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GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES

CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

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Preface

With the Paris Agreement all countries are encouraged to contribute their best to climate change mitigation. To meet the targets of the Paris Agreement all different sectors need to be involved from energy and infrastructure to agriculture, land use, land use change and forestry. Climate mitigation in the agricultural sector is a very sensitive topic as it addresses and impacts on food security, on the environment and on rural livelihoods, at the same time, just to name a few. Furthermore, with the growing world population and increasing climate variability more pressure is expected on food production in the coming decades and more conflicts can be expected in designing climate change mitigation policies and implementing these.

Countries have increasingly developed innovative measures to mitigate GHG emissions and are focusing on win-win-solutions for agriculture. Many countries are making explicit commitments also from their agricultural sector to contribute to climate change mitigation. Research in this area has been enforced during the last years and innovative ideas and new solutions have been presented by experts and research projects. The ”International Conference on Agricultural GHG emissions and Food Security” thus focus on gathering, distributing and discussing current state of the art of research and possibilities to transfer best-practice measures into other contexts. The aim is further to envisage options, challenges and barriers in implementing measures on the ground and to analyse how research can support these processes.

Under the guiding questions: What are options, global potentials and visions to the mitigation of greenhouse gases and the enhancement of carbon sinks by agriculture? we broaden the scope and focus on holistic, integrative state-of the art research in the light of political and societal challenges relevant for implementing climate action under the Paris agreement.

This volume of abstract summarizes all abstracts that have been selected for presentation at the conference and show highlights and current research. Field and questions that are addresses in these contributions are

1. Innovative approaches in GHG monitoring and MRV

What are new innovative approaches in monitoring of GHG emissions and of carbon sinks and how can MRV options be integrated internationally?

2. Mitigation potential

What are innovative measures to mitigate GHG emissions in livestock, cropland, rice production and carbon rich-ecosystems? How can intelligent land use management contribute to less GHG emissions? What is the mitigation potential on the regional, national and global scale of new and innovative action and measures?

3. Cost and implementation

How can cost-effective GHG measures be integrated and implemented? What are current best practice instruments to integrate GHG emissions by agriculture in NDCs and how are they implemented? What are innovative integrative approaches with multiple benefits / win-win options that can be transferred to other regions? What are the barriers to the uptake of mitigation options?

4. Global challenges and policies

What are possible policy design and implementation options from scientific point of view? What are the challenges in mitigation regarding food security and other political priorities (natural resources management and biodiversity) and how can solutions look like?

The Editors

Claudia Heidecke, Hayden Montgomery, Hartmut Stalb, Lini Wollenberg

Kurzfassung

Dieser Tagungsband beinhaltet alle Kurzfassungen von Beiträgen, die für Präsentationen oder Poster im Rahmen eines Begutachtungsprozesses für die Konferenz: International Conference on Agricultural Greenhouse Gases and Food Security" ausgewählt wurden. Die Konferenz fand vom 10. bis 13. September 2018 in Berlin statt.

Schlüsselwörter: Klimaschutz, Landwirtschaft, Tagungsband

Abstract

This Volume of Abstract includes all contributions for presentations and posters that were selected during a review process for the 'International Conference on Agricultural Greenhouse Gases and Food Security'. The conference took place from 10–13 September 2018 in Berlin, Germany.

Keywords: Climate change mitigation, Agriculture, Volume of Abstracts

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Agricultural GHGs: from a Global Research Alliance to shared policies and practices

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The global food system as a whole is estimated to currently contribute between one quarter and one third of total global greenhouse gas emissions. Minimising emissions from the food system is therefore a necessary element of any strategy that seeks to achieve the temperature goals of the Paris Agreement. However, pathways to substantially lower food-related emissions that ensure food and nutrition security for a growing and rapidly developing global population are contested, and policy approaches remain highly uneven across countries and sectors. I will review the evidence base of the vital role that land-based mitigation will likely need to play if the goals of the Paris Agreement are to be met, and explore the validity of some common assumptions that underpin different and sometimes divergent strategies to manage emissions from the food system.

Intensification of food production is often seen as necessary to meet food security goals and to spare land that can be used for biodiversity and/or carbon sequestration purposes, but the recent literature suggests that the drivers and governance of such intensification strongly influence whether climate-related objectives are indeed achieved. Novel mitigation technologies could greatly expand the mitigation potential especially in already intensive and/or high-producing systems but may rely on additional policy drivers for their adoption.

While there is an increasing, and increasingly credible focus on demand-management to reduce food-related emissions, the evidence of effective policies, let alone the political economy of such approaches, remains limited or highly contingent on regional and/or cultural drivers. The interplay between food waste and dietary change and international market responses also needs to be explored more fully to provide robust guidance to policymakers and avoid inadvertent side-effects.

The unevenness in policy approaches is mirrored in uneven capabilities across the world to measure, report and verify emissions and emission reductions. Addressing such capability gaps could greatly increase the potential for flexible policies that seek synergies, rather than focus on managing trade-offs between climate change and economic development objectives. Even though globalisation of markets could in theory deliver efficient emission reductions simply by allocating production to the most efficient regions, broader trade relationships and local socio-economic as well as other environmental considerations are also powerful impediments.

In my reflections I intend to draw on experiences generated through the Global Research Alliance on Agricultural Greenhouse Gases and its partnerships with other organisations as well as examples from New Zealand. As a developed economy with a high reliance on the export of livestock products to distant markets, New Zealand can serve as a microcosm for climate policy challenges in the agriculture sector that many other countries are only beginning to consider.

Addressing climate change mitigation potential in agriculture

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The agricultural sector accounts for about 12 % (global warming potential over 100 years: GWP100) man-made global greenhouse gas (GHG) emissions, although this estimate varies according to different metrics and time horizons (7 % Global Temperature change Potential over 100 years: GTP100 vs. 22 % GWP20) (IPCC, 2014). Moreover, this choice of metric and horizon should depend on the policy context (Levasseur et al. 2016; Reisinger & Clark, 2018). Agricultural contribution to global warming through non-CO_2 GHG emissions is particularly large as it contributes to about 58 % of nitrous oxide (N_2O) and 47 % of methane (CH_4) (IPCC, 2014).

Managing GHG linked with agriculture involves strategic and local land use decisions (e.g. changes in farm management), including land clearing and restoration, reforestation, agro-forestry, wetland management and biofuel production. In a broad sense, agricultural climate change mitigation options can be seen from the supply side as well as from the demand side (Smith et al., 2013). For supply-based measures, strategies lead to an increase in net GHG efficiency of agricultural production. These measures can be further defined as either technical or structural options. Whereas technical options reduce agricultural emissions using technologies like anaerobic digesters, feed supplements, soil nitrogen inhibitors, structural ones usually refer to more fundamental improvements such as transition towards high intensity management systems (e.g. sustainable intensification and land sparing: e.g. Lamb et al., 2016) or relocation of production across regions (e.g. Frank et al., 2018). For demand-based measures, these options target to reduce consumption of GHG-intensive products and reduction of waste.

Recent studies have summarised the potential scope of climate change mitigation options for agriculture globally (e.g. Livestock: Gerber et al., 2013; Bellarby et al. 2013; Herrero et al., 2016; rice: Islam et al., 2018; agroforestry: Verchot et al., 2007; Torres et al., 2010; bioenergy: Creutzig et al., 2015) and regionally (e.g. Mediterranean: Sanz-Cobeña et al., 2016). Also, uncertainties (Eory et al., 2018), potential co-benefits, trade-offs, barriers and policies have been discussed for agricultural mitigation options (Bustamante et al., 2013).

For policy purposes it is important to convert these measures into a feasible economic potential, which provides a perspective on whether agricultural emissions reduction (measures) are low cost relative to mitigation measures. Marginal abatement cost curve (MACC) representing the cost of mitigation measures applicable in addition to business-as-usual agricultural practices have been produced for different countries (e.g. China: Wang et al., 2014; France: Pellerin et al., 2017).

In the context of the Paris Agreement's 2 °C goal where CO_2 emissions are projected to decline to 0 and considering that agriculture comprises over 75 % of remaining emissions by 2100, countries will need to tackle agricultural emissions to have a chance of meeting the 1.5 °C target (Richards et al., 2018). Recent studies have simulated national climate change mitigation targets to achieve a sectoral reduction in agricultural emissions, e.g. in the EU (Fellman et al., 2018), leading to projections with some implementation of technical measures together with land use and livestock production changes. Furthermore, Fellmann et al (2018) highlighted challenges around: (i) targeted but flexible mitigation, (ii) supporting full implementation of technological mitigation options, (iii) dealing with emission leakage (e.g. N_2O leakage through imported feed: Lassaletta et al., 2016) and (iv) potential regulation of consumption and waste issues.

Climate-smart land use management (Carter et al., 2018) through frameworks comprising spatially explicit modelling may also be instrumental to provide local solutions. Examples for potential strategies to enhance SOC and address trade-offs and synergies were recently illustrated by Schulte et al. (2016) and Pardo et al. (2017) for Ireland and Spain, respectively.

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Cost and implementation of mitigation in agriculture

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It is clear that the agricultural sector is part of the problem that generates climate change but can also be part of the solution. What do we know about the costs of implementing mitigation actions in the agricultural sector?

Some of the main issues the literature has addressed with respect to costs of mitigation actions include:

High initial investment costs: For instance, thinking about selling carbon credits, where farmers need to invest in mitigation activities long before they receive payments (Wollenberg et al., 2012); or implementing silvopastoral systems which are characterized by starting periods where no income is perceived from the trees; or the use of optical sensors combined with decision tools for providing field-specific guidelines on nutrient management. If a solution that allows farmers to avoid having to pay the full, up-front cost of the sensor can be found, optical sensors would also be cost-efficient for farmers (Basak, 2016a).

Subsidies: Smart public subsidies could be the solution to overcome initial barriers/ establishment costs for carbon financing and engage a minimum threshold of farmers to make carbon finance viable. Designing agricultural investment and policy to provide up-front finance and longer term rewards for mitigation practices will help reach larger numbers of farmers than specialized mitigation interventions (Wollenberg et al., 2012).

Lack of data: As countries plan implementation, they have very little data regarding the cost of mitigation actions in agriculture. As of December 2015, 16 countries had provided costs associated with agricultural and land use mitigation measures. Countries need cost data to build a business case for financing climate change mitigation. The challenge is to fill in the cost data gap, especially projects that benefit smallholder farmers (Basak and White, 2016).

Monitoring, reporting and verification (MRV) costs: MRV could potentially increase the costs of implementing mitigation actions. Coordination with existing data-gathering and management systems through strategic partnerships with domestic institutions and implementing partners would help to drive down costs while also increasing the quality of MRV systems (Basak, 2016b).

Some of the main issues the literature has addressed with respect to the implementation of mitigation actions include:

Synergies between adaptation and mitigation: Synergies between adaptation and mitigation are essential for achieving mitigation targets since adaptation is more palatable to farmers than mitigation. In this way, adaptation becomes the entry point to implement practices that can have benefits of both adaptation and mitigation. Also through synergies between adaptation and mitigation, Greenhouse Gas (GHG) emissions reduction may be achieved more rapidly if there is a widespread implementation of adaptation practices with mitigation co-benefits (Martinez-Baron, et al., 2018).

Scaling best practices: Successfully scaling up mitigation practices requires both appropriate practices, technologies or models within favourable enabling environments, such as supportive institutional arrangements, policies and financial investments at local to international levels. Mitigation interventions need to be flexible enough to take into account local contexts while recognizing the impacts they can contribute to at scale (Neufeldt, et al., 2015).

Gender: There is a danger that, depending on the characteristics of the mitigation projects, these activities could present benefits steered towards men and therefore could reinforce gender roles that are often disempowering to women. Gender impacts should be considered at all stages of the mitigation projects, and women should be included in decision making roles at all project management levels (Shames, et al., 2012).

Land tenure and carbon rights: In many countries land has been adjudicated but most people don't actually have title deeds to their land. The latter becomes a barrier to implement projects that consider returns in the long run. On the other hand, international rules do not stipulate who has the right to benefit from sequestered carbon or emissions reductions. Policies on this topic are left to the host country. Many countries have yet to address the legal status of carbon so that projects can start to be implemented (Shames, et al. 2012).

Climate finance: Public and private climate finance is needed that can address mitigation and adaptation in integrated ways. Financing smallholder climate smart agriculture will require linking international finance with a range of existing credit and insurance institutions and providing innovative mechanisms to reduce risk. In the context of smallholder agriculture, farmer income from carbon finance will rarely be significant but carbon finance may still have an important role to play in financing climate smart agriculture at landscape scale (Agriculture, Landscapes and Livelihoods Day 5, 2012).

Below are some examples that address mitigation costs and associated barriers to implement these actions in specific countries:

Rice in Vietnam:

A study conducted for the rice sector in Vietnam showed that Alternative Wet and Dry (AWD) has high potential for GHG emission reduction and results in higher returns of 9.43 % to 22.91 % (equivalent to 2.16 to 5.67 million VND/ha as compared to conventional rice cultivation). With these results, the study developed the plan for investing in AWD and recommended that the government should consider improving institutions and policies; enhancing capacity for policy-makers, private sector partners and farmers; building national capacity for Nationally Determined Contributions (NDC) implementation in general, and for AWD in rice production in particular; and improving the coordination and collaboration mechanism for AWD in rice production to mobilize domestic and international financial sources.

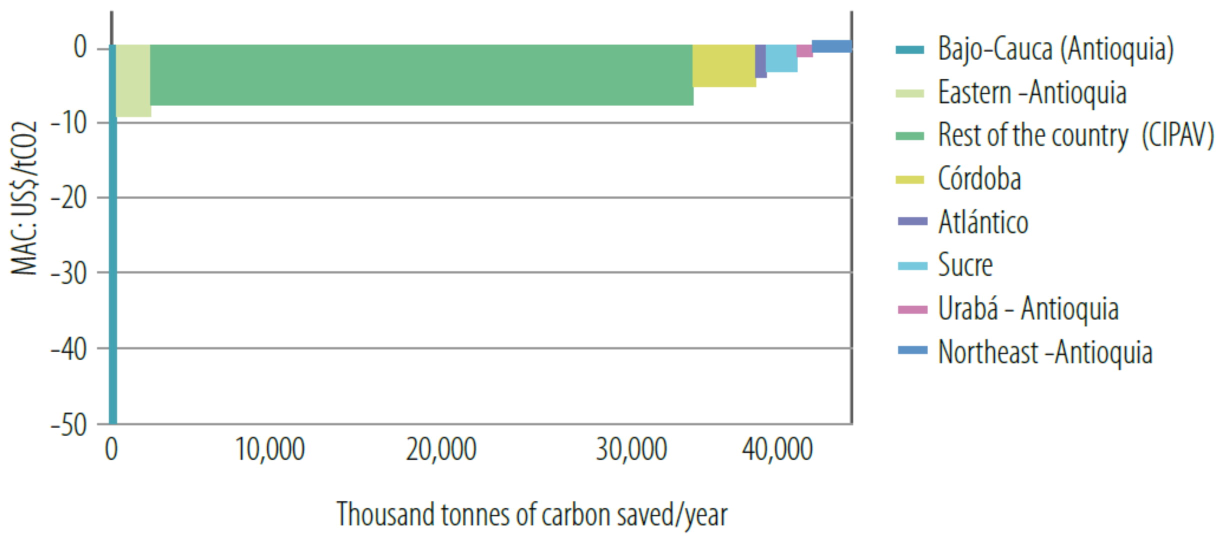
Livestock in East Africa:

According to Ericksson (2018) improving the productivity of livestock production can have a significant impact on the emissions intensities of GHGs from domestic animals in East Africa. The three top recommended practices for reducing GHG emissions intensities in this region according to this study are: increased production of improved forages in mixed systems and intensive dairy (this could potentially reduce emission intensities by 8–24 % in Kenya, and up to 27 % on mixed systems in Ethiopia), the increased use of biodigestors in intensive dairy (can cut total emissions from manure by 60–80 %) and improving the management of grazing for pastoral systems (produce similar mitigation results to improving forage quality). Some options were interesting in terms of reducing emissions intensities but with high costs to implement (supplementation with concentrates, biodigestors, and reduced age at slaughter). Some other barriers relevant to the implementation of practices for improving the efficiency of livestock production involving intensification are cost of the displacement of a large portion of the rural population, attracting investments, low institutional capacities, and finance for adaptation is a greater priority and represents the bulk of donor commitments.

Silvopastoral systems in Colombia:

According to the World Bank (2012), Colombia can expand Intensive Silvopastoral Systems (ISS) to about 3.8 million ha in various areas of the country. The most suitable production systems vary by region: They involve low and high timber density, a system with animal feed production from species that includes fruit trees combined with timber production from native species, and a system with timber trees. The GHG mitigation potential of converting 3.8 million ha is estimated at about 28.9 million t/CO_2e/year. Nevertheless this area could be reduced drastically to approx. 500.000 ha. if elements such as protected areas, land use vocation, and capacity of ranchers to implement these systems are considered.

Figure 38 | MAC curve - silvopastoral systems



Marginal abatement cost (MAC) curves are a powerful tools to represent the costs and mitigation potential of various options. Nevertheless it is very important to consider the existence of high institutional and transaction costs not easy to quantify but that can have relevant impacts in terms of implementation. For the case of Colombia, some of the main barriers associated to these costs include tradition, land tenure, rural land rights, tax incentives and subsidies that provide distorted support to large landholders, armed conflict, long term credit, legal stability, smallholder access to credit, technical assistance and technology transfer.

An important message is that, in general terms, mitigation in agriculture will face two main challenges: (i) developing transformative technical options to achieve the mitigation targets required; and (ii) massively implementing technologies that already exist. For most of the cases studied, mitigation actions can generate interesting returns on investments but barriers such as low capacity, weak institutions and policies, lack of financial resources to implement actions and appropriate MRV systems will definitely determine the future of the implementation of these existing technologies.

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Global policy options and challenges and policies for GHG mitigation in agriculture

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There is growing recognition that agriculture must play its part in reaching the Paris Agreement goal of limiting global warming to well below 2 °C, with scenarios showing that methane and nitrous oxide emissions, mainly from agriculture, could become the largest source of global emissions by mid-century (Gernaat et al. 2015; Wollenberg et al. 2016). This recognition is reflected in the inclusion of agriculture in the majority of the NDCs submitted by signatories of the Paris Agreement. However, as very few NDCs include sector-specific targets, the contribution of agricultural emission reductions to achieving these pledges remains unclear. An overriding challenge for analysts therefore is to identify policies that can unlock the sector's mitigation potential, generate socio-economic benefits and minimise negative effects on food security and agricultural competitiveness.

For almost one century the economics discipline has offered an elegant solution to efficiently manage environmental pollutants, by pricing them at a rate equivalent to their marginal damage costs. Despite this, and the subsequent evolution of a range of market-based instrument designs with comparable economic efficiencies, but with differing distributions of economic impacts for target sectors and government, they remain underutilised. Economic theory is, however, somewhat equivocal about which type of market-based instrument should be used. Given their vastly different distributional impacts, the choice of the most suitable policy mainly depends on the relative importance of different, and often competing, objectives in a particular region or sector. The main point of difference between instruments and their distributional impacts depends on whether they adhere to either the "polluter pays" principle (e.g. emission taxes, tradable permits) or the "beneficiary pays" principle (e.g. abatement subsidies). The instruments based on these different principles provide equivalent incentives on reducing emissions at the what is termed the "intensive margin" of production, which can be measured by the amount of emissions per unit of a particular commodity. These emission reductions occur through changes in the production process, including the adoption of new cleaner technologies. However, the similarities between these two categories of instruments diverge sharply in terms of their impacts on what are termed the "extensive margin", which describes the share of producers' land and other limiting resources used to produce one commodity versus another, and the "entry and exit margin", which affects the total number of producers in an agricultural sector. Abatement subsidies only incentivise the emission reductions at the intensive margin, whereas emission taxes cause emissions to fall across all three margins, which makes them a much more effective policy instrument.

Where economic efficiency and environmental effectiveness are the primary goals, emission taxes and tradeable permit schemes (with auctioned permits) will be the best performing instruments. However, given that much of the mitigation achieved by these instruments is derived from a contraction of agricultural output, these instruments create the largest reductions in food production and, by extension, food security. When these instruments are applied to agriculture in a single country or group countries, these impacts on production and commodity prices will also result in an increase in production in other non-regulated countries, partially offsetting the mitigation gains. Given these vastly different distributional and leakage impacts, the political economy of the main classes of mitigation policy instruments also diverge considerably. Consequently, agriculture tends to either be absolved of mitigation responsibilities in countries that apply mandatory mitigation policies to industrial sectors, or it faces voluntary policies that provide either weak mitigation incentives or are that are ineffective in their scale of application. For example, both the EU Emission Trading Scheme (EU ETS) and the New Zealand Emission Trading Scheme (NZ ETS), which are two of the world's most notable national level mitigation policy instruments, exclude emissions from agriculture. However, the inclusion of agriculture in the NZ ETS is currently being considered, with the proviso that producers will receive a 95 % free emission permit allocation. Such concessions remove much of the financial burden of mitigation, but are naturally less effective at lowering emissions. Another such example is the Emission Reduction Fund in Australia, initially established as an offset mechanism for the national carbon pricing scheme introduced by Australia's Labor government in 2011, allowing industrial emitters facing a carbon tax to purchase emission reductions from land use sectors. With a change of government the scheme was repealed in 2014, but the offset market was retained with government replacing the industrial sector as the main customer. As with the proposal to give agriculture an essentially free permit allocation in the NZL example, its inclusion as an offset supplier provides agricultural producers with a genuine but voluntary incentive to abate emissions. Since 2015, the Fund has been used to contract 18 million tonnes CO_2-eq of abatement in the agricultural sector, with a further 124 and 14 million tonnes CO_2-eq contracted in land vegetation and savannah burning projects, respectively (Clean Energy Regulator, 2018). Aside from this, there are several national R&D initiatives underway to identify improved mitigation practices and technologies often involving improved production outcomes. Another voluntary, but ambitious scheme is Brazil's Low Carbon Agriculture (ABC) Plan, provides a substantial amount of credit to finance the implementation of sustainable practices in agriculture, including carbon sequestration from restoring 15 million hectares of degraded pasturelands, by 2030. While the ambition of these national policies is promising, concerns have been raised about their effectiveness, which can only be judged in the future if and when they can deliver their scheduled targets.

Some countries have also specified national targets for GHG reductions in agriculture. Switzerland, for example, has proposed to reduce agricultural emissions by one-third by 2050, contributing to a two-thirds reduction of emissions across the whole agro-food chain. Vietnam proposes to reduce emissions by 20 % every ten years, while increasing production by 20 %, prioritising research on range of measures, while China has a specific target for achieving zero growth in fertiliser (a major source of nitrous oxide emissions) and pesticide use by 2020. Most national policies for emission reductions in the agriculture sector rely on R&D and the transfer of knowledge regarding low emission practices and technologies. New Zealand is a notable example, with these activities supported through national research programmes and its leading role in co-ordination with the 49 member countries of the Global Research Alliance on Agricultural Greenhouse Gases (GRA). Several other countries have indicated that R&D and the promotion of low emission practices are central to their national ambitions to lower agricultural emissions, including Canada, Japan, Costa Rica, Japan, Mexico, Vietnam and a number of European Union member States.

Despite the lack of any mandatory policies or voluntary policies with strong incentives or large-scale coverage, to regulate emissions, these early stages of GHG policy development can help analysts to anticipate the types of mitigation policy options governments might favour when enlisting the agricultural mitigation measures to meet their economy-wide mitigation goals. In the quantitative part of this study, a range of policy options are assessed to try and identify policy solutions that can unlock the large greenhouse gas (GHG) mitigation potential of the agricultural sector, without compromising food security in low income regions, while helping regions to maintain their competitiveness. The selection of mitigation policies assessed for this purpose, using the MAGNET CGE model (Woltjer and Kuiper, 2014), each appear to generate trade-offs among these policy objectives. Among the assessed policy instruments, a global mitigation subsidy appears to strike the best balance between these objectives, offering the prospect of appreciable global emission reductions without harming agricultural producers or food consumers. In contrast, a global tax on GHG provides the largest mitigation potential, but is also likely to induce large reductions in agricultural production, particularly in emission intensive livestock sectors in non-OECD regions, such as Sub-Saharan Africa and Latin America. Some agricultural commodities in OECD regions with high levels of export trade, such as ruminant products in Australia – New Zealand are also likely to experience relatively large falls in output from a GHG tax, especially if it is restricted to OECD countries. On the other hand, paddy rice production in East and South East Asia offers opportunities for significant emission reductions with relatively little impact on output. The global GHG emission tax and mitigation subsidy however have vastly different budgetary consequences for governments, with the subsidy requiring funds and the tax generating substantial revenues. Both of these instruments also face significant challenges associated with the measurement of emissions which are mainly related to the agricultural sector being comprised of numerous heterogeneous producers. These challenges may however be more significant for the tax instrument.

The effect of the implementation of mitigation policies at the OECD-level has also been assessed in response to expectations for high-income countries to shoulder the economic burden of ambitious global mitigation efforts. A tax on agricultural GHG emissions in OECD countries would result in the significant leakage of GHG emissions into non-OECD countries, lowering the effectiveness of the instrument. Moreover, because of its negative impacts on the competitiveness of OECD agriculture, it is unlikely to attract much support from OECD countries. A subsidy for the mitigation of agricultural emissions in OECD countries could control these negative impacts and deliver a similar level of mitigation as the tax. The use of a consumer-level tax in OECD countries, which levies an equivalent tax rate on domestic and imported ruminant food products, was also shown to effectively address these leakage and competitiveness issues. This instrument also has the practical advantage of removing the need to measure and verify GHG emissions and mitigation at the individual producer level. However, these benefits would likely involve a substantial reduction in mitigation effectiveness; a trade-off which relates to the policy being linked too indirectly to producer emissions and its inability to incentivise producer-level adoption of low emission practices.

Several challenges remain for analysts to be able to present a more complete picture of the potential for agriculture to contribute to global mitigation goals, not least is the scarcity of data on the marginal costs of abating emissions at the global level. At present there is with near complete reliance by global economic analyses, such as this study, on the US EPA abatement cost estimates (UE EPA 2013), which represent a commendable and pioneering effort, but only offers very partial cover soil carbon sequestration options.

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1 Innovative approaches in GHG monitoring and MRV

Abstracts in alphabetical order

Improving the UK Agricultural Greenhouse Gas Emissions Inventory

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Research and industry have collaborated to develop an improved national Agricultural Greenhouse Gas Emissions Inventory for the United Kingdom, based upon a synthesis of country specific (IPCC Tier 2) emissions measurements and farm management data, supported by computer modelling (IPCC Tier 3). The inventory is disaggregated by farm system and by soil and climate zones, to take account of environmental and management interactions affecting farm inputs and emission factors. We will summarise the improvements made to the UK Agricultural Greenhouse Gas Inventory, with a focus on the use of computer models in the grassland and sheep sectors.

Default IPCC (Tier 1) emission factors for manufactured fertiliser nitrogen, managed manure, dung and urine returns to grassland have been updated with the results of United Kingdom field trials. Feed intake, volatile solids and nitrogen excretion for sheep have been updated with model based calculations of the energy balance and protein requirements of ruminants, and new enteric methane conversion factors have derived from the results of field and chamber measurements of methane from animals maintained on diets representative of a range of farming systems. Calculations of indirect nitrous oxide emissions from leached nitrogen and atmospheric nitrogen deposition have been improved by model based calculations of nitrate leaching from grassland, and adoption of an explicit nitrogen mass transfer methodology for the manure management chain that integrates with the national Ammonia Emissions inventory. These new improved emissions factors have been supported by an in-depth review and disaggregation of farm activity data sources, and a framework for calculating and apportioning uncertainty in inventory emissions calculations has been developed.

Integrating data management systems and agro-ecosystem models to improve greenhouse gas reporting

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Most nations use IPCC Tier 1 emissions factor methodology to estimate agricultural GHG emissions reported in national inventories and to satisfy treaty obligations. In 2005, the US became the first UNFCCC signatory to report Soil N_2O emissions using a Tier 3 approach (DayCent Model). DayCent simulations for N_2O were initially at very coarse spatial resolution (62 agro-economic regions in US) but starting in 2007 model runs were conducted at the county level (~3,000 counties in US). In 2006, the US began using the CENTURY model for soil C stock changes at a much finer resolution (~350,000 National Resources Inventory points in the US) and starting in 2013, DayCent was used for both the N_2O and soil C inventories at the NRI level. Uncertainty in model input data is assessed using a Monte Carlo approach involving probability density functions for weather, soils, and N fertilizer additions. Model structural uncertainty is quantified by using a linear mixed effect modeling analysis that compares ground based N_2O emission and soil C stock change measurements to model predictions. Estimates and 95 % confidence intervals for soil N_2O emission and C stock change are reported at the state and national levels in the US GHG Inventory. This talk will show how databases from GRACEnet (Greenhouse Gases and Agricultural Enhancement network) and other sources are used for model development, testing, and uncertainty quantification. Observational data from Canada and some other northern field sites shows that spring time N_2O emissions associated with snow and soil melting events can account for a significant portion of total annual emissions. Current efforts to represent freeze/thaw related N_2O emissions in DayCent will be emphasized as well as recent use of top-down data to evaluate model function. Specifically, data from 3 sites (one in eastern Canada, one in western Canada, and one in northern Colorado) were used for model calibration while multiple additional sites were used for independent testing. The implications of representing spring freeze/thaw emissions in DayCent for the US national GHG inventory will be explored as well as the impacts on estimated uncertainty bounds. Data sets that could be used for further model evaluation of both direct and indirect N_2O emissions will be identified and challenges that make comprehensive model testing difficult and ways to facilitate this process will be discussed.

Keywords: GHG inventory, ecosystem model, GRACEnet, nitrous oxide, DayCent

The IPCC and UNECE approaches to gaseous emissions from manure management differ. Should they be more alike?

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Every emission inventory methodology is a compromise. The primary aim of an inventory is to calculate emissions as accurately as possible. A secondary aim is often to identify intervention points that can be used to reduce those emissions. Methodologies typically consist of an activity and an emission factor. The choice of that activity is based on a consensus among relevant international scientists concerning the main processes driving emissions (the underlying model) and the value of the emission factor (the model parameter) is obtained from a review of the global scientific literature. There will be uncertainty (error) in both the model and the parameter. There will also be uncertainty concerning the activity data but this will vary between countries, depending on the statistics and resources available to the national inventory compilers. When formulating inventory methodologies, increasing the level of detail reduces model error but risks increasing the errors associated with parameterization and the acquisition of activity data. Furthermore, creating a high demand for activity data in a Tier 2 methodology can lead poorly-resourced inventory compilers to resort to a Tier 1 methodology, even for a key source. The IPCC Guidelines methodology for GHG emissions from animal husbandry and manure management is currently under refinement while a revision of the methodology for NH_3 emissions in the EMEP/EEA Guidebook will begin this year. Both GHG and NH_3 emissions vary with climate and from which part of the farm the emissions occur. The Tier 2 methodology in the IPCC Guidelines takes more account of climatic effects while the EMEP/EEA Guidebook takes more account of the emission sources. Does this reflect the differences in the processes driving GHG and NH_3 emissions or could the two methodologies learn from one another?

