PhD PROPOSAL FOR THE DOCTORAL SCHOOL
« Ecologie, Géosciences, Agronomie, ALimentation »

GENERAL INFORMATION

Thesis title: Modelling and Monitoring of Ammonia and Greenhouse Gas Fluxes in Grazed Grasslands
Acronym: MOPPEMAG
Disciplinary field 1: Geosciences **Disciplinary field 2:** Select an element
Three keywords: Ammonia, Greenhouse Gases, Modelling
Research unit : UMR 1069 INRAE/Institut Agro Sol, Agro-hydrosystème, Spatialisation (SAS), Rennes
Name of the thesis director HDR (Habilitation thesis to supervise research) required: Valérie Viaud **Email address of the thesis director:** valerie.viaud@inrae.fr **Name of the thesis co-director (if applicable): HDR (Habilitation thesis to supervise research) required:** **Email address of the thesis co-director (if applicable):** **Name of the thesis co-supervisor 1 (if applicable):** Christophe Flechard **Email address of the thesis co-supervisor 1 (if applicable):** christophe.flechard@inrae.fr **Name of the thesis co-supervisor 2 (if applicable):** Anne-Isabelle Graux **Email address of the thesis co-supervisor 2 (if applicable):** anne-isabelle.graux@inrae.fr
Thesis grant (funding origin and amount): INRAE Dept AgroEcoSystem (50%); Région Bretagne ARED (50%)
Contact(s) (mailing address and E-mail): Christophe Flechard, INRAE, UMR SAS, 65 rue de Saint-Brieuc, 35042 Rennes, France. christophe.flechard@inrae.fr
Recruitment process: Recruitment process depends on thesis funding. To select the corresponding recruitment process, please visit the EGAAL website here. This information is needed for proposal publication. ☐ **Doctoral school contest** ☒ **Interview** ☐ **Other (indicate) :**

SCIENTIFIC DESCRIPTION OF THE PhD PROJECT

Socio-economic and scientific context : (10 lines)

Grazed grasslands play an important role in herbivore animal husbandry in most regions of the world, especially in milk production systems. Their surface area worldwide is 2.2 times larger than that of arable and permanent crops combined and has increased by 9% over the last 50 years. From an environmental viewpoint, the extension of the grazing season and of grazing areas has been suggested as an effective means to optimize grassland management and land use to increase soil carbon storage as part of global agro-ecological transitions. In fact, depending on management and meteorology/climate, grazed grasslands may behave as net sinks or net sources of atmospheric CO_2 and greenhouse gases (GHG) including N_2O and CH_4. In addition, as a result of urea hydrolysis in deposited urine patches, intensive grazing and certain areas of grazed fields may lead to large emissions of ammonia (NH_3), a major atmospheric pollutant and a chemical precursor of sub-micron aerosols. This PhD thesis will investigate NH_3 and GHG fluxes in grazed grassland through in-situ flux measurements and coupled modelling of biogeochemical processes and ecosystem functioning.

Hypotheses and science questions (8 lines)

This PhD project is based on the assumption that, to understand and quantify NH_3 and GHG fluxes in grazed grasslands, it is necessary to consider carbon (C), nitrogen (N) and water fluxes of the whole ecosystem (soil, plants and animals) in an integrated manner.
- A key question is how to couple biogeochemical (C, N, GHG) modelling of the ecosystem and the modelling of physical and chemical processes underlying NH_3 emissions during and after grazing, especially the turnover of nitrogen between soil, plants and herbivores.
– What is the impact of grassland management (frequency, grazing density, full-time versus part-time grazing, feed complementation) on field-scale NH_3 emissions, as well as other C, N and GHG fluxes in the ecosystem?
- What is the impact of climate on field-based NH_3 emissions, both direct (impacts of temperature and rainfall on the thermodynamics of urea hydrolysis, and effects of turbulence on vertical transport), and indirect (impacts of weather on grass growth patterns) ?

