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2002 Achievement Award Recipient
Soil Science Society of North Carolina

During his entire professional career, Dr. Milton Ray Tucker has been a faithful and dedicated employee of the Agronomic Division of the N.C. Department of Agriculture and Consumer Services (NCDA&CS). He has made numerous contributions to North Carolina agriculture and to soil testing around the world. He has been a member of the Soil Science Society of North Carolina for about 25 years and a friend to everyone in the agricultural community across our state.

Dr. Tucker was hired in 1973 to set up and manage the Agronomic Division's new plant tissue analysis laboratory. He established a firm foundation for the plant nutrition program, which has grown to provide thousands of analyses and serve hundreds of farmers each year. This vital agronomic service is now widely recognized as a critical tool for enhancing nutrient management and environmental quality, especially in our agricultural communities.

In 1984, Dr. Tucker was appointed head of the Agronomic Division's soil testing section. He conducted field research and calibration studies for developing specific fertilizer and lime recommendations for many North Carolina crops. In 1994, he coordinated major operations and installation of new instruments during the relocation of the NCDA&CS soil laboratory to its new building.

As a result of Tucker's outstanding leadership, the NCDA&CS soil testing lab has become extremely productive and achieved international stature. The lab has analyzed approximately four million soil samples during his tenure. In fiscal year 2000–2001 alone, the laboratory processed 322,000 samples.

Tucker is a national authority on improved soil test methodologies, and his advice and counsel are frequently sought and highly respected around the world. He has hosted more than 100 foreign visitors to the Agronomic Division. In addition, he has worked closely with university researchers, regulatory agencies and colleagues at public and private laboratories across the country to improve crop production efficiency, increase agricultural profitability and protect our natural resources.

Over the years, Dr. Tucker has served the SSSNC on various committees, including the Executive Committee in 1986–87. He has written dozens of technical articles and publications; made hundreds of presentations at local, state, regional, national and international meetings; and conducted training for thousands of farmers, gardeners, fertilizer dealers, extension agents, agricultural consultants, field inspectors, and homeowners. Along the way, he has answered innumerable phone calls from these same clientele.

Dr. Ray Tucker has provided a lifetime of exemplary service in soil science for the benefit of all the citizens of North Carolina and beyond. He truly deserves to receive the N.C. Soil Science Society Achievement Award. Congratulations to Dr. Tucker for an outstanding career.

Remote Sensing in Soil Science and Agriculture

By Jeffrey White

Remote sensing, i.e., the acquisition of data without contact, can be used to characterize soils in numerous ways for a variety of purposes. All remote sensing is based on the detection and recording of energy from various portions of the electromagnetic spectrum. This energy is interpreted using an iterative process which usually includes verification known as “ground truthing.”

Aerial black and white photography is generally recognized as the first remote sensing technology and has been used extensively for soil mapping, usually via “interpretation by proxy.” Color-infrared photography is especially useful in classifying and delineating natural vegetation and crops. It has proven useful in detecting soil-related problems with plant growth, such as nutrient deficiencies, toxicities, diseases, and moisture stress.

Multispectral sensors aboard satellites provide similar capabilities, although usually at lower resolution. Hyperspectral sensors, which provide information in ten or more portions of the electromagnetic spectrum, provide advanced capabilities useful in classifying surficial soil properties and vegetation. Ground penetrating radar (GPR) can provide valuable information about soil stratigraphy and hydrology. Electromagnetic induction measurement of soil electrical conductivity responds to factors such as soil texture, organic matter, cation exchange capacity, and porosity. Light detection and ranging (LIDAR) from aerial and space platforms is being used for detailed intensive aerial topographic mapping. Passive microwave radiometry is useful in quantifying surficial soil moisture content.

The spatial and spectral resolution of remote sensing devices is improving rapidly, as are automated techniques for processing and analyzing massive amounts of remote sensing data. New aircraft, satellites and other remote sensing platforms are being launched and flown by the government and private sector. Research and development applying remote sensing to soil characterization, natural resource management, and agriculture are expanding rapidly, and the future of remote sensing in soil science is bright!

Jeffrey White, Assistant Professor, NCSU Soil Science Dept., Raleigh, NC

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Update on Digital Soil Survey – SSURGO

By Dan Good

Abstract

Accuracy and precision represent two unique concepts in the realm of digital mapping. Accuracy relates to the quality of data collection—the degree of difference in the position of a map feature from its true position on the ground. Precision, on the other hand, relates to a statistical measure of repeatability, usually expressed as an acceptable variance from the true position of a map feature.

As the advance in technology pervades the way we live and work, the need for contemporary products to support the capabilities of technology has increased. In the past, the culmination of a detailed soil survey project has been the release of a soil survey publication. Today, a myriad of products are produced, each with a specific audience and filling a specific need in society. The challenge we face is in producing products that consistently produce accurate representations of the information collected, with some assurance to end users that any specific product is developed with an acceptable level of precision as it relates to its source.

What is SSURGO?

SSURGO is a set of standards for the digital representation of a detailed soil survey. It consists of both spatial and database components released in a specified format. It does not necessarily represent a complete digital reproduction of a published soil survey; however, its scope and level of detail are intended to serve the same purpose.

Spatially, it consists of a county coverage that is contiguous with adjoining counties. Areas where there have been overlaps or gaps in field mapping are resolved and updated. Errors in the compilation and map finishing are identified and corrected. Occasionally, recompilation to standardized scales of 1:12000 and 1:24000 to coincide with USGS 7.5-minute quadrangles and quarter quadrangles occurs. In addition, some soil surveys were originally published on unrectified photography, and this needed to be transferred to orthoimagery to facilitate accurate georeferencing.

The database consists of 26 text files that include the interpretations for each of the map units in the survey area. These data are tab delimited and include a unique map-unit ID that allows users to evaluate unique one-to-many relationships between the interpretive tables. As interpretations for specific map units have been refined over the years, SSURGO represents state-of-the-art information about map units and does not strictly adhere to that information published in the original document.

SSURGO data are released in decimal-degrees projection in a datum that matches the source material. If the source material was NAD27, a reprojected version in NAD83 is also provided. Spatial data include map-unit data (polygons) as well as special features (both point and linear). The formats it is released in are as follows:

- 7.5-minute, quadrangle-based, digital line graphs (DLG2-optional with major and minor code pairs),
- an ArcInfo workspace that includes a county coverage as well as 7.5-minute quadrangle coverages,
- an ArcInfo interchange file (or export file) of the same information.

SSURGO Availability in North Carolina

Currently there are 31 counties that have been certified and are available for distribution. This

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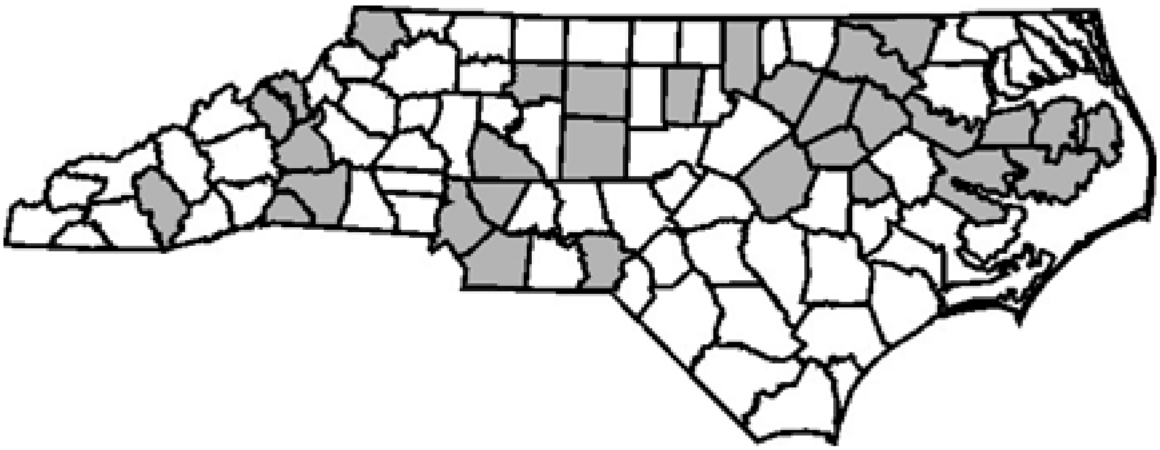
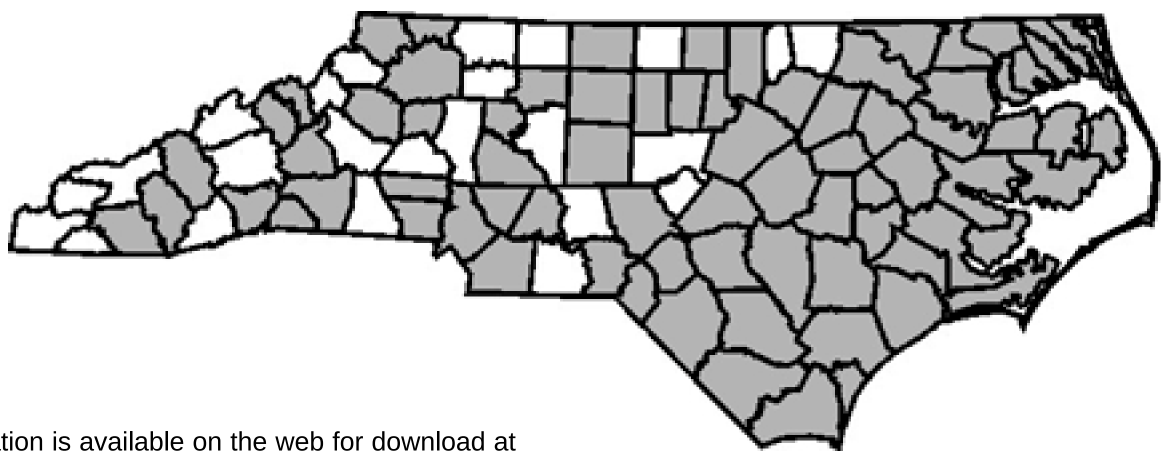
Digital Soil Survey Products Available
SSURGO Certified
January 2002



Digital Soil Survey Products Available
All Sources
January 2002



information is available on the web for download at the following address:

http://www.ftw.nrcs.usda.gov/ssur_data.html.

Those counties in dark shade are available as SSURGO certified.

Digital soil surveys are also available from other sources and are available from the North Carolina Center for Geographic Information and Analysis, 301 N Wilmington Street, Suite 700, Raleigh, NC 27601-2825, or call (919) 733-2090.

It is important to note that new GIS information is constantly being produced and updated. Existing releases of digital data may become obsolete and replaced with updated information. You can obtain the latest information on the status of digital soil surveys at: http://www.nc.nrcs.usda.gov/ResConditions&Trends/soilsurvey.htm.

SSURGO products are data and are not stand-alone entities. Geographic Information System (GIS) software or some comparable viewer is needed to be able to use these data. In addition, these data represent polygon line and point data for soils features and do not include other data, such as aerial photography, roads or streams as typically found in soil survey publications.

Using Geographic Information Systems to Address Nonpoint Pollution in the Pigeon River Watershed, Haywood County, N.C.

By Ron Moser

Watershed associations often have difficulty planning, prioritizing and funding projects to address sources of nonpoint pollution. This is particularly true when dealing with watersheds that are hundreds of thousands of acres in size. The Haywood Waterways Association, Inc., (HWA) addressed this issue through the use of the Tennessee Valley Authority's Integrated Pollutant Source Identification (IPSI) model.

Using color infrared leaf-off photography, a team of skilled photo interpreters, ground truthing, and local Universal Soil Loss Equation parameters, a geographic information systems (GIS) database was developed within ArcView to identify and quantify nonpoint pollution sources in the Pigeon River Watershed. As a result of this work, the sources of nonpoint pollution in the Pigeon River Watershed have been mapped and quantified. Relative significance of the various sources has been identified and charted.

Limitations inherent in the interpreted data have been recognized. This information has been a key component of a watershed action plan, successful grant applications, and public information and education forums. The equipment and training required to use this GIS data have changed the way conservation work is accomplished within Haywood County.

Other themes have been added to the initial data—property record information, soils data, global positioning system (GPS) data, and orthophotos—to expand the usefulness of the data. Other planning efforts within the County make use of this information.

Small watershed analysis starts with this GIS information. The Haywood Soil and Water Conservation District uses GIS and GPS to map and analyze conservation plan information. HWA newsletters, brochures, and presentations are developed within this digital environment. The demonstrated success of the use of this technology has enhanced public interest and support for watershed protection efforts.

Ron Moser, Director, Haywood Waterways Association, Inc., Waynesville, NC

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Case Studies—Precision Technologies in Environmental Health: Orange County

By Alan Clapp

History

Orange County started using GPS and GIS data in 1996 as part of a departmental cooperation among Planning, Land Records, Tax, EMS, Soil & Water, Information Systems and Environmental Health. Currently, we take a handheld GPS unit out for well grouting inspections. The well location is then downloaded onto the county GIS database along with the well data, including well depth, well yield, casing depth, water bearing zones, grout type, and static water level. We currently have over 1200 wells plotted and in the county database.

GPS Model Used: Geoexplorer II by Trimble

Accuracy: 3–5 meters

Data Capture

The PIN (Property Identification Number) is entered on the data capture module of the GPS unit and the well position is recorded. We try to capture 100 points before closing the file. The data are differentially corrected from the USGS base files using Pathfinder Office and exported into ArcView as a shapefile.

Other Data Capture Options

Septic Tank, Pump Tank, Drain field, and Approved Areas

Time

It usually takes no more than 5 minutes (depending on satellite availability), and the data are collected concurrently with the well grouting inspection.

Limitations

Having to manage battery charging among several staff, remembering to take the units out, periods of low satellite visibility, cloud cover and heavy foliage blocking the satellites.

GIS Database

We have used ArcView and GIS extensively to help generate site plans to scale as attachments to our permits. It is especially helpful to use some of the layers available. Can print tax parcel to various scales (1” =50’, 1” = 100’, etc.).

Can view tax parcel. County overviews available include: Wells, Public Water Supplies, Contours (topo), Street view, Soil Types, Soil boundary, 1993 Orthophoto, 1998 Orthophoto, Existing building outline, USGS stream location and Planning and Zoning Limits.

GIS databases include well data, property owner data, watershed data, and tax information and EMS data.

Entering the following can access GIS databases: PIN, Owners name, Street Address, Tile, Subdivision name and TMBL (Tax Map Block and Lot Number). The Health department maintains all of the paper files by TMBL.

Limitations

Only one computer is available in the office. Our GIS and ArcView runs on a 233 MHz and 9 GB machine, and the ArcView software is operated on Windows NT Workstation. Needs a color printer to differentiate the details of each layer. The orthophoto views do not match data from Land Records. Properties near county lines have trouble with the digitized soil survey not matching. Maps printed with orthophoto views can take up to 20 minutes to print.

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Ozone Technology in Production Agriculture and Food Processing

By Charles D. Sopher, Dee M. Graham, Rip G. Rice, Jurgen H. Strasser

Abstract

Ozone (O_3) is a powerful oxidizer that has the capability of acting as an Antimicrobial Agent against many harmful microorganisms found in foods, agricultural products and soils. With ever increasing food safety concerns and the removal of pesticides from the marketplace, ozone gas and ozonated water are being investigated as contact Antimicrobial Agents for the removal and/or reduction of harmful pathogens. In 1995, an Expert Panel convened by the Electric Power Research Institute affirmed ozone as GRAS (Generally Recognized as Safe) for direct contact with foods. With the GRAS affirmation many food processors investigated the use of ozone as a contact Antimicrobial Agent. Because the FDA did not challenge the GRAS Affirmation, companies were free to use ozone at their own risk. At the same time, USDA-FSIS did not recognize or sanction ozone as a food additive. On August 15, 2000, the Electric Power Research Institute and other interested parties petitioned the FDA to allow the use of Ozone as an Antimicrobial Agent for direct contact with food. The petition was placed in expedited review by FDA, and approval of the petition was published in the Federal Register June 26, 2001. Final FSIS acceptance was published December 21, 2001. The development of the GRAS Affirmation and the Food Additive Petition approval has fostered increasing numbers of research projects in food processing, crop storage, irrigation, agricultural wastewater treatment, odor abatement, soil fumigation and pesticide removal from groundwater. This paper addresses these studies and the potential for future uses of ozone with emphasis directed toward North Carolina.

Background

In the early 1990s, the Electric Power Research Institute (EPRI) was directed by its members to investigate technologies that would enhance Food Safety. Emphasis was placed on non-thermal methodologies, and the use of ozone or (triatomic oxygen O_3) as a direct contact Antimicrobial Agent emerged as a promising mechanism to enhance the safety of food products by eliminating food-borne pathogens through non-thermal techniques. Although ozone showed promise as an Antimicrobial Agent, the FDA had never sanctioned it as a direct contact food additive. This lack of FDA sanction effectively banned all ozone use in fresh and processed foods.

The GRAS Affirmation

In 1996, Dr. Dee Graham working on behalf of EPRI pursued both general and governmental acceptance of the use of ozone as an Antimicrobial Agent in food processing. The first mechanism used to win acceptance of ozone as a legal and safe food additive was a “Generally Recognized as Safe” (GRAS) Declaration by an Expert Panel. This procedure was possible because ozone had been used to reduce levels of pathogens for over 50 years and a large amount of evidence is available in the literature.

For approximately two years, Dr. Graham chaired an Expert Panel that reviewed all available previous research and uses of ozone as an Antimicrobial Agent. In 1997, the Expert Panel declared ozone GRAS and published the results of their studies as EPRI Report TR-108026, Volumes

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1-3. A summary of the Expert Panel report was published in *Food Technology*. Findings of the panel and the GRAS Declaration were presented to the FDA. The FDA did not publish an objection in the Federal Register within their self-imposed 90 days, thus, leaving all food processors falling under the jurisdiction of FDA food inspection services free to use ozone in food processing. However, this use of ozone was always at the food processors' risk, as the FDA never actually sanctioned nor denied the GRAS Affirmation.

Although interest in ozone use was increasing, processors were very cautious about using a food additive that was not officially recognized by the FDA in the Federal Register and the Code of Federal Regulations. Furthermore, the lack of written recognition of ozone as a food additive by the FDA left the acceptance of the GRAS Affirmation by the USDA-FSIS in a very gray area. Without the official written FDA recognition of the GRAS Affirmation, meat and poultry industry inspectors did not recognize, accept or allow the use of ozone. Acceptance of the use of ozone was further complicated when it was found that a statement in FDA's GRAS approval of the use of ozone for bottled water required that all other food uses for ozone must be subject to Food Additive Petitions.

At this point the Food Processing Community was faced with three choices:

- abandon previous efforts,
- go to court, or
- work with the FDA to rectify the situation.

To abandon previous efforts would have resulted in the loss of considerable momentum. Further, several customers already using ozone as an Antimicrobial Agent would have been forced to abandon its use. Taking the FDA to court would have been very expensive and would have ultimately led to an adversarial win-lose situation regardless of the outcome.

Food Processors, ozone proponents and the FDA discussed this dilemma. After the discussions and at the suggestion of the FDA, it was decided to submit a Food Additive Petition to the FDA requesting the use of ozone as an Antimicrobial Agent in food processing.

Agricultural Background

Although the use of ozone started as a *food* safety technology, it quickly generated considerable interest in the agricultural community. This interest began as a desire to test the use of ozone in the following areas:

- use of ozonated water for washing of agricultural crops such as vegetables and fruits,
- use of gaseous ozone in conjunction with chilled air to reduce levels of pests in stored crops,
- use of both gaseous and aqueous ozone treatments as soil fumigants,
- use of ozone in irrigation water,
- ozone as an Antimicrobial Agent used in washing dairy facilities,
- ozonation of drinking water supplies for "at risk" animals such as baby calves, pigs and chicks,
- potential use of ozone in odor abatement in confined animal operations (COAs), and
- zonation of water in aquaculture tanks.

The emerging interest in the agricultural arena was developing at the same time the food safety interests were experiencing problems with recognition of the GRAS Affirmation and in light of the bottled water classification for the use of ozone. With these converging interests, the development of an **Ozone Food Additive Petition** evolved after a series of meetings between ozone vendors, food processors, interested electric utilities and both FDA and USDA representatives. Dr. Dee Graham, with his broad experience and background, spearheaded the effort. Based on guidance from the FDA, an outline was developed. Dr. Rip Rice provided much of the technical writing, Dr. Jurgen Strasser provided engineering expertise throughout all investigations, and Dr. Charles Sopher provided agricultural expertise and assisted with editorial efforts.

Utilizing the original literature search compiled by the GRAS Expert Panel, additional literature sources, and unpublished data provided by industry, the Food Additive Petition was completed and delivered to the FDA on August 2, 2000. After processing the materials, the FDA recognized the filing of the petition on August 15, 2000.

Based on the urgent need for better Antimicrobial Agents, the FDA assigned the petition to an expedited review process. With the exception of minor questions from an excellent review panel, the petition was reviewed and approval of ozone as an Antimicrobial Agent for direct contact with foods was published in the Federal Register on June 26, 2001. On December 21, 2001, FSIS acceptance was published. The publication in the Federal Register was the culmination of efforts that began in 1997 with the GRAS Declaration.

In the course of developing the petition, 360 pages of carefully written text on all known phases of the use of ozone as a food additive were presented. Additionally, nearly 2000 pages of reference materials were reproduced and appended to the petition as support materials. Upon delivery, the Food Additive Petition became FDA property. The availability of the petition is at the discretion of the FDA, and through the Freedom of Information Act can be obtained from the FDA by request. Printing costs and report delivery schedules are at the discretion of the FDA. This publication is also available in the May 2001 Proceedings of the International Ozone Association's Annual Conference *Advances in Ozone Technology*, held in Newport Beach, California. The Proceedings are available as a CD for approximately $100.00. For further details, call 203-348-3542.

Supporting Research Studies

During the development of the GRAS Affirmation and the preparation of the Food Additive Petition, several research studies were undertaken by EPRI and various supporting utilities. Studies that were completed were published by EPRI in the following reports. The EPRI publication number and year of publication follow each title.

- Ozone and UV for Grain Milling Systems (1000591, 2000)
- Membrane Filtration and Ozonation of Poultry Chiller Overflow Water: Study of Membrane Treatment to Reduce Water Use and Ozonation for Sanitation at a Poultry Processing Plant in California (TP-114435, 1999)
- Ozone Sanitizing for Meat Processing Equipment: TechApplication (TA114172, 1999)
- Ozone Conference II: Abstract Proceedings (GC-113975, 1999)
- Ozone in the Food and Agriculture Industries (TC-113814, 1999)
- Ozone Gas as a Soil Fumigant (TR-113751, 1999)
- Ozone Applications in Apple Processing (TA-112064, 1998)
- Ozone Use in Agriculture and the Food Industry (CR-110735, 1998)
- Expert Panel Report: Evaluation of the History and Safety of Ozone in Processing Foods for Human Consumption, volumes 1-3 (TR-108026, May 1997)

In addition to the above, Dr. Rip Rice published an ozone guidance document, entitled *Ozone Reference Guide*, EPRI Report CR-106435, 1996. Dr. Graham authored an article in *Food Technology* entitled "Use of Ozone for Food Processing," volume 51, no. 6, June 1997.

Ozone Safety

Questions concerning ozone safety in both the workplace and in final products are very common. Before discussing either of these topics, it needs to be noted that **it is not legal to "off-gas" or allow ozone to escape into the atmosphere.** In operations using ozone, strict air quality standards that are continually monitored are required. OSHA Worker Safety levels (Permissible and Short-Term Exposure Limits) are defined by the following:

- Workers can be exposed to ozone levels of 0.1 ppm, time-weighted average over 8 hours, 5 days per week (PEL).
- Workers can be exposed to ozone levels of 0.3 ppm for no longer than 15 minutes, such exposure not to exceed twice daily.

It is recommended that ozone detectors with audible and visual warnings as well as automated shutdown mechanisms be installed wherever ozone is used in food or agricultural processes. **(Exposures above the allowable limits may cause lung and nasal damage.)** A very good rule to follow is "if you can smell ozone, check its level and if greater than 0.1 ppm, leave the area and turn off the system."

The effects of ozone on final products are generally nonexistent. In only a few cases are final reaction products of ozonation detectable (which may be natural oxidation products like aldehydes or ketones). If the system is professionally installed and properly operated, detectable reaction byproducts will not be present.

As a general rule, ozone is much safer to handle than chlorine gas and because it is generated on site, it doesn't present the storage problems associated with chlorine tablets or liquid hypochlorite.

The Design of Ozone Systems

In the United States, the use of ozone as an Antimicrobial Agent in agriculture and food systems is still a very new and expanding technology. System designs must be tailored for specific uses and expertise is always a necessity. Because the technology is new and defined standards have not been developed, numerous examples of systems that were expensive, ineffective and unsafe already exist. These systems were all the result of poor designs in the absence of proven technology. To attain the desired results from the use of ozone, **always deal with companies that have a proven record** in food and agriculture applications and will provide references and guarantee results.

The Future of Ozone in Food Processing and Agricultural Production

The Food Additive Petition is in place, and sufficient research has been conducted to demonstrate the feasibility of ozone use in both agriculture and food systems. The keys to successful use are more education and further technology development**.** As we look toward the future, there is considerable interest in ozone in the following areas, many of which are of importance in North Carolina:

- reduction of mycotoxins and specifically aflatoxin in corn and peanuts,
- reduced water use in poultry processing,
- reduced chlorine use by utilizing ozone in poultry drinking water,
- ozone use in post harvest treatments of sweet potatoes,
- sanitation in swine facilities,
- ozone in odor abatement in confined animal operations (COAs),
- odor abatement in seafood facilities,
- reduction of microbial activities in drip irrigation systems,
- ozone as a soil fumigant, and
- ozone use in sanitation and on-site waste disposal systems.

As the future of ozone is explored and technologies are developed, uses that are not considered at this time will emerge. The technology is not a panacea but another effective tool to control pathogens in air, water and food supplies.