Greenhouse gas fluxes from organic soils in Germany – synthesis and derivation of emission factors for the national greenhouse gas inventory

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Drained organic soils are large sources of anthropogenic greenhouse gases (GHG) in many European and Asian countries including Germany. Therefore, they urgently need to be considered and adequately be accounted for when attempting to increase the carbon sequestration in agricultural soils. Here, we synthesise a large data set of GHG fluxes from organic soils and describe the detailed methodology for reporting anthropogenic GHG emissions from drained organic soils developed for, and applied in, the German GHG inventory under the UNFCCC and the Kyoto Protocol. The approach is based on national data and offers the potential for tracking changes in land-use and water management associated with intensification, peatland restoration or GHG mitigation measures in case time series of relevant activity data are available.

Drained organic soils were defined as soils with a mean annual water level of -0.1 m below surface or drier. Activity data comprise high resolution maps of climate, land-use, the type of organic soil and the mean annual groundwater level. The groundwater map was derived by a boosted regressions trees model from data from > 1000 dipwells.

Carbon dioxide and methane emissions were synthesized from a unique national data set comprising more than 200 GHG balances in most land-use categories and types of organic soils. The measurements were performed with fully harmonized protocols. Non-linear response functions describe the dependency of carbon dioxide and methanefluxes on the mean annual groundwater level, stratified by land-use and organic soil type where appropriate. Resulting "applied emission factors" for each land-use category take into account both the uncertainty of the response functions and the distribution of the groundwater levels within each land-use category. No functional relationships were found for nitrous oxide emissions. Emission factors for nitrous oxide were thus calculated as the mean observed flux by land-use category. IPCC default emission factors were used for minor GHG sources such as methane emissions from ditches and the losses of dissolved organic carbon (DOC). In Germany, drained organic soils annually emit nearly 50 million tons of GHGs, equivalent to 5 % of the national GHG emissions. They are the largest GHG source from German agriculture and forestry. The described methodology is applicable as well to the project scale as to other countries where similar data is available.

Keywords: peatlands, carbon dioxide, methane, nitrous oxide, land-use

Extracting spot measurements of enteric methane from cow breath

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Historically most studies assessing CH_4 emissions from cattle have been done using respiration chambers, which is impractical for large-scale estimation of emissions by individual animals in national populations and on commercial farms. Due to the availability of more portable gas analysis equipment and the considerable interest in the possibility of identifying high and low CH_4 emitters for benchmarking farms, improving national emissions inventories and/or genetic selection, approaches to measure enteric emissions from individual animals on commercial farms are being developed. The frequent 'spot' sampling of breath concentrations when an animal is at a feed bin shows great promise, and allows assessment of between-cow, within-cow, diet and temporal effects on emissions when sampled over several days. The aim of this study was to assess different approaches for filtering CH_4 concentration measurements from raw gas analysis data, and assess the association between each filtered measure with feed intake variables; CH_4 emissions are know to be highly correlated with daily feed intake. Gas concentrations were measured continuously by an infrared analyser whilst cows were being milked in an automatic (robotic) milking station. Concentrations of CH_4 emitted during milking were calculated using a custom-designed program to determine average emissions as: concentration during milking, height of peaks and area under peaks. Milkings with less than 3 peaks for CH_4 concentration were excluded from the analysis. Emissions of CH_4 from 36 cows were measured during two consecutive feeding Periods, for a total of 84 days. In Period 1, the 36 cows were fed a high forage partial mixed ration (PMR) containing 75 % forage. In Period 2, cows were fed a commercial PMR containing 69 % forage. Cows were offered PMR *ad libitum* plus concentrates during milking and CH_4 emitted by individual cows was sampled from the feed bin during 8,662 milkings. A linear mixed model was used to adjust CH_4 emissions for diet and time of day, and derive variance components. Pearson correlation was used to assess the association between daily feed intakes of dry matter, forage, total concentrate and robot concentrate. All CH_4 measures assessed were positively associated with dry matter intake and forage intake, but differences between filtering approaches existed. These findings are important for CH_4 monitoring techniques that involve taking spot measurements over short periods within a day.

Keywords: Cattle, emissions, measurements, gas analysis

Improved methodologies for the measurement of organic carbon and estimation of stock changes in agricultural soils and their potentials for offsetting greenhouse gases

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Reduction of greenhouse gas (GHG) assessment uncertainties and improvement in the quantification of sinks and offsetting mechanisms are required to develop appropriate mitigation measures aimed at keeping global temperature <2 °C. The key factors that are needed to fulfil these objectives are a precise, verifiable estimation of soil organic carbon (SOC) and its variation at field scales. For SOC measurements, land use (LU)/soil type-specific and consistent sampling protocols (e.g., method and timing of samplings) together with a consideration of other factors (e.g., soil moisture and carbon) that influence soil mass and volume, are required. For accurate estimations, the determination of SOC by 'mass by volume' on an equal soil mass basis, in a defined but adjustable soil layer is essential. The Intergovernmental Panel on Climate Change (IPCC) proposes a proportional (%) approach, as a SOC density (here used instead of stock) change factor (DCF), for application across key agricultural LUs, managements and inputs. Methodologies developed with higher spatial resolution databases, coupled with two-phase modelling and GIS approaches, could provide robust estimates. The range of SOC density (SOCρ) using this approach was in the order, rough grazing (R)>grassland (G)>rotation/ley (GT)>tillage (T), and was highest in the organic soils. The IPCC DCF factors overestimated the SOCρ changes by 42–156 %, which were corrected by models developed using depth ratio functions. These resulted in a sequestration rate of 0.23, 0.42 and 0.53 t C ha^{-1} yr^{-1} for 0-10, 0-30 and 0-100 cm depths in Irish agricultural soils over 25 years. The corresponding national agricultural SOC stocks measured in 2006 were 316, 838 and 1679 Tg with an average change of 1.20, 2.93 and 5.41 Tg C yr^{-1}. An estimated potential of offsetting GHGs through SOC sequestration was 24, 59 and 106 % of the total emitted from Irish agriculture. These findings suggest the replacement of the apportioning approach, by a 'mass by area' (depth-specific) one for more precise estimations. This includes the disaggregation of soil types, and the calculation of country-specific DCFs and weighting factors for individual LUs, management practices and inputs for upscaling to regional/international level.

Keywords: SOC, Soil mass by area, GIS & empirical modelling, SOC density/stocks, agricultural land uses

Regional-scale simulations of N2O emissions from agriculture

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Sustainable intensification (SI) options for agriculture have been mainly designed to identify optimal trade-offs among primary production, conservation of soil organic carbon and the control of nitrogen leaching. However, in the context of climate change mitigation, it is crucial to assess how the implementation of SI options at large scale will influence the emissions of greenhouse gas (GHG). As GHG emission inventories mostly use coarse emission factors to estimate large-scale GHG from agriculture, they appear inadequate to differentiate emissions under a variety of SI scenarios, which are often based on incremental changes applied to current agricultural systems. Process-based simulation models provide the additional insight on the conditions under which GHG emissions occur and can be used to quantify the climate effect of SI options tailored to improve on other criteria.

Large-scale, high-resolution simulations are a viable tool to test alternative strategies to maintain –or increase– productivity while reducing environmental impact at the regional level. In a set-up of spatially distributed crop rotations, we demonstrate such an application using the MONICA model to simulate N_2O emissions in the German state of North-Rhine Westphalia under baseline and different SI scenarios for nitrogen and residues management. A rule-based nitrogen fertiliser scheme based on official recommendations is used to represent current practices, while a more advanced strategy simulates nitrogen fertilization aided by the most recent technologies. For residue management, baseline scenario considers the exportation of one third of the cereal residues, whereas the SI leaves a recommended amount of residues in the field for soil organic matter conservation. The simulations demonstrate the spatial heterogeneity of the N_2O emissions across the region and the potential to capture the differential regional emission under scenarios based on the representation of current and improved agricultural settings.

Grassland contribution to carbon sequestration in the LULUCF inventory for Northern Ireland

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The early recognition that there has been a considerable increase in greenhouse gas (GHG) emissions emitted from agriculture practices, has led to improve grassland management to store carbon (C) and offset anthropogenic emissions of the farming sector. The United Kingdom (UK) Climate Change Act 2008, which extends to Northern Ireland (NI), requires an 80 % reduction in emissions across all sectors by 2050. Grassland in NI, represents 79 % of the agricultural land area and agriculture is the largest source sector of GHG emissions. Under this commitment and other international agreements, it is required to provide information and land use change data for reporting GHG emissions and removals from Land Use, Land Use Change and Forestry (LULUCF). The UK has chosen to use a wide definition of grassland in its LULUCF inventory which includes improved and semi natural grassland and other habitats that may not be grassy vegetation. Further, there are other sources of activity data that are currently excluded from the inventory that may also benefit NI's inventory such as hedgerows, sequestration value of scrub, woodland strips and agroforestry.

Hence, to ensure that any benefit to NI's inventory is not overlooked, this study analysed and evaluated activity data and emission factors that are currently applied in the NI LULUCF inventory and to derive more accurate estimates relevant to NI's conditions.

The study found important gaps in activity data for NI such as C stock changes in grassland living biomass, dead organic matter and soil C changes in mineral or organic grassland soils. These gaps are particularly important in long-term grassland where equilibrium in C accumulation is assumed be reached in 20 years (IPCC, 2006). Other activities not included in the LULUCF inventory were hedge management, C dynamics in soils below hedges and application of manure to grassland which is a potential mitigation strategy. Therefore in order to establish a clear link between land use management practices and the reporting mechanism used to monitor emission changes in NI, the current gaps and assumptions in relation to the LULUCF inventory need to be addressed. This will help to ensure that C sequestration activities in the country are better represented in the inventory.

Keywords: LULUCF, Inventory, grassland, carbon sequestration

A new approach to estimation of methane emissions from manure management

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Liquid manure is currently responsible for >90 % of CH_4 emissions from manure management within EU. Furthermore, the share of liquid manure management is growing due to intensification of livestock production, and storage time is increasing in order to recycle manure nutrients in spring. These trends increase the need for methods to verify CH_4 emissions from liquid manure, and to quantify effects of mitigation measures.

In the IPCC methodology, emission inventories are based on CH_4 emission potentials (B_0, or BMP) and CH_4 conversion factors (MCF) for individual livestock categories, manure management systems, and regions. However, emission estimates are uncertain, because they must represent a wide range of local circumstances such as housing conditions, feeding, and manure handling routines. For verification, a more dynamic approach is needed which can relate CH_4 emissions to the specific storage conditions.

We propose a new method, which is based on *in-vitro* determination of CH_4 production rates at the ambient temperature. This approach was successfully tested in a pilot study [Petersen et al., 2016; PLoS ONE 11(8): e0160968] and, if further validated, allows for estimation of CH_4 emissions on individual livestock farms. This in turn would provide a database of observations to predict CH4 emissions from manure management for each livestock category and system, including uncertainty estimates.

Evaluation of mitigation scenarios requires, in addition to verification of emissions, that a prediction model is defined. The method proposed here uses an existing empirical model, which relates CH_4 emissions to manure VS and storage temperature. The temperature response (but not magnitude) of methanogenesis was found to be independent of manure type or pre-treatment, and therefore such a model could be widely applicable. A key parameter in the temperature response function is CH_4 emission potential, which will be unknown in partly degraded manure samples, but this potential can be estimated from CH_4 production rates. Emissions of CO_2 are not estimated with the current IPCC methodology, but required for a prediction model in order to calculate VS degradation. This aspect requires further research and development.

Model results are easily recalculated to MCF values and thus would comply with the UNFCCC reporting system. Calculated effects of management changes (in-house retention time, anaerobic digestion) will be presented, and upscaling to national inventory.

Keywords: manure management, methane, model parameterisation, mitigation scenarios, inventories

Improving the dairy farm efficiency with a milk low carbon action plan

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Milk carbon footprint represents a challenge and an opportunity for the dairy sector to highlight its current and future accomplishments. Although environmental drivers are not well received by farmers, evidences are available to illustrate that lower GHG emissions are associated with reduced operational costs. The French Livestock Institute (Institut de l'Elevage), in association with key players in the French dairy sector i.e. dairy advisory enterprises and French dairy board (CNIEL), has launched the LIFE CARBON DAIRY project with the main objective to reduce the milk carbon footprint at farm level by 20 % over 10 years. To reach this goal, project's partners developed a Life Cycle Assessment tool named CAP'2ER® aiming at measuring the milk carbon footprint in dairy farms in France. Answering the LCA approach, the milk carbon footprint assessed in CAP'2ER® is covering the greenhouse gases (GHG) emissions to determine the milk Carbon Footprint (CF) and the carbon sequestration. Following IPCC methodology, CAP'2ER® has been certified by Ecocert and is now disseminated in France. With the first applications on 3,348 farms representing various milk production systems in France, the project provides a good overview of the average national CF. On these farms, the average CF is 1.04 kg CO_2e per liter Fat and Protein Corrected Milk. The carbon sequestration represents a potential in GHG compensation in a range of 5 to 30 % according the production system. Variations in CF are explained by discrepancies in farm management. Practices with the largest impact on CF average are milk yield, age at first calving, quantity of concentrate, N-fertilizer used and fuel consumed.

The project show that it exist a difference of 30 €/1000 l between the lowest 10 % milk carbon footprint and the highest 10 %. This reinforces the fact that improving production efficiency and reducing the carbon footprint of milk production are highly complementary. So, the milk carbon footprint assessment is a good means to provide dairy farmers with information about GHG emissions and the link with farming practices. These first results encourage now the dairy sector to develop the Low Carbon Dairy Farm action plan at a national level on the 60,000 dairy producers.

Keywords: dairy, GHG, carbon sequestration

Reducing methane emissions will decrease benefits for producers. How can genomics face this limitation?

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Breeding programs are an efficient strategy to mitigate greenhouse gas emissions (GHG) in livestock while ensuring an economic profit to producers. They are cheap to implement, have a worldwide impact and accumulate gains along generations. However, GHG emissions, in particular methane from cattle, are not included yet in the breeding goals, mainly because the policy at tackling GHG has not yet been defined. The objectives of this study were 1) to determine the expected changes in dairy and beef cattle under different policies to tackle emissions in livestock and 2) to show the potential of genomic strategies to mitigate methane emissions.

Our results showed that breeding programs could effectively reduce methane emissions under different policies such as a carbon tax or a carbon quota using the current situation (no carbon footprint penalizes) as benchmark. This reduction can be up to 4 kg/cow/year in dairy cattle and up to 1.65 kg/cow/year in beef cattle. However the lower methane production is at the expenses of reducing (up to 10 %) the economic response for the producer. Besides, methane produced by the fattening calf will increase regardless the scenario (between 2.30 and 2.90 kg/calf/year).

We provide updates from the METALGEN project that collects direct observations for methane emissions in commercial dairy farms with automated milking systems using sniffer devices (Guardian NG; Edinburgh Instruments Ltd., Livingston, UK). All cows with methane observation are genotyped, and serve as a reference population for genomic selection. The project also evaluates the role of the microbiome as a proxy for methane emissions, and the effect of the cow genotype at controlling the microbiome. Rumen content was extracted from 10 Holsteins and 8 Brown Swiss cows to determine the microbiota composition by sequencing the hypervariable region V4 of the 16S rRNA amplicon. We determined that there is a host genetic background effect that controls the microbiota composition, and this can be used in the breeding programs to accommodate the microbiota of future generations to a more efficient composition with reduced methane emissions and at reduced costs.

Keywords: genomics, breeding programs, microbiome

Eddy Covariance´s data preprocessing in livestock agroecosystems

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This study evaluated *Eddy Covariance* (EC) technique in a representative livestock agroecosystem (455.623 ha) in a homogeneous landscape unit conforming a mixed piedmont in Meta, Colombia. Vickers and Mahrt's (1997) quality control criteria was applied to the data, which required ulterior processing to discern infrequent events related to animal presence. The implementation was made to register animal presence in CO_2 fluxes that marked as errors, since either absence and presence of the animal register flagging. Elimination criteria was formulated in terms of statistical properties since the magnitude of observed variables, measured over pastures, were highly dependent of biomass' quality and quantity, animal species and weight. The criteria, Spikes, Amplitude Resolution, Dropouts, Higher Moments, Discontinuities and Lag Correlation were implemented to find and analyze the technique and animal presence through flagging, in terms of CO_2 concentration, temperature and wind speed, being only filtered through data quality, which allowed to identify interaction between livestock and pasture in CO_2 fluxes. It was found that there's no standard procedure or recommendations that operate universally to remove spurious data. Each test is specific to the site's conditions and its application must be made carefully, without it being just an elimination procedure. This procedure depends on the study area, the measurement equipment and the quality criteria's choice. The measurements in livestock agroecosystems must be designed and adapted to specific conditions of the study area, and standardized methods can't be replicated without implementing the modifications needed to fit the local biophysical conditions. In this case, the study area presented interactions between livestock, pasture, and man, and these modified and influenced the lower layer of the troposphere, in which the wind (friction forces), radiation (heat transportation), photosynthesis and respiration, alter transport, heat and CO_2 fluxes by changing turbulence and its relationship with other climate conditions specific to the study area that characterize it as an open system. Also, each criterion has its own way to be detected and adjusted, and these must be established to correct the data captured by the EC tower, since these modify the flux calculation and are easily altered from atypical data.

Keywords: Eddy Covariance Livestock GHG

Quantification of greenhouse gas mitigation measures in an experimental dairy housing at herd level on a practical scale

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Dairy farming causes a large proportion of global GHG emissions, which also applies to Switzerland. The Swiss "Agricultural Climate Strategy" defines a reduction of at least one third in greenhouse gas emissions from Swiss agriculture by 2050 compared with 1990 (BLW 2011). To achieve this goal, effective GHG emission mitigation strategies have to be developed and evaluated. Up to now GHG emission measurements are mostly restricted to individual animal level (metabolic studies, respiration chamber). Whereas the efficiency of abatement strategies on herd level has hardly been investigated. However, these data are needed for national inventories and the development of suitable mitigation strategies, which form the basis for agricultural and environmental policy decisions.

Comparative emission measurements on a practical scale were conducted in the experimental dairy housing at Agroscope. It consists of two spatially separated experimental compartments – each for 20 dairy cows – and a centre section for milking and analytics. Thereby, the reduction potential of abatement measures can be quantified relative to reference conditions. To determine emissions under natural ventilation, a tracer-ratio method with two tracer gases, SF_6 and SF_5CF_3 is used. The diluted tracer gases are dosed continuously via steel tubes with critical capillaries into different experimental compartments. Integrative air samples are collected with a piping system consisting of teflon tubes and critical glass capillaries. The analytical instrumentation for CH_4 and CO_2 (CRDS, Picarro Inc., USA) as well as tracer gas analysis (GC-ECD, Agilent, USA) are located in an air-conditioned trailer.

Systematic validation experiments with different dosing variants demonstrate that this technique is suitable for areal and point emission sources and the equivalence of both tracer gases (Mohn et al. 2018). The accuracy of the tracer ratio method was demonstrated by CH_4 dosing experiments and the uncertainty of the tracer ratio method, which is in the range of 3–10 % and considered superior to existing alternative approaches.

In this experimental set-up, the sum of enteric and slurry-derived emissions of feeding measures (e.g. supplementation with extruded linseed) as well as structural (e.g. floor type) and organizational measures (e.g. dung removal interval) were quantified. At the conference, first results will be presented, showing typical diurnal patterns of concentrations and emissions of CH_4 and CO_2.

Keywords: greenhouse gas, dairy cows, methane, tracer ratio method, mitigation

Eddy covariance measurements of N_2O emissions under intensive grazing before, during and after pasture renewal

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Soils under pastoral land utilised for dairy and meat production are a major source of the greenhouse gas nitrous oxide (N_2O). In New Zealand, N_2O contributes ~10.5 % (carbon dioxide equivalents) to the domestic gross emission profile. To date, the quantification of N_2O emissions from soils requires the use of emission factors that are based on chamber measurements. Data derived from these chambers are commonly used to build greenhouse gas inventories in New Zealand and elsewhere by extrapolation from point to national scales but do not provide a broader spatial and temporal perspective. Recent advances in detector technology offer the ability to now observe N_2O fluxes over space and time when coupled with the eddy covariance technique. In November 2016, an eddy covariance tower measuring N_2O fluxes was established on a New Zealand dairy farm with year around grazing. Using a quantum cascade laser absorption spectrometer (Aerodyne), the eddy covariance system quantified the concentration of N_2O, methane and water vapour simultaneously at 10 Hz over a footprint of 6 ha. Our objectives were to: 1) measure annual fluxes of N_2O under ryegrass-clover at paddock scale, 2) evaluate the effect of pasture renewal on N_2O emissions, and 3) test whether a diverse sward comprising 60 % plantain (*Plantago lanceolata*) could mitigate the emission of N_2O from pastoral soil. Addressing objective 1, baseline nitrous oxide fluxes (F_{N2O}) in summertime were found to be around 0.5–1.0 nmol N_2O m^{-2} s^{-1}. Under grazing in dry conditions, F_{N2O} remained moderate (1.0–2.0 nmol N_2O m^{-2} s^{-1}); however, large and short-lived flux pulses (6–8 nmol N_2O m^{-2} s^{-1}) occurred coinciding with precipitation during or after grazing. Maximal F_{N2O} were detected at ~70 % soil water-filled pore space (WFPS). In winter, F_{N2O} were generally greater than 0.5 nmol N_2O m^{-2} s^{-1}. Related to increased soil moisture (>70 % WFPS), winter F_{N2O} did not show a clear response to wet-drying and grazing cycles. To assess the effect of pasture renewal on N_2O emissions, 50 % of the area under the eddy covariance footprint was treated with herbicide and direct drilled with new seed in March 2018. The new pasture sward consisted of plantain (7 kg ha^{-1}), perennial ryegrass (2x3 kg ha^{-1}), white (1 kg ha^{-1}) and red clover (2 kg ha^{-1}); the other half of the footprint area remained unmodified. Here, we report the response of N_2O fluxes before, during and after pasture renewal in comparison with the flux pattern observed previously.

Keywords: Nitrous oxide, eddy covariance, pasture renewal, plantain, mitigation

HUNTER – Developing, Testing and Introducing an Excel Tool for sustainability benchmarking in plant production

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In the joint project "Climate Effects and Sustainability of Agricultural Systems – Analyses in a Network of Pilot Farms" almost 80 farms and diverse scientific institutions have been working together throughout Germany to compare and benchmark their plant production. For calculating various balances at the farm-level we used a special program called REPRO (REPROduction of soil fertility). With REPRO it is possible to make a very detailed analysis of a farm, but this requires a lot of time and thorough knowledge of the software. Our goal, in the context of the network of Pilot farms was to develop a free and easy to use tool for making these calculations.

The HUNTER tool (acronym for HUmus, Nutrition, Total greenhouse gases and Energy Reckoning) is based on Excel and consists of different input-sheets to be filled in by the user. Data for a complete year is required but one is free to decide how detailed and precise the results should be. After finishing the first sheet, the user already has results for the humus and nutrition balances. Other input-sheets are concerned with tillage, plant protection, mineral and organic fertilization and harvesting. HUNTER automatically calculates balances for energy use and greenhouse gas emissions and the results are shown in tabular and chart form. A very useful feature is the comparison of many farms in a scatter-plot, enabling scientists and farmers to see how different farms compare in these important parameters.

The dataset for comparing ones own farm with other farms derives from long-term calculations in the network of Pilot farms for energy use and the ongoing collection of new data for greenhouse gases.

During numerous visitations for data collection at the farms, we occasionally presented farmers with current results for their farms. Farmers were interested to see how their farms compared with other farms. They were especially interested in differences between the groups practicing organic farming and those using conventional methods. With the exception of humus and nitrogen, most farmers did not have experience with the other parameters. This lack of scientific background requires, on the one hand, some brief introductions within the HUNTER tool, and on the other hand, good counceling by the consultants. A practiced consultant can use the results from HUNTER to give advice for improving the sustainability of a farm. First results of calculations with HUNTER will be presented.

Keywords: humus-balance, energy balance, nitrogen balance, sustainability benchmarking, plant production, greenhouse gases, do-it-yourself-tool

Using the EU Farm Accountancy Data Network to track GHG farm level emissions in the Republic of Ireland

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This paper explores the challenges in applying national inventory based methodology (IPCC) to farm level data to calculate GHG emissions at farm scale across a range of different farm systems in the Republic of Ireland. Data from the Teagasc National Farm Survey which is part of the EU Farm Accountancy Data Network is used to generate GHG emissions on a per hectare and kilogramme of product basis across multiple farm systems and multiple years. This methodology allows the issues of emission intensity versus absolute emission across different farm system to be explored. This methodology has the potential to be expanded to other members of the EU Farm Accountancy Data Network to allow for cross country comparisons in GHG emissions from Agriculture.

Keywords: Sustainability Indicators, FADN

Controlling GHG emissions by soil pH management: a kill or cure?

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Most cultivated soils in the cool-temperate zone are limed periodically to counteract natural and cultivation-induced acidification. In addition to securing crop productivity, soil pH management affects biological diversity and functions in soils. For example, N_2O reductase, the enzyme reducing nitrous oxide (N_2O) to harmless N_2 during denitrification, is impaired at low pH values. Soil pH is also an important factor for the abundance of ammonia-oxidizing bacteria and archaea, which differ in their ability to produce N_2O during nitrification. Although pH is recognized as an important factor for a soil's potential to emit or consume greenhouse gases, the potential for soil pH management to mitigate GHG emission has never been explored systematically. The FACCE ERA-GAS project "Mitigating Agricultural Greenhouse Gas Emissions by improved pH management of soils (MAGGE-pH)" builds on the emerging understanding of how soil pH controls carbon and nitrogen turnover in soils with the ultimate goal of identifying pH management strategies that reduce yield-scaled N_2O emissions. For this, an international consortium of soil scientists, microbial ecologists, crop scientists, modelers and practitioners has been assembled. N_2O emissions in relation to various pH treatments are studied in field experiments and under controlled conditions, drawing on a broad network of existing and new field experiments in Europe and New Zealand and using high-end biochemical approaches. The results will be used to parameterize existing N_2O models for pH effects. These models will be linked with socio-economic models to study the effects of regulations and subsidies promoting a climate-smart pH regulation. Cost-benefit analyses will be used to illustrate the mitigation potential of soil pH management for selected regions, which can be implemented promptly and cost-efficiently. Besides conventional liming by calcareous minerals (dolomite, calcite), we will study the liming potential of siliceous minerals (mafic minerals and other side products from the mining industry) and the interaction between soil pH management and GHG mitigation tools such as nitrification inhibitors, acidification of manure, Controlled Uptake Long Term Ammonium Nutrition (CULTAN) and biochar. The project will generate yield-scaled N_2O emission factors and fosters innovations both at the farm level and in collaboration with industries that provide tools and materials for management of soil and its pH.

Keywords: N_2O, liming, nitrification, denitrification

Exploring the relationship between vegetables and greenhouse gas emissions in the Czech Republic

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The study explored the relationship between vegetables and greenhouse gas emissions in the Czech Republic. An attempt is made to identify where the significant emissions hotspots lie along the life cycle, taking into account vegetable production, transport, processing, and cold storage. Vegetable crop production generates high economic returns per unit of land and thus offers promising income prospects. Due to climate change in Elbe lowland, the breeding of new and improved vegetable crop varieties may lead to an expansion of the areas that are suitable for the profitable cultivation of vegetables. In addition to the current assortment of vegetables that are grown under the present-day climate, non-traditional vegetables could also be grown in open field conditions. We have used computer simulation models of the soil-plant-atmosphere system to evaluate these impacts. The crop models calculate expected growth and development based on equations that describe how a crop responds to soil, CO_2 and weather conditions. Expected the potential impacts of climate change on the types of vegetable crops grown under open field conditions in the Elbe River lowland illustrated by the outputs of various regional climate models, regression models and dynamic growth models will allow to determine new prospective areas for growing thermophilic cultivars outside of the current profitable cultivation boundaries. However, vegetable crops vary widely in their total greenhouse gas emissions as well as emissions by area of production. Perhaps the most important consideration for those concerned about this issue is the emissions per tonne of crop produced. Lower yielding, although high value, crops such as peas and asparagus are the highest emitters of CO_2-e per tonne, while tomatoes, cucumbers, celery and carrots are the lowest. Proposed study can be crucial in development of strategies on climate change adaptation for different varieties of thermophile crops for future climate change in different regions in order to increase productivity, while reducing both the cost of farmers and the water footprint of agriculture per unit product.

Keywords: Vegetable crops, dynamic crop model, tomato

Development of a farm-level greenhouse gas emission assessment tool for Welsh livestock agriculture

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The agricultural sector contributed an estimated 13 % to total Welsh greenhouse gas (GHG) emissions in 2015. Under the Welsh government's decarbonisation programme, the sector is expected to mitigate these emissions in line with UK and international reduction targets. Meeting mitigation targets requires a robust means of estimating baseline (pre-mitigation) emissions and detecting and predicting the impacts of potential mitigation options. As part of the Climate Smart Agriculture Wales project, we assessed the suitability of currently available off-the-shelf GHG assessment tools for estimating emissions and sequestration, and monitoring the impacts of mitigation option implementation within the context of Welsh beef, lamb and dairy production.

An initial list of relevant farm-scale GHG assessment tools was identified from the literature and evaluated using criteria developed with input from industry, policy and academic stakeholders. A multi-criteria analysis (MCA) was used to score the tools remaining after the initial filtering process ($n = 10$) with a focus on detailed features of GHG calculation methods and user-friendliness. The three highest-ranking tools were further evaluated using identical sets of real-farm data from farm types representative of the most economically important livestock systems in Wales (a lowland dairy farm and an upland mixed beef cattle and sheep farm). Comparisons of the tools were undertaken focussing on: i) functioning in terms of the technical rigour and completeness criteria used in the MCA, ii) the variability of outputs, iii) redundancy in functioning, and iv) potential sensitivity to the impacts of implementing GHG mitigation options.

Results indicate that while a large range of agricultural GHG emission assessment tools are publically available, calculation methods and the presentation of outputs vary widely. Transparency was a major limiting factor in tool assessment. None of the tools examined were entirely suited for aiding implementation of the Welsh decarbonisation programme. We recommend the development of a new tool, building on the strengths of existing tools and customised to the needs of the Welsh livestock industry and policy environment.

Keywords: Greenhouse gases, livestock, modelling, multi-criteria analysis

2 Mitigation potential

Abstracts in alphabetical order

Reducing greenhouse gas emissions from a rangeland beef system

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Methane is a potent greenhouse gas contributing to climate change, and ruminant livestock are the dominant source of anthropogenic methane. Research has shown that dietary inclusion of 3-nitrooxypropanol (3-NOP) can reduce enteric methane production in ruminants. For cattle grazing rangelands the most practical method for feeding 3-NOP would be to deliver it as part of a lick block somewhere near water points. However, it has been reported that cattle grazing in the northern Australian rangelands typically only access the water point once every 3 days. The objective of this partial farm-gate life cycle assessment was to quantify the effect of 3-NOP on whole farm GHG emissions of a rangeland beef farm. The beef farm modelled was located in Queensland, Australia and included a cow-calf and beef stock operation over a 10 year period, to cover a breeding herd from birth to slaughter and six production cycles. The breeder herd began with the farm retaining 1,206 female and 21 male calves. Offspring were kept on the farm and were sold for meat at an age of 18 months at a live weight of 370 kg. The Australian National Greenhouse Gas Inventory method was used for estimating GHG emissions. Feeding of 3-NOP at a rate of 200 mg/kg DMI was assumed to reduce daily methane emissions by 54.1 %, based on a feedlot study. Two 3-NOP feeding scenarios were considered; 1) 3-NOP fed daily to the entire herd and 2) 3-NOP fed every 3 days, assuming a ruminal passage rate of 4 %/h, the effect of 3-NOP was assumed to decline linearly for 24 h. Gross revenue generated from methane mitigation was estimated through the sale of Australian carbon credit units (ACCU), which is the equivalent to one tonne of CO_2 abated, at a price of $11.82/t CO_2e. In scenario 1, feeding 3-NOP reduced whole farm GHG emissions by 29 %. The sale of ACCU increased gross revenue by $7,595/year or $20/head of grown steer and heifer (hd). With an average reference price of $998/hd, this scenario increased revenue by 2 %. Scenario 2 reduced whole farm GHG emissions by 4 %, generated an increase in gross revenue of $993/year or $3/hd which was an increase of 0.5 %. It is concluded that 3-NOP can make an important contribution to reducing whole farm greenhouse gas emissions. However, the effectiveness of feeding 3-NOP on whole farm GHG emissions was considerably diminished when 3-NOP was not fed daily. Further research into slow release delivery would therefore be a priority for extensive grazing systems.

