PROJECT PLAN
202 Soil Resource Management
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12-15 December 2000

Management Research Unit
MU 6612-09 Southern Piedmont Conservation Research Unit

Old CRIS Project Number
6612-12000-008-00D

Location
Watkinsville, Georgia

Title
Enhancing soil-water-nutrient processes in Southern Piedmont pasture and crop systems

Scientists
Alan J. Franzluebbers, Lead Scientist *(Soil Ecologist)* 100%
John A. Stuedemann *(Animal Scientist)* 70%
Harry H. Schomberg *(Agroecologist)* 50%
Ronald R. Sharpe *(Soil Chemist)* 40%
Dinku M. Endale *(Hydrologist)* 30%
Dorcas H. Franklin *(Geographer)* 30%
Michael B. Jenkins *(Soil Microbiologist)* 20%
Jean L. Steiner, Research Leader *(Microclimatologist)* 20%
Dwight S. Fisher *(Rangeland Scientist)* 10%
Lowry A. Harper *(Atmospheric Physicist)* 10%

Total Scientific Staff Years
3.8

Planned Duration
60 months

Signatures

/s/
Research Leader — Date Approved

/s/
Lab, Center, or Institute Director — Date Approved

/s/
Area Director — Date Approved

/s/
National Program Team Representative — Date Approved

Project Summary

The Southern Piedmont (16.5 million ha) is a region of high potential productivity because of the warm-moist climate, but suffers also from periodic drought, high erosion potential, and relatively poor soils due to low organic matter and high subsoil acidity. These environmental conditions, along with relatively small land holdings by most agricultural producers, pose unique challenges to increase productivity while maintaining environmental integrity. Fortunately, soil and water resources are very responsive (both positively and negatively) to management. Our general objective is to better understand the processes of soil, water, and nutrient transformations and movement and mechanisms that will lead to sustainable agricultural systems in the southeastern USA.

Specifically, our objectives are to:

(1) refine cropping strategies for the Southern Piedmont region to enhance nutrient cycling, soil, water, and air quality, and plant water availability through an integration of crop and cover crop selection, type and frequency of tillage, and fertilization source,

(2) refine cattle management strategies to increase productivity, nutrient cycling, and soil and water quality by increasing forage availability during a greater portion of the year, optimizing forage quality, utilizing regionally available animal manures, and optimizing stocking density,

(3) improve recommendations for poultry litter application to cropland and pastureland as a nutrient source by understanding the impacts on agronomic productivity, animal health, nutrient cycling, soil quality, and water quality (i.e., surface runoff and leachate),

(4) develop strategies to optimize soil carbon (C) sequestration of crop and pasture management systems to increase soil quality and reduce atmospheric emissions of CO_2, and

(5) develop strategies to limit phosphorus (P) transport to surface waters in the southeastern USA.

Our approach will be to utilize several current long-term crop and pasture research sites and develop new long-term field experiments designed to measure animal, plant, soil, water, and atmospheric responses to management variables. In addition, appropriate laboratory and greenhouse experiments will be conducted to specifically test hypotheses and validate field observations. We expect to (1) develop quantitative and qualitative relationships among management and ecosystem response variables, (2) collect valuable field and laboratory data to develop and validate ecosystem models, and (3) develop and publish unique experimental protocols to measure ecosystem response to management.

Objectives

Our general objective is to better understand the processes and mechanisms of sustainable agricultural systems in the Southern Piedmont USA. This overview can be divided further into five general objectives.

Objective 1:
We want to refine cropping strategies for the Southern Piedmont region to enhance nutrient cycling , soil, water, and air quality, and plant water availability through an integration of crop and cover crop selection, type and frequency of tillage, and fertilization source. Within this broad crop management objective, we will specifically
(i) determine surface runoff and subsurface leachate quantity and quality, nutrient cycling, and plant water availability as affected by tillage management and nutrient source application,
(ii) determine surface runoff quantity and quality, surface soil organic matter preservation, atmospheric fluxes, and soil nutrient transformations as affected by variations of two conservation tillage systems with poultry litter application, and
(iii) determine agronomic productivity, plant water availability, and soil quality with variations in cover crop growth habits.

Objective 2:
We want to refine cattle management strategies to increase productivity, nutrient cycling, and soil and water quality by increasing forage availability during a greater portion of the year, optimizing forage quality, utilizing regionally available animal manures, and optimizing stocking density. Within this broad animal management objective, we will specifically
(i) relate animal productivity and performance to changes in soil quality,
(ii) determine the effects of cattle grazing pressure and level of poultry litter application on soil organic matter and nutrient cycling,
(iii) determine spatial (vertical and lateral) patterns of nutrient accumulation in pastures,
(iv) determine the impact of overseeding a cool-season forage into established warm-season forage on animal productivity, nutrient cycling, and soil and water quality,
(v) determine the physiological responses of cattle grazing endophyte-infected tall fescue,
(vi) determine cattle parasite responses to limited anthelminthic treatment and grazing management on newly established pastures, and
(vii) determine difference in runoff P with variable filter-strip width and different field manipulation techniques at the plot scale with variable nutrient application rates.

Objective 3:
We want to improve recommendations for poultry litter application to cropland and pastureland as a nutrient source by understanding the impacts on agronomic productivity, animal health, nutrient cycling, soil quality, and water quality (i.e., surface runoff and leachate). Within this broad poultry litter management objective, we will specifically
(i) determine the rate of accumulation of soil nutrients, potential runoff characteristics, and changes in soil quality from the application of poultry litter to differently managed forages,
(ii) determine the fate of nutrients (i.e., soil, leachate, surface runoff) from surface-applied poultry litter in conservation-tilled cropland and grazed pastures, and
(iii) derive runoff coefficients for the P-Index manure source factor for various manures (broiler, layer, dairy slurry) applied to benchmark soils with time.

Objective 4:
We want to develop strategies to optimize soil C sequestration of crop and pasture management systems to increase soil quality and reduce atmospheric emissions of CO_2. Within this broad soil C sequestration objective, we will specifically

(i) determine the rate of soil C sequestration in grazed and ungrazed pastures, in cool-season and warm-season pure and mixed stands of forage, and in pastures fertilized organically and inorganically,

(ii) determine the relationships among soil C sequestration and a suite of soil biological, chemical, and physical properties to help natural resource managers appreciate the value of soil organic C and provide quantitative relationships between soil organic C and soil functions.

Objective 5:
We want to develop strategies that limit P loss from soils in the southeastern USA. Within this broad P loss objective, we will specifically

(i) determine relationships between soil test P and runoff P on benchmark agronomic soils in the southeastern USA , and

(ii) evaluate soil sampling strategies for best defining soil-test P and runoff P relationships in Southern Piedmont grazinglands.

Need for Research

Description of the Problem to be Solved
Soils are very responsive to management in the warm, moist environment of the Southern Piedmont region. Degradation of soil and water resources affect not only rural communities, but the population in general due to increasing cost of production, instability in supply of agricultural products, food safety concerns, and restrictions on the uses of surface and groundwater. For cropping and grazing systems to be sustainable, they must address both production issues (increasing profit without enormous capital investment, overcoming soil acidity and drought, reducing water runoff, increasing infiltration, reducing input costs by recycling nutrients and ecologically controlling pests, and successfully integrating multiple operations) and environmental issues (improving water quality of surface and ground water resources by reducing soil erosion and preventing nutrient and fecal-borne pathogen movement; improving soil quality and C sequestration by reducing soil disturbance, adopting conservation practices, and expanding the growing season to increase photosynthetic capacity; reducing greenhouse gas emissions from animal production systems; and finding suitable alternatives to the concentrated disposal of animal manures). The objectives of this CRIS project are aimed at enhancing biogeochemical processes to improve productivity, nutrient cycling, and soil and water quality in pasture and crop lands of the southeastern USA.

Relevance to ARS National Program Action Plan
Our research objectives relate directly to several components of both the Soil Resource Management National Program (i.e., Productive and Sustainable Soil Management Systems; Nutrient Management; Soil Conservation and Restoration; Soil Water; and Soil Biology) and the Rangeland–Pasture–Forages National Program (Ecosystems and their Sustainable Management; Forage Management; and Grazing Management, Livestock Production, and Environment), specifically the need to:

(1) identify and develop research protocols,
(2) evaluate soil, crop, and animal management strategies,
(3) define the biological, chemical, and physical interactions, and
(4) relate ecosystem productivity (i.e., crop and animal production) to environmental health (i.e., soil, water, and air quality),

which will lead to the development and implementation of sustainable agricultural ecosystems in the southeastern USA. Two other CRIS projects within our management unit contribute significant relevant information to this project and are coded to Integrated Agricultural Systems, Water Quality and Management, Manure and Byproduct Utilization, and Global Change.

Potential Benefits
Development of sustainable agricultural systems for the region, recommendations to producers and natural resource planners for improving soil and water quality, and scientifically-based strategies to balance profitability, environmental quality, and productivity.

Anticipated Products
Improved best management practices for cropping and grazing systems in the Southern Piedmont region, improved land application strategies for poultry litter, management strategies to maximize soil C sequestration, and a database for testing single- and multiple-objective decision-support models.

Customers
Crop, cattle, and poultry producers, as well as producers of less dominant crops and livestock (e.g., exotic animals, mixed small-farming activities) in the southeastern USA, Natural Resources Conservation Service, Cooperative Extension Service, state environmental protection divisions, and sustainable agricultural resource providers.

Scientific Background

<u>Soils in the humid southeastern USA</u> have undergone severe erosion and degradation as a result of historically intensive crop production with conventional tillage (Trimble, 1974; Langdale et al., 1992). Soil organic C (SOC) levels following long-term cultivation have been reported to be as low as 30% of precultivation levels (Giddens, 1957). Extreme losses of SOC occurred in this region, because erosive forces preferentially remove the lower density components of soil (i.e., organic matter), which are concentrated near the surface (Lowrance and Williams, 1988). Sequestration of organic C in degraded soils is necessary to not only improve physical, chemical, and biological properties of soils (Follett et al., 1987), but also to help mitigate potential greenhouse effects from rising atmospheric CO_2 (Lal et al., 1998).

Crop production systems
Crop management systems can vary greatly in their production potential and impacts on the environment. <u>Tillage, crop rotation, and nutrient applications</u> are important management variables that influence long-term sustainability. Restoration of eroded cropland in the southeastern USA has been demonstrated with the development of conservation tillage systems, which limit soil disturbance and allow surface residue accumulation (Langdale et al., 1992). Long-term no-tillage management can increase infiltration by increasing soil macroporosity (Edwards et al., 1988). Many of the management options for achieving

sustainability, however, are regionally specific, with variations due to soil type, climatic conditions, and landscape ecology.

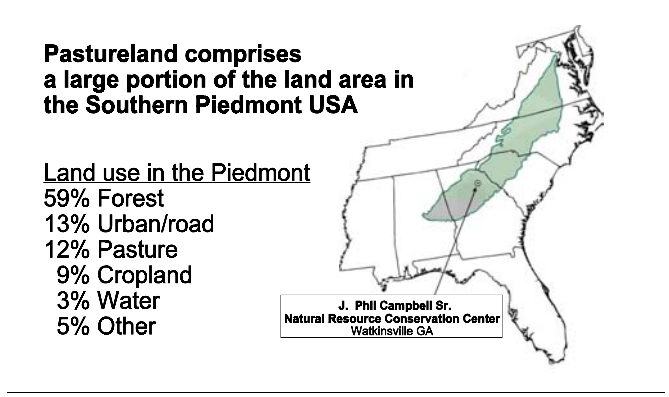
Ecological strategies to create more favorable habitat for beneficial insects could be further developed with the use of cover crops, various crop rotation sequences, and surface residue management (Altieri, 1994). Several types of cover crops may be appropriate for use in the southeastern USA, but further information is needed to evaluate the effects of these cover crops on nutrient and water availability in various crop rotations, on various soil types, and within specific management conditions. Information is needed on crop productivity, economics, ecological responses, and transferability of technology from one enterprise to another.

The quantity of nitrogen (N) available from soil and crop residues is important to make recommendations for additional fertilizer N to crops. Nitrogen availability in conservation tillage systems is often difficult to assess because of uncertain interactions of surface residues with N mineralization processes. The CERES plant growth models use a moderately complex N submodel to simulate the many interacting factors influencing net N mineralization and could be useful as a tool to estimate N needs of crops grown in the southeastern USA (Quemada et al., 1997).

Poultry production in the Southern Piedmont is extensive (Census of Agriculture, 1992). Manure is often mixed with bedding material at the end of the production cycle, cleared from confinement housing, and applied as litter (manure plus bedding) to nearby land as a source of nutrients. Depending upon management, however, repeated application of poultry litter could become a source of excessive nutrients (Vervoot et al., 1999). Surface application of poultry manure without soil incorporation may potentially cause unwanted nutrient enrichment in surface water runoff, which can be high in the high-rainfall region of the southeastern USA. Of increasing concern is the unbalanced load of P in poultry manure compared with N. Crop production in the southeastern USA benefits greatly from P application, because these soils have a great capacity to fix P, especially in the subsurface clayey horizons. However, little information is available to predict the impact on surface water concentration of and soil profile distribution of P from poultry manure application to conservation tilled cropland.

