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The European pasture sensitivity to climate change

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AnimalChange E-Newsletter

AN Integration for Mitigation and Adaptation options for sustainble Livestock production under climate CHANGE

November 2013

In This Issue

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www.animalchange.eu

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About the project

The demand for livestock products is growing and climate change threatens food security and rural livelihoods. Policies that are currently in place may prove insufficient. Livestock systems are a significant contributor to greenhouse gases (GHG) but there is much uncertainty.

AnimalChange will for the first time provide a vision of the future of the livestock sector under climate change.

AnimalChange will

- **Reduce uncertainties** concerning GHG emissions from livestock systems.
- **Include climate variability** as part of impact assessment.
- **Develop cutting-edge technologies** for mitigation and adaptation to climate change.
- **Assess economic and societal costs** of business as usual and of adaptation and mitigation scenarios.
- **Assess the vulnerability of livestock** to climate change and feedbacks on GHG emissions.
- **Provide direct support to set up policies** for mitigation and adaptation to climate change for the livestock sector.
- **Reach out to stakeholders** by organising symposia, training of scientists, technicians and policy makers and forming a network to alert stakeholders of project outputs and events.

For more information on the project, please contact the following people:

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Mitigation & adaptation options: grass-legume mixtures

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Legumes, either alone or in mixtures with grasses, offer the potential to mitigate Greenhouse Gas (GHG) emissions. Research in AnimalChnage has shown that legumes can substantially reduce N_20 losses, a major contributor to GHG without loss in productivity. Studies are also in progress to examine the resilience of mixtures in adaptation strategies.

Figure 1. Series of 32 shelters used to exclude rain for ten weeks in a drought simulation at Teagasc (Ireland), and Agroscope (Switzerland). The 5m x 3m plots contain different species in monocultures, two-species and four-species plant communities.

Introduction

Legumes form a symbiotic relationship with nitrogen-fixing bacteria in their roots, and can produce between 100 and 200 kg ha^{-1} of plant-available nitrogen (N) through biological nitrogen fixation (BNF) in grazed grassland systems. Through this source of nitrogen for plant growth, grass-legume mixtures offer livestock farmers a 'win-win' scenario both in terms of reducing costs associated with reduced nitrogen fertilizer inputs, as well as reducing reactive nitrogen emissions from farms. These emissions include nitrate losses to groundwater as well as ammonia and nitrous oxide emissions to the atmosphere.

Some of the studies being performed as part of AnimalChange and the associated Legume Futures projects have been exploring options to reduce greenhouse gas emissions from grassland systems. They have been investigating mitigation and adaptation benefits of either a) introducing legumes into grass monocultures, or b) replacing grass monocultures with mixtures containing several grasses and legumes.

Potential mitigation options

The introduction of clover into grazed pasture systems has been shown to substantially reduce nitrous oxide (N_2O) emissions due to reductions in N fertilizer input. In addition, studies have indicated that the actual BNF N_2O emission factor (kg N_2O produced per kg N fixed) can be extremely low (between 0% and 0.5%). In pasture-based dairy production systems, the introduction of white clover (*Trifolium repens*) into grazed swards, combined with an N fertilizer reduction from 230 kg N ha^{-1} to 60 kg N ha^{-1}, resulted in a 30% reduction in N_2O emissions. Importantly, these reductions were achieved without any reduction of either stocking rates or milk production, making incorporation of legumes into grassland swards an attractive option for sustainably maintaining production potential, particularly at moderate stocking rates. We have also shown that experimental mixtures of two grasses and two legumes had 57% higher yields compared to monocultures at the same level of fertilizer input. The mixtures (containing about 50% legumes) with only 50 kg ha^{-1} of N fertilizer produced comparable yields to Lolium perenne monocultures with 450 kg ha^{-1} of N fertilizer. In terms of yield and the reduced need for inputs, these multi-species mixtures may play a significant role in both reducing N emissions and could also aid soil carbon sequestration via higher inputs. These aspects are currently under investigation in workpackages (WP) 6 and 7 of AnimalChange.

Figure 2. Effects of the experimental drought under the rain shelter.