Keywords: methane, ruminants, 3-nitrooxypropanol, LCA

Silvopastoral systems can reduce emissions and create multiple wins in cattle farming

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Traditional livestock production systems in Latin America – based on grass monoculture – tend to deplete natural resources in a process of continuous degradation. This process is currently exacerbated by the pressure of a globally increasing demand for food as well as climate change and hence it is imperative to identify livestock production alternatives which consider sustainability in the long term. Silvopastoral systems (SPS) are agroforestry arrangements that allow the intensification of cattle production based on natural processes.

Linked to the Global Agenda of Sustainable Livestock, Colombia – where silvopastoral systems form part of Colombia's NAMA commitments – was chosen as a case study. The introduction of silvopastoral systems was identified, specified and quantified with local producers, experts and researchers. Six case studies with different production systems (2 dairy, 2 dual purpose dairy, cow-calf, beef finishing) in different regions were selected. The transition from the existing systems to silvopastoral systems was analyzed from a performance, economic, environmental and animal welfare perspective using the methods and tools available from the *agri benchmark* Beef and Sheep Network. The results show in general an improvement of all criteria considered. The extent of the improvements depends on the level in the status quo situation.

- **Performance:** The SPS provide a better supply of fodder in terms of quantity and quality. This leads better individual animal performance and allows higher stocking rates. Thus, less land is required to produce the same quantity of animals, milk and meat.
- **Environment:** Reduction of greenhouse gases emissions were between 11 to 40 percent. A denser vegetation cover protects the soil from erosion, and there is a better use of groundwater. Trees and fodder shrubs' roots contribute to soil fixation, reducing the impact of erosive elements.
- **Animal welfare:** SPS have the potential to deliver optimal animal welfare, including good feeding, good housing, health and behaviour, especially where breeds are selected to be well adapted to the climate.
- **Economics:** Despite the disadvantage of requiring large initial investments, economic results are favorable after a period ranging from 3 to 6 years.

A briefing paper on the results is available from the *agri benchmark* Website. A report produced with the support of the Global Agenda of Sustainable Livestock is in print and includes new case studies in Mexico and Argentina.

Keywords: GHG-Mitigation, Milk production, Beef production, Silvopastoral systems, Economics

Evaluation of silvopastoral systems as a strategy to mitigate GHG emissions in the amazon tropics

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Deforestation in the Amazon Tropics of Peru has increased in recent years amounting to 10 million deforested hectares by 2015. This deforestation process being linked among other interventions to the inappropriate installation and management of pastures for livestock production that encourages the use of more sustainable production schemes with potential for mitigation of emissions such as silvopastoral systems (SPS). In that sense, Nationally Determined Contributions, as defined by the Peruvian government, contemplates a reduction of 30 % of the greenhouse gas emissions projected for the year 2030 considering among other strategies the recovery of degraded soils with SPS in the Peruvian Amazon to mitigate 1,344 MtCO2eq arising from the intervention of 102,000 has. It is important to consider that families in the same tropical area belong to the population group in the Peru with high incidence of malnutrition. As not integral evaluation of existing SPS in "high" Amazonian tropics has been done, we first conducted field assessment of prevalent silvopastoral units in that region. Results indicate that 54 % of them base their production on mixed farming practices (agriculture with corn and rice and livestock), allocating an average of 10 has of their land to livestock. mainly cattle, under traditional grazing management. In addition, it was found that 44 % of respondents use live fences and 47 % use dispersed trees as silvopastoral system arrangement. In order to contribute to their better understanding, it was identified important to develop a semi deterministic bio-mathematical model integrating in a logical and coherent way the interactions of the components and evaluation of various possible arrangements for the SPS in the Amazon Tropics. The model included forage, cattle, trees, soil and economic components with information obtained from representative SPS in the region. Results using this model with different arrangement of production factors of prevalent SPS are presented in relation to determine their impact on mitigation of emissions and on food security through changes in family income.

Keywords: Silvopastoral systems, mitigation, modelling

Challenges to implementing greenhouse gas mitigation measures in Welsh livestock agriculture: A conceptual framework

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Livestock agriculture in Wales contributed an estimated 13 % to total Welsh greenhouse gas (GHG) emissions in 2015. The sector is expected to mitigate these emissions as part of the Welsh Government's decarbonisation programme. Within the Climate Smart Agriculture – Wales project, work was undertaken to analyse challenges to implementing GHG mitigation measures on sheep, beef and dairy farms.

Data were gathered from 18 stakeholder organisations including farming unions, farm advisors, industry bodies, environmentalists, policymakers, consultants and researchers, and from farmers themselves, using semi-structured interviews and during two facilitated workshops. Participants were asked about the challenges to implementation in relation to options associated with different aspects of farm management (e.g. animal diet, husbandry, land management) as well as potential solutions. Thematic analysis (a form of grounded theory approach) was used to examine the data. This analysis seeks to draw out underlying categories from data to shed light on the research question, rather than fitting data to pre-defined classifications.

Analysis identified four categories of challenge: practical, knowledge and cognitive limitations, and interests (motives). These types of challenge map against two solutions categories: levels of change (working around, overcoming or altering challenges) and philosophy of change (facilitation, control, empowerment) underpinned by two further solutions categories: basis of change (referring to societal knowledge, communication skills and organisation capacity) and type of change (practical mitigation options or organisational changes).

The described categories form a conceptual model which can be used by stakeholders including policymakers to classify challenges that hinder the deployment of specific mitigation measures, and to evaluate and select the appropriate tools to support change. Future work will further explore and deepen the described concepts and their interactions, to compare the framework with similar conceptual models in the literature, and to test its applicability to other types of change in agricultural systems (e.g. implementation of climate change adaptation options).

Keywords: barriers to change, implementation, livestock systems, mitigation measures, stakeholders

Nitrogen and Rice Straw management for mitigation of CH_4 and N_2O Emissions under water saving paddy fields of Central Vietnam

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Growing rice with aerobic or AWD reduces CH_4 emissions, improves water productivity with variability in grain yield but results in increased N_2O emissions. Impact of nitrogen rates (0, 40, 80, 120 kg ha^{-1}) and fertilizer types (urea, ammonium chloride and calcium nitrate) including rice straw incorporated into soil (5 t ha^{-1}) or burnt in situ was assessed. The CH_4 and N_2O emissions, dry matter production and grain yield including water productivity were compared for rice grown with direct seedling or AWD (-5, -10 and -15 cm) in spring and summer seasons with continuous flooding (CF) of central Vietnam. Mean CH_4 and N_2O emissions decreased by 33 % and 20 % for urea than ammonium chloride at 120 kg N ha^{-1} in summer and spring seasons. Highest rice yields and agronomic N use efficiencies ranged from 6.09 t ha^{-1} to 6.45 t ha^{-1} at 120 kg N ha^{-1} and 20.8 to 22.5 kg grain yield kg N^{-1} for urea applied at 80 kg N ha^{-1} in summer and spring growing seasons, followed by ammonium chloride. While these gases emissions reduced and increased rice grain yield significantly using 80 kg N ha^{-1} urea following ammonium chloride. Likely, burning of rice straw in situ reduced 18–34 % and 21–32 % seasonal cumulative CH_4 and N_2O emissions in both growing seasons respectively concomitantly lowered rice yield by 8–9 % than rice straw incorporation. However, AWD reduced 22.6–41.5 % CH_4 production and increased N_2O emission by 25–26 % without any yield penalty while rice straw incorporation into the top soil had 23–37 % higher water productivity than rice straw burning in situ with CF irrigation. In conclusion, optimizing N fertilizer and rice straw management can be viable mitigation strategies for CH_4 and N_2O emissions under water saving paddy cultivation in Central Vietnam.

Keywords: GHG emissions, N rates and types, rice straw, rice yield, water regime

Recently discovered high nitrous oxide fluxes at rice farms worrisome but manageable with co-management of water and fertilizers

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Methane (CH_4) from global rice cultivation accounts for ~50 % of all crop related GHG emissions. Emissions of nitrous oxide (N_2O), a long-lived GHG, from rice farms are considered negligible relative to CH_4, a short-lived greenhouse gas. Based on an as of yet unverified assumption that almost all irrigated rice fields are continuously-flooded, the global community has focused heavily on alternate flooding and drying forCH_4 mitigation which, unfortunately, increases N_2O emissions.

During 2012-2015, as an integral part of our coalition's climate-smart rural development projects, we measured GHG emissions as well as soil, weather and management parameters at five non-continuously flooded farms across three Indian rice producing belts. At each farm, we compared results from conventional management practices with potential climate-smart farming practices.

We showed that N_2O emission rates can be three times higher (33 kg-N_2O ha^{-1} season^{-1}) than ever previously reported, and N_2O emissions increase inversely with the degree of flooding. Because of soil texture & irrigation related infrastructural constraints, non-continuous flooding at rice farms is likely much more common (especially in South-Asia, Africa and South America) than acknowledged in existing studies and/or in UNFCCC reports.

We quantified the potential global risk of a large climate impact due to rice-N_2O emissions through a geospatial extrapolation of observed correlations between N_2O emissions and multiple management parameters. This extrapolation suggests that under reduced flooding conditions, annual global rice-N_2O emissions might be 30 times higher than current estimates. The scale of this problem could be large (450–700 MMT CO_2e), potentially making the net climate impact from global rice cultivation equivalent to the national GHG emissions of India or Brazil (~1500–1930 MMT CO_2e).

Fortunately, we also showed that integrated co-management of water-levels with inorganic nitrogen and/or organic matter inputs can decrease climate net impacts by 60 %. Different scenarios will be discussed in our presentation.

Region-specific studies that map flooding-regimes at rice farms and measure effects of multiple co-managed variables on CH_4 and N_2O emissions are necessary to determine and lower the climate impacts of rice cultivation over both the short- and long-term. We also recommend visualizing the relative and time-dependent climate implications of different flooding regimes.

Keywords: Nitrous oxide, Rice cultivation, Alternate wetting and drying, Intermittent flooding, Climate smart agriculture

Bio-physical and Socio-economic Assessment for Scaling of Alternate Wetting and Drying in Vietnamese Rice Production

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Vietnam's NDC states that the country will reduce 8 % of GHG emissions unconditionally and increase this target to 25 % with international support. While Vietnam has included the agriculture sector in its NDC, this will automatically require mitigation in rice production which is responsible for around 50 % of agricultural GHG emissions at national scale. Water-saving techniques of irrigated rice, i.e. moving from continuously flooded fields to practices such as alternate wetting and drying (AWD), represent the main mitigation strategy because of high mitigation potential. However, identification of suitable areas for AWD is a pre-requisite for introducing AWD at larger scale. Furthermore, policy makers have to create economically enabling environments to foster uptake of AWD by farmers.

This presentation will explain the various steps involved in the multi-layered suitability mapping at province scale. A simple model to assess climatic suitability for AWD has been developed in order to identify high priority areas. This assessment has then been refined for target provinces through participatory suitability rating of the provinces by groups of local experts. This assessment at the lowest administrative units ('sub-districts') was necessary to identify local needs for investments, training, etc. The assessment was complemented by an analysis of costs and benefits associated with different farming practices.

Results for the example of Thai Binh province in the Red River delta show that almost the entire rice area of the province (>70,000 ha) is climatically highly suitable for AWD in the spring season while in the summer season less than 20,000 ha fall into this category with 30,000 ha still being moderately suitable. For both seasons the suitable rice area has further been reduced through the expert rating at sub-district level. The main barriers identified were low elevation of rice land and thus limited drainage capacity as well as poor irrigation infrastructure that hampers the application of AWD. In addition, economic factors that may influence the adoption decision were investigated. One substantial finding is that the irrigation subsidy that some farmers receive is found to significantly reduce the likelihood of AWD adoption.

Keywords: rice, Vietnam, water management, GIS, cost-benefit analysis

System of Rice Intensification (SRI) method for more rice production and less GHG emission

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Rice is a main staple food crop in Nepal. Its demand has been increasing and it becomes challenging by increasing rice production with reducing water use. Nepal faced acute shortage of food since last decade because of stagnant productivity of rice. Since then, efforts have been made into increasing the rice productivity. System of Rice Intensification (SRI) has emerged as an alternative, eco-friendly method to traditional way of flooded rice cultivation and is showing great promise to address the problems of water shortage by increase the rice yield. In an effort to evaluate the SRI adoption and potential environmental benefits of SRI. This study was conducted in Morang district of Eastern Nepal. For this study data were collected through household survey with structured questionnaire and field observations at weekly interval from seeding to harvesting. With SRI methods seed requirement was reduced by 80 percent, water use by 50 percent and the cost of pesticide was reduced by 90 percent. In addition, the farmers in the study area were found to achieve 80 percent increase in rice yield with SRI methods compared to conventional methods. Several studies investigated the effect of SRI on GHG emission particularly CH_4 and N_2O. In one study conducted in Morang district by used closed chamber method to collect the gas has found the emission of CH_4 from SRI soil exhibited 4 times less than that of non-SRI soil whereas N_2O flux from SRI soil was 5 times less than non-SRI soils. It is well known that rice field releases significant amount of CH_4 and N_2O into the atmosphere and that the global warming induced by the concentration of such GHGs is a matter for great environmental concern nowadays. SRI practices not only help to minimize CH_4 emissions but also reduce N_2O emissions. SRI practice was found to have double benefits: increase yield and have potential to reduce GHG emission to the atmosphere.

Keywords: GHG, Food security, SRI, Eco-friendly method, Rice

Mitigation in Rice Production Systems: Prioritization of Technologies and Practices based on Transformative Potentials

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Rice fields are a major source of GHG, namely through emissions of methane generated in flooded soils and – to a lesser extent – nitrous oxide from fertilization. Given the enormous diversity of rice production systems, GHG mitigation cannot be accomplished by a single (blanket) strategy, but will require a spectrum of technical options to be selected according to local settings. This presentation comprises a new prioritization framework which is illustrated for the most promising mitigation Technologies and Practices (T&P) in rice production: 1) Alternate Wetting and Drying (AWD), 2) Land Laser Levelling (LLL), 3) Alternative straw management, and 4) Short-duration varieties.

These T&P are assessed in terms of their transformative potential through a set of five criteria: A) Incentives for adoption by farmers (co-benefits) B) Geographic scope for different rice production systems, C) Mitigation efficiency, D) Alignment with policies and development projects, E) Innovative features for paradigm shift. The results from this assessment are displayed in spider-web diagrams that highlight the specific pros and cons of each T&P.

Unlike adaptation, possible mitigation options do not always provide direct incentives for farmers and thus, rely on co-benefits in terms of yield increase or reduced inputs. AWD reduces costs as long as farmers have to pump irrigation water, so its geographic scope will exclude non-irrigated rice and seasons with very high rainfall. Moreover, AWD also scores high with the other prioritization criteria which is even enhanced as long it will be combined with LLL. This new technology is not yet common in rice production, but is gaining momentum in many Asian countries.

While large quantities of rice straw are currently burnt on the field, this practice affects local air quality and also emits sizable amounts of GHG. High labor inputs for straw collection are currently constraining alternative uses, but ongoing mechanization will make the use of this biomass more profitable. Finally, variety selection affects GHG emissions because early maturing rice varieties reduce the flooding periods.

While this presentation addresses rice production as a whole, this newly developed prioritization framework will in the next step be applied for countries and sub-national scale. The goal is to identify the most appropriate set of T&P for any given region as a means to maximize their transformative potentials.

Keywords: Rice, mitigation, prioritization, incentives, scope

A new scientific assessment on changes in carbon fluxes and stocks in North America

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The Second State of the Carbon Cycle Report (SOCCR2) with a focus on North America, including contributions from the United States, Canada, and Mexico is about to be released. *The report includes relevant carbon management science perspectives and tools for supporting and informing decisions and impacts on societally relevant issues such as energy, food and fiber production. In addition to addressing the current state and identifying uncertainties in the carbon cycle, the report addresses projections into the next several decades, needs for improving measurements and projections, and opportunities for improved management to stabilize carbon stocks and reduce emissions.* This presentation will give some important highlights from the report that are particularly relevant to agricultural greenhouse gases Some examples of key findings are:

- The relevance of carbon cycle changes to people's everyday lives is clear and understanding how carbon is embedded in social systems reveals feasible pathways to reduce emissions.
- **Trends in food production and agricultural management can fluctuate significantly with changes in global markets, diets, consumer demand, regional policies, and incentives.**
- **Most carbon stored in croplands is in the soil but management practices can increase or decrease soil carbon stocks.**
- **Various strategies are available to mitigate livestock enteric or manure CH_4 emissions by up to 30 and 80 %, respectively.**
- **Demand for beef is diminishing in North America, dairy consumption is up and production of both has increased but the number of livestock has declined, thus there is a significantly lower GHG per unit of product.**
- US grasslands are carbon sinks, but smaller than forests and like the forests, uptake rate is projected to decline due to conversion to cropland.
- **Carbon stocks and net carbon uptake in grasslands can be maintained with appropriate land management including moderate levels of grazing or intensively managed grazing strategies.**
- Soil carbon stocks are sensitive to agricultural development and practices, global warming, and development and loss of carbon-rich soils such as wetlands. Soils have lost, on average, 20 to 75 % of their original top soil carbon with conversion to agriculture.
- The impact of soil movement across the landscape via erosion or management is highly variable, but soil carbon burial and accumulation of carbon in eroded soils is estimated to have caused a net carbon sink since 1850.

Keywords: carbon cycle, soil carbon, grasslands, methane, North America

Transforming Indian Agriculture into Climate Friendly by Reducing Nitrous Oxide Reduction through Need Coated Urea

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Two factors, viz., meeting food grain demand by growing population and increased consumption of animal protein would warrant agricultural production to be increased in most of Asian countries in years to come. As the option of bringing new land into cultivation is not available, intense agriculture with increased use of agrochemicals, such as Urea, appears to be most possible course of agriculture in coming decades and it would increase GHGs. For instance, increased use of Urea will contribute to proportionally higher emission of Nitrous Oxide through volatilization, thus presenting a Catch 22 situation. If volatilization of Urea reduced, emission of nitrous oxide could also be reduced to that extent. In addition, subsequent contamination of groundwater with Nitrate can be reduced and also inputs costs would also decrease for farming community and that could be Win-Win Situation of lower GHG emission and better Use of Urea as well and fortification of Urea in India offers that.

India, by 2030, will become most populated country and to feed them it need to produce an additional 100 million tonnes of food grains, hence, it has to adopt intensive agriculture leading to increase N_2O emissions from N fertilizer use. Currently, N_2O from N Fertilizer application is about 268.70 gigagram and projections indicate that it would touch 41.6 million tons by 2020–21 and so is N_2O emissions, affecting India's commitment to reduce GHG emission under Intended Nationally Determined Contributions. In such background, Indian Government decision of making Neem (*Azadirachta indica*) seed oil Coated Urea (NCU) mandatory and ban of normal urea use. Indian scientific body has proven that Neem coated Urea (40 ml per ton of Urea) has lower solubility and volatility than normal urea. It has made more urea available to crop as a) it reduced volatilizaiton losses, b) reduced solubility has resulted in mach between crops urea uptake efficiency and available urea to crop, thus preventing leaching loss as well. This shift over was made from 2016 and initial studies report that there has been about 10 per cent decrease in urea and this reduction in urea use is expected to increase in coming years.

This simple but scientific innovation may also be encouraged in other countries where the field conditions promote volatilization of Urea into Nitrous Oxide to reduce GHG emissions and also increase farm productivity.

Keywords: Nitrogen Fertiliser Use, Green House Gases Emissions, Need Coated Urea, Reduced Nitrous Oxide Emissions, Reduced input costs

Climate smart reduction of N fertilizer for a cost-efficient GHG mitigation

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The intensification of N fertilizer use in agriculture over the last decades made it possible to feed the growing world population. Nevertheless, it led to concerns on environmental harms, including GHG emissions. A reduction in N fertilization can mitigate GHG emissions, nonetheless, it may result in crop yield penalties and consequently income loss. The magnitude of yield loss depends on how yields respond to reduced N supply. Yield responses differ due to plant genetic variability, climate and soil properties. Therefore, assessment tools are necessary to understand the dynamics of N management issues both in environmental and economic aspects, and also at low and high aggregation levels. There is lack of studies identifying costs of GHG mitigation by selective N supply reduction considering differences in yield response to N. This may have an impact on GHG mitigation cost structures, and thus, underestimate the economic relevance of site-dependent GHG mitigation potentials. Our study presents a model approach based on transformation of empirical data for winter wheat and winter rye from two long-term field experiments with yield response data to N, to estimate site-dependent GHG mitigation costs. The response data were used to build yield functions based on a normalization approach to simulate the implications of N reduction on GHG mitigation potential at five yield-zones with different soil fertility in the state of Brandenburg, Germany. The study aimed at identifying the comparative costs of GHG mitigation by N fertilizer reduction at yield-zones with different crop yield responses to N. Results suggested that differences in yield response lead to considerable differences in GHG mitigation costs. Overall, cost-efficiency of GHG mitigation by N fertilizer reduction can be substantially improved, if crop and site-dependent yield responses are taken into account. The output of this study can be used as an aiding tool to design cost-efficient agri-environmental policies targeting sites with specific crop yield response functions.

Keywords: yield response function, economic optimum, social optimum, agri-environmental policies, comparative advantage

The challenge of reducing carbon footprint and promoting food quality – A pilot study on durum wheat in Italy

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The cultivation of durum wheat is an important and strategic sector, not only for the primary sector but also for the whole food value chain in Italy. To respond to the double challenge of quality and sustainability, this sector is also looking for innovative strategies that are able to guarantee high quality raw materials for pasta production and to improve the sustainability and resilience of cereal cropping systems. Sustainability is becoming an important condition to meet the consumer expectations and, thus a competitive advantage for firms that can guarantee the monitoring of the processes' environmental performance.

The use of innovative decision support systems (DSS), combined with durum wheat supply contracts, could be an effective response to the needs of the various operators in the supply chain. The ICAFRUD pilot study made it possible to evaluate the results achieved by the cereal growers who have adopted the Sustainable Cultivation of Quality Durum Wheat proposed by Barilla compared to the ordinary management of the crop represented by farms belonged to the sample of the Farm Accounting Data Network (FADN). A web-based DSS (granoduro.net®) was made available to farmers who agreed to follow the guidelines proposed by Barilla by signing a cultivation contract. A pilot survey was conducted on a sample of 136 FADN farms, data from last four agrarian seasons was collected and used to estimate the carbon footprint of durum wheat cultivation processes. Technical, environmental and economic indicators were used to explore the trade-offs and the win-win solutions emerging from innovative management strategies.

Although the pilot study was conducted on a limited number of farms, the first results – also assessed with specific statistical tests – seem to highlight the greater sustainability and better quality of durum wheat produced by cereal growers that decide to sign supply contracts and follow the technical advices of granoduro.net®. The results from the pilot study suggest that taking better account of farmers' preferences (economic, social and cultural) should be the main approach to enhancing cultural sustainability and ensuring long-term trust on innovative management strategies between agri-food value chain actors. Looking at these results from a market perspective, the transition to sustainable practices could lead to certification of benefits (carbon credits) in terms of reduced GHG emissions.

Keywords: carbon footprint, sustainability, contract farming, durum wheat, agricultural technology

Fertiliser type controls N_2O emissions on wet grassland soils

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Fertiliser nitrogen (N) is a cornerstone input in many intensive agricultural systems including those prevalent in Irish temperate grassland. However, N fertiliser is associated with environmental loss of the potent greenhouse gas nitrous oxide (N_2O). Agriculture faces the challenging target of reducing greenhouse gas emissions while also remaining economically competitive. Nitrogen fertiliser form and the use of N stabilisers have potential to improve fertiliser efficiency and reduce N_2O emissions while maintaining production. Five N fertiliser formulations; 1. calcium ammonium nitrate (CAN), 2. urea 3. urea+NBPT 4. urea+DCD and 5. urea+NBPT+DCD were evaluated for agronomic and environmental performance on three Irish grassland soils. The study followed a randomised block design with 6 replicates per treatment. The static chamber technique was used to measure N_2O and NH_3 was measured using wind tunnels. Emissions of the greenhouse gas N_2O were highest and most variable for CAN which had an emission factor (EF) of 1.49 %. Emissions for the urea treatments were lower at all site-years, mean emission factors were 0.25, 0.4, 0.11 and 0.11 % for urea, urea+NBPT, urea+NBPT+DCD and urea+DCD, respectively. N_2O emissions from urea fertilisers were less variable than CAN with CVs ranging for urea based treatments 14–38 % compared to 61 % for CAN. Thus urea based fertilisers reduced N_2O emissions by 58–87 %. All fertiliser options gave similar grass dry matter annual yields across the sites and years, with the exception of urea+DCD which had significantly lower yield than the other treatments at three site-years. Urea and urea+DCD had significantly lower apparent fertiliser N recovery efficiency than CAN and urea+NBPT which were consistently equal. The urea+NBPT treatment had significantly lower NH_3 emissions compared with urea; on average 78.5 % lower. Switching fertiliser type from CAN to urea stabilised with NBPT and DCD is a tool that reduces N_2O emissions by 58–87 %. The use of NBPT with urea does not substantially increase NH_3 emissions. Urea with NBPT matches the grass yield and N fertiliser recovery of CAN on Irish grassland soils while reducing N_2O emissions and not increasing NH_3 emissions. Fertiliser formulation including the use of nitrogen stabilisers is a useful tool for meeting agronomic and environmental goals without reducing the N rates that underpin production.

Keywords: fertiliser type, nitrous oxide, mitigation, wet soil

The Full Lands Integration Tool and moja global: New systems to support advanced integration in GHG inventory systems

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Estimating emissions from agriculture and the land sector is a complex task. To provide policy relevant information, emissions estimation systems require inputs from experts across many different fields from agricultural scientists, foresters, ecologists, modelers, GIS and remote sensing experts and land managers. While much of the core science that underpins emissions estimation is completed on specific species or land management systems, the knowledge and data generated by these groups eventually needs to be brought together in a system that meets the policy and reporting requirements. However, due to the challenges in developing a single, coherent framework to integrate these data, we often see separate, and non-consistent, systems being developed for different land-uses and policy questions.

While this approach can work for the single purpose of national scale estimates, with the increasing focus on mitigation actions, systems have to do more than just estimate past emissions. Increasingly policy makers need information on how changing land management practices effects emissions, as well as competitiveness, costs and productivity. All of these factors need to use consistent data and systems if the advice is to be useful. To produce results for the whole land sector requires more advanced data integration systems.

Moja global aims to remove the barriers for countries and allow them to rapidly move to more advanced systems. Moja global is a new open source project under the Linux Foundation that is supporting the development of a new, generic integration tool the Full Lands Integration Tool (FLINT). Collaboration between countries and sectors on the same tool allows for specialisation while ensuring the results can be integrated into the land-sector wide estimates. Further, a generic integration tool such as the FLINT, serves as a framework that allows for countries to design their systems more easily. This includes model and data selection, and driving outputs.

Together, moja global and FLINT provide a new and unique data integration solution that all users can contribute to and benefit from. This presentation will highlight this opportunity and describe the process of developing the FLINT, including key policy and reporting issues, the technical challenges and the role of commercial-style open source processes.

Keywords: integration, whole-land-sector, consistency, open source, MRV

Land management impact on soil organic carbon stocks – what do we really know?

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Agricultural management depletes soil organic carbon stocks with global impact on the carbon cycle. However, there are several management options that aim at recovering the lost carbon and aim to sequester additional carbon. We reviewed several of these options performing quantitative meta-analysis in order to compile existing knowledge on their impact on soil organic carbon stock. Land use change from grassland to croplands had the strongest impact on total soil carbon stocks with 30 to 40 % less carbon in tropical and temperate croplands as compared to grassland. Our result revealed that measures that increase the carbon input to the soil are the most effective to enhance soil organic carbon stocks. Regular cultivation of cover crops during winter season and subsequent use a green manure could increase soil carbon stocks by 300 kg ha^{-1} a^{-1}. In contrast, reduced or no-tillage did not significantly increase soil carbon stocks in temperate soils but only redistributed carbon in the soil profile. Moreover, no-tillage increased nitrous oxide emissions which strongly affected the greenhouse gas balance of no-tillage fields as compared to conventional tilled fields. Opposing to reduced tillage we also assessed the impact of deep tillage down to 100 cm and its long term effect on total soil carbon stocks. Surprisingly, we found more than 40 % higher soil carbon stocks several decades after the deep ploughing event. We also explored new management techniques related to bioenergy production such as plantations of Miscanthus or short rotation coppice. Such perennial crops partly also increase soil carbon stocks. Soil carbon sequestration should be one out of several measures to combat climate change. However, in order to implement agricultural soil carbon management, our abilities need to be increased to better site specifically predict the effects of different land management options. With our extensive meta-analysis on different land use and management options with contributed to compile scattered knowledge into a more comprehensive picture. Agricultural measures to enhance soil organic carbon should aim at synergies with other soil functions such as nutrient and water retention.

Keywords: Soil organic carbon, land management, C sequestration options, tillage

High resilience of soil carbon stocks to grassland intensification

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Human-managed grassland soils have the ability to accumulate and sequester carbon (C) thus potentially acting as terrestrial sinks of atmospheric CO_2. Increases in soil C stocks not only contribute reducing the C-footprint of intensively managed grassland ecosystems but also lead to significant improvements in soil health. There is, however, high uncertainty associated with the degree of resilience of these grassland soils to management intensification. In particular soils' ability to conserve and/or enhance C stocks through time can be greatly affected by repeated additions of nutrient fertilizers or by frequent soil tillage associated with the practice of grassland reseeding.

In this paper we specifically ask how soil C stocks might respond to (i) repeated nutrient additions to permanent grassland over 47 years, and (ii) the frequency of plough & reseeding events which have occurred over 50 years in 126 grassland fields across 11 farms in Northern Ireland, UK. We estimate soil C stocks resilience by quantifying (1) rates of soil C stocks change over 47 years of repeated inorganic and organic nutrient fertilization, (2) C stocks changes in increasingly deeper soils from 0 to 90 cm soil depth, (3) the contribution of different soil aggregate fractions to overall soil C pools and at different soil depths, and (4) the response of soil C stocks to changes in tillage frequency over > 50 years of grassland management.

