Proceedings of the 35th Annual
Mississippi Water Resources Conference

April 26 - 27, 2005 Cabot Lodge - Millsaps Jackson, Mississippi

Sponsors:
GeoResources Institute, Mississippi State University
U.S. Geological Survey
Mississippi Department of Environmental Quality
Mississippi Water Resources Association

35th Annual Mississippi Water Resources Conference
and 2nd Symposium on Safe Management and Utilization of Animal Waste
Cabot Lodge Millsaps - Jackson, Mississippi
April 26-27, 2005

Day 1: Tuesday, April 26, 2005

7:30AM **Registration and Continental Breakfast**

8:15AM **OPENING PLENARY SESSION - Opening Remarks and Introductions: David Shaw**
8:30AM Charles Chisolm - Executive Director, Mississippi Department of Environmental Quality (Invited)
9:15AM Don Parrish - Senior Director, Regulatory Relations, American Farm Bureau Federation (Invited)
10:00AM Worth Hager - Chair, National Waterways Conference, Inc. (Invited)

10:45AM **BREAK**

11:00AM **Water Resources Research Poster Session**

Goff	Usage Survey of Mississippi's Coastal Recreational Beaches
Cooper	Plants of the Coldwater River, Mississippi, USA: Community Records Along the Hydrologic Gradient in the Loess Hills
Faulkner	An Eight-Year Vegetative Study of Long-Term Monitoring Plots at the University of Mississippi Field Station
Holder	Environmental Stewardship Education for Mississippi Agricultural Producers
Jackson	GIS Geodatabase Data Model Building for Road Management: The USACE Tenn-Tom Waterway (Mobile District)
Rajkarnikar	Soil Resilience in Disturbed Forests and Associated Wetlands following Timber Harvest
Rivera	Bacterial Source Tracking of a Prarie Watershed System Using AFLP
Smith	Improved Irrigation Efficiency and Reduced Surface Water Contamination...in Rice Production
Steil	Social Capital: A Unifying Framework for Understanding Conservation Decisions
Tagert	Using the AGNPS Model and GIS to Locate Areas that May Be Vulnerable to Runoff
Weston	Analytical Detection and Quantification of Chemical Mixtures: WNV Eradication Compounds and Other Xenobiotics
Wilson	Conservation Effects Assessment Project (CEAP)-Watershed Assessment Studies: Yalobusha River Watershed

Animal Waste Symposium Poster Session:

Armstrong	Comparison of Broadcast and Band Application of Poultry Litter on Cotton
McLaughlin	Isolation of Salmonella Bacteriophages from Swine Waste Lagoons
Pratt	Fungicide-Based Estimates of Yield Losses Caused by Fungal Diseases in Bermudagrass on Swine Waste Application Sites
Reid	The Effect of Further Hatchery Waste Processing on Soil Acidity Amelioration and Plant Response in Two Mississippi Soils
Sistani	Nutrient Uptake and Runoff from Alum-treated Broiler Litter Tall Fescue Plots
Sleugh	Nutrient Uptake and Forage Quality of Sorghum-Sudangrass Under Different Poultry Litter Fertility Programs
Tewolde	Applying Poultry Litter in the Fall Diminishes its Fertilizer Value
Willian	Soil Nutrient Accumulation and Field Corn Yield as Influenced by Poultry Litter Application Rate

12:00PM **LUNCHEON -** Bo Robinson, Northern District Mississippi Public Service Commission (Invited)

1:00PM **CONCURRENT SESSION A - Policy - Moderator: Deirdre McGowan**
Ken Griffin, Manager of Pearl River Valley Water Supply District (Invited)
Nick Walters, Mississippi State Director for USDA Rural Development (Invited)
Bob Lord, Mississippi Development Authority (Invited)
Barry Royals, Waggoner Engineering (Invited)
Worth Hager, Chair, National Waterways Conference, Inc. (Invited)

1:00PM **CONCURRENT SESSION B - Waste Management Symposium - Moderator: Dennis Rowe**

1:00PM	Loughrin	Evaluation of an Advanced Waste Treatment System for Reduction of Malodorous Compounds from Swine Waste
1:20PM	Johnson	Iron Humate for Manure Treatment and Phosphorus Control on Small Dairy and Swine Farms
1:00PM	Johnson	Manure Treatment Systems and Nutrient Control of Dairy Waste
2:00PM	Oldham	Addressing the Non-Traditional Nutrient Management Education Needs of Mississippi Poultry Producers
2:20PM	Whitely	Solving the Chicken Litter Problem: Development of Novel Practices for Chicken Litter Management and Disposal
2:40PM	Lee	Using Hatchery Waste By-Products as a Source of Lime and Nitrogen

3:00PM **BREAK**

3:20PM **CONCURRENT SESSION B (Cont'd) - Waste Management Symposium - Moderator: Karamat Sistani**

3:20PM	Hatten	Leaching of Nitrogen, Phosphorus, and Potassium from Sawdust Amended with Chicken Litter
3:40PM	Gilfillen	Accumulations of Nutrients in Corn Soil as Influenced by Poultry Litter Application Rate
4:00PM	Read	Bermudagrass Production and Nutrient Uptake When Substituting Broiler Litter Nitrogen with Mineral Nitrogen
4:20PM	Rowe	Winter Cover Crop Management Systems Increase Annual Extraction Rates of Manure Nutrients in Swine…
4:40PM	Adeli	Phosphorus and N Fractions in Surface Runoff from a No-Till Cotton Field Fertilized with Broiler Litter

3:20PM **CONCURRENT SESSION C - Ecology - Moderator: Fred Howell**

3:20PM	Madsen	Developing Plans for Managing Invasive Aquatic Plants in Mississippi Water Resources
3:40PM	Herman	Evaluation of a Wetlands Floristic Assessment Method that Incorporates Invasive Species Information & Wetland Indicator…
4:00PM	Sthapit	Temporal and Spatial Variation in Phytoplankton Community Biomass, Production and Composition...in Sardis Reservoir
4:20PM	Kroger	Duplicity of Plants in Nutrient Uptake within Agricultural Drainage Ditches in Mississippi: The Role of…in Different Seasons

5:00PM **SOCIAL**

35th Annual Mississippi Water Resources Conference
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Day 2: Wednesday, April 27, 2005

7:30AM **Continental Breakfast**

8:00AM **CONCURRENT SESSION D - Hydrology in Modeling - Moderator: Dave Reed**

8:00AM	McAnally	Hydrologic Modeling of an Industrial Development Site
8:20AM	Roth	Hydrologic Operations of the Lower Mississippi River Forecast Center
8:40AM	Wasson	GIS and Remotely Sensed Precipitation Data for Watershed Models
9:00AM	Fox	Simulating the Erosion of Streambanks by Lateral, Subsurface Flow

8:00AM **CONCURRENT SESSION E - Water Quality - Moderator: Mickey Plunkett**

8:00AM	Cerdiera	Effects of Tillage Systems on Triazine Herbicides Leaching on Guarany Aquifer in Brazil
8:20AM	Ampim	Factors Influencing Runoff of Pesticides from Warm Season Turfgrasses
8:40AM	Capel	Mass Balance Studies of Pesticides in Agricultural Watersheds: Importance of Agricultural Deposition
9:00AM	Willett	CYP1B-Gene Expression in Channel Catfish as a Biomarker for Sediment Contaminant Exposure
9:20AM	Rebich	Determination of Trends in Nutrient and Sediment Concentrations and Loads in Major River Basins…

9:45AM **BREAK**

10:00AM **CLOSING PLENARY SESSION - Coastal Issues - Moderator: Phil Bass**
10:00AM Bob Fairbanks, Director, Mississippi Power Company (Invited)
10:40AM Bill Walker, Executive Director, Mississippi Department of Marine Resources (Invited)
11:20AM Bryon Griffith, Director, EPA / GMPO (Invited)

12:00PM **LUNCHEON -** Scott Gordon, Region IV, EPA (Invited)

PREFACE

The 35th Annual Mississippi Water Resources Conference was held April 26-27, 2005 at the Cabot Lodge Millsaps in Jackson, Mississippi.

Conference Sponsors:

Mississippi Water Resources Research - GeoResources Institute
U.S. Geological Survey
MS Dept of Environmental Quality's Offices of Land and Water Resources and Pollution Control
Mississippi Water Resources Association

Conference Moderators:

David Shaw, Director, GeoResources Institute, Mississippi State University
Deirdre McGowan, Mississippi Water Resources Association
Dennis Rowe, Supervisory Research Geneticist, USDA-ARS
Karamat Sistani, Research Leader, USDA-ARS
Fred Howell, Biological Sciences, University of Southern Mississippi
Dave Reed, National Weather Service, Lower Mississippi River Forecast Center
Mickey Plunkett, District Chief, U.S. Geological Survey
Phil Bass, Director, Office of Pollution Control, MDEQ

Conference Speakers:

Charles Chisolm, Executive Director, MDEQ
Don Parrish, Senior Director, Regulatory Relations, Farm Bureau Federation
Worth Hager, Chair, National Waterways Conference, Inc.
Bo Robinson, Northern District Commissioner, Public Service Commission
Ken Griffin, Manager, Pearl River Valley Water Supply District
Nick Walters, Mississippi State Director, USDA Rural Development
Bob Lord, Mississippi Development Authority
Barry Royals, Waggoner Engineering, Inc.
Bob Fairbanks, Director, Mississippi Power Company
Bill Walker, Executive Director, Mississippi Department of Marine Resources
Bryon Griffith, Director, EPA/GMPO
Scott Gordon, Deputy Director, Water Management Division, US EPA, Region 4

Opening Plenary Session

Dr. David Shaw
Director
GeoResources Institute
Mississippi Water Resources Research Institute
Mississippi State University

Charles Chisolm
Executive Director
Mississippi Department of Environmental Quality

Don Parrish
Senior Director, Regulatory Relations
American Farm Bureau Federation

Worth Hager
Chair, National Waterways Conference, Inc.

Poster Session
Mississippi Water Resources

Usage Survey of Mississippi's Coastal Recreational Beaches

Steve Goff, Environmental Administrator II, Mississippi Department of Environmental Quality

The Beaches Environmental Assessment and Coastal Health Act (BEACH Act of 2000) requires states to develop a risk-based beach monitoring, notification and implementation process. The Mississippi Department of Environmental Quality's goal in this process is to evaluate usage of Mississippi's coastal recreation waters adjacent to the beaches and classify those waters based upon the potential risk to public health presented by pathogens and the use of the water. MDEQ identified twenty-two beach segments and similar points of access that are used by the public for swimming, bathing, surfing, or similar water contact activities.

As growing numbers of people move to, or visit, Mississippi coastal areas and pollution threatens the waters in which people swim and play, there exists a risk of illness from exposure to waterborne pathogens. The frequency of use, and thus the potential exposure to pathogens, can be measured by determining how many people use the beach. Mississippi does not maintain historical detailed records of the number of people using its beaches. Therefore, the task or purpose of the Usage Survey of Mississippi's Coastal Recreational Beaches was to develop a methodology and implement a process for determining frequency of public use.

The months of May through October are the primary recreational season in Mississippi. Therefore, to determine maximum exposure, the twenty-two beach segments were surveyed during the three major holiday weekends (Memorial, Independence, Labor) plus one non-holiday weekend and three week days for a total of five data collection sets. To ensure data quality and consistency, a standardized survey instrument was used, the same survey group collected data on the same beaches through out the five survey periods, and surveys were conducted during the hours of 11:00 a.m. and 4:00 p.m. on the designated dates. Results of this survey will be used to assist Mississippi's effort to manage a beach specific monitoring and notification program consistent with the requirements of the BEACH Act of 2000 and the Environmental Protection Agency's performance criteria guidance.

PLANTS OF THE COLDWATER RIVER, MISSISSIPPI, USA: COMMUNITY RECORDS ALONG THE HYDROLOGIC GRADIENT IN THE LOESS HILLS

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Keywords: Ecology, Water Quality, Conservation, Management and Planning

ABSTRACT

The natural channel of the upper Coldwater River, which drains a large (565 km^2) multi-use catchment in the loess hills of Mississippi upstream of Arkabutla Reservoir, has been predominantly un-impacted by channel modifications or recent large-scale land clearing. The river is generally bordered by floodplain forest in various stages of growth, and stream-floodplain interaction occurs frequently. Currently, however, pervasive residential sprawl from the highly urbanized region near Memphis, Tennessee, is altering land use and eventually may alter significantly the hydrology, floodplain land-use, and biological communities occurring along this natural resource.

To document existing conditions, a study of plant communities at eight locations along this river reach was conducted with recurring visits to sixteen 100m transects over a period of one year. A total of 294 species from 86 families were recorded. Greatest community richness was observed at the most upstream location with 165 plant species in 111 genera representing 59 plant families. Lowest richness (84 species) occurred at the mid-reach location. The most commonly encountered species were *Lonicera japonica* Thunb. (Japanese honeysuckle), *Impatiens capensis* Meerb. (jewelweed), *Fraxinus americana* L. (American ash) and *Sambucus nigra* L. (elderberry).

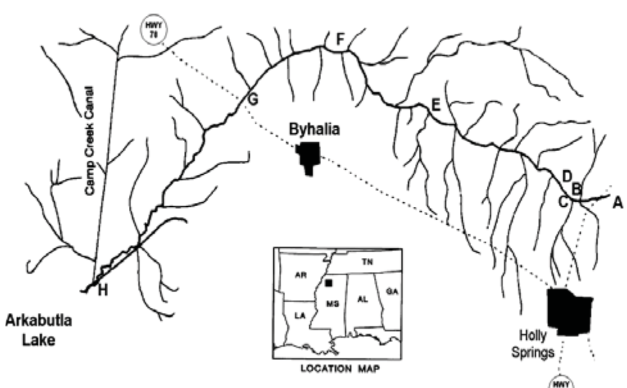
Seventeen species were collected at all eight locations while 103 species were recorded at single locations only. No records of federally-listed threatened or endangered species were made, but observations were made for *Platanthera flava* (L.) Lindl. (the palegreen orchid) which is listed as endangered, threatened or of special concern in sixteen states. Our observations also included 45 species considered to be obligate inhabitants of wetlands, including *Chelone glabra* L. (white turtlehead). Two species [*Carex pensylvanica* Lam., pensylvanica sedge; and *Lactuca biennis* (Moench), tall blue lettuce] are potentially herein reported from the state for the first

time. The upper reach of the Coldwater River is the only major hill land drainage in the Yazoo Basin which is unchannelized. Its richness of flora is reflective of its value as natural habitat.

INTRODUCTION

The Coldwater River watershed is an important stream system located in northern Mississippi, USA, which provides habitat for a large number of native plant species. It is a part of the Yazoo River drainage (32,600 km^2) that ranks 2nd in species diversity of native freshwater fishes among the state's ten river basins. A total of 119 fish species have been documented in this drainage (ROSS 2002), and biodiversity within the lotic ecosystems of the southeastern United States is comparable to the biodiversity levels found in terrestrial ecosystems in the tropics (LYDEARD & MAYDEN 1995). This region harbors numerous native plant species that have potential as sources of new medicinal compounds. The area is also noted as a historically rich region for fur trapping and fishing.

FIGURE 1. Illustration of the upper Coldwater River watershed, indicating plant sampling transect locations (A – H) in relation to landmark features in north-central Mississippi.



UPPER COLDWATER RIVER WATERSHED AND TRANSECT LOCATIONS

The Coldwater River watershed has been selected for study under the United States National Water-Quality Assessment Program, the Vigil Network Global Climatic Change monitoring program, and the federal inter-agency Demonstration Erosion Control Project in the Yazoo Basin due to valued natural characteristics in some of its regions and high potential for damage from anthropogenic disturbances. The presence of a non-channelized river with natural riparian vegetation along its corridor has provided water quality protection both within the study area and further downstream. Land-cover and water quality conditions in the upper Coldwater River directly influence two important downstream resources: Arkabutla Lake, a large flood control, fishing and recreational use reservoir located above the edge of the Mississippi Alluvial Plain, and, further downstream, the Coldwater River National Wildlife Refuge that encompasses over 10 km^2 of protected wildlife habitat.

The study watershed (565 km^2) consisted of the river drainage area upstream of Arkabutla Reservoir, where the Coldwater River flows generally westward for approximately 56 km across northern Mississippi from Benton County through Marshall, DeSoto and Tate counties. The river was bordered by floodplain forest in various stages of growth, and stream-floodplain interaction occurred frequently.

The Hills portion of the Yazoo basin lies within the Gulf Coastal Plain Physiographic Province and is composed of three major subdivisions. The western-most subdivision is the Loess Hills that is comprised of loess-covered hills rising 30 meters or more above the Yazoo Delta area (Schumm, et al., 1984).

The region was historically disturbed by agricultural investiture, beginning in 1832-1834 when it was ceded from the Chickasaw Indian Nation. Harper (1857) provided the first mention of gully formation in the hills. Hildgard (1860) gave a detailed description of massive soil loss that accompanied farming and also documented valley sedimentation which rendered the floodplains unusable and created swamps; thus, the description "swamped-out" valleys or bottoms. A series of channel cleanouts and enlargements began in the late 19th century throughout the region and continued through the 1960s, but wholesale channelization did not result as in nearby watersheds. While adjacent watersheds were completely or nearly completely channelized to promote drainage, the upper Coldwater River was only slightly affected. Floodplain habitats were allowed to regenerate, probably because the natural meandering channel promoted frequent stream-floodplain interaction which discouraged farming. Although somewhat influenced by invasive and escaped species, the upper Coldwater River represents a regional reference area for comparisons of plant community composition in the Loess Hills region of north Mississippi. Recent rural development in the upstream portion of the region, and "escapist" and "bedroom community" developments in the downstream portion of the watershed near the metropolitan region of Memphis, Tennessee, however, threaten to significantly alter the land and drainage of the study watershed, with an attendant change in the plant communities.

We hypothesized that the upper Coldwater River locations would harbor a rich and potentially important population of plants that contribute to the area's value as a reference for the region. We also believed that there might be differences in the plant community makeup along the hydrological gradient from upstream to downstream. With this study, we document the composition of the plant community along the upper Coldwater River from northeast of Holly Springs, MS, to near Hernando, MS, prior to the beginning of the 21st century. We also discuss the importance of selected plant species occurring along the river and differences in the communities from the upstream to downstream locations we studied.

Methods

Sixteen transects, each 100 meters long, were censused for plant species at eight locations in the Loess Hills region of Mississippi along the Coldwater River in Marshall and DeSoto counties (FIGURE 1). Transect locations were selected based on explorations throughout the study area where markedly different habitat types were observed. Greater diversity of habitats was found in the extreme upstream eastern portion of the watershed, resulting in closer proximity of transect locations in that area. Gross characteristics of each transect are given in TABLE 1, and illustrated in figures A through H.

Transects at each location originated at the center of river water surface width to allow documentation of aquatic plant species and continued, perpendicular to the thalweg, over the river bank and through the riparian zone to a point 100 m from the origin. Markers were inserted in the ground at the 5, 15, 30, 60 and 100 meter points to delineate the transect location for repeated visits and allow sub-transect assessment of community makeup. Two transects were established at each location, each originating at the same mid-river point, but extending in opposite directions perpendicular to the river thalweg.

Each transect was sampled at least 4 times during 42 collecting trips between August 1989 and November 1990. Sampling visits were not made during the cold season months of December through February. Sampling was done by walking the transect length and identifying and recording all plant species which occurred within one meter on either side of the transect line. Specimens (usually only portions of individuals) were taken for any individual that required additional scrutiny. Specimens were identified to species if possible. Multiple visits throughout the growing season targeted specimens that were ephemeral or that produced structures required for identification during only a portion of the year. A total of 2,576 observations of plant species were made during the study.

TABLE 1. General characteristics and location of plant transects sampled during this study.

TRANSECT	DESCRIPTION	LOCATION
A-North A-South	Bottomland Hardwood Swamp-bottomland Hardwood-Field	N34° 50.710' W89° 25.063'
B-North B-South	Bottomland Hardwood Open Marsh	N34° 50.852' W89° 26.763'
C-North C-South	Bottomland Hardwood Swamp / Marsh	N34° 50.976' W89° 26.819'
D-North D-South	Open Marsh Open Marsh	N34° 51.057' W89° 26.932'
E-North E-South	Bottomland Hardwood Bottomland Hardwood	N34° 53.747' W89° 33.836'
F-North F-South	Bottomland Hardwood Bottomland Hardwood	N34° 56.320' W89° 39.499'
G-North G-South	Bottomland Hardwood- Open Marsh Bottomland Hardwood	N34° 54.961' W89° 44.416'
H-North H-South	Bottomland Hardwood, note: both sides of transect H traverse a large levee Bottomland Hardwood to Wet Meadow	N34° 47.941' W89° 52.589'

An attempt was made to identify every encountered plant to species level, but this was not possible in a few cases due to unavailability of necessary fruiting or other discriminatory structures at the time of visits. Such taxa, identified only to genus or a higher level, were included in the taxonomic list and counted in taxa richness tabulations if weight of evidence indicated they represented a separate taxon not already identified to species within that sub-transect. In a few cases, more than one species was possibly represented by a higher identified taxon, especially in the cases of Poaceae (grasses) and Cyperaceae (sedges).

Taxonomy, remarks on species characteristics, and distributions were taken mainly from the PLANTS database (USDA, NRCS 2004), with additional support and anecdotal information taken from RADFORD et al. (1968), RICKETT (1975) and TIMME (1989). The Morisita-Horn index of community similarity has been shown to be a robust indicator for comparing community makeup between locations (MAGURRAN 1988), and is calculated according to COLWELL (1997).

Results

<u>Taxa Richness and Importance</u>

A total of 294 plant species from 86 families and 189 genera were recorded. Greatest community richness was observed at the most upstream location with 165 plant species in 111 genera representing 59 plant families. Lowest richness (84 species) occurred at the mid-watershed location. A summary of total plant taxa richness at each transect and location is given in TABLE 2.

The most commonly encountered species were *Lonicera japonica* Thunb. (Japanese honeysuckle), *Impatiens capensis* Meerb.

(jewelweed), and *Sambucus nigra* L. (elderberry). Other species observed with 50% or greater overall frequency of occurrence during our study [number of occurrences at any sub-transect range at any location or transect divided by 80 (total number of sub-transect ranges as defined above)] were *Fraxinus americana* L. (American ash), *Acer negundo* L. (boxelder), *Bignonia capreolata* L., *Boehmeria cylindrica* (L.) Sw., *Smilax rotundifolia* L., *Polygonum hydropiperoides* Michx., and *Commelina virginica* L.. (Note that sub-transects were unequal in length and presence/absence frequency calculations given here are not density values.)

Seventeen species were collected at all eight locations (TABLE 3), while 103 species were recorded at only one location (TABLE 4). No collections of federally-listed threatened or endangered species were made, but observations were made for *Platanthera flava* (L.) Lindl. (the palegreen orchid) which is listed as endangered, threatened or of special concern in sixteen states. Our observations also included 45 species considered to be obligate inhabitants of wetlands (TABLE 4), including *Chelone glabra* L. (white turtlehead). Two species, *Carex pensylvanica* Lam. and *Lactuca biennis* (Moench), are herein reported from the state potentially for the first time.

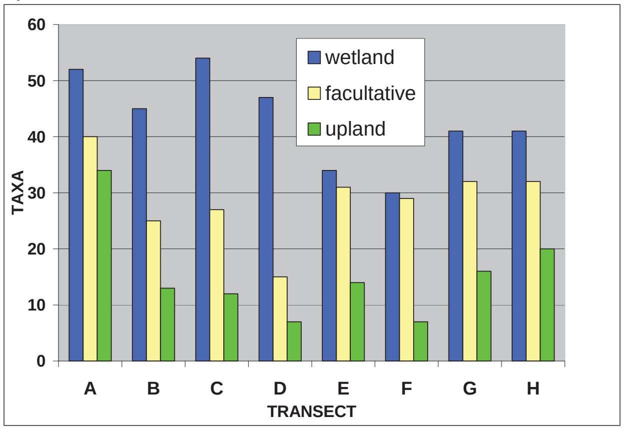
TABLE 2. Summary of total plant taxa richness measured at each 100-meter transect and location (two transects, north and south of the river, combined for each location) in the upper Coldwater River watershed.

LOCATION - TRANSECT	TRANSECT RICHNESS	LOCATION RICHNESS
A-North	88	-
A-South	133	165
B-North	58	-
B-South	80	102
C-North	81	-
C-South	94	118
D-North	63	-
D-South	61	85
E-North	81	-
E-South	69	102
F-North	73	-
F-South	67	84
G-North	72	-
G-South	86	111
H-North	76	-
H-South	94	121

Differences Along the Hydrologic Gradient

Wetland affiliated taxa dominated at all sites, as would be expected due to the influence of the river (FIGURE 2). Locations A, B, C and D near the upper end of the river system harbored the largest number of obligate and facultative wetland species. In addition to having the second highest number of wetland species, the most upstream location, A, also had the highest number of facultative and upland taxa, reflecting the diversity of land relief and cover there. Location A was similar in community makeup to sites B and C (Morisita-Horn community similarity indexes 0.68 and 0.67 respectively) but not nearly as similar to location D (index 0.51), though distances between sites B, C and D were small. Low community similarity also was observed between location A and locations E, F and G, but with somewhat heightened similarity to site H (FIGURE 3).

FIGURE 2. Number of plant taxa at each location that characteristically prefer wetland or upland habitats, or are facultative.



Discussion and Conclusion

The most commonly encountered species was a non-native species. *Lonicera japonica* (commonly known as Japanese honeysuckle) is an introduced perennial vine that occurs throughout much of the continental United States and has been listed as an invasive and noxious weed by numerous authorities. It was once a common stock of nurseries for household plantings and has lived as an escaped ornamental for decades. Japanese honeysuckle occurred at all 8 locations and was encountered with a 76.25% frequency of occurrence. Perhaps this should emphasize the importance of describing and monitoring the community makeup of our natural resources in order to identify and track the progress of invasions.

Impatiens capensis is a native herbaceous annual species found throughout the continental U.S. with the exception of the southwest. Jewelweed (also known as “lady's-earrings”, “orange balsam”, “orange touch-me-not”, “snapweed”, and “spotted jewelweed”) is commonly found in boggy shaded areas and is a facultative wetland species (estimated 67%-99% probability of occurrence in wetlands). Historically, it had ethnic use as a treatment for eczema and rashes. It has been used by at least 14 Native American tribes as an ingredient in various medicines, especially to relieve itching associated with poison ivy, stinging nettle and insect bites, and as a dye. Jewelweed had a 75% frequency of occurrence during our study.

Sambucus nigra, or common elderberry (ssp. *canadensis* (L.) R. Bolli) is a large deciduous shrub that is a facultative wetland inhabitant (estimated probability 67%-99%). Its known range includes most of the continental United States except the extreme northwestern and west-central states. Elderberry produces a showy edible fruit that attracts many species of birds and other wildlife and is used by humans to make preserves, jellies, pies and wine. Portions of this plant have been shown to contain 49 phytochemicals with a variety of medicinal or toxicological actions. The plant has been used widely by the Native American tribes throughout the United States for both medicinal and food purposes. Elderberry was encountered with a 67.50% frequency in our study.

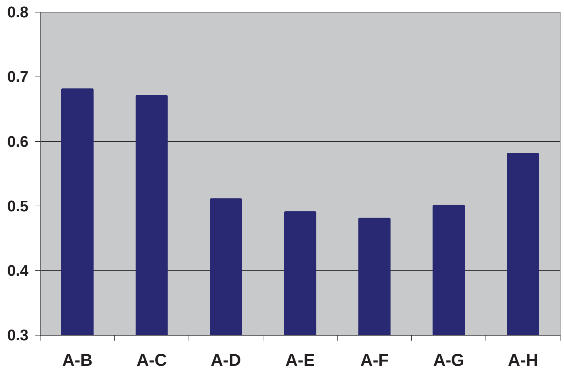
TABLE 3. Plant taxa collected at all eight locations and their wetland affinity (USFWS 1988 – legend repeated at end of this paper**).

Scientific Name	Wetland Affinity
Acer negundo L.	FACW
Acer rubrum L.	FAC
Betula nigra L.	FACW
Boehmeria cylindrica (L.) Sw.	FACW+
Chasmanthium latifolium (Michx.) Yates	FAC-
Cicuta maculata L.	OBL
Clematis virginiana L.	FAC+
Commelina virginica L.	FACW
Fraxinus americana L.	FACU
Impatiens capensis Meerb.	FACW
Lonicera japonica Thunb.	FAC-
Lycopus virginicus L.	OBL
Onoclea sensibilis L.	FACW
Polygonum hydropiperoides Michx.	OBL
Sambucus nigra L.	NI
Smilax rotundifolia L.	FAC
Viola L.	NI

Fraxinus americana is a common large woody native tree known as American ash or white ash. This species usually occurs in other settings but is occasionally found in wetlands (estimated probability 1%-33%). [Authors note: Records of this species in our study probably include immature specimens of *Fraxinus caroliniana* P. Mill. (Carolina ash) which is an obligate wetland inhabiting species.] It occurs throughout the eastern and most of the central United States, and is cultivated in Hawaii. Wood from this tree is economically important, especially for use as tool handles and baseball bats. American ash provides a seed that is an important food source for numerous birds including wood ducks and quail, as well as many small mammals, and the bark is eaten by deer, cattle, beaver, porcupine and rabbits. If broken, this tree readily forms cavities that are very important to tree nesters such as red-headed, red-bellied, and pileated woodpeckers, and are secondarily used by wood ducks, owls, nuthatches, and gray squirrels. American ash has been shown to contain the phytochemical, Betulin that has pharmacologic antiHIV, anticarcinomic, antifeedant, antiflu, anti-inflammatory, antitumor, antiviral, aphidifuge, cytotoxic, hypolipemic, prostaglandin-synthesis-inhibitor, and topoisomerase-II-inhibitor activities. Parts of the plant have been used ethnobotanically by at least 8 Native American tribes as an aperitif, aphrodisiac, astringent, treatment for snakebite, cancer, a diuretic, medicine poultice, puerperium, for sores, as a sudorific, and as a tonic for other medicinal purposes. American ash occurred with 58.75% frequency during our study.

Acer negundo, or boxelder, is a small to large tree with irregular form that occurs throughout the United States. It is noted to grow along lakes and streams, in floodplains, and in other low-lying wet places with abundant moisture. Boxelder has little economic importance because its branches are weak and break easily, and the soft wood of the trunk is susceptible to rot. The species is, however, very important to wildlife for the habitat it creates within the riparian corridor, and its seeds are eaten by both birds and squirrels. The sap of boxelder contains abundant sugar, and has been used by humans to make a pleasant beverage, boiled for its sugar, and mixed with inner animal hide scrapings to make a type of candy by Native American tribes. Also known as ash-leaf maple and three-leaf maple, we encountered boxelder with a 56.25% frequency of occurrence.

FIGURE 3. Morisita-Horn community similarity index values for the plant community at location A (most upstream location where highest overall diversity occurred) and each other location sampled in this study. Higher values indicate more similarity.



Bignonia capreolata is a native vine that may grow up to 15 meters, usually along forest edges or gaps, with fragrant showy orange-red trumpet-shaped flowers. It is often found climbing the trunks of tall trees or sprawling along the ground through east-central and the southeastern United States. Known as crossvine, this species is noted to grown in low woods and swamps, but is facultative, with about an even chance of occurrence within or outside of wetlands. It occurs throughout the eastern U.S., where it has been used as a cover for fences, arbors, walls, pillars or large trellises. It has been used ethnobotanically as an alterative, analgesic, antirheumatic, for obesity, to cleanse the blood, for “thirst”, and to make soap. The common name derivation may be discerned by cutting the stem, which reveals a marking resembling the Greek cross. The cylindrical pod-like seed capsules, that are about 7 inches long, often persist from late summer through fall. The foliage remains evergreen in much of the South, including Mississippi. It occurred in our study with a 52.50% frequency, as did the following two species.

Boehmeria cylindrica, or smallspike false nettle (sometimes called bog-hemp), occurs as a perennial herb throughout the eastern and central U.S. It is most likely to be found in wetlands, but is facultative, and may be found occasionally in upland forest, shrub and sedge-meadow habitats. Its common habitat, however, is low ground, bogs, swamp forests, marshes and alluvial woods. This species resembles stinging nettles (*Urtica* spp.) but lack the stinging trichomes. Alkaloids from this species have been found to have active antimicrobial, antiviral and strongly anticarcinomic properties (FARNSWORTH ET AL. 1969, KRMPOTIC ET AL. 1972, AL-SHAMMA ET AL. 1982).

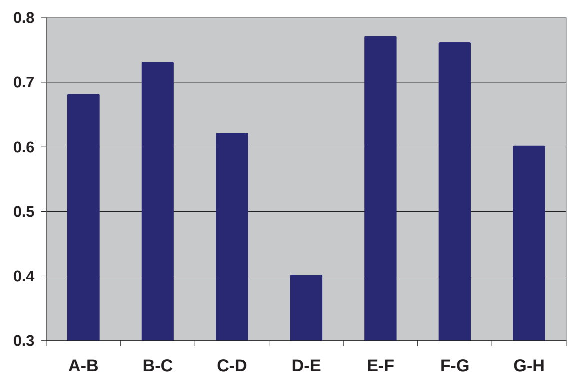
Smilax rotundifolia is a native woody vine that may climb 3 to 6 meters. Known as roundleaf greenbrier or common greenbrier, this species occurs throughout the eastern and central U.S. but is listed as invasive in the northeast. It is a facultative species that is equally likely to occur within or outside of wetlands. Roundleaf greenbrier regenerates by rhizomes and seeds from berries. The rhizomes have been shown to survive for years after the plant has been top-killed by fire or other disturbances. The persistent fruits are an important late winter and early spring food for wintering birds, and white-tailed deer browse foliage, shoots and canes of this plant. Because it may form a prickly impenetrable thicket, this plant can provide protective habitat for birds and other small animals. It has been used by Native American tribes as an analgesic, antirheumatic, and as a dermatologic aid for skin burns, galls, and boils.

Polygonum hydropiperoides is a small perennial upright plant with “spiked” pinkish flower heads. It is an obligate wetland plant species. Swamp smartweed, as it is known, occurs throughout most of the United States with the exception of the west-central mountain states. It is listed as threatened in both Indiana and New York. Swamp smartweed has been found to contain at least 11 phytochemicals of interest, and has also been found capable of the phytoaccumulation of potentially toxic trace elements (QIAN ET AL. 1999), making it of potential use in remediation of contaminated lands.

Commelina virginica is a perennial herb that grows to a height of 1 meter in wet places, especially swamps, river and stream banks, ditches, and bottomlands. It occurs throughout the southeastern U.S. toward the northeast, where it has been listed as extirpated from Pennsylvania. Virginia dayflower, as it is commonly called, is a predominantly wetland species, with an estimated probability 67%-99% of occurrence in wetland habitats but can be facultative and occasionally occurs elsewhere. It flowers in mid-summer with pale blue petals. It has been used ethnically as a diuretic, for fever, nerves and spasm. *Commelina virginica* occurred with 50.00% frequency during our study.

Of those taxa found at all locations (TABLE 3), most were facultative wetland inhabitants, but three were obligate wetland species. *Cicuta maculata*, or spotted water hemlock, occurs throughout the continental United States and is an obligate wetland species in our region. Its toxic effects on man have been known for nearly two centuries (ELY 1814). It is also the culprit in numerous accounts of livestock poisoning dating back to at least 1899 (WILCOX 1899, BURROWS 1989), probably accounting for one of its other common names, spotted cowbane. The phytochemical, cicutine, has been isolated from spotted water hemlock, but no useful medical activities have been associated with this compound, Researchers (KONOSHIMA & LEE 1986) have studied the extract, cicutoxin, and its derivatives as an anti-leukemic principle. The plant has been used ethnobotanically for contraception (chewing the root to cause sterilization) and to treat tumors but is most notably used for suicide. Native American tribes have used spotted water hemlock as an insecticide, disinfectant, and as an anti-rheumatic and dermatologic aid for sores or lesions.

FIGURE 4. Morisita-Horn similarity indices for site-to-site community comparisons along the hydrologic gradient from the most upstream location, A, to the most downstream location, H.



The obligate wetland species *Lycopus virginicus* (Virginia water horehound) occurs throughout the east and most of the central U.S. in North America and is a member of the mint family, Lamiaceae. It contains at least 24 phytochemicals with wide-ranging actions (245 potential economic actions studied and reported) (DUKE 2005). The root of this plant was used by the Cherokee as a snakebite remedy and to give them “eloquence of speech”, while other ethnic uses have been as an astringent, narcotic, sedative, for diabetes and diarrhea, and for ailments of the lung, including cough and tuberculosis.

Polygonum hydropiperoides (discussed earlier) is the final obligate wetland inhabitant found at all locations during our study. The species occurs throughout most of the contiguous United States, with exception of the four west-central states of Colorado, Utah, Wyoming, and Montana. Known as swamp smartweed or false water-pepper, the 11 phytochemicals produced by this plant have been shown to have over 200 potential economically exploitable actions. While references to ethnic uses for this plant were not available, it seems likely from the known activities of this plant that use did occur.

While the river channel has not been straightened nor the entire floodplain cleared, most of the Coldwater River landscape has been impacted by human activities. It is likely that the floodplain forest was spoiled with the rest of the landscape after 1832 although recent timber harvest has been fragmented. The array of plants found at each of the cross-sections provided a successionally-oriented snapshot of a dynamic floodplain. Few trees were observed that were estimated to be over 60 years old. Tree growth in some sections was much younger as suggested by both diameter and species. Topographical features that provided elevation differences always provided species variability. Species diversity was affected most visibly by ponding, especially in reaches where excessive sediments were deposited, old cutoffs collected water, or where natural levee-building was dominant. Lowest diversity in mid-reach was at sites D and E which were strongly influenced by habitat type. As an open marsh, Site D was dominated by grasses and sedges. Site E supported hardwoods with a dense canopy which shaded out potential herbs.

The upper reach of the Coldwater River is the only major hill land drainage in the Yazoo Basin that is unchannelized. Its richness of flora is reflective of its value as natural habitat. Its botanical characteristics and floral diversity provide a snapshot of not just a river corridor exhibiting stream/floodplain interactions, but one which reflects stream/floodplain/human interactions. Such landscapes supply habitat not found otherwise and provide helpful ecosystem functions such as water quality improvement and flood flow retardment. Their plants may also provide us with an array of natural products.

Acknowledgements

This research was accomplished as part of the Demonstration Erosion Control Project in the Yazoo Basin. Partial funding was received from the U.S. Army Corps of Engineers, Vicksburg District. P.G. McCoy, T.D. Welch, Kenneth Dalton and S.S. Knight provided assistance necessary to complete this research, and their efforts are appreciated. Voucher specimens are housed in the University of Mississippi herbarium.

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This publication is dedicated to co-author Dr. Maeburn Bruce Huneycutt, who passed away on December 20, 2004, at the age of 81. Dr. Huneycutt is the former curator of the Herbarium at the University of Mississippi, Chair of the Department of Biology, Dean of the College of Liberal Arts, Chair of the Senate of the Faculty, president of the local chapters of Phi Kappa Phi, Sigma Xi, and Mississippi Academy of Sciences, as well as serving on numerous other academic committees at the University of Mississippi and directing institutes of the National Science Foundation. But for an unfortunate combination of events, Dr. Huneycutt would still be with us, wandering through the fields, pastures, woods and swamps, searching out the interesting or odd plant that occurred, or should occur, there in the wild places of Mississippi. He will be missed.

Table 4. Taxonomic list of plants recorded, with wetland affinity designations and locations of collection.

Scientific Name	Common Name	Family	Wetland Status **	Locations (see Fig. 1)
Acalypha rhomboidea Raf.	Virginia threeseed mercury	Euphorbiaceae	NI	BEFH
Acer negundo L.	boxelder	Aceraceae	FACW	ABCDEFGH
Acer rubrum L.	red maple	Aceraceae	FAC	ABCDEFGH
Acer saccharinum L.	silver maple	Aceraceae	FACW	FGH
Aesculus pavia L.	red buckeye	Hippocastanaceae	FAC	ABCG
Ageratina altissima (L.) King & H.E. Robins.	white snakeroot	Asteraceae	FACU-	FGH
Agrostis L.	bentgrass	Poaceae	NI	A
Allium canadense L.	meadow garlic	Liliaceae	FACU-	AE
Allium L.	onion	Liliaceae	NI	ABC
Allium vineale L.	wild garlic	Liliaceae	FACU	A
Alnus serrulata (Ait.) Willd.	hazel alder	Betulaceae	FACW	ABCD
Alopecurus carolinianus Walt.	Carolina foxtail	Poaceae	FACW	AC
Ambrosia artemisiifolia L.	annual ragweed	Asteraceae	FACU	ABCDGH
Ambrosia trifida L.	great ragweed	Asteraceae	FAC	ABCDEFH
Ammannia coccinea Rottb.	valley redstem	Lythraceae	OBL	GH
Ampelopsis arborea (L.) Koehne	peppervine	Vitaceae	FAC+	H
Apios americana Medik.	groundnut	Fabaceae	FACW	ABCDGH
Arabidopsis thaliana (L.) Heynh.	mouseear cress	Brassicaceae	NI	B
Aralia spinosa L.	devil's walkingstick	Araliaceae	FAC	A
Arisaema dracontium (L.) Schott	green dragon	Araceae	FACW	ABCGH
Aristolochia serpentaria L.	Virginia snakeroot	Aristolochiaceae	FACU	EF
Arthraxon hispidus (Thunb.) Makino	small carpgrass	Poaceae	FACU+	ABCDG
Arundinaria gigantea (Walt.) Muhl.	giant cane	Poaceae	FACW	ACEG
Asclepias variegata L.	redring milkweed	Asclepiadaceae	FACU	A
Berchemia scandens (Hill) K. Koch	Alabama supplejack	Rhamnaceae	FACW	G
Betula nigra L.	river birch	Betulaceae	FACW	ABCDEFGH
Bidens L.	beggarticks	Asteraceae	NI	CDE
Bignonia capreolata L.	crossvine	Bignoniaceae	FAC	ABCDEFG
Boehmeria cylindrica (L.) Sw.	smallspike false nettle	Urticaceae	FACW+	ABCDEFGH
Botrychium dissectum Spreng.	cutleaf grapefern	Ophioglossaceae	FAC	EG
Botrychium virginianum (L.) Sw.	rattlesnake fern	Ophioglossaceae	FACU	E
Bromus L.	brome	Poaceae	NI	H
Brunnichia ovata (Walt.) Shinners	American buckwheat vine	Polygonaceae	FACW	EFGH
Callitriche heterophylla Pursh	twoheaded water-starwort	Callitrichaceae	OBL	ACE
Campsis radicans (L.) Seem. ex Bureau	trumpet creeper	Bignoniaceae	FAC	ABCEFGH
Cardamine bulbosa (Schreb. ex Muhl.) B.S.P.	bulbous bittercress	Brassicaceae	OBL	ACEGH
Cardamine hirsuta L.	hairy bittercress	Brassicaceae	FAC	AH
Carex albolutescens Schwein.	greenwhite sedge	Cyperaceae	FAC+	D
Carex blanda Dewey	eastern woodland sedge	Cyperaceae	FAC-	BCEFGH
Carex caroliniana Schwein.	Carolina sedge	Cyperaceae	FACW	G
Carex cephalophora Muhl. ex Willd.	oval-leaf sedge	Cyperaceae	FAC	H
Carex complanata Torr. & Hook.	hirsute sedge	Cyperaceae	FAC+	AH
Carex crinita Lam.	fringed sedge	Cyperaceae	FACW+	ABCD
Carex festucacea Schkuhr ex Willd.	fescue sedge	Cyperaceae	FACW	A
Carex frankii Kunth	Frank's sedge	Cyperaceae	OBL	BCDH
Carex grayi Carey	Gray's sedge	Cyperaceae	FACW	G
Carex laevivaginata (Kükenth.) Mackenzie	smoothsheath sedge	Cyperaceae	NI	D
Carex lupulina Muhl. ex Willd.	hop sedge	Cyperaceae	OBL	ABD
Carex lurida Wahlenb.	shallow sedge	Cyperaceae	OBL	ABCD
Carex muehlenbergii Schkuhr ex Willd.	Muhlenberg's sedge	Cyperaceae	NI	BDH
Carex pensylvanica Lam.	pensylvanica	Cyperaceae	NI	A
Carex retroflexa Muhl. ex Willd.	reflexed sedge	Cyperaceae	NI	A
Carex rosea Schkuhr ex Willd.	rosy sedge	Cyperaceae	NI	BCEFG
Carex L.	sedge	Cyperaceae	NI	ADGH
Carex triangularis Boeckl.	eastern fox sedge	Cyperaceae	FACW	A
Carex tribuloides Wahlenb.	blunt broom sedge	Cyperaceae	FACW+	ADH
Carex vulpinoidea Michx.	fox sedge	Cyperaceae	OBL	D
Carpinus caroliniana Walt.	American hornbeam	Betulaceae	FAC	BCDEFGH
Carya alba (L.) Nutt. ex Ell.	mockernut hickory	Juglandaceae	NI	AEGH
Catalpa speciosa (Warder) Warder ex Engelm.	northern catalpa	Bignoniaceae	FACU	DE

Celtis laevigata Willd.	sugarberry	Ulmaceae	FACW	G
Celtis occidentalis L.	common hackberry	Ulmaceae	FAC*	H
Cephalanthus occidentalis L.	common buttonbush	Rubiaceae	OBL	ABCDEFH
Cerastium L.	mouse-ear chickweed	Caryophyllaceae	NI	A
Ceratophyllum demersum L.	coon's tail	Ceratophyllaceae	OBL	D
Chaerophyllum tainturieri Hook.	hairyfruit chervil	Apiaceae	FAC	ABE
Chamaecrista fasciculata (Michx.) Greene	sleepingplant	Fabaceae	FACU	AH
Chamaecrista nictitans (L.) Moench	partridge pea	Fabaceae	NI	A
Chamaecrista (L.) Moench	sensitive pea	Fabaceae	NI	A
Chasmanthium latifolium (Michx.) Yates	Indian woodoats	Poaceae	FAC-	ABCDEFGH
Chelone glabra L.	white turtlehead	Scrophulariaceae	OBL	CD
Chenopodium ambrosioides L.	Mexican tea	Chenopodiaceae	FACU	AH
Cicuta maculata L.	spotted water hemlock	Apiaceae	OBL	ABCDEFGH
Cinna arundinacea L.	sweet woodreed	Poaceae	FACW	ABCDEF
Cirsium carolinianum (Walt.) Fern. & Schub.	soft thistle	Asteraceae	NI	A
Claytonia virginica L.	Virginia springbeauty	Portulacaceae	FACU-	AB
Clematis virginiana L.	devil's darning needles	Ranunculaceae	FAC+	ABCDEFGH
Commelina communis L.	Asiatic dayflower	Commelinaceae	FAC	E
Commelina L.	dayflower	Commelinaceae	NI	EG
Commelina virginica L.	Virginia dayflower	Commelinaceae	FACW	ABCDEFGH
Conoclinium coelestinum (L.) DC.	blue mistflower	Asteraceae	NI	CFGH
Conyza canadensis (L.) Cronq.	Canadian horseweed	Asteraceae	FACU	ABC
Coreopsis major Walt.	greater tickseed	Asteraceae	NI	C
Coreopsis L.	tickseed	Asteraceae	NI	A
Coreopsis tripteris L.	tall tickseed	Asteraceae	FAC	ABDH
Cornus amomum P. Mill.	silky dogwood	Cornaceae	FACW+	B
Cornus florida L.	flowering dogwood	Cornaceae	FACU	ABC
Cornus foemina P. Mill.	stiff dogwood	Cornaceae	FACW-	ABCD
Corylus americana Walt.	American hazelnut	Betulaceae	FACU	ABC
Cryptotaenia canadensis (L.) DC.	Canadian honewort	Apiaceae	FAC+	ABCEFG
Cuscuta compacta Juss. ex Choisy	compact dodder	Cuscutaceae	NI	ABCDEGH
Cynanchum laeve (Michx.) Pers.	honeyvine	Asclepiadaceae	FAC	EF
Cyperus odoratus L.	fragrant flatsedge	Cyperaceae	FACW	A
Cyperus L.	flatsedge	Cyperaceae	NI	A
Cyperus strigosus L.	strawcolored flatsedge	Cyperaceae	FACW+	DH
Desmodium nudiflorum (L.) DC.	nakedflower ticktrefoil	Fabaceae	NI	A
Desmodium Desv.	ticktrefoil	Fabaceae	NI	A
Dichanthelium scoparium (Lam.) Gould	velvet panicum	Poaceae	FACW	ABCFH
Diodia virginiana L.	Virginia buttonweed	Rubiaceae	FACW	DG
Dioscorea oppositifolia L.	Chinese yam	Dioscoreaceae	NI	AH
Diospyros virginiana L.	common persimmon	Ebenaceae	FAC	BEGH
Duchesnea indica (Andr.) Focke	Indian strawberry	Rosaceae	FACU*	G
Echinochloa crus-galli (L.) Beauv.	barnyardgrass	Poaceae	FACW-	D
Eclipta prostrata (L.) L.	false daisy	Asteraceae	FACW-	ACGH
Eleocharis obtusa (Willd.) J.A. Schultes	blunt spikerush	Cyperaceae	OBL	A
Elephantopus tomentosus L.	devil's grandmother	Asteraceae	NI	ACEFG
Elymus virginicus L.	Virginia wildrye	Poaceae	FAC	ABCEFH
Eragrostis von Wolf	lovegrass	Poaceae	NI	D
Erigeron philadelphicus L.	Philadelphia fleabane	Asteraceae	FAC	A
Erigeron L.	fleabane	Asteraceae	NI	C
Erigeron strigosus Muhl. ex Willd.	prairie fleabane	Asteraceae	FAC	H
Euonymus americana L.	strawberry bush	Celastraceae	NI	ABCEG
Eupatorium fistulosum Barratt	trumpetweed	Asteraceae	FAC+	A
Eupatorium serotinum Michx.	lateflowering thoroughwort	Asteraceae	FAC	AD
Fabaceae gen. sp.	bean	Fabaceae	NI	BH
Festuca subverticillata (Pers.) Alexeev	nodding fescue	Poaceae	FACU	E
Fraxinus americana L.	white ash	Oleaceae	FACU	ABCDEFGH
Fraxinus profunda (Bush) Bush	pumpkin ash	Oleaceae	OBL	ACDEFGH
Galium aparine L.	stickywilly	Rubiaceae	FACU	ABCDEGH
Geum canadense Jacq.	white avens	Rosaceae	FAC	BCEFG
Gleditsia triacanthos L.	honeylocust	Fabaceae	FAC	FG
Glyceria striata (Lam.) A.S. Hitchc.	fowl mannagrass	Poaceae	OBL	F
Glycine max (L.) Merr.	soybean	Fabaceae	NI	A
Gratiola L.	hedgehyssop	Scrophulariaceae	NI	ACH
Helenium flexuosum Raf.	purplehead sneezeweed	Asteraceae	FACW	A
Helianthus divaricatus L.	woodland sunflower	Asteraceae	NI	AC
Helianthus L.	sunflower	Asteraceae	NI	A

Heliotropium indicum L.	Indian heliotrope	Boraginaceae	FAC+	G
Hordeum pusillum Nutt.	little barley	Poaceae	FACU	H
Houstonia pusilla Schoepf	tiny bluet	Rubiaceae	FAC-	A
Hydrangea arborescens L.	wild hydrangea	Hydrangeaceae	FACU	C
Hypericum hypericoides (L.) Crantz	St. Andrew's cross	Clusiaceae	NI	A
Hypericum mutilum L.	dwarf St. Johnswort	Clusiaceae	FACW	ADEH
Hypericum L.	St. Johnswort	Clusiaceae	NI	AE
Ilex decidua Walt.	possumhaw	Aquifoliaceae	FACW-	EFGH
Impatiens capensis Meerb.	jewelweed	Balsaminaceae	FACW	ABCDEFGH
Ipomoea purpurea (L.) Roth	tall morning-glory	Convolvulaceae	FACU	ABG
Ipomoea L.	morning-glory	Convolvulaceae	NI	FH
Itea virginica L.	Virginia sweetspire	Grossulariaceae	FACW+	CD
Juncus debilis Gray	weak rush	Juncaceae	OBL	A
Juncus effusus L.	common rush	Juncaceae	FACW+	ABCDH
Juncus tenuis Willd.	poverty rush	Juncaceae	FAC	ABH
Juniperus virginiana L.	eastern redcedar	Cupressaceae	FACU-	H
Krigia caespitosa (Raf.) Chambers	weedy dwarfdandelion	Asteraceae	NI	DH
Krigia dandelion (L.) Nutt.	potato dwarfdandelion	Asteraceae	FACU	H
Kummerowia striata (Thunb.) Schindl.	Japanese clover	Fabaceae	FACU	H
Lactuca biennis (Moench) Fern.	tall blue lettuce	Asteraceae	FACU	A
Lactuca canadensis L.	Canada lettuce	Asteraceae	FACU-	H
Lactuca floridana (L.) Gaertn.	woodland lettuce	Asteraceae	FACU	AEFG
Lactuca L.	lettuce	Asteraceae	NI	F
Leersia hexandra Sw.	southern cutgrass	Poaceae	OBL	ADEG
Leersia oryzoides (L.) Sw.	rice cutgrass	Poaceae	OBL	ABCDF
Leersia virginica Willd.	whitegrass	Poaceae	FACW	ABCEFG
Lespedeza cuneata (Dum.-Cours.) G. Don	Chinese lespedeza	Fabaceae	UPL*	AH
Ligustrum sinense Lour.	Chinese privet	Oleaceae	FAC	AFGH
Lindera benzoin (L.) Blume	northern spicebush	Lauraceae	FACW	C
Lindernia All.	false pimpernel	Scrophulariaceae	NI	GH
Liquidambar styraciflua L.	sweetgum	Hamamelidaceae	FAC+	ACDEFGH
Liriodendron tulipifera L.	tuliptree	Magnoliaceae	FACU	AC
Lobelia cardinalis L.	cardinalflower	Campanulaceae	FACW+	BCEF
Lonicera japonica Thunb.	Japanese honeysuckle	Caprifoliaceae	FAC-	ABCDEFGH
Ludwigia alternifolia L.	seedbox	Onagraceae	OBL	ABDH
Ludwigia palustris (L.) Ell.	marsh seedbox	Onagraceae	OBL	A
Ludwigia repens J.R. Forst.	creeping primrose-willow	Onagraceae	OBL	ABC
Ludwigia L.	primrose-willow	Onagraceae	NI	A
Lycopus americanus Muhl. ex W. Bart.	American water horehound	Lamiaceae	OBL	ACD
Lycopus L.	waterhorehound	Lamiaceae	NI	C
Lycopus virginicus L.	Virginia water horehound	Lamiaceae	OBL	ABCDEFGH
Lysimachia radicans Hook.	trailing yellow loosestrife	Primulaceae	OBL	FGH
Lysimachia L.	yellow loosestrife	Primulaceae	NI	G
Maclura pomifera (Raf.) Schneid.	osage orange	Moraceae	FACU	EFH
Matelea carolinensis (Jacq.) Woods.	maroon Carolina milkvine	Asclepiadaceae	NI	FG
Micranthemum umbrosum (J.F. Gmel.) Blake	shade mudflower	Scrophulariaceae	OBL	F
Mikania scandens (L.) Willd.	climbing hempvine	Asteraceae	FACW+	ABCDGH
Mimulus alatus Ait.	sharpwing monkeyflower	Scrophulariaceae	OBL	BCDEGH
Morus rubra L.	red mulberry	Moraceae	FAC	AEFGH
Muhlenbergia Schreb.	muhly	Poaceae	NI	H
Myosurus minimus L.	tiny mousetail	Ranunculaceae	FACW-	C
Nuphar lutea (L.) Sm.	yellow pond-lily	Nymphaeaceae	OBL	D
Nuttallanthus canadensis (L.) D.A. Sutton	Canada toadflax	Scrophulariaceae	NI	H
Nyssa sylvatica Marsh.	blackgum	Nyssaceae	FAC	AEG
Onoclea sensibilis L.	sensitive fern	Dryopteridaceae	FACW	ABCDEFGH
Oxalis stricta L.	common yellow oxalis	Oxalidaceae	UPL	CDEGH
Packera glabella (Poir) C. Jeffrey	butterweed	Asteraceae	NI	EFG
Panicum L.	panicgrass	Poaceae	NI	ABCFH
Panicum virgatum L.	switchgrass	Poaceae	FAC+	G
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper	Vitaceae	FAC	ABCEFGH
Passiflora lutea L.	yellow passionflower	Passifloraceae	NI	CEFG
Peltandra sagittifolia (Michx.) Morong	white arrow arum	Araceae	OBL	E
Peltandra virginica (L.) Schott	green arrow arum	Araceae	OBL	E
Penthorum sedoides L.	ditch stonecrop	Crassulaceae	OBL	BCDEGH
Phlox divaricata L.	wild blue phlox	Polemoniaceae	FACU-	A
Physalis L.	groundcherry	Solanaceae	NI	G
Phytolacca americana L.	American pokeweed	Phytolaccaceae	FACU+	AFGH

Pilea pumila (L.) Gray	Canadian clearweed	Urticaceae	FACW	ABCEFGH
Plantago aristata Michx.	largebracted plantain	Plantaginaceae	NI	H
Plantago rugelii Dcne.	blackseed plantain	Plantaginaceae	FAC	EF
Platanthera flava (L.) Lindl.	palegreen orchid	Orchidaceae	FACW	EGH
Platanus occidentalis L.	American sycamore	Platanaceae	FACW-	ABCEFGH
Pleopeltis polypodioides (L.) Andrews & Windham	resurrection fern	Polypodiaceae	NI	CE
Pluchea foetida (L.) DC.	stinking camphorweed	Asteraceae	OBL	CG
Poa annua L.	annual bluegrass	Poaceae	FAC	ABC
Poa L.	bluegrass	Poaceae	NI	ACG
Podophyllum peltatum L.	mayapple	Berberidaceae	FACU	A
Polygonum caespitosum Blume	oriental ladysthumb	Polygonaceae	NI	ABCEFH
Polygonum hydropiperoides Michx.	swamp smartweed	Polygonaceae	OBL	ABCDEFGH
Polygonum pensylvanicum L.	Pennsylvania smartweed	Polygonaceae	FACW	ABH
Polygonum sagittatum L.	arrowleaf tearthumb	Polygonaceae	OBL	ABCD
Polygonum scandens L.	climbing false buckwheat	Polygonaceae	FAC-	AH
Polygonum L.	knotweed	Polygonaceae	NI	AB
Polygonum virginianum L.	jumpseed	Polygonaceae	FAC	ACEFGH
Polypremum procumbens L.	juniper leaf	Buddlejaceae	FACU-	G
Poncirus trifoliata (L.) Raf.	hardy orange	Rutaceae	NI	C
Potentilla simplex Michx.	common cinquefoil	Rosaceae	FACU	A
Prunella vulgaris L.	common selfheal	Lamiaceae	FAC-	C
Prunus serotina Ehrh.	black cherry	Rosaceae	FACU	AH
Pseudognaphalium obtusifolium (L.) Hilliard & Burtt	rabbittobacco	Asteraceae	NI	H
Ptilimnium capillaceum (Michx.) Raf.	herbwilliam	Apiaceae	OBL	H
Quercus alba L.	white oak	Fagaceae	FACU	A
Quercus falcata Michx.	southern red oak	Fagaceae	FACU-	A
Quercus lyrata Walt.	overcup oak	Fagaceae	OBL	EFG
Quercus macrocarpa Michx.	bur oak	Fagaceae	FAC	E
Quercus michauxii Nutt.	swamp chestnut oak	Fagaceae	FACW-	BCEFG
Quercus nigra L.	water oak	Fagaceae	FAC	CEFG
Quercus phellos L.	willow oak	Fagaceae	FACW-	ACEFGH
Quercus shumardii Buckl.	Shumard's oak	Fagaceae	FACW-	ACGH
Quercus L.	oak	Fagaceae	NI	AH
Ranunculus abortivus L.	littleleaf buttercup	Ranunculaceae	FAC	BCDE
Ranunculus laxicaulis (Torr. & Gray) Darby	Mississippi buttercup	Ranunculaceae	OBL	C
Ranunculus parviflorus L.	smallflower buttercup	Ranunculaceae	FAC	A
Rhus copallinum L.	flameleaf sumac	Anacardiaceae	FACU-	AH
Rhus glabra L.	smooth sumac	Anacardiaceae	NI	AH
Rorippa islandica (Oeder) Borbás	northern marsh yellowcress	Brassicaceae	NI	G
Rosa palustris Marsh.	swamp rose	Rosaceae	OBL	BD
Rubus argutus Link	sawtooth blackberry	Rosaceae	FAC	E
Rubus L.	blackberry	Rosaceae	NI	ABCDEFH
Rubus trivialis Michx.	southern dewberry	Rosaceae	FAC	AH
Rumex crispus L.	curly dock	Polygonaceae	FAC	A
Rumex L.	dock	Polygonaceae	NI	H
Sagittaria latifolia Willd.	broadleaf arrowhead	Alismataceae	OBL	ABCDE
Sagittaria montevidensis Cham. & Schlecht.	giant arrowhead	Alismataceae	OBL	BD
Salix nigra Marsh.	black willow	Salicaceae	OBL	ABCDH
Sambucus nigra L.	European black elderberry	Caprifoliaceae	NI	ABCDEFGH
Sanicula canadensis L.	Canadian blacksnakeroot	Apiaceae	FACU	AEG
Sassafras albidum (Nutt.) Nees	sassafras	Lauraceae	FACU	A
Saururus cernuus L.	lizard's tail	Saururaceae	OBL	BCEFG
Scirpus atrovirens Willd.	green bulrush	Cyperaceae	OBL	BCD
Scirpus cyperinus (L.) Kunth	woolgrass	Cyperaceae	OBL	CDH
Scutellaria lateriflora L.	blue skullcap	Lamiaceae	FACW+	BD
Sida rhombifolia L.	cuban jute	Malvaceae	FACU	ABG
Sida spinosa L.	prickly fanpetals	Malvaceae	FACU	G
Silphium perfoliatum L.	cup plant	Asteraceae	FAC+	AH
Smilax bona-nox L.	saw greenbrier	Smilacaceae	FAC	ACEFG
Smilax glauca Walt.	cat greenbrier	Smilacaceae	FAC	FG
Smilax rotundifolia L.	roundleaf greenbrier	Smilacaceae	FAC	ABCDEFGH
Smilax L.	greenbrier	Smilacaceae	NI	EG
Solanum carolinense L.	Carolina horsenettle	Solanaceae	FACU	AG

Solanum nigrum L. – black nightshade	black nightshade	Solanaceae	NI	ABG
Solidago canadensis L.	Canada goldenrod	Asteraceae	FACU	ACD
Solidago L.	goldenrod	Asteraceae	NI	ABCD
Sorghum halepense (L.) Pers.	Johnsongrass	Poaceae	FACU	ABE
Sparganium americanum Nutt.	American bur-reed	Sparganiaceae	OBL	BC
Stachys floridana Shuttlw. ex Benth.	Florida hedgenettle	Lamiaceae	FAC	BCD
Stachys L.	hedgenettle	Lamiaceae	NI	DE
Stellaria media (L.) Vill.	common chickweed	Caryophyllaceae	FACU	AB
Strophostyles helvula (L.) Ell.	trailing fuzzybean	Fabaceae	FAC	BC
Stuckenia pectinatus (L.) Boerner	sago pondweed	Potamogetonaceae	NI	ABCD
Symphyotrichum dumosum (L.) Nesom	rice button aster	Asteraceae	NI	EFGH
Symphyotrichum ericoides (L.) Nesom	white heath aster	Asteraceae	NI	ABEFH
Symphyotrichum lateriflorum (L.) A.& D. Löve	calico aster	Asteraceae	NI	EF
Symphyotrichum shortii (Lindl.) Nesom	Short's aster	Asteraceae	NI	CDEF
Symphyotrichum Nees	aster	Asteraceae	NI	ACDEGH
Taxodium distichum (L.) L.C. Rich.	bald cypress	Taxodiaceae	OBL	FG
Thalictrum revolutum DC.	waxyleaf meadow-rue	Ranunculaceae	FAC+	A
Toxicodendron radicans (L.) Kuntze	eastern poison ivy	Anacardiaceae	FAC	ACEFGH
Triadenum walteri (J.G. Gmel.) Gleason	greater marsh St. Johnswort	Clusiaceae	OBL	ACD
Triodanis perfoliata (L.) Nieuwl.	clasping Venus' looking-glass	Campanulaceae	FACU+	H
Ulmus alata Michx.	winged elm	Ulmaceae	FACU+	ABCEFGH
Ulmus americana L.	American elm	Ulmaceae	FACW	ABCDFGH
Utricularia L.	bladderwort	Lentibulariaceae	NI	D
Verbesina alternifolia (L.) Britt. ex Kearney	wingstem	Asteraceae	FAC	ACG
Vernonia Schreb.	ironweed	Asteraceae	NI	B
Viburnum rufidulum Raf.	rusty blackhaw	Caprifoliaceae	FACU	E
Viola affinis Le Conte	sand violet	Violaceae	FACW	E
Viola bicolor Pursh	field pansy	Violaceae	FAC	AF
Viola primulifolia L.	white violet	Violaceae	FACW	B
Viola sororia Willd.	common blue violet	Violaceae	FAC	G
Viola L.	violet	Violaceae	NI	ABCDEFGH
Vitis aestivalis Michx.	summer grape	Vitaceae	FAC-	ABDFGH
Vitis rotundifolia Michx.	muscadine	Vitaceae	FAC	ACEFGH
Vitis vulpina L.	frost grape	Vitaceae	FAC+	FH
Vulpia myuros (L.) K.C. Gmel.	rat-tail fescue	Poaceae	FACU	H
Wisteria frutescens (L.) Poir.	American wisteria	Fabaceae	FACW	H
Xanthium strumarium L.	rough cockleburr	Asteraceae	FAC	BGH

****** (US Fish and Wildlife Service 1988.) + indicates affinity higher in range, - indicates affinity lower in range

Code	**Wetland Type**	**Comment**
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

FIGURE A1. View from hillside above location A showing terrain relief. Near channel is derelict stagnant highflow braid.

