Technological options, potentials and costs for mitigation of agricultural greenhouse gas emissions in Austria (reclip:tom)

Barbara Amon[1], Marion Ramusch[1], Wilfried Winiwarter[2]*
[1]University of Natural Resources and Applied Life Sciences, Department of Sustainable Agricultural Systems, Division of Agricultural Engineering, Peter Jordan Strasse 82, A-1190 Vienna, Austria; Phone: ++43 1 47654 3502, Fax: ++43 1 47654 3527
Email: barbara.amon@boku.ac.at
[2]Austrian Research Centers GmbH –Tech Gate Vienna, Donau-City-Straße 1, 1220 Wien

Introduction

The reclip program (research for climate protection) has been initiated by the Austrian Research Centers under a collaborative scheme between applied research institutions and universities. Within this framework, two diverging aspects related to climate change have been investigated. In the light of an impact of anthropogenic activities to climate, strategy for action extends into two fundamentally different directions: adaptation to a changing climate, and mitigation of effects by reducing anthropogenic emissions of greenhouse gases (GHG's).

reclip:tom (research for climate protection: technological options for mitigation) started in 2005. The project attempts to provide a common platform for evaluating potential options for reducing emissions of greenhouse gases in Austria and their costs. Austria is committed to a 13% reduction of greenhouse gas emissions compared to the 1990 levels in the Kyoto protocol. Instead of focusing on just one source sector, reclip:tom aims at covering all potential sources, and make abatement options comparable, while also considering interactions (synergies or conflicts of interest) between source sectors. Austria's national GHG emissions have been broken down into four sectors: energy, processes, agriculture, and soils. These are being dealt within individual work packages, with the respective sector experts in charge. The identification, and quantification of interactions between emission sectors is given high priority in reclip:tom. The options covered are limited to technological and technology-related options, based on external constraints and assumptions like energy projections, and the potential of switching consumer behaviour is not touched (Winiwarter et al. 2007). This paper describes the agricultural part of reclip:tom. Information on the full project are given in Winiwarter et al. (2008).

Approach

Basically, so-called "entities" have been defined which cover a certain section of similar activities, a source sector. Reclip:tom uses these entities to re-create GHG emissions for the year 2000 based on emission balances as published by the Austrian Federal Environment Agency. A "business-as-usual" scenario for the further development of emissions allows to estimate emissions to the years 2020 and 2050. Available and officially accorded activity projections, and extrapolations are used from sources external to this project.

For each entity, one or more abatement options can be defined. Abatement options are measures either affecting the release of greenhouse gases from an entity (change of emission factor) or changing the underlying activity (statistical parameter). Especially changing activities is an important but challenging concept, as these – by definition – derive from external sources. In practice this means that a measure can affect such a predefined (external) datum in an organized manner. Process chains (options and measures may be applied at different process levels) as well as linkages and interferences between entities can all be integrated in this concept.

Results (Agricultural sector of reclip:tom)

Projections of animal numbers

Emission projections in the agricultural sector will to a great extent depend on the development of animal numbers. For Austria, emission projections until the year 2030 have been set up within the CAFE programme (Clean Air for Europe) of the EU. The CAFE national programme gives an estimation of livestock numbers in 2020. CAFE (Clean Air For Europe) is a programme of the European Commission (COM(2001)31), which was installed in the course of the 6th environmental action plan. CAFE has the general aim of developing a long-term, strategic, and integrated policy to protect against the effects of air pollution on human health, and the environment. As required by the Treaty, policy will aim at a high level of environmental protection based on the precautionary principle, taking account of the best available scientific, and technical data, and the costs of benefits of action or lack of action (COM(2001) 245). Under the CAFE programme, different scenarios for the future development of livestock numbers have been created. The “CAFE baseline scenario” gives the expected evolution in EU-25 pollutant emissions up to 2020 assuming that current legislation to reduce air pollution is implemented. The baseline – or “Business-as-usual” – is based upon forecasts of economic growth and changes in energy production, transport and other polluting activities (SEC (2005) 1133). The CAFE national scenario includes national projections of activity data up to 2030. Livestock numbers for the reclip:tom database for 2050 were extrapolated from the CAFE national scenario trend between 2020 and 2030.