We found evidence of high soil C stocks resilience to grassland intensification including (1) soils' ability to actively sequestering C for decades (e.g. soils have not yet reached C saturation after 47 years of different nutrient fertilization regimes); (2) changes in either total soil C stocks or in the C pool of different soil physical fractions (after 47 years of management) were only significant in the top 20 cm (not in deeper soils) and only between extreme treatments (i.e. unfertilized vs. highly fertilized soils with organic nutrients from animal liquid manures); (3) frequency of soil disturbance measured as number of 'plough + reseeding' events occurred over 50 years has not affected soil C stocks or C allocation into different soil physical fractions.

Our study suggests that grassland soil C stocks can be quite resilient to management intensification thus showing mitigation potential while sustaining plant biomass production.

Keywords: Agricultural grasslands, nutrient fertilization, soil tillage, animal manures, soil carbon saturation

Impact of forage production and conversion of coastal grasslands of Ghana on soil carbon stock and soil quality

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Enhancing the capacity of forage production systems to sequester carbon could help reduce the high carbon footprint associated with ruminant livestock production in sub-Saharan Africa. Nevertheless, pasture screening programmes rarely consider the carbon sequestration potential of species being screened. This study evaluated the impact of some tropical forage species established in the coastal grasslands of Ghana on soil carbon stock and soil nutrient pool. It also investigated the relationships between forage polyphenols (tannins) and soil carbon storage. Soil samples (0–30 cm depth) and biomass samples were taken from over 40 year-old forage plots containing pure stands of 58 different species, consisting of 11 herbaceous legumes, 38 C4 grasses and 9 shrubs. Additionally, soil samples were taken from seeded grazing fields, food-crop fields and natural vegetation located close to the forage plots. Soil carbon stocks in the study area ranged from 16.6–64.1 *ton C/ha* (*mean±s.e* =33.1±1.13 *ton C/ha*) and were lower ($P<0.01$) for grazed seeded-pasture fields and herbaceous legume plots compared to the other land-use categories, except for non-legume browse plots. Conversion of natural vegetation in the study area to agriculture resulted in a mean loss of 2.42 *ton C/ha*, with grazed seeded-pasture fields registering the highest loss (15.4 *ton C/ha*). *Paspalum dilatatum, Macroptilium atropurpureum (Siratro) and Cajanus cajan* topped the group of grasses, legume herbs and browse species, respectively, with 64.1, 45.6 and 61.1 *tons C/ha*, respectively. Soil N reserves ranged from 1.0–4.9 *ton N/ha* and were lower ($P<0.01$) for legume herbs compared to fodder grass. Whereas *CN* ratio was similar ($P>0.05$) among the land-use categories, a regression test showed strong positive correlation ($r=0.86$, $P<0.0001$) between soil C-change and soil N. Plant available *P* ranged from 0.04–4.7 *ton P/ha* and were higher ($P<0.01$) for crop fields compared to fodder grass, grazing fields and legume herbs. K reserves ranged from 0.72–8.8 *ton/ha* and were only higher ($P<0.01$) for food crop fields compared to the other land-use categories. Soils were acidic (pH ranged from 4.1–6.7) but were more acidic (P<0.0001) in grazing fields and legume herb plots. Polyphenol concentrations were lower ($P<0.01$) in legume herbs compared to legume browses. A regression test between change in soil C stocks and extractable tannins yielded a correlation coefficient of $r=0.68$, ($P<0.01$). With tannins having been observed to positively affect carbon sequestrations, further research with experiments using these plant species seems promising. Generally, it can be said that increased N input, improved grazing land management and adoption of crop plants with enhanced soil C sequestration potential could reverse the declining soil C stock in the study area.

Keywords: C4 grasses, carbon sequestration, polyphenols, soil nutrients, sub-Saharan Africa

Realising the global technical, economic and social potential of soil carbon sequestration as a greenhouse gas removal technology

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In order to have a greater than 50 % chance of avoiding warming of more than 2 °C, most integrated assessment models (IAMs) rely on the large-scale deployment of greenhouse gas removal technologies (GGRTs). One such GGRT is the sequestration of soil carbon in agricultural land (SCS). In addition to its role in mitigating climate change, SCS is also critical for the maintenance of soil quality and food security and growing recognition of this is reflected in its incorporation into international initiatives such as the four-per-mil (4 ‰) proposal.

Several factors challenge the practical application of SCS. The complexity of the field means that there exists a disconnect between bottom-up reviews of the primary literature, and broader top-down integrated assessments. The former focus on specific regions or practices, yielding precise estimates, but extrapolation of these is problematic. The latter implicitly consider existing systems and practices, but provide limited insight into the practical realisation of estimated potential. This analysis seeks to close this gap. The novelty of this approach lies in a) the breadth of the scope of practices considered, b) the distillation of available practices into a subset of specific measures, and c) the multi-disciplinary discussion of the barriers and potential pathways toward practical implementation of these practices.

Initially, specific practices which have the potential to positively impact SCS at farm level are identified. These practices focus on:

1. increasing productivity (e.g. nutrient optimisation, pH management, soil water management),
2. reducing soil disturbance and maintaining soil aggregate stability (e.g. improved rotations, minimum till),
3. minimising lateral transport of soil carbon via erosion processes (e.g. support measures, bare fallow reduction),
4. addition of externally produced C to the system (e.g. organic manure amendments, biochar addition),
5. provision of additional C inputs in the cropping system (e.g. agroforestry, cover cropping).

Following this, we consider the potential intended and unintended impacts of implementation of these measures, providing a framework and reference point for holistic assessment of the impacts of SCS implementation. Finally, we summarise and discuss the ability of extant scientific approaches to provide policy makers with the means to identify and unblock barriers to implementation of SCS in global agricultural systems.

Keywords: soil carbon, carbon sequestration, greenhouse gas removals, agriculture

3 Cost and implementation

Abstracts in alphabetical order

Farmers' preferences for an agri-environmental measure designed for climate friendly peatland management

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Well-managed, agriculturally used peatlands play an important role for the storage of greenhouse gases. A new agri-environmental measure (AEM) was established in the European Common Agricultural Policy to incentivise land management, which conserves climate functionality of peatlands through high water levels.

To investigate which factors influence the willingness of farmers to participate in this measure, we carried out an empirical study applying a discrete choice experiment (DCE). We conducted a survey among farmers in Northern Germany, and 3000 letters were sent to farmers in postal areas that have a high share of peatlands. The aim is to identify optimal contract designs for farmers. Along with a monetary element, we especially focus on the role of non-monetary attributes that are relevant for farmers' willingness to participate, such as support for cooperation with neighbouring land managers, and regional value chain approaches (guaranteed purchase of cut grass, e.g. through a local bio-energy power plant).

Results show that the average willingness to adopt the measure is set at 522 €/ha*a. Based on the model results the compensation payment could be significantly reduced by two means. First, offering support for cooperation by the water and soil associations would reduce the minimum financial compensation level by 53 €/ha*a. Second, new value chain approaches, such as the guaranteed purchase of the cut grass would reduce monetary compensations by 77 €/ha*a. As a result, under an adjusted design farmers would be willing to participate in the scheme for a compensation of 392 €/ha*a.

Considering the costs of the climate friendly peatland management AEM and the avoided greenhouse gas (GHG) emissions, we can estimate the price of metric tonnes CO_2 equivalent. Through the change from drained medium-intensive grassland management to extensive wet grassland management about 15 t CO_2-Eq/ha*a emissions could be avoided. Hence, combining the costs of 522 €/ha*a and the 15 t CO_2-Eq/ha*a avoided GHG emissions, the price for saved carbon is calculated as 35 €/t CO_2-Eq.

We conclude, a mix of governance mechanisms consisting of I) AEM targeted at climate friendly peatland management II) support for cooperation among farmers III) Value chain opportunities through market innovations could increase the climate protection potential of the proposed measure.

Keywords: Agri-Environmental Measure, Climate Change, Farmers' Preference, Discrete Choice Experiment, Transaction Costs

An Analysis of Abatement Potential of Greenhouse Gas and Ammonia Emissions in Irish Agriculture to 2030

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A marginal abatement cost analysis was used in order to assess the abatement potential of a range of mitigation measures, as well as their associated costs/benefits on both greenhouse gas (GHG) and ammonia emissions for the period 2020–2030. This analysis was necessitated a) by increases in Irish agricultural output that have occurred post milk-quota removal and as a consequence of the national FoodWise 2025 initative and b) requriements to achieve national GHG and ammonia reduction targets. The achievement of these targets are challenging considering that agriculture comprises 32 % of GHG and 98 % of national ammonia emissions.

Measures were sub-divided into four different categories: a) Measures with reduced agricultural GHG (i.e. directly reduce methane and nitrous oxide); b) measures that reduced ammonia, c) Measures which enhance CO_2 removals from the atmosphere in terms of land management or Land-Use, Land-Use Change in Forestry (LULUCF), and d) reductions from displacement of fossil fuels via enhanced cultivation of biomass and/or adoption of anaerobic digestion.

The total level of GHG abatement of all three categories averaged over the period 2021–2030 was 6.9 Mt CO_2-e yr^{-1}. When broken down between subsectors, the total mean abatement potential arising from cost-beneficial, cost-neutral and cost-effective mitigation measures for agricultural emissions (methane and nitrous oxide) and assuming linear rates of uptake was 1.91 Mt of carbon dioxide equivalents (CO_2-e) per annum from 2021–2030 with over half of this potential either cost beneficial or cost-neutral. Nitrogen management and animal breeding were identified as the most effective options. The enhancement of CO_2 removals, particularly from afforestation and management of high organic soils could potentially remove another 2.94 Mt CO_2-e from 2021–2030 reaching a maximum of 3.25 Mt CO_2-e by 2030. The cultivation of biofuel / bioenergy crops, and AD has potential to account for a further reported reduction of 2.05 Mt of CO_2-e per annum by 2030, mainly associated with the displacement of fossil fuel usage. In terms of ammonia, the abatement potential was estimated between 17–21 kT NH_3 by 2030, with urea substitution, N management, low-emission landspreading of manures and slurry acidification identified as the primary abatement strategies.

Keywords: MACC, ammonia, GHG, AFOLU

Cost-effective measures for agricultural greenhouse gas emissions in Uganda

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Agricultural activities in Uganda have been and remain a substantial contributor to greenhouse gas (GHG) emissions, accounting for about 60 % of Uganda's anthropogenic non-carbon dioxide GHG emissions and 16 % of all anthropogenic GHG emissions, and agriculture is often viewed as a potential source of relatively low-cost emissions reductions. The costs of GHG mitigation is estimated, taking into account net GHG reductions, yield effects, livestock productivity effects, commodity prices, labour requirements, and capital costs where appropriate. For croplands and rice cultivation, we use biophysical, process-based models to capture the net GHG and yield effects of baseline and mitigation scenarios for different areas in Uganda.

Keywords: Cost-effective, Measures, Agricultural, Greenhouse gas emissions, Uganda

Greenhouse gas emissions from Indian agriculture, mitigation options and associated costs

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This paper describes an analysis of GHG emissions and mitigation potential of Indian agriculture that are sensitive to climate, soil and management conditions. We used a range of data sources including India's 'cost of cultivation survey' and the '19th livestock census' together with soil, climate and management data for each location. Mitigation options together with associated costs and benefits were identified for croplands, livestock and restoration of degraded land using a range of sources including published literature, stakeholder workshops and expert opinion. Results are presented in the form of Marginal Abatement Cost Curves (MACC). We estimate that by 2030, business-as-usual GHG emissions from the agricultural sector in India as 515 million tonne CO_2e ($MtCO_2e$) yr^{-1} with a technical mitigation potential of 86 $MtCO_2e$ yr^{-1} and ca. 80 % of which could be achieved through adoption of mitigation practices that increase yield and/or reduce costs of inputs and so are cost negative. More than half of the technical mitigation potential by 2030 could be achieved through adoption of three mitigation options: efficient fertiliser use, zero-tillage and water management in rice. The implications for policies and incentives to promote large-scale adoption of these mitigation practices in the context of Indian agriculture are discussed.

Keywords: Greenhouse gas, Agriculture, Climate Change, mitigation, Marginal abatement cost curve, India

Tunisian Greenhouse Gas emission and methane mitigation options

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Most of world's rural population, especially in the Mediterranean areas, depends on livestock for their livelihood. To reduce poverty, fight hunger and ensure global food security, the increase of livestock production was adopted as a sustainable strategy. However, livestock industry, including the raising of cattle, sheep, goat, pigs and poultry and the manufacturing of meat and dairy products, is a significant source of greenhouse gas (GHG) emissions worldwide. The six main GHGs which have a direct impact on climate change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6). Emissions of CH_4, N_2O, HFCs, PFCs and SF6 can be converted to CO_2 equivalents. HFCs, PFCs and SF6 do not occur naturally in the atmosphere but have been introduced by human activities such as industry, agriculture and energy generation. For about a thousand years before the industrial revolution, the amount of GHG in the atmosphere remained relatively constant. However, since 1970 total concentration of GHG has increased by more than 80 % and since 1990 by 45 % to reach 54 Gt CO_2eq. in 2013 against 49 Gt CO_2eq. in 2010.

In Tunisia, four complete greenhouse gas inventory operations have been carried out in the past, bringing the number of years of complete inventory to 5 years. According to the last inventory, Tunisia's net emissions reached 32.6 million tons of CO_2 equivalent (tCO_2) in 2012. Dominance was accorded to CO_2 emission (69 %) followed by CH_4 (21.9 %) and N_2O (7.9 %). The same inventory revealed that agriculture, forest and use land (AFUL) are the major contributor to global GHG emission (11 million tons). Livestock contributes by 26 % of the global GHG issued from AFUL, principally in CH_4 (2.6 million tons) and N_2O (0.23 million tons) form.

GHG emissions in Tunisia are projected to increase significantly in the future due to increased demand for agricultural products and changing consumption patterns (e.g., increased meat consumption). Therefore mitigation options of CH_4 emission will be recommended as when as it has not result in an increase in the emission of other GHGs such as CO_2 and N_2O. We have to keep in mind that farmers will adopt the solution only if there is a positive economic impact on animal production and farm profitability.

Keywords: Greenhouse gase, Tunisia methane mitigation monitoring

Exploring technical and political measures for agricultural greenhouse gas mitigation in Switzerland

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According to the national greenhouse gas (GHG) inventory, agriculture causes 15 % of all Swiss emissions. In 2011, the Federal Office for Agriculture developed the *Climate Strategy* for Agriculture, with the target to reduce these emissions by 2050 by one third with technical measures and by two thirds with a corresponding development of consumption patterns. In the course of the revision of the Swiss CO_2 Act, this target will be incorporated into the agricultural legal provisions, strengthening the commitment.

This study explores the mitigation potentials of approximately 20 technical and political mitigation options. A grouping along two axes, *demand-side vs. production-side* and *process-oriented vs. target-oriented* options, is proposed. Emphasis is placed on the technical potentials without detailed consideration of practical feasibility. The assessment is based on a compilation of literature data and subsequent modelling and upscaling of the potentials within the framework of the national GHG inventory. Emissions beyond the respective system boundaries are not considered.

Results show that in general demand-side mitigation options have the greatest potential. Yet, the way in which the necessary behavioral change can be achieved is unclear. The modelling of a consumption levy on meat and milk, for example, shows limited effects. Production-side options usually have small potentials, though target-oriented measures could promote the simultaneous implementation of many technical measures. An example is a system of maximum allowable nitrogen surpluses. Such arrangements allow flexibility for individual farms to exploit site-specific potentials. The effect of the latter however remains limited as long as the major emission sources from enteric fermentation and manure management are not addressed. Major potentials might also lie in the field of soil carbon sequestration. However, several drawbacks such as large uncertainties, reversibility and saturation effects should be clarified.

In conclusion, the results suggest that the intermediate target of the Swiss *climate strategy* for agriculture can be met by demand-side mitigation options. Likewise, the objective can theoretically be achieved by combining a set of technical production-side measures. Uncertainties in the implementation as well as possible negative side effects and prohibitive costs of production-side measures suggest that demand-side options should be emphasized much more than was previously the case.

Keywords: mitigation measures, National GHG Inventory, agricultural policy

The role of agricultural intensification in Brazil's Nationally Determined Contribution on emissions mitigation

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Brazil has become the first developing country to provide an absolute emissions cut as its Nationally Determined Contributions (NDC), which seeks to reduce total greenhouse gas (GHG) emissions by between 37 % and 43 % below 2005 levels by 2025 and 2030 respectively. The majority of the NDC mitigation potential is noteworthy in focussing on emissions from deforestation control and land use change. The NDC also states an ambition to achieve zero net deforestation in the Amazon by 2030. Agricultural intensification in beef cattle systems via restoration of degraded pastures is a key component of the offer, potentially allowing the country to make credible mitigation commitments aligned with a national development strategy of halting deforestation by land sparing while increasing livestock production. This apparent contradiction is potentially resolved by understanding the technical, economic and policy feasibility of intensification via pasture restoration and but also animal efficiency measures. We use bio-economic modelling to estimate the cost-effective mitigation potentially delivered by these measures, which we represent on a Marginal Abatement Cost Curves (MACC). Our results suggests the restoration of around 20 Million hectares (M ha) of degraded pastures from 2020-2030 is necessary to meet demand and the zero deforestation target by 2030 via land sparing. The study provided the basis of the livestock sector contribution to the NDC, and highlights the on-going role of effective deforestation control policies. It also contributes to the global debate on land sparing by sustainable agricultural intensification.

Keywords: Mitigation; sustainable intensification; Deforestation; MACC; NDC, NAMA

Mitigation targets for agriculture in the German Climate Action Plan 2050

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The Climate Action Plan 2050 adopted by the German government in November 2016 sets domestic greenhouse gas mitigation targets in line with the Paris Agreement, and defines measures in the areas of energy, buildings, transport, industry, agriculture, land use and forestry. In this contribution, results of an impact assessment on the implementation of the Climate Action Plan 2050 in agriculture and agricultural land use are presented. The analysed mitigation measures will be presented with regard to mitigation potential, abatement cost, possible leakage effects, socio-economic effects, impacts on other environmental goods and potential policy instruments supporting their implementation.

While the German overall greenhouse gas reduction target until 2030 is 55 % compared to 1990, agricultural emissions shall be reduced by 31 to 34 %. Although the mitigation target for agriculture is lower compared to all other sectors, and current agricultural emissions are already about 18 % below 1990 levels, the remaining emission reductions pursued will require considerable additional effort.

One of the key measures is a significant improvement of nitrogen use efficiency in agriculture, while curbing ammonia emissions by about 30 %, in order to reduce N_2O emissions. A further increase of N use efficiency is possible using available low-emission technologies e. g. for fertiliser and slurry application, and with improved fertiliser management. Farm level data show that many farms already reach efficiency levels fairly above the average. The challenge is to implement better technologies and management area-wide.

Another important mitigation option is the increase of slurry and manure used for biogas production, thus minimizing CH_4 emissions from manure management. Currently, about 17 % of slurry and manure is used in biogas fermenters. However, estimates of feasible amounts available for biogas production exceed 60 %. To exploit this potential, new policy measures for improved manure management would be required.

There are a number of other measures mentioned in the action plan: The area of organic farming shall be expanded which will contribute to the reduction of N_2O emissions. With regard to agricultural land use, conversion of grassland to arable land shall be restricted, and emissions from drained organic soils are to be reduced. Finally, with a view to the food value chain and food consumption, food loss and waste shall be reduced.

Developing investment plan for low emission development interventions from rice production in Vietnam's Nationally Determined Contributions

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In Vietnam, rice is the most important crop. In 2010, the GHGs from rice production was estimated at about 88.36 million tons of carbon dioxide equivalent ($MtCO_2e$), which accounted for 33.2 % of the total national GHGs emission. Given the fact that Vietnam committed to reduce the GHGs up to 25 %, applying LED interventions in rice production has significantly contributed to the implementation of NDCs. CCAFS and USAID supported the conduct of this study aimed at supporting the NDCs implementation and specifically in developing a plan for domestic investment and identifying the most promising international finance sources for LED interventions in alternative wet and dry (AWD) and mid-season drainage (MSD) in rice cultivation. A package of methodologies was applied including policy gap analysis, PRA, bottleneck analysis, SWOT, CBA and MACC. The study found out that there are plenty of relevant policies, national strategies and plans to support GHGs emission reduction and many policy levers to support LED interventions. In fact, some of them have too ambitious targets in the context of limited supportive sources and unspecific regional priority for AWD and MSD. The study also showed that AWD is one of the most important technical solutions in the NDCs implementation plan, which has high potential for GHGs emission reduction and results in higher returns of 9.43 % to 22.91 % (equivalent to 2.16 to 5.67 million VND/ha as compared to conventional rice cultivation). With these results, the study developed the plan for investing in AWD and recommended that the government should consider improving institutions and policies; enhancing capacity for policy-makers, private sector partners and farmers; building national capacity for NDCs implementation in general, and for AWD in rice production in particular; and improving the coordination and collaboration mechanism for AWD in rice production to mobilize domestic and international financial sources. Domestic sources might include action plans for responding to climate change, sectoral and national GHG emission reduction project, agricultural restructuring program, national targeted program in building new rural areas, socio-economic development plans, and investment from enterprises and private partners, while international sources could be GEF, IKI, NAMAs, loan and technical assistance from international development banks, and bilateral and multilateral sources.

Keywords: Alternative Wet and Dry Irrigation (AWD), cost and benefit analysis, rice cultivation, low emission development, national determined contribution

Climate change beliefs and behaviour – Why (or not) farmers adopt GHG mitigating production practices in Canada

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With roughly 10 % of greenhouse gas (GHG) emissions in Canada coming from agricultural sources (ECCC 2017), climate policy in agriculture provides a considerable GHG reduction potential, if producers can be swayed towards GHG mitigative practices.

While the literature offers insights mainly into economic rationales behind adoption decisions, the latency in which decision maker's values and beliefs surrounding climate change affect GHG mitigative adoption behaviour remains vague (Baumgart-Getz et al. 2012). Yet, knowledge of how latent values, beliefs and attitudes facilitate or oppose adoption decisions under alternative policy and delivery frameworks may play a key role in achieving often-ambitious sector GHG targets. This project quantifies the impacts that producer values and climate change beliefs have on past and present adoption rates of mitigative practices, and investigates how experiences with governmental agencies and NGOs shape producers' preferences for GHG policies and implementation pathways in Canada.

Data from an online survey of 300 Canadian livestock and grain producers included questions on farm managers' beliefs surrounding climate change and environmental issues (Arbuckle et al. 2013), existing adoption of 21 selected climate change mitigative practices (Smith et al. 2008) and related motivating factors. Respondents were also asked about their preferences for different GHG policies and delivery agents, history of implementing new management practices and farm characteristics.

Conditional logit and mixed logit models were employed to estimate farmer preferences and heterogeneity for GHG mitigation, policy and delivery agencies. Results indicate, first, climate change beliefs do not predict decisions to adopt GHG mitigative practices. Reductions in GHG emissions are largely viewed as a co-benefit of adoption decisions, where cost, revenue, or increased productivity are primary motivators behind adoption decisions. On average, surveyed producers had adopted 8 of 21 select GHG mitigative practices, relevant to their operations. Lower-effort practices were typically adopted more widely than higher-effort/cost alternatives. Preferences for on-farm GHG mitigation policies are tilted towards voluntary measures including monetary compensation or in-kind support to help offset the cost of adoption. However, producers are not uniform in their policy preferences suggesting scope for a tiered approach to agricultural GHG mitigation program design.

Keywords: Agricultural GHG mitigation, Producer adoption behaviour, Climate change beliefs, Survey

Farmers' Willingness to Participate in Environmental Service Provision: The Case of Evergreen Agriculture in Ethiopia

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This study examines farmers' preferences for adopting evergreen agriculture and identifies demographic, socioeconomic, and farm-related factors that significantly affect their choice. A discrete choice experiment was conducted with 200 smallholder farmers in Ethiopia to elicit their willingness to participate in hypothetical payment for environmental service (PES) programme that incentivizes integrating *faidebia albida* (a fertilizer tree) in their mono-cropping farming system. Attributes evaluated are "number of planted trees", "annual payment amount," "payment type", and "duration of the contract". Generalized Multinomial Logit (GMNL) is found to be the most appropriate model specification than the mixed logit (MIXL) model which has become the standard to use in choice analysis. All of the attributes considered in our PES contract are statistically significant, which provides evidence for the relevance of the attributes we picked. Farmers demonstrate strong preferences for the higher amount of payment in the form of food. Moreover, fewer numbers of required planted trees and short-term contract periods are also found to be important positive attributes that shape farmers' decisions to take up contractual evergreen farming practice. Farmers with larger landholding and those who own television or radio have stronger preferences for the PES contract than the status quo. These findings, therefore, shade light on the design considerations that must be taken into account for implementing PES contracts that accommodate evergreen agricultural practice in smallholder farming systems.

Keywords: Discrete choice experiment, payment for environmental service, evergreen agriculture, *faidebia albida*, generalized multinomial logit, Ethiopia

Why adoption of low-cost technologies and practices for livestock is lagging in low-medium income countries?

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The livestock sector contributes to climate change through the emission of GHGs and is vulnerable to climate change due to its dependence on climate-sensitive natural resources. Livestock supply chains account for 14.5 percent of total anthropogenic emissions. According FAO, under a business as usual scenario, meat demand in low-medium income countries (LMICs) will increase by a further 80 % by 2030 and by over 200 % by 2050. The extent to which the livestock sector can continue to feed a growing global population sustainably will largely be determined by its ability to innovate and to adapt to climate change. This will require significant changes throughout the sector. Stronger efforts are required for livestock to reduce its contribution to climate change. As emission reductions in the sector are particularly complex due to the biological nature of the production process, a large and growing range of mitigation options have been identified. Considerable work has been undertaken to understand and identify technologies and practices that can help the livestock sector increase productivity, reduce its emissions and adapt to the impacts of climate change. Moving beyond the technical feasibility of mitigation, studies have analyzed the costs of different measures, and used the results to draw conclusions on the cost of each measure. These analyses show that there are measures that can generate economic gains for farmers via a cost reduction (win-win), while others can be implemented at very little cost and generate benefits. Yet, the uptake of these low or "negative" cost measures is low, resulting in a gap between technically possible and feasible emission reductions. This paper will present findings from the project "Reducing enteric methane for improving food security and livelihoods" implemented in 13 countries in South America, Sub-Saharan Africa and South Asia. A multitude of potential barriers exist that prevent farmers from adopting low cost measures, ranging from bio-physical constraints to cognitive and behavioral barriers at the farm level, to others operating at the supply chain level, through to social and cultural factors to complex institutional constraints. Policies themselves may generate barriers to the adoption of practices. The paper also discusses the role for policy in addressing these barriers and incentivizing adoption and will explore the possibility of "technological leap forward" in LMICs.

Keywords: Barriers to adoption, adoption rates, livestock, technology adoption, climate mitigation and adaptation

Digital Learning for Climate-Smart Agriculture Practices in Mali

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In Mali, cereals are produced for subsistence by 90 % of farmers (UNDP, 2012). Despite the high importance of cereal to the livelihood of people in Mali, their production has been limited by a number of constraints of which Striga is ranked first. In addition, farmers in Mali faced the problems of declining soil fertility which is a serious threat to sustainable agricultural land use in the country (Kidron et al., 2010). In order to manage Striga and improve soil fertility for ensuring food security, a comprehensive series of ten learning videos related to practical and profitable integrated striga and soil fertility management were developed by ICRISAT and disseminated to farmers by local NGOs in Mali. The aim of the videos was to train farmers and strengthen their capacity to manage Striga and to enable them to benefit from integrated soil fertility management. However, Africa faces a wide range of challenges in the agricultural production. One of the key among these challenges is the impact of climate change.

This paper assesses the climate smart agricultural practices triggered by learning videos on integrated striga management, soil fertility and cost and benefit evaluation practices. Using household head interviews and focus group discussions, this study revealed in video-villages and non-video-villages farmers have similar perceptions of climate change and related impacts. However, farmers' observation of climate change and related impacts depend on gender; and men perceived more climate change and related impacts than women. The proportion of respondents who adopted crop rotation, intercropping, crop diversification, improved short-cycle seed varieties and zaï techniques as climate change adaptation strategies was very low in non-video villages. Videos contribute more to the adoption of crop rotation, intercropping and fertilizer application for men than women. We also found that the yield of sorghum, millet and maize is high in video-villages and low in non-video-villages. Thus, using videos as extension tool is suitable for knowledge development and lead to high adoption of climate-smart agricultural practices for food security.

Keywords: climate change, climate-smart agriculture, learning video, striga and soil fertility management, food security

A reductive interpretation of Climate Smart Agriculture limits its positive effects

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Though a substantial amount of resources has been mobilized to promote CSA and a growing share of the literature is dedicated to the subject, researchers have not analyzed the potential global benefits of widespread adoption of CSA.

In this study, we used a suite of models to gain some insights in the potential benefits but also the limits of using climate smart agriculture as a development approach. We perform an ex-ante assessment of the effects of the adoption of selected CSA practices by linking spatially-disaggregated data from three different models and focus on three crops, maize, wheat, and rice, which represent about 41 % of the global harvested area and 64 % of GHG emissions generated by crop production. Four agricultural practices considered consistent with the CSA approach are simulated. The impact of adoption of these practices is evaluated against a plausible business-as-usual scenario for the period 2010–2050 under two climate change scenarios.

We find that the highest possible impact of the CSA practices considered is to increase global maize and wheat production by about 4 %, and global rice production by 9 %. These changes lead to a decrease in the number of people at risk of hunger estimated to be between 23 and 40 million worldwide. Average annual reduction of GHG emissions ranges between 44 and 101 Mt CO_2 e. While substantial, this reduction is only 4–10 % of the estimated global reduction in emissions from the agricultural sector necessary to remain below a 2 °C warming. We also provide some quantities in terms of tradeoffs between increasing productivity and emission reduction in this context. Productivity gains are reduced by about 19 % when emissions reduction becomes the main objective of adoption of the selected CSA practices. This means that while win-win outcomes in which both productivity and reduction of emissions are achieved appear possible, they are not universal and significant tradeoffs are present. Furthermore, results indicate that for these benefits to reach levels that contribute significantly to improving global food security and to meeting emission abatement targets, proper incentives and policies must be in place. Results also clearly indicate that CSA should be interpreted more broadly than a list of acceptable practices from which to choose, and they must encompass activities across the entire agricultural sector including interaction with other carbon-rich land uses such as forests.

Cropland Restoration as an Essential Component to the Forest Landscape Restoration Approach — Global Effects of Wide-Scale Adoption

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Existing approaches and methodologies that investigate effects of land degradation on food security vary greatly. Although a relatively rich body of literature that investigates localized experiences, geophysical and socioeconomic drivers of land degradation, and the costs and benefits of avoiding land degradation already exists, the global effects of restoring degraded landscapes are less rigorously explored. The current scale of land degradation is such that the problem can be meaningfully addressed only if local successes are upscaled and a large number of landowners and land managers implement restoration activities. Significant global efforts to address degradation exist, but studies that evaluate the global benefits of these efforts generally do not account for global market forces and the complex web of relationships that determine the effects of wide-scale restoration on production and food security. This paper provides important insights into how a meaningful integration of crop production in restoration efforts could impact food production levels, commodity prices, food security, and other environmentally significant metrics. Specifically, this paper explores the impact on food security and carbon sequestration of meeting the Bonn Challenge requirements of restoring 350 million hectares of degraded land. The results of this study reveal that the full inclusion of crop production in the forest landscape restoration approach could produce large-scale, worldwide benefits for food security and therefore facilitate a wide uptake of restoration practices and the implementation of large restoration projects. The positive impacts are multifaceted and significant in size: a reduced number of people at risk of hunger, estimated to be between 10 and 3 million; reduced pressure for expansion of cropland; increased soil fertility, up to about 1 Gtons of CO_2e of reduced greenhouse gas emissions from crop production, and up to 3 Gtons of CO_2e of accumulated carbon from forest restoration. As important results are, the limits of the modeling employed indicate that these are still underestimates of the full potential of a widespread adoption of restoration practices. The results indicate that agroforestry and silvopastoral systems are essential components of restoration if the objective is reducing GHG emissions. Preventing degradation in forests and soils is also key to reducing projected emissions.

