Elevated CO_2 effects on plant growth and soil C and N cycling over 5 years in a grazed pasture on a seasonally dry sand

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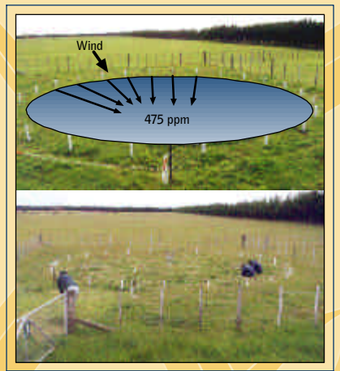
Background

Climate change and rising concentrations of atmospheric CO_2 can influence the species composition and quantity and quality of plant dry matter in grassland ecosystems (Newton 1991), and thereby soil C and N pools and cycling rates (Tate and Ross 1997; van Veen et al. 1991). We here describe the influence of elevated CO_2 on plant yield and botanical composition, and soil biochemical properties, in a sheep-grazed pasture over a 5-year period; the atmospheric CO_2 level used was 475 µl l^{-1}, the concentration expected in 2030. In spite of the world-wide importance of grasslands, similar studies using grazing animals have not been made elsewhere.

Site

Site and trial design

- A fertilised (superphosphate and potassium sulphate), species-rich, permanent pasture on a seasonally dry sandy soil (Pukepuke sand; a Psammaquent) near Bulls (40° 14′ S, 175° 16′ E), North Island
- Three rings (12 m diam, ≥ 20 m apart) received elevated atmospheric CO_2 (475 µl l^{-1} during the photoperiod) via 24 equi-distant stand pipes in a Free Air Carbon dioxide Enrichment (FACE) system
- Three rings (12 m diam, ≥ 20 m apart) were under ambient CO_2
- All rings were intermittently grazed by sheep (Edwards et al. 2001)



FACE ring

Objectives

To test the hypotheses that elevated CO_2 would:

- Increase herbage yields and influence plant species composition
- Increase soil labile C and N, but not total C and N, pools
- Increase mineralisation rates of soil C and N over the 5 years of the trial

Methods

- Plant biomass and species composition measured just before grazing by cutting herbage 2 cm above ground level (four quadrats per ring)
- Soil sampled seasonally [18 cores (25 mm diam; 0–50 mm depth) across the diam of each ring] from October 1997–July 2002
- Soil moisture, pH (water), different C and N pools, and CO_2-C (0–14 days) and net mineral-N (0–56 days) production (at 25°C and 60% of water-holding capacity) determined essentially according to Ross et al. (1996)
- Analysis of variance, repeated measures analysis and t-tests used for estimating CO_2-treatment effects

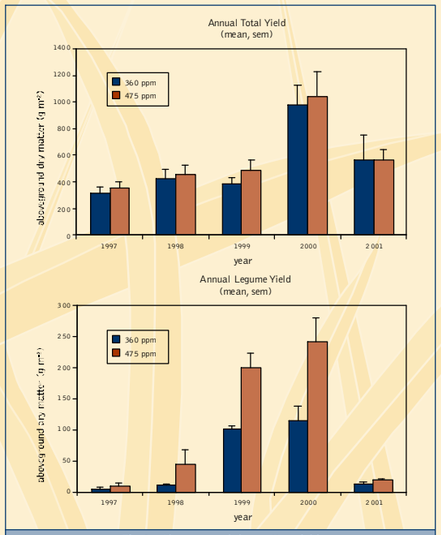


Fig 1. Aboveground dry matter yield

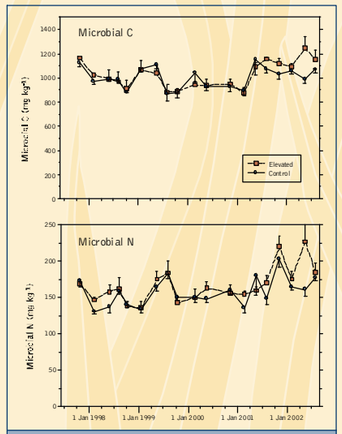


Fig 2. Soil microbial C and N

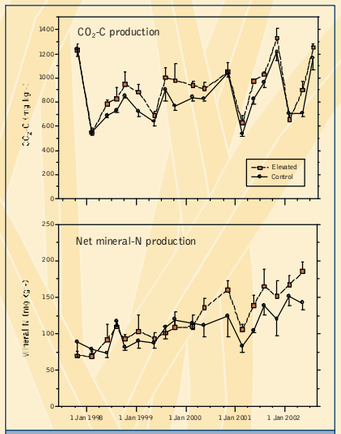


Fig 3. Soil CO_2-C and net mineral-N production

Results

Under elevated CO_2:

- Annual herbage yields were slightly higher than in the control, but varied markedly between years in both treatments (Fig. 1). Proportions of legumes (3–43%) and herbs (3–8%) were usually much higher than in the control (3–27% and 2–4%, respectively)
- Soil moisture, pH, total C and N, extractable C and extractable organic N did not, overall, change significantly (Table 1). Soil microbial C and N increased slightly (Fig. 2). Nearly all properties varied significantly with sampling time
- Soil CO_2-C production, particularly under dry summer or autumn conditions, was often higher. Net mineral-N production increased significantly over the last 2 years (Fig 3)

Table 1. Mean (sem) soil property values from October 1997 – July 2002

Property	Ambient CO_2	Elevated CO_2
PH	5.7 (0.1)	5.8 (0.1)
Total C (g kg^{-1})	52 (1)	50 (1)
Total N (g kg^{-1})	4.2 (0.1)	4.1 (0.1)
Extractable C (mg kg^{-1})	126 (12)	134 (12)
Extractable organic N (mg kg^{-1})	18 (3)	19 (3)
Mineral-N (mg kg^{-1})	12 (2)	12 (3)

Conclusions

After exposure to 475 µl l^{-1} atmospheric CO_2 for 5 years at this seasonally dry site:

- Total herbage yields marginally increased. Species composition changed more markedly
- Total soil organic matter concentration unaffected. Incipient increases in microbial C and N are suggested
- Increases in soil net mineral-N production probably associated with increased legume-N inputs
- Overall, rates of C and N mineralisation responded more readily than C and N pools to the elevated-CO_2 treatment.

Continuation of the trial is needed to determine whether increases in atmospheric CO_2-C will eventually be partly offset by increases in soil C pools at this site.

References

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