Cattle production systems

In the Southern Piedmont region, an increasing portion of land supports small-farm grazing cattle production systems (Census of Agriculture, 1992). Despite the abundance and importance of managed pastures in the southeastern USA, relatively little information is available to describe rates of soil organic C and N accumulation (Schnabel et al., 2001) and potential loss of P under pasture management systems. Pastures, because of their extensive distribution throughout the humid regions of the USA, are capable of storing an enormous amount of SOC (Follett et al., 2001). Pastureland throughout the humid regions of the USA accounts for 51 million ha of land (NRCS, 1997). Assuming a reasonable average of 40 $Mg \cdot ha^{-1}$ to a depth of 20 cm in all pastures of the USA, this particular land use may contain -2 Pg of C stored in surface soil.



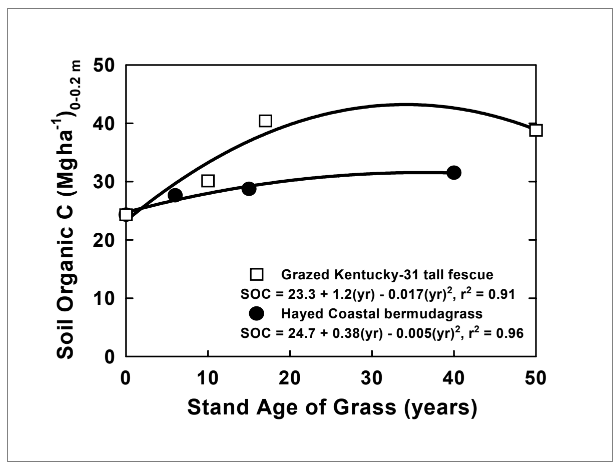
Soil organic C storage under native grasslands of the Great Plains of North America was 30 to 150% greater than following cultivation (Haas et al., 1957; Burke et al., 1989; Davidson et al., 1993). Research on the abandoned cropland in this semiarid region suggests a very slow recovery rate (i.e., >100 yrs) of SOC, depending upon plant and climatic variables (Dormaar and Smoliak, 1985; Burke et al., 1997). In the humid eastern USA, clearing of native forests for crop production also caused a major decline in SOC and severe soil loss through erosion (Giddens, 1957). However, in contrast to the semiarid Great Plains region, recovery in SOC in humid regions can be rapid when shifting from clean tillage cropping to various pasture management systems (Hendrix et al., 1998; Franzluebbers et al., 2000). Fixation of CO_2 via pasture plants and deposition of organic residues via litter and roots is much greater with adequate moisture under pastures of the eastern USA than under rangelands of the western USA. Unfortunately, much of the work on SOC sequestration in grazinglands of the USA has been conducted under semiarid rangeland conditions (Milchunas and Lauenroth, 1993). Until recently, little information has been gathered on the impacts of various pasture management systems on SOC sequestration in the eastern USA. A recent investigation indicates that the magnitude and rate of SOC sequestration in the humid regions of the USA may be extremely important towards offsetting emissions of atmospheric CO_2. Soil organic C under a 17-year-old tall fescue (*Festuca arundinacea* Schreb.) pasture was 40 Mg · ha^{-1} to a depth of 20 cm (+ 2 Mg · ha^{-1} in surface litter C), while SOC under long-term row cropping was 24 Mg · ha^{-1} (+ 2 Mg · ha^{-1} in surface litter C) and in a nearby 130-year-old forest was 29 Mg · ha^{-1} (+19 Mg · ha^{-1} in surface litter C) (Franzluebbers et al., 2000). Assuming the difference we observed between tall fescue and long-term cropping (i.e., 16 Mg · ha^{-1}) was applied to all of the 14 million ha of land planted to tall fescue, the amount of C stored in surface soil due to planting of tall fescue alone would be 224 Tg.

Grazing of a forage crop compared with haying returns much of the biomass directly to the land with a positive impact on soil organic C and N accumulation (Franzluebbers et al., 2000), but the impact of stocking density on plant productivity, soil compaction, and soil organic C, N, S, and P cycling in the eastern USA is not well known. Further, the impact of whether forage is mechanically harvested or not on soil organic C and N deserves attention, based on the extent of land currently managed under the Conservation Reserve Program (CRP). Harvest management would be expected to alter the distribution of C, N, P, and S among surface residue and soil depths, because of the effects of animal traffic, ruminant processing of forage, and hay removal.

The effect of fertilization strategy on SOC dynamics in managed pastures is variable (Schnabel et al., 2001). In some cases, increased fertilization may improve forage yield but have little effect on SOC (Owensby et al., 1969; Ross et al., 1995). In other cases, increased fertilization improves both forage yield and SOC in the long-term (Schwab et al., 1990; Haynes and Williams, 1992; Malhi et al., 1997). The impact on soil organic C and N dynamics of whether fertilization comes from an organic or an inorganic source has received limited attention. Soil organic C was little affected whether grass received manure or inorganic fertilizer in a long-term experiment at Rothamsted (Jenkinson, 1988). However, greater accumulation of SOC was observed under fertilized ryegrass (*Lolium perenne* L.) than under ryegrass-white clover (*Trifolium repens* L.) (Hatch et al., 1991). Much more work is needed to understand sequestration of soil organic C and N and associated impacts on soil and water quality in response to organic and inorganic amendments to grazed and ungrazed pastures.

<u>Lateral and vertical distribution of nutrients</u> in pastures can limit plant-animal productivity or pose environmental threats, depending upon quantities available and the type of management employed. In the southeastern USA where rainfall is abundant and soils are weathered, nutrient applications are susceptible to both runoff and leaching losses. Environmental regulations to protect water quality have been and will continue to be developed, especially with the increased competition for water resources among agricultural-, urban-, wildlife-, and recreational-supporting sectors of our increasingly affluent society. Unfortunately, details on nutrient accumulation and distribution in pasture soils are limited, but necessary for legislators to make rational decisions on land use and nutrient management based on scientific evidence.

<u>Hybrid bermudagrass</u> (*Cynodon dactylon* L.) is a widely planted forage in the southern USA, because of its excellent productivity and palatability. A chronosequence of hayed hybrid bermudagrass following conversion from cropland suggested a SOC sequestration rate of 330 kg · ha^{-1} · yr^{-1} during the first ten years and 170 kg · ha^{-1} · yr^{-1} during the period of 10 to 30 years (Franzluebbers et al., 2000). In this same study, however, SOC sequestration rate of grazed endophyte-infected tall fescue was 1000 kg · ha^{-1} · yr^{-1} during the first ten years and 480 kg · ha^{-1} · yr^{-1} during the period of 10 to 30 years. This study revealed intriguing differences in SOC sequestration among these two forage systems that require further research. Could endophyte-infected tall fescue, an adaptable and persistent cool-season grass, consistently sequester SOC at a rate more than double that of hybrid bermudagrass? If so, then forage recommendations in the eastern USA might need to be balanced among the economics of production, method of forage harvest, soil quality considerations, and the global concern of rising atmospheric CO_2 concentration.



Data from Franzluebbers et al. (2000). Soil organic C at 0 years was assumed from data collected under cropland.

<u>Tall fescue</u> is a widely disseminated, perennial forage across the world. In the USA, tall fescue is grown on more than 14 million ha throughout the humid regions of the midwest, southeast, and northeast (Buckner et al., 1979). The reason for superior persistence of tall fescue may be related to a mutualistic association it has developed with a <u>fungal endophyte</u>, *Neotyphodium coenophialum*, first reported by Bacon et al. (1977). This fungus resides in the above-ground portions of tall fescue, where it produces alkaloids that have been shown to be toxic when consumed by grazing cattle, sheep, and horses (Stuedemann and Hoveland, 1988). Cattle grazing or fed tall fescue hay with a high endophyte level ingested 65 to 92% as much forage,

Soil properties (0-15 cm depth) under tall fescue as affected by endophyte infection level (data from Franzluebbers et al., 1999).

Soil property	Endophyte level High		Low
Total organic C (Mg · ha^{-1})	31.2	**	29.1
Potentially mineralizable C (kg · ha^{-1} · d^{-1})	48.5	*	53.9
Ratio of mineralizable-to-total	1.56	**	1.87

* and ** are significant at P#0.1 and P#0.01, respectively.

produced 57 to 83% as much milk, gained 21 to 78% as much weight per day, and gained 65 to 89% as much weight per hectare compared with animals fed tall fescue having a low endophyte level (Stuedemann and Hoveland, 1988). In addition to the negative effects on grazing cattle, toxic alkaloids produced in leaf tissue of endophyte-infected forage deter herbivorous insects (Prestidge et al., 1982; Latch, 1993; Rowan and Latch, 1994) and other pests such as pathogenic fungi, viruses, and root-feeding nematodes (Latch, 1997), leading to greater persistence of endophyte-infected forage. Endophyte infection also enhances drought tolerance (Bouton et al., 1993; West et al., 1993), allows rapid decline in water conductance during stomatal closure (Buck et al., 1995), enhances osmotic adjustment in the meristematic region (Elmi and West, 1995), and induces greater root proliferation under drought-stressed conditions (Richardson et al., 1990).

In previous work, SOC at the end of 15 years under tall fescue with high endophyte infection was 18% greater at a depth of 0-2.5 cm than under tall fescue with low endophyte infection (Franzluebbers et al., 1999b). The difference in SOC storage between two animal production strategies approaches the increase in SOC upon conversion of land from conventional-tillage crop production to no-tillage crop production [2.3±1.5 Mg · ha^{-1} (Franzluebbers et al., 1999a) and 4.6 Mg · ha^{-1} (Beare et al., 1994)]. In addition to differences in the quantity of SOC, particulate organic C and N (i.e., macroorganic matter >0.25 mm, which is indicative of plant root residues below the surface layer) were 12 and 21% greater, respectively, with high than with low endophyte infection. More biochemical analyses are needed to determine whether endophyte infection leads to a direct effect on soil microflora or an indirect effect via plant production differences.

Reasons for the greater SOC sequestration under tall fescue with high compared with low endophyte infection were not fully elucidated, but there was evidence that soil microbial activity may have been inhibited with high endophyte infection (e.g., specific respiratory activity of soil was 17% lower with endophyte infection and microbial community structure estimated via fatty acid methyl esters was altered in the residue-enriched surface layer) (Franzluebbers et al., 1999b). Soil microbial activity controls the rate of decomposition of plant-fixed organic C and subsequent standing stock of C in soil. If in fact, endophyte-infected tall fescue limits soil microbial activity, then this mechanism needs to be more fully understood and exploited to maximize potential C sequestration in pasture soils. We have gathered enough preliminary evidence to begin (1) testing hypotheses of how this phenomenon of enhanced SOC sequestration under endophyte-infected tall fescue would be regulated and (2) characterizing physiological and environmental conditions under which enhanced SOC sequestration could be maximized.

In addition to cattle production, farms in the southeastern USA produce large numbers of poultry. Tall fescue pastures are often fertilized with litter cleaned from nearby poultry houses.

Poultry litter can be a valuable resource by providing a wide range of nutrients and organic matter. It is often an economical alternative to inorganic fertilizer. However, continuous application of poultry litter to supply plant N requirements can lead to excessive nutrient loading of P, Cu, and Zn (Wilkinson et al., 1997) and potentially contribute to nutrient and fecal-borne pathogenic contamination of surface waters (NRC, 1993). Surprisingly little information is available that documents the effect of poultry litter application compared with conventional inorganic fertilizers on the rate and magnitude of SOC sequestration. A fair amount of research has focused on N and P runoff characteristics and potential surface water contamination from the application of animal manures to pastures at the plot scale (Sharpley et al., 1981; 1996), but more research is needed at the field and landscape level. Limited scientific evidence indicates that eutrophication could be related to N and P losses from agricultural lands. Phosphorus has little or no gaseous phase and could be more manageable than N. Although there is an abundance of literature on plant response to P, more information is needed on P adsorption and desorption in various soils and P concentration in runoff derived from a variety of management conditions. In pastures, P in surface residue and recent amendments may be as important, or more so, than soil-test P in determining the potential for P loss through runoff.

Nutrient losses from runoff in grazinglands are costly to both the land manager and the environment. Management strategies that reduce runoff and nutrient movement are needed to optimize nutrient use, farm productivity, and environmental quality. Relatively little is known about the effectiveness of filter strips in the Southern Piedmont under pasture conditions. Phosphorus loss from cropped fields is predominantly in the form of particulate P. However in pastures, P loss is predominantly in a soluble form (Edwards and Daniel, 1993; Udouj and Scott, 1999). Recent evidence has indicated that filter strips might be an effective strategy to capture sediments and particulate P, but less effective in capturing dissolved P. More research is needed to determine the effectiveness of various filter strip widths, species composition, planting techniques, and management following establishment to reduce runoff and P loss from pastures.

Both poultry litter and endophyte-infected tall fescue are sources of endocrine disruptors (i.e., estradiol and testosterone in poultry litter, alkaloids in tall fescue) that could negatively impact the health of cattle on pasture and humans and wildlife that might consume water from receiving bodies (Wright et al., 1998). There is an urgent need for quantitative information on the interactions of tall fescue genotype and fertilizer source (i.e., inorganic versus animal manures) in pastures on water quality, especially with regard to N, P, endocrine disruptors, and fecal-borne pathogen concentrations.

Forage quality estimates are needed to increase productivity and more efficiently utilize pastures. Even moderate temperatures to dry forage samples for laboratory analysis has been shown to alter forage chemistry. Near infrared reflectance spectroscopy (NIRS) is a viable alternative method of estimating forage quality. Calibration equations for NIRS are available commercially that were developed with oven-dried samples, but these estimates are inaccurate because oven-drying affects the results used for calibration. Scans of freeze-dried samples can be used to predict laboratory analyses of freeze-dried samples (Villalobos et al., 1991). For research locations conducting pasture research with access to NIRS, but without freeze driers or analytical laboratories, it would be of benefit to have a calibration using NIRS scans of oven-dried samples to predict the forage quality of freeze-dried samples.

