Soil C, N, and P from Poultry Manure on Grazed and Ungrazed Bermudagrass in the Southeastern USA

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Abstract

The impact of animal manure application to grasslands is of importance to the understanding of agronomic and animal productivity, soil quality, greenhouse gas emissions, and environmental quality. Pastures have the potential to serve as a significant sink for carbon (C) sequestered in soil organic matter. Efficient utilization of nitrogen (N) is of concern agronomically and environmentally. Plant production can be limited by low levels of available phosphorus (P) due to high P fixation capacity in soils of the southeastern USA. On the other hand, there is increasing concern about the excessive application of P to soil, especially when manure application rate is based upon N content.

We evaluated the changes in soil C, N, and P during the first five years of bermudagrass [*Cynodon dactylon* (L.) Pers.] management varying in fertilization [(1) inorganic, (2) crimson clover (*Trifolium incarnatum* L.) cover crop plus inorganic, and (3) chicken (*Gallus gallus*) broiler litter] and harvest strategies [(1) unharvested, (2) low and (3) high cattle (*Bos taurus*) grazing pressure, and (4) haying).

Fertilization strategy had the greatest impact on total and extractable soil P, while soil organic C and total soil N were minimally affected. At a depth of 0 to 6 cm, extractable soil P increased at a rate of 0.8 mg · kg^{-1} · yr^{-1} (4 % of total P added) with inorganic only, 2.4 mg · kg^{-1} · yr^{-1} (9 % of total P added) with clover + inorganic, and 8.7 mg · kg^{-1} · yr^{-1} (6 % of total P added) with broiler litter fertilization. At the end of five years of broiler litter application to grazed land, extractable soil P was 135, 50, 22, and 4 mg · kg^{-1} higher than with inorganic fertilization at depths of 0 to 3, 3 to 6, 6 to 12, and 12 to 20 cm, respectively, primarily because of greater P application with broiler litter.

Harvest strategy had large impacts on all soil elements. Soil organic C sequestration during the first five years of management was similar between low and high cattle grazing pressures (140 g · m^{-2} · yr^{-1}), but much less in unharvested (65 g · m^{-2} · yr^{-1}) and hayed (29 g · m^{-2} · yr^{-1}) management. Most of the net change in soil organic C and total soil N occurred in the 0- to 2-cm depth. With cattle grazing of forage, fertilizer applications contributed to forage and animal production and 67-75% of the total N applied was subsequently stored as total soil N.

Broiler litter fertilization was effective at increasing extractable soil P to an agronomically acceptable level (50 to 60 mg · kg^{-1} · 15 cm^{-1}) during the first five years, but continued application could lead to excessive P accumulation that could threaten water quality from surface runoff unless appreciable soil fixation or removal of forage biomass were to occur.

Rationale

Conversion of cropland to forages has the potential to restore soil organic matter and build fertility. Cattle consume forage and deposit manure, which alters the timing and spatial distribution of nutrient cycling in pastures.

Chicken litter is a relatively inexpensive source of nutrients that is often applied to pastures to supply N, P, and other nutrients. Soils in the Appalachian Piedmont are relatively poor in C, N, and P. Therefore, plant production would likely respond positively to chicken litter application. However, excessive N and P can threaten water quality.

Objective

Determine changes in soil C, N, and P in response to:

- type of fertilization (i.e., inorganic or organic)
- forage harvest strategy (i.e., grazed or ungrazed)

during the first 5 years of bermudagrass management.

Materials and Methods

Soil
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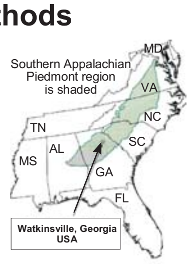
Ap horizon (21±12 cm) mostly sandy loam



Environment
Mean annual temperature: 16.5 °C
Mean annual precipitation: 1250 mm
Mean annual evaporation: 1560 mm
'Coastal' bermudagrass beginning in 1994.

Experimental design
Randomized complete block
3 fertilization x 3 replications x 4 harvest strategy x 5 years

(a) inorganic only	(a) unharvested
(b) clover + inorganic	(b) low cattle grazing pressure
(c) broiler chicken litter	(c) high cattle grazing pressure
	(d) hayed monthly

Each fertilizer was targeted to supply 20 g N m^{-2} yr^{-1}
Cattle grazing pressure was adjusted with a put-and-take system to a target of either 3 or 1.5 Mg/ha of available forage for low and high grazing pressures, respectively.