FIGURE A2. Flowing channel at most upstream location A, where water width is about 5 m and active floodplain is ~30 m.

FIGURE B1. At location B, bottomland hardwoods cover the northern transect and the channel meanders along open marsh.

FIGURE B2. Hazel alder, river birch and several other woody plants occurred in the upstream marshy locations A, B, C and D.

FIGURE C1. Typical bottomland hardwood species occurred on drained soils of the northern side transect at location C.

FIGURE C2. Soils of the south transect at location C were saturated with standing water, creating swamp-like conditions.

FIGURE D1. Although there were some isolated woody plants at location D, the area was predominately open marsh.

FIGURE D2. Within the open marsh, species of grasses and sedges dominated the community, but jewelweed and smartweed were common.

FIGURE E1. Bottomland hardwood species created dense canopy at location E so light penetration was low except during winter.

FIGURE E2. American hornbeam and swamp chestnut oak were frequently encountered at both transects at location E.

FIGURE F1. The community at location F, also dense bottomland hardwood in makeup, was highly similar to location E

FIGURE F2. Forest canopy gaps allowed understory grass and herbaceous species to grow despite the dense hardwoods.

FIGURE G1. Vines were common at location G, including Japanese honeysuckle, crossvine, roundleaf greenbrier, trumpet and Virginia creeper, and summer grape.

FIGURE G2. Boxelder was the most common hardwood at location G, with American hornbeam, swamp chestnut oak, winged elm, and ash trees.

FIGURE H1. Along with boxelder and white ash, sycamore, black willow and elm trees lined the river banks at location H.

FIGURE H2. Both sides of location H had large levees used as roadbeds parallel to the river channel, bisecting the transects.

AN EIGHT-YEAR VEGETATIVE SURVEY OF LONG-TERM MONITORING PLOTS (LTMP's) AT THE UNIVERSITY OF MISSISSIPPI FIELD STATION

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INTRODUCTION

Since 1996, the Department of Biology at The University of Mississippi has been taking biannual surveys of both understory and overstory vegetation in the Long-Term Monitoring Plots (LTMP's) at the University of Mississippi Field Station (UMFS) in Bay Springs, Mississippi. Twenty 400-square meter plots were randomly selected from 302 possible plot sampling sites on the over 296-hectare property. Land use maps were created and used to determine both past and future plant community changes, as well as land and natural resource management of these areas. Basic understory parameters such as species richness, foliar cover, species frequency, and foliar density have been compiled for 1996, 1998, 2000-2001, and 2003-2005, to monitor both the rate and dynamics of vegetative changes over time in these ecologically diverse plots.

The purpose of this data compilation is to assess any vegetative changes that may have occurred over an eight-year period in the LTMP's. Of particular interest are any changes in species numbers of woody versus herbaceous plants, and also the species numbers of introduced versus native plant species (Mastin 1996; Holland and Chambers-Strong 2001).

BACKGROUND

In 1995, certain forested areas of the University of Mississippi Field Station (UMFS) were harvested due to a pine bark beetle infestation. In 1996, UMFS established

Twenty 400 m² long-term monitoring plots (LTMP's), several of which were located near or within these harvested areas. The purpose and lower seed production, which would be evident in the following year. The second possibility that relates to the decease in species richness and foliar cover is development of a denser overstory, which may have shaded the understory species (Holland and Chambers-Strong, 2001).

Importance values (see Appendix for calculations used) through 2001 showed that *Lonicera japonica* has decreased in importance in the LTMP's, although in all three sampling periods it was the dominant plant species sampled. *Vitis rotundifolia*, a native vine, was not found to be a dominant species in 1996 when sampling began, but has gradually increased in importance (Figures 1-3).

Twenty-two plots were sampled in 2003-2005, which is the fourth complete data set on LTMP understory vegetation to date. The overall species richness is increasing from the last sampling period (2001), with 115 total species observed in the plots. Percent foliar cover has also made a recovery from the 2001 decrease (Figure 7).

Importance values calculated for the 2003-2005 sampling period (Figure1) showed the appearance of *Microstegium vimineum*, an aggressive C4 annual grass that has invaded much of the Northeastern United States (Tu, 2000). In 2003, this grass appeared in plot U10, with a percent foliar cover of over 72%. Since then, four additional plots have been invaded and dominated by *M. vimineum* (L19, N18, L11, and K12). *Microstegium vimineum* has been observed along stream banks, seeps, roadsides, eroded hillsides, and forested areas at the UMFS.

CONCLUSIONS

The importance values for the past eight years show that, while initially high, *Lonicera japonica* and *Vitis rotundifolia* have declined in the sampled LTMP's. Plots that were harvested in 1995 due to a pine bark beetle infestation created disturbance conditions favored by *Lonicera japonica*. However, over time, succession by native woody, herbaceous, and graminoid species has increased the overall species diversity and has essentially diluted the dominance previously seen of this invasive exotic vine. *Microstegium vimineum*, which began appearing in plots in 2003, has since become a dominant species in those plots where it has successfully invaded. The rapid, aggressive spread of this grass should be carefully monitored in future samplings since it has the ability to transform heterogeneous plant communities into monocultures in a period of only a few years.

The overall diversity of the LTMP's at the University of Mississippi Field Station has shown a gradual increase, and will continue to be monitored on a regular basis for changes in the vegetative composition here.

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Tu, M. 2000. Elemental Stewardship Abstract for Microstegium vimineum. The Nature Conservancy's Wildland Invasive Species Program.

APPENDIX: FIGURES, CALCULATIONS, AND ACKKNOWLEDGEMENTS

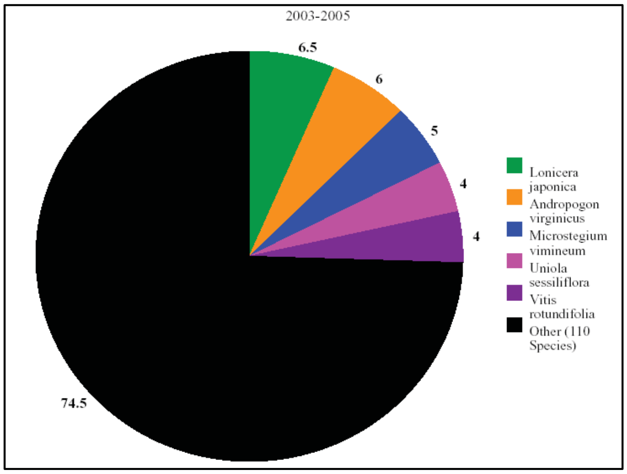

Figure 1: Importance Values for 2003-2005

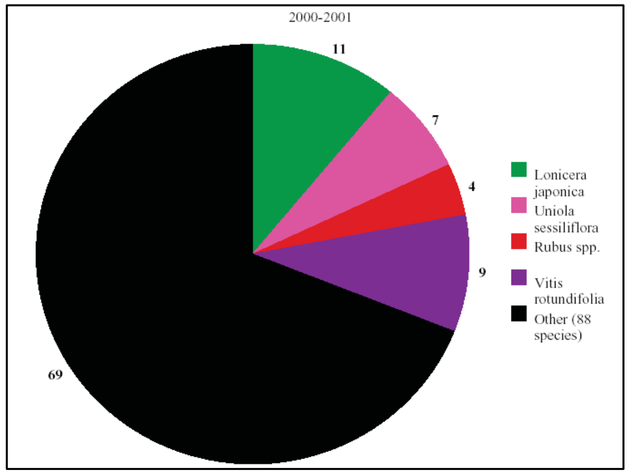

Figure 2: Importance Values for 2000-2001

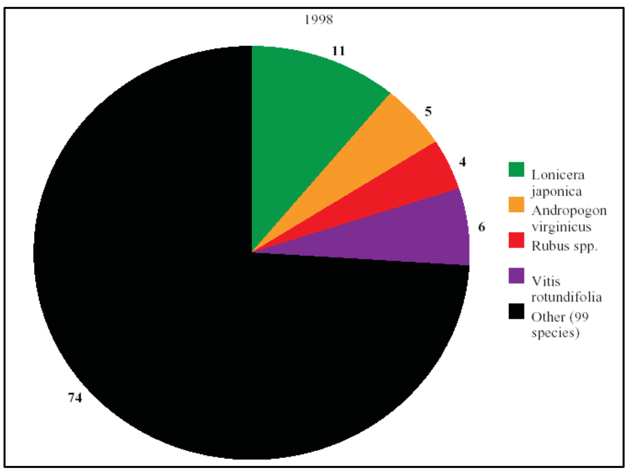

Figure 3: Importance Values for 1998

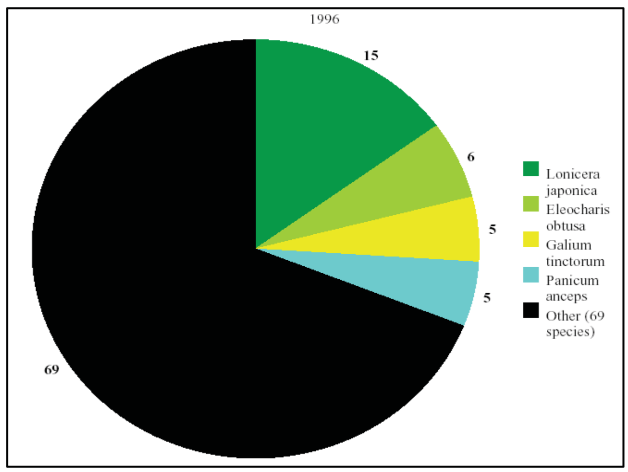

Figure 4: Importance Values for 1996

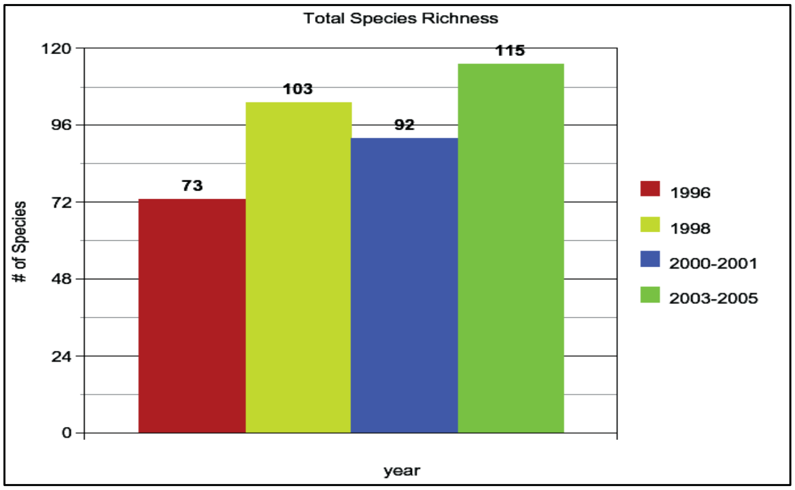

Figure 5: Total Species Richness for the 8-Year Sampling Period

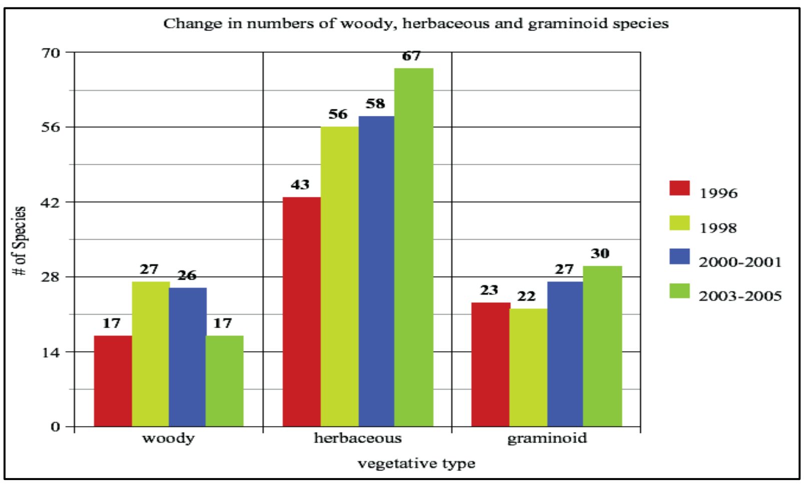

Figure 6: Changes in numbers of woody, herbaceous, and graminoid species ("graminoid" refers collectively to plant species belonging in Families Poaceae, Cyperaceae, and Juncaceae)

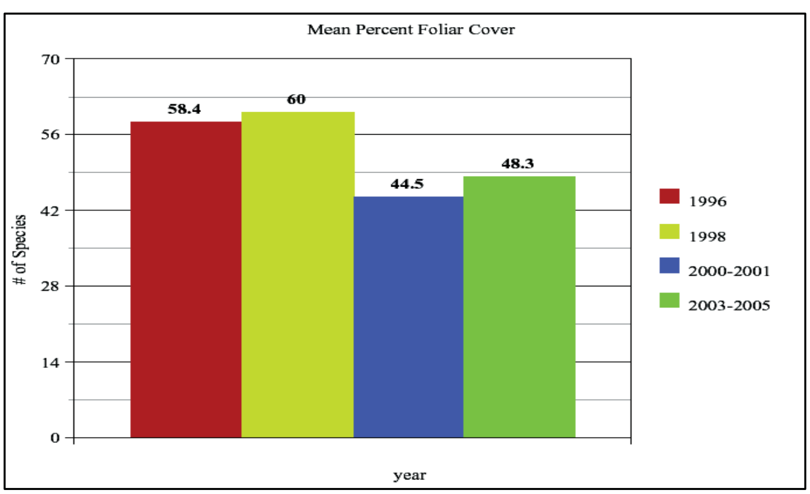

Figure 7: Mean Percent Foliar Cover for the 8-Year Sampling Period

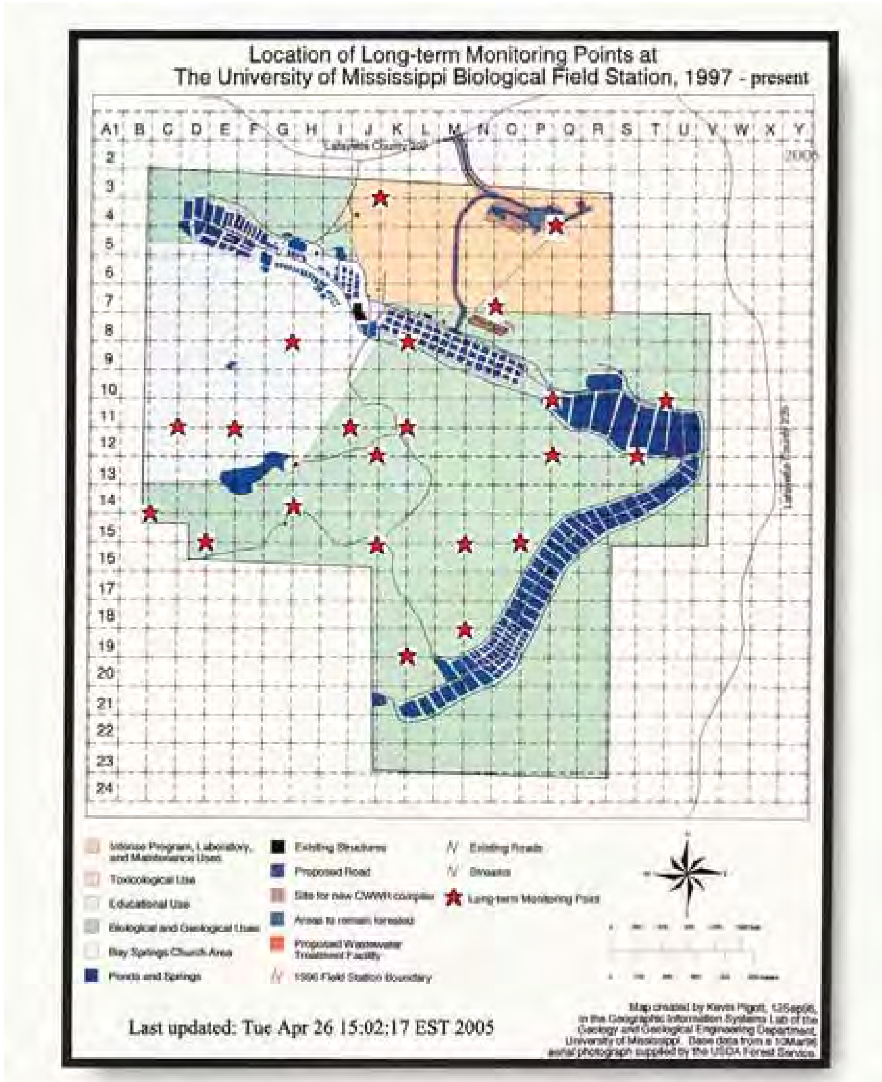

Figure 8: Grid Map Locations of 22 Long Term Monitoring Plots (LTMP's) at the University of Mississippi Field Station

Calculations used to determine percent foliar cover, frequency, relative values, and importance values (From Holland and Chambers-Strong 2001):

- **Species Richness** = total number of species recorded for 20 plots
- **Foliar Cover** = total area covered by vegetation
- **Frequency** = percentage of plots in which species were sampled
- **Relative Values** = value for species divided by total values for all species multiplied by 100
- **Importance Value** = relative percent cover + relative frequency / 2

ACKNOWLEDGEMENTS

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Environmental Stewardship Education for Mississippi Agricultural Producers

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Agricultural related water quality concerns are major issues throughout the country, the south, and Mississippi. At one time, Mississippi accounted for 61% of the stream miles listed in the United States as impaired by pollutants such as sediment, nutrients, and pathogens. Several actions have improved the situation in recent years: improved monitoring, an active Total Maximum Daily Load (TMDL) program, improved interagency networking, and educational efforts. Each state has unique watershed and commodity specific factors to consider in developing effective educational programs to build awareness of the issues, challenges, and opportunities, and foster voluntary and positive environmental actions.

Louisiana State University developed an Environmental Stewardship educational module in an agricultural proficiency "Master Farmer" program. For the stewardship module, multiple state agencies and advocacy groups developed a three tier process by which farmers receive instruction on environmental issues, participate in Best Management Practice demonstrations, and develop Conservation Plans. By late 2004, over 2400 farmers have participated in the educational phase of the program, and are continuing in the subsequent processes through development of model farms and conservation plans.

Based on needs assessment surveys among stakeholders, Mississippi State University Extension Service, with Mississippi-based agency and advocacy group partners, began development of a watershed-based agricultural-environmental stewardship educational program named Medallion Producer. While similar to the Louisiana effort, the name was changed to avoid client confusion with other Extension programs with the "Master" designation which require volunteers pay back time in return for a higher level of specific subject matter instruction and training.

Curriculum materials, lesson plans, and an outreach plan are being developed for the Medallion Producer effort. Curriculum subjects include water quality issues, laws, and regulations, agricultural air and soil quality issues, conservation/reduced tillage, Integrated Pest Management, nutrient management, structural soil management measures, the roles and duties of Conservation Districts, the Natural Resource Conservation Service, and other agencies, Best Management Practices, and relevant cost-share programs.

Implementation of the Mississippi program will begin in 2005. In addition to the Mississippi and Louisiana efforts, this model is being developed in several other states through the Southern Region Extension Water Quality Program.

GIS Geodatabase Model Building for Road Management: The Army Corps of Engineers Tennessee-Tombigbee Waterway (Mobile District)

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The Army Corps of Engineers Tennessee Tombigbee Waterway located in the Mobile District, is responsible for 234 miles of the Tombigbee River. On both sides of the river, roads are used to manage the river and the activities associated with the river. The Corps has approximately 53 miles of paved roads and 130 miles of unpaved roads. These roads have various functions. Roads are used as access roads into the waterways ten locks and dams, as well access into roads into campground and day camp use facilities. Managing the maintenance of these roads can prove to be difficult without an appropriate system set in place to record and update road maintenance projects.

Accordingly, the Corps is developing a geographic information system (GIS) geodatabase to assist in these activities. A GIS geodatabase stores spatial as well as attribute data. The key component in the geodatabase is its ability to efficiently relate spatial data and attribute data in a management system. The geodatabase will be used in conjunction with PAVER, Pavement Maintenance Management System, a pavement inventory software and DYNASTAR, Millwide Maintenance Management System, a inventory maintenance activities software to help the Corps more efficiently plan and prioritize their long term maintenance needs and manage day to day roads management.

A data model of the Corps GIS geodatabase, along with Paver and DynaStar is being built using Microsoft Visio 2002. Visio is a diagramming program that can be used to illustrate complex databases. A data model shows how the geodatabase is constructed, and how each of components in the geodatabase is related. A diagram of the geodatabase of the Corps roads network would enable Corps personnel to quickly distinguish how each component of the network interrelates, making it a valuable decision making tool.

SOIL RESILIENCE IN DISTURBED FORESTS AND ASSOCIATED WETLANDS FOLLOWING TIMBER HARVEST

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Abstract

This research focuses on quantifying the resilience of disturbed forested wetland habitats by studying the physical and biogeochemical properties of soil. The need for knowledge about ecosystem resilience following disturbance is becoming more critical for curbing the loss of natural resources. Using soil parameters as environmental indicators may lead to a better understanding of managing these resources. The aim of the study is to estimate resilience data from the study site and incorporate it with similar pre-existing studies to provide a wider perspective on soil processes occurring throughout the watershed (the Yazoo-Tallahatchie River Basin). Soil samples were taken from three disturbed sites of different ages (6 months, 7 years and 18 years since last harvest) and one undisturbed site (94 years since last harvest) from Northern Webster County, Mississippi. Six sampling points -three uphill and three streamside- were sampled in each of the sites. Soil samples were tested for concentrations of Total Soil Organic Matter (SOM), Total Carbon (TC), Total Nitrogen (TN), Total Phosphorous (TP), pH, Compaction, and Moisture Content. The TC and the Soil Compaction showed a decreasing trend with increasing age of the sites, with the 6 months site showing the highest values. The moisture content in the 7 year site was significantly lower than other sites, and 6 month streamside samples had significantly higher moisture content than uphill samples. TP was highest in the 6 month sites, followed by the uncut sites. There were no differences in SOM and TN levels among all sites, but a consistent trend of an initial decrease and a gradual increase can be observed in comparisons between pre-researched sites within the watershed. A Soil Perturbation Index (SPI), which incorporates these soil parameters and predicts the regeneration period needed for the disturbed areas with respect to the undisturbed reference sites, has further explained the biogeochemical dynamics of the study sites. Data from past sites within the watershed (in Calhoun, Issaquena, Leflore and Lafayette Counties, MS) where similar studies have been conducted have been compared to project a comprehensive picture of the biogeochemical processes taking place within the watershed's timber producing forests and associated wetlands. The results of this study will be beneficial for forest and wetland resource user groups in the region such as foresters, landowners, timber companies, farmers, conservation and government agencies, and the local stakeholders in utilizing and sustainably managing the available natural resources.

Introduction

The problem of diminishing natural resources is becoming more complex throughout the world (Mitsch 1993). Human activities have altered natural functions of ecosystems; humans are using more resources, resulting in stressed systems (Lubchenco et al. 1991). Wetlands are one of the most vulnerable systems prone to alteration and destruction, and more than 50 percent of the world's original wetlands have been lost (Dugan, 1993).

Recent focus on curbing the loss of natural resources has been placed on restoration of ecosystems that are sustainable (Mitsch 1993). Here, information about resilience, the ability of a system to respond to stress, is important. The need for knowledge about wetland resilience following disturbance is becoming more critical (Mitsch and Gosselink 2000), but it is often difficult to assess impacts on the system and predict the resilience (Holland 1996). It has been suggested that using soil parameters as environmental indicators may provide resilience information for sustainable resource management (Smith 1997).

A simple index to determine resilience of forested bottomland wetlands using multiple biogeochemical indicators, named the Soil Perturbation Index (SPI), was first developed and applied by Rebecca Smith Maul (Smith 1997, Maul et al. 1999). The SPI is based on soil nutrient contents such as total nitrogen (TN), total phosphorous (TP), total carbon (TC), and soil organic matter (SOM), and helps evaluate how different successional stages (=*time since harvest*) compare to mature uncut forested wetlands from a biogeochemical standpoint. It helps predict the time for the different stages to grow back to pre-disturbance conditions and shows the general trend in biogeochemical changes in disturbed systems.

The objective of this study is to examine the difference in biogeochemical and physical soil properties of forested wetlands which have been disturbed due to timber harvesting in Webster County, MS, and to predict the resilience of these systems. The study also focuses on comparing biogeochemical trends of wetland forests within the same watershed *(The Yazoo River Basin)* but with different topography and soil associations. There have been similar soil biogeochemical and resilience studies undertaken within the watershed in the past (Balducci et al. 1998), which makes the comparison possible. Balducci (1998) conducted soil resilience studies in the Mississippi Delta in Leflore County. A very similar study was done in the Agricultural Wetlands in the Delta in Issaquena County by Maul and Holland (2002). Recently, another soil study was completed in the Mississippi Hilly Coastal Plains (Calhoun and Lafayette counties) by Chambers-Strong (2003). All of these studies looked at the same soil parameters and followed similar research guidelines.

Site Description

The study area lies at the headwaters of the Yalobusha River and is located near the boundary of the Yazoo-Tallahatchie River Basin in Northern Webster County in Northern Mississippi (Figure 1). The area lies in the coastal plains of Mississippi with low rolling forested hills. Three timber harvested sites of different ages (six months, seven years, and 18 years since cutting) and an uncut site (~90 years since cutting) were selected within the study area. All the different aged sites had been clear cut for timber harvesting, and had been allowed to regenerate naturally since clearcutting. The six month, seven year and uncut sites were located in lands owned and managed by the Weyerhaeuser Timber Company. The 18 year site was located in private lands owned by the family of Dr. Jim Anderson of the University of Mississippi Field Station. Each site was separated into an 'upland' section (pertaining to areas on ridges, highland, etc), and a 'lowland' section (pertaining to areas near streams, valleys, etc). The presence of rolling hills and streams nearby all the sampling sites made this classification of upland and lowland sites possible.

Methods

Soil samples were collected from 24 sampling plots of various ages within Webster County. Six plots were established at each of the uncut (reference), six months, seven years and 18 year old sites - three sampling plots for upland and three plots for lowland areas for all four sites. Each plot was divided into four quadrants (NW, NE, SE, and SW) and a random soil sample was taken from each quadrant. Soil cores were collected using a stainless steel split core sampler 5cm in diameter x 30 cm in length. Soil samples were taken to a depth of five centimeters, including the litter layer. Soil compaction and Soil Moisture Content were measured on site using a DICKEY–John Soil Compaction Tester® and a Hydrosense® Water Content Meter respectively. Samples were kept in a cooler during transport from the site to the laboratory and were frozen in the lab until analyses could be conducted. Samples were homogenized before analyses. All field sampling was conducted within the month of June in 2004.

Total soil organic matter (SOM) was determined through loss on ignition (LOI) in a muffle furnace at 550ºC for 5 hours. Total carbon (TC) and total nitrogen (TN) were determined using the standard procedure for a COSTECH Elemental Analyzer (COSTECH Analytical Technologies, Inc. 2002). Total phosphorous (TP) was determined by performing an aquaregia digestion and analyzing samples via an Optical Emission Inductively Coupled Plasma Spectrometer (ICP-OES) (EPA Method 200.7 1994). Soil pH was measured by creating an aqueous solution of the soil sample and taking the pH of the solution. All soil analyses were performed in the Analytical lab at the University of Mississippi Field Station.

A Soil Perturbation Index (SPI) was developed using SOM, TC, TN and TP values from the sites as calculated by R.L. Smith (1997). The mean for each parameter per site was converted to a unit-less value using the following equation:

$$[(u - c) / u] \times 100 = \text{perturbation index number}$$

where, u = mean value of the 0 (mature) successional stage wetlands, and
c = mean value of the cut wetland in question.

The SPI numbers were compiled for all parameters for all sites and then plotted on a graph according to successional stage (=time since harvest). A second degree polynomial best fit line was drawn to illustrate the overall pattern of biogeochemical change among different aged sites (see Smith 1997, Maul et al. 1999).

Results

There was no difference in soil pH among different sites (Figure 2). Soil Compaction showed a decreasing trend among sites with the six month site showing the highest compaction and the uncut site showing the lowest (Figure 3). The seven year site had significantly lower moisture content than any other site. Also, the six month upland site had significantly lower moisture content than six month lowland sites (Figure 4). TC showed a decreasing trend with age with the six month site having the highest concentration and the uncut site having the lowest (Figure 5). SOM was higher in lowland sites than upland sites except for the seven year site where lowland concentrations were lower than upland sites (Figure 6). TN was also higher in lowland sites than upland sites except for the six month site where upland concentrations were higher than lowland concentrations (Figure 7). TP was highest in the six month sites and then decreased in the seven year and 18 year sites (Figure 8). The uncut site had higher phosphorous concentrations than the seven year and 18 year sites.

The Soil Perturbation Index derived from the formula mentioned above suggested that it would take 19-20 years for the soil biogeochemical properties of the three disturbed forests to return to preharvest conditions (Figure 9). It also suggested that the changes in the biogeochemical functions will be greatest (~90%) from the uncut conditions at nine to ten years after harvest. The SPI derived from only upland sites suggests the regeneration period to be around 22-24 years (Figure 10). The SPI derived from only lowland sites also suggests a very similar time frame (Figure 10). The upland SPI shows the maximum change from uncut to be around 90% while the lowland SPI shows the change to be nearly 200%.

Implications

The soil pH for all sites were not significantly different and were all found to be slightly acidic with pH values ranging from 4 to 6. Increased soil compaction in the six month site can be attributed to absence of vegetation and pressure form heavy machinery during timber harvest. A decreasing compaction shows that as plant communities start to grow, the soil is loosened by plant roots and other microbiological activities occurring in the rhizosphere. The seven year site soil was visibly sandier than other sites and could be the reason for its significantly lower moisture content. The six month lowland sites were inundated by water in most cases and the upland sites were very dry with no vegetation cover which explains the difference in moisture content between the two sites.

The results from the analyses of individual soil nutrients show that there is not a distinct linear pattern to biogeochemical changes and most may not be significant from a statistical viewpoint. The SPI helps incorporate these soil parameters into a single, efficient index and gives a clearer picture of all the different biogeochemical processes occurring within the study sites. Looking at previous study sites and their SPI results within the watershed, the upland SPI regeneration time is quicker than neighboring Calhoun and Lafayette county sites (~ 60 years; in the Mississippi Hilly Coastal Plains), similar to the lowland Issaquena county site (~ 24 years; agricultural wetlands in the Delta), and slower than lowland Leflore county site (~ 12 years; in the Mississippi Delta).

The SPI helps indicate a regeneration period and the overall resilience of forested habitats disturbed by timber harvesting. This index helps project long term biogeochemical trends which may not be apparent when looking at each of the soil parameters separately. This study helps establish a background data set for the greater Yazoo River Basin and the study can be utilized as a reference for future studies within the watershed or in similar ecotypes around the Southeastern region. The results of this study will be beneficial for forest and wetland resource user groups in the region such as foresters, landowners, timber companies, farmers, conservation and government agencies, and the local stakeholders in utilizing and sustainably managing the available soil and forest resources.

Acknowledgement

Various sources of funding are gratefully acknowledged: Agreement No. 68-7482-7-234 between the Univ. of MS and the USDA-NRCS Wetland Science Institute [work in MS Delta]; Agreement No. X – 974060-00-0 between the Univ. of MS and the US Environmental Protection Agency, Region 4, Atlanta office [work in Calhoun and Lafayette counties]; and Agreement No. 58-6408-1-095 between Univ. of MS and the USDA-ARS-National Sedimentation Laboratory. We would also like to thank the University of Mississippi Field Station and its entire staff for providing the analytical tools. This project would not have completed without the help of Mr. Ricky Hegwood form Weyerhaeuser in showing us the various study sites and helpful background information. We are also very thankful for Dr. Jim Anderson and his family for providing the study sites.

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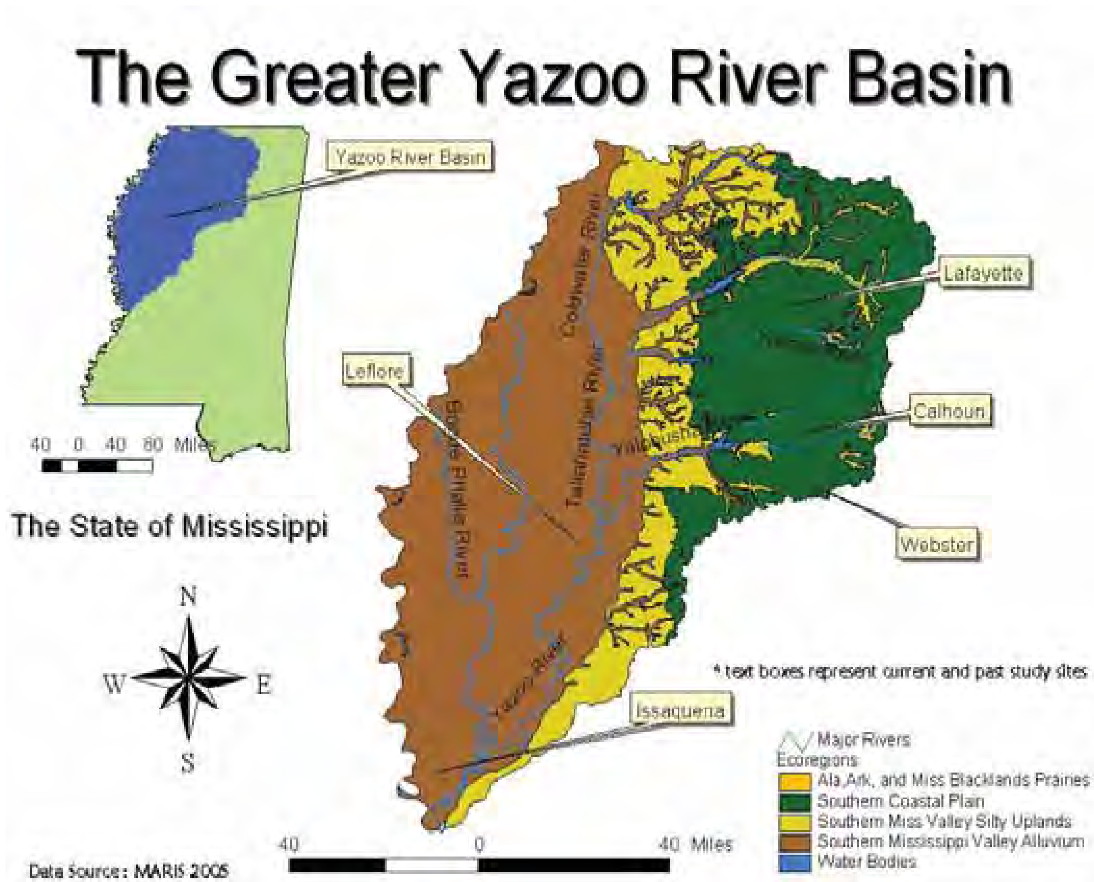

Figure 1: The Greater Yazoo River Basin in Northern Mississippi and the different ecoregions within the watershed and the different study sites

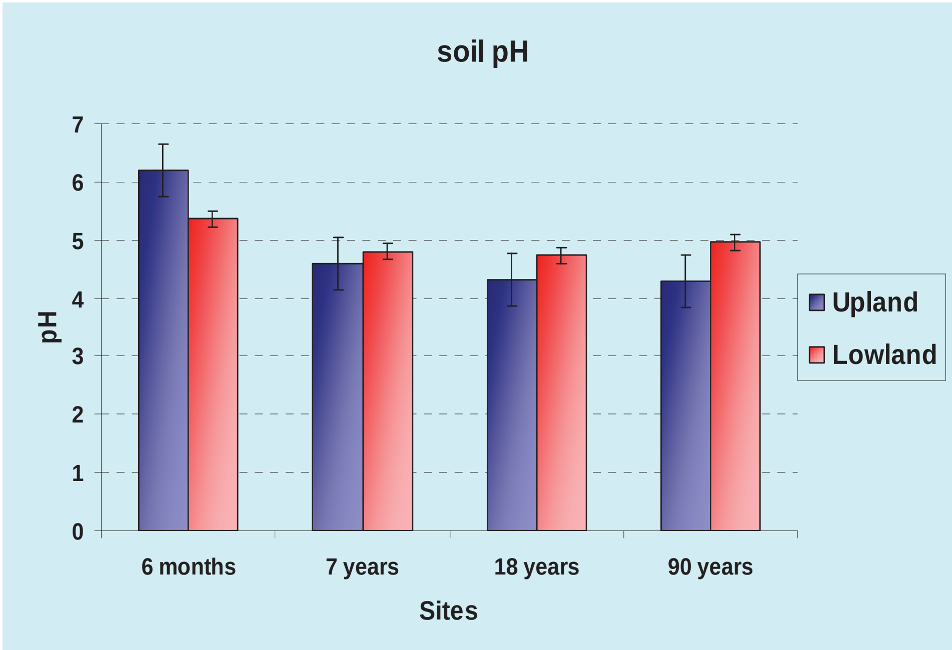

Figure 2: Average soil pH for Webster County soil samples.

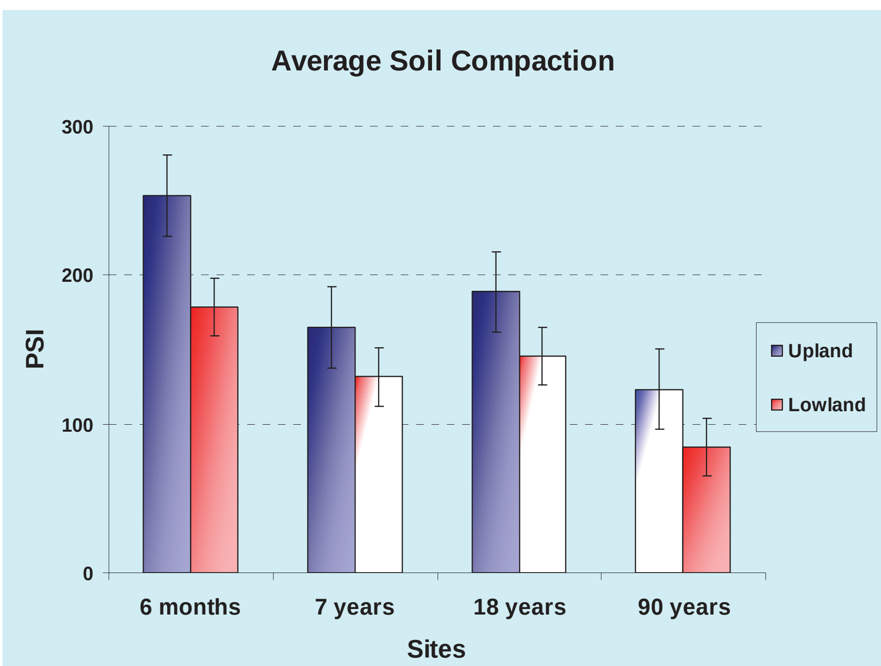

Fig 3: Average Soil Compaction for Webster County soil samples.

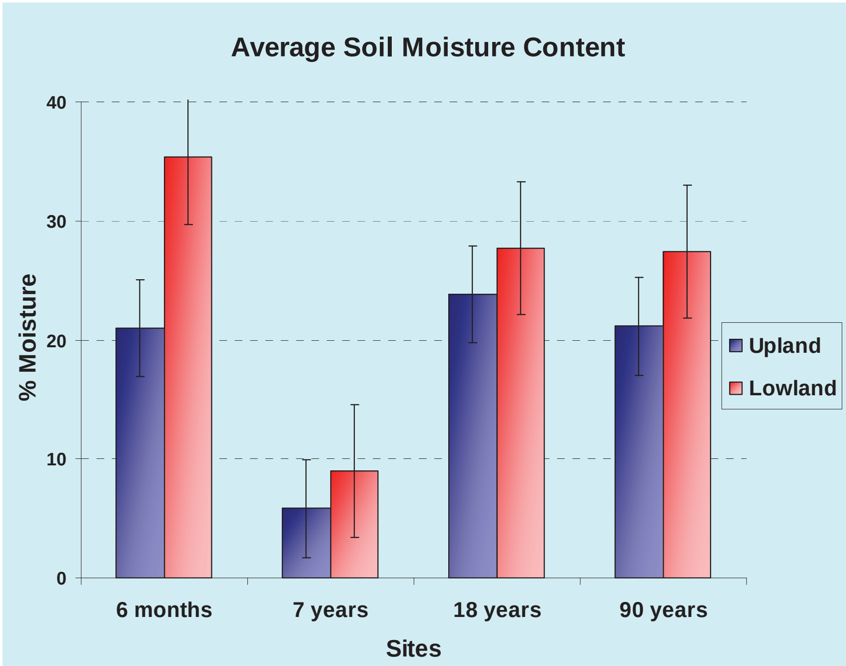

Figure 4: Average Soil Moisture Content for Webster County soil samples.

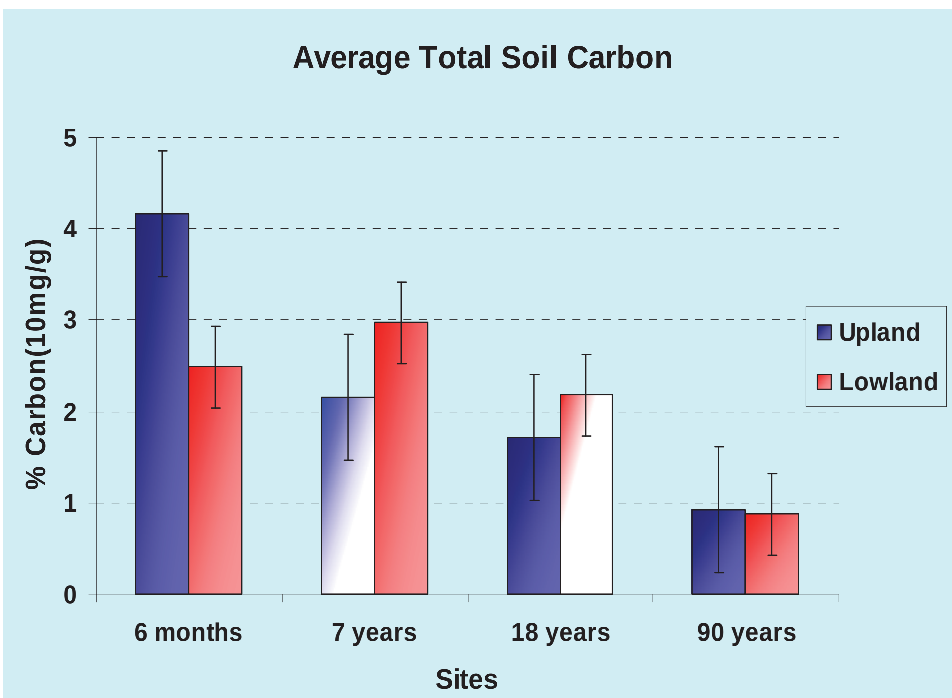

Figure 5: Average Total Soil Carbon for Webster County soil samples.

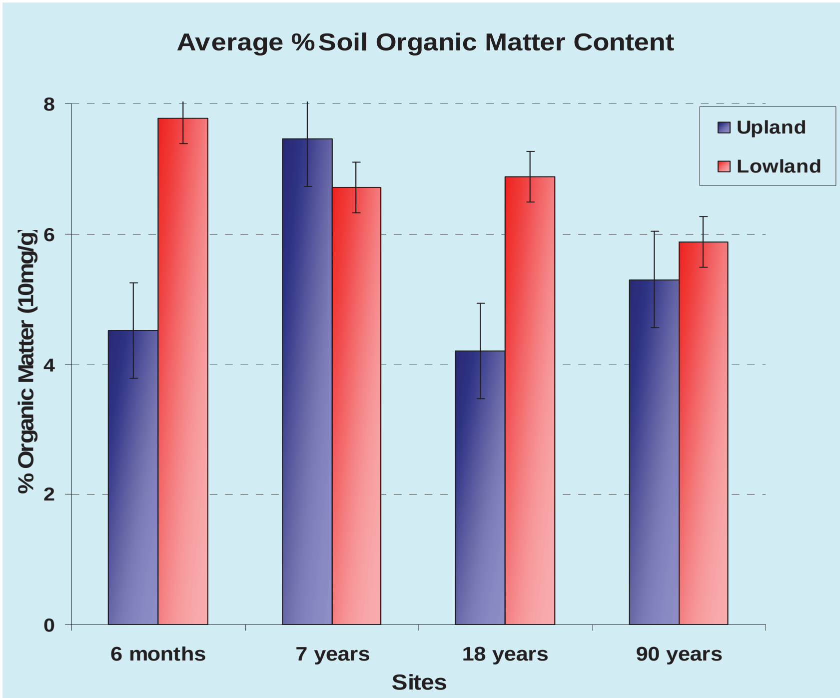

Figure 6: Average Soil Organic Matter Content for Webster County soil samples.

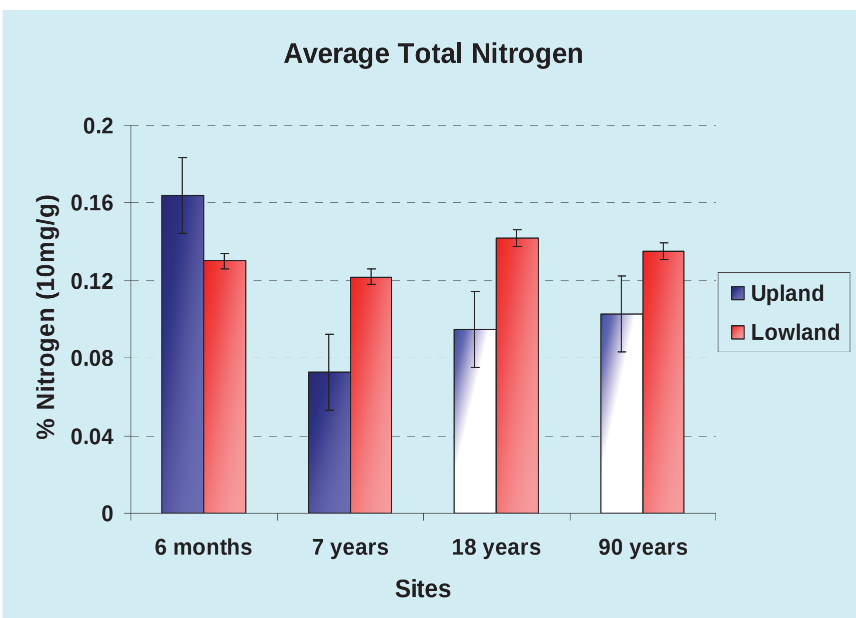

Figure 7: Average Total Nitrogen for Webster County soil samples.

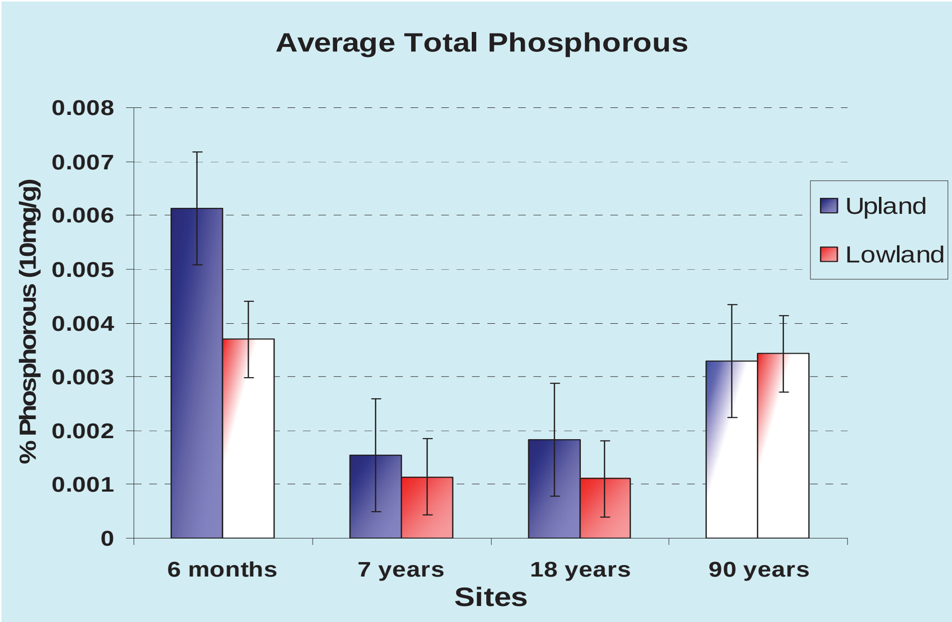

Figure 8: Average Total Phosphorous for Webster County soil samples.

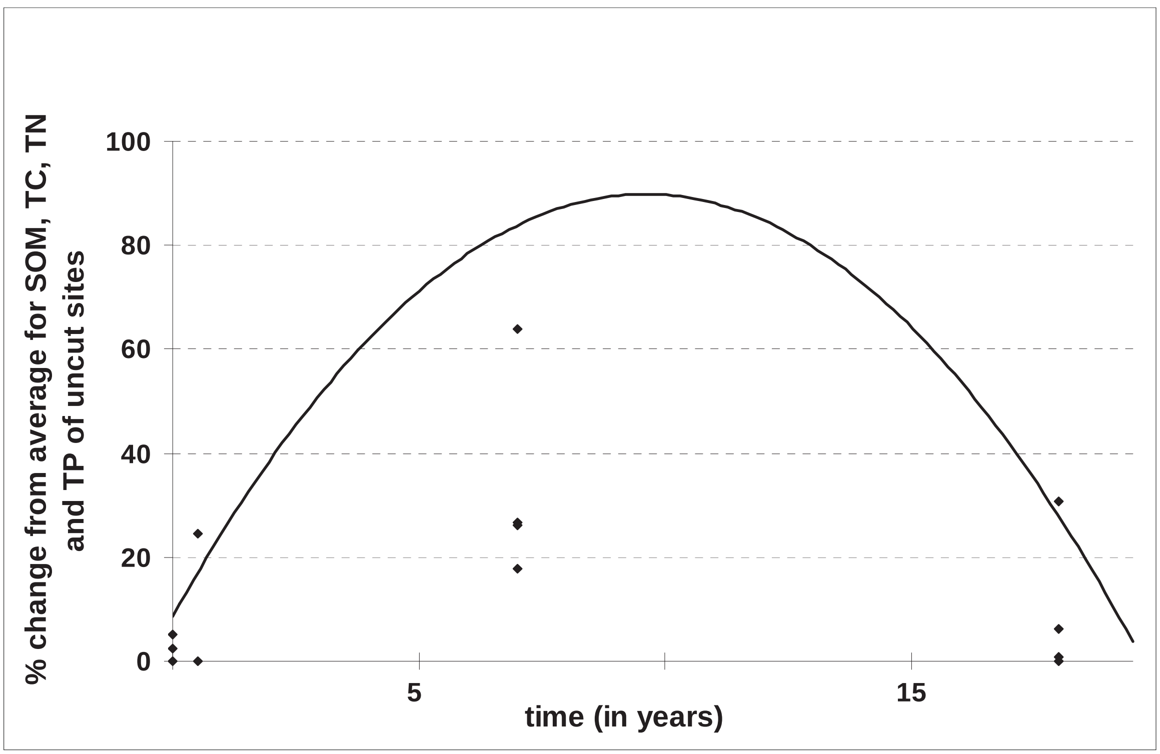

Figure 9: Combined Soil Perturbation Index for the four study sites in Webster County, Mississippi.

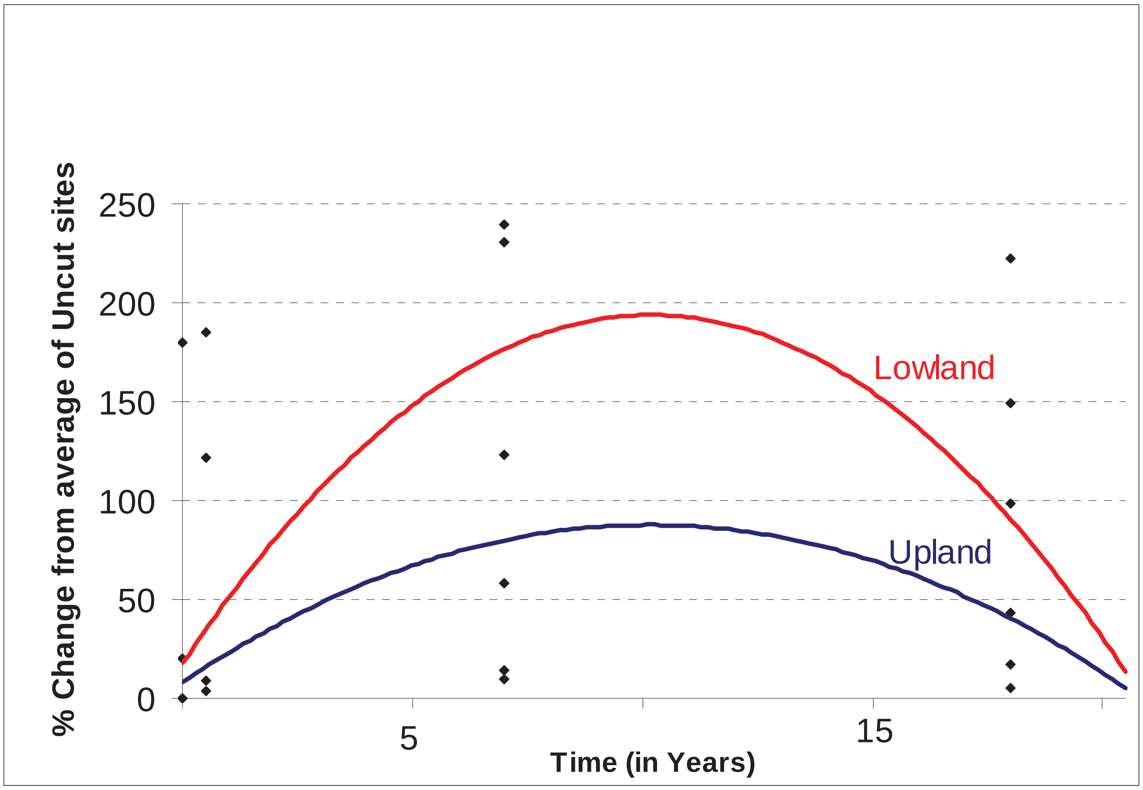

Figure 10: Soil Perturbation Index for the four study sites when separated into Upland and Lowland sites in Webster County, Mississippi.

