Sources and sinks of greenhouse gases from European grasslands and mitigation options: the 'GreenGrass' project

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Introduction Adapting the management of grasslands may be used to enhance carbon sequestration into soil, but could also increase N_2O and CH_4 emissions. In support of the European post-Kyoto policy, the European 'GreenGrass' project (EC FP5, EVK2-CT2001-00105) has three main objectives: i) to reduce the large uncertainties concerning the estimates of CO_2, N_2O and CH_4 fluxes to and from grassland plots under different climatic conditions and assess their global warming potential, ii) to measure net greenhouse gas (GHG) fluxes for different management which reflect potential mitigation options, iii) to construct a model of the controlling processes to quantify the net fluxes and to evaluate mitigation scenarios by up-scaling to a European level.

Materials and methods Net exchange of greenhouse gases (CO_2, N_2O and CH_4) was measured at nine European grassland sites, using eddy correlation techniques and soil respiration chambers for CO_2, static chambers, soil diffusion tubes and eddy correlation for N_2O and an *in-situ* SF_6 tracer technique for the emission of CH_4 by herbivores at grazing. First estimates of the annual net global warming potential from these grassland sites have been calculated. A quality analysis/quality check procedure has been used for the flux data. To gain further understanding, detailed experiments on micro-plots and pasture monoliths have been established at four sites with a range of management and mitigation options. The components of the net ecosystem exchange of CO_2 and the mean residence time of C in above and below-ground compartments were studied in two of these experiments by measuring continuously above and below-ground CO_2 exchanges and by steady-state or pulse labeling with $^{13}CO_2$. A detailed and mechanistic grassland ecosystem model (PASIM) has been improved to better simulate N_2O and CH_4 emissions from grasslands. After being parameterized, this model was tested against the flux data of the nine sites and has been used to assess the mitigation potential of field-level grassland management options. A simulation tool, FARMSIM, was designed in order to describe in a consistent way the C and N fluxes in cattle breeding farms and calculate the net balance of greenhouse gas emissions from 8 representative farms. Continental upscaling of net CO_2, N_2O and CH_4 exchanges with European grasslands were simulated applying a more detailed (PASIM) and a simpler (DNDC model) approach and preliminary maps of greenhouse gas fluxes have been prepared. Finally, a sensitivity analysis of the grassland carbon stocks to climate change has been run using the RothC model.

Results Net ecosystem exchange in the first year resulted in an average sink activity of 0.27 kg C m^{-2} yr^{-1} for atmospheric CO_2 with a coefficient of variation of 57 % among grassland sites. Assuming that 70% of the C that is harvested as hay or silage is respired within one year, the average net annual biome productivity was estimated at -0.13 kg C m^{-2} yr^{-1} (range -0.40 to +0.11). A further offset of the grassland sink activity occurred through the emissions of N_2O and CH_4. When converted to C equivalents, N_2O emissions reached on average, 6 % (0.015 kg equivalent CO_2-C m^{-2} yr^{-1}) of the NEE. Moreover, at the three sites where estimates are currently available, the CH_4 emissions from cattle reached 0.08 kg equivalent CO_2-C m^{-2} yr^{-1}, that is 32% the average NEE for these sites. The N_2O emission factor (EF1, according to IPCC Tier 2 methodology) reached 0.69%, on average, but with a large coefficient of variation (107 %) between sites and years. Pasture monolith experiments showed that both past and current extensive grassland management favored C sequestration, partly by increasing the mean residence time of C in soil organic matter fractions. This was also consistent with results from the PASIM model. First simulation results with FARMSIM for a case study dairy and beef farm in France showed that, on an annual average, the farm was a net source (1.7 tC-CO_2 equivalent ha^{-1} yr^{-1}) of GHG. European upscaling and sensitivity analyses were conducted for PASIM and DNDC focusing on management parameters and with RothC focusing on climate scenarios. First simulation results have shown that potentially productive grasslands are more likely to become larger sources of GHG when they are managed close to their optimum than less productive grasslands and that grasslands are likely to behave more frequently as sources of CO_2 under a changed climate.

Conclusion The results from this project will be used to refine the emissions factors used in national inventories, and address the mitigation potential of management scenarios in support of the EU response to Kyoto.