Soil, Leaf and Petiole Analysis Data in Support of Potassium Recommendations for Cotton

By Carl R. Crozier, F.R. (Bobby) Walls, L. Gaylon Ambrose, and Wayne Nixon

Abstract

Producers' and agricultural consultants' concerns about the ability of cotton plants to take up sufficient potassium (K) during flowering and fruiting, coupled with the availability of leaf potassium data obtained as a result of the mid-season petiole nitrate sampling program, have led us to reexamine potassium guidelines for cotton in North Carolina. Current guidelines recommend fertilizer applications based on soil test K levels. Leaf samples collected during the vegetative period can also be used to assess K deficiency. We summarize yield responses for several K tests at sites with a wide range of initial soil test K levels. Correlations between leaf blade K and petiole K levels at different growth stages are also summarized for test plots and for statewide commercial farm samples.

Introduction

Current K management recommendations for cotton in North Carolina are based on soil test K level (Tucker et al., 1997; Hodges, 2001). Mehlich-III extractable K (ppm) is divided by 1.955 to convert to an index value (I). The recommended fertilizer rate (lbs/A K_2O) is then calculated as: $0.0120\ I^2 - 2.90\ I + 165$ (Tucker et al., 1997). All recommended material can be broadcast pre-plant, except in the case of low CEC soils, for which split or sidedress applications minimize leaching losses.

Plant tissue analysis can be used to assess the status of a current crop and serve as a guide for the likelihood of response to in-season fertilization. Typically, plant leaf tissue interpretations have been provided for samples collected during the vegetative and initial reproductive stages of cotton. Recently, petiole nitrate calibrations have been developed for cotton plants during the first several weeks of the bloom period.

Laboratories generally analyze both leaf and petioles of tissues submitted to them, so many of the leaf tissues currently being analyzed are well beyond the vegetative stage. Tissue K sufficiency ranges in North Carolina are only based on values published for leaf tissues in the vegetative and early bloom stages. Late bloom period leaf K data is available from other southeastern states; and petiole K data collected throughout the bloom period is available from California (Table 1, Mitchell and Baker, 2000; Basset and MacKenzie, 1976).

Recently, producers and consultants have expressed concerns about K deficiencies due to the planting of higher yielding varieties and more continuous cotton, reports of deficiencies from other states, and the use of early-season sufficiency ranges for leaves collected later in the season in conjunction with samples collected for petiole nitrate determination.

The objective of this paper is to review K management guidelines for cotton in North Carolina, discuss ongoing field verification data, and summarize with implications regarding possible changes to the NCDA&CS plant tissue analysis protocol.

Materials and Methods

Tests were conducted on a Goldsboro soil at the Peanut Belt Research Station in Lewiston (1999), in three on-farm trials with soil and foliar K on Roper

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and Pettigrew mucks in Hyde County (1999, 2001) and a Tomotley fine sandy loam in Beaufort County (2000), and in six on-farm trials on sandy loam soils in Gates, Robeson and Wayne counties (2000, 2001).

Soil samples collected from all sites were analyzed by the NCDA&CS Agronomic Division Laboratory, using Mehlich-3 extractant with K reported as an index value (equivalent to ppm Mehlich-3 divided by 1.955, Tucker et al., 1997). All field tests were conducted with four replications.

Pre-plant soil K applications were allocated based on a randomized complete block design, and foliar K applications (when used) were randomly allocated to half of each main plot, resulting in a split-plot design. Pre-plant soil K was applied as broadcast muriate of potash (KCl, 0-0-60) at the specified rate, and foliar K was applied as two applications of 10 lbs/A of potassium nitrate (KNO_3, 13-0-44) dissolved in 10 gallons of water per acre (total 9 lbs/A K_2O).

The tractor drove through plots assigned to the treatment not receiving foliar N, avoiding differences in mechanical damage due to vehicular traffic. Harvest data were based on mechanized harvesting of at least 100 feet of crop row. Total seed cotton weights were adjusted based on a standard factor of 38 percent lint weight.

Leaf and petiole samples were collected on multiple dates in the trials at the Peanut Belt Research Station and in the Gates-, Robeson- and Wayne-county on-farm trials. Correlations between leaf K and petiole K were calculated for the on-farm trials mentioned, and for a larger set of tissue samples sent to the NCDA&CS Agronomic Division laboratory from commercial farms during the period 1999–2001. Statistical analyses were performed using the CORR and GLM procedures available in SAS (SAS Institute, Inc., 1990). A linear-plateau regression analysis of the effect of soil test K on relative lint yield, leaf K and petiole K from the 1999 tests at the Peanut Belt Research Station was performed using the NLIN procedures available in SAS (SAS Institute, Inc., 1990).

Results and Discussion

There was a dramatic increase in lint yield as soil K index increased from <10 to approximately 50 in the 1999 Lewiston test (Figure 1). The linear-plateau regression procedure identified a yield plateau at a soil K index of 48 in this test. In previous tests at the same site, critical soil K levels for cotton were as low as 20 in some trials and were not observed in others (Cox and Barnes, in review). In the three on-farm trials with foliar K, soil K index levels were >60; no significant response to soil applied K was observed in any year; and slight yield reductions occurred when foliar K was applied (Table 2). Yield reductions were relatively small, approximately 50 lbs/A lint, but were statistically significant in 1999 and 2001. In the six on-farm trials in Gates, Robeson and Wayne counties, soil K index levels were also >60, and there were also no significant responses to soil-applied K (data not shown).

Leaf K data suggest that as the soil K index nears 50, considered a level above which responses to fertilizer are unlikely, leaf tissue K 1 week after first bloom also approaches the critical level of 1.5% (Figure 2). Maximum tissue K concentrations declined progressively at later sampling dates but are not inconsistent with a critical level of 0.75

Table 1. Cotton Tissue K sufficiency ranges according to Mitchell and Baker (2000); petiole data are from Basset and MacKenzie (1976).

- - - - - - - - - - Leaf - - - - - - - - - -		- - - - - - - - - - Petiole - - - - - - - - - -	
Stage	%	Week (post-bloom)	%
Vegetative	1.5–3	0	4–5.5
Early bloom	1.5–3	+4	3–4
Late bloom/maturity	0.75–2.5	+6	1.5–2.5
		+8	1–2

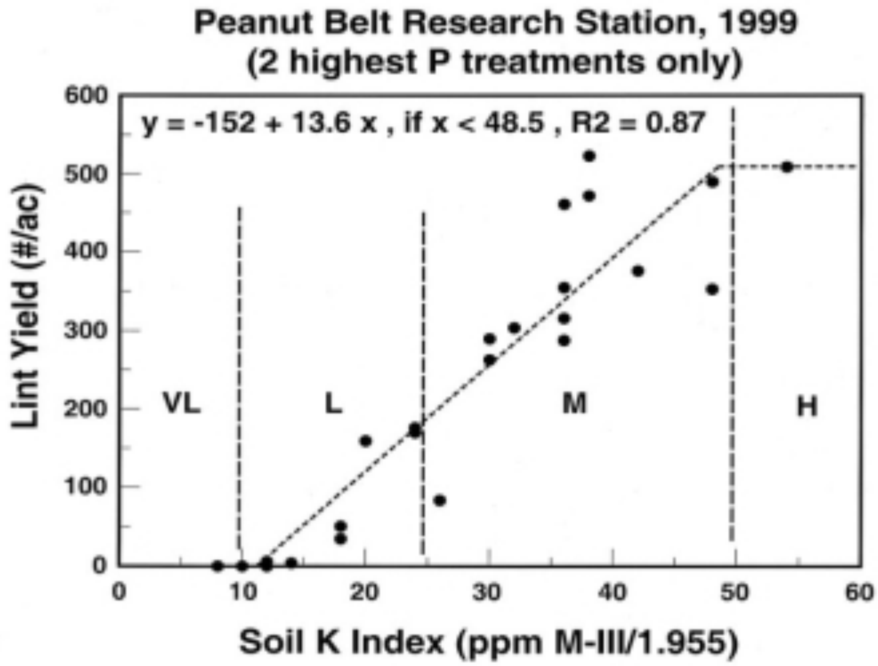

Figure 1. Yield response of cotton to soil K level at the Peanut Belt Research Station, 1999. Vertical lines indicate general soil test category ranges: VL-very low, L-low, M-medium, H-high.

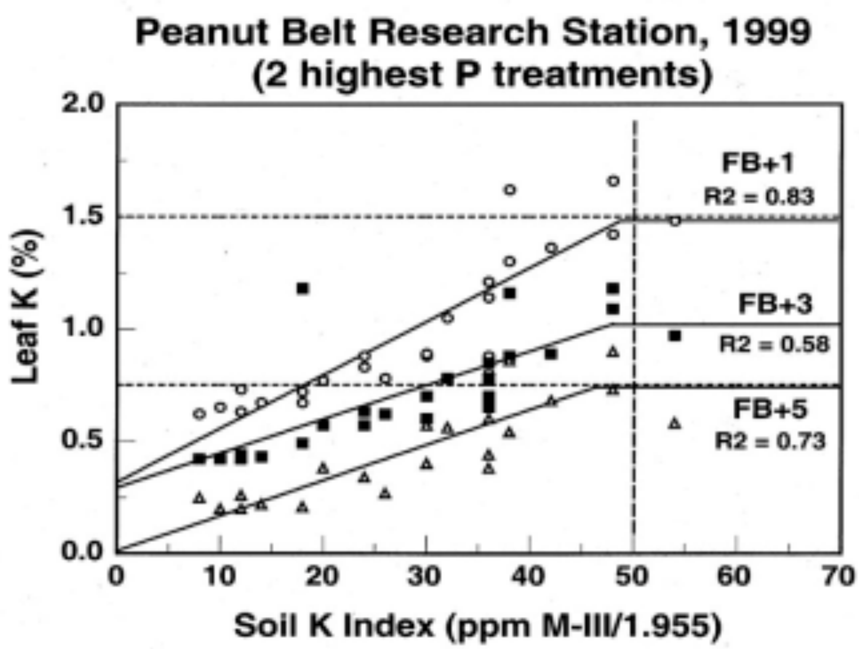

Figure 2. Leaf tissue K of cotton across a soil K level gradient at the Peanut Belt Research Station, 1999. Samples were collected at either 1 week (FB+1), 3 weeks (FB+3), or 5 weeks (FB+5) after first bloom. Horizontal lines indicate published leaf tissue critical levels of 1.5 percent for vegetative and early bloom stages, and 0.75 percent for late bloom and later stages. Regression equations are FB+1: $y = 0.32 + 0.024 x$, if $x < 48.6$; FB+3: $y = 0.29 + 0.015 x$, if $x < 48$; FB+5: $y = 0.012 + 0.016 x$, if $x < 46.2$.

Table 2. Yield response of cotton to soil- and foliar-applied K level in Hyde County (1999, 2001) and Beaufort County (2000) tests. Symbols at the bottom of each column indicate whether foliar K treatments were significant ($p<0.05$) or not (ns). There were no significant soil K or soil K x foliar K interaction effects.

- - - - Soil K (lbs/A)	1999 - foliar	- - - - + foliar (9 lbs/A)	- - - - Soil K (lbs/A)	2000 - foliar	- - - - + foliar ((9 lbs/A)	- - - - Soil K (lbs/A)	2001 - foliar	- - - - + foliar (9 lbs/A)
0	849	814	0	1184	1123	0	1205	1165
40	911	868	60	1140	1071	40	1185	1145
80	910	836	120	1114	1088	80	1172	1158
mean	890	839		1146	1094		1188	1156
	p<0.05			ns			p<0.05	

percent suggested by Mitchell and Baker (2000) for the late bloom stage. Petiole K data are also consistent with a critical level of 40,000 ppm (4 percent) suggested by Basset and MacKenzie (1976) for the early bloom stage (Figure 3).

As was observed with leaf K, maximum petiole K concentrations declined progressively at later sampling dates and appear reasonably close to critical levels of 30,000 ppm (3 percent) at 4 weeks and 15,000 ppm (1.5 percent) at 6 weeks after first bloom (Basset and MacKenzie, 1976).

Although correlations between leaf and petiole K concentrations were often statistically significant, correlation coefficients were not high enough to permit reliable estimation of one value from the other: r values ranged from –0.1 to 0.8 for six on-farm research sites, and from 0.4 to 0.5 for samples collected from across the state. Unfortunately, response data are not available that allow us to determine whether leaf K or petiole K would be a better predictor of likelihood of response or of rates of fertilizer K to apply to correct mid-season deficiencies.

Conclusions

Based on limited data from our study and from work by Cox and Barnes (in review), yield responses to soil test K are not likely if soil test K index is >60. Both leaf and petiole K appear to provide a useful verification of K sufficiency and suggest that K deficiency is avoided when the soil test-based K recommendations are followed. Although no yield increase, and even yield reductions were observed following foliar K applications, this test was not performed at any sites where K was likely to be deficient.

Future work should measure cotton yields across a wider range of soil K gradients in an effort to more precisely document the response plateau level. They should also attempt to identify K-deficient sites and evaluate whether or not leaf K or petiole K analyses are more useful in prescribing mid-season K applications. Critical levels for either leaf K or petiole K will need to be adjusted to consider the sampling date, since concentrations of both decline progressively during the bloom period.

Laboratories should consider the following issues which may affect sample handling protocols:

1) Critical leaf and petiole K levels will need to be adjusted based on crop growth stage. Ongoing studies in North Carolina should provide values to compare with published guidelines from other states.

2) There is no current response data suggesting whether leaf K or petiole K is a better predictor of cotton K status. Ongoing studies might resolve this issue.

3) If critical petiole K values can be identified, then later season samples could be analyzed for petiole nitrate and K, with leaf analysis limited to samples collected up to the first week after bloom. This would still provide verification of sufficiency of a broad spectrum of nutrients early in the season, with the focus shifting to petiole nutrients (N, K) later.

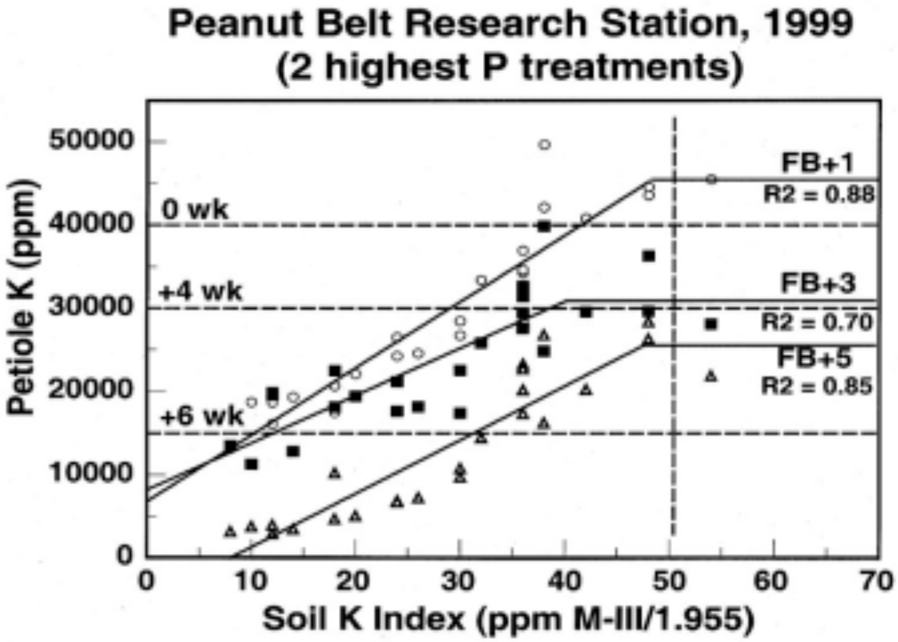

Figure 3. Petiole K of cotton across a soil K level gradient at the Peanut Belt Research Station, 1999. Samples were collected at either 1 week (FB+1), 3 weeks (FB+3), or 5 weeks (FB+5) after first bloom. Horizontal lines indicate published petiole critical levels of 40,000 ppm for the week of first bloom (0 wk); 30,000 ppm for 4 weeks after first bloom, and 15,000 ppm for 6 weeks after first bloom. Regression equations are FB+1: $y = 6792 + 800x$, if $x < 48.3$; FB+3: $y = 8181 + 566x$, if $x < 40.1$; FB+5: $y = -5150 + 645x$, if $x < 47.6$.

Acknowledgments

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Cotton Multispectral Reflectance Patterns and NDVI-days Nitrogen Uptake and Lint Yield Modeling

By Hong Li

A two-year (1998–1999) remote-sensing study was conducted on the semiarid Southern High Plains of Texas to characterize cotton (*Gossypium hirsutum* L.) reflectance and to predict nitrogen uptake and lint yield using the Normalized Difference Vegetation Index (NDVI) days concept. Treatments consisted of irrigation at 50 percent and 75 percent cotton potential economic threshold (ET), and nitrogen rates of 0, 90 and 135 kg/ha arranged in an incomplete block design. Irrigation had significant effect on near infrared reflectance (NIR), NDVI, nitrogen uptake, and lint yield ($p<0.0012$). The NDVI-days modeling was useful to predict cotton nitrogen uptake and lint yield based on real-time crop nitrogen status.

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Summary Yields from Corn, Wheat, Soybean, Cotton and Peanut — the Cropping System Effects and Certain Soil Physical Properties in a Study of Long-Term Conservation Tillage

By G. C. Naderman, B. T. Marcom, R. Sasser, and E. Pitzer

In a cropping systems experiment we have completed six years of continuous conservation tillage in contrast with conventional tillage for three locally important crop rotations. The crops included are corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), soybean (*Glycine max* L.), peanut (*Arachis hypogaea* L.) and cotton (*Gossypium hirsutum* L.). The rotations studied are corn/full-season soybean, corn-wheat/double-cropped soybean and corn/peanut/cotton. In all of the conservation tillage treatments a small grain cover crop is grown and killed just before planting. Conventional tillage involves chisel plowing with use of the disk and field cultivator for secondary tillage. All crops are grown under both tillage approaches each year, and these 16 “systems” constitute the treatments in the experiment. The study includes four replications.

Systems effects noted have included increased problems under the conservation tillage treatments with wireworm (*Limonius agonus*) damage on corn seedlings in some areas, and major Hessian fly (*Phytophaga destructor*) damage on wheat in one season. There also was seriously-reduced, early plant growth, especially on soybean, in the fourth and fifth year of no-tillage culture. All of these effects were reduced or absent in the sixth year (2001), and the reasons are not completely clear.

In contrast, reduced surface soil crusting with conservation tillage was especially beneficial to cotton plant population in 2001. Measurements of soil porosity and bulk density as affected by the contrasting tillage will be reported, but generally have not shown clear differences. As is typical of land in proximity of major rivers, the Neuse in this case, soils in this experiment vary in internal drainage and permeability. This results in wetness effects most seasons and has caused a lot of within-plot yield variability.

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Yield Responses of Cotton and Corn to Different Forms of Deep Tillage and the Respective Zones of Soil Loosening as Determined by Penetrometer Readings on a Two-Inch Grid

By G. C. Naderman and G. P. Love

Deep tillage has long been accepted by many farmers as necessary on pan-layer prone land. These "tillage pans" occur in the better-drained soils with sandy influence in the coastal plain region from Virginia to Texas. Especially for cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.), this commonly is done with subsoilers directly under the crop row. Under conventional tillage the ripper/bedder is commonly used. Recently several brands of effective conservation tillage equipment, known as "strip tillage," are quite popular. These combine in-row rippers with disk closure assemblies, rolling baskets and/or other devices to prepare the row zone for planting.

For several years the DMI brand has offered another deep tillage approach. It features shanks of variable spacing (commonly 30 inches apart); "winged" points; and in recent years our area representatives suggest the tillage be done in late winter/early spring at a 45 degree angle to the intended crop row. It offers practical benefits to farmers and is popular, but some question its tillage effectiveness.

This two-year study in productive but pan-layer prone soils tested the response of two crops to KMC Strip Till; the DMI equipped with shanks spaced at 30 in (76 cm), using their "no till" point (wing span of about 8. 3 inches, 21 cm) operated at angle to the crop rows; to both forms of deep tillage; and to a "no till" check treatment where neither form of deep tillage was applied. A rye (*Secale cereale* L.) cover crop was used both years, and all treatments qualified as conservation tillage. To determine the zone of soil loosened by the treatments we used a blunt-ended penetrometer, measuring soil resistance on the vertical face of soil pits, done at grid positions of 2 in (5 cm) in both directions. All three forms of deep tillage were significantly better than the check, but the DMI was significantly poorer than KMC Strip Till in crop yield and effectiveness of the zone of soil loosened.

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Phosphorus Loss Assessment in North Carolina

By A.M. Johnson, D.L. Osmond, S.C. Hodges, R.L. Hansard

Prior to 1999, state and federal nutrient management regulations used nitrogen as the rate-determining nutrient for animal waste applications to agricultural fields. In recent years, however, the scientific community has addressed the problem of excess phosphorus in the environment. States are now required to develop new tools for assessing potential water quality impairment due to phosphorus loss from agricultural fields.

The method that is currently being proposed in North Carolina is a site-specific phosphorus-index system called the Phosphorus Loss Assessment Tool, or PLAT. This tool designates four distinct pathways of phosphorus loss: 1) particulate phosphorus loss due to erosion, 2) loss of soluble phosphorus due to runoff, 3) subsurface phosphorus loss via leaching, and 4) loss from applied phosphorus sources.

An initial sampling phase was conducted in which 85 fields from eight counties were selected to assess how well the tool is predicting phosphorus loss from different animal manure management systems, soil groups and physiographic regions within the state. Results from this first sampling phase show that the tool predicts higher levels of particulate phosphorus loss and lower levels of soluble phosphorus loss for finer textured soils than for coarser soils. Sandy soils showed a trend toward greater leaching of phosphorus, while the tool indicated that poultry manure was much more susceptible to phosphorus losses than other manure or fertilizer types.

A more rigorous sampling phase is planned in order to further assess PLAT and its effect on producers within the state.

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A Suggested Water Table Monitoring Method Based on Soil Color Patterns

By J.P. Williams, D.L. Lindbo, and M.J. Vepraskas

Abstract

Soil colors are typically used in evaluating sites for on-site wastewater systems. In general, the presence of gray, low chroma colors (<2) is used to estimate the seasonal high water table. These colors are formed due to the reduction and subsequent removal of iron-oxide coatings from individual mineral soil grains. The low chroma colors therefore are not only a good indicator of saturated soil conditions but also of anaerobic conditions, both of which are detrimental to system treatment. Simply using the first occurrence of low chroma colors in estimating seasonal high water table, although generally accurate, does not address the duration or frequency of saturated and reduced conditions.

Soil morphological, hydrological, and physical properties from several soil toposequences on the North Carolina coastal plain have been used to calibrate the soil color patterns to frequency and duration of water table levels and reducing conditions. Each soil was monitored for daily water levels and reducing conditions for between 3 to 5 years. These data were used to calibrate DRAINMOD and simulate water table dynamics for a 30^{+}-year period using historic rainfall. Low chroma colors were related to saturation and reduction event of 21 days or more.

Site evaluation for on-site wastewater systems often includes an estimation of seasonal high water table based on soil morphology. However, sites do exist where the actual depth to water table may be deeper than what the morphological indicators suggest due to external changes in the local or regional hydrology. These sites can be evaluated by direct observation of the water table during wet periods.

The objectives of this paper are to introduce a monitoring method. Research in eastern North Carolina suggests that it takes a 21-day period of saturation to form chroma-2 iron depletions. It is suggested that saturation of 21 days recorded in a monitoring well be an “equivalent standard” to chroma-2 colors on those sites that have had changes in hydrology due to drainage or other factors. Since the number of days saturated are critical, only daily readings can be accepted as data recorded less frequently will not accurately describe the site hydrology. In order to determine at which depth 21-days of saturation occurs, a hydrograph of depth to water table over time must be produced. The hydrograph will show how the water table fluctuates over time during the winter monitoring period, and must be combined with long-term rainfall data. Only the portion of the hydrograph that represents “normal” rainfall will be evaluated to estimate water table.

Introduction

It has long been documented that soil color patterns are related to saturated conditions in the soil (Franzmeier et al., 1983; Vepraskas and Wilding, 1983; Pickering and Veneman, 1984; Evans and Franzmeier, 1986; Veneman et al., 1998). Soil saturation alone does not change the soil color. The color pattern forms due to the microbial activity that depletes the soil of any free oxygen (0_2) causing the soil to become anaerobic. Under anaerobic conditions, ferric iron (Fe^{3+}) is microbially converted to ferrous (Fe^{2+}). This process is referred to as iron reduction. This process causes the rusty colored Fe coatings on soil particles (Fe^{3+} oxides) to dissolve off the particles and into the soil solution,

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resulting in the gray color (low chroma) of the mineral grains to show through (Figure 1).

The formation of these low chroma colors (also known as redox depletions) in soils allows the site evaluator to reliably predict the level of seasonal saturation and reduction in the soil if the site has not been hydrologically altered. Drainage ditches and subsurface tile drains are two ways in which hydrology is altered. When this occurs redox depletions may no longer be reliable indicators of the saturation and anaerobic conditions (James and Fenton, 1993). Features observed at hydrologically altered sites are referred to as “relict” features. However, accurate identification of relict features must be done with knowledge of the degree of alteration (Vepraskas, 1994; Hayes and Vepraskas, 2000).

As suggested soil site evaluators commonly use colors. This works well in most areas but additional data and interpretation of that data are needed. Collection of hydrologic data in the form of water table monitoring can be a costly and time-consuming process that all landowners are not able to do. Thus some water table monitoring method based on the scientific data related to the formation of soil colors is needed. The objectives of this paper are to introduce a suggested method and illustrate this method with specific examples.

Soil Color, Water Table and Site Evaluation Rules

Evaluation of soil color patterns to determine seasonal high water table is used commonly. The rules for interpreting and designing on-site systems based on this determination vary from state to state. In order to simplify the discussion in this paper, we will use soil color as defined in *North Carolina Laws and Rules for Sewage Treatment and Disposal Systems.* By rule, the depth to soil wetness condition (seasonal high water table) is determined by the depth to common (2–20%) or more soil colors (redox depletion or mottles) of chroma 2 or less (Munsell Color Chart).

As indicated, >2% redox depletions are used to determine the seasonal high water table in an unaltered site. In order to establish a water table monitoring method, the relationship between the frequency and duration of that water table needed to develop this color pattern needs to be established. A study undertaken by M.J. Vepraskas and E.S. Stone (unpublished data) looked at daily water table data collected at several wells in eastern North Carolina over a 3-year period. These results were then used to calibrate DRAINMOD (Skaggs, 1978) to develop a 32-year hydrologic simulation for the sites.

