LONG-TERM ACCUMULATION OF SOIL CARBON AND NITROGEN IN GRAZED BERMUDAGRASS PASTURES

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Summary and Application

Managed pastures have potential for carbon and nitrogen sequestration in addition to providing forage for livestock. Increasing soil carbon and nitrogen sequestration can improve soil fertility and provide nutrients to forage, thus lessening the dependence on fertilizers. Our objectives were to investigate long-term changes in soil organic carbon (SOC) and organic nitrogen (SON) concentrations in cattle-grazed bermudagrass pastures after 32 years. Pastures were subjected to low- and high-grazing intensity, fertilization, and winter overseeding with annual ryegrass and/or clover. Soil (0 to 6 inches) was sampled 7, 15, 26, and 32 years after establishment of Coastal and common bermudagrass pastures. No differences in SOC or SON concentrations were observed between Coastal and common bermudagrass pastures, but SOC and SON were greater at low- than high-grazing intensity. Soil organic C and SON concentrations increased from 7 to 26 years at low-grazing, but only from 7 to 15 years at high-grazing intensity. An exception was the Coastal bermudagrass+ryegrass pastures, which exhibited higher SON at 32 years than at 7 years at both grazing intensities. Bermudagrass+ryegrass pastures exhibited higher SOC and SON than bermudagrass+clover pastures at high-grazing intensity, but no differences were observed at low-grazing intensity.

Introduction

Grasslands have potential for sequestering large quantities of carbon in plant biomass or soil organic matter with proper management. Various practices are utilized to increase forage production for livestock, including altered grazing patterns, fertilization, and selective establishment of improved forage mixtures of grasses and legumes. These management practices may have other potential benefits, such as increased soil organic matter content and improved soil fertility.

Improvements in management resulted in average SOC increases of 51% in a recent review of carbon sequestration studies (3). However, results varied due to forage composition, fertilization, grazing intensity, temperature, and rainfall. Grazing often enhances soil carbon and nitrogen mineralization rates, resulting in release of nutrients and subsequent increases in plant productivity. Improved grazing and fertilization strategies have been shown to increase SOC by 2.9% and 2.2% annually (3). The addition of legumes to pastures enhanced SOC contents by 2% annually (3). The introduction of legumes increases soil nitrogen by promoting nitrogen fixation, which enhances soil carbon and nitrogen sequestration.

The objectives of this study were to determine the influences of long-term grazing management and forage species composition on SOC and SON concentrations in bermudagrass pastures overseeded with ryegrass and/or clover.

Materials and Methods

Common and Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] pastures were established in 1968 on a Troup loamy fine sand (pH=6.2). From 1968 through 1984, bermudagrass was overseeded in October with a mixture of annual ryegrass (*Lolium multiflorum*) and clover (*Trifolium* sp.). Various clover cultivars were grown during the experiment, but the same cultivars were grown at given years for all treatments and pastures. Pastures were fertilized annually with 100 lb P_2O_5 ac^{-1}, 100 lb K_2O ac^{-1}, and 200 lb N ac^{-1}, with applications split several times during the year. From 1984 to 2000, common and Coastal bermudagrass pastures were divided: half overseeded with annual ryegrass and half with clover. Pastures overseeded with ryegrass received nitrogen (300 lb N ac^{-1} yr^{-1}), while pastures overseeded with clover only received potassium (115 lb K_20 ac^{-1} yr^{-1}). No phosphorus was applied after 1984 in any pasture because previous fertilization increased soil phosphorus to acceptable levels.

Pastures were continuously grazed by cattle from late February to October at either a low- or high-grazing intensity. Stocking rates were based on available forage, so the number of cattle per acre varied from year to year and from pasture to pasture. Approximate stocking rates were 1 and 3 cow-calf pairs ac^{-1} for Coastal and 0.8 and 2 cow-calf pairs ac^{-1} for common bermudagrass pastures for low- and high-grazing intensities, respectively. Soil samples, consisting of the top 6 inches of 4 replicate soil cores, were taken in November 1975, March 1983, August 1994, and July 2000, corresponding to 7, 15, 26, and 32 years after establishment of bermudagrass pastures. Soil was analyzed for nitrate, ammonium, SOC, SON, and potentially mineralizable carbon and nitrogen.