Keywords: land degradation; restoration; food security; carbon sequestration

Greenhouse gas mitigation in dairy production – an environmental win-win or dilemma?

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Cattle production is considered as one the most significant sources of ghg-emissions from anthropogenic activities. While a considerable switch from high emission energy production to renewable sources is on the horizon and supported by various policies, the demand for dairy products is growing globally. These trends in conjunction with the global reduction targets in ghg-emissions, highlight the need to produce milk with less carbon intensity. In Europe, more expectations on the environmental performance of farming stem from justifying the subsidies to the public, as well as from the concerns of fair global burden sharing, capacity to mitigate and adapt to climate change. In the EU, the Common Agricultural Policy (CAP) steers the development and emissions. Subsidies are coupled with farm field areas, keeping land in production and increasing the costs of farm restructuring.

While in many other European countries, forest clearance for agriculture has halted; in Finland the adoption of CAP has sustained a favorable economic environment for clearing new fields. This trend has been obvious in dairy farming, as the comparatively small Finnish dairy farms have sought to catch up with the larger European counterparts and have faced high field prices and demands for keeping animal intensity below 1.3 animal units per ha. As Finland is littered with peat land (1/3 of land area), a significant share of the new fields has been established on organic soils.

Our study compares the cost-effectiveness of the afforestation of organic fields with other measures typically available on dairy farms. We develop a non-linear optimization model which considers both the ghg- and water emissions along with the different policy frames (the impact of CAP in contrast to the impact of nationally implemented policies, in particular the agri-environmental regulation). Our results show that policies aimed at reducing the nutrients to water by capping the cattle intensity or manure use per ha can lead to adverse effects for both climate and water quality, when clearing new fields on organic soils is possible. Reforestation of organic fields is costly even when losing the existing agricultural subsidies is not included as a cost. The social optimum for the dairy farm is characterized by giving up protein crop production, instead of afforestation of organic soils. The complementarity of environmental protection measures depends on the overall development of European agricultural policies.

Keywords: dairy, organic soils, abtement, policy

Assessment methods of animal food systems' sustainability and climate impact

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In assessing the sustainability of agricultural systems several approaches have been used depending on the purpose of indices and the complexity of the aimed indicators. Life Cycle Assessment (LCA) is the most common method. Greenhouse gas (GHG) emissions of livestock have been widely investigated using LCA by summarizing Carbon dioxide, Methane and Nitrous oxide into a global "carbon footprint" (CF).

All sources of emissions in LCA are identified from e.g. fossil fuels and biological processes in soils and animals metabolism are accounted for in the CF within certain boundaries of the production. However, there are flaws in the use of LCA for assessing CF in biological systems found in agriculture and livestock that have to be considered. A major concern is that LCA is a static approach that cannot provide predictions on a long-term basis. Different scenarios can be compared but it is not possible to evaluate or predict the impacts of factors of importance for land-based production systems such as soil carbon, fertility, and water holding capacity. This is because LCA treats all carbon emissions equally, whereas loss of soil carbon should be a matter of great concern in the long term. There are also difficulties and uncertainties in the LCA calculations of the biological systems because LCA uses steady state and linear approaches whereas it is well established that in agricultural systems, and in livestock systems, most of the mechanisms are based on dynamic relationships with a lot of integrated feedback loops.

Another major flaw is that foods are treated equally using the same functional unit (e.g. CF per kg grains, milk or bone free beef) without correcting for water or nutrient content. When comparing protein-rich food sources this is somewhat adjusted for, at best, by using human edible protein as the functional unit. To capture the composite value of a food, the use of an index which reflects the nutrient demand of humans have been proposed.

There is an urgent need to develop integrated systemic methods and indicators to assess sustainability and climate impact of agricultural systems. Creating a conceptual map of the production system will provide a basis for developing a systemic and dynamic approach. This will allow a multi-criteria assessment of sustainability. Such approach will be able to consider geographical contexts of production and to predict the short and long-term effects of various actions and scenarios.

Keywords: sustainability, life cycle analysis, methods, food systems modelling

Coastal salinity intrusion and food security in South Asia: best management practices with greenhouse gas benefits

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Global food security has been threatened due to various climate change related impacts including the sea level rise and salinity intrusion in coastal agricultural areas. South Asia produces ~ one third of the global rice, and rice is the staple food in the region. Sea level rise and various anthropogenic activities causing salt water intrusion have affected the low-lying agricultural areas of South Asia. In addressing the impacts of climate change, both mitigation of GHG emissions and adopting appropriate adaptation measures to minimize the impacts are necessary. In addressing the salinity issue, remedial measures adopted on salt-affected soils to reduce the salinity effect could enhance future climate change if they cause high levels of net GHG emissions. The current study has focused on selecting the best agricultural management practices for the salt-affected soils in rice cropping systems of the South Asian region considering net GHG emissions and other socioeconomic benefits associated with the adopted measures. The current on-going collaborative project involves several four countries of South Asia (i.e. Sri Lanka, India, Bangladesh, and Pakistan). Measurements of soil electrical conductivity and greenhouse gas emissions have been taken under different management practices at the selected sites within the participating countries. Farmer surveys have been conducted to collect information on productivity and socio-economic data. Final analysis for identifying the best management practices will involve multi criteria decision analyses incorporating both GHG emissions and socioeconomic benefits. The outcome of the project will be used to raise awareness among farmers for adopting climate-friendly best management practices (BMPs) with greenhouse gas benefits for salt-affected soils and make recommendations for policymakers in developing adaptation policies and strategies within the respective countries and the South Asian region as a whole.

Keywords: agricultural soils, coastal salinity intrusion, greenhouse gas emissions, best management practices

4 Global challenges and policies

Abstracts in alphabetical order

Agricultural adaptation and mitigation review: Evidence for synergies and tradeoffs

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Agricultural practices that can both mitigate climate change and help to facilitate adaptation are critical for reducing greenhouse gas (GHG) emissions while enhancing food security. While stakeholders are increasingly calling for joint consideration of these objectives to improve synergies and avoid tradeoffs, there remain complications. Lack of clear conceptual frameworks, knowledge gaps in scientific understanding, and lack of evidence associated with adaptation and mitigation outcomes can limit the ability of stakeholders to consider both objectives.

We review the literature on agriculture adaptation and mitigation post-1990. We provide an in-depth analysis of 56 peer-reviewed publications that assess a variety of agricultural practices and evaluate both adaptation and mitigation outcomes. We characterize the publications (e.g. study approach, location, agricultural land use, and specific practices), and examine the nature of the evidence provided to answer: To what extent is there evidence for claims of synergistic adaptation and mitigation outcomes, and what does this evidence show? How strong is the evidence, and what are the errors and uncertainties considered?

The majority (80 %) report synergistic outcomes, with both adaptation and mitigation objectives able to be met via the agricultural practices evaluated. Less than half (40 %) report tradeoffs. We hypothesize that, while synergies are claimed more frequently than tradeoffs across all land uses, tradeoffs are substantiated more frequently and with more convincing evidence. We use three metrics to evaluate the evidence provided for synergy or tradeoff interactions: Whether publications (1) used an empirical approach (e.g. direct measurements) (2) provided any consideration for error or uncertainty (3) statistically quantified error or uncertainty. Our results highlight major concerns. Research on agricultural practices for both adaptation and mitigation objectives is gaining important traction, yet evidence is often either nonexistent, not well substantiated, or at questionable scales. If evidence is provided, the evaluation of potential error and uncertainty can range from non-existent to well-documented and statistically quantified. There is a lack of clear and ubiquitous terminology and framing for conceptualizing and describing these synergies and tradeoffs. We discuss how these concerns could be addressed to advance the critical goal of jointly achieving adaptation and mitigation.

Keywords: Climate Change, Adaptation, Mitigation, Synergies, Tradeoffs

Reducing greenhouse gas emissions in agriculture without compromising food security?

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Agriculture, climate change, and human welfare have numerous linkages. First, agriculture is among the sectors most sensitive to the impacts of climate change which could impact future productivities significantly, especially in the tropics. Second, large-scale afforestation and increased biomass use for energy production, as well as population and income growth, is exacerbating the competition for fertile land, and raising challenges about how to provide sufficient food and biomass for a growing and richer world population. Third, agriculture is an important contributor to climate change, accounting for up to 24 % of anthropogenic GHG emissions, including indirect emissions from land use change mainly caused by deforestation. Given these linkages, agriculture must be an integral part of any global strategy to stabilize the climate. At the same time, climate change mitigation policies must be designed carefully to minimize trade-offs with food security and farmers' livelihoods. In this study we assess the contribution of win-win mitigation options to reduce trade-offs between GHG mitigation and food security to achieve ambitious climate stabilization targets. We apply a global economic land use model (GLOBIOM) and run several mitigation scenarios to assess implications of agricultural mitigation efforts for food security (people undernourished) and strategies how to alleviate trade-offs. We show the 1.5 °C target can be met at considerably lower costs in terms of calorie loss and people undernourished if for example, SOC sequestration measures on agricultural land are promoted while without these measures agricultural mitigation efforts could translate into a rise in undernourishment of 80–300 million people in 2050. Our results also indicate that targeting countries with high emissions from land use change allows to minimize trade-offs with food security while at the same time achieving significant reductions in GHG emissions. Steering mitigation efforts to countries that are land rich and are thus able to mitigate proportionally more from land use change, rather than agriculture, achieves mitigation and food security more cost-efficiently. With respect to agricultural non-CO_2 emissions we show that agriculture could still achieve already at a carbon price of 25 \$/tCO_2eq non-CO_2 reductions of around 1 GtCO_2eq/year by 2030 mainly through the adoption of technical and structural mitigation options.

Keywords: AFOLU mitigation, food security

Detecting the status of climate mitigation strategies for agriculture

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Climate change mitigation in the agricultural sector is a controversial issue. On the one hand, concerns about food security point to prioritize adaptation, on the other hand the below 2 °C target of the Paris-Agreement can not be achieved without a significant decrease in agricultural emissions. While many discussions often circle around such fundamental questions like what should or could be done by whom, many countries have already started national climate-mitigation programs that often also include the agricultural sector. The aim of this paper is to leave the normative debate and, by using a systematic approach, to get a better impression of the status of climate change mitigation in agriculture.

Which of those countries that are contributing to 90 % of global agricultural emissions, have integrated targets or measures regarding this sector in their climate- mitigation-programms? What measures are described and how can they be evaluated in terms of reportability and permanence? What different positions are to be found amongst them? What is their main impetus of acting and non-acting? The study wants to picture the potentially diverse field of agricultural climate policy, the problem-structure, barriers and ways forward, by categorizing different national approaches. It takes into account, that countries‘ starting-points and capacities as well as the nature of their agricultural sectors vary significantly.

The analysis is based on information given by countries in their “(Intended) Nationally Determined Contributions” (NDCs). It further combines them with information given in other submissions under the UNFCCC-procedure, agricultural emission-data and further country indicators. In this regard, results can be derived from a two-step empirical approach. First, a qualitative content analysis of the respective political documents was conducted. Afterwards the data was further analyzed by using quantitative empirical methods. Hence, it‘s possible to give a clustering of countries regarding their agricultural climate-mitigation approach.

The paper presents not only a picture of the status of agriculture-climate-mitigation activities already undergoing, but also serves as a basis to discuss further challenges and needs for sectoral contributions to achieve the Paris Agreement.

Keywords: agriculture mitigation policy, NDCs, comparative country analysis

National contributions to climate change mitigation from agriculture: allocating a global target

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ABSTRACT Globally, agriculture and related land use change contributed about 17 % of the world's anthropogenic GHG emissions in 2010 (8.4 $GtCO_2e\ yr^{-1}$), making GHG mitigation in the agriculture sector critical to meeting the Paris Agreement's 2 °C goal. This article proposes a range of country-level targets for mitigation of agricultural emissions by allocating a global mitigation target of 1 $GtCO_2e\ yr^{-1}$ according to five approaches to effort-sharing for climate change mitigation: responsibility, capability, equality, responsibility-capability-need and equal cumulative per capita emissions. Allocating mitigation targets according to responsibility for total historical emissions or capability to mitigate assigned large targets for agricultural emission reductions to North America, Europe and China. Targets based on responsibility for historical agricultural emissions resulted in a relatively even distribution of targets among countries and regions. Meanwhile, targets based on equal future agricultural emissions per capita or equal per capita cumulative emissions assigned very large mitigation targets to countries with large agricultural economies, while allowing some densely populated countries to increase agricultural emissions. If countries consistently choose the most ambitious targets from among effort-sharing approaches, then global agricultural emissions would be reduced by 4.6 $GtCO_2e$ in 2030, vastly exceeding the 1 $GtCO_2e\ yr^{-1}$ of mitigation needed. On the other hand, if countries consistently choose minimum mitigation targets, then global agricultural emissions would actually increase 1.9 $GtCO_2e\ yr^{-1}$ above the 2030 baseline. The 11 countries that estimated mitigation targets from agriculture and land use in their Nationally Determined Contributions were aligned with the ambition needed to limit warming to 2 °C. It will take similarly high levels of ambition from other countries to meet the 2 °C target.

Keywords: climate targets, food security, international negotiations, nationally determined contributions

What are the linkages between carbon neutral coffee and food security? Insights from Costa Rica

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Coffee covers more than 10 million hectares and provides livelihoods to 4.3 million smallholders in 14 developing countries. Increasing productivity in smallholder systems is central for food security and poverty reduction. At the same time consumer demand for carbon neutral agri-food products increases.

This study examines the Costa Rican case of the world's first coffee certified as carbon neutral in compliance with the Publically Available Specification (PAS) 2060. The study analyses the linkages between carbon neutral value chains and food security in order to minimize trade-offs between productivity and carbon neutrality in coffee agroforestry systems.

Interviews were carried out with key-informants from different relevant backgrounds. Household interviews on food security and coffee productivity were conducted using a semi-structured questionnaire. A dynamic carbon sequestration model, based on a carbon inventory in selected transects was developed to estimate annual emission-compensation-rates.

Product emissions are being related to the coffee's carbon footprint functional unit of kg-green-coffee, implying that use-efficiency of agricultural inputs relative to productivity is determining the product carbon footprint, while productivity is closely linked with food security. Agrochemical inputs constitute 62 % of the coffee carbon footprint, thus, reducing emissions would affect productivity. At the same time, accounting for temporal carbon sequestration to mitigate emissions could reduce the footprint while providing important food products by shade trees. The results also show how shade tree incorporation might lower coffee productivity, however, is linked with improved food intake by coffee farmers and a close link with nutrition of seasonal workers.

Prioritizing input-use-efficiency could motivate investment and research to improve technologies and draw attention to maintaining productivity. Accounting for on-farm carbon sequestration requires relating it to the same functional unit, so productivity also negatively influences the potential to compensate emissions. However, accounting for on-farm carbon sequestration could convince consumers, increase local income and incentivize tree incorporation into plantations, supporting sustainable livelihoods and food security.

Keywords: Mitigation, food security, coffee, biodiversity, trade-offs

Postharvest food waste reduction measures net effects on GHG emissions

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Reducing post-harvest food waste generally requires measures that may significantly affect the product's impact through direct and indirect effects:

- Measures for food waste reduction or valorisation require energy, packaging, additional logistics or other efforts. These imply additional impact.
- Due to food waste, extra production (including some handlings in the supply chain for losses in later stages of the chain) is required, with embedded emissions.

Analysis of greenhouse gas emissions and their reduction in food supply chains has traditionally focused on primary production based on case studies in which the majority of emissions occurred at the field and input level. Consequently, many studies have relied on general assumptions and rough estimates regarding postharvest activities, mostly neglecting impact of post-harvest operations (Porter et al., 2016).

However, FAO (2013) deduced that the average climate impact per kilogram of postharvest loss is more than twice the impact per kilogram of loss in agricultural production. This means that it is highly relevant to include climate change impacts from both agricultural production and postharvest operations when estimating emissions and potential emission reductions from food loss. Especially loss-reducing measures – which may cost significant amount of energy, fuels or materials – may have significant impact.

Within the context of CCAFS we are supporting a number of post-harvest food waste reducing initiatives through analysing direct and indirect GHG effects in relation to food security effects. Cases we look at include various livestock and plant product categories. Considered measures include spoilage reducing measures and surplus processing. We will present direct and net effects of a variety of these cases at the conference.

Because each supply chain has specific configuration, relating food loss quantities to GHG emissions is generally quite complex (Scholz et al., 2015). For practical applicability we have set up a generic method that – based on secondary data – can assess GHG emissions of reference chains and adapted chains for a broad category of products. This trade-offs between food waste reduction and climate impact.

This work was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

The methodology was extended with support by EU Horizon2020 projects (NoAW and REFRESH) and the Dutch Top institute Food & Nutrition.

Keywords: Post-harvest, alternative valorisation, processing

A multi-model quantification of agricultural non-CO2 emission reductions to achieve the 1.5 °C target

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Agricultural methane and nitrous oxide emissions play a key role to achieve the 1.5 °C climate stabilization target. First, they represent around 10–12 % of total GHG emissions and second, their importance in total anthropogenic emissions is projected to increase even further with stringent climate stabilization efforts as they are relatively difficult to mitigate and hence will be the main source for future residual emissions. Using a multi-model assessment, we quantify the potential contribution of agriculture to the 1.5 °C target. We apply four global agricultural sector models (CAPRI, IMAGE, GLOBIOM, and MAGNET) to provide a comprehensive assessment of the potential supply- and demand side contribution of the food system to ambitious mitigation efforts. We identify a mitigation potential for agricultural non-CO_2 emissions by running a consistent set of carbon price and diet shift scenarios across models compatible with the 1.5 °C target. We then decompose the total mitigation potential to gain insights on the representation of agricultural non-CO_2 mitigation across models and identify robust mitigation strategies both on the supply- and demand side. We differentiate between technical mitigation options including technologies such as animal feed supplements, anaerobic digesters etc., structural changes through shifts in management systems, production portfolio, and international trade, and changes in overall production levels across regions. On the demand side, we assess implication for GHG mitigation and food availability in developing countries by shifting to healthy diets in developed and emerging countries. Results show that the livestock sector and ruminants in particular will be vital to achieve emission reductions consistent with the 1.5 °C target mainly through technologies that reduce emissions directly or structural changes that target livestock productivity. Models project at carbon prices of 100 USD/tCO_2e a significant potential for emission reductions, ranging from 1.6 to 2.6 GtCO_2e/yr by 2050 corresponding to a 22–35 % reduction to baseline levels. However, with increasing levels of mitigation efforts, model results show a trade-off with food production once the cost-effective mitigation option portfolio is exhausted. Hence, agricultural mitigation efforts should be accompanied by supporting policies that enable the widespread adoption of low cost mitigation options across regions to avoid undesirable effects on agricultural production.

Keywords: agricultural sector modelling, non-CO_2 mitigation, diet change, food security

Large-scale bioenergy production: how to resolve sustainability trade-offs?

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Large-scale 2nd generation bioenergy deployment is a key element of 1.5 °C and 2 °C transformation pathways. However, large-scale bioenergy production might have negative sustainability implications and thus may conflict with the Sustainable Development Goal (SDG) agenda. Here, we carry out a multi-criteria sustainability assessment of large-scale bioenergy crop production throughout the 21st century (300 EJ in 2100) using a global land-use model. Our analysis indicates that large-scale bioenergy production without complementary measures results in negative effects on the following sustainability indicators: deforestation, CO_2 emissions from land-use change, nitrogen losses, unsustainable water withdrawals and food prices. One of our main findings is that single-sector environmental protection measures next to large-scale bioenergy production are prone to involve trade-offs among these sustainability indicators — at least in the absence of more efficient land or water resource use. For instance, if bioenergy production is accompanied by forest protection, deforestation and associated emissions (SDGs 13 and 15) decline substantially whereas food prices (SDG 2) increase. However, our study also shows that this trade-off strongly depends on the development of future food demand. In contrast to environmental protection measures, we find that agricultural intensification lowers some side-effects of bioenergy production substantially (SDGs 13 and 15) without generating new trade-offs — at least among the sustainability indicators considered here. Moreover, our results indicate that a combination of forest and water protection schemes, improved fertilization efficiency, and agricultural intensification would reduce the side-effects of bioenergy production most comprehensively. However, although our study includes more sustainability indicators than previous studies on bioenergy side-effects, our study represents only a small subset of all indicators relevant for the SDG agenda. Based on this, we argue that the development of policies for regulating externalities of large-scale bioenergy production should rely on broad sustainability assessments to discover potential trade-offs with the SDG agenda before implementation.

Keywords: large-scale bioenergy, trade-off, sustainable development goal (SDG), land-use change, environmental protection, land-sparing measure, global land-use modeling

Carbon emission avoidance and costs of Soil carbon sequestration and agroforestry land-use options

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This paper summarizes studies of carbon mitigation potential and costs of forestry options in Uganda with a focus on the role of agroforestry. A common methodological approach known as comprehensive mitigation assessment process was used to estimate the potential and costs between 2000 and 2030. The approach requires the projection of baseline and mitigation land-use scenarios derived from the demand for forest products and forestland for other uses such as agriculture and pasture. By using data on estimated carbon sequestration, emission avoidance, costs and benefits, the model enables one to estimate cost effectiveness indicators based on monetary benefit per t C, as well as estimates of total mitigation costs and potential when the activities are implemented at equilibrium level. The results show that about half the mitigation potential of 6.9 Gt C (an average of 223 Mt C per year) between 2000 and 2030 in Uganda could be achieved at a negative cost, and the other half at costs not exceeding $100 per t C. Negative cost indicates that non-carbon revenue is sufficient to offset direct costs of about half of the options. The agroforestry options analysed bear a significant proportion of the potential at medium to low cost per t C when compared to other options. The role of agroforestry in Uganda varied between 6 % and 21 % of the mitigation potential, though the options are much more cost effective than most due to the low wage or opportunity cost of rural labour. Agroforestry options are attractive due to the large number of people and potential area currently engaged in agriculture, but they pose unique challenges for carbon and cost accounting due to the dispersed nature of agricultural activities, as well as specific difficulties arising from requirements for monitoring, verification, leakage assessment and the establishment of credible baselines.

Keywords: Carbon mitigation potential, Costs, Soil carbon sequestration, Agroforestry, Land-use

Forest Land Use Change and Carbon Sequestration Cost Estimates among Rural Farm Households in Nigeria

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The incidence of forestland conversion among rural farm households in Nigeria contributes significantly to atmospheric carbon, a major culprit that precipitates climate change. The study examined the level of forest land use change and cost of promoting forest areas for carbon sequestration within farmland, among rural farm households in south-west Nigeria. Secondary data involving Satellite imageries of 1986, 2000 and 2016 were obtained from the United State Geographical Service. The data were used to examined land use change and current carbon stock in the study area. In addition, primary data on socio-economic and community characteristics as well as land use system were obtained from 300 farm households. The data were obtained to examine factors promoting forest land conversion and to estimate cost of carbon sequestration among farm households. The study showed an increase in human settlements (94.0 %) and cultivated land (48.6 %) respectively between 1986 and 2016 while the rate of forest degradation was estimated 2.6 % at 14 years interval. Current carbon stock in the study area was estimated at 15,269,015.05 Mg C (113). Furthermore, leaving the existing forest area undisturbed for the next 14 years would yield carbon sequestration capacity of 880,253 Mg C (5.4). Cost of growing forest areas by an average farm household range between $270 and $712 per ha/yr. The study concludes that forest areas in south-west Nigeria have been mainly dominated by farm land, but there exist some significant forest areas with substantial volume of carbon stock. Moreover, the cost of carbon sequestration among rural farm households is relatively inexpensive. The study suggests that there is the need to revise and strictly implement forestland use policy in Nigeria in a way that will ensure involvement of farm households in carbon sequestration program.

Keywords: Forest, Farm households, Carbon sequestration, Land use, Nigeria

Multi-model assessment of mitigation options on GHG emissions and soil C stock in agrosystems worldwide

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The need to mitigate climate change requires the abatement of greenhouse gas (GHG) emissions and the sequestration of organic carbon (C) in cropland and grassland soils. Simulation models facilitate the construction and analysis of scenarios as a basis for policy decisions and improved emission inventories (IPCC Tier 3). The JPI-FACCE funded CN-MIP project (2014–2017) evaluated, improved and compared the ability of state-of-the-art biogeochemical models to simulate the impact of farm management in a set of cropland and grassland sites worldwide.

A series of 13 crop and 8 grassland models were calibrated by Ehrhardt et al. (2018) in ten long-term field experiments worldwide (India, France, Australia, Canada and Brazil for croplands; USA, New Zealand, France, UK and Switzerland for grasslands). These calibrated models were then applied to evaluate the effects of mitigation options, combining: i) for cropland, a range of crop and site-specific N doses, irrigation amounts, and management of crop residues and, ii) for grassland, the density of grazing animals (down to 50 % of baseline values), in combination with decreasing N fertilisation levels (down to zero from initial levels). Multi-model ensemble medians were used to interpret individual model responses and improve the accuracy of estimates.

For croplands, overall results indicate that a reduction of fertilisation towards minimum N doses may reduce considerably the emissions of nitrous oxide (N_2O) while maintaining biomass production. Varying irrigation amounts over ±50 % of baseline volumes produced ~±10 % variation of N_2O emissions and biomass production. No significant effects were observed with changing the crop residues management. For grasslands, N input reduction would lead to an increase in the C sink strength in intensive grazing systems while reducing considerably N_2O emissions. As well, simulated decline in grazing intensity had only limited impact.

With a multi-model assessment, this comprehensive work quantifies for the first time the impact of mitigation options in a large range of agro-climatic conditions while quantifying the uncertainties associated to such assessment.

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Keywords: agricultural practices, biogeochemical models, greenhouse gas, mitigation, Tier 3 approach

Agroforestry and climate change: European policies

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Agroforestry is considered a sustainable form of land management that optimizes the use of natural resources (nutrients, radiation, water). Agroforestry is defined as the deliberate integration of woody vegetation with agricultural activities in the lower story. It provides a higher biomass production per unit of land, while providing more ecosystem services than woody-less agricultural lands, such as the reduction of soil erosion and nitrogen leaching, and increase carbon sequestration and landscape biodiversity. Within the AGFORWARD project we aimed at evaluating the recent and current European Union Common Agricultural policies aiming at promoting the afforestation or reforestation of lands, as the introduction of trees can be seen as a first step to carry out agroforestry practices in former agricultural or forest lands. Agroforestry was a traditional land use system in Europe before modern times. However, before the sixties land intensification and consolidation destroyed millions of trees all over Europe. On the contrary, some good examples of agroforestry promotion are found in Eastern European countries in order to reduce the effect of extreme events such as winds, flooding at the beginning and mid of the last century. In Western European countries, the introduction of trees in the land has been promoted by agroforestry, afforestation and reforestation at the end of the last century. Afforestation of agricultural lands have been the most successful CAP measure (over 1 million hectares) while agroforestry measures were not extensively adopted which may be explained by the funds associated to afforestation measure which compensated the losses of income 15 or 20 years in afforested lands. Agroforestry was poorly adopted in the CAP 2007–2013, having a better success in the CAP 2014–2020 due to the recognition of woody vegetation and the compensation of 5 years given for maintenance once agroforestry is established. However, policy rules ensuring Pillar I payment when agroforestry measure is adopted such as a management plans ensuring that maximum tree density (100 trees per hectare) is not reached, should be pursued.

Keywords: Common Agraricultural Policy, Pillar I, Pillar II

Engaging local communities in REDD+ and enhancement of carbon stocks: case study from Ghana

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Land degradation, desertification, and drought are widespread global issues that increasingly threaten the future of our environment. They result in the loss of ecosystem services from land and land-based ecosystems that are necessary for human livelihoods. Food production, water availability, energy security, and other services provided by intact ecosystems are jeopardized by the ongoing loss of land and soil productivity. The depletion of ecosystem services also negatively impacts the productive capacity of economies. Additionally, current agricultural management and fertilization practices are highly inefficient with strong negative effects on the environment, and need to be changed to counteract further land degradation and to ensure sufficient agricultural production. The study is aimed at strengthening communities' capacity to adapt to climate change through the promotion of more resilient agroforestry schemes. The promotion of agroforestry will also enhance carbon stocks, enhance soil conservation, and increase climate resilience, mitigating in particular the effects of drought and desertification. Other positive impacts will include biodiversity. Through stakeholder consultation, identifiable technologies to integrate tree crops on agricultural farming systems to increase yields, resilience and carbon stocks were identified. A demonstration trial was established in each of the two regions (Brong Ahafo and Western region). The demonstration trial involved five technologies laid out in a randomized complete block design with four times. Each plot size measured 23 m x 18 m. The treatments were: 1) Farmer Managed Natural Regeneration (FMNR), 2) Evergreen Agriculture, 3) Integrated Soil Fertility Management (ISFM), 4) Biochar from corn cob and 5) Combined biochar from poultry manure and sawdust. Maize was used as test crop. From the demonstrations plots small holder farmers selected innovative technologies based on resource endowment, adaptability to farming conditions and return to investment for on-farm testing. 1000 farmers each cultivating about 3 ha of land are participating in the program. Results on crop yields, carbon stocks, soil microbial diversity from demonstration trials and farmers' fields will be highlighted. Through the innovative technologies, rural livelihoods are improved and small holder farmers empowered.

Keywords: Biochar, Carbon stocks, Evergreen Agriculture, Farmer Managed Natural Regeneration, Resilience

Analyzing the distributional effects of climate change mitigation in developing country livestock systems: Cross-scale political economy of low emission development in East African dairy sectors

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The 2015 Paris Climate Agreement specifies that climate change mitigation should be pursued in alignment with broader development goals. While much research focuses on ways of reducing agricultural GHG emissions intensities, there has been little analysis of how the costs and benefits of low-emissions development (LED) will be distributed. While LED interventions are aimed at achieving Nationally Determined Contributions, they are also poised to transform rural livelihoods through the reorganization of policy and commercial actors around the new capital influx, as well as aby socially differentiating effects of technological upgrading among smallholders. This is especially true in African livestock sectors, which have high GHG emissions intensities due to low-productivity in smallholder systems. It follows that LED interventions need to be analyzed not only for their mitigation potential, but for their politcal economic impact. As a part of initiatives aimed to stimulate LED in Kenyan and Tanzanian dairy sectors, the Greening Livestock project is conducting a cross-scale political economy analyses of dairy development. The objective is to understand variability in intensification patterns so that we can anticipate how implementation of LED will transform the dairy sectors and rural livelihoods. This, in turn, will enable policymakers to consider social equity outcomes in their LED initiatives.

This presentation highlights the importance of cross scale political economic analyses for the mitigation agenda, outlining our research design and methodologies, preliminary findings and their policy implications. The research design analyses dynamics of intensification, including gendered labor patterns, interhousehold variability in adoption of LED practices, value chain organization and the policy environment. Findings show that adoption of LED practices negatively affect women's labor, as well as their ability to engage in commercial marketing, leading to their economic marginalization from dairy. Findings also highlight variability in households' ability to adopt and implement LED practices, pointing toward the possibility that promotion of LED as a national policy objective risks exacerbating socio-economic differentiation of rural society. While much conceptual work on climate smart agriculture emphasizes "triple wins", cross-scale political economic analysis shows the importance of tradeoffs between environmental goals and socio-economic development goals.