A CRIS search conducted in August 2000 identified 29 university and ARS projects matching the keywords “Soil Resource Management” and “Pasture; Forage”. Many of these projects conduct research in the semiarid and arid regions of western USA, such that very little duplication of information will be obtained. In contrast, conducting similar ecosystem process research in different regions of the country will be of great value. Collaborative efforts among ARS laboratories across the country will likely be developed during the life of this project to coordinate research approaches and define differences among regions in grassland ecosystem responses to soil resource management. A CRIS search of “soil processes” and “pasture” returned ARS projects being conducted in Arizona, Colorado, North Dakota, Oklahoma, Oregon, Pennsylvania, and West Virginia. Our project is a necessary addition to the limited number of ARS locations conducting soil process studies in grassland ecosystems.

A CRIS search of “Soil Resource Management” and “conservation tillage” indicated 33 projects in Alabama, Iowa, Idaho, Indiana, Minnesota, Mississippi, Missouri, North Dakota, Oregon, Pennsylvania, South Carolina, Texas, and Washington. Regional-specific information is needed to develop locally appropriate management strategies to increase productivity and preserve natural resources. Our location fits in well with the other southern locations situated in different agroecological zones of the Coastal Plain in South Carolina and Alabama, the Mississippi Delta, and the High Plains of Texas.

Approach and Research Procedures

Objective 1: Develop sustainable crop management strategies

Experimental Design

(1a) A field experiment (Water Quality Plots) with surface water collection and subsurface drainage collection has been fully instrumented since 1996. A total of 12 plots (10 x 30 m) will be planted to maize in summer and rye as a winter cover crop. Plots have been randomly allocated to a factorial arrangement of fertilizer strategy (inorganic vs poultry litter) and tillage management (conventional disk vs no tillage) with three replications each. Treatment allocation has been permanent with response variables as repeated measures with time. Broiler litter will be applied at a rate of 9 Mg ha^{-1} yr^{-1} to obtain the same rate of available N (assuming 50% of total) applied with inorganic fertilizer (i.e., 168 kg ha^{-1} yr^{-1}). The experiment will relate crop production (seasonal plant biomass, grain production), soil properties (total organic C, inorganic N and P depth distribution, soil pH, water content, temperature), and water runoff and leachate (quantity, inorganic N and P concentrations, fecal-borne pathogens, hormones) to fertilizer and tillage variables throughout the 5-year period. Water runoff and leaching will be collected based on rainfall events that trigger automated digital recording and refrigerated subsampling equipment. Data will be incorporated into the CERES (a part of DSSAT) and Root Zone Water Quality models to simulate crop growth and nutrient cycling under various soil and climatic conditions of the southeastern USA. Crop management systems will be analyzed economically with cooperation from the USDA-ARS-National Peanut Research Laboratory.

Hypothesis: Our hypotheses include (1) the lack of surface soil disturbance with no tillage and enrichment of surface soil with organic matter via poultry litter and cover cropping will preferentially move nutrients through the soil profile past the crop root zone or alternatively (2) crop production could be significantly enhanced by no tillage and broiler litter application to make greater use of available water, and therefore, circumvent greater opportunities for nutrient flow via macropores.

Management: Endale DM (agronomic activities, water runoff and leachate measurements, hydrologic modeling), Schomberg HH (agronomic activities, crop response variables, soil sampling and analyses, crop growth modeling), Jenkins MB (microbiological and hormonal characteristics of water runoff and leachate), Steiner JL (soil water and temperature measurements, nutrient and water model validation), Cabrera M (soil and water nutrient analyses, crop growth modeling), Radcliffe D (soil hydraulic characterization).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Complete previous phase of project	x					
Publish results from previous phase	x	x	x			
Crop, soil, water data collection		x	x	x		
Crop, soil, water data analyses				x	x	
Hydrologic modeling	x	x			x	x
Crop growth (CERES) modeling					x	x
Formulate new objectives for study						x
Publish results						x

(1b) Four water catchments (P Watersheds; 1.3, 1.3, 1.4, and 2.7 ha) that have more than 25-year histories of various crop and tillage management and surface runoff measurements have been combined into a common experimental design beginning in autumn 1998. Water catchments have been permanently allocated to two treatments (i.e., deep ripping with no other tillage vs complete no tillage) with two replications. Summer crops (millet, sorghum, corn) and winter crops (rye, barley, wheat) will be planted for high grain and residue production. Broiler litter will be applied prior to each crop at a rate of -3 Mg ha^{-1} to meet N requirements and enrich soil in available P. The experiment will relate crop production (seasonal plant biomass, grain production), soil properties (surface residue accumulation, total organic C, soil microbial biomass, mineralizable C and N, inorganic N and P depth distribution, soil pH, water content, temperature), water runoff (quantity and inorganic N and P concentrations, fecal-borne pathogens), and atmospheric nutrient transport (NH_3 volatilization, N_2O emission) to tillage variables throughout the 5-year period. Surface soil (0-3, 3-6, 6-12, 12-20 cm) and deep-profile soil (0-15, 15-30, 30-60, 60-90, 90-120, 120-150 cm) will be sampled in winter each year. Runoff samples will be collected based on precipitation events with data used to test various hydrologic and water quality models. Atmospheric transport will be measured for -7 days prior to and 21 days following poultry litter application. Net N mineralization and plant availability from ^{15}N-labeled poultry litter will be measured, with subsequent evaluation in a N mineralization-immobilization model.

Hypothesis: Our hypothesis is that reduced soil disturbance with no tillage results in an enrichment of surface soil organic matter, nutrients, and water leading to greater nutrient losses from runoff and leaching below the root zone via macropore flow. However, greater surface residues under no tillage will likely reduce runoff water, sediments, and nutrients compared with conventional tillage. Additionally, nutrients and potential pathogens may be retained within the zone of enriched organic matter and nutrients cycled more efficiently with enhanced plant growth, resulting in minimal nutrient leaching under no tillage compared with conventional tillage.

Management: Schomberg HH (agronomic activities, crop response variables, soil water measurements, in situ soil N mineralization, deep soil sampling), Endale DM (water runoff, lysimeters, hydrologic modeling, soil water measurements), Sharpe RR (atmospheric transport of gases, N mineralization-immobilization from poultry litter), Jenkins MB (fecal-borne pathogens in soil and runoff), Franzluebbers AJ (soil organic matter properties, soil P depth distribution, soil aggregation and porosity).

Timeline:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Initiation of poultry litter application	x					
Crop-soil-water-pathogen data collection	x	x	x	x		
Crop-soil-water-pathogen data analyses			x	x		
Atmospheric transport studies	x	x				
Hydrologic modeling			x	x	x	
N mineralization-immobilization modeling				x	x	
Formulate new objectives for study				x		
Publish results				x	x	x
Initiate new experimental design					x	

(1c) A field experiment (Brazilian Cover Crop Study) of traditional and Brazilian cover crops began in 1998 and will be completed in 2002. Cotton and soybean will be no-till planted into the cover crops with the following factors evaluated: (1) Cover crop, rye, crimson clover, black oat, and oilseed radish, (2) Method of killing cover crop, mechanical roller and herbicide, and (3)Calcium level, 0 and 1 t/ha at the beginning of study. Treatments have been arranged in a strip-strip plot with three replications as randomized complete blocks. Plots are 6 x 15 m. Soybean was grown in 1999 and cotton in 2000. Rotation of the summer crops is planned. Biomass production of each cover crop will be determined by harvesting two 1 m^2 areas in each plot before killing. Summer crop biomass will be determined at the end of the growing season. Soil samples have been collected in four depth increments (0 to 2.5, 2.5 to 7.5, 7.5 to 15, and 15 to 30 cm) at planting of the summer crop for evaluation of nutrients and soil C and N. In situ N mineralization cores will be analyzed seasonally to validate a simple N mineralization-immobilization model. Sampling to 1.5 m in 15 to 30 cm increments will be made initially and after 3 yr to evaluate Ca movement. Infiltration measurements will be made at the end of the study to determine cover crop effects on soil physical conditions. Biologically active soil C and N pools will be measured at the beginning and end of the study. Data will be analyzed using the general linear models procedure of SAS with mixed and repeated measures procedures where appropriate.

Hypothesis: Our hypotheses is that type of cover crop influences longer-term productivity by improving soil physical (porosity, aggregation), chemical (soil organic matter, Ca distribution, soil pH), and biological (soil microbial biomass, mineralizable N) properties.

Management: Schomberg HH (agronomic activities, soil and crop response variables, N mineralization-immobilization modeling), Endale DM (infiltration measurements), Reeves DW (cover crop advisor), Cabrera M (Ca movement, N mineralization-immobilization modeling).

Timeline:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Initiate project	x					
Crop, soil collection	x	x	x			
Crop, soil analyses			x	x		
Infiltration studies			x			
N mineralization-immobilization modeling				x	x	
Publish results				x	x	

(1d) A cooperative research and demonstration field experiment at the Central Savannah River Area Conservation Tillage Demonstration Farm near Waynesboro GA will evaluate the effects of tillage and cover crops on cotton production, residue cover, soil organic matter, and nutrient and water availability in irrigated cotton cropping systems. Seven cover crops including, rye, black oat, oilseed radish, crimson clover, vetch, Austrian winter pea, and balansa clover and no cover crop will be evaluated. Tillage comparison will be strip tillage versus no tillage. Cover crops will be managed with either chemical kill or mechanical rolling. The design is a strip-strip randomized block with three replications of each cover crop-tillage combination. Cover crops will be planted with a no-till grain drill (4.5-m wide, 19-cm-wide rows) on plots 18-m wide by 22.8-m long and split in half for tillage treatments. Cotton will be planted with a four-row (0.95-m-wide rows), strip-till (0.36-m wide) planter or a no-tillage planter. Irrigation will be applied with a center-pivot system controlled manually to maintain water availability to cotton with minimal stress. Plant biomass and soil cover will be determined for each cover crop. Crop residues will be analyzed for C, N, K, P, and Ca content. Cotton emergence will be evaluated three to four weeks after planting. Water availability to cotton and photosynthetic activity of cotton will be evaluated at specific growth phases using time-domain reflectrometry and infrared gas analysis. Cotton growth characteristics will be determined three times during the year. Cotton yield will be determined from four rows of each plot and lint subsamples will be analyzed for fiber length and strength, micronair, length uniformity, and lint percentage. Soil C, total N, NO_3 and NH_4 to a depth of 90 cm (0 to 2.5, 2.5 to 15, 15 to 30, 30 to 60, and 60 to 90 cm) will be determined in the spring and fall of each year. The study will be conducted for three years and analyzed economically based on inputs, yield properties, and changes in nutrient availability.

<u>Hypothesis</u>: Our hypotheses include (1) cover crops and conservation tillage will improve productivity and sustainability of irrigated cotton and (2) mechanical killing of cover crops will be as effective at increasing cropping system productivity as herbicide killing of cover crops.

<u>Management</u>: Schomberg HH (soil and crop response variables, economic analyses), Reeves DW (cover crop advisor), McDaniel R (farm management)

<u>Timeline</u>:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Initiate study	x					
Photosynthetic measurements	x					
Crop, soil collection	x	x	x			
Crop, soil, water analyses			x	x		
Annual farm field days	x	x	x			
Publish results				x		

Collaborations

(a) Necessary (within ARS):
Dr. Wayne Reeves, Research Agronomist, Auburn AL

(b) Necessary (external to ARS):
Dr. Miguel Cabrera, Agroecologist, University of Georgia, Athens GA
Mr. Richard McDaniel, Burke County Extension Agent, University of Georgia
Dr. David Radcliffe, Soil Scientist, University of Georgia, Athens GA

<u>Objective 2</u>: Develop sustainable animal management strategies

Experimental Design

(2a) A field experiment (Salem Road) with 18 grazed paddocks (0.7 ha each) and 18 hayed and unharvested exclosures (0.01 ha each) was initiated in 1994. ‘Coastal’ bermudagrass was sprigged as the primary forage for summer grazing during the first five years. In autumn 1998, ‘Georgia 5' tall fescue was overseeded to provide spring and autumn grazing during at least the next five years. Experimental treatments (12 total x 3 replications each) are currently arranged as repeated measures with time according to fertilizer source (i.e., inorganic, single broiler litter application plus inorganic N, and triple application of broiler litter) as main plots and harvest strategy (i.e., unharvested, hayed, low grazing pressure, and high grazing pressure) as split plots. Angus weanling steers will be stocked on grazed paddocks beginning in November of each year according to a put-and-take system to maintain - 1.5 and 3.0 Mg ha^{-1} of forage on high- and low-grazing-pressure treatments, respectively, at 28-day intervals whenever forage growth is substantial (i.e., primarily November-December and March-October). Fertilizer treatments will supply equal quantities of N (i.e., 270 kg ha^{-1} yr^{-1} in spring, summer, and autumn). Low and high broiler litter application rates will simulate strategies focusing on P management (i.e., low broiler litter application rate of 2.3 Mg ha^{-1} yr^{-1} in spring supplying 90 kg N ha^{-1} and 40 kg P ha^{-1} and supplemented with ammonium nitrate to supply 180 kg N ha^{-1} yr^{-1} in summer and autumn) and N management (i.e., high broiler litter application rate of 270 kg N ha^{-1} yr^{-1} and 120 kg P ha^{-1} yr^{-1}). Animal response variables (production, performance, internal parasite load and diversity) will be measured monthly, soil response variables (total organic C-N-S, surface residue C-N-S, particulate organic C and N, soil microbial biomass, mineralizable C and N, soil aggregation, inorganic N and P depth distribution, metal contents, pH) will be measured yearly, plant response variables (dry matter production, plant stand and composition, endophyte infection level) will be measured seasonally, and water runoff quality (inorganic N and P) will be measured following rainfall events. Soil variables will be measured within zones of grazed paddocks according to distance from shade and water (i.e., near, mid, and far) to determine animal behavioral effects on soil organic matter and nutrient cycling. Three edge-of-field runoff collectors within paddocks will be used to measure surface runoff characteristics.