Results and Discussion

Inorganic nitrogen concentrations were quite variable between sampling years. Nitrate concentrations averaged 1.4, 1.4, 3.0, and 11.2 ppm at 7, 15, 26, and 32 years, respectively. Few treatment effects were noted, except that Coastal and common bermuda+ryegrass pastures at both grazing intensities had significantly higher nitrate concentrations than bermuda+clover pastures. Ammonium concentrations were also variable between sampling years. Ammonium was significantly higher than nitrate, being approximately 62, 99, 11, and 11 ppm at 7, 15, 26, and 32 years, respectively. Nitrate plus ammonium comprised only 2% of soil total nitrogen.

Similar SOC concentrations were observed for Coastal and common bermudagrass pastures (Fig. 1). Averaged between them, SOC significantly increased from 7 to 15 years at both grazing intensities. Soil organic C increased from 15 to 26 years for both bermuda+clover and bermuda+ryegrass pastures at low-grazing intensity, but no changes were observed between 26 and 32 years. Soil organic C increased 13% from 7 to 15 years, and 67 and 39% from 7 to 26 years under low-grazing intensity for bermuda+ryegrass and bermuda+clover pastures, respectively. At high-grazing intensity, SOC did not increase from 15 to 32 years in bermuda+clover pastures, and was highest at 32 years in Coastal bermuda+ryegrass pastures. Soil organic C increased 22% from 7 to 15 years, and 41% in high-grazing intensity bermuda+ryegrass pastures from 7 to 32 years. Averaged over all pastures, high-grazing significantly decreased SOC compared to low-grazing intensity. At low-grazing intensity, no differences between bermuda+clover and bermuda+ryegrass were observed. At high-grazing intensity, however, bermuda+ryegrass pastures showed higher SOC than bermuda+clover pastures at 26 and 32 years in common bermudagrass and at 32 years in Coastal bermudagrass pastures.

Soil organic N was significantly related to SOC. Overall, no significant differences in SON between common and Coastal bermudagrass pastures were observed (Fig. 2). Averaged between them, SON significantly increased from 7 to 15 years at both grazing intensities. Soil organic N in bermuda+ryegrass+clover pastures increased 24 and 30% from 7 to 15 years at low- and high-grazing intensity, respectively. However, after 15 years, no further increases in SON were observed, except for Coastal bermuda+ryegrass pastures at both grazing intensities. By 32 years, SON increased 83 and 45% in Coastal bermuda+ryegrass pastures at low- and high-grazing intensity, respectively, compared to 7 years. Soil organic N was higher at low-grazing than at high-grazing intensity. No differences in SON were observed between bermuda+clover and bermuda+ryegrass pastures at low-grazing intensity. At high-grazing intensity, SON was higher in bermuda+ryegrass than bermuda+clover for common and Coastal bermudagrass pastures at 26 and 32 years.

No differences in potentially mineralizable C were observed between Coastal and common bermudagrass pastures or between low- and high-grazing intensity, although potentially mineralizable C tended to be higher in Coastal compared to common bermudagrass pastures (Fig. 3). Increases in mineralizable C were observed from 7 to 15 years for both Coastal and common pastures at both grazing intensities. However, few increases in mineralizable C were observed beyond 15 years.

Potentially mineralizable N was more variable than mineralizable C due to large differences in ammonium and nitrate concentrations at sampling years. No significant differences in mineralizable-N were observed from 7 to 15 years for any pasture, but mineralizable N significantly increased at 32 years compared to 7 and 15 years for Coastal and common bermuda+clover pastures at both grazing intensities, and for common bermuda+ryegrass pastures at low-grazing intensity (Fig. 4). For both Coastal and common bermudagrass pastures, mineralizable N was higher for bermuda+clover at both grazing intensities compared to bermuda+ryegrass. This may be the result of cattle preferentially grazing clover; with returned excreta being rapidly degraded, resulting in increased potentially mineralizable N and nitrogen loss from the system, and thus resulting in lower SON concentrations in bermuda+clover than bermuda+ryegrass pastures. In our study, these conclusions were supported by evidence of higher N-mineralization rates and lower SON concentrations for bermuda+clover than bermuda+ryegrass.