Keywords: Africa, dairy, livestock, political economy, inclusive LED development

Nutrient Uptake and Outcome network (NUOnet): Connecting Nutrient Management to GRACEnet

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One of the most immense challenges of the 21st century will be finding ways to produce enough food for the increasing global human population in the face of a changing climate, extreme weather events, and other environmental variables that impact agricultural production. Nutrient management to increase production per unit area will be essential in responding to this enormous challenge. One big impact that has been reported is increased emission of N_2O, which has been linked to climate change and O_3 depletion. Nutrient use efficiency could be increased with adoption of best management practices that can increase agricultural production and lower losses of nutrients via surface runoff, leaching, or emissions of greenhouse gases. USDA-ARS developed a database that has been well received at a national and international level called the Greenhouse Gases and Agricultural Enhancement network (GRACEnet), which houses a large collection of greenhouse gas data. However, GRACEnet does not store information about nutrient loss pathways that contribute to indirect emissions of N_2O via leaching of NO_3 and NO_x/NH_3 volatilization, or losses of carbon due to wind erosion. To provide an expanded database that can house information about best nutrient management practices for increasing productivity and reducing the losses of nutrients such as N and P, as well as information about the pathways for indirect emissions of GHG, USDA-ARS is currently developing a national network called the Nutrient Uptake and Outcome network (NUOnet), which aims to build upon the framework of GRACEnet and REAP (Resilient Economic Agricultural Practices). NUOnet will be linked with other USDA-ARS databases, for example: DAWG, LTAR, the (surface and wind) erosion databases; and the USDA Food Data System (FooDS). The current effort includes cooperators from ARS and others in North America. Users of the NUOnet database will be able to enter and download information about nutrient management at a given site, including management information for their field studies as well as measurements of nutrient losses via different pathways and how best management practices contribute to reduced losses for a given region. The presentation will cover the current status of the development of this database. A prototype is already available at the USDA National Agricultural Library, but the current prototype is being edited and modified to add recent improvements to expand the databases to be more extensive.

Keywords: database, GRACEnet, nitrogen management, NUOnet, nutrient use efficiency

Multi-criteria approach to greenhouse gases emission reduction

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The European Union (EU) policy of greenhouse gases (GHG) emission reduction is based on general volume of said emission per country. However, such approach is difficult to apply in science and have its disadvantages in politics because of significant socio-economic differences between countries. Authors believe it would be advisable to base both scientific studies and policy on a comparative multi-criteria analysis. Based on the concept of sustainable development, we propose the use of three criteria: environmental – emission per area; social – emission per capita and economic – emission per added value. Rankings of countries differs significantly when considering different indicators. For example, Polish agriculture was the 6th biggest EU emitter in 2015. Similarly, Polish agriculture was the 4th biggest emitter in case of emission per gross added value. However, Polish agricultural GHG emission per annual work unit was relatively low – the 5th lowest emission among EU countries and 3-times lower than in EU mean. In case of agricultural GHG emission per utilised agricultural area Poland was placed in the middle of the list. It shows, that by changing criteria we change the outcomes. It is therefore advisable to apply a complex multi-criteria approach, that allows to look more comprehensively at the country or the economic sector and apply more adequate reduction solutions. Such multi-criteria approach is more difficult, because one must compare several indexes, however can better explain GHG emission and can be used to create better adjusted reduction policy.

The aim of our presentation is to point out advantages and disadvantages of multi-criteria approach to the sectoral and national comparative analysis of GHG emissions.

Keywords: GHG emission, GHG measurement, agriculture, EU comparison, multi-criteria approach

Sustainable intensification of maize production and greenhouse gas emissions: the road ahead for sub-Saharan Africa

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Food production in sub-Saharan Africa (SSA) must increase in coming decades to maintain or improve food security for a growing population. Maize – the most important staple crop in many SSA countries – currently yields only ca. 20 percent of its potential under rainfed conditions. This is both alarming and promising. The latter because it points at the huge opportunity to improve food security. Current greenhouse gas emissions associated with maize production are relatively low in SSA. This may change when nutrient inputs increase to match crop demands for higher yields (as will happen in agricultural intensification). An alternative route is for maize cultivation to continue with limited external inputs and low yields (i.e. current extensive agricultural practices), potentially increasing agricultural expansion into forests or grassland areas. Besides their biodiversity values, forests and grassland are important stocks of carbon which will then be converted into CO_2 emissions.

The objective of our study is to compare implications of different scenarios of either continuing extensive agricultural practices or intensification of maize production for greenhouse gas emissions in SSA. Four future (2050) scenarios to achieve self-sufficiency in maize production were established for nine SSA countries. The results show that under the assumption of balanced crop nutrition, intensification of maize production will cause less greenhouse gas emissions than continuing current extensive agricultural practices, but only with yield levels up to a certain percentage of the potential yield and with high nitrogen use efficiency. To preserve forests and grasslands and prevent agricultural expansion, substantial additional conservation efforts might be needed.

Intensification of maize production will require an increase in nitrogen application of approximately twenty times current use in SSA. Preliminary farm level analyses show that such increased use of N inputs might be beneficial for farmers' income (serving as an impetus for uptake), but more likely under conditions of good market access (for external inputs and to sell produce) and with uptake of good agronomic practices (such as the use of hybrid maize). Successful intensification of maize production (with limited greenhouse gas emissions and benefits for farmers' income) will therefore require strong efforts in promoting market access to farmers, prudent use of external inputs and good agronomy.

Keywords: sub-Saharan Africa, maize, sustainable intensification, mitigation, food security

Agroforestry: an indispensable tool for climate-smart agriculture in Europe

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Agroforestry, a "*land use system in which trees are grown in combination with agriculture on the same land*", provides multiple benefits for farmers and society. Adding trees to agricultural land reduce temperature and water evaporation while improving micro-climatic conditions and soil water holding capacity. In addition, agroforestry can mitigate carbon emissions whilst at the same time reducing the negative effects of climate change on crops and agriculture.

Against this background our study (1) identified areas affected by environmental problems on European agricultural land; (2) used regional experts to propose appropriate agroforestry systems for the identified deficit regions, and, (3) estimated the potential of agroforestry systems to capture carbon and mitigate climate change.

In the first step, we identified environmental deficit regions in European grassland and cropland. We quantified areas potentially affected by i) soil degradation, in particular soil erosion and low soil organic carbon; ii) water pollution caused by nitrate leaching; iii) biodiversity deficits with a focus on pollination, pest control, and soil biodiversity, and, iv) high temperature increases caused by climate change. All indicators were spatially aggregated into a heatmap of European farmland environmental deficits. The worst 10 % of the areas were selected to be target regions for introducing agroforestry systems. The maps showed major environmental deficits in the north-western part of France, in Denmark, in central Spain, in North and south-western Italy and in Eastern Romania.

In the second step, experts from different geographic regions proposed suitable agroforestry systems for the target regions. In total data on 64 agroforestry systems were collected and the recommendations were grouped into Atlantic, Continental, Mediterranean and Steppic systems. A wide range of systems were proposed, including hedgerow systems, coppice systems, and alley cropping systems.

Finally, the potential carbon capture per hectare per year was assessed and resulted into a storage potential between 0.33 and 26.75 t **CO_2eq** ha-^{1} a-^{1}. Under a range of scenarios, converting 7 % of European farmland to agroforestry was found to reduce the carbon emissions of agriculture by up to 40.2 %. We conclude that agroforestry has the potential to both mitigate and adapt to the challenges of future climate change and secure an unremitting, sustainable, and climate-smart agricultural production in Europe.

Keywords: Environmental assessment, ecosystem services, soil, water, biodiversity

Fostering climate-smart agriculture on peatlands – Strategies and policies for implementation of paludiculture

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Peatlands are Europe's largest terrestrial carbon store. Draining peatlands for agriculture, forestry, and peat extraction, however, turns peat soils into important sources of GHG emissions. Further challenges are the loss of organic matter, subsidence, degradation and finally depletion of fertile organic soils. Climate-smart land use with close-to-surface groundwater levels (paludiculture) can minimize or even stop emissions and subsidence, thus considerably contribute to reach EU's and Member States' climate mitigation and adaptation targets. EU climate policy recognizes peatlands as key ecosystems (e.g. 2030 Climate & Policy Framework incl. LULUCF decision) but remains vague in giving incentives to Member States to specifically invest in peatland measures to fulfil climate commitments.

EU's Common Agricultural Policy (CAP) remains arguably the single most important EU policy instrument in the context of peatland management as the majority of peatlands is drained for agriculture. Until now, 1st and 2nd Pillar payments support drainage-based peatland use whereas the implementation of large-scale paludiculture to stop degradation and secure these lands for future productive agriculture is hindered by contradicting regulations and missing economic incentives for farmers. Adapting peatland agriculture to higher water levels is a challenging task for the society. Prerequisites for implementation are awareness raising, participation and communication with all stakeholders (farmers, but also water management, administration, conservation, tourism and others), cooperation in the hydrological catchment area, knowledge transfer and professional advisory services. The FACCE-JPI project "CINDERELLA" and "MireDialogue" by the German National Climate Initiative (NKI) tackled different approaches of initiating and facilitating the transition to climate-smart paludiculture.

Additionally, paludiculture needs to be incorporated into national and regional strategies to steer spatial and rural development planning, including delineation of target areas of organic soils to create common understanding for all affected stakeholders and authorities. Examples are the "Paludiculture Strategy of the German federal state Mecklenburg-Western Pomerania" and the feasibility study on the use of peatland areas drained for agriculture in Baltic countries Estonia, Latvia, Lithuania. The results are aimed to feed into general national climate and agriculture strategies in the countries.

Keywords: climate-smart, organic soils, peatlands, paludiculture, policy

5 Poster Session

Abstracts in alphabetical order

Ammonia and GHG Emissions from Livestock Buidlings – LivAge COST action

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While livestock production forms one of the pillars of the EU food industry it faces many societal challenges, not least from the rising demand for meat protein, increasingly stringent environmental regulations, coupled with the falling numbers of young farmers entering the industry. Modern farm animal production is increasingly regarded as a source of solid, liquid and gaseous and dusts emissions which can be both a nuisance and environmentally harmful. The global livestock sector, particularly ruminants, contributes approximately 18 % of total anthropogenic GHG emissions. In the EU, the livestock sector accounts for about 13 % of total GHG emissions. LivAGE is a recent (2017) funded COST action (CA16106) with overall objective to enhance international discipline cooperation so as to exchange ideas, share good practices and assess technologies that could result in reducing the emissions of ammonia and GHGs from livestock buildings and thus to lead to a more environmental friendly and sustainable livestock production. Specific objectives of the LivAGE action are:

- Assessment of techniques that could be applied to monitor GHGs and ammonia concentration will be assessed.
- Compilation of a reference methodology to calibrate over methods and to have standard protocols that will make easy the comparison of the results and to certify the measured emissions levels.
- Establishment of an agreement on measurement methodologies and techniques that will allow comparing results from different experiments carried out across Europe.
- Identification of approaches for simulation-oriented analysis of emissions from livestock buildings that reduces the uncertainty of simulations.
- Environmental assessment using the Life Cycle Approach.
- Development of a dissemination and exploitation strategy able to reach the main stakeholders and end- users (relative industry and SMEs, the scientific community, farmers, as well as a more general audience).

The LivAGE COST Action brings together a critical mass of experts from a range of disciplines to create an effective network of knowledge and expertise in the area of ammonia and GHG emissions from livestock buildings in order to enchases the development of low emission building design.

Keywords: ammonia, livestock buildings, modelling, environemtnal assessment

Scaling up climate-smart farming practices through ICT enabled platforms in India

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In developing countries, small-holder farmers' access to quality inputs, climate-smart technologies and markets are constrained. Thus, innovative methods are required to overcome a broken agriculture value chain to achieve triple win (improved yields and farm economics while reducing climate impacts).

Since 2015, Environmental Defense Fund (EDF) in collaboration with Farms n Farmers (FnF) have been utilizing an ICT based platforms and mobile applications to drive farm level efficiency by providing climate-smart and/or 360^{o} agricultural services across the state of Bihar through a network of micro-entrepreneurs.

This EDF-FnF initiative is built upon five years of work in south India with a network of NGOs from Fair Climate Network where we 1) started using IT platforms to get higher levels of transparency and accountability for monitoring and verification of our climate-smart projects; and 2) measured climate impacts of 4 crops in 4 micro-climates over 3-4 years.

Our digital information mobile app in Bihar, named "Dehaat" (village in Hindi) provides farmers with advisories on and access to soil testing, quality seeds, improved nutrient efficiency, soil and water management technologies and market linkages. This "Dehaat" service delivery model has already been tested with >30,000 farmers in India and Nepal. In Bihar, our target is to reach 20,000 farmers across ~80 villages by the end of 2018.

We analyze the datasets collected through our measurements and/or digital platforms to determine how well our potential climate-smart interventions are driving efficiency across the value-chain while reducing environmental pollution and climate impacts. In 2016, preliminary results indicate that DeHaat intervention increased both rice yields and farm gate prices by ~15 % while decreasing total input costs, nitrogen use, fertilizer costs by 7 %, 26 % and 35 %, respectively, as compared to hundreds of baseline farmers. We are currently collecting many new parameters through our digital platform in Bihar to be able to use internationally approved greenhouse gas estimation methodologies and measuring soil carbon/health indicators. These efforts will help estimate reduction in GHG emissions and improvement in soil carbon/health due to our interventions.

Our presentation will also discuss the efforts to scale up these interventions at new sub-national (e.g., state) levels such that they can act as an impetus for a positive change in Indian national agricultural policy.

Keywords: Information and communication technology platforms, Implementation strategies, Triple win

Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture (CIRCASA)

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Agricultural soils carry a large potential for carbon sequestration, especially degraded soils. On the one hand, world soils contain a total organic carbon stock of about 1,500±230 GtC, equivalent to twice the amount of carbon as CO_2 in the atmosphere. On the other hand, close to half of all agricultural soils are estimated to be degraded, which raises threats for food production, as climate change is likely to accelerate land degradation. Targeting ambitious changes in agricultural practices that would preserve restore and enhance soil carbon and soil health requires a better-structured international research cooperation. In this context, overarching goal of CIRCASA (Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture) is to develop international synergies concerning research and knowledge exchange in the field of carbon sequestration in agricultural soils at European Union and global levels. By bringing together the research community, governments, research agencies, international, national and regional institutions and private stakeholders, CIRCASA takes stock of the current understanding of carbon sequestration in agricultural soils, identifies stakeholders' knowledge needs, and fosters the creation of new knowledge. A 2020–2025 Strategic Research Agenda on agricultural SOC sequestration will be co-designed with stakeholders, grounded on scientific evidence and stakeholders' knowledge demands. The project will create significant outcomes for the implementation of the UN Sustainable Development Goals (SDGs) and of the Paris Agreement (COP21, 4 per 1000 voluntary initiative) of the UN Framework Convention on Climate Change (UNFCCC).

Keywords: soil carbon sequestration, agriculture, stakeholders, international research cooperation

Microbial dynamics during slurry self-acidification on inhibition methane emissions on stored slurry by fermented carbohydrate source

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Liquid dairy manure stored producing significant amount of methane (CH_4) and ammonia (NH_3) gas from biological fermentation. Series of studies during storage of slurry with fermentable carbohydrate sources had shown potential in reducing both of these environmentally damaging gases emitted to troposphere. This investigation was intended to evaluate the microbial dynamics in self-acidification and methane production. In this study, a surplus brewing sugar (10 % $^{w}/_{w}$) was used as fast fermentable carbohydrates to induce self-acidification in stored slurry at <15°C during 30 days storage period. A metagenomics study by next generation sequencing (NGS) using an Illumina MiSeq platform used to determine the microbial (bacteria and archaea) diversity and dynamics. Biological fermentation induced self-acidification resulting a significant pH drop from pH 7.0 to 4.7 within four days with the accumulation of lactic acid. This resulting in reduction cumulative $NH_3$and CH_4 emission by 60 and over 95 %. The 16S ribosomal ribonucleic acid (rRNA) sequences data indicates the presence of the Order of *Lactobacillales* which was responsible for the lactic acid generation. The abundancy of the operational taxonomic units (OTUs) indicates the dynamics of the slurry bacteria over 30 days storage period. Meanwhile, the presence of methanogens from the Order of *Methanobacteriales*, *Methanomicrobiales*, and *Methanosarcinales* suggesting the CH_4 emission from the stored slurries mainly emitted by the hydrogenotrophic pathway. The decreased of intolerant methanogen in self-acidified slurry was probably the main reason for the reduced methane emission. The discovery from this investigation affirm the mechanism of inhibiting CH_4 generation at the microbial level during storage under a mild atmosphere. Additional observation is needed to understand the dynamics of this CH4 inhibition mechanism beneath warmer, mesophilic, conditions.

Keywords: slurry storage, methane mitigation, microbial diversity, lactic acid bacteria, hydrogenotrophic methanogen

Coffee, climate and certification: experiences and implications from the world's first carbon neutral certified coffee

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Recently, the demand for particular climate standards and labels has increased, however little is known about their potential and challenges. In general, a comprehensive approach to study sustainability certifications is rare and, thus challenges are overlooked and proposed solutions remain limited in scope. Moreover, LCA-based certifications addressing climate change mitigation present a new field of research.

This study aims to elicit the challenges, potential and success factors of the world's first carbon neutral coffee. Thereby, it examines the complete chain – from standard development to consumer choices. The carbon neutral coffee is produced by a Costa Rican cooperative and it is certified in compliance with the Publicly Available Specification (PAS) 2060 for carbon neutrality since 2011. It is the first independent international standard for carbon neutrality that provides common definition, a recognized method and is based on a life cycle assessment (LCA).

The research follows a case study approach for an in-depth analysis. It addresses existing knowledge gaps regarding the role of social network dynamics, actor characteristics and linkages for successful pioneering in sustainable development, and investigates the challenges of implementing PAS 2060 by Coopedota. Qualitative research methods, such as in-depth interviews, participatory social network and process mapping as well as field observations were applied. The study found the prior achievements of the cooperative (e.g. compliance to ISO norms) and a 'fertile ground' in terms of ongoing climate change mitigation policies, as important factors for the successful implementation of the standard. Further success factors were a strong central and visionary actor and a diverse network of supporting actors from science, business and politics. The main challenges in implementing the carbon neutral certification were the acquirement of reliable farm data and the communication of the label to consumers.

Concluding, LCA-based certification for carbon neutrality can be a promising market-based tool for the agri-food sector to mitigate climate change, since it can benefit producers, the environment and consumers alike. Examples of these benefits include a competitive advantage in the niche markets, a potential increase in resource use efficiency, identification and minimization of GHG emission hot spots and trustworthiness among consumers due to the prescriptive nature of the standards.

Keywords: carbon neutrality, coffee, LCA, success factors, innovation

Effects of different grassland renewal techniques on N_2O emissions

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The demand of intensive dairy farming for high yielding grass swards with very good forage quality forces famers to optimise their grassland management. Grassland renewal is a common practice in north-western Europe to improve sward composition of unproductive grasslands. However, grassland break-up (i.e. the destruction of the grass sward and soil disturbance) is associated with increased decomposition of soil organic matter and the old grass sward. Both processes will lead to enhanced direct and indirect nitrous oxide (N_2O) emissions.

Field experiments with the following replicated treatments were set-up at two sites to investigate the effects of different grassland renewal techniques on direct N_2O emission and the risk of nitrate (NO_3^-) leaching: i) keeping the old sward and improving by reseeding, ii) chemical sward killing followed by reseeding, iii) chemical killing of the sward followed by ploughing and reseeding and iv) permanent grassland (control). The sites (soil types: Histic Gleysol and a Plaggic Anthrosol) differed in soil organic matter content and drainage regime. N_2O fluxes were measured weekly using static closed chambers for a period of two years. Residual soil mineral nitrogen contents (N_{min}, 0–90 cm) in autumn and spring were used to estimate the risk of NO_3^- leaching over winter.

Grassland renewal was not a significant source of direct N_2O emissions at either experimental site during the two years of the study. Elevated N2O fluxes (up to 1.6 kg N_2O ha^{-1} day^{-1} in the Histic Gleysol) and differences among treatments were only found for a two-month period following grassland break-up. N fertilisation (as reflected in the N_{min} content), soil moisture, and respiratory activity were identified as important drivers of N_2O emission. However, the destruction of the grass sward by grassland renewal resulted in a strongly increased N mineralisation and net release of soil N_{min} during the first year. Dynamics of soil N_{min} indicated a high risk of NO_3^- leaching and indirect N_2O emission, especially on the Plaggic Anthrosol. With respect to climate protection, we can conclude that maintaining and improving the old grass sward was the best treatment. If it really necessary to destroy the old sward, N_2O emission and NO_3^- leaching should be reduced by re-establishing the new sward and its N uptake potential as fast as possible. The increased concentrations of mineral following grassland renewal have to be taken into when applying N fertiliser.

Keywords: nitrous oxide, soil mineral nitrogen, mineralisation, grassland renewal, plant nitrogen removal

Misconceptions surrounding the role of methane in New Zealand's impact on global climate

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Misconceptions are prevalent regarding the impact of methane on global warming, with diverse publications describing methane's impact on warming as anything between 4 and 84 times greater than carbon dioxide, depending on the metric and timescale quoted. The root of this inconsistency is the 12 year lifetime of methane, which means that is does not accumulate in the atmosphere as carbon dioxide (CO_2) does. Therefore, calculating a "CO_2-equivalent" value for an emission of methane by multiplying by a single number (typically Global Warming Potential, GWP, over a chosen timescale) to represent its true impact on global temperatures is impossible.

Here, we use New Zealand as a case study as a country with a large ruminant livestock sector relative to other sectors, and therefore has relatively high methane emissions compared to CO_2. Traditional methods for valuing methane emissions (using GWP) understate the immediate warming effect of an emission of methane, and overstate the long-term impact. Under the Paris Agreement, countries are aiming to limit warming to well below 2 degrees Celsius, but beyond envisaging a 'balance of sources and sinks' before the end of the century, how different greenhouse gases should be treated is not specified. If methane is to play a part in this balance, it is essential to attribute the correct amount of warming to an emission of methane when deciding suitable targets for emissions reductions. It has long been shown in the scientific literature that using GWP does not do this for methane because of its short lifetime.

We propose a simple solution (denoted GWP* as it is a revised usage of GWP), which treats a permanent increase in methane emission rate as equivalent to one-off release of a fixed number of tonnes of carbon dioxide (Allen et al, 2016, 2018). This correctly values the warming impact of methane emissions, so the CO_2-equivalent emission does actually generate the same amount of warming as the original methane emission. This is a useful tool for evaluating how methane-intensive sectors such as agriculture can contribute to climate mitigation.

In the case of New Zealand, GWP100 suggests the country's methane emissions are more important than the CO_2 emissions. However, the impact of future warming is much greater for the CO_2 emissions than methane because of the long lifetime of CO_2. Using GWP*, cumulative emissions of methane correctly predict their warming implications, and so are a better way of evaluating policy actions that would bring New Zealand into alignment with temperature goals, and of generalising the concept of "net zero" emissions beyond CO_2.

Greenhouse gas balances in organic and conventional farming in Germany – results from the Network of pilot farms

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Agriculture releases greenhouse gases by soil cultivation, livestock and the use of fertilizers and manure. Nevertheless, there are some opportunities to reduce emissions e.g. storage of carbon on agricultural lands. A network of 40 pairs of organic and conventional farms in four regions of Germany was established focusing on research on climate impacts and sustainability indicators in agricultural production. In one part of the joint project "Climate Effects and Sustainability of Agricultural Systems – Analyses in a Network of Pilot Farms" greenhouse gas balances were investigated and compared.

The GHG-balance of plant production takes into account N_2O-emissions from soil, emissions from the use of fossil energy and C sequestration. Balances were estimated according to standardized methods in the model REPRO (REPROduction of soil fertility), which can be used to evaluate and optimise environmental effects of farming systems. Nutrient and energy-balances were calculated for 64 pilot farms (13 organic cash crop farms and 19 organic mixed farms respectively conventional farms) between 2009 and 2012. The elevation of the farms ranged from 0 to 780 m and the annual precipitation from 536 to 1507 mm. The size of the farms was between 30 and 1317 ha.

The results suggested differences between systems as well as farm types (cash crop, dairy farm and farming structure). The humus-balance of the farms showed the potential of organic dairy farms to sequester C (mean 280 kg C ha^{-1} a^{-1}) while organic cash crop systems were estimated to have a constant humus-content. Negative humus-balances (mean -158 kg C ha^{-1} a^{-1}) were calculated for conventional cash crop farms. The N balances of the organic farms (cash crop: 21 kg N ha^{-1}; dairy: -5 kg N ha^{-1}) were lower than the N balances of the conventional farms (cash crop: 74 kg N ha^{-1}; dairy: 62 kg N ha^{-1}). Energy demands were affected mainly by application of mineral N and pesticides suggesting differences in management intensity. The energy use efficiency of the farms ranged from 6.8 to 26.2. The dairy farms had lower site- and product-related CO_{2eq} -emissions than cash crop farms. The organic farms had lower emissions than the conventional farms. In organic farming the site-related emissions were lower, but the product-related emissions were higher than in conventional farming.

The generalization of this results is difficult. Nevertheless, they showed the need to take into account site conditions and management practices.

Keywords: climate effects, humus-balance, energy balance, nitrogen balance

Economic and ecological assessment of solid fuels from re-wetted peatlands

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The use of biomass from rewetted peatlands can combine positive effects by the reduction of environmental impacts from peatland drainage induced by rewetting with the benefits of the substitution of non-renewable fossil resources by renewable raw material and fuel harvested from the rewetted peatland site. The purpose of this contribution is to evaluate costs and ecological impact of the utilization of this biomass as solid fuels.

The scenarios considered in the study include three harvest schemes, summer harvest of hay round bales with an adapted grassland machinery, winter harvest of chaff with specialized tracked vehicles and winter harvest of reed for thatching. It covers the use of the biomass as chaff, bales or processed in a mobile pelleting plant. Three alternatives for fuel combustion are considered (1) a small 100 kW boiler, (2) a 800 kW boiler within a local heating grid and (3) a hard coal power plant.

The study is based on direct cost calculation and greenhouse gas and energy balance largely following the guidelines of the ISO standards 14040 and 14044 for life cycle assessments. Primary data was collected on biomass productivity, harvesting, mobile pelleting, fuel properties and small and middle scale combustion. Further data was taken from literature and databases.

The results show harvesting costs between 11 and 32 €/MWh, high processing costs for mobile pelleting (139 €/t) and heat generation costs starting from 50 €/MWh mainly influenced by usage rate and fuel costs. The results of the greenhouse gas and energy balance show net savings of around 80 to 95 % compared to the fossil equivalents.

The study presents direct cost calculations and greenhouse gas and energy balances from harvest to utilization highlighting benefits as far as greenhouse gas and energy balances are concerned while revealing that heat generation costs are hardly competitive compared to fossil equivalents, mainly because of high investment costs for machinery and boilers. Thus financial incentives are necessary to promote the sustainable use of rewetted peatlands.

Keywords: life cycle assessment, organic soils, peatlands, rewetting, solid fuel

Capturing Effects of Diet on Emissions from Ruminant Systems (CEDERS)

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Feed management in ruminant production systems strongly affects agricultural greenhouse gas (GHG) emissions. Better understanding the effects of ruminant diet on GHGs will enable development of low-GHG feed management systems. CEDERS is a project funded by FACCE ERA-GAS and national governments. By combining and interpreting existing global data it aims to (i) delineate effects of ruminant diet on on-farm GHGs, at the farm and national scales; and (ii) align national agricultural GHG inventory and mitigation research across an international consortium of nine countries (eight European countries plus New Zealand). The research activities and aims include

(1) Database and model development to evaluate dietary mitigation strategies;

(2) Experimental work to fill high-priority knowledge gaps including manure emissions;

(3) Process-based modelling to evaluate consequences of dietary mitigation measures on emissions on selected farm cases;

(4) Improve farm accounting and national inventory methodologies to capture effects of dietary mitigation measures;

(5) Dissemination of insights to end-users of GHG accounting and inventory. This will include extending activities to other partners (e.g. the FACCE-JPI Global Network, the GRA Network and Database on Feed and Nutrition Network (FNN), the GRA Manure Management Network (MMN), Food and Agriculture Organisation (FAO) and Agricultural Research for Development (CIRAD)).

The project will expand current databases from the FACCE-JPI Global Network, UK GHG platform projects and French GHG database. By interrogating these extended databases, we will provide empirical evidence for the effects of dietary measures on animal, excreta/manure and soil related GHG emissions. Through this empirical evidence, as well as newly derived experimental results, our methodologies will be refined to capture these dietary effects on total on-farm GHG emissions.

The refined insights into the inter-dependencies of on-farm GHG emissions, and the consequences for farm- and country-specific methodologies of GHG accounting, will enable us to provide country and end-user specific recommendations on how to capture and account for the consequences of dietary measures on GHG emissions with on-farm accounting tools and national GHG inventory methodologies. We will also develop guidelines for non-partner countries on how to use the new knowledge to improve their farm and inventory models.

Keywords: Diet, Methane, Nitrous oxide, Ruminants

Refining direct fed microbials (DFM) and silage inoculants for reduction of methane emissions from ruminants

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Agriculture currently produces 14 % of the world's annual Green House Gases (GHGs), and by 2050, developed countries are required to reduce their emissions by 80–95 %. Ruminants produce methane as a result of enteric fermentation by the resident methanogenic micro-organisms, which contribute to 20 % of global warming levels. Enteric methane emissions correlate with beef, dairy, sheep and other polygastric animal production cycles, of which domesticated ruminants such as livestock produce around 86 million metric tonnes of methane per annum. This is a problem for the agricultural industry as the ability of methane to trap infrared radiation is significantly high in comparison to other GHGs.

This research focuses on refining and implementing the use of direct fed microbials (DFM) for GHG mitigation strategies. Lactic acid bacteria (LAB) inhabit the gastrointestinal tract of mammals, including ruminants, and are well recognized for their use in the production of a wide range of human foods and animal feeds, meaning that their use as additives should be met with little opposition due to their natural presence in food. The use of LAB is considered relatively straightforward due to their commercial availability as DFMs and silage inoculants, accepted and used in on-farm technologies worldwide.

It is anticipated that novel LAB would be isolated, identified and screened for antimethanogenic properties. As some LAB are known bacteriocin producers, these could target methanogens, or their secondary effectors in the rumen. The route of application is using these micro-organisms as Direct Fed Microbials (DFMs) and silage inoculants, where a short term impact would be experienced by the ingesting ruminants and possibly maintained long term due to the colonisation of the rumen by the LAB. Strain selection and combination play a major role in determining the effect of LAB on ruminants, as well as improving animal efficiency. Other possible strategies for GHG Methane reduction which may be explored include: Archaeal Phage, chemical inhibition and alternative hydrogen sinks.

Employing various *in vitro* methods such as headspace Gas Chromatography, spectrophotometry, qPCR and subsequent *in vivo* studies such as F6 Tracer Technique would allow for the quantification of methane emitted.

LAB will be adopted to modify the function of the rumen, sequentially reducing methane emission levels and thus developing a competitive, sustainable and profitable global Agri-food sector.