<u>Hypothesis</u>: This study has multiple objectives and some of our hypotheses being tested are (1) harvest management of forage will affect animal productivity and soil quality (e.g., soil organic C, soil porosity, mineralizable N, soil aggregation), (2) there will be a positive relationship between animal productivity and soil organic C accumulation, (3) poultry litter application rate will affect water runoff quality and soil nutrient distribution, and (4) environmental consequences of repeated broiler litter application will be delayed with decreasing intensity of forage management.

<u>Management</u>: Franzluebbers AJ (forage composition and management, soil sampling and analyses), Stuedemann JA (animal management and response variables, forage availability), Franklin DH (water runoff quantity and nutrient concentration), Jenkins MB (fecal-borne pathogens in cattle and water runoff), Steiner JL (soil water), Kaplan R (cattle parasites), Burke R (soil C isotopes), Hill N (tall fescue alkaloid concentration).

<u>Timeline</u>:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Initiate phase II of project	x					
Publish phase I results	x	x	x			
Soil, plant, animal data collection	x	x	x	x	x	x
Soil, plant, animal analyses			x	x	x	x

Formulate new objectives for phase III					x	x
Initiate phase III of project						x
Publish phase II results						x

(2b) A field experiment (Dawson Field) with 12 grazed paddocks and 2 hayed exclosures (1.0 ha each) bermed as water catchments will be initiated in 2001. Tall fescue was seeded in autumns of 1998 and 1999 for grazing during the next five years. Experimental treatments will be arranged as repeated measures with time according to a factorial arrangement of fertilizer source (i.e., inorganic vs broiler litter application) and forage type (i.e., high endophyte–high alkaloid, high endophyte–low alkaloid, and low endophyte–low alkaloid) with two replications of each treatment. Two additional catchments were planted to high endophyte–low alkaloid tall fescue as ungrazed controls. Angus weanling heifers will be stocked on grazed paddocks beginning in November of each year according to a put-and-take system to maintain -2 Mg ha^{-1} of forage at 28-day intervals whenever forage growth is substantial (i.e., primarily November-December and March-July). Fertilizer treatments will supply equal quantities of N (i.e., 200 kg ha^{-1} yr^{-1} in spring and autumn). Animal response variables (production, performance, toxicological responses, internal parasite load and diversity) will be measured monthly, soil response variables (total organic C-N-S, surface residue C-N-S, particulate organic C and N, soil microbial biomass, mineralizable C and N, soil aggregation, inorganic N and P depth distribution, metal contents, pH) will be measured yearly, plant response variables (dry matter production, plant stand and composition, endophyte infection level, alkaloid concentration) will be measured seasonally, and water runoff quality (inorganic N and P) will be measured following rainfall events. Soil variables will be measured within zones of grazed paddocks according to distance from shade and water (i.e., near, mid, and far) to determine animal behavioral effects on soil organic matter and nutrient cycling. Paddocks will be instrumented with flumes, recording equipment, and sampling devices to measure water runoff characteristics.

Hypothesis: Our hypotheses include (1) high endophyte-low alkaloid tall fescue will lead to improved animal productivity compared with high endophyte-high alkaloid tall fescue, but also improved plant vigor/survivability/stress tolerance compared with endophyte-free tall fescue, (2) high endophyte-low alkaloid tall fescue will lead to enhance soil C sequestration, (3) endophyte infection will affect surface water runoff quality, and (4) endophyte effects on cattle and soils will be altered by poultry litter versus inorganic nutrients.

Management: Franzluebbers AJ (forage management, soil sampling and analyses), Stuedemann JA (animal management and responses, forage availability), Endale DM (water runoff quantity and quality), Jenkins MB (fecal-borne pathogens), Franklin DH (phosphorus in water runoff), Bacon CW (endophyte survival), Wright S (glomalin analyses), Hill N (endophyte and alkaloid characteristics), Kaplan R (cattle parasites), Burke R (soil C isotopes).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Build infrastructure and establish grass	x	x				
Grazing of paddocks		x	x	x	x	x
Soil, plant, water data collection		x	x	x	x	x
Conduct greenhouse and lab studies		x	x	x		
Soil, plant, water analyses				x	x	x
Formulate new objectives for study						x
Publish results of phase I						x

(2c) A set of four 0.8-ha paddocks (Fescue Paddocks) with two treatments (endophyte-free and 95%-endophyte-infected tall fescue) and two replications was established in autumn 1988. In combination with the newly established Dawson Field experiment, this field experiment will serve to evaluate physiological responses of cattle to toxic alkaloids produced by endophyte-infected tall fescue and evaluate the long-term effects of endophyte infection on changes in soil microbial diversity and soil organic matter dynamics.

Hypothesis: Our hypotheses include (1) endophyte infection of tall fescue will affect animal productivity and performance and this malady can be ameliorated with various management techniques such as vaccines and (2) the mechanism of greater soil organic matter with endophyte-infected tall fescue can be elucidated with incubation studies comparing soil and plant materials with and without the presence of the endophyte.

Management: Stuedemann JA (forage management, animal responses), Franzluebbers AJ (soil sampliIng and analyses), Hill N (alkaloid concentrations), Hawkins L (animal physiological responses).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Complete previous phase of project	x					
Replant endophyte-free grass	x					
Conduct laboratory incubations		x	x	x		
Grazing of paddocks		x	x	x		
Soil and plant data collection		x	x	x		

(2d) Field studies will be conducted to investigate the effect of surface soil and residue roughness on runoff quality from pastures. Plot treatments will include variable filter strip width and location, mechanical modification of surface roughness, and vegetative manipulation of the surface roughness. Runoff will be collected from 10 x 20 m plots and runoff will be generated from natural rainfall.

Hypothesis: Our hypothesis is that runoff quantity from pastures will be reduced and water runoff quality will be improved with manipulation of surface roughness patterns and soil infiltration rates. These modifications would slow down runoff, potentially increase infiltration rates, and the P adsorption capacity of the soil surface, thus, reducing field nutrient losses.

Management: Franklin DH (experimental setup and analyses).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Finalize research plans and designs	x	x				
Initiate treatments		x	x			
Collect and analyze data			x	x	x	
Conduct rainfall simulations; pending grant funding		x	x	x		
Analyze and publish results				x	x	

(2e) Animal physiology studies will be conducted to evaluate the chemical species of alkaloids in ruminal fermentations and urine. We will determine which of the alkaloid species move across the ruminal and omassal epethelia. Ergot alkaloids found in tall fescue pastures will be chemically speciated prior to and following ruminal digestion. The alkaloid profile will be compared to alkaloid species found in blood and urine.

Hypothesis: Our hypothesis is that knowledge of how and where alkaloids interact with cattle tissues will lead to better vaccinations or management strategies to overcome fescue toxicosis.

Management: Stuedemann JA (animal management), Thompson F (laboratory analyses), Hill N (alkaloid analyses).

Timeline:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Conduct laboratory investigations	x	x				
Analyze and publish results		x	x			

(2f) Forage quality studies will initially focus on tall fescue and bermudagrass, which are dominant forages in the Southern Piedmont. Samples will be collected at various maturities and seasons and over multiple years for NIRS calibration. It is anticipated that initially a separate calibration equation for each species will be used to improve predictions but as the data set grows we will attempt to pool the data for NIRS calibration and extend the sampling to other forage species naturalized on the Conservation Center. Matched NIRS in Raleigh and Watkinsville will be used for scanning samples. Oven dried samples will be scanned in Watkinsville and shipped to Raleigh, scanned again and then tested for in vitro dry matter disappearance, neutral detergent fiber, acid detergent fiber, lignin, cellulose, hemicellulose, ash, and crude protein. Freeze-dried samples will be scanned in Raleigh and then tested for in vitro dry matter disappearance, neutral detergent fiber, acid detergent fiber, lignin, cellulose, hemicellulose, and crude protein. The number of samples of each species will be adjusted based upon the diversity of the sample set as estimated by NIR but will be in excess of 75 samples of each forage species prior to calibration.

Hypothesis: Our hypothesis is that forage quality will be adequately estimated using near infrared reflectance spectroscopy (NIRS) of oven-dried samples to accurately predict the results from wet chemical analysis of freeze-dried samples.

Management: Fisher DS (sample collection and NIRS), Burns J (wet chemical sample processing).

Timeline:

	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Conduct NIR analyses		x	x			
Conduct wet chemistry analyses				x		
Analyze and publish results				x	x	

Collaborations

(a) Necessary (within ARS):
Dr. Charles Bacon, Research Mycologist, Athens GA
Dr. Joe Burns, Research Plant Physiologist, Raleigh NC
Dr. Sara Wright, Research Microbiologist, Beltsville MD

(b) Necessary (external to ARS):
Dr. Roger Burke, Biogeochemist, US–EPA, Athens GA
Dr. Larry Hawkins, Veterinarian, University of Georgia, Athens GA
Dr. Nick Hill, Agronomist, University of Georgia, Athens GA
Dr. Ray Kaplan, Veterinary Parasitologist, University of Georgia, Athens GA

Objective 3: Improve recommendations for poultry litter application

Experimental Design

(3a) Four previously described field experiments (Water Quality Plots, P Watersheds, Salem Road, and Dawson Field) will be examined to understand the effect of poultry litter application on the rate of accumulation of soil nutrients, potential runoff and leaching characteristics, and interaction with endophyte-infected tall fescue on animal health. The results of these specific experiments will be integrated into a longer term perspective to describe broiler litter impacts on productivity, environmental quality, and profitability.

Hypothesis: Our hypothesis is that certain management strategies (e.g., no-tillage crop production, mixed-grass pasture composition, low-grazing-pressure grazing) will be effective at retaining the benefit of animal manure application without negatively affecting the environment. Since we are investigating several crop and animal management studies simultaneously, we will be able to get realistic interpretations of the boundaries of poultry litter application on agricultural sustainability.

Management: Steiner JL, Stuedemann JA, Franzluebbers AJ, Endale DM, Jenkins MB, Franklin DH (collaborative integration of information for technology transfer).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Conduct individual studies	x	x	x	x	x	x
Collect and analyze data	x	x	x	x	x	x
Publish results						x

(3b) Small-plot experiments (1 x 2 m) will be conducted to determine the relationship between flow-weighted dissolved reactive P in runoff and water-soluble P applied with broiler litter or inorganic P fertilizer. Three rates of broiler litter, three rates of inorganic P fertilizer, and an unamended control will be replicated three times. Applications will be repeated in the spring and autumn on the same plots. Rainfall simulations (70 mm h^{-1}) will be in spring, summer, autumn, and winter with runoff collected for 30 minutes and analyzed for total and dissolved-reactive P. Results will be disseminated to develop a Georgia P-index and assist with the efforts of the nationally organized P program.

Hypothesis: Our hypothesis is that runoff coefficients can be developed for various land management systems with manure application that will allow decision makers and land managers to make recommendations for manure application on a scientific basis.

Management: Franklin DH (experimental setup and analysis), Franzluebbers AJ (pasture management and soil sampling), Stuedemann JA (animal management), Daniel T (national P-index collaboration), Moore P (national P-index collaboration), Hubbard R (regional P-index collaboration).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Conduct individual studies		x	x	x		
Collect and analyze data		x	x	x	x	
Publish results				x	x	x

Collaborations

Same as for objectives 1, 2, and 5.

Objective 4: Develop strategies to optimize soil C sequestration

Experimental Design

(4a) All previously described field experiments will be utilized to obtain estimates of soil C sequestration rates and changes in soil quality. These experiments will allow us to characterize differences in management due to tillage (Water Quality Plots, P Watersheds), fertilizer source (Water Quality Plots, Salem Road, Dawson Field), cattle grazing pressure (Salem Road), grazed vs ungrazed pastures (Salem Road, Dawson Field), endophyte-infection level (Dawson Field, Fescue Paddocks), and crop vs pasture management. The integration of these results is a long-term effort to describe management effects on productivity, environmental quality, and profitability.

Hypothesis: Our hypothesis is that certain management strategies (e.g., no-tillage crop production, high-grazing-pressure grazing, multiple-species pastures) will be more effective at sequestering soil organic C, but not necessarily the associated benefits in soil quality (e.g., excessive nutrient accumulation, soil porosity, surface roughness).