Potential adaptation options

Climate change, particularly precipitation changes, combined with elevated atmospheric CO_2 levels will affect future herbage yields, seasonality and quality in pastures. In terms of adaptation, there are indications that multispecies mixtures have improved resilience to environmental stress. Researchers at Agroscope (Switzerland) and Teagasc (Ireland) are currently comparing the ability of monocultures and multi-

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species grass-legume mixtures to resist and recover from experimental drought (Fig. 2). Furthermore, mixed swards are more resistant to weed invasion, which are projected to be increasingly prevalent under climate change due to invasive plant species. Results from a pan-European study, COST Action 852, clearly demonstrated yield benefits of grass–legume mixtures compared to monocultures in 31 sites across a range of climatic conditions (Finn *et al*., 2013). AnimalChange is focusing specifically on the resilience of mixtures and grass monocultures to varying degrees of drought stress, particularly in terms of short- and long-term effects on yields and maintenance of forage quality.

Finn et al. (2013) *Ecosystem function enhanced by combining four functional types of plant species in intensively-managed grassland mixtures: a three-year continental-scale field experiment*. Journal of Applied Ecology 50: 365-375.

Li, D., Lanigan, G., Humphreys J. (2011) *Measured and simulated N2O emissions from ryegrass and ryegrass/clover swards in a Moist Temperate Climate*. PLOS ONE 6(10), e26176. doi 10.1371/journal.pone.0026176

Lüscher, A., Mueller-Harvey, I., Soussana, J.F., Rees, R.M. and Peyraud, J.-L. (2013) *Potential of legume-based grassland-livestock systems in Europe*. Grassland Science in Europe 18: 3-29.

Nyfeler, D., Huguenin-Elie, O., Suter, M., Frossard, E., Connolly, J. & Lüscher, A. (2009) *Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding*. Journal of Applied Ecology, 46, 683-691.

Greenhouse gas emissions from livestock production in Africa and Latin America

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The GHG contribution of livestock is relatively high but very variable across regions of the world. Using up to date modelling techniques AnimalChange has characterised the uncertainties and the variability across regions. As a consequence of this diversity mitigation options and potentials are different and this needs to be accounted for in climate policies.

The global animal food production chain, including land use and land use changes it involves, generates about 15% of global greenhouse gas (GHG) emissions. The contribution of livestock production to global emissions is high, however variable across regions in the world. The largest contributors from livestock production to the GHG budget are (i) methane (CH_4) emissions from ruminant production systems, (ii) nitrous oxide (N_2O) emissions related to manure management and feed production, and (iii) net CO_2 emissions from land use changes related to feed production and also CO_2 from energy use and transport and food processing (not considered here). With increasing global food demand and stronger international GHG reduction targets, the pressure to reduce the GHG emissions of livestock production increases.

The objective of WP3 of the AnimalChange project is to analyse, describe and decrease key uncertainties in the GHG budget of livestock production at regional scales. So far, the availability of studies and data on livestock GHG emissions and mitigation options is rather limited for many regions in Africa and Latin America compared to Europe, which makes quantification of emission budgets challenging. Within the AnimalChange project we developed the MITERRA-Global model to assess GHG emissions from livestock production and mitigation potentials for Africa and Latin America.

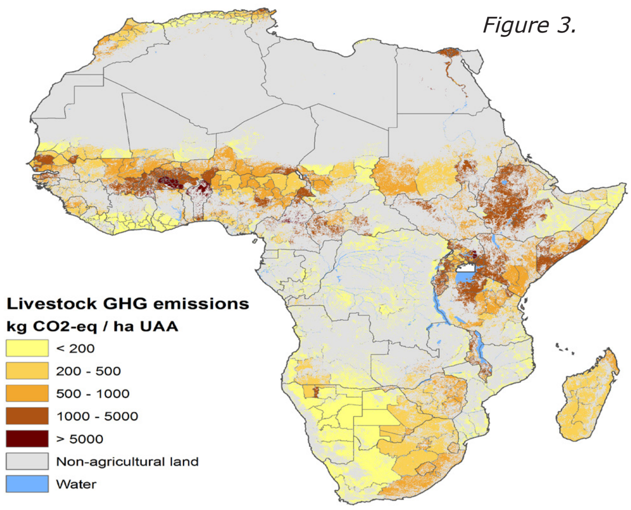

Figure 3.