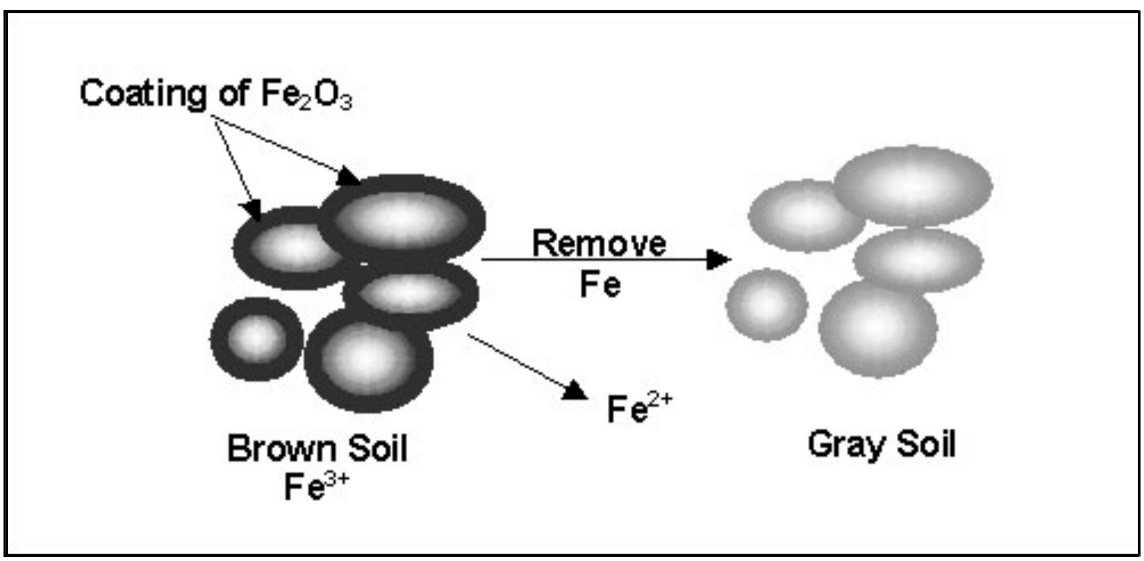

Figure 1. Schematic of the formation of a redox deletion (low chroma mottle). Fe-oxide coatings are dissolved off the gray soil mineral particles as Fe^{3+} is reduced to Fe^{2+} in saturated and anaerobic soil. The Fe^{2+} is soluble in water and is removed as soil water flows away.

Frequency and duration of saturation events were then correlated to the soil morphology from each site. Saturation durations were broken into 3 groups; 7-14 days, 14-21 days and >21 days. The DRAINMOD simulation data was used to compute the number of times per year the water table was above a given depth.

Statistical analysis of the data showed that redox depletions were significantly correlated to periods of >21 days saturation (R^2 = 0.93). The actual percentage of redox depletions increased each time the soil was saturated for >21 days. Although these finding are important it must be noted that they are still preliminary and need to be refined with data from additional sites. However, the implication from the data is that the common or more (>2%) occurrence of redox depletions (low chroma colors) used in the rule can be correlated to a saturation event of >21 days (Figure 2).

Suggested Well Monitoring Method

The correlation of 21 days of saturation to redox depletions at undisturbed sites provides the basis for developing an “equivalent standard” for direct water table observations. The equivalent standard assumes continuous saturation therefore the water table measurements need to be taken at least on a daily basis. This can be done with either automated wells or manually. Well data recorded less frequently may not accurately describe the hydrology of the site. From this data, a hydrograph of depth to water table over time is produced and used to determine the duration of saturation at any given depth. For North Carolina water tables are highest during the winter and early spring. This is the critical time in which the maximum water table is to be observed directly. Therefore, the suggested monitoring period is from January 1 to May 31

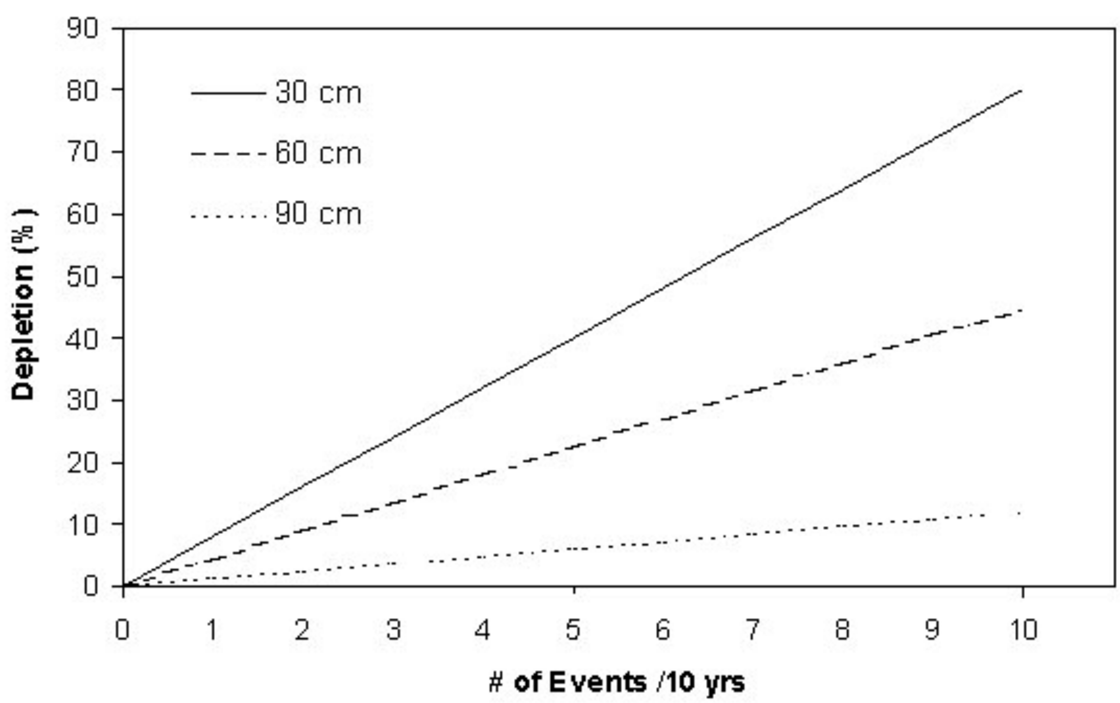

Figure 2. Relation between frequency and abundance of redox deletions for saturation events >21 days.

(Figure 3). This monitoring period would have to be evaluated for other regions. During this period the water table will rise and fall depending on the rainfall, thus on-site rainfall data will have to be recorded.

Long-term rainfall data (>30 yrs if possible) from the closest NOAA weather station are used to determine if the monitoring period represents a "normal" or wetter period. For the purposes of the remainder of this paper, "normal" is defined as 30-day total rainfall that exceeds the 30th percentile of normalcy based on the 30+ year historic record (Figure 4). The 30th percentile was chosen because it will exclude that 30% of time when rainfall is at a minimum and the 30th percentile is easily acquired from established websites for climate data.

Drier than normal rainfall periods are excluded from this method since the observed water table is likely to be lower (deeper) than expected. Wetter than normal periods are included even though the observed water tables are likely to be higher (shallower) than normal. A rainfall period that is above the 75th percentile of normalcy (wetter than normal) may only occur 25 percent of the time, but any septic system must work during this time period. These events should not be ignored; therefore, only the lower limit of rainfall will be used to define a normal period. There will be no upper limit to normalcy. Designs using a higher than normal water table are seen as being more conservative.

The "normal" rainfall based on the 30 year, 30th percentile data is compared to the observed on-site rainfall data. The dates that actual rainfall (30-day totals) exceeds the 30th percentile will be considered normal, and the well data from these dates can be evaluated. Thus, only the dates with normal or more rainfall will be evaluated.

Although a 21-day period of continuous saturation is correlated to redox depletions, this proposed method does allow for the 21 days of saturation to be achieved by multiple events of at least seven consecutive days of saturation. The depth at which 21 days of saturation (cumulative or consecutive) is achieved is used to the calculate water table in that well (Figure 5). The rationale for allowing the 21 days of saturation to be composed of individual seven-day events is that the lag time in between rainfall events will dry the soil to the point that soil water will not flow freely into the well, but the soil is very near saturation, may still be

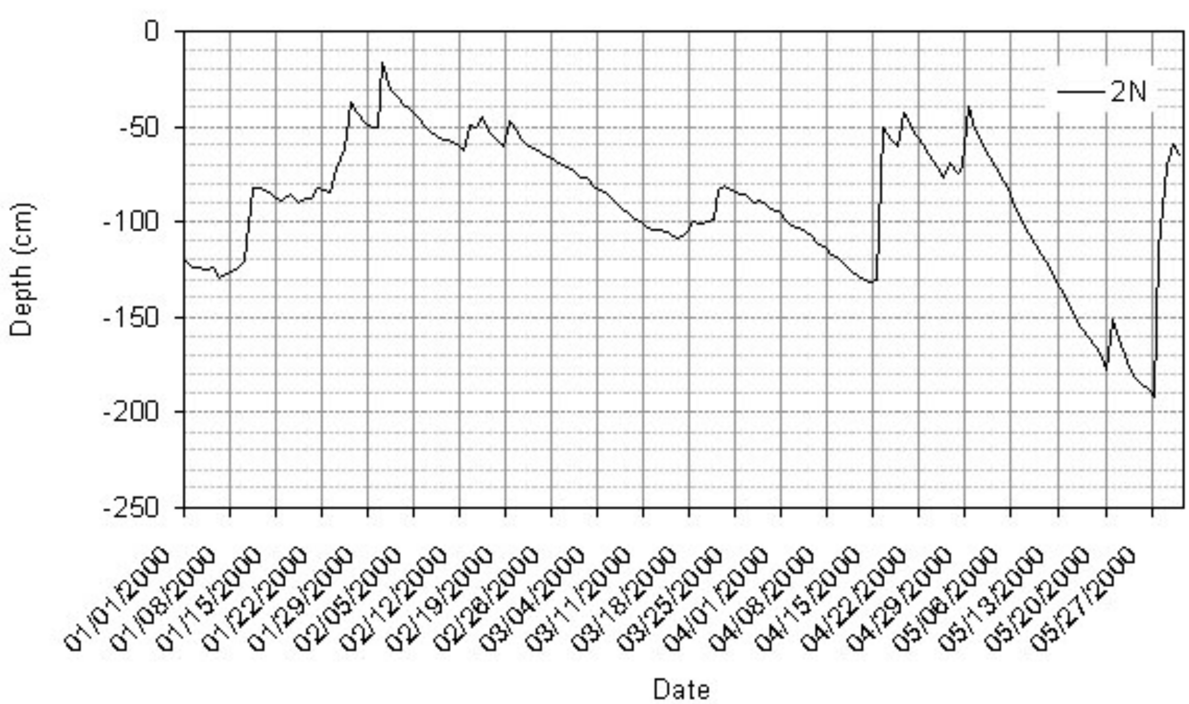

Figure 3. Hydrograph showing daily water level fluctuations in a well between 01/01/2000 and 06/01/2000. Note that the water level may fluctuate greatly in a 24-hour (1-day) period. The amount of fluctuation reinforces the idea that daily measurements are needed to accurately determine the water table for design purposes.

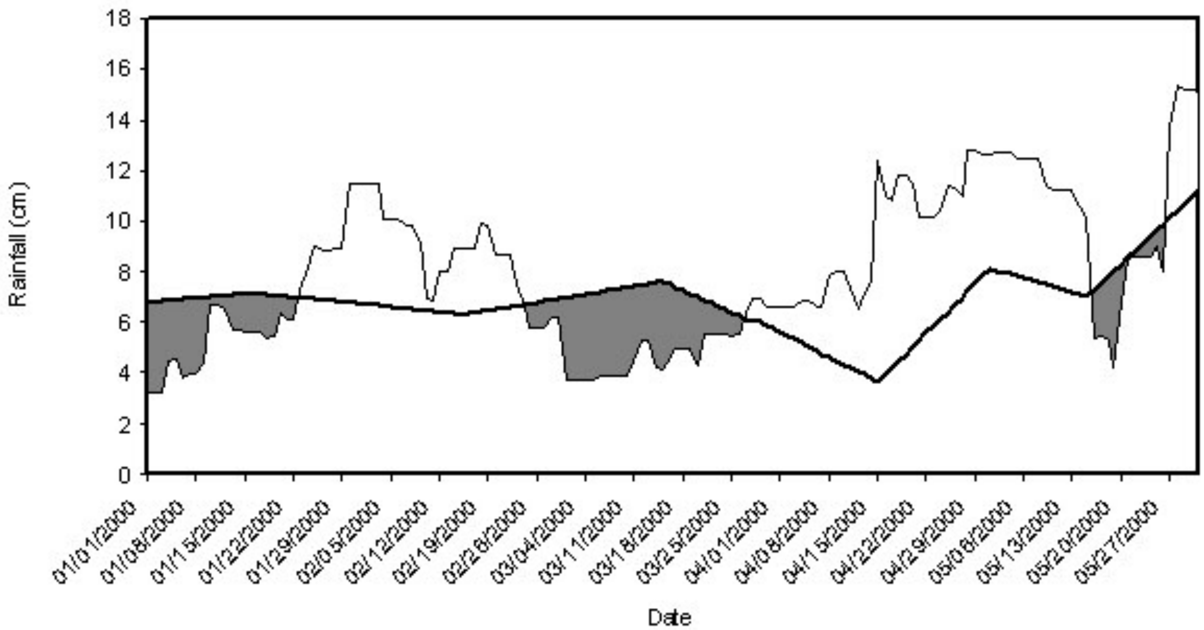

Figure 4. Rainfall analysis from Plymouth, NC, and on-site data. The heavy solid line represents the 30th percentile of normalcy for Plymouth, NC. The light line represents the 30 day running total of on-site rainfall for the period 01/01/2000 to 05/31/2000. The shaded zone represents the area where the 30 day running total is below the 30th percentile line. Water level readings during this period would be excluded from the analysis.

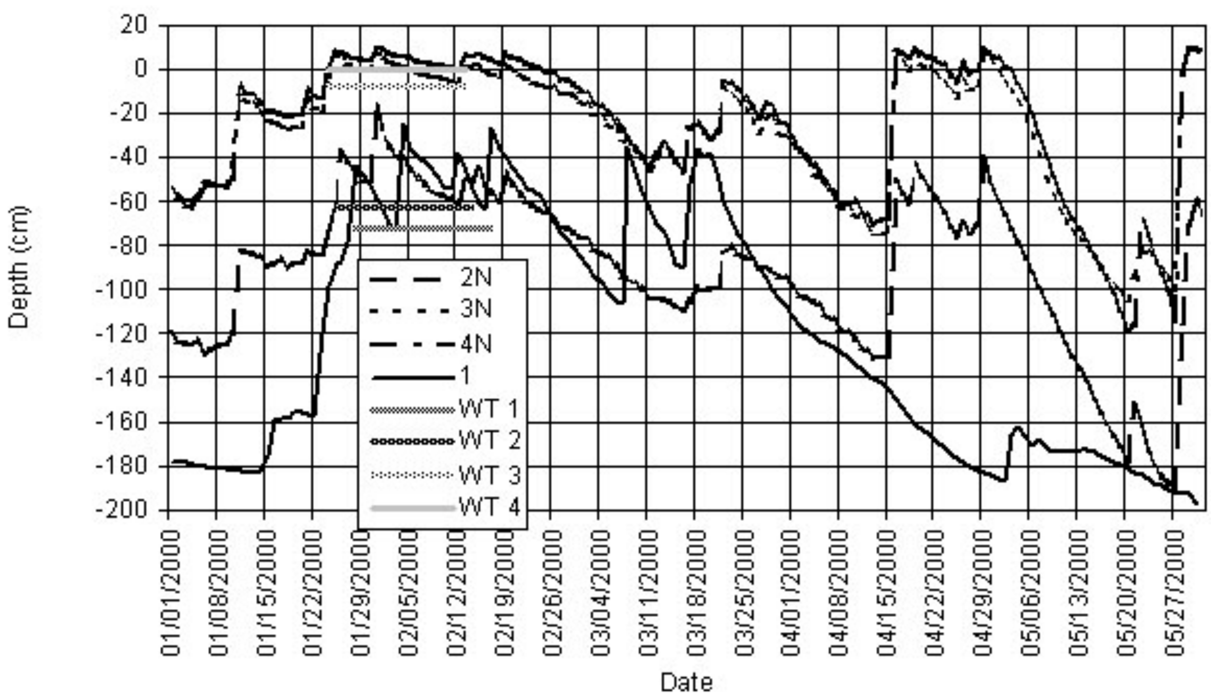

Figure 5. The shaded area of the hydrograph represents the zone that is too dry (below the 30th percentile of rainfall) to be considered following this method. The shallowest depth at which 21 days of continuous saturation occurs within the non-shaded zone is indicated by bars for each hydrograph.

anaerobic, and would not provide adequate treatment to the sewage effluent. Using seven-day periods should, therefore, account for a portion of the capillary fringe common above the saturated zone.

Examples

Several hydrographs have been plotted on Figure 5 in order to determine the depth to water table. The corresponding rainfall analysis indicating the dry time periods has been overlain on the graph. Only the dates not in the shaded zone are considered normal and can be evaluated. Bars mark the periods of 21-day saturation. The shallowest depth at which 21 days of saturation occurs is at 72 cm (28 in.) for well 1, 62 cm (24 in.) for well 2N, 7 cm (3 in.) for well 3N, and 0 cm (0 in.) for well 4N.

The only way to demonstrate if the suggested method provides for an accurate estimate of depth to water table is to compare the well monitoring method water level to the depth determined using the soil morphology (Table 1). The sites included in Table 1 are all located in eastern North Carolina and have a minimum of three years of daily water table measurements and rainfall data. Profile descriptions were made from backhoe pits dug adjacent to the wells. The water level in the well during the entire monitoring period was evaluated using the suggested method to determine the shallowest occurrence of 21 days of saturation.

Suggested Procedure for Using the Suggested Water Table Monitoring Method

The method discussed thus far should allow the substitution of direct observations of the water table in areas where the soil morphology is in question to determine soil wetness for design considerations. The method should only be applied in areas where permanent or near-permanent alteration of the hydrology has occurred. In order to apply the method, the following procedure is suggested.

First, a detailed plan for conducting a water table observation study shall be submitted to the

Table 1: Comparative values of water table depth based on soil morphology according to NC rules vs. the water table depth (21-day saturation) based on the suggested well monitoring method.

Soil Type	Depth to water table based on morphology cm (in.)	January to May well data		Depth to 21-day saturation cm (in.)
		Minimum cm (in.)	Maximum cm (in.)	
Noboco (Well 1)	91 (36)	33 (13)	200+ (80+)	72 (28)
Goldsboro (Well 2N)	66 (26)	0 (0)	200+ (80+)	62 (24)
Goldsboro	81 (32)	15 (6)	114 (45)	69 (27)
Lynchburg	51 (20)	0 (0)	89 (35)	53 (21)
Lenoir (Well 3N)*	23 (9)	0 (0)	140 (55)	7 (3)
Rains*	23 (9)	0 (0)	76 (30)	0 (0)
Rains*	23 (9)	0 (0)	63 (25)	7 (3)
Leaf (Well 5N)*	25 (10)	0 (0)	165 (65)	0 (0)

* Depth to water table may also be determined at 0 cm in these soils based on morphology if the black (10YR 2/1 or 3/1) is considered as an indicator.

local health department or other regulatory agency at least 30 days prior to the beginning of the study. The plan shall include a site plan or plat and a detailed soil and site description. Landscape and soil morphologic information shall be used to justify the need for the study, including the number and location of the wells. This statement shall provide a technical explanation of why the applicant disputes the soil morphological determination of depth to the water table.

Second, the well must be 2-inch-diameter slotted well screen or larger. This size is to prevent erroneous reading due to condensation on the edge of the well. If episaturation is suspected, wells at multiple depths will be required.

Third, the monitoring period will commence on January 1 and proceed until May 31 (depending on regional climate, these dates may be altered). Daily readings will be required. A licensed professional or someone under the direct supervision of a licensed professional shall take the readings.

Fourth, a daily recording rain gauge will be required at every site, unless otherwise specified. In order to attain 30-day running total rainfall, the on-site recorded rainfall must commence at least 30 days prior to the first water level reading in the well. Long-term rainfall data shall be obtained from the closest NOAA or equivalent recording station with 30+ years of rainfall data that accurately represents the site.

Fifth, the depth to the soil wetness condition will be determined by evaluating that portion of the hydrograph that represents rainfall above the 30th percentile of normal (based on 30+ years of data). The soil wetness condition (water table for design purposes) will be the shallowest of a) the depth at which 21 days of consecutive saturation is achieved or b) the depth at which 21 days cumulative saturation of individual events of at least seven consecutive days occurs.

Summary

This paper has suggested a well monitoring method to estimate a water table for the purpose of designing an on-site waste water system. This method is based on some preliminary soil morphology-water table data that need to be expanded and refined. Despite this shortcoming, the suggested method is at least if not more conservative in determining the water table as illustrated in Table 1. The greatest advantage of this method is that it will standardize well monitoring across wide areas. This will then make data sets comparable and should make the job of the regulator and consultant easier in the long run. More work will be done to fine tune the suggested method so that the regulatory community can adopt it as rule or policy.

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Selected Physical and Chemical Properties That Affect Water Movement in Selected Saprolites

By C.D. Peacock, Jr., J.F. Conta, T.P Sexton, and J.M. Galbraith

Introduction

While some states may prohibit or restrict the use of saprolite for septic drainfield use (Arnold et al., 1996), Virginia has a long history of drainfield installation in saprolitic materials. The onsite regulations in Virginia are brief and general in their reference to saprolite (Virginia State Board of Health, 2000) and make no specific reference to design concerns or criteria when utilizing such materials. Historically, thousands of onsite systems are installed annually in saprolite in Virginia. The vast majority of these have done an admirable job of treating and disposing of residential wastewater.

In Virginia, one of the most important components of a drainfield evaluation is the soil texture and its estimated permeability. Since few drainfield evaluations involve actual permeability measurements, it is important that the estimated permeability rates accurately reflect the hydraulic potential at the site. Work involving the repair of prematurely failing septic systems highlighted the fact that while some saprolites had soil textures with estimated suitable permeability, the drainfields quickly malfunctioned. That was the impetus for this research.

Extensive work has been done in North Carolina on saprolite characterization. Amoozegar et al. (1995) noted that inter/intraparticle pores were the dominant pore type found in gneiss saprolite. They also noted that higher saturated hydraulic conductivity (Ksat) in saprolite may result in higher pore water velocity and lower filtering efficiency. This has implications for wastewater disposal and groundwater quality.

Schoeneberger and Amoozegar (1989), studying Cecil and Pacolet soils, noted the lack of preferential water flow in the foliation bands seen in felsic crystalline rock saprolites. In addition, the average Ksat rates they reported were similar to those measured on Cecil and Pacolet soils in Virginia.

Smith and Buol (1988) noted that soils derived from diabase were expected to have dispersive tendencies. A number of the soils studied in Virginia formed from mafic or mixed mineralogy saprolites and had very low Ksat rates.

Simpson (1986) noted that the Ksat of saprolite may be more predictable than previously expected. In Virginia, that was true only on the acid crystalline-derived saprolites. Measured Ksat rates associated with mafic or mixed mineralogy saprolites were much slower than estimated, based on soil textures and/or ease of soil augering.

Materials and Methods

Based on the literature and field experience of the lead authors, saprolite type and properties have a profound effect on Ksat rates in the Piedmont of Virginia. The objectives of this study were to group soils into three categories of saprolite type and then compare the correlation between measured Ksat and physical and chemical properties within and between the categories. This paper represents a preliminary report on the results of an ongoing study, scheduled for final results and publication at a later date.

A soil auger hole of 5 cm diameter was bored to the desired depth in the saprolite. After scarifying

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the lower hole sidewall and removing all loose material from the hole bottom, the Compact Constant Head Permeameter (CCHP) was used to measure Ksat (Amoozegar and Warrick, 1986). After completion of the Ksat test, another hole was augered immediately adjacent to the Ksat hole. Soil was collected from the same horizon and depth tested. This soil sample was later dried and submitted for laboratory analysis. A brief soil profile description was made of the soil tested using standard methods (Schoeneberger et al., 1998) and the soil series was identified (USDA-SCS, 1996).

Laboratory tests were run on all soils for exchangeable potassium (29-3.5.2 modified), available phosphorus (24-5.1 Bray 1), exchangeable calcium and magnesium and sodium (13-3.5.2 and 14-4), extractable manganese (19-3.4), pH (12-2.6), and CEC (Sum of Cations) using Methods of Soil Analysis Part 2 (1982). In addition, total manganese was determined (USEPA, 1998).

For all soils, particle size analysis was determined by hydrometer (Day, 1965). On all samples, triplicate determinations of liquid limit and plastic limit were averaged, respectively, and the mean values used (USDA-NRCS, 1996).

Results and Discussion

The soil series used in this study and their taxonomic classification are as follows:

Appling	fine, kaolinitic, thermic Typic Kanhapludults
Cecil	fine, kaolinitic, thermic Typic Kanhapludults
Cullen	very-fine, kaolinitic, thermic Typic Hapludults
Fluvanna	fine, mixed, active, thermic Typic Hapludults
Georgeville	fine, kaolinitic, thermic Typic Kanhapludults
Mecklenburg	fine, mixed, thermic Ultic Hapludults
Iredell	fine, mixed, active, thermic Oxyaquic Vertic Hapludalfs
Trenholm	fine, mixed, thermic Albaquic Hapludalfs

For the benefit of sampling and comparison, we have grouped the soils in this study as follows:

Acid-Crystalline	Mixed Acid-Crystalline	Basic (Mafic)
Appling	Cullen	Iredell
Cecil	Fluvanna	Trenholm
Georgeville	Mecklenburg	

Particle Size Analysis (PSA) had a wide range of values for saprolites from acid-crystalline rocks, mixed acid-crystaline rocks and basic (mafic) rocks. PSA ranged from sand to clay loam in the acid-crystalline saprolites, sandy loam to clay in the mixed acid-crystalline saprolites and loamy sand to clay in the basic (mafic) saprolites. This indicator was not reliable to separate one saprolite from another.