Bacterial Source Tracking of a Prairie Watershed System Using AFLP

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Bacterial contamination of groundwater is a key concern in developing environmental protection regulations. Bacteria originate from many different sources, and determining the source is essential in order to reduce the contamination in our watersheds. Since 2002, MAFES and the Forest Products Lab have been tracking the numbers of three different fecal coliforms—E. coli, Enterococcus, and fecal Streptococcus—from a watershed impacted by beef cattle production (located at the MAFES Prairie Research Unit). These data were used to demonstrate the seasonal and site fluctuations from four locations; pristine (no cattle, no humans), high-load prairie (125-150 cows with calves on 275 acres), variable-load prairie (125 acres), and normal roadside runoff (human contribution). There are significant bacteria contributions from wildlife (especially blackbirds) during certain winter months and from humans on occasion. In order to determine the contribution of the beef cattle to the watershed contamination, an E. coli library is being built for the Prairie cows. Thirty-five samples were collected from cow patties at the Prairie station, fecal coliforms were isolated and confirmed on selective media, and stored in a -70°C freezer. DNA is being extracted by two procedures, and subjected to AFLP. AFLP will be used in this research because it can distinguish between closely related strains. Once complete, the AFLP library will be evaluated for selectivity to cow fecal coliform and, if successful, used to track the contribution of cows to the watershed contamination under best management studies.

Improved Irrigation Efficiency and Reduced Surface Water Contamination Using Intermittent plus Multiple-Inlet Irrigation in Rice Production

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Increased competition for finite water resources, and concerns over groundwater depletion, will reduce the amount of irrigation water available for future agricultural production. Our project aims to reduce water use in rice production by coupling intermittent irrigation with multiple-inlet irrigation techniques. The combination of these techniques at the production-scale has not been investigated, but preliminary research indicates that the combination may reduce water use by as much as 50% over conventional (continuously flooded) practices without significantly affecting yield. Reduced irrigation pumping of rice fields will also increase the rainfall holding capacities of rice paddies, resulting in less non-point source agrochemical contamination. A production-scale project was begun in Mississippi and Arkansas in 2004 to compare water consumption, agronomics, and non-point source runoff in continuously flooded and intermittently flooded rice systems. A total of five producer sites were located in Mississippi (3) and Arkansas (2); field sizes ranged from ca. 27 to 40 A. Rice yields, pest levels, water use rates, rainfall holding capacities in paddies, and non-point source runoff potentials for rice pesticides and nutrients were determined.

As expected, the rice producers were initially uncomfortable with allowing the flood in the intermittently flooded field to subside to the target depth, resulting in similar water use during the first 30 days after flood initiation. As their initial reluctance was overcome, the daily irrigation rate typically dropped from ca. 0.35 A-inch/day in the continuously flooded fields to ca. 0.16 A-in/day in the intermittently flooded systems. The continuously flooded system typically used a total of ca. 30 A-in of water as compared to ca. 20 A-in in the intermittently flooded systems. Disease and weed infestations did not differ significantly between the two rice flood systems. At the one producer site where rice yields were available at the time of this writing, rice grown in the intermittently flooded system yielded ca. 189 vs. 183 bu/A from rice in the continuously flooded system. Analyses of water samples used to compare non-point source runoff potentials between the two systems are on-going, as are tabulations of rainfall holding capacities for the study sites.

Social Capital: A Unifying Framework for Understanding Conservation Decisions

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Abstract

Agricultural pollution is believed to be a leading contributor to nonpoint source pollution. Whereas most industrial polluters are subject to state and federal environmental regulations, historically, agriculture has been exempted. Most states depend on voluntary participation in technical assistance and educational programs to promote best management practices (BMP) adoption. The decision of agricultural producers to engage in BMPs is shaped by a number of forces. Research indicates that two of the most significant factors influencing the adoption of BMPs are farm size and education.
However, social factors associated with the adoption of agricultural practices that improve water quality have received less attention. A notable exception is a 1998 survey of farm operators in the Mississippi Delta which highlighted the importance of institutional factors, such as the influence of information sources and attitudes toward government regulations, in the decision process.
This poster presents a literature review using a social capital framework to better understand the interplay between social, economic, and environmental factors affecting adoption of new agricultural technology and best management practices. The trust, reciprocity, information, and cooperation associated with social networks create value, or social capital, in the norms, shared values, and behaviors that bind people and communities together and make cooperative action possible. Understanding environmental stewardship decisions within the context of a social capital framework can assist policy makers promote participation in technical assistance and educational programs.

Introduction
Agricultural pollution is believed to be a leading contributor to nonpoint source pollution (Carpenter et al., 1998). Whereas most industrial polluters are subject to state and federal environmental regulations, historically, agriculture has been exempted. Most states depend on voluntary participation in technical assistance and educational programs to promote best management practices (BMP) adoption. Research indicates that two of the

most significant factors influencing the decision of agricultural producers to engage in BMPs are farm size and education. Social factors associated with the adoption of agricultural practices that improve water quality have received less attention (Gill, 2001). Yet, as uncertainty continues among agricultural interests regarding water quality issues, cost-benefit implications, environmental benefit measurements, existing and potential regulations, available resources, and agency responsibilities: social dynamics warrant further investigation.

Review of Program Success Factors

Several factors contribute to the uneven success of programs advocating environmental stewardship in the agricultural community. Many producers are apprehensive about working within an environmental framework; they may agree that water quality problems attributable to agriculture exist, but do not recognize that their individual farms contribute (Christensen and Norris, 1983; Halstead et al., 1990; Lichtenberg and Lessley, 1992; Pease and Bosch, 1994; Napier and Brown, 1993). Motivation of farmers to address environmental issues through management varies. Negative strategies such as existing or proposed regulations are very influential in farmers adopting environmentally friendly production practices (Napier et al., 2000; Ribaudo, 1998). Other studies have shown that farmers often recognize that larger scale environmental issues are important for farmers to consider (Musser et al., 1994; Richert et al., 1995). For example, Supalla et al. (1995) found that factors influencing farmer environmental behavior regarding nitrogen fertilizer management were environmental attitudes, demographics, economic situation, and farm location. Specifically, they found that environmentally concerned, well educated, well informed, and younger producers with smaller acreages were more likely to apply nitrogen at or near recommended levels. Further, Fulgie and Kasacak (2001) found that education and farm size have significant and consistent effects on adoption of soil testing, integrated pest management, and conservation tillage by farmers. Higher levels of education are positively associated with higher adoption rates, but not necessarily post-secondary education as findings indicate that those with a high school education or more adopted these three practices more rapidly than those without a high school education (Fulgie and Kascak, 2001).

Implications for Program Design

Successful agricultural environmental stewardship education programs must include acknowledging and defining agricultural contribution to water quality problems (Elnagheeb et al., 1995; Ribaudo, 1998), demonstrating business value (Napier et al., 2000; Poe et al., 2001; Ribaudo, 1998; Ribaudo and Horan, 1999), and coordinating among agencies providing educational, technical, and financial assistance (Ribaudo, 1998; Forster and Rausch, 2002). Programs should be locally oriented due to differing soils, geology, and other watershed characteristics. In addition, other factors such as community attitudes and perceptions, and the predominant commodity and production infrastructure need to be considered in program development (Coughenour, 2003). Each state has unique watershed and commodity specific factors (such as environmental issue awareness, site-specific challenges, and opportunities) that influence individual decisions and actions.

Social Factors

Although several aspects of agriculture/environmental stewardship programs point to the importance of social factors, research related to educational outreach and conservation practices has primarily focused on individual farm and/or farmer characteristics. These approaches are based on traditional innovation, adoption, and diffusion models that explain the diffusion of new ideas from an economic perspective and an individual's willingness to assume risk. Concerned that traditional adoption and diffusion models may miss other influences, Gill (2001) studied sociological factors influencing adoption of BMPs as part of the Mississippi Delta Management Systems Evaluation Area (MDMSEA) interdisciplinary research effort. His review of the literature indicated that other factors may be important in the adoption process when water quality issues are at stake (see Rogers and Shoemaker, 1971; Christensen and Norris, 1983; van Es, 1983; Heffernan, 1984; Rikoon and Heffernan, 1989; Bouwer, 1990; Rikoon, 1991; Vogel, 1996). Furthermore, although social scientists have studied water quality issues within a broader natural resource context, Gill (2001, p.105) noted a lack of attention to social factors associated with adopting agricultural practices that improve water quality.

Gill (2001) used a mail survey to collect information from Mississippi Delta farmers for three categories: farm characteristics, demographics, and social/attitudinal characteristics. Specifically, farmers were surveyed on farm operation characteristics, awareness and use of BMPs, evaluation of information sources, attitudes, and socio-demographic characteristics. An innovation index based on 25 BMPs was developed to measure the extent to which practices had been used by each respondent (Table 1).

Table 1. Mississippi Delta Farm Operators Who Have Ever Used Particular Best Management Practices *(Practices represent the selected items for Innovation Index)*

Practice	n	%	Practice	n	%
Cover Cropping	159	48%	Custom Application of Lime	225	68%
Filter or Buffer Strips	70	21%	Variable Rate Fertilization	72	22%
Slotted Board Risers	163	49%	Variable Rate Liming	44	14%
Grass Waterways	65	20%	Variable Rate Pesticide Application	65	20%
Sediment & Water Retention Basins	55	17%	Yield Monitoring for Precision Agriculture	42	13%
Riparian/Wetland Zones	29	9%	Hooded Sprayers	76	23%
Land Formed Fields	234	70%	Integrated Pest Management	100	31%
Deep Tillage	276	84%	Baculovirus	10	3%
No Tillage	198	60%	Transgenic Cotton	153	47%
Minimum Tillage Stale Seedbed	244	74%	Transgenic Soybeans	141	43%
Custom Application of	287	85%	Transgenic Corn	13	4%

Other study variables included farm size, farm sales, land adjacent to a stream or creek, land adjacent to an oxbow lake, education (high school or less, some college, college degree), age, attitudinal scales on influence of information, support for soil conservation, barriers to BMP adoption, government regulation of agrichemicals, environmental concerns about the use of pesticides and fertilizer, and outdoor recreation behavior. Results from a Pearson's Correlation Coefficient analysis of farm and farmer characteristics indicated that farm sales and farm size were most strongly correlated with BMP adoption. The influence of information sources and education were also strongly correlated with BMP adoption.

Gill (2001) developed a set of regression models to further investigate variables related to higher BMP adoption levels. The innovation index served as the dependent variable and independent variables were grouped into three categories: farm characteristics, demographic characteristics, and social characteristics. The final reduced model included variables that were significant at the .10 level or less. Results indicated that variables pertaining to farm characteristics and attitudinal characteristics explained almost 33 % of the variance (Table 2).

Table 2: Block Regression Analysis for Variables Related to Adoption of Best Management Practices Among Mississippi Delta Farmers

	Model I		Model II		Model III		Reduced Model	
Variables	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Farm Characteristics								
Land adjacent to a stream or creek	.235	.000	.215	.000	.171	.000	.188	.000
Total farm sales	.223	.000	.189	.000	.178	.000	.211	.000
Land adjacent to an oxbow lake	.204	.000	.193	.000	.187	.000	.207	.000
Total acres farmed	.136	.012	.120	.026	.082	.116		
Demographic Characteristics								
Education			.121	.017	.053	.299		
Age			-.095	.050	-.024	.632		
Attitudinal Characteristics								
Influence of information sources					.137	.013	.154	.005
Attitudes toward government regulations					-.128	.008	-.147	.002
Attitudes toward adoption of BMPs					.116	.032	.121	.023
Outdoor recreation activities in MS Delta					.074	.134	.086	.067
R^2	.244		.267		.328		.323	

Adapted from Gill 2001, p. 112

Although farm characteristics accounted for about 24 % of the variance in BMP adoption levels, social characteristics were found to play an important role as well. As a group, the influence of information sources, attitudes toward government regulations and adoption of BMPs, and participation in outdoor recreation activities explained almost 20% of the variance in the level of innovation. These social/attitudinal variables contributed an additional 8% to the variance explained by the farm characteristics, increasing the explained variance from 24.4% to 32.3%.

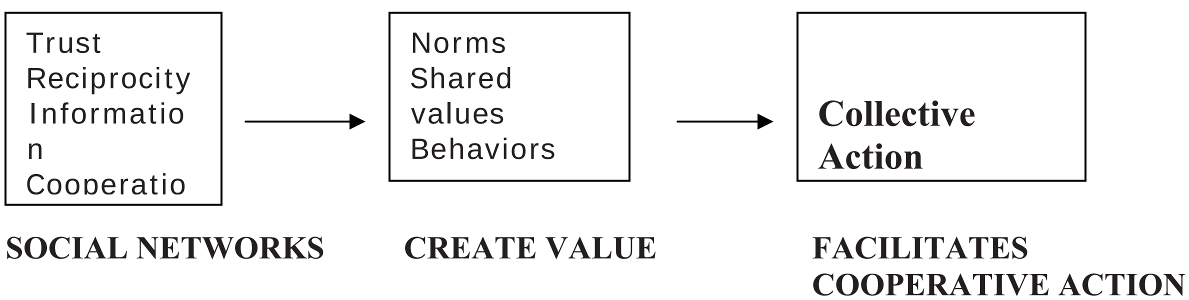
Gill situates the findings in a broader discussion of the social, cultural, political, and economic environment in which Mississippi Delta farmers operate. He notes the particularly important role of information sources and credits agencies such as the Mississippi State University Extension Service, Mississippi Soil and Water Conservation Commission, Natural Resource Conservation Service, Yazoo-Mississippi-Delta (YMD)

Joint Management District, and local soil and water conservation districts with being successful in encouraging farm operators to adopt BMPs, and urges these entities to continue their efforts to expand adoption of BMPs. Acknowledging the importance of economic factors, particularly farm sales, to the adoption of BMPs, Gill (p. 107) concludes that “programs that build upon social as well as economic factors must be developed to improve success of BMP adoption and thereby improve water quality in the MDMSEA.”

Gill’s research demonstrates that factors at the social/community level play an important role in shaping conservation decisions. A significant finding is that farmers who rely on agencies that provide educational programs and technical assistance used more BMPs. The role of information sources is in part related to communication channels, as traditional adoption-diffusion models suggest. However, exploring relationships between farmers, educational instructors, and technical assistance providers within a social context may aid policy makers in promoting participation in educational and technical assistance programs, and thereby expand BMP adoption. Social capital theory can inform these issues.

Social Capital

Social capital is generally defined as those resources inherent in social relations, which facilitate collective action (Bourdieu, 1983; Coleman, 1988; 1990; Lin, Cook, and Burt, 2001). Social capital resources include trust relations, norms, and networks of association. An underlying premise of social capital is that investments in social relations “yield expected returns” (Lin, Cook, Burt, 2001, p. 6). Although social capital can be treated at the individual level, the focus here is at the group level.



Trust Relations and Norms

As previously mentioned, voluntary education and technical assistance programs, along with conservation practice utilization subsidies have been primary strategies used by resource management agencies to influence land managment choices (Barrios, 2000; Hite et al., 2002). When implementation of government programs depends more on mobilizing policy stakeholders and less on authority and control, social capital becomes a key to success. According to Schneider and Ingram (1990, p. 517), capacity-building policy tools are appropriate where a target population may “lack sufficient resources or support (financial, organizational, social, political) to carry out [policy activity] with a reasonable probability of success." A critical assumption of this type of policy tool is that the potential target population(s) will welcome the information and assistance. Although a valid point of departure, such an assumption requires a very high degree of trust.[1]

Networks

Networks are mechanisms through which trust is developed, legitimacy is established, and information is exchanged. Networks are most effective when they are "diverse, inclusive, flexible, horizontal (linking those of similar status), *and* vertical (linking those of different status, particularly local organizations…with external organizations and institutions…" (Flora, 1998, p. 493). Knowledge networks build on and are linked to existing social networks. However, it is not clear that a causal relationship exists (Fesenmaier and Contractor, 2001).

Horizontal and Vertical Linkages

The term "social capital" has come to be widely used in the social sciences, especially in the discipline of rural sociology (Castle, 2002). Taylor (1996) uses a social capital framework to define good government, arguing that good government requires a cooperative approach to hierarchical government. Assuming government intervention is aimed to assist people in achieving their common purposes by overcoming collective action problems, cooperative hierarchies can help people to help themselves. Contrasted with coercive, top-down hierarchies, cooperative hierarchies are characterized by a recognition and respect for the capacity of subordinates to play a role in regulating their own behavior. Taylor defines this capacity found in the local community, networks, and organizations as horizontal social capital. In addition, cooperative hierarchical approaches feature long-term, repeated interaction, cooperation, reciprocity and trust - which may be described as vertical social capital. Thus, good government is supported by the important roles played by horizontal and vertical social capital. Unfortunately, scholars have paid little attention to how institutional arrangements affect levels of social capital (Schneider et al., 1997).

How local organizations relate to each other and to the larger society is an important area of research for rural sociologists, and in particular, community scholars. Drawing on 15 years of research on rural communities, Flora and Flora assert that social infrastructure is "the key to linking individual leadership to physical infrastructure (1993, p. 49). Warner (1999) also reports important links between social capital and the productivity and efficiency of community services. These authors conclude that strong social capital at the community level supports both formal and informal decision making processes and stimulates public involvement. In effect, it "provides organized spaces for interaction [and] networks for information exchange…" (Warner, 1999, p. 374).

Conclusion

A broad discussion of the social, cultural, political, and economic environment in which farmers operate is essential to advancing our understanding of conservation decisions.

[1] Social capital distinguishes between trust experienced as a personal attribute and as a characteristic of the system (Baron, Field, and Schuller, 2000).

Further research is necessary to better understand the influence of social factors in the BMP adoption decision process. The role that information sources play is particularly important.

Acknowledgements

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Using the AGNPS Model and GIS to Locate Areas that May Be Vulnerable to Runoff

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The USDA Agricultural Nonpoint Source (AGNPS) runoff pollution model is being used, in combination with geographical information systems (GIS) and remote sensing, to predict water, sediment, and pesticide nonpoint source runoff in the uppermost portion of the Pearl River Basin. The AGNPS model includes a GIS interface that processes a digital soils layer, digital elevation models (DEM), digital land cover from Landsat satellite imagery, climate stations, and other inputs to the AGNPS model. AGNPS, using the DEM as the main input, performed a topographic evaluation of the watershed, drainage area identification, synthetic channel networks, watershed segmentation, and subcatchment parameters. Two National Weather Service (NWS) rain gauges were located within the drainage area at Louisville and Gholson, and one additional gauge was just outside the drainage area at Philadelphia. Measured precipitation data was obtained from January 1994 through December 2003 for these three gauges. Thiessen polygons were created to determine the weighting of the rain gauges for precipitation values over the drainage area. Once the watershed segmentation was performed and subwatershed cells were delineated, the AGNPS GIS interface intersected the soils, land use, and climate information with the subwatershed cells. The Input Editor component of the model was then used to combine all necessary information, such as climate data, watershed cell and reach data, and management information into an input file that was utilized by the pollutant loading portion of the model. For the ten-year period that was modeled, AGNPS predicted the average annual rainfall for the watershed to be 1450 mm, with a watershed average annual loading of 463 mm. Sediment loading (clay, silt, and sand combined) at the outlet was predicted to be 27 mg/ha/yr, and nitrogen loading (dissolved and attached) was predicted at 19 kg/ha/yr. Average annual loading was predicted to be 284 and 67 kg/ha/yr for organic carbon and phosphorus, respectively. Results of the AGNPS DSS are also being analyzed for pesticide runoff, as well as for specific rainfall events, and compared to measured results for validation.

Analytical Detection and Quantification of Chemical Mixtures: WNV Eradication Compounds and Other Xenobiotics

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Persistence of West Nile Virus (WNV) throughout the United States, particularly in the Mississippi Valley States, supports the continued efforts to control mosquito vectors such as *Culex spp*. Chemical agents commonly used to control mosquito vectors are non-species specific pesticides that may potentially interact with non-target aquatic organisms. Through direct or indirect routes these compounds eventually become part of water and sediment matrices. Individually or as mixtures with other co-occurring persistent or transient xenobiotics, e.g. agricultural and urban pesticides, these anthropogenic compounds can potentially degrade the water quality and aquatic habitat of aquatic organisms.

Our group will present preliminary findings which are part of a multi-year study evaluating the co-occurrence and ecotoxicity of vector eradication compounds individually and in mixtures with agricultural and urban pesticides. Currently, development of analytical methods focused on the model mosquitocide methoprene, a commonly used mosquito larvicide, and chlorpyrifos, a commonly used organophosphate pesticide (chlorpyrifos has recently been severely restricted in indoor and outdoor residential/business use but continues to be used in agriculture). In our effort to evaluate the habitat quality along Mississippi's and Alabama's coasts water and sediment samples collected from these areas will be assessed using the analytical methods presented in this poster.

Conservation Effects Assessment Project (CEAP)-Watershed Assessment Studies: Yalobusha River Watershed

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The USDA ARS-NRCS has established a joint Conservation Effects Assessment Project (CEAP) that will assess the environmental benefits due to conservation practices on 12 benchmark watersheds. The Yalobusha River Watershed (YRW), which covers 168,750 ha consisting of 18% cropland, 19% pasture areas, 53% forested areas, 6% wetland, and 4% surface water, was selected as a benchmark watershed. The MLRA for the YRW is Southern Coastal Plain with alluvial soils comprised of dispersive silt topsoil over sand and clay layers overlying consolidated clay. Major features of the river system include: 1) erosion-resistant cohesive streambeds; 2) channelized stream network; 3) channelized main stem terminates in an narrower unmodified, sinuous reach; and 4) a debris plug on the lower end of the channelized main stem. The YRW experiences deposition and flooding problems in downstream reaches and excessive erosion via gully inlet erosion and bank failures along upstream reaches. The major water quality issue is sediment. Historically high rates of sediment yield reached levels about twice the national average. Other contaminants include residual organochlorine insecticides, some current use insecticides, metals (e.g. mercury and arsenic), atrazine, and coliforms. The objectives of the CEAP activities for YRW are: (1) Synthesize baseline data by (i) working with USGS, NRCS, CoE and other agencies to identify and locate Cps, (ii) acquire topographic and soils data in digital format, and (iii) compile historical hydrologic and water quality data including: precipitation, streamflow, suspended-sediment, nutrients, and pesticide concentrations; and (2) Quantify the water and contaminant transport processes at different scales by (i) evaluate the juxtaposing of two or more practices (eg. an in-field and an edge-of-field practice), (ii) conduct upstream/downstream comparisons, and pre/post implementation comparisons, and (iii) conduct thorough site investigations to define a mechanistic understanding of CP function. Research will focus on evaluating field and stream responses to drop pipe and riparian forest buffer conservation practices. Fields with and without these practices will be instrumented for runoff and sediment transport measurement along with upstream and downstream measurements in the stream.

Poster Session
Animal Waste Symposium

Subsurface band and Surface broadcast Application of Broiler litter: Effect on Soil Nitrogen Spatial Distribution

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ABSTRACT

Nitrogen content of broiler litter is vulnerable to volatilization loss when litter is surface-applied to fields as a fertilizer. Recently, researchers of the USDA-ARS at Auburn, AL have designed a new implement that applies litter in bands under the soil surface. Field research was conducted at the North Farm of the Mississippi Agricultural and Forestry Experiment Station in Starkville, MS to compare the effect of the new subsurface band application and the conventional surface broadcast application of litter on soil nitrogen distribution and concentration. Fertilizer treatments included no fertilizer (control), Broiler litter (BL) surface broadcast before planting at 6720 kg ha^{-1}, and (BL) broiler litter subsurface banded at 20-cm from the center of the cotton row before planting at 6720 kg ha^{-1}. Soil samples were taken at 24 and 73 days after BL application at 0, 10, 20, 30, 40 cm from the cotton row. Soil analysis results showed that application method does have an effect on the available N pool. When the litter was subsurface banded NH_4-N was only elevated 20-cm from the center of the cotton row, where the BL was subsurface banded, 24 days after application. Yet, the average concentration of NH_4-N across all sampled positions at the 0-15 cm depth was 47% greater when PL was subsurface banded than when BL was surface broadcast applied. The subsurface band NO_3-N concentration 24 days after litter application at the 20-cm position was significantly higher than the broadcast and the control and 73 days after litter application at 0-15cm depth, the band NO_3^-N at the same sampling position was 25% higher than the broadcast or the control. These results suggest that applying broiler litter in bands under the surface can have a positive effect on the spatial distribution and concentration of inorganic soil N in close proximity to the root zone of cotton.

INTRODUCTION

The most common method of applying broiler litter to agricultural land is by broadcasting, using a spinning spreader applicator. However, research has shown that surface application of broiler litter results in nutrient losses. The major process of N loss is volatilization of N in the form of the gas NH_3. Sharp et al (2004) evaluated the ammonia volatilization from surface-applied broiler litter under conservation tillage and they found that within 7 to 8 days after applying broiler litter to supply 90 to 140 kg N ha$^-$

[1], the NH_3 flux range from 3.3 to 24% of the total N applied during both the winter and summer.

Cattle and swine slurry are also used as organic fertilizer for row crops. However, when these manures are used, similar to PL surface broadcast application, a percentage of the applied N is lost to volatilization. According to Beauchamp et al. (1982), about 24 to 33% of the ammoniacal N of the liquid cattle slurry is volatilized as NH_3 during a week after application in early May. Safley et al. (1992) reported that using a central pivot to broadcast swine effluent averaged 20% loss of NH_4-N and the traveling gun broadcast system averaged about 26% loss. Due to concerns of N losses through volatilization after surface broadcasting, an alternative application method has been developed, subsurface band application.

The advantages of subsurface banding are (1) fertilizer nutrients are applied in close proximity of plant roots, (2) it allows application after the establishment of canopy in contrast to the broadcast application that is most commonly applied before planting, (3) and it reduces volatilization of N fertilizer. The concept of subsurface banding nutrients has never been applied to broiler litter, so to evaluate the results of a new implementation of subsurface banding PL, the research on subsurface banding or injection of chemical fertilizers and manures is essential. Banding K fertilizers increased corn yields that were under the no-till system in early season drought conditions in Ohio (Yibirin et al., 1993), Iowa (Bordoli and Mallarino, 1998) and Ontario, Canada (Vyn and Janovicek, 2001). Also, Rehm (1995) reported that deep banding K increased K availability and corn yield in ridge-tillage systems. Lehrsch et al. (2000) studied the effect of banding and side dressing N fertilizer on a non-irrigated side of a corn row. They found that compared with broadcast application of fertilizer, the band application maintained grain yield in the first year of the study and increased yield by 11% in the second year. Lamond et al. (1984) reported that knife banding application of urea/ NH_4NO_3 solution (UAN (urea/ammonium nitrate), 280g N kg^{-1} to smooth bromegrass generally resulted in higher yield and protein concentration than broadcast application. Howard and Tyler (1989) evaluated the N efficiency of urea-ammonium nitrate, urea, and urea-urea phosphate when broadcasted, banded, and injected for no-till corn. They reported that yield, leaf N concentration, or N uptake significantly varied among N sources or application methods.

Recent research indicates that broadcasting chemical fertilizer and manures results in substantial N loss through volatilization, but applying fertilizer beneath the soil surface resulted in less N loss with concurrent increased plant yield and nutrient availability. Therefore, the objective of this study is to compare the effect of the new subsurface band application to conventional surface broadcast application of broiler litter on soil N fertility and distribution.

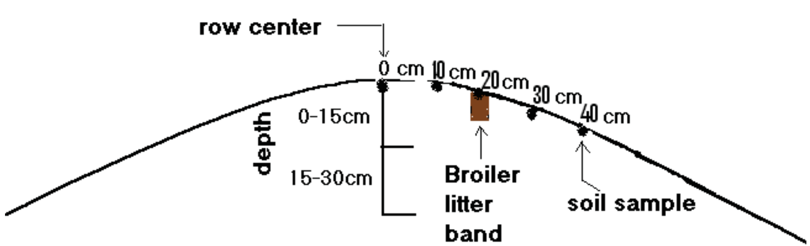
MATERIALS AND METHODS

This research was conducted in 2003 at the North Farm of the Mississippi Agricultural and Forestry Experiment Station in Starkville, MS at the Mississippi State University on a silty clay loam soil. The treatments included a no-fertilizer control, broiler litter (BL) surface broadcast before planting at 6720 kg ha^{-1}, and PL subsurface banded 20-cm from the center of the row before planting at 6720 kg ha^{-1}. A randomized complete block design with 4 replications was used. The plots were 3.9 m x 24.32 m, which included 4 rows with a row spacing of 0.97 m on center. Cotton was grown on conventionally tilled beds.

Broadcast application of broiler litter was accomplished by utilizing a litter spreader that applied litter uniformly across two rows followed by incorporation after several hours using a pre-plant chisel cultivator. The band application was accomplished with a prototype litter spreader (designed and built by scientists from USDA-ARS at Auburn, AL) that creates a 8 x 10 cm trench approximately 20 cm from the center of the cotton row, drops the litter into the trench, and covers it with loose soil within a few seconds. The broiler litter was analyzed for total N using the dry combustion method (Dumas, 1831). Cotton cultivar Delta Pine BR 451 was planted on May 31, 2003 and herbicide mixture of Zorial and Roundup was applied to all plots for weed control.

Systematic soil samples were taken 24 and 73 days after broiler litter application to compare lateral and downward movement of soil N. Systematic soil sampling consisted of taking core samples at later location from the center of the cotton row, 0, 10, 20, 30, 40-cm, at depths of 0-15 and 15-30 cm. This sampling technique is similar to that of Zebarth et al. (1999). The soil samples were analyzed for total N, nitrate-N, and ammonium-N. To determine total N, 0.6g of soil was weighed and analyzed by the dry combustion method mention previously. Ammonium and nitrate concentrations were determined by extracting 2 g of the soil sample with 2 M KCl and analyzing the extract using the Quick Chem Flow injection analyzer 8000 series (Keeney and Nelson, 1982). All analysis was accomplished using ANOVA at 0.05 alpha levels and SAS version 2002.

Fig. 1 Soil sampling model



RESULTS AND DISSCUSSION

Soil total N 30-cm from row center 24 days after litter application was slightly greater when PL was broadcast than when PL was banded (fig. 1). Broadcast total N was significantly higher than the band and control treatments at 15-30cm depth. Total N at the 20-cm position was greater for both the band and broadcast applications than the control. Differences among the three treatments in total N at the other sampling positions and both depths were small. Total N distribution across the sampled positions in the second sampling date was similar to that of the first sampling date.

Ammonium-N concentration at the 20-cm position and 0-15cm depth 24 days after litter application was much greater (17.94 mg/kg) when litter was banded than broadcast (2.34 mg/kg) (Fig. 3). The control had only 1.41 mg/kg ammonium at the same depth. Ammonium concentration at the same position and depth on the second sampling date 73 days after application was also greater when litter was band applied than broadcast applied. At the lower depth 24 days after planting, the band treatment had also gretaer (6.46mg/kg) ammonium concentration than the broadcast or control treatments (1.68 and 1.50 mg/kg, respectively). In addition, at the 40cm position the ammonium concentration of the band treatment (8.72 mg/kg) was also higher than, that of broadcast and the control at 2.54 and 1.86 mg/kg respectively. The ammonium had been depleted at both depths and in both application methods 73 d after application and planting due to plant uptake (Fig. 4). Data from both sampling dates show that band ammonium is greater relative to broadcast at 20 cm from the center of the cotton row where the band is located. At 0, 10, 30, 40-cm positions NH_4-N concentration of the band application was not significantly different from the broadcast application. Zebarth et al., (1982) who investigated the fertilizer banding influence on spatial and temporal distribution of soil inorganic nitrogen in a cornfield found similar results. They reported that when NH_4N0_3 is applied in a fertilizer band the nitrate concentration was elevated at soil sampling positions nearest to the fertilizer band at both depth 0-15 and 15-30cm.

Broadcasting litter resulted in a significantly higher concentration of NO_3-N at 0-cm from the cotton row and 0-15cm depth than the band and control treatments 24 days after litter application (fig. 5). But, at the lower depth and 0-cm position sampled, the broadcast treatment NO_3-N concentration was only 5% higher than band and 11% higher than the control. At 10-cm from the center of the cotton row, when litter is banded relative to broadcast, there was a 15% increase in the concentration of NO_3-N and a 28% increase when compared to the control 24 days after litter application at the 0-15cm depth. The increase in soil nitrate 10-cm from the row could be due the movement of NO_3-N from where the PL band was applied at 20-cm form the row. This indicates that plant roots are most likely to encounter a larger soil NO_3-N pool when PL is band compared to broadcast applied.

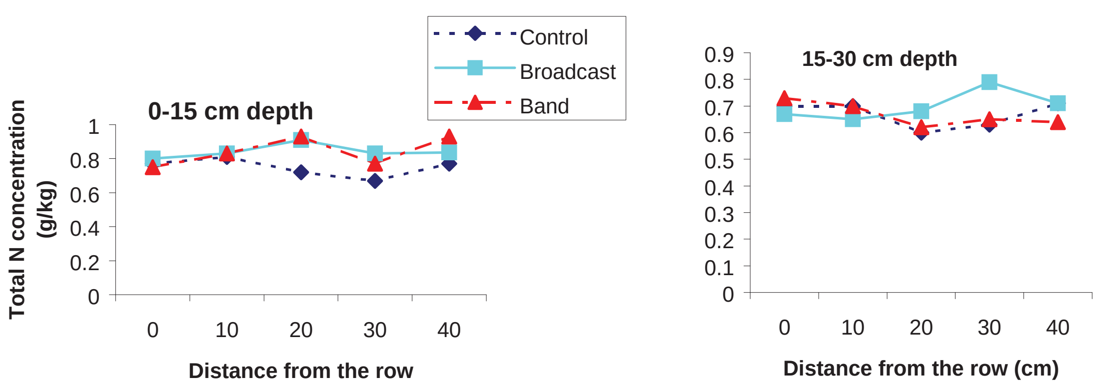


Fig. 2. Soil total N concentrations 24 days after application at the 0-15 and 15-30 cm depths at different distances from the center of the row on June 23, 2003.

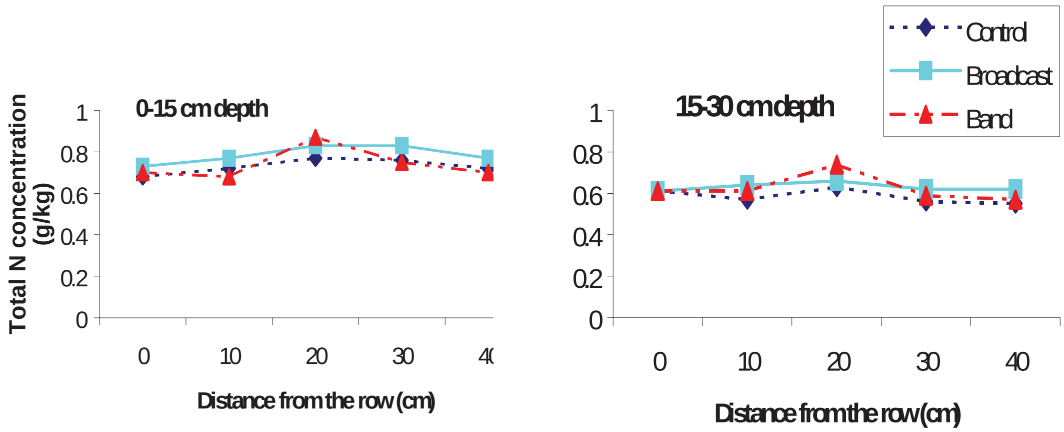


Fig. 3. Soil total N concentrations 73 after application at the 0-15 and 15-30 cm depths on Aug. 11, 2003.

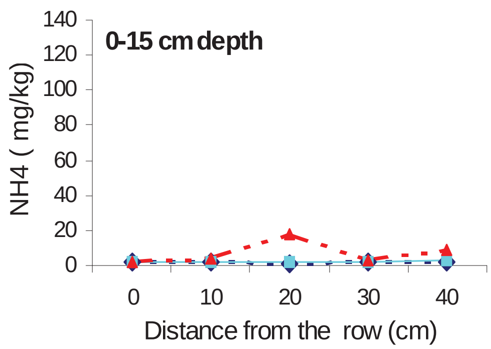


Fig. 4. Soil NH_4-N concentrations 24 days after application at the 0-15 and 15-30 cm depths at different distances from the center of the row in June 23, 2003

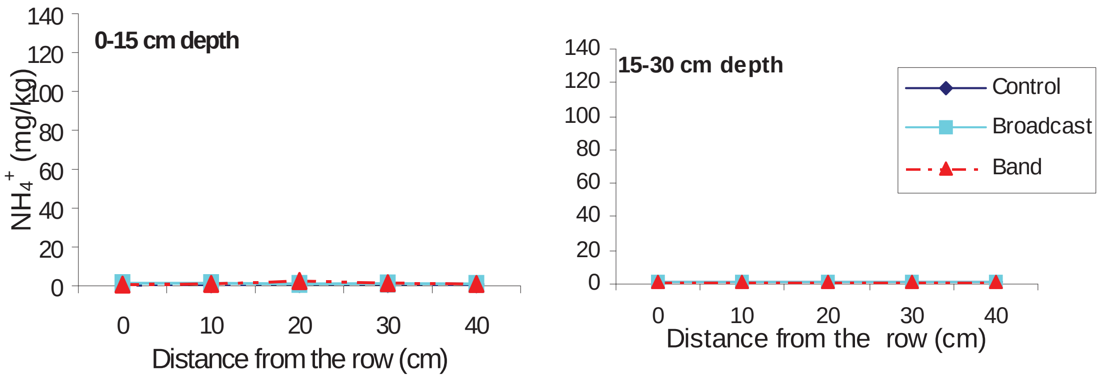


Fig. 5. Soil NH_4-N concentrations 73 days after application at the 0-15 and 15-30 cm depths at different distances from the center of the row in Aug. 11, 2003

At the lower depth and 10-cm position, the broadcast NO3- was slightly higher than the band and control NO_3-N 24 days after litter application. Finally, at the 40cm position the band NO_3-N concentration was 7% higher than broadcast at 24 days after litter application at the 0-15cm depth and at the 15-30 cm depth the broadcast NO_3-N was 6% higher than band and 10% higher than the control.

The band NO_3-N concentration 24 days after litter application at the 20-cm position was significantly higher than the broadcast and the control. At the lower depth the broadcast application was greater than band and the control. On the second sampling data 73 days after litter application and at 0-15cm depth, the band NO_3-N at the same sampling position was 25% higher than the broadcast or the control treatments. At the deeper depth and the 20-cm sampling position, the band NO_3-N concentration (7.9 mg/kg) was higher than the broadcast (2.69mg/kg) and the control (1.90 mg/kg) treatments. These results are also similar to the results of Zebarth et al. (1982) with applied inorganic N.

At the 0-15 cm depth and 30-cm from the center of the cotton row, when litter is banded there is 20% increase in the NO_3-N concentration compared to when litter is broadcasted at the same rate (Fig. 5). In addition, at the 15-30 cm depth the band NO_3-N was 26% higher than broadcast NO_3-N concentration. So, movement of NO_3-N 10cm on either side of the PL band resulted in an increase in band soil NO_3-N compared to broadcast. However, data from the second soil sampling show that there was a decrease in the concentration of NO_3-N that could be due to plant uptake and leaching.

Fig. 6. Soil NO_3-N concentration 24 days after application at 0-15 and 15-30 cm depths at different distances from the center of the row on June 23, 2003.

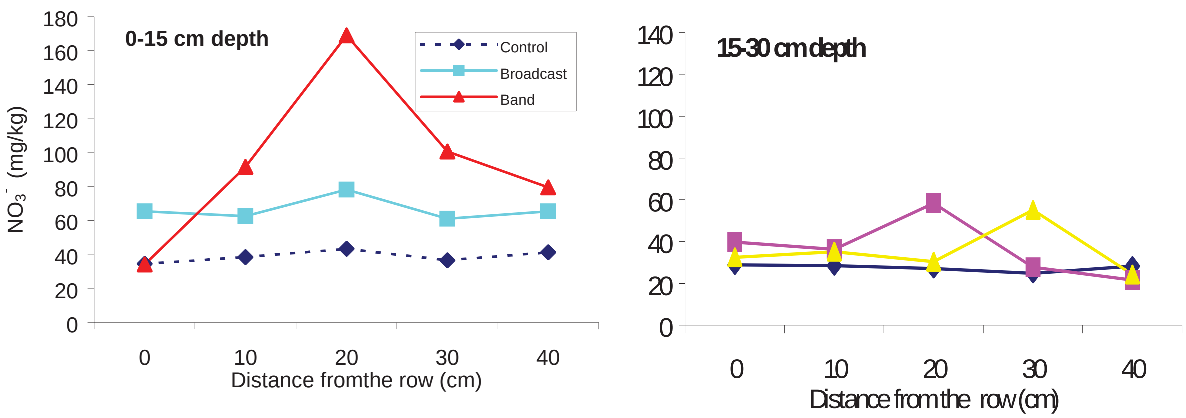
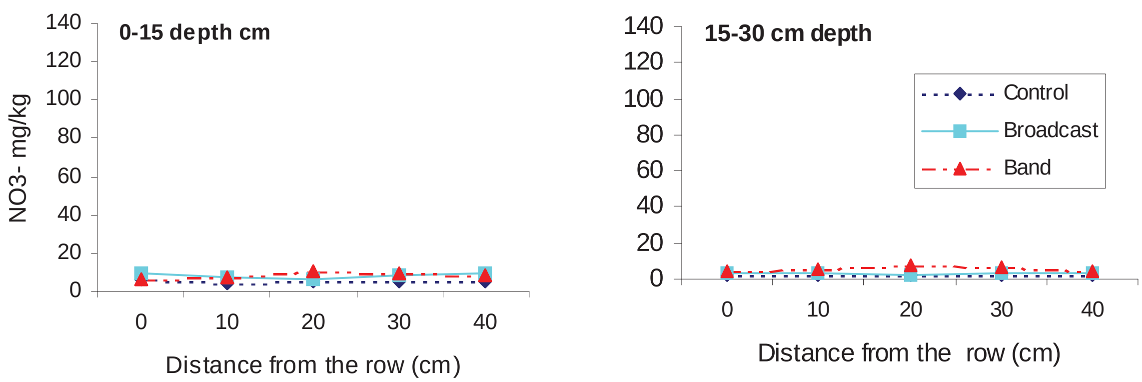


Fig. 7. Soil NO_3-N concentration 73 days after concentration at 0-15 and 15-30 cm depths at different distances from the center of the row in Aug. 11, 2003.



SUMMARY

Spatial data, at five positions from the center of the row, has indicated that nitrate is mobile when BL is band applied. Also the data show that the nature of the application method does have an effect on the available N nutrient pool. When the broiler litter was banded, ammonium 24 days after application was only elevated at 20-cm, where the band was located. However, the average concentration of NH_4-N across all sampled positions at 0-15 depth was 47% higher when PL was banded relative to broadcast applied. Band NO_3-N concentration was significantly greater 24 days after application at 20 cm from the center of the cotton row and 0-15 cm depth, compared to when litter is broadcast applied. Broiler litterbanded in close proximity to the root zone resulted in a higher concentrations of soil inorganic N.

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Isolation of Salmonella Bacteriophages from Swine Waste Lagoons

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Bacteriophages (phages), viruses that infect bacteria, occur wherever bacteria occur. Like other viruses, phages infect specific hosts. Phages which infect and lyse their respective host bacterium are called lytic phages. Specificity of lytic phage-host relationships is the basis of phage typing, which is used in identification and tracking of human bacterial pathogens, including Salmonella. Lagoon samples from nine hog farms in Mississippi were tested for the presence of phages and Salmonella-specific lytic phages were isolated. Phages were isolated using an enrichment method or directly from clarified filtered effluent. For enrichment, samples were treated to eliminate bacteria, then mixed with nutrient broth containing a Salmonella cocktail (serotypes Typhimurium and Enteritidis) to favor growth of Salmonella phages. After overnight incubation, Salmonella were killed and enriched samples were tested by double agar layer (DAL) plaque assays against individual Salmonella isolates. Enrichment produced lytic phage titers of 2.9×10^8 to 2.1×10^9 plaque forming units (pfu) per ml. For direct isolation, effluent was clarified by centrifugation and filtration, then used in DAL plaque assays against host isolates of serotypes Typhimurium; Enteritidis; Agona; Michigan; Montevideo and Gaminara. Isolates were recovered by the direct method for all serotypes except Gaminara, but plaque formation varied among host isolates and lagoon samples. The most sensitive host for direct isolation of phages was *S. typhimurium* ATCC 13311. The direct method was used with ATCC 13311 to estimate phage titers among the lagoons, which ranged from 12-148 pfu per ml. Host range tests of phage isolates from enriched samples, showed all were specific for *S. enteritidis* and *S. typhimurium* and none produced plaques on lagoon isolates of *Citrobacter youngae, Escherichia coli, E. fergusonii, Proteus mirabilis, Providencia rettgeri* or *Serratia marcescens*. Electron microscopy (EM) with enriched samples showed phages with icosahedral heads about 50 nm in diameter with tail spikes, but lacking a tail shaft. EM of concentrated filtered lagoon samples, without selection for Salmonella specificity, revealed other phage types, including tailed phages. Swine waste lagoons proved to be rich in phages and good sources of Salmonella phages. These phages have potential uses in phage typing and as Salmonella indicators and biocontrol agents.

Fungicide-Based Estimates of Yield Losses Caused by Fungal Diseases in Bermudagrass on Swine Waste Application Sites

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Bermudagrass (*Cynodon dactylon* L.) is one of the principal forage grasses to which swine wastes are applied for the uptake and assimilation of phosphorus (P) to prevent its movement into surface waters to cause eutrophic pollution. Fungal plant diseases that reduce the yield and survival of bermudagrass may limit its usefulness for the uptake of P from applied wastes and prevention of water pollution. Previous observations indicated that fungal diseases of roots, rhizomes, and stolons may be major factors that limit forage production and P removal by bermudagrass on swine waste application sites. Therefore, this study was undertaken to provide quantitative estimates of yield losses caused by fungal diseases in bermudagrass sod on three swine waste application sites in Mississippi. In 17 experiments, samples of sod from areas of stands with disease symptoms, or from healthy-appearing areas, were collected, potted up in the greenhouse, clipped, and grown for 5-10 weeks with or without weekly fungicide drenches applied to sod. Foliage then was harvested and dry weights were determined. Losses in forage yield were estimated according to differences in foliar dry weights between untreated controls, where development of fungal diseases in sod was unimpeded, and in pots with weekly fungicide drenches, where disease development was suppressed or arrested. Of four fungicides tested, mancozeb usually gave the greatest growth responses and the highest yield-loss estimates. In 12 experiments with samples of diseased-appearing sod from three commercial swine farms, estimates of losses in potential forage yields obtained with mancozeb ranged from 0-68% with a mean loss estimate of 44%. In five experiments with samples of healthy-appearing sod, loss estimates obtained with mancozeb ranged from 0-35% with a mean loss estimate of 17%. Significant differences in disease losses between sites were observed. Results indicate that on some swine waste application sites, major losses in forage yield of bermudagrass are occurring as a result of fungal diseases in roots, stolons, and rhizomes. Genetic improvement of bermudagrass for disease resistance, or the development of other effective control measures, could greatly increase its capacity for forage production and P removal on some swine waste application sites.

The Effect of Further Hatchery Waste Processing on Soil Acidity Amelioration and Plant Response in Two Mississippi Soils

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Larry Oldham, Mississippi State University Extension Service
Michael Cox, Mississippi State University

Soil acidity decreases yields of hay, pastures, and row crops throughout Mississippi. Except for marl or chalk, Mississippi liming materials are imported which increases the cost of ameliorating soil acidity relative to neighboring states with native calcitic or dolomitic limestone quarries. Alternative liming materials may offer significant lower application costs. Crushed eggshells from poultry hatchery operations, largely composed of calcium, usually are landfilled in the south-central Mississippi poultry production cluster. This work evaluates the effectiveness of dry versus wet hatchery waste as soil liming materials. It is part of a larger effort examining agronomic efficacy and soil chemistry effects of hatchery waste in the state. Two greenhouse pot studies used Ruston soil (fine-loamy, siliceous, semiactive, thermic Typic Paleudult) and Urbo soil (fine, mixed, active, acid, thermic Vertic Epiaquept) soils collected from the surface 15 cm at mapped locations in Oktibbeha County, MS. Using standard soil testing procedures of the Mississippi State University Extension Service Soil Testing Laboratory, the lime requirement for the Ruston soil (pH 5.3) was 1.5 tons 100% Calcium Carbonate Equivalent (CCE) per acre, and 4 tons 100% CCE per acre for the Urbo soil (pH 5.1). One study examined the effect of application rates based on wet weight of the waste material; waste material was dried, ground, and sieved for the second study. Treatment design of each study was a Completely Randomized Block with four replications. Application rates of the material for both wet and dry studies were 1, 2, 3, 4, and 5 tons acre^{-1} with an assumed 75% CCE (actual analysis 79.8%). Hydrated lime treatments were used as controls. Soils were mixed with the various rates of material and distributed to 15 cm diameter pots. Pots were watered and equilibrated 24 hours, then seeded with annual rye grass (Lolium multiflorum). The effect of drying, crushing, and sieving the by-product prior to soil application will be contrasted with applying wet, 'as is' material in this report. Changes in soil pH over incubation through 90 days, ryegrass germination rates, and plant growth responses will be reported.

Nutrient Uptake and Runoff from Alum-treated Broiler Litter Tall Fescue Plots

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Land application of poultry litter as fertilizer may lead to impaired surface and ground water quality. An experiment was conducted at Crossville, AL to study the effects of alum [$Al_2(SO_4)_3,14H_2O$] treatment of broiler litter on the yield and nutrient uptake of tall fescue (*Festuca arundinaceae*) and the nutrient content of runoff water exited from treated plots. Alum treatments had no effect on tall fescue dry matter yield, and the herbage nutrient concentrations were within acceptable limits. We noted significant reductions in the runoff concentrations of NH_4-N (28.6 mg L^{-1} for untreated litter VS 15.0 mg L^{-1} for alum-treated litter), total P (11.5 mg L^{-1} VS 5.1 mg L^{-1}), soluble reactive P (10.4 mg L^{-1} VS 4.7 mg L^{-1}) , and particulate P (1.9 mg L^{-1} VS 0.8 mg L^{-1}). This practice should receive serious consideration as a method of reducing the adverse environmental impact of broiler chicken production when the litter is applied to pasture land.

Nutrient Uptake and Forage Quality of Sorghum-Sudangrass Under Different Poultry Litter Fertility Programs

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R.A. Gilfillen - Western Kentucky University
W.T. Willian - Western Kentucky University
H. Henderson - Western Kentucky University

More producers now use poultry litter as fertilizer because of increasing inorganic fertilizer cost. Poultry litter is often over-applied and may cause water pollution and soil nutrient imbalances. Our objective was to evaluate nutrient uptake of sorghum-sudangrass to determine its viability as a nutrient removal tool while providing adequate forage yield and quality. Treatments included: litter applied at recommended nitrogen (N) rate; recommended phosphorus (P) rate plus supplemental inorganic N; recommended P rate; and inorganic fertilizer. Samples were analyzed for acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), P, Cu, Zn, and Fe. The treatment by year interaction was significant for most variables analyzed so the data will be presented by year. All variables were affected by treatment but generally, P concentration increased from 2001 to 2003 with the largest increases in plots receiving inorganic fertilizer (30%) only and those receiving litter based on the P recommendation (31%). There was a 60% increase in Fe concentration in plots receiving litter at the recommended N rate. Our findings suggest that applying poultry litter at a lower rate can significantly reduce P and Fe concentration when compared to other treatments. When lower rates of poultry litter are applied based on P recommendation, supplemental inorganic N could be added to ensure adequate N nutrition. In our study, supplementing inorganic N on plots receiving low rates of litter produced forage of similar quality to inorganic fertilizer in 2 of 3 years.

Applying Poultry Litter in the Fall Diminishes its Fertilizer Value

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ABSTRACT

Applying poultry litter in the fall to cotton and other row crops may be a practical option for farmers that have no time to manage litter application in the spring. However, whether fall-applied litter is as effective as spring-applied litter is not well investigated. On-farm research conducted at three locations in Mississippi indicated that applying litter in the fall may not be as effective as applying litter in the spring. Cotton responded very poorly to broiler litter in two of three years at Macon, MS where the litter was applied in the fall. Broiler litter applied in the fall at this location increased lint yield by only 62 lbs lint acre^{-1} ton^{-1} litter in 2003 and by 40 lint acre^{-1} ton^{-1} litter in 2004 compared with 230 lbs acre^{-1} ton^{-1} litter in 2002. The yield response to litter at two other locations in 2003 and 2004 where the litter was applied shortly before or after planting in the spring ranged between 121 and 161 lbs acre^{-1} ton^{-1} litter. These results suggest that there is substantial risk of mineralization and loss of mineralized litter-N before planting when litter is applied in the fall. We suspect leaching and denitrification as the primary causes of N loss when soil moisture and temperature conditions in the fall and winter after applying litter are ideal for the mineralization of litter-N.

INTRODUCTION

The vast majority of the estimated one million tons of litter generated by Mississippi's poultry industry is land-applied usually within short distances of confined poultry production areas on pastures as a fertilizer. This practice is likely to be gradually reduced and eventually eliminated because continued litter application to the same land for an extended period usually leads to environmentally unsustainable overload of nutrients particularly that of phosphorus. Land planted to cotton can ease the enormous burden placed on pastures nearby chicken houses because cotton is a million-acre crop in the state and consumes up to 120 million lbs of nitrogen, 23 million lbs of phosphate, and 82 million lbs of potash annually (USDA, 2004). Poultry litter can supply all of these nutrients implying that land under cotton has the capacity to assimilate a large fraction of the litter produced in the state with relatively minimum concerns of nutrient buildup and environmental risks in the immediate future.

Typically, spring is the ideal time to apply litter to cotton and other row crops (Mitchell, 2003). However, many growers of cotton and other row crops choose to not use litter as a fertilizer partly because applying litter in the spring competes with other farm activities. Applying litter in the fall or winter may be an alternative practice to applying litter in the spring for farmers that have little or no time to manage litter application in the spring. However, according to Mitchell (2003) applying litter more than one month prior to planting in Alabama is risky because spring rains could cause leaching or denitrification loss of readily available litter-N. Mitchell's (2003) advice is not supported with research results and whether fall-applied litter is as effective as spring-applied litter is not well investigated. On-farm research conducted at three locations in Mississippi between 2002 and 2004 assessed the effectiveness of fall-applied broiler litter as the primary fertilizer for cotton grown conventionally, under no-till, or reduced tillage.

MATERIALS AND METHODS

On-farm research was conducted at three locations (Macon, Cruger, and Coffeeville) in Mississippi in 2002, 2003, and 2004. At each location, fresh broiler litter was applied at 0, 1, 2, or 3 tons/acre and compared against a standard farm fertilization program. The standard farm fertilization included N rates of 105 to 120 lbs/acre; P and K fertilizers were applied as needed based on pre-plant soil analysis. The treatments were compared in a randomized complete block design with three or four replications. The plots at each location were as large as 4933 ft^2 at Cruger, 6000 ft^2 at Macon, and 6080 ft^2 at Cofeeville.

Litter at Macon was applied in the fall on 8 November 2001, 3 December 2002, and 14 November 2003 and plots were planted with cotton the following spring on 25 April 2002, 8 May 2003, and 7 May 2004. Litter at Cruger was applied in the spring on 16 April 2002, 15 April 2003, 9 April 2004 and planted on 19 April 2002, 16 April 2003, and 19 April 2004. Litter at coffeeville was also applied in the spring on 29 April 2002, 27 May 2003, 7 May 2004 and planted on 21 May 2002, 2 May 2003, and 28 April 2004. Litter at all locations was applied using a commercial spreader equipped with speed-sensing ground radar, electronic scale, and rate-control computer system. At Macon and Cruger, the litter was soil-incorporated within one day of application while the litter at Coffeeville was not incorporated as this location grows cotton with no-till. Differences in management of the farms and background soil properties are shown in Table 1.

Table 1. Management variations and background soil properties before initiating the research at each of the three farms where broiler litter was tested as a fertilizer for cotton.

Location	Tillage	Row spacing	Season litter applied	Initial pH	Initial Organic matter
		inch			%
Cruger	Conventional	40	Spring	5.8	1.3
Macon	Reduced	30	Fall	6.5	2.0
Coffeeville	No-till	38	Spring	5.9	1.5

RESULTS AND DISCUSSION

Broiler litter applied in the spring within few days of planting cotton in responsive soil resulted in good lint yield response. The yield response to litter at Coffeeville and Cruger in 2003 and 2004 where the litter was applied just before planting in the spring ranged between 121 and 161 lbs lint per acre for every ton of applied litter (Table 3, Fig. 1). The response to litter in 2002 at both locations was smaller most likely because the soil was less responsive as this was the first season of the test. The amount of total litter needed to bring the yield comparable to that of the conventional fertilization was determined to be 3.5 ton/acre (average across the three years) at Coffeeville and 4.3 ton/acre at Cruger. These litter rates are not unreasonable considering the conventional N fertilization rates at each of these locations was ≈120 lbs/acre at Cruger and ≈105 lbs/acre at Coffeeville and the N content of the litter used was ≈2.5 to 3.0% on a fresh weight basis.

Similar to that of Cruger and Coffeeville, the yield response of cotton to litter at Macon where the litter was applied in the fall several months before planting in 2002 was also large, 230 lbs lint per acre for every ton of applied litter (Table 3, Fig. 1). At this rate in 2002, only 2.4 ton/acre of litter would have been sufficient to increase yield to be comparable to that of the conventional N fertilization. In sharp contrast to 2002, cotton responded very poorly to litter in 2003 and 2004 at Macon where the litter was applied in the fall. Fall-applied litter at this location increased lint yield by only 62 lbs/acre/ton in 2003 and by 40 lbs/acre/ton in 2004 compared with 230 lbs/acre/ton in 2002 (Table 3). It would have been necessary to apply 7.6 ton/acre in 2003 and 15.6 ton/acre in 2004 to obtain lint yield comparable to the yield of the conventional fertilization.

