Farming for a better climate by improving nitrogen use efficiency and reducing greenhouse gas emissions (FarmClim)

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Abstract

The FarmClim project applies a new approach towards implementing scientific results in the agricultural practice. While application of nitrogen fertilizer in crop production is indispensable, its adverse environmental effects have been known for long. Increasing nitrogen use efficiency, i.e. higher production for less nitrogen applied, therefore has been on the agenda of environmental scientists as well as agronomists. In FarmClim, scientific evidence is being used to create a priority list of actions. Combined with economic evaluation this provides hands-on guidance to agricultural support agencies. For the situation of Austria, a concrete set of measures is being suggested that will allow to improve the ratio of production over environmental pollution.

Introduction

Responding to new challenges, agriculture not only needs to focus on productivity increases but also address environmental concerns. The project FarmClim assesses impacts of agriculture on greenhouse gas fluxes in Austria and proposes measures for mitigating emissions, including their economic assessment. Including stakeholders` views at a very early project state will contribute significantly to closing the science-policy gap in the field of climate friendly farming. The FarmClim consortium comprises the University of Natural Resources and Life Sciences, Vienna, the Austrian Agency for Health and Food Safety, the Austrian Umweltbundesamt GmbH, the Chamber of Agriculture of Lower Austria, the University of Graz, the Austrian Federal Forest Office and the Research Center Raumberg-Gumpenstein.

The general objectives of FarmClim are: Optimise N use in Austrian Agriculture; Minimise N and GHG (greenhouse gas) losses to the environment; Identify intervention points in agriculture which are relevant for a general N and GHG strategy; Develop a common understanding for establishing practical guidelines for agricultural advisory services on potential optimisation measures and their economic impact; Close the science-policy gap on the possibilities to optimise N use and minimise GHG losses. FarmClim started in May 2012 and will last until April 2014.

Material and Methods

The tasks of FarmClim are addressed in individual work packages. In attributing parts of the overall work to these work packages, both the respective expertise of partners and the overall project objectives were considered.

First, we address nitrogen and greenhouse gas fluxes in Austrian agriculture, both for animal husbandry and in crop production. As part of these tasks, we not only assess the respective fluxes and possibilities to improve their quantification, but we also provide information on mitigation measures, their efficiency and the related costs of implementation. As a next stage, we use soil modelling to assess the formation of nitrous oxide under specific Austrian conditions, with a scope to provide country-specific emission factors. Mapping these emissions will also allow hot-spots and hot moments (areas and periods of critically high emissions) to be identified and focus measures towards such high-level situations. These inputs are used in an economic assessment to determine the economic effects of the mitigation measures proposed, and to compare their diverse effects. In order to render mitigation measures accountable under international agreements, the improved emission assessment methodology needs to also allow reporting. Specifically, integration in the Austrian National Inventory Report (NIR) prepared for submission to UNFCCC (UN Framework Convention on Climate Change) will be required. Emissions reported on the basis of the project results are expected to become more robust and less prone to uncertainties. Finally, in collaboration with an agricultural advisory organization, possibilities for practical application of the recommendations discussed and provided in the project will be examined. The focus here is to liaise the legitimate interest of the farming industry to the requirements of limiting N-related environmental pollution and greenhouse gas release.

Results

N and GHG fluxes in Austrian agriculture – livestock production

The working package "N and GHG fluxes in Austrian agriculture" focusses on fluxes, possibilities for future refinement of flux estimation and a range of potential mitigation measures. The recently updated reporting guidelines prepared under the CLRTAP (Convention on Long Range Transboundary Air Pollution) now require an N flow model to be applied when estimating agricultural NH_3 and NO_x emissions, as scientific evidence proves that accurate emission estimates need to take into account the full flow of N starting from the animal feed to manure application. The harmonisation between CLRTAP and UNFCCC reporting is a promising starting point to a full environmental assessment, but still needs further refinement and additional efforts for a convincing implementation. A strong interaction exists between science (BOKU), reporting organisation (Umweltbundesamt) and stakeholders (Landwirschaftskammer). Only this interaction guarantees that a) optimisation measures will show up in the national emission inventory and b) commercial farms will be able to put mitigation measures into practice.

