sites are shown in Figures 13-29.

Deaf Smith County Soil Results
DSC-1

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	11	26	20
Sub-area	16	21	28
Down 1	24	23	31
Down 2	14	24	37

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	8	12	33
Down 1	15	10	21
Down 2	12	11	26

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	64	56	70
Sub-area	40	30	66
Down 1	27	21	34
Down 2	30	24	32

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	16	14	91
Down 1	23	12	30
Down 2	24	15	36

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	608	576	627
Sub-area	589	524	619
Down 1	596	503	607
Down 2	562	549	602

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	370	325	556
Down 1	544	395	547
Down 2	573	570	643

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.3	2.0	1.7
Sub-area	1.4	1.9	1.7
Down 1	1.3	1.6	1.8
Down 2	1.0	1.5	1.6

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.9	1.4	2.8
Down 1	1.4	1.4	1.7
Down 2	1.0	1.5	1.6

Figure 13. Demonstration site, and downgradient soil sampling location for DSC-1. Downgradient soil samples were taken from a channel that starts in the field and exits the crop circle.

Deaf Smith County Soil Results
DSC-2 (SW Sub-area)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	28	48	32
SW Sub-area	20	28	71
SW Down 1	11	25	22
SW Down 2	19	28	32

Nitrogen 6-24" (ppm)

	2010	2011	2012
SW Sub-area	20	15	59
SW Down 1	13	16	16
SW Down 2	17	20	26

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	87	75	90
SW Sub-area	97	29	94
SW Down 1	30	11	22
SW Down 2	26	12	27

Phosphorus 6-24" (ppm)

	2010	2011	2012
SW Sub-area	54	16	91
SW Down 1	32	17	29
SW Down 2	29	18	25

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	631	649	555
SW Sub-area	497	435	610
SW Down 1	474	418	507
SW Down 2	487	431	496

Potassium 6-24" (ppm)

	2010	2011	2012
SW Sub-area	437	278	502
SW Down 1	494	316	519
SW Down 2	499	330	552

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.7	1.9	1.8
SW Sub-area	1.2	1.8	2.0
SW Down 1	0.9	1.6	1.5
SW Down 2	0.9	1.5	1.2

Organic Matter 6-24" (%)

	2010	2011	2012
SW Sub-area	1.3	1.4	1.8
SW Down 1	1.2	1.4	1.4
SW Down 2	1.4	1.4	2.2

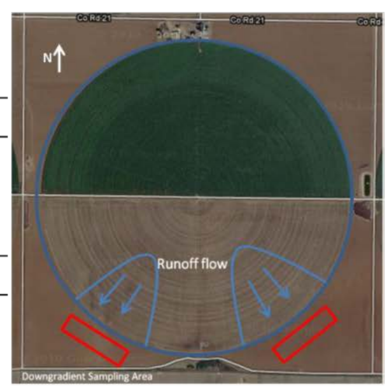


Figure 14. Demonstration site and downgradient soil sampling locations for DSC-2. Downgradient soil samples were taken from a two channels that start in the field and exits the crop circle.

Deaf Smith County Soil Results DSC-2 (SE Sub-area)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	28	48	32
SE Sub-area	14	19	67
SE Down 1	13	20	27
SE Down 2	13	19	18

Nitrogen 6-24" (ppm)

	2010	2011	2012
SE Sub-area	7	7	52
SE Down 1	14	12	29
SE Down 2	15	12	19

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	87	75	90
SE Sub-area	60	35	54
SE Down 1	15	10	17
SE Down 2	16	10	13

Phosphorus 6-24" (ppm)

	2010	2011	2012
SE Sub-area	48	10	60
SE Down 1	16	7	20
SE Down 2	18	10	14

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	631	649	555
SE Sub-area	493	409	486
SE Down 1	372	383	420
SE Down 2	442	417	454

Potassium 6-24" (ppm)

	2010	2011	2012
SE Sub-area	698	257	487
SE Down 1	455	293	408
SE Down 2	478	320	457

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.7	1.9	1.8
SE Sub-area	1.0	1.7	1.9
SE Down 1	0.6	1.2	2.4
SE Down 2	0.8	1.2	1.7

Organic Matter 6-24" (%)

	2010	2011	2012
SE Sub-area	0.8	1.2	1.9
SE Down 1	0.8	1.4	2.3
SE Down 2	1.0	1.8	1.6

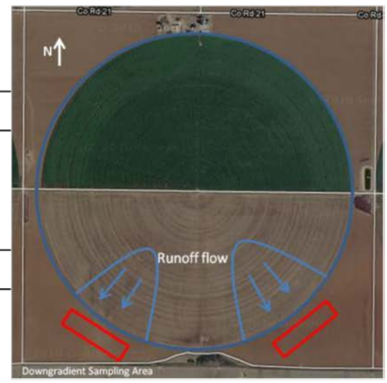


Figure 15. Demonstration site and downgradient soil sampling locations for DSC-2. Downgradient soil samples were taken from a two channels that start in the field and exits the crop circle.

Deaf Smith County Soil Results
DSC-3

Nitrogen 0-6" (ppm)	2010	2011	2012
Circle	27	40	33
Sub-area	23	22	19
Down 1	21	29	31
Down 2	24	27	27

Nitrogen 6-24" (ppm)	2010	2011	2012
Sub-area	19	10	23
Down 1	19	18	26
Down 2	22	15	21

Phosphorus 0-6" (ppm)	2010	2011	2012
Circle	129	67	151
Sub-area	74	25	60
Down 1	38	26	31
Down 2	26	15	31

Phosphorus 6-24" (ppm)	2010	2011	2012
Sub-area	74	9	50
Down 1	50	9	49
Down 2	31	11	29

Potassium 0-6" (ppm)	2010	2011	2012
Circle	747	582	765
Sub-area	588	464	483
Down 1	506	420	471
Down 2	448	388	427

Potassium 6-24" (ppm)	2010	2011	2012
Sub-area	575	261	477
Down 1	547	290	529
Down 2	441	264	468

Organic Matter 0-6" (%)	2010	2011	2012
Circle	1.7	1.8	2.4
Sub-area	1.4	1.7	1.7
Down 1	0.9	2.3	1.4
Down 2	0.7	1.4	1.3

Organic Matter 6-24" (%)	2010	2011	2012
Sub-area	1.3	1.2	1.6
Down 1	0.8	1.1	1.4
Down 2	0.9	1.1	1.4

Figure 16. Demonstration site and downgradient soil sampling location for DSC-3. Downgradient soil samples were taken from a channel that starts in the field and exits the crop circle.

Deaf Smith County Soil Results
DSC-4

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	5	80	26
Sub-area	5	70	54
Down 1	20	59	100
Down 2	21	52	110

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	6	40	45
Down 1	25	44	90
Down 2	30	42	120

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	105	155	170
Sub-area	82	162	102
Down 1	56	56	78
Down 2	70	44	87

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	30	71	60
Down 1	69	28	81
Down 2	56	27	82

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	582	772	722
Sub-area	583	742	612
Down 1	617	577	595
Down 2	681	567	617

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	416	521	575
Down 1	661	455	561
Down 2	710	498	559

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.2	2.2	2.4
Sub-area	1.4	2.0	1.9
Down 1	1.1	1.7	<0.2
Down 2	1.2	1.7	1.5

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	1.2	1.8	1.8
Down 1	1.1	1.6	1.7
Down 2	1.2	1.6	1.3

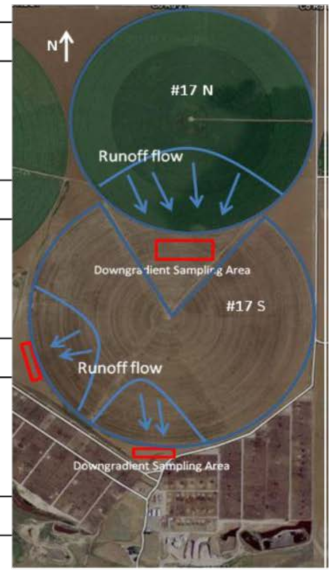


Figure 17. Demonstration site and downgradient soil sampling location for DSC-4. Downgradient soil samples from field 17N were from a channel that starts in the field and exits the crop circle. The downgradient soil sampling site for 17N is located in the circle 17S, but does not influence the sampling areas in 17S due to topography. Downgradient soil sampling was from a channel that started in the field and exited the crop circle.

Deaf Smith County Soil Results
DSC-5 (SW Sub-area)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	15	35	70
SW Sub-area	22	61	59
SW Down 1	120	140	140
SW Down 2	100	140	160

Nitrogen 6-24" (ppm)

	2010	2011	2012
SW Sub-area	37	47	62
SW Down 1	100	120	100
SW Down 2	110	200	170

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	42	40	52
SW Sub-area	67	82	103
SW Down 1	267	154	218
SW Down 2	268	164	217

Phosphorus 6-24" (ppm)

	2010	2011	2012
SW Sub-area	57	30	70
SW Down 1	257	100	348
SW Down 2	271	100	255

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	468	408	509
SW Sub-area	385	464	583
SW Down 1	1056	879	1073
SW Down 2	1146	949	1178

Potassium 6-24" (ppm)

	2010	2011	2012
SW Sub-area	446	327	605
SW Down 1	1088	645	1355
SW Down 2	1106	661	1178

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.1	1.8	2.0
SW Sub-area	1.4	2.2	2.4
SW Down 1	1.9	2.4	2.5
SW Down 2	2.3	2.4	2.5

Organic Matter 6-24" (%)

	2010	2011	2012
SW Sub-area	1.9	1.7	2.4
SW Down 1	2.3	2.1	2.6
SW Down 2	2.3	2.1	2.5

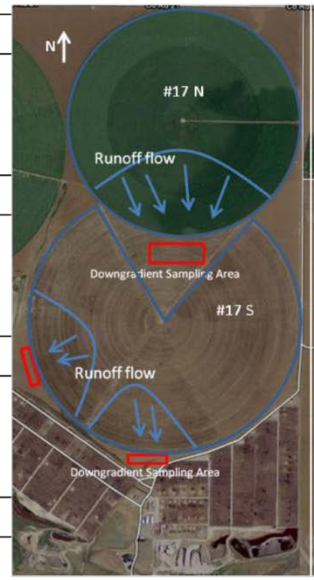


Figure 18. Demonstration site and downgradient soil sampling locations for DSC-5. Downgradient soil samples from field 17S were from a channel that starts in the field and exits the crop circle. Downgradient soil sampling in 17S were from channels that started in the field and exited the crop circle in two different areas.

Deaf Smith County Soil Results
DSC-5 (S Sub-area)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	15	35	70
S Sub-area	26	51	61
S Down 1	80	180	100
S Down 2	80	170	160

Nitrogen 6-24" (ppm)

	2010	2011	2012
S Sub-area	25	37	55
S Down 1	100	150	110
S Down 2	110	130	140

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	42	40	52
S Sub-area	54	62	69
S Down 1	226	238	192
S Down 2	236	199	219

Phosphorus 6-24" (ppm)

	2010	2011	2012
S Sub-area	16	42	103
S Down 1	216	122	277
S Down 2	242	172	293

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	468	408	509
S Sub-area	270	360	639
S Down 1	1118	1160	1075
S Down 2	1346	1143	1247

Potassium 6-24" (ppm)

	2010	2011	2012
S Sub-area	270	360	639
S Down 1	1079	816	1096
S Down 2	1229	948	1226

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.1	1.8	2.0
S Sub-area	1.3	1.9	1.9
S Down 1	2.2	2.5	2.1
S Down 2	2.0	2.3	2.3

Organic Matter 6-24" (%)

	2010	2011	2012
S Sub-area	0.7	1.6	1.9
S Down 1	2.2	2.1	2.5
S Down 2	2.1	2.1	2.5

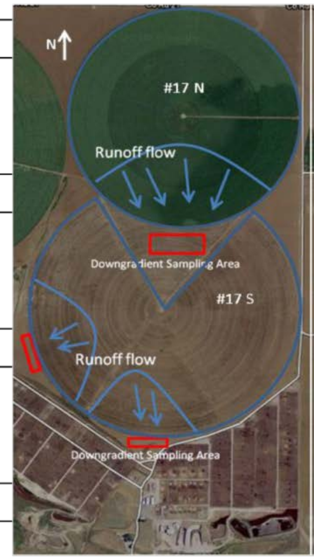


Figure 19. Demonstration site and downgradient soil sampling locations for DSC-5. Downgradient soil samples from field 17S were from a channel that starts in the field and exits the crop circle. Downgradient soil sampling in 17S were from channels that started in the field and exited the crop circle in two different areas.

Donley County Soil Results
DC-1

4 Ton/Acre Compost 3/10

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	1	3	3
Sub-area	2	2	2
Down 1	2	2	5
Down 2	1	3	6

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	2	2	1
Down 1	1	3	5
Down 2	1	3	3

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	33	38	27
Sub-area	31	28	44
Down 1	26	24	29
Down 2	19	17	14

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	36	26	41
Down 1	12	16	15
Down 2	14	16	15

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	96	93	94
Sub-area	93	90	68
Down 1	132	149	149
Down 2	142	129	116

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	85	84	67
Down 1	89	104	104
Down 2	108	93	117

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.5	0.3	0.3
Sub-area	0.3	0.2	<.02
Down 1	0.8	0.4	0.8
Down 2	0.7	0.4	0.4

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.3	0.2	<.02
Down 1	0.3	0.2	0.7
Down 2	0.5	0.2	0.5

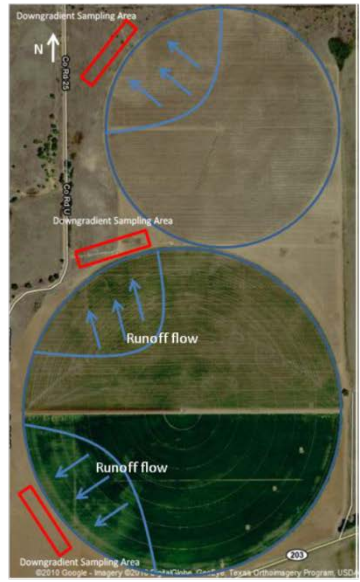


Figure 20. Demonstration site and downgradient soil sampling location for DC-1.

Donley County Soil Results
DC-2 (NW Sub-area)

North 1/2:
4 Ton/Acre Compost 4/12

South 1/2:
4 Ton/Acre Compost 3/11

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	3	4	7
NW Sub-area	5	4	5
NW Down 1	2	2	2
NW Down 2	1	1	3

Nitrogen 6-24" (ppm)

	2010	2011	2012
NW Sub-area	8	6	9
NW Down 1	2	2	2
NW Down 2	<1	1	2

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	47	52	58
NW Sub-area	73	75	85
NW Down 1	54	45	36
NW Down 2	24	19	26

Phosphorus 6-24" (ppm)

	2010	2011	2012
NW Sub-area	26	55	59
NW Down 1	21	30	16
NW Down 2	13	15	10

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	99	97	147
NW Sub-area	137	147	155
NW Down 1	154	158	119
NW Down 2	131	120	257

Potassium 6-24" (ppm)

	2010	2011	2012
NW Sub-area	163	163	166
NW Down 1	101	107	195
NW Down 2	84	106	195

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.4	0.2	0.3
NW Sub-area	0.6	0.4	0.4
NW Down 1	0.7	0.5	0.4
NW Down 2	0.6	0.4	1.5

Organic Matter 6-24" (%)

	2010	2011	2012
NW Sub-area	0.5	0.4	0.4
NW Down 1	0.3	<0.2	0.9
NW Down 2	0.4	0.3	1.2

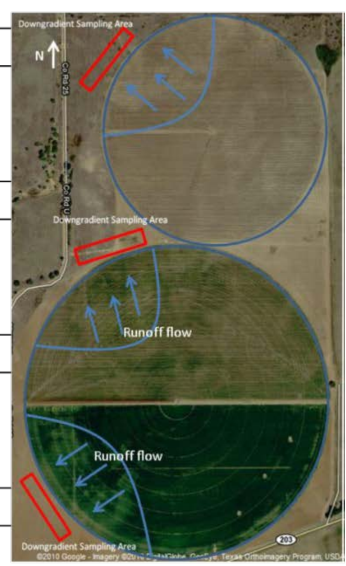


Figure 21. Demonstration site and downgradient soil sampling locations for DC-2.

Donley County Soil Results
DC-2 (SW Sub-area)

North 1/2:
4 Ton/Acre Compost 4/12

South 1/2:
4 Ton/Acre Compost 3/11

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	3	4	7
SW Sub-area	3	5	2
SW Down 1	1	<1	3
SW Down 2	1	<0.2	3

Nitrogen 6-24" (ppm)

	2010	2011	2012
SW Sub-area	2	4	3
SW Down 1	3	1	3
SW Down 2	2	<0.2	2

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	47	52	58
SW Sub-area	24	19	26
SW Down 1	82	48	15
SW Down 2	70	53	51

Phosphorus 6-24" (ppm)

	2010	2011	2012
SW Sub-area	41	32	33
SW Down 1	65	35	48
SW Down 2	45	36	47

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	99	97	147
SW Sub-area	131	120	257
SW Down 1	107	125	224
SW Down 2	120	108	131

Potassium 6-24" (ppm)

	2010	2011	2012
SW Sub-area	114	109	112
SW Down 1	120	104	151
SW Down 2	112	99	97

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.4	0.2	0.3
SW Sub-area	0.3	<0.2	0.2
SW Down 1	0.3	0.2	1.4
SW Down 2	0.3	<0.2	0.3

Organic Matter 6-24" (%)

	2010	2011	2012
SW Sub-area	0.3	0.3	0.3
SW Down 1	<0.2	<0.2	0.3
SW Down 2	<0.2	<0.2	0.2

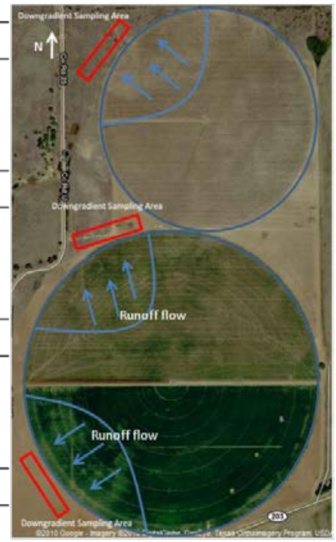


Figure 22. Demonstration site and downgradient soil sampling locations for DC-2.