These results suggest that the fall-applied litter in 2003 and 2004 lost its fertilizer potency most likely because of leaching and denitrification of mineralized N. We suspect soil temperature and moisture conditions in 2003 and 2004 were more ideal for the mineralization of litter N and for the loss of mineralized N by leaching, denitrification, or by both means. Daily soil temperature measured and recorded at a weather station adjacent to the study site indicates soil temperature was more ideal to N mineralization in the few months before planting in 2003 and 2004 than in 2002. There were much fewer days with ≤40°F minimum soil temperature at the 2-inch depth in February and March in 2003 and 2004 than in 2002 (Table 2). Rain records further showed that the 2003 and 2004 seasons were more ideal for loss of mineralized N by leaching and denitrification than the 2002 season. In addition to receiving more rain (20.5 inches in 2003 and 19.3 inches in 2004 compared with 15.6 inches in 2002), there were more days with rain ≥2.0 inches between January 1 and April 30 in 2003 and 2004 than in 2002. Records show 3.4, 3.1, and 3.5 inches of rain was received on February 21, April 6, and April 24, 2003, respectively. There was one day with 4.86 inches of rain on February 5 in 2004 while none of the rain measured between January 1 and April 30, 2002 was ≥2.0 inches. Both the rain pattern and the soil temperature records suggest that conditions were more ideal in 2003 and 2004 than in 2002 for mineralization and loss of litter N by leaching and denitrification. The results of this research indicate that the effectiveness of fall-applied litter in increasing cotton yield depends on soil temperature and moisture conditions between application and planting.

Table 2. Number of days with ≤40°F minimum soil temperature at 2-inch depth.

Year	December	January	February	March	April
	------------*Days with ≤40°F soil temperature*------------				
2002	12	23	24	13	3
2003	6	22	6	0	0
2004	24	19	9	2	0

Findings of this research seem to support the advice of Mitchell (2003) that litter should not be applied earlier than one month before planting. Our results demonstrate that applying litter in the fall during certain years may not be as effective as applying litter in the spring. Therefore, we discourage applying litter in the fall or winter to cotton in Mississippi and similar other southeastern cotton-producing states as it is difficult, if not impossible, to predict weather conditions during the four to five months preceding cotton planting.

none to up to 3 ton/acre. The projected or estimated lint yields were derived from regression equations of actual lint yield and applied poultry litter.

Location	Season	Actual yield of standard	Projected yield of control	Actual yield of control	Estimated yield increase	Projected optimum litter rate
		------------------	*lbs/acre*	---------------	*lbs/acre/ton litter*	*ton/acre*
Coffeeville	2002	1142	780	786	114	3.2
	2003	1111	669	645	160	2.8
	2004	1155	607	667	121	4.5
Cruger	2002	1489	1335	1312	44	3.5
	2003	1594	840	827	160	4.7
	2004	1427	692	649	161	4.6
Macon	2002	1408	846	915	230	2.4
	2003	930	460	460	62	7.6
	2004	950	326	284	40	15.6

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USDA, National Agricultural Statistics Service. 2004a. Agricultural Chemical Usage 2003 Field Crops Summary. Ag Ch 1 (04) a. [Online.] [158 p.] Available at http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/agcs0504.pdf, accessed 16 March 2005.

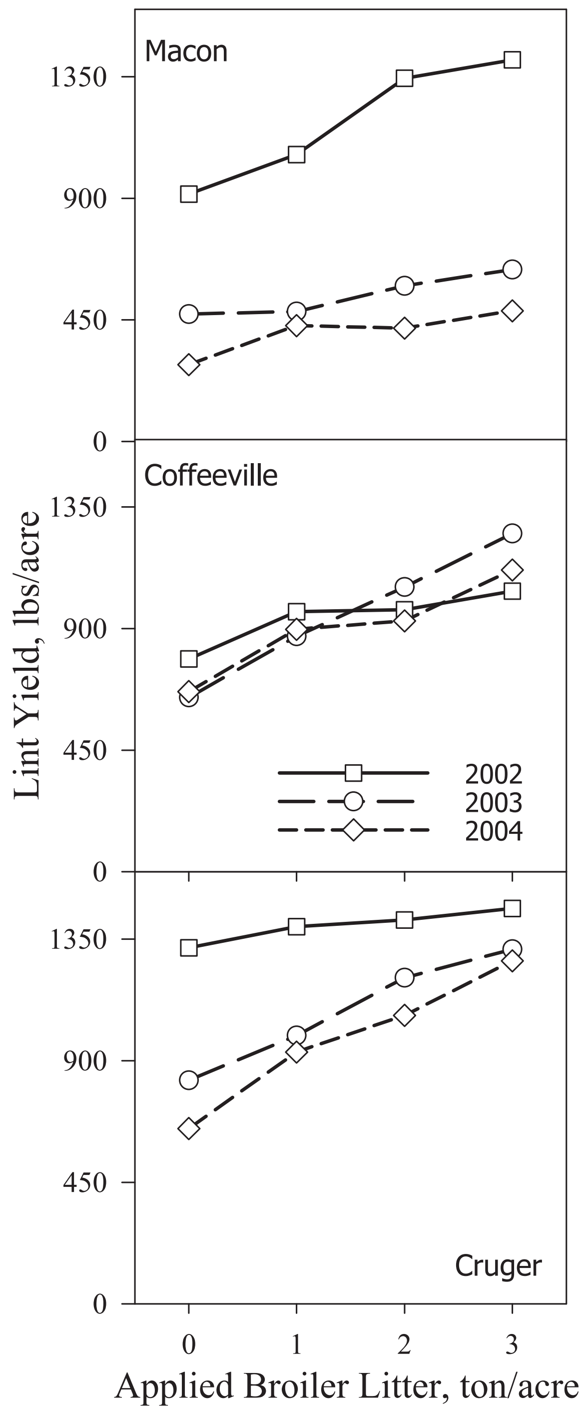

Fig. 1. Cotton lint yield response to broiler litter applied in the fall (Macon, MS) or spring (Cruger and Coffeeville, MS) in 2002-2004.

Soil Nutrient Accumulation and Field Corn Yield as Influenced by Poultry Litter Application Rate

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Previous research has indicated that broiler litter can increase field crop yields but may provide amounts of some nutrients in excess of crop needs, resulting in excessive soil accumulation. A field experiment was conducted from 2002-2004 to investigate the influence of broiler litter application rate on field corn grain yield and soil nutrient concentration. Broiler litter was applied at 0, 4.5, 9.0, and 13.5 Mg ha^{-1} and incorporated prior to crop establishment. An inorganic fertilizer treatment was included for comparison purposes. Soil samples were taken (0-15 cm depth) prior to planting in 2003 and 2004 and analyzed for pH, organic matter content, available P, K, Cu, and Zn. Grain yield was taken at crop maturity. Broiler litter rates of $\geq$ 9.0 Mg ha^{-1} were required to produce grain yield comparable to a standard inorganic fertilizer program. Application rates that produced grain yield equivalent to that of inorganic fertilizer simultaneously increased available P, K, and Cu in surface soil. Annual fertility amendments increased soil organic matter content by 4.5 g kg^{-1} and soil pH by 0.21 units. These results suggest that field corn producers wishing to utilize broiler litter as a nutrient source should consider a nutrient management program in which broiler litter rates of < 9.0 Mg ha^{-1} are supplemented with inorganic nitrogen.

Luncheon Speaker:
Bo Robinson
Mississippi Public Service Commission
Northern District

Concurrent Session A
Policy
Moderator: Deirdre McGowan

Speakers:

Ken Griffin
Pearl River Valley Water Supply District

Nick Walters
USDA Rural Development

Bob Lord
Mississippi Development Authority

Barry Royals
Waggoner Engineering, Inc.

Worth Hager
National Waterways Conference, Inc.

Concurrent Session B
Waste Management Symposium
Moderators:
Dennis Rowe and Karamat Sistani

Evaluation of an Advanced Waste Treatment System for Reduction of Malodorous Compounds from Swine Waste

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USDA-ARS
Animal Waste Management Research Unit

Ariel A. Szogi Ph.D. and Matias B. Vanotti Ph.D.
USDA-ARS

Technologies are needed that reclaim nutrients, kill pathogens and reduce emission of ammonia and nuisance odors from animal waste. A full-scale system (4,360-pigs) was implemented as part of the Smithfield Foods/Premium Standard Farms/Frontline Farmers Agreement with the North Carolina Attorney General to develop technologies that accomplish these goals and offer alternatives to waste-treatment lagoons. The system increases the efficiency of liquid/solid separation by injection of polymer to increase solids flocculation. Ammonia emission is reduced by passing the liquid through modules with immobilized nitrifiers/denitrifiers. Subsequent alkaline treatment of the wastewater in a phosphorus module precipitates calcium phosphate and kills pathogens. Previous reports have shown that this system effectively reduces nutrients and pathogens of high strength wastewater. This report evaluates the system's effectiveness for the remediation of malodorous compounds from waste. Preliminary headspace analyses showed that the levels of five key malodorous compounds (phenol, *p*-cresol, 4-ethylphenol, indole and skatole) were reduced by over 90% in treated water as compared to raw flushed manure. Subsequent solid phase extraction measured levels of volatile compounds at each stage of the treatment process in order to identify stages that reduce malodorous compounds and potential control points for the reduction of odors in the treatment system. Seventeen volatile compounds consisting of aromatics, hydrocarbons, and brominated aliphatics were identified from swine wastewater. As seen in headspace analyses, the levels of compounds with objectionable odors were reduced by an average of more than 90 percent during treatment: in effect, wastewater odor reduction was achieved during denitrification of the wastewater. Experimental results are discussed in relation to sampling methodology and wastewater treatment stage.

Iron Humate for Manure Treatment and Phosphorus Control on Small Dairy and Swine Farms

Victor B. Johnson, Johnson Kemiron Company; Bob Rehberg, Vigiron, Inc.

Focus on animal waste treatment for phosphorus control has small farmers in a quandary. This presentation will focus on a system using Iron Humate, the co-product created during the treatment process of Potable water treatment plants. The costs and simplicity of this technology provides an alternative that can be employed by smaller (<500 Head) operations common in Mississippi.

Sophisticated systems for manure dewatering and treatment involving centrifuges, screw presses, belt presses, dissolved air floatation units, and other devices common in municipal sludge dewatering are well beyond the capital, operation, and maintenance capabilities smaller enterprises. Further, the level of expertise required is not usually available in the workforce at hand, forcing the dairy or swine operator to do it themselves or go outside the normal workforce and hire more expensive employees with additional training and skills. These technologies appear out of the reach to all but the largest farms. One new technology holds promise for many operations. This technology uses Iron Humate and coagulants for nutrient removal from the waste stream as means for effectively binding and removing the phosphorus. This also provides a beneficial re-use of the Iron Humate co-product created during the water treatment process. The resultant iron humate/phosphate filtrate material may also be used as an excellent source of iron and Phosphorus for pasture fertilization. This alternative provides a low maintenance alternative for the smaller livestock operation and does not require the capital expense or operational expertise required with more sophisticated systems. The waste stream is filtered through the Iron Humate which effectively absorbs the nutrients from the waste stream while retaining solids for further treatment or disposal. Current data shows phosphorus removal efficiencies greater than ninety percent. Application technology for Dairy and Swine operations as well as parameters required by Water Utilities to incorporate this process into their system will be presented.

Manure Treatment Systems and Nutrient Control of Dairy Waste

Victor B. Johnson, Kemiron Company

Retrofitting municipal and industrial dewatering technology for dairy waste treatment has met with limited success. Many waste treatment systems use various components from different industries in an attempt to find an efficacious fit. Further employing conventional static separators designed to remove or reclaim fiber and bedding materials may not provide the nutrient removal efficiency required. Emerging technologies for animal waste treatment have promised innovative and brilliant systems, but they are untried and out of the economic reaches of many operations. These new systems require specialized operation and maintenance expertise not common in the workforce easily available to the Dairy or Swine operator.

Recently a systems approach to dairy waste treatment has been introduced specifically suited to animal waste treatment and the livestock operation's ability to operate and maintain equipment. Several systems are currently in use on Dairy and Swine facilities in the U.S. These systems employ either mechanical or passive fiber separation. Mechanical systems add components such as static screens, screw presses, sequential centrifuges and in some cases a dissolved air floatation unit for additional removal and nutrient recovery. Passive systems employ a geosynthetic material for nutrient removal and fiber recovery. Use of chemical precipitants (aluminum sulfate, ferric sulfate, ferrous sulfate) and polymeric flocculants improve removal efficiencies of phosphorus to >80% and are used in both systems. A brief overview of typical system design, nutrient removals and capital costs will be presented in a case study format for Dairy and Swine facilities currently utilizing these technologies.

Addressing the Non-traditional Nutrient Management Education Needs of Mississippi Poultry Producers: History, Action, and Future

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Abstract

Poultry production, the largest grossing agricultural enterprise in Mississippi, is concentrated in the south central region of the state. The industry cluster increases concerns about nonpoint source pollution and water resource quality in the region. Site specific nutrient management plans are required by the Mississippi Department of Environmental Quality for poultry farms that have changed production levels since 1994, or are classified as Concentrated Animal Feeding Operations (CAFO's) according to Environmental Protection Agency regulations. In recent years, Mississippi State University Extension Service (MSU-ES) and Experiment Station personnel have worked closely with all segments of the industry and other agencies to expand the research base and to provide training in nutrient management. Reorganization of MSU-ES in 2002 addressed the need for more non-traditional education programs in environmental issues in general, and nutrient management in particular. Mississippi based research and outreach programs were reviewed at a symposium in December, 2003. Facilitated discussion among symposium attendees focused the perceived strengths and weaknesses of the effort, and offered suggestions for improvement. The Environment/Nutrient Management Program Priority Group was organized to plan and implement programming efforts using multiple disciplines and university units. An Extension area agent specialty was defined, advertised, hired, and placed in the poultry region to provide educational programs and serve as a resource. Recent changes in state CAFO permit requirements (2004) further increased the educational needs of poultry producers in nutrient management, record keeping, and other management skills.

Introduction

Poultry is integral to Mississippi agriculture, both by meat production and providing soil amendments to support cattle production. Mississippi State University (MSU) has worked in numerous capacities to support the best interests of the people of the state with respect to poultry production management, avian health, environmental issues, economics, and human nutrition. Interest in agricultural environmental issues in recent decades has increased as the population has urbanized and agricultural production models have become more centralized. This paper examines how MSU addressed growing concerns about nutrients in the landscape in south central Mississippi.

History

Poultry is the largest farm gate contributor to the Mississippi agricultural economy; it is the fourth largest broiler producing state in the nation and has significant fresh egg production. The largest segment, broilers or chickens grown for meat production, are grown by individual farmers under contract to integrated poultry production companies. Chicks are hatched in a central location and delivered to the farms for growing. For economies of scale and transportation, most production for a particular company is situated about a one hour drive around centralized processing plants. This hub and spoke setup is called a complex. Over time, several complexes have located primarily in the south central region of Mississippi; broiler production contributed approximately $100,000,000 to agricultural income in 2000 in seven counties. Other counties also had significant broiler income (Morgan and Murray, 2002)

Litter from periodical cleanout of growing houses is commonly applied to pastures and forages on the producing farm. The Mississippi Department of Environmental Quality requires growers who have ‘significantly changed’ their operation since 1994 to have an environmental operating permit that includes a Nutrient Management Plan (NMP). These plans are usually developed for the poultry growers by local field staff of the United States Department of Agriculture Natural Resource Conservation Service (NRCS) using the published practice standards and formats of the Field Office Technical Guide (FOTG) of the agency. Mississippi NRCS bases the specific guidelines on Experiment Station research and Extension information generated by the Mississippi State University and other institutions, including the Agriculture Research Service of the United States Department of Agriculture.

When NRCS Practice Standards were revised in the mid-1990’s, a phosphorus-based (P-based) Nutrient Management Plan was included in the Animal Waste Management standard of the Mississippi FOTG. In the same era, some integrators required all growers to develop and follow NMP’s, irregardless of regulation. Various agricultural stakeholder groups realized that P-based plans required large land areas for successful implementation. Furthermore, tne MSU Extension Service Soil Testing Laboratory recommended no P fertilizer application, whether organic or inorganic, on soils with more than 144 pounds acre^{-1} soil test P (STP) as determined by the Mississippi Soil Test procedure (Crouse, 2001). Many fields with poultry litter application histories have elevated STP because the litter has more available P than crops can assimilate in a relatively short time span (Read et al., 2005). This situation involving the growers, agencies, companies, and academia became untenable.

Action

After interaction with several concerned stakeholders, Mississippi State University developed a 'Water Quality and Nutrient Management Task Force' (Task Force) to focus research and outreach services required by the industry segments: growers, poultry companies, government agencies, and non-government organizations. The multi-discipline Task Force involved the agricultural units of MSU, units of the Agricultural Research Service, and non-agricultural units of MSU. The Task Force allowed better communication among the diverse academic units, and simplified the university entry point for stakeholders with poultry-related issues. Several projects were initiated and combined.

The Task Force worked in tandem with the Southwest Mississippi Resource and Conservation and Development Council in administering an Environmental Protection Agency 319 grant through the Mississippi Department of Environmental Quality that addressed development of alternate nutrient management options for poultry litter. The objectives of the work were:

1) Economic analysis of alternative poultry litter use;
2) Assess quality and quantity of poultry litter produced in Mississippi;
3) Provide demonstrations that would increase poultry litter demand; and
4) Determine and develop options for alternative poultry litter use.

Several initiatives by 23 faculty and professional staff addressed these concerns through research and demonstration projects, and Extension publications and programs (Vizzier-Thaxton, 2002).

Concomitantly, the MSU Extension Service was reviewing its organization and delivery mechanisms for non-traditional education opportunities that enhance the Mississippi quality of life. In this process, environmental issues and nutrient management were recognized as vital to Agriculture and Natural Resource programming, and as such, a Program Priority Group was developed in the Extension Service reorganization implemented in July, 2002. Many activities previously coordinated through the Task Force were subsumed by the Environment/Nutrient Management Program Priority Group (E/NM PPG).

The second group adopted a mission "to expand the focus on extension, education, and research on environmental issues related to the natural resource base that sustains and improves the landscape, integrating the importance of water quality, soil quality, and air quality in food and fiber production, human capital, and asset stewardship". Reporting areas in the E/NM PPG are animal waste management, water quality, soil management, and environmental stewardship. An area agent position for E/NM was allocated by the reorganization plan. A first task for the E/NM PPG was defining, searching, and interviewing for that position which was filled in November, 2003.

During the transition period between the two systems, internal support to two current authors through the William White Fund of the MSU Division of Agriculture, Forestry, and Veterinary Medicine supported a review process of the poultry litter efforts by the university and partners. The Nutrient Management Symposium in December, 2003 involved stakeholders from industry, producers, agricultural organizations, and academia. Following four presentations describing 41 different recently completed or ongoing projects related to poultry litter utilization, participants were engaged in facilitated discussion regarding the MSU effort.

Strengths and opportunities for improvement in the Mississippi effort as identified by the stakeholders are listed in Table 1 as presented by the participants of the facilitated discussion.

Future

The Environmental Protection Agency promulgated new rules for Animal Feeding Operations and Concentrated Animal Feeding Operations in 2003. Legal action is refining the applicable scope of the rules in 2005, however the Mississippi Department of Environmental Quality promulgated state rules under the EPA guidelines in January, 2004. One requirement in the Mississippi version not mandated at the national level is required annual continuing education for animal waste permit holders. However, prior to this commitment, the Extension Service, in cooperation with integrators and agencies, is providing programming on the new rules, how they will be administered in the state, national nonpoint discharge elimination permitting requirements, CAFO definitions, and producer rights.

Other programming targeted to the poultry communities includes principles of nutrient management, environmental issues, soil sampling and testing, soil management, soil amendment application timing, P environmental flux risk assessment, and calibration of application equipment.

In response to concerns listed in Table 1, Excel-based record keeping programs have been developed that can used on computers or printed for hand calculations. Several instructional methods are being used or planned to transfer the record keeping programs because of the diverse computer skills, interests, and learning styles of the producers. These include individual sessions, a mobile teaching lab for small groups in remote locations, and cooperation with community college computer teaching laboratories.

In addition to the poultry-centric program described, the Extension Service, with Mississippi-based agency and advocacy group partners, is developing a watershed-based agricultural-environmental stewardship educational program named Medallion Producer (Holder and Oldham, 2005). This program will include a poultry producer track that will include water quality issues, laws, and regulations, agricultural air and soil quality issues, Integrated Pest Management, nutrient management, structural soil management measures, the roles and duties of Conservation Districts, the Natural Resource Conservation Service, and other agencies, Best Management Practices, and relevant cost-share programs.

Summary

Poultry is a major component of the Mississippi economy. Mississippi State University has supported the industry, the producers, and the general public over the past few years through research, Extension, resident education, and agency interaction.. Some MSU programming was reactive due to the circumstances, but over time potentially controversial issues were addressed through focusing the assets and talents available. Now MSU, through Extension and research teamwork, is implementing planned, proactive programming.

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Table 1. Perceived strengths and needed improvements in Mississippi-based poultry litter research and Extension as determined by facilitated discussion with industry and academic stakeholders.

Strengths: • Involves many stakeholders • Demonstrated ability to bring research to producers and agencies (opened the gate on cooperation) • Good interagency relationships • Having personnel for support structure • Extension Service is offering more to poultry producers • Mississippi "Medallion" will be a good opportunity for farmers to participate in a positive program • Good to have personnel to facilitate transfer of research • Involvement through a multi-disciplinary approach
Opportunities for improvement: • Determine a 'best' mechanism to implement a package of the research • Continue outreach through Field Days, local, and regional meetings • More outreach and research on various aspects • More outreach concerning record keeping programs

Solving the Chicken Litter Problem: Development of Novel Practices for Chicken Litter Management and Disposal

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Studies have shown that the over usage of chicken litter on agricultural land can lead to air and water pollution. The EPA is beginning to limit litter spreading for fertilization based on the geography, soil, and proximity of the land to bodies of water. The decreasing volume of chicken litter spread as a fertilizer will urge the scientific community to develop novel uses or disposal methods to remedy the current problem.

Chicken litter has much potential at providing energy and materials. Much research has shown that chicken litter having calorific values equivalent to low rank coals (on the order of 5000 BTU/lb) can be combusted either has the sole fuel or as a co-firing agent to coal to generate energy. Upon pyrolysis, chicken litter primarily yields active carbon useful for generating numerous other materials; however, gas and liquid fractions collected can be used for energy and chemicals.

In this current study, the evolved gases of chicken litter and chicken litter/coal blends are investigated using thermogravimetric-mass spectrometry (TG-MS), thermogravimentric-Fourier-transform infrared spectroscopy (TG-FTIR), and pyrolysis gas chromatography mass spectrometry (GC/MS). Both the combustion and pyrolysis mechanisms are studied. Devising a decomposition mechanism for the chicken litter into its evolved gases, especially ammonia and sulfur compounds, is of great importance. Understanding the emissions and decomposition characteristics will serve to optimize the combustion and pyrolysis of chicken litter.

Using Hatchery Waste By-Products as a Source of Lime and Nitrogen

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Currently, hatchery waste generated by Mississippi poultry integrators is processed and landfilled. Land application of the hatchery–origin material as a soil amendment on agricultural land may be an alternative to landfill disposal due to its calcium carbonate equivalent and nitrogen content. A greenhouse experiment to evaluate the effects of the by-product on soil pH and plant nutrient bioavailability was conducted at the Rodney Foil Plant Science Center at Mississippi State University using two soil series: Ruston (fine-loamy, siliceous, semiactive, thermic Typic Paleudult) and Urbo (fine, mixed, active, acid, thermic Vertic Epiaquept). Hydrated lime was used as a comparison liming material. The hatchery waste by-product was chemically analyzed to determine the calcium carbonate equivalency of 79.6% and nitrogen of 18 g kg^{-1}. Soil samples were analyzed by the Mississippi State University Extension Service Soil Testing Laboratory for lime requirement: Ruston soil (pH 5.3), 1.5 tons 100% Calcium Carbonate Equivalent (CCE) per acre, and Urbo soil (pH 5.1) 4 tons 100% CCE per acre. Five rates of the hatchery by-product (1, 2, 3, 4, and 5 ton(s) $acre^{-1}$ equivalent) were mixed with soil and distributed to 15 cm diameter pots using a Completely Randomized Block treatment design with four replications. Pots were watered and equilibrated 24 hours, then seeded with annual rye grass (Lolium multiflorum). Data detailing the effect of hatchery by-product applications on soil acidity amelioration and plant nutrient bioavailability will be presented.

LEACHING OF NITROGEN, PHOSPHOROUS, AND POTASSIUM FROM SAWDUST AMENDED WITH CHICKEN LITTER

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ABSTRACT: A six month study evaluated composting effects on nitrogen (N), phosphorus (P), and potassium (K) leaching from hardwood and furniture sawdust amended with 20% and 30% chicken litter. Toxicity Characteristic Leaching Procedure (TCLP) was used to obtain leachates from substrates. Moisture was provided through precipitation, and the substrate was aerated once or twice per week, depending on the amount of rainfall. Samples were collected at 45 day intervals for analysis. A significant reduction in N and K concentrations occurred for all amended compost by day 180. Hardwood substrate matured quicker than furniture compost based on a radish seed germination test. Toxicity reduction occurred in every treatment by day 180. Chicken litter control showed the best overall weight loss; however, its toxicity levels were still much higher on day 180.

INTRODUCTION

The disposal of furniture wood waste, hardwood waste, and poultry manure has become a major problem throughout the southeastern United States. In Mississippi, it is estimated that 600,000 tons of poultry litter are produced each year (Borazjani, 2004). The forest products industry also produces approximately 12 million tons of wood waste and bark residues throughout their production process (Borazjani et al., 2000). However, since landfills are becoming increasingly expensive and on site incineration, which is governed by strict Environmental Protection Agency (EPA), emissions regulations is not economical; thus, alternate disposal methods are needed (Borazjani et al., 1997).

Several options have been investigated within the poultry industry to deal with their waste disposal. A computer simulation determined that broiler litter had a value of $684 per metric ton as cattle feed. This method of litter disposal would be very economical, but cattle industry numbers are limited (Zimet et al., 1988). The litter was also tested as a fuel source for a gasification furnace. However, this technology resulted in high levels of slag, which reduces the heat output efficiency of the furnaces (Muir, 1987). The most common practice of litter disposal is to use the raw manure as a fertilizer for land applications. However, since the poultry industry in the south generates large quantities of waste, over fertilization of pasture lands often occurs. This results in ground and surface water contamination due to the excess nutrients and pathogens that runoff the land and into streams and rivers (Borazjani et al., 2000).

States are required to establish and regulate water quality standards through total maximum daily loads (TMDLs). The TMDL program requires states to determine the “impairment” level of a given river, stream, lake or watershed through sampling and identifying the types of pollutants (fecal coliform, nutrients, sediments) in that body of water. The states also determine what pollutant levels are “acceptable”, the background level of pollution, and the pollution from point source. The remaining pollution is attributed to non-point sources. The TMDL program could require a reduction of source pollutants if the watershed exceeds acceptable state levels.

Composting is a simple solution for reducing the above waste problems because of its environmental friendliness and cost. Composting wood and poultry litter residue biologically decomposes the waste material into a stable state. Once stable it can then be handled or applied to land without adversely affecting the environment.

The objective of this study was to compost poultry litter, furniture wood waste, and hardwood waste, and measure: 1) the leachability of nitrogen (N), potassium (K), and phosphorous (P) using the toxic characteristic leaching procedure (TCLP) test during different stages of composting; and (2) the correlation between leaching and compost maturity.

MATERIALS AND METHODS

Hardwood sawdust used in this experiment was obtained from a sawmill located in Waynesboro, Mississippi. Furniture sawdust was obtained from a local manufacturing facility in Starkville, Mississippi. Poultry manure was acquired from a farm located in Forest, Mississippi. Both manure and sawdust were dried under a hood and used on a dry weight basis. The poultry manure and sawdust were cleared of larger debris using a series of screens. Eighteen twenty-gallon plastic containers with pre-drilled holes in the bottom were used to hold the sawdust and poultry manure amendments. Due to the small volume of available manure, three five-gallon plastic containers held the poultry manure control samples. Small screens were placed in the bottom of the containers to ensure that no compost would be lost over the 180 day time period. The drilled holes regulated the composts moisture content (MC) and prevented water retention that would have resulted in anaerobic conditions. The following treatments were evaluated:

1. Hardwood sawdust control with no chicken manure
2. Hardwood sawdust amended with 20% chicken manure (dry-weight basis)
3. Hardwood sawdust amended with 30% chicken manure
4. Furniture sawdust control with no chicken manure
5. Furniture sawdust amended with 20% chicken manure
6. Furniture sawdust amended with 30% chicken manure
7. Chicken manure control with no sawdust

The treatments were replicated three times, and thoroughly hand mixed before placing them into the containers. The compost cans were placed outdoors in a random arrangement for a maximum of 180 days.

Aeration of the furniture, hardwood, and poultry manure substrate was done by two methods; 1) an auger bit attached to a cordless power drill; then 2) the compost was then physically turned by hand. Aeration of the compost ensured that the MC remained around 50%-70% within each container to prevent anaerobic conditions. MC was also adjusted through rain fall or by adding distilled water. Compost cans were aerated once or twice per week depending on precipitation conditions or how much distilled water was added.

Samples were collected in 45 day intervals for 180 days to analyze for pH, leachate, MC, and toxicity. Each compost can was turned thoroughly before an initial collection sample was made. During the collection process approximately two handfuls (0.6lbs dry weight basis) from each compost can were placed in a plastic gallon bag, then placed into a freezer. A sample of around 11g was taken from each bag and placed in an aluminum dish. The aluminum dish was then placed into an oven at 200^{o}C and allowed to dry over night. The dry weight sample was used to accurately calculate MC. The MC for this experiment was maintained around 55 to 70%.

To determine whether or not the compost had matured, a compost maturity test was administered. The test was conducted on all compost samples from day 0 through day 180. Potting soil was used for six control samples, and two samples of compost were placed in an eight ounce paper cup. Each cup contained six fast germinating radish seeds that were placed approximately one-quarter inch under the top layer of each sample. The samples were irrigated regularly to ensure that the compost cups remained moist. After seven days the number of seeds germinated was recorded and a germination rate was calculated. According to Florida's on-line composting center, a germination rate of eighty percent or higher indicates that the compost is matured (www.compostinfo.com).

Leachate from each sample was produced by TCLP test (EPA, 1983) and was analyzed for N, P, K, and Mn. Ten grams from each compost sample were measured on a dry weight basis then placed into 1000 ml bottles. The bottles were then filled with 750 ml of rain water and placed in a rotary mixer at 30 revolutions per minute (rpm) for 16 hours. After mixing the compost with the rain water, the substance was allowed to settle for 12 hours before being filtered through 125 mm pore size filter paper with the aid of an aspirator. A 1000 ml volumetric flask was used to collect the leachate water after it passed through the filter paper. 250 ml of effluent water was placed in amber bottles and a pH reading was taken for each sample. The pH was taken using an Accument® model AB 15 pH meter probe. pH levels for all treatments were between 6and 7 after day 90. The bottles were then sent to Mississippi State University soil testing laboratory for P, K, and Mn by Inductivity Coupled Plasma Atomic Emission Spectrometry. A 50-ml sample was taken from each 250-ml sample and was sent to Environmental Laboratories Incorporated located in Starkville Mississippi, for Total Kjedahl Nitrogen (TKN) using EPA Method 351.4

The toxicity test determined whether or not the leachate water would pass a chronic Ceriodaphina test. The test was only conducted on samples from day 0, 90, and 180. An average of 15g from each compost sample were combined together in a gallon size plastic bag and mixed thoroughly to ensure even distribution throughout the samples. Approximately 2g of each compost treatment was placed in a 40-ml glass vial and 18-ml of distilled water added. The vials were then placed into a sonicator for 10 minutes, and allowed to settle for 12 hours inside a refrigerator. After settling the top 10-ml of water was removed, transferred into test tubes, and placed into a centrifuge for 5 minutes at 50,000 rpm. 2.5-ml of water from each tube was removed and placed in a cuvette that contained 0.05g of NaCl. From the 2.5-ml cuvette, 500 microliters (µl) were removed and placed in four other cuvettes. This gave a total of 500-µl distributed evenly throughout five cuvettes. For each individual test, five control cuvettes containing ultra-pure water were used for comparison with each sample set. Exactly 10-µl of microtox reagent was added to each cuvette 5 minutes prior to being analyzed for toxicity using Microbics® M 500 toxicity analyzer. The toxicity analyzer measures the luminescence reduction of marine bacteria challenged with the sample solution to determine relative toxicity levels.

The compost cans were weighed on day 0 and day 180. MC was determined to adjust each compost can to a dry weight basis. The two samples of compost that were taken out on day 45 through day 180 were added to each can to ensure that the weight loss was based solely on composting.

The nutrient concentrations and weight loss within the compost study were determined using a completely randomized design. Three replications were used for each treatment. Mean comparisons were made using a least significant difference at the P=0.05 probability level by the Statistical Analysis System (SAS).

RESULTS AND DISCUSSION

Compost Maturity Test Results

Table 1 indicates that by day 90 all control and amended samples were matured. A higher level of germination for both hardwood and furniture controls could be attributed to excess N in amended treatments. Leachate results confirm that when N is lower, germination from the radish seeds occurred at higher rate. By day 180 all the seeds had a germination rate of 100%. Giusquiani et al. (1995) found that composting can adjust the nutrient levels to ratios which are desirable for the plant. According to Florida's online composting center a germination rate of 80% or higher determines whether or not the compost has matured (www.compostinfo.com).

Table 1- Seed Percent Germination rate.

Radish seed Test

Seed Percent Germination

Sample	Day 0	Day 45	Day 90	Day 135	Day 180
Top Soil Control	100%	100%	100%	100%	100%
Hardwood Control	83%	100%	100%	100%	100%
Hardwood Control	83%	100%	100%	92%	100%
Hardwood Control	75%	100%	92%	100%	100%
Hardwood 20%	0%	92%	100%	92%	100%
Hardwood 20%	58%	100%	100%	100%	100%
Hardwood 20%	0%	92%	92%	100%	100%
Hardwood 30%	25%	92%	92%	83%	100%
Hardwood 30%	16%	75%	100%	100%	100%
Hardwood 30%	25%	100%	100%	100%	100%
Furniture Control	42%	100%	92%	92%	100%
Furniture Control	42%	92%	100%	92%	100%
Furniture Control	25%	92%	83%	100%	100%
Furniture 20%	33%	83%	100%	83%	100%
Furniture 20%	25%	100%	100%	100%	100%
Furniture 20%	42%	92%	100%	100%	100%
Furniture 30%	33%	100%	92%	100%	100%
Furniture 30%	8%	100%	100%	100%	100%
Furniture 30%	58%	92%	92%	100%	100%
Chicken litter	0%	0%	0%	42%	100%
Chicken litter	0%	0%	0%	0%	100%
Chicken litter	0%	0%	0%	33%	100%

Nitrogen, Phosphorus, and Potassium Results

Hardwood Control

Most treatments showed a significant lower N, P, and K level on day 180 as compared with day 0. The average total concentration of nutrients for the hardwood control samples are illustrated in Figure 1. Since this is a control sample, the values for TKN, P, and K are very low. K showed a significant reduction from day 90 to 135. P levels were significantly lower on days

135 and 180. TKN levels were significantly higher on day 135 than any other day with regard to the hardwood control samples. This could be due to biodegradation of lignin, resulting in the fungi releasing bound N and P from the wood source.

Furniture Control

The furniture control samples, however, showed no significant difference for TKN (Figure 2). This could be attributed to the storage place of the sawdust. The furniture sawdust was stored inside, (before collecting it for the experiment) while the hardwood sawdust was stored outdoors. As a result, the furniture control samples may lack the microorganisms that the hardwood samples already contained. The furniture control samples also showed that K was significantly higher on day 0 with a mean value of approximately 17mg/L. P significantly decreased by day 45, compared to day 0, and also significantly decreased by day 135 compared to day 90. There was no change between days 135 and 180. Overall, with the exception of TKN the other two showed significantly lower P and K by day 180. One reason attributed to the unchanged TKN level could be related to less degradation of the furniture control (weight loss) vs. hardwood control.

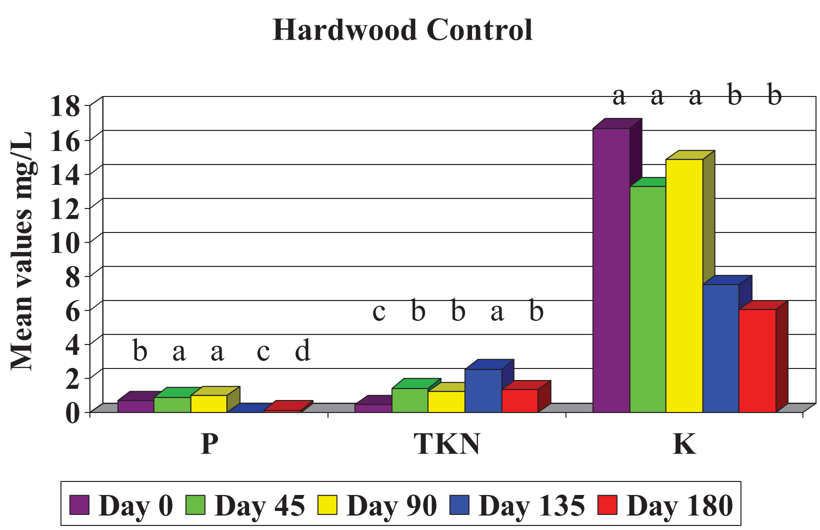

Figure 1. Hardwood control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

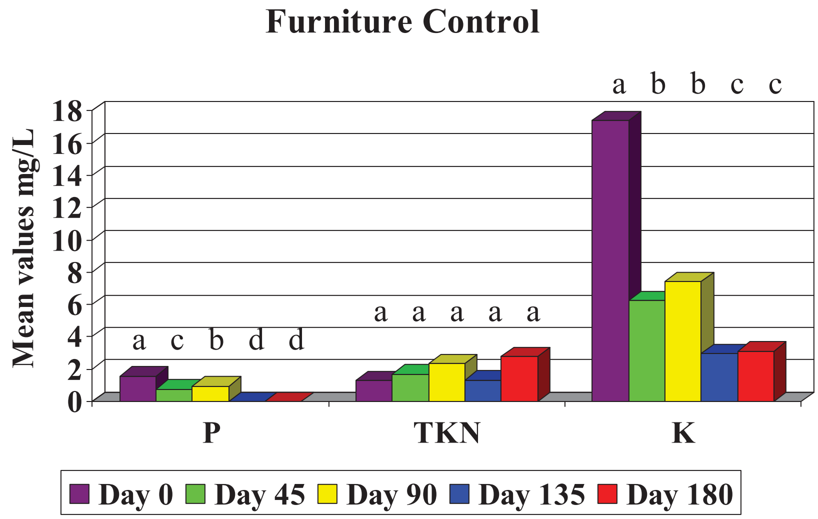

Figure 2. Furniture control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

Hardwood/Litter amended

The hardwood sawdust amended with 20% chicken litter showed a significant difference for K on day 0 composed to the level on the other days, but no significant differences were observed in K levels among the other dates (Figure 3). The TKN level for day 0 was also higher than any of the other days and significantly decreased between day 0 and day 45. There were fluctuations but no significant change during the remaining days. P levels, however, showed no significant change throughout any of the test days. Hardwood sawdust amended with 30% chicken litter did show a significant difference in P for day 0 when compared to the days 135 and 180 (figure 4). P appears to be the only element not declining, but increasing from day 0 to 135. This could be attributed to amount of chicken litter used in these treatments. Fontenot et al. (1983) points out that larger quantities of chicken manure contain high levels of P. Wood (1996) reported that poultry manure applications will increase concentrations of extractable P. Reuther (1973) suggests that P is chemically bound to aluminum and iron compounds within animal manure. When the samples were allowed to weather outdoors the P was released because it is soluble in water. This is why P levels are rising in the amendments. The TKN level for the 30% amendment was also higher on day 0 than any of the other days. There was a significant decrease from day 0 to day 45, 90, and 180. But day 135 showed a significant decrease from all of the days. K also showed a significant decrease from day 0 to all other days. Its lowest concentration was at day 180, although this value was not significantly different from days 45, 90, and 135.

Furniture/Litter amended

The furniture sawdust amended with 20% chicken litter also showed a significant reduction in K on day 0, but not any of the other days (Figure 5). TKN was also significantly higher on day 0 as compared to the rest of the days. Again the results indicate that the lowest concentration for TKN was found on day 135 but this time it is not significantly different from day 45, 90, or 180, however, it is still significantly different from day 0. P levels showed a significant difference between day 0 and 180. P levels for the furniture sawdust amended with

30% chicken litter showed no significant difference from day 0 through day 180 (Figure 6). The TKN level indicates that a significant reduction only appears after day 0, but the lowest concentration is still day 135. K levels indicate a significant reduction throughout the study. The lowest concentration was found on day 180, with this level being significantly different from any of the other days.

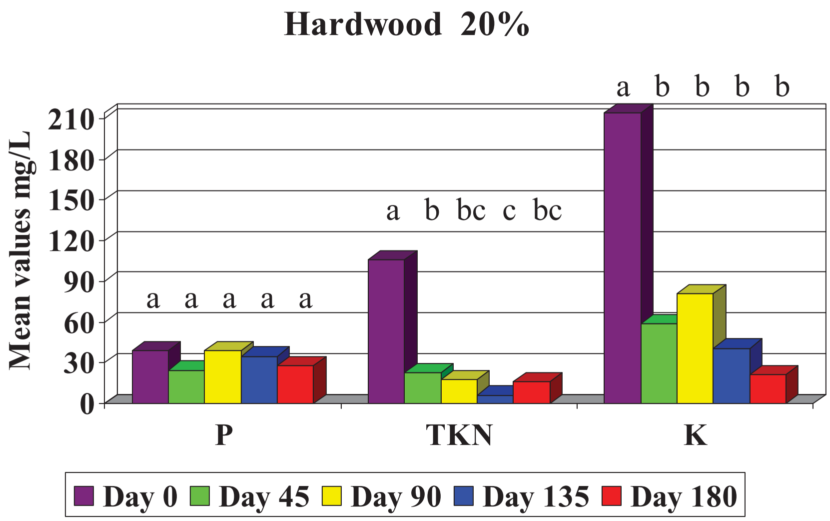

Figure 3. Hardwood amended with 20% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

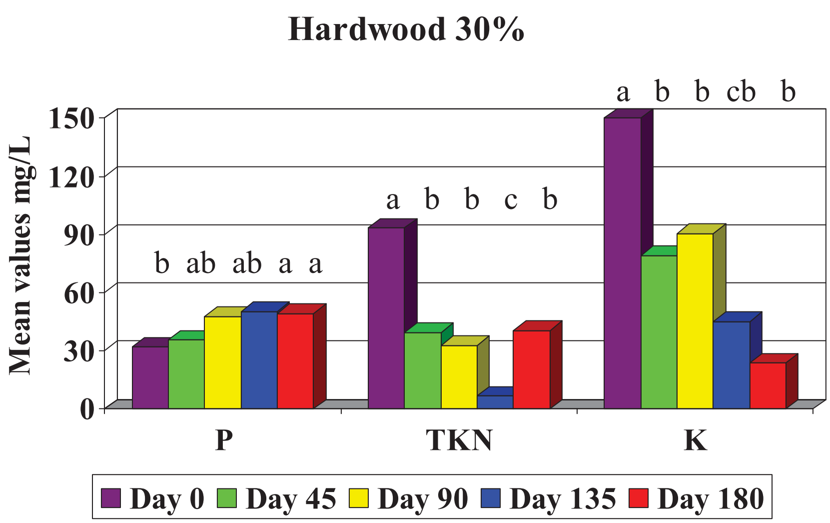

Figure 4. Hardwood amended with 30% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

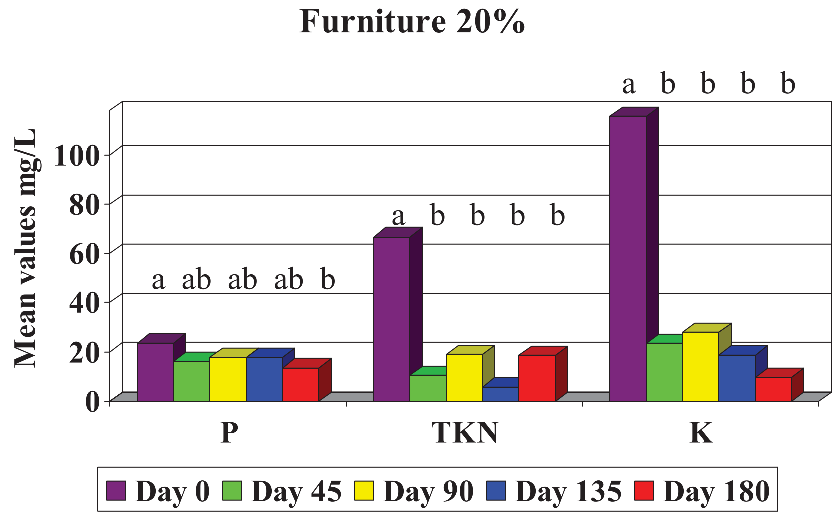

Figure 5. **Furniture amended with 20% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.**

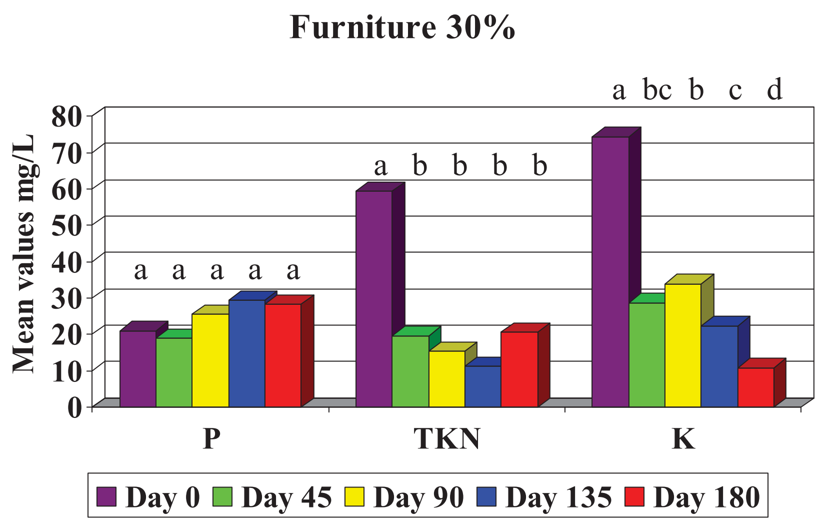

Figure 6. Furniture amended with 30% chicken litter. Nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

Overall both the hardwood and furniture composts amended with chicken manure showed a significant reduction in TKN and K from day 0. Many researchers agree that composting will significantly reduce the amount of nutrients (Tyson and Cabrera, 1993; Wilde, 1958; Borazjani et al., 1998; Rynk et al., 1992). Nutrients such as N, P, and K promote the growth of decay organisms, which use the nutrients as an energy source to break down and decompose material within a compost. This is why composting dramatically lowers the potential for leaching nutrients.

Chicken Litter Control

Figure 7 illustrates the chicken litter control samples. The statistical analysis indicates a significant decrease in K after day 0 as compared to day 45, 90, 135, and 180. TKN levels were significantly higher on day 0 verses day 90 and 135 but not 180. P shows a significant decrease only on day 135. The nutrient values for the chicken litter control samples are much higher as compared to all other samples. This is in agreement with Tyson and Cabrera (1993) who state that poultry litter is excellent for the composting process due to the available amounts of nutrients that the litter contains. N levels for the chicken litter control samples have a range over 150 mg/L. This was the main reason for lack of germination in the radish seed test (Table 1). Overall, composted litter followed similar patterns as those of 20% and 30% amended treatments.

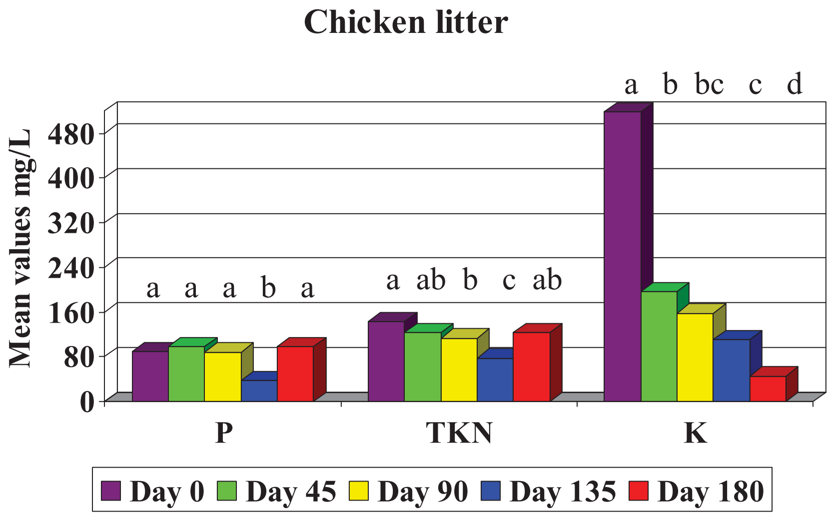

Figure 7. Chicken litter control nutrient values from the leachate water samples. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

Toxicity

During the composting process both the hardwood and furniture sawdust amendments showed a reduction in toxicity by day 90 (figure 8). The lowest overall toxicity for hardwood control, hardwood 30%, furniture 30% and chicken litter was observed on day 180. Chicken litter control showed the best overall weight loss; however, its toxicity levels were still extremely high on day 90 and 180 compared with the other treatments. Chicken litter contains more microorganisms than the sawdust, and this could explain why the amended treatments (day 0) and chicken litter control samples are higher. After day 90 however, the amended treatments composted lowering the toxicity. This is in agreement with Borazjani et al. (1998) who also found that that chicken litter amended with furniture wood waste has a lower toxic effect than unamended controls after 180 days of composting.

Weight loss

A reduction in weight loss was also evident as indicated by Figure 9. Hardwood amended with 20 % chicken litter was not significantly different from the 30% mixture. However, it was significantly different for both of the furniture amendments. Both hardwood and furniture sawdust amended with the poultry litter showed a high weight reduction. Although the chicken litter control showed the highest percent of weight loss, its toxicity levels are still high. This is why an amendment such as sawdust should be added. Poincelot (1974) found that amendments, such as sawdust from hardwood and furniture, increase the C content.

Cabrera et al. (1993) continues by stating that the growth of bacteria, fungi, and actinomycetes are stimulated by the C content; while the N content provides certain types of proteins and enzymes. Edward and Daniel (1992) point out that poultry manure contains a very high level of N. Thus, the content of C within the wood combined with the levels of N in the poultry manure significantly reduces the weight and bulk of a compost.

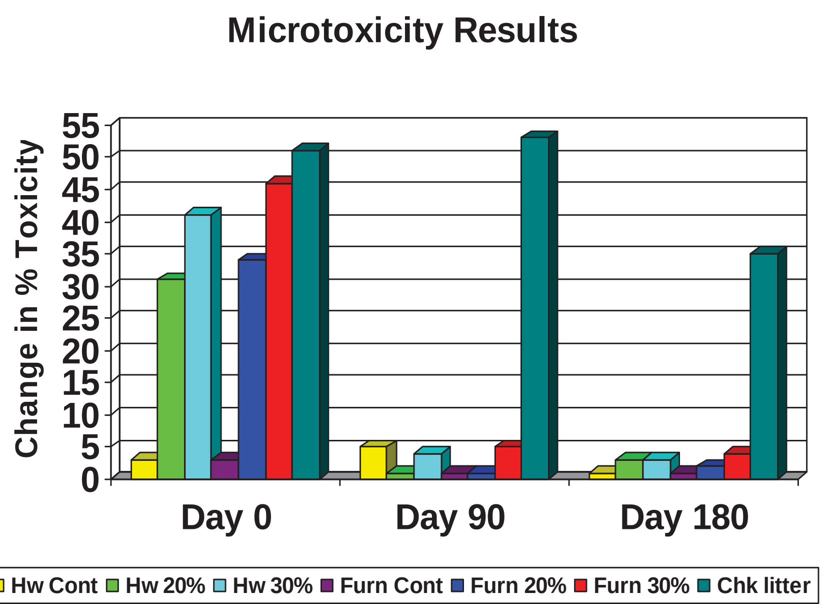

Figure 8. Percent effects of more or less than 5% indicates that effluent will likely not pass a chronic Ceriodaphnia test.

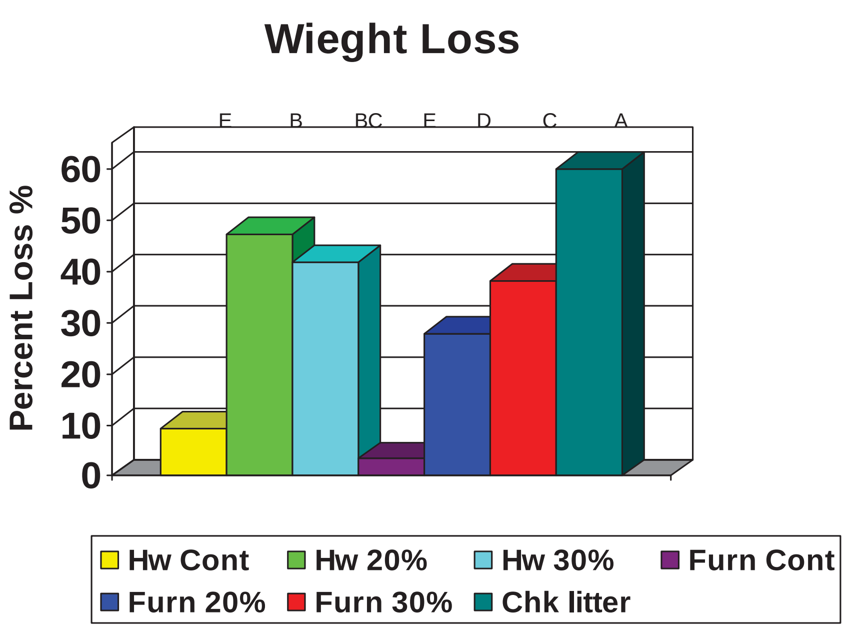

Figure 9. Percent weight loss on day 180. Columns with the same letter indicate no significant difference in nutrient values at the α = 0.05 probability level.

CONCLUSION

This study found that sawdust amended with chicken litter and then composted reduces the leaching potential of N and K, thus helping to prevent contamination which may adversely affect the environment. The leachability of P, however, generally stayed the same throughout the study or slightly increased. The composted product could be used in areas which contain P deficient soils or nurseries which require P for plant material.

Nitrogen amendments such as chicken litter can increase the rate at which a compost is degraded, and since the poultry industry is primarily located in the southeastern United States the nitrogen source is available. Many sawmills and furniture facilities are also located within the southeastern United States. The carbon from the sawdust amended with the chicken litter and composted would produce a value added product. The radish seed maturity test showed that even partial composting of sawdust and chicken litter had an advantage over uncomposted raw material.

Composting is an effective way of dealing with both sawdust and chicken litter. The composted amendments reduce the weight, leaching potential, bulk, and toxicity. This could solve problems not only in the southeast, but other regions as well. The finished compost could be used as a soil additive in areas with low organic matter. This would make it popular among nurseries and farmers throughout the southeastern United States. This could be of great importance to poultry producers, forest product companies and land farmers.

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Accumulations of Nutrients in Corn Soil as Influenced by Poultry Litter Application Rate

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ABSTRACT

Poultry litter can be a valuable resource when applied at rates required by a given crop. However, nutrients being present in higher concentrations than needed, or not available when needed, are obvious concerns for producers when using poultry litter as a fertilizer. During 2001-03, silage corn plots were established under no-till and conventional till conditions with three fertility treatments superimposed over the tillage treatments. The fertility treatments were (1) ½ rate of poultry litter at N rate and ½ inorganic N, (2) poultry litter applied at the N rate, and (3) inorganic fertilizers. Soil samples were taken from 0-15 cm prior to planting, at mid-season, and at corn harvest. The harvest soil samples were analyzed for nutrient content and comparisons are as follows. Over the three year observation, very few differences were seen between tillage treatments. Interactions existed between tillage and fertility for available Mg and Cu, along with organic matter and CEC. Differences were observed between fertility treatments in the following measurements: water pH, available P, K, Zn and ortho-phosphate content. Water pH was greater in treatments receiving poultry litter than inorganic fertilizers alone. Available P and Zn were higher in treatment 2 than 3. Available K was higher in treatment 2 than either 1 or 3. Ortho-phosphate content was greater in treatment 2 than in 3. Indications are that poultry litter applied at the N rate resulted in excess levels of available P, K, Zn, and ortho-phosphate in comparison to the inorganic fertilizers.

INTRODUCTION

Poultry production in Kentucky has increased by 2.5 times from 1997 to 2002 (KASS, 2004). Most of the production is located in 4 western counties of the state, which gives limited land area for poultry waste application. Similar to other poultry producing areas, excess poultry litter application can lead to nutrient accumulations in soil and water pollution (Lander et al., 1998).

Excess application of poultry litter can negatively impact water quality via runoff and groundwater contamination after application (Kingery et al., 1994, Edwards & Daniel, 1993, and Sharpley et al., 1993). A 4.5 Mg ha^{-1} rate resulted in significantly higher N & P concentrations in runoff (Sauer et al., 2000). Sharpley and Moyer (2000) also found that 20% of total P was lost after just 5 rainfall events.

Poultry litter is deemed an excellent nutrient source due in part to being inexpensive. When broiler litter is applied to meet crop N requirements, this can lead to 6x (Kingery et al., 1994) to 8x (Franzluebbers et al., 2002) as much P as needed. In turn long term application of litter can lead to soil nutrient imbalances (Sistani et al., 2004). Kingery et al. (1994) found accumulations of NO_3-N, along with extractable P, K, Ca, Mg, Cu, and Zn up to 60 cm of depth. Wood et al.

(1996) found accumulations of C, P, K, Ca, Mg, Cu, and Zn after litter application to corn fields. Increased surface N, C, K, and P content were seen in no-till cotton fields after litter application (Sistani et al., 2004). Soils that were amended with poultry litter for 25 years have shown excess accumulations of Cu and Zn (Han et al., 2000).

The first purpose of this study was to determine if soil nutrients are accumulating at a higher amount due to the three fertility treatments. The second purpose was to observe if differences existed in soil nutrient accumulation based on two different tillage systems in corn soils.

MATERIALS & METHODS

This study was conducted at the Agricultural Research and Education Center in Bowling Green, KY. Soil type is a Pembroke silt loam (Mollic Paleudalf) on a 0-1% slope. Soil samples were taken to a depth of 15 cm at planting, midseason, and harvest.

Soil fertility treatments consisted of an N rate of poultry litter (NPL), a ½ rate of poultry litter + ½ rate of inorganic fertilizer (HPL), and a recommended inorganic rate (I). Poultry litter and inorganic fertilizer application rates are found in Table 1.

Harvest soil samples were analyzed for water pH (1:1 water extraction), orthophosphate by the Lachat QuickChem 8000, and all other nutrients by Mehlich-I extraction and measured on the ICP.

RESULTS

No statistical differences were observed to exist between tillage and nutrient content over this three year period ($p<=0.10$). Based on this, soil nutrient content was analyzed based on fertility treatment for the rest of this paper.