Grazing strategy significantly influenced SOC and SON concentrations. High-grazing intensity decreased SOC and SON compared to low-grazing intensity, likely due to enhanced turnover of plant material and excreta, physical disruption of soil, and soil incorporation of plant residues for high-grazing intensity pastures. Pasture grazing increases forage turnover and uptake; and transformations within the rumen alter the composition of returned manures. This makes organic materials more biodegradable and hastens losses of soil nitrogen from excreta and returned residues (2). Thus, carbon and nitrogen from bermuda+clover pastures may have been recycled through vegetation, cattle, and soil to a greater extent than carbon and nitrogen from bermuda+ryegrass pastures. This resulted in greater nitrogen loss, via volatilization from excreta and enhanced N-mineralization rates, which likely increased potential nitrate leaching, especially in the sandy soils of these pastures.

Rates of N-mineralization are often dependent on the C/N ratios of organic substrates. Higher rates of carbon accumulation for ryegrass than clover stands have been attributed to the higher C/N ratios of ryegrass organic inputs, which limited nitrogen availability through immobilization. The differences in potential carbon and nitrogen mineralization between bermuda+clover and bermuda+ryegrass pastures may have been a result of lower C/N ratios of clover compared to ryegrass, in addition to the selective grazing of clover by cattle, which increased the turnover of organic matter in bermuda+clover pastures. Hence, microbial degradation of low C/N manures and residues in bermuda+clover pastures, as evidenced by the loss of carbon and nitrogen from soil organic matter mineralization, resulted in decreased SOC and SON concentrations. The loss of inorganic nitrogen from bermuda+clover pastures by leaching or volatilization would explain the lower SON concentrations observed in bermuda+clover pastures compared to bermuda+ryegrass pastures.

Available dry matter contents were higher for grazed bermuda+ryegrass than for bermuda+clover pastures at both low- and high-grazing intensity (4,6,7). Aboveground production was often 33 to 50% greater in Coastal than in common bermudagrass pastures (1,5). However, greater forage production of Coastal compared to common bermudagrass pastures did not result in significantly higher SOC and SON concentrations in our study. This discrepancy between Coastal and common bermudagrass forage production and SOC and SON concentrations suggests that there were more significant losses of carbon and nitrogen from Coastal compared to common bermudagrass pastures. Indeed, both potentially mineralizable C and N tended to be greater in Coastal than in common bermudagrass pastures. Thus, the similarity in SOC and SON concentrations between Coastal and common bermudagrass pastures was due to the increased forage production of Coastal pastures being offset by increased losses of SOC and SON due to organic matter degradation.

In our study, SOC concentrations appeared to stabilize at 26 years after bermudagrass establishment at low-grazing intensity and at 15 years at high-grazing intensity. An exception was the 32 year old Coastal bermuda+ryegrass pastures at high-grazing intensity, which showed significantly higher SOC than at 7 or 15 years. In addition, SON for Coastal bermuda+ryegrass pastures was significantly higher at 32 years than at 7 or 15 years at both grazing intensities. Thus, Coastal bermudagrass pastures overseeded with ryegrass plus nitrogen fertilization showed the greatest SOC and SON sequestration potential.

