Effects of Elevated Atmospheric CO_2 and N Fertilization on Bahiagrass Pastures in the Southeastern U.S.

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ABSTRACT

In the Southeastern US, both managed and unmanaged pasture systems remain understudied agro-ecosystems in terms of the effects of elevated atmospheric CO_2 concentration. Therefore, we initiated a long-term study of bahiagrass (*Paspalum notatum* Flüggé) response to elevated CO_2 using open top field chambers in 2005 on a Blanton loamy sand (loamy siliceous, thermic, Grossarenic Paleudults). The study has run for 9 years with biomass production and tissue carbon and nitrogen assessed. Plants were exposed to ambient or elevated (ambient plus 200 ppm) CO_2. After a one-year establishment period, an N treatment was applied where half of all plots received N [$(NH_4)_2SO_4$] at 90 kg ha^{-1} three times yearly; the remaining plots received no N fertilization. These two treatments represent managed and unmanaged pastures, both of which are common in the Southeast. Prior to N treatment initiation (establishment phase) biomass production was unaffected by CO_2 treatment. Harvests after N treatment initiation (Spring 2006) showed a strong effect of N treatment on cumulative biomass production (>300% increase with N); the main effect of CO_2 was also significant (16% increase with high CO_2). A significant interaction between treatments showed that CO_2 had no impact on bahiagrass production with no N added (as observed in establishment year); however, biomass production was increased by 21% under high CO_2 with N added. In general, this same pattern of treatment response was observed in subsequent years. Tissue C concentration was unaffected by CO_2 treatment, while N concentration was slightly reduced under high CO_2. However, total C content was usually higher under elevated CO_2 while total N content was unaffected by CO_2. For C:N ratio, a treatment interaction indicated that high CO_2 grown plants had lower C:N in the no N treatment, but the opposite was observed with N fertilization. As with biomass, this same general pattern was observed in subsequent years. Results to date show that N fertilization can increase biomass productivity under elevated CO_2, but forage quality (in terms of C:N ratio) may decline slightly. Efforts are also underway to assess impacts of these treatments on belowground biomass, soil trace gas efflux, and soil carbon storage.

Keywords: carbon dioxide, pasture, bahiagrass, nitrogen fertilization, global change

INTRODUCTION

The level of carbon dioxide (CO_2) in the atmosphere is increasing at an unprecedented rate due primarily to fossil fuel burning and land use change (Keeling and Whorf, 2001). Plant responses to elevated CO_2 are well documented showing increased photosynthesis and resource use efficiencies that lead to increased growth for most plants (Amthor, 1995). In some instances plants do not respond to increased atmospheric CO_2, particularly when soil resources such as N are limiting. Nitrogen is the element most limiting to biomass production and is key to both plant and soil C dynamics. Understanding CO_2-induced changes in plant/soil N interactions will be critical to N management for both profitable and environmentally sound agricultural systems of the future.

Pastures occupy 80 million acres in the southeastern U.S., which is about 75% of the total pasture acreage in the eastern U.S (Ball et al., 2002). While the effects of elevated CO_2 on natural grasslands have received some attention, managed pastures - particularly those in the southeastern United States - remain an understudied agroecosystem. Therefore a long-term experiment examining the response of a southeastern pasture system (bahiagrass, *Paspalum notatum*) to current and elevated levels of CO_2 with a nitrogen management treatment (no nitrogen = unmanaged and added nitrogen = managed) was implemented using open-top chambers on a soil bin located at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL.