Soil water pH was found to be higher in the poultry litter treatments (NPL and HPL) than the I treatment (Table 2). Soil P availability (Table 3) was highest in the NPL soils, which was greater than the I soils ($p<=0.10$). Soil P availability was not different between the HPL and the NPL or I treatments ($p<=0.10$). Soil K availability (Table 3) was higher in the NPL soils than the other two treatments ($p<=0.05$). The HPL and I treatments were statistically similar to one another ($p<=0.05$). Available Zn (Table 4) was highest in the NPL soils which was significantly higher than the I treatment ($p<=0.10$). There were no differences between the HPL and the NPL or I soils ($p<=0.10$). Orthophosphate content (Table 5) was higher in the NPL soils than the I soils ($p<0.10$). The HPL soils were not different from either the NPL or I soils ($p<0.10$).

DISCUSSION

Many researchers have observed that poultry litter application can significantly raise soil water pH. Kingery et al. (1994) found that poultry litter application can result in an increase of up to 0.5 units. Nutrient accumulations are often found in soils that have received poultry litter application. In this study, P, K and Zn were found to increase with poultry litter application. In a study by Sistani et al. (2004), available soil P was found to increase by 8 fold under high poultry litter application rates. Wood et al. (1996) saw an increase in available K and heavy metals with broiler litter application. Orthophosphate content is used to symbolize water soluble P, which was found to be higher in the litter soils than the non-litter treatment. If soluble P is present and not uptaken by the plant, then the concern focuses on water quality degradation from those treatments.

CONCLUSIONS

If poultry litter is applied at a rate that meets N requirements for the crop, accumulations of available P, K, Zn and orthophosphate will likely occur with time. Accumulations of nutrients in the soil is similar when using solely inorganic fertilizer (I) or ½ poultry litter + ½ inorganic fertilizer (HPL). According to our results, if a producer is going to use poultry litter as a fertilizer source, it is best to use ½ as much poultry litter as required and supplement the other nutrients from inorganic fertilizers.

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Table 1. Nutrient addition to soil by treatment.

Treatment	May 16, 2001	May 23, 2002	May 22, 2003	Material	Application Unit
NPL	11	18	20	Litter	Mg ha^{-1}
HPL	5.5	9.2	10	Litter	Mg ha^{-1}
	100	101	109	Inorganic N	Kg ha^{-1}
	45	24	34	Inorganic P_2O_5	Kg ha^{-1}
	45	38	31	Inorganic K_2O	Kg ha^{-1}
I	201	202	218	Inorganic N	Kg ha^{-1}
	90	47	68	Inorganic P_2O_5	Kg ha^{-1}
	90	76	62	Inorganic K_2O	Kg ha^{-1}

Table 2. Soil water pH values by treatment.

Treatment	Average pH value
NPL	6.4 a
HPL	6.42 a
I	6.12 b

Indicates statistical significance at the $p<=0.05$ level.

Table 3. Soil P and K availability by treatment.

Treatment	Average P content	Average K content
	-----------------Kg ha^{-1}-----------------	
NPL	254 a*	590 a**
HPL	152 ab	444 b
I	120 b	389 b

* Indicates statistical significance at the p<=0.10 level.
** Indicates statistical significance at the p<=0.05 level.

Table 4. Soil Zn availability by treatment.

Treatment	Average Zn content (Kg ha^{-1})
NPL	6.8 a
HPL	4.5 ab
I	3.5 b

Indicates statistical significance at the p<=0.10 level.

Table 5. Soil orthophosphate availability by treatment.

Treatment	Average ortho-PO_4 content (mg kg^{-1})
NPL	509 a
HPL	247 ab
I	151 b

Indicates statistical significance at the p<=0.10 level.

Bermudagrass Production and Nutrient Uptake when Substituting Broiler Litter Nitrogen with Mineral Nitrogen

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Abstract

Achieving adequate hay production from hybrid bermudagrass [*Cynodon dactylon* (L.) Pers.] when plant P nutrition is the basis for broiler litter application rates will require supplementation with mineral nitrogen (N) fertilizer. The objective of this research was to determine yield and uptake of N and P in hybrid 'Coastal' bermudagrass fertilized with different rates of broiler litter in combination with applications of ammonium nitrate (34-0-0). Plots (4 x 6 m) were established at Mize, MS in a pasture with 30+ year history of litter and soil test P (STP, by Mehlich III analysis) of about 409 kg P ha^{-1}, and at Newton, MS in a pasture with no litter history and STP of about 52 kg P ha^{-1}. Broiler litter rates of 0, 4.5, 8.9, 13.4, and 17.9 Mg ha^{-1} were obtained by monthly applications of 4.5 Mg ha^{-1} beginning in April, and these rates were supplemented, respectively, with 67 kg ha^{-1} mineral N (the highest rate beginning in April) in order to achieve 269, 202, 134, 67, and 0 kg N ha^{-1}. Thus, the annual N requirement of bermudagrass of about 269 kg N ha^{-1} was first met with broiler litter and then with mineral N. Treatments, including an unfertilized 'check', were repeated on the same plot areas in 1999, 2000, and 2001. Because forage dry matter (DM) was consistently low in unfertilized bermudagrass, averaging 12% (Newton) and 55% (Mize) of the highest average yield, these data were often used for comparison only. When analysis of variance was conducted without the 'check' plots, treatment difference in forage dry matter (DM) and P uptake were significant at Newton ($P<0.01$), but not at Mize ($P>0.50$). A significant treatment by year interaction was detected for yield and P uptake at both sites, primarily because these traits were greater in 2001 than 1999 and 2000 due to increased rainfall. At Newton, fertilization with only mineral N led to 2.0-3.0 Mg ha^{-1} lower DM as compared to other treatments, and the 8.9 Mg litter + 134 kg N treatment appeared to maximize DM and nutrient uptake. At Mize, forage yield and P concentration ≥90% of maximum relative yield were obtained from 4.5 Mg + 202 kg N treatment. Results indicate broiler litter rates should not exceed 8.9 Mg ha^{-1} yr^{-1} and be supplemented with mineral N to meet the crop N requirement. Although pasture N fertilization is costly, the practice may minimize environmental impacts when litter nutrients, particularly P, are applied in excess of crop needs.

Keywords: Bermudagrass, Nitrogen Management, Phosphorus Management, Poultry Waste

Introduction

The poultry industry in Mississippi produces about 450,000 Mg (500,000 tons) of broiler litter annually (Morgan and Murray, 2002). This product, a mixture of manure, wasted feed, and bedding materials, is commonly used as fertilizer on pasture and hay fields, particularly in south central Mississippi where broiler production is concentrated. A large proportion of this acreage is devoted to growing bermudagrass [*Cynodon dactylon* (L.) Pers.] for hay and grazing (Lang and Broome, 2003). Land application of litter has traditionally been limited to forage N requirements to minimize potential N leaching to ground water. But the difference in average N-P-K ratio in the litter (2.1:1:1.3) (Sims and Wolf, 1994) and the observed nutrient uptake ratio by hybrid bermudagrass at 90% of maximum yield (9:1:6) (Robinson, 1996), means that using litter as the sole nutrient source will increase soil test phosphorus (STP) (Sharpley, 1999). Accumulation of P in pasture soils has received increased attention from potential eutrophication it causes when receiving waters are P-limited (Daniel et al., 1994). As a result, regulatory agencies are moving to consider allowable litter application rates on crop P needs and site-specific STP concentrations (USEPA, 1996). The agronomic and environmental soil P threshold strategies suggested by the USDA and USEPA provide narrow, often incomplete, assessments of the risk of P losses, since variables other than soil P concentration control losses from field and landscapes (Sims, 2000). Thus, site-specific management strategies must be developed to minimize the nutrient discharge to the surface water by reducing system inputs of P in manure-producing areas.

When plant P nutrition is the basis for broiler litter rates, producing adequate quantities of high quality bermudagrass hay will require supplementation with mineral N fertilizer, a practice that may also enhance plant uptake of P (Adams, 1980). Evers (2002) found that supplementing broiler litter with mineral N fertilizer increased dry matter yield and uptake of P and K in Coastal bermudagrass. Complex relationships exist between forage productivity, nutrient recovery, soils, and farmer options, such as changes in manure nutrient application rate/time and crop system management. With good management practices, hybrid bermudagrass can remove about 45 kg P ha^{-1} $year^{-1}$ or more if water is not limiting growth (Evers, 1998). At yield levels of 14-16 Mg ha^{-1} on a previously manure-impacted site, hybrid bermudagrass removed about 50 kg ha^{-1} yr^{-1}, which was less than half of the P applied in litter at rates of 9 and 18 Mg ha^{-1} (Brink et al., 2002). In that study, annual P uptake was not affected by timing of litter application, perhaps due to already high STP levels, but applications in April and June to coincide with favorable growth temperatures appeared to maximize P uptake. It is apparent that depending on soil P bioavailability, timing mineral N applications to substitute for broiler litter N could be important for increased utilization of fertilizer nutrients by bermudagrass (Evers, 2002). Mismanagement of manure nutrients is more likely with hybrid bermudagrass hay production, which responds favorably to increasing rates of organic or inorganic N sources (Overman et al., 1993; Osborne et al., 1999) and to intensive harvest management (Overman et al., 1990). Hay production certainly has a place in remediation of high STP situations, as STP is decreased through removal of harvested hay or silage from the site (Novak and Chan, 2000; Pant et al., 2004). In these situations, lower rates of broiler litter supplemented with mineral N fertilizer are more appropriate.

Sistani et al. (2004) noted pasture soils receiving long-term broiler litter applications will likely accumulate excess P and some micronutrients (Cu and Zn) unless the principal components of nutrient management are used: (i) continuous soil test monitoring, (ii) proper litter application rate, and (iii) crop management to maximize nutrient uptake and removal. Therefore, information is needed on how to account for broiler litter N in order to use this manure efficiently and safely. Among Midwest corn producers, the average rate of N applied before soil sampling was 137 kg N ha^{-1} for manured soils and 150 kg N ha^{-1} for soils that did not receive animal manures. A difference in rate is expected because growers have long been advised to give credit for N in manure when selecting N fertilization rates (USDA, NRCS, 1999). The approximate difference in average rates of 15 kg N ha^{-1} is much smaller than would occur if growers believed the manure application rates were large enough to supply adequate N for crop growth. The relatively small credit for N in animal manures is consistent with the results of surveys of farming practices (Nowak et al., 1998), which show that most farmers make little or no downward adjustment in fertilization rates to account for N applied as animal manure.

Forage producers need comparative information regarding mineral fertilizer or manure N efficiency to improve farm profitability and minimize agricultural impacts on water quality (Chambers et al., 2000; Sims et al., 2000). The present research was conducted to (i) determine if substituting mineral N (NH_4NO_3) for broiler litter N would increase P uptake (= forage biomass x nutrient concentration) in 'Coastal' bermudagrass hay fields with different STP levels, and (ii) determine the appropriate combination of mineral-N and litter-N treatments to maximize forage yield and nutrient uptake.

Materials and Methods

Studies were conducted in 1999, 2000, and 2001 in existing swards of 'Coastal' hybrid bermudagrass at two sites in south central Mississippi. One site near Mize, MS on a Savannah fine sandy loam (fine-loamy, siliceaous, semiactive, thermic Typic Fraqiudults) was on a commercial farm. The second site on a Ruston fine sandy loam (fine-loamy, siliceaous, semiactive, thermic Typic Paleudults) was at the MAFES Coastal Plain Experiment Station near Newton, MS. The Mize pasture site is typical of many in the region where broiler litter has been applied to bermudagrass on an N basis (about 9.0 Mg ha^{-1} yr^{-1}) for many years. In contrast, the Newton pasture has no known history of broiler litter application. Soils were sampled at 0- to 5-cm and 5- to 15-cm depths in March 1999 prior to first litter application, and in May 2001 prior to the end of experiment (Table 1).

The bermudagrass sward was cleared of any weeds or senesced plant material in early Spring 1999. The 4- by 6-m plots were arranged in a randomized complete block design with four replicates. The fertilizer treatments were five combinations of broiler litter and mineral fertilizer that would meet bermudagrass N requirement of 269 kg N ha^{-1} (for an expected yield level of 9 Mg ha^{-1}) and unfertilized check (Table 2). Treatments were repeated on the same plot areas each year. At Mize, broiler litter was obtained from a nearby broiler house at each application time. At Newton, litter from a broiler house was delivered in spring each year and stored outdoors on a concrete floor under a polyethylene cover. Subsamples of broiler litter were obtained for nutrient determination prior to each application. In general, the chemical composition changed little for either source, so results from April were used to represent an approximate average of what was applied to plots (Table 3).

Broiler litter was applied by hand on a “as is basis”. Annual broiler litter rates of 0, 4.5, 8.9, 13.4, and 17.9 Mg ha^{-1} were obtained by monthly applications of 4.5 Mg ha^{-1} beginning in April, and these litter rates were supplemented, respectively, with 67 kg ha^{-1} mineral N (the highest rate beginning in April) that applied 269, 202, 134, 67, and 0 kg N ha^{-1} as NH_4NO_3 (34% N) as a substitute for N not applied in broiler litter (Table 2). Thus, bermudagrass N requirement of 269 kg N ha^{-1} was first met with broiler litter and then with mineral N. Providing 50% of N is mineralized, a rate of 17.9 Mg ha^{-1} would meet the expected annual N requirement (Tables 2 and 3). The amount of mineralizable N supplied by broiler litter in the first season of application is based on total N analysis of litter and on certain assumptions (Cabrera and Gordilla, 1995).

Forage harvests began in late May to early June, at approximately a 30-d interval depending on rainfall and forage growth. Plots were harvested five times in 1999, three times in 2000, and four times in 2001. Forage dry matter (DM) yield was determined by cutting a 1- by 6-m swath at a 7-cm stubble height through the center of each plot using a sickle-bar mower. Subsamples (600-800 g) of forage were dried at 65 °C for 48 h and the dry weight recorded. The dry forage was ground to pass a 1-mm screen, sealed in plastic containers, and subsequently analyzed for mineral nutrients. Forage nutrient uptake was calculated as the product of DM yield and nutrient concentration at each harvest, and values were summed across all harvests. Efficiency of N and P uptake for the growing season was calculated as total uptake divided by the total quantity in the litter only. Analysis of variance was used to determine treatment differences in DM yield and nutrient uptake using PROC MIXED and PROC GLM procedures in SAS (Littell et al., 1996). Because unfertilized plants were consistently low yielding, data from these ‘check’ plots were sometimes excluded from analysis of variance in order to gain greater precision in separating differences among the five fertilizer treatments. A probability level of $P \leq 0.05$ was considered significant.

The following chemical analyses were performed on samples of soil, broiler litter, and bermudagrass hay. Soil and litter pH was measured using 10 g sample mixed in 10 ml water. Soil, litter and plant total N and total C were determined from duplicate subsamples using an automated dry combustion analyzer (Model NA 1500 NC, Carlo Erba, Milan, Italy). The concentration of P, K, Ca, Cu, Fe, Mg, Mn, and Zn in forage was determined from duplicate subsamples using emission spectroscopy on an inductively coupled argon plasma spectrometer (ICP, Thermo Jarrell Ash Model 1000 ICAP, Franklin, MA) following procedures described by Sistani et al (2004). Soils were extracted following Mehlich 3 procedures (Mehlich, 1984) and the extracts analyzed for P, K, Ca, Cu, Fe, Mg, Mn, and Zn using ICAP. The Mississippi State Soil Testing Lab routinely uses Lancaster method for nutrient analysis. Cox (2001) compared Mehlich 3 and Lancaster methods in various soils collected from eight fields in Mississippi and found weak correlation for soil P (r=0.38), though they gave similar results up to about 57 mg P kg^{-1}, beyond which Mehlich 3 extracted more P. The initial soil chemical properties for the present study are presented in Table 1.

Results and Discussion

The initial STP value based on Mehlich III analysis of 0-15 cm depth was about 8-fold greater at Mize than Newton (409 vs. 52 kg ha^{-1}) (Table 1). This result was expected due to long-term application of broiler litter at Mize before establishment of our experimental plots. The soil at Mize also had greater amounts of total N, and plant available K, Cu, Mn, and Zn. As expected, the amounts of N, P, and K applied to the soil surface increased four-fold as litter rate increased from 4.5 to 17.9 Mg ha^{-1} (Table 4). While the different sources of broiler litter provided similar amounts of total N at both sites, about 20-60 more units of P and K were provided at Mize than Newton. Assuming half of the total P is mineralized in the first year, the 4.5 Mg ha^{-1} rate provided sufficient P to maintain hybrid bermudagrass yields of 8.9-13.4 Mg ha^{-1} (Lang and Broome, 2003). There is little literature available on K in litter, but assuming 100% is plant available, the 13.4 Mg ha^{-1} litter application rate provided sufficient K for maximum hay production. Hybrid bermudagrass has high annual K requirements (Brink et al., 2003). At the Newton site in 2001, K uptake exceeded N uptake by bermudagrass receiving litter rates of 8.9, 13.4 and 17.9 kg ha^{-1}. Heavy usage of soil K in Coastal bermudagrass is also apparent from consistently greater K uptake in the broiler litter only treatment, as compared to mineral N only treatment that added no K over three years.

At Newton, rainfall followed closely the historical pattern except for lower monthly rainfall in July all three years, and large rainfall accumulation in March and September 2001 (Fig. 1). Similarly, rainfall at Mize followed closely the 30-yr mean, except in 2001 when heavier than normal rainfall was recorded in March, June, August and September. Forage DM yields were lower in 2000 than 1999 (Fig. 2) even though annual rainfall amounts were similar. This difference may be explained by above average rainfall in April 2000 that possibly washed some of the litter or fertilizer from the plots. Rainfall in 2001 was about 18% above the long-term average at both sites (Fig. 1). Consequently, DM yield and N uptake were significantly greater in 2001 than either 1999 or 2000 (Figs 2 and 3.), with 2000 experiencing some droughty, summer conditions. Across all treatments in 2001, total N uptake averaged about 259 kg ha^{-1} at Newton and 409 kg ha^{-1} at Mize. Lower N uptake at Newton was associated with 50% lower total N content in soil, as well as somewhat lower N concentration in the litter, as compared to soil and litter at Mize (Tables 1 and 3). Because annual rainfall was similar at both sites, factors other than soil moisture apparently limited bermudagrass yield and N uptake at Newton.

When unfertilized checks were excluded, annual forage DM averaged 13.7 Mg ha^{-1} at Mize (range: 7.8-21.1 Mg ha^{-1}) and 12.5 Mg ha^{-1} at Newton (range: 6.6-19.5 Mg ha^{-1}). With adequate fertilizer, Coastal bermudagrass may yield 11.2 to 13.4 Mg of hay per hectare (5-6 tons $acre^{-1}$) (Lang and Broome, 2003). Forage DM yield at Mize did not differ significantly across the five fertilizer treatments (Fig. 2), which might be expected due high soil nutrient levels observed initially due to long-term litter applications. Forage DM yield at Newton was lowest in bermudagrass fertilized with mineral N only, a treatment that produced significantly low yields in 2000 and 2001 (Fig. 2). Relatively high DM yields were obtained using 4.5 kg litter and 202 kg N ha^{-1} and did not differ from the other litter treatments in 1999 and 2001. Applying 8.9 Mg litter led to increased DM yield under droughty conditions in 2001. While these results at Newton may refute our hypothesis that 269 kg N ha^{-1} would meet N requirement of 'Coastal' bermudagrass, they do illustrate the value of poultry litter as a soil amendment and nutrient source for bermudagrass.

The treatment by year interaction was significant for forage DM at both sites (Fig. 2). This interaction resulted from greater DM production in 2001 than either 1999 or 2000 and from variable DM yields obtained at 17.9 Mg ha^{-1} litter. With increased rainfall in 2001, the highest litter rate of 17.9 Mg ha^{-1} led to high DM accumulation, and high N and P uptake in bermudagrass (Figs. 2, 3 and 4). Increased rainfall at Mize led to slightly greater DM accumulation and nutrient uptake in bermudagrass fertilized with a combination of 13.4 Mg litter and 67 kg N ha^{-1} (Figs. 2, 3 and 4). Similar to forage DM, the treatment by year interaction was significant for total uptake of N and P in bermudagrass.

Analysis of variance across years without unfertilized 'check' plots found significant difference in DM yield and P uptake between N fertilizer treatments at Newton ($P<0.01$), but not at Mize ($P>0.50$) (Figs 2 and 4). As mentioned above, the treatment by year interaction was significant for total N and P uptake at both Newton ($P<0.01$) and Mize ($P<0.05$). We found moderate rates of poultry litter of 4.5-8.9 kg ha^{-1} in combination with mineral N fertilization led to high nutrient uptake, particularly in drier years of 1999 and 2000. This result supports studies showing N supplementation of broiler litter N in bermudagrass has potential to improve yield and plant nutrient uptake (Evers, 2002). The timing of mineral N additions may also be important to P uptake in bermudagrass, as Sistani et al. (2004) found total soil N and P decreased during the maximum uptake in late spring and summer in heavily-manured Ruston soil. Soil moisture is another factor that influences growth and nutrient uptake in bermudagrass, with N or P concentration often inversely related to forage DM accumulation. In the present study, tissue P concentration was consistently greater in unfertilized 'checks' than plants fertilized with litter or/and mineral N (data not shown), but yields were least in unfertilized plants. Total uptake of P was maximal at about 60 kg ha^{-1} in 2001 in the litter only treatment of 17.9 Mg ha^{-1}, when rainfall was above average and plants accumulated the most forage DM (Fig. 2). Brink et al. (2002) reported annual P uptake ranged from 27-50 kg ha^{-1}when 18 Mg ha^{-1} broiler litter was applied to common and six hybrid bermudagrass cultivars on a heavily-manured Ruston soil at Mize, MS. Forage DM also was somewhat less in that study, ranging from about 9 Mg ha^{-1} in common bermudagrass to 19 Mg ha^{-1} in Alicia, Russell and Tifton 44 hybrids.

Broiler litter promotes biological and physical properties that make soil more productive and less erosive, but the risk of environmental impacts can be high when improper amounts of litter are applied (Han et al., 2000). In agreement with other manure rate studies (Brink et al., 2002; Brink et al., 2003), bermudagrass P recovery decreased as litter rate increased across the different treatments. Because manure was not used as the sole fertilizer source, results from this present study indicated N fertility per se can enhance P uptake in bermudagrass. Applications of 269 kg N ha^{-1} as 34-0-0 increased P uptake by 10-20 kg ha^{-1} at Mize and by 10-14 kg ha^{-1} at Newton (Fig. 4). In combination with broiler litter, the potential for mineral N to maximize P uptake was evident at Newton in 2000 only, when the 4.5 Mg litter + 202 kg N ha^{-1} treatment removed about 25 more kg P ha^{-1} than mineral N only treatment. The increase in P uptake by this treatment is certainly of environmental benefit since the amount of P applied at 8.9 Mg ha^{-1} (167-200 kg ha^{-1}) exceeds the observed maximum uptake rate. At Mize, soils had high concentration of nutrients and heavy metals, as well as high N content that apparently precluded significant treatment differences in yield or nutrient uptake when mineral N was substituted for litter N.

Nutrient uptake in forage grasses is primarily a function of plant biomass, but varies due to differences in weather, cultivar, soil properties, and management practice (McLaughlin et al., 2004). Burns et al. (1985) reported 'Coastal' hybrid bermudagrass receiving 670 kg N ha^{-1} and 153 kg P ha^{-1} from swine effluent removed an average of 382 kg N ha^{-1} and 43 kg P ha^{-1} yr^{-1}. In the present study, P uptake was closely associated with forage DM across the different treatments (n=24), and slightly stronger correlation was obtained at Mize (r = 0.92-0.98) than at Newton (r = 0.86-0.92). This positive relationship would largely explain treatment difference in P uptake by bermudagrass, because tissue P concentration is stable relative to other nutrients (Brink et al., 2002; Evers, 2002). Plant uptake of N and other minerals increased with increasing rainfall, illustrating the impact of rainfall on hay production and nutrient recovery. At Newton, N recovery by plants fertilized with 269 kg ha^{-1} mineral N only relative to check plots was 45% in 1999, 30% in 2000, and 57% in 2001. At Mize, the corresponding values for N recovery were 38% in 1999, 15% in 2000, and 52% in 2001. The somewhat greater N recoveries at Newton than Mize appear to reflect a larger N limitation on growth due to less total N in soil (Table 1). In general, these results support evidence that crop yield and N uptake are directly related to the amount of N fertilizer applied (Pant et al., 2004) and nutrient recovery is enhanced under favorable growth conditions and perhaps more frequent harvests (Brink et al., 2002).

Conclusions

With respect to year and N fertility effects, our results are similar to those for bermudagrass grown in a swine effluent spray field (McLaughlin et al., 2004). In that study, DM yield and nutrient uptake appeared to be enhanced from increased rainfall, and hence soil moisture, and from additional N supplied in the swine-effluent. Overall, our results support the use of mineral N fertilizer in a nutrient management plan when broiler litter is applied to hybrid bermudagrass hay field, including high STP situations. A grower needs to consider local soil and climate conditions to ensure maximum nutrient uptake, and begin applying litter or fertilizer to pasture when daytime temperatures are about 24-27 °C, a range considered favorable for bermudagrass growth (Brink et al., 2002). Although fertilizing pasture with mineral N source is costly, the practice may minimize environmental impacts when broiler litter nutrients, particularly P, Cu, and Zn, are applied in excess of crop needs. Nitrogen application rates and sources, however, should be carefully determined to avoid soil acidification.

At Mize, a site with high STP and high soil N, the mineral N only treatment and the 4.5 Mg ha^{-1} litter + 202 kg ha^{-1} N treatment had high yield and P uptake in the relatively dry years of 1999 and 2000. This suggests that the use of mineral N fertilizer in high STP situations may lead to increased soil P availability when soil moisture conditions are less favorable for growth. For instance, we did not observe a significant yield response to mineral N substitution when rainfall increased in 2001, suggesting the soil or the plant process was not N limited.

At Newton, a site with no known litter history, substituting mineral N at litter rates of either 4.5 or 8.9 Mg ha^{-1} produced the most forage that sometimes removed more soil nutrients than bermudagrass fertilized with mineral N only. Applying 269 kg N ha^{-1} from mineral N only did not produce hay yields comparable to plants fertilized with a combination of broiler litter and mineral N fertilizer. This illustrates the value of poultry litter as a soil amendment and nutrient source for bermudagrass production. Therefore, when plant P nutrition is the basis for broiler litter application rates, bermudagrass growth and P uptake can be enhanced by organic amendments to soil, as well as timely applications of a readily available mineral N source. Because substituting mineral N for litter N stimulated P uptake at Newton, knowledge of average N content of litter and mineralization rate of that N will improve our knowledge of how to manage broiler litter applications based on forage P requirement. The amount of mineralizable N supplied by litter in the first season of application is typically estimated from analytical N content of the litter and on certain assumptions (Cabrera and Gordillo, 1995). To avoid uncertainty it may be necessary to empirically determine a rate that results in plant growth and productivity equivalent to that of conventional fertilizer (Westerman et al., 1988). Broiler litter has potential for rapid nutrient mineralization rate which may pose a risk of nutrient loss and leaching in pastures when applied in early spring or late fall (Cabrera et al., 1994).

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Tables and Figures

Table 1. Soil pH, total nitrogen (TN), and concentration of selected minerals (by Mehlich 3 extraction) at 0-5 and 5-15 cm depths in Spring 1999 before applying broiler litter to bermudagrass pastures at Newton, MS and Mize, MS.

Site and Depth (cm)	pH	TN	P	K	Ca	Mg	Cu	Fe	Mn	Zn
		--------------------- g kg^{-1} ------------------					------------ mg kg^{-1} -----------			
Newton										
0 – 5	5.9	1.30	0.05	0.06	1.35	0.12	2	159	104	3
5 – 15	6.1	0.53	0.01	0.04	0.82	0.06	1	124	93	1
Mize										
0 – 5	5.8	2.34	0.23	0.23	0.82	0.11	13	102	214	16
5 – 15	5.9	0.60	0.16	0.10	0.47	0.05	4	95	206	3

Table 2. Treatment combinations applied to bermudagrass in order to substitute broiler litter N with mineral fertilizer (NH_4NO_3, 34-0-0). Based on average N content in litter and mineralization rate of that N, applying 17.9 kg litter ha^{-1} would meet annual N requirement of 269 kg ha^{-1}. A rate of 4.5 kg litter ha^{-1} is expected to meet annual P requirement.

Broiler Litter Application	Litter Rate	Mineral N Application	Total N Rate[a, b] (Litter-N + NH_4NO_3-N)	
4.5 Mg $month^{-1}$		67 kg $month^{-1}$	Newton	Mize
	Mg ha^{-1}		---------- kg ha^{-1} ----------	
Apr, May, Jun, Jul	17.9		300	315
Apr, May, Jun	13.4	Jul	291	303
Apr, May	8.9	Jun, Jul	283	291
Apr	4.5	May, Jun, Jul	276	285
	0	Apr, May, Jun, Jul	269[b]	269[b]

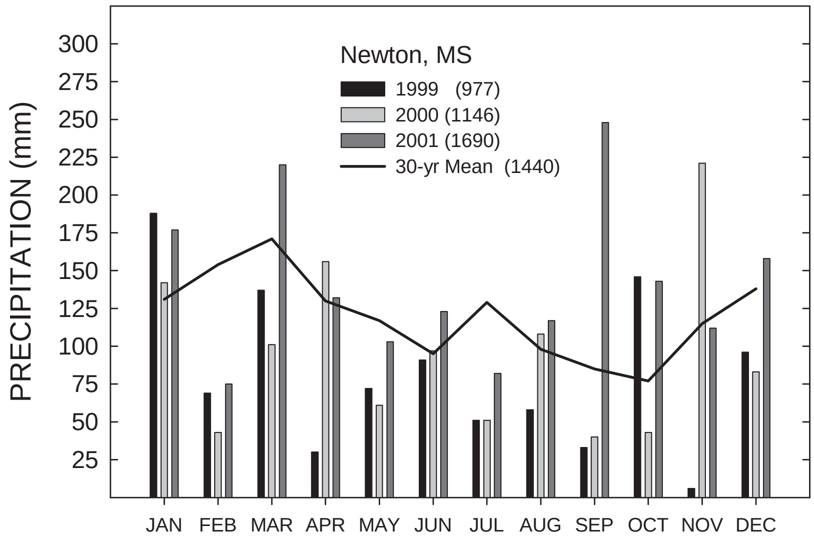
[a]Assumes 50% of N in litter is available for plant uptake during the first year.
[b]Assumes 100% of N applied as 34-0-0 is available for plant uptake.

Table 3. Broiler litter pH and concentration of selected minerals (by ICP-IOCEAS) in broiler litter applied as fertilizer to bermudagrass pastures in at Newton and Mize, MS in May 1999, 2000, and 2001.

		pH	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
			-------------------- g kg^{-1} ----------------					-------------- mg kg^{-1} ------------			
1999	Newton	7.4	35.7	17.6	25.8	26.6	5.4	621	1581	639	449
	Mize	7.5	38.3	24.2	31.3	31.0	7.7	838	832	837	591
2000	Newton	7.6	31.8	18.6	26.4	27.1	5.7	648	1985	692	496
	Mize	7.7	34.9	22.5	29.6	30.1	6.1	687	837	631	416
2001	Newton	7.5	33.1	20.1	26.7	26.8	6.0	496	2003	476	409
	Mize	7.4	32.5	20.8	29.1	30.9	6.4	541	1033	657	455

Table 4. Average amount of total nutrients in broiler litter applied at four rates in 1999, 2000 and 2001, based on average chemical analysis of nutrient in litter (Table 3.)

Site and Litter Rate	N	P	K	Cu	Zn
	----------------------------------- kg ha^{-1} --------------------------------				
Newton					
4.5	150	84	118	2.6	2.0
8.9	300	168	236	5.3	4.0
13.4	450	252	354	7.9	6.0
17.9	600	336	471	10.5	8.1
Mize					
4.5	158	101	134	3.1	2.2
8.9	316	202	269	6.2	4.4
13.4	474	302	403	9.2	6.5
17.9	631	403	538	12.3	8.7



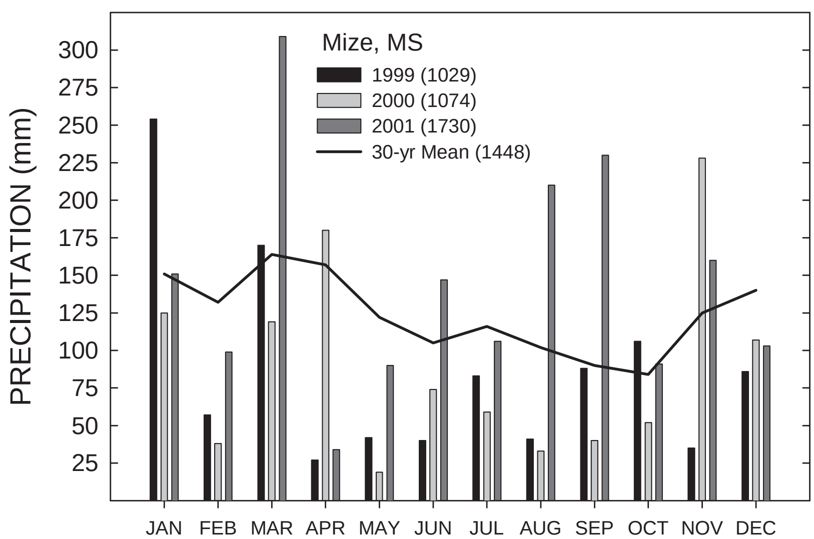


Figure 1. Monthly rainfall for 1999, 2000, and 2001, and long-term average rainfall. Cumulative amounts are presented in parenthesis.

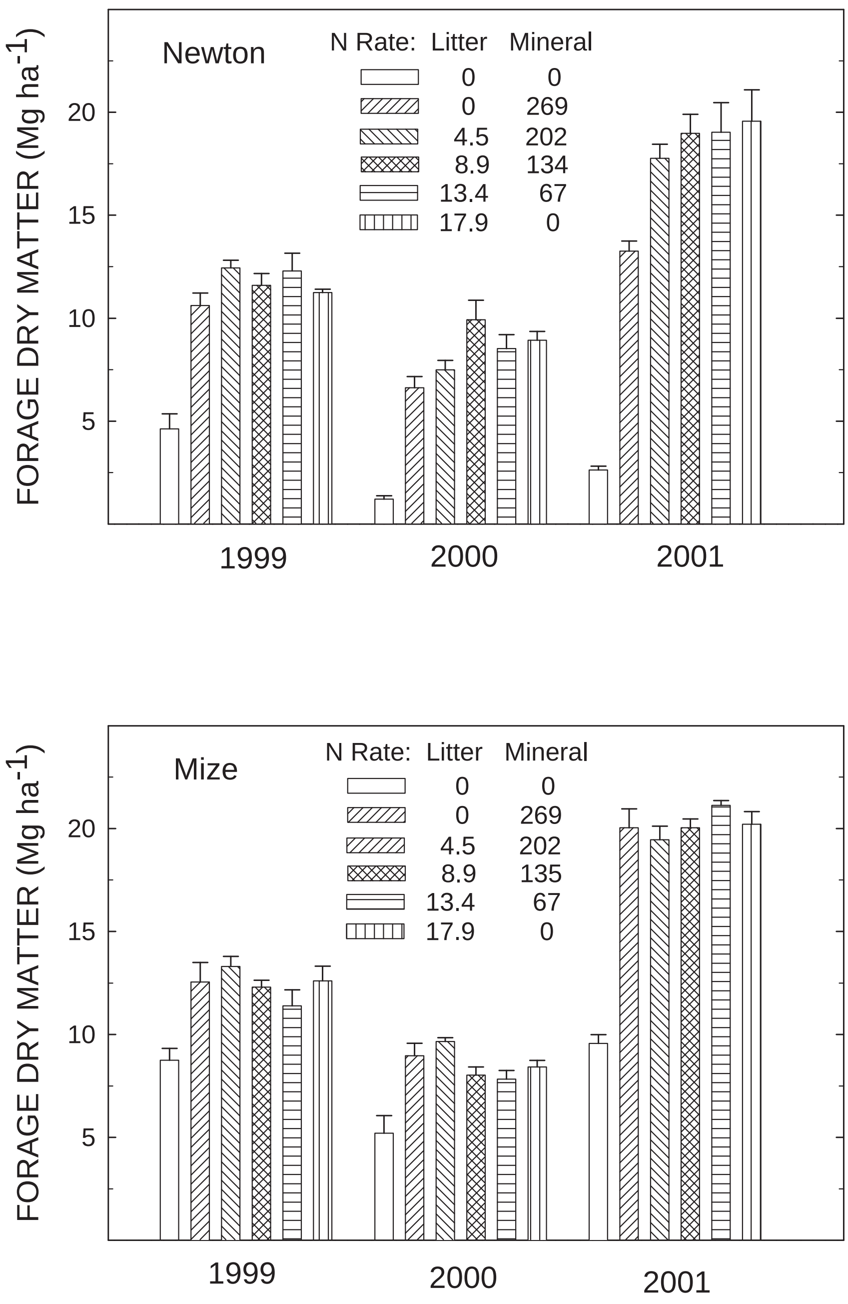
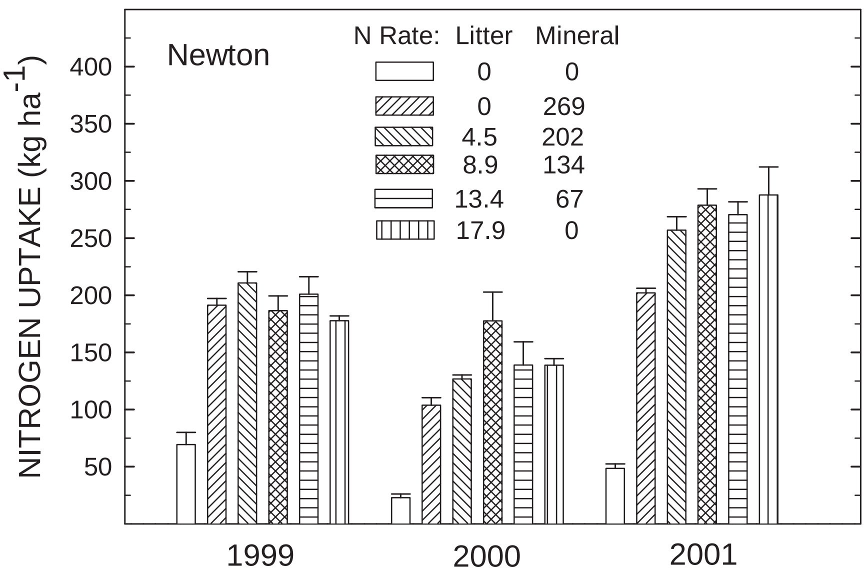


Figure 2. Annual forage dry matter (DM) yield of Coastal bermudagrass receiving broiler litter in combination with different rates of mineral N. Including the no litter and no mineral N treatment, values for LSD (P=0.05) at Newton were 1.77, 1.72 and 2.59 in 1999, 2000 and 2001, respectively. Values for LSD (P=0.05) at Mize were 1.90, 1.58 and 1.81 in 1999, 2000 and 2001, respectively.



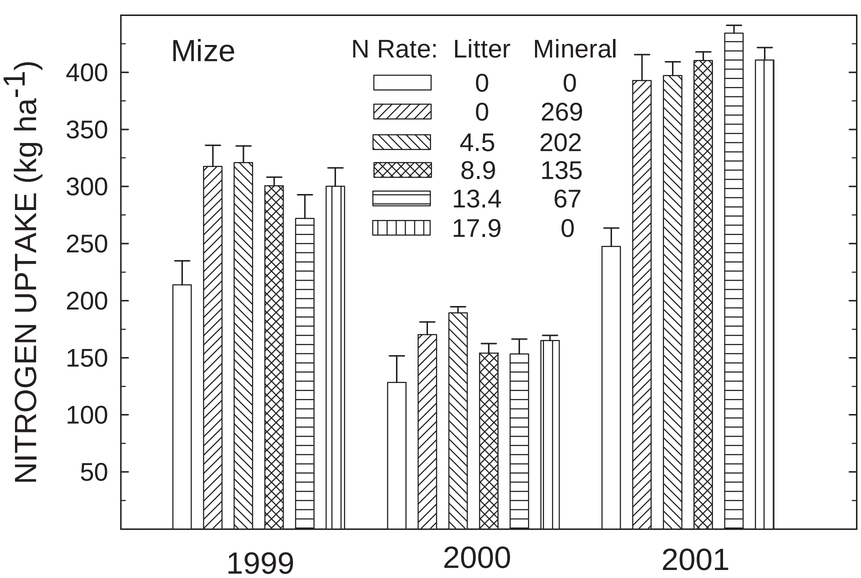


Figure 3. Annual nitrogen uptake in Coastal bermudagrass receiving broiler litter in combination with different rates of mineral N. Including the no litter and no mineral N treatment, values for LSD (P=0.05) at Newton were 32, 38, and 37 in 1999, 2000 and 2001, respectively. Values for LSD (P=0.05) at Mize were 43, 40 and 40 in 1999, 2000 and 2001, respectively.

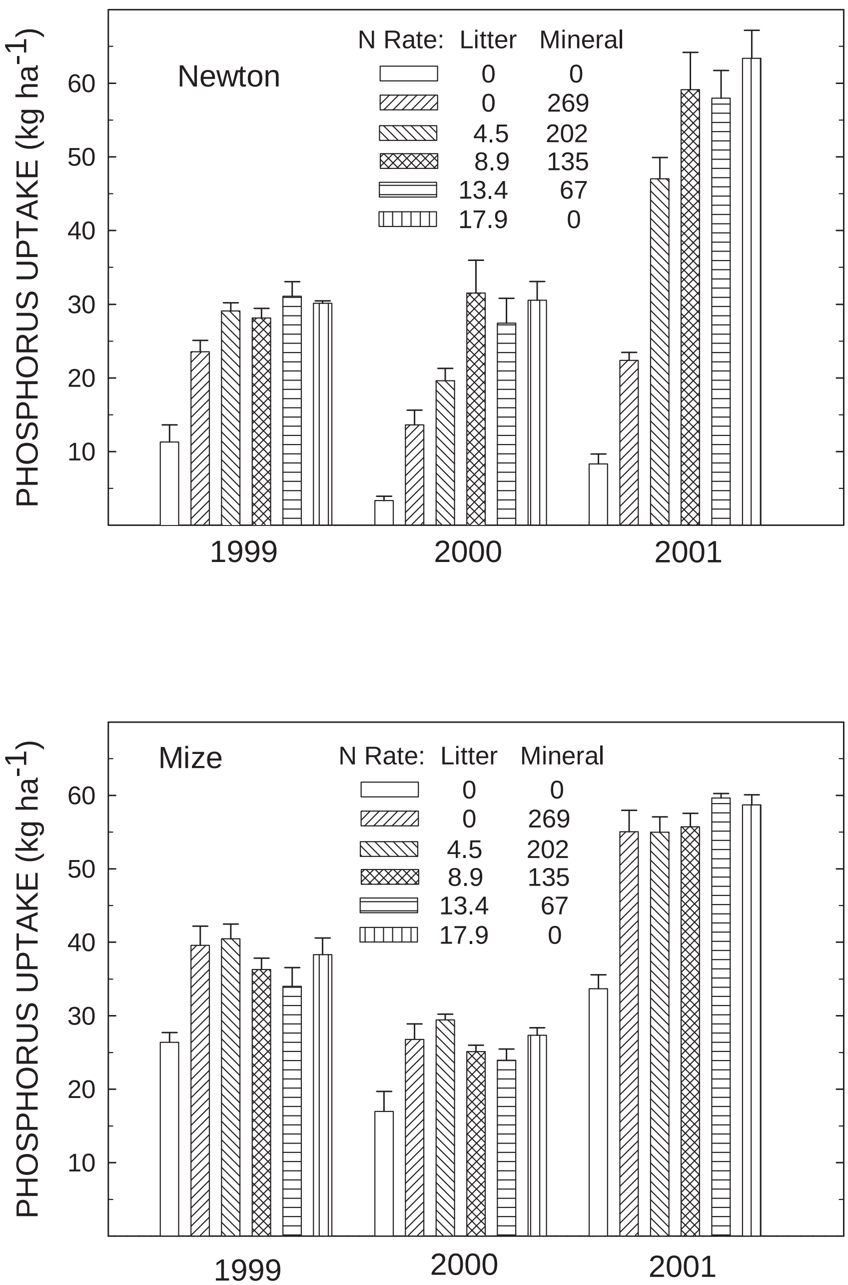
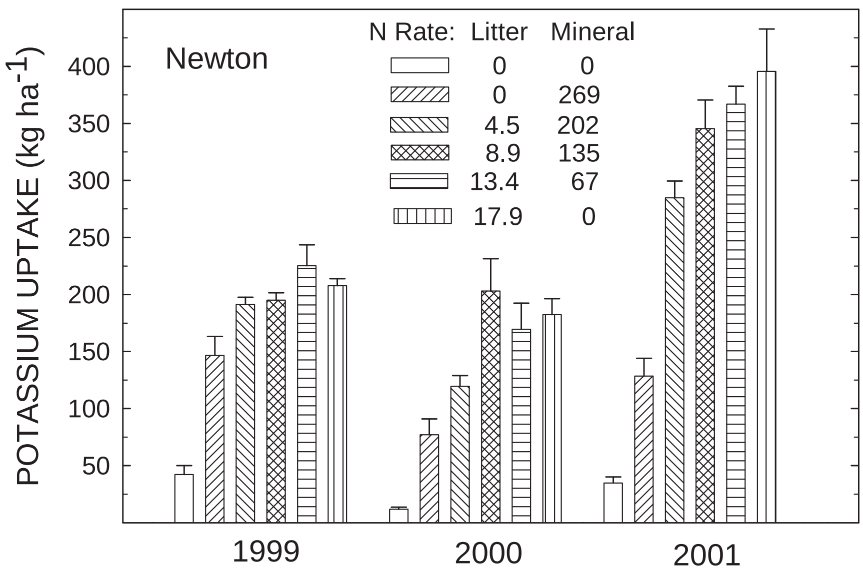


Figure 4. Annual phosphorus uptake in Coastal bermudagrass receiving broiler litter in combination with different rates of mineral N. Including the no litter and no mineral N treatment, values for LSD (P=0.05) at Newton were 4.8, 7.3 and 8.3 in 1999, 2000 and 2001, respectively. Values for LSD (P=0.05) at Mize were 5.7, 5.3 and 5.9 in 1999, 2000 and 2001, respectively



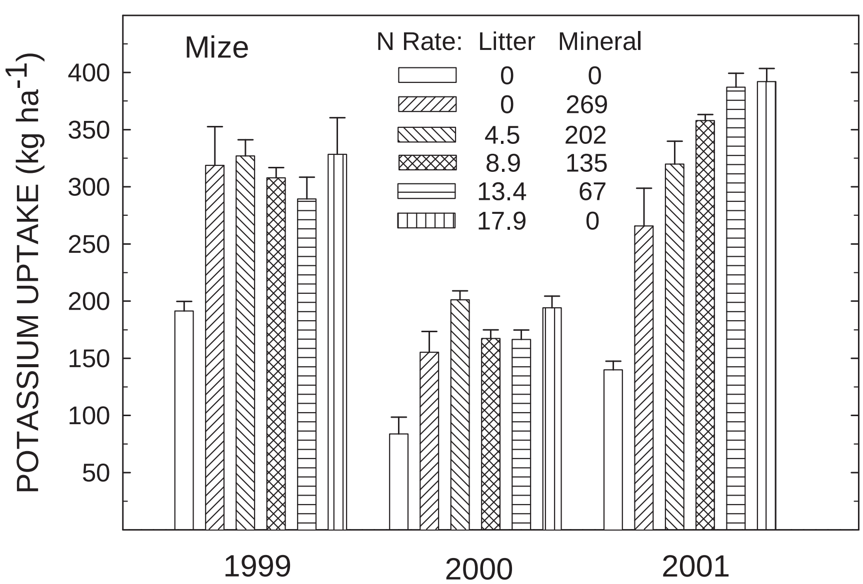


Figure 5. Annual potassium uptake in Coastal bermudagrass receiving broiler litter in combination with different rates of mineral N. Including the no litter and no mineral N treatment, values for LSD (P=0.05) at Newton were 38, 53 and 64 in 1999, 2000 and 2001, respectively. Values for LSD (P=0.05) at Mize were 67, 37 and 64 in 1999, 2000 and 2001, respectively.

Winter Cover Crop Management Systems Increase Annual Extraction Rates of Manure Nutrients in Swine Effluent Spray Field

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Swine effluent is repeatedly applied to the same fields via irrigation because the economics of transporting the effluent is prohibitive. The sustained safe use of a spray field is immediately linked to the rates of removal of potentially polluting nutrients. In the South researchers are determining the best winter cover crop and its management to use with bermudagrass summer crop to maximize winter and annual uptake of nutrients in harvested hay. Early studies indicated the value of bermudagrass as the summer perennial forage and annual ryegrass as the winter forage. Harvesting the annual ryegrass winter cover crop increases annual P uptake by about 30% over the summer harvests. Subsequent research shows that use of berseem clover, a winter annual, when harvested twice instead of once increased uptake of P, Zn, and Cu in the ranges of 20 to 60%. The winter cover crop species and its management have residual effects on productivity of the summer forage. Competition between winter and summer forages complicates agronomic recommendations for management of swine effluent spray field.

Runoff losses of Nitrogen and Phosphorus from a No-till Cotton Field Fertilized with Broiler Litter

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Abstract

Broiler litter is rich in plant nutrients that increase cotton production, but surface application of broiler litter on no-till cotton allows nutrients to be transported from fields in surface runoff, while much of the ammonia-N volatilizes. Incorporation of broiler litter into the soil surface can reduce such problems, but has not been investigated for no-till cotton systems. A field experiment was conducted on an Atwood silt loam (fine-silty, mixed, thermic Typic Paleududalfs) soil at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc County, MS in 2004 to determine if surface incorporation of broiler litter applied to a no-till cotton influences the runoff loss of nutrients. The experimental design was a randomized complete block with 4 treatments replicated 3 times. Treatments included untreated control with and without surface incorporation and broiler litter applied at the rate of 8.2 Mg ha^{-1} with and without surface incorporation. Runoff volume increased by 30 % when litter was incorporated. Incorporation of broiler litter into soil surface decreased dissolved P and NH_4-N and increased NO_3-N concentrations of runoff water samples. Total suspended solids, total P and particulate P were greater for surface incorporation than non-incorporated treatments, indicating that greater soil loss resulted in greater amounts of particulate and total P being transported in runoff. Therefore, preliminary results suggest that incorporation of broiler litter into the soil surface of a no-till cotton field could be advantageous if erosion is controlled.

Introduction

Commercial broiler production in Mississippi generates 450, tons y^{-1} of broiler litter (manure and bedding material) which is applied to nearby pastures or cropland (Mississippi State University, 1998). Continuous applications of broiler litter to same land will increases the potential for enrichment of NO_3-N in groundwater and P in surface water (Edwards et al., 1992; Sharpley et al., 1996). To minimize these risks, producers must obtain additional land area to dilute the litter using N demanding crops and/or using alternative crops to receive broiler litter. The use of animal manure as fertilizer in row crop production have been encouraged. Substantial studies have been conducted to determine the effects of broiler litter on corn (*Zea mays* L.) (Brown et al., 1994; Wood et al., 1999) and cotton (*Gossypium hirsutum* L.) (Burmster et al., 1991; Glover and Vories, 1998; Malik and Reddy, 1999). Adoption of conservation tillage and use of poultry litter as an alternative source of fertilizer in cotton is increasing in the Southeastern USA. Manure application to no-till without surface incorporation may reduce its effectiveness as a nutrient source because of potential N loss (Eghball and Gilley, 1999). Surface application of broiler litter for no-till cotton productions may allow nutrients to be transported off the fields in runoff water, while much of the ammonia-N volatilizes. Elevated concentrations of nitrogen (N) and phosphorus (P) in surface runoff may degrade surface water quality. Phosphorus transported by surface runoff to streams and lakes often accelerates eutrophication, thus affecting the usage of water resources for many purposes such as drinking, fishing, and recreation (Foy and Withers, 1995). Water quality becomes a concern when using broiler litter as a nutrient source. Researchers have shown that broiler litter has increased nutrient levels and metals in surface runoff (Westerman et al., 1983; Edwards and Daniel, 1993; Woods et al., 1999), and may cause concern for surface water quality degradation. Muller et al. (1984) found that application of 8 Mg ha^{-1} (dry wt) dairy manure resulted in significantly greater dissolved and bioavailable P loss in no-till as compared to conventional till. Ammonium loss into surface waters can result in poisoning of aquatic organisms if the concentration is >2.5 mg L^{-1} (USEPA, 1986). Nitrate in runoff from fields receiving manure or fertilizer may be carried to rivers and lakes which may contribute to the hypoxia condition that is a zone depleted of oxygen and marine life. The water quality impact of these alternative cropping methods needs investigation. Findings by Vories et al. (1999) suggest nutrients from litter applied to cotton could be lost in runoff water particularly shortly after application when the incorporation is not effective. Incorporation of animal manure generally reduces the potential for P in runoff (Eghball and Gilley, 1999: Tabara, 2003). With no-till management of corn, dissolved P increased in the surface runoff (Bundy et al., 2001; Zhao et al., 2001). The magnitude of nutrient losses due to runoff under no-till or reduced-till cotton production system is not well documented. Incorporation of broiler litter into surface soil can reduce nutrient losses, but has not been used for row crops under a no-till cropping systems. The need exists for broiler litter management strategies that include surface incorporation techniques to minimize movement of nutrients off the field in runoff water. This study was conducted to determine the effects of surface incorporation of applied broiler litter to a no-till cotton field on nutrient losses in runoff.

Materials and Methods

Research was conducted on an Atwood silt loam (fine-silty, mixed, thermic Typic Paleududalfs) soil at the Pontotoc Ridge-Flatwoods Branch Experiment Station in Pontotoc County, MS in 2003 and continue until 2006. The experiment design for the study was a randomized complete block with a 2x2 factorial arrangement of treatments replicated three times. Treatments were broiler litter rate (0 and 8.2 Mg ha^{-1}) and application method (incorporation and non-incorporation). Before broiler litter application, soil samples were taken at the depth of 0-15 cm and analyzed for NH4-N and NO3-N (Keeney and Nelson, 1982), Mehlich 3P (Mehlich,1984), water soluble P, soil texture (Day, 1965), and soil pH. Broiler litter was also analyzed for nutrient concentrations. The results of chemical analyses of soil and broiler litter are shown in Table 1. Cotton was planted with 100 cm in row spacing on May 6, 2004 using a six-row 7340 MaxEmerge no-tillage vacuum planter. After cotton emergence, runoff micro plots were established. Individual runoff micro plot size was 120 by 130 cm with 10 cm hieght. Plots were established in 2004 using stain less steel. Runoff samples were collected in 5 gallon plastic container via a gutter equipped with a canopy to exclude direct input of rainfall. Runoff water samples were collected after each runoff producing rainfall event. The amount of rainfall and runoff volume was measured and recorded after each rain event. A 0.25-L aliquot of runoff water was collected from each plot in a plastic bottle, and frozen until analyzed.

Prior to chemical analyses, runoff water samples were filtered through a 0.45 µm filter. Nitrate-N and NH4-N concentrations were determined using aLachat (Zellwegger Analytics, Milwaukee, WI) system. Sediment from 50 mL of runoff water was collected on a 0.45 µm filter. The filter and sediment were dried to a constant weight and then weighed to determine suspended solids. To determine P on the sediment, the filter and sediment were then ashed in a muffle furnace at 450oC for 12 h followed by addition of 10 mL 1N HNO3 and heating at 200oC until dryness, and addition of 10 mL of 1.0 N HCl prior to ICP analysis for P (particulate P). Dissolved P concentration was determined using ICP. Non-filtered runoff samples were analyzed for total P (Johnson and Ulrich, 1959) , total N (Bremner, 1965) , K, Ca, Mg, Mn, Cu, and Zn concentrations. Runoff water samples were used for measurement of pH and electrical conductivity. The General Linear Model (GLM) procedure in SAS (SAS Inst., 1987) was used to perform analysis of variance. All statistical tests were performed at a 0.05 level of significance.

Results and Discussions

Rainfall patterns were typical of the Southeast with most rain occurring early spring. Surface runoff water losses followed rainfall patterns in both incorporated and non-incorporated litter. Averaged across runoff events, runoff volume from incorporated plot was 38 % greater compared to not-incorporated treatment (Fig. 1).

Runoff concentrations of total N and NH_4-N were greater for non-incorporation of broiler litter versus incorporated broiler litter. The results of this study are in agreement with the findings of Eghball and Gilley (1999) who reported that surface application of manure without incorporation is further susceptible to runoff losses of NH_4 and P, especially when rainfall events occur soon after application. With non- incorporation of broiler litter, NH_4-N concentration in runoff water samples was greater than the critical 2.5 mg L^{-1}. Ammonium-N concentration >2.5 mg L^{-1} may be harmful to fish (USEPA, 1973). Ammonium is relatively immobile and generally followed the same trend as dissolved P. This can be attributed to the NH_4 content of broiler litter at the time of application (Table 1). However, NO_3-N concentration was significantly increased with incorporation of broiler litter into the soil surface. This could be due to an inherently high NO_3-N concentration in the untreated surface soil (Table 1) and incorporation of surface soil disturbed the soil and increased runoff loss of NO_3-N. Sharpley et al. (1985) found that the NO_3-N concentration of the top 0 to 5 cm soil did not have a significant effect on runoff NO_3 concentration but the 0 to 5 cm soil concentrations of dissolved P, particulate P and total N had significant effect on losses of these parameters. Nitrate concentration exceeded the 10 mg L^{-1} criterion recommended by the U.S. Environmental Protection Agency for primary drinking water supplies (U.S. Environmental Protection Agency, 1986).
Runoff concentration of dissolved P was greater for non-incorporated than the incorporated treatment (Tables 2 and 3). The concentration of dissolved P in runoff samples was <1mg L^{-1} for all treatments in the incorporated condition. However, the concentrations of total P and particulate P (sediment P) were greater for incorporated than not-incorporated treatments (Table 2 and 3) indicating that greater erosion from the incorporation of broiler litter into the soil surface resulted in more particulate and total P being carried by runoff. These results are in agreement with the work of Gilley and Eghball (1998) who found that total P and particulate P concentrations in runoff water was less for no-till than disked conditions. Regardless of surface soil management, the concentration of N and P for all runoff components were greater than untreated check plots. The trends for the load of nutrients in runoff were similar to those of concentration for all parameters. Dissolved P accounted for about 55% of the total P in runoff indicating the importance of dissolved P in water pollution. Runoff concentration of K, Ca, Mg, Mn, Cu and Zn decreased by approximately 28% when broiler litter was incorporated into the soil surface (Table 3).

Conclusion

Preliminary results from the first year of this study indicated that incorporation of broiler litter into the soil surface in a no-till cotton field increased runoff volume, total suspended solids, particulate P and total P concentrations reflecting greater soil loss. In contrast to P, runoff N

(NH4-N and total-N) concentration decreased with incorporation practice and NH4-N concentration was less than 2.5 mg L^{-1}, the critical runoff NH_4-N concentration for growth and reproduction of algae. Incorporation of broiler litter into the soil surface in a no-till cotton field could be agronomically and environmentally advantageous if erosion is controlled.

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Table 1. Selected properties of the soil and broiler litter used in the study at 0-15cm.