Liquid Limit (LL) and Plasticity Index (PI) had a wide range of values for saprolites from acid-crystalline rocks, mixed acid-crystalline rocks and basic (mafic) rocks. LL values ranged from 26 to 49 with a mean of 40 in the acid-crystalline saprolites, 29 to 70 with a mean of 50 for the mixed acid-crystalline saprolites and 29 to 47 with a mean of 42 in the basic (mafic) saprolites. PI values ranged from 25 to 45 with a mean of 34 in the acid-crystalline saprolites, 25 to 51 with a mean of 37 for the mixed acid-crystalline saprolites and 22 to 41 with a mean of 30 in the basic (mafic) saprolites. These indicators were not reliable to separate one saprolite from another.

Calcium (Ca) clearly separated acid-crystalline saprolites from basic (mafic) saprolites (Figure 1). Ca values ranged from 10 to 570 ppm in the acid-crystalline, 60 to 1700 ppm in the mixed acid-crystalline saprolites and 400 to 3500 ppm in the basic (mafic) saprolites. Mixed acid-crystalline saprolite values more closely related to but did not separate from the acid-crystalline.

CEC (by sum of cations) clearly separated acid-crystalline saprolites from basic (mafic) saprolites (Figure 2). Acid-crystalline saprolites had low CEC values with a mean of 6 meq/100g of soil, while basic (mafic) saprolites had high CEC values with a mean of 28 meq/100g of soil. Mixed acid-crystalline saprolites had a mean CEC value of 7 meq/100g of soil. Mixed acid-crystalline saprolite values more closely relate to but do not separate from the acid-crystalline.

Sodium (Na) values clearly separated acid-crystalline saprolites from basic (mafic) saprolites (Figure 3). Acid-crystalline saprolites had low Na values of less than 35 ppm while basic (mafic)

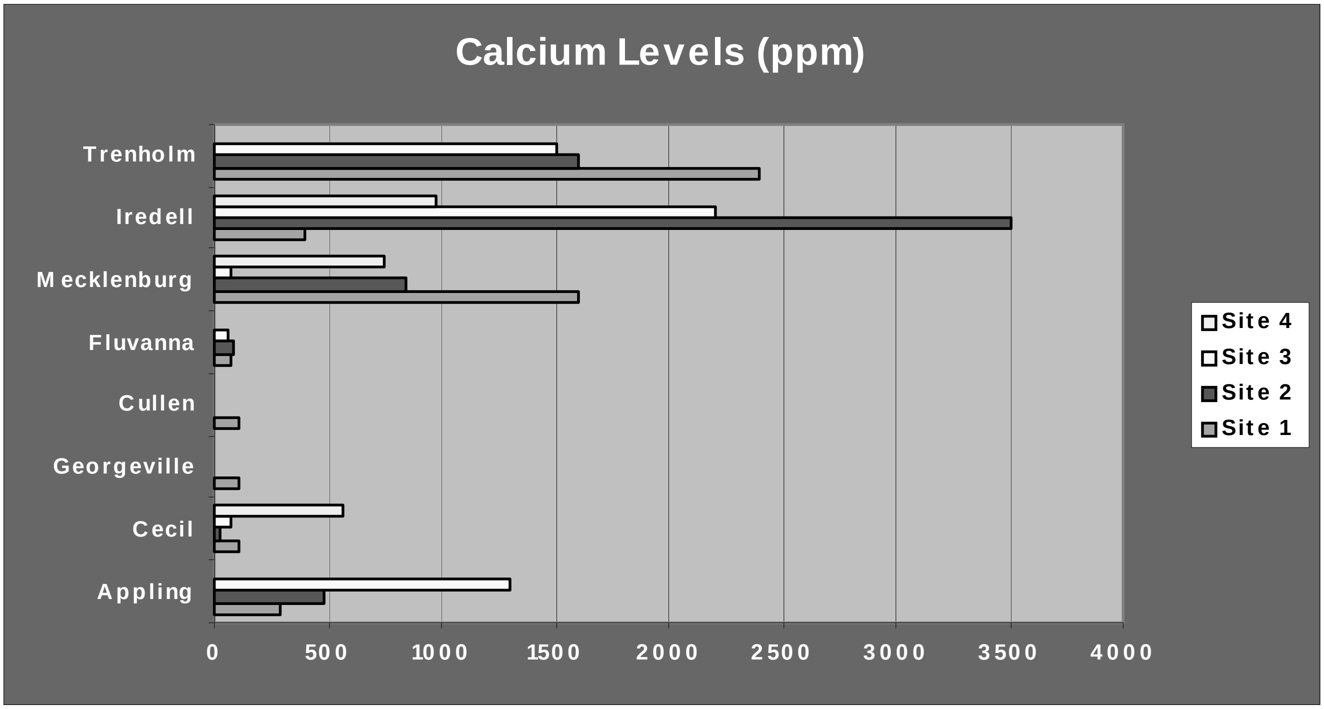

Figure 1. Calcium levels of selected saprolites.

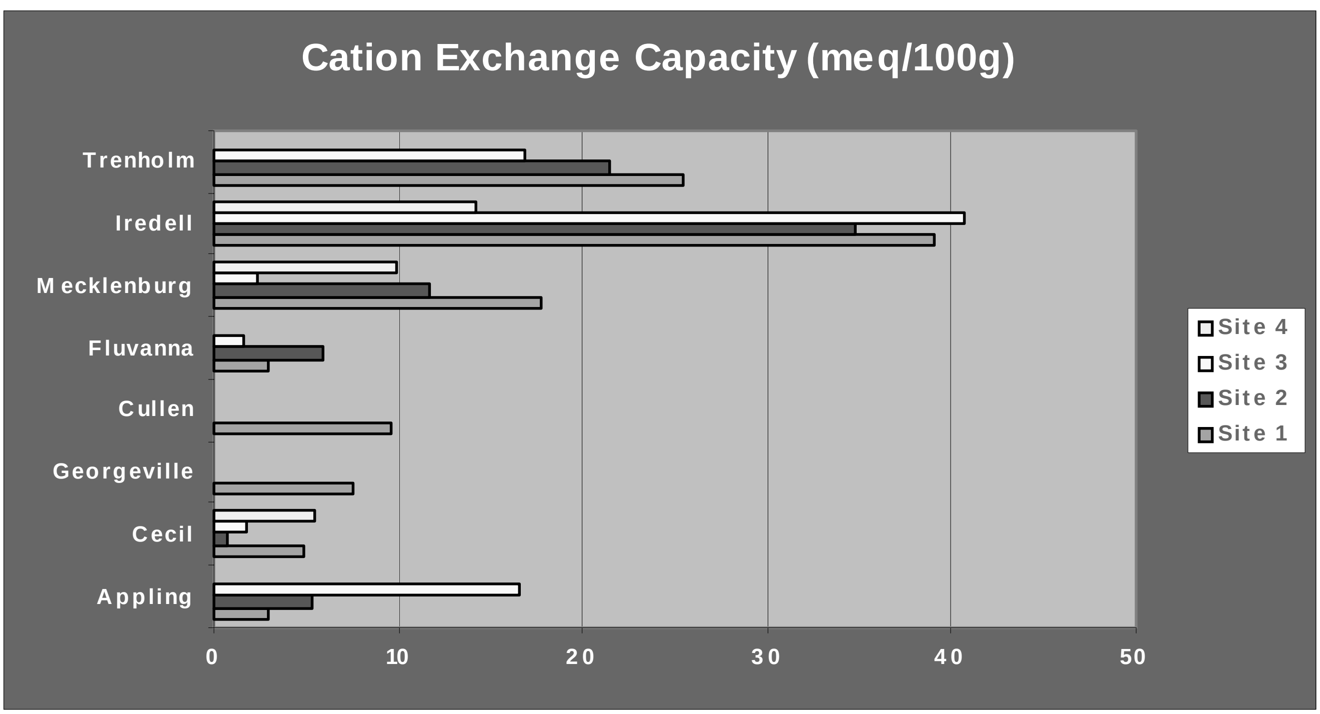

Figure 2. Cation exchange capacity (by sum of cations) of selected saprolites.

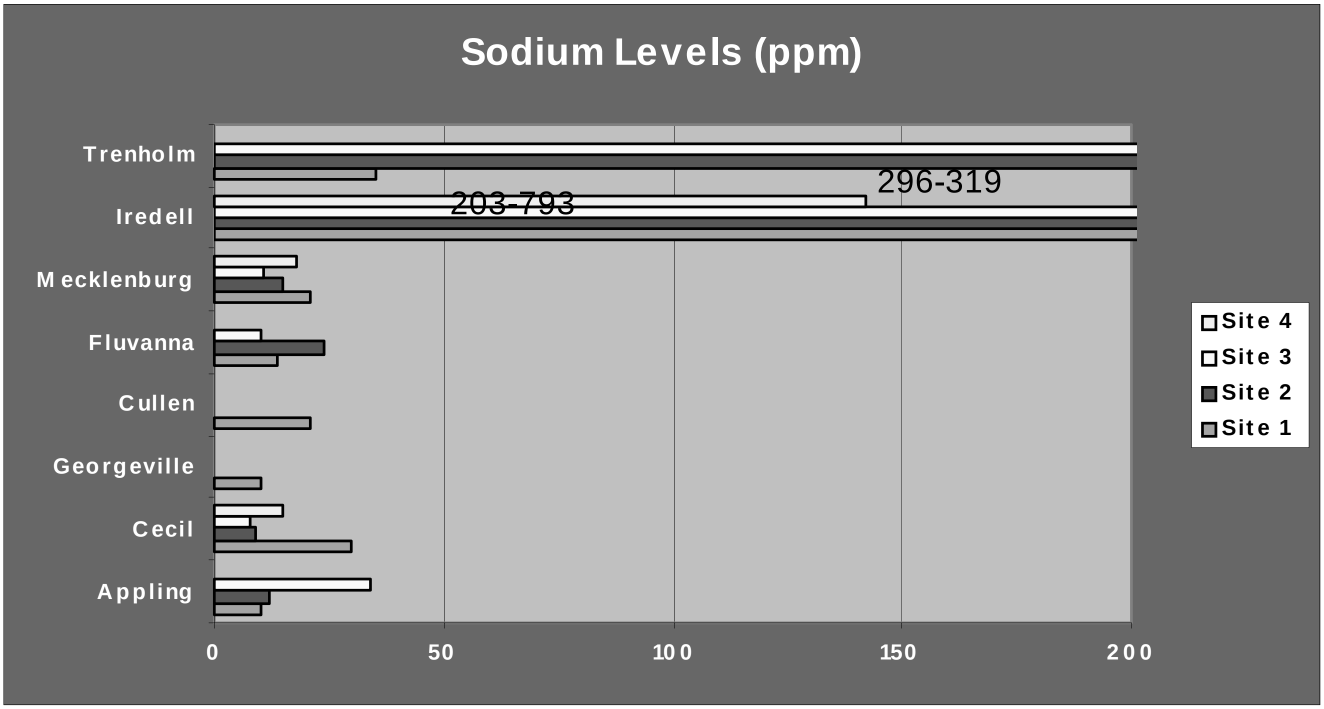

Figure 3. Sodium levels of selected saprolites.

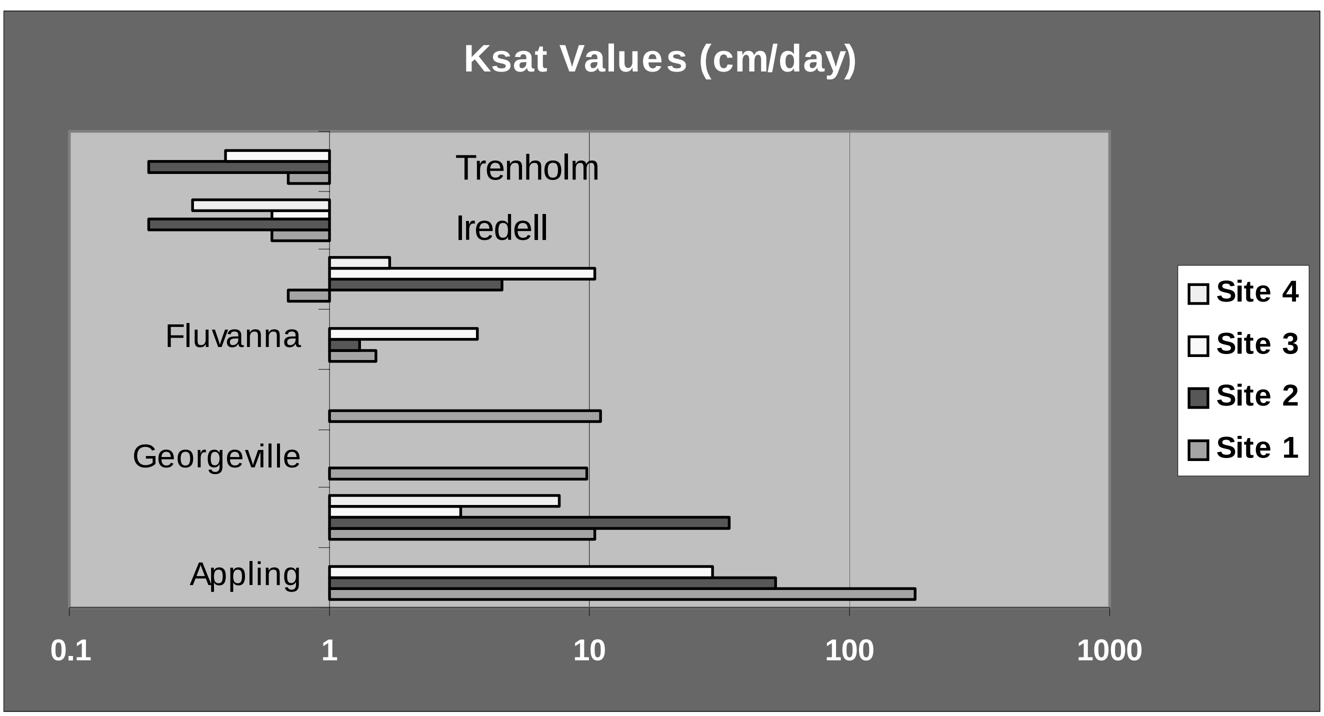

Figure 4. Ksat levels of selected saprolites.

saprolites had high Na values greater than 145 ppm. Mixed acid-crystalline saprolites had low Na values less than 28 ppm. Mixed acid-crystalline saprolite values more closely relate to but do not separate from the acid-crystalline.

Ksat values clearly separated each of the three types of saprolites (Figure 4). Acid-crystalline saprolites had Ksat values that ranged from 3.8 to 35.8 cm per day with a mean of 17.1. Mixed acid-crystalline saprolites had Ksat values that ranged from 0.3 to 6.2 cm per day with a mean of 3.3. Basic (mafic) saparolites had Ksat values that ranged from 0.2 to 0.6 cm per day with a mean of 0.4 cm per day.

Summary and Conclusion

Neither particle size analysis, liquid limit nor plasticity index were reliable indicators to separate one type of saprolite from another.

Calcium, sodium and CEC (by sum of cations) values clearly separated acid-crystalline saprolites from basic (mafic) saprolites. Calcium, sodium and CEC (by sum of cations) values for mixed acid-crystalline saprolites were not clearly different from those of acid-crystalline saprolites.

Ksat values clearly separated each of the three saprolite types. Acid-crystalline saprolites had higher values than mixed acid-crystalline saprolites while basic (mafic) saprolites had the lowest values.

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Models for Field Determination of Saturated Hydraulic Conductivity

By Aziz Amoozegar

Abstract

The Glover equation has been used to determine the saturated hydraulic conductivity (K_{sat}) of the vadose (unsaturated) zone by the constant-head well permeameter technique. In this procedure the steady-state rate of water flow (Q) from a cylindrical auger hole of known diameter ($2r$) under a constant head of water (H) is used to measure K_{sat} in situ. The objective of this paper is to show that the Glover equation is an appropriate model for determining K_{sat} by this procedure. The Glover equation was developed based on the saturated flow alone. Other models developed within the last 20 years consider both saturated and unsaturated flow of water around the hole where measurements are made. For these models the unsaturated flow is accounted for by a single parameter that must be estimated or determined independently. The major assumptions for developing these models are examined in the context of field measurement of K_{sat}. Based on field-measured data, and considering the heterogeneous and variable nature of the soils, most of these assumptions appear to be invalid. In addition, the K_{sat} values calculated by the Glover equation for various sets of field data are numerically close to the results obtained by the other models using a prescribed value of the unsaturated parameter. The Glover equation is recommended for use in conjunction with the constant-head well permeameter technique because it only uses field measure data, is relatively simple, and does not require estimation of any soil parameter. In addition, its results are numerically comparable with the values obtained by other models providing that the ratio H/r is greater than or equal to 5.

Introduction

Solving many agricultural and environmental problems requires a value of the saturated hydraulic conductivity (K_{sat}) of the soil. Constant-head well permeameter technique, also known as shallow well pump-in technique, is the most versatile procedure for measuring saturated hydraulic conductivity of the vadose (unsaturated) zone (see Amoozegar and Wilson, 1999). This procedure was introduced over 50 years ago, and R. E. Glover developed a simple mathematical equation (also known as the Glover solution) for calculating the K_{sat} value using field measured data (Zangar, 1953).

In the original procedure, it was suggested to bore a relatively large (e.g., 20 cm in diameter) cylindrical hole to a desired depth and to maintain a constant depth of water at the bottom of the hole using a float system. In addition, it was believed that steady-state could only be achieved after applying a substantial amount of water to the hole. As a result, the technique was considered difficult and time consuming. Development of equipment [Compact Constant Head Permeamter (Amoozegar, 1992), and Guelph Permeameter (Norris and Skaling, 1992)] and the use of small diameter (in the order of 6 cm) hole for the field procedure in the last 20 years (Amoozegar, 1992; Reynolds et al., 1983; Talsma and Hallam, 1980) have made it possible to measure K_{sat} from the soil surface to depths exceeding a few meters using less than 5 L of water in many soils. Briefly, to measure K_{sat} of the soil by the constant-head well permeameter technique a cylindrical hole of radius r is dug to the desired depth. Using a device, such as the one shown in Figure 1, water is applied to the bottom of the cylindrical hole. After maintaining a constant depth of water in the hole (head, designated as H) and reaching steady-state, the final (i.e., steady-state)

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rate of water flow into the soil (Q) is measured for calculating a K_{sat} value using an appropriate equation.

The available equations to calculate K_{sat} can be written in the form of

$$K_{sat} = AQ \qquad [1]$$

where Q is the steady-state flow rate of water from the bottom of the hole into the soil and A is a factor that must be calculated with a model. The A factor in the Glover equation is given by

$$A = [\sinh^{-1}(H/r) - (1+ r^2/H^2)^{1/2} + (r/H)]/(2\pi H^2) \qquad [2]$$

where $\sinh^{-1}$ is the hyperbolic sine function and r and H are as defined before (Zangar, 1953). In the Glover equation only the saturated flow of water around the hole is considered. Based on their initial analysis of saturated and unsaturated water flow from a cylindrical hole (Reynolds et al., 1983), Reynolds et al. (1985) (also see Elrick et al., 1989) introduced an analytical model for calculating K_{sat} in which A in Eq. [1] is given by

$$A = C/(2\pi H^2 + \pi r^2 C + 2\pi H/\alpha) \qquad [3]$$

In the above equation C is related to r and H and is obtained from graphs developed for different soils (see Elrick and Reynolds, 1986) or from fitting equations presented by Radcliffe and West (2000), and α is a parameter related to the unsaturated flow away from the hole. The α parameter must be determined independently or be estimated based on other soil properties. Using a similar concept, Philip (1985) introduced yet another analytical model for calculating K_{sat}. In Philip's model the A factor can be written in the form of

$$A = 1/(r^2 B) \qquad [4a]$$

in which

$$B = (H^2/r^2 - 1)^{1/2}\left\{\frac{4.117(1- r^2/H^2)}{\ln[H/r + (H^2/r^2 - 1)^{1/2}] - (1- r^2/H^2)^{1/2}} - \frac{2(4.028 + 2.517H/r)}{\alpha\, r \ln[H/r + (H^2/r^2 - 1)^{1/2}]}\right\} \qquad [4b]$$

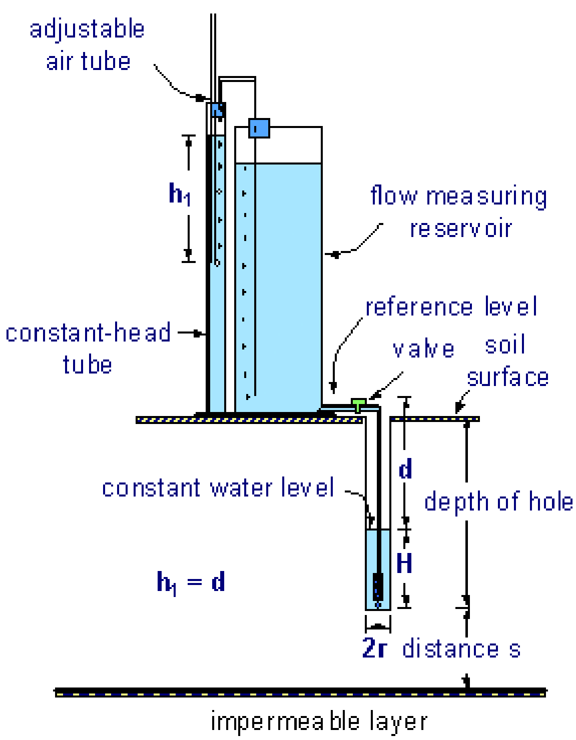

Figure 1. A schematic diagram of a constant head permeameter maintaining a constant depth of water (H) at the bottom of a cylindrical hole of radius r.

As indicated above, both Reynolds *et al.* and Philip's models (Eqs. [3] and [4]) were developed based on water flow in the saturated and unsaturated zones around the hole. The unsaturated flow parameter α, referred to as capillary factor or sorptive number, is related to the matric flux potential introduced by Gardner (1958). [NOTE: Stephens et al. (1987) also presented a regression equation for calculating K_{sat} using r, H, and Q in addition to an α_1 parameter related to the water flow in the unsaturated zone around the hole.]

Reynolds et al. (1985) used the simultaneous equation approach and presented a procedure to calculate both K_{sat} and α using two sets of field measurements of the steady-state flow rate from a cylindrical auger hole under two different heads (i.e., depth of water in the hole). Amoozegar (1989a) showed that a negative K_{sat} value is obtained by the simultaneous equation approach for some cases where the soil hydraulic conductivity increases with depth. Elrick et al. (1989) presented a new approach for calculating K_{sat} using pre-assigned values to α based on soil texture and structure.

The Glover equation has been criticized because only the saturated flow around the hole was considered in its development (Reynolds et al., 1983, 1985; Radcliffe and West, 2000). Amoozegar (1989b), however, demonstrated that the Glover equation results are relatively close to the results obtained by Philip (1985) and Reynolds et al. (1985) models for most practical applications. In light of the assumptions used in the development of the models, and the closeness of calculated K_{sat} values by the available models for similar conditions the criticism of the Glover equation is unjustified.

Objective

The goal of this paper is to demonstrate that the Glover equation is an appropriate model for determining the saturated hydraulic conductivity of the vadose zone by the constant-head well permeameter technique. This objective will be achieved through an assessment of the assumptions made for developing the models and with a direct comparison between their results.

Assumptions for Developing the Models to Calculate K_{sat}

All the models developed for calculating K_{sat} are based on the assumptions that

(1) Darcy's law is valid and can be applied to both saturated and unsaturated flow, and

(2) the soil under consideration is homogeneous and isotropic (i.e., soil hydraulic properties are the same in horizontal and vertical directions).

Furthermore, Reynolds et al. (1985) and Philip (1985) also made the following assumptions:

(1) soil water regime around the hole is divided into a saturated zone (referred to by Philip, 1985, as the saturated bulb), and a transmission zone (wetted but unsaturated) that extends to infinity at steady-state (see Fig. 2); and

(2) the unsaturated flow outside of the zone of saturation around the hole is explained by the matric flux potential (Gardner, 1958)

$$\Phi = \int_{h_i}^{0} K(h)\mathrm{d}h \qquad [5]$$

and that the unsaturated hydraulic conductivity is defined by the empirical equation

$$K(h) = K_{sat}\exp(\alpha h),\ h_i = h = 0. \qquad [6]$$

Instead of independently determining the α parameter, Elrick et al. (1989) suggested the following values for calculating the *A* factor of Eq. [3]:

$\alpha = 1\ \mathrm{m}^{-1}$ for compacted clays (e.g., landfill liner),
$\alpha = 4\ \mathrm{m}^{-1}$ for unsaturated fine textured soils,
$\alpha = 12\ \mathrm{m}^{-1}$ for most structured clayey soils to unsaturated medium and fine sands (the first choice suggested for most soils), and
$\alpha = 36\ \mathrm{m}^{-1}$ for coarse sand and highly structured clayey soils with large macropores.

Examination of Assumptions

1. *Darcy law is valid.* There is no dispute that Darcy law governs water flow for both saturated and unsaturated conditions. Therefore, we consider this assumption to be valid for all models.