CAFE concludes the following general trends: A reduction in dairy cow numbers, a slight reduction in calf numbers, a slight increase in suckling cows, a slight increase in pig numbers, no or little changes in sheep and goat numbers. For exaxt numbers please refer to Winiwarter et al. (2008).

The RAINS model has been chosen by the European Community for providing the scientific and technical basis for the CAFE integrated policy advice. It has been developed at IIASA (International Institute for Applied Systems Analysis), and combines information on economic and energy development, emission control potentials and costs, atmospheric dispersion and environmental sensitivities towards air pollution (Schöpp et al., 1999). Agricultural activities considered in the RAINS model include two major categories, i.e., livestock production and application of mineral N fertilizers. Projections of animal numbers are based on results of a number of European and global models. The GAINS (GHG-Air pollution Interaction and Synergies)[1] model was developed as an extension of RAINS and will allow the assessment of emission control costs for the six greenhouse gases covered under the Kyoto Protocol (CO_2, CH_4, N_2O and the three F-gases) together with the emissions of air pollutants SO_2, NO_x, VOC, NH_3 and PM.

Entities

The “Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories” (IPCC, 1997) require emissions from the following categories to be quantified: CH_4 emissions from enteric fermentation, CH_4 and N_2O emissions from manure management, Direct N_2O emissions from agricultural soils, and indirect N_2O emissions from N use in agriculture. The Austrian emission inventory estimates include the animal categories “cattle” (dairy cows > 2 years, mother, and suckling cows > 2 years, young cattle < 1 year, young cattle 1 – 2 years, cattle > 2 years), “swine” (fattening pigs > 50 kg, swine for breeding > 50 kg, young pigs < 50 kg), “sheep and goats”, and “poultry” (chicken, other poultry). Liquid and solid manure systems are differentiated within the animal categories.

[1] http://www.iiasa.ac.at/rains/gains-online.html?sb=9

The category “soils” is split into direct and indirect emissions from soils: Direct emissions are broken down in the categories: N from fertilizer, N from N-fixation, N from crop residues, N from sewage sludge, N from grazing and N from animal manure. Indirect emissions are broken down in indirect emissions from atmospheric deposition and from N leaching.

Mitigation options and emission projections

A range of potential mitigation options has been proposed, and fed into the reclip:tom data base. The most prominent ones are given in this section.

An ***increased milk yield per cow*** can mitigate CH_4 emissions (Müller 2002, Vabitsch 2006) and causes a reduction in dairy cow numbers. The reduction in CH_4 emissions per kg of produced milk is due to two reasons: 1) the percentage of energy needed for the cows´ maintenance is reduced and 2) the diet of higher yielding cows contains more concentrate and less roughage which results in lower CH_4 emissions per kg of food intake. Limitations to this measure result from the limited production potential of arable land and grassland and from the minimum amount of roughage required by dairy cattle to maintain their health and animal welfare. Ecological side effects of this measure – especially in Alpine regions – must be considered, as well.

In Austria, the average milk yield per cow more than doubled from 2512 kg to 5902 kg between 1960 and 2006 (Grüner Bericht 2001, 2007). There is still potential for further increase in the productivity per cow through the use of cattle breeds, feeding practices, progress in breeding, and optimized use of livestock. Assuming a milk yield of 10.000 kg per cow and year, the reduction potential is 36 % (CH_4) of total CH_4 emissions from enteric fermentation of dairy cattle, and 22.7 % (N_2O) of total N_2O emissions from manure management of dairy cattle when this measure is fully implemented.