Parameter	Soil	Broiler litter
Dry matter, %	-----	87.6
pH	6.5	7.4
Mehlich 3 P, mg kg^{-1}	13.2	-----
Total N, g kg^{-1}	1.9	33.5
NH4-N, mg kg^{-1}	27.6	3552
NO3-N, mg kg^{-1}	52.4	1991
Carbon, g kg^{-1}	-----	308
Organic matter, g kg^{-1}	7.3	---
Texture	Silt loam	------
C to N ratio	-----	8

Table 2. Effect of surface incorporation on runoff N and P in a no-till cotton field fertilized with broiler litter averaged across runoff events.

Treatment	DP	PP	TP	NH4	NO3	TN	TSS
Control	------------------------------ mg L^{-1} --------------------- -------						g L^{-1}
Incorporated	0.43 b	0.66 b	1.14 c	0.52 c	4.8 c	4.5 c	1.31 a
Non-incorporated	0.48 b	0.25 c	0.66 d	0.85 c	3.0 d	5.5 c	1.00 b
Broiler litter							
Incorporated	0.56 b	1.86 a	3.96 a	2.2 b	10.0 b	12.1 a	0.66 c
Non-incorporated	1.48 a	1.00 b	2.24 b	4.1 a	6.0 a	15.0 b	0.25 d

DP = Dissolved Phosphorus
PP = Particulate Phosphorus
TP = Total Phosphorus
TN = Total Nitrogen
TSS = Total suspended solids

Table 3. Effect of surface incorporation on runoff K, Ca, Mg, Mn, Cu and Zn in a no-till cotton field fertilized with broiler litter

Treatment	K	Ca	Mg	Mn	Cu	Zn
Control	------------------------------ mg L^{-1} ---------------------------					
Incorporated	2.9 b	3.2 c	3.7 c	0.49 b	0.20 a	0.33 b
Non-incorporated	2.3 b	2.5 c	3.2 c	0.63 b	0.20 a	0.35 b
Broiler litter						
Incorporated	2.2 b	6.6 b	6.6 b	0.38 b	0.25 a	0.34 b
Non-incorporated	5.4 a	10.0 a	8.0 a	1.24 a	0.34 a	1.23 a

DP = Dissolved Phosphorus
PP = Particulate Phosphorus
TP = Total Phosphorus
TN = Total Nitrogen

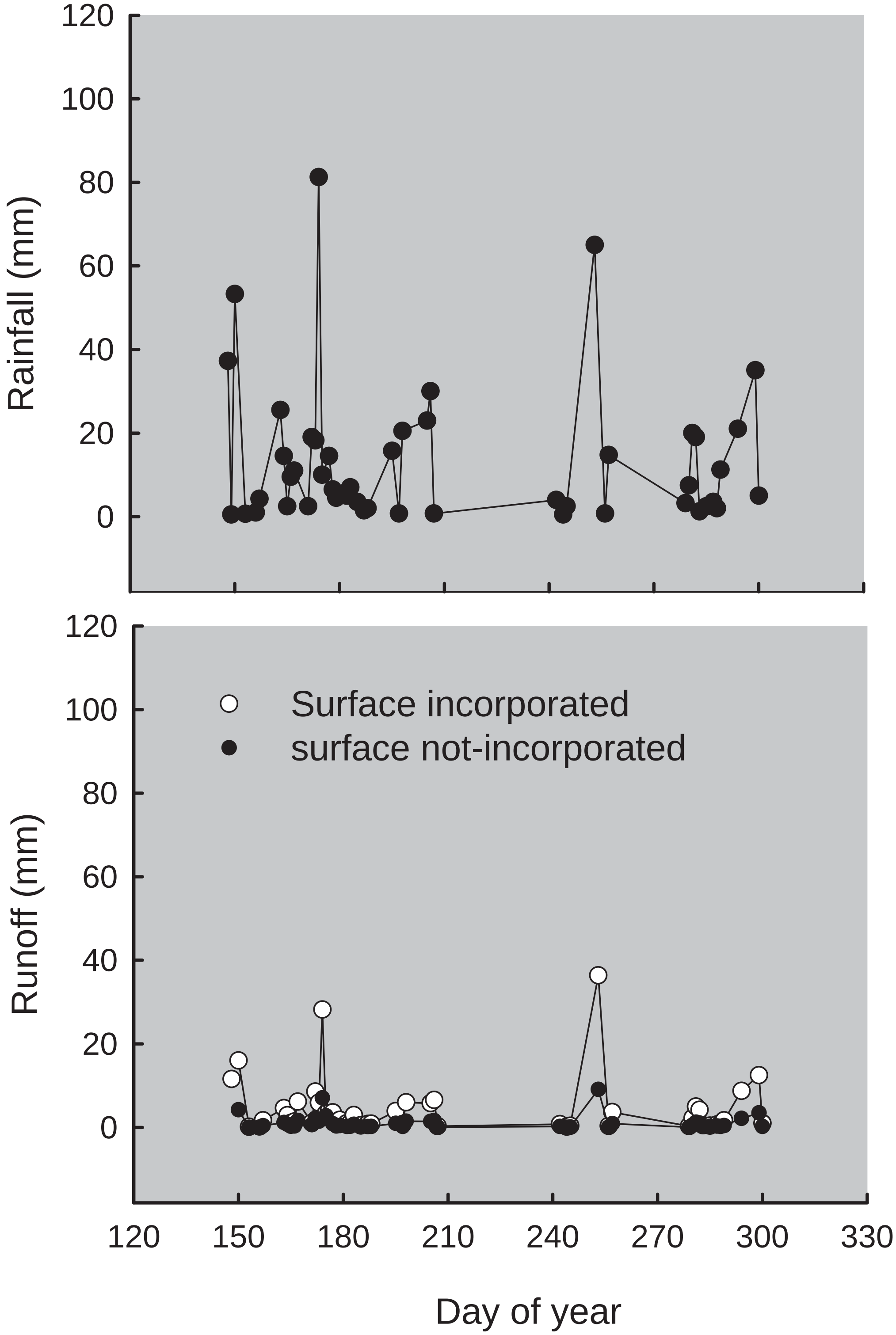

Fig. 1. Amount of rainfall and runoff volumes during the cotton growing season in 2004

Concurrent Session C
Ecology
Moderator: Fred Howell

Developing Plans for Managing Invasive Aquatic Plants in Mississippi Water Resources

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Abstract

Invasive aquatic plants are an ever-growing nuisance to water resources in Mississippi and the rest of the United States. These plants are generally introduced from other parts of the world, some for beneficial or horticultural uses. Once introduced, they can interfere with navigation, impede water flow, increase flood risk, reduce hydropower generation, and increase evapotranspirational losses from surface waters. Invasive species also pose direct threats to ecosystems processes and biodiversity. All agencies and individuals responsible for water resources in Mississippi should be prepared for invasive aquatic plants through developing an aquatic plant management plan. Components of a plan include: Prevention, Problem Assessment, Project Management, Education, Monitoring, Site- or problem-specific management goals, and Evaluation. Prevention seeks to reduce the influx of new invaders into the resources, and respond rapidly once they are found. Problem assessment is to quantify the distribution and abundance of the target plant and its impacts on the resource. Project Management includes tracking available resources to fight the problem, including funds and labor. Education involves informing both the resource agency and the public in the problem and potential solutions. A monitoring component tracks the general condition of the resource in both biotic and abiotic attributes, to detect other changes associated with the resource. Site- or problem-specific goals addresses the management of target species based on a specific site basis, rather than attempting to find a single solution to the target plant problem through time for all locations. Finally, an evaluation plan quantifies the success of the management efforts based on economic, environmental, and efficacy thresholds. These components in a management plan will increase the likelihood of a successful approach to invasive plant problems.
Keywords: Invasive Species, Management & Planning, Recreation, Wetlands

Introduction

Invasive aquatic plant species are a major problem for the management of water resources in the United States (Madsen 2004). Nonnative invasive species cause most of the nuisance problems in larger waterways, often causing widespread dense beds that obstruct navigation, recreation, fishing, and swimming; and interfere with hydropower generation. Dense nuisance plants increase the likelihood of flooding and aid in the spread of insect-borne diseases. Invasive plants often reduce both water quality and property values for shoreline owners (Carpenter 1980, James et al. 2001, Rockwell 2003).

Invasive species also impact the ecological properties of the water resource. They may degrade water quality, reduce species diversity, and suppress desirable native plant growth. They may alter the predator/prey relationship between game fish and their forage base, resulting in stunted game fish (Lillie and Budd 1992). Invasive species may also change ecosystem services of water resources, altering nutrient cycling patterns, sedimentation rates, and increasing internal loading of nutrients (Madsen 1997).

For Mississippi water resources, the most likely or troublesome invasive plants to cause problems are likely to be one of seven species: alligatorweed, Eurasian watermilfoil, giant salvinia, hydrilla, waterhyacinth, and waterprimrose (Table 1). While these are the species most likely to cause the greatest concerns, many other native and nonnative species can cause nuisance problems, particularly in small areas.

Table 1. The six most likely invasive aquatic plant species in Mississippi.

Common name	Scientific name	Growth form
Alligatorweed	*Alternanthera philoxeroides*	Emergent
Eurasian watermilfoil	*Myriophyllum spicatum*	Submersed
Giant salvinia	*Salvinia molesta*	Floating
Hydrilla	*Hydrilla verticillata*	Submersed
Waterhyacinth	*Eichhornia crassipes*	Floating/Emergent
Waterprimrose	*Ludwigia* spp. (*L. grandiflora* and *L. hexapetala*).	Emergent

These species, as well as others, have been discussed extensively elsewhere (www.gri.msstate.edu, Madsen 2004). Species-specific management recommendations are available elsewhere (AERF 2005).

To manage these species for the long-term, water resource managers need to have an aquatic plant management plan – even for those water bodies that currently do not have invasive plant species. An aquatic plant management plan will establish protocols to prevent the introduction of nuisance plants, provide an early detection and rapid response program the water body so new introductions can be managed quickly at minimal cost, and aid in identifying problems at an early stage. A plan will assist in identifying resources, stakeholders, and build coalitions to manage problem species. The planning process will identify information already collected, and gaps in information that are needed. A plan will help in communicating the need to manage, and provide a rationale or approach for management.

An aquatic plant management plan should have eight components: prevention, problem assessment, project management, monitoring, education, management goals, site-specific management, and evaluation (Table 2).

Table 2. Components of an aquatic plant management plan.

Component	Description
Prevention	Education and quarantine combined with proactive management of new infestations (early detection and rapid response)
Problem Assessment	Identify problem, collect information, and formulate specific problem statements
Project Management	Accounting for your resources: financial, personnel, partnerships, and volunteers
Monitoring	Quantifying change in the water body
Education and Outreach	Learning about the problem and potential solutions, and informing the public about the program
Management Goals	Specific milestones by which to assess success or failure
Site-Specific Management	Select management techniques to specific parameters
Evaluation	Quantitatively assess success of management

Prevention

In most instances, invasive plants are introduced to a water body by human activity. Most commonly, invasive plants are transported to water bodies on boats and boat trailers. Prevention activities can include signage at boat launches and marinas, and other educational activities. Other successful prevention programs have included federal and state legislation, enforcement, educational programs in broadcast and print media, and volunteer monitoring programs (Baumann et al. 2001).

Combined with these prevention activities, an early detection and rapid response (EDRR) program is necessary to control new infestations at an early stage. Proactively controlling new infestations before they become large infestations is both technically easier and less expensive, resulting in cost savings in the long run. Eradication of small populations is much more likely than when managing large populations. Early detection and rapid response is emphasized by federal agencies involved in invasive species management (Westbrooks 2003).

Problem Assessment

Problem assessment is the process of both acquiring objective information about the problem, such as maps and data on plant distribution, and identifying groups or stakeholders that should have input into formulating the problem statement. A specific problem statement will help refine the issues of users and the nature of the nuisance problem. Problem assessment should also include identifying causes of the problem, and develop an understanding of the water resource by both identifying information already collected, and additional information needs.

Project Management

Project management is often a neglected aspect of managing invasive plants, particularly when volunteers manage the project. Successful projects are the result of good planning and management of assets, which would include financial resources, partnerships with others, and personnel (including volunteers). Adequate records of expenses are required, particularly if the project is funded by government entities. In addition, a good evaluation of success will include the expenditure of both time and labor.

Education and Outreach

Education and outreach should be initiated at the beginning of the program, and continue throughout the project. Education initially will consist of having the project group learn about the problem and possible solutions, which will help to build a consensus on the solution. As time progresses, education effort will extend outward to the public to inform them of the problem, possible solutions, and what the project is doing about the problem. As much as possible, inform the public openly about management activities. A public web page is one successful tool, but the project group can also utilize local media outlets, such as newspapers and radio. Lastly, if you have a successful project, share your success with others through professional or resource organizations, such as the Mississippi Water Resources Conference.

Monitoring

A monitoring program would not only include assessing the distribution of the target plant species, but would also include a program of monitoring other biological communities (including desirable native plant communities) in the reservoir, and water quality parameters, to evaluate if there are longer-term changes to the water body, or if management might have a positive or negative effect on other aspects of the water resource. Monitoring would include baseline data collection (as above), compliance monitoring involving a permit, assessments of management impacts to the environment at large, and could also include a "citizen" monitoring program. For instance, citizen monitors have been used for several decades to assess water quality in many water bodies, and can be as simple as measuring water clarity using a Secchi disk.

Plant Information and Methods

When monitoring invasive plant communities, the first question is what types of information are needed. Information needs would include a plant species list, including both invasive and nonnative species and other species of concerned (such as federally threatened or endangered species), maps for locations of species of concern or targeted for management, locations of nuisance growth, and bathymetric maps.

As much as possible, quantitative plant data should be used for assessment, monitoring, and evaluation. Quantitative data is more desirable because for four reasons (Madsen and Bloomfield 1993):

- Objective quantitative data produces facts on the distribution and abundance of plants; subjective surveys lead to opinion, rather than fact, as the basis for management decisions.
- Quantitative data allows for rigorous statistical evaluation of plant trends in assessment, monitoring, and evaluation.
- Quantitative data and surveys may eliminate costly but ineffective techniques in a given management approach.
- Quantitative data allows individuals other than the observer evaluate the data and produce their own conclusions on assessment, monitoring, and evaluation data.

Plant quantification techniques vary in their purpose, scale, and intensity (Table 3). Cover techniques include both point and line intercept techniques (Madsen 1999). These techniques give the best information on species diversity and distribution, and are statistically robust to small changes in plant community composition. Point intercept is also a good technique for ground-truthing remotely sensed data. The best method for measuring plant abundance remains biomass measurement, but it is time-intensive and best used for management evaluations (Madsen 1993). Hydroacoustic surveys are excellent for assessing the underwater distribution and abundance of submersed plants, but do not discriminate between species (Sabol et al. 2002, Valley et al. 2005). Hydroacoustic surveys are essentially a remote sensing technique, measuring submersed plant canopies while they are still underwater. Visual remote sensing techniques, whether from aircraft or satellite, have also been widely used to map topped-out submersed plants or floating and emergent plants (Everitt et al. 1999). While maps alone are useful, digital images can be used for statistical analysis by random or regular pixel sampling.

Table 3. Aquatic plant quantification techniques.

Technique	Utility
Cover Techniques: Point Intercept (Madsen 1999)	Species composition and Distribution, Whole-lake
Cover Techniques: Line Intercept (Madsen 1999)	Species composition and distribution, study plot
Abundance Techniques: Biomass (Madsen 1993)	Species composition and Abundance
Hydroacoustic Techniques: SAVEWS (Sabol et al. 2002, Valley et al. 2005)	Distribution, Abundance (no species discrimination)
Remote Sensing: Satellite, Aircraft (Everitt et al. 1999)	Distribution (near-surface plants only, no species discrimination)

Goals

As part of the plan, specific management goals should be formulated that are reasonable and testable. These goals will provide the basis to assess if the management program is successful. Goals should be as specific as possible, including indicating areas that have a higher management priority. Without specific goals, stakeholders will argue whether management was successful. With a specific goal, the evaluation data will indicate whether or not that goal was met. For instance, if vegetation obstructs recreational use of the water body, a goal of "unobstructed navigation" may result in unending management. If, however, the goal is to maintain navigation channels open to navigation 90% of the time, that is a testable and specific goal.

Once goals are made, these goals should be implemented to manage plants using techniques that are acceptable based on environmental, economic, and efficiency standards, acceptable to stakeholders, and acceptable to regulatory agencies. The techniques selected to manage plants will vary both spatially throughout the water body, and through time. I refer to this as site-specific management.

Site-Specific Management

Site specific management means that management techniques are selected based on their technical merits, and are suited to the needs of a particular location at a particular point in time. The techniques need to be selected based on the priority of the site, the environmental and regulatory constraints of the site, and the potential of the technique to control plants under those particular conditions.

Spatial selection criteria will include how dense the species are, how large an area is covered, the target species in question, water flow characteristics, other uses of the area, and potential conflicts between technique use restrictions and primary uses. For instance, you may have an area of nuisance growth that occurs close to a drinking or irrigation water intake (Figure 1). The primary use may disallow the use of herbicides based on use restrictions, so this might be an appropriate area for benthic barrier and suction harvesting. Another site may be located more than a mile from the same intake. This site might be amenable to an herbicide application, without competing with other uses. Lastly, you may have an area of scattered plants. If you had volunteers and the goal was to eradicate the plant from the waterbody, then hand pulling these plants to prevent the formation of a dense bed might be appropriate.

Through time, the selection of management techniques will also change based on the success (or failure) of the management program. For example, a small lake was dominated by Eurasian watermilfoil throughout more than 90% of the littoral zone (Figure 2). The best option might be a whole-lake treatment of the lake with fluridone, which would reduce the biomass by more than 90%. In the second year, small remaining beds might be managed with diver-operated suction harvesting, benthic barrier, or spot treatment with contact herbicides. By the third or fourth year, routine surveys may find only sporadic Eurasian watermilfoil fragments, which can be removed by hand harvesting. The foregoing example is essentially the history of Long Lake, WA.

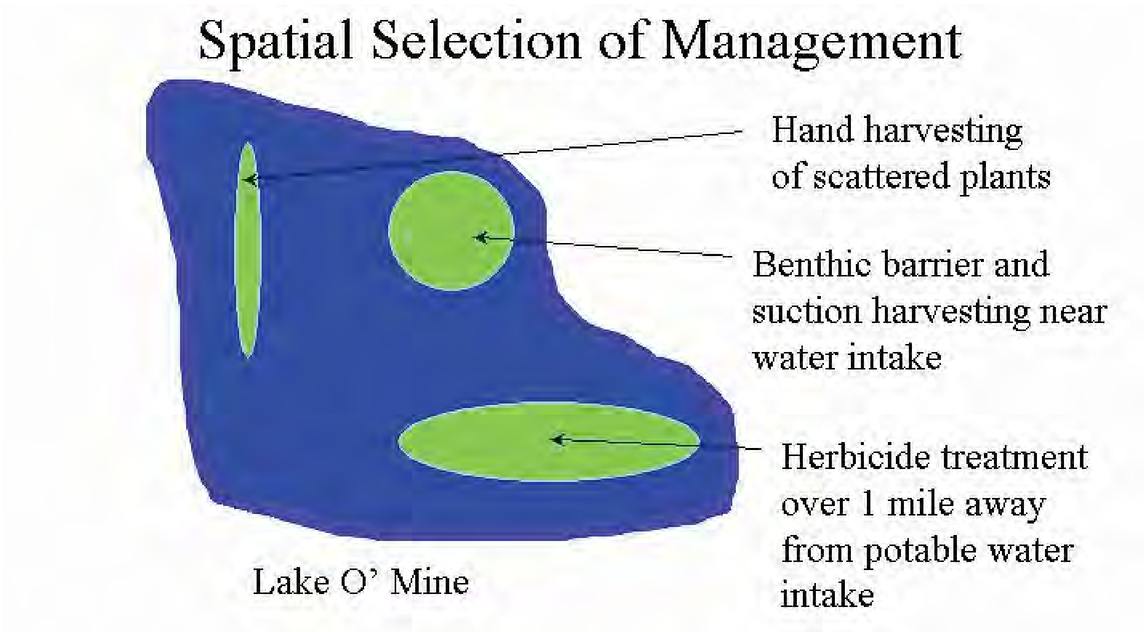

Figure 1. Spatial selection of management techniques.

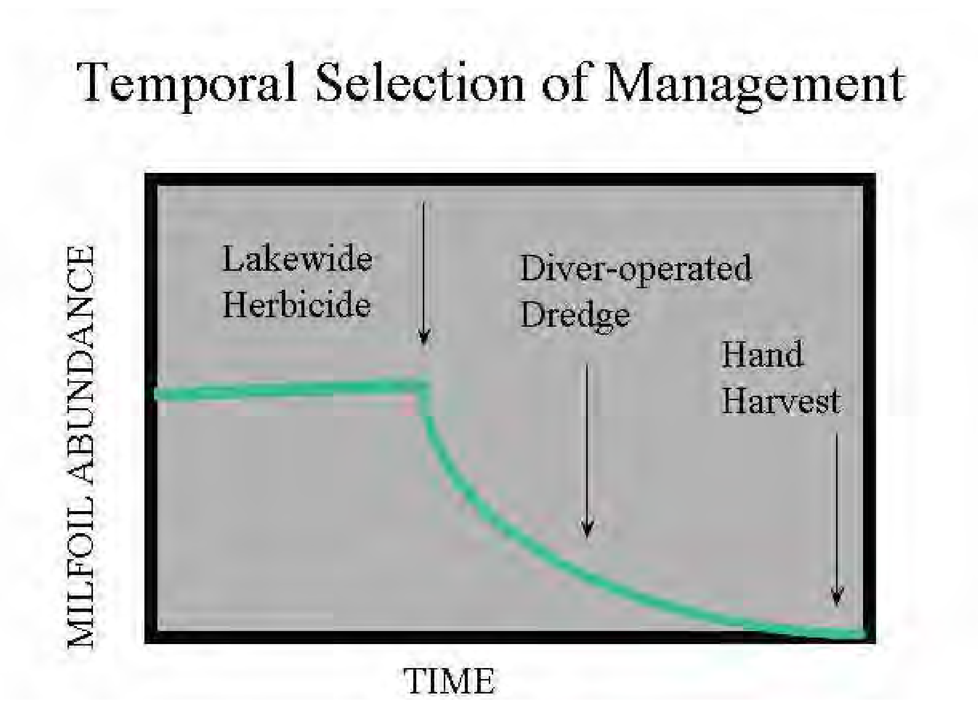

Figure 2. Temporal selection of management techniques.

Aquatic Plant Management Techniques

The basic types of aquatic plant management techniques include biological, chemical, mechanical, and physical control techniques. These techniques have been explained at length elsewhere (Madsen 2000, AERF 2005). All techniques should be selected based on their technical merits, as limited by economic and environmental thresholds.

Evaluation

Evaluation of management techniques and programs is typically lacking in even large-scale management programs. A quantitative assessment should be made of the effectiveness of management activities to control plants, the environmental impact (both positive and negative) of management activities, the economic cost per acre of management, and stakeholder satisfaction.

Summary

Planning should be iterative; a process that is ongoing and learning from past successes and failures. Learn from your assessments, and improve on management. The planning process helps to prepare for the unexpected in management, but likewise the plan may not survive intact after management activities commence.

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AN APPROACH TO INCORPORATE INVASIVE SPECIES AND WETLAND INDICATOR STATUS INTO WETLAND FLORISTIC QUALITY EVALUATION

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ABSTRACT

We evaluated four potential indices of wetland floristic quality, based on the general Floristic Quality Assessment Indices (FQAI) that have been developed and used extensively in various regions of the United States. The four indices that were evaluated, termed Floristic Assessment Quotients for Wetlands (FAQWet), incorporated components of overall species richness, wetland affinity, and the contribution of native versus exotic species to overall wetland vegetation quality. Index values for a set of ten wetlands in north Mississippi were evaluated against relative disturbance rankings of study sites, based on local and landscape-scale impacts from anthropogenic habitat modification and use (e.g., agricultural use, forest land cover, hydrologic and other on-site habitat modifications), the principal causes of habitat degradation in ecosystems worldwide. The adequacy of our four indices also was compared with that of the FQAI for the same set of wetlands. Of the indices evaluated, the one that correlated most closely with wetland disturbance rankings was that which incorporated the most information on relative importance of native and exotic plant species, in addition to wetland affinity:

FAQWet Index value =

$$\frac{\sum WC}{\sqrt{S}} \times \frac{\sum f}{\sum F},$$

wherein *WC* is the Wetness Coefficient for each species present, based on wetland indicator status; *S* is total species richness for the site; *f* is the sum of frequencies of native species among all sample plots; and *F* is the sum of frequencies of all species among all sample plots.

These results highlight the important effects attributable to exotic species dilution of native richness and have yielded a potentially useful criterion for evaluating ecological integrity of wetland ecosystems.

Keywords: aquatic plants, biological indicators, ecological integrity, exotic species, native species, wetland indicator status, wetlands

INTRODUCTION

Numerous organizations and resource management agencies recently have been involved in developing assessment protocols for aquatic and wetland ecosystems. Although much progress has been made in assessing aquatic systems, primarily streams and rivers, methodology for wetland evaluation lags considerably. Some of the methods in use for quantifying wetland "health," or integrity, include the HGM Functional Index approach (Smith et al., 1995), various Indices of Biotic Integrity (US EPA, 2002), and the Floristic Quality Assessment Index (Andreas and Lichvar, 1995).

Floristic Quality Assessment Indices (FQAI) for evaluation of ecological integrity have been developed for a number of states whose flora are well-studied (Illinois: US EPA, 2002; Wisconsin: Nichols, 1999; US EPA BAWWG, 2002; Ohio: Andreas and Lichvar, 1995; Lopez and Fennessy 2002; and Michigan: Herman et al., 1997). These indices are attractive management and assessment tools because herbaceous plants respond rapidly to both improvement and degradation of wetland health, integrating disturbance at numerous biological scales (from point-source pollutant discharge to non-point source factors such as urbanization and erosion/ siltation), and numerous regional keys exist for relatively efficient species-level identification of vascular plants (vs. identification of aquatic invertebrates, difficult even to the level of Family in some cases) (Lopez et al., 2002).

Floristic Quality Assessment Indices are calculated as the average per-species coefficient of conservatism (*C*), weighted against the square root of native species richness, *N*, or

$$\mathrm{FQAI} = \overline{\mathrm{C}} \times \sqrt{N} = \frac{\sum C}{N} \times \sqrt{N} = \frac{\sum C}{\sqrt{N}}$$

(Andreas and Lichvar, 1995).

Values for *C* are assigned based upon the origin and local or regional distribution of individual species; for example, exotics and widespread native species receive very low scores (0), and rare native species receive high scores (10). These coefficients usually are assigned regionally, in consultation with persons familiar with the native flora and the affinity of species for pristine, versus human-altered habitats (Herman et al., 1997). For most of the U. S., however, there presently exist no comprehensive listings of flora and their distribution that could be used to rapidly develop coefficients of conservatism to be used in the calculation of FQA Indices for use in biological assessment.

Herman et al. (1997) presented an alternative index (termed *Wetness Index*) for use in assessments of wetland vegetation, based upon species' wetland indicator status (Reed et al., 1996), rather than coefficients of conservatism. Each wetland indicator status category was assigned a value from +5 (UPL) to –5 (OBL), termed wetness coefficient, *WC* (note sign reversal in our Table 1). Whereas comprehensive records of species coefficients of conservatism are unavailable for most states, regional lists of most vascular plant species' wetland indicator status are available for all of the U.S. from the US Fish and Wildlife Service's Branch of Habitat Assessment (http://www.nwi.fws.gov/bha/). Thus, Wetness Index (WI) could be used similarly to FQAI to indicate the weighted proportion of species present that are adapted to wetland conditions without the need for laborious development of extensive regional lists of conservativeness coefficients.

Herman et al. (1997) further proposed that the WI should be based on wetness coefficients for native species only because most non-native species in their study area were associated with upland areas. However, disregard for non-native species may result in overestimation of ecological integrity, despite accurately indicating the "wetness" of the plant assemblage under investigation. In fact, one criticism of using wetland indicator status in the development of indices for ecological integrity of aquatic systems has been the increasing frequency with which non-native wetland-adapted species are encountered in wetlands (US EPA, 2002). Exotic species include (but are not limited to) those that are recognized noxious weedy invaders that may degrade wetland ecological integrity through multiple mechanisms. The presence of even one exotic species (such as *Hydrilla verticillata* or *Lythrum salicaria*) may have disastrous consequences for wetland health, regardless of the number and regional conservatism of native species present. Thus, exotic species should be incorporated into any proposed method of quantifying wetland health.

Here, we describe and evaluate the relative effectiveness of floristic indices depicting both "wetness" and "nativeness" of wetland plant assemblages, including the Wetness Index discussed by Herman et al. (1997). We refer to these indices as Floristic Assessment Quotients for Wetlands, or *FAQWet* indices.

MATERIALS AND METHODS

Proposed Indices

The methods of FAQWet Index calculation to be tested are:

1. *FAQWet* 1 = $\dfrac{\sum WC_N}{\sqrt{N}}$
2. *FAQWet* 2 = $\dfrac{\sum WC}{\sqrt{S}}$
3. *FAQWet* 3 = $\dfrac{\sum WC}{\sqrt{S}} \times \dfrac{N}{S}$
4. *FAQWet* 4 = $\dfrac{\sum WC}{\sqrt{S}} \times \dfrac{\sum f}{\sum F}$,

where WC_N is the Wetness Coefficient for native species only (WC, Table 1), N is the number of native species, S is the total species richness, f is the frequency of native species among all quadrats, plots, or sample points, and F is the total number of all species occurrences among all quadrats. These formulas combine attributes of the Wetness Index described by Herman et al. (1997) and the formula for FQAI (see *Introduction*; Andreas and Lichvar, 1995). Equation 1 simply replaces C with WC in the FQAI and is the native-species-only Wetness Index suggested by Herman et al. (1997). Equation 2 (FAQWet 2) is the equivalent of FQAI, based on *all species present*. Index formula 3 weights FAQWet 2 against the proportional richness of native species, and formula 4 weights FAQWet 2 against the proportional frequency of native species among all survey plots.

Site disturbance ranking and index evaluation

Using methodology presented by Lopez and Fennessy (2002; US EPA, 2002), we ranked the wetlands included in this evaluation based upon intensity of human impact within the immediately surrounding landscape. Each site was evaluated, in a hierarchical manner, on whether it **(1)** was surrounded within the landscape by a) forest or grassland, b) fallow agricultural, c) active agricultural, or d) urban land use, **(2)** was surrounded by an immediately adjacent a) forest, b) grassland, or c) no buffer zone, and **(3)** possessed obvious signs of hydrologic alteration. Each of the landscape-scale factors has been linked to wetland plant response at the level of species and functional guilds (Table 2; Lopez et al., 2002). We also developed our own *a priori* ranking scheme based on aspects of our set of study wetlands that differed from those of Lopez and Fennessy. None of our wetlands was situated in an urban setting, and all were surrounded by vegetated buffers, so those portions of the hierarchical classification scheme were removed or altered appropriately. The result was a ranking based on whether each site **(1)** was surrounded within the landscape by a) mature forest, b) grassland or young secondary growth forest, c) recently fallowed agricultural, or d) active agricultural land use, **(2)** was surrounded by an immediately adjacent a) forest or b) grassland buffer zone, and **(3)** possessed obvious signs of hydrologic alteration. The range of possible disturbance rankings with our modified chart was 1 to 16, whereas the range spanned from 1 to 24 with the chart provided in Lopez and Fennessy (2002). The results of each FAQWet calculation then were tested against results of both relative ranking methods to determine the efficacy of each index at indicating impinging anthropogenic disturbance within the local area, and thus, indirectly, the potential ecological integrity of the wetlands.

Linear regression analyses were used to determine the degree to which each FAQWet Index correlated with our site rankings, as has been done in previous work (Lopez and Fennessy, 2002; US EPA, 2002); we also included an evaluation of the FQAI in these comparisons. Additionally, each of these five index formulas was regressed against total species richness and total area surveyed in our sample plots, to determine whether these indices would be subject to direct influence by sampling effort or site richness, rather than solely by degree of ecological integrity.

Site descriptions

Data for this work were obtained from vegetation surveys conducted in ten wetlands located in north Mississippi. The least heavily impacted wetland (HSBP) was a beaver pond located near Holly Springs, MS, situated on a tributary of the Cold Water River (approximately 173 km northwest of Mississippi State University in Starkville, MS). The HSBP was approximately 20 years old and surrounded by mature, mixed hardwood forest. Although HSBP represented the least disturbed site, it did remain impacted hydrologically by former drainage ditches from agriculture in the associated floodplain. No agricultural practices had been conducted in the immediate floodplain for the previous 8 to 10 years. Other nearby sites (HSM1, HSM2, and HSFP) were chosen as intermediately disturbed sites. These were located in recently fallowed (4 to 7 years) cattle pastures and within 1.5 to 2.5km of the beaver wetland.

Three other intermediately disturbed wetlands (Nox 10, Nox 8 and Nox 11B) were chosen from a wetland complex in the moist soil management area of the Noxubee National Wildlife Refuge, located 22 km south of Starkville, MS. The wetland complex had been managed actively for migratory waterfowl for approximately 20 years and was surrounded completely by secondary growth forest. Management regimes in this wetland complex have included rotations of draw-downs, disking and mowing, and occasional planting of waterfowl forage species (e.g., Japanese millet, *Echinochloa crus-galli* (L.) Beauv. var. *frumentacea* (Link.) W.Wight.).

Three highly disturbed wetland sites (MP2, MP4 and NFP) were located in a landscape dominated by agricultural practices. All three sites were situated in pastures actively managed for cattle and hay production. Site NFP was located 20 km south of Starkville, MS; MP2 and MP4 were 11 km northwest of Starkville.

Plant surveys

Vegetation was surveyed during August and September of 2003. Sites NFP, Nox 11B, Nox 8, Nox 10, HSFP, MP2, and MP4 were surveyed by establishing ten transects evenly spaced around the perimeter, beginning from a random starting point. Based on visual inspection of the extent of the wetland vegetation, transects started at the outer portion of the vegetated zone and ended in the center of the wetland. At each 5m interval, two 0.25 m^2 quadrats were placed side by side, and all individual plants within each were identified to species and recorded. This continued until open water was reached and no submerged vegetation was present. Sites HSBP, HSM1, and HSM2 were surveyed from a random starting point along transects of 20 to 26 0.25m^2 quadrats placed approximately in the center of the wetland vegetated zone, running parallel to the edge of standing water present at the time.

Species identified in these surveys were assigned coefficients of conservatism based on a combination of origin, local and regional distributions, and degree of fidelity to a range of environmental disturbance, from pristine areas to frequently or intensively disturbed sites. Initial coefficients were assigned based on range and other descriptors used in Godfrey and Wooten (1979, 1981) and on nativity data provided in the PLANTS database (USDA NRCS, 2004). Coefficients were reviewed and revised in consultation with Dr. Mark Fishbein (Director, Mississippi State University Herbarium) and Ronald G. Wieland (Ecologist/Botanist, Mississippi Museum of Natural Science and Natural Heritage Program) prior to calculation of FQAI.

RESULTS

The disturbance rankings resulting from hierarchical classification of our sites are listed in Table 3, with the resulting index values for each site. Although the rankings of index values among sites were similar for all indices, the FQAI spanned a slightly smaller range than did the FAQWet formulas.

The results of our regression analyses, comparing the index values with site disturbance rankings from both the Lopez and Fennessy (2002) flow chart and our modification, suggested that all four FAQWet calculation methods may be effective at representing anthropogenic impacts to freshwater wetlands, and all are considerably better than the FQAI (Table 4). The best index appeared to be that which included the most information on the importance of invasive species in the habitats surveyed (FAQWet 4). This more complex index resulted in a correlation coefficient of 77% between our disturbance rank and FAQWet score, with a highly significant statistical P-value (0.001) (Table 4, Figure 1). Furthermore, FAQWet 4 was not significantly correlated with species richness (P = 0.10) or area surveyed (P = 0.88), whereas FQAI was correlated significantly with species richness (P = 0.03), but not area surveyed (P = 0.38). This last effect reflects the lack of correlation between species richness and area surveyed (or natural logarithm of area) in our study ($F_{1,8} = 0.17$, $R^2 = 0.02$, P = 0.69 for linear relation; $F_{1,8} = 0.35$, $R^2 = 0.04$, P = 0.57 for log-linear relation).

DISCUSSION

One major concern with methods such as those presented here is the correlation of area surveyed with species richness. This phenomenon has been cited as one potential cause of high floristic quality scores in previous assessments (Francis et al., 2000; Matthews, 2003). In one study, it was shown that FQAI values increased with area in four of the five wetland types surveyed (classified as floodplain forest, marsh, sedge meadow, and wet meadow) (Matthews, 2003). However, the results of that study indicated that in the best fit species-area regression (sedge meadows), natural log of surveyed hectares explained only 36% of variance in species richness ($R^2 = 0.36$) and had a slope of 0.17, indicating that for every additional hectare (2.47 acres) of wetland area, species richness increased by only 0.44 species (back-transformed data). In the other three wetland types included in that study, correlation coefficients (R^2) ranged from 0.05 to 0.06, and slopes from 0.05 to 0.12, indicating low correlation of richness with wetland area. Those data, although indicating statistically significant relationships between species and area surveyed, do not provide strong support for a position against using FQAI or similar indices in estimating ecosystem health or quality. Similarly, with the FAQWet Index evaluations presented here, we found significant relationships between species richness and index value (P < 0.05) only for FAQWet 1, FAQWet 2, and the FQAI, and we found no correlation between species richness and area surveyed.

Another difficulty in utilizing wetland plants as biological indicators is the slow response rate of woody vegetation to disturbance, such as altered hydrology (Cronk and Fennessy, 2001; Ehrenfeld et al., 2003). In fact, responses of trees to altered hydrology may even indicate improved growth conditions because of the alleviated stress from saturated, anoxic soils (Shawn Clark, Mississippi Department of Environmental Quality, personal communication). Forested wetlands also may present another problem, as forest canopy can reduce species richness in the herbaceous understory, and areas adjacent to logging operations may exhibit altered understory vegetation resulting from increased light availability, sedimentation, etc. (Ron Wieland, MS Museum of Natural Science and Natural Heritage Program, personal communication). However, the herbaceous layer responds rapidly to changes in local environment (Cronk and Fennessy, 2001; personal observations), and the presence of local human-induced disturbance (such as logging operations) often is accompanied by immigration of exotic and/or invasive species into the herb layer, even in forested wetland systems. Thus, our proposed methodology likely would capture the results of any such acute within-watershed disturbances, without being influenced by potentially conflicting signals of the overstory tree canopy. Conversely, analogous and frequently occurring natural canopy disturbances, such as windthrows or the creation of a new beaver impoundment, would be less likely to result in an accompanying introduction of exotic species, giving those areas a higher index score than a wetland impacted by human activities. Nevertheless, the approach we present here still requires additional evaluation for use in forested wetlands, and we would recommend separate analyses of datasets including and excluding data on overstory tree species.

The index recommended here, FAQWet 4, addresses contemporary wetlands research and conservation concerns by providing a mechanism through which managers and environmental monitoring agencies may evaluate directly wetland ecosystem status (degree of development of hydrophytic vegetation) and ecological integrity (proportion of exotic species within the plant assemblage). This index also may evaluate indirectly the interactive ecological effects of anthropogenic watershed stressors, such as water quality degradation through the response of wetland plants to point (effluent discharge) or non-point source factors (urbanization, intense agriculture). A more utilitarian benefit of the FAQWet Index is the ease of rapid implementation, as managers in regions with no current comprehensive listing of coefficients of conservatism have access to detailed lists of wetland indicator status (Reed, 1988; Reed et al., 1996: http://www.nwi.fws.gov/plants.htm) and information on the invasive nature of most exotic species one would encounter during wetland surveys (e.g., USDA PLANTS Database: http://plants.usda.gov/). Furthermore, in instances where new exotic species are encountered, determination of wetland indicator status for a single new species would be far easier than development of numerous local to regional lists of coefficients of conservatism for all plant species encountered.

Finally, the use of methods other than those that combine coefficients of conservatism with disturbance rankings is needed because of the inherent circularity of such approaches. Specifically, coefficients of conservatism are determined to some extent based on affinity of species with low quality, altered habitats, such as roadsides and waste areas (Herman et al., 1997). Disturbance ranking systems, such as that employed in this and other studies (Lopez and Fennessy, 2002; Fennessy et al. 2002) obviously include decisions pertaining directly to whether a site may be of low quality. Thus, one always would expect an index based on coefficients of conservatism to be correlated closely with degree of human impact on ecosystems. The method we present here addresses this issue to some extent by using a more objective plant metric based on species-level biology; however, further improvement could be made by incorporating more objective measures of human impact on ecosystems, such as may be available in GIS databases.

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Table 1. Wetland indicator status categories and equivalent wetness coefficients (Reed et al. 1996; Herman et al. 1997). Note that signs of wetness coefficients are reversed from Herman et al. (1997) to yield a positive correlation between wetness coefficient and indicators for sites with a predominance of wetland species.

Indicator Status	Probability of occurrence in Wetlands	Wetness Coefficient
Obligate wetland (OBL)	> 99%	+5
FACW+		+4
Facultative wetland (FACW)	67-99%	+3
FACW-		+2
FAC+		+1
Facultative (FAC)	34-66%	0
FAC-		-1
FACU+		-2
Facultative upland (FACU)	1-33%	-3
FACU-		-4
Upland (UPL)	< 1%	-5

Table 2. Effects of within-watershed land cover on relative contribution of native and wetland-adapted species to wetland plant assemblages (Lopez et al. 2002).

Plant group	Land Cover	Direction of effect	Effect on
All vascular plants	Grassland	Positive	%FACW spp.
	Open water	Positive	%OBL spp.
	Forest	Positive	%Native spp.
	Agriculture	Negative	%Native spp.
All woody spp.	Urban	Negative	%OBL
	Agriculture	Negative	%Native
All herbaceous spp.	Grassland	Positive	%FACW & %Native
	Open water	Positive	%OBL
	Forest	Positive	%Native
	Agriculture	Negative	%OBL & %Native
Emergent herbaceous spp.	Grassland	Positive	%FACW
	Open water	Positive	%OBL
	Forest	Positive	%Native
	Forest	Negative	%Invasive
	Agriculture	Negative	%OBL & %Native

Table 3. Site disturbance rankings and index values for FAQWet equations 1 through 4 and the Floristic Quality Assessment Index (FQAI). Disturbance rank (“Dist. Rank”) is based on the chart provided by Lopez and Fennessy (2002; “L&F”) and on our modification (“E&H”).

	Dist. Rank		FAQWet Indices				
Site	**L&F**	**E&H**	**#1**	**#2**	**#3**	**#4**	**FQAI**
HSBP	2	2	19	19	19	19	21
HSFP	10	12	11	11	11	11	16
HSM1	10	12	9	9	7	8	12
HSM2	10	8	14	15	13	14	14
MP2	10	16	13	12	10	9	17
MP4	10	16	14	13	12	12	18
Nox8	4	4	17	17	14	15	22
Nox10	4	4	14	15	12	14	17
Nox11B	4	4	19	18	17	16	20
NFP	10	16	8	7	5	7	12

Table 4. Comparison of analyses for our proposed indices (FAQWet 1 through 4) and the Floristic Quality Assessment Index (FQAI). The heading "L&F Dist. Rank" refers to disturbance ranks determined by the chart in Lopez and Fennessy (2002).

Index	Slope	R^2	$F_{1,8}$	P
vs. L&F Dist. Rank				
FAQWet 1	-0.88	0.62	13.3	0.007
FAQWet 2	-0.92	0.67	15.9	0.004
FAQWet 3	-0.91	0.57	10.6	0.01
FAQWet 4	-0.93	0.70	18.4	0.003
FQAI	-0.79	0.59	11.5	0.01
vs. our Dist. Rank				
FAQWet 1	-0.52	0.59	11.5	0.01
FAQWet 2	-0.57	0.70	19.0	0.002
FAQWet 3	-0.56	0.61	12.5	0.008
FAQWet 4	-0.60	0.78	27.9	0.001
FQAI	-0.39	0.39	5.0	0.06
vs. Species Richness				
FAQWet 1	+0.30	0.59	11.5	0.009
FAQWet 2	+0.28	0.47	7.1	0.03
FAQWet 3	+0.26	0.39	5.0	0.06
FAQWet 4	+0.22	0.30	3.5	0.10
FQAI	+0.27	0.53	9.1	0.02
vs. Area Surveyed				
FAQWet 1	+0.20	0.03	0.3	0.6
FAQWet 2	+0.15	0.02	0.1	0.7
FAQWet 3	+0.05	0.002	0.01	0.9
FAQWet 4	+0.06	0.003	0.02	0.9
FQAI	+0.28	0.07	0.6	0.5

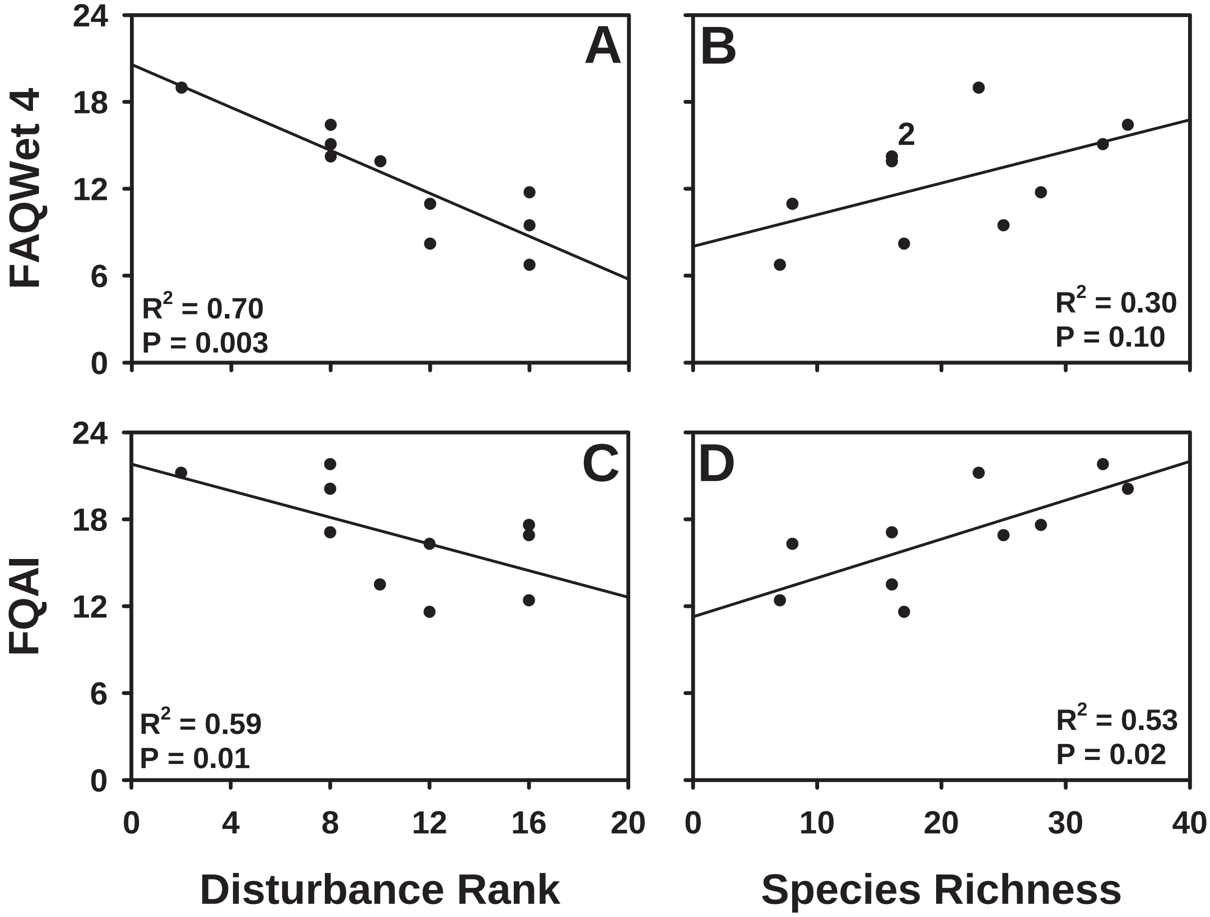

Figure 1. Comparison of regression analyses for FAQWet Index 4 and the Floristic Quality Assessment Index (FQAI) for the ten wetland sites represented in this study. A) FAQWet4 vs. Site disturbance rank, B) FAQWet4 vs. Species richness, C) FQAI vs. Site disturbance rank, D) FQAI vs. Species richness. Correlation coefficients (R^2) and statistical significance (P-value) are indicated in the lower-left of each panel. The inset number “2” in panel **B** indicates overlapping data points.

SEASONAL AND SPATIAL VARIATION IN PHYTOPLANKTON COMMUNITY DYNAMICS IN SARDIS RESERVOIR, NORTHEASTERN MISSISSIPPI.

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ABSTRACT

Reservoirs, formed by river impoundment, can exhibit longitudinal spatial gradients in physical and chemical characteristics such as water transparency, chemical availability, and depth. Development and maintenance of these gradients is influenced by reservoir management operation affecting the rate at which water flows through the reservoir (hydrologic residence time). This research was conducted in Sardis Reservoir, in northeastern Mississippi. When flux of water out of the reservoir is restricted, as during the summer, hydrologic residence time increases and gradients develop in physicochemical characteristics along a transect from the riverine to the lacustrine (near dam) end of the reservoir. We hypothesized that, associated with these gradients, there would develop spatial variation in phytoplankton community composition, biomass, and productivity. To test this hypothesis, we made measurements over an annual cycle along the main longitudinal axis of Sardis Reservoir as well as in the embayment of three major tributaries. This reservoir, built for flood control, functions more like a lake during spring and summer when flood control gates are nearly closed, but more like a river during fall and winter. For examination of phytoplankton biomass and community composition we measured concentrations of taxon-specific photosynthetic pigments using high pressure liquid chromatography. Total phytoplankton biomass generally increased from spring through summer into fall. Based on indicator pigment concentrations, chlorophyte biomass peaked in summer, cyanobacteria were most common in summer and fall, and chrysophyte biomass peaked in both spring and fall. There were three distinct peaks in diatom abundance, one each in spring, summer and fall. Spatial heterogeneity in phytoplankton communities was most distinct in summer, especially between the two most distant sampling stations. The proportion of the total phytoplankton community of chlorophyll b, an indicator of chlorophytes, was consistently higher at the riverine end of the reservoir than at the lacustrine end. In contrast, the proportion of

diatoxanthin, a diatom indicator pigment, was consistently higher nearest the dam in the lacustrine portion of the reservoir. Seasonal variation in phytoplankton community biomass, composition and productivity can be linked to seasonal changes in water temperature, light and nutrient conditions, along with hydrologic changes associated with reservoir operation.

INTRODUCTION

Development of heterogeneous aquatic communities within a lake is a common phenomenon due to spatial and temporal variation in physical and chemical processes acting in the lake. The complexity of processes occurring in man-made systems like reservoirs, built by damming a river, is further compounded by their operating conditions. Reservoirs often exhibit spatial and temporal diversity in plankton distribution, composition, productivity and biomass due to longitudinal gradients in morphology, water inflow, retention time, and light and nutrient conditions (Kimmel et. al 1990). There is a general increase in light availability and residence time, and general decrease in nutrient availability and abiogenic turbidity along the longitudinal transect from up-lake to down-lake regions of a reservoir. River and lake interactions form a basis of such heterogeneity, where riverine conditions are prevalent in up-lake section whereas lacustrine conditions occur in the areas near the dam. But every reservoir is a unique system due to differences in operating conditions, size, morphology and location. Any changes in water conditions would be expected to reflect in phytoplankton community responses. A reservoir can harbor phytoplankton populations having different growth requirements, and communities often being continuously replaced in the course of time. Knowledge about the extent of diversity occurring within a system and how the variation in external factors affects the phytoplankton community dynamics would be valuable for an aquatic ecologist and a useful management tool for a reservoir resource manager.

Furthermore, studies of phytoplankton communities in reservoirs often focus on a single sampling location, usually the deepest point in the reservoir (Chrzanowski 1985; McGaha 1966). But a single sampling location may not be a representative condition to make inferences for the whole reservoir.

The purpose of this study was to evaluate the seasonal patterns in phytoplankton community characteristics along the longitudinal transect of Sardis reservoir. This is a descriptive study where the physicochemical factors and phytoplankton responses are measured in the natural setting. We study major factors relevant to the reservoir, especially nutrient availability, light conditions and water residence time that can limit phytoplankton biomass, production and composition. The phytoplankton composition was determined for six major taxonomic groups by measuring their characteristic pigment signatures with high performance liquid chromatograph. HPLC can detect pigments for fragile or small phytoplankton that are difficult to identify with microscopic counts (Roy et al. 1996).

METHODS

Study site

Sardis Reservoir is a flood control reservoir built in 1940 by damming the Little Tallahatchie River located in north eastern Mississippi. It lies in the Little Tallahatchie Watershed of the Yazoo river basin and covers a drainage area of 526 sq. miles (Fig. 1). Flood control operations and variable amounts of runoff from flowing streams results in large seasonal changes in water level and flow rates (Aumen et al. 1992). The surface area of the lake is greater than 12000 ha in summer which is reduced to less than 5000 ha by winter due to hypolimnetic water releases beginning in early fall and the water level starts to gradually rise from early spring. The water residence time is longest in summer and shortest in winter (Ochs and Rhew 1997).

Sampling

The lake was sampled for a suite of limnological parameters including phytoplankton community characteristics from March 2004 to April 2005 with one to two site visits per month. Samples were collected from three stations along the longitudinal transect of the reservoir and three major tributary embayment. Station 1 is the down-lake station representing the lacustrine zone, Station 3 is the mid-lake station representing a transitional zone, Station 6 is the up-lake station representing the riverine zone, Station 2 is Clear Creek embayment area, Station 4 is Toby Tubby Creek embayment area and Station 5 is Hurricane Creek embayment area (Fig. 1).

Field samples were taken from March 2004 to November 2004 with a total of thirteen sampling dates. The first four dates in March, April and May represent spring samples, the next five dates in June, July and August represent summer samples, and the last four dates in September, October and November represent fall samples.

Water samples were collected at 0.5 m depth at all stations as three replicates in 2 liter HDPE Nalgene bottles and kept cool and in the dark until sample processing, usually within 2-4 hours after collection.

Physical and chemical properties

Temperature and oxygen profiles were measured using a YSI Model 57 oxygen meter. Light extinction profiles were obtained using LI-1000 radiometer with spherical quantum sensor and deck mounted reference cell. Water transparency was measured with a 20-cm diameter Secchi disc. Turbidity was measured in the laboratory with Hach Model 2100A turbidimeter.

Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) were measured with an Astoria auto-analyzer in water filtered through Whatman GF/F filters (0.75µm), after digestion with alkaline persulphate (Charles et al. 2003).

Phytoplankton community analysis

Phytoplankton pigment extraction and determination was carried out using the method outlined in Jeffery et al. (1997) (modified). The water samples (200-400ml) were filtered through Whatman GF/F filters (0.75-µm) under low vaccum (<380 mm Hg) and the filters stored in a ultra-cold freezer (-70^{o}C) until pigment extraction. For extraction, the filters were cut into small pieces and soaked in 90% acetone for 2 hrs at 4^{0}C in the dark. The samples were sonicated under low light and in an ice-bath for 30-60 seconds. The sonicated filters with the acetone were emptied into plastic test tubes pierced at the bottom and placed in a scintillation vial and centrifuged at 2000 rpm for 3 minutes. The supernatant was filtered through a 0.4-µm Millex hydrophilic LCR (PTFE) filter prior to pigment separation by high performance liquid chromatograph.

Phytoplankton community composition was identified for major taxonomic groups (Table. 1) by pigment analysis using reverse phased Dionex HPLC. The HPLC system consisted of a photodiode array detector (Dionex PDA 100), pump (Dionex P580) and silica C8 column (Alletech Allsphere ODS-2 5 µ). The system used a 1 ml/ min flow rate and 3-solvent gradient system (see Jeffery et al. 1997 for details). Pigments were identified by retention time and absorption spectrum and their concentration analysed using Dionex Chromeleon software. The HPLC had been calibrated with pigment standards obtained from the International Agency for ^{14}C Determination (DHI Water and Environment), Hørsholm, Denmark.

Volumetric primary production was measured in all sites at all dates by the ^{14}C-method as explained in Wetzel and Likens (1991). Twenty-four ml of water sample in glass serum vials loosely topped with rubber stoppers were inoculated with 25 µl of $NaH^{14}CO_3$ (20 µCi/ml) and incubated in a laboratory incubator at in situ temperature and at saturating light levels (560 µmolar irradiance) for 2-3 hours. The total dissolved inorganic carbon (DIC) assimilated was estimated from the radiolabeled carbon assimilated and available DIC in water (Ochs and Rhew 1997).

RESULTS

Light and nutrient conditions

There was steady decrease in turbidity from spring to summer and increase during fall (Fig. 2A). There were statistically significant differences in turbidity at five of the six sites in summer with the up-lake station (station 6) having the highest and the down-lake station (station 1) having the lowest mean values (Table 2). During spring, the turbidity conditions were similar at all stations and in fall, the up-lake and down-lake stations were the only sites different from each other (Table 2). TDN and TDP concentrations did not show any statistically significant differences among the sites in any season (Table 2), but there was a seasonal difference with high spring values and generally low summer values (Fig 2C, 2D). TDP was reduced to negligible amounts in summer.

Phytoplankton biomass, production and Production:Biomass (P:B) ratio

Phytoplankton biomass, estimated as chlorophyll a (chl a) pigment, tended to increase steadily from spring to fall with two distinct peaks in spring and summer and maximum values in late fall (Fig. 3A). The mean values were highest at the up-lake station and lowest at the down-lake station. These two stations were significantly different at all times whereas station 2 and 3 were similar to down-lake and station 4 and 5 were similar to the up-lake station (Table 2).

Productivity decreased from spring to summer and rose again in fall (Fig. 3B). Photosynthetic capacity (P:B ratio) was highest in spring, and least during summer and slowly increased during fall at all stations (Fig. 3C). There were no statistically significant differences in spring and fall at all stations. The only difference was between station 1 and 6 in summer.

Phytoplankton community composition by HPLC pigment analysis

The amount of chlorophyll b (chl b), a signature pigment for chlorophytes, was higher in summer than spring and fall at all stations (Fig. 4A). Differences in chl b concentration between up-lake and down-lake stations were statistically significant in all three seasons (Table 2). The three stations near the dam (Station 1, 2, 3) were different than three stations near the river (Station 4, 5, 6) but there was similarity among the three in both groups.
The amount of diatoxanthin, a signature pigment for diatoms, showed three distinct peaks in spring, summer and fall (Fig. 4B). Spatial differences in diatoxanthin were not obvious in all three seasons (Table 2).

The amount of fucoxanthin, a signature pigment for chrysophytes, declined from spring to summer and increased in fall at all stations (Fig. 4C). The differences between the up-lake and down-lake station were statistically significant in spring and summer but not in fall (Table 2). The other stations had intermediate mean values.

The amount of zeaxanthin, a signature pigment for cyanobacteria, was only detected during late spring with high mean values in summer at all stations (Fig. 4D). Zeaxanthin concentrations were not statistically different among sites in all three seasons (Table 2).

Phytoplankton community composition, as indicated by indicator pigments as a ratio of total phytoplankton biomass, differed at the two spatially extreme stations of up-lake and down-lake, during summer (Fig. 5). The chl b/chla ratio, the chlorophyte indicator, was higher at the up-lake station than the down-lake station (Fig. 5A). The fucoxanthin/chl a ratio, the chrysophyte indicator, was consistently higher at the up-lake station than the down-lake station even though the differences were smaller (Fig 5C). In contrast, the diatoxanthin/chl a ratio, the diatom indicator, was higher at the down-lake station than up-lake station (Fig. 5B). The zeaxanthin/chl a ratio, the cyanobacteria indicator, was similar at both stations (Fig. 5D).