MATERIALS AND METHODS

- ✓ The response of a southeastern pasture system (bahiagrass, *Paspalum notatum*) to current and elevated (current plus 200 ppm) levels of CO_2 is being examined in a study that was initiated in the spring of 2005, using an outdoor soil bin (7m x 76 m) at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama, USA.
- ✓ After an 1-yr establishment period, a nitrogen management factor [no nitrogen (N) added vs. N added] was added using a split-plot design replicated three times with N as main plots and CO_2 level as subplots within open top field chambers (Rogers et al., 1983) on a Blanton loamy sand (loamy, siliceous, thermic Grossarenic Paleudult). Nitrogen was applied to the managed plots according to extension soil test recommendations; N [$(NH_4)_2SO_4$] was applied three times per year (2 months prior to the first harvest, and immediately after harvests in June and August) at 90 kg ha^{-1} per application.
- ✓ These two nitrogen treatments represent managed pastures versus unmanaged pastures; both types of pastures are common in the Southeast. Extension soil test recommendations were used in managing soil fertility (i.e., other than nitrogen requirements) for the improved pastures only. This ongoing experiment was scheduled to run for 10 years and will be terminated in the fall of this year; data presented here are for the first 9 years.
- ✓ Aboveground forage biomass was harvested three times per year (June, August, and October). At each harvest, plants were mowed (to simulate a haying operation) and total fresh weights recorded. A forage subsample was weighed, dried at 55^{o}C, and used to calculate total dry mass. Data presented here are the cumulative forage amounts for each growing season.
- ✓ Forage quality, in terms of carbon (C) and nitrogen (N), was determined each year. Subsamples of ground biomass (1 mm sieve) were analyzed for C and N by dry combustion using a LECO TruSpec analyzer (LECO Corp., St. Joseph, MI). These data will not be presented here.
- ✓ Data analysis was conducted using the using the Mixed Models Procedure (Proc Mixed) of the Statistical Analysis System (Littell et al., 1996). Error terms appropriate to the split-plot design were used to test the significance of main effects and their interactions. A significance level of ($P \leq 0.10$) was established *a priori*.

Soil bin facilities with CO_2 field exposure chambers at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL.