The main steps of the thesis and scientific procedure (10-12 lines)

The PhD work will be organized in four work packages:
1- The PhD candidate will take part in both long-term and short-term NH_3 and GHG field flux measurement campaigns at the ICOS-Méjusseaume flux monitoring station, and will be in charge of data post-processing, evaluation and integrated analysis.
2- Implementation and coupling of the BASGRA_N and GAG models. Creation of a data exchange module between the two models to deal with ecosystem processes at different time steps (daily for BASGRA_N, hourly for GAG). Two visits of 1.5 months each to the UK Center for Ecology and Hydrology (UK CEH) Edinburgh will be used for training, and then advanced operations, on the two models.
3- Bayesian calibration of the coupled model, initially for the specific case of a Lolium perenne L. monoculture, using ecosystem data from the ICOS-Mejusseaume monitoring site and from other flux tower sites, where appropriate data can be found.
4- Study of the influence of climate and grassland/grazing management on NH_3 emissions and on the net ecosystem-scale GHG balance. This will be done by simulations of the coupled model, applied to several flux tower locations, constrained by contrasted climate (RCP) scenarios and grassland management systems (intensive vs extensive grazing, feed complementation, etc).

Methodological and technical approaches considered (4-6 lines)

The grassland ecosystem model envisaged for this work is BASGRA_N (code available on https://doi.org/10.5281/zenodo.1493404), developed by UK CEH in Edinburgh (UK) and NIBIO (Norway), a new version of the mechanistic BASic GRAssland (BASGRA) model. The NH_3 emission model (Generation of Ammonia by Grazing) is also developed by UK CEH, and the work will be carried out in close collaboration between INRAE and UK CEH. The calibration and validation of the coupled model will be based on ecosystem data and C, N and GHG micrometeorological flux data from the ICOS (Integrated Carbon Observation System) monitoring site at Méjusseaume (FR-Mej), located on the INRAE-IEPL experimental dairy farm near Rennes, NW France.

Scientific and technical skills required by the candidate

- In-depth knowledge of biogeochemical processes in grassland ecosystems, esp. regarding C and N cycling and GHG fluxes
- Programming skills (R, Fortran, etc) and Bayesian calibration statistics
- Micrometeorological measurement techniques for surface-atmosphere exchange / trace gas fluxes
- Numerical analysis of environmental, ecosystem and ecophysiological data
- Ability to work in a multi-disciplinary team and an international context

THESIS SUPERVISION[1]

Unit name:	Team name:
UMR 1069 INRAE/Institut Agro Sol, Agro-hydrosystème, Spatialisation (SAS)	Systems and Fluxes
Unit director name:	**Team director name:**
Christian Walter	C. Flechard, A. Michaud
Mailing address of the unit director:	**Mailing address of the team director:**
christian.walter@agrocampus-ouest.fr	christophe.flechard@inrae.fr
02 23 48 54 39	02 23 48 52 22

Thesis director

Surname, first name: Viaud, Valérie

Position: Research Director

Obtained date of the HDR (Habilitation thesis to supervise research): 2020

Employer: INRAE

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 40%

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 160%

Number of current thesis supervisions/co-supervisions: 2

Thesis co-director

Surname, first name:

Position:

Obtained date of the HDR (Habilitation thesis to supervise research):

Employer:

Doctoral school affiliation:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

Thesis co-supervisor 1 (if applicable)

Surname, first name: Flechard, Christophe

Position: Researcher

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[1] **In EGAAL Doctoral School, if only one scientist in thesis supervision = 100% of supervision rate; if 2 people involved in thesis supervision = from 50% to 70% of supervision rate for the director; if 3 people involved in thesis supervision = 40% / 30% / 30% of supervision rate distribution among supervisors.**

Habilitation thesis to supervise research ☐ yes ☒ no   If yes, date diploma received:

Employer: INRAE

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 30%

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0%

Number of current thesis supervisions/co-supervisions: 0

Thesis co-supervisor 2 (if applicable)

Surname, first name: Graux, Anne-Isabelle

Position: Researcher

Habilitation thesis to supervise research ☐ yes ☒ no   If yes, date diploma received:

Employer: INRAE

Doctoral school affiliation: EGAAL

Rate of thesis supervision in the present project (%): 30%

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%): 0%

Number of current thesis supervisions/co-supervisions: 0

Private partner (if CIFRE funding, private funding,…)

Surname, first name:

Position:

Employer:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

International partner (if Cotutelle thesis)

Surname, first name:

Position:

Employer:

Rate of thesis supervision in the present project (%):

Total rate of thesis supervision in ongoing theses (supervisions and co-supervisions) (%):

Number of current thesis supervisions/co-supervisions:

Professional status of previous PhD students supervised by both director and co-supervisors (from 5 years)

Please provide the following information for each PhD students supervised

Surname, first name: Bell, Michael

Date of PhD beginning and PhD defence: 2014-2017

Thesis supervision: Benjamin Loubet, INRAE-ECOSYS, Grignon

Professional status and location: Environmental consultant, Glasgow, UK

Contract profile (post-doc, fixed-term, permanent): permanent

List of publications from the thesis work:

Bell M., Flechard C., Fauvel Y., Hani C., Sintermann J., Jocher M., Menzi H., Hensen A., Neftel A. (2017). Ammonia emissions from a grazed field estimated by miniDOAS measurements and inverse dispersion modelling. Atmospheric Measurement Techniques, 10 (5), 1875-1892, https://dx.doi.org/10.5194/amt-10-1875-2017, https://hal.inrae.fr/hal-02629147

Bell M.W., Tang YS, Dragosits U., Flechard CR, Ward P, Braban CF (2016). Ammonia emissions from an anaerobic digestion plant estimated using atmospheric measurements and dispersion modelling. Waste Management 56: 113–124.

Sintermann, J., Dietrich, K., Häni, C., **Bell, M**., Jocher, M., and Neftel, A.: A miniDOAS instrument optimised for ammonia field measurements, Atmos. Meas. Tech., 9, 2721–2734, https://doi.org/10.5194/amt-9-2721-2016 , 2016.

Five main recent publications of the supervisors on thesis subject:

Souhar, O., Fauvel, Y., **Flechard, C.** (2022). Measuring and Modeling Atmospheric Ammonia from Agricultural Sources at a Landscape Scale. Environmental Engineering Science, https://doi.org/10.1089/ees.2021.0371 .

Puche N., Senapati N., **Flechard C**., Klumpp K., Kirschbaum M. U., Chabbi A. (2019). Modeling Carbon and Water Fluxes of Managed Grasslands: Comparing Flux Variability and Net Carbon Budgets between Grazed and Mowed Systems. Agronomy, 9 (4), 183, https://dx.doi.org/10.3390/agronomy9040183, https://hal.inrae.fr/hal-02101575

Bell M., **Flechard C**., Fauvel Y., Hani C., Sintermann J., Jocher M., Menzi H., Hensen A., Neftel A. (2017). Ammonia emissions from a grazed field estimated by miniDOAS measurements and inverse dispersion modelling. Atmospheric Measurement Techniques, 10 (5), 1875-1892, https://dx.doi.org/10.5194/amt-10-1875-2017, https://hal.inrae.fr/hal-02629147

Graux A.-I., Delaby L., Peyraud J.-L., Casellas E., Faverdin P., Le Bas C., Meillet A., Poméon T., Raynal H., Resmond R., Ripoche D., Ruget F., Therond O., Vertès F. (2017). Les prairies françaises : production, exportation d'azote et risques de lessivage. (INRA), 74 p., https://hal.inrae.fr/hal-01814120

Graux A.-I., Resmond R., Casellas E., Delaby L., Faverdin P., Le Bas C., Ripoche D., Ruget F., Therond O., Vertès F., Peyraud J.-L. (2020). High-resolution assessment of French grassland dry matter and nitrogen yields. European Journal of Agronomy, 112, 125952, https://dx.doi.org/10.1016/j.eja.2019.125952, https://hal.inrae.fr/hal-02628325

Launay C., Constantin J., Chlebowski F., Houot S., **Graux** A.-I., Klumpp K., Martin R., Mary B., Pellerin S., Therond O. (2021). Estimating the carbon storage potential and greenhouse gas emissions of French arable cropland using high-resolution modeling. Global Change Biology, 27 (8), 1645-1661, https://dx.doi.org/10.1111/gcb.15512, https://hal.inrae.fr/hal-03128111

THESIS FUNDING

Origin(s) of the thesis funding: INRAE Dept. AgroEcosystem (50%) ; Brittany Regional Council ARED (50%)

Gross monthly salary: 1975 EUR

Thesis funding state : Acquired

Funding beginning date/Funding ending date: 2022-2025

Date: 17 Mai 2022

Name, signature of unit director:

Christian Walter

Name, signature of team director:

Christophe Flechard

Name, signature of thesis project director:

Valérie Viaud