CONCLUSION

As indicated by the four signature pigments of chl b, diatoxanthin, fucoxanthin and zeaxanthin representing chlorophytes, diatoms, crysophytes and cyanobacteria respectively, the phytoplankton groups showed distinct and consistent differences both seasonally and spatially. Their abundance changed on a seasonal basis (Fig. 4). The proportion of each pigment to total phytoplankton biomass showed distinct spatial variation at the two most extreme stations of up-lake and down-lake during summer (Fig. 5). Chlorophytes were an important part of the phytoplankton population in summer (Fig. 4A) whereas cyanobacteria only appeared in summer and were not prevalent in fall (Fig. 4D). Chrysophytes were abundant in spring and fall (Fig.

4C). Diatoms were an important part of the phytoplankton population at all times with three distinct seasonal peaks for spring, summer and fall (Fig. 4B).

These changes in the phytoplankton community might be linked to seasonal changes in temperature (Fig. 2B) and changes in light (Fig. 2A) and/or nutrient (Fig. 2C, 2D) conditions. Phytoplankton with differing growth responses to nutrient concentrations, mixing and turbidity will produce taxonomically distinct populations and the effect of each factor will shift the community composition, even though there might not be any consistent pattern (Pickney et al. 2001). The seasonal changes in abundance of differing phytoplankton groups (Fig. 4) are also parallel to reservoir operation. Water was turbid with lower surface temperature in spring and fall whereas water was clearer with higher surface temperature in summer throughout the reservoir (Fig.2). The dam gates are opened at the beginning of fall and closed at the beginning of spring which creates turbid conditions in fall, winter and early spring. The water level gradually rises through spring and summer. As a result of this, the reservoir is expected to be more heterogeneous in summer when stations near the dam are more like a lake and stations near the river are more like a lotic system. Spatial variation in physicochemical conditions of water and phytoplankton response characteristics was most distinct in summer when the reservoir is heterogeneous, especially at the two extreme stations of up-lake and down-lake.

Phytoplankton biomass generally increased from spring to fall with peaks in spring and summer and a less evident peak in fall (Fig 3A). At some stations, there was a decline in phytoplankton biomass at the end of spring and possibly lesser decline at the end of summer (Fig. 3A). The decline in phytoplankton biomass at the end of spring might be due to a decline in mainly crysophytes and diatoms (Fig. 4B, 4C), favored by lower temperature, higher turbidity and higher nutrient conditions of early spring (Fig. 2). The decline in phytoplankton biomass at the end of summer might be due to a decline in population of mainly chlorophytes, cyanobacteria and possibly a different population of diatoms (Fig. 4A, 4B, 4C), favored by higher temperature, lower turbidity and probably lower nutrient conditions of summer (Fig. 2). The abundance of chlorophytes and cyanobacteria decreased at the beginning of fall with the regain of turbid conditions and decreasing temperature, when crysophytes and diatoms, as in the spring, became more abundant (Fig. 4B, 4C).

The proportion of chlorophytes to total phytoplankton biomass was more important at the up-lake station than the down-lake station in summer, suggesting their ability to thrive in more turbid and a possibly nutrient richer environment (Fig. 5A, 2). The pattern was similar but less prominent for crysophytes (Fig. 5C). In contrast, the proportion of diatoms to total phytoplankton biomass was more important at the down-lake station than up-lake station in summer, suggesting their ability to thrive in the less turbid and possibly more nutrient deficient environment of down-lake (Fig. 5B, 2). Even though the dissolved nutrient concentration was not different at these two stations in summer (Table 2), nutrient availability at the up-lake station might be higher, as suggested by the substantial difference in phytoplankton biomass. The proportion of cyanobacteria to total phytoplankton biomass was important at both stations in late summer and early fall, suggesting nitrogen deficiency in the reservoir during those periods (Fig. 5D). The per capita productivity of the phytoplankton was low in summer as illustrated by the P: B ratio (Fig. 2C). This can most likely be attributed to the deficiency in nutrients.

In this descriptive study of changes in phytoplankton community dynamics in a reservoir, we found that, on an annual basis, seasonal variation is more distinct than spatial variation. During summer the spatial separation is more distinct, especially between the two most distant stations. The seasonal variation can be linked to seasonal changes in water temperature, light and nutrient conditions, along with dramatic changes causes by with the reservoir operation.

List of Figures:

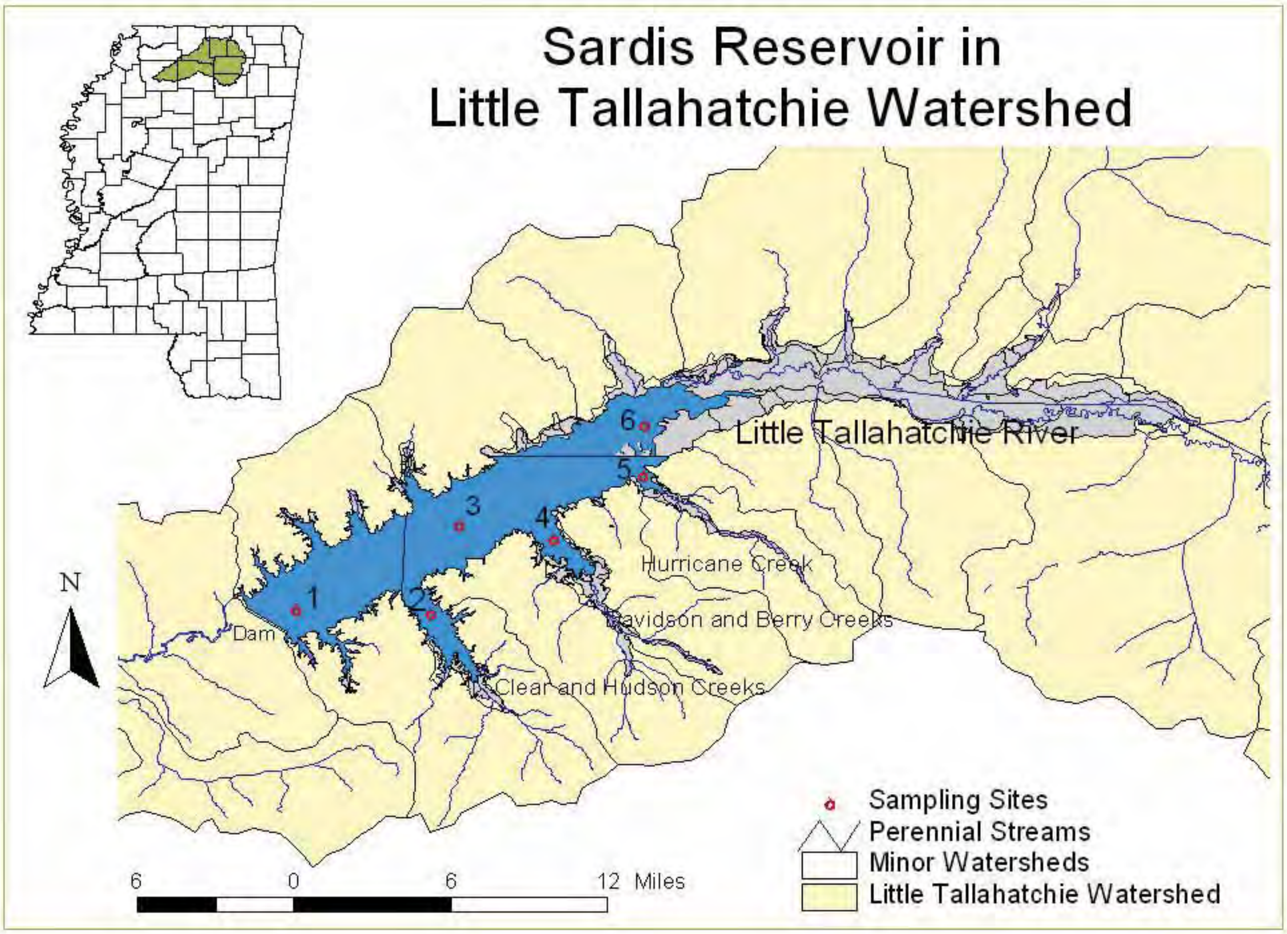
Figure 1. Sardis Reservoir in Little Tallahatchie Watershed, northeastern Mississippi (www.maris.state.ms). Map indicates six sampling locations. The dark area illustrates conservation pool water level (71.9 m above MSL) and shaded area illustrates flood-control pool water level (85.8 m above MSL) (Ochs and Rhew 1997). Numbers indicated sampling locations.

Figure 2. A. Turbidity by season in 2004. B. Surface temperature. C. Total dissolved nitrogen. D. Total dissolved phosphorus

Figure 3. A. Phytoplankton biomass by season in 2004. B. Phytoplankton production by season. C. Production to biomass ratio.

Figure 4. A. Chl b concentration by season in 2004. B. Diatoxanthin concentration. C. Fucoxanthin concentration. D. Zeaxanthin concentration. Lines indicated sequential measurements above zero.

Figure 5. A. Chl b: Chl a ratio by season in 2004. B. Diatoxanthin: Chl a ratio. C. Fucoxanthin: Chl a ratio. D. Zeaxanthin: Chl a ratio.



Station 1: Down-lake (DL)
Station 2: Clear creek embayment (CC)
Station 3: Mid-lake (ML)
Station 4: Toby Tubby (Davidson and Berry) embayment (TT)
Station 5: Hurricane creek embayment (HC)
Station 6: Up-lake station (UL)

Figure 1

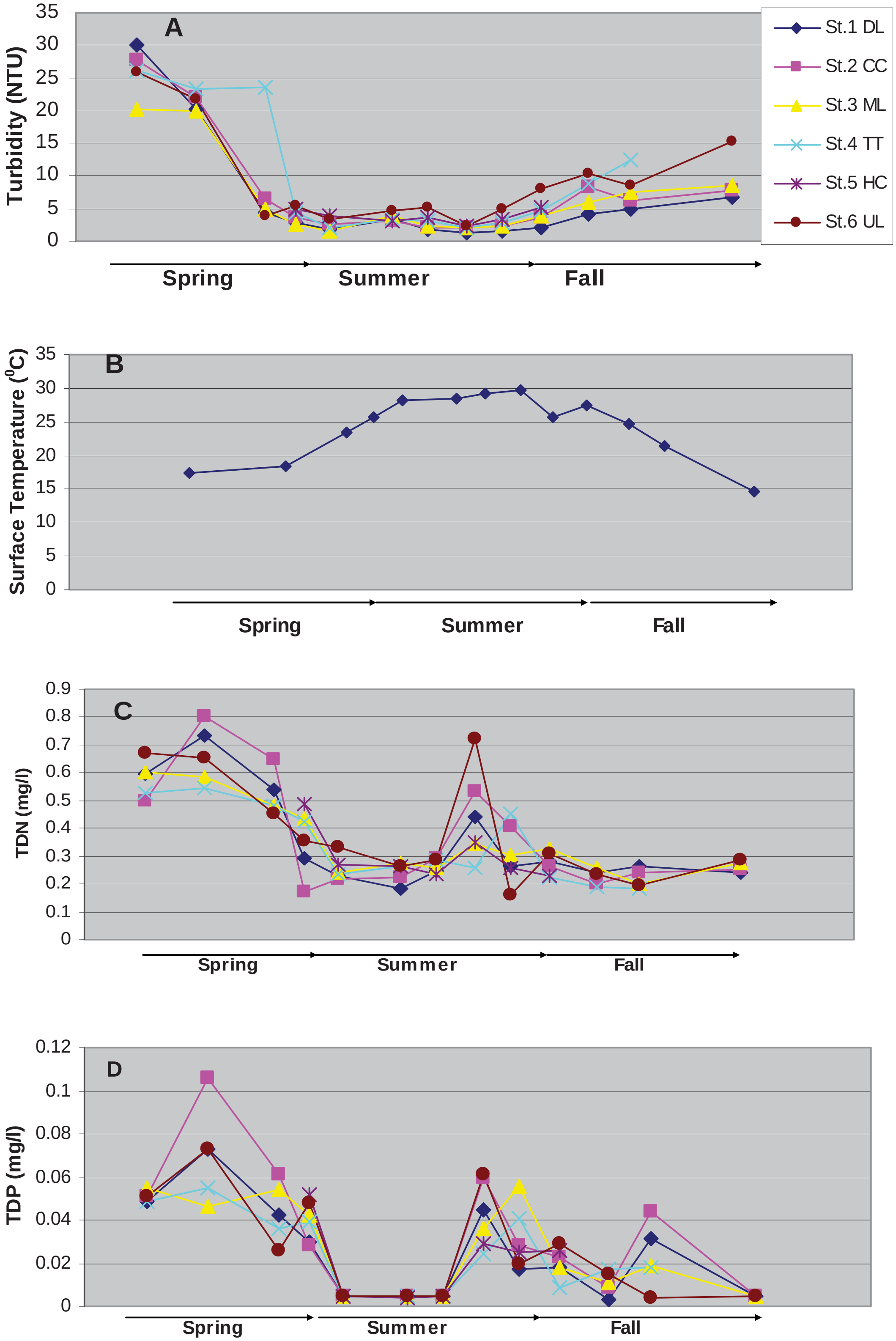

A
Turbidity (NTU)
35
30
25
20
15
10
5
0
St.1 DL
St.2 CC
St.3 ML
St.4 TT
St.5 HC
St.6 UL
Spring
Summer
Fall
B
Surface Temperature (^{0}C)
35
30
25
20
15
10
5
0
Spring
Summer
Fall
C
TDN (mg/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Spring
Summer
Fall
D
TDP (mg/l)
0.12
0.1
0.08
0.06
0.04
0.02
0
Spring
Summer
Fall

Figure 2

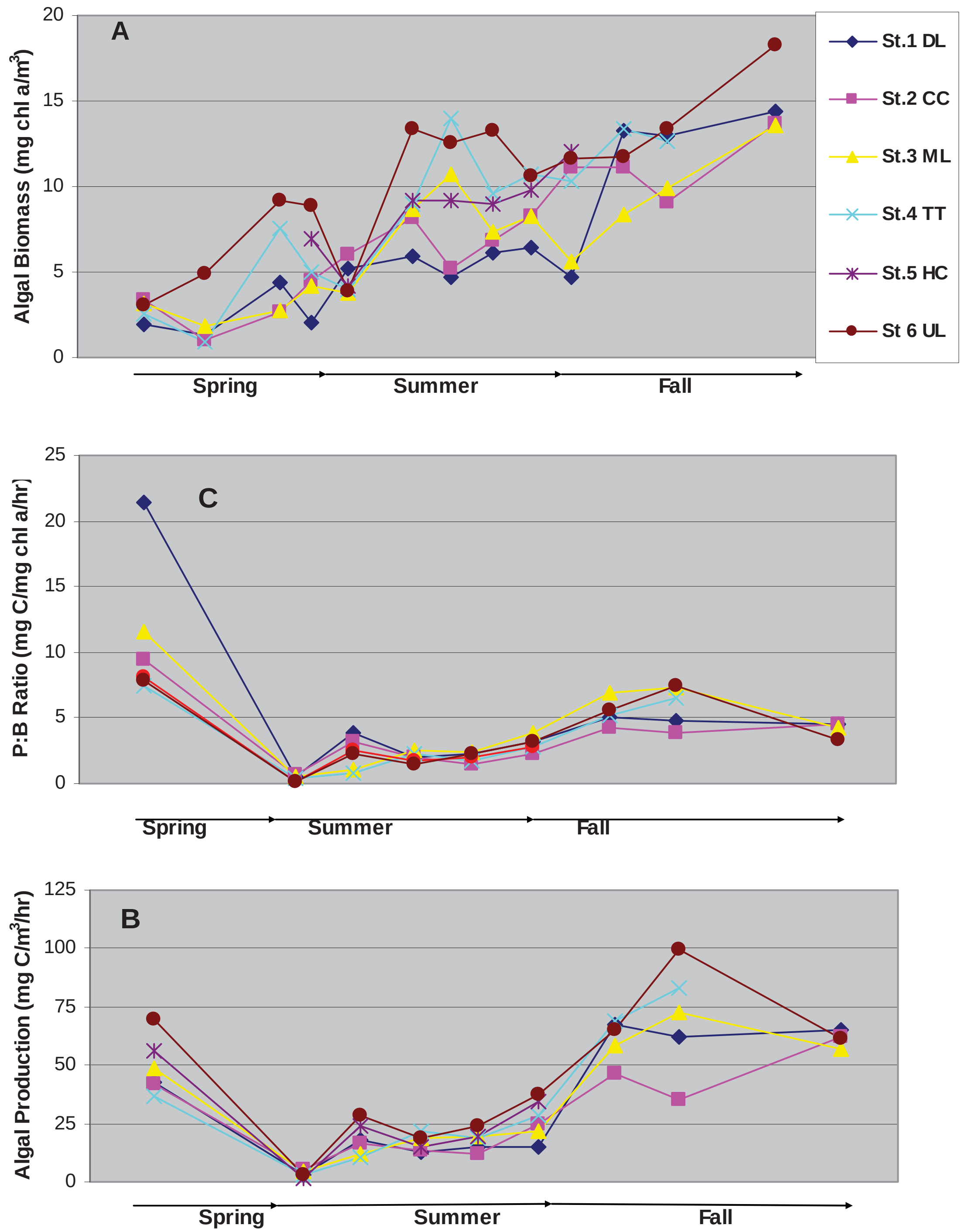

A
Algal Biomass (mg chl a/m^3)
0
5
10
15
20
St.1 DL
St.2 CC
St.3 ML
St.4 TT
St.5 HC
St 6 UL
Spring
Summer
Fall
C
P:B Ratio (mg C/mg chl a/hr)
0
5
10
15
20
25
Spring
Summer
Fall
B
Algal Production (mg C/m^3/hr)
0
25
50
75
100
125
Spring
Summer
Fall

Figure 3

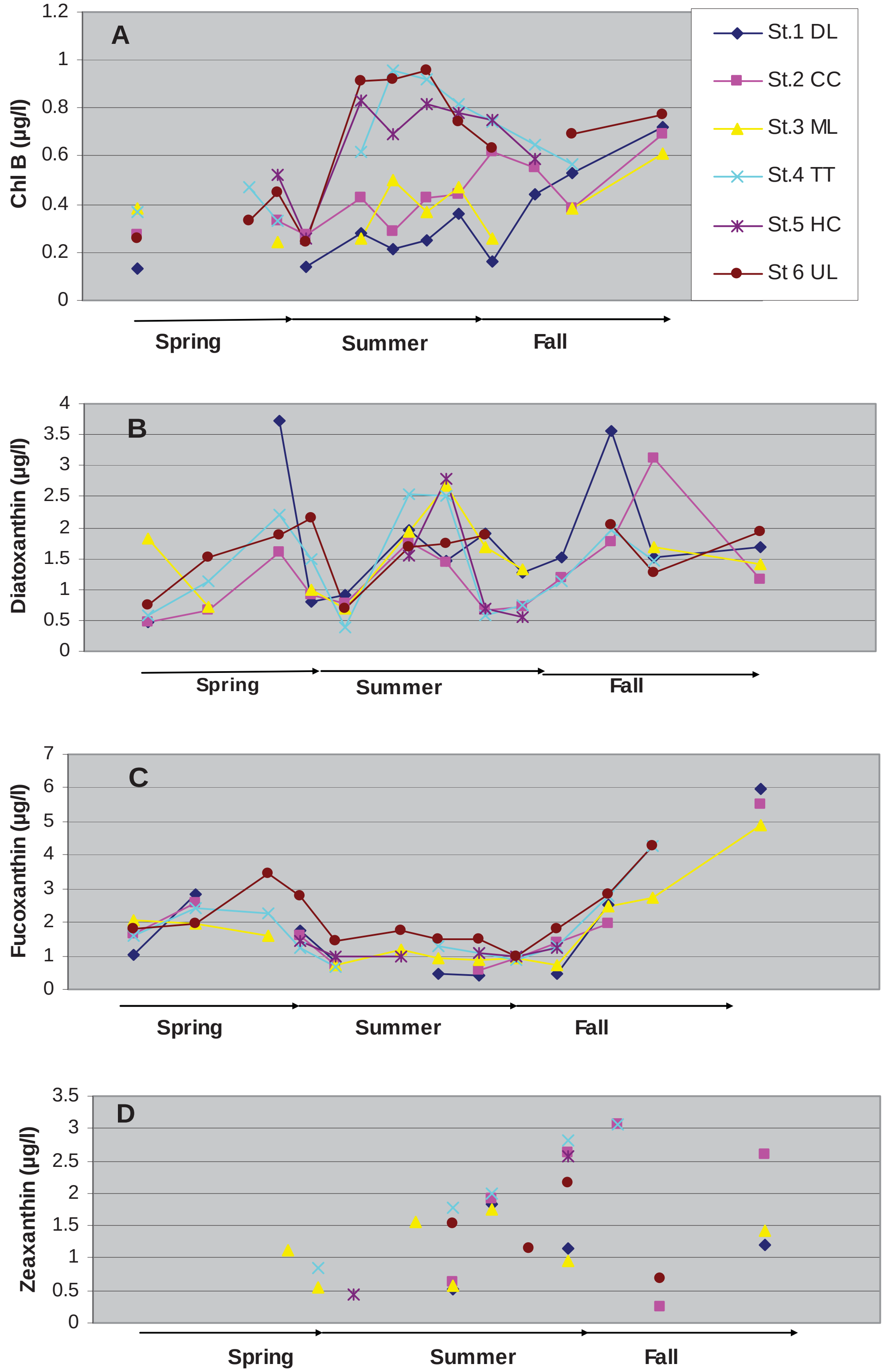

A
B
C
D
1.2
1
0.8
0.6
0.4
0.2
0
Chl B (µg/l)
St.1 DL
St.2 CC
St.3 ML
St.4 TT
St.5 HC
St 6 UL
Spring
Summer
Fall
Diatoxanthin (µg/l)
4
3.5
3
2.5
2
1.5
1
0.5
0
Fucoxanthin (µg/l)
7
6
5
4
3
2
1
0
Zeaxanthin (µg/l)
3.5
3
2.5
2
1.5
1
0.5
0

Figure 4

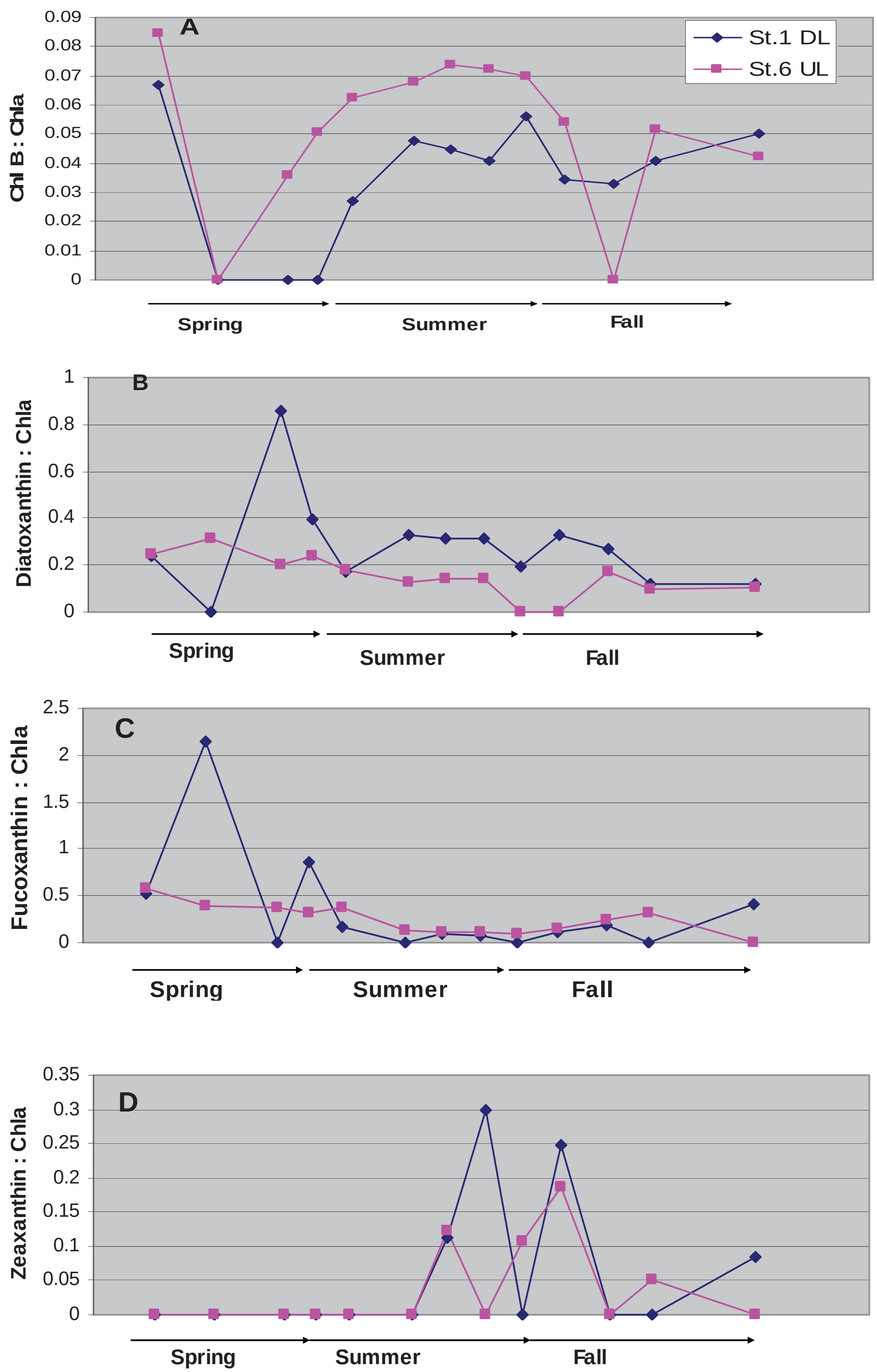

A
B
C
D
St.1 DL
St.6 UL
Chl B : Chla
Diatoxanthin : Chla
Fucoxanthin : Chla
Zeaxanthin : Chla
Spring
Summer
Fall

Figure 5

Table 1: Taxonomic diagnostic pigments (chlorophylls and carotenoids) used in classifying phytoplankton composition (modified from Vinebrooke and Leavitt 1998)

Pigment	Phytoplankton Group
Chla	All phytoplankton
Chl b	Chlorophytes
ß-carotene	All phytoplankton
Alloxanthin	Cryptophytes
Diatoxanthin	Diatoms, few Chrysophytes
Fucoxanthin	Chrysophytes, diatoms, and some dinoflagellates
Lutein	Chlorophytes
Zeaxanthin	Cyanobacteria
Peridinin	Dinoflagellates

Table 2. Two way ANOVA for parameters listed in the study. Two main effects of date and station location were tested for the given variables. Station means having the same subscript are not significantly different from each other at $P<0.05$. NS = not significant. Cells lacking values indicate no measurements. Zero values indicate no detection.

Variables		Date		Station		Station Means					
		P	df	P	df	1	2	3	4	5	6
Biomass (mg chl a /m^3)											
	Spring	0.0001	3	0.0001	4	2.41 ^{a}	2.87 ^{a}	2.99 ^{a,b}	4.01 ^{b}		6.52 ^{c}
	Summer	0.0001	4	0.0001	5	5.12 ^{a}	6.31 ^{a,b,d}	7.76 ^{b,c,d}	9.45 ^{c,d,e}	8.27 ^{d}	10.73 ^{e}
	Fall	0.0001	3	0.0001	4	11.35 ^{a}	11.25 ^{a}	9.38 ^{b}	12.28 ^{a,c}		13.76 ^{c}
P:B (mg C /chl a/hr)											
	Spring	0.0001	3	NS	4	2.48 ^{a}	1.51 ^{a}	1.93 ^{a}	1.22 ^{a}		1.29 ^{a}
	Summer	0.0001	4	0.019	5	1.85 ^{a}	1.37 ^{a,b,c}	1.37 ^{a,b,c}	1.02 ^{b,c}	1.23 ^{a,b,c}	1.08 ^{c}
	Fall	0.0001	3	0.0001	4	4.42 ^{a,c}	3.74 ^{c}	5.72 ^{b}	5.25 ^{a,b}		4.93 ^{a,b}
TDN (mg/l)											
	Spring	0.005	3	NS	4	0.54 ^{a}	0.53 ^{a}	0.53 ^{a}	0.49 ^{a}		0.52 ^{a}
	Summer	0.01	4	NS	5	0.27 ^{a}	0.32 ^{a}	0.28 ^{a}	0.3 ^{a}	0.28 ^{a}	0.31 ^{a}
	Fall	0.0001	3	0.0001	4	0.26 ^{a}	0.24 ^{a,b}	0.27 ^{a}	0.19 ^{b}		0.26 ^{a}
TDP (mg/l)											
	Spring	0.04	3	NS	4	.05 ^{a}	.06 ^{a}	.05 ^{a}	.04 ^{a}		.05 ^{a}
	Summer	0.0001	4	NS	5	.02 ^{a}	.03 ^{a}	.02 ^{a}	.02 ^{a}	0.18 ^{a}	.02 ^{a}
	Fall	0.0001	3	NS	4	.01 ^{a}	.02 ^{a}	.013 ^{a}	.016 a		.013 ^{a}
Turbidity (NTU)											
	Spring	0.0001	3	0.0001	4	14.43 ^{a}	14.95 ^{a}	11.97 ^{a}	19.36 ^{b}		12.16 ^{a}
	Summer	0.001	4	0.0001	5	1.87 ^{a}	2.34 ^{b}	2.45 ^{b}	2.73 ^{c}	3.25 ^{d}	4.08 ^{e}
	Fall	0.0001	3	0.0001	4	4.44 ^{a}	6.48 ^{b}	6.46 ^{b}	9.62 ^{c}		10.56 ^{c}
Chl B (µg/l)											
	Spring	0.0001	3	0.003	4	0.02 ^{a}	0.1 ^{a,b,c,d}	0.15 ^{b,c,d}	0.18 ^{c,d}		0.19 ^{d}
	Summer	0.0001	4	0.0001	5	0.16 ^{a}	0.29 ^{a}	0.25 ^{a}	0.66 ^{b}	0.62 ^{b}	0.74 ^{c}
	Fall	0.001	3	0.0001	4	0.38 ^{a}	0.56 ^{b}	0.31 ^{a}	0.63 ^{b}		0.62 ^{b}
ß-carotene (µg/l)											
	Spring	NS	3	NS	4	0	0	.004 ^{a}	0		.03 ^{a}
	Summer	0.0001	4	0.004	5	0.08 ^{a}	0.11 ^{a,b}	0.09 ^{a}	0.1 ^{a}	0.2 ^{b}	0.12 ^{a,b}
	Fall	0.0001	3	NS	4	0.09 ^{a}	0.2 ^{a}	0.07 ^{a}	0.14 ^{a}		0.2 ^{a}
Alloxanthin (µg/l)											
	Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Summer	NS	4	NS	5	0.19 ^{a}	0.03 ^{a}	0	0.1 ^{a}	0.03 ^{a}	0.13 ^{a}
	Fall	NS	3	NS	4	0	0.06 ^{a}	0	0		0.17 ^{a}
Diatoxanthin (µg/l)											
	Spring	NS	3	NS	4	0.73 ^{a}	1.09 ^{a}	0.74 ^{a}	0.65 ^{a}		1.18 ^{a}

	Summer	0.0001	4	0.03	5	1.2 [a,b,c]	0.79 [a,b,c]	1.3 [b]	0.45 [c]	0.69 [a,b,c]	0.92 [a,b,c]
	Fall	0.0001	3	0.014	4	1.81 [a]	1.47 [a,b]	0.76 [b]	1.14 [a,b]		0.98 [a,b]
Fucoxanthin (µg/l)											
	Spring	0.0001	3	0.0001	4	1.11 [a]	1.32 [a,b]	1.14 [a,b]	1.66 [b]		2.49 [c]
	Summer	NS	4	0.0001	5	0.26 [a]	0.26 [a]	0.59 [a,b,c]	0.7 [b,c]	0.67 [c]	1.3 [d]
	Fall	0.0001	3	0.002	4	2.21 [a]	1.18 [a]	2.41 [a,b]	3.04 [a,b]		1.2 [a]
Zeaxanthin (µg/l)											
	Spring	NS	3	NS	4	0.0002 [a]	0	0.0001 [a]	0.00001 [a]		0
	Summer	0.0001	4	0.003	5	0.0002 [a]	0.0004 [a,b]	0.0002 [a,b]	0.0006 [b]	0.00003 [a]	0.0005 [a]
	Fall	0.011	3	0.006	4	0.0002 [a]	0.001 [b]	0.0002 [a,b]	0.001 [a,b]		0.0002 [a,b]
Lutein (µg/l)											
	Spring	0.0001	3	NS	4	0.2 [a]	0.16 [a]	0.17 [a]	0.41 [a]		0.36 [a]
	Summer	0.001	4	0.005	5	0.17 [a,b,c]	0.21 [a,b,c]	0.1 [b]	0.55 [c]	0.57 [c]	0.38 [a,b,c]
	Fall	0.0001	3	0.034	4	0.72 [a,b]	0.62 [a]	0.78 [a,b]	0.8 [a,b]		1.32 [b]

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Duplicity of wetland plants in nutrient flux within agricultural drainage ditches in Mississippi

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Abstract

Drainage ditches, as integral components of the agricultural landscape, remove surface run-off and act as major conduits of nutrients from agricultural lands to receiving waters. These ditches are filled with wetland plants, providing additional surface area for microbial interactions as well as acting in a small, yet important assimilatory capacity. However, their assimilatory function is negated in winter with seasonal die-back and the release of assimilated nutrients into the system. We tested the hypotheses of whether plants, given the opportunity, will firstly assimilate higher concentrations of nutrients, such as nitrogen and phosphorus, and whether with subsequent decomposition these concentrations are released back into the water column. Given the opportunity *Leersia oryzoides,* a dominant wetland ditch plant species, will assimilate significantly higher concentrations of nitrogen ($p < 0.001$) and phosphorus ($p < 0.001$) in aboveground biomass. Subsequently, the senescence of aboveground biomass yielded significantly higher levels of phosphorus ($\pm$ 5.2 mg/l). However, there were no significant differences in nitrate, nitrite or ammonia levels between treated and untreated treatments, suggesting that denitrification and microbial processes were removing these products from the system. Using *Leersia oryzoides* as our model the seasonal dieback and duplicity of drainage ditch vegetation in nutrient assimilation during the growing season and re-release of phosphorus in the winter will have effects on downstream environments.

Key words: nutrients, wetland, assimilation, drainage ditch

Introduction

Wetlands have numerous mechanisms by which nutrients are assimilated and transformed. One such mechanism of nutrient removal is plant nutrient uptake. Wetland plants generally take up only very small quantities (<5%) of nutrients from influent waters(Hammer 1992). This amount is still insignificant compared to the loading rates measured flowing into the wetlands (Brix 1994, Younger & Batty 2002). However, plant uptake of nutrients is of quantitative importance in low-loaded wetland systems, such as drainage ditches associated with agricultural runoff (Peverly 1985, Richardson 1985).

Vegetation assimilation rates and nutrient concentrations tend to be highest in the early growing season and decrease as the plant matures and senesces (Johnston 1991). A distinct seasonal response is noted in temperate wetland system drainages: senescence in the winter and growth in the summer (Dolan et al. 1981). Emergent macrophytes lose nutrients rapidly upon death and decomposition (Boyd 1970, Gaudet 1977), with nutrient loss highest through rain leaching. *Typha latifolia* L. and *Phragmites australis* (Cav.) Trin. ex Steud. leaves lost 90 – 93% of their potassium, sodium, nitrogen and phosphorus after 20 days of tissue senescence (Boyd & Hess 1970, Gaudet 1977). With the possibility of using vegetation for pollution control, there have been several efforts to determine the relationships between the nutrient status of emergent macrophytes and their environment (Klopatek 1978). However, it has been noted in most studies that the contribution of plants to nutrient removal is often only temporary because of the loss of nutrients at senescence(Cronk & Fennessy 2001). Greenway (1997) compared nutrient levels in plant tissues between high nutrient loaded wetlands and control wetlands: total phosphorus and total nitrogen levels were 2 mg/g and 7mg/g higher respectively in high loaded wetlands than in control wetlands. Very few studies have examined the associated re-release of nutrients of wetland species following senescence.

In this study we tested two hypotheses. The first was to test the theory of luxury uptake (Cronk & Fennessy 2001), whether plants given the opportunity will assimilate higher concentrations of nutrients, such as nitrogen and phosphorus. The second hypothesis suggested plants that do assimilate higher concentrations of nutrients will, with subsequent tissue senescence, release higher concentrations back into the water column.

Methods and Materials

The decomposition experiment took place in a temperature controlled greenhouse at the University of Mississippi Field Station (UMFS). The purpose of the decomposition experiment was to follow up on work already undertaken at the UMFS (Davis & Holland 1998) on understanding the dynamics and relationships between nutrients in simulated agricultural runoff and wetland vegetation. Vegetation was collected from ponds at the UMFS in the summer and winter of 2004. These ponds were selected as they formed the basis of a simulated nutrient release experiment by the USDA-ARS National Sedimentation Laboratory over the last calendar year, and thus provided an excellent opportunity to compare between nutrient uptake and release of treated and non-treated ponds. A measured 25ha runoff concentration of nitrogen and phosphorus was applied to each simulated agricultural drainage ditch every two weeks for one year**.** The vegetation was taken out of the ponds in summer, as it was at this time when plant nutrient uptake is maximized, and again in winter after the first frost, as this the time when the plant was naturally beginning to senesce.

Leersia oryzoides (L.) Sw. was chosen, as it was found to be the most abundant and dominant species within the wetland mesocosms sampled. The experiment consisted of three treatments. Treatment 1 was labeled "treated" and consisted of nutrient enriched vegetation. Treatment 2 was labeled "untreated" and consisted of vegetation from a control pond that was not treated with nutrient runoff. Treatment 3 was the control and no vegetation was placed in these decomposition bags. Treatments 1 and 2 consisted of eight ¼ 55 gallon plastic drums, while treatment 3 had four plastic drums. Each drum was filled with 95L groundwater from the UMFS. A set mass of dry weight (approx. 800g) (minus the bag's weight for comparative purposes) of *L. oryzoides* was placed in decomposition bags in each drum of standing water for 12 weeks. The decomposition bags had a 5mm mesh diameter and were weighted to submerge the vegetation. Water samples were taken on a weekly basis and analyzed for total nitrogen, total phosphorus and ammonia. Nitrate and nitrite were determined using a Dionex Ion Chromatograph fitted with a conductivity detector for seven anion analysis. Total phosphorus and ammonia were determined analytically using the ammonia persulfate and phenate digestion methods respectively. The control was used primarily to show that water nutrient concentrations were not fluctuating throughout the course of the experiment.

Results and Discussion

A comparison between the nutrient contents of *Leersia oryzoides* in the treated and untreated ponds reveals significant differences in tissue nutrient concentrations. Given the opportunity *L.oryzoides* undertakes luxury uptake. The total nitrogen content was significantly ($p < 0.001$) higher in treated vegetation (13.20 mg/g $\pm$ 2.08) than untreated vegetation (8.4 mg/g $\pm$ 0.5) (Figure 1). Similarly, total orthophosphate was significantly ($p < 0.001$) higher in treated vegetation (3.85 mg/g $\pm$ 0.25) than untreated vegetation (1.91 mg/g $\pm$ 0.32). These results have significant effects on the C:N ratio within the plant tissue.

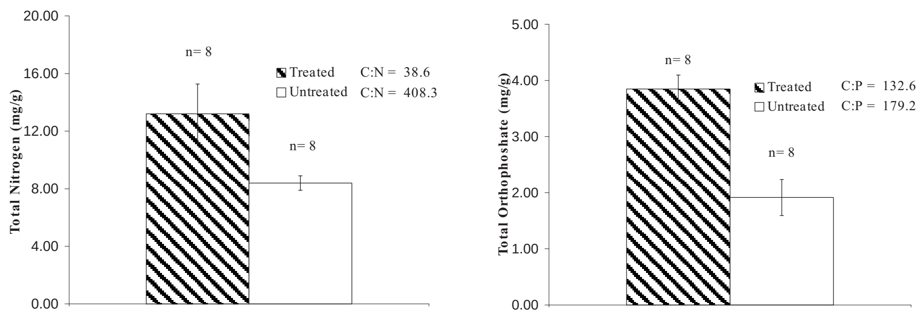

Figure 1. A comparison of total nitrogen and phosphorus concentrations (mg/L) between nutrient treated and untreated *Leersia oryzoides* in summer 2004

A higher tissue phosphorus concentration in summer resulted in a higher phosphorus concentration being re-released when the plants senesce (Figure 2). The significant difference is evident throughout the course of the experiment, and at termination, the water column of the treated vegetation had a significantly higher concentration than the untreated. The control shows that the water nutrient content does not change throughout the course of the experiment. Thus changes in nutrient concentrations within each treatment's water column were a result of the release of nutrients through tissue senescence. However, there is a reduction over time in total orthophosphate (TOP) concentration without the presence of an outlet (Figure 2). This reduction in concentrations was hypothesised as a result of microbes and algae assimilating and utilizing the leached inorganic P in metabolism and organic matter production.

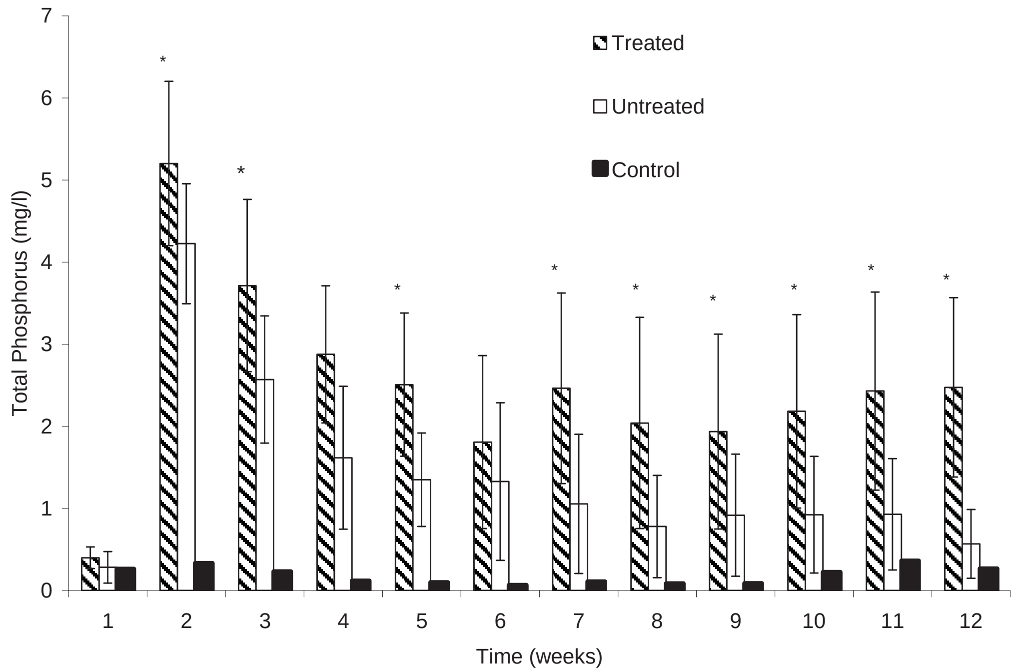

Figure 2. Total orthophosphate concentrations in the water column as a result of tissue senescence, July – September, 2004. *p < 0.05, 2 sample equal variance t-test

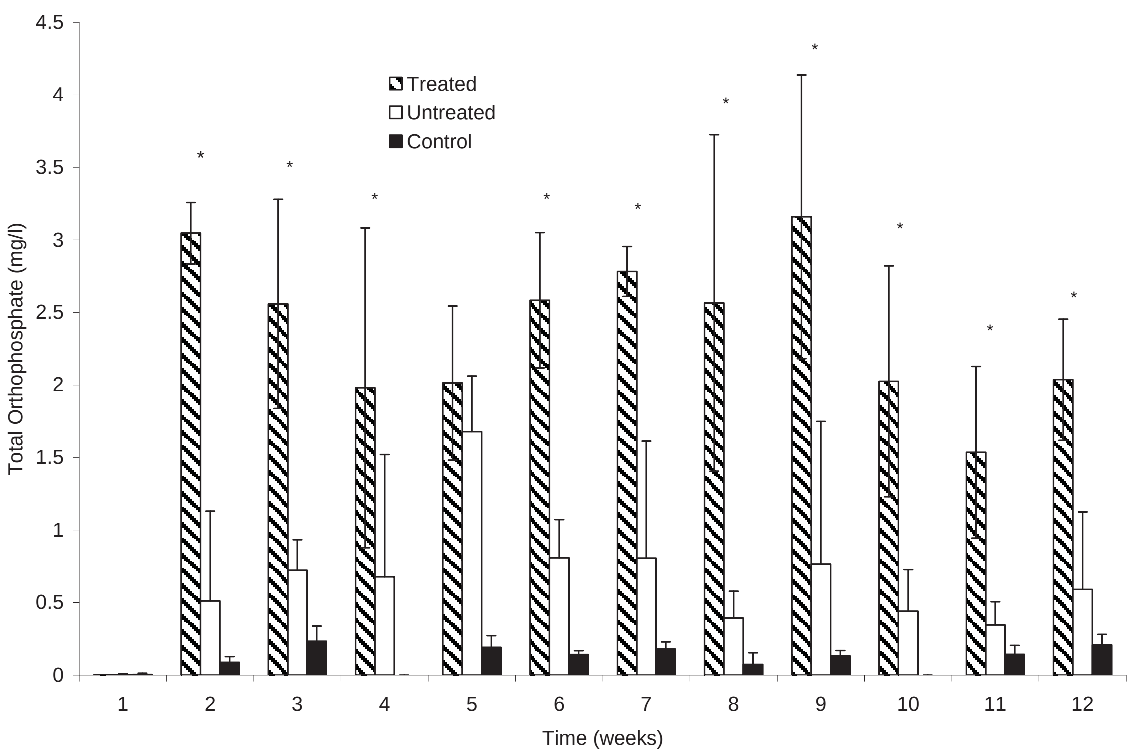

Figure 3. Total orthophosphate concentrations in the water column as a result of tissue senescence, November, 2004 – February 2005. *p < 0.05, 2 sample equal variance t-test

In winter (Figure 3) the treated vegetation again released significantly higher concentrations of TOP into the water column, however, the pattern of TOP concentration within the water column lacked the reduction observed over the summer (Figure 3). Most likely the lack of P utilization was a result of microbe temperature dependence. Microbial activity is temperature dependent and colder temperatures resulted in less effective use of TOP in the water column.

Nitrate levels over the summer and winter were highest in the control tubs and remained around 1.2mg/l throughout both experiments (Figure 4). The nitrate levels within the untreated and treated barrels were significantly reduced from control levels to zero (Figure 4). Even though plant tissue concentrations in the treated and untreated barrels were initially different, the result of tissue senescence was the same. The removal of nitrate from the system through nitrate ammonification is hypothesised as the reason nitrate levels were absent. Simple bacterial diagnostic tests suggested that there were nitrate ammonification bacteria present (e.g. *Agrobacterium* and *Bacillus*).

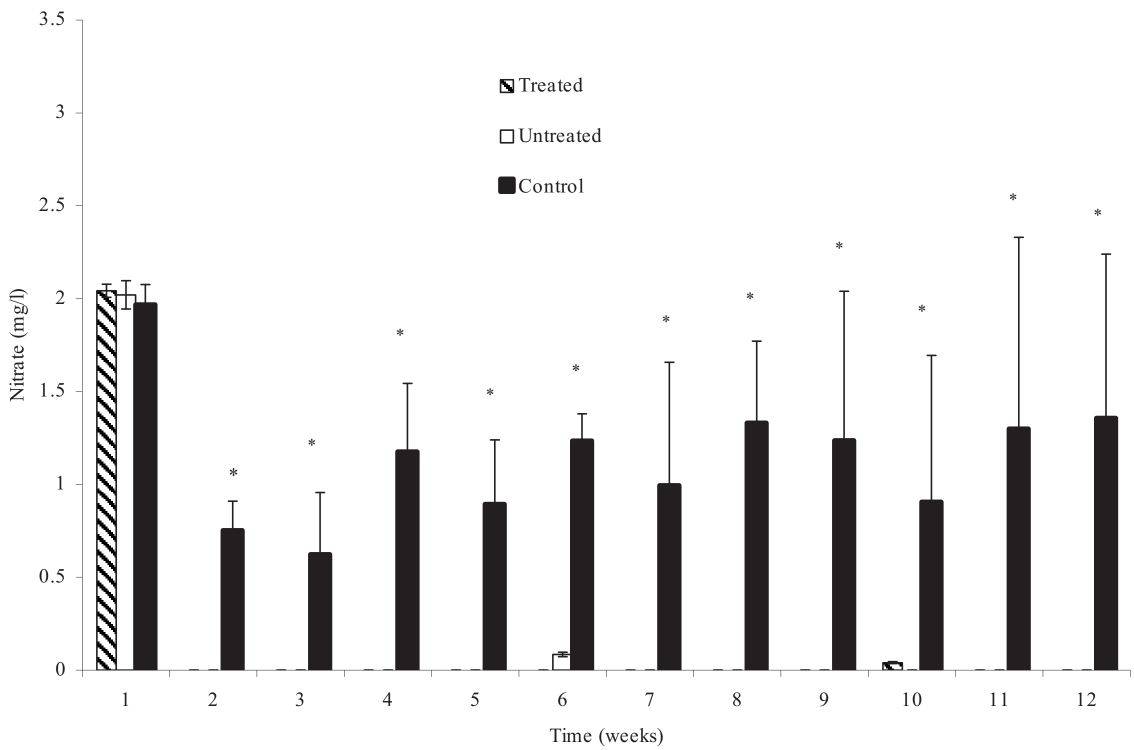

Figure 4. Nitrate concentrations in the water column as a result of tissue senescence July – September, 2004. A similar result occurred over winter, where the control barrels had significantly higher concentrations of NO_3^- than treated and untreated barrels.

The presence of nitrate-ammonification bacteria could provide reasons for the low concentrations of ammonia that occurred in both treated and untreated treatments. There were no significant differences in ammonia concentrations between treated, untreated and control barrels. Low concentrations of ammonia, the absence of nitrate and nitrite and the high C:N ratios of both treated and untreated vegetation suggests the nitrate ammonification was the dominant process in nitrogen flux within the barrels, rather than nitrification/denitrification (Cronk & Fennessy 2001).

Conclusions

Theory states that given the opportunity wetland vegetation will assimilate higher concentrations of nutrients even though it's not needed for growth or other metabolic functions. This indiscriminate uptake of nutrients is termed luxury uptake (Cronk & Fennessy 2001). *Leersia oryzoides* is a perennial emergent wetland species, which when exposed to elevated nutrient runoff concentrations assimilates higher concentrations of nitrogen and phosphorus in its above ground plant tissue (Figure 1). Subsequently, under senescence *L.oryzoides* re-releases higher concentrations of nutrients, specifically phosphorus in both summer and winter experiments. Nitrate and nitrite release is negated by denitrification, and a small proportion is converted to ammonia by facultative nitrate ammonification bacteria (Laanbroek 1990).

Plants exposed to low-load conditions, such as agricultural runoff, will significantly contribute to the assimilation of nutrients. However, in environments where seasonal shifts in temperature cause senescence of many wetland species, that assimilatory capacity could be negated potentially by the re-release of nutrients into receiving waters specifically phosphorus. Potential solutions to this problem of phosphorus leaching during the winter is the installation of slotted board outlets, increasing retention times in high rainfall periods, and aiding in sedimentation and accumulation of particulate bound phosphorus. Further, the interaction between specific bacterial components and the concentrations over time of nitrate, ammonia and ammonium would be an interesting avenue of research. The interaction between species-specific bacterial associations and specific wetland plants will be the next point for research to truly understand the dynamics of nutrient flux within wetland ecosystems.

Acknowledgements

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Concurrent Session D
Hydrology in Modeling
Moderator: Dave Reed

Hydrologic Modeling of an Industrial Development Site

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Environmental challenges associated with commercial, industrial, and residential development include site plans that minimize disruption of the natural hydrologic regime of the area, especially the impact on water quality. Site development plans that maintain the hydrologic regime and sustain water quality downstream are consistent with an approach described as smart growth.

Significant advances have been made in the use of spatial models, including geographical information systems (GIS) and sophisticated hydrologic models, to assess the impact of potential development. Similarly, experience with best management practices (BMP) provides good insight into how various management practices such as stormwater detention and vegetated areas contribute to improved water quality.

The purpose of this work is to determine if EPA's BASINS GIS data and modeling system, including the hydrologic model HSPF, can be used to examine balancing watershed protection with low impact site development strategies. HSPF was applied to the Eurocopter factory site in Lowndes County, Mississippi as a test case. It showed that HSPF can readily model the hydrology of such a site and test common management practices, but the BASINS system design, which is intended for larger watersheds and simpler applications, makes it awkward to apply. Recommended actions to make the system more applicable include automating some manual procedures and creation of a simple graphical interface to facilitate site descriptions.

Hydrologic Operations of the Lower Mississippi River Forecast Center

By: Kai Roth: Hydrologist: Lower Mississippi River Forecast Center

Introduction

The National Weather Service Lower Mississippi River Forecast Center (LMRFC) is a multi-functional public service organization which uses cutting edge technology to prepare flood forecasts for dissemination to the public. The preparations of these forecasts are done daily using a combination of hydrologic experience, historical data, and real-time hydrologic / hydraulic models. The Sacramento Soil Moisture Accounting Model (SAC-SMA) is the soil moisture accounting model used at the LMRFC. The Dynamic Wave Operational Model is used for larger, more complex "mainstem" river forecasts, such as the Mississippi River. For most reaches, the Lag/K hydrologic routing technique is used. The forecast prepared using these models are disseminated to the public through the Weather Forecast Offices and in the form of a user friendly website. This website, along with all the graphics displayed on it are generated and maintained at the LMRFC.

The LMRFC is responsible for preparing forecasts for a service area of approximately 220,000 sq. miles and parts of 12 states (fig. 1). Within this area, a network of 2900 rain and 500 river gages are utilized. These gages transmit information back to the LMRFC for use in the forecast model, which in turn is used to prepare five day forecasts. The data from these gages is used to prepare forecasts for 220 points. These forecasts are disseminated to the public every morning and updated as needed in times of flooding.

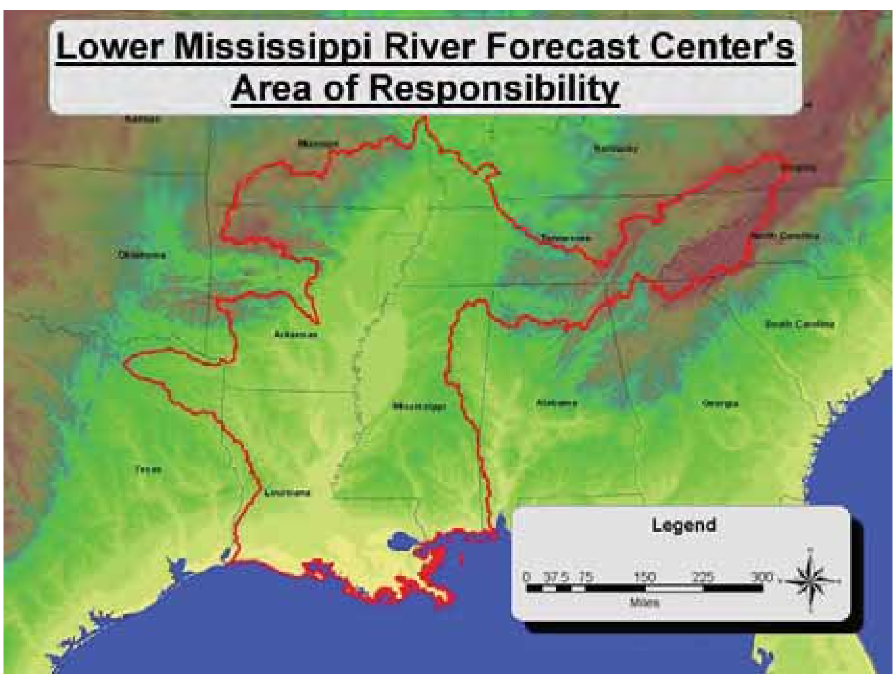

Figure 1: Lower Mississippi River Forecast Center 's area of responsibility.

Daily Operations

Making 5 day forecasts is the primary function of the LMRFC. The LMRFC has a total of 220 forecast points. 189 of these forecast points are forecasted daily while the other 31 are forecasted only in times of flood. The forecasts are generated using a combination of experience, historical hydrographs, and model output and disseminated to the public daily. Rainfall, forecasted rainfall, stage data, and soil moisture conditions are ingested into the Sacramento Soil Moisture Accounting Model and a forecasted hydrograph for the next five days is generated. The model output is then inspected by a hydrologist for accuracy. The forecaster can adjust the forecast up or down to improve its accuracy. This forecasted flow is then routed downstream to the next forecast point using the Lag/K technique where the forecast process is done again. When the forecasts for an entire river system are finished, they are disseminated to the public through a user friendly web site and the Weather Forecast Office. In times of flood these forecasts are updated nightly or as necessary.

LMFRC Model Efforts

Model output is an integral portion of the forecast process. The Sacramento Soil Moisture Accounting Model is used to track soil moisture and estimates runoff. This model is a continuous model as opposed to being “event driven”. The SAC-SMA model is broken down into two soil zones (fig. 2), the upper zone and the lower zone. Each zone has free water and tension water. Tension water is the water that is held so tightly in the pores of the soil that it can only be removed by evaporation. Free water is the water that is free to move about the soil profile and can eventually make its way into the river system or groundwater. This model has a total of 17 parameter. These parameters take into account, but not limited to, the amount of water that can be held in the soil, the amount of impervious area rainwater has to run off of, and vegetation. With precipitation and evapo-transpiration as input, the model simulates tension water and free water and generates surface flow, lateral drainage, and percolation. The SAC-SMA model takes into account areas impervious to infiltration including areas covered with rock, and areas that are covered by streams or marshes that are already linked to the hydrologic system. Losses from evaporation from the soil and transpiration from plants play a vital role. Evapo-transpiration is estimated using wind speed and direction, solar radiation, and humidity which are input into the Penman Equation.

The Sacramento Soil Moisture Accounting model accounts for the amount of water that enters a river system through run off, interflow, and long term base-flow. This water, along with the current flow, flow from upstream, and forecasted rainfall makes up the total amount of water in a river at a given point. To route the water downstream, the LMRFC uses the lag/K routing technique. This technique along with the Sacramento Model outputs a hydrograph the forecaster can use to create a river forecast.