For CH_4 emissions from manure management, a ***shift from liquid systems to solid systems*** would result in a decrease in emissions as the methane conversion factor is 39 % for liquid systems, and only 1 % for solid systems (IPCC 1997). On the other hand, the N_2O emission factor is higher for solid systems than for liquid systems, which counteracts the reduction in CH_4 emissions. The reduction potential ranges from 87 to 96 % of total CH_4 emissions from manure management depending on the animal category. At the same time, N_2O emissions for cattle increase between 21 and 37 %, and for pigs by 69 % (high share of liquid systems in the baseline scenario). Despite of the higher N_2O emissions, total GHG emissions from manure management decrease from 21 % to 69 %. GHG emissions from manure management are more dependent on the amount of CH_4 emissions than on the amount of N_2O emissions. This measure is mainly interesting for new buildings. It is unlikely that existing houses would switch because of the high investment costs and new machinery for manure management and manure handling.

Biogas production is a very effective means to reduce CH_4 emissions from manure management (IPCC 2001, Clemens et al. 2006). Biogas production reduces the organic carbon content of animal manures, and increased their NH_4-N content. Both measures should not only reduce CH_4 emissions from manure management, but as well N_2O emissions during manure storage, and after manure application. For N_2O emissions, the trend is not as clear as for CH_4 emissions due to the generally high variability of N_2O emission. Total GHG emissions however are always lower with biogas slurry than with untreated slurry (Wulf et al. 2001, 2002a, 2002b).

Biogas production is mainly implemented for energy production reasons. The reduction potential for methane, if the measure is fully implemented, is 66 – 74 % of total CH_4 emissions from manure management depending on the animal category. Although biogas production results in increased emissions of nitrous oxide of 37.5 % (pigs) and 30.30 %

(cattle) of total N_2O emissions from manure management, total GHG emissions decline of 19.9 % (pigs) (Amon et al. 2004), and 59 % (cattle) (Amon et al. 2006).

Slurry based systems offer the possibility of ***separating solids from the slurry***. This manure treatment option results in a solid fraction that may be stored and composted, and a liquid fraction with a lower organic carbon content. Amon et al. (2004, 2006) showed in extensive research trials that slurry separation results in a reduction of GHG emissions from manure management. The reduction potential for methane is 41.6 – 71.3 % of total CH_4 emissions from manure management depending on the animal category. Separation of pig slurry leads to lower N_2O emissions. With cattle slurry, higher N_2O emissions were measured after slurry separation. The increase in emissions mainly results from the storage of the solids separated from cattle slurry. Total GHG emissions decline by 49.4 % (pigs) (Amon et al. 2004) and 36.7 % (cattle) (Amon et. al. 2006).

Especially with pig husbandry, it should be an aim to ***match N in the diet to the pigs´ requirements***. For fattening pigs, this means the introduction of phase feeding with a higher diet N content in the first half of the fattening period and a lower N content in the second half. Phase feeding is common in many European countries and has been proven to be applicable on commercial farms. In Austria, phase feeding has so far not been implemented on many farms, and so the potential for mitigation of GHG emissions through this measure is high. If the measure was fully implemented, a reduction of 12 % N_2O of total N_2O emissions from manure management would result (Kirchgessner et al. 1993).

N input must meet crop demand, N must be readily available to the plants, technologies must be available that apply N during the vegetation period (this is sometimes difficult for animal manures). Farmers sometimes do not rely on their crops to grow on animal manures alone, but fertilize additional N. ***Lower N input to crops*** leads to lower direct N_2O emissions from agricultural soils and to lower indirect N_2O emissions from agricultural activities. At the same time, GHG emissions from mineral fertilizer production are reduced. A reduction in N fertilization might not only be achieved through avoidance of N surplus, but as well through a better utilization of fertilized N. This may be achieved through an optimized timing of fertilizer application, through application of slow-release fertilizers, through the growing of crops to shorten the fallow period, through an increased frequency of slurry application and through the application of nitrification inhibitors. The GAINS estimates the potential of decreased fertilizer input and lower emissions at about 6 % N_2O of total N_2O emissions from manure management (Winiwarter 2005).

Conclusions

Emissions sources and processes were identified and mitigation measures proposed. Possible side effects and interactions within the agricultural sector and with the other sectors were also identified. The proposed mitigation measures offer significant emission reductions at a low cost level. The reclip:tom database offers for the first time a comprehensive possibility to check Austrian GHG reduction potentials across all emission sectors.

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