Conclusions

Proper management of grazed pastures has the potential for SOC and SON sequestration. Increases in SOC and SON concentrations were observed up to 32 years after establishment of bermudagrass pastures. Thus, long-term increases in SOC and SON in grazed pastures were achieved, but increases were dependent upon grazing management and forage composition. Grazing strategies played important roles in carbon and nitrogen sequestration, as high-grazing intensity significantly decreased SOC and SON concentrations compared to low-grazing intensity. Differences in SOC and SON between pastures overseeded with various winter annuals were also observed. The introduction of clover to pastures decreased SON sequestration at high-grazing, but not at low-grazing intensity. Bermudagrass pastures overseeded with annual ryegrass and receiving nitrogen increased SOC and SON compared to overseeding with clover, likely due to enhanced turnover of clover residues and loss of nitrogen from the system. Management practices, such as variable grazing intensities and forage composition, have potential for significantly increasing SOC and SON sequestration and improving soil fertility.

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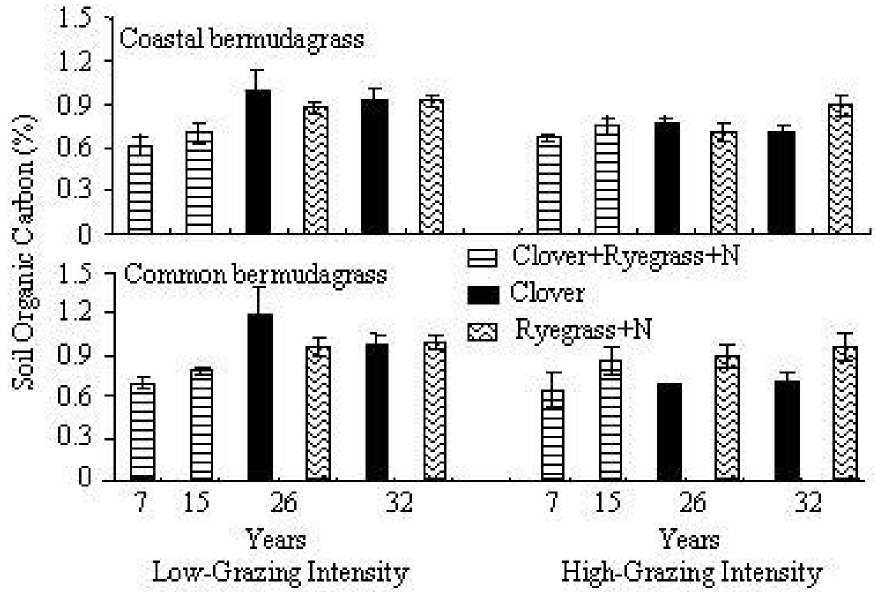

Fig. 1. Soil organic carbon contents in overseeded bermudagrass pastures at 7, 15, 26, and 32 years after establishment.

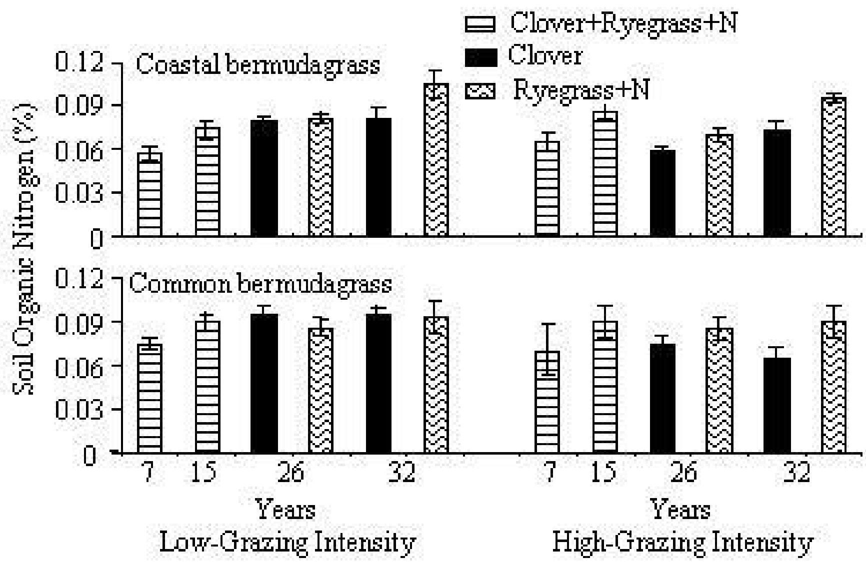

Fig. 2. Soil organic nitrogen contents in overseeded bermudagrass pastures at 7, 15, 26, and 32 years after establishment.