Donley County Soil Results
DC-3

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	2	4	2
Sub-area	4	3	2
Down 1	9	3	2
Down 2	6	2	2

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	4	6	4
Down 1	7	1	1
Down 2	4	2	2

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	24	17	24
Sub-area	20	17	22
Down 1	30	11	52
Down 2	18	10	25

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	16	7	14
Down 1	15	9	13
Down 2	9	8	16

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	128	136	165
Sub-area	144	132	185
Down 1	246	195	91
Down 2	213	206	94

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	117	111	185
Down 1	181	168	90
Down 2	129	165	112

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.8	0.7	0.7
Sub-area	0.8	0.7	0.8
Down 1	1.3	0.1	0.2
Down 2	1.1	0.1	0.3

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.6	0.7	0.9
Down 1	0.8	0.1	0.3
Down 2	0.9	0.2	0.5

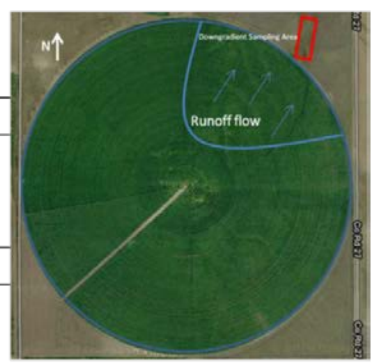


Figure 23. Demonstration site and downgradient soil sampling locations for DC-3. Downgradient soil samples were taken from a channel that started in the field and exited the crop circle.

Wheeler County Soil Results
WC-1

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	2	3	11
Sub-area	2	1	6
Down 1	2	4	5
Down 2	3	3	3

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	3	6	10
Down 1	4	5	7
Down 2	4	5	6

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	30	25	33
Sub-area	27	30	31
Down 1	60	29	5
Down 2	65	53	3

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	23	9	29
Down 1	26	21	7
Down 2	38	18	6

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	76	77	84
Sub-area	67	50	100
Down 1	47	90	51
Down 2	39	83	69

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	77	65	97
Down 1	60	96	32
Down 2	51	73	45

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.4	0.4	0.9
Sub-area	0.4	0.4	0.6
Down 1	<0.2	0.2	0.2
Down 2	<0.2	<0.2	0.2

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.5	0.4	0.6
Down 1	<0.2	<0.2	0.2
Down 2	<0.2	<0.2	0.3

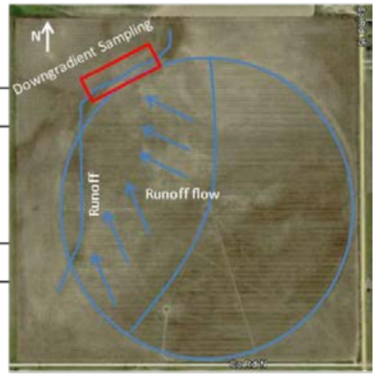


Figure 24. Demonstration site and downgradient soil sampling locations for WC-1. Downgradient soil samples were taken from a channel that started in the field and exited the crop circle.

Wheeler County Soil Results
WC-2

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	7	4	11
Sub-area	5	7	7
Down 1	8	32	5
Down 2	14	38	30

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	7	12	5
Down 1	8	34	4
Down 2	12	38	19

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	52	32	43
Sub-area	54	49	52
Down 1	46	110	63
Down 2	112	133	127

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	29	28	48
Down 1	30	50	36
Down 2	65	87	109

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	176	161	160
Sub-area	180	160	143
Down 1	152	290	179
Down 2	307	330	388

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	127	137	158
Down 1	150	373	228
Down 2	400	397	415

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	0.3	0.3	0.7
Sub-area	0.4	0.6	0.5
Down 1	0.3	0.8	0.5
Down 2	1.2	1.1	1.2

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.4	0.2	0.6
Down 1	0.3	0.9	0.7
Down 2	1.3	1.5	1.3

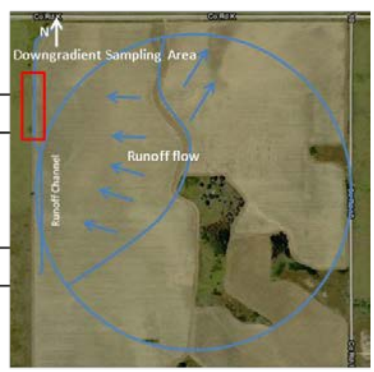


Figure 25. Demonstration site and downgradient soil sampling locations for WC-2. Downgradient soil samples were taken from a channel that started in the field and exited the crop circle.

2 T/ac compost in 4/11 and 4/12

Wheeler County Soil Results
WC-3 (Field #1)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	12	23	10
Sub-area	17	27	17
Down 1	14	40	9
Down 2	18	54	11

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	17	26	26
Down 1	4	13	5
Down 2	4	18	9

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	23	27	18
Sub-area	72	47	32
Down 1	81	77	88
Down 2	76	56	55

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	39	17	73
Down 1	25	18	36
Down 2	18	13	30

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	210	176	134
Sub-area	329	290	338
Down 1	711	736	761
Down 2	742	816	827

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	239	229	376
Down 1	351	471	513
Down 2	501	554	561

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.3	1.3	1.5
Sub-area	1.5	1.6	1.6
Down 1	2.7	3.8	3.8
Down 2	3.2	4.3	4.0

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	1.2	1.5	1.7
Down 1	1.2	1.4	1.7
Down 2	1.2	1.8	2.3

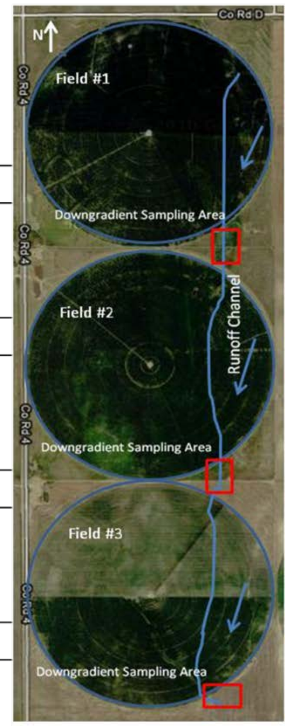


Figure 26. Demonstration site and downgradient soil sampling location for WC-3 Field #1. Downgradient sampling locations were located within the same channel to evaluate the net as well as the cumulative contributions of runoff from each field to the watershed.

Wheeler County Soil Results
WC-4 (Field #2)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	11	26	20
Sub-area	13	15	11
Down 1	8	17	6
Down 2	10	14	8
Down 3	24	27	36
Down 4	22	31	44

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	9	18	11
Down 1	2	6	5
Down 2	3	5	6
Down 3	24	24	19
Down 4	17	33	22

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	77	44	58
Sub-area	81	42	52
Down 1	41	25	42
Down 2	50	31	38
Down 3	87	72	74
Down 4	44	25	55

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	49	20	49
Down 1	14	8	33
Down 2	18	10	31
Down 3	45	14	66
Down 4	34	15	58

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	264	233	320
Sub-area	233	214	254
Down 1	628	581	607
Down 2	569	613	650
Down 3	569	463	539
Down 4	490	292	476

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	180	171	250
Down 1	258	340	426
Down 2	349	411	518
Down 3	569	463	539
Down 4	490	292	476

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.3	1.4	1.9
Sub-area	1.0	1.0	1.0
Down 1	1.9	2.5	2.6
Down 2	2.1	2.4	2.8
Down 3	2.0	2.0	1.9
Down 4	1.6	1.7	1.8

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.8	1.0	1.2
Down 1	1.3	1.8	2.6
Down 2	1.3	1.6	2.3
Down 3	1.5	2.1	2.4
Down 4	1.7	2.0	2.3

10 T/ac manure 3/10
2 T/ac compost 4/12

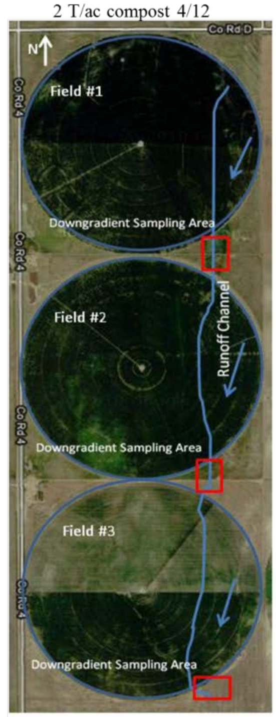


Figure 27. Demonstration site and downgradient soil sampling location for WC-4 Field #2. Downgradient sampling locations were located within the same channel to evaluate the net as well as the cumulative contributions of runoff from each field to the watershed.

Wheeler County Soil Results
WC-5 (Field #3)

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	10	9	14
Sub-area	10	3	12
Down 1	19	16	9
Down 2	30	23	4

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	14	11	11
Down 1	18	25	7
Down 2	27	37	4

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	46	41	62
Sub-area	39	74	48
Down 1	72	63	65
Down 2	87	75	74

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	37	25	40
Down 1	66	56	65
Down 2	71	58	65

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	273	235	282
Sub-area	216	265	236
Down 1	223	188	235
Down 2	204	196	205

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	206	186	224
Down 1	210	231	267
Down 2	228	209	240

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.0	1.7	1.7
Sub-area	0.7	0.8	1.2
Down 1	0.8	0.5	0.8
Down 2	0.7	0.6	0.7

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.8	0.4	1.1
Down 1	0.7	0.6	0.9
Down 2	0.7	0.8	0.7

North ½: 2 T/ac compost 4/11
South ½: 10 T/ac manure 3/10
2 T/ac compost 4/12

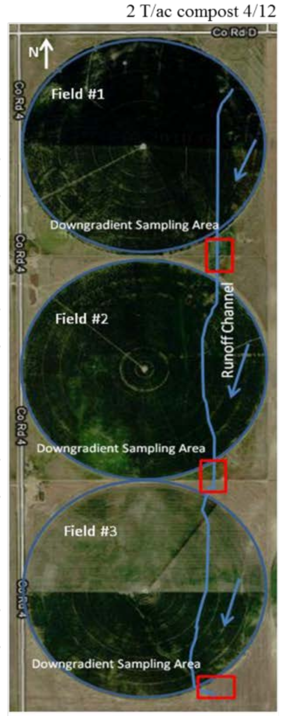


Figure 28. Demonstration site and downgradient soil sampling location for WC-5 Field #3. Downgradient sampling locations were located within the same channel to evaluate the net as well as the cumulative contributions of runoff from each field to the watershed.

Wheeler County Soil Results
WC-6

Nitrogen 0-6" (ppm)

	2010	2011	2012
Circle	6	19	36
Sub-area	4	18	20
Down 1	7	6	5
Down 2	2	6	3

Nitrogen 6-24" (ppm)

	2010	2011	2012
Sub-area	4	26	37
Down 1	4	5	2
Down 2	<1	3	2

Phosphorus 0-6" (ppm)

	2010	2011	2012
Circle	127	96	97
Sub-area	134	121	110
Down 1	186	129	209
Down 2	168	136	185

Phosphorus 6-24" (ppm)

	2010	2011	2012
Sub-area	77	82	91
Down 1	131	110	174
Down 2	82	94	112

Potassium 0-6" (ppm)

	2010	2011	2012
Circle	148	111	132
Sub-area	143	122	136
Down 1	194	236	272
Down 2	218	226	231

Potassium 6-24" (ppm)

	2010	2011	2012
Sub-area	145	147	168
Down 1	210	286	266
Down 2	165	223	221

Organic Matter 0-6" (%)

	2010	2011	2012
Circle	1.1	0.8	0.9
Sub-area	0.7	0.8	0.9
Down 1	0.8	0.5	1.1
Down 2	0.7	0.8	0.9

Organic Matter 6-24" (%)

	2010	2011	2012
Sub-area	0.4	0.5	0.9
Down 1	0.6	0.7	1.0
Down 2	0.3	0.6	0.9

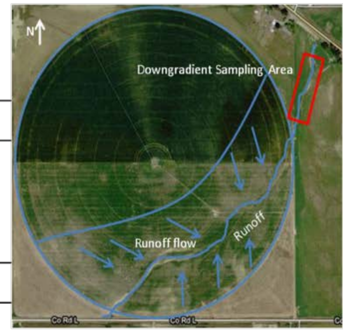


Figure 29. Demonstration site and downgradient/up gradient soil sampling locations for WC-6. Up gradient soil samples were collected to determine background concentrations.

RUNOFF WATER SAMPLES

One of the primary objectives of this task was to monitor the effectiveness of manure/compost BMPs through collection of rainfall runoff using automatic water samplers. The water-sampling program was designed to characterize water quality in rainfall and irrigation runoff from constructed watersheds receiving various rates of manure and compost. The experimental design consisted of 4 treatment plots at the DSC-6 demonstration site, as shown in Figure 12. The plots were labeled 1-4 from east to west. The treatment for plot #1 consisted of a single application of manure at a rate of 20-25 tons/acre. The treatment for plot #2 consisted of 4-5 tons/acre of composted cattle manure applied annually. Commercial fertilizer was applied annually to plot #3 by the producer at standard agronomic rates based upon whole-field, soil-test recommendations. The treatment for plot #4 had 10 tons/acre of cattle manure applied annually.

Project members started construction of the treatment plots for the water quality demonstration site located in Deaf Smith County in November 2010. Treatment plots were marked, and GPS locations of the perimeters were collected. A tractor mounted disk implement was used to make berms around each plot to prevent "run on" from the surrounding areas, and to direct the runoff from each plot to an automated water sampler. Water samplers were installed in January 2010, and black plastic was used to line the diversion berms at the downgradient side of each treatment plot to (a) prevent erosion by the runoff water, and (b) to help with long term berm stability in and around the water samplers. Figure 30 shows an upclose view of the ISCO® water samplers, diversion berms, and H-flumes used to collect water during runoff events. AgriLife Research installed ISCO 6712 samplers at the beginning of the project to collect runoff water that was channeled through H-flumes down gradient of each treatment plot. Due to EPA guidance, refrigerated ISCO Avalanche samplers were installed in May 2012. During the transition period, the most intense storm event of the study occurred and no data were collected. Water samples were analyzed for total phosphorus, total kjeldahl nitrogen, and *E. coli* by the AgriLife Research laboratory at Vernon. Diversion berms surrounded each plot so as to isolate it from "run-on" from other adjacent sources as well as to direct the flow toward the water-sampling devices. Each plot had a separate sampling device, and efforts were made to ensure that the water sample was representative. This included the topographical isolation previously mentioned, as well as a protective cover to prevent contamination or dilution. Composite samples were taken, labeled, filtered, preserved, and properly stored until analysis was completed.

Figure 30. Water sampler, diversion berms, and H-flumes used to collect water during runoff events at the water quality demonstration site (DSC-6).

Table 2 shows the amount of nutrients applied, runoff events, and runoff water nutrient and bacteria concentrations when samples met QAPP specified holding parameters. It should be noted that the majority of the monitoring period occurred under severe to exceptional drought conditions. The greatest number of runoff events occurred during 2011. All of these runoff events were a result of irrigation and not natural precipitation. Coupled with a high water use crop (corn) and drought conditions, irrigation demand was greater and more frequent in 2011. Total P, TKN, and *E. coli* concentrations in runoff water were greater from plots receiving the 20 ton/ac manure rate. However, this treatment (20 ton/ac) did not result in the greatest cumulative nutrient loss for the year. The commercial fertilizer treatment resulted in the highest nutrient loss among all treatments. Although nutrient concentrations were much lower from the commercial fertilizer treatment compared with the high manure rate, the amount of runoff volume generated from this plot was much greater, resulting in a higher nutrient mass loss. An irrigation wheel track was within the border of plot 3 (commercial fertilizer treatment), which seemed to expedite runoff. In 2012 and 2013, the wheel track was isolated from the actual plot. The compost and low manure rate resulted in lower nutrient and bacteria concentrations in the runoff water. Based upon data collected in 2011, we can conclude that nutrients and bacteria can be transported off-site due to irrigation alone, as much as 7.4 lb P/ac/yr and 16.7 lb N/ac/yr in this demonstration. However, these runoff events were generally short and transport of nutrients were relatively close to the edge of the irrigated field.

In 2012 and 2013, irrigation was less frequent and intense as compared with 2011. This is partly due to the planting of sorghum (silage) on the demonstration sites and corn being planted on the majority of the pivot area. Thus, most water was directed toward the more demanding corn. Due to light irrigation and some moderate storm events, runoff volumes generated were very small compared to 2011. As a result, there were several instances when runoff was not generated on every plot. There were also instances that low runoff volumes resulted in inadequate sample volumes for sample collection. For example, there was only one runoff event in 2012 that generated more than 150 gallons. In 2011, runoff amounts varied from 1000 to 128,000 gallons. Since runoff volumes were not recorded for every event, we reported concentration data only for 2012 and 2013. Nutrient concentrations dropped dramatically for the 20 ton/ac manure treatment in 2012 and 2013, which was expected since no manure was applied for this treatment during the second and third year. Annual applications of compost and manure resulted in increasing P runoff concentrations each year. This may be attributed to a build-up of soil P over time and subsequently P runoff. It could also be a factor of very low runoff volumes, leading to more concentrated flow compared with a larger storm or irrigation event. In 2013, manure and compost was not incorporated after application. This seemed to have the greatest effect on *E. coli* concentrations, which were greater in 2013 from compost and manure annual applications.

Based upon the limited water quality data that were collected, we can make some general observations:

• The risk of contaminant loss is greater when a 20-25 ton/ac manure application is made compared with a lower rate, although the risk can subside in subsequent years when no manure is applied.

• Proper irrigation management and crop selection can reduce the risk of contaminant loss from the edge of field.

• Annual applications of manure above crop nutrient needs can increase the risk of nutrient loss.

• Although annual applied nutrients were lower as a result of commercial fertilizer compared to manure and compost applications, nutrient concentrations among treatments were similar.

• Surface applications of manure without incorporation can increase the risk of bacteria loss via runoff.

	20 ton/acre manure every 3rd year			5 ton/ac compost annually			Fertilizer annually			10 ton/ac manure annually		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
Total N Applied (lb/ac)	752	0	0	163	179	173	125	125	125	376	387	414
Total P Applied (lb/ac)	325	0	0	82	65	65	0	0	0	162	232	157
# of Runoff Events	7	6	5	10	3	2	10	2	6	8	4	5
Avg P (ppm)	4.85	1.56	2.41	2.63	2.55	7.03	3.66	7.27	2.94	2.31	4.34	5.1
Avg TKN (ppm)	16.7	7.42	7.68	7.49	7.93	19.3	5.97	28.2	15.5	3.69	21.7	13.3
TP Loss (lb/ac)	6.9	-	-	1.31	-†	-	7.4	-	-	1.53	-	-
TKN Loss (lb/ac)	10.9	-	-	3.41	-	-	10	-	-	2.02	-	-
Avg *E. coli* (cfu/100 ml)	83	48	103	15	16	228	16	NS	104	10	0	699

Table 2. The amount of nutrients applied, runoff events, and runoff water nutrient and bacteria concentrations when samples met QAPP specified holding parameters at the water quality demonstration site. †Cumulative loss was not calculated in 2012 and 2013.

