Integrated observations of greenhouse gas budgets at the ecosystem level

Hendriks, D.M.D.

2009

document version
Publisher's PDF, also known as Version of record

1

Introduction

1.1 Background

Over the past 100 years global mean surface temperatures have risen 0.74°C ± 0.18°C at a relatively high rate and precipitation patterns have significantly changed (Le Treut et al., 2007). These recent climatic changes are, at least partly, caused by the impact of human activities on the earth's natural greenhouse effect. This enhanced greenhouse effect is caused by a strong increase of long lived greenhouse gases (GHG's) in the atmosphere (H_2O, CO_2, CH_4, and N_2O). These GHG's are produced and emitted to the atmosphere in large amounts due to human activities, like industrial processes, energy production, agriculture, biomass burning and waste management (Forster et al., 2007). However, the atmospheric CO_2 concentration increases at about half the rate implied by human induced emissions. The remainder of these anthropogenic emissions is currently being taken up by the ocean and terrestrial ecosystems (Denman et al., 2007).

Peat areas in temperate and arctic regions play an important role in the terrestrial carbon cycle. Despite the relatively low uptake rates, they have accumulated about half of the current total atmospheric carbon content since the last glacial maximum (455 Gt g C). Both management and climate change can however turn peat areas into hot spots of GHG emissions. In Europe 50% of the peat areas is subject to various forms of management, often associated with drainage of water. In the Netherlands even 85% of the peatlands is managed. These management practices in peat areas currently lead to strongly enhanced GHG emissions that account for up to 2.3 to 4.5% of total national emissions in industrialized countries (Drösler et al., 2008). A reduction of GHG emissions might be achieved by restoration of disturbed peat areas. Reliable estimates of emissions and emission factors in peat areas are still lacking and the effect of management, drainage, restoration and climate change on CO_2, CH_4 and N_2O fluxes in peatlands is not yet well known.

The research presented in this thesis was part of a sub-project of the Dutch program 'Climate changes Spatial Planning' (www.klimaatvoorruimte.nl). The focus of the program is to establish climate change and climate variability as one of the guiding principles for spatial planning in the Netherlands. The aim of the sub-project was to perform integrated observations and modelling to obtain GHG budgets at the ecosystem level. The research was also embedded in the CarboEurope-IP program, which aims to understand and quantify the present terrestrial carbon balance of Europe and the associated uncertainty at local, regional and continental scale (www.carboeurope.org).

1.2 Objectives and approach

The objective of this thesis was to asses the effect of changing environment and management practices on GHG fluxes (CO_2, CH_4, N_2O) in temperate peat meadow areas. To improve the estimate of the contribution of the peat meadow areas to total GHG emissions from the Netherlands, the first aim was to quantify the full GHG balance of an abandoned peat meadow area. The next objective was to investigate the effect of water table manipulation as a management tool for GHG mitigation in peat meadow areas. Additionally, assessing the effect of climate change on GHG emissions from peat meadows was an important objective. The final objective was to improve the understanding of the controlling mechanisms of GHG fluxes (CO_2, CH_4, N_2O) in peat meadows and the relative influence of vegetation, soil and climatic factors. In this, the effect of vegetation on methane (CH_4) fluxes was a significant point of interest since vegetation affects both the production of CH_4 in the soil as well as the transport of CH_4 from the subsoil to the atmosphere.

The approach of this research was to quantify the full GHG balance and investigate the effects of environmental characteristics and management on the variability of GHG fluxes in an integrated way. The fluxes of all GHG's were measured simultaneous over several years using a combination of measurement techniques. When quantifying the full GHG balance of the research area, not only the vertical losses and gains through atmosphere were assessed, but also vertical and lateral losses of dissolved gases through water. For improvement of CH_4 flux observations at the ecosystem scale a new eddy covariance measurement technique was developed and explored. Subsequently, this new technique was combined with existing methods to compare the quality of the data as well as to analyze CH_4 fluxes at multiple scales. Finally, to improve the understanding of the relative influence of vegetation, soil and climatic characteristics on GHG fluxes, a thorough ecosystem analyses was made including investigation of vegetation, soil and climatic variables.

1.3 Outline of this thesis

This chapter contains a general introduction of the background, the objectives and the approach of this PhD thesis. Also, an outline of the contents of all chapters is given. To further clarify the relevance and contents of this thesis, chapter two gives an overview of the existing knowledge on peat areas, GHG balances, the greenhouse effect, and measurement techniques. Managed and abandoned peat meadows in temperate regions are described in more detail as well as the existing knowledge of the influence of management and climate change in these areas. Also, an overview of previous research on GHG fluxes from comparable peat areas is given. In chapter three the full spectrum of GHG fluxes and the characteristics of the peat meadow, which has been transformed from an agricultural area into a wetland nature reserve, is described. Subsequently, the full GHG balance of the abandoned peat meadow is quantified in an integrated way. Chapter four describes the applicability and quality of the Fast Methane Analyser (FMA) for eddy covariance field measurements of CH_4. The first data series are analysed and compared with data obtained by existing measurement techniques. Additionally, measurements techniques that could

replace eddy covariance in case of a lack of power supply are investigated. In chapter five spatial and temporal variability of CH_4 fluxes in a peat meadow are assessed. CH_4 flux observations in the abandoned peat meadow made by eddy covariance, flux chambers and soil CH_4 profiles are described, and the driving factors of temporal and spatial variability of the CH_4 fluxes are analysed in an integrated manner. Furthermore, the comparison of the eddy covariance technique and the flux chamber technique for CH_4 flux measurements was extended and the advantages and disadvantages of both techniques were evaluated. Chapter six describes carbon fluxes (CH_4 and CO_2) in an abandoned peat area with respect to vegetation types and vegetation and soil characteristics. Net carbon balances and net GHG balances of seven different vegetation types are quantified and the implications of the findings with respect to management practices and climate change are discussed. Chapter seven contains a general synthesis based on the findings of this research. Also, a perspective on future research of GHG fluxes and mitigation management in peat areas is given.

References

Drösler, M., Freibauer, A., Christensen, T.R., Friborg, T., 2008. Observations and status of peatland greenhouse gas emissions in Europe. In: Dolman AJ, Valentini R, and Freibauer A. Observing the continental scale greenhouse gas balance. Springer Ecological series 203: 243-262.

Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.