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A thesis presented in partial fulfilment of the requirements for the degree of Ph D in Plant Science at Massey University and the degree of “Docteur en Sciences”, speciality “Sciences Agronomiques” at the Institut National Polytechnique de Lorraine

Vincent Allard, 2003

**Effects of Elevated Atmospheric CO₂
Concentrations on Carbon and
Nitrogen Fluxes in a Grazed Pasture**

**Effets de l'Élévation de la
Concentration en CO₂ Atmosphérique
sur les Flux de Carbone et d'Azote en
Prairie Pâturée**

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“Je suis le luxe des civilisations occidentales”

Guillaume Clémentine (1999), *Le Petit Malheureux*
éditions “Le serpent à plumes”

Abstract

Predicting the response of grazed grasslands to elevated CO₂ is of central importance in global change research as grasslands represent 20% of the world's land area and grassland soils are a major sink for carbon (C). Grasslands responses to elevated CO₂ are strongly controlled by the availability of other nutrients and nitrogen (N) in particular. There have been many previous studies of N cycling in grasslands exposed to elevated CO₂ but none of these experiments were grazed. In this thesis I present data on CO₂ effects on N cycling from an experimental system (FACE: Free Air Carbon dioxide Enrichment) that enabled grazing to be included. The thesis focuses on the effects of elevated CO₂ on the different processes involved in organic matter (OM) returns from the plant to the soil and the consequences for N availability. In Chapter 1, it was shown that elevated CO₂ modified N returns by grazing animals by altering the partitioning of N between faeces and urine creating a potential for enhanced N losses at elevated CO₂. Plant litter decomposition rates were, at the ecosystem scale, not affected by elevated CO₂ (Chapter 3), but a marked increase in the organic matter fluxes, from roots, led to an accumulation of coarse OM in the soil (Chapter 4). In Chapter 5, using ¹⁴C and ¹⁵N labelling, I compared short-term (plant mediated) and long-term (soil mediated) effects of elevated CO₂ on soil OM dynamics and concluded that soil OM accumulation under elevated CO₂ was not caused by C or N limitation but probably by the availability of other nutrients. The thesis demonstrates that the inclusion of grazing animals can strongly modify N cycling under elevated CO₂. As most grasslands are grazed, the prediction of grassland responses to elevated CO₂ must be derived from systems in which animals are an integral part.

Résumé

Prédire la réponse des prairies pâturées à l'élévation de la concentration en CO₂ revêt une importance majeure dans la mesure où cet écosystème représente environ 20% de la surface terrestre non immergée mais aussi, parce que les sols prairiaux représentent un important puit de carbone (C). La réponse des prairies au CO₂ est fortement contrôlée par la disponibilité des autres nutriments et en particulier l'azote (N). De nombreuses expériences ont par le passé étudié le cycle de l'azote en prairie sous CO₂ enrichi mais aucunes de ces études n'a inclus le pâturage. Dans le cadre de cette thèse, je présente des données concernant les effets du CO₂ sur le cycle de l'N provenant d'un système expérimental (FACE: enrichissement en dioxyde de carbone à l'air libre) permettant d'inclure des ruminants. Cette thèse est dédiée à l'étude des effets de l'élévation en CO₂ sur les différents processus impliqués dans les retours de matière organique (MO) de la plante vers le sol et leurs conséquences pour la disponibilité en N. Dans le Chapitre 1, il a été montré que le CO₂ pouvait modifier les retours d'N par les ruminants en affectant la partition d'N entre l'urine et les faeces, ce qui induisait des pertes d'N potentiellement accrues. La décomposition de la litière végétale, considérée à l'échelle de l'écosystème, n'a pas été affectée par le CO₂ (Chapitre 3) mais une forte augmentation du volume de MO retournant au sol depuis les racines a induit une accumulation de MO grossière dans le sol (Chapitre 4). Au cours du Chapitre 5, à l'aide d'un double marquage isotopique ¹⁴C et ¹⁵N, nous avons comparé les effets court terme (transmis par la plante) et long terme (transmis par le sol) du CO₂ sur la dynamique de la MO du sol et il a été conclu que l'accumulation de MO n'était pas causée par une limitation en C ou en N mais probablement par la disponibilité des autres nutriments. Cette thèse démontre que les ruminants peuvent fortement modifier la réponse des prairies au CO₂. Dans la mesure où ce mode d'utilisation des pâtures est largement majoritaire, prédire les réponses des pâtures à un enrichissement en CO₂ doit provenir de systèmes où les ruminants sont partie intégrante.

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Structure of the thesis

This thesis is based on a series of papers. Chapter 2 has been accepted for publication in *Global Change Biology*. Chapters 3 and 4 have been prepared for submission in *Global Change Biology* and *Plant and Soil* respectively. A decision on submission of Chapter 5 for publication is pending. The references relevant to individual chapters are at the end of each chapter.

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