2. *The soil under consideration is homogeneous and isotropic.* With few exceptions (e.g., dune sands), soils are composed of various layers (horizons) and vary across landscape. This is particularly true for soil hydraulic properties. Warrick and Nielsen (1980) presented the coefficient of variability (CV) of more than 100 percent for K_{sat} of a number of soils and declared this parameter to be a highly variable soil property. Amoozegar et al. (1993) reported CV values ranging between 100 and 450 percent for the laboratory determined K_{sat} of the Bt horizon of 11 soils from the piedmont and mountain regions of North Carolina. They also reported that the CV for the in situ determined K_{sat} of the Bt horizon of 8 of the soils ranged between 55 and 256 percent. The CV for the in situ K_{sat} of the saprolite for the same eight soils ranged between 22 and 160 percent. In a field experiment, Niewoehner

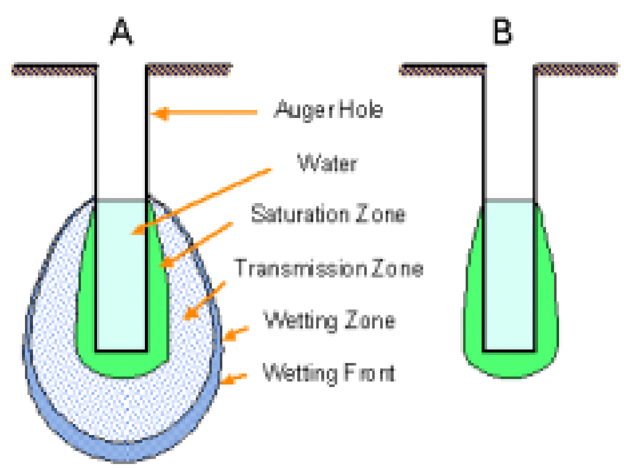

Figure 2. A schematic diagram of the soil water regime around a cylindrical hole under a constant head of water during early stages of infiltration (A) and at steady-state (B).

and Amoozegar (2002) used water and a dye solution and measured in situ K_{sat} of one saprolite (Site 1) and the Bt horizons of two clayey soils (Site 2 and 3) at six locations along a 2.5 m long transect (50 cm spacing between the holes) by the constant-head well permeameter technique. At each site, they used 6-cm diameter holes and maintained 15 cm depth of water or dye solution at the bottom of each hole by a Compact Constant Head Permeameter (Amoozegar, 1992). The in situ K_{sat} of the saprolite along the 2.5 m long transect varied between 22 and 150 cm d^{-1}. For the two Bt horizons, the ranges of K_{sat} along the 2.5 m long transects were 0.26 to 0.78 cm d^{-1} for Site 2 and 1.0 to 12.2 cm d^{-1} for Site 3. These ranges show the high variability of K_{sat} in different soils. Based on soil horizonation and spatial variability of K_{sat}, we consider the soils to be, in general, heterogeneous and anisotropic, therefore, this assumption should be considered invalid.

3. *Soil water regime around the hole is divided into a saturated bulb, and a transmission zone.* In general, the majority of the volume of water flowing in clayey soils under saturated conditions is through tubular (e.g., root channels, worm holes) and planar (e.g., interped) pores (see Buol, 2000) As was mentioned earlier, Niewoehner and Amoozegar (2002) applied a dye solution to six 6-cm diameter cylindrical holes dug along a 2.5-m-long transect in one saprolite and the Bt horizons of two clayey soils. After excavating the soils and saprolite they determined that water flow from the cylindrical hole through the clayey Bt horizons was not divided into distinct zone (see Fig. 3). Instead, most of the water moved through certain passageways associated with tubular and interped planar voids and not through the soil matrix. The saprolite used in their study is considered massive (i.e., no structure) with minimal tubular pores associated with roots or animals. Most of the water flow in this saprolite was through interparticle pores. Despite that, the stained areas around the auger holes (Fig. 3) were irregular and did not resemble the saturated bulb as depicted in Figure 2. Based on this study and our knowledge of water flow through soils, this assumption does not

Figure 3. Photograph of the vertical cross section of the profile around holes #1 and #3 in the Bt horizon at Site 3 and saprolite at Site 1 of the study by Niewoehner and Amoozegar (2002) showing the dye-stained areas around the auger holes.

hold for a majority of soils used for agricultural or environmental purposes. Therefore, we should consider this assumption invalid for most soils.

4. *The unsaturated hydraulic conductivity (K_{unsat}) is defined by the empirical equation $K(h) = K_{sat}exp(\alpha h)$, $h_i \leq h \leq 0$.* This empirical equation has been used extensively to model soil water flow under unsaturated conditions. However, there is not a universal agreement between the measured K_{unsat} curves and the results obtained by this model for various α values. Here we will use the K_{unsat} curves presented by Bouma (1975) for one sandy, one silt loam, and one clayey soil. For comparison, we will use the α values suggested by Elrick et al. (1989) for calculating K_{sat} of sandy, loamy, and clayey soils using Eq. [3]. Figure 4 presents the measured K_{unsat} curve and the calculated curves for two α values suggested for coarse and fine sandy soils. It is obvious that none of the empirical curves resembles the actual (measured) K_{unsat} for the sandy soil studied by Bouma (1975). Similarly (see Fig. 5), there is no agreement between the measured curves for a silt loam and a clay soils with either of the empirical curves obtained for fine textured soils (α = 4 m^{-1}) and most structured clayey soils to medium and fine sands (α = 12 m^{-1}, the first choice suggested for most soils). Based on these results, we should consider this assumption invalid for most practical applications.

Comparison of the Glover Equation with other Models

A 6-cm diameter hole (r = 3 cm) has been recommended for measuring K_{sat} of the unsaturated zone by the constant-head well permeameter technique (Amoozegar and Wilson, 1999). Furthermore, for using the Glover equation to calculate K_{sat} it is recommended that the ratio H/r be at least 5 (see Amoozegar, 1992). For our purpose, we will compare the calculated A factor for the Glover equation (Eq. [2]) with the corresponding values for Reynolds et al. (1985) and Philip (1985) models (Eqs. [3] and [4], respectively). For comparison we will use α = 12 m^{-1}, a value suggested for most soils by Elrick et al. (1989), in Eqs. [3] and [4]. The C factor of Eq. [3] was obtained from the respective graphs presented by Reynolds and Elrick (1986). Figure 6 presents the values of the A factor calculated by Eqs. [2], [3], and [4] for the Glover equation (Zangar, 1955), Reynolds et al. (1985), and Philip (1985) models, respectively. It is obvious that there is no significant difference

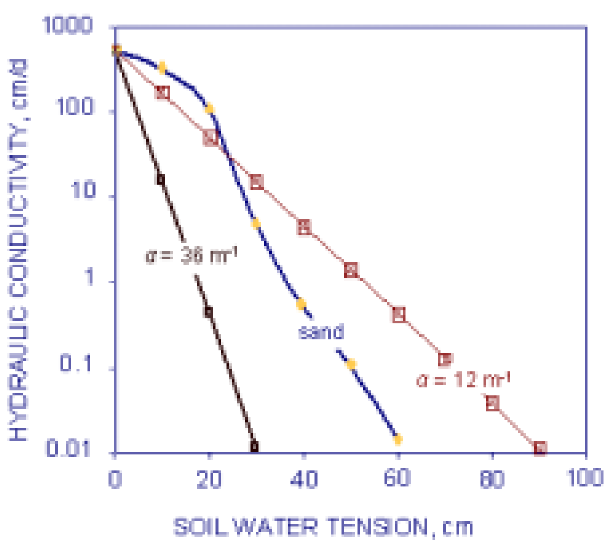

Figure 4. Measured unsaturated hydraulic conductivity as a function soil water tension (soil water pressure head h with a positive sign) for a sandy soil (after Bouma, 1975) and the calculated values by the empirical Eq. [6] for two α values.

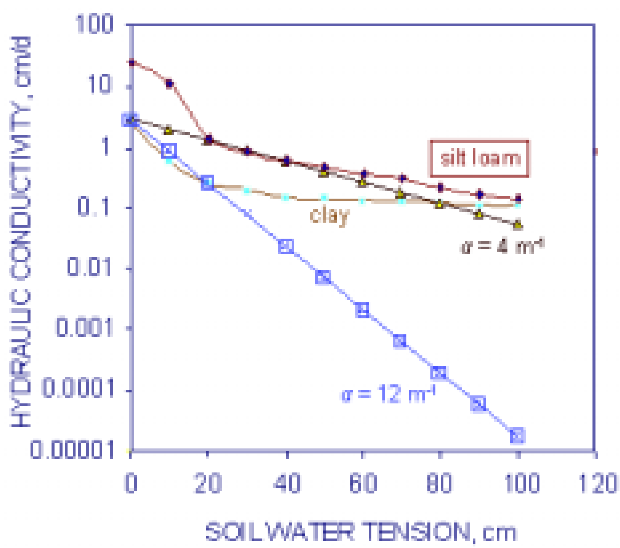

Figure 5. Measured unsaturated hydraulic conductivity as a function soil water tension (soil water pressure head h with a positive sign) for a silty loam and a clayey soils (after Bouma, 1975) and the calculated values by the empirical Eq. [6] for two α values.

between the A values calculated by the three models for all H/r values greater than 5. In fact, at *H/r* = 10 the difference between the *A* factor for the Glover equation and the other two models is less than the difference between the *A* factors for the Reynolds et al. and Philip models. At H/r = 5, the *A* factor for the Glover equation is approximately 20 percent more than the *A* factor for Philip and 50 percent more than the *A* factor for the Reynolds et al. model. Similar results are obtained for other α (and *C* factor of Eq. [3]) values.

Use of Fixed Values for the α Parameter

Because of problems associated with independently determining the α parameter Elrick et al. (1989) suggested to use four predetermined values for different soils. The drawback in using predetermined values for this parameter is that they may influence the calculated K_{sat} significantly.

The α values presented in literature vary substantially among various soils (see Bresler, 1978). Therefore, selecting only four values to represent all 12 textural classes (Fig. 7) does not appear to be logical. Furthermore, misjudging the soil texture and structure may significantly impact the resulting K_{sat} calculated for a set of field measurements. For example, for a 6-cm diameter hole (*r* = 3 cm) and 15 cm of water head (*H* = 15 cm), the error in misjudging the soil texture and selecting an α value of 36 instead of 12 m^{-1} results

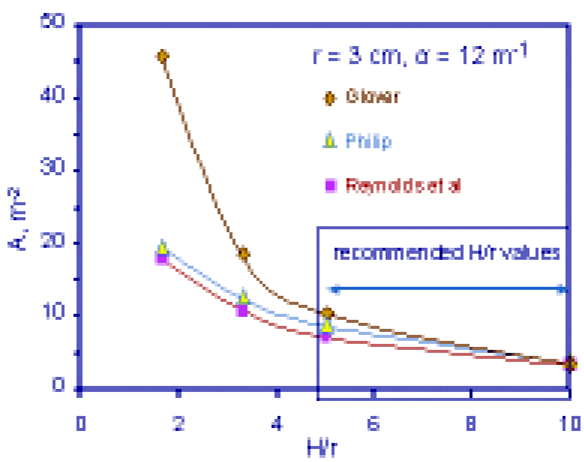

Figure 6. Comparison among the *A* factors obtained for the Glover equation and Reynolds et al. (1985) and Philip (1985) models for a 6-cm diameter hole in a soil with α value of 12 m^{-1}.

in an overestimation of K_{sat} by more than 38 percent. The error will be more than 87 percent if a clay soil with structure is considered to be structureless. Significantly higher over- or under-estimation will result if the true α value for a given soil is larger or smaller than the selected value by an order of magnitude. Also, Schoeneberger et al. (1995) measured K_{sat} and other properties of a clayey soil at three different landscape positions and demonstrated that K_{sat} of this clayey soil is independent of its texture (Fig. 8).

Conclusions

In the constant-head well permeameter technique, the saturated hydraulic conductivity, K_{sat}, of the soil is calculated after determining the steady-state rate of water flow, *Q*, from a cylindrical hole of known radius, *r*, under a constant depth (head) of water, *H*, at the bottom of the hole. The Glover equation developed for calculating K_{sat} ignores the water flow that may take place in the unsaturated zone away from the hole. However, its resulting outcome for a set of *r*, *H*, and *Q* is fairly close to the K_{sat} values calculated using the models that consider both saturated and unsaturated water flow from the cylindrical hole. The models that consider both saturated and unsaturated flow, on the other hand, are based on questionable assumptions and require knowledge of an empirically derived parameter, α, referred to as capillary factor or sorptive number. To calculate K_{sat} this unsaturated parameter must be determined independently or be assigned a value based on soil texture and structure. In this paper it was demonstrated that the majority of the assumptions made for developing the models that consider saturated and unsaturated flow are invalid for most soils. Furthermore, it was discussed that substantially more significant error may result if a wrong α parameter is selected based on soil texture and structure. In light of the closeness of the results of all the models available for calculating K_{sat} using H/r $\geq$ 5, the Glover equation is recommended for calculating this important soil property providing that *r*, *H*, and *Q* are measured accurately. The Glover equation is recommended over other models based on the following factors:

- The Glover equation is simple and can be calculated using a hand-held scientific calculator.
- The Glover equation does not require a separate *C* factor for different soils.
- All necessary parameters for calculating K_{sat} are measured in the field.

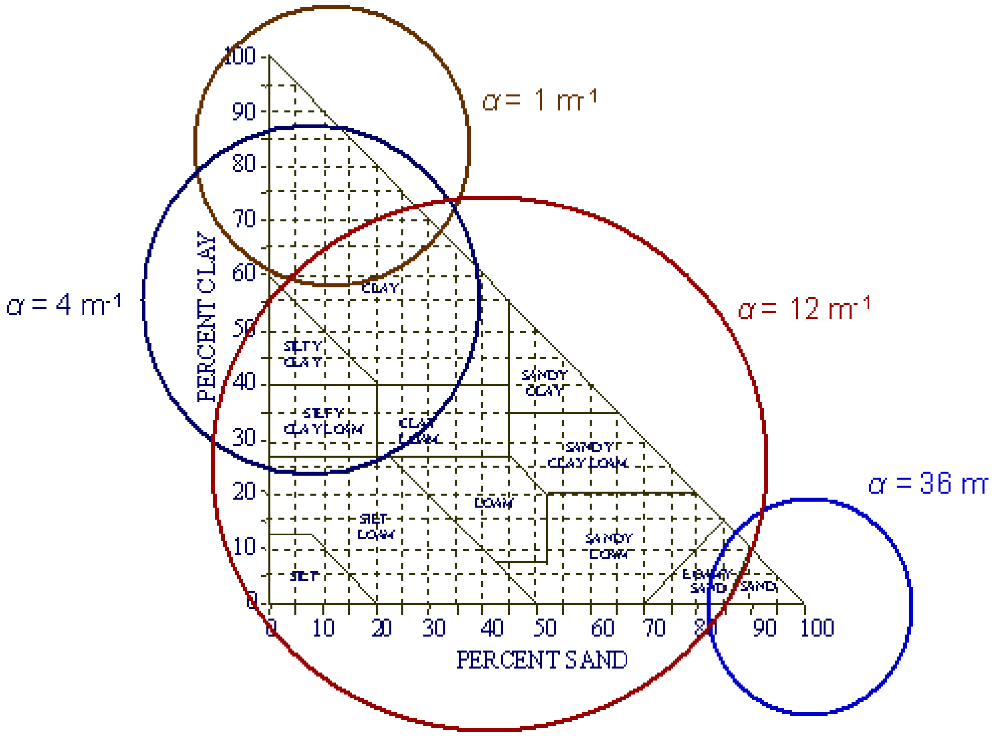

Figure 7. The textural triangle divided into regions based on predetermined α values.

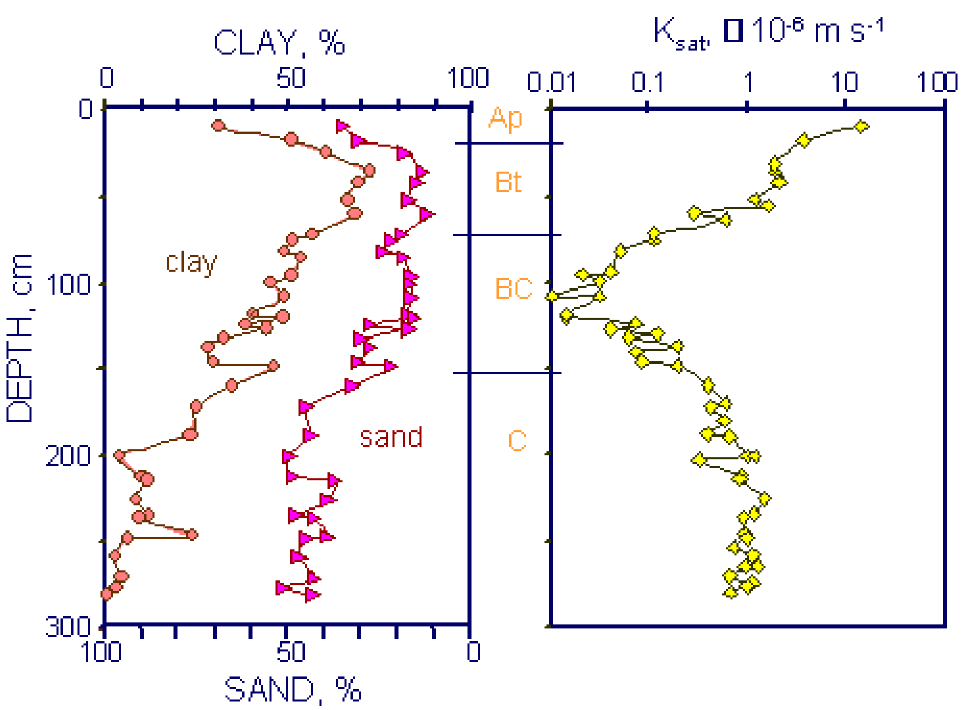

Figure 8. Soil clay and sand distribution and the associated saturated hydraulic conductivity of various horizons of a Cecil soil at a ridge top landscape position (after Schoeneberger et al., 1995).

- The Glover equation does not require estimation of any soil property.
- The calculated K_{sat} is comparable with the values obtained by other models providing that the ratio *H*/*r* is greater than or equal to 5.

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Testing Polyacrylamides for Turbidity and Erosion Control

By S.A. Hayes, R.A. McLaughlin, and D.L. Osmond

Sediment is the most widespread pollutant of streams and rivers in North Carolina, with construction sites a major source of accelerated erosion. This study was conducted to determine if the application of polyacrylamide (PAM) to soil surfaces on construction sites reduces erosion and turbidity. PAM has been demonstrated to greatly reduce erosion in furrows during irrigation events, and there is limited evidence it controls erosion when applied to bare soil.

Two PAMs applied at manufacturer's recommended rates (11.2 and 1.68 kg/ha) and one half the recommended rates (5.6 and 0.84 kg/ha), with and without straw mulching and grass seeding were tested on a N.C. Department of Transportation construction site in Raleigh. Runoff volumes, sediment in runoff and runoff turbidity data were collected after rain events.

On a 2:1 fill slope location, erosion rates were observed to be 20 times greater on bare soil plots after the first seven events, with or without PAM, compared to those mulched and seeded. During the eighth and last event, in which over 6 cm of rain was recorded for a nine-hour period, rates of 35–50 metric tons/ha of sediment were eroded from the bare soil plots compared to 3–9 metric tons/ha on the mulched and seeded plots.

Results at a second location with 4:1 slope showed mulching and seeding reduced sediment loss by 90 percent and decreased turbidity by 92 percent. Preliminary statistics have shown no affect of PAM in reducing sediment loss or turbidity on construction sites.

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Polyacrylamide for Sediment and Turbidity Control on Construction Sites

By Richard A. McLaughlin

There are many devices and systems designed to reduce the amount of sediment in runoff from construction sites. While these can retain over 90 percent of entrained sediment, the resulting discharge water is usually highly turbid, resulting in substantial impacts on receiving waters. One of the more promising and practical approaches to reducing turbidity is to add polyacrylamide (PAM) to flocculate the suspended particles and improve settling.

We tested several PAMs for their effectiveness in reducing turbidity in sediment traps and basins under simulated runoff conditions. The PAMs were commercially available as formulated blocks of approximately 4 kg of anionic PAM. The test system involved water flowing under gravity in a 30-cm pipe at variable rates of 850–2500 L/min with soil added approximately 10 m above the discharge into the sediment basins. Both flow and sediment concentrations were designed to simulate a 2.5-cm storm event.

The PAM blocks were placed inside the pipe below the point where the soil was added. Turbidities within the basin ranged up to 5,000 nephelometric turbidity units (NTU) during the peak of the events, and dropped to 200–400 NTU toward the end of the discharge period. Adding PAM to the system dropped the turbidity in the discharge at all points of discharge and NTU values were often below 100. Modifying the basins to slow the discharge or reduce turbulence further reduced the discharge turbidity. Increasing the PAM dosage by adding blocks to the system did not improve performance.

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Alternative Substrates for Estimating TCE-Degrading Capabilities of Toluene-Oxidizing Bacteria

By Kristin Hicks

One of the primary impediments to the implementation of bioremediation is uncertainty about success in the field. Biodegradation potential can be estimated in soil microcosm studies. However, the soils and microbial populations in contaminated sites are usually very heterogenous, and it is difficult to extrapolate biodegradation rates from small samples to field scale. One method used to estimate biodegradation rates in the field is the newly developed Push-Pull technique.

In a Push-Pull test, a prepared test solution containing a non-reactive tracer and one or more reactive ones is injected using an existing monitoring well. Within the aquifer, biologically reactive components are converted to various products by the indigenous microbial community. During the extraction phase, flow is reversed and the test-solution/groundwater mixture returns to the well where the concentrations of tracer, reactants, and products are measured. Analysis of recovered concentrations allows prediction of reaction stoichiometries and rates. The method is simple and fast.

The method has been widely used to measure rates of aerobic respiration, denitrification, sulfate reduction, and methanogenesis at gasoline-contaminated sites. In this study, we lay the groundwork for using this method to examine aerobic transformations of chlorinated solvents.

This technique involves injection and extraction of reactive and unreactive tracers into/from contaminated groundwater followed by the construction of mass balances and extrapolation of degradation rates. While these tests can be conducted on site, it is normally not possible to use target pollutants as the reactive tracers, and alternative, benign reactive tracers must be used. Ideally, these alternative reactive tracers interrogate the same enzymes systems that are responsible for the biodegradation of the target pollutant.

In this study we are interested in developing reactive tracers that can be used to assess toluene-dependent trichloroethylene (TCE) degradation. Our approach has been to determine whether a series of pure strains of toluene-oxidizing bacteria, each with different toluene-oxidizing enzymes systems, are capable of oxidizing a series of 11 potential alternative substrates. These substrates include simple alkenes and cyclic alkanes. The kinetics (K_s and V_{max}) of the biotransformation of these compounds have been determined. The next aim of this project is to use microcosm studies to compare the rates of alternative substrate transformation with observed rates of TCE transformation. The long-term aim is to implement these alternative tracers in field scale Push-Pull studies of TCE degradation at Edwards Air Force Base in California.

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POSTERS

Neuse Crop Management Project: Application of Environmental, Agronomic, and Economic Principles to Assist Agriculture

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Growers in the Neuse River Basin located in southeastern North Carolina are currently mandated to reduce nitrogen loading by 30 percent through implementation of best management practices (BMPs) over a five-year period ending August 1, 2003. This legislation is the result of recurring algal blooms and fish kills caused by eutrophication.

Neuse Crop Management Project is educating growers and industry personnel in the basin on strategies to effectively restore water quality. The three-year project combines efforts of growers, industry, agencies, and N.C. State University to work through solutions that apply sound economic, agronomic and environmental principles to implement BMP systems at the farm level. Demonstration farms are located in piedmont and coastal plain regions of the Neuse Basin.

At these locations, nutrient management, filter strips and controlled drainage are implemented and promoted to restore and protect surface water quality. The economics of BMP implementation are also being evaluated to help growers make the most cost-effective decisions. An Integrated Pest Management aspect of the project focuses on proper herbicide selection through the promotion of weed identification and the utilization of a decision aid called Herbicide Application Decision Support System (HADSS).

Our efforts are made possible through funding from the N.C. Clean Water Management Trust Fund, U.S. Environmental Protection Agency and the Pew Charitable Trust in cooperation with the Center for Agricultural Partnerships.

Enhanced GIS Procedures for Assessment of Nitrogen Loading from On-site Septic Systems to the Neuse River Basin

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Approximately 50 percent of North Carolina's population use on-site septic systems as their primary domestic wastewater treatment system. The existing models used to estimate pollutant loads consider categories such as agricultural, forested, and urban land uses that completely overlook the potential contribution due to the presence of on-site septic systems. Nitrogen contribution from on-site septic systems is significant since North Carolina has one of the highest rural, nonfarming populations in the country.

Effectiveness of Shrub Buffers on Nitrate-N Removal

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Elevated nitrate concentrations have been determined to be one of the major contributors to decreased water quality in the Neuse River Basin. This work is being conducted to evaluate the use of shrub buffers as a best-management practice for removal of nitrate from shallow groundwater before entering surface waters. Four buffers (three 15 feet wide and one 30 feet wide) situated between crop fields and drainage ditches were examined at a Lenoir County farm in the coastal plain region of North Carolina.

Sampling occurs monthly. The groundwater and surface water samples are analyzed for nitrate, orthophosphate, and ammonium. Groundwater samples were taken from wells, at depths of 7 to 8.5 feet and 9 to 11 feet, and surface water samples were taken from drainage ditches. The wells were located at the edge of the ditch, 15 feet from the ditch and 30 feet from the ditch (30-foot buffer only).

Preliminary data (2000) show that 60 percent and 57 percent of the nitrate entering the 15-foot buffers was removed by the time the water reached the edge of the ditch, in the shallow wells and deep wells, respectively. In the 30-foot buffers, 98 percent and 71 percent of the nitrate entering the buffer was removed from the shallow and ddep wells, respectively, before the water reached the ditch edge.

Future work using nitrate-chloride ratios and redox probes will be performed to assess the methods of nitrate removal. Preliminary data show that the greater the width of the buffer, the greater amount of nitrate removal from groundwater before contributing to surface water concentration in the drainage ditch.

Measuring Denitrification from Golf Courses in North Carolina: An Assessment of Acetylene Injection Methodologies

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Denitrification is one pathway in which nitrogen can be lost from a turf system. Preliminary research has characterized the loss of nitrogen by way of leaching and plant uptake. Determining the loss of nitrogen from a turf system through denitrification is essential in order to account for all avenues of loss.

Research is currently being conducted to assess the loss of nitrogen from a turf system by way of denitrification. The acetylene block technique is being used to assess the loss. Acetylene is used to block the reduction of nitrous oxide to dinitrogen gas.

Ryden et al. stated that between 0.1 and 1 percent acetylene vol./vol. is needed to completely inhibit the reduction. Acetylene can be injected in to the turf system through either headspace or soil injection.

Research was conducted to compare both methodologies. Methodologies were compared based on concentrations of acetylene found in the soil atmosphere. The methodology study was essential in order to prevent underestimation of denitrification.

Waste Analysis—A Tool for Improving Nutrient Management and Enhancing Environmental Quality

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The waste analysis laboratory of the N.C. Department of Agriculture and Consumer Services' (NCDA&CS) Agronomic Division provides chemical analyses of agricultural waste to protect the environment and preserve water and soil resources. Analyses of both liquid and solid waste samples are offered to serve North Carolina's nationally ranked livestock and poultry industries.