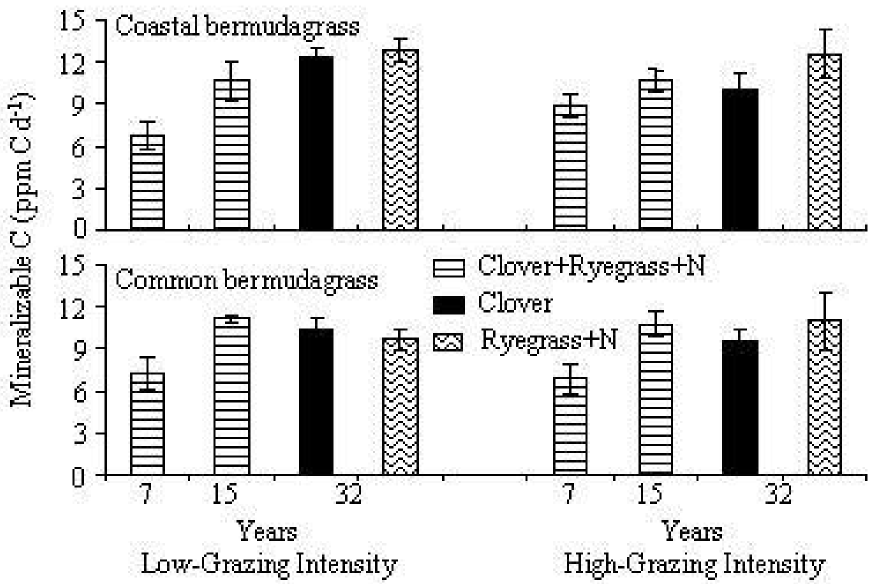

Fig. 3. Soil potentially mineralizable-C in overseeded bermudagrass pastures at 7, 15, and 32 years.

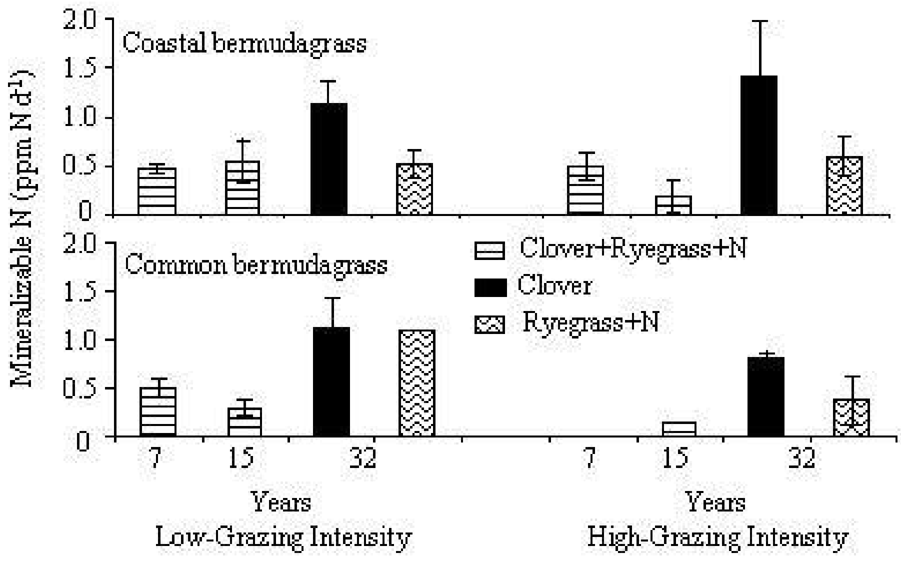

Fig. 4. Soil potentially mineralizable-N in overseeded bermudagrass pastures at 7, 15, and 32 years.