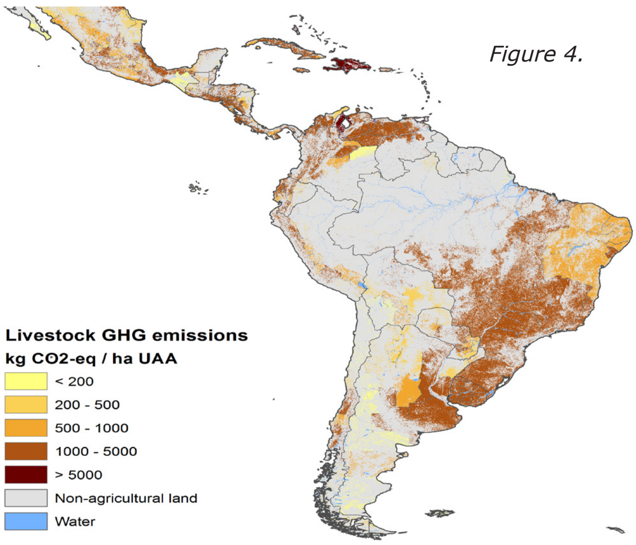

Figure 4.

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MITERRA-Global is an environmental impact assessment model at global scale, based on the MITERRA-Europe model. The model uses detailed activity data (livestock numbers and crop areas) from sub-national statistics, combined with spatial data sources (land cover, soil and climate maps). GHG and N emissions and soil carbon stock changes are calculated on a deterministic and annual basis, using emission factors, mainly based on the IPCC 2006 guidelines.

Figures 3 and 4 show the GHG emissions from livestock production for Africa and Latin America (respectively). These maps show the CH_4 and N_2O emissions from livestock production. Emissions from land use change soil C sequestration and fossil fuel use are not included yet due to lack of data. For certain regions emissions can therefore be underestimated (*e.g.* Brazil), whereas for grassland rich regions emissions might be overestimated. The variation in GHG emissions can be explained by differences in livestock numbers and systems. In Africa the main GHG sources from livestock production are CH_4 from enteric fermentation and N_2O from grazing animals. Another important source not shown is savannah burning. Due to the low fertilizer use, the direct N_2O soil emission is only a minor source. In Latin America enteric fermentation is by far the largest source, due to the large number of cattle, followed by N_2O emissions from grazing and CO_2 from land use change and pasture degradation.

Due to major differences in livestock production systems among and within countries, the GHG emissions and GHG sources are regionally diverse. As a consequence the GHG mitigation options and potentials are different per region, which should be accounted for in climate policies. In the coming period we will further quantify the GHG mitigation potentials for livestock production at a regional scale, which can be used to define more specific and effective mitigation strategies and emissions targets.

The European pasture sensitivity to climate change

Gianni Bellocchi, Romain Lardy, Raphaël Martin

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Vulnerability analysis show an increased exposure to heat and drought stress, except for Eastern and Scandinavian Europe more productive grasslands at high latitudes, in the British islands and Central Europe. Large areas of the Mediterranean region as well as the Atlantic sector of France could experience yield losses.

The vulnerability of a system is a function of the character, magnitude, and rate of climate variations (including extremes) to which a system is exposed, its sensitivity and its adaptive capacity. Understanding what climatic change might do to the integrity and functioning of ecosystems is perceived as a central issue in a range of regional and national concerns.

Vulnerability analysis serves the purpose of indicating areas where systems are most likely to be negatively affected by projected climatic changes and may help prioritizing adaptation efforts in those areas. Mathematical modelling and computer simulation are at the core of many approaches to assess vulnerability to climate change, as shown by assessing grassland sensitivity to hazardous climatic conditions in Europe.
Variations of gross primary productivity between future (2011-2060) and past (1961-2010) conditions were investigated using the Pasture Simulation model (PaSim) to simulate the impact of climate on grassland systems. To do this, a "business-as-usual" type scenario (A1B) was used to represent future conditions, in which current trends in emissions continue, leading to a doubling in CO_2 levels by the end of the 21th century.
To quantify the probability for grassland systems to incur potentially hazardous climate events, precipitation and temperature hazardous events in each year were quantified via an agro-climatic metric of aridity (b, ≥0). As aridity is represented by small values of b, the sensitivity to aridity conditions was assessed by estimating gross primary productivity of grasslands subjected to moderately intensive management for arid years taken from both 2011-2060 and 1961-2010. Arid years are represented by values of b falling into the bottom 25 percent of all calculated aridity values (that is, below the 25th percentile).