Management: Franzluebbers AJ (soil sample collection and analyses), Jenkins MB (soil biological diversity with genetic techniques), Hons F (soil sample collection, soil biological analyses), Zuberer DA (soil biological diversity with BIOLOG).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Analyze results from previous studies	x	x				
Publish initial results		x				
Conduct ongoing studies			x	x	x	x
Refine estimates and publish results					x	x

(4b) Soil sampling surveys on- and off-station will be conducted to be able to make quantitative relationships between various soil functions (i.e., water retention and infiltration, nutrient cycling capacity, plant growth medium) and levels of total soil organic C and N, particulate organic C and N, and soil microbial biomass and diversity. Studies described in Objectives 1b, 2a, 2b, and 2c will be the primary experimental conditions for developing quantitative mechanistic relationships among variables, as well as describing the economic value of soil quality improvement. This will be a long-term effort with continual updating of relationships whenever new information becomes available.

Hypothesis: Our hypotheses include (1) simple soil biological assays will be acceptable within reasonable limits to predict more complex soil attributes and (2) land management systems will greatly affect soil microbial diversity and associated soil functions. Enhancing the functional attributes of soil with increasing organic C needs to be quantitatively described.

Management: Franzluebbers AJ (soil sampling and analyses), Jenkins MB (soil microbial diversity), Brock B (site location and characterization), Dean J (site locationand characterization), Hons F (soil sample collection, soil biological analyses), Zuberer DA (soil biological diversity with BIOLOG).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Finalize research plans and design	x	x				
Analyze inventoried soil samples		x	x	x		
Conduct soil sampling surveys			x	x		
Publish results					x	x

Collaborations

(a) Necessary (within ARS):
None developed to date.

(b) Necessary (external to ARS):
Dr. Roger Burke, Biogeochemist, US–EPA, Athens GA
Field offices of USDA–Natural Resources Conservation Service in the Southern Piedmont region coordinated by Mr. Bobby Brock (Raleigh NC) and Mr. James Dean (Athens GA)
Dr. Frank Hons, Soil Scientist, Texas A&M University, College Station TX
Dr. Dave Zuberer, Soil Microbiologist, Texas A&M University, College Station TX

Objective 5: Define P loss potential from soils in the southeastern USA

This objective is new and research plans are still being refined in collaboration with researchers in the SERA-17 working group.

Experimental design

(5a) Rainfall simulation tests will be conducted on benchmark soils near Watkinsville. The relationship between soil-test P and dissolved-reactive P in runoff will be evaluated for different benchmark soils in the Piedmont and Ridge and Valley physiographic regions in Georgia. Triplicate plots (1 x 2 m) will be established on benchmark sites with low (<10 mg P kg^{-1}), medium (10-20 mg P kg^{-1}), and high (>20 mg P kg^{-1}) soil-test P levels. Rainfall simulations will be in accordance with the National P Project and will be used to develop the Georgia P-Index to assess the risk of P loss from surface runoff.

Hypothesis: Our hypotheses include (1) as environmental conditions vary and benchmark soil remains the same, P concentration in runoff will vary (contrasting the magnitude of change for each environmental factor assessed will allow us to determine which environmental factor(s) will best serve as an indicator to predict environmental health and vulnerability to nutrient loss) and (2) soils with similar mineralogy will have similar loss of P in runoff (if so, then soil associations can be grouped when developing environmental indices for potential phosphorus loss).

Management: Franklin DH (experimental setup and analyses), Cabrera M (site locations), Radcliffe D (soil hydraulic characterization), Risse M (site locations), Hubbard R (site locations), Moore P (national soil P-index collaboration), Daniel T (national soil P-index collaboration).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Finalize research plans	x	x				
Initiate field treatments		x	x	x		
Rainfall simulations		x	x	x		
Collect and analyze data		x	x	x		
Publish results			x	x	x	

(5b) Soil and surface residue samples from the Salem Road experiment will be collected to determine extractable P at different depths (i.e., 0-2, 0-5, and 0-15 cm). Rapid and long-term assessment strategies will be evaluated using rainfall simulators within each paddock and from natural rainfall conditions, respectively. Rapid assessment will be conducted with the National P Work Group rainfall simulation protocol, accompanied by additional soil sampling depths and residue sampling strategies. Long-term assessment of P runoff potential will be collected using small, in-field runoff collectors (SIRC) placed in individual paddocks.

Hypothesis: Our hypothesis is that P concentration and load (kg P/ha) in surface runoff will be more closely associated with P content of surface residues and the first 2 cm of topsoil than current soil sampling techniques analyzing 0-15 cm of soil.

Management: Franklin DH (water runoff sampling, soil and water P analyses), Franzluebbers AJ (pasture management and soil sampling), Stuedemann JA (animal management), Cabrera M (regional P-index collaboration), Hubbard R (regional P-index collaboration), Moore P (national soil P-index collaboration), Daniel T (national soil P-index collaboration).

Timeline:	Previous	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Finalize research plans and design	x	x				

Collect soils	x	x	x	
Conduct soil analyses	x	x	x	
Publish results			x	x

Collaborations

(a) Necessary (within ARS):
Dr. Robert Hubbard, Research Soil Scientist, Tifton GA
Dr. Phillip Moore, Research Soil Scientist, Fayetteville AR

(b) Necessary (external to ARS):
Dr. Miguel Cabrera, Soil Scientist, University of Georgia, Athens GA
Dr. Tommy Daniel, Soil Scientist, University of Arkansas, Fayetteville AR
Dr. David Radcliffe, Soil Scientist, University of Georgia, Athens GA
Dr. Mark Risse, Pollution Prevention Specialist, University of Georgia, Athens GA

Contingencies

Inclement weather (e.g., summer drought, severe freezing in winter, tornadoes, ice storms, etc.) could pose short-term breaks in data collection, as well as force us to allocate more financial resources than normal to repair and maintenance of equipment. Fortunately, our research team continues to garner external financial support to help mitigate some of these potential natural disasters, as well as to expand our research objectives. Further, much of our work focuses on long-term ecological effects of land management systems, such that short-term breaks in data collection would not seriously jeopardize our research objectives and the collection and interpretation of data.

It could be possible that scientific and technical staff retire, transfer to other locations, or seek other employment during this project plan period. We would seek to rehire competent employees to fill these gaps. Fortunately, many of our research objectives are multi-disciplinary, such that long-term continuity of projects could be maintained with remaining team members until vacant positions were to be filled.

Resources (Physical)

The J. Phil Campbell Sr. Natural Resource Conservation Center consists of -450 ha of land with research plots, fields, controlled water catchments, and a 600-head herd of Angus cattle managed as a cow-calf operation. We have 10 category-I scientists and four category-III scientists and six technicians to support them. We have a full-time herdsman to care for animals, two full-time technicians to support field operations, a full-time mechanic, a full-time technician to support the analytical laboratory, two full-time administrative support personnel, a full-time janitor, and typically six to ten temporary and/or student-level technicians. We maintain a full fleet of field vehicles (cars, trucks) and farm equipment (tractors, sprayers, balers, trailers, mowers, front-end loader, dump truck, road grader, etc.) to support diverse field research programs under cropland, hayland, and pastureland. On the station, we maintain 12 highly instrumented water quality plots to monitor surface runoff and subsurface drainage as impacted by cropping systems. In addition, we have weather stations, six other instrumented catchments in cropping and grazing management, observation wells to monitor shallow groundwater and various springs, streams, and ponds. We have global positioning systems with cm-scale resolution and a geographic information system laboratory with ARC-INFO, ARC-VIEW, and Imagine software. We have instrumentation to measure field soil water content. We have expertise in and instruments for collecting soil and water samples and monitoring various soil and water properties. In the laboratory, we have analytical capabilities and experienced personnel to determine total C with a Leco CNS-2000, various fractions of organic matter using dispersing equipment, chloroform fumigation, incubation vessels, and chemical fractionation schemes, inorganic nutrients with an automated segmented flow analyzer, various gases with gas chromatographs and tunable lasers, and cations with an atomic absorption spectrometer. We have standard grinding equipment, ovens, refrigerators, freezers, and sample storage areas for processing large numbers of plant, soil, and water samples. We support microbiological research with a biological safety cabinet, autoclave, incubators, microscope, centrifuge, thermacycler, and gel electrophoresis.

Milestones and Expected Outcomes

Milestone 1 (12 months–March 2002)
We expect to have most, if not all publications prepared from the previous CRIS project period of (1996 to 2001). These will include reports from the Salem Road grazing study, fescue toxicosis research, and Water Quality Plots. All long-term experiments will be underway. Most of rainfall simulations will be underway.

Milestone 2 (36 months–March 2004)
We expect to provide preliminary reports of research findings at meetings of the Soil Science Society of America, Animal Science Society, American Society of Veterinary Parasitologists, American Society of Agricultural Engineers, International Soil Tillage Research Organization, and other relevant, organized research and technology transfer meetings, as well as local and regional field days. We will have initiated rainfall simulations on 10 x 20 m plots.

Milestone 3 (60 months–March 2006)
We expect to have submitted several reports from the Salem Road grazing study, Dawson Field grazing study, P Watershed study, Water Quality Plots, and Pasture-Crop Rotation study for peer-review in high-ranking agroecosystem, soil science, hydrology, and animal science journals.

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Past Accomplishments of Alan J. Franzluebbers, Lead Scientist

Education:
1995, Texas A&M University, Soil Chemistry/Microbial Ecology, Ph.D.
1991, University of Nebraska, Soil Fertility, M.S.
1985, University of Nebraska, Horticulture, B.S.

Experience:
Research Ecologist. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1996 to present.
Canadian Government Laboratory Visiting Fellow. Agriculture and Agri-Food Canada, Northern Agriculture Research Centre, Beaverlodge, Alberta. 1995 to 1996.

Accomplishments:
Detailed characterization of the distribution and ecological role of various SOM fractions has allowed soil scientists to move beyond mere conceptual ideology of agricultural sustainability towards practical evaluation of management impacts on important long-term soil functioning. Dr. Franzluebbers has cooperated with several researchers using long-term field experiments under different climatic conditions to define and understand the role of various physically and chemically defined pools of soil organic matter on nutrient cycling and soil structural development. He led investigations to show that biological and physical fractions of SOM (i.e., potential C mineralization, microbial biomass, particulate organic matter, and macroaggregate-protected organic matter) could be used during the first few years of a change in management as sensitive indicators to predict decade-long changes in total SOM.

Soil microbial biomass is an important metabolic component of soil organic matter dynamics. However, reliable measurement of microbial biomass has been debated, because of methodological limitations under certain environmental conditions. Dr. Franzluebbers has shown that the original chloroform fumigation-incubation method can be modified to produce reliable estimates of microbial biomass under diverse environmental conditions when dried soil is preincubated as a standard protocol.

Soil C sequestration has the potential to partially mitigate rising atmospheric CO_2 concentration, which contributes to the greenhouse effect on global warming. Land management systems that increase soil C storage have been identified. Dr. Franzluebbers has collected data from several long-term studies that has contributed to development of effective strategies to increase soil C sequestration potential, including (1) reducing soil disturbance to avoid stimulation of decomposition and reduce erosion, (2) increasing length of time during the year that a crop extracts moisture and fixes C, and (3) returning as much plant residue C back to the soil.

Work under the previous CRIS project led to the discovery that tall fescue infected with an endophyte was able to sequester more soil organic C than uninfected tall fescue. Dr. Franzluebbers' research program was awarded a 3-year, $220K grant from US–Department of Energy beginning in FY2001 to continue investigations to elucidate the mechanisms of action of the tall fescue–endophyte association on soil organic matter dynamics.

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Past Accomplishments of John A. Stuedemann

Education:
1970, Oklahoma State University, Ruminant Nutrition, Ph. D.
1967, Oklahoma State University, Animal Science, M. S.
1964, Iowa State University, Farm Operation, B. S.

Experience:
Research Animal Scientist. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1970 to present.

Accomplishments:
Dr. Stuedemann played a key role in determining the impact of endophyte-infected (E+) tall fescue on cattle, including the discovery that altered lipid metabolism was a characteristic response in cattle grazing E+ tall fescue and not a separate response originally associated with the use of poultry manure as a fertilizer for tall fescue. Patents covering the use of substituted benzamides for overcoming fescue toxicosis and a vaccine for preventing fescue toxicosis have been developed from concepts, hypotheses, and experiments developed in part by Dr. Stuedemann, with the experimental designs often being exclusively planned by Dr. Stuedemann. Dr. Stuedemann hypothesized that excretory pathways of ergot alkaloids from cattle grazing E+ fescue could lead to improved understanding of the mechanisms of action of ergot alkaloids in fescue toxicosis and could aid in the discovery of ways to overcome fescue toxicosis. This led to the discovery that urinary alkaloid levels were very responsive to consumption of the alkaloids and could be used as a diagnostic tool to determine if animals are consuming toxic alkaloids.

Dr. Stuedemann has been a key member of a team of researchers investigating the restoration of degraded cropland with grazing systems. Results showed that soil C change at the 0-2 cm depth was directly associated with forage utilization method, with the greatest accumulation in grazed systems. In grazed systems, after five years of spring-summer-autumn grazing, for each 100 day increase in steer grazing days, there was a 65 g/sq. M (65 kg/ha) increase in soil organic C. It was also determined that parasite-free pastures can be maintained in such a condition for at least seven years if animals are prevented from carrying larvae to the site.

Dr. Stuedemann has investigated the use of poultry manure as a pasture fertilizer both from the standpoint of its role in beef cattle health problems and it role in soil restoration. After 5 years, it was found that poultry litter fertilization did not increase soil organic C as compared to inorganic fertilizer.

Dr. Stuedemann investigated the importance of internal parasites in cow-calf production. The most important discovery was that cow reproductive efficiency could be improved by strategic treatment with an anthelmintic.