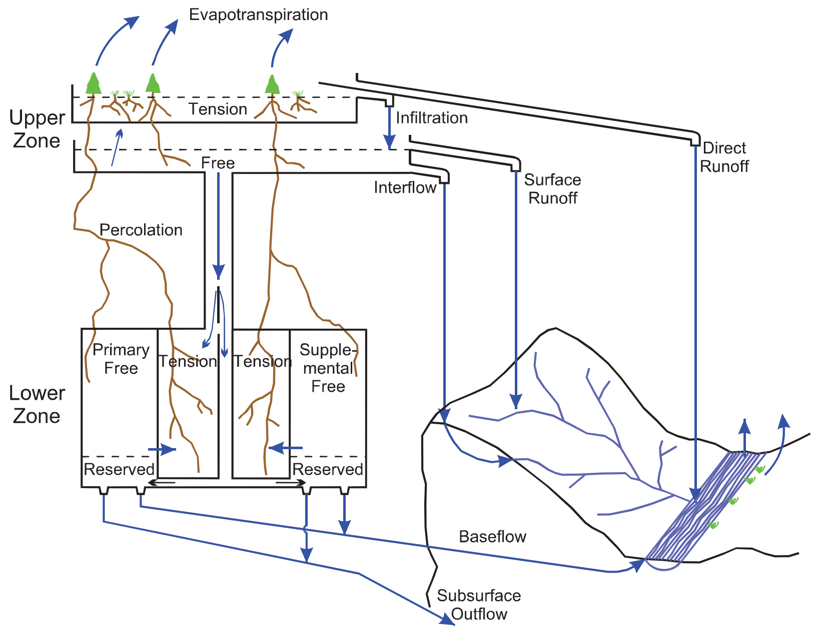

Figure 2: Conceptual Representation of the Sacramento Soil Moisture Accounting Model.

To route water downstream, LMRFC uses the hydrologic technique, Lag/K and the Dynamic Wave, a one-dimensional unsteady flow hydraulic model. DWOPER solves the St. Venant equation of one dimensional unsteady flow. This model can handle the problems associated with larger more complex river systems, such as the Mississippi River and can take into account issues such as backwater, tides, and levee overtopping. All the features associated with this model make it the logical choice for use on the Lower Mississippi and Ohio Rivers.

To route water downstream, DWOPER obtains initial river conditions from either an observed / estimated stage or discharge. Boundary conditions include known stage, discharge hydrograph, tides, or a rating curve. Off channel storage is also a component of DWOPER that is described as an area that does not pass flow to the active channel of the river. This can be an area such as an embayment or a tributary. Flooded woodlands can also serve as an area of storage. In these examples, a flow velocity of zero is used for the areas of storage to more accurately model the river instead of the average velocity of the main channel and the storage area. Channel roughness is modeled with Manning's n, which is used to describe things such as bends in the river, bank vegetation, or anything that would impede the flow or the river. In addition to the components just mentioned, DWOPER can take into account wind effects on the surface of a river, inflows from any number of tributaries, and changing conditions from lock and dam operation. Taking into consideration these many components of DWOPER, it is a powerful model used for the Lower Ohio and Mississippi Rivers at the LMRFC.

The maintenance of the models used in our forecasting is the responsibility of the LMRFC. Therefore the models need to periodically be calibrated. To do this the model output is compared with historical data. The 17 parameters in the Sacramento model are modified in the Interactive Calibration Program (ICP) through a trial and error process until the model output closely matches both statistically and visually with the historical stage data. Once a model is calibrated, the new Sacramento parameters are input into the operational model and used in the daily forecast.

Development Work

In addition to flood forecasting, the LMRFC is involved in developmental work. Geographic information systems (GIS), scripting, and web design are a few of the developmental projects the LMRFC is involved in. GIS is an integral part of our forecast dissemination process. Over 5000 graphics on the LMRFC's web pages are created daily with a GIS. These graphics are generated daily by scheduling Avenue and VBA scripts to run at certain times. These scripts were generated and are maintained in house at the LMRFC. In addition to updating maps on the web page daily, GIS are also used in the creation of the base maps used to display river conditions on the web page (www.srh.noaa.gov/lmrfc) and in manipulating data for our calibration activities. Data such as basin delineation, statistics on potential evaporation and long term precipitation, forest type and cover, and soil conditions for 11 of the 17 Sacramento model parameters can be estimated using GIS software.

Many scripts are written at the LMRFC for use on a LINUX platform to do tasks such as pulling data off of websites or move graphics to the web. SQL scripts are also written to pull off data stored on an Informix database and used for various purposes, such as creating historical hydrographs. In addition to these developmental projects, the LMRFC also designs and maintains an informative web site. This website contains all the forecast information and precipitation data the LMRFC uses and produces daily. One of the more useful pages is the quick briefing page (fig. 3). This page contains all the flood forecast data, historical precipitation data, and forecasted precipitation data. This page also contains a graphic which depicts where significant flooding is occurring or forecasted to occur. With one click, the majority of the information the LMRFC provides can be accessed.

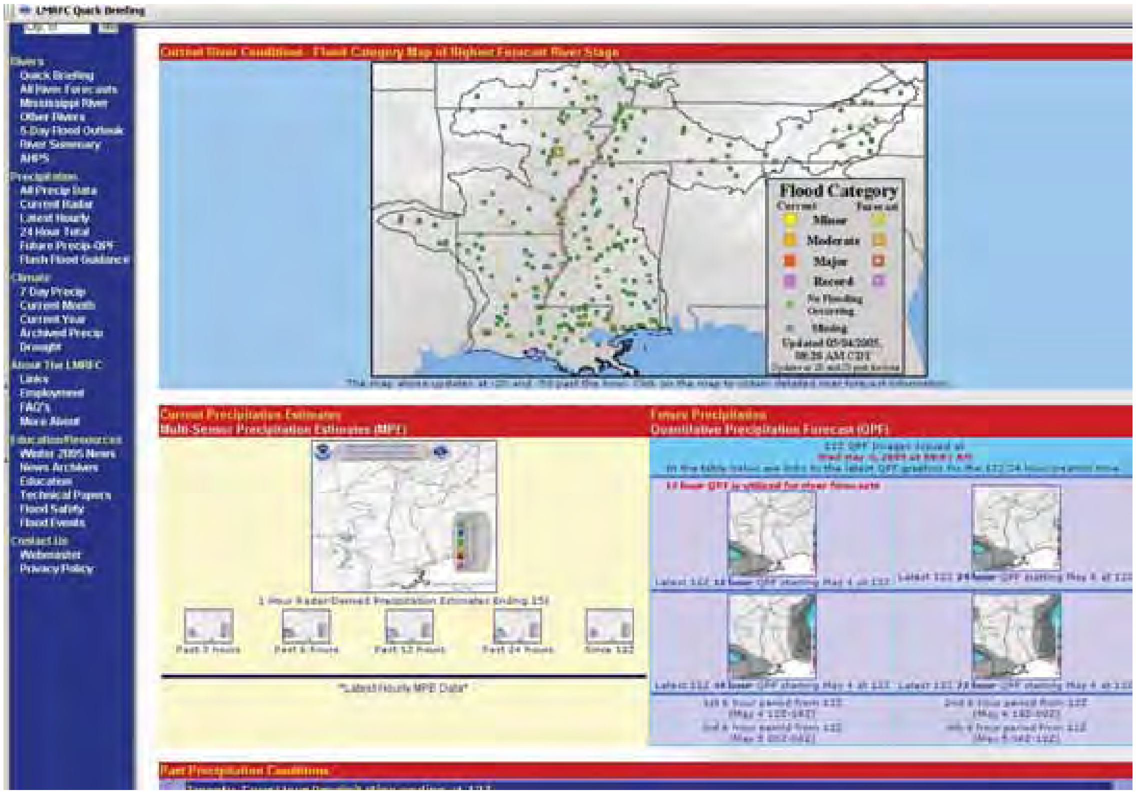

Figure 3: The Lower Mississippi River Forecast Center's quick briefing page.

Conclusion

The National Weather Service Lower Mississippi River Forecast Center is the government office that is responsible for preparation of the river forecasts for the Lower Ohio and Mississippi River drainages along with all Gulf drainages from the Calcasieu River in southwest Louisiana to the Pascagoula River in southeast Mississippi. They use and maintain two hydrologic / hydraulic models for forecasting. These models are maintained through calibration and by keeping boundary and soil moisture conditions current and accurate in their values. The LMRFC also is a developmental office. Projects such as web design and maintenance, programming, and GIS are just a few of the developmental activities done at the office when forecasting is not being done. The LMRFC is instrumental in saving life and property through their timely and accurate forecasts.

GIS and Remotely Sensed Precipitation Data for Watershed Models

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The Upper Pearl Watershed located in central Mississippi covers over 2000 square miles in 15 counties. The environment of the Upper Pearl Watershed is rapidly changing due to residential and commercial development in the Jackson metropolitan area, the state capital, and further upstream near Philadelphia, MS. These changes may present water quality challenges to both the Pearl River and the Gulf of Mexico coastal waters. Heavy precipitation events in Upper Pearl can significantly impact coastal fisheries and essentially close near shore oyster reefs for several days until the transported pollutants from the Pearl River dilute to safe levels. Modeling the relationship between meteorology and climatology and water quality could provide valuable management insights to upstream managers on downstream, coastal impacts. Developing such a model faces some daunting challenges. Surface weather stations are the typical source for meteorological data but the distribution of these stations results in large spatial gaps in data coverage. It can rain in one part of the watershed but never be recorded and placing a weather station every few kilometers would be unrealistic. This paper examines the validity of using remotely sensed meteorological observations using NASA's Tropical Rainfall Measurement Mission (TRMM) satellite, NOAA's Multi-Precipitation Estimate (MPE) and GOES satellite Hydro Estimator (HE). Arc Hydro, ESRI's new water resources data model, will systematically bring in the different data formats for use in the Army Corps of Engineers HEC simulation models.

Simulating the Erosion of Streambanks by Lateral, Subsurface Flow

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Sediment from agriculture impairs more stream miles on the US EPA's Clean Water Act 303(d) list than any other contaminant. As much as 80% of the sediment entering streams in some agricultural watersheds originate from the streambank. Fluvial processes are generally the only mechanisms considered in contributing to streambank erosion. Limited information exists about lateral, subsurface flow as a mechanism of streambank erosion, even though subsurface flow erodes streambank sediment in numerous geographical settings. The objective of this research is to evaluate the importance of subsurface flow erosion and quantify the contribution of streambank erosion by ground water mechanisms. Field experiments are performed at Little Topashaw Creek (LTC) within the Yalobusha Watershed in Northern Mississippi. Streambanks at LTC are commonly stratified consisting of alternating layers of alluvial sand and clay. Initial soil characterizations are performed at three identified sites where subsurface erosion of LTC streambank sediment is occurring. The potential for substantial, lateral subsurface flow is prevalent due to alternating layers of less permeable clay and high conducting sand below a layer of topsoil. Laboratory analyses on each soil type indicate a considerable hydraulic conductivity and water retention contrast and therefore a substantial difference in the flow characteristics of each of these horizons. Intermediate scale experiments are performed using lysimeters constructed to simulate LTC streambank soil profiles and instrumented with an array of mini-tensiometers for soil water measurement. The lysimeters simulate the dynamics of bank undercutting due to sediment loss as water flows through the more permeable sand layer, causes sapping erosion and undermining of the sand, and eventual bank collapse of the overburden or topsoil. Lysimeter experiments are performed with varying boundary conditions including hydraulic gradient, overburden height, and lysimeter slope. Conclusions are drawn regarding the relative importance of each of these boundary conditions on the subsurface erosion process.

Concurrent Session E
Water Quality
Moderator: Mickey Plunkett

Soil Tillage Systems and Herbicide Leaching in Brazil.

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ABSTRACT

The Guarany aquifer located in South America has a dimension of approximately 1,200,000 Km^2 and spreads to areas of eight Brazilian states plus parts of Argentina, Uruguay and Paraguay. The region of Ribeirao Preto City, located in Southeast of Brazil, Sao Paulo State, is a sugarcane, soybean, peanuts, and corn producing area. This region is also an important recharge area to the aquifer. Intensive farming on the area has demanded constant use of herbicides and fertilizers. Triazine herbicides such as atrazine, ametryn, and simazine are used on the area and are known to have potential for groundwater contamination. Currently most of the sugar cane crop is mechanically harvested without burning. This practice allows the straw to decompose in soil, maintain a better soil structure, and interferes with the movement and leaching of solutes. It is a common practice to sow peanuts after sugarcane harvest using no-tillage or conventional planting systems. To evaluate the effects of herbicide leaching into groundwater during no-tillage planting of peanut after mechanically harvested sugarcane, a soil leaching study using soil columns has been conducted. The results showed a general trend of higher density and lower porosity in soils under no-tillage, mainly at the top layer. The Hydraulic Conductivity determined in soil columns was higher for soils under conventional system than no-tillage, 10.82 and 4.59 cm/h respectively, indicating higher leaching potential for conventional system.

Keywords: Groundwater, Nonpoint Source Pollution, Hydrology, Agriculture, Solute Transport.

INTRODUCTION

The state of Sao Paulo, located in Southeast of Brazil, is an important sugarcane, soybean and corn producing area with high use of chemicals in agriculture with potential risk of environmental contamination (Pessoa et al. 1998). This region is also an important recharge area for groundwater of the Guarany aquifer. Several studies have demonstrated the possibility of pesticides leaching to groundwater

(Smith et al., 2001; Bouwer, 1990). Among them, triazine herbicides such as atrazine, (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) ametryn, (2-(ethylamino)-4-isopropylamino-6-methyl-thio-s-triazine), and simazine[2-chloro-4,6-bis(ethylamino)-1,3,5-triazine] are used in Brazil and are known to have potential of groundwater contamination (Cerdeira et al., 2000). The Brazilian Health Ministry has set the maximum amount of atrazine and simazine in drinking water to 2 ug/L, or ppb, (Pessoa, 1998).

Since we have different cropping systems, literature indicates that there is a relationship of tillage systems and leaching, the region is located on an aquifer recharge area and herbicides are heavily used, this research was conduct to evaluate the effect of harvesting and soil preparation systems on triazine leaching. A field experiment was set and a soil leaching study was conducted in columns to determine the movement of triazines where mechanical sugarcane harvesting has been followed by No-tillage (NT) and Conventional Tillage (CT) peanuts production. Although not all the triazines are necessarily used at same level on all crops, we have used the three, atrazine, simazine and ametryn as models to study the effect of soil preparation systems on leaching on those soils.

MATERIALS AND METHODS

Field research was conducted at the Alta Mogina Sao Paulo State Experiment Station, Ribeirao Preto, SP, Brazil, and laboratory studies were conducted at the Research Division of the Brazilian Department of Agriculture, Embrapa/Environment, Jaguariuna, SP, Brazil. The experimental design consisted of mechanically harvested sugarcane followed by NT and CT peanuts in a RCB, Randomized Complete Block with four replications and plots of 10X30 m.

Sugar cane was planted in 1977 and mechanically harvested until the last cutting in October 2002. After sugar cane last mechanical harvesting in October, soil samples were collected from trenches before and after peanuts sowing under NT and CT systems. Samples were collected from 0 to 100 cm depths, for every 10 cm. in November and March of years 2002/2003 and taken to the laboratory. Soil density ($g.cm^{-3}$), the relation of soil mass and volume was measured using the Kopeck ring method described by Black, (1965). Total porosity was measured based on percentage of saturation in volume (Vomocil, 1965). Microporosity was determined by the tension table method at 0,006 Mega Pascal (Mpa). After saturation and drying under tension, the samples were dried in oven at 105^0C to obtain the volume of micropores ≤ 0.05 mm. Macroporosity was obtained by the difference of micro and total porosity. It were also evaluated the % Organic Matter and physical properties of the soils for each depth (Klute 1986). The soil saturated hydraulic conductivity and the leaching potential of the herbicides were accomplished with leaching experiments conducted in PVC columns of 20 cm diameter. The soil samples were collected from the field experiment and placed in the column at the same depths and density as in the field with a vacuum extractor for collecting solutes.

Soil columns were saturated with water from bottom to top to extract the remaining air, the soil saturated hydraulic conductivity was measured and it was left to dry for three days to reach field capacity water level according to Klute, (1965). After that, the soil was drained by gravity for three days and then it was applied the volume of 1570 ml of solution with 8 Kg/ha a.i. of each of the herbicides.

The herbicides were applied at the top of the columns. Water was applied until it reached 5cm; equivalent to a 50 mm rain. The time interval for the solution to reach the bottom was measured. The solutes were collected at 20 cm depths using vacuum extractors for each 10 cm depth and analyzed for residues by HPLC.

RESULTS AND DISCUSSION

Samples collected from different depths, from 0 to 100 cm have shown a high percentage of clay and no effect of the depths on the physical properties of the soils under NT or CT system was observed. Organic carbon content was higher at top layer 0 to 10 cm. for NT soils. There was also a trend of increasing the moisture content and decreasing organic carbon to deeper depths under both cultivation systems.

Our results have shown a general trend of higher density in soils under NT, mainly at the top layer (Table 1). Roscoe and Buurman (2003) studying the Brazilian cerrados (savannas) following cultivation on a Dark Red Latosol (Oxisol) also found that cultivation led to compaction, which significantly increased soil bulk density and that using (CT) or (NT) system did not alter the total C and N stocks in the first 45 cm depth at the end of 30 years of cultivation.

Table 1. Soil density ($g.cm^{-3}$) under No-tillage (NT) and conventional tillage (CT) peanuts at various depths.

Depth (cm)	**NT**	**CT**	**F Value**
0-10	1.24	1.12	23.27*
10-20	1.22	1.14	5.53
20-30	1.30	1.19	1.82
30-40	1.20	1.20	0.00
40-50	1.16	1.14	1.27
50-60	1.09	1.09	0.37
60-70	1.06	1.04	0.29
70-80	1.05	1.04	0.02
80-90	1.03	1.06	NA*

* Significant different at $p \leq 0.005$ NA: Not available

Most of literature is also contradictory on the effects of tillage systems on micro, macro, and total porosity of soils submitted to these tillage systems. Our data have shown no effect on these parameters when under the CT or NT systems.

Some authors found reduction in runoff and increasing in leaching of atrazine and simazine in NT as opposed to CT, (Triplett et al., 1978; Edwards et al., 1980), which is contradictory to our findings (Figure 1, Table 2). Others have found the opposite, NT runoff was higher and leaching was lower, Baker and Johnson, (1979), results similar to those found in our study (Figure 1). There were also reports of no effect of the cropping systems, CT or NT on runoff of pesticides (Logan, 1990). Wauchope, (1987) considered that the results and conclusions of effects of tillage on runoff and leaching losses of pesticides are generally inconsistent and often contradictory.

There were also great differences in literature regarding the tillage effects on hydraulic conductivity. In our study, there was a higher conductivity for soils submitted to CT than NT but this did not reflect on the movement of the triazines (Figure 1, Table 2).

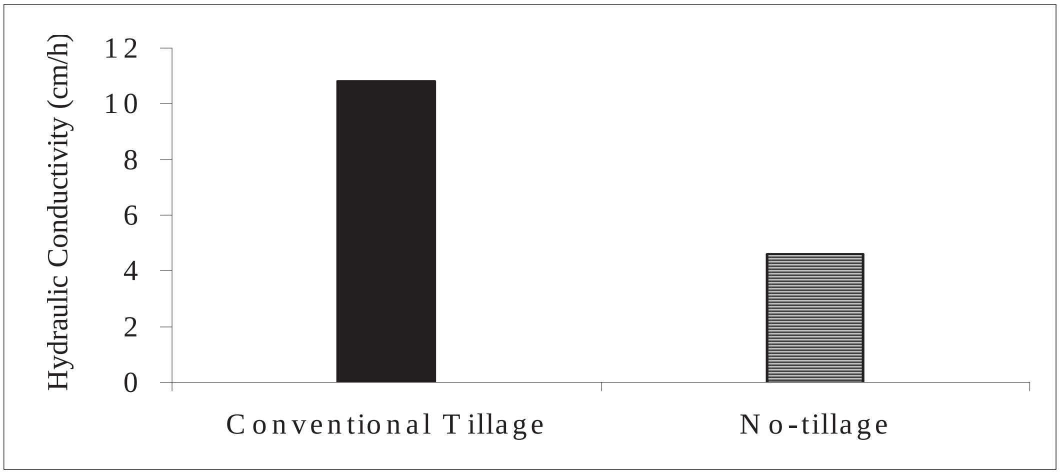

Figure 1. Hydraulic conductivity (cm/h) of soils under No-tillage (4.59*) and conventional tillage systems (10.82). *Statistically different F=0.0034

The soil columns studies have shown the leaching of the herbicides atrazine and simazine down to the maximum of 20 cm. No herbicide was detected under 20 cm for the conditions of the experiment indicating less mobility under the experimental conditions than in mathematical modeling simulations, (Pessoa et al., 1998). Ametryn was not detected in any depths (Table 2).

Atrazine and simazine were just found at the top layer from 0 to 20cm in the soil columns studies. In both systems NT and CT, atrazine has leached more than simazine, what was expected according to studies conducted with mathematical simulation (Pessoa et al., 1998). There was no clear difference on mobility of both herbicides due to the tillage systems (Table 2).

Table 2. Maximum amount of the herbicides measured (ppb) of the herbicides found from zero to 20 cm. in solution extracted from the columns.

Herbicides	**Tillage systems**	
	No-tillage	Conventional tillage
Ametryn	ND[1]	ND
Atrazine	85.8	72.6
Simazine	28.5	31.4

ND[1] = Not detected. Average of three replications.

Since most of the soil properties that affect leaching were similar in both systems at various depths, the lower leaching capacity of soils under NT system could be attributed mainly to the higher density of the top layers of soils under this system, NT (Table 1). Although organic carbon content was not statistically different, those parameters were also higher for soils under NT at top layers and could also play an important role in lower hydraulic conductivity (Figure 1).

Further studies will be conducted with lysimeters in order to understand better the effects of those soil tillage systems and consequent impact on ground water quality.

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Factors Influencing Runoff of Pesticides from Warm Season Turfgrasses

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There is growing concern over the environmental fate of pesticides applied to turfgrasses. Of key interest is that pesticides used to maintain golf courses and home lawns will pollute drinking water sources and impact human health. In addition, there is the possibility that pesticide runoff could impact the ecology of surface waters and the health of wildlife. Understanding the fate of turf applied pesticides and predicting possible environmental concentrations requires knowledge of the factors affecting their movement or transport.

This study was conducted using 2, 4-D herbicide (2, 4-dichlorophenoxy acetic acid), flutolanil fungicide (trifluoro-3`-isopropoxy-o-toluanilide) and chlorpyrifos insecticide (O, O-diethyl hexahydro-4, 7-methanoindene) applied at maximum label rates to two turfgrasses maintained as either golf course fairways or residential lawns. The turf species used were Tifway 419 bermuda grass (Cynodon dactylon [L] Pers. X Cynodon transvalensis Burtt-Davy) and Meyer zoysia grass (Zoysia japonica). The plots were 3.65 m x 9.14 m in size and sloped at 3 %. The plot arrangement is a split design. Simulated rainfall was applied to the plots to generate runoff within 24 hr of pesticide application. Runoff from the plots was collected at 5 minutes intervals. The targeted rainfall application rate was 2.5 cm hr-1.

Average runoff rates for the three pesticides were 25% for 2,4-D herbicide, 2% for flutolanil fungicide, and 0.5% for chlorpyrifos insecticide. The runoff results correlated well with the soil-water distribution coefficients that were determined for the Brooksville silty clay soil (fine montmorillonitic, thermic Aquic Chromudert) present at the runoff site. Soil organic carbon adsorption coefficients were 73 ml/g for 2,4-D, 576 ml/g for flutolanil, and 3551 ml/g for chlorpyrifos, indicating weak adsorption potential for 2,4-D, moderate to strong adsorption for flutolanil, and high adsorption for chlorpyrifos. Runoff potentials for these compounds were anticipated to be indirectly correlated with the adsorption coefficients of the pesticides; the runoff data support this hypothesis. Maximum observed concentrations in turf runoff were 962 ppb for 2,4-D, 1336 ppb for flutolanil, and 23 ppb for chlorpyrifos. The maximum concentration observed in runoff is a function of wash-off potential, persistence, and application rate. Flutolanil had the highest application rate at 8.7 lb ai/A, chlorpyrifos was applied at 1 lb ai/A, and 2,4-D was applied at 0.24 lb ai/A. These edge of field concentrations exceed published aquatic toxicity threshold values for 2,4-D and chlorpyrifos. However, actual impacts on aquatic organisms would likely be greatly attenuated by dilution from runoff from non-treated areas.

Mass Balance Studies of Pesticides in Agricultural Watersheds: Importance of Agricultural Deposition

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The U.S. Geological Survey's National Water-Quality Assessment Program (NAWQA) is conducting a number of studies in small agricultural watersheds with the lofty goal of constructing annual mass budgets for water, nutrients and selected pesticides. One of these studies is starting in the Bogue Phalia in Mississippi in 2005. After a pesticide is applied, it can undergo transformation in the soil, be taken up by the plant, be stored in the field, or be transported to the broader environment, such as the atmosphere, surface water or ground water. When a pesticide enters the atmosphere, it will eventually be reintroduced to the terrestrial system either by wet (e.g., rain, snow) or dry (e.g., dry fall, air-soil exchange) deposition, if it does not undergo reaction in the air. Atmospheric deposition is then a part of a pesticide's overall mass budget. These USGS studies have measured the concentration of pesticides in the rain and air to estimate the magnitude of this term in the mass budget. In most locations, the most frequently detected pesticides in air and rain were the herbicides acetochlor, atrazine, and metolachlor. The seasonal concentration patterns of the atmospheric pesticides mimicked the agriculture activities of the area. The dry atmospheric flux was calculated based on the concentrations of weekly integrated air samples and modeled aerosol deposition velocities. The wet atmospheric flux of pesticides was calculated based on the concentrations of weekly integrated rain samples and the volume of rain. The rain data, together with companion studies of the same pesticides in streams, were used to compare the relative importance of atmospheric deposition to surface runoff. The load of pesticides deposited by rain to each watershed was compared to the load of pesticide in surface runoff (as quantified by the stream load) from the watersheds in this study and from data available from the literature for other watersheds. The annual load of any given pesticides deposited by rain was generally equal to or greater than its annual load in runoff. Even though the atmosphere is important for moving many pesticides through the environment, atmospheric deposition is still a minor term in their overall mass budget.

CYP1B-Gene Expression in Channel Catfish as a Biomarker for Sediment Contaminant Exposure

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Sediments in some Mississippi rivers and lakes contain significant concentrations of environmental contaminants including pesticides and industrial by-products. Our previous analyses of sediments collected from three Mississippi Delta waterways (Lake Roebuck, Bee Lake and Sunflower River), suggested that polycyclic aromatic hydrocarbon (PAH) and organochlorine pesticides were detectable and highest at Lake Roebuck. We hypothesized that quantitating induction of CYP1B mRNA in catfish could potentially be a useful biomarker of exposure to these persistent contaminants. Specifically, we use primary cultured channel catfish liver hepatocytes and gill cells to determine the inducibility and/or inhibition of CYP1B. When cells were exposed to BaP concentrations ($5x10^{-9}$ to $5x10^{-5}$ M) CYP1B was significantly ($p< 0.01$) induced in gill cells compared to DMSO treated control cells. Furthermore the CYP1B message was inducible by BaP in a dose-dependent manner. In contrast to the primary cultured gill cells, there was no significant CYP1B induction in liver hepatocytes. Ongoing studies are investigating the tissue specific effects of other contaminants including PCB 77, PCB 126, PCB 153, p,p'-DDT, and TCDD. These results will ultimately help characterize the utility of CYP1B as a marker of environmental contamination and the physiological significance of CYP1B in fish.

Project Description for the Regional Assessment of Trends in Nutrient and Sediment Concentrations and Loads in Major River Basins, South-Central United States

by

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INTRODUCTION

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program is conducting regional assessments of water-quality conditions and trends in 16 principal aquifers and eight major river basins (Hamilton and others, 2005). These assessments build on the NAWQA studies conducted from 1991 to 2001 in 51 river basins (fig. 1). NAWQA studies were designed to describe how natural features, land use, and human activities interact with and affect ground- and surface-water quality and aquatic communities. The regional assessments began in 2004 and will continue with findings and final publications scheduled to be available in 2007.

The intent of these assessments is to summarize water-quality conditions in a regional context. The regional assessments of the eight major river basins (MRB) (fig. 1) will focus on chemicals in water and other water-quality issues relevant to surface waters in each region (Hamilton and others, 2005). In general, each MRB regional assessment will address trends in nutrients and sediment, pesticides, and biological-response data (chlorophyll, algae). The study area for each MRB regional assessment comprises more than one NAWQA study unit, and data used for trend testing will include data from NAWQA studies supplemented with data from other USGS studies, as well as available data collected by other agencies. In addition, trend tests will be coordinated to document temporal changes and spatial differences for a particular water-quality constituent, not only within a particular MRB study area, but also among study areas nationwide.

The USGS Mississippi Water Science Center will complete an assessment of trends in nutrient and suspended-sediment concentrations and loads for rivers in the study area of the south-central United States, which is defined as the Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Region in figure 1. Several reports describe trends in nutrient and sediment data for this region. For example, studies by Van Metre and Reutter (1995), Demcheck and others (2004), Davis and Bell (1998), and Coupe (2002) document loads and trends in concentrations and loads of nutrients and/or sediments for statewide assessments or for selected river basins included in this region. National studies, such as work by Mueller and others (1995), include assessments of nutrient data from both ground-water wells and surface-water data-collection sites within this region. Studies summarized by Goolsby and Battaglin (2000), Meade (1995), and Turner and Rabalais (2004) assess nutrient concentrations and loads delivered by the Mississippi River Basin to the Gulf of Mexico; although these studies include data and results from this particular region, most of their focus is on the Upper Mississippi River Basin upstream of this region. The U.S. Environmental Protection Agency recently released results from its Nutrient Pilot Study, which included an assessment of nutrient concentration and loads from coastal or near-coastal waters draining into the northern Gulf of Mexico from Louisiana, Mississippi, and Alabama (U.S. Environmental Protection Agency, 2004). Therefore, this assessment is unique and timely in that it primarily will be focused on the entire Lower Mississippi, Arkansas-White-Red, Texas-Gulf Region, not just portions of the region.

The water-quality constituents included in this assessment are dissolved ammonia, total ammonia plus organic nitrogen, nitrite plus nitrate, dissolved orthophosphate, total phosphorus, suspended sediment, and total suspended solids. Loads will be calculated, and both temporal and spatial trends for constituent concentrations and loads will be investigated. Trends in sources of nutrients (point and nonpoint) and sediment will be used to explain trends in the surface-water data that are identified. This assessment will help resource managers understand changes in concentrations and loads of nutrients and sediment entering the northwestern Gulf of Mexico from the study area. This paper presents descriptions of the study area, data sources, site selection, and methods of analysis to be used in the regional assessment of trends in nutrient and sediment data from rivers in the south-central United States.

STUDY AREA

The study area comprises river systems in the following 2-digit hydrologic unit codes: 08, Lower Mississippi Region; 11, Arkansas-White-Red Region; and 12, Texas-Gulf Region (fig. 2; U.S. Geological Survey, 1998; Seaber and others, 1987). The study area includes all of Oklahoma and Arkansas; nearly all of Texas and Louisiana; and parts of Mississippi, Tennessee, Kentucky, Missouri, Kansas, Colorado, and New Mexico (fig. 3). Major cities in the study area include: Memphis, New Orleans, Baton Rouge, San Antonio, Houston, Dallas, Ft. Worth, Tulsa, Oklahoma City, Colorado Springs, Little Rock, Wichita, and Springfield (fig. 3). Major rivers in the study area include the lower Mississippi, Yazoo, Canadian, Cimarron, Arkansas, White, Red, Trinity, Brazos, Colorado, and Guadalupe (fig. 3).

The geology, geography, hydrology, and land use within the boundaries of the study area are complex and diverse. The western part of the study area is fairly arid [annual rainfall less than about 25 inches total per year (Owenby and others, 2001)] with topography ranging from flat to gentle, rolling hills within the Great Plains and Interior Highlands (Birdsall and Florin, 1998) and is fairly rural with few large cities. Land use primarily is grass and fallow land with some row and small grain crops (fig. 4). Water-resource issues in this part of the study area are related to water use, water rights, and irrigation as much as they are related to water quality. The eastern part of the study area has a humid, sub-tropical climate with annual rainfall amounts ranging from 40 to greater than 50 inches per year (Owenby and others, 2001); subsequently, water resources are fairly abundant. Elevations decrease from west to east toward the Mississippi River, and decrease from north to south toward the Gulf-Atlantic Coastal Plain (Birdsall and Florin, 1998). Land use in the eastern part of the study area is primarily forest and pasture land; however, row crops are abundant in the fertile Mississippi River Alluvial Valley (fig. 4). The eastern part of the study area is fairly rural with respect to land area, but is the more populous part and contains many of the previously mentioned cities (fig. 3). With the extreme ranges in geology, geography, hydrology, and land use within the study area, it is expected that trends in concentrations and loads of nutrients and sediment in surface waters also will vary considerably.

DATA SOURCES

The two types of data that will be assembled for this assessment are the water-chemistry and flow data used for trend and load analyses, and ancillary data used to assist in explaining any identified trends. All data assembled for this assessment will be stored and archived in the databases of the USGS Mississippi Water Science Center.

The primary source of water-chemistry and flow data for this assessment will be from the USGS. Since the early 1970's, the USGS has collected water-quality information from major river basins throughout the United States as part of three national programs: the Hydrologic Benchmark Network (HBN), the National Stream Quality Accounting Network (NASQAN), and the NAWQA Program. In addition, other long-term water-quality monitoring stations operate as part of USGS cooperative projects in the various States. All data from these USGS efforts have been compiled and are available to the public by means of the internet as part of the National Water Information System web-server (NWISweb). Another source of water-chemistry and flow data that will be considered is from ambient data-collection programs of each State within the study area. These data typically are stored and archived in the U.S. Environmental Protection Agency's (USEPA) Legacy Data Center (LDC) and the Storage and Retrieval (STORET) database (U.S. Environmental Protection Agency, 2004). Prior to being used, State's data sets will be evaluated as to their compatibility with USGS data sets. Differences among analytical methods, sample-collection protocols, and quality-assurance procedures are important issues to be considered.

In order to explain trends in surface water-quality data, it is important to identify and understand temporal and spatial patterns in source data. For example, land is constantly being converted in favor of urban development; therefore, can trends in phosphorus data for a particular sub-basin in this region be attributed to a change from a nonpoint agricultural source of phosphorus to a waste-water treatment plant point source as land is converted during the study period? For this assessment, ancillary data sources will be identified to assess trends in both point and nonpoint sources of pollutants. An example of point source information includes locations, waste streams, and loading amounts from municipal and industrial wastewater treatment plants. Such information typically is provided by the treatment plant operators to State regulatory agencies, who then submit this information to the USEPA Permit Compliance System (PCS) database (U.S. Environmental Protection Agency, 2005). An example of nonpoint source information are aggregate Geographical Information System (GIS) data layers of agricultural-related statistics for the study area, such as those available from the U.S. Department of Agriculture, Natural Resources Conservation Service, National Resources Inventory (U.S. Department of Agriculture, 2004).

SITE SELECTION

Site selection primarily is dependent upon three issues for this assessment: time period, minimum data requirements for analysis, and spatial coverage. There are at least two time periods under consideration for this assessment. The first time period considered is near-term and is defined as the most recent period of available USGS data, 1993-2003. This period provides the most recent decadal "snapshot" of nutrients and sediment being discharged from this region to the northern Gulf of Mexico. In addition, this near-term period is being considered as a common time period to interpret results from all MRB's to provide national perspective for recent trends in nutrient and sediment data. Such information will be the most useful to resource planners and regulatory agencies who are responsible for developing Total Maximum Daily Loads (TMDLs), nutrient criteria, and remediation or restoration efforts in impaired watersheds. A second time period under consideration is longer term, 1980-2003. Sites which have continuous or near continuous data for this longer period will help provide perspective to trends found in the shorter 1993-2003 time period. For example, if a trend is detected in total phosphorus data at a particular site that only has near-term data available, did that trend occur during a period of record flooding, average flow conditions, or drought for that particular watershed? Alternate time periods may be considered if data from more sites become available for the alternate time period. However, for this study area, it appears from initial site and data inventories that the time period 1993-2003 has the most sites available to be considered for analysis.

Site selection also is dependent upon the amount and frequency of data required to complete the statistical analysis used in this assessment (described in the next section). In general, data requirements include a minimum of 5 years of data and at least 50 data points. However, a certain number of samples per year with minimal gaps in the period of record for that data set to be considered for analysis is also required. For this assessment, there must be a minimum of quarterly samples in at least 70 percent of the years for the trend time period, and at least 4 samples per year in the first and last 20 percent of years sampled (D.K. Mueller, USGS, written commun., 2005). In addition, daily values of streamflow are necessary to calculate loads at each of the sites.

Finally, site selection (and to some extent, data source) is dependent on spatial coverage. For this analysis, lists of USGS sites will be generated from NWISweb by time period (1993-2003 and 1980-2003) for each of the constituents considered for trend analysis and load calculation. These sites will be plotted on a map that includes all of the State boundaries, majors rivers and streams, and the study area boundary. All of the major rivers and streams in the study area should have an adequate number of sites to address trends and loadings from that particular watershed. Ideally for the study area, sites would be selected with respect to spatial distribution as follows:

- At or near termination points for rivers that empty into the Gulf of Mexico (but upstream of tidal influences);
- On major rivers with drainage areas larger than about 10,000 square miles;
- Near locations where major tributaries empty into rivers;
- Upstream of Gulf of Mexico and tributary entry points at equidistant locations (about every 100 miles) or above/below strategic tributary locations; and
- Smaller tributaries primarily influenced by a specific land-use type.

Where USGS sites do not provide adequate spatial coverage, other data sources such as USEPA's LDC and STORET will be considered to complete spatial coverage. In addition, previously-mentioned time periods may require some adjustment in order to increase the number and spatial distribution of sites considered for analysis.

METHODS OF ANALYSIS

This section includes a general discussion of trend test selection and a discussion of methods used to estimate loads and test for trends for this assessment. This section also documents specific computer programs and software packages used to analyze the data.

Trend Test Selection: A trend is defined as a systematic change in a water-quality constituent over time (D.L. Lorenz, USGS, written commun., 2004). In order to complete trend tests for water-quality data, one must understand the complexities and processes that influence water-quality conditions in surface waters. Natural influences include climate, hydrology, precipitation, soil erosion, chemical reactions, and biological activities. Human influences include chemical applications, flow regulation, addition or removal of wastewater treatments plants, and land-use changes. The difficulty in interpreting trends in water-quality data is the ability to separate actual trends in the data from natural variability, as well as from artificial trends (trends resulting, for example, from database artifacts related to changes in method reporting levels for nutrient species through the time period of interest).

There are other characteristics that can influence water-quality data sets used for trend tests. Water-quality data are highly variable and do not follow any “known” distribution pattern such as a normal distribution. Water-quality databases can include “censored” data, which are values in which a constituent is detectable but reported as below some value (for example, an orthophosphate value of less than 0.01 milligram per liter). Other characteristics include changes in sample collection, sample processing, and laboratory analytical methods over time. All of these influences and characteristics must be considered when interpreting results of trends analysis in water-quality data.

There are many methods of analysis that can be used to determine trends. For example, highly sophisticated deterministic models can be used. These models require a large amount of input data such as flow, basin characteristics, chemical sources, and transport mechanisms at multiple locations throughout a particular watershed for calibration purposes. These models can be used to assess trends, but also can be used to “predict” trends should influences or stressors change over time.

Statistical methods also can be used for trend testing. These methods are less data intensive compared to deterministic models, are empirically based, and are more widely applicable and useful. To select an appropriate statistical method, several questions must be answered about the data set to be tested. First, is the distribution of the data set known? Parametric tests, such as simple linear regression, can be used for data that are normally distributed. Ordinary least squares is the method for calculating the slope and intercept coefficients for a linear regression equation. Another example of a parametric trend test is Tobit regression, which is utilized for data sets that contain censored data. Tobit regression is similar to linear regression except that maximum-likelihood estimation (MLE) is used to estimate values below censoring levels (Helsel and Hirsch, 1992). If the distribution of the data does not follow a normal distribution, then non-parametric, or distribution-free, methods should be used to test for trends. Non-parametric trend tests include the Mann-Kendall test, where time is considered a variable and the median value of a particular water-quality constituent is tested to determine if it changes over time.

The second question to be answered is related to study period and whether or not gaps exist in the data set to be tested for trends. For shorter study periods (less than about 15 years) and either no gaps or a limited number of gaps in the data set, then monotonic trends tests, such as linear regression or the Mann-Kendall test, can be used. Trends detected in monotonic tests indicate changes in the data set that are gradual and continuing over time. Results of monotonic trends tests give the overall direction of the trend if detected, and the slope of that trend is linear. For longer study periods (greater than about 15 years) that have no major gaps, non-monotonic trends tests such as time-series analysis can be used. Non-linear variations in trend direction that correspond to stressors or climatic changes can be observed in time series results. If there are large gaps in the data set, or if there is a known event that may have caused a dramatic change in trend direction (for example, construction and subsequent operation of a dam), then step trend methods, such as the two-sample t-test for parametric data sets or the rank-sum test for non-parametric data sets, should be used (Helsel and Hirsch, 1992).

The third question involves adjusting trend tests to account for natural variability, primarily seasonality and streamflow. An example of seasonal variability in nutrient and sediment data includes peak concentrations that occur in the spring shortly after fertilizers are applied to freshly plowed agricultural fields. These peak events typically occur each year, and their influence in water-quality trend results must be accounted for or removed. Seasonal terms, such as a sine or cosine function, can be added in linear regression (parametric) trend tests to account for seasonal variability. The Seasonal Kendall (non-parametric) trend test is a variation of the Mann-Kendall test in that trend statistics (Kendall's Tau) are computed for specified seasons (for example, quarterly or monthly) and then summed to determine the trend in the data for an overall time period.

Flow adjustment is a technique used to understand actual changes in a water-quality constituent without influence of trends in flow. Data are flow adjusted by establishing a relation between flow and the water-quality constituent prior to trend testing. This relation is developed by means of regression or by using a smoothing technique such as Locally Weighted Scatterplot Smooth (LOWESS, Helsel and Hirsch, 1992). Once a relation is developed, then a particular trend test can be run on residuals produced from that relation (residuals are the differences between actual and predicted data).

It is important to decide if flow adjustment is necessary in trend testing. If trends tests are used to determine impacts to aquatic communities, then flow adjustment is not important. For example, total ammonia (NH_3 plus NH_4^+) exceeds chronic criterion for aquatic organisms for concentrations above about 2.1 milligrams per liter (when pH is within the range of 6.5 to 9.0 and temperature from 0 to 30 degrees Celsius) (Mueller and others, 1995). Therefore, to determine the effects to a particular ecosystem, it is not pertinent that increases in streamflow were the primary cause for the increases in total ammonia over time, but simply that ammonia concentrations increased and exceeded the criterion. However, if it is important to understand why ammonia concentrations exceeded the criterion over time, then the trend test should be run with flow-adjusted data to determine if the trend is retained once adjusted for the effect of streamflow. If the trend was retained using the flow-adjusted ammonia data, then the increase may have been caused by a human-related action such as an increase in fertilizer usage. For this example of ammonia, it is important to the study objectives to run trends tests on both the unadjusted and the flow-adjusted data to understand the overall "picture" of what was happening in relation to ammonia concentrations within this watershed.

Load Estimation and Trend Test Methods Used In This Assessment: A load is defined as the mass of a water-quality constituent that passes a point on a river over a given amount of time (D.L. Lorenz, USGS, written commun., 2004). Loads will be estimated using the USGS computer program Load Estimator, or LOADEST (Runkel and others, 2004), for this assessment. LOADEST utilizes a seven-parameter linear regression model that incorporates flow, time, and seasonal terms to estimate loads of concentration over time for specific time periods (annual, monthly, or daily loads). The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. The first two methods, MLE and Adjusted Maximum Likelihood Estimation (AMLE) are appropriate when the calibration model residuals are normally distributed. Of the two, AMLE is more appropriate when the calibration data set (time series of streamflow and concentration data) contains censored data. The third method, Least Absolute Deviation (LAD), is an alternative to MLE when residuals are not normally distributed (Runkel and others, 2004). Once calibrated, daily values of streamflow are used as independent variables to produce the load results. LOADEST is available as a "USGS plug-in" (S-LOADEST) to the S-PLUS statistical software package, which is a PC-based statistical software package (Insightful, 2002).

Statistical methods will be used to test for trends in nutrient and sediment concentrations and loads in this assessment. Tobit regression trend tests will be used for sites that have near-term data (1993-2003). Tobit regression is preferred because of the likelihood that censored values will exist in the data sets used in this assessment. Although Tobit regression is considered a parametric test, it also can be used with non-parametric data sets by transforming streamflow and water-quality data (using transformations such as common logs, exponentials, hyperbolic, or some other mathematical change), and then developing the liner regression model with the transformed data. Because the LOADEST program uses Tobit regression (seven parameter model), LOADEST will be used to estimate trends in the near-term data sets, and AMLE will be the preferred choice for calibration of the model coefficients. Trend direction and magnitude are estimated using the coefficient for time in the LOADEST program. Because flow terms are incorporated into the seven-parameter model in LOADEST, the trend results are considered flow adjusted and represent trends in concentration data caused by some external influence such as a change in fertilizer inputs. In order to analyze the concentration data to determine impacts to aquatic communities, the LOADEST model and/or results will require some modification to identify trends in unadjusted concentrations.

The Seasonal Kendall Test will be used on unadjusted and flow-adjusted concentrations for data sets that are non-parametric or for data sets that cannot be transformed to parametric using a mathematical expression. Results of the Seasonal Kendall test include trend direction and magnitude. The computer program Estimate Trend, or ESTREND, developed by the USGS, includes the Seasonal Kendall Test (Schertz and others, 1991), and ESTREND is also a "USGS plug-in" to S-PLUS (S-ESTREND).

Time series modeling will be used to estimate trends (nonlinear, non-monotonic) for sites that have long-term data (1980-2003). In time series analysis, flow and concentration data are modeled at the same time, thus sites that have poor relations between flow and concentration can be modeled more successfully using the time series model. The time series model is also based on MLE, and the model can be used for explanatory purposes. Ancillary data can be incorporated in the time series model, and results can include a detailed analysis from several inter-related sites from the same watershed. The USGS computer program QWTREND will be used for time series modeling. Data requirements for QWTREND are fairly complex: period of record is at least 15 years (but not necessarily consecutive); there must be an average of at least 4 samples per year, although the sampling frequency may vary from year to year; at least 10 samples during each 3-month season (January to March, February to April, March to May … December to February); less than 10 percent censored data; and full record of daily streamflow from 5 years before the first year through the period of record (A.V. Vecchia, Jr., USGS, written commun., 2004).

SUMMARY

The USGS will assess trends in nutrient and suspended-sediment concentrations and loads for rivers in the South-Central United States, which is defined as the Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Region. Water-quality constituents included in this assessment are dissolved ammonia, total ammonia plus organic nitrogen, nitrite plus nitrate, dissolved orthophosphate, total phosphorus, suspended sediment, and total suspended solids. Both temporal and spatial trends for each constituent will be investigated, and loads will be estimated. Trends in sources of nutrients (point and nonpoint) and sediments will be investigated to help explain those trends that are identified in the nutrient and sediment data. This assessment will help resource managers understand changes in concentrations and loads of nutrients and sediments to the northwestern Gulf of Mexico.

The study area includes all or parts of 11 States. The geology, geography, hydrology, and land use within the boundaries of the study area are complex and cover a range of extremes. Therefore, it is expected that trends in concentrations and loads of nutrients and sediment in surface waters within the study area also will vary considerably.

The primary source of water-chemistry and flow data for this assessment will be data collected at USGS water-quality sites that were part of three national USGS programs and data collected as part of other USGS projects in the various States in the study area. Other sources of data will be considered, such as from State ambient data-collection programs. If used, State data sets will be assessed as to their compatibility with USGS data sets. Ancillary data sources will be identified to explain trends that are identified. Ancillary data sources will address both point and nonpoint sources of pollutants.

Site selection primarily is dependent upon three issues: time period used for analysis, minimum data requirements for analysis, and spatial coverage. There are at least two time periods under consideration for this assessment. The first time period under consideration is near term and is defined as the most recent period of available USGS data, 1993-2003. A second time period under consideration is longer term, 1980-2003. Sites which have continuous or near continuous data for this longer period will help provide perspective to trends found in the shorter 1993-03 time period. In general, data requirements include a minimum of 5 years of data and at least 50 data points. However, software may also require a certain number of samples per year with minimal gaps in the period of record for that data set to be considered for analysis. With regard to spatial coverage, all of the major rivers and streams in the study area should have an adequate number of sites to address trends and loadings from that particular watershed.

Statistical methods for load estimation and trends testing will be used for this assessment. Loads will be estimated using a seven-parameter linear regression model that incorporates flow, time, and seasonal terms to estimate loads of concentration over time for specific time periods (annual, monthly, or daily loads). Once calibrated, daily values of streamflow are used as independent variables to produce the load results. Tobit regression, which is based on the same regression methods used for load estimation, will be used to estimate trends for sites that have near-term data (1993-2003). Time series modeling will be used to estimate trends (nonlinear, non-monotonic) for sites that have long-term data (1980-2003).

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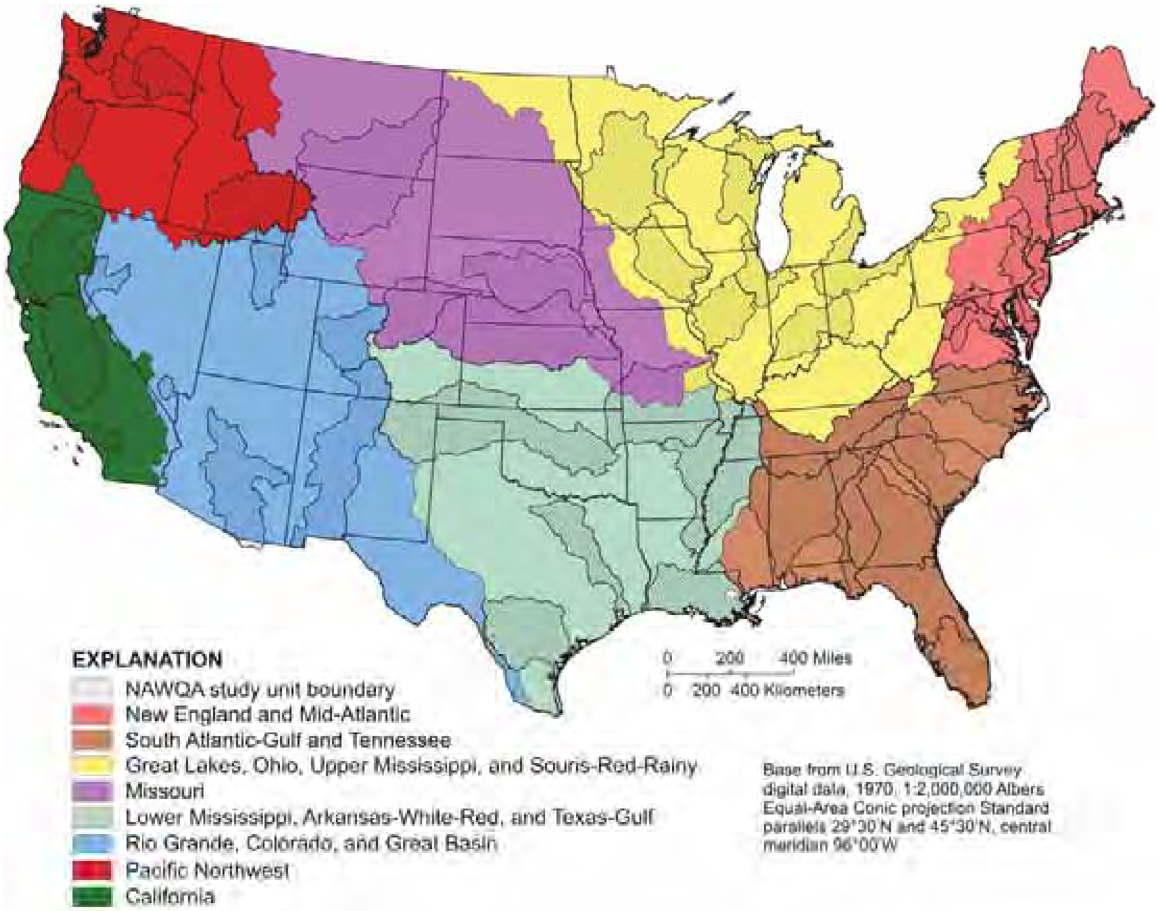

Figure 1. Locations of major river basin (MRB) and National Water-Quality Assessment (NAWQA) study areas.

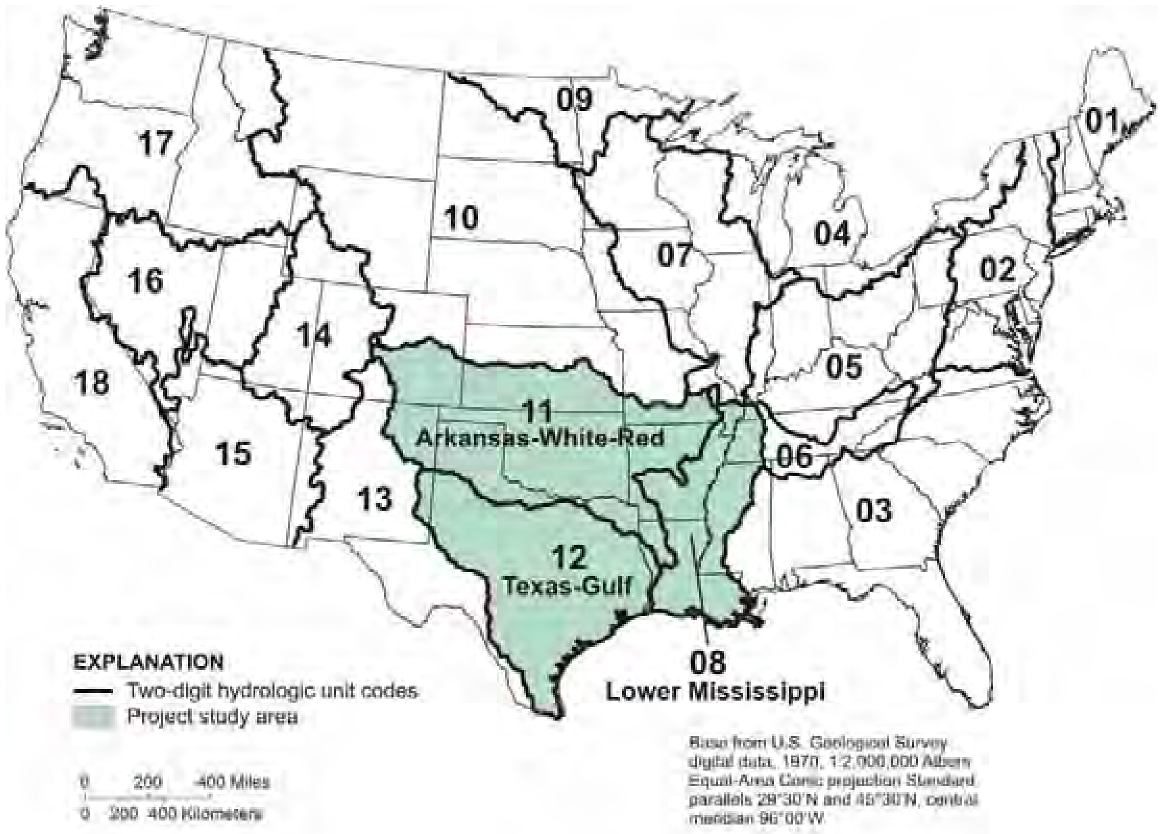

Figure 2. Two-digit hydrologic unit codes and the study area.

Figure 3. States, cities, and major rivers in the study area.

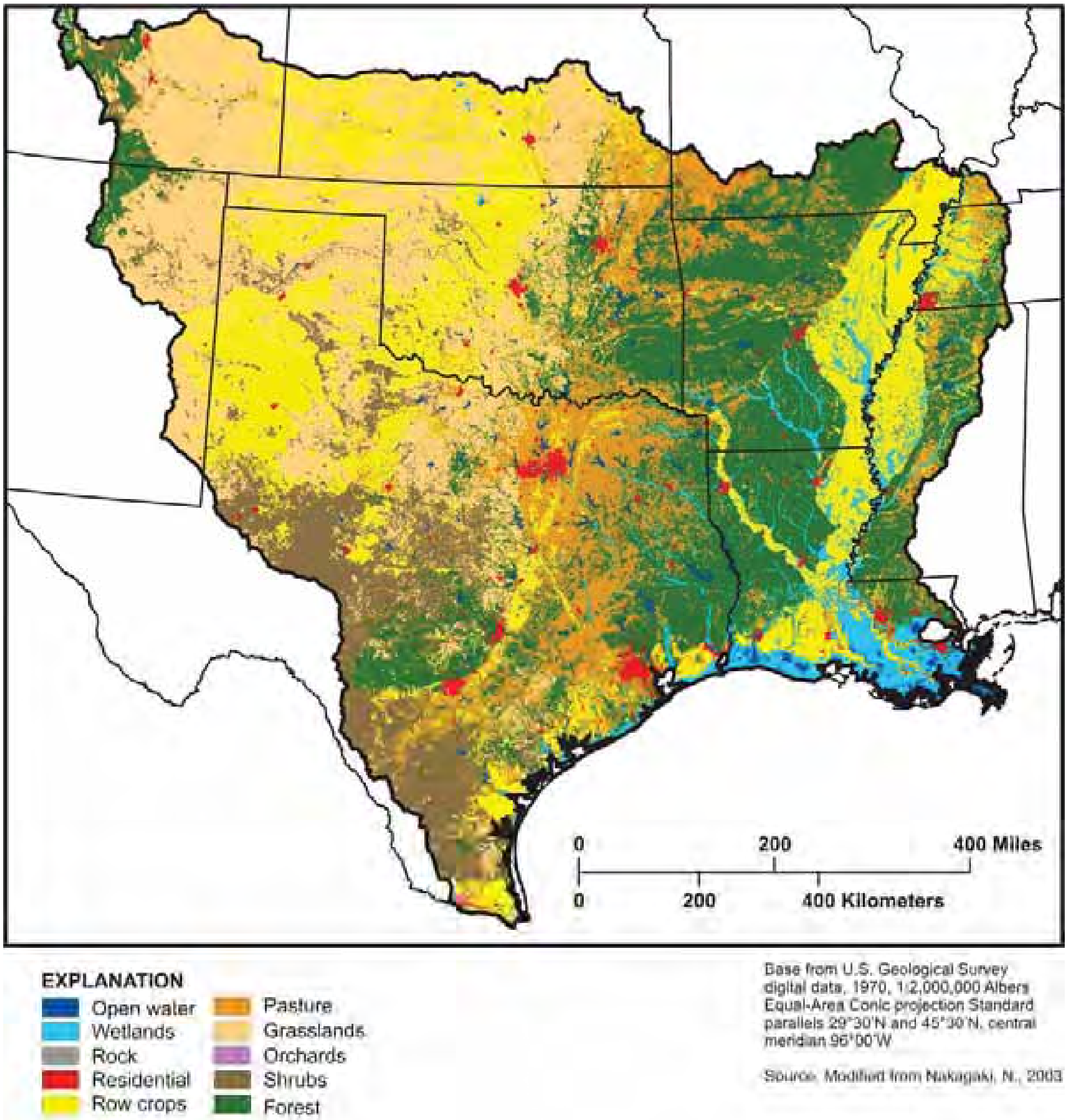

Figure 4. Land use within the study area.

Closing Plenary Session
Coastal Issues
Moderator: Phil Bass

Speakers:

Bob Fairbanks
Mississippi Power Company

Bill Walker
Mississippi Department of Marine Resources

Bryon Griffith
EPA / GMPO

Luncheon Speaker:
Scott Gordon
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STATEMENT OF AAEO

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