The first project year focussed on identifying mitigation measures and data input for the economic assessment. With regard to animal husbandry strategies, resulting production levels as well as data on resulting GHG mitigation have been delivered. Three promising mitigation measures in animal husbandry have been identified to undergo a detailed economic assessment: dairy cattle diet, phase feeding for pigs, and anaerobic digestion of animal manure.

N and GHG fluxes in Austrian agriculture – crop production

For crop production, upgraded regional yield data and information on the N content of arable crops have been delivered from field experiments. These data complement official statistics which are in use for the Austrian OECD agricultural nutrient balance. This allows to assess the effect of increasing legume crops in crop rotations and reducing fertilizer input on GHG emissions and to derive the economic effects connected with such change. Thus recommendations on N-fertilizer demand can be improved if actual mean crop yield and N-uptake figures are available on regional scale.

As an example, we present the results for winter wheat. Due to regional climatic conditions many different soft winter wheat varieties, intended for different uses, are cultivated. Especially in the semiarid North-eastern region, wheat production for high and medium baking quality (HBQ and MBQ) is predominating, requiring grain protein contents above 14 or 15%. In other, semi-humid regions yield potential and also infection risks are higher. Here wheat production for medium baking quality with protein contents above 12,5% and for feed stuff is situated. N-fertilization regimes are adapted to the different production goals.

Field experiments are conducted for official cultivar registration on sites characterized by soil quality conditions allowing above-average yield levels following good agricultural practice. Due to the varying weather conditions within the period of the last 13 years and within the same region, the yield, grain protein content and N-uptake vary in a wide range: fluctuations are 2–3 tons per ha, 3-4% grain protein content and 30 – 50 kg per ha grain-N-uptake (Table 1). If the different cultivar properties and sites with medium and lower soil quality are included, the variation of the production parameters increase markedly because of lower average yields on farm level. The same evaluation is performed for all important arable crops and establishes regional mean yields and grain N-uptake levels, which should be referred to for calculating adequate N fertilizer doses.

This information, available for all major corps, allows to assess the effect of increasing amounts of legume crops in crop rotations and reducing fertilizer input on GHG emissions, a foundation for subsequently deriving its economic consequences.

Table 1: Range of grain yield, grain protein content and grain N-uptake within the period 1999 – 2012 in Austrian regions.

Region	Use of Wheat	Grain yield (t/ha)			grain protein conc. (% DM)			grain N-uptake (kg/ha)		
		Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Northeast	**HBQ**	4.60	**5.97**	6.85	13.71	**14.91**	17.15	106	**118**	134
	MBQ	4.90	**6.31**	7.33	12.82	**14.01**	16.69	103	**114**	131
Alpen-vorland	**MBQ**	6.28	**7.41**	8.54	12.12	**13.13**	14.13	125	**146**	168
	Feed	6.59	**7.58**	8.85	11.79	**12.79**	13.90	124	**145**	167
Wald- und Mühlviertel	**MBQ**	5.40	**6.83**	8.61	10.42	**11.89**	13.41	106	**122**	140
	Feed	5.25	**6.91**	8.97	9.73	**11.47**	13.07	102	**118**	134
Southeast	**MBQ**	5.76	**7.00**	7.85	11.65	**13.47**	15.14	121	**143**	169
	Feed	6.11	**7.23**	8.67	11.01	**13.15**	14.85	120	**143**	169

Mapping emissions and improving inventory reporting

Two model regions have been identified as test regions for soil emission modelling, using the "Landscape DNDC" model [1]. The model can assess and predict the C and N bio-geo-chemistry in agricultural ecosystems at site and regional scale. It consists of sub-models and –components that calculate denitrification, nitrification, and fermentation in soils in order to predict NO, N_2O, N_2, and NH_3 fluxes based on environmental factors. The model functions as a bridge between the ecological drivers (climate, soil, vegetation, human activity) and the C and N cycles. The input-data needed are based on site parameters, vegetation characteristics, management and meteorology. Details required include e.g. crop rotation, maximum yield, C/N ratio, soil texture, bulk density, wilting point and precipitation. The time steps of calculations are on a daily scale. The current work focuses on gathering the required input parameters from several organisations in Austria and to establish a database for selected regions (e.g. Marchfeld) in Austria. The coded data will be used to produce input-files for the main drivers in model, which are climate, soil, management and vegetation. In the long run it is aimed to run simulations on a site or on a regional scale to predict N-oxide emissions from agricultural soils in Austria. However, at the moment the model is used in the site-mode for sensitivity studies, as currently not all required data can be obtained. Missing parameters may be generated using pedotransfer functions. The analysis of present agricultural practices is basis for assessing further mitigation practices specifically focussing on the hot spots and hot moments of nitrogen emissions on a regional scale.