Animal manure is a valuable fertilizer. It contains the nutrients essential for crop production and improves soil nutrient-holding capacity and physical properties. Nutrient composition of animal waste varies widely with animal species, waste collection systems, types of growing operations and many other factors.

Waste analysis helps growers assess the potential of animal waste as a plant nutrient source by quantifying nutrient content and nutrient availability to crops. It also enhances environmental quality by providing information on potential hazards that might be created by over-applying waste materials.

Waste analyses measure concentrations of macronutrients (nitrogen, phosphorus and potassium); secondary nutrients (calcium, magnesium and sulfur); and micronutrients (such as iron, manganese, zinc, copper and boron). Other determinations—such as pH, carbon-to-nitrogen ratio and electrical conductivity (soluble salts concentration)—can be made on certain types of waste samples.

As regulations regarding animal waste disposal have increased, so have the number of samples processed by the Agronomic Division's waste analysis laboratory. Swine lagoon samples increased from 2,206 in fiscal year 1995–96 to more than 11,200 in fiscal year 2000–01. The same is true for the poultry industry samples, which increased from 353 in 1995–96 to 3,649 in 2000–01. Currently, more than 17,000 agricultural waste samples from all categories are processed at the lab each year.

Laboratory results are presented to the producer in a waste analysis report. Each report contains three sections: 1) chemical data from the laboratory analysis, 2) nutrient availability for the first crop and 3) specific comments and recommendations concerning the use of the waste material as a nutrient source.

Nutrient concentrations of waste vary, and waste samples should be analyzed on a systematic basis for each type of animal operation prior to land application. Summary data for samples submitted by growers in North Carolina during fiscal years 1996–2001 are presented by major animal waste categories and application types. Nitrogen, phosphorus and potassium content are summarized for anaerobic swine lagoon liquid, dairy manure liquid slurry, broiler house litter and turkey house litter. Values given represent amounts of *plant-available nutrients*: those estimated to be available to the crop the first year after application of animal waste.

The Agronomic Division's waste analysis laboratory makes chemical determinations for total Kjeldahl nitrogen, total phosphorus, copper and zinc that are certified by the N.C. Department of Environment and Natural Resources' (NCDENR) Division of Water Quality for compliance with North Carolina environmental regulations. Laboratory methodology, equipment and procedures are approved by NCDENR. The specific methods used are described by U.S. Environmental Protection Agency (USEPA) 351.2 and USEPA 200.7 designations.

Nutrient Removal from Swine Lagoon Wastewater by Constructed Wetlands

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Constructed wetlands have been considered to be a possible solution to the growing problem of managing excessive nutrients in areas of concentrated hog production. This study was conducted to evaluate nitrogen and phosphorus removal from swine lagoon effluent by constructed wetland microcosms. The study compared the nutrient removal efficiency of two species of wetland plants when treated with various concentrations of lagoon effluent (100, 75, and 50 percent strength).

In the second year, 50-percent-strength treatment was replaced by full-strength effluent that was nitrified by pretreatment with a gravel-based trickling filter. Water samples were collected from the microcosms and analyzed for total nitrogen (TN), ammonium N (NH_4-N), nitrate-N (NO_3-N), total phosphorus (TP), and phosphate phosphorus (PO_4-P).

The best plant growth and removal efficiency occurred when the effluent was 75 percent strength in 1997 when retention time was three weeks. Removal efficiency of TN was 47 percent for the no plant treatment, 91 percent for *Juncus effusus*, and 96 percent for *Scirpus validus*. TN removal efficiency was 30 percent less when two-week retention times were used in 1998. There was no significant difference in removal efficiency of NH_4-N between the no-plant treatment and the two-plant treatments.

In 1998, the best removal efficiency was found in nitrified lagoon effluent. The no-plant treatment removed 39 percent, *J. effusus* 73 percent, and *S. validus* 85 percent of TN. The nitrification/denitrification process was probably the dominant nitrogen removal mechanism. In the case of P removal, removal efficiency of TP was 34 percent for the no-plant treatment, 57 percent for *J. effusus*, and 76 percent for *S. validus* when retention time was three weeks (1997).

Phosphate-P removal followed the same trend. TP removal efficiency was 50 to 70 percent less when the two-week retention time was used in 1998. Phosphorus adsorption capacity of wetland soil was more saturated in second year, and it significantly decreased the P removal efficiency.

Wetland vegetation had a significant impact on nutrient removal from swine lagoon effluent, and *S. validus* was found to be more effective than *J. effusus* in nutrient removal. Nitrogen-loading concentration also had a significant effect on nutrient removal, and the best nutrient removal occurred when the concentration was 75 percent of full-strength lagoon effluent.

Transport of Dissolved and Particulate Phosphorus from Animal Manure under Simulated Rainfall

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No-till farming is used as a best management practice to reduce erosion and limit the entry of particle-bound P into surface water. However, it may do little to impede losses of dissolved reactive phosphorus (DRP), which is considered immediately available to algae and can promote eutrophication in fresh water. Areas with high-density animal husbandry use manure as a nutrient source, and it is surface applied to fields under no-till.

This study was designed to measure runoff losses of DRP and bioavailable particulate phosphorus (BPP) released from surface-applied animal manure. Simulated rain was applied at a rate of 75 mm/hr to topsoil packed to a bulk density of 1.5 g/cm^3 in 1-m by 0.5-m stainless steel boxes set at a five percent slope.

Broiler litter, solid swine manure, and triple superphosphate were surface applied at a rate of 224 kg/ha of P. Runoff was sampled five minutes after it began and every five minutes following for 30 minutes. Concentration and volume of DRP and BPP (estimated by 0.1 M NaOH extraction) were determined from the samples.

Using Struvite (Magnesium Ammonium Phosphate) as a Slow-Release Fertilizer

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Precipitation and removal of magnesium ammonium phosphate ($MgNH_4PO_4$-$6H_2O$), commonly known as struvite, is a promising mechanism for efficient nutrient removal from swine lagoon effluent. In addition to reducing soluble phosphate concentrations in waste, struvite can be used as a slow-release fertilizer and would, therefore, be a valuable waste by-product.

The objectives of this research were to (i) compare the nitrogen-release rate of struvite, when used as a fertilizer, to a highly soluble nitrogen source and a slow-release nitrogen source, and (ii) to evaluate the effects of struvite particle size on nitrogen-release rate.

In a greenhouse experiment, nitrogen uptake by ryegrass was measured 3, 6, 9, 12, and 15 weeks after planting following fertilization with coarse, medium, and fine particle-sized struvite and compared with ryegrass fertilized with ammonium phosphate and Osmocote®. Nitrogen uptake from struvite was less than ammonium phosphate for the first six weeks but greater than ammonium phosphate for weeks nine to 15.

Overall, the nitrogen-release pattern from struvite resembled that of ammonium phosphate more than Osmocote®. Based on this research, struvite is a valuable fertilizer with release properties slower than highly soluble fertilizers but faster than commercial slow-release fertilizers. Therefore, these results indicate that struvite would be a valuable nutrient source derived from anaerobic swine lagoon liquid.

Soil Spatial Variability and Management Zones in a Coastal Plain Field

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We characterized soil spatial variability in a field used for remote-sensing-informed nitrogen management and water quality research at the Lower Coastal Plain Tobacco Research Station. Our objectives were to assess the spatial variability of soil chemical properties across a landscape containing different soil types, and to determine management zones for improving N-use efficiency and soil productivity. Soils were sampled from 0–0.2 m at 568 sites in a 15-m equilateral triangular grid. Soil organic matter (SOM) was correlated with cation exchange capacity (CEC) and extractable sulfur (S), phosphorus (P), calcium, magnesium, potassium (K), and iron ($0.42 < r < 0.89$).

Semivariogram ranges for SOM, pH, P, and K varied from 45 to 90 m, and SOM spatial patterns were correlated with soil map units. Spatial patterns of SOM, P, K, S, and soil map units appear to be likely determinants for management zones within this field.

Determination of the Seasonal High Water Table in a Quartzipsamment Using Remote Recording Wells

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A site in the lower coastal plain of North Carolina has been proposed for residential development. The site is characterized as an iron-poor Quartzipsamment with few contemporary redoximorphic features. The site is composed of a ridge, shoulder slope, and side slope landscape position.

The governing regulatory agency evaluated the soils to determine suitability for the application of wastewater and determined that the site was limited by a seasonal high water table at the soil surface due to the observation of low chroma colors. The site was instrumented with remote water-table-monitoring devices manufactured by Remote Data Systems, Inc., to record the actual fluctuations of the free water surface from December 27, 2000, through April 30, 2001. The data were graphed to determine the number of days the soil was saturated at any given depth.

Watertable data were correlated with rainfall data to ensure that weather conditions were normal or above normal for the study period. Hydrographs were evaluated using an equivalent standard previously demonstrated by He and Vepraskas in eastern North Carolina that relates 14 to 21 days of continuous saturation in a well to morphologic features of chroma 2 or less that are indicative of seasonal saturation. The monitoring well data showed that the actual depth to the seasonal high watertable was between 69 cm and 102 cm below the soil surface and was proportional to landscape position.

A Remote Data Recording Device for Documenting Water Level Fluctuations

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Remote Data Systems, Inc., has developed a capacitance-based, electronic instrument for documenting water-level fluctuations. This device has applications in numerous environmental studies. Typical applications include determination of seasonal high water table for wastewater drainfield location, stream level monitoring, documentation of tidal fluctuations, and observation of wetland hydrology.

A specific application of the WL Series was to determine wetland hydrology for a proposed wetland mitigation site for a highway construction project. The mitigation site is a 182.5-hectare tract in the lower coastal plain of North Carolina. Twenty-three WL-40's were installed in various locations to accurately represent the hydrology of the site. The instruments were configured using a Hewlett Packard 48G calculator with a custom Remote Data Systems, Inc., software package to record water-level measurements every 24 hours. The first WL instruments were installed in October 1999 and will remain on site monitoring the wetland hydrology for a period of 5 years to determine regulatory compliance.

Using GIS and Spatial Analysis to Evaluate the Realistic Yield Expectations of Soil Types in the North Carolina Coastal Plain

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Realistic yield expectations (RYE) have been developed in North Carolina to assist in site-specific farming decisions that will improve nitrogen-use efficiency and reduce nitrogen contamination of ground and surface water, particularly in the Neuse

River Basin. We will be working on two spatially related coastal plain fields in Wayne County. Yield monitoring data have been collected in these fields for two years. This study will be conducted to determine whether correlations exist among RYE, fertilizer application rates, actual yield, soil type, and soil test results. Yield maps will be generated and overlain with soil map units and their associated RYEs. Soil samples will be collected on an equilateral triangle grid, analyzed, and used to map phosphorus, potassium, pH, and lime requirement. We will use the results to evaluate RYE and to help optimize strategies for sampling and management to improve nitrogen-use efficiency and minimize nitrogen loss.

Determining a Boron Deficiency Threshold for a Tobacco Float System

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In young tobacco transplants produced in hydroponic float culture, the visual symptoms of boron deficiency are so similar to those of chilling injury that they cannot be distinguished readily by gross morphological characteristics. The objectives of this study were to determine the mechanisms that produce boron deficiency and chilling injury symptoms and to examine the possibility of any related mechanisms between boron deficiency and chilling injury.

Four varieties of tobacco were grown under controlled-environment conditions in floatbed culture at three concentrations of boron between 0.19 and 19 mM in the hydroponic solution to evaluate thresholds of boron deficiency in young transplants. In a second study, the four varieties were grown in a floatbed system under four day/night temperature regimes of 32/14, 26/22, 26/26, and 21/21 °C and two boron concentrations of 0.19 and 19 mM to examine the compounded effects of temperature and boron concentration on development of visual symptoms.

Plants were harvested at five- or seven-day intervals over a 30- to 54-day treatment period for determination of fresh and dry mass, leaf area, plant height and tissue boron concentration. Boron deficiency symptoms were produced in hydroponic solutions containing concentrations of boron below 1.9 mM.

Nutrient Release Rates from Two Tropical Forage Legumes in a Kenyan Environment.

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Soil fertility decline is one of the factors limiting food production on the east coast of Africa. Increased awareness by smallholder farmers of the role of legumes as food, fodder, and for soil fertility improvement has stimulated research on the influence of herbaceous legumes in various cropping systems. Decomposition and nutrient release from foliage of forage legume species clitoria (*Clitoria ternatea*) and dolichos (*Lablab purpureus*) planted in monoculture or as an intercrop with tropical food crops cassava (*Manihot esulenta*) and maize *(Zea mays*) were evaluated under field conditions in a sandy, kaolinitic, isohyperthermic typic Eutrustox/ Paleustalf.

Clitoria was harvested every 6 or 10 weeks after the first harvest, while dolichos was harvested two and four months after planting. Nylon mesh bags (50µm openings) were placed in the field following each legume harvest management and then retrieved at 0, 1, 2, 4, 8 and 16 weeks after placement.

A single exponential model fit clitoria and dolichos dry matter disappearance across the different harvest management strategies. The rate coefficients for dry matter disappearance ranged from 0.5 to 0.28 k week^{-1}. Legume residue from the shorter harvesting interval disappeared faster than that of the longer harvesting interval.

Across all cropping systems, an exponential model best fit nutrient release from clitoria residue, with the exception of K, which was described by a double exponential model. An asymptotic model best described N, P, and Mg release from dolichos residue while K was best fit with a single exponential model.

Overall, the k-values obtained for clitoria were much lower (0.01 to 0.11 k week^{-1}) than those for dolichos (0.05 to 2.50 k week^{-1}). The shorter harvesting strategy resulted in higher nutrient release rates of N, P, K, and Mg in clitoria; and K and Mg in dolichos. Results for Ca release did not fit any of the NLIN regression models, thus not allowing the release estimate of k-values.

The lowest *k*-values were found for organic C (0.01 for clitoria and 0.05 for dolichos), implying a low rate of decay and long periods of organic C retention under the environmental conditions of the study. Relatively slow N release was observed for clitoria (0.05 k week^{-1}), suggesting that factor(s) other than the C:N ratio, perhaps polyphenolics, were governing release.

Further research is needed to characterize the synchronization between residue nutrient availability and crop nutrient demand.

Cotton Response to Potassium Applications

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The Agronomic Division of the N.C. Department of Agriculture and Consumer Services (NCDA&CS) conducted a two-year study to evaluate the effect of soil-applied potassium on yield of cotton (*Gossypium hirsutum* L.). Growers in North Carolina routinely make spring applications of potassium to cotton fields to ensure a high level of soil fertility. Historical NCDA&CS soil test data indicate that a cotton crop grown on a soil containing 176 ppm of Mehlich-3 extractable potassium [potassium index (K-I)=90] does not require additional potassium. Still, many growers continue to apply potassium, believing it is necessary to achieve “highest possible” yields.

The primary objective of this study was to study the influence of soil-applied potassium on cotton yield. Leaf and petiole potassium were measured periodically throughout the growing season to check plant uptake and determine whether potassium is, in fact, a yield-limiting factor.

Field studies were conducted in Cumberland, Gates and Wayne counties during 2000 and 2001. These fields had an average pH of 6.3 and an average NCDA&CS soil-test K-I value of 73.

Plots were laid out in a modified complete block design with three replications. There were three preplant potassium treatments: 0, 67.2 and 134.4 kg of potash (K_2O) per hectare supplied from blended fertilizers. All treatments were disked and row beds established in 2000; plots were strip tilled in 2001.

Standard cotton varieties for the area were planted in May of 2000 and 2001. All other management considerations were left to the growers’ discretion. Leaf and petiole samples were collected from each plot at four stages of plant growth. Plot yields were measured for all locations in 2000 and for the Gates and Wayne county sites in 2001.

In 2000, varied growing conditions existed for each test, with the Gates County location being very wet, the Cumberland County location being dry early in the season, and the Wayne County location having the most optimum weather for cotton production. Yield data from the three sites show no response to soil-applied potassium. The soil potassium values of the control plots at each site were approximately 140 ppm (NCDA&CS K-I=70) so minimal benefit from extra potassium was anticipated. In 2001, there was also no yield response to applied potassium.

Leaf and petiole data show declining potassium levels after bloom. In cotton, the uptake rate and accumulation of potassium has been shown to reach a maximum at peak bloom then decline until maturity of the crop (Mullins and Burmester, 1990). During the peak period, plants can take up 1.4–1.8 kg K_2O daily.

Sufficiency ranges for leaf and petiole potassium have been compiled, and critical levels of potassium in the leaf and petiole have been shown to decline after bloom. At bloom, the critical value for leaf potassium is 1.5 percent (NCDA&CS K-I=50). As plants mature, the accepted critical value is 0.75 percent.

These researchers also report petiole potassium critical values during bloom and document declining values as bloom progresses. The critical value is 4 percent at bloom and 3 percent four weeks after bloom. Data from the current study confirm movement of potassium from leaves and petioles, but even so, leaf and petiole potassium levels remained well above critical values for each fertilizer regime.

Cotton does not require additional K fertilizer if soil potassium levels are at or above 140 ppm or if the NCDA&CS soil-test K-I value is 70 or higher.

Speciation and Dissolution of Phosphorus in an Ultisol as Affected by Redox Potiential

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Soil redox potential affects the solid phase speciation and dissolution of soil P. At neutral to slightly acidic pH, more reducing conditions often lead to enhanced P mobility and more oxidizing conditions may inhibit P mobility. The objective of this research was to determine differences in the dissolution and solid phase chemical speciation of P as an acidic soil sample underwent reduction.

A sample of surface soil (0–7 cm) collected from Tidewater Research Station, Plymouth, NC, was analyzed for pH, and oxalate and citrate bicarbonate dithionite (CBD) extractable P, Fe, Mn and Al. The soil sample contained about 900 mg/kg of P. An aqueous suspension of the silt + clay fraction was reduced for 40 days by incubating in a continuously stirred reactor under dinitrogen gas, after adding dextrose. Suspension samples collected periodically from the stirred reactor were analyzed for P, Fe, Mn and Al in the aqueous and solid phases, respectively.

As Eh decreased and pH increased over time, dissolved P increased from an initial concentration of 1.3 mg/L to a maximum concentration of 11.0 mg /L. Dissolved Fe increased from 0.34 mg/L to 2.1 mg/L, suggesting that Fe-oxide minerals may play a role in redox-dependent P dissolutions.

Retention of Iodide by Silver Chloride

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The development of geochemical barriers to retard the migration of radioactive anions is important in the design of systems for radioactive waste isolation, such as at the high level waste (HLW) repository at Yucca Mountain Nevada. One major anion of concern is radioactive iodide. Our research objective was to determine the iodide retention characteristics of silver chloride (AgCl). Sorption isotherm experiments were completed at pH 5.9 in 25 mM sodium nitrate electrolyte background, and with 48 hours of equilibration. Thermodynamics show that iodide would be retained by dissolution of AgCl and precipitation of less soluble AgI. The maximum level of iodide on sorbed silver chloride was 2.8 mmol/kg, which is 40 percent of the stoichiometric transformation of AgCl to AgI. Iodide retention in the AgCl system was nine-fold greater than that previously found for tuff, a material from the HLW site at Yucca Mountain.

Dissolution of Heavy Metal Contaminants from Soils as Affected by pH

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The solubility of heavy metal contaminants in soils depends on metal concentration, chemical speciation and conditions such as pH. For example, metal cation solubility typically increases with decreasing pH. Our objective was to determine the pH-dependent dissolution (mobilization) of metal contaminants in soil samples collected from two abandoned incinerator sites at a Marine base in eastern North Carolina.

Concentrations of heavy metals in 17 samples were 1–101 mg/kg zinc (Zn), 2–45 mg/kg copper (Cu), 3–105 mg/kg lead (Pb), 0.3–12 mg/kg chromium (Cr), and 0 –10 mg/kg arsenic (As). Acidified calcium chloride solutions were flowed through soil columns 1-cm long by 3 cm in diameter to decrease effluent pH from near neutral to about 4 over 300 hours.

As pH decreased, dissolved Cu, Pb and Zn concentrations in the column effluent solutions increased to maximum concentrations of 0.16 mg/L Zn, 0.054 mg/L Cu and 0.045 mg/L Pb at pH 3.8–4.1. Dissolved Cr concentration remained below our analytical detection limits of 0.42 mg/kg. Synchrotron X-ray-absorption-near-edge-structure (XANES) analysis showed soil samples from around incinerator sites contained predominantly As(V) and Cr(III), the less toxic and less mobile forms of these elements. Results indicate that heavy metals in soils at concentrations less than 100 mg/kg may become mobilized when soil becomes extremely acid.

Phosphorus Adsorption in Mixed-Mineral Systems

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The capacity of soils to bind phosphorus depends in part on the amounts and types of Fe- and Al-oxide minerals present. In soils that undergo periodic changes in redox conditions (wetting and drying), phosphate associated with Fe(III)-bearing minerals may be affected more than that associated with Al-bearing minerals. To understand such processes, we used phosphorus K-XANES (x-ray absorption near edge spectroscopy) analysis to try to assess the distribution of phosphate between Fe- and Al-oxide minerals in mixed mineral systems.

Phosphate was adsorbed at levels between 5 and 500 mmol/kg to single- and mixed-mineral systems containing goethite and gibbsite at pH 6. The maximum phosphate adsorption capacities were about 500 mmol/kg (goethite) and 100 mmol/kg (gibbsite). Because P K-XANES spectra varied with the amount of adsorbed phosphate, single-mineral systems containing different levels of adsorbed phosphate were used as standards in linear combination fitting to determine whether the distribution of phosphate between each mineral in the mixed system could be quantified.

Phosphorus K XANES spectra of phosphate adsorbed on goethite and gibbsite showed similar concentration dependent spectral features, including a diminishing shoulder intensity and a shift in white line peak energy with increasing level of adsorbed phosphate. These similarities in XANES spectra diminished the power of linear combination fitting.

Dissolved Soil Organic Carbon in the Rhizosphere of Bermudagrass Turf

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Since the dissolved organic carbon (DOC) is important as an energy source for soil microorganisms, measurement of DOC might provide an indirect assessment of denitrification potential. The objective of this study was to determine DOC concentrations at three North Carolina golf courses as a function of soil depth and landscape position.

Suction cup lysimeters were installed along transects crossing the fairway, roughs, and adjacent non-play areas. They were positioned at 30, 60 and 90 cm soil depths. Soil solution samples were collected from June to October 2000.

Mean DOC values for the fairway positions at Kinston (493 to 606 ppm) were higher compared with the fairways at Wilmington (221 to 231 ppm) and Pinehurst (161 to 176 ppm). The DOC concentrations for the rough and wooded non-play positions (181 to 269 ppm) were similar among the three sites. The higher DOC at Kinston may have been due to winter overseeding the fairways with perennial ryegrass (*Lolium perenne* L.). The results indicate that the golf course turf-ecosystem contains extremely high DOC, considerably greater than agro-ecosystems, that could provide substrate for denitrifying microbial populations.

Soil Translocation by Tillage on Steeplands in Nicaragua

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One process contributing to the degradation of tilled steeplands is the movement or translocation of soil downslope due to tillage. The objective of this study was to evaluate the rate of soil translocation on steepland soils, tilled manually using a hoe, in the El Pital Watershed in Nicaragua. Erosion plots, 3 m wide and 20 m long, were installed in 1994 on volcanic soils with slopes ranging from less than 10 to greater than 50 percent.

One experimental approach evaluated the soil translocation rate due to tillage operations associated with growing two crops per year for the 1994–1999 period. Detailed measurements of soil surface elevation within the borders of the erosion plots were compared with the soil surface elevation of the grass-covered soil surrounding the erosion plots.

The second approach assessed the movement of small brass ‘soil translocation markers’ placed at the 5-cm depth at exactly measured loci in the plots. After one year, each marker was located using a metal detector and its exact loci recorded. Soil translocation rates based on these markers ranged from less than 10 to greater than 70 cm per year.

Zones of Soil Loosening Produced at Differing Depths by a New "Variable Depth Ripper" as Compared to Other Deep Tillage Machines

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Many farmers feel that deep tillage is important to reach the yield potential of large areas of their pan-layer prone land. This tendency for "tillage pans" occurs in the better-drained soils with sandy influence in the Coastal Plain region from Virginia to Texas. Well-recognized research publications from institutions in the Southeast and Mid-South have clearly documented the nature of these root-impeding pan layers, how these layers limit normal root uptake of potentially available soil moisture and the resulting restriction of crop yields.

Research projects have also noted that these dense soil pan layers are associated with textures that include marked influence of sand (especially loamy sand and sandy loam), and with a soil horizon low in organic matter (typically most or all of an E horizon and a little of the lower part of a sandy A horizon). Generally the dense layers do not occur in soil horizons with greater clay content (sandy clay loam, clay loam, silty clay loam), because of the effects of greater soil structural strength and porosity that are associated with the influences of greater clay content.

Clearly, for the most effective operation of deep tillage equipment a working knowledge of these soil characteristics is needed. Of most importance, is having the practical equipment capability to readily adjust tillage depth to match the existing and varying soil properties. A desired tillage depth ranging from 6 to 16 inches (15 to 40 cm) is not uncommon. The PATS brand of strip tillage has just developed a very effective version that hydraulically varies ripper depth "on the go," and within about 40 inches (1 m) of travel distance. The zone of soil loosening of its modified ripper compares favorably to other subsoiler points and deep tillage tools. This opens a new opportunity for agronomists who advise farmers, in helping them utilize this proven area of soil science knowledge more effectively and efficiently than was possible in the past.

Effects of Ruts in Piedmont Soils, Caused by Heavy Waste Application Equipment, as Shown by Bulk Soil Density and Porosity and the Associated Corn Silage Yields

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Studies were conducted for two years in two fields of the North Carolina Piedmont region to evaluate the effects of equipment ruts on soil bulk density and porosity, and on corn (*Zea mays* L.) yields under conservation tillage culture. Compaction and rutting had been caused by truck application of dairy lagoon waste in winter and early spring in wet fields. We studied areas of multiple tracking (main entry paths in the fields) as well as single-pass tracks made by the spreading operation.

In one field the first year, we were able to apply and compare the effects of several forms of pre-plant, corrective tillage in parts of the rut areas. The first year, corn silage yields were collected. Several sets of undisturbed soil cores were taken over the two years from the rut and from nearby non-rutted areas. Cores were also taken from areas of corrective tillage¸ which had been applied the first year.

Unfortunately for the objectives of the project, in the spring and summers of the study period, soil conditions were generally dry. This prevented additional rutting from second-year waste applications, which we had planned to study. It also made core sampling difficult and less valuable at some sampling times.