WELL WATER SAMPLES

Water samples were collected by TCFA from all water wells located within the boundaries of the demonstration areas as well as any water wells (where access was granted) within 500 feet down-gradient. Water samples were analyzed for bacteria and nutrients. Groundwater samples were collected from the well head only after the pump has been running for at least 1 hr. Water was collected in a syringe and immediately filtered through a 0.45 µm membrane and acidified to pH 2 with H_2SO_4. Samples were transported to the ESSL and stored in a refrigerator at 4^oC. A sample was also collected in a sterile syringe and collected/transported in sterile bags or containers for *E. coli*. Samples were primarily collected from April to September depending on crop rotation and field conditions. Well water samples collected at the demonstration sites are shown in Table 3. *E. coli.* concentrations were zero for all samples analyzed in table 3.

	N (ppm)			P (ppm)			NH3 (ppm)			TP (ppm)			TKN (ppm)		
Site/year	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
WC-1	NA	16.97	34.73	NA	0.08	0.07	NA	0.18	0.04	NA	0.21	0.58	NA	2.66	1.69
WC-2	NA	13.94	30.33	NA	0.10	0.03	NA	0.19	0.01	NA	0.32	0.61	NA	8.28	1.90
WC-2	NA	3.18	13.27	NA	0.06	0.00	NA	0.08	0.08	NA	0.18	0.55	NA	4.64	3.09
WC-3	NA	1.88	1.71	NA	0.08	0.00	NA	0.19	0.03	NA	0.19	0.54	NA	3.77	5.44
WC-5	NA	2.84	3.17	NA	0.09	0.07	NA	0.18	0.07	NA	0.17	0.55	NA	3.21	3.73
WC-6	NA	15.69	29.01	NA	0.07	0.01	NA	0.26	0.02	NA	0.20	0.56	NA	4.77	1.77
DSC-1	6.2	9.53	9.08	0.02	0.06	0.06	0.07	0.17	0.01	0.18	0.22	0.59	12.46	6.86	3.60
DSC-2	2.54	4.00	2.55	0.02	0.07	0.00	0.11	0.07	0.04	0.17	0.20	0.55	16.58	7.43	3.92
DSC-2	4.47	6.55	6.31	0.01	0.07	0.00	0.11	0.17	0.00	0.01	0.13	0.57	12.66	8.87	6.88
DSC-2	3.08	5.37	3.51	0.02	0.07	0.00	0.46	0.19	0.05	0.2	0.11	0.59	0.53	8.31	4.77
DSC-2	2.84	5.53	3.06	0.02	0.08	0.03	0.1	0.20	0.00	0.15	0.20	0.56	5.71	6.94	5.01
DSC-3	2.37	4.24	2.76	0.02	0.08	0.00	0.42	0.30	0.11	0.16	0.23	0.59	8.79	11.34	4.78
DSC-3	2.03	3.86	2.71	0.02	0.12	0.00	0.62	0.30	0.00	0.16	0.20	0.58	0.89	6.20	5.00
DSC-4	NA	3.92	3.48	NA	0.11	0.01	NA	0.19	0.03	NA	0.21	0.58	NA	5.34	2.99
DSC-4	NA	4.98	3.15	NA	0.08	0.07	NA	0.14	0.09	NA	0.21	0.54	NA	5.31	6.12
DSC-5	NA	7.95	2.55	NA	0.08	0.02	NA	0.25	0.05	NA	0.23	0.57	NA	6.35	4.21
DSC-6	NA	7.57	5.16	NA	0.07	0.00	NA	0.18	0.01	NA	0.23	0.55	NA	6.18	9.28
DC-1	NA	14.43	12.89	NA	0.08	0.00	NA	0.22	0.04	NA	0.19	0.73	NA	6.77	5.64
DC-2	NA	14.19	15.14	NA	0.09	0.00	NA	0.33	0.11	NA	0.18	0.79	NA	3.67	6.08
DC-3	NA	11.09	8.41	NA	0.09	0.00	NA	0.21	0.12	NA	0.26	0.68	NA	3.93	5.92

Table 3. Well water samples collected at the demonstration sites within the boundaries of the demonstration areas as well as any water wells (where access was granted) within 500 feet down-gradient.

MANURE/COMPOST SAMPLING

Manure and compost samples were collected prior to any land application event to obtain the nutrient concentration of the manure/compost. Samples were collected from the manure/compost storage location when in-field stockpiles were available as shown in Table 4. Multiple sub-samples (i.e. 3-6) of manure/compost were collected using a clean shovel and sub-samples were then composited into a one-gallon plastic Ziploc bag and delivered to Servi-Tech Laboratories in Amarillo, Texas.

Isolates from manure samples representing 29 feedyards in the Texas High Plains were collected and submitted by AgriLife Research for addition to the bacterial source tracking (BST) state library.

Demonstration site	Year	%MC	%N	%P	%K	%Ca	%Mg	%Na	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
WC-3 Manure	2011	29.2	1.05	0.637	0.599	2.73	0.401	0.89	317	1940	42	173
WC-3 Compost	2012	15.1	1.98	0.086	1.62	2.19	0.796	0.333	333	5610	54	337
WC-4 Compost	2012	15.7	1.93	0.768	1.57	2.17	0.765	0.39	323	5990	52	343
DC2 Compost	2010	20.8	0.778	0.632	1.34	2.31	0.494	0.33	244	3000	33	153
DC2 Compost	2012	8.2	0.686	0.575	0.883	2.59	0.469	0.206	225	4880	32	191
DSC-1 Manure	2010	28.4	1.68	0.788	1.93	2.75	0.635	0.4	120	3060	19	140
DSC-2 Manure	2010	20.1	1.68	0.733	1.74	3.1	0.627	0.436	120	4330	21	173
DSC-2 Manure	2011	13.7	2.05	0.97	2.35	3.25	0.882	0.5	222	4070	36	220
DSC-2 Manure	2012	20.2	1.13	0.879	1.62	3.8	0.683	0.385	150	5120	25	206
DSC-4 Manure	2010	15.6	1.55	0.829	1.91	3.23	0.666	0.476	136	4600	23	186
WQ Demo Manure	2011	18.6	1.63	0.821	1.78	3.33	0.749	0.319	281	5150	51	328
WQ Demo Manure	2012	21.8	1.45	1.43	1.87	2.5	0.495	0.411	114	3780	21	151
WQ Demo Manure	2013	33.7	1.67	1.73	2.23	1.69	0.549	0.5	126	2570	22	145
WQ Demo Compost	2011	28.6	1.88	0.812	1.69	2.2	0.58	0.389	122	3390	20	144
WQ Demo Compost	2012	25.2	1.64	1.47	2.19	2.61	1.17	0.304	293	5120	55	306
WQ Demo Compost	2013	19.4	1.53	1.44	2.05	3	1.15	0.308	247	5290	45	271

Table 4. Manure and compost samples collected from in-field stockpiles prior to land application.

DEMONSTRATION PLOT SAMPLING

Forage yields and nutrient results were obtained only for the water quality demonstration plots on a yearly basis at harvest time. The plots were harvested and weighed individually by the cooperating producer and recorded by onsite project personnel as shown in Figure 31. Sub samples of the harvested material were then collected and analyzed by AgriLife Extension for moisture and nutrient content as shown in Figure 32. The crops (harvested as silage) included: corn in 2011 and a hybrid sorghum variety in 2012 and 2013. The types and management of crops were left to the discretion of the cooperating producer.

Treatments for each of the plots at the water quality demonstration site were discussed by the project advisory group (PAG) and their recommendations were considered before treatments to individual plots were applied. The treatments for each plot were as follows: compost every year (5 tons/acre), manure every year (10 tons/acre), commercial fertilizer (producer’s current practice), and a single, high frequency manure application (20 tons/acre). The producer incorporated the manure/compost with a disk plow after the demonstration plots received the treatments.

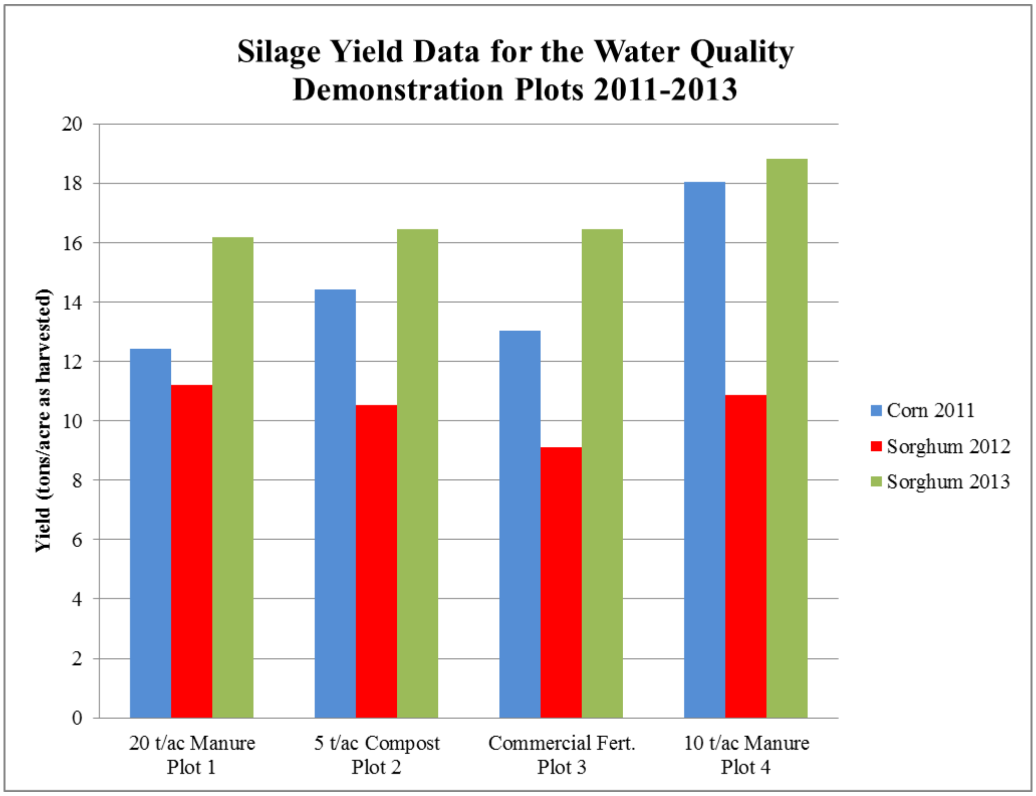


Figure 31. Forage yields obtained from the water quality demonstration plots on a yearly basis at harvest time. The plots were harvested and weighed individually by the cooperating producer and recorded by onsite project personnel.

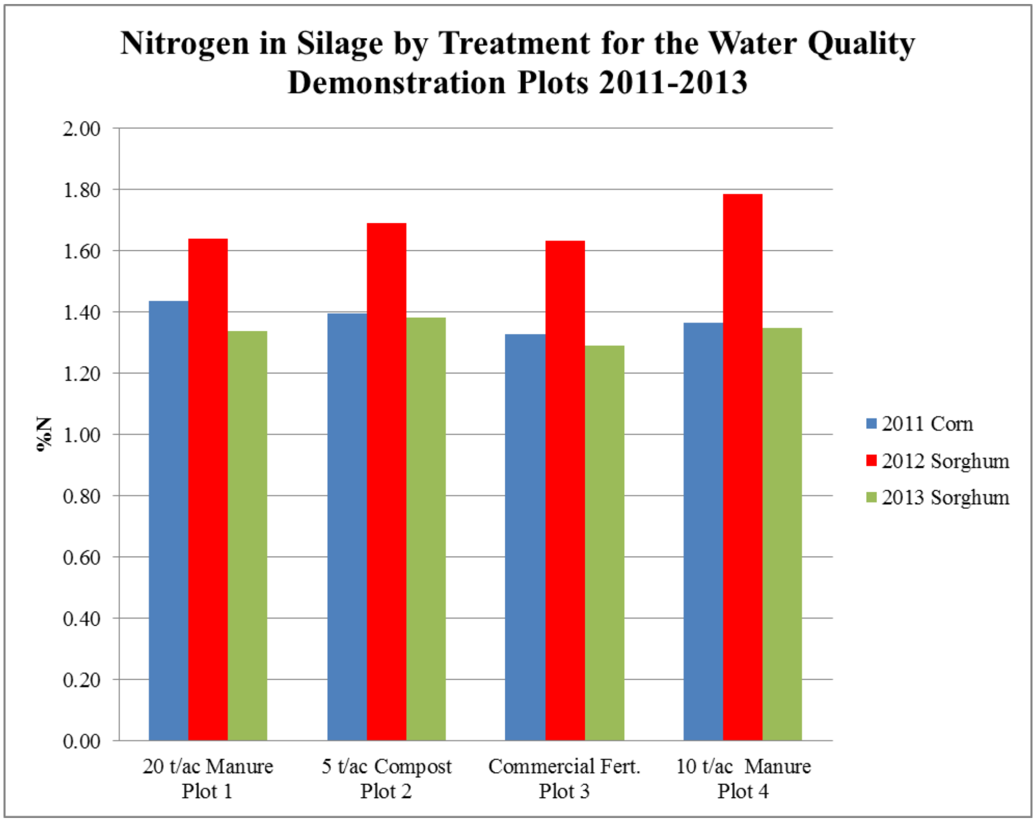


Figure 32. Nutrient concentrations for the silage were obtained from the water quality demonstration plots on a yearly basis at harvest time Sub samples of the harvested material were collected and analyzed by Texas A&M AgriLife Extension Service for moisture and nutrient content.

MANURE/COMPOST TRUCK CALIBRATION

The single pass calibration method was field tested on October 18-20, 2010 at the Texas A&M AgriLife Research facility in Bushland, Texas. Project personnel attempted to estimate the precision of the single pass calibration method by capturing the manure as it was being land applied on tarps placed in the path of the manure truck during applications. The tarps varied in size, and were placed in different locations along the centerline path of the manure truck. The tarps ranged in size from 28″x28″ (aspect ratio 1:1), 56″x56″ (aspect ratio 1:1) and 28″x112″ (aspect ratio 1:4). In the 11 calibration test runs conducted the aspect ratio of the tarps appeared to be the determining factor in the precision of the estimate. The 1:1 aspect ratio of the larger 56”x56” tarps proved to be too wide for the spreading trucks to pass over without running them over. In most cases the 1:1 aspect tarps would be rolled up or otherwise wrinkled by the trucks. These preliminary results were presented at the second Project Advisory Group meeting held on January 5, 2011 at the Texas A&M Research and Extension Center in Amarillo.

TCFA helped to identify options for field calibration of manure/compost spreader trucks. These options included single-pass calibration using the calibration kits and/or calibration using a whole-truck method (weight of manure/compost applied by a single truck to a given area) . The proper use of the spreader truck calibration kits were demonstrated to three different owner/ operators and their employees. Compost/manure trucks were calibrated on site and adjustments were made to achieve the targeted land application rate specified by the producers. The results of these three field demonstrations are shown in Figures 33-36. The results of these measurements were shared with each of the contractors and their employees on site and at the environmental training seminars and field days hosted by project personnel. In one instance the single pass truck calibration method was used constructively to refine and justify post-hoc billing arrangements that did not match application rates. In all field measurements the 28x112" tarps were placed along the centerline of the spreading truck. Each measurement accounts for one pass by one truck over a calibration tarp. The measurements for the manure trucks do not account for overlap since the effective spreader width was 12 feet wide and the trucks did not overlap between each pass, but the compost truck calibrations did allow for overlap.

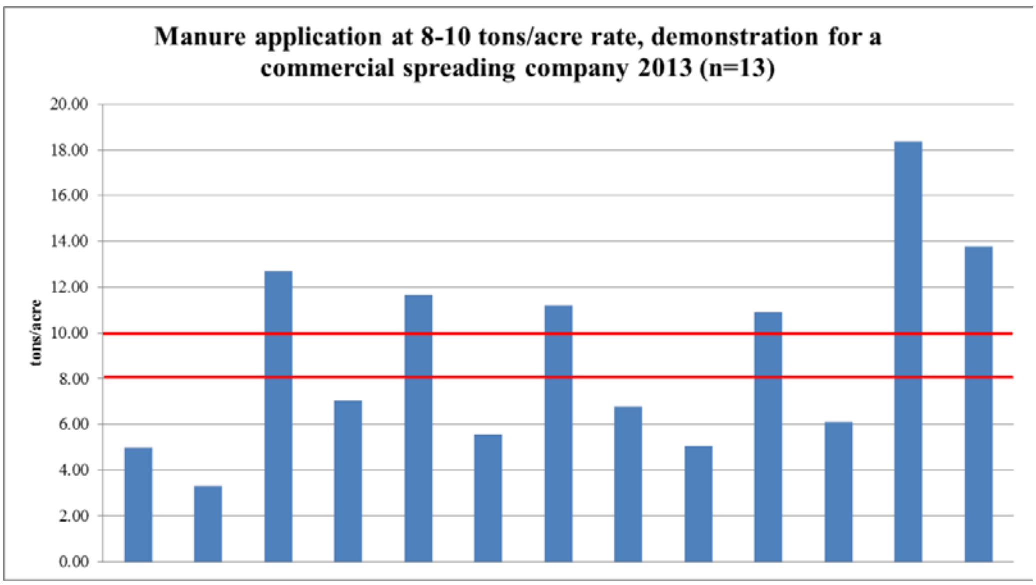


Figure 33. Manure application with a targeted rate of 8-10 tons per acre as specified by the land owner. This manure was land applied by a local manure contractor.