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Fisher DS, Steiner JL, Endale DM, Stuedemann JA, Schomberg HH, Franzluebbers AJ, Wilkinson SR. 2000. The relationship of land use practices to surface water quality in the Upper Oconee watershed of Georgia. *Forest Ecology Management* 128:39-48.

Franzluebbers AJ, Nazih N, Stuedemann JA, Fuhrmann JJ, Schomberg HH, Hartel PG. 1999. Soil carbon and nitrogen pools under low- and high-endophyte-infected tall fescue. *Soil Science Society of Americva Journal* 63:1687-1694.

Semen DH, Stuedeman JA, Hill NS. 1999. Behavior of steers grazing monocultures and binary mixtures of alfalfa and tall fescue. *Journal of Animal Science* 77:1402-1411.

Haitt III EE, Hill NS, Bouton JH, Stuedemann JA. 1999. Tall fescue endophyte detection: Commercial immunoblot test kit compared with microscopic analysis. *Crop Science* 39:796-799.
Brink GE, Pederson GA, Alison MW, Ball DM, Bouton JH, Rawls RC, Stuedemann JA, Venuto BC. 1999. Growth of white clover ecotypes, cultivars, and germplasms in the southeastern USA. *Crop Science* 39:1809-1814.
Franzluebbers AJ, Wright SF, Stuedemann JA. 2000. Soil aggregation and glomalin under pastures in the Southern Piedmont. *Soil Science Society of America Journal* 64:1018-1026.

Past Accomplishments of Harry H. Schomberg

Education:
1989, Texas A&M University, Agronomy, Ph.D.
1984, University of Georgia, Agronomy, M.S.
1977, University of Georgia, Agronomy, B.S.
1975, Abraham Baldwin Agricultural College, Agricultural Sciences

Experience:
Research Ecologist. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1996 to present.
Research Agronomist. USDA–Agricultural Research Service, Dryland Cropping Systems Research Unit, Conservation and Production Research Lab, Bushland, TX. 1989 to 1996.

Accomplishments:
Established quantitative relationships for water effects on decomposition and N dynamics of surface and buried crop residues using line-source irrigation and furrow irrigation.

Developed routines and new relationships for the residue decomposition submodels in the Wind Erosion Prediction System (WEPS) and Revised Wind Erosion Equation (RWEQ) that account for standing, flat, and buried residues as multiple pools over several cropping seasons.

Evaluated decomposition submodels in RUSLE, RWEQ, WEPP, and WEPS as part of an ARS and NRCS commonality project and validate the submodels in WEPS and RWEQ.

Developed relationships between residue biochemical quality, microbial activity and nutrient availability that can be used to estimate residue decomposition coefficients used in decomposition models.

Demonstrated that C and N conservation was greater using no-tillage compared to stubble mulch tillage under dryland cropping systems and greater C accumulation with more intensive cropping frequency.

Established that nutrient (P and Mg) distribution in grazed paddocks was altered due to the presence of an ergot alkaloid producing endophyte within tall fescue.

Publications [Schomberg HH]:

Schomberg HH, Ford PB, Hargrove WL. 1994. Influence of crop residues on nutrient cycling and soil chemical properties. In: Unger PW (Ed.) *Managing Agricultural Residues*, CRC Press.

Schomberg HH, Steiner JL, Unger PW. 1994. Decomposition and nitrogen dynamics of crop residues: Residue quality and water effects. *Soil Science Society of America Journal* 58:372-381.

Steiner JL, Schomberg HH, Douglas CL Jr, Black AL. 1994. Standing stem persistence in no-tillage small-grain fields. *Agronomy Journal* 86:76-81.

Unger PW, Jones OR, Schomberg HH.1994. Innovative crop residue management systems for the U. S. Southern Great Plains. *Agronomy (Trends in Agricultural Sciences)* 2:49-61.

Schomberg HH, Steiner JL, Evett SR, Moulin AP. 1996. Climatic influence on residue decomposition prediction in the Wind Erosion Prediction System. *Theoretical and Applied Climatology* 54:5-16.

Steiner JL, Schomberg HH. 1996. Impacts of crop residue at the earth-atmosphere interface: Introduction. *Theoretical and Applied Climatology* 54:1-4.

Schomberg HH, Steiner JL. 1997. Comparison of residue decomposition models used in erosion prediction. *Agronomy Journal* 89:911-919.

Schomberg HH, Steiner JL.1997. Estimating crop residue decomposition coefficients using substrate-induced respiration. *Soil Biology and Biochemistry* 29:1089-1097.

Unger PW, Schomberg HH, Dao TH, Jones OR. 1997. Tillage and crop residue management practices for sustainable dryland farming systems. *Annals of Arid Zone Agriculture* 36:209-222.

Franzluebbers AJ, Nazih N, Stuedemann JA, Fuhrman JJ, Schomberg HH, Hartel PG. 1999. Soil carbon and nitrogen pools under low- and high-endophyte infected tall fescue. *Soil Science Society of America Journal* 63:1687-1694.

Franzluebbers AJ, Langdale GW, Schomberg GW. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. *Soil Science Society of America Journal* 63:349-355.

Schomberg HH, Jones OR. 1999. Carbon and nitrogen conservation in dryland tillage and cropping systems. *Soil Science Society of America Journal* 63:1359-1366.

Schomberg HH, Steiner JL. 1999. Nutrient dynamics of crop residues decomposing on a fallow no-till soil surface. *Soil Science Society of America Journal* 63:607-613.

Steiner JL, Schomberg HH, Unger PW, Cresap J.1999. Biomass and residue cover relationships of fresh and decomposing small grain residue. *Soil Science Society of America Journal* 63:1817-1824.

Allmaras RR, Schomberg HH, Douglas CL Jr, Dao TH. 2000. Soil organic carbon sequestration potential of adopting conservation tillage in US croplands. *Journal of Soil and Water Conservation* (In Press).

Endale DM, Schomberg HH, Steiner JL. 2000. Long term sediment yield and mitigation in a small Southern Piedmont watershed. *International Journal of Sediment Research* 15:60-68.

Fisher DS, Steiner JL, Endale DM, Stuedemann JA, Schomberg HH, Franzluebbers AJ, Wilkinson SR. 2000. The relationship of land use practices to surface water quality in the upper Oconee watershed of Georgia. *Forest Ecology and Management* 128:39-48.

Franzluebbers AJ, Haney RL, Honeycutt CW, Schomberg HH, Hons FM. 2000. Flush of carbon dioxide following reweting of dried soil relates to active organic pools. *Soil Science Society of America Journal* 64:613-623.

Franzluebbers AJ, Stuedemann JA, Schomberg HH, Wilkinson SR. 2000. Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. *Soil Biology and Biochemistry* 32:469-478.

Franzluebbers AJ, Stuedemann JA, Schomberg HH. 2000. Spatial distribution of soil carbon and nitrogen pools under grazed tall fescue. *Soil Science Society of America Journal* 64:635-639.

Schomberg HH, Stuedemann JA, Franzluebbers AJ, Wilkinson SR. 2000. Spatial distribution of extractable P, K, and Mg as influenced by fertilizer and tall fescue endophyte status. *Agronomy Journal* (In Press).

Past Accomplishments of Ronald R. Sharpe

Education:
1982, University of Georgia, Agronomy, Ph.D.
1979, University of Tennessee, Agronomy, M.S.
1975, University of Tennessee, Microbiology, B.S.

Experience:
Research Soil Scientist. USDA–Agricultural Research Service, J. Phil Cambell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1991 to present.
Research Soil Scientist. USDA–Agricultural Research Service, Southeastern Fruit and Tree Nut Research Lab, Byron, GA. 1983 to 1991.

Accomplishments:
Dr. Sharpe and coworkers evaluated N dynamics in relation to atmospheric transport of NH_3 under different cropping systems. These studies help establish the soil and environmental factors which affect the influx and efflux of NH_3 in different cropping systems. The results show that plants respond to atmospheric NH_3 concentrations and can absorb and desorb NH_3 depending on environmental conditions.

Dr. Sharpe and associates were the first to measure CH_4 emissions from anaerobic waste lagoons using non-interference techniques. Previous estimates of CH_4 emissions were from theoretical potential from excreta. Direct measurements of CH_4 emissions were less than those used by regulatory agencies. A significant portion of the N losses from the lagoon were unaccounted, which subsequently was found to be released as environmentally harmless N_2.

Using N isotope procedures, Dr. Sharpe demonstrated plant to plant transfer of NH_3 through the atmosphere. This study showed that unaccounted for losses of ^{15}N from microplot studies, assumed to be gaseous losses, may be losses from the microplot area only and not net losses from the crop. These studies have shown decades of N isotope use to be potentially questionable and has altered the use of N isotopes in plant studies.

Land application of animal waste is the preferred method of disposal and utilization of nutrients. Dr. Sharpe determined that most of the N in lagoon waste effluent applied through sprinkler irrigation is volatilized as NH_3 or N_2O and is not available for plant uptake. Quantity of effluent applied to crops is usually by crop N requirements. The large losses of N when effluent is applied through overhead sprinkler irrigation makes it difficult to schedule irrigations based on N requirements and results in N enrichment of the environment.

Dr. Sharpe and associates evaluated CH_4 and NH_3 gas emissions from swine houses with different manure management systems. Under house storage substantially increased gas emissions in the houses. Methane emission factors developed from the data were 73% less than those currently used by USEPA to estimate national CH_4 emission inventories. The US has signed international agreements to reduce CH_4 emissions and accurate estimates of agriculture's contribution to global warming are needed to indicate areas for potential reduction.

Publications [Sharpe RR]:

Harper LA, Sharpe RR. 1993. Nitrogen dynamics in irrigated corn: soil-plant nitrogen and atmospheric ammonia transport. *Proceedings, Agricultural Research to Protect Water Quality* 2:653-656.

Harper LA, Sharpe RR. 1994. Soil-plant nitrogen and atmospheric ammonia transport in irrigated corn. *Proceedings, Agricultural Research to Protect Water Quality*, Vol. 2, Soil and Water Conservation Society, Ankeny, IA.

Harper LA, Sharpe RR. 1995. Nitrogen dynamics in irrigated corn: Soil-plant nitrogen and atmospheric ammonia transport. *Agronomy Journal* 87:669-675.

Sharpe RR, Harper LA. 1995. Soil, plant and atmospheric conditions as they relate to ammonia volatilization. *Fertilizer Research* 42:149-158.

Harper LA, Sharpe RR. 1996. Trace gas emissions from agricultural cropping systems: Plant and animal production. *Proceedings, ARS Global Change Workshop*, ARS Global Change Research Program, Norman OK, Vol II, p.159-161.

Harper LA, Sharpe RR. 1997. Lagoon nitrogen cycling and atmospheric losses. *Proceedings of the Southeastern Sustainable Waste Management Workshop*, Feb. 11-12, Tifton, GA. p. 223-229.

Sharpe RR, Harper LA. 1997. Methane emissions from swine lagoon waste treatment. *Proceedings of the Southeastern Sustainable Waste Management Workshop*, Feb. 11-12, Tifton, GA. p. 237-241.

Sharpe RR, Harper LA. 1997. Ammonia and nitrous oxide emissions from sprinkler irrigation applications of swine effluent. *Journal of Environmental Quality* 26:1703-1706.

Harper LA, Sharpe RR. 1997. Ammonia emissions from swine production in Georgia. *Proceedings, Air Quality Workshop*, Mar. 18-20, Raleigh, NC. p. 242-258.

Sharpe RR, Harper LA. 1997. Apparent atmospheric nitrogen loss from hydroponically grown corn. *Agronomy Journal* 89:605-609.

Harper LA, Sharpe RR. 1998. Atmospheric ammonia: Issues on transport and nitrogen isotope measurement. *Atmospheric Environment* 32:273-277.

Denmead OT, Harper LA, Freney JR, Griffith DW, Leuning R, Sharpe, RR. 1998. A mass balance method for non-intrusive measurements of surface-air trace gas exchange. *Atmospheric Environment* 32: 3679-3688.

Harper LA, Sharpe RR. 1998. Ammonia emissions from swine waste lagoons in the southeastern U.S. Coastal Plains. Grant Report submitted to Division of Air Quality, North Carolina Department of Environment and Natural Resources, Raleigh, NC, USDA-ARS Agreement No. 58-6612-7M-022. Dec., 27pp.

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Harper LA, Denmead OT, Sharpe RR. 2000. Identifying sources and sinks of scalars in a corn canopy with inverse Lagrangian dispersion analysis. II. Ammonia. *Agricultural and Forestry Meteorology* (Accepted Feb. 7, 2000).

Denmead OT, Harper LA, Sharpe RR. 2000. Identifying sources and sinks of scalars in a corn canopy with inverse Lagrangian dispersion analysis. I. Heat. *Agricultural and Forestry Meteorology* (Accepted Feb. 1, 2000).

Sharpe RR, Harper LA, Simmons JD. 2000. Methane emissions from swine houses in North Carolina. *Chemosphere* (Accepted March 30, 2000).
Harper LA, Sharpe RR, Robarge WP. 2000. Ammonia and other nitrogen emissions from swine waste lagoons in the U.S. Southeastern Coastal Plains. *Proceedings, Workshop on Atmospheric Nitrogen Compounds II: Emissions, Transport, Transformation, Deposition, and Assessment*, Jun 7-9, 1999, Chapel Hill, NC. 27 pp (in press)
Harper LA, Byers FM, Sharpe RR. 2000. Direct measurements of methane emissions from grazing cattle: Treatment effects. *Proceedings, Second International Methane Mitigation Conference*, Novosibirsk, Russia, Jun 18-23, 2000. (Accepted Jan.4, 2000).

Past Accomplishments of Dinku M. Endale

Education:
1995, Texas A&M University, Agricultural Engineering, Ph.D.
1985, Wageningen University, Soil Science and Water Management, M.S.
1973, National College of Agric. Engineering, Silsoe, England, Agricultural Engineering, B.S.

Experience:
Agricultural Engineer. USDA–Agricultural Research Service, Watkinsville, GA. 1997 to present.
Support Scientist. University of Georgia, Department of Soil and Crop Sciences, Athens, GA. 1996 to 1997.
Lecturer. Texas A&M University, Department of Agricultural Engineering, College Station, TX. 1992 to 1995.
Guest Researcher. Wageningen University, International Soil Reference and Information Center, Wageningen, The Netherlands. 1987 to 1988.
Researcher. Wageningen University, Department of Soil Science and Geology, Wageningen, The Netherlands. 1985 to 1987.
Irrigation Engineer. Amibara Irrigation Project, Awash Valley, Ethiopia. 1976 to 1983.

Accomplishments:
Developed, calibrated and validated IRDDESS (Irrigation District Decision Support System), a computer program to analyze complicated relationships in irrigation districts related to crop production, soils, weather, irrigation timing and amount, wet and dry conditions, water supply capacity and management. Modeling enables systematic analysis of the crop production system including prediction of crop performance and water use in space and time.

Played a key leadership role in a large team field study that evaluated effects of tillage (no-till vs conventional tillage) and nutrient source (poultry litter vs conventional fertilizer) on runoff, drainage, water quality, soil water use and yield in a cotton/rye production system. Greatly improved data availability, reliability and integrity. Improved the sample collection and processing activities, and took the lead in evaluating, interpreting, and reporting results. Results demonstrate both positive production and environmental impacts resulting from alternative cotton production systems in the Southern Piedmont, which is consistent with the growing national need for identifying alternative tillage strategies and use of animal manures.

Provided a strong leadership in instrumentation and hydrologic site development. Is directly responsible for conceiving, designing, modifying and implementing plans for flexible yet efficient monitoring program both on new and historic catchments. Developed an experimental watershed with automated and manual measurements of hydrologic parameters and developed other watershed sites for future research. The experimental watershed being developed has generated keen interest by outside researchers and has lead to many requests for new research cooperation. Contribution to problem identification, experimental design and interpretation of results in collaborative studies has lead to acquisition of crucial base line hydrologic and water quality data. Member of a team on a successful grant from American Water Works Association Research Foundation studying sub-surface transport of Cryptosporidium to surface waters.

Publications [Endale DM]:

Endale DM. 1996. The art of using a level. *Grounds Maintenance* February: G14-G18.
Endale DM, Fipps G. 1996. Modeling irrigation strategies and scheduling in irrigation districts. p.639-643. In: Camp CR, Sadler EJ, Yoder RE (Eds.) Evapotranspiration and irrigation scheduling. Proceeding of the International Conference, San Antonio, Texas, November 3-6. ASAE. St. Joseph, MI.
Fipps G, Endale DM. 1996. Irrigation district modeling for water conservation planning. *Hydrological Science and Technology* 12:131-135.
Endale DM, Steiner JL, Radcliffe DE, Cabrera ML, Vencille WK, Lohr L, Schomberg HH. 1999. Differences of soil water use, lint and biomass yield in no-till and conventionally tilled cotton in the Southern Piedmont. p. 570-573. In: Hatcher KJ (Ed.) Proceedings of the 1999 Georgia Water Resources Conference, March 30-31, 1999, Athens, GA. Institute of Ecology, UGA, Athens, GA.
Fisher DS, Endale DM. 1999. Total coliform, E coli, and enterococci bacteria in grazed and wooded watersheds of the Southern Piedmont. p. 283-286. In: Hatcher KJ (Ed.) Proceedings of the 1999 Georgia Water Resources Conference, March 30-31, 1999, Athens, GA. Institute of Ecology, UGA, Athens, GA.
Franklin DH, Cabrera ML, Endale DM, Steiner JL, Miller WP. 1999. Evaluation of a small, in-field runoff collector. p. 275-278. In: Hatcher KJ (Ed.) Proceedings of the 1999 Georgia Water Resources Conference, March 30-31, 1999, Athens, GA. Institute of Ecology, UGA, Athens, GA.
Cabrera ML, Endale DM, Radcliffe DE, Steiner JL, Vencille WK, Lhor L, Schomberg HH. 1999. Tillage and fertilizer source effects on nitrate leaching in cotton production in Southern Piedmont. p. 49-50. In: Hook JE (Ed.) Proceedings of the 22nd Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Tifton, GA. July 6-8, 1999. Georgia Agricultural Experiment Station Special Publication 95. Athens, GA.
Endale DM, Steiner JL, Radcliffe DE, Cabrera ML. 1999. Drainage and runoff differences under contrasting tillage systems in a Cecil soil of the Southern Piedmont. ASAE Paper No. 992119 ASAE St. Joseph, MI.
Cabrera ML, Endale DM, Radcliffe DE, Steiner JL, Vencille WK. 1999. Water quality concerns under contrasting tillage and nutrient management of cropping systems in a Cecil soil of the Southern Piedmont. ASAE Paper No. 992096, St. Joseph, MI.
Fisher DS, Steiner JL, Endale DM, Stuedemann JA, Schomberg HH, Franzluebbers AJ, Wilkinson SR. 2000. The relationship of land use practices to surface water quality in the Upper Oconee watershed of Georgia. *Forest Ecology and Management* 128:39-48.
Endale DM, Schomberg HH, Steiner JL. 2000. Long term sediment yield and mitigation in a small Southern Piedmont watershed. *International Journal of Sediment Research* 15:60-68.

Past Accomplishments of Dorcas H. Franklin

Education:
2000, University of Georgia, Agronomy, Ph.D.
1994, University of Georgia, Agronomy, M.S.
1981, Stephen F. Austin State University and Texas A&M, Forestry, B.S.

Experience:
Geographer. USDA–Agricultural Research Service, Watkinsville, GA. 1997 to present.
Graduate Research Assistant. University of Georgia, Department of Crop & Soil Sciences, Athens, GA. 1994 to 1997.
Laboratory Technician III. University of Georgia, Department of Crop & Soil Sciences, Athens, GA. 1988 to 1994.
Cartographic Technician. USDA–Soil Conservation Service, Athens, GA. 1984 to 1987.
Soil Scientist. USDA–Soil Conservation Service, Swainsboro, GA. 1981 to 1984.

Accomplishments:
Coordinated the development and publication of Workbook “Nutrient Cycles in the Southern Piedmont”. Editor Dorcas H. Franklin in collaboration with (chapter follows each corresponding author): Jean Steiner (Hydrologic Cycle) John Stuedemann and Dwight Seman (State of Agriculture in the Southern Piedmont), Alan Franzluebbers (Carbon Cycle), Miguel Cabrera (Nitrogen Cycle), Stan Wilkinson and Dorcas Franklin (Phosphorus Cycle), Mark Risse (Best Management Practices). The workbook has been used to train farmers and extension agents in the Southern Piedmont and has also been distributed to other land managers across the Southeast.

Has designed, implemented, summarized and presented methodology for installation of small, in-field runoff collector (SIRC) with known contributing area (+/-0.03ha) using computerized software and global positioning systems. This runoff collection system has now been adopted in other states to better understand both the quality and quantity of nutrient, sediment and pathogen transport. Summary presented as a poster at the American Society of Agronomy 1999 Annual Meeting. Authors were D.H. Franklin, J.L. Steiner, D.M. Endale, M.L. Cabrera, and W.P. Miller.

Has participated in the Sera 17 information exchange group on phosphorus since 1995. This year Dr. Franklin was placed on the soil to water impact committee.

Was asked to participate in the Southeastern P-Index Development Workshop held February 7-8, 2000, in Atlanta Georgia. From this workshop Dr. Franklin was asked to participate in the development of a Georgia State P-Index in collaboration with the USDA Natural Resource Conservation Service and the University of Georgia.

Publications [Franklin DH]:

Franklin DH. 1994. Computed tomography and morphological evaluation of preferential flowphaths in a Georgia Piedmont Ultisol. *International Winter Meeting of the American Society of Agricultural Engineers*, Atlanta, GA, Paper No. 94-3584.
Gupte SM, Radcliffe DE, Franklin DH, West LT, Tollner EW, Hendrix PF. 1996. Anion transport in a Piedmont Ultisol: II. Local-scale parameters. *Soil Science Society of America Journal* 60:762-770.
Franklin DH, Cabrera ML, Franzluebbers AJ, Risse LM, Seman DH, Steiner JL, Stuedemann JA, Wilkinson SR. 1998. Nutrient cycles in the Southern Piedmont: A workbook for managing nutrients at the watershed scale. *University of Georgia Miscellaneous Departmental Publication* ENG98-012, Athens, Georgia.
Franklin DH, Cabrera ML, Steiner J, Endale D, Miller WP. 1999. Evaluation of a small, in-field runoff collector. p. 2275-278. In: Hatcher KJ (Ed.) *Proceedings of the 1999 Georgia Water Resources Conference*, University of Georgia, Athens, GA.

Past Accomplishments of Michael B. Jenkins

Education:
1984, Oregon State University, Microbiology, Ph.D.
1979, Oregon State University, Microbiology, M.S.
1966, University of California–Berkeley, German, B.A.

Experience:
Research Microbiologist. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1999 to present.
Research Associate IV. Cornell University, Department of Microbiology, Ithaca, NY. 1994 to 1999.
Research Associate IV. Cornell, University, School of Civil and Environmental Engineering, Ithaca, NY. 1991 to 1994.
Visiting Scientist. National Institute of Biotechnology, Braunschweig, Germany, 1990 to 1991.
Assistant Research Scientist. San Diego State University, Systems Ecology Research Group, San Diego, CA. 1988 to 1990.
Postdoctoral Soil Scientist. University of California, Department of Soil and Environmental Sciences, Riverside, CA. 1984 to 1988.
Graduate Research Assistant. Oregon State University, Departments of Microbiology and Soil Science, Corvallis, OR. 1979 to 1984.

Accomplishments:
Developed complementary methods of strain identification that was used to delineate an indigenous population of *Rhizobium meliloti* nodulating field grown alfalfa. With these analytical tools the dynamics several strains of *R. meliloti*, including one dominant nodule occupant, were identified, and their seasonal dynamics characterized.

Demonstrated the presence of rhizobia in deep-root systems of the tree legume mesquite, and that rhizobial populations associated with surface and deep root systems differed. Quantified diverse rhizobial populations in the rhizosphere of mesquite and was the first to demonstrate that rhizobia can be established at depths of 10 m.

Demonstrated that mobile bacteria can facilitate the transport of pollutants in aquifer material. Designed and performed experiments that quanitifed the microbial decrease in the partitioning coefficient of phenanthrene in aquifer material. Demonstrated the potential that stimulating indigenous populations of methanotrophic bacterial populations would have on enhancing the transport and bioavialability of pollutants like phenanthrene in aquifer ecosytems.

Developed methods for the detection, viability assessment, and survival of *Cryptosporidium parvum* oocysts in the environment. Designed and performed experiments that correlated results of a dye permeability assay with mouse infectivity and in vitro excystation. Designed and performed experiments that established rates of oocyst inactivation under controlled conditions. Developed a sentinel chamber system that enabled field experiments with regard to oocyst survival in soil and calf litter to be carried out. Results of these experiments led to development of best management practices.
Publications [Jenkins MB]:

Jenkins MB, Lion LW. 1993. Mobile bacteria and transport of polyaromatic hydrocarbons in porous media. *Applied and Environmental Microbiology* 59:3306-3313.

Jenkins MB, Chen J-H, Kadner DJ, Lion LW. 1994. Methanotrophic bacteria and facilitated transport of pollutants in aquifer material. *Applied and Environmental Microbiology* 60:3491-3498.

Jenkins MB, Anguish LJ, Bowman DD, Walker MJ, Ghiorse WC. 1997. Assessment of a dye-permeability assay for determination of inactivation rates of *Cryptosporidium parvum* oocysts. *Applied and Environmental Microbiology* 63:3844-3850.

Jenkins MB, Bowman DD, Ghiorse WC. 1998. Inactivation of *Cryptosporidium parvum* by ammonia. *Applied and Environmental Microbiology* 64:784-788.

Jenkins MB, Anguish LJ, Bowman DD, Walker MJ, Ghiorse WC. 1998. Response to Robertson et al. Letter to the Editor: Viability of *Cryptosporidium parvum* oocysts: assessment by the dye-permeability assay. *Applied and Environmental Microbiology* 64:3544-3545.

Walker MJ, Montemagno CD, Jenkins MB. 1998. Source water assessment and nonpoint sources of acutely toxic contaminants: A review of research related to survival and transport of *Cryptosporidium parvum* oocysts in the terrestrial environment. *Water Resources Research* 34:3383-3392.

Jenkins MB, Walker MJ, Bowman DD, Anthony LC, Ghiorse WC. 1999. Use of a sentinel system for field measurements of *Cryptosporidium parvum* oocyst inactivation in soil and animal waste. *Applied and Environmental Microbiology* 65:1998-2005.

Past Accomplishments of Jean L. Steiner

Education:
1982, Kansas State University, Agronomy, Ph.D.
1979, Kansas State University, Agronomy, M.S.
1974, Cornell College, Mt. Vernon IA, Geology, B.A.

Experience:
Center Director and Research Leader. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1994 to present.
Research Soil Scientist. USDA–Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, TX. 1983 to 1994.
Research Scientist. CSIRO Center for Irrigation Research, Griffith, New South Wales, Australia. 1982 to 1983.
Graduate Research Assistant and Research Assistant. Kansas State University. 1978 to 1982.

Accomplishments:
Co-leader in development of major energy and water balance research facilities at USDA-ARS, Bushland, TX, and identified limitations to widely used evaporation equations for estimating evaporative potential in highly advective environments such as that in the Southern High Plains of the US. Daily water requirements for wheat in late spring were found to exceed mid-summer water requirements for corn and sorghum, due to higher windspeed, higher vapor pressure deficit, and greater radiation load, along with lower leaf resistance to water loss.

Led development of a residue decomposition model based on simple climatic indices of limiting factors to biological and chemical processes. The model was designed to be applicable throughout the USA, as part of the USDA Wind Erosion Prediction System.

Conducted field, laboratory, and simulation research to quantify crop residue impacts on soil and plant microclimate and water conservation, use, and quality in rainfed agriculture in semiarid and humid conditions. Edited a special issue of Theoretical and Applied Climatology on Crop Residue Effects at the Earth: Atmosphere Interface that highlighted wide-ranging impacts of residues on physical and biological processes, synthesized key findings, and identified areas where theory is incomplete.

Established an hierarchal watershed research program scaling from plot to field to catchment to stream to river for analysis of water quality as impacted by land management. The research is supported by blending base funds with funds from the Southern Region SARE, Georgia Department of Natural Resources, and the USDA-CREES-NRI and involved diverse partnerships with University of Georgia and Fort Valley State University, action agencies at local, state, and federal levels, land owners, producer organizations, educators, and others.

Organized a 1997 Soil and Water Conservation Society Conference on Investigating Ecosystem Dynamics at a Watershed Level and led in development of a white paper that identified key requirements for such analysis and research, education, and policy needs to support this broad integrated approaches to ecosystem and natural resources research.

Publications [Steiner JL]:

Steiner JL, Howell TA, Tolk JA, Schneider AD. 1991. Evapotranspiration and growth predictions of CERES -Maize, - Sorghum, and -Wheat for water management in the Southern High Plains. p. 297-303. In: Proc. ASCE Natl. Conf. on Irrig. and Drainage Req., Honolulu, HI, July 1991.

Steiner JL, Howell, TA, Schneider, AD. 1991. Lysimetric evaluation of potential evaporation prediction. *Agronomy Journal* 83:240-247.

Steiner JL. 1991. Residue effects on soil water storage at planting and grain sorghum water use. p. 223-230. In: Hanson JD, Shaffer MJ, Ball DA, Cole CV (Eds.) *Sustainable Agriculture for the Great Plains, Symposium Proceedings*, USDA-ARS, ARS-89, 255 pp.

Schneider AD, Howell TA, Steiner JL. 1993. An evapotranspiration research facility using monolithic lysimeters from three soils. *Applied Engineering in Agriculture* 9:227-235.

Steiner JL, Schomberg HH, Douglas Jr CL, Black AL. 1994. Standing stem persistence in no-tillage small grain fields. *Agronomy Journal* 86:76-81.

Steiner JL 1994. Crop residue effects on water conservation. p. 41-76. In: Unger PW (Ed.) *Managing Agricultural Residues.* Lewis Publ. Boca Raton, FL.

Schomberg HH, Steiner JL, Unger PW. 1994. Crop residue decomposition under a line-source-sprinkler system. *Soil Science Society of America Journal* 58:372-381.

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Past Accomplishments of Dwight S. Fisher

Education:
1985, North Carolina State University, Crop Science (Biomathematics minor), Ph.D.
1983, North Carolina State University, Crop Science (Nutrition minor), M.S.
1975, University of Arizona, Agriculture, B.S.

Experience:
Rangeland Scientist. USDA–Agricultural Research Service, Watkinsville, GA. 1997 to present.
Plant Physiologist. USDA–Agricultural Research Service, Raleigh, NC. 1985 to 1997.
Professor of Crop Science. North Carolina State University, Raleigh, NC. 1995 to 1997.
Associate Professor. North Carolina State University, Raleigh, NC. 1990 to 1995.
Assistant Professor. North Carolina State University, Raleigh, NC. 1985 to 1990.
Research Assistant. North Carolina State University, Raleigh, NC. 1980 to 1985.
Biological Technician. Oregon State University, Corvallis, OR. 1978 to 1980.
Research Technician. University of Arizona. 1977 to 1978.

Accomplishments:
Dr. Fisher has published extensively on the use of alternative forage species to extend the grazing season and to improve forage quality. His studies of forage-animal interactions have focused on animal behavior and forage physiology as related to grazing management strategies. Much of his work has involved the use of native species such as gamagrass (*Tripsacum dactyloides*) and switchgrass (*Panicum virgatum*) to provide diets for ruminants with increased forage quality to improve productivity and profitability in grazing systems. Comparisons have been made with widely planted introduced species such as bermudagrass (*Cynodon dactylon*) and fescue (*Festuca arundinacea*). He was also part of a team that was first to evaluate a species from Afghanistan called flaccidgrass (*Pennisetum flaccidum*) in grazing experiments. This species has now been released by the North Carolina State Agricultural Research Service. Dr. Fisher's research has extended our theoretical understanding of various aspects of forage utilization and animal behavior in order to aid in the development of a scientific basis for modification of grazing systems to improve productivity and profitability. Research in these areas has resulted in numerous invitations to author book chapters and journal articles on forage quality, management, and physiology, ruminant behavior and digestion, as well as recommended methodologies for conducting grazing trials.

Over the last ten years Dr. Fisher has received the following USDA awards for research relevant to objective 2 in this CRIS proposal; 1) For superior research on the application of mathematics to modeling dry matter intake of ruminants, 1991; 2) For outstanding research on modeling of forage intake and animal behavior during meals, 1992; 3) For outstanding accomplishments in the mathematical treatment of forage intake and digestion parameters, 1992; 4) For outstanding contributions to integrated systems research, particularly in the area of grazing lands and whole-farm management, 1998; 5) For superior research that has helped quantify grazing animal impacts on the environment, 1999.

Publications [Fisher DS]:

Fisher DS, Burns JC, Pond KR, Mochrie RD, Timothy DH. 1991. Effects of grass species on grazing steers: I. Diet composition and ingestive mastication. *Journal of Animal Science* 69:1188-1198.

Burns JC, Pond KR, Fisher DS. 1991. Effects of grass species on grazing steers: II. Dry matter intake and digesta kinetics. *Journal of Animal Science* 69:1199-1204.

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Luginbuhl J.-M., Pond KR, Burns JC, Fisher DS. 2000. Intake and chewing behavior of steers consuming switchgrass preserved as hay or silage. *Journal of Animal Science* 78:1983-1989.

Past Accomplishments of Lowry A. Harper

Education:
1971, University of Georgia, Agronomy and Agricultural Engineering, Ph.D.
1966, University of Florida, Soil Physics and Agricultural Enginnering, M.S.
1964, University of Florida, Agricultural Engineering, Soils minor, B.S. Ag.E.

Experience:
Research Soil Scientist. USDA–Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. 1966 to present.

Accomplishments:
Dr. Harper led a team of researchers that succeeded in an effort to release CO_2 into two plant canopy types in the first recorded field CO_2 release where aerial concentrations were increased sufficiently enough to affect crop photosynthesis. This research found surprisingly high CO_2 concentrations could be maintained at the crop surface due to CO_2 "fertilization". They showed that increased CO_2 would significantly increase crop photosynthesis, which led the way to free-air-CO_2 research, which is currently used for studying the effects of high atmospheric CO_2 concentrations in agriculture and forestry on global climate change.

A cooperative research project with CSIRO scientists (Queensland, Australia) was led by Dr. Harper to study aerial transport and cycling of N compounds in a tropical pasture-cattle system in relation to soil, microclimate, plant, animal, and management. This was the first study to determine the management effects of a plant canopy on aerial NH_3 losses from fertilizer and the first study to determine aerial seasonal and annual N losses. These studies showed the impact of atmospheric NH_3 losses from fertilizer and the importance of absorption by plant systems on its total N cycling. Results from these studies provided a basis for development of atmospheric NH_3 transport models to be used in large-scale environmental models.

The study of N dynamics in a wheat cropping system was conducted using a systems' analysis approach. Dr. Harper designed, coordinated, and led the effort to measure N transport between the soil surface and/or plant canopy and the atmosphere, to evaluate N mineralization in the soil, and to determine system input and output of N via external factors such as rainfall, runoff, and leaching. It was the first study to determine the quantities of N lost from plants as gaseous NH_3 during periods of high soil N (with concentrations in excess of the plants' capability to assimilate it) and lost due to plant senescence. Additionally, it was the first study to document the ability of plants to absorb atmospheric NH_3 in response to soil N deficit and the soil's capability to supply the plants' N requirement. This study was the most detailed N dynamics study at the time; revolutionizing future N research in the U.S. and Europe.

Dr. Harper designed new technology, called the micrometeorological mass difference, to measure methane emissions from cattle under pasture or feedlot conditions. This was the first non-invasive methodology for measuring methane emissions from animals under natural conditions. Results from these non-invasive studies have shown previous invasive measurements to be relatively insensitive to feedstuffs quality and animal activity suggesting that current world animal-emission estimates, are in error.

Publications [Harper LA]:

Sharpe RR, Harper LA. 1995. Soil, plant, and atmospheric conditions as they relate to nitrogen volatilization. *Fertilizer Research* 42:149-158.

Harper LA, Sharpe RR. 1995. Nitrogen dynamics in irrigated corn: Soil-plant nitrogen and atmospheric ammonia transport. *Agronomy Journal* 87:669-675.

Harper LA, Hendrix PF, Langdale GW, Coleman DC. 1995. Clover management to provide optimum nitrogen and soil water conservation. *Agronomy Journal* 35:176-182.

Harper LA, Bussink DW, van der Meer HG, Corre WJ. 1996. Ammonia transport in a temperate grassland: I. Seasonal transport in relation to soil fertility and crop management. *Agronomy Journal* 88:614-621.

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Sharpe RR, Harper LA. 1997. Ammonia and nitrous oxide emissions from sprinkler irrigation applications of swine effluent. *Journal of Environmental Quality* 26:1703-1706.

Sharpe RR, Harper LA. 1997. Apparent atmospheric nitrogen loss from hydroponically grown corn. *Agronomy Journal* 89:605-609.

Harper LA, Sharpe RR. 1998. Atmospheric ammonia: Issues on transport and nitrogen isotope measurement. *Atmospheric Environment* 32:273-277.

Denmead OT, Harper LA, Freney JR, Griffith DW, Leuning R, Sharpe RR. 1998. A mass balance method for non-intrusive measurements of surface-air trace gas exchange. *Atmospheric Environment* 32: 3679-3688.

Harper LA, Denmead OT, Freney JR, Byers FM. 1999. Direct measurements of methane emissions from grazing and feed lot cattle. *Journal of Animal Science* 77:1392-1401.

Sharpe RR, Harper LA. 1999. Methane emissions from an anaerobic swine lagoon. *Atmospheric Environment* 33:3627-3633.

Denmead OT, Harper LA, Sharpe RR. 2000. Identifying sources and sinks of scalars in a corn canopy with inverse Lagrangian dispersion analysis. I. Heat. *Agricultural and Forest Meteorology* 104:67-73.

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Harper LA, Sharpe RR, Parkin TB. 2000. Gaseous nitrogen emissions from anaerobic swine lagoons: Ammonia, nitrous oxide, and dinitrogen gas. *Journal of Environmental Quality* 29:1356-1365.

Sharpe RR, Harper LA. 2000. Methane emissions from swine houses in North Carolina. *Chemosphere* (Accepted Mar 30, 2000).

Health, Safety, and Other Issues of Concern Statement

Animal Care
This research involves work with bovidae. An animal care and use proposal will be submitted for approval by the SPCRU Animal Care and Use Committee.

Endangered Species
Not relevant.

Environmental Impact Statement
The research project has been examined for potential impacts on the environment and has been found to be categorically excluded under ARS regulations for the National Environmental Policy Act.

Human Study Procedures
Not relevant.

Laboratory Hazards
All hazardous materials will be handled with appropriate protective clothing and used in fume or biological hoods as required. All pipetting is done mechanically.

Occupational Safety & Health
This research involves working with microorganisms and chemicals; accordingly, annual medical surveillance is provided. Safety courses, training, and protective clothing and equipment are provided as needed.

Recombinant DNA Procedures
Not relevant.

While preparing the Project Plan, I (Alan J. Franzluebbers) have carefully examined all aspects of the planned research to ensure that appropriate safety concerns are addressed, all necessary permits have been identified, and that environmental issues have been considered in making the National Environmental Policy Act (NEPA) decision documented in the statement. All permits are in hand or have been requested. Documentation supporting NEPA decision is in the MU project file and available for review upon request.

I (S. Karl Narang) certify that the proposed research conforms to current regulations and guidelines regarding the above issues and concerns.

Appendices

Page

USDA–Agricultural Research Service Collaborators

External Collaborators