Analyses of improvement potential in emission reporting

N and N_2O fluxes of the Austrian agriculture influence the overall GHG reporting on national level. An intensive analysis on the reporting system shall isolate improvement points in the light of the selected mitigation measures. In this research, the focus lies in the analysis of default and national input data and methods applied in the GHG inventory, possibilities of improvements and causal data demand. Furthermore, improved inputs derived from this project need scientific sound efforts and translation in terms of reporting requirements to UNFCCC. A regional reporting set will segment the calculation to match the output of model results in animal husbandry, crop production and N_2O emissions from soils. Findings of specific regional effects have to prorate on the national reporting system, extended data requirements have to be formulated

Analyses of mitigation measure costs
The analysis of adaptation costs with N and GHG mitigation potentials has started. Selected agricultural measures with a high mitigation potential of N and GHG are subject to agro-economic assessment. Costs which arise for farmers for establishing those measures (adaptation costs) will be calculated. In order to provide appropriate information for decision makers, adaptation costs will be contrasted with N and GHG mitigation potentials and the most relevant cost factors will be pinpointed. The analysis requires data delivered by the project work packages dealing with animal husbandry and crop production, based on previous research by [2] and [3]. In animal production, the calculation model will concentrate on feed intake and manure management options. In crop production, an optimisation potential remains with respect to N fertilization and nutrient uptake efficiency.

Implementation of FarmClim results
FarmClim recognizes that the effects of all mitigation measures will only come to life if optimisation measures are implemented at farm level. It is of great concern to the researchers involved in FarmClim to have practical views and opinions integrated in the project. Intensive communication with stakeholders thus is on-going, there is first experience on the process to be reported. Stakeholders' views and needs are to be integrated into considerations for environmentally-friendly management options. The intensive communication with stakeholders from the very beginning of the project is a central feature of FarmClim. It culminates in the final work package, where a basis for recommendations is created that will – after the project end – undergo tests on commercial farms and pass the relevant authorising steps which are necessary for an implementation on commercial farms.

Conclusion and perspectives
Already at this stage it is clear that a set of very concrete emission mitigation actions can be recommended. A priorization according to the respective economic impacts can be provided, but will need to be evaluated for its robustness.

While integrating agricultural support organizations throughout the project creates additional challenges within the project, we expect that understanding the interest and the worries of farmers from the beginning supports creation of realistic output that can lead to a practical implementation. A consistent set of recommendations applicable for all environmental concerns generally, as is the scope of an N flow approach, is expected to reflect the interest of farmers also.

Combining this transdisciplinary approach with activities on the international scale (nitrogen budgets, European and global assessments) may guide the efficiency improvements also for other countries in order to provide reductions in nitrogen release urgently needed to combat climate change while maintaining food production for a globally still growing population.

References
[1] Haas, E; Klatt, S.; Fröhlich, A.; Kraft, R.; Werner, C.; Kiese, R.; Grote, R.; Breuer L.; Butterbach-Bahl, K.: 2012: LandscapeDNDC: a process model for simulation of biosphere-atmosphere-hydrosphere exchange processes at site and regional scale. Landscape Ecol. DOI 10.1007/s10980-012-9772-x

[2]Anderl M., Bednar W., Fischer D., Gössl M., Heller C., Jobstmann H., Ibesich N., Köther T., Kuschel V., others (2012a), Klimaschutzbericht 2012, Umweltbundesamt GmbH, Wien

[3]Anderl M., Heller C., Ibesich N., Jobstmann H., Karigl B., et al. (2012b), Begleitung des politischen Entscheidungsprozesses zur Ermittlung von Sektorzielen gemäß dem Klimaschutzgesetz - Analyse der Sektoren, Umweltbundesamt GmbH, Wien

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