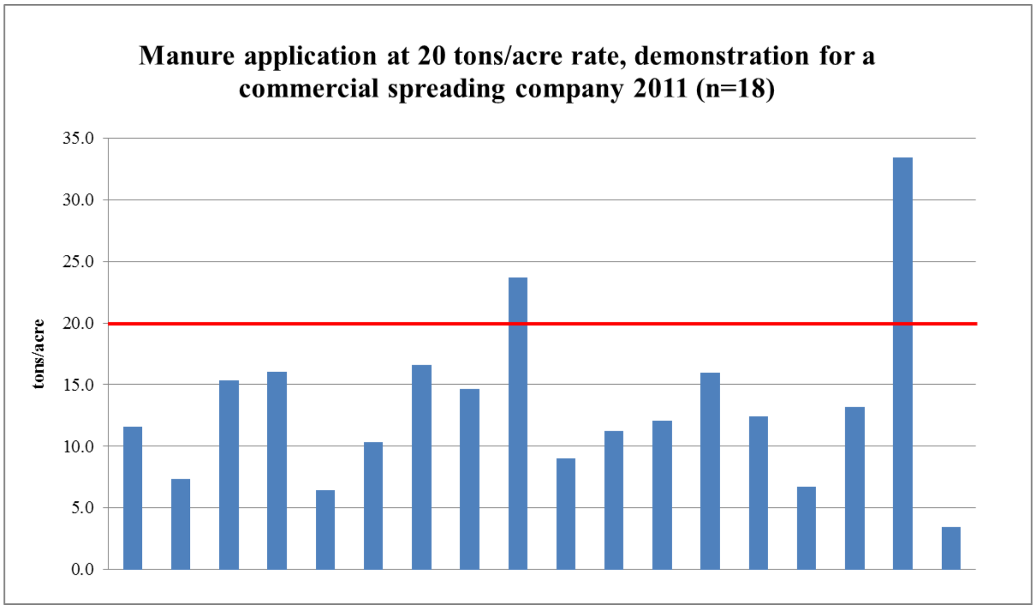


Figure 34. Manure application with a targeted rate of 20 tons per acre as specified by the land owner. This manure was land applied by a local manure contractor.

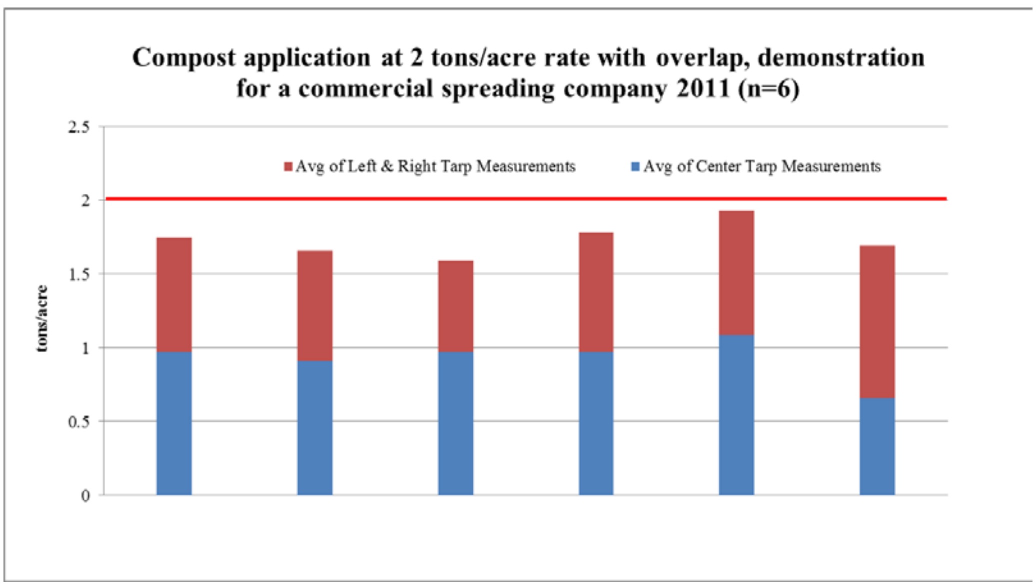


Figure 35. Compost application with a targeted rate of 2 tons per acre. This compost was not applied to crop land as it was broadcast spread on an empty section of the composting facility. This compost company used GPS technology along with calibrated load cells to deliver a very consistent application rate.

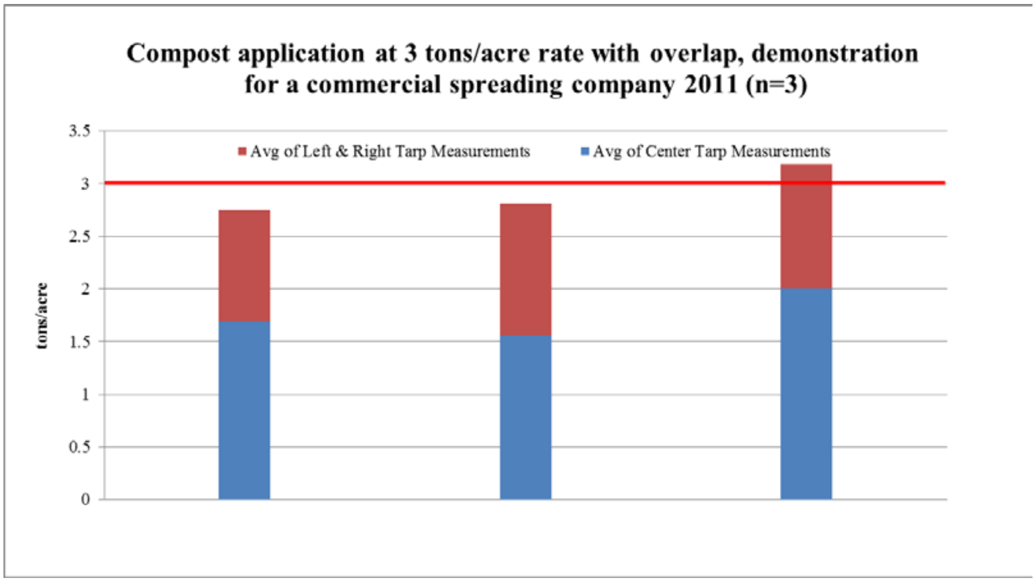


Figure 36. Compost application with a targeted rate of 3 tons per acre. This compost was not applied to crop land as it was broadcast spread on an empty section of the composting facility. This compost company used GPS technology along with calibrated load cells to deliver a very consistent application rate.

Calibration methods were confirmed at the water quality demonstration site during annual manure and compost applications to treatment plots as seen in figures 37-39. Project personnel used two calibration tarps with a 4:1 aspect ratio (28"x112") to verify the amounts of compost and raw manure applied to treatment plots. Manure was applied at a target rate of 10 and 20 tons/acre, and compost was applied at a target rate of 5 tons/acre. Manure was applied by the WTAMU manure truck, while compost was applied by a small scale, tractor-pulled compost spreader. Each spreader was calibrated before applications were made to each treatment plots in 2011, 2012 and 2013.

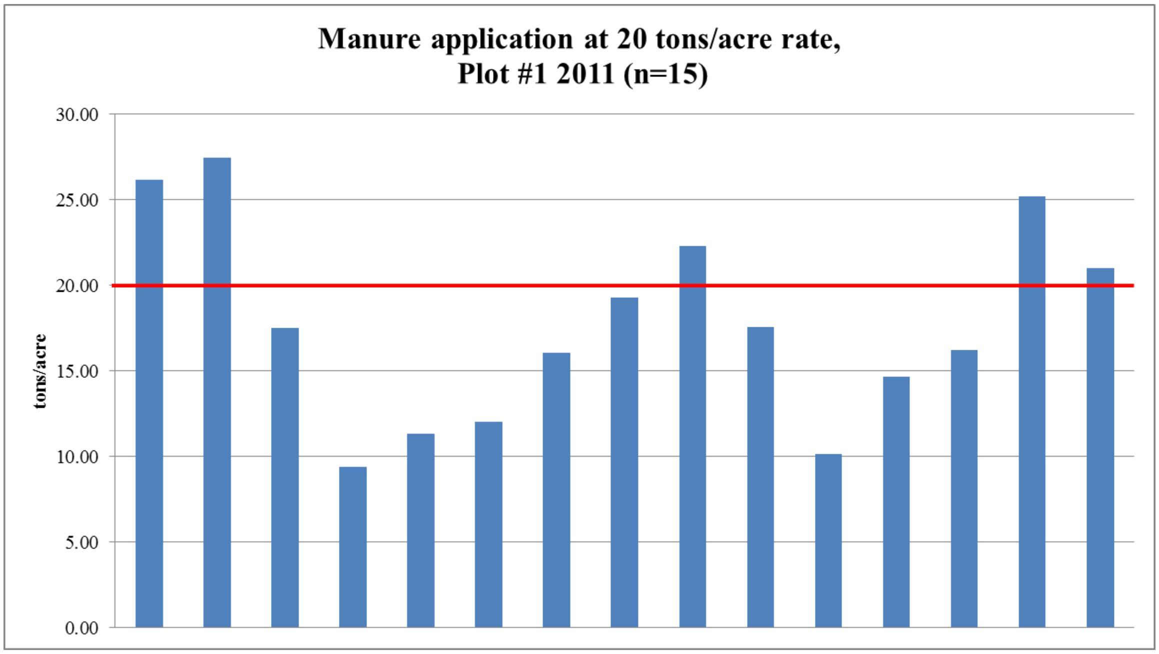


Figure 37. Manure application with a targeted rate of 20 tons per acre as specified by the project advisory group. This manure was land applied by the manure spreader owned and operated by West Texas A&M University.

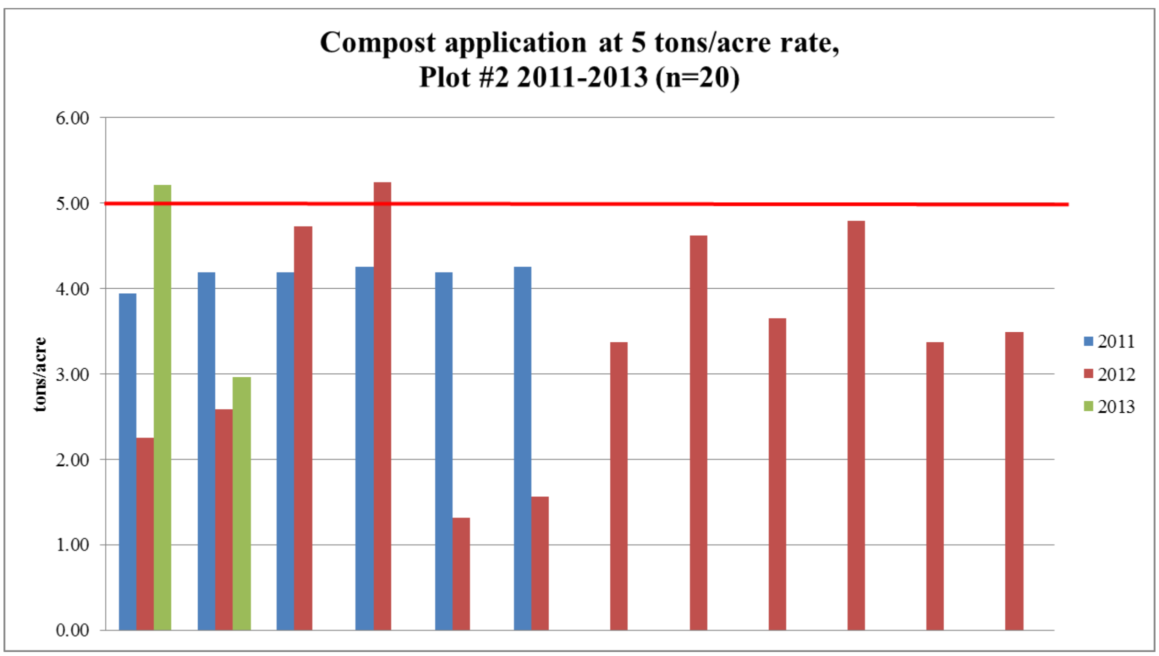


Figure 38. Compost application with a targeted rate of 5 tons per acre as specified by the project advisory group. This compost was donated by a commercial composting facility and applied by Texas A&M AgriLife Extension Service with a small compost spreader pulled behind a tractor.

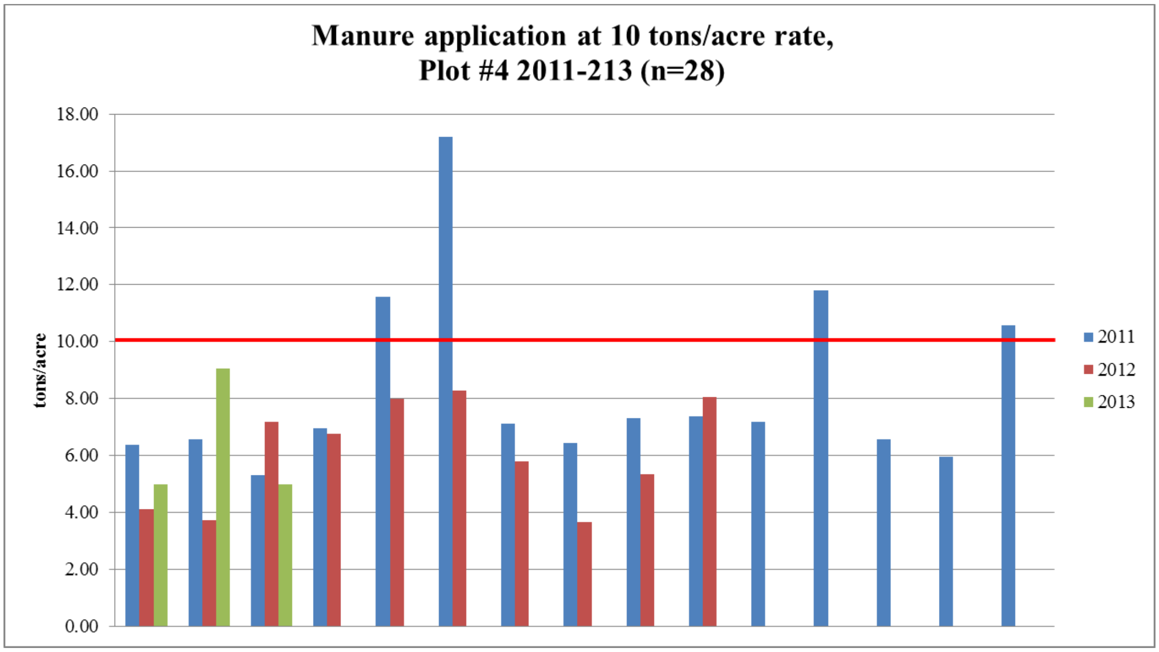


Figure 39. Manure application with a targeted rate of 10 tons per acre as specified by the project advisory group. This manure was land applied by the manure spreader owned and operated by West Texas A&M University.

SURVEYS AND KNOWLEDGE ASSESSMENTS

Results of the surveys and environmental knowledge assessment portion of this project are included in the Appendix.

APPENDIX

APPENDIX A: EDUCATIONAL MATERIALS

Instructions for Field Calibration of Manure and Compost Trucks

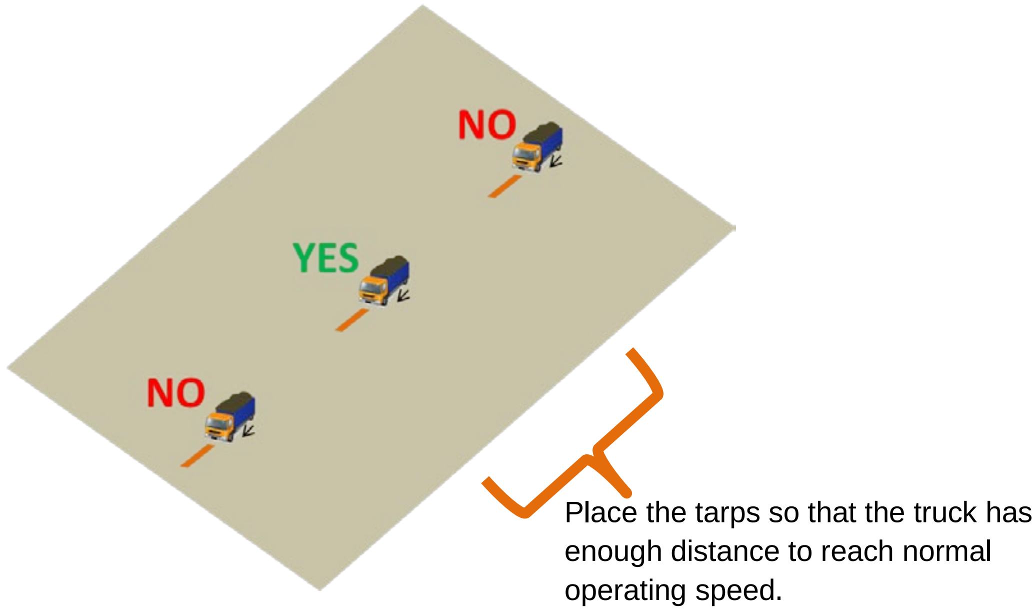
Development and Implementation of an Environmental Training Program for Manure and Compost Haulers/Applicators in the Texas High Plains. Clean Water Act §319(h) Nonpoint Source Grant Program

Step 1

Place the long rectangular calibration tarp directly in line with the travel path of the manure/compost truck. The truck should drive directly over the center of the tarp. The tarp should be aligned so the rear dual wheels do not run over the edges of the tarp and the driver does not have to alter the driving path to go over the tarp. Place the 2 ½ lb weights on each corner of the tarp to prevent it from blowing away as the truck passes.

Step 2

The tarp should be placed far enough out in the field so the driver has enough distance to get up to normal operating speed. Don't place tarps at the beginning or end of the field.



Step 3

The collected manure will need to be weighed once the truck has driven over the calibration tarp. Remove the 2 ½ lb weights from the corners of the tarp and then transfer the manure to the square tarp where it will be weighed with the hand held scale.

Step 4

Weigh the collected manure by attaching the four corners of the tarp to the handheld scale. Do not forget to subtract the weight of the empty tarp from the total weight. Each pound of manure that is collected on the tarp is equal to 1 ton of manure applied per acre. For instance, 5 pounds of manure collected on the tarp equals 5 tons of manure applied per acre.

Step 5

Repeat steps 1-4 until consistent application numbers are achieved (approximately 3 to 5 calibration test runs).