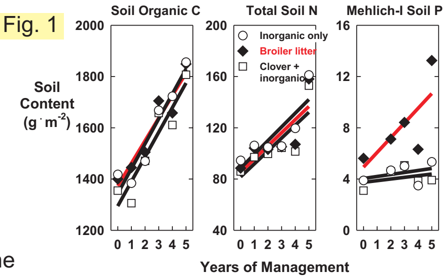
Sampling and analyses
Soil was sampled in April prior to grazing (1994-1998) at a depth of 0-6 cm. In 1999, sampling was in February at 0-3, 3-6, 6-12, and 12-20 cm in 3 zones according to shade/water.
Soil organic C and total soil N were determined by dry combustion.
Extractable soil P was determined with Mehlich-I.

Results and Discussion

5-year mean inputs (g · m^{-2} · yr^{-1}):

Type	C	N	P
Inorganic	0	22.5	1.6
Clover + inorganic	0	24.5	2.3
Broiler litter	183	19.4	12.4

Fig. 1



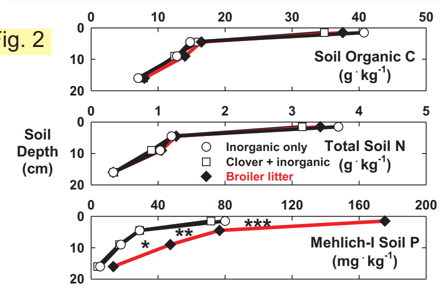
Fertilization strategy

Type of fertilization had little effect on the rate of accumulation of soil organic C and total soil N, but had a major effect on Mehlich-I soil P (Fig. 1).

SOC = 94 g · m^{-2} · yr^{-1}
TSN = 10.3 g · m^{-2} · yr^{-1}
$MSP_{(broiler\ litter)}$ = 1.15 g · m^{-2} · yr^{-1}
$MSP_{(others)}$ = 0.14 g · m^{-2} · yr^{-1}

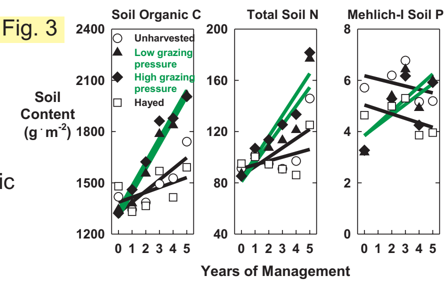
The additional C with broiler litter had no effect on soil organic C.

Fig. 2



Surface accumulation of all nutrients occurred (Fig. 2). Mehlich-I soil P was greater with broiler litter than other fertilization strategies at depths to 12 cm. The change in extractable soil P represented only 15% of applied P.

Fig. 3

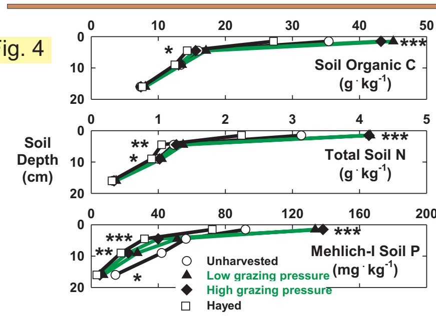


Harvest strategy

Grazed systems had higher rates of accumulation (g · m^{-2} · yr^{-1}) of soil organic C (140 vs 47), total soil N (15.6 vs 5.2), and Mehlich-I soil P (5.2 vs -0.2) than ungrazed systems (Fig. 3).

Sequestration of N into the surface 6 cm of soil represented an average of 71% of applied fertilizer under grazed and 24% under ungrazed systems.

Fig. 4

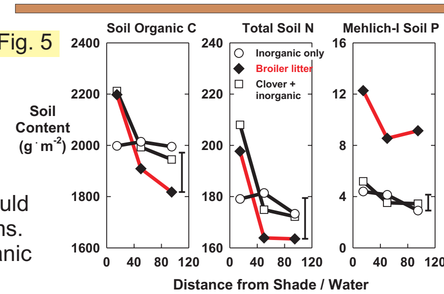


Much of the effect of grazing occurred within the surface 0-3 cm (Fig. 4).

Spatial distribution within pasture

Nutrients within grazed pastures were generally greater near shade and water sources as a result of preferential deposition of feces and urine (Fig. 5). Cattle seek water, minerals, and relief from the sun in these areas.

Fig. 5



Conclusions

Broiler litter was effective at increasing soil P levels, but further application could cause unwanted water quality problems.
Grazing had positive effects on soil organic C and total soil N conservation.