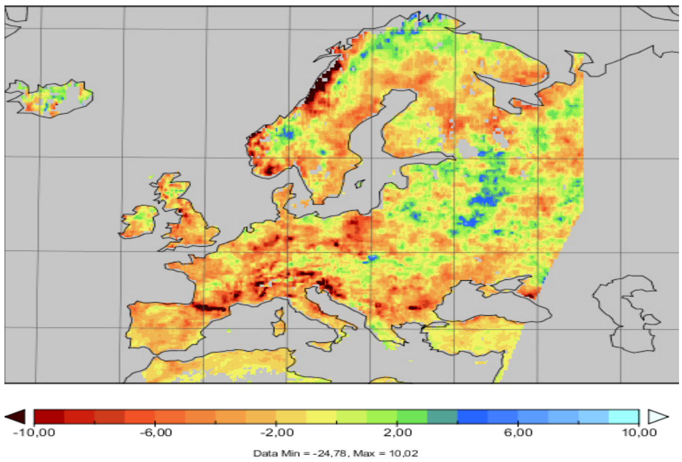

Figure 5. Difference between the mean values of the aridity index (b) calculated for years of P2 (2011-2060) and P1 (1961-2010) with b<25th percentile, as represented by the scenario A1B. Yellow to brown colours indicate growing aridity under future climate (and vice versa for light green to light blue colours). Weather data were generated via the ensemble of regional climatic models used in the EU-FP6 ENSEMBLE.

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The results, rendered out in the form of smoothed, pixelated European maps, indicate: 1) a general climate shift towards an increased exposure to heat and drought stress, with the exception of eastern and Scandinavian Europe (Fig. 5), and 2) more productive grasslands at high latitudes, in the British islands and Central Europe, while large areas of the Mediterranean region as well as the Atlantic sector of France could experience yield losses associated to climate-change induced conditions of aridity (Fig. 6).

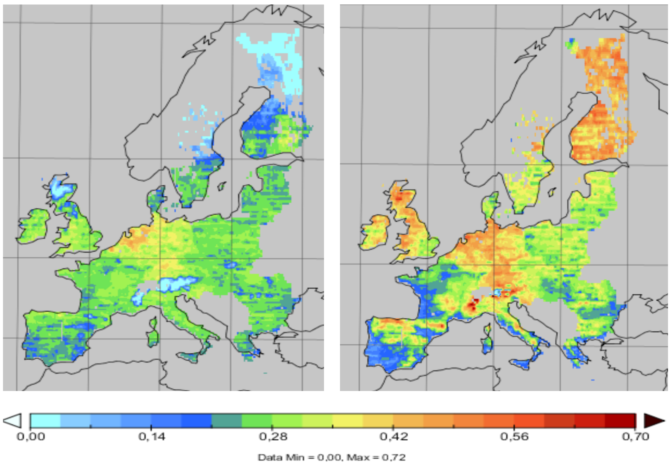

Figure 6. Average values of dry matter yield (kg DM m^{-2}) for years experiencing conditions of aridity (b<25th percentile), represented by the scenario A1B; left: 1961-2010; right: 2011-2060. Yellow to brown colours indicate high levels of dry matter yield (and vice versa for light green to light blue colours).

Pasture intensification in Brazil

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Major land use changes and pasture degradation have characterized livestock production in Brazil. Major changes in pasture productivity are needed to meet future demand for beef and to reduce GHG emission. AnimalChnage has modeled and optimized mitigation strategies. In this respect pasture restoration is the most promising measure to reduce GHG for the cattle sector in Brazil.

In Brazil, the expansion of land use by agriculture has been historically driven by demand for food, fiber and fuel but also by a number of other factors. There was concern of the governments to expand the occupied territory towards the borders for national security reasons besides promoting development to the Northern region of the country. From the private sector perspective, timber extraction, wood for still mills and land speculation were among the drivers for expansion. Fast land clearance in places with limited infrastructure resulted in large areas of cheap land particularly suitable for cattle raising. In the agricultural frontier regions cattle raising is one of the option with highest output per labor unit and with low production and price risk. Additionally land and cattle were good reserves of value in the Brazilian instable economy in the mid-20th century. The Brazilian Cerrado and, more recently, the borders of the Amazon rainforest, mostly in the transition between Cerrado and the Amazon biome were turned into some of the most important cattle production regions in Brazil. Currently, agriculture uses a land area of around 350 million ha, out of the vastness of the 850 million ha of the Brazilian territory. Most of the agricultural land, c.a. 160 - 200 million ha being currently covered by grasslands.