Calibration Kit Materials:

1 calibration tarps 28"x112"
1 weighing tarp 56"x56"
4 weights (2 ½ lbs each)
1 duffel bag to hold the calibration materials
1 digital weighing handheld scale

For more information:

manurespreading.tamu.edu

Texas Cattle Feeders Association
5501 I-40 West
Amarillo, TX 79106
(806) 358-3681

Texas A&M AgriLife Extension Service
6500 Amarillo Blvd. West
Amarillo, TX 79106
(806) 677-5600

INSTRUCCIONES

PARA

CALIBRACIÓN EN EL CAMPO DE

CAMIONES DE ESTIÉRCOL/COMPOST

Los fondos para este proyecto fue proporcionado a través de Clean Water Act §319(h) subvención de Texas State Soil and Water Conservation Board y el U.S. Environmental Protection Agency.

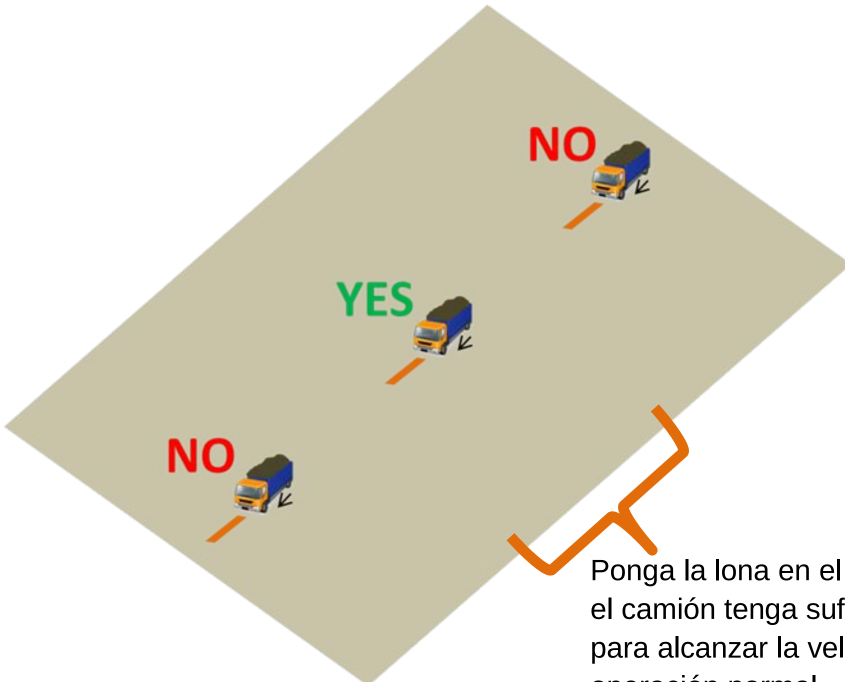
Spanish Version
August 2012

Paso 1

Ponga la lona larga rectangular de calibración (28 pulgadas x 112 pulgadas) en linea directa con el recorrido del camión de estiércol/compost. La lona debe estar alineada para que las ruedas traseras duales no pase encima de los bordes de la lona y el conductor no tenga que cambiar la ruta para ir conduciendo sobre la lona. Ponga las pesas de 2 ½ libras en cada esquina de la lona para evitar que se vuele cuando el camión pase. El camión debe conducir directamente sobre el centro de la lona.

Paso 2

Ponga la lona suficiente distancia en el campo para que el conductor tenga suficiente distancia para alcanzar la velocidad de operación normal. No ponga las lonas al principio o al final del campo.



Ponga la lona en el campo para que el camión tenga suficiente distancia para alcanzar la velocidad de operación normal.

Paso 3

El estiércol recolectado tundrá que ser pesado cuando el camión se ha conducido sobre la lona de calibración. Quite las pesas de 2 ½ libras de las esquinas de la lona y luego transferir el estiércol a la lona cuadrada (56 pulgadas x 56 pulgadas) que se pesara con la escala de mano.

Paso 4

Para pesar el estiércol recogido ponga las cuatro esquinas de la lona en la escala de mano. No se olvide de quitar el peso de

la lona vacia del peso total. **<u>Cada libra de estiércol que se recoge en la lona es igual a una tonelada de estiércol aplicado por acre.</u>** Por ejemplo, 10 libras de estiércol recogidos en la lona es igual a 10 toneladas de estiércol aplicado por acre.

Paso 5

Repita los pasos 1-4 hasta consistente aplicación numerous se consiguen (aproximadamente de 3 a 5 calibracion prueba se ejecuta).

Materiales del kit de calibración:

- 1 lona de calibración 28"x112"
- 1 lona para pesar 56"x56"
- 4 pesas (2 ½ libras cada uno)
- 1 escala digital de pesa de mano
- 1 bolsa de lona para contener los materiales de calibración

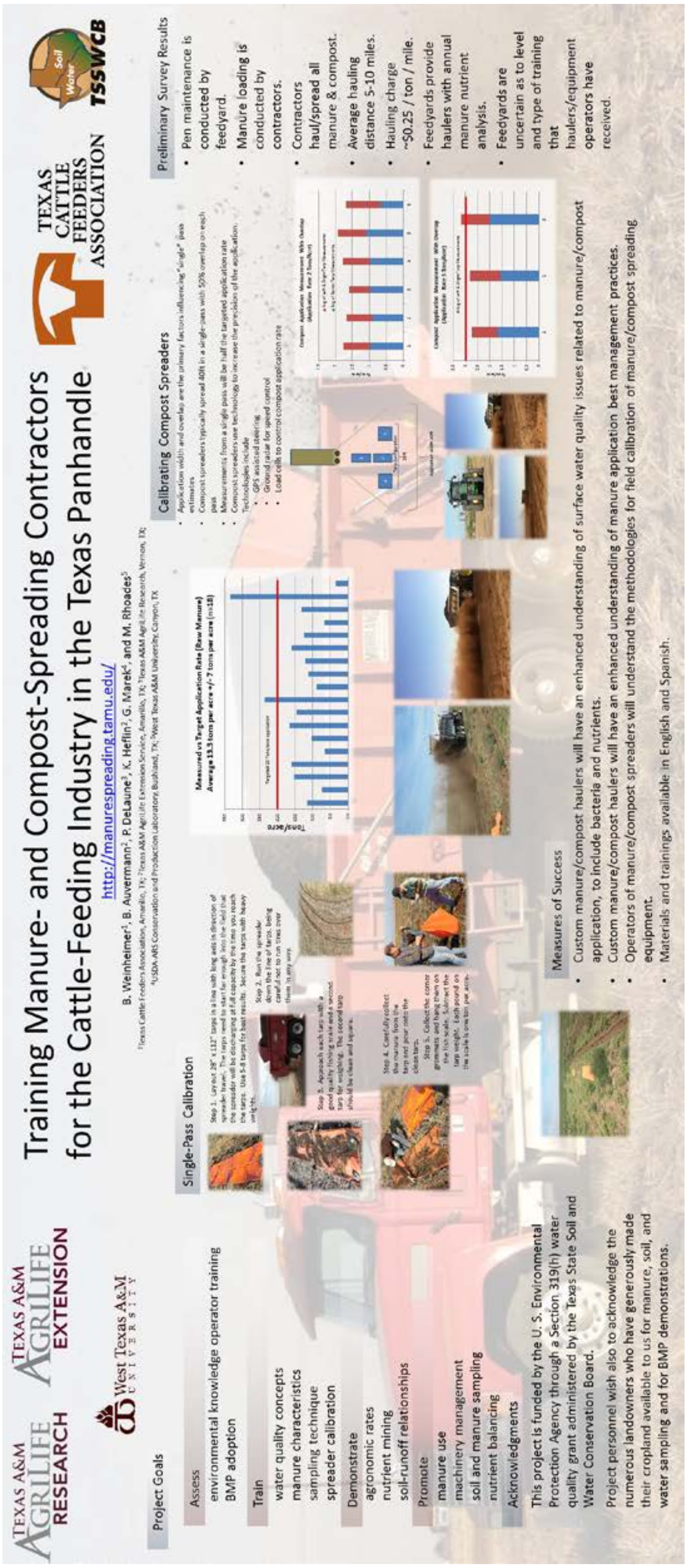
Para más información:

manurespreading.tamu.edu

Texas Cattle Feeders Association
5501 I-40 West
Amarillo, TX 79106
(806) 358-3681

Texas A&M AgriLife Extension Service
6500 Amarillo Blvd. West
Amarillo, TX 79106
(806) 677-5600

Poster – From Waste to Worth: "Spreading" Science and Solutions. Denver, CO 2013



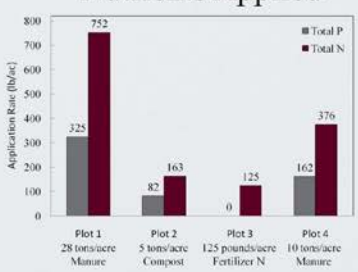
Posters used in educational seminars

Water Quality Demonstration

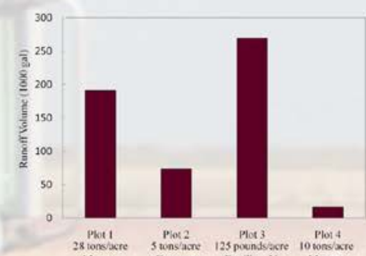
Deaf Smith County Plots

Plot 1 – 20 tons/acre Manure
Plot 2 – 5 tons/acre Compost
Plot 3 – 125 pounds/acre of Fertilizer N
Plot 4 – 10 tons/acre of Manure

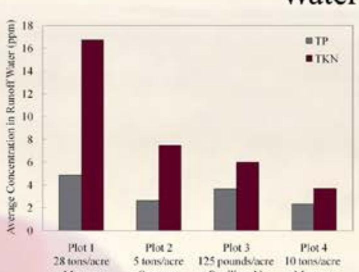
Nutrients Applied

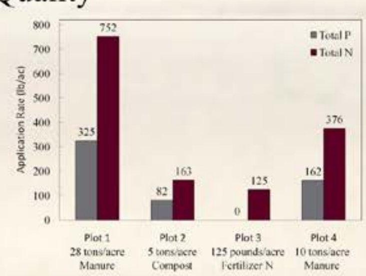


Measured Runoff



Water Quality





Whole-Truck Spreader Calibration

Weigh truck empty and full. Calculate net manure weight.

Load evenly and within truck load limitations.

Know your equipment well and keep it in good repair.

Spread manure evenly on a planned track.

Verify width and length of manure application swath.

Determine application rate (weight/area).

Multi-Pass Spreader Calibration

Distribute standardized tarps across manure spreader track.

Land apply at proper ground speed and discharge rate.

Gather the manure caught on the tarps for weighing.

One pound on a standard tarp equals one ton of manure per acre.

Account for overlap of manure spread on adjacent tracks.

Adjust ground speed, discharge rate, and/or centerline interval.

Situation

Transfer of feedyard manure to third parties is an important tool for balancing nutrient flows and achieving water quality goals.

Voluntary adoption of land-application BMPs helps to protect ground and surface water quality.

Audiences

Manure/Compost Contractors

Certified Crop Advisors and Nutrient Management Planners

Crop Producers

APPENDIX B: SURVEYS AND KNOWLEDGE ASSESSMENTS

During the spring of 2013, we conducted a series of seven regional, land-application workshops in Texas, two in South Texas (April) and five in the Panhandle/South Plains (May). Because the two in South Texas were not associated with the project watersheds, we did not attempt to measure the increase in environmental knowledge relevant to non-point source water quality. During the five May workshops, held in Perryton and Wheeler (5/14), Dalhart (5/15), and Hereford and Olton (5/16), we conducted brief demographic/operational surveys prior to the workshops and then pre-workshop and post-workshop tests focusing on the central ideas, regulations, and management practices for land application of solid feedyard manure. After the Perryton and Wheeler workshops on the first day of the series, we modified several of the test questions for the sake of clarity. All surveys and knowledge assessments were conducted using an anonymous, wireless, participant-response system known as TurningPoint^{TM}. To compute summary statistics for the knowledge assessments, non-responses were assigned a value of "incorrect." The survey and assessment results follow.

PARTICIPANT DEMOGRAPHICS AND OPERATIONAL SURVEYS

During the five May workshops in the Texas Panhandle and South Plains, we began each program with a series of survey questions intended to measure both the market penetration of the workshops and the operational and market trends affecting the flow of manure from feedyard to cropland and its pricing influences. Although we adjusted the questions we asked slightly in reaction to participant responses in the early workshops, fifteen of the questions we asked were common across all five workshops. The results are summarize below.

1. What is the ONE-TIME feedyard capacity represented by your company?
    a. 1-10,000 head
    b. 10-30,000 head
    c. 30-50,000 head
    d. More than 50,000 head
    e. I am not a cattle feeder OR question does not apply to me

Among participants directly involved in cattle feeding, most (>50%) represented feedyards with one-time capacities greater than 50,000 head, as shown in the chart below. With a total attendance around 90, an average of 1.5 attendees per facility, and the percentages shown in figure A-1, the workshops appear to have reached an aggregate, one-time feeding capacity of about 2 million cattle.

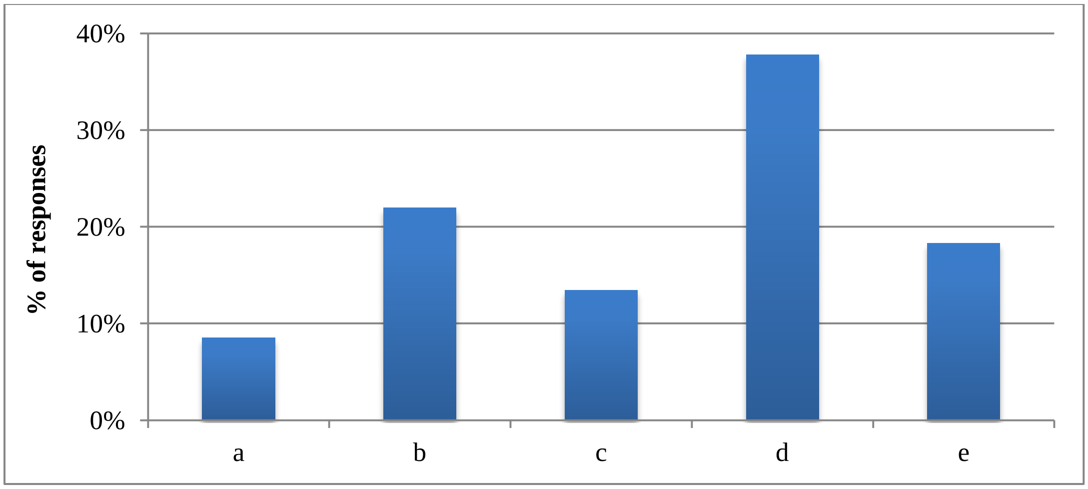


Figure A-1. Distribution of answers to survey question 1.

2. Who does the manure harvesting/removal at your feedyard(s)?
   a. In-house personnel and equipment
   b. Independent contractor handles both manure harvesting and removal
   c. Our holding company owns an affiliated company that handles these operations
   d. We collect the manure and load it into a contractor's manure trucks
   e. Does not apply/not a cattle feeder

Nearly all of the cattle feedyards represented at the workshops have outsourced one or more manure-harvesting and land-application operations. That indicates that the primary point of leverage for ensuring that manure from the cattle-feeding industry is land applied according to beneficial management practices and manure-quality considerations is *education of third-party manure haulers and contractors*. A secondary control point is feedyard personnel operating machinery within the pens.

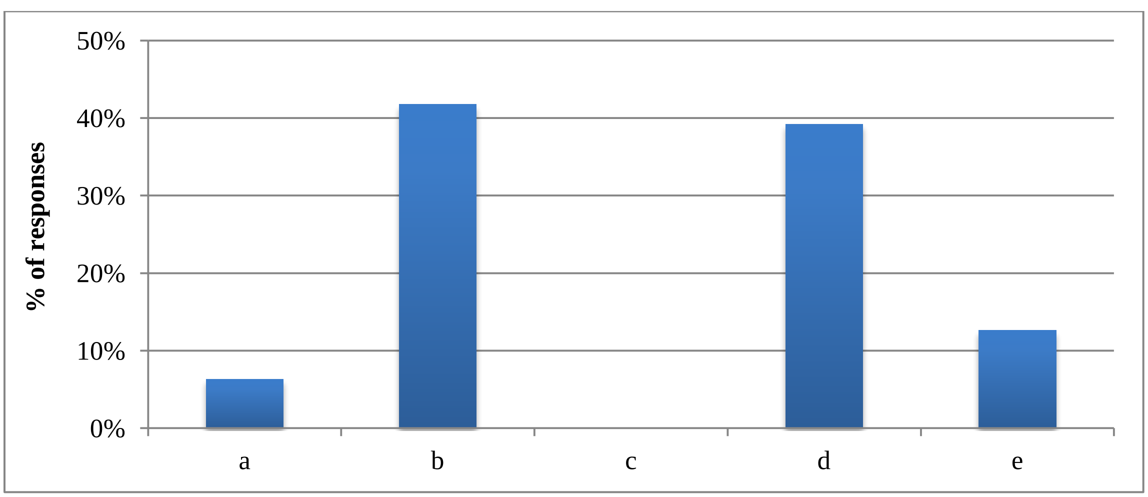


Figure A-2. Distribution of answers to survey question 2.

3. Where does MOST of the manure/compost from your feedyard go?
    a. Land owned or managed by the feedyard or feedyard holding company
    b. Independent farmers' farmland
    c. Some beneficial use other than land application
    d. Does not apply/not a cattle feeder

As expected, nearly all of the manure generated by participating feedyards is destined for off-site transfers to independent farmers. The net effect is to disperse nutrients over a wider area than would be the case if feedyards were restricted to land application on their own fields. Absent the off-site option, the cost of dispersing the nutrients at a level comparable to the current practices would have to rise as a result of feedyards being required to purchase additional cropland.