Keywords: Methane, Lactic acid Bacteria, Ruminants, Direct Fed Microbials, Silage

Nitrogen use efficiency and fluxes affected by timing and N management practices in a rice-wheat cropping system in India

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The need to optimize agricultural nitrogen (N) use is fast emerging as a key global challenge where international collaboration can play a transformational role. We have established a Virtual Joint Centre (VJC) that focuses on India-UK cooperation to improve **N**itrogen **E**fficiency of **W**hole-cropping **S**ystems (NEWS India-UK). The VJC builds on existing research by UK and Indian N researchers to develop and test innovative approaches to optimize N management that help meet food security goals while reducing multiple environmental threats. The overall scientific goal is to show how a combination of agronomic and biological improvements can contribute to raising nitrogen use efficiency (NUE) at field, farm and national scales and to demonstrate by how much these improvements will reduce N losses to the environment (including NH_3, NO, N_2O, N_2, NO_3-, etc.) and thereby contributing to increased resilience of Indian agriculture. To achieve this, the Centre includes an interdisciplinary programme linking complementary science areas and scales. We aim to quantify the effect of different N management (including leaf colour chart and farmyard manure as well as neem coated urea) on growth, yield, N uptake, and NUE of rice in a rice-wheat rotation.

Additionally, in order to better quantify N fluxes, we carried out an experiment using ^{15}N labelled neem coated urea (10 % enriched) applied to three replicate plots in two varieties of rice (CR Dhan 310 and Pusa 44). The ^{15}N labelled neem coated urea was applied twice in one growing season (26 and 48 days after transplanting) with a rate of 30 kg N h^{-1}, respectively. Measurements of ^{15}N in N_2, N_2O, NH_4 & NO_3 and total N in vegetation (root, stem, leaf, grain) were taken in order to determine the fate of the fertiliser applied N. Gas samples were taken at days -1, 0, 1, 2, 4, 7 after fertilisation using the static chamber method. Soil samples were taken at 0-15 cm depth and samples were extracted in KCl for available NH_4 and NO_3 and further converted using the diffusion method for ^{15}N enrichment on filter paper before analysis. Vegetation samples were taken at maximum tillering, flowering, panicle initiation and harvest. Here we will present initial results from this experiment which include high ^{15}N enrichment in the plant itself and virtually no enrichment in N_2.

Keywords: GHG, rice, nitrogen-use-efficiency, N-management, India

The use of peat-based biochar as an additive to manure management systems to reduce greenhouse gas emissions

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Climate change is a naturally occurring phenomenon which is affected by anthropogenic greenhouse gas emissions. The agricultural sector accounts for 10–12 % of global emissions. Out of which manure management causes almost 10 % of global agricultural greenhouse gas emissions, making it an important target area for mitigation strategies. The Irish agriculture sector accounts for nearly 33 % of the total national greenhouse gas emissions in Ireland and is obliged by national and EU-Kyoto Protocol regulations to lower these emissions. The use of biochar has been recognized in the abatement of greenhouse gas effluxes in the manure management cycle. Biochar is the product of the thermochemical conversion of biomass in a process called pyrolysis. Although the production from many common sources is well understood, there remains considerable uncertainty over the efficacy of biochar production from peat. At the moment, peatlands (blanket and raised bogs) cover approximately 17 % of Ireland, suggesting that a small portion of the overall peatland area could provide a significant feedstock bio-resource for biochar production. In this study the profile and character of peat-based biochar relative to other feedstock sources will be explored, its potential to mediate reductions in greenhouse gas emissions for manure management systems will be evaluated. Initial analysis will focus on peat samples selected from the upper layers of a drained raised bog and the extracted fiber content of this peat as a biochar feedstock.

Keywords: peat biochar manure emission reduction

Livestock's Role in Climate Change: Do we need a shift of paradigm?

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Climate dictates farm management practices. In recent years, however, we have been confronted with claims that agriculture, livestock husbandry and even food consumption habits are forcing the climate to change. Consequently, reduction of meat consumption and of global livestock numbers has been recommended for Climate Change mitigation.

However, the basic assumptions made to come up with such kind of recommendations reveal severe shortcomings: (1) Carbon footprint, emission intensity, and life cycle assessments of domestic livestock products reported in scientific literature consistently overlooked the necessity of correcting non-CO_2-GHG (greenhouse gas) emissions (N_2O and CH_4) from managed ecosystems for baseline scenarios over time and space (pristine ecosystem and/or pre-climate change emissions). Therefore, livestock-born emissions, particularly from grazing systems, have been systematically overstated. (2) Livestock- and human-born CO_2-emissions form part of the natural carbon cycle with no net-effect on atmospheric CO_2-levels, except for emissions form land use change and from fossil fuel consumption during production and marketing of food and feed. In almost all climate-change-related publications CO_2-emissions are considered undesirable; there is however a wealth of evidence that manmade CO_2 has been beneficial for nature, agriculture and global food security. (3) Considerable inconsistencies in the methodological treatment of land use change (deforestation) in CO_2-emission intensity calculations (per unit of animal product) can be detected in scientific publications. (4) The lack of any discernible livestock fingerprint in global methane distribution and historical methane emission rates has not been acknowledged in scientific literature. (5) Uncertainties associated with climate sensitivity of anthropogenic GHG-emissions have been ignored. There is irrefutable evidence of prominent warm periods during the Holocene (in spite of preindustrial CO_2-levels). These are incompatible with the global warming forcing agents as defined in the latest IPCC-report miniaturizing the solar influence. There is clearly no need for anthropogenic emissions of GHGs to explain eternal Climate Change.

A tremendous overestimation of potential livestock contribution to Climate Change is the logical consequence of these important methodological shortcomings which have been inexorably propagated through recent scientific literature.

Keywords: methane, nitrous oxide, agro-ecosystems, deforestation, climate-sensitivity

Comparing direct N2O soil emissions and indirect N-fluxes from a Mediterranean agro-pastoral system using DNDC model and IPCC approach.

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Direct and indirect nitrous oxide (N_2O) emissions from croplands and grasslands are required for compiling national inventories of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC) methodology estimates direct N_2O emissions and indirect N-fluxes from the source and size of anthropogenic N inputs in the system, using a default emission factor for each source. Although these emission factors are measured under a defined range of conditions, the IPCC methodology does not account for differences in soil or climatic conditions thereby causing substantial errors when applied to specific geographical sites. Agro-ecosystem models, such as the DNDC (DeNitrification-DeComposition) model, are tools that are increasingly being used to examine the potential impacts of management and climate change in agriculture. DNDC estimates field emissions taking into account site-specific input data. This study was aimed to compare the DNDC model and the IPCC methodology in assessing direct N_2O emissions and indirect N-fluxes of a typical agro-pastoral system of the Mediterranean area. The study area (450 ha) is located in central Italy (Rome) and it is managed according a six-year crop rotation: four-year of no-fertilized alfalfa, one-year of organic fertilized (52 kg N ha^{-1}) ryegrass/clover meadow and one-year meadow-pasture with an average stocking rate of one Livestock Unit (LU) ha^{-1} for beef/cattle and 0.2 LU ha^{-1} for horses. The comparisons showed that, with the exception of the indirect N-volatilized, the DNDC model predicted a much lower yearly average direct N_2O emissions and indirect N-leached (0.18 kg N_2O $ha^{-1}yr^{-1}$, 5.56 kg N-leached $ha^{-1}yr^{-1}$ and 6.98 kg N-volatilized $ha^{-1}yr^{-1}$) than the IPCC method (1.66 kg N_2O $ha^{-1}yr^{-1}$, 28.09 kg N-leached $ha^{-1}yr^{-1}$ and 4.29 kg N-volatilized $ha^{-1}yr^{-1}$). The average annual amount of direct N_2O emissions and indirect N-leached estimated with the DNDC model resulted 90 % and 80 % lower than the respective estimates obtained through the IPCC approach, but the indirect N-volatilized was about 40 % higher, mainly due to the volatilization coming from the pasture year. In addition, the uncertainty analysis showed that the IPCC method leads to higher variability than the DNDC model. According to other studies, our results suggest that, in order to obtain site-specific direct N2O emissions and indirect N-fluxes, agro-ecosystem models such as the DNDC can provide more accurate estimates than the ones obtained by the IPCC method.

Keywords: IPCC, DNDC, Direct nitrous oxide emissions, Indirect nitrogen fluxes, Mediterranean area

Diurnal patterns, seasonality and ebullition: A comparison of gap-filling strategies for closed-chamber CH_4 measurements to derive a "best-practice" approach and give implications for future study designs

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Due to their operational simplicity allowing for spatially distinct measurements as well as their low costs and power consumption, manual closed-chamber systems are widely applied for obtaining ecosystem CH_4 emissions. This is in particular the case for rice paddies and rewetted grasslands, which are usually hard to access, miss power supply, but also represent one of the most important hot spots for spatial and temporal highly variable CH_4 emissions. However, CH_4 emission estimates based on periodically conducted chamber measurements are prone to a high temporal uncertainty, mainly related to the excessive filling of long gaps. Hence, diurnal and seasonal measurement frequencies as well as the applied gap-filling strategy are crucial factors, influencing the reliability of derived CH_4 emissions.

To date no comprehensive analysis of the influence and interactions of these factors has been performed, nor does a widely accepted standard procedure exist. As a result, it remains largely unclear whether CH_4 emission estimates, resulting from closed-chamber measurements are comparable or not and to which extent differences in measurement design and gap-filling add to the overall uncertainty of derived emission factors.

Here, we present continuous automatic closed-chamber CH_4 measurements obtained during the year 2015 for a rewetted grassland on peat and a pristine mire (Germany and Poland). These data is used to compare commonly applied gap-filling approaches. Different sampling scenarios were used to compare 11 different gap-filling strategies and analyse the influence of seasonal and diurnal measurement frequency on derived CH_4 emissions. The performance of gap-filling strategies was evaluated by comparing modelled (gap-filled) with continuously measured CH_4 fluxes and their resulting emission estimates.

Out of the different gap-filling strategies, simple interpolation methods and empirical modeling with environmental drivers (e.g. temperature and water table) were most suitable. Compared to monthly or fortnightly measurements, the precision of CH_4 emissions is substantially improved when applying a weekly measurement frequency. However, multiple measurements per day better reflect the average daily flux and thus reduce the potential bias of derived CH_4 emissions. Thus, a lower seasonal measurement frequency could partially be compensated by enhancing the number of diurnal measurements.

Keywords: CH_4, gap-filling, manual closed chambers

The German Agricultural Soil Inventory – Soil sampling for climate change abatement

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Due to several international agreements on climate change abatement (UN Framework Convention on Climate Change, Decision 529/2013/EU of European Parliament and of the Council) Germany is in duty to report greenhouse gas emissions from agricultural soils. Moreover, enhanced carbon storage in soils can be accounted for as greenhouse gas mitigation strategies. For such reports and policy decision making, a harmonized, representative, and reliable database of soil carbon stocks was missing so far. Thus, the German Agricultural Soil Inventory started over in 2011 assessing soil carbon contents and stocks in a nation-wide harmonized sampling system. A 8*8 km grid defined the 3100 sampling points under arable land, grassland and plantation crops. Landscape and soil type were described for each point and disturbed and undisturbed soil samples were taken from a 1 m3 pit. Sampling depths were 0–10, 10–30, 30–50, 50–70, and 70–100 cm. Further, from carbon rich soils, an additional sampling of the subsoil was conducted at 100–150 and 150–200 cm. In order to evaluate the spatial heterogeneity on the field scale, eight additional soil cores were taken in a distance of 10 m around the pit. All samples were analyzed in the same lab following standardized protocols. In order to evaluate effects of arable management on soil carbon contents, farmers managing the field of a sampling point filled in a questionnaire covering the last ten years before sampling. Thus, we are able to link land use and arable management (e.g. tillage, fertilization, carbon input into the soil) information with the carbon stock measured. This enormous database of harmonized soil carbon data is a valid basis of several ongoing and future subprojects. Currently, the team is working on (i) site specific and anthropogenic drivers of arable soil's carbon stocks via machine learning, (ii) vulnerability of carbon in organic and mineral soils via density fractionation and incubation, (iii) predictability of soil carbon fractions via near infrared spectroscopy, (iv) models which predict if a soil is losing or sequestering carbon, (v) stratification of the sampling area (Germany) in order to enhance the predictability of soil carbon stocks, and (vi) regionalization of soil carbon data for the generation of maps via machine learning. The contribution will present the design of the project. Moreover, selected results on effects of arable management on soil carbon stocks will be shown.

Keywords: soil carbon stocks, national inventory, arable management

Gaps, needs and options – A design study for long-term greenhouse gas observation in Africa

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Adverse impacts of climate change (CC) are currently observed across Africa. Population growth along with, land-use change (LUC), increased energy demand and the development of industry and transport infrastructure, all contribute to increasing greenhouse gases (GHG) emissions. The availability of sufficient qualitative and quantitative data regarding GHG emissions is essential. However, there is a lack of *in situ* observations across the atmospheric-terrestrial-oceanic continuum for the African continent. To fill that gap, project SEACRIFOG (www.seacrifog.eu) is developing a design study for a pan-African GHG observation system.

The project utilises an interdisciplinary approach. Findings from three stakeholders' consultation workshops held in Africa, demonstrate the knowledge gaps on GHG emissions in Africa and climate-smart options, and highlight the need for consolidated and sustainable capacity building aiming to ensure food security. An assessment on GHG measurement stations reveals a sparse and uneven distribution of monitoring platforms over the continent. A set of essential variables is being defined via experts' consultation. Based on those variables and existing observations, the specific gaps and needs to be addressed for the development of a future pan-African observation network will be determined. A permanent stakeholder dialogue platform is established in order to ensure long-term networking.

Keywords: Africa, GHG-observation, research infrastructures, Land use change

A Relaxed eddy accumulation system to measure greenhouse gas fluxes from agricultural ecosystems

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Eddy covariance (EC) systems are currently state-of-the-art in measuring greenhouse gas fluxes from terrestrial ecosystems. Yet, they are limited to a few trace gases due to the lack of fast response analysers. High financial costs and high power consumption may further restrict their suitability.

An alternative to EC systems is the relaxed eddy accumulation (REA) technique. REA avoids the need for a fast response analyser by collecting air from upwards and downwards moving air parcels into separate reservoirs at a constant flow rate (Businger and Oncley, 1990). After collecting the air over a predefined time period the air in the reservoirs is analysed by a slow response analyser and the average flux can be calculated. Currently, we are developing and testing a REA system that is capable of measuring CO_2, CH_4, N_2O, NH_3 and H_2O fluxes simultaneously with only one gas analyser (Picarro G2805).

This system is compatible with virtually any gas analyser and thus supports the flux analysis of a wide range of other tracers like volatile organic compounds, isotopes and aerosols. Furthermore, the modular design and rugged casing makes the sampling system very robust and portable, and 12 V DC operation makes it suitable for a wide range of field campaigns.

The performance of the system is tested in during the growing season of 2018 on an agricultural managed organic soil in central Sweden. The results will be compared to established EC systems for CO_2, CH_4, H_2O and N_2O.

Keywords: eddy covariance, greenhouse gas, nitrous oxide, flux measurements

Wise use of drained peatlands in a bio-based economy: development of improved assessment practices and sustainable techniques for mitigation of greenhouse gases

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Drained peatlands are important contributors to GHG emissions. For sound land management policies and decision making, an improved scientific knowledge base of GHG fluxes and transparent and verifiable methods for measuring and accounting for emissions reductions is needed. PEATWISE will build on past experience and interdisciplinary research to quantify emission factors from different land uses and production systems such as agriculture, silviculture, and paludiculture. PEATWISE will develop and refine sustainable soil and water management technologies for managed peatlands to reduce GHG emissions and maintain biomass production in different land use systems. A combination of on-going long term studies carried out in different regions and studies refining or testing new innovative ideas will be used. A general water table-GHG relationship will be developed which enables land-users and land and water authorities to quantify the effects of water management mitigation technologies. Paludiculture, involving production of flooding tolerant species which can be used for biorefinery, biomaterials and bioenergy, is another mitigation option that will be tested. Soil management technologies will be tested in field trials. PEATWISE will work with stakeholders such as farmers, policy makers and industry. Incentivizing management options that reduce emissions from the use of peatlands will be essential to policy that integrates land use change in the 2030 GHG mitigation framework. Collaborations between European and New Zealand researchers will provide opportunities for knowledge transfer across a wider peatland context than has been achieved before. PEATWISE will analyze existing incentive based policy instruments for different ecosystem services in each case study country to develop a coherent strategy that allows complementarity and bundling of governmental and private sector incentive funding schemes.

Keywords: peatlands, GHG, mitigation, agriculture, paludiculture

Assessment of losses from animal excreta on wet soils

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Up to 41 % of a potent greenhouse gas (GHG) nitrous oxide (N_2O) produced from Irish agriculture comes from excreta deposited by grazing animals. Currently, Ireland uses the IPCC default emission factor (EF) of 2 % to estimate excreta-derived N_2O. However, N_2O can vary greatly with type and composition of excreta, soil type and timing of application. Urine constituents hippuric acid (HA) and benzoic acid (BA) have previously shown potential to reduce N_2O.

The aims of this work were to (1) quantify N_2O and EFs from grazing returns, (2) assess impact of environmental drivers on N_2O (3) and assess potential urine-N_2O mitigation by manipulating grazing timing and urine composition.

Two experiments were conducted. In the first experiment, a randomised split-plot design with five replicates, real ruminant urine and dung were applied to three pasture soils of varying properties (well, moderately and imperfectly drained) in spring, summer and autumn. Nitrous oxide was measured with a manual static chamber method for 365 days following treatment application. In the second experiment, a randomised block design with six replicates, urine with incremental additions of minor constituents hippuric acid (HA) and/or benzoic acid (BA) was applied to pasture and N_2O measured using the same method for 66 days.

The average N_2O emission factor was 0.31 % and 1.18 % for cattle dung and urine, respectively. N2O loss was driven by rainfall, temperature and soil moisture, with highest N_2O EFs in autumn and from the imperfectly-drained soil. These N_2O EFs were lower than the current default value and highlight that N_2O emissions from animal excreta deposited on pasture by grazing animals in Ireland may be over-estimated. Country-specific N_2O emission factors for ruminant excreta will feed directly into the refinement of Ireland's national GHG inventory. This will, in future, allow disaggregation of EFs between types of excreta, soil type and timing of deposition.

Manipulation of ruminant urine by adding HA and/or BA was found to have no effect on N_2O emissions in situ. Although manipulation of hippuric and benzoic acids concentration in urine had no mitigating effect, other urine manipulations, such as reducing N content or inclusion of novel inhibitory products might prove successful.

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Keywords: nitrous oxide, urine, dung, hippuric acid, benzoic acid

FACCE ERA-GAS: ERA-NET Cofund for monitoring & mitigation of Greenhouse gases from agri- and silvi-culture

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FACCE ERA-GAS is the ERA-NET Cofund for monitoring & mitigation of Greenhouse gases from agri- and silvi-culture. The project receives funding from the European Union's Horizon2020 Research & Innovation Programme under grant agreement No 696356. The aim of FACCE ERA-GAS is to strengthen the transnational coordination of research programmes and provide added value to research and innovation on greenhouse gas (GHG) mitigation in the European Research Area (ERA). FACCE ERA-GAS is initiated by the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI).

The agricultural sector in Europe faces significant challenges in curbing GHG emissions while maintaining food security and sustainability in a changing climate. EU policy proposals requiring a 40 % reduction in emissions without a corresponding decrease in primary production pose significant challenges. As a result, incorporation of abatement strategies into tailored sustainable production systems and the implementation of these strategies on the ground are of the upmost importance. In addition, the inclusion of carbon sinks as an offsetting option, particularly in forestry and agricultural soils, means that verification of sinks and the impact of management on those sinks is vital.

FACCE ERA-GAS covers aspects of monitoring and mitigation of agricultural GHGs, including reducing uncertainties and improving national agricultural GHG inventories, the role of climatic variability and agricultural and forestry practices for GHG emissions, the technical and economic potential of CH_4 and N_2O mitigation, carbon sequestration and reduced emissions from energy use and pre-chain inputs, emissions/removals certification, economic and policy measures, including trade, barriers to implementation and life cycle assessment.

The FACCE ERA-GAS consortium consists of 19 partners from 13 countries: DE, Denmark, Finland, France, Ireland, Latvia, Netherlands, Norway, Poland, Romania, Sweden, Turkey and United Kingdom. The consortium is led by Teagasc (Ireland).

FACCE ERA-GAS launched one transnational joint call funding 10 research projects. A second joint call together with the ERA-NET Cofund SusAn (Sustainable Animal Production Systems) is planned to be launched autumn 2018. Furthermore the project organised two joint workshops together with the ERA-NET Cofund SusAn and the ERA-NET ICT-AGRI 2 (Information and Communication Technologies and Robotics for Sustainable Agriculture).

Keywords: ERA-NET Cofund, Greenhouse gases

MAGGnet: A Meta-Database to Support Greenhouse Gas Mitigation Research

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Concurrent efforts to mitigate agricultural greenhouse gases (GHGs) while adapting production practices to anticipated hardships of climate change are needed to ensure long-term sustainability and food security. In response to these challenges, the Global Research Alliance on Agricultural Greenhouse Gases (GRA) was formed in 2009 to develop trans-national strategies for reducing GHG intensity of agricultural production. The GRA is organized in four research groups (Cropland, Livestock, Paddy Rice, Integrative), each of which is guided by work plans to enable successful collaborations that move towards transformative solutions to reduce agricultural GHG emissions. The Managing Agricultural Greenhouse Gases Network (MAGGnet) was established within the GRA Croplands Research Group in 2012 to provide a metadata platform for the inventory and analysis of cropland GHG mitigation research. Using a standardized spreadsheet template, metadata from over 350 experimental sites in 23 countries have been compiled, organized, and summarized in the following categories: Experiment Description, Experiment Location, Experiment Duration, Climate Attributes, Soil and Drainage Attributes, Data Type, Treatments, Key Findings, Journal Citations, and Primary Contact. Based on a recent compilation, most sites report results from 1–3 year studies (68 %) and include measurements of soil carbon and N_2O flux (78 and 79 % across sites, respectively). Treatment components most frequently included in compiled studies include synthetic fertilizer rate/type, manure application, and tillage. Experimental site metadata compiled by MAGGnet has served to link researchers with appropriate datasets for global meta-analyses and modelling studies. Future improvements to MAGGnet will focus on development of an ARC GIS web-based application for site selection, an online platform for metadata sharing, and inclusion of experimental site metadata from underrepresented regions.

Keywords: Carbon sequestration, Global Research Alliance, Metadata, Nitrous oxide

Shaded coffee: An adaptation strategy mitigating short-term fertilizer-based soil N_2O emissions from hilly landscapes

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Coffee is an important source of livelihood for smallholder farmers in different regions of Colombia. The production of coffee on hilly landscapes and adopted management practices are expected to influence the spatial distribution of soil carbon (C) accumulation as well as soil nitrous oxide (N_2O) emissions. The objective of this study was to quantify N_2O emissions and total C stocks in soils under non-shaded and shaded (plantain and agroforestry) coffee, grown along three case-study soil toposequences on three neighbouring similar soil type (*Oxic Dystropets*) farms in the climate smart village of Los Cerrillos in Popayan, Cauca, Colombia. Following the application of inorganic nitrogen fertilizer, measurements of short-term soil N_2O emissions were collected over a one month period from three replicate static chambers placed at upslope, midslope and footslope positions in each of the neighbouring ~ 10-year old coffee fields. In addition, four replicate soil samples (0–10, 30–40, 60–80 cm depths) were collected at each slope position along the three soil toposequences and used to quantify soil C stocks. Results show that soil C stocks significantly differed at the coffee production systems level. Specifically, observed soil C stocks in the studied depths were highest in soil under unshaded coffee systems (previously under pasture), compared to soil under plantain and tree shaded coffee which was previously under maize and forest, respectively. In these young coffee-fields, soil C stocks, which change rather slowly, where probably strongly influenced by previous land-use options. At the coffee production system level, short-term cumulative soil N_2O emissions (853 mg N_2O-N m^{-2}) were significantly higher ($P<0.0001$) for the non-shaded compared to the agroforestry (41 mg N_2O-N m^{-2}) and coffee + plantain system (138 mg N_2O-N m^{-2}). Significant system × slope interactions on cumulative short-term N_2O emissions were observed. Our findings suggest shaded coffee production with either plantain of native trees (agroforestry); which is considered a climate adaption strategies that also increase coffee bean quality, has N_2O mitigation co-benefits. To further reduce short-term fertilizer-based soil N_2O emissions, mitigation actions on hilly landscapes should take into consideration the topography-induced spatial heterogeneity of N_2O emissions.

Keywords: Climate change mitigation, Nitrogen fertilization, Plantain, Shaded coffee systems, Topography

Is pasture-based milk production a climate-friendly alternative to confinement systems? A meta-analysis

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Life cycle assessment (LCA) is widely applied as a method to assess the environmental impact of milk production, using the carbon footprint (CF) as a parameter to describe the global warming potential. Aiming to identify the production system, releasing least emissions per unit product, a large number of LCAs were published in recent years.

Meta-analysis has been used to evaluate the outcomes of 30 publications containing in total 87 LCAs on cow milk. To increase the comparability of their results, standardisation to a common functional unit and allocation technique was applied where necessary.

Based on feeding parameters, 3 production systems were defined and LCAs assigned to compare the associated average carbon footprints:

- pasture (low-input) system (minimum 50 % of feed intake from pasture and maximum 25 % concentrate feeding),
- mixed system (less than 50 % of feed intake from pasture and/or more than 25 % concentrates),
- confinement system (zero grazing during lactation period).

Analyses of covariance were performed to test for effects of various production parameters. Pasture intake, milk yield and feed efficiency showed significant negative effects on the CF, similar for all production systems ($p<0.05$). Whilst controlling for milk yield per cow, the pasture system showed lower CFs compared to the other two systems.

It was shown that all three production systems are capable of producing milk with an equally low CF, even though different prerequisites exist. The confinement system relies on high milk yields per cow to achieve a low CF, whereas in a pasture system lower milk yields are sufficient. However, simultaneously the pasture system requires environmental conditions allowing a long grazing season enabling a high percentage of feed intake from pasture whereas the confinement system requires the provision of feed meeting the requirements of high-performance cows. The results of the present study indicate that whether a system can produce at a lower CF compared to another one depends on whether it can be managed in the most climate-friendly way.

Keywords: meta-analysis, milk production, pasture, carbon footprint

Developing a model to quantify change in greenhouse gas emission intensity of agricultural commodities over time

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The UNFCCC requires signatory nations to establish and regularly update a national GHG inventory. Inventory results reflect both the *scale* of activities and the *efficiency* with which the activities are undertaken. They can therefore be misleading as reductions in emissions can arise from reductions in the scale of domestic production as well as from reductions in emissions intensity (the amount of greenhouse gas emissions per unit of output, or EI) – for example fewer beef cattle would achieve lower emissions, but would also produce less food. Reducing domestic production is likely to simply displace production and the associated emissions to other countries, rather than to reduce global emissions. This project develops a method of calculating the EI of agricultural commodities over time that complements the national GHG inventory by enabling spatial and temporal trends in EI to be analysed.

The Scottish Agricultural Emissions Model (SAEM) was developed perform the analysis. This model calculates the amount of commodity produced by a herd/flock (or per hectare of crop) and the GHG emissions arising as a result of this production. It then calculates the emissions intensity of the commodity at the point where it leaves the farm. SAEM includes the emissions arising on-farm, and the emissions arising pre-farm from the production of inputs such as feed, fuel and fertiliser. Post-farm emissions arising from the distribution, processing and consumption of commodities are not included.

In order to help policy makers understand the factors driving change in EI, a set of explanatory variables is provided (e.g. herd productivity; crop nutrient use efficiency, feed conversion ratios, livestock growth rates and feed EI). Users can select two scenarios (a scenario is a combination of a distinct farming system and a year, e.g. “hill sheep 2015”, “hill sheep 2010”, “lowground beef 2010”), compare the EI and examine the explanatory variables in order to identify the drivers of change.

SAEM provides users with significant scope for investigating the drivers of agricultural emissions. New scenarios can be created, thus enabling values to be updated as they change over time (or in response to new evidence) and new agricultural systems to be introduced. In principle SAEM can be used to answer “What if?” questions, i.e. the values of a particular parameter (such as lamb mortality) can be changed to see what effect it has on emissions intensity.

Keywords: ghg accounting, trend analysis, life cycle analysis, ghg policy

Improved greenhouse gas emission factors for smallholder livestock systems in East Africa

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Existing GHG emissions estimates for livestock systems in East Africa are based on IPCC Tier 1 (default) methodology, that are based on (annual enteric methane production) Emission Factors (EF) derived from a combination of data from livestock systems in developed agricultural systems and “expert opinion”. Due to the Tier 1 approach considerable uncertainties around GHG emissions from African livestock systems are expected. Accurate GHG emissions estimates are not only necessary following the Paris Climate Agreement (COP21), where the majority of countries agreed to (improved) Tier 2 GHG reporting for the agricultural sector, but also to reliably assess potential mitigation options. Within the framework of climate smart agriculture (CSA) and the required sustainable intensification of livestock systems in Africa to achieve food security, reliable estimates of GHG emissions from livestock systems are absolutely essential. Additionally livestock intensification can clearly contribute to the Sustainable Development Goals.

We have developed more accurate EFs from livestock systems on enteric fermentation and manure management in three counties in Western Kenya through field measurements on animal and production performance enabling us to estimate energy expenditure, intake, in combination with digestibility of defined seasonal feed-basket. Based on this data, Tier 2 GHG EFs for enteric fermentation from livestock (methane, CH_4) and manure management (CH_4 and nitrous oxide, N_2O) were calculated. Our estimated CH_4EFs from livestock ranged between 40 % lower and 20 % higher EFs than existing Tier I estimates and highlight that our data diverges in several important ways from the default estimates. These differences were not uniform across animal classes, highlighting the heterogeneity and complexity of smallholder livestock systems. Additionally, we calculated Tier 2 CH_4 and N_2O EFs for manure management for one county in Kenya. We found greater CH4 and slightly lower N_2O emissions compared to the Tier 1 approach. The observed divergence is likely as the Tier 1 approach assumes that all African livestock manure is deposited on rangelands, rather than conserved and managed. Lower N_2O emissions are related to low-quality feeds resulting in lower N excretion. Our findings highlight the necessity for region specific and accurate GHG emission estimates from smallholder livestock systems in East Africa to achieve reliable reporting and identification of mitigation options.

Keywords: emission factors, enteric methane, manure management, nitrous oxide

Towards the quantification of SOC sequestration potential in the grasslands of East Africa

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Grasses provide great potential to sequester carbon in soils, due to their fast establishment, growth and biomass production. Grasslands in East-Africa cover about 80 million hectares, making it the biggest land cover in the region with a huge –but as of yet: unquantified– potential for climate change mitigation. As few as 23 studies were found on field estimates of soil C sequestration potentials in the grassland systems in East Africa. They report a wide range and lots of uncertainty in both SOC stocks (30–100 tonnes/ha in the upper 0–30 cm of the soil profiles) and SOC sequestration rates (0.1–3.1 tonnes/ha/year).