Pasture degradation was probably a consequence of this process, as it would frequently be more attractive to speculate with cheap land and to have cattle as reserve of value rather than invest in improving pasture productivity with long term payback and very high interest rates. The rising beef demand obviously could not be met by increasing pasture area through deforestation and degradation

Conditions for beef production have changed, particularly since the mid 90's. Since then, the Brazilian economy stabilized and, consequently, the attractiveness of cattle and land as reserve of value diminished. In parallel, exports have rocketed in the 90's after the BSE disease outbreak and the rise in global demand for beef.

Despite the increasing demand, production could not expand though the incorporation of new grassland areas anymore. The fast expansion of cropping and lower deforestation rates, due to more restrictive legislation and the enforcement of deforestation contrrol led to the end of expansion and, perhaps, the beginning of contraction of grassland area in Brazil. Therefore, animal productivity has increased from 28 to 44.5 kg of carcass weight equivalent per head per year from 1990 to 2007 while stocking rates increased from 0.79 to 1.08 heads per hectare in the same period.

With the largest commercial herd in the world, enteric emissions made up a large part of total GHG emissions of Brazil, 11.1 Tg CH_4 per year (2005). There is also, a lot of opportunity to mitigate emissions through the accumulation of soil carbon as a result of higher pasture productivity in beef production systems. Current estimates point to 40 million ha of degraded pastureland that could produce over 20 t DM ha per year. Therefore, pasture recovery and crop-livestock-forestry integrated systems, apart from the reduction of deforestation, are pointed as the main mitigation

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options in the Brazilian Nationally Appropriate Mitigation Actions, presented at COP 15. It is important to notice that increasing beef productivity is also a necessary condition to simultaneously avoid deforestation and meet the beef demand.

In AnimalChange, successful work has been carried out on modeling mitigation options at farm and regional scales for the Brazilian conditions through a novel mathematical programming model for optimizing mitigation strategies of greenhouse gases emissions in beef cattle production systems. The model, coined EAGGLE, was developed in a cooperative work between Embrapa, the Institute of Mathematics and Statistics (IMECC) of the University of Campinas and the Scotland's Rural College (SRUC). The model represents in monthly periods the herd dynamics, financial resources, feed budgeting, pasture recovery dynamics, and soil carbon(C) stock dynamics, in a matrix of about 20 thousand variables. The computation of soil carbon dynamics is one of the novelties in EAGGLE.

A MACC (Marginal Abatement Cost Curve) curve constructed with EAGGLE has shown that pasture restoration is the most promising mitigation measure for the Brazilian cattle industry, in terms of abatement potential responding for 23.4 MMT CO_2-e.yr^{-1}, which is over 17 times the abatement potential of all the others mitigation measures included in the analysis put together.

At the farm level, EAGGLE is able to identify economically optimal trajectories for pasture productivity recovery as well as financial credit barriers. EAGGLE has shown that optimum economic levels of restoration are, sensitive to beef prices. The higher the beef prices, the higher the economically optimum pasture productivity level and, consequently, the lower the emissions intensities. The model indicates, therefore, an indirect consequence of low beef prices, which would be higher emission intensities.

EAGGLE was also applied to a regional analysis to study mitigation options for the Brazilian Cerrado. A sensitivity analysis of the beef demand, under the assumptions of our analysis and within a 20 years period, has shown that reducing beef consumption (demand) is ineffective to mitigate emissions in the short term. The MACC curves have shown that the mitigation potential would be lower and abatement costs higher in a scenario of lower beef demand. This is because productivity is given by the production by grassland area and production is driven by demand. Therefore, lower beef demand would result in lower productivity through either lower animal productivity or lower pasture productivity, both resulting in higher emission intensities which offsets the effect of lower consumption. Such effects would not be captured by standard attributional lifecycle analysis. Currently, Embrapa's team is working to include upstream lifecycle analysis into EAGGLE. Most of the papers with those results are about to be submitted to high impact international journals.

Another important ongoing cooperation in AnimalChange which would allow for important analysis of the most appropriate strategies for mitigation and adaptation of the Brazilian cattle production is through the evaluation, calibration and adaptation of Pasture Simulation Model (PaSim) with INRA. PaSim will be used for regional analysis in Brazil, including vulnerability. Historical and projected climate data were organized and a computational infrastructure, including automatic workflow and parallel computing, has been tested to give support to the simulations needed at Embrapa Agricultural Informatics. A first set of evaluations of PaSim has already been carried out and calibration to the Brazilian conditions will start before the end of 2013.

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