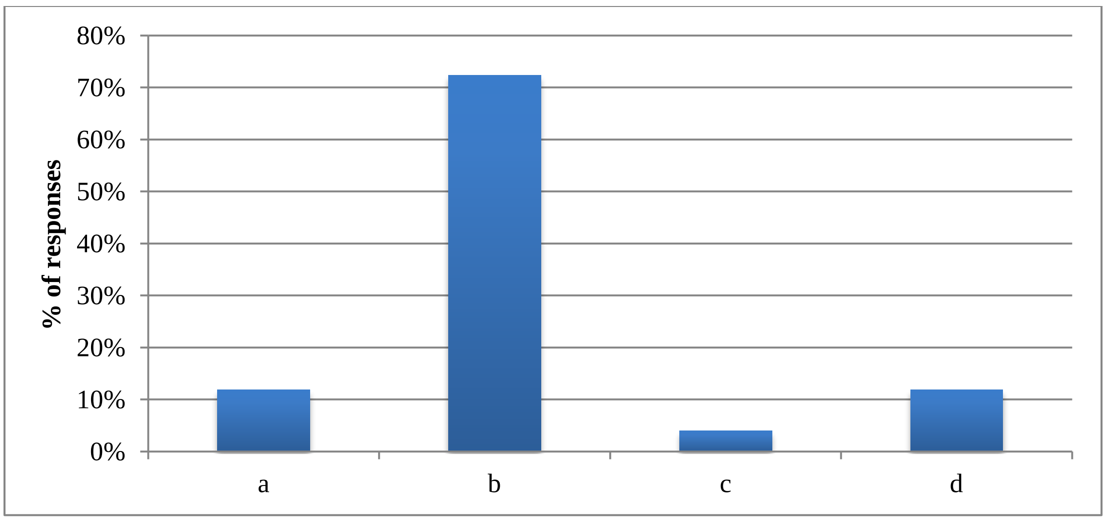


Figure A-3. Distribution of answers to survey question 3.

4. Estimate the AVERAGE or MOST FREQUENT hauling distance for the manure/compost from your feedyard OR from your composting facility.
    a. 0-1 miles
    b. 1-5 miles
    c. 5-10 miles
    d. >10 miles
    e. Does not apply/neither a cattle feeder nor a manure/compost contractor

The responses to question 4 describe what appears to be a favorable market for feedyard manure. The rule of thumb for the past 15-20 years has been that the break-even hauling distance for solid manure is on the order of 10 miles, but the data shown in the figure below suggest that nearly half of the manure that is moved off cattle feedyards in the Texas Panhandle goes to cropland more than 10 miles away. Sustaining and enhancing the dispersal of nutrients implied by off-site manure transfers should be a primary policy objective to protect surface water in the Texas Panhandle.

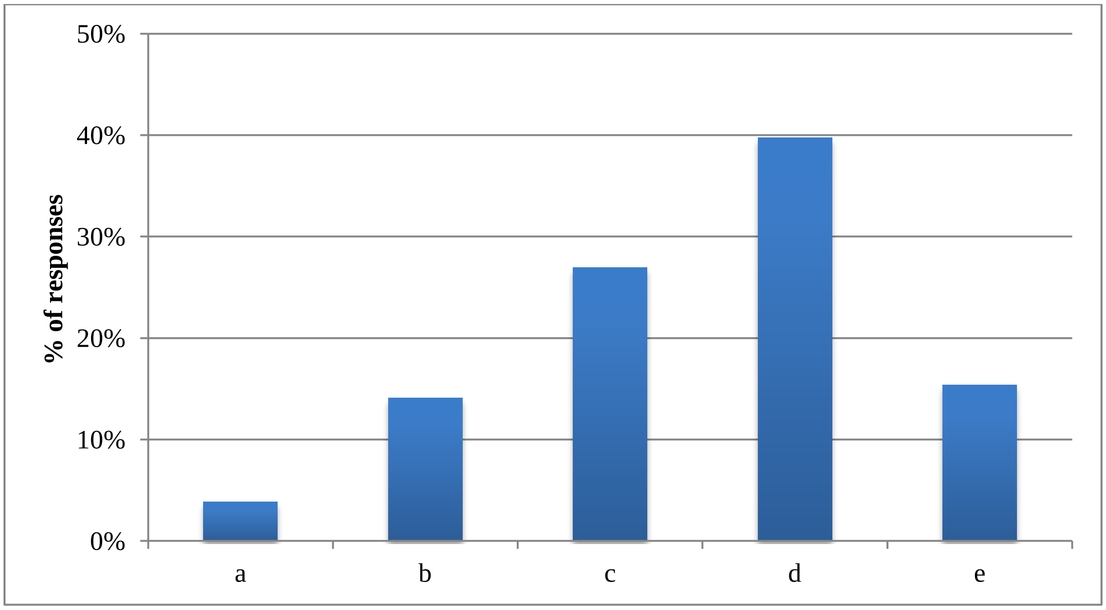


Figure A-4. Distribution of answers to survey question 4.

5. Is there a composting facility on your feedyard?
    a. Yes, and we compost both manure and mortalities
    b. Yes, and we compost only manure (with or without carbon amendments)
    c. No, we have no composting facility on our feedyard(s)
    d. Does not apply/not a cattle feeder

Between 40 and 50% of the cattle feeders represented in the workshop series are now involved in composting in some way, with a growing number adopting composting as a meta-disposal technique for premature mortalities. Given that composting generally results in significant ammonia losses to the atmosphere, the increasing prevalence of composting activities suggests that the cost of inorganic nitrogen fertilizer is still low enough that gaseous ammonia loss from manure is not a major concern to farmers. It is reasonable to suppose that manure functions primarily as a source of phosphorus for many of the farmers whose demand for manure products is responsible for the stability of today's manure market.

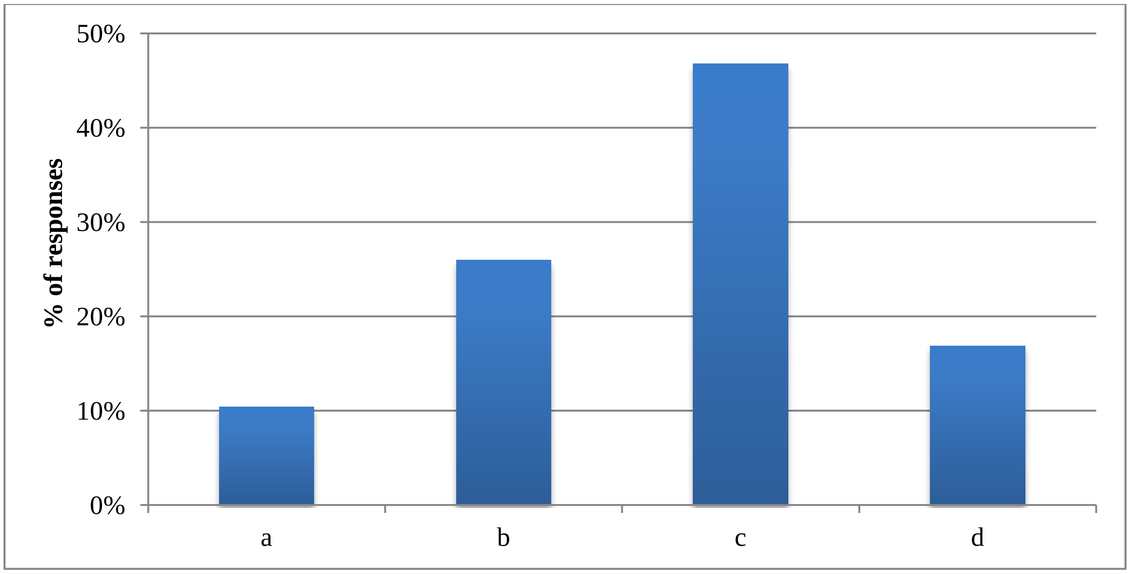


Figure A-5. Distribution of answers to survey question 5.

6. What is the manure COLLECTION/REMOVAL frequency at your feedyard?
   a. Three or more times per year
   b. When a pen of fat cattle is shipped, we harvest manure immediately
   c. Once per year
   d. Only when it's needed
   e. Does not apply/not a cattle feeder

At present, the average number of days a beef animal remains on feed until slaughter is on the order of 150-170, which means that a given pen of cattle will be shipped at least twice per year. As a result, answer (b) reflects a manure-harvesting frequency of at least twice per year. According to the survey data in the figure below, nearly 40% of cattle feedyards now harvest manure from the pen surfaces at least twice per year. As the industry-average frequency of manure harvesting increases, we can expect to see improving manure quality (nutrient density) and correspondingly higher prices for manure and manure products.

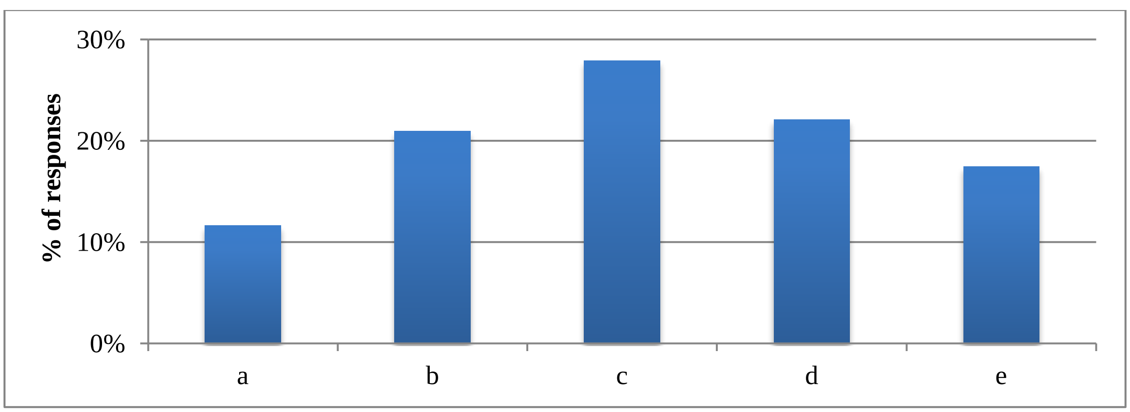


Figure A-6. Distribution of answers to survey question 6.

7. In what arrangement does your feedyard transfer manure to second parties, if applicable?
    a. Does not apply/not a cattle feeder
    b. We use all feedyard manure on our own land
    c. We give the manure away
    d. We pay others to take the manure
    e. We sell the manure
    f. Prefer not to say

According to the data in figure A-7, slightly more than 40% of participating cattle feeders are able to generate revenue from their off-site manure transfers. Clearly, there is still plenty of room for feedyards to market higher-quality manure to landowners who either have not used manure in the past or who have used it but have been discouraged with the results for a variety of reasons. We did not conduct a correlation analysis between these data and those from question 5 (composting), but it is possible that those who give away their manure or who pay others to take it (43% in the aggregate) are primarily those who arrange with composting contractors to handle their manure for them as a means of outsourcing the waste management function; it may also follow that those who are successfully generating direct revenue from their manure are selling it as freshly harvested, "green" manure.

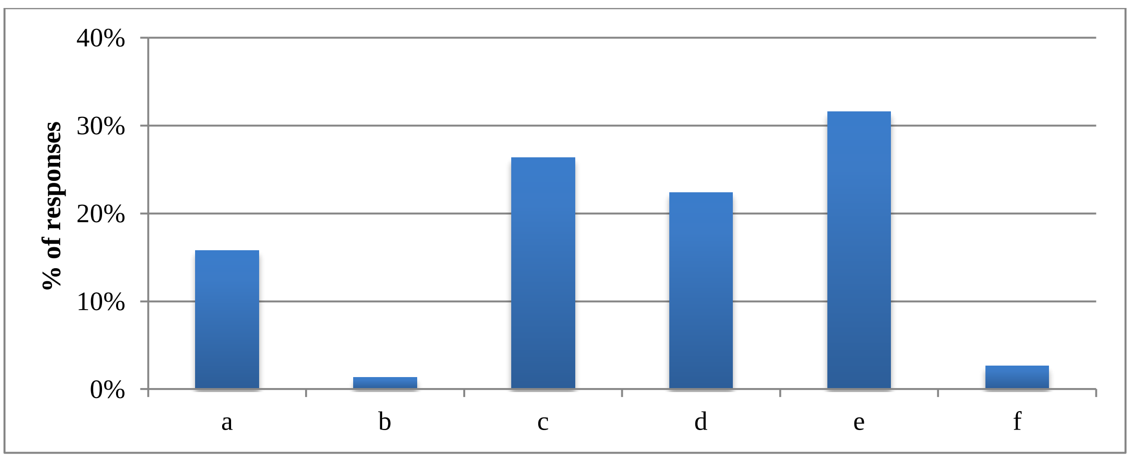


Figure A-7. Distribution of answers to survey question 7.

8. What is the AVERAGE or MOST FREQUENT price or subsidy for second-party customers?
    a. Does not apply/not a cattle feeder
    b. We do not engage in off-site manure transfers
    c. We receive more than $2 per ton
    d. We receive something, but less than $2 per ton
    e. We give our manure away
    f. We pay farmers up to $2 per ton to take it off our hands
    g. We pay farmers more than $2 per ton to take it

The responses documented below confirm that most (~70%) of the manure transfers in which money changes hands occur within the price range of -$2.00 to +$2.00. As in question 7, we find that there is still plenty of room for marketing higher quality, "green" manure for a higher price. It appears likely that, because of the machinery time and labor required to manufacture compost, the compost contractors that are able to remain in business have done so by capturing the demand for value-added manure products. The emergence of an active compost market appears, on balance, to have dramatically increased the off-site acreage available to cattle feeders to disperse manure nutrients.

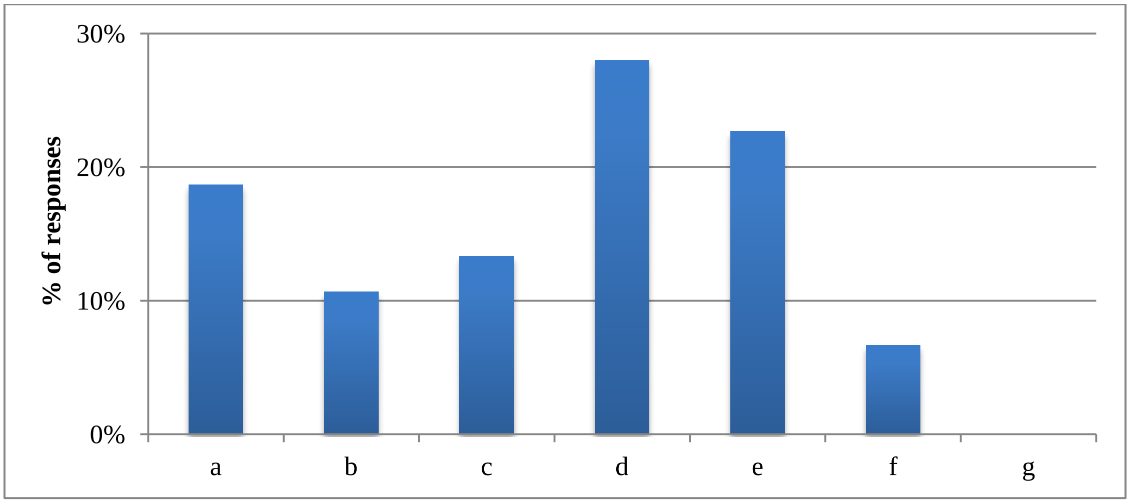


Figure A-8. Distribution of answers to survey question 8.

9. Does your feedyard or composting company provide a laboratory analysis of manure/compost that you transfer to off-site users?
    a. Does not apply/not a cattle feeder or manure contractor
    b. We do not transfer manure or compost to off-site users
    c. We provide a recent lab analysis as a standard feature of each transaction
    d. We provide lab analysis upon request
    e. We do not provide lab analysis to our customers; they're on their own

The manure market in the Texas Panhandle clearly does not require manure marketers to provide a laboratory analysis documenting the nutrient density of their products. In part, that may be attributable to an overall, modest increase in manure quality over the last two decades. Anecdotal evidence from conversations at our seven workshops, however, indicates that significant numbers of independent farmers are already persuaded that (a) "green" manure at less than $2/ton or (b) composted manure at market prices is the preferred way of managing soil fertility. That interpretation of these data is further bolstered by the responses to question 12, which confirm that repeat customers are the norm, not the exception.

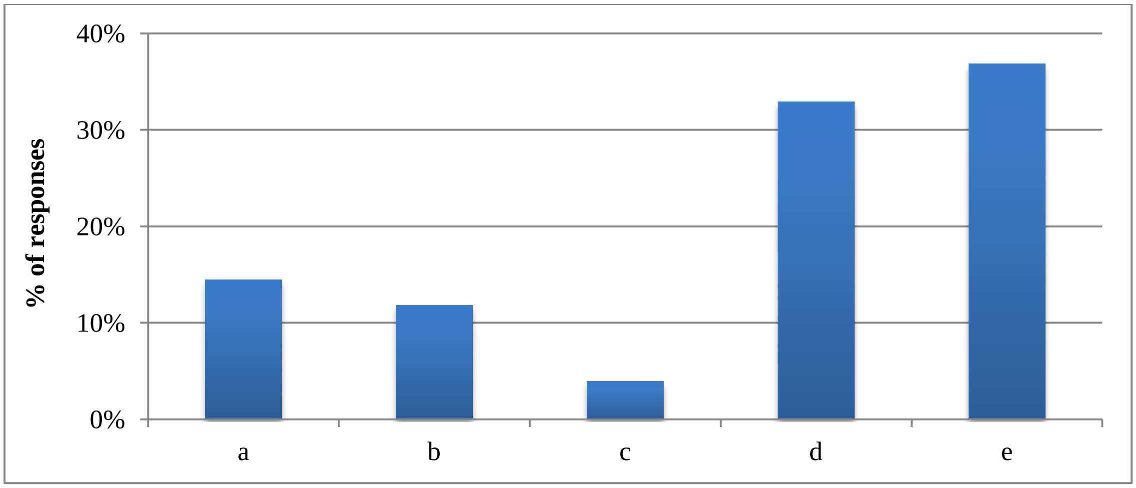


Figure A-9. Distribution of answers to survey question 9.

10. What machinery or combination of machinery is used to harvest manure from your feedyard's pen surfaces?
    a. Does not apply/not a cattle feeder
    b. Paddle scraper
    c. Front-end loader only
    d. Box scraper + front-end loader
    e. Maintainer (maybe plus box scraper) + front-end loader
    f. Other machinery or combinations

Ease of use, maneuverability, and versatility appear to be the watchwords that govern machinery selection for manure-harvesting operations. Although paddle scrapers are capable of moving huge volumes of manure quickly, they have a relatively large turning radius compared to the alternatives. Maintainers have a large turning radius as well, making both machines poorly suited for feedyards that feature a wide range of pen sizes and/or shapes. The precision depth-of-cut of which a maintainer is capable of is useful in preserving original grade, but because it does not actually harvest any manure (requiring auxiliary equipment for that operation), it and the paddle scraper remain niche machinery.

