Nitrogen fluxes in grassland in response to inter-annual climate variability

P. Calanca and J. Fuhrer
Agroscope FAL Reckenholz, Swiss Federal Research Station for Agroecology and Agriculture, Air Pollution/Climate Group, CH-8046 Zürich, Switzerland, Email: pierluigi.calanca@fal.admin.ch

Keywords: inter-annual variability, N-pools, N-fluxes

Introduction Most model studies dealing with the response of grassland dynamics to climate change (e.g. Thornley & Cannell, 1997; Riedo *et al*., 2000) consider either step changes or a smooth transition in the climatic drivers, therefore neglecting short-term variations. However, the inter-annual variability of the climatic and edaphic elements (Calanca, 2004) can be substantial, with important consequences for the fluxes of nitrogen (N). The objective of this study is to investigate the response of nitrogen fluxes to this type of variability with the help of the Pasture Simulation Model (PaSim), looking at years considerably differing in terms of temperature, radiation and precipitation conditions.

Model and model experiment PaSim is a process-oriented model that simulates dry matter production and fluxes on C, N, water and energy in permanent grasslands. For the present experiment, we considered an extensively managed grassland located at Oensingen, on the Swiss Plateau. The model was driven with hourly meteorological data for 2002 and 2003. While the summer of 2002 was close to the norm, the summer of 2003 was characterized by drought conditions, with temperature, precipitation and radiation anomalies significantly above, below and above the respective long-term mean. The model was started with the soil organic pools in equilibrium. The clover fraction of the sward was set at 0.25. The management consisted of 3 cuts each year.

Results Table 1 presents selected averages of N-pools and N-fluxes for June-July-August. The differences between 2002 and 2003 are striking. Drought conditions during the summer of 2003 completely shut down leaching (Leach), reduce grass growth, thus limiting the biological N fixation (BNF), and foster biomass turnover. As a consequence of an increased flux of residue (F_{res}) to the soil organic pools and a sustained mineralisation, mineral N (N_{min}) availability in 2003 is four times as large as in 2002. Higher nitrification rates are explained by soil water contents at or below field capacity, while higher denitrification rates and N_2O emissions follow from a larger availability of nitrate.

Table 1 Simulated N-pools and N-fluxes of an extensively managed grassland at Oensingen (pools in kg-N/ha, fluxes in kg-N/ha/d), and difference 2003-2002 relative to 2002. Averages for June-July-August

year	N_{min}	F_{res}	Nitrif	Denitrif	Leach	N_2O-Em	BNF
2002	1.1	0.72	0.10	0.001	0.002	0.001	1.60
2003	5.3	1.08	0.31	0.011	0.000	0.005	0.90
rel. diff	4	0.5	2	10	---	4	-0.5

Conclusions The present results demonstrate that the inter-annual variability of climatic conditions can affect the fluxes of N in grassland by orders of magnitude. This has to be borne in mind in studying the consequences of anthropogenic climate change, given a probable increase in this type of variability, at least in mid-latitudes (Schär *et al*., 2004). Weaknesses of the present investigation are: (i) a constant fraction of clover; (ii) the lack of a N_2O uptake by the soil in PaSim; (iii) the sensitivity of the results to the initial conditions of the organic pool.

References

Calanca, P. (2004). Interannual variability of summer mean soil moisture conditions in Switzerland during the 20th century: A look using a stochastic soil moisture model. *Water Resources Research*, 40, W12502, doi:10.1029/2004WR003254.

Riedo, M., D. Gyalistras & J. Fuhrer (2000). Net primary production and carbon stocks in differently managed grasslands: simulation of site-specific sensitivity to an increase in atmospheric CO2 and to climate change. *Ecological Modelling*, 134, 207-227.

Schär, C., P.L. Vidale, D. Lüthi, C. Frei, C. Häberli, M.A. Liniger, & C. Appenzeller (2004). The role of increasing temperature variability in European summer heatwaves. *Nature*, 427, 332-336.

Thornley, J.H.M. & M.G.R. Cannell (1997). Temperate grassland responses to climate change: an analysis using the Hurley Pasture Model. *Annals of Botany*, 80, 205-221.