As the SOC sequestration potential is understood to be even higher in degraded soils, a future focus on restoration of grasslands is proposed, to concurrently contribute to climate change mitigation and increase productivity. Grassland degradation manifests itself as a change in physical and chemical soil characteristics. This influences (and interacts with) the primary biomass productivity and eventually livestock productivity, and as such threatens the livelihoods of the communities inhabiting and depending upon them. A focused literature review on the causes, consequences and remedies for rangeland restoration, revealed another data gap. Out of 102 articles reviewed, 59 focused on Africa. Only 25 of those provide a qualitative estimate on the extent of rangeland degradation and/or rangeland condition while quantitative information about remedies and impacts of such remedies is largely missing.

Clearly, more studies are needed to increase our understanding of the quantitative impact of major drivers of SOC concentrations in grassland soils. In the meantime, SOC modelling can enable us to compare alternative management approaches, develop scenario forecasts and eventually facilitate the scaling-up of observed information. Initial runs with the DAYCENT model to investigate the impact of different grazing regimes on SOC in the top 20 cm. Grazing regimes assessed included: (i) light grazing; GL (20 % removal of plant mass), (ii) moderate grazing; GM and (iii) moderate grazing with a fallow phase; MF (25 % removal of plant mass). After a 20 year simulation period, GM resulted in a 0.3 % loss of total SOC, MF increased carbon by 2.4 %, GL increased SOC by 122 kg C/ha/yr. The results so far indicate that reduction of grazing pressure and improved rangeland management are promising interventions which could result in SOC sequestration.

Keywords: mitigation, livestock, review, modeling

Emissions of nitrous oxide from crop residues – the overlooked source

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The nitrogen (N) content of crop residues is used in national GHG emission inventories to estimate nitrous oxide (N_2O) emissions from agriculture. Crop residues also make a major contribution to sustaining or enhancing soil carbon (C) stocks. Recent studies suggest that concurrent C and N transformations are critical for N_2O emissions from crop residues. Depending on the amount of C and N in crop residues and their contributions to N_2O emissions or to the soil C and N balance, residues might increase or decrease the GHG footprint of agricultural systems. In the EU, current emission methodologies identify crop residues as the third largest source of direct N_2O emissions from agricultural soils. Yet the quantification of this source is largely neglected, resulting in large uncertainties in national GHG inventories. These uncertainties relate to: 1) the amount and N concentration of residue returned to soil; 2) the magnitude of N_2O emissions associated with application of crop residues of different quality; and 3) how N_2O emissions and uncertainties differ with crop species, soils, climate and management practices.

A new European research project (ResidueGas) addresses the estimation of N_2O emissions from soil amended with crop residues, including cover crops and incorporation of grassland swards. Preliminary hypotheses in the ResidueGas project illustrate the importance of critical moments during crop management cycles for N_2O emissions from crop residues. High N_2O emissions have been associated with low residue C:N ratios; however, residue C and its degradability are also important for emissions, and in some cases may be a greater driver than total N input. This indicates that crop residue properties, beyond N supply, such as chemical composition, and the mode of residue application influence N_2O emissions, and that C and N availability in residues as well as management need to be considered. This points to components of cropping systems that are particularly at risk of large N_2O emissions and should be studied for inclusion in inventories and for developing mitigation strategies. These include: 1) Incorporation of fresh crop residues after harvesting in summer or autumn of vegetative crops; 2) winter periods where N-rich crop residues remain on the soil surface; 3) incorporation in spring of N-rich residues of cover crops; 4) cover crops that are frost-killed during winter; and 5) termination of grasslands where degradable C and N support denitrification.

Keywords: nitrous oxide, crop residues, inventory

GHG-MANAGE: Managing and reporting of greenhouse gas emissions and carbon sequestration in various landscape mosaics

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We present information on a new project consortia funded under the European FACCE-JPI ERA-GAS programme, focusing on GHG-exchange at the landscape scale and how this is influenced by agricultural management decisions. Different landscape mosaics contribute an as yet poorly quantified contribution to greenhouse gas (GHG) emissions and carbon sequestration, as well as having an uncertain direct warming effect through variations in their surface properties thereby limiting our ability to implement mitigation measures at the farm scale. In this project we aim to assess the GHG characteristics and surface-related warming effects of different European landscape types and examine the optimum configuration of different land uses and management interventions, including afforestation-related GHG offsetting, to minimise GHG emissions. We will provide information that can be utilized for on-farm reporting tools, including an economic tool and a module interface for the Cool Farm Tool (CFT), whilst also improving our understanding of landscape level CH_4 and N_2O fluxes and the effects of soil type. Important compensation mechanisms will be quantified and their impact on regional to national scale GHG emissions and soil carbon stocks assessed. Finally, appropriate methodologies to report and verify the effects of landscape scale GHG emission compensation mechanisms, both top-down and bottom-up, will be developed. These methodologies include low-flying airplane sensing of land-atmosphere exchange fluxes, that can be statistically dis-aggregated into averages and components (NEE, GPP, Re for CO_2) for each land use type. Bottom-up (leaf to field/stand) scaling methods will also be explored, and simplified methods using concentration variance or budget methods will be revisited.

Keywords: Greenhouse Gases, Management, Offsetting, Landscape mosaic

Decoupling greenhouse gases emissions in conservation agriculture system: adaptive nitrogen and weed management

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Increasing N fertilisation to improve crop yield in the early transition periods of conservation agriculture (CA) increases nitrous oxide (N_2O) emission, yet retaining crop residue influences mineralisation and carbon dioxide (CO_2) emission. These precipitated a need for an adaptive N fertilisation management involving soil testing and normalized difference vegetation index measurement by GreenSeeker™ technology in a maize-wheat system under CA in the Indo Gangetic Plain. Our results indicate that adaptive N fertiliser application reduces surplus N fertilisation. Although N_2O and CO_2 emissions and the global warming potential were higher with the adaptive N fertilisation than whole N basal application at sowing, the carbon efficiency ratio was greater in the adaptive N fertilisation with the GreenSeeker than whole N basal application. Here we demonstrate that the adaptive N fertiliser management decouples environmentally damaging greenhouse gases emissions from yield-related crop productivity.

Keywords: Greenhouse gases emissions, Carbon efficiency ratio, Conservation agriculture, Maize-wheat

Whole-farm greenhouse gas emissions and trade-offs across smallholder livestock systems in Babati, Northern Tanzania

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Livestock productivity in East Africa, and especially in Tanzania, remains persistently low. At the same time, livestock in the region has one of the lowest feed use efficiencies and highest greenhouse gas (GHG) emission intensities per unit product worldwide. In this mixed methods study, we aimed to quantify GHG emissions and trade-offs with other dimensions of farm performance across smallholder livestock production systems, and explore climate-smart intensification options in Babati, Northern Tanzania. Using multivariate statistics, a smallholder livestock system typology was constructed from a household survey dataset. Representative farms were selected and assessed with the whole farm multi-objective optimization model FarmDESIGN. More than 90 % of on-farm GHG emissions came from livestock, though emissions in Babati (2.9 to 16.2 t CO_2e) were higher than in other smallholder systems in East Africa. Emission intensity per kg milk was lowest for the DAIRY type (2.1 kg CO_2e kg^{-1}), which also showed the lowest trade-offs with income. All livestock systems had alternatives available to increase income while decreasing GHG emissions, thereby reducing agro-environmental trade-offs. These options included reducing ruminant numbers, replacing local cattle with improved dairy breeds, improve feeding through on-farm Napier grass (*Pennisetum purpureum*) cultivation, and reduce crop residue feeding to leave them on the field. However, main obstacles to adoption of these technologies included high skill level required to re-organize entire production system, loss of some multi-functionality of livestock, and higher production risks. Low baseline farm emissions in Tanzania underline that mitigation cannot be a main objective but rather a co-benefit. If climate change mitigation is synergetic with much needed productivity improvements, and if possible opening avenues to potential financing options, climate-smart livestock intensification options should be a building block of Tanzania's climate policies.

Keywords: whole farm modeling, sub-Sahara Africa, climate-smart intensification, farming systems research

Study on early fattening in sheep as a strategy to reduce nitrogen emissions

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Nitrogen is one of the contributors of greenhouse gases (GHG). In ruminants, more than 60 % nitrogen was excreted in feces and urine during the animal life. Therefore, the faster the animal can be slaughtered the less nitrogen excreted. The aimed of this study to evaluate the decrease of nitrogen emissions by using early fattening in sheep after weaned. Thirty Thin Tailed lambs (aged 4 months; 13.70± 1.93 kg of BW) were used in this study. The feed was pelleted complete feed that contained 14 %–18 % crude protein (CP) and 60 %–70 % total digestible nutrients (TDN). The nitrogen emission was analyzed from urine and feces. Feed, feces and urine were collected during 7 days using total collection method. Nitrogen (N) was analyzed using Kjeldahl method. The data were analyzed using descriptive analysis. The results showed that lambs fattened during 3 months had 24.32 kg of slaughter weight, with an average daily gain (ADG) was 126.4 g/d, which is in traditional farmers in Indonesia required at least 12 months to achieve 24 kg of slaughter weight. It indicated that early fattening can be faster 5 months than that of the traditional farmer. In this study, the daily N emissions from feces and urine were 13.43 g/d, the emissions of N_2O was 0.27 g/d and potential of CO_2 was 80 g/d. Those results could be calculated total emissions of N, N_2O and potential of CO_2 between early fattening (7 months) and traditional farmer (12 months). The total emissions of N were 2.82 kg vs 4.83 kg, N_2O was 56 g vs 96 g and CO_2 potential was 16.80 kg vs 28.80 kg, respectively. Based on the result, it could be concluded that shortening rearing period in sheep can reduce the emissions of N, N_2O and CO_2 until 41 %.

Keywords: Sheep, early fattening, reduce nitrogen emissions

Novel management practices on cultivated peat soils in Finland

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In Finland, emissions of carbon dioxide and nitrous oxide from cultivated peat soils consist 10 % of the national total and 60 % of agricultural greenhouse gas emissions (in sectors Agriculture and LULUCF). They are the most promising target for mitigation actions but the past and current agri-environmental measures have not attracted farmers to change the cultivation practices. Regionally targeted mitigation measures that take into account the significance of the field for food production and depth of the peat layer would enhance efforts in greenhouse gas mitigation. Most research on the greenhouse gas fluxes of cultivated peat soils has concentrated on the conventional management options and there is lack of information on the effects and practical implementation of emerging novel practices like paludiculture.

We combined different georeferenced datasets (soil database and crop data from the land parcel identification system) to evaluate current agricultural use of peat soils. The area was divided regionally in different classes based on depth of the organic layer and intensity of cultivation, and the most feasible mitigation measures for each identified class was depicted.

In the three most northern administrative regions more than 25 % of fields are on peat soils. However, the fields of the northern regions are mostly in perennial cultivation with relatively low environmental impact. More than half (60 %) of the total area still has a peat layer deeper than 0.6 m indicating long lasting mitigation potential with measures capable of slowing down peat decomposition. The analysis revealed that 13 % of the total area of cultivated peat soils is in extensive use suggesting that this share is not vital for agricultural production. Part of this area, especially the deep peat soils, could be turned to paludiculture with the right incentives. On the contrary, the area that has already lost most of the peat layer and is now classified as thin peat soil, especially in regions with poor availability of mineral soils for replacement, could remain in production but with improved practices like no-till or cover crops.

We established new field experiments in 2018 to study the practical implementation of the potential mitigation measures. The management options include paludiculture, no-till and cover crops, and the first results on greenhouse gas fluxes from these sites will be presented.

Keywords: Peat, agriculture, paludiculture, mitigation

Making trees count: MRV of agroforestry under the UNFCCC

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Agroforestry — the integration of trees with crops and livestock — is not mentioned explicitly in the UNFCCC's Koronivia Joint Work on Agriculture. However, agroforestry generates many benefits directly relevant to the topics addressed, including: (i) building resilience, (ii) increasing soil carbon and improving soil health, (iii) providing fodder and shade for sustainable livestock production and (iv) diversifying human diets and economic opportunities. Despite its significance, agroforestry may not be included in measurement, reporting and verification (MRV) systems under the UNFCCC. Here we report on a first appraisal of how agroforestry is treated in national MRV systems under the UNFCCC. We examined national communications (NCs) and Nationally Determined Contributions (NDCs) of 147 countries, 73 countries' REDD+ strategies and plans, and 283 Nationally Appropriate Mitigation Actions (NAMAs) and conducted interviews with representative of 17 countries in Africa, Asia and Latin America. Our assessment found that there is a significant gap between national ambition and national ability to measure and report on agroforestry. Forty percent of the countries assessed explicitly propose agroforestry as a solution in their NDCs, with agroforestry being embraced most widely in Africa (71 %) and less broadly in the Americas (34 %), Asia (21 %) and Oceania (7 %). Seven countries have proposed 10 agroforestry-based NAMAs. Of 73 developing countries that have REDD+ strategies, about 50% identify agroforestry as a way to combat drivers of forest decline. Despite intentions, however, agroforestry is still not visible in many MRV systems. For example, though 66 % of the countries reported non-forest trees in their national inventory, only 11 % gave a quantitative estimate of number or areal extent of these trees. Interviews revealed a suite of definitional, institutional, technical and financial challenges preventing more comprehensive and transparent inclusion of agroforestry in MRV system. This absence has serious implications. If such trees are not counted in inventories or climate change programs, then in many ways they don't count. Only if agroforestry resources are measured, reported and verified will they gain access to finance and other support. This paper will discuss finding of the assessment, successes by countries to improve agroforestry MRV and specific Investments needed to help ability match ambition.

Keywords: agroforestry, MRV, NDC

Validation of the Ruminant model to obtain accurate estimates of enteric methane emissions to support the Colombian NDCs

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Taking into consideration the need to generate quick and reliable data of enteric methane emissions in livestock systems to find mitigation options, the present work aimed to validate the "Ruminant" model to predict methane emissions in bovine production systems under low tropic conditions in Colombia. In order to achieve this goal, enteric methane measurements were made through the polytunnel methodology in steers (n = 25) fed with seven different diets based on tropical forages. Initially, a sensitivity analysis of the model was performed to each of the input nutritional variables to determine its influence on the estimated methane values; This exercise allowed identifying the key input variables of the model that influence the calculations or methane estimates. Subsequently, detailed determinations of the nutritional composition of forages used for the different diets were made and this information was used to set the parameters of the "Ruminant" model. This information allowed the model to estimate the enteric methane production of fattening steers for each of the diets. Then, the methane values obtained by both methodologies ("Ruminant" vs. Polytunnel) were compared, evidencing a high correspondence between the methane values estimated by the model and those reported trough the Polytunnel, with a coefficient of determination (R 2) of 0,7 and an average value of difference (observed value / simulated value) of 1.4. In conclusion, the "Ruminant" model has a valuable predictive capacity for the behavior of methane gas emissions based on precise knowledge of the nutritional composition of forages. It is suggested to continue with the validation of the model with other diets, other types of animals and in other places in order to corroborate these results. The "Ruminant" model is suggested as an important tool to find mitigation strategies in the agricultural sector that help to reach the goals of the Nationally Determined Contributions (NDC) of Colombia and likewise support the process of identifying Nationally Appropriate Mitigation Actions (NAMA) for example in monitoring, reporting and verification systems (MRV).

Keywords: Climate Change, Greenhouse gases, Mitigation, Adaptation, Monitoring reporting and verification (MRV)

Livestock Key Facts: Investigating Popular Facts to Ensure Discussions and Decisions are Well Informed

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It is widely recognised that data relating to livestock and associated impacts on the environment, economics and society, is severely limited; particularly in Low to Middle income countries (LMICs). Subsequently, a lack of information hinders discussions and decisions.

With these challenges in mind a community of practice, Livestock Data for Decisions (LD4D), has been established to support better use of livestock data. LD4D's activities include 'matchmaking data holders and users', sharing best practice, convening practitioners to facilitate collaboration, and capacity building through accessing expertise within the community of practice.

One of the initial activities that LD4D has conducted is Livestock Key Facts; this project examines the evidence behind popular livestock facts, investigating how, when, and in what context, facts were derived. Key Facts looks to raise awareness and promote discussion around the robustness, relevance and appropriate interpretation of popular beliefs about livestock, particularly when used in decisions, or for advocative and critical discussions. This is done with a view to provide impartial insight and challenge unfounded assumptions.

As a demonstration, eight facts were tracked through literature to their origins; with topics covering environmental, economic and social aspects of livestock:

- **Livestock and Livelihoods** – Livestock support around one billion poor people
- **Livestock and Economy** – Globally, the livestock sector contributes 40 % to total agricultural GDP
- **Livestock and Zoonotic Disease** – 75 % of human disease epidemics have been of animal origin and 60 % of human pathogens are zoonotic
- **Livestock Disease Eradication** – The eradication of rinderpest brought about billions of dollars of benefit
- **Livestock and Greenhouse Gas Emissions** – GHGs could be reduced by up to 30 % through improved practices
- **Livestock Yield Gaps** – Yield gaps exist, and packages of interventions can improve productivity
- **Livestock Multi-functionality** – Livestock in LMICs provide nutrition, income, traction, financial assets and cultural values
- **Livestock Disease Burdens** – Disease limits livestock production in LMICs. But, by how much?

The Key Facts project is not about defining facts as right or wrong, instead LD4D has an objective to improve the transparency of information and facilitate appropriate data for decisions. To this end, this paper describes the activities of LD4D, with a focus on the outputs of the Livestock Key Fact project.

Keywords: livestock, data, facts, transparency, discussion

Greenhouse gas emissions of organic and conventional dairy farms – results from a pilot farm network in Germany

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In 2009, a network of paired organic and conventional dairy farms in various climatic and soil regions in Germany was started within the project 'Climate effects and sustainability of organic and conventional farming systems' (www.pilotbetriebe.de). This abstract presents some key results in regard to greenhouse gas (GHG) emissions of milk production. The farm model REPRO was used to calculate complete GHG balances of 34 farms. Total GHG emissions of milk production at the farm gate were (mean (min-max)) 983 (835–1397) and 1047 (911–1248) g CO_{2eq} kg^{-1} energy corrected milk (ECM) for organic (n=16) and conventional farms (n=18), respectively. The values were rather farm individual and means did not differ. Product related GHG emissions declined with increasing milk yields up to approximately 9000 kg ECM cow^{-1} a^{-1} and reached a plateau at milk yields beyond that level. The results confirm the importance of methane (CH_4) emissions from enteric fermentation in dairy cows as the main source of GHG emissions. REPRO estimated enteric CH_4 emissions based on daily dry matter intake (Ellis et al., 2007). As feeding practices of dairy cows differ between organic and conventional farming, enteric CH_4 emissions from cows were additionally estimated by taking results of feedstuff analysis of the pilot farms into consideration (Kirchgeßner et al., 1995). These values were on average 0.11 kg CO_{2eq} kg^{-1} ECM higher than those based on Ellis et al. (2007). Apart from feeding, milk yield is also influenced by cow health and welfare, thus affecting product related GHG emissions. Hence, cow welfare was determined on all pilot farms in the course of the ongoing project by applying the Welfare Quality® assessment protocol for cattle. In a preliminary study with four pilot farms, scenarios to improve cow health and welfare (e.g., by introducing pasture to dry cows) on environmental burdens and resource efficiency were calculated. Overall, effects on GHG emissions per kg ECM were relatively small (-5 to 2.6 %). Simultaneously considering animal related parameters, management procedures, and environmental performance of production provides an innovative possibility to address different sustainability goals on whole farm level and to approach win-win solutions. Advisory tools to perform individual calculations of GHG emissions in crop production and to evaluate cow welfare in farms were made available to the public. Currently, the scientific work within the network is being completed.

Keywords: modelling, methane, organic, conventional, animal welfare

Integrative Research Group: a cross-cutting Group in the Global Research Alliance on Agricultural Greenhouse Gases

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The Integrative Research Group (IRG) is one of the four groups of the Global Research Alliance on Agricultural Greenhouse Gases (GRA), which has 40 member countries. The central objective of the GRA is to support research to develop knowledge and collaboration on ways to produce more food while limiting greenhouse gases (GHG) emissions. This cross-cutting research group aims at estimating GHG emissions across agricultural systems at different scales, from the field to the region, to mitigate the impact of agriculture on climate change, relying on activities led by the three other Research Groups of the GRA (Livestock, Croplands and Paddy Rice). Many research projects are already supported by countries to better respond to this challenge. By pooling their efforts within the IRG, progress towards appropriate solutions will be faster. Like the GRA, the IRG is based on the voluntary efforts of countries members of the GRA by enhancing international collaboration, providing cooperation and sharing knowledge on data, models and assessment tools through members and partners. In this way, the organisation of major events can be encouraged by the IRG. It also has a role in upskilling network members and in contributing to capacity building, for instance to support mitigation policy design, including Nationally Determined Contributions (NDCs) to the Paris agreement on climate change. The IRG is organised in four research Networks: the Field Integration Network, the Farm to Regional Integration Network, the Soil Carbon Sequestration Network and the Greenhouse Gas Inventories Network, all four boosted by two Flagships, one on Soil Carbon Sequestration and the second on Agricultural Greenhouse Gas Inventory. The two first Network aim at integrating knowledge and developing tools on assessing agricultural productivity and GHG emissions and removals at field scale and at farm and regional scale across agricultural systems. The Soil Carbon Sequestration Network intends to estimate potential soil carbon sequestration across spatial and temporal scales, to develop methods of monitoring and to assess co-benefits (climate change, environment, agricultural production) and trade-offs (non-CO_2 GHG emissions, costs, barriers to adoption). The Greenhouse Gas Inventories Network supports the improvement of national GHG inventories by developing and promoting consistent methodologies to quantify mitigation and adaptation options.

Keywords: Integrative Research Group, Global Research Alliance, soil carbon sequestration, greenhouse gases inventories, monitoring scale

Greenhouse Gas emissions from arable farming: knowing the farming system is crucial

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Background

Various modelling approaches to estimate Greenhouse Gas (GHG) emissions from arable farming have been created in the last years. Researchers have developed ever more specific approaches with the aim of increasing the estimation´s accuracy and comprehensiveness. The gain in precision has however also implied the need to have access to more detailed and disaggregated farm data. Consequently, to obtain precise results, the need to gather precise data about agricultural inputs and operations arises. Moreover, utilizing a standardized procedure enhances comparability and helps explain results from different approaches – e.g. compare emissions from a standard fertilizer with the emissions from the actual fertilizers used.

One of the practical and highly relevant applications of GHG emission estimates is the Renewable Emissions Directive (RED), which establishes predefined emissions values for the cultivation of the crops used in biodiesel production. These are obtained by making broad assumptions regarding a production system which is then estimated using statistical data, often stemming from multiple sources combining different locations and years. As a result, the question arises how those estimates compare to bottom-up generated data from farming system analysis and to what factors can the possible differences be attributed to.

Goal

Inform decision makers about the potential shortcomings from GHG estimates for crop production based on highly aggregated and/or diffuse data sources.

Approach and delivery

Utilizing the agri benchmark Cash Crop database which contains rather detailed data on input use and operations for so-called ”typical farms”, readily available GHG estimation tools and formulas, as well as databases of public access, this study will:

(6) Calculate GHG emissions for various crop production systems by using agri benchmark data.

(7) Compare those results to standard values applied in the RED directive.

(8) Analyze the drivers of differences and draw conclusions for further work on GHG estimates from crop production.

To make the excise presentable on a poster the analysis will be focusing on rapeseed.

Keywords: Renewable Emissions Directive, rapeseed, statistical data, Typical Farm

DATAMAN: Establishment of a database on greenhouse gas emissions from manure for refinement of national inventories

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Livestock production is responsible for approximately 18 % of global greenhouse gas (GHG) emissions, with almost half this total arising from methane (CH_4) and nitrous oxide (N_2O) arising from manure management during housing and storage, as well as from both nitrogen (N) inputs upon application to soils and from direct deposition by livestock. These emission sources represent a key uncertainty category within national emission inventories, with the majority of countries currently reporting emissions using the default (Tier 1) approach from the Intergovernmental Panel on Climate Change (IPCC). A large body of data, quantifying emissions arising from each step of the manure management and N cycle chain has been generated over the last decade. However, there has been no consolidation of these data into a central data repository. The construction of such a repository with associated data tools would allow countries using Tier 1 emission factors to upgrade their inventories, as the IPCC allows the development of emission factors using third party datasets with similar livestock systems, soils and climate, as long as adequate activity data is available.

DATAMAN is a Global Research Alliance (GRA) Nitrogen flagship project that seeks to establish such a database consisting of both emission factors and all relevant activity and ancillary data. The project seeks to collate, consolidate and unify CH_4, N_2O and ammonia (NH_3) emission datasets associated with manure from international project participants along with ancillary data to create a central database. Analysis of the resulting data will allow the project team to generate empirical relationships between ancillary manure composition, climate, abiotic data and emission factors, which will provide a global resource for upgrading national inventories.

This project will liaise with the Manure Management Network of the Global Research Alliance and the IPCC. This will allow us to generate recommendations for the calculation of GHG emissions from manures and deposited excreta to soils for inventory purposes.

We will present progress made in the first four months on the development of the DATAMAN database.

Keywords: manure management, database, inventory, refinement

CH_4 emitted by dairy cows estimated from milk MIR spectra: model based on data collected in 7 countries

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Greenhouse gases (GHG) emissions from livestock and more especially methane (CH_4) emissions from cattle related to ruminal fermentations remain the most important source of GHG within the agricultural sector. Main levers to reduce those emissions are the diet and the genetic selection. To study the impact of those levers and how reduce CH_4 emissions, a large amount of reference measurements are needed. However, existing techniques to measure CH_4 emissions from dairy cows are expensive, time consuming and difficult to apply on a large amount of animals. This is why the availability of a robust proxy to estimate individual daily CH_4 emissions from dairy cows would be valuable. Estimate CH_4 emissions from milk mid infrared (MIR) spectrum present potential to meet this aim as it can be obtained routinely at reasonable cost through milk recording process. Develop this equation is particularly challenging as the CH_4 prediction equation from milk MIR spectra as CH_4 is not a direct milk component but an indirect phenotype linked to milk composition through ruminal fermentations which theoretically influence both. To increase the variability of the calibration set, two datasets (CH_4 measurements and milk MIR spectra) have been merged: A) 532 data from 156 cows of Ireland and Belgium using the SF_6 tracer technique; B) 584 data from 147 cows of Switzerland, United Kingdom, France, Denmark and Germany collected in respiration chambers. In addition of the calibration using the raw reference values, a second calibration was performed with a reduction of 8 % to CH4 values from chambers evaluate the need to correct the potential method bias in accordance with literature. A 5-groups cross-validation was performed to test the robustness of the models. Those equations showed a R^2 and a standard error of cross-validation of 0.63 and 62 g/day respectively for the calibration on raw values and 0.65 and 59 g/day when respiration chamber values are adjusted. The slight improvement due to adjustment of chamber measurement is not significant. With errors around 60 g/day, the current equations does not permit to distinguish slight variation of CH_4 emissions as it is often required in nutritional context. However, more variability is included (cows, breeds, diets, and country specific information), marked trends can be differentiated and statistics confirming its potential as proxy especially for genetic evaluations or life cycle analyses.

Keywords: Milk, Methane, dairy, MIR

The '4 per 1000: Soils for food security and climate' initiative: The international scientific and cooperation program

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The '4 per 1000: Soils for Food Security and Climate' initiative, launched at COP 21 in Paris, aims to increase food security, mitigate and adapt to climate change through carbon sequestration in agricultural and forest soils, based on the results of scientific research. This international multi-stakeholder initiative consists of an action plan and a scientific and cooperation program. The 4 per 1000 action-oriented research program aims to address knowledge gaps to best enhance global SOC stocks, while also ensuring food security; to provide evidence-based options for stakeholders; and to facilitate the development of national policies. This requires a multidisciplinary and integrated approach. This program develops by strengthening complementarities and synergies among the international scientific community. The Scientific and Technical Committee (STC) of the Initiative has recommended research priorities grouped in four pillars: 1) Estimating the soil organic carbon (SOC) storage potential, 2) Developing management practices, 3) Defining the enabling environment and 4) Monitoring, reporting and verification (4 per 1000 STC, 2017). It has been shown recently that the 4 per 1000 target, calculated relative to global top soil SOC stocks, is consistent with literature estimates of the technical potential for SOC sequestration (Soussana et al. 2017). Moreover, recent studies show the link between the increase of SOC sequestration in agricultural land and food security in a 1,5°C scenario (Frank et al. 2017). Socio-economic constraints influencing the adoption rate, the permanence of carbon storage in soil and the duration of improved soil management practices bring uncertainties on the capability to reach the 4 per 1000 target that still have to be assessed.

Keywords: Carbon sequestration, Climate change, Soil organic carbon, 4 per 1000 initiative, Research program

Mitigating greenhouse gas and ammonia emissions from beef cattle feedlot production – a system analysis

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The enteric fermentation and manure management during beef cattle production contribute a substantial amount of greenhouse gas (GHG) and ammonia (NH_3) from agriculture globally, leading the beef cattle sector to be a priority of mitigation target. Here, we present the first meta-analysis and integrated assessment of gaseous emissions and mitigation potentials for methane (CH_4), nitrous oxide (N_2O) and NH_3 losses from a typical beef cattle feedlot system, including both enteric fermentation and manure management. Through our meta-analysis of 109 studies, a database comprised of the gas emission factors for each stage of beef cattle feedlot system, also the mitigation efficiencies for 18 available mitigation options are compiled, facilitating the GHG and NH_3 emissions and mitigation potential from the feedlot system to be estimated. Enteric CH_4 fermentation and feed pad manure contributed 67.5 % and 80.8 % of total system GHG and NH_3 emissions, respectively, which indicated that the GHG and NH_3 mitigations should be focused on enteric fermentation stage and feed pad manure management stage. The recommended mitigation combinations can lead the system NH_3 being reduced by 50.9 % in largest. The result has important implication for developing sustainable beef cattle feedlot system from the viewpoint of GHG and NH_3 mitigation.

Keywords: beef cattle feedlot, enteric fermentation, manure management, GHG, NH_3, mitigation

Paludiculture – climate smart land use on peatland

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Conventional peatland utilisation requires drainage, which results in enormous emissions of greenhouse gases and nutrients. Almost 25 % of worldwide carbon dioxide (CO_2) emissions from the LULUCF sector is caused by drained peatlands. Peatland degradation is also responsible for ongoing land subsidence, with annual height losses of 1–2 cm in the temperate zone and about 5 cm in the tropics. Rewetting of drained peatlands is essential to reduce emissions and peat degradation, but rewetting has hitherto resulted in the loss of productive land. Here we present the basic principles of paludiculture, a new land use concept involving the sustainable use of wet and rewetted peatlands for agriculture and forestry, i.e. combining production with soil conservation and possibly even renewed peat growth.

Paludiculture

- is the agricultural or silvicultural use of wet and rewetted peatlands under conditions in which the peat is conserved or even newly formed.
- differs fundamentally from drainage-based conventional peatland use, which leads to huge emissions of greenhouse gases and nutrients and eventually destroys its own production base through peat soil degradation.
- allows the re-establishment and maintenance of ecosystem services of wet peatlands such as carbon sequestration and storage, water and nutrient retention, as well as local climate cooling and habitat provision for rare species.
- cultivates crops that do not require regular tillage or other major soil works. An overview of potential paludiculture plants is given in the Database of Potential Paludiculture Plants (DPPP).
- should in its implementation always consider existing nature conservation values.

Paludiculture is the only land use concept for peatland that can combine the provision of essential mire ecosystem services with the production of useful biomass. Ideally even carbon sequestration can be achieved by the formation of new peat. In future paludiculture should be the normal case for land use on peat soils, drained peatland use should be the exception.

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