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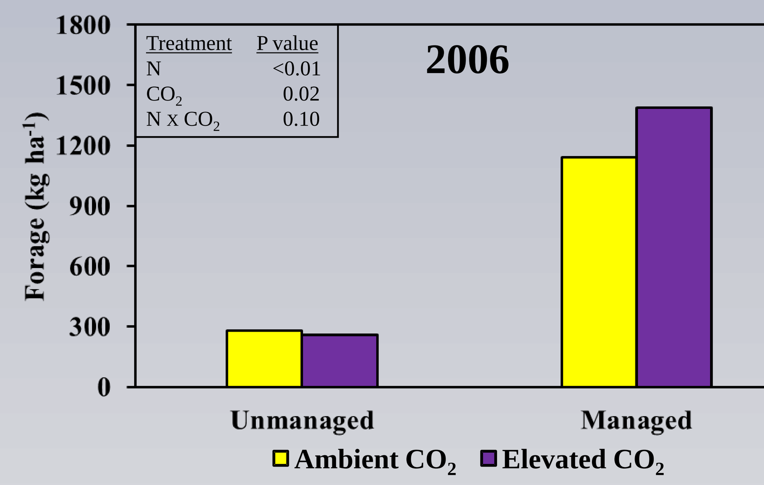
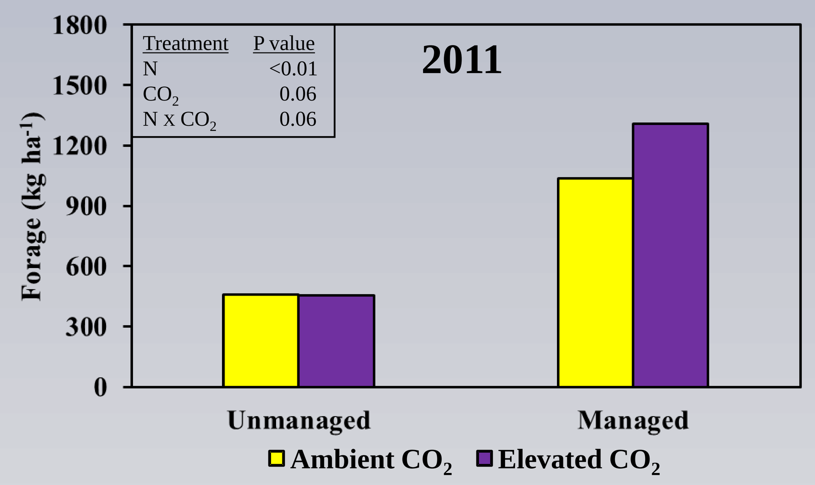
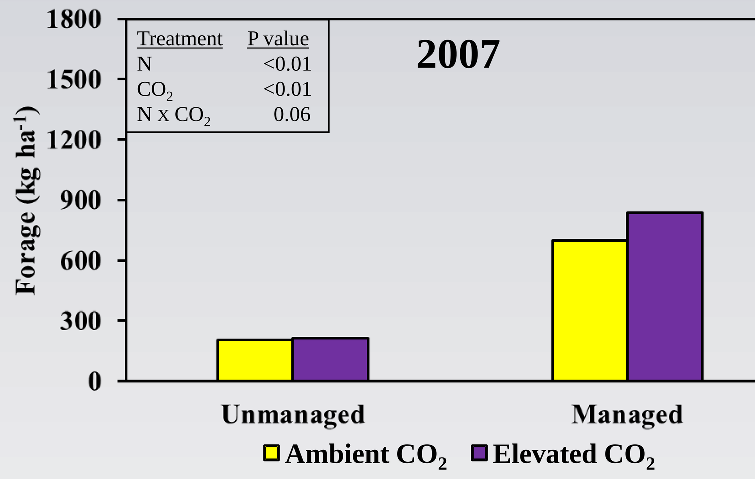
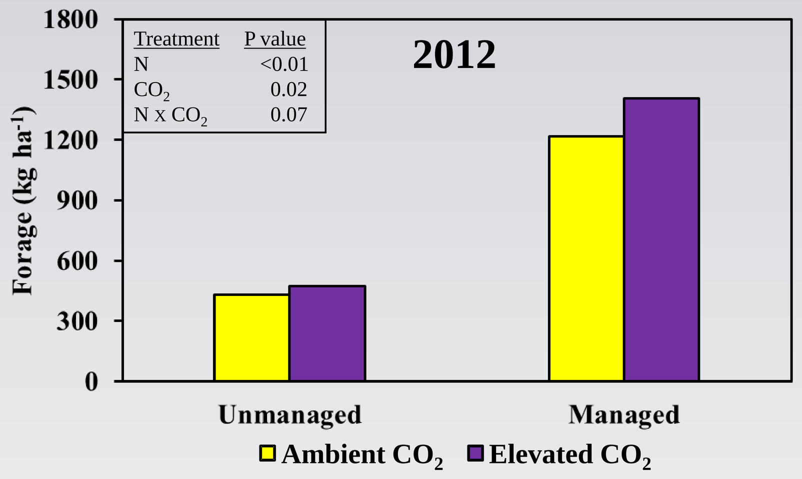
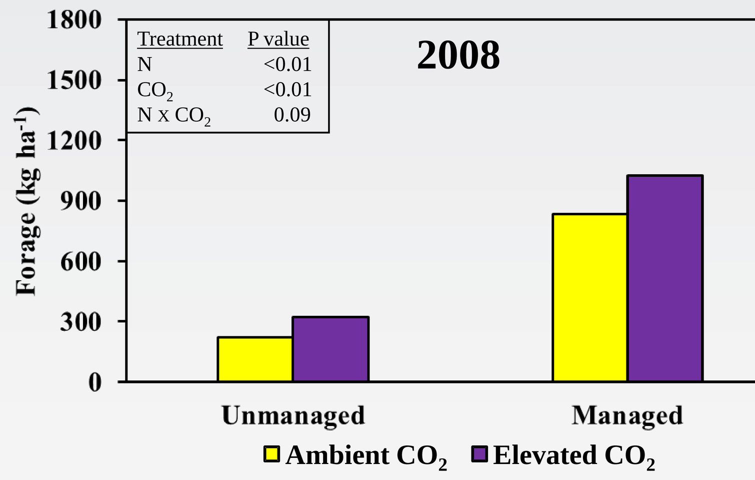
RESULTS