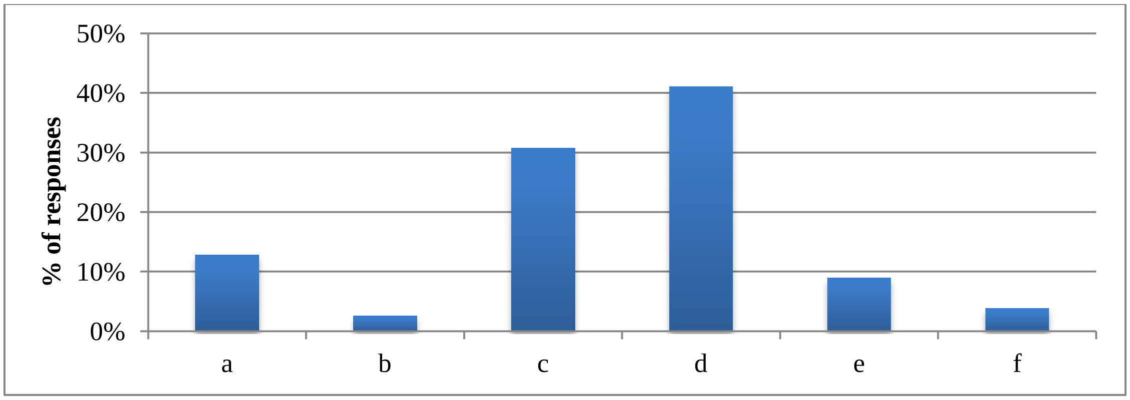


Figure A-10. Distribution of answers to survey question 10.

11. How are machinery operators trained, if at all, for manure-harvesting operations?
    a. Why would they need training for that?
    b. We train them only at hiring
    c. We train them recurrently as a standard management strategy
    d. Does not apply/not a cattle feeder
    e. Feedyard personnel are not involved, so does not apply

As reported by survey respondents, more than 75% of cattle feeders involved in manure-harvesting activities conduct recurrent training in machinery operations for their employees.

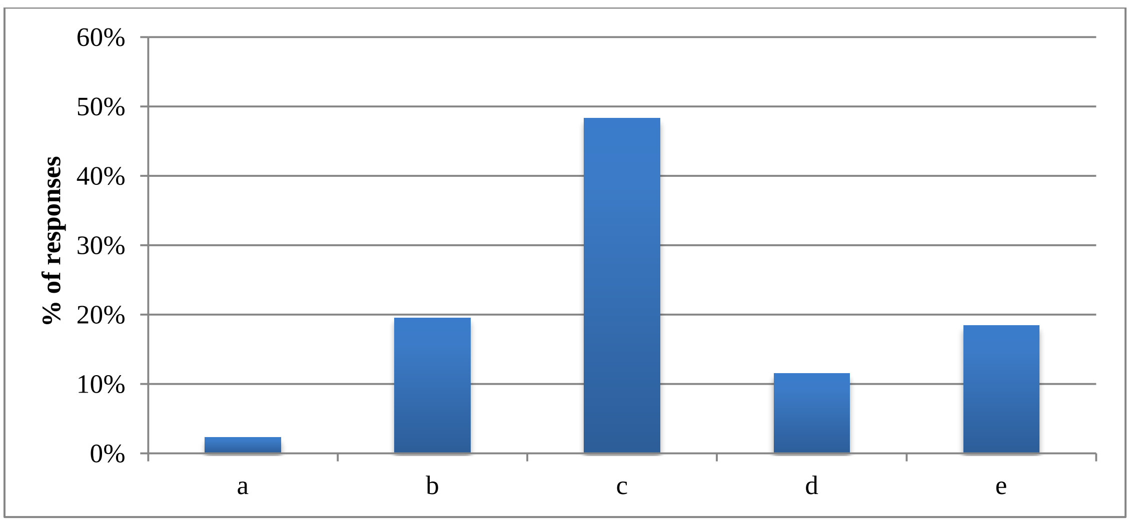


Figure A-11. Distribution of answers to survey question 11.

12. Does your feedyard/compost operation enjoy repeat customers/transferees?
    a. Yes, the same people come back just about every year/season
    b. No, we are always dealing with different transferees or users
    c. All of our manure goes to feedyard-controlled land
    d. Does not apply/not a cattle feeder or manure contractor

As observed previously (see questions 7-9), these survey data appear to confirm that manure's benefits as a soil amendment, whether for organic matter or nutrient density or both, are a settled matter for a significant number of independent farmers. Over time, as the cattle-feeding industry seeks to grow in the Texas Panhandle, preserving an adequate land base for manure application at agronomic rates will likely require concerted efforts to (a) improve industry-average manure quality and (b) market high-quality manure to new users.

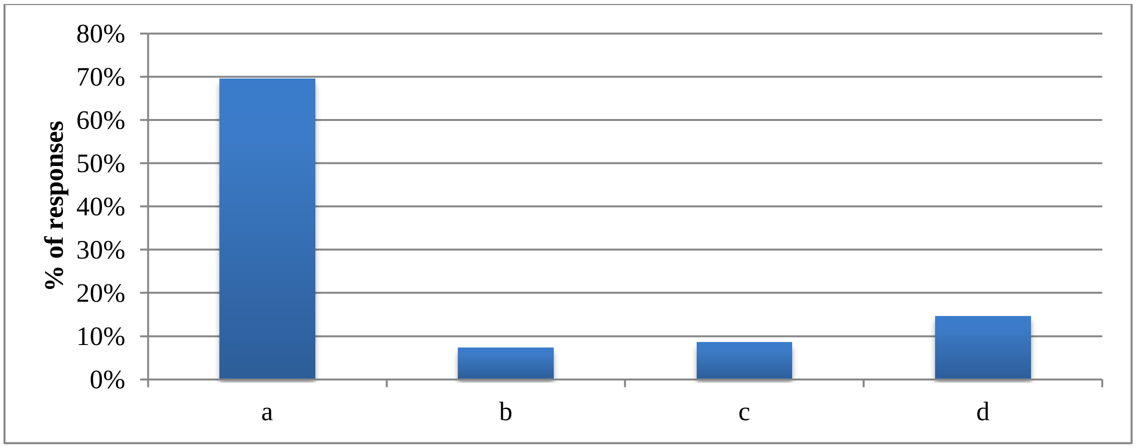


Figure A-12. Distribution of answers to survey question 12.

13. How would you characterize the supply/demand relationship for your feedyard manure or compost?
    a. We can't keep up with demand; more inquiries than we can fill
    b. We have a hard time finding takers
    c. Demand and supply are pretty balanced
    d. Does not apply/not a cattle feeder or manure contractor

The answers to question 13 further confirm the perception among cattle feeders and manure contractors that the current manure market is stable, although there remain pockets of both deficit and surplus supply. Improvements in manure quality and marketing are likely to affect the manure market on the margins (~17% of those engaging in off-site transfers) unless the number of cattle on feed grows substantially.

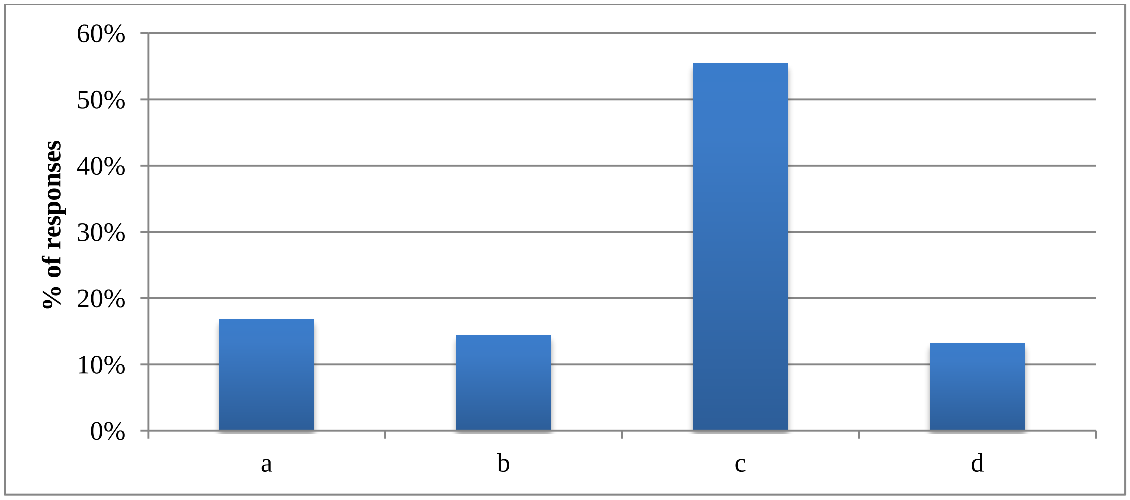


Figure A-13. Distribution of answers to survey question 13.

14. How frequently does your company calibrate your manure or compost spreaders?
    a. Not involved in land application operations; does not apply to us
    b. We calibrate our spreaders every year
    c. We calibrate our spreaders every few years
    d. Our machinery has on-board, real-time calibration technology
    e. We do not calibrate our spreaders

Because 85% of workshop participants were not involved in land application operations, the message of the responses to question 14 are obscured. Of participants actually engaged in land-application operations, 33% claim to calibrate their spreaders every year, and another 40% have on-board, real-time calibration technology. The latter group is almost certainly the compost contractors, whose margins are sufficient to underwrite the capital expense and whose product is of a texture most amenable to on-board, real-time calibration. The 17% of respondents who are involved in land application but who do not calibrate manure spreaders are, accordingly, likely to work only with chunky, raw manure of variable quality; the most accurate, precise technique for calibrating spreaders for that group is likely to be the whole-truck method, not the single-pass method.

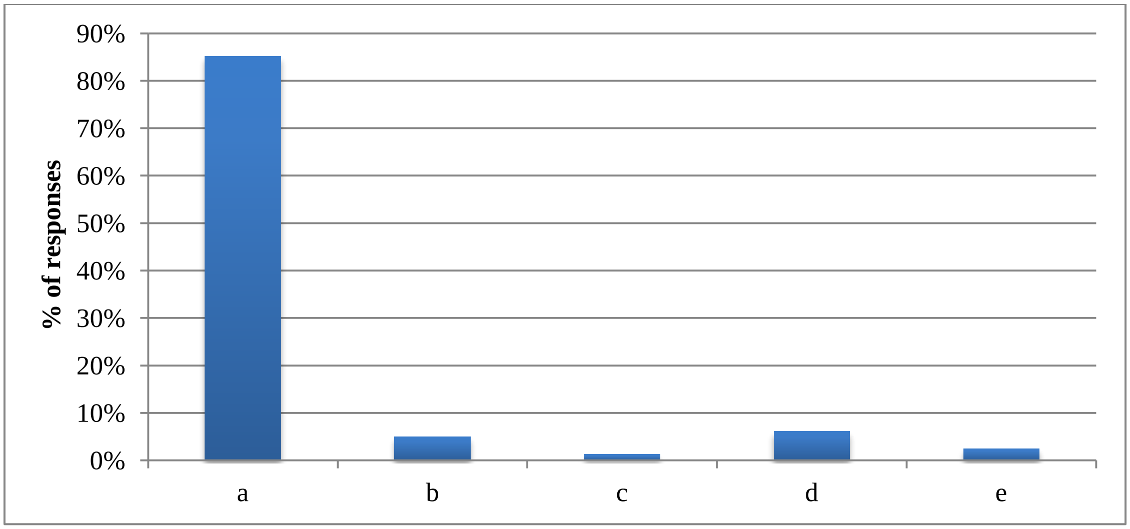


Figure A-14. Distribution of answers to survey question 14.

15. How do you decide what rate of manure or compost will be applied to a field?
    a. Not involved in land application or farming; does not apply
    b. Whatever we put out last year
    c. Crop advisor's or other expert's recommendation
    d. Soil and manure testing; phosphorus basis
    e. Soil and manure testing; nitrogen basis
    f. Other rationale (organic matter, gut feeling, etc.)

As with question 14, the number of respondents who are not involved with land application obscured the important information we can glean from question 15. Of the respondents who are involved with land application, over 40% rely exclusively on recommendations from a crop fertility specialist; the next greatest proportion of respondents (~30%) makes judgments on the basis of a crop's nitrogen and/or phosphorus requirements. Given the substantial variability we observed in spreader calibration data, especially for uncomposted ("green") manure, reliance on agronomic rate recommendations to achieve predetermined yield goals implies a need for "insurance" bias in those recommendations. Simply, to ensure that field-averaged crop yield meets the farmer's expectations and needs, the variability of manure application rates achievable even with calibrated manure spreaders may be overcome by (a) deliberate over-application of manure or, more desirably, (b) long-term farmer experience and record-keeping. Our survey data do not conclusively identify which of the two options is the dominant management approach by the farmers in the region, but the responses to question 12 suggest that long-term experience with manure may play the more important role in surface water protection vis-à-vis (a) land application strategies and (b) the preservation of off-site manure transfers as a key waste management tool for cattle feedyards.

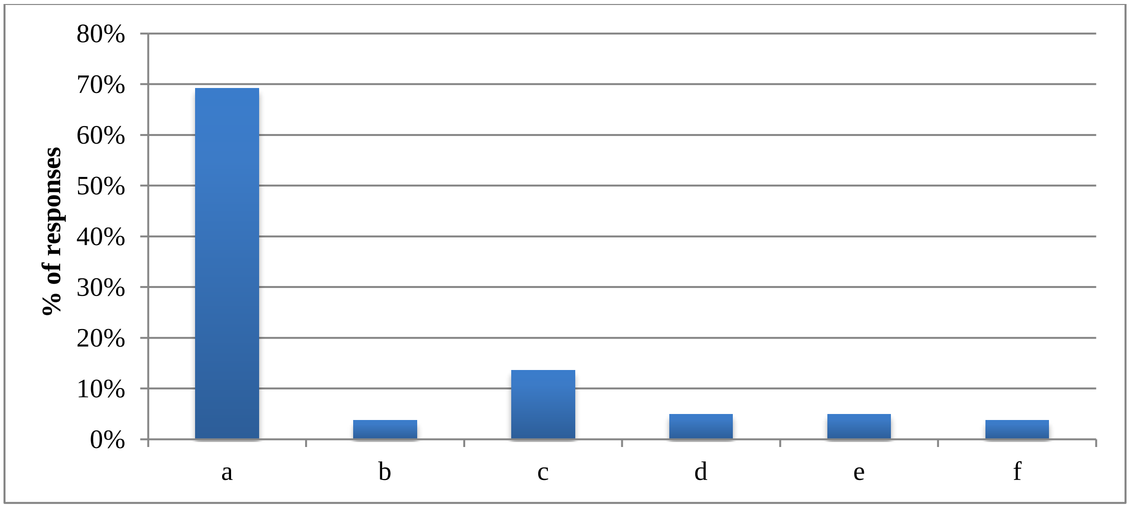


Figure A-15. Distribution of answers to survey question 15.

KNOWLEDGE ASSESSMENTS

PERRYTON-WHEELER

Only one individual attended our first regional workshop, in Perryton, on the morning of 14 May 2013. There are several large feedyards in the Perryton area; the reason for low attendance is unknown. We have therefore combined the Perryton data with the data from the Wheeler workshop that same day. In total, eleven individuals participated in our initial knowledge assessments. The questions asked were:

1. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application activities and an irrigation well?
    a. More than 100 feet (correct)
    b. Less than 100 feet
    c. More than 500 feet
2. (CONTROL) Ammonia loss from manure spreading can be reduced by:
    a. Increasing crude protein in cattle diets
    b. Aging the manure before spreading it
    c. Incorporating manure after it’s applied (correct)
    d. Irrigating pond effluent over the top
3. Which nutrients (N, P, K) are most likely to accumulate in or near the soil surface?
    a. Nitrogen (N)
    b. Phosphorus (P) (correct)
    c. Potassium (K)
    d. All three
    e. None of the three is more likely to accumulate in the soil surface

4. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application areas and a "bar" ditch?
   a. 100 feet or more (correct)
   b. Less than 100 feet
   c. 500 feet or more
5. If your objective is to maximize the fertilizer value of manure harvested from feedyard pen surfaces, which management strategy is most likely to achieve it?
   a. Collect as much material as possible from the pen surface
   b. Avoid using heavy machinery
   c. Cut only as deep as the manure/soil interface (correct)
   d. None of the above will maximize manure quality
6. What information is needed if you wish to calibrate a manure spreader using the "whole-field method?"
   a. Truck capacity, in tons
   b. Swath width, in feet
   c. Tons in stockpile at the edge of the field
   d. Field area, in acres
   e. Both A and B
   f. Both C and D (correct)
   g. A, B, C, and D
7. What information is needed if you wish to calibrate a manure spreader using the "whole-truck method?"
   a. Spreader capacity, in tons
   b. Width of spreader pattern, in feet
   c. Field area, in acres
   d. Swath length, in feet
   e. Distance between the centerlines of adjacent passes, in feet
   f. A, B, and D
   g. A, D, and E (correct)
8. What information is needed if you wish to calibrate a manure spreader using the "single-pass method?" The mass of manure collected in:
   a. One centerline tarp, sized so that each pound collected represents 1 T/ac
   b. Centerline tarps (averaged) plus offset tarps (averaged)
   c. Two centerline tarps
   d. Centerline tarps and offset tarps: add them all up

Question 2 pertained to technical material not ultimately covered in our workshops and was interpreted *post hoc* as a negative control. As such, we expected that the apparent knowledge of the correct answer would either remain constant as a result of the workshop (indicating no net increase in knowledge) or would decrease (indicating that some participants may have simply assumed their pre-workshop answers were incorrect). The following column chart shows the percentages of correct responses to each of the eight questions.