Soil bulk density and porosity were determined on the core samples. Percentage pore volume at several pressures up to 500 cm water tension was measured.

In general, single-pass ruts caused no clear reduction in crop yields the first or second seasons afterward, and did not justify corrective tillage unless ruts were deep enough to cause equipment damage or inability to establish crop seedlings there. In the rutted, severely-compacted areas, where multiple tracking over several years had occurred, even corrective tillage did not consistently improve yield. These areas should be kept to a minimum and be considered roadways. Where there is risk of water pollution from sediment or waste sources, this should be prevented by appropriate soil berms and vegetated buffers.

Atmospheric Concentrations of Ammonia/um Aerosols in a Region with Large-Scale Animal Production Facilities

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Walker, J.T., Chemist, U.S. Environmental Protection Agency, Research Triangle Park, NC

In this study, we present approximately two years (January 1999 to December 2000) of ammonia (NH_3), ammonium (NH_4^+), hydrochloric acid (HCl), nitrate (NO_3^-), nitric acid (HNO_3), nitrous acid (HONO), sulfate ($SO_4^=$), sulfur dioxide (SO_2), and chloride (Cl^-) concentrations measured by the annular denuder method at an agricultural site in North Carolina's coastal plain region. This site is in a multi-county region that has experienced a significant increase in cumulative NH_3 emissions from agriculture over the last decade.

The 2-year mean ambient NH_3 concentration at this site is 5.6 (±5.13) µg m^{-3}. On average, NH_3 comprises 72 percent of total $NH_3 + NH_4^+$. The excess of NH_3 during all seasons indicates that NH_4^+-based aerosol formation is limited by the availability of HNO_3 and sulfuric acid (HSO_4) and is, therefore, sensitive to changes in emissions of nitrogen oxides (NO_x) and SO_2.

The average concentration of total NH_4^+-based particulate matter with aerodynamic diameters < 2.5 µm ($PM_{2.5}$), including $SO_4^=$, NO_3^-, NH_4^+, and Cl^-, for the entire 2-year period is 8.0 (±5.84) µg m^{-3}. $PM_{2.5}$ concentrations are highest during warm months, when $SO_4^=$ becomes the primary constituent. On average, $SO_4^=$, NO_3^-, NH_4^+, and Cl^- account for 53, 24, 22, and 1percent of total NH_4^+-based $PM_{2.5}$ mass.

Daily average maximum and minimum NH_4^+-based $PM_{2.5}$ values are 31.2 and 0.36 µg m^{-3}, respectively, while the first quartile (Q_1) = 3.55 and the third quartile (Q_3) = 10.9 µg m^{-3}. Observed Cl^- concentrations are likely biased low, due to dissociation of ammonium chloride ($NH_4^+Cl^-$) aerosol on the primary Teflon collection filter. Quantification of Cl^- on the backup nylon filter would correct this bias.

Use of Simulants to Determine the Fate of Chemical Warfare Agents in Soils

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The fate of a chemical discharge to the soil environment is controlled by the nature of the soil and a substance's physical-chemical properties. Sorption studies were conducted using the following chemical warfare (CW) agent simulants: Bis 2-ethylhexyl phosphonate (BIS) (simulant for VX), 2-chloroethyl ethyl sulfide (CEES) (simulant for mustard), and malathion (simulant for sarin) to determine the major chemical and physical parameters controlling the environmental fate and transport of CW agents and related compounds in well-defined soils.

Eighteen soil samples (4 Entisols, 4 Alfisols, 4 Ultisols, 3 Mollisols and 3 Aridisols) from Department of Defense CW sites in the United States were obtained and their soil physical-chemical properties determined (sand, silt, clay content, clay types, organic carbon (OC) content, pH and surface area). CW sorption data were obtained by equilibrating 2-g samples in 20 ml of water containing various rates of CW simulants for 18 hrs. Concentration of CW simulants remaining in solution was determined by GC-MS.

The amount of CW simulants sorbed increased with increased rates applied for all soil samples. On average, the Mollisol samples with higher organic carbon content sorbed the highest amounts of CW simulants. Calculated distribution coefficients (K_d) for the different soil samples and size fractions varied from 1.2 in Sassafras sand (an Ultisol) to 185 in the Oneil clay fraction (a Mollisol).

There was little variation in partitioning coefficients (K_{oc}) among whole soil samples for a given CW agent simulant. However, higher K_{oc} values for soil clay fractions with low organic matter content suggest that mineral clay surfaces may contribute to retention of CW agent simulants in soils. The K_d values of CEES, BIS, and malathion were correlated to organic carbon content (R^2 = 0.85, 0.75, and 0.92, respectively) showing the influence of OC on CW simulant retention.

Perchlorate Content of Fertilizer Raw Source Material and Blends

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Perchlorate contamination of surface water and groundwater has been detected in parts of the United States. Improper handling of perchlorate waste from repacking of solid-fuel rockets and the manufacture of pyrotechnics are identified sources of this contamination. However, commercial fertilizers have also been implicated as a potential source.

Fertilizer source materials (ammonium nitrate, ammonium sulfate, dihydrogen ammonium phosphate, granular urea, KCl, liquid UAN, monohydrogen ammonium phosphate, single super phosphate, triple super phosphate, phosphate rock) produced in North America were analyzed for perchlorate content using ion chromatography (Dionex AS-16 anion column) following a 24-hr extraction with distilled water (1:10 solid to solution ratio). In addition, various lawn and garden fertilizer blends were obtained from across the United States.

After two years worth of intensive investigation only fertilizer products produced or which contain fertilizer source materials generated from specific nitrate deposits in Chile have been found to contain detectable levels of perchlorate.

Atmospheric Ammonium in a Region with Large-Scale Animal Production Facilites

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There have been substantial changes in animal populations (swine, poultry, turkey, cattle) and nitrogen fertilizer use in the N.C. coastal plain region over the past ten years. For the entire state, swine production accounts for 46.5 percent (77,700 tons NH_3-N; 1996 populations) of all estimated NH_3-N emissions (167,200 tons NH_3-N).

Within the six-county area in eastern North Carolina with the highest swine population densities, swine production accounts for approximately 80 percent of the estimated emissions from domestic animals. Ammonia concentrations measured immediately adjacent to a swine waste lagoon during 1999 reached a maximum of 1,244 parts per billion (ppb), which is below the state's Acceptable Ambient Limit of 3,900 ppb.

Measurements of throughfall in forest canopies within the immediate vicinity (less than 3 km) of swine production facilities show enhanced deposition of ammonium-N as compared to forest canopies more than 5 km from such facilities. The measured ^{15}N isotopic composition of ammonia emitted from a swine waste lagoon and ammonium in rainwater deposited near a large-scale swine production facility demonstrates that local emissions of ammonia are contributing to the ammonium in rainfall.

Statistical modeling demonstrates a correlation between enhancement of ammonium in weekly rainwater collected at coastal plain NADP/NTN sites and tracks of storm events passing over the counties with the highest density of animal production facilities. Directly or indirectly deposited, organic nitrogen, nitrate, and ammonium appear to contribute between 15 and 40 percent of the externally supplied nitrogen being introduced into the Neuse River estuary. Research conducted thus far suggests that animal production in eastern North Carolina is influencing direct and indirect nitrogen input to the state's coastal aquatic systems.

Stratigraphy Below a Migrating Carolina Bay

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Carolina Bays are elliptical depressions found along the Atlantic coastal plain and are oriented NW-SE. Juniper Bay is a 296-hectare bay in Robeson County, North Carolina. To determine the geological setting and natural history of this bay, 28 cores located on the rim, inside, and outside the bay were collected on an equilateral triangle grid, to depths of 6 and 15m.

Observations indicate a buried surface within the bay between 1 and 2.7 m. A stratum between 3.6 and 7.3 m that contained fossilized shells from the Yorktown or Duplin Formation (Pliocene) was penetrated. Coarse sand or laminated clay occurred near those depths throughout the bay.

A wavy-flaser unit, identified as the Black Creek Formation (Cretaceous), extended downward from depths between 6.8 and 7.3 m. Outside the bay, the top of this unit occurred between 7.5 and 11.4 m. Rim cores consisted of 4.9 m of sand overlying finer-grained sediment.

Interpretations suggest that the bay is underlain by the Black Creek Formation, which is overlain by an eroded member of the Yorktown or Duplin Formation. Juniper Bay formed on this surface, likely in a sand blanket that had covered the erosion surface. The depression was then shaped by episodic wind and water events and was filled-in with alluvial and eolian material. Observations from aerial photos and core data suggest that this bay has migrated northward and is merging with another bay.

Soil Development in a Chronosequence of Created Salt Marshes

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Development in coastal areas frequently impinges upon salt marsh wetlands. New wetlands are constructed to mitigate damage to these ecologically important areas, but they are often established on dense, sandy, dredge material that lacks the organic matter and nutrients characteristic of natural marshes. Since soil characteristics are useful indicators for ecological function, it is important to assess the time required for constructed marshes to develop soil properties equivalent to those of natural marshes.

Ten constructed salt marshes, ranging in age from 1 to 28 years, provided a chronosequence of soil development. Ten natural marshes provided a reference against which the soil properties of the developing marshes could be compared in terms of bulk density, particle size distribution, soil organic carbon content, soil and root [macro-organic matter (MOM)] nutrient levels.

The 0–10-cm layer of the constructed marshes has strong trends of decreasing bulk density and increasing MOM nitrogen, silt content, soil organic carbon and nitrogen content with age. A comparison of predicted values for the constructed marshes with average values for the natural marshes indicates that in the first 13 years after establishment, the constructed marshes have higher bulk density, lower soil carbon, nitrogen and phosphorus content, and lower MOM nitrogen than an average natural marsh in both soil layers.

However, by 24 to 28 years, the constructed marshes have soil properties in the 0–10-cm layer not significantly different from those of an average natural marsh. In the 10–30-cm layer, the constructed marshes remained significantly different from the average natural marsh. This indicates that soil development in constructed marshes is restricted to a thin surficial layer.

The Effects of Fire Frequency and Fire Intensity on VAM Fungal Population at Schenck Forest

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Prescribed burning can affect the dynamics of the microorganism communities, such as VAM fungi, living in the forest ecosystem. The effects of prescribed fire on VAM fungal population was assessed in an annually burned eight-acre loblolly pine stand and in a 24-acre, seven-year burned rotation stand at Schenck Forest, Raleigh, NC.

About 150 g of ten pre-fire and post-fire samples and ten controls were randomly collected from each site at a depth of 1–2 cm and 5–6 cm during summer 2000/2001 and winter 2000/2001. Each sample point consisted of three composite samples, totaling 30 samples from each site. All soil samples were air-dried at room temperature (23°C) then stored at 4°C before each spore extraction with wet sieving and sucrose density centrifugation (3500 RPM).

Spore counts of each soil sample were done using the Grid Method. Trap culture of all samples was conducted in a greenhouse. One spoon of about 30 seeds of Sudangrass, a local leguminous species known to form VAM, was planted in pasteurized clay pots in a 1:1 ratio of sandy loam and sand.

A simple t-test was used to see the difference between post-burn versus pre-burn plot spore density and diversity and between control and post-burn plots. A t-test was also used to compare the variation in spore density and diversity between year-one and year-two winter and summer data.

Preliminary results (15 percent of data processed) showed that prescribed fire intensity (average 350°F) does not affect the spore density at depths below 2 cm. Higher fire frequency in plot #11 compared to lower fire frequency in plot #24 decreases the spore density and diversity in all treatments. The major spore population in the burned sites are different from the main spore population in the controls in both #24 and #11 plots. Spore diversity was less in post-burn plots in the annually burned stand compared with the control.

Measuring Nitrogen Availability in a Loblolly Pine Stand with Ion-Exchange Resins

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Evaluating the fundamental relationships between soil type, drainage class, long-term productivity, and forest management practices is an integral part of deepening our understanding of the lasting effects of modern silvicultural techniques. As part of the USDA Forest Service Long-Term Site Productivity study, the effects of harvest intensity, site preparation, and weed control on nitrogen form and availability were analyzed.

Three levels of organic matter removal (stem only, whole tree, and whole tree plus forest floor) and two levels of compaction (none and severe) were assessed on the herbicided plots of Blocks 1, 2 and 3 throughout the growing season (year 2000). Block 1 consists primarily of moderately well-drained Goldsboro soil while Blocks 2 and 3 consist of somewhat poorly drained Lynchburg soil. Plant Root Simulator™ probes were used to assess the supply rate of soil nitrogen in the test plots at two depths: 0–5 cm and 5–10 cm.

Two hypotheses are tested in this research:

(1) whether the interaction of soil drainage class and silviculture treatments have a longer-lasting effect than the silviculture treatments alone, and

(2) whether, in better drained soils, the compaction and organic matter removal effects on nitrogen form and availability at year ten will have diminished.

Water Movement from a Cylindrical Auger Hole in the Vadose Zone

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The constant head well permeameter technique is commonly used for measuring the saturated hydraulic conductivity (Ksat) of the vadose zone in situ. In this procedure, the steady-state rate of water flow under a constant head of water in a cylindrical auger hole dug to the desired depth is used to calculate the corresponding Ksat value. One of the main assumptions used for developing the models used for calculating Ksat is that the soil is homogeneous and isotropic.

The objective of this paper is to evaluate water flow from cylindrical auger holes in different soils. A series of cylindrical holes were dug in different soils. A constant depth of a tracer dye solution was maintained in each hole, and after reaching steady-state, the Ksat of the soil was determined for each hole using the Glover model. At the termination of the dye application, the soil was dug and the dye-stained areas around each hole was assessed visually. The patterns of water flow from the holes through each soil will be presented and the soil homogeneity assumption used for developing mathematical models will be discussed.

Predicting the Probability of Soil Saturation Using Redoximorphic Features

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The depth to a soil's seasonal high water table can determine whether a soil is in a jurisdictional wetland or is suitable for a septic system. Determining which soils meet this requirement is difficult because long-term water table records are rarely available. This research is testing the hypotheses that soil color patterns can be related to long-term water table levels, and that such relationships can be used to estimate the frequency and duration of seasonal saturation from soil color patterns.

The basic approach is to: 1) *monitor* water table levels for 3 years at selected sites, 2) *calibrate* a hydrologic model to simulate the water table levels, 3) *compute* a 30 year record of water table levels using historic rainfall data, and 4) *correlate* the water table data to the abundance of certain soil colors.

The study is conducted at two locations in the Coastal Plain—Pitt County and Bertie County. Soils range from moderately well to poorly drained and are members of the Goldsboro, Lynchburg and Rains series. Percentages of redoximorphic features (red and gray soil colors) were estimated by eye in pits.

DRAINMOD was the hydrologic model used to simulate water table levels. Water tables were monitored daily for three years to calibrate the model. Daily water table levels were simulated for a 40-year period using historic rainfall data. Average absolute deviations between simulated and measured water table levels ranged between 15 and 30 cm for wet periods.

Redox depletions (gray soil colors) were related to the frequency of saturation events lasting more than 21 days. The 40-year water table record was summarized by computing a saturation index by depth for each plot, where the index was related to the number of times the soil at a given depth was saturated on average over the 40-year period.

Saturation event indices were significantly correlated with the percentages of redox depletions and concentrations. Relationships varied by depth and site, but not by soils for a given site. For example, saturation events at 30 cm produced more depletions than those occurring at 90 cm.

Horizons that had 20 percent redox depletions at a depth of 30 cm were saturated once in four years. Smaller amounts of depletions were related to events occurring once in 40 years. Results of this study show that soil morphology can be used to predict both frequency and duration of saturation at specific sites following calibration.

The hydric soil field indicator, the depleted matrix, was found in soils that were saturated for at least 3 weeks in more than 7 out of 10 years. This suggests that hydric soils with this field indicator also exceed the minimum requirement for wetland hydrology that is needed for jurisdictional wetlands.

MINUTES OF THE 2002 ANNUAL MEETING OF THE SOIL SCIENCE SOCIETY OF NORTH CAROLINA

President John Allison called the business session of the Forty–Fifth Annual Meeting of the Soil Science Society of North Carolina to order at 1:15 on January 15, 2002, at the McKimmon Center in Raleigh. President Allison asked that members review the meeting agenda, bylaws and other materials contained within the registration packets. The location of the sign-up sheets for professional development hours was announced. President Allison noted that the membership had swelled to over 350 members of whom, over 200 were present today. Presenters were urged to provide written abstracts to the executive committee. The Forty-Sixth Annual meeting will be held at the McKimmon Center on January 14 and 15 of 2003.

President Allison called for comments on the minutes of the 2001 business meeting. Copies of the minutes were distributed at the registration area. A motion was made and seconded to approve the minutes as reported. The motion was approved by a voice vote.

President Allison called on Robin J. Watson, Secretary-Treasurer, for the treasurer's report. Watson stated that at the time of this meeting, expenses were $13,085.23. $17,493.00 of income was received. Membership fees have increased resulting in increased income. The account balance was $13,133.22 as of June 30. A motion was made and seconded to approve the treasurer's report. The motion was approved by a voice vote.

The committee reports followed. The Auditing Committee composed of Drs. Rob Mikkelsen and Gordon Miner reported first. Mikkelsen stated that the books were balanced and in order. Mikkelsen stated that Miner would like to be released from this capacity after many years of service to the society. A motion was made and seconded to approve the Auditing Committee report. The motion was approved by a voice vote.

The Continuing Education Committee was composed of John Gagnon, Vince Lewis, Carl Crozier, Bill Dunlop and Ajmal Heshaam. Gagnon reported the committee met last week and many ideas resulted. The committee will continue to explore these ideas with input from other committees. Additional nutrient management, environmental law, internet classes for professional development were briefly mentioned. The committee hopes to follow up on these ideas in the upcoming year. President Allison called for a motion to accept the Education Committee report. A motion was made and seconded to approve the Continuing Education Committee report. The motion was approved by a voice vote.

Jennifer Sutherland reported for the Editing and Publishing Committee. The committee was composed of Catherine Stokes, Roger Leab and Jennifer Sutherland. The proceedings from the 2001 meeting are available from the website, http://agronomy.agr.state.nc.us/sssnc/index.htm; no "books" were published. Of the 13 presentations given in 2001, six were submitted and placed in the proceedings. Fourteen posters were exhibited in 2001, with four submitted to the committee and appearing in the proceedings.

Sutherland indicated that she was resigning from the committee and urged all presenters to provide a hard copy and an electronic copy of papers presented to the editor as soon as possible. Dr. Richard Reich noted that a box was present in the back of the room for the collection of these materials. The group was asked to provide feedback on the electronic version of the proceedings. If a hard copy or a CD of the proceedings is required, please meet with Roger Leab.

The committee asked how long the proceedings should be available via the Web site. At this time, the Society will pay for any hard copies or CDs required. After this year, hardcopies and CDs will not be paid for by the Society. Discussion ensued about website space, cost and maintenance.

Sutherland suggested that an abstract should be prepared and submitted with PowerPoint presentations. Placing the PowerPoint presentations on the web was very difficult. It was noted that hard copies should be provided to the NCSU library so that a record of the papers presented will be preserved. Robin Watson suggested keeping one CD of the proceedings with the records of the Editing and Publishing Committee. At this time, no cost is imposed by the Web site on the Society. Presently, there are no concerns of limited webspace on the site.

President Allison presented an honorarium of $250.00 from the Society to Sutherland for her hundreds of hours of work on the proceedings and also to Catherine Stokes for all of her work on the Web site.

Dr. Aziz Amoozegar pointed out that discussion about placing the proceedings on the Web site ensued last year, but no vote was taken. Secretary-Treasurer Watson reviewed the minutes and concurred with Dr. Amoozegar. President Allison conferred with Phil Tant to be sure that proper procedures were being followed. Per Tant's recommendation, a motion was made and seconded to approve the Editing and Publishing Committee report. The motion was approved by a voice vote.

A motion was made by Barrett Kays to place the proceedings on the Web site indefinitely and that a searchable index be placed on the Web site for use in accessing papers. John Kelly seconded the motion. President Allison asked Bill Yarborough to carry the microphone from speaker to speaker so that comments can be heard by all present. Discussion ensued about hard copies, PowerPoint, and the bylaws. President Allison called for a voice vote on the motion. It was unclear as to whether the motion had passed so a hand vote was taken. The motion carried via the hand vote. It was noted that the searchable index would be difficult to facilitate.

Dr. Naderman presented the Century of Soil Science Committee report. The original Committee was composed of Dr. Donald Eaddy, Dr. Stan Buol, Dr. Ray Campbell, Hubert Byrd, Dr. Jim Shelton and Dr. Eugene Kamprath. Naderman contacted Mr. Paul Lilly about adding his paper on the history of organic soils to the Web site. Drs. Wendell Gilliam, Eugene Kamprath and George Naderman reviewed the paper. "An Anthology of Soil Science of North Carolina" by Dr. Stan Buol and "Ten Milestones in Conservation Tillage" by Brock et al., as well as some color photographs were proposed to be added to the Century of Soil Science portion of the Web site. Naderman reminded the group that hard copies of the Century of Soil Science publications would be available for a fee of $16 to $20 to interested parties. The hard copy and a list were placed on the back table for review. A motion was made and seconded to approve the Century of Soil Science Committee report. The motion was approved by a voice vote.

Robert Brown presented the Nominating Committee report. Alan Clapp and Don Wells were nominated for the Board-Member-at-Large position on the Executive Committee. Dr. Aziz Amoozegar and Joe Hinton were nominated for the position of President-Elect. The floor was opened for additional nominations. A motion was made and seconded to close nominations. The motion was approved by a voice vote. Ballots were distributed and collected by the nominations committee. The results of the elections are to be announced the following day. This concluded the committee reports.

President Allison announced that Robin J. Watson has resigned the Secretary-Treasurer position effective after the conclusion of this meeting. Steve Dillon was appointed as Secretary and Roberta Miller-Haraway was appointed as Treasurer.

Dr. Joe Kleiss reported on the Soil Judging Team and thanked the Society for their support. The team competed in a national contest at Penn. State last spring and placed third out of twenty-some teams. The team competed in a regional competition at Murray State last fall in western Kentucky and earned the right to compete in the National competition in Minnesota during April 2002. President Allison asked for discussion. A motion was made and seconded to continue provide support of $500 to the Soil Judging Team. The motion was approved by a voice vote.

The Future Farmers' of America representative was not present so President Allison deferred this matter to a later time dependent upon the arrival of the representative.

President Allison called for any other old business for discussion. There was none.

President Allison called for new business items to be discussed. Dr. Richard Reich reported on the establishment of a scholarship for an undergraduate student. Reich had met with Dr. Maurice Cook to discuss possibilities of establishing a scholarship and a Scholarship Committee. Eight members of the committee met this morning—Roy Mathis, Chuck Sopher, Dr. Steve Broome, Caroline Edwards, Sandra Weitzel, John Kelly, Dr. Joe Kleiss and Dr. Richard Reich—to discuss the Society's support of a scholarship. The committee recommended establishing a scholarship for this coming academic year. Dr. Reich made a motion to set up a Scholarship Committee and to award a $500.00 scholarship for the 2002–03 academic year, funded from the Society's budget with the committee focusing on options for setting up an endowment toward a permanent scholarship to be sponsored by the Society with society members given the opportunity to contribute to the scholarship fund as well. The motion was seconded from the floor. Discussion followed concerning naming the scholarship, restricting awards to soil science majors and the tax status of donations to the scholarship fund.

Phil Tant served as Parliamentarian and stated that the motion would have to amend the motion to name the scholarship. The motion was amended by

Dr. Reich to establish a scholarship committee and that a $500.00 scholarship named the Hubert J. Byrd Memorial Scholarship be awarded for the 2002–03 academic year, funded from the Society's budget with the committee focusing on options for setting up an endowment toward a permanent scholarship to be sponsored by the Society with society members given the opportunity to contribute to the scholarship fund as well.

Discussion on endowment of a scholarship followed. NCSU needs $15,000 to create an endowed scholarship within five years. Jerry Stimpson has agreed to serve on a scholarship committee. The amended motion was seconded from the floor. A question was called on the amendment. The amendment to the motion passed by a voice vote. The motion to create the Hubert J. Byrd Memorial Scholarship passed via voice vote. The Scholarship Committee will be posted on the Internet site along with contact information for anyone wishing to contribute. A sign-up sheet will be provided for anyone wishing to contribute to the scholarship.

Old business was reopened when Ms. Becky Hines from FFA arrived. Ms. Hines gave an overview of FFA activities in the state and nation. In the past the Society has contributed to the Soil and Water Management Proficiency Award. Due to changes in the structure of FFA, this award is no longer offered. FFA has asked that the Society co-sponsor the Agronomy Category. Ms. Hines answered questions from Richard Brooks and other members about the land-judging competition. Duke Power and Carolina Power and Light currently sponsor the land-judging category. Discussion followed among the members.

Richard Brooks made a motion to give $1,000 to the FFA Foundation with $400 going to expenses for the 2002 state land-judging contest and $600 in matching funds to the second place team towards expenses to attend the national competition. The motion was seconded from the floor. Much discussion followed. Hal Owen commented that if the contribution to FFA was increased that the contribution to the Soil Judging Team should also be increased. The question was called. The motion carried via a hand vote.

President Allison asked the members to review the proposed changes to the bylaws as contained in the registration packets. President Allison addressed growth and diversity of the society membership. The first change discussed was in Article 3, membership. Students will be exempt from registration fees but must pay dues. Honorary life and retired members are exempt from dues. President Allison suspended the business meeting until after the Agency Updates.

The business meeting reconvened and the proposed changes to the bylaws were outlined and discussed by President Allison. A motion was made and seconded to accept the changes to the bylaws. The split of the Secretary-Treasurer position into two separate positions will be addressed at a later date.

President Allison adjourned meeting at 5:49. The next general meeting will be at 1:15 on January 14, 2003, in Raleigh.

SOIL SCIENCE SOCIETY OF NORTH CAROLINA
Audit Committee Report: 7/1/2000 to 6/30/2001

July 2001

The financial records of the Soil Science Society of North Carolina, as maintained by the Treasurer, Robin J. Watson, have been examined and found to be in order, as follows:

	GENERAL FUND		
Item	Receipt	Disbursement	Balance
BEGINNING BALANCE [7/1/2000]			8,822.47
INCOME:			
Membership Fee	3,645.00		
Preregistration/Registration Fee	8,828.00		
Lunch/Banquet	2,438.00		
Vendors	1,800.00		
Promotional T-Shirts/Hats	215.00		
Cash from Private Auction	67.00		
EXPENDITURES:			
McKimmon Center Rental		5,277.08	
Show Services Rental		259.70	
Meals and Social Functions		3,157.31	
Speaker and Expenses		48.00	
Awards		197.05	
Contribution to Soil Judging Team		500.00	
Postage, Office Supplies		653.26	
Printing – Proceedings		1,355.01	
President's Expenses		198.00	
Contribution to N.C. Association of Licensed Soil Scientists		20.50	
Contribution to FFA in 2000 and 2001		1,000.00	
Miscellaneous Expenses		16.34	
TOTAL	16,993.00	12,682.25	
ENDING BALANCE [6/30/2001]			13,133.22

Rob Mikkelsen, Chairman

Gordon Miner

SOIL SCIENCE SOCIETY OF NORTH CAROLINA
2002 COMMITTEES

Executive Committee

Richard C.Reich, President
Aziz Amoozegar, President-Elect
Steve Dillon, Secretary
Roberta Miller-Haraway, Treasurer
Alan Clapp, Board Member
Roy Mathis, Board Member
John Allison, Past President

Nominating Committee

Robert Brown, Chairman
Perry Wyatt
Alan Clapp

Awards Committee

M. Ray Tucker, Chairman
Roberta Miller-Haraway
Elwood Black

Program & Arrangements Committee

Aziz Amoozegar, Chairman
David Hardy
Richard Hayes
Steven Stokes

Editing & Publishing Committee

Catherine Stokes, Chairman

Public Relations Committee

Tony Jacobs, Chairman
David Knight
Marty Allen

Auditing Committee

Keith Cassel, Chairman
John Kelley
J. Kent Messick

Continuing Education Committee

John Gagnon, Chairman
Ajmal Heshaam
Bill Dunlop
Carl Crozier
Vincent Lewis

Trade Show Committee (ad hoc)

Steve Stadelman, Chairman
Richard Brooks
Jerry Stimpson

Century of Soil Science Committee (ad hoc)

George Naderman, Chairman

Scholarship Committee (ad hoc)

Maurice Cook, Chairman

Paul Blizzard
Steve Broome
Steve Clayton
Caroline Edwards
John Kelley
Joe Kleiss
Paul Lilly
Roy Mathis
Richard C. Reich, Ex Officio (President of SSSNC)
Chuck Sopher
Steve Steinbeck
Jerry Stimpson
F.R. (Bobby) Walls
Sandra Weitzel

SOIL SCIENCE SOCIETY OF NORTH CAROLINA
HISTORICAL PROCEEDINGS

SOIL SCIENCE SOCIETY OF NORTH CAROLINA ACHIEVEMENT AWARDS

2002	M. Ray Tucker
2001	Aziz Amoozegar
2000	Horace Smith
1999	Ray Campbell
1998	Andy Goodwin
1997	Stephen W. Broome
1996	Kevin C. Martin
1995	Gordon Miner
1994	Joe A. Phillips
1993	Robert L. Uebler
1992	Donald W. Eaddy
1991	J. Paul Lilly
1990	H. J. Kleiss
1989	Keith Cassel
1988	Ernest N. Hayhurst
1987	Robert E. Horton
1986	Paul T. Blizzard
1985	William T. Barnhill
1984	Ray Daniels
1983	Wendell Gilliam
1982	Stanley Buol
1981	Maurice Cook
1980	Joel Cawthorn
1979	Steve Barnes
1978	Bill Pickett
1977	Hubert Byrd
1976	Guy Jones
1975	Walton Dennis
1974	Louis Aull
1973	Roy Tillery
1972	Jack V. Baird
1971	W. G. Woltz
1970	Bill Lamm & W. B. Bartholomew
1969	G. Winchester & R. J. McCracken
1968	S. N. Hawks & E. J. Kamprath
1967	Bryce Younts & W. A. Jackson
1966	Brodie Harrell & J. W. Fitts
1965	Norfleet Sugg & Forest Steele
1964	S. E. Younts & C. B. McCants
1963	E. Goldston & W. W. Woodhouse
1962	J. F. Lutz & W. H. Rankin
1961	E. V. Floyd & A. Mehlich
1960	E. R. Collins & W. D. Lee

SOIL SCIENCE SOCIETY OF NORTH CAROLINA
ACTIVE MEMBERS, YEAR 2002

Connie Adams
Irvin M. (Marty) Allen
Jennifer L. Allen
John B. Allison
Aziz Amoozegar
Deborah T. Anderson
Moulton A. Bailey
Susan S. Baker
Keith R. Baldwin
Larry Baldwin
Steve Barnes
Kirk W. Becker
James (Jim) L. Beeson
Barry N. Bennett
Gregg Bennett
John Bizic
Elwood Black
Stuart B. Black
Daniel J. Bliley
Paul T. Blizzard
Clyde R. Bogle
Thomas J. Boyce
Bob Branch
Gregory R. Brannon
Steve Bristow
Bobby G. Brock
Richard Brooks
Steve Broome
Adrienne Brown
R. Jeremy Brown
Robert M. Brown
Wyatt Brown
Gary R. Buel
Stanley W. Buol
Charles Cahill
C. Ray Campbell
William P. Carlin
W. Edward Casavant
D. Keith Cassel
Darren N. Cecil
Stephen B. Chambers
Dolores M. Chandler
Earl H. Chipman
Alan Clapp
David C. Clapp
George B. Clark
Greg Clark
Steve Clayton
Everett Coates
Chester Cobb
Albert Coffey
Stephen Colbert
Raymond Coltrain
Stephanie J. Connolly
Maurice G. Cook
James Cooper
David A. Crouse
Stanley (Stan) Crownover
Carl R. Crozier
Charles B. Davey
Jennifer Davis
John R. Davis
Sam Davis
Clay H. DeVane
W. A. (Bill) Dickerson
H. Steven Dillon
Timothy L. Donnelly
William (Bill) Doucette
W. R. (Bill) Dunlop, Jr.
Donald W. Eaddy
Mike Eaker
Gary L. Easter
Christopher Edmonds
Caroline J. Edwards
Ellis Edwards
Robert D. (Bob) Edwards
Robert O. Evans
Steve T. Evans
Richard Farris
Frank Feldenzer
Neal Floyd
Laura Fortner
John A. Gagnon, Jr.
Jan Gay
J. Wendell Gilliam
R. Andy Goodwin
Dwayne A. Graham
Christopher Greene
R. Scott Greene
Tom Gulley
Steve Gurley
Jason Hall
R. Jay Ham
Roger G. Hanson
Roberta Miller Haraway
David H. Hardy
Timothy (Tim) P. Harlan
J. David Harper
J. Craig Harris
John Havlin
Richard Hayes
William Allen Hayes, Jr.
Ernest N. Hayhurst
Michael Henderson
Ajmal A. Heshaam
Dean Hesterberg
Peter T. Hight
Jonathan Hill
Dwane Hinson
Thomas Hinson
Joseph A. Hinton
Phyllis D. Hockett
Michael (Mike) T. Hoover
Robert (Bob) E. Horton, Sr.
Lynn Howard
Mark S. Hudson
Sheila J. Hughes
Daniel W. Israel
Tony C. Jacobs
Robert S. Jordan
Eugene J. Kamprath
Ed Karnowski
Barrett L. Kays
Jay Keller
John Kelley
Paton H. (Pat) Kelley
Harold Kelly
James H. (Jimmy) Kimsey
Joe Kleiss
David T. Knight
George Lankford
Lynn Lazzara
Roger J. Leab
Grant Lewis
James W. Lewis, Jr.
Vincent Lewis
Ron Lilley
David L. Lindbo
David Little
Robin Little
Peggy Longmire
Pedro Luna-Orea
Everette Lynn
Ted Lyon

SOIL SCIENCE SOCIETY OF NORTH CAROLINA
ACTIVE MEMBERS, YEAR 2002 (continued)

Martin E. Mabe
Lee Mallard
William R. (Bill) Marlin
Brett Martin
Kevin Martin
Milton Martinez
Roy L. Mathis, Jr.
Dana F. Mayberry
David V . McCloy
Dennis E. McCoy
Kirk McEachern
Richard McLaughlin
Betty F. McQuaid
J. Kent Messick
Albert S. Mills, Jr.
Gordon Miner
Frank Minton
Amber Moore
George Naderman
Theresa Nartea
Kevin M. Neal
Nathan O. Nelson
Wes Newell
Chris Niewoehner
Wayne Nixon
Clayton Norton
Michael A. Norton
Kevin Nunnery
Mike Ortosky
Dennis J. Osborne
Deanna Osmond
Wendell Overby
Hal Owen
Kenneth (Kenny) Owens
Carl D. Peacock, Jr.
Roger Pearce
Paul G. Penninger
Richard Pontello
Steve Price
Wayne Ragland
Chad Rakes
Noah Ranells
Robert H. Ranson, Jr.
Richard C. Reich
Brianna Roberts
Ken Roeder
Samuel Ashley Rollans
Thomas Schmitt
Karl Shaffer
Todd Shearin
Michael L. Sherrill
Larry T. Sink
Clark Sizemore
Bill R. Smith
Bruce (Chip) P. Smith, Jr.
Fred Smith
Horace Smith
Charles D. Sopher
R. Hank Sowers
Dan Spangler
Willie E. Spruill
Jerry Sroka
Steve Stadelman
Miranda Stamper
Steve J. Steinbeck
Jerry V. Stimpson
Catherine Stokes
Steven F. Stokes
Scott Stone
Robert E. Stott
Brad Suther
Marlene Talley
Phil Tant
Eric Thompson
M. Ray Tucker
Craig Turner
Danny Turner
John (Wes) Tuttle
Robert Uebler
Godfrey A. Uzochukwu
Willem Van Eck
Jeffrey Vaughn
Mike Vepraskas
Roy L. Vick
F. Robert (Bobby) Walls
Nathan Ward
R. Barry Ward
James H. Ware
Robin Watson
Jerome B. (Jerry) Weber
Sandra Weitzel
Donald Wells
Eric West
Jeffery G. White
Gary F. Whitley
Rob Wilcox
John P. Williams
Channa D. Witanachchi
Josh Witherspoon
Michael Wood
William E. Woody
Perry Wyatt
Jerry Yarborough
T. Kent Yarborough
William E. (Bill) Yarborough
Lawrence E. (Gene) Young, Jr.
Robert J. Zupancic

PAST EXECUTIVE COMMITTEE MEMBERS

2001 John Allison, President
Richard C. Reich, Robin Watson, Roy Mathis, Bill Yarborough, John Kelley

2000 John Kelley, President
John Allison, Robin Watson, Joseph Hinton, Bill Yarborough, George Naderman

1999 George Naderman, President
John Kelley, Robin Watson, Joseph Hinton, Steve Stadelman, Richard Brooks

1998 Richard C. Brooks, President
George Naderman, Aziz Amoozegar, Mike Ortosky, Joe Zublena

1997 C. Ray Campbell, President
Richard Brooks, Aziz Amoozegar, Mike Ortosky, Joe Zublena

1996 Mike Vepraskas, President
Ray Campbell, Steve Hodges, Mike Ortosky, Dan Bliley

1995 Karl Shaffer, President
Mike Vepraskas, Steve Hodges, Richard Brooks, R. Campbell, Horace Smith

1994 Everette Lynn, President
Karl Shaffer, Gordon Miner, Richard Brooks, Ray Campbell, Horace Smith

1993 Horace Smith, President
Everette Lynn, Gordon Miner, Karl Shaffer, Richard Brooks, Steve Barnes

1992 Steve Barnes, President
Horace Smith, Gordon Miner, Dennis Osborne, Karl Shaffer, Steve Clayton

1991 Steve Clayton, President
Steve Barnes, Gordon Miner, Debbie Anderson, Dennis Osborne, Mike Hoover

1990 Mike Hoover, President
Steve Clayton, Bob Uebler, Steve Barnes, Debbie Anderson, Andy Goodwin

1989 Andy Goodwin, President
Mike Hoover, Bob Uebler, B. Yarborough, Steve Barnes, Jerry Stimpson

1988 Jerry Stimpson, President
Andy Goodwin, Bob Uebler, B. Yarborough, P. Denton (Resigned), Jim Canterberry, Paul Lilly

1987 J. Paul Lilly, President
Jerry Stimpson, Bob Uebler, R. Rucker, P. Denton

1986 Bob Uebler, President
Paul Lilly, Jack Baird, R. Tucker, Gordon Miner

1985 Keith Cassel, President
Berman Hudson (Resigned), Bob Uebler, Jack Baird, Paul Blizzard, Gordon Miner

1984 Darwin Newton, President
Keith Cassel, Jack Baird, Paul Blizzard, Jerry Stimpson, Bob Uebler

1983 Paul Blizzard, President
Darwin Newton, Jack Baird, Joe Kliess, Jerry Stimpson, Paul Lilly

1982 Joe Kliess, President
Paul Blizzard, Darwin Newton, Ernest Hayhurst, Paul Lilly, L. Jackson

1981 Ernest Hayhurst, President
Joe Kliess, Darwin Newton, L. Jackson, Steve Barnes, Keith Cassel

1980 John Nicholaides, President
Ernest Hayhurst, Darwin Newton, Joel Cawthorn, Steve Barnes

1979 Joel Cawthorn, President
John Nicholaides, Ernest Hayhurst, J. W. Gilliam, Steve Barnes, S. Broome

1978 J. Wendell Gilliam, President
Joel Cawthorne, Ernest Hayhurst, Bobby Carlile, R. Hoague, S. Broome

PAST EXECUTIVE COMMITTEE MEMBERS (continued)

1977 Bobby Carlile, President
J. W. Gilliam, J. Reeves, R. E. McCollum, Jim Ware, R. Hoague

1976 R. E. McCollum, President
Bobby Carlile, J. Reeves, Steve Barnes, John Carpenter, Jim Ware

1975 John A. Carpenter, President
R. McCollum, J. Reeves, Ed Karnowski, Steve Barnes, Hubert Byrd, W. Pickett, Chuck Sopher

1974 Hubert Byrd, President
Chuck Sopher, John Carpenter, Ed Karnwoski, W. Pickett, C. Willey

1973 Joseph A. Phillips, President
Hubert Byrd, Chuck Sopher, C. Willey, Ed Karnowski, Louis Aull

1972 Louis E. Aull, President
Joe Phillips, Hubert Byrd, W. L. Barnhill, B. Nelson

1970-1971 W. K. Collins, President
Louis Aull, Joe Phillips, L. Jackson, W. L. Barnhill, H. Smith

1969 Fred R. Cox, President
H. Smith, Louis Aull, W. Campbell, Ed Karnowski, Jack Baird

1968 Jack V. Baird, President
Fred Cox, Louis Aull, W. Barley, Ed Karnowski, M. McCants

1967 C. B. McCants, President
A. Plant, C. Davey, C. Watts, J. Perry

1966 J. M. Spain (Elected President)
C. B. McCants (Completed Term)
C. McCants, C. Davey, A. Plant, J. Perry, S. Younts

1965 S. E. Younts, President
J. Spain, C. Davey, A. Plant, Louis Aull, E. Kamprath

1964 E. J. Kamprath, President
S. Younts, J. Spain, W. Dickens, Louis Aull, W. Bartholomew

1963 W. V. Bartholomew, President
E. Kamprath, S. Dobson, J. Sedberry, J. Watts, N. Sugg

1962 N. L. Sugg, President
W. Bartholomew, S. Younts, A. Baxter, J. Watts, W. White

1961 W. C. White, President
L. Hunt, S. Younts, A. Baxter, W. D. Lee, J. Lutz

1958-1959 J. P. Lutz, President
F. Steele, W. White, K. Shaw, J. Fitts

CONSTITUTION AND BYLAWS
OF THE
SOIL SCIENCE SOCIETY OF NORTH CAROLINA

PREAMBLE

The following Constitution and Bylaws shall govern the activities of the Soil Science Society of North Carolina. This Constitution and Bylaws, when adopted, shall supersede and nullify all previous Constitutions and Bylaws of the Society.

ARTICLE I: Name and Organization

Section 1. The name of the organization shall be: “Soil Science Society of North Carolina”.

Section 2. The organization shall consist of the membership as designated in Article III.

ARTICLE II: Objectives

Section 1. The objectives of the Society shall be to promote the accumulation, dissemination, and utilization of knowledge pertaining to the soils of North Carolina and to provide a medium for exchange of information by those interested in Soil Science and in closely related subject matter areas.

ARTICLE III: Membership

Section 1. There shall be six classes of membership as follows:

a. Individual: Persons who maintain active status by payment of annual dues as prescribed in Article IX.

b. Organizational: Any organization that pays dues as specified in Article IX. Each group may designate one individual who shall have the same rights as an individual member.

c. Sustaining: Industrial and/or other organizations that pay dues as specified in Article IX. Each group shall designate one individual who shall have the same rights as an individual member. Sustaining members are those who wish to support the Society financially to an extent over and above that set forth in a and b immediately above.

d. Active Life: This membership classification is reserved for those individuals who are now retired from their principal career responsibilities; and who for at least three years prior to retirement were active members of the Society. These members shall have all the privileges of individual members including attending and participating in the annual meetings, voting rights, and receiving Society materials and publications. They shall be exempt for life from payment of annual dues.

e. Honorary Life: This membership classification is reserved for those individuals who throughout their career have made a lasting impact on Soil Science. This category differs from the Annual Achievement Award in that it is awarded based on the sum total of the individual's career. Any member can nominate someone for this membership distinction. The executive board will make the final determination. Recipients shall have all the privileges of Active Life Members.

f. Student: This membership classification is reserved for those individuals who are now undergraduate or graduate students in Soil Science or a related field of study. Individuals involved in post-doctorate work are not included. These members shall have all the privileges of individual members. They shall be exempt from registration fees.

Section 2. The membership may further participate in the following divisions:

a. Academic and Research.

b. Business, Consulting, and Industry.

c. Public Health.

d. Governmental Agencies.

Divisions will meet during the annual meeting before the Society business meeting. They are to inform and promote to the general membership the specific interests of the divisional membership. They are responsible for electing a division chairperson who will serve on the Executive Committee. Divisional activities are subject to full Executive Committee approval.

ARTICLE IV: Officers, Duties, and Election

Section 1. *Officers.* The officers of the Society shall consist of a President, a President-Elect, and a Secretary-Treasurer. There shall be an Executive Committee consisting of the President of the Society (Chairperson), the President-Elect, the Secretary-Treasurer, the most recent past President, and the chairpersons of each of the four divisions in Article III, section 2, elected by that division membership. Section 4 immediately below shall apply for non-functioning divisions.

Section 2. *Duties of Officers.*

a. The President shall preside at meetings of the Executive Committee, at business meetings of the Society, and at other meetings of the Society as he (and the Executive Committee) may deem appropriate. He shall appoint the necessary committees as provided for in Article VI and shall have general supervision of all the affairs of the Society.

b. The President-Elect shall serve as Chairman of the Committee on Program and Arrangements and shall be generally responsible for preparing the program and making the other necessary arrangements for the annual meeting.

c. The Secretary-Treasurer shall keep the minutes of the Executive Committee and regular Society meetings, handle the financial affairs, keep the financial record of the Society, and perform such other duties as may be appropriate to that office.

d. The Divisional Chairperson shall preside over their respective division meetings. They shall appoint subcommittees pertinent to the division. Division chairpersons shall report to the President.

e. The Executive Committee shall be empowered to act for the Society between annual or duly called meetings. It may make recommendations for appointments of ad hoc or standing committees and shall be empowered to fill vacancies in any office of the Executive Committee until the next regular meeting of the Society.

Section 3. *Election.* The President-Elect shall be elected by ballot at the annual meeting of the Society. The President shall appoint a Nominating Committee. This committee shall nominate at least two candidates for the office of President-Elect. Other nominations may be made from the Floor. Election shall be by a majority of the votes cast. In case no nominee receives a majority on the first ballot, the two receiving the highest number of votes on the first ballot shall be voted upon in a second balloting The Division Chairperson shall be elected by procedures established by the division membership.

The President-Elect shall serve in that capacity for one year and then shall succeed to the Presidency for one year. The elected members of the Executive Committee shall serve for a term of two years, with terms of office expiring in alternate years. The Secretary-Treasurer shall be appointed by the Executive Committee and shall serve for a term mutually agreeable to him and to the Executive Committee.

Section 4. *Filling Vacancies.* If a vacancy should occur in one or more of the offices, or in the Executive Committee, the remaining members of the Executive Committee shall be empowered to fill the vacancy until such time as a regular business meeting of the Society shall be convened.

ARTICLE V: Government and Meetings

Section 1. The major business and governmental affairs of the Society shall be transacted at the annual meeting, or at the other duly called meeting. A majority vote of those present at a duly constituted meeting shall be required for approval of any and all business matters, except the changing of this Constitution and Bylaws (See Article X, Section 1). The Executive Committee shall be empowered to act for the Society between duly constituted meetings.

Section 2. The Society shall hold an annual meeting at a time and place to be determined by the Executive Committee. Other meetings, conferences, or tours may be arranged by the Executive Committee on their own initiative or in response to requests from members of the Society.

Section 3. All business meetings of the Society shall be conducted in accordance with Robert's Rules of Order.

Section 4. The annual business meeting of the Society should provide for the following:

a. Approval of the minutes of the last meeting.

b. Report of the President.

c. Report of the Secretary-Treasurer.

d. Report of the Auditing Committee.

e. Reports from the Division Chairpersons.

f. Old business.

g. New business.

h. Election of President-Elect.

i. Adjournment.

Section 5. A quorum at a meeting of the Executive Committee shall consist of a majority (that is, at least five) of the members.

Section 6. A quorum at any duly called business meeting of the Society shall consist of at least fifteen percent of the active membership, with the number of active memberships being certified to by the Secretary-Treasurer.

ARTICLE VI: Committees

To assist in the various duties and responsibilities of the Society, the committees listed below shall be appointed. Ad hoc or special committees may be appointed as deemed necessary by the President and/or Executive Committee.

Section 1. *Executive Committee.* This committee shall consist of the President as Chairman, the President-Elect and the Secretary-Treasurer, the immediate past President, and four Divisional Chairpersons to be elected as specified in Article IV, Section 3.

Section 2. *Nominating Committee.* There shall be a Nominating Committee of three, at least two of whom shall be past Presidents of the Society, to make nominations for officers as specified in Article IV. Section 1.

Section 3. *Committee on Awards.* There shall be a committee to select, with the approval of the Executive Committee, an individual to receive the Annual Achievement Award as specified in Article VII.

Section 4. *Program and Arrangements Committee.* The President shall appoint a committee on program and arrangements with the President-Elect to serve as Chairperson.

Section 5. *Editing and Publishing Committee.* The President shall appoint an Editing and Publishing Committee to be responsible for editing and publishing the proceedings of the annual meeting and other material as might be deemed necessary from time to time.

Section 6. *Public Relations Committee.* The President shall appoint a committee on public relations, the duties of which shall include the following:

a. Membership: To serve as a liaison and information medium between the Society and prospective new members.

b. Cooperation: To serve as a liaison between the Soil Science Society and other related societies or agencies.

c. Necrology: To secure a list of names of any members that might have passed away during the year and to prepare a suitable memorial statement for them.

d. Resolutions: To prepare resolutions pertaining to any phase of the operations of the Society or otherwise as the committee may deem pertinent.

Section 7. *Auditing Committee*. The President shall appoint an Auditing Committee consisting of at least two members of the Society to audit the Treasurer's books and to certify as to their correctness. The Auditing Committee's report shall be presented at the general business meeting immediately following the report of the Secretary-Treasurer.

Section 8. *Continuing Education Committee*. Through this committee, the Society shall sponsor and/or conduct educational programs of significant interest in soil science and closely related subject matter areas. The committee shall submit program proposals to the Executive Committee for approval.

ARTICLE VII: Awards

Section 1. The Society has an award in the form of a certificate which can be given for outstanding achievement in soil science. The work for which the recognition is given may be in research, teaching, extension, administration, or other; but it must be principally and directly related to soil science. Not more than one such award shall be given per year. None may be given if, in the opinion of the Awards Committee with the approval of the Executive Committee, there is no worthy candidate in any particular year.

ARTICLE VIII: Publications

Section 1. The Society shall publish the proceedings of the annual meetings in a publication to be designated as Soil Science Society of North Carolina Proceedings. The Proceedings shall contain the papers presented at the meeting (with written summaries from poster presentations optional and left to the discretion of the presenter). Submitted papers shall be a maximum of 5,000 written words or maximum of 10 pages of total text, double spaced, including tables and references: unless prior clearance is received from the editor of the Proceedings. The Proceedings shall also contain the minutes of the business meeting, including the results of the election, a list of the various committees, the citation pertaining to the recipient of the Achievement Award, and other committee reports and materials as deemed necessary by the Editing and Publishing Committee with the approval of the Executive Committee.

ARTICLE IX: Dues and Finances

Section 1. Membership dues shall be as recommended by the Executive Committee, with the dues for various classes of membership as follows:

a. Individual membership - Dues shall be set by the Executive Committee.

b. Organization membership - $50.00.

c. Sustaining membership - $75.00, minimum.

d. Active Life membership - exempt as per Article III, Section 1d.

e. Honorary Life membership - exempt as per Article III, Section 1e.

f. Student Life membership - as per Article III, Section 1f.

Section 2. Dues are payable on a calendar year basis. Dues are expected to be paid prior to or at the time of the annual meeting. Any dues received after the annual call for dues, and prior to the call for annual dues for the subsequent calendar year, shall be for that calendar year in which received. New members shall pay dues at the time of application.

Section 3. To defray cost of the annual meeting, a registration fee will be charged those registering for the annual meeting. The amount of this fee will be determined by the Executive Committee.

Section 4. Proceedings will be published on the Society's web page. Cost of publishing and maintaining the web page will be offset by receipts of member's dues and annual meeting registration fees.

ARTICLE X: Amendments

Section 1. This Constitution and Bylaws may be amended by a two-thirds majority vote of the members present at any duly constituted annual meeting, provided such amendments have first been presented to the Executive Committee at least thirty days prior to the time of the annual meeting and have been mailed to the membership at least two weeks prior to the annual meeting.

NOTE: Approved by membership January 15, 2002.