Project Title	Do microbe-mineral interactions influence nitrogen cycle dynamics?
University (where student will register)	University of Warwick
Theme **(Max. 2 selections)**	Climate & Environmental Sustainability ☒ Organisms & Ecosystems ☒ Dynamic Earth ☐
Supervisory team (including institution & email address	**PI:** Ryan Mushinski University of Warwick Ryan.Mushinski@warwick.ac.uk **Co-I:** Gary Bending University of Warwick Gary.Bending@warwick.ac.uk

Flagship Criteria Intake 2023	**Score**	
CENTA2 L1/2 end-user co-development and supervision 2 for a L1/2 partner that have no prior CENTA collaborations: Jacobs, Marine Biological Association, AstraZeneca	**(2+2)**	**0**
CASE project, confirmed by a specific letter of support from the CASE partner, projects without such a letter clearly stating commitment will not be awarded a point.	**1**	**0**
Diversity of the supervisory team (diversity towards e.g., gender, ethnicity, disability, and cultural background)	**1**	**0**
Career development of the supervisory team: specifically targeted at projects led by an academic who is seeking their first PhD student as lead supervisor.	**1**	**0**
Collaboration project with one of our Research Centre Partners (BGS, CEH, NCEO, NCAS) led by an academic from an HEI partner	**2**	**0**
Applicant co-development of the project	**1**	**0**
Sum	**10**	**0**

Project Highlights:

- New research to unravel the significance of volatile nitrogen oxide emissions from natural ecosystems. Understanding nitrogen oxide fluxes is important for human and wider environmental well-being.
- A blend of laboratory and field experience, accessing skills ranging from molecular techniques to *in-situ* trace gas measurement
- Access to state-of-the-art instrumentation and opportunities for wider collaboration in funded research projects.

Overview (including 1 high quality image or figure):

The majority of organic N in soil is often held in the mineral-associated organic matter (MAOM) fraction of soil, which has slow turnover rates and is thought to be largely inaccessible to microbes and plants (Cotrufo et al. 2013). Partially decomposed plant material constitutes the particulate organic matter (POM) fraction in soil, which typically holds a smaller proportion of total organic N. Thus, MAOM can be viewed as a bottleneck to N-availability within the rhizosphere, with N mineralization rates depending on the structure of organic matter and its interaction with soil minerals and microbial communities.

The underlying goal of this project is to investigate how ecosystem-microbe-mineral interactions drive nitrogen oxide fluxes [N_2O + NOy] from soils. While fluxes of nitrous oxide have been well quantified from ecosystems, fluxes of reactive nitrogen oxides [NOy ≡ NO + NO_2 + HONO] are poorly studied owing to their highly reactive nature. Our incomplete understanding of the factors that control these fluxes has limited our ability to predict the air quality and climate impacts of soil N emissions. We aim to uncover the factors that determine nitrogen oxide fluxes in natural ecosystems (primarily woodlands and grasslands), using an approach that combines field experiments with state-of-the-art analytical capabilities and metagenomic analyses. Both N_2O and NOy fluxes will be quantified to better determine edaphic factors responsible for both, and their potential interactions.

Our hypothesis is that nitrogen oxide emissions are controlled by three factors: i) the activities of soil microbes that will vary depending on the ecosystem, the proportion of POM and MAOM, and the underlying soil mineralogy. To test our hypothesis, we will: (1) Determine the relationship between soil mineralogy and soil organic matter composition on soil outgassing of nitrogen oxides in field experiments; (2) determine how SOM-mineral interactions affect N availability and mineralization rates in different soil fractions and in varying ecosystems; (3) determine which soil fractions are targeted by N-mining microbes and which taxa produce the enzymes needed to mobilize N in those fractions.

Methodology:

Aim 1. Measure soil outgassing of nitrogen in the field from varying natural ecosystems and as a function of soil mineralogy. Here we will install field sampling infrastructure and perform a subsequent field sampling campaign.

Aim 2. Determine how SOM-mineral interactions affect N availability and mineralization rates. Here we will prepare samples for analysis (taken from Aim 1), including ^{1}H and ^{13}C NMR, ToF SIMS, and High-resolution MS. Data will be analysed, and a manuscript will be prepared and submitted for publication.

Aim 3. Determine which soil fractions are targeted by N-mining microbes and which taxa are producing the enzymes that mobilize N and release volatile nitrogen in those fractions. Here we will extract DNA and RNA from collected soil samples, shotgun sequence extracts, and analyse the resulting data using bioinformatic pipelines, targeting genes involved in nitrogen mineralisation. A second manuscript will be prepared and submitted for publication.

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and 'free choice' external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

Training during this fellowship includes a wide range of molecular techniques and analyses (DNA extraction from soil, PCR, sequencing, and bioinformatics) as well as analytical chemistry (nitrogen oxide quantification, reactive oxygen extraction from soil and subsequent quantification, and building sampling mesocosms). Field-based sampling and measurements from natural ecosystems will also be emphasized with additional training opportunities through possible collaboration with UK-CEH scientists.

Partners and collaboration (including CASE):

Name of L1/L2 Partner (where applicable)	Not applicable
Name of CASE partner (where applicable – project proposal **must** be accompanied by a letter of support from the CASE partner)	Not applicable

<u>Respiratory and Contact Infection Resilience of the Project:</u>

The School of Life Science at the University of Warwick has SOP's in place to allow research to continue in light of respiratory infection outbreak. This includes reducing the capacity of people in laboratory spaces, placing protective barriers between workstations, and working from home when possible. The laboratory portion of this work will proceed as normal, within the scope of the SOP's. All meetings associated with this project will be in line with current guidelines. The field component will proceed within the confines of a subsequent SOP - to be developed between the PI in accordance with all University- and government-mandated requirements.

Possible timeline:

Year 1: Measure soil outgassing of nitrogen oxides in the field from varying natural ecosystems and as a function of soil mineralogy.

Year 2. Determine how SOM-mineral interactions affect N availability and mineralization rates.

Year 3. Determine which soil fