Pasture-Crop Rotation Study

(Funding from USDA–NRICGP, Oct 2001 to Sep 2004)

Rationale

<u>Tillage management under conditions of high soil organic matter content</u>. Soil organic matter is a critical component in maintaining soil quality in the Southern Piedmont. Pastures are known to improve soil organic C and N, which leads to retention of organically-bound nutrients and improved water relations. Cropping systems that are appropriate in this region under conditions of high soil organic matter have not been evaluated since much of the cropland has been stripped of soil organic matter from previous degradative cropping practices. Crop productivity response to tillage management following pasture termination may be significantly different than following a previously degraded land usage due to the presence of a large storage of nutrients, soil biological potential, and improved physical structure.

<u>Time of grain cropping</u>. Climatic conditions in the Southern Piedmont are characterized by high precipitation-to-potential evapotranspiration during the winter growing season, but low precipitation-to-potential evapotranspiration during the summer growing season. The impact of time of grain cropping (i.e., winter versus summer) on grain yield, forage availability, and soil properties has not been well described, especially under conditions of initially high soil organic matter following pasture. Under a potentially double-cropping environment in the southeastern USA, a cover crop following grain cropping could provide high-quality forage to supplement shortages in supply from perennial pastures.

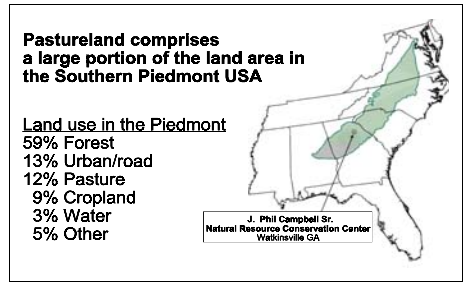
<u>Cover crop management (impact of grazing cattle)</u>. The impact of grazing animals on the environment is more often than not viewed as negative. A large portion of the land area in the Southern Piedmont USA is devoted to pasture production of cattle. Our previous work has shown that grazing of warm-season grasses in the summer can have positive impacts on soil organic C and N accumulation and no observable detriment to surface soil compaction. However, the role of grazing animals in pasture–crop rotations does not have to be limited to the medium- or long-term pasture phase alone. Cover crops following grain crops can be an excellent source of high quality forage to be utilized in small, mixed-use farming operations, such as those commonly found in the Southern Piedmont region. A potential impact of animals grazing cover crops, however, could be compaction due to hoof action, as observed in Southern Piedmont soils under relatively low soil organic matter conditions. Surface residue cover may provide a significant buffer against animal trampling effects, such that no tillage crop production following long-term pasture could alleviate negative animal trampling effects. The impacts of grazing cattle on soil compaction and parasite load during different times of the year, however, have not been quantitatively described.

<u>Soil quality and biological diversity</u>. Soil quality is a reflection of management strategies that

(1) sustain a supply of nutrients to plants for long-term productivity,
(2) improve water infiltration into soil to avoid erosion,
(3) promote root growth to increase nutrient acquisition and water utilization for optimum plant production, and
(4) maintain soil biological habitat, activity, and diversity for effective nutrient cycling, biodegradation capacity, and ecosystem stability.

The impacts of tillage management, timing of grain cropping, and cover crop management on total, particulate, and biologically active soil C and N pools, on soil biological diversity, and on soil physical properties including porosity, aggregation, and infiltration have not been comprehensively studied in the Southern Piedmont or elsewhere. Further, these soil properties have not been adequately evaluated under management systems that will likely alter different elements of soil fertility, which should not be viewed only as chemistry, but also the combination with the physics and biology of soil.

Objectives



Land use in the Southern Piedmont USA.

In a broad sense, our objective is to quantitatively evaluate three management factors (i.e., tillage, time of grain cropping, and cover crop management) for their impacts on plant and animal productivity, soil quality, and fluxes of potential pollutants to the environment. The factorial arrangement of treatments will allow us to isolate significant interactions among management factors, which should lead to a better understanding of the processes controlling productivity and environmental quality.

Specific objectives will be to:

1) quantify the rate of soil organic C and N loss following conversion of long-term pasture to short-term cropping,
2) quantify the responses in soil properties, plant and animal productivity, and water runoff due to tillage management under cropping systems that include grazing cattle and high cropping intensity,
3) quantify the relative stability of plant production during winter versus summer growing seasons and that effect on productivity and environmental quality,
4) quantify the changes in soil compaction, surface water runoff, and water infiltration due to the presence of grazing cattle during winter versus summer grazing periods,
5) quantify the changes in total cattle parasite load and species composition following summer versus winter grazing of cover crops,
6) quantify cattle productivity and performance during short-term grazing alternatives to perennial pastures,
7) evaluate the interrelationships among soil properties following adoption of land management systems, which may alter soil organic matter dynamics and plant productivity, and
8) develop a minimum dataset approach for assessing the basic changes in soil quality due to differences in management in the Southern Piedmont region.

Hypotheses

<u>Tillage management under conditions of high soil organic matter content</u>. No-tillage crop production following termination of pasture will preserve more of the stored soil organic C and N than with conventional tillage. However, the rate of decline under these two tillage systems in the Southern Piedmont has not been established. Alternatively, grain cropping with a cover crop may utilize much of the available water and shade the soil surface to effectively eliminate much of the stimulation of decomposition brought about by tillage.

Time of grain cropping. Winter grain production will be more reliable and greater in the long-term than summer grain production due to milder temperature and higher precipitation-to-potential evapotranspiration ratio. It is possible that time of grain production could interact significantly with tillage management, such that no tillage would have a positive impact on summer grain cropping, but a negative impact on winter grain cropping due to lower temperature and increased soil moisture. Winter grazing of the cover crop will compact soil compared with summer grazing, especially under conventional tillage. Winter grazing of the cover crop will also retain a high load of the most detrimental internal cattle parasites, which would reduce animal productivity in a whole-farm system. It may be possible to eliminate parasites from intermittently grazed areas if grazing were in the summer only.

Cover crop management (impact of grazing cattle). Cover crops will provide an economical short-term forage crop without negatively impacting soil quality. Grazing of cover crops could increase compaction and reduce water infiltration capacity under conventional tillage due to animal trampling effects following redistribution of surface soil organic matter with inversion tillage. Selection of the optimum grain cropping–cover crop system could be dependent upon whether cattle are allowed to graze the cover crop or not. This study will provide options for crop and animal producers to select appropriate timing of grazing and tillage management so that any negative cattle impacts on soil quality could be minimized.

Soil quality and function.

(1) Changes in soil organic C with time and with management system will be a suitable soil quality indicator that reflects the soil's *function to supply nutrients to plants*. Soil organic C will be compared with changes in total N, soil pH, extractable bases, extractable phosphorus, deep soil-profile distribution of inorganic N, and above-ground plant biomass production.
(2) Changes in water-stable aggregate distribution with time and with management system will be a suitable soil quality indicator that reflects the soil's *function to resist water erosion and avoid detriment to water quality from runoff of sediments, nutrients, and pathogens*. Water-stable aggregate distribution will be compared with field measurements of ponded ring infiltration, penetrometer resistance, water runoff collection, and surface residue mass.
(3) Changes in particulate organic C and N contents with time and with management system will be a suitable soil quality indicator that reflects the soil's *function to provide a suitable rooting environment for acquisition of nutrients and water*. Particulate organic C and N contents will be compared with deep soil-profile inorganic N concentration and bulk density.
(4) Changes in the flush of CO_2 following rewetting of dried soil with time and with management will be a suitable soil quality indicator that reflects the soil's *function to cycle nutrients, decompose organic amendments, and catalyze and stabilize ecosystem processes through diversity of organisms.* The flush of CO_2 following rewetting of dried soil will be compared with total soil organic C, longer term C and N mineralization, microbial biomass determination with chloroform fumigation–incubation, and fatty-acid methyl ester profiles and substrate utilization estimates of microbial diversity.

Interrelationships exist among soil properties that will lead to a minimum data set of only a few key dynamic soil properties that can explain changes in soil functions with time and with management system.

Experimental design

A set of 18 experimental paddocks (0.7 ha each) were previously arranged as six cattle grazing treatments in three blocks. Previous treatments included low (134-15-56 kg N-P-K · ha^{-1} · yr^{-1}) and high fertilization rates (336-37-139 kg N-P-K · ha^{-1} · yr^{-1}) imposed upon four grass variables ('Kentucky-31' tall fescue with low and with high endophyte infection, 'Johnstone' tall fescue with low endophyte infection, and 'Triumph' tall fescue with low endophyte infection). Previous treatments were part of a long-term experimental design initiated in 1981 to study tall fescue–endophyte effects on cattle productivity, performance, and other miscellaneous animal response variables until 1997. Fertilization was terminated prior to 1998 and forage grazed on an *ad hoc* basis thereafter. Pasture growth during the past three years without fertilization was expected to remove any differences among paddocks in residual inorganic soil N.

The 18 experimental paddocks should be regarded as an excellent starting point for the proposed research because soil organic matter will be at a high level and grazing infrastructure is already in place at the site (including fencing, gates, shades, mineral feeders, and watering troughs).

The proposed experimental design will consist of a completely randomized design with a split-plot arrangement within main plots. Main plots will be a factorial arrangement of (a) tillage and (b) time of grain cropping and split plots within main plots will be (c) cover crop management. Main plots will be replicated four times. Two paddocks will remain in tall fescue forage to serve as uncropped controls.

Tillage management

(1) Conventional disk tillage following harvest of each grain and cover crop
(2) No tillage with glyphosate to control weeds prior to planting

Time of grain cropping

(1) Winter grain cropping (wheat; November planting and May harvest) with summer cover cropping (pearl millet + soybean; June planting and October termination)
(2) Summer grain cropping (sorghum; June planting and October harvest) with winter cover cropping (rye + crimson clover; November planting and May termination)

Cover crop management (impact of grazing cattle)

(1) Mechanical rolling at maturity without animals
(2) Cattle grazing for 60-90 days prior to reproductive stage development

Each grain and cover crop will receive top-dressing applications of 40 kg N · ha^{-1} as ammonium nitrate shortly after planting and no other fertilizer amendment. The basal application of N will assure early plant growth and development with further growth dependent upon the mineralization of stored nutrients in soil organic matter. Extractable P and K concentrations in the surface 7.5 cm of soil are greater than 100 mg P · kg^{-1} soil and 400 mg K · kg^{-1} soil, levels considered adequate for crop production.

Soil at the site is a Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults) on 2-4% slopes. Cecil soils are widespread throughout the Southern Piedmont region and are considered excellent soils for agronomic purposes.

Table 1. Field layout (8 north). Existing paddocks (denoted by double line) will be divided into grazed (68 x 73.5 m) and ungrazed (27.4 x 73.5 m) areas. A central roadway divides the two columns of paddocks. Shade, water, and mineral feeders have been permanently installed at the top of the landscape near the central roadway.

NT Summer grain Winter cover crop Ungrazed	No Tillage Summer grain Winter cover crop Grazed Rep 3	Conventional Tillage Summer grain Winter cover crop Grazed Rep 3	CT Summer grain Winter cover crop Ungrazed
NT Winter grain Summer cover crop Ungrazed	No Tillage Winter grain Summer cover crop Grazed Rep 3	No Tillage Summer grain Winter cover crop Grazed Rep 4	NT Summer grain Winter cover crop Ungrazed
CT Winter grain Summer cover crop Ungrazed	Conventional Tillage Winter grain Summer cover crop Grazed Rep 3	Tall fescue Grazed Rep 2	Tall fescue Grazed
CT Summer grain Winter cover crop Ungrazed	Conventional Tillage Summer grain Winter cover crop Grazed Rep 2	Conventional Tillage Winter grain Summer cover crop Grazed Rep 4	CT Winter grain Summer cover crop Ungrazed
NT Winter grain Summer cover crop Ungrazed	No Tillage Winter grain Summer cover crop Grazed Rep 4	No Tillage Summer grain Winter cover crop Grazed Rep 2	NT Summer grain Winter cover crop Ungrazed
NT Winter grain Summer cover crop Ungrazed	No Tillage Winter grain Summer cover crop Grazed Rep 2	Conventional Tillage Winter grain Summer cover crop Grazed Rep 2	CT Winter grain Summer cover crop Ungrazed
CT Winter grain Summer cover crop Ungrazed	Conventional Tillage Winter grain Summer cover crop Grazed Rep 1	Conventional Tillage Summer grain Winter cover crop Grazed Rep 4	CT Summer grain Winter cover crop Ungrazed
Tall fescue Grazed	Tall fescue Grazed Rep 1	Conventional Tillage Summer grain Winter cover crop Grazed Rep 1	CT Summer grain Winter cover crop Ungrazed
NT Summer grain Winter cover crop Ungrazed	No Tillage Summer grain inter cover crop Grazed Rep 1	No Tillage Winter grain Summer cover crop Grazed Rep 1	NT Winter grain Summer cover crop Ungrazed

Expected results

We expect there to be a *loss of soil organic matter pools* with time in all cropping systems following conversion from pasture. However, the rate of decline and the vertical distribution of this organic matter may be significantly different based on the three levels of management imposed. Because we are imposing relatively intensive cropping systems within this rotation sequence with pasture, the rate of decline in soil organic matter pools even with conventional tillage is not expected to be as severe as commonly envisioned. We do expect lower levels of soil organic matter pools with conventional tillage than with no tillage.

We expect the retention of surface residues and high soil organic matter at the soil surface to *buffer the impact of grazing animals* on soil physical properties, water runoff, and soil organic matter changes. Conventional tillage may stimulate nutrient release from soil organic matter, but also result in soil crusting and greater potential for compaction by grazing cattle. The divergent impacts of conventional tillage on nutrient release (i.e., positive impact) and soil surface condition (i.e., negative impact) should be reflected in plant and animal productivity. As a means of soil quality evaluation, plant and animal productivity will be directly related to changes in soil properties.

We expect to find a combination of management systems that will allow effective *integration of grazing cattle* throughout the pasture-crop rotation sequence. Initially, we view no tillage management with summer grazing of cover crops as perhaps the best combination to achieve successful grazing throughout this period. We may find that winter grazing of cover crops along with no tillage management could be as effective in achieving high productivity and avoiding soil degradation (or summer grazing of cover crops along with conventional tillage management). The interpretation of these effects may change with the number of years during this cropping phase following pasture conversion.

We expect *better grain production under winter cropping* and summer grazing because of more reliable precipitation during winter cropping and avoidance of cattle traffic during winter when soil remains wet for long periods of time. Summer cropping may produce excellent yields in some years when rainfall is adequate, but the chances for severe drought stress are higher. Summer grain cropping would potentially be more productive because of warmer temperatures and longer days.

We expect that a small *subset of the soil response variables* will explain the majority of the variation in plant and animal productivity and environmental health. Selecting a few key response variables to predict productivity and environmental changes due to management will be useful to assess soil quality, recommend successful management strategies to producers, and understand the interrelationships among soil, plant, and animal responses.

We expect *active soil organic matter pools to respond more rapidly* to changes in management and years following conversion from pasture. These active pools would be the flush of CO_2 following rewetting of dried soil, soil microbial biomass, and mineralizable C and N. We will be able to relate both spatially due to management and temporally due to years following conversion from pasture the associations between these active soil organic matter pools and soil biological diversity.

Investigators / responsibilities

Alan Franzluebbers (Steve Knapp): shallow and deep soil sampling, fertilizer applications, crop management, water infiltration, laboratory analyses of soils for bulk density, total C and N, microbial biomass C, mineralizable C and N, water-stable aggregation, particulate organic C and N, inorganic N and P;
(temporary-full time technician): crop and animal management, site maintenance
(Robert Martin): soil C, N, and P analyses (144 shallow soil/year, 216 deep soil/year), water analyses for NH_4, NO_3, PO_4, and DOC (540/year)

John Stuedemann (Dwight Seman): animal productivity, animal performance, stocking adjustment, available forage, mineral salts, internal parasites

Dory Franklin (Beth Barton): installation of runoff collectors, collection and analysis of runoff samples

Mike Jenkins (Shaheen Humayoun): detecting fecal-borne pathogens in runoff water samples, characterizing soil microbial diversity

Dave Zuberer (Texas A&M University): characterizing carbon utilization profiles

Ray Kaplan (University of Georgia): collection of feces and characterization of internal parasites