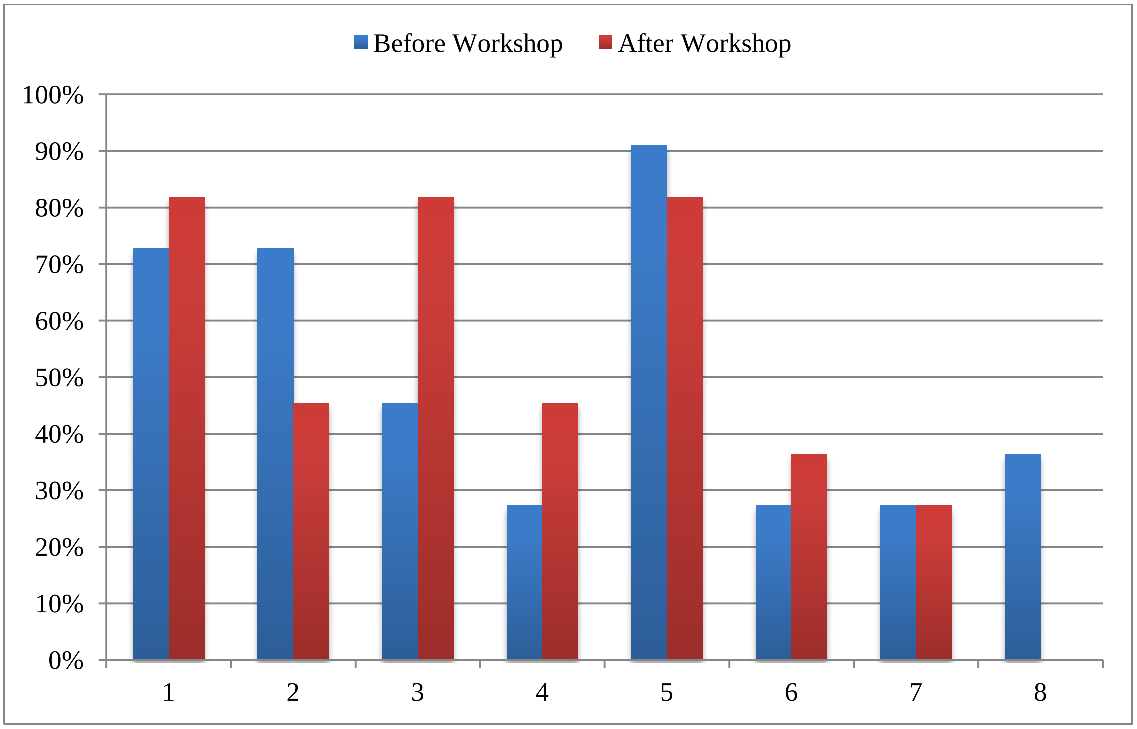


Figure A-16. Summary results (% of participants giving the correct answer) of pre- and post-workshop knowledge assessments in the Perryton and Wheeler, TX, workshops on 14 May 2013.

The disappointing results from questions 7 and 8 (important questions about measurements required for different spreader-calibration methods) indicated that we had formulated the questions and answers in a confusing or overly cumbersome way given the pace of the assessments, so we re-formulated those questions and answers for the subsequent workshops. As we reflected on question 8, however, it became apparent that our repeated field evaluations of the single-pass calibration method had generated conclusive results in only two generic respects:

- The *precision* (repeatability) of the single-pass method is consistently better for composted manures, which have a relatively high textural uniformity, than for raw, stockpiled, or "green" manures, which tend to generate chunks and aggregates of widely varying size; and

- The *accuracy* of the single-pass method is subject to an important methodological bias that is directly traceable to the variations in optimum centerline spacing across the range of spreader machines currently in use.

Further evaluations of the single-pass method are certainly warranted, but at this point in our workshop series, we elected to delete question 8 for subsequent workshops, at least until greater clarity is achieved on how the single-pass method ought to be conducted (for the sake of *accuracy*) and how many repetitions are required to reach a stable, central tendency in the calibration results. As expected, the answers to the control question (question 2) did not indicate an increase in knowledge as a result of the workshops.

DALHART

Sixteen individuals participated in the Dalhart workshop on the afternoon of 15 May 2013. The questions posed in the Dalhart assessments were:

1. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application activities and an irrigation well?
    a. More than 100 feet (correct)
    b. Less than 100 feet
    c. More than 500 feet
2. (CONTROL) Ammonia loss from manure spreading can be reduced by:
    a. Increasing crude protein in cattle diets
    b. Aging the manure before spreading it
    c. Incorporating manure after it’s applied (correct)
    d. Irrigating pond effluent over the top
3. Which nutrients (N, P, K) are most likely to accumulate in or near the soil surface?
    a. Nitrogen (N)
    b. Phosphorus (P) (correct)
    c. Potassium (K)
    d. All three
    e. None of the three is more likely to accumulate in the soil surface
4. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application areas and a "bar" ditch?
    a. 100 feet or more (correct)
    b. Less than 100 feet
    c. 500 feet or more
5. If your objective is to maximize the fertilizer value of manure harvested from feedyard pen surfaces, which management strategy is most likely to achieve it?
    a. Collect as much material as possible from the pen surface
    b. Avoid using heavy machinery
    c. Cut only as deep as the manure/soil interface (correct)
    d. None of the above will maximize manure quality
6. If you wish to calibrate a manure spreader using the "whole-field method," which information is NOT needed?
    a. Width of the spreader pattern, in feet (correct)
    b. Tons of manure stockpiled at the edge of the field
    c. Field area, in acres
7. If you wish to calibrate a manure spreader using the "whole-truck method," which information is NOT needed?

a. Spreader capacity, in tons
b. Width of spreader pattern, in feet (correct)
c. Distance driven to empty the spreader, in feet
d. Distance between the centerlines of adjacent passes, in feet

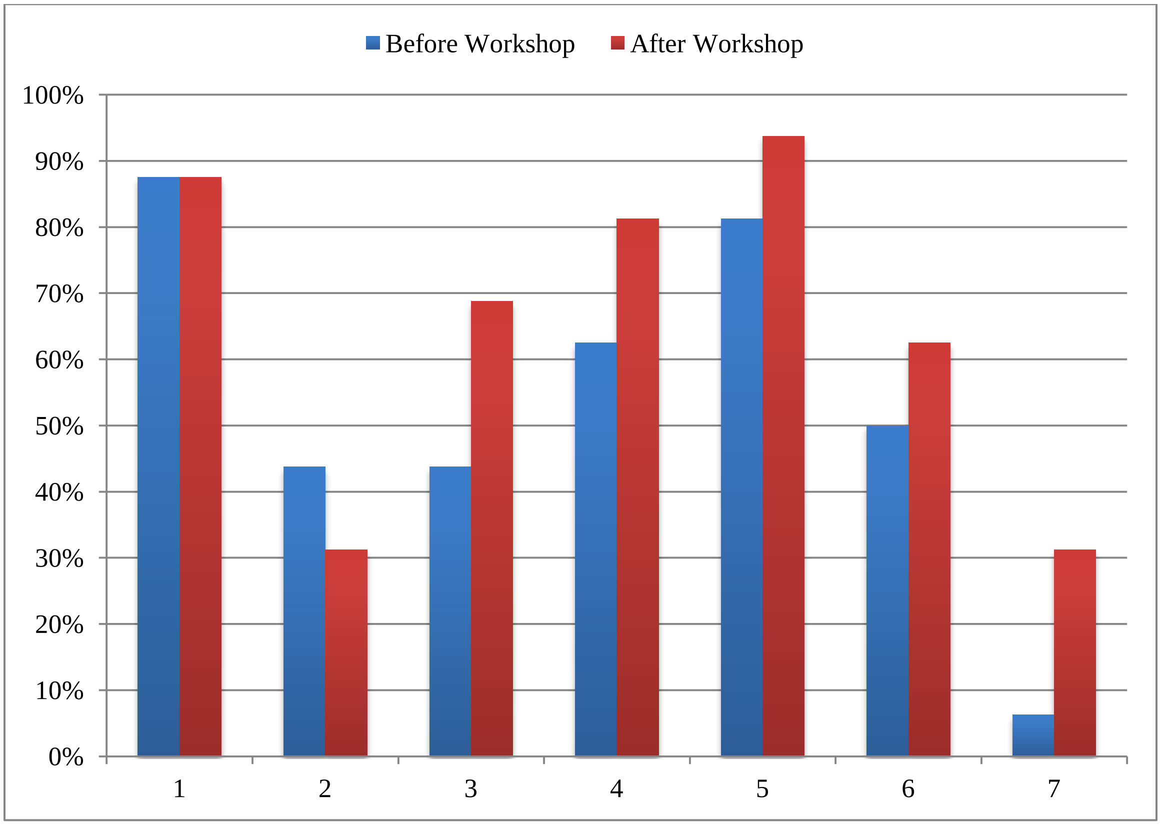


Figure A-17. Summary results (% of participants giving the correct answer) of pre- and post-workshop knowledge assessments in the Dalhart, TX, workshop on 15 May 2013.

Cattle feeders and manure/compost contractors representing the Dalhart area appeared to have considerable prior knowledge of setback distances from irrigation wells (88%; 14 of 14 respondents answered correctly). Excluding that question and the control question, participants' knowledge of the key ideas increased across the board, indicating both that the workshop was achieving its educational objective and that the newly formulated questions about calibration equipment were clearer than the corresponding questions from the Perryton/Wheeler assessments. Overall understanding of the relevant material increased among Dalhart participants by an average of about 20% (54% before the workshop, 65% afterwards).

HEREFORD

Fifty-six individuals attended the Hereford workshop on the morning of 16 May 2013, the largest audience of the workshop series. These participants also represented the highest concentrations of (a) fed cattle, (b) fed cattle in proximity to irrigated cropland, and (c) manure/compost contractors among all five Panhandle/South Plains workshops.

The questions asked of the Hereford participants were:

1. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application activities and an irrigation well?
   a. More than 100 feet (correct)
   b. Less than 100 feet
   c. More than 500 feet
2. (CONTROL) Ammonia loss from manure spreading can be reduced by:
   a. Increasing crude protein in cattle diets
   b. Aging the manure before spreading it
   c. Incorporating manure after it's applied (correct)
   d. Irrigating pond effluent over the top
3. Which nutrients (N, P, K) are most likely to accumulate in or near the soil surface?
   a. Nitrogen (N)
   b. Phosphorus (P) (correct)
   c. Potassium (K)
   d. All three
   e. None of the three is more likely to accumulate in the soil surface
4. According to Texas rules (30 TAC 321 Subchapter B), what is the minimum buffer distance between land-application areas and a "bar" ditch?
   a. 100 feet or more (correct)
   b. Less than 100 feet
   c. 500 feet or more
5. If your objective is to maximize the fertilizer value of manure harvested from feedyard pen surfaces, which management strategy is most likely to achieve it?
   a. Collect as much material as possible from the pen surface
   b. Avoid using heavy machinery
   c. Cut only as deep as the manure/soil interface (correct)
   d. None of the above will maximize manure quality
6. If you wish to calibrate a manure spreader using the "whole-field method," which information is NOT needed?
   a. Width of the spreader pattern, in feet (correct)
   b. Tons of manure stockpiled at the edge of the field

c. Field area, in acres

7. If you wish to calibrate a manure spreader using the "whole-truck method," which information is NOT needed?
   a. Spreader capacity, in tons
   b. Width of spreader pattern, in feet (correct)
   c. Distance driven to empty the spreader, in feet
   d. Distance between the centerlines of adjacent passes, in feet

Figure A-18 represents the apparent educational effectiveness of the Hereford workshop with respect to the key ideas. Hereford cattle feeders and manure contractors appeared to have an excellent handle on maximizing manure quality for farmer-clients (question 5), which is consistent with the historically active manure market and excess demand for manure along U. S. Highways 60 and 385 corridors.

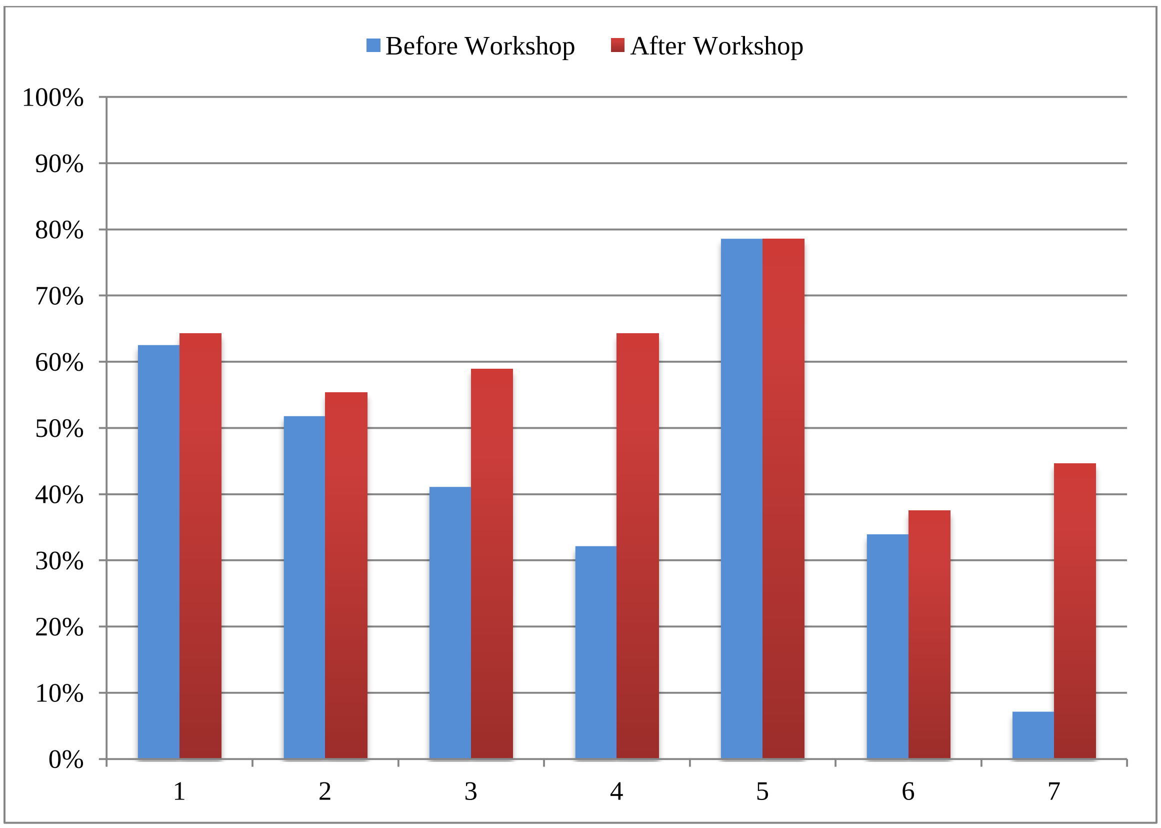


Figure A-18. Summary results (% of participants giving the correct answer) of pre- and post-workshop knowledge assessments in the Hereford, TX, workshop on the morning of 16 May 2013.

Excluding the control (question 2), the apparent overall understanding of key ideas increased as a result of the Hereford workshop by about 30% (44% correct pre-workshop; 58% afterwards).

OLTON

Wrapping up the seven-workshop series across the state, eighteen cattle feeders and manure/compost contractors participated in the Olton workshop on the afternoon of 16 May 2013. After returning to Amarillo, we discovered that the TurningPoint^{TM} data-collection system had malfunctioned for the last two of the seven questions during the pre-workshop assessment, so we were unable to compute summary statistics for those two questions. The seven questions asked at the Olton workshop were the same as those asked in Hereford (see above). Figure A-19 represents the apparent increase in knowledge of key ideas among the Olton participants (excluding questions 6 and 7 due to system malfunction).

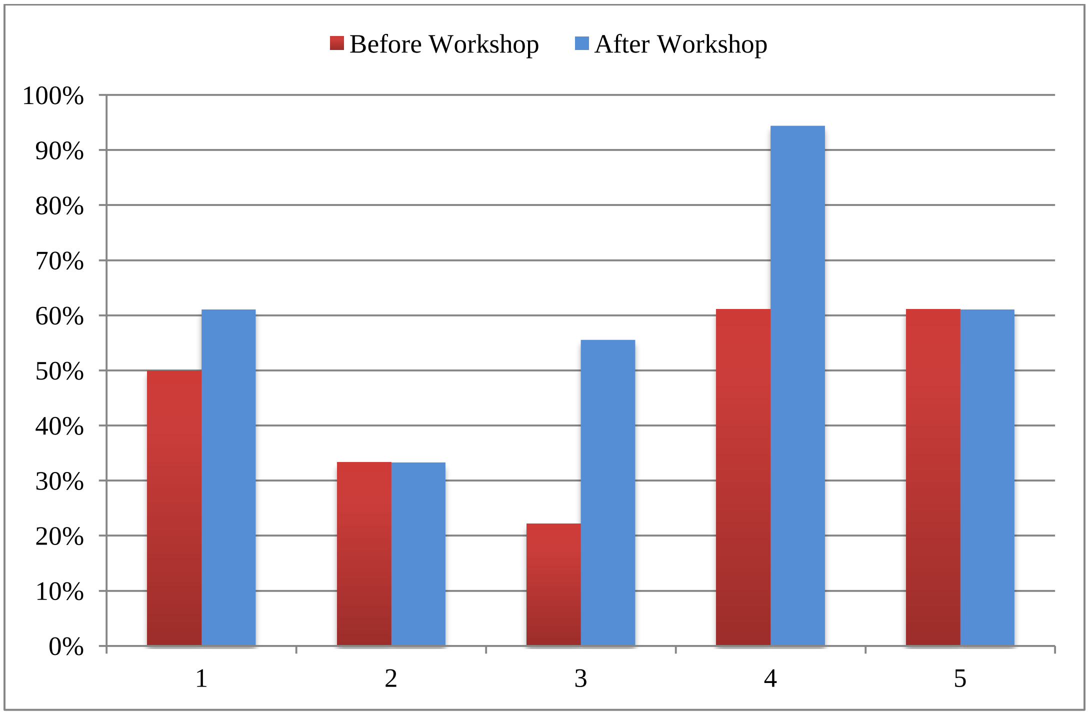


Figure A-19. Summary results (% of participants giving the correct answer) of pre- and post-workshop knowledge assessments in the Olton, TX, workshop on the afternoon of 16 May 2013.

Similar to previous workshops, understanding of key ideas (excluding the control) increased virtually across the board, with ~30% increase in assessment scores (46% correct before, 61% correct afterwards) attributable to the Olton workshop.

SUMMARY – KNOWLEDGE ASSESSMENTS

The five workshops in and hydrologically adjacent to the project watersheds appeared to achieve our educational objectives, with an overall increase of 20% in assessment scores on the five common questions (54% correct prior to the workshops, 65% correct afterwards). The TurningPoint™ audience-response system is a helpful assessment tool but requires thoughtful formulation of the questions and answers because of the rapid pace at which participants are expected to read and respond to what is shown on the screen. Control questions, the material for which was highly technical but was not covered at all within the workshops, elicited the expected net changes in the aggregate scores (neutral to decrease) as a consequence of the workshops. County-level and small-regional workshops are still an effective educational tool in relation to surface water quality learning objectives, but a greater degree of clientele engagement will be needed as environmental regulatory requirements intensify and as they address technical matters of increasing subtlety.