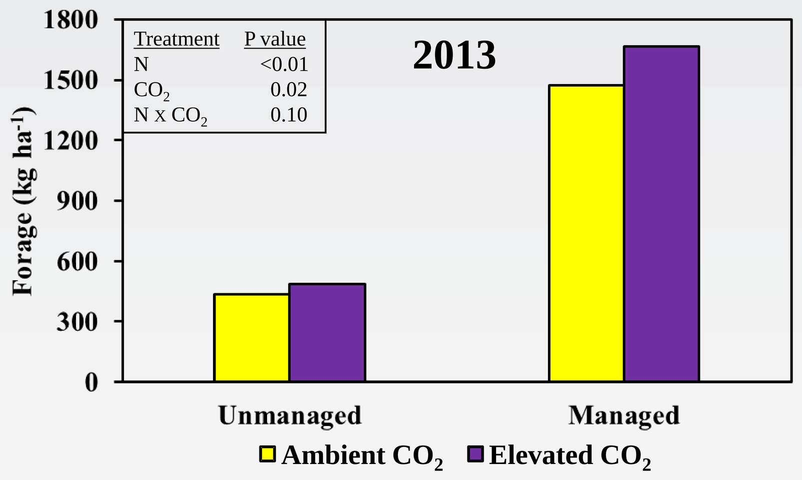


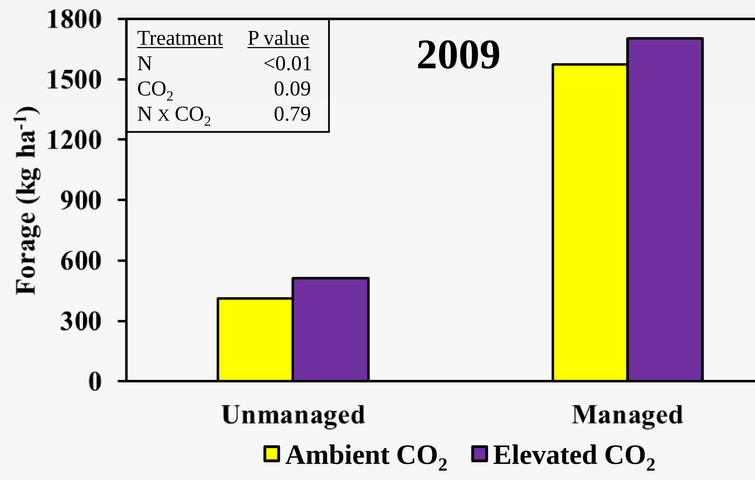


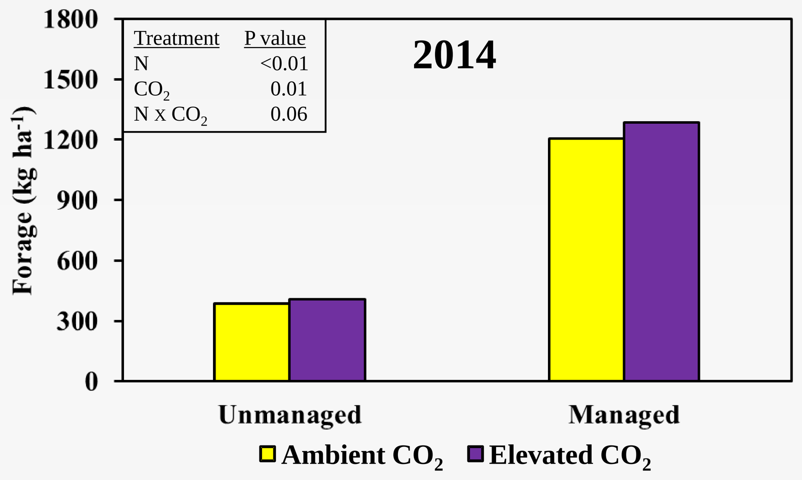


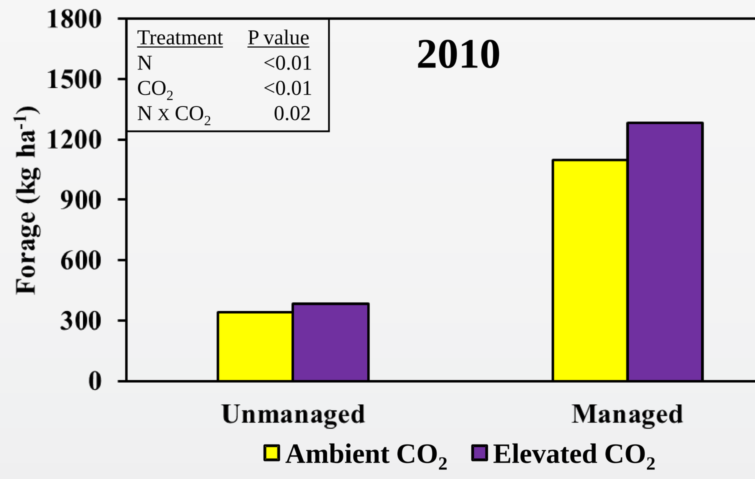


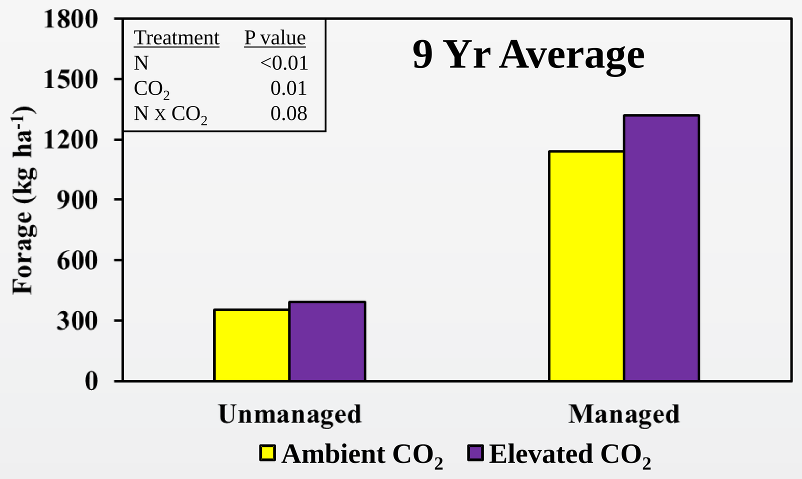












CONCLUSIONS

- ✓ Prior to N treatment initiation (establishment) biomass production was unaffected by CO_2 treatment (data not shown)
- ✓ Main effect of CO_2 was significant in all 9 years – the average increase under elevated CO_2 was 15%
- ✓ Main effect of N was highly significant in all 9 years – the average increase from added N was 230%
- ✓ The interaction of CO_2 x N was significant in 8 of 9 years–forage increased under elevated CO_2 only with N (16%)
- ✓ Tissue analysis indicated that high CO_2 lowered the C:N in the no N treatment, but the opposite was observed with N fertilization (data not shown)
- ✓ Results to date show that N fertilization can increase biomass productivity under elevated CO_2, but forage quality (in terms of C:N ratio) may decline slightly
- ✓ Ongoing efforts will examine changes in soil organic carbon and nitrogen, including assessing the potential of this pasture system to sequester CO_2 as soil carbon and the influence on trace gas emissions (CO_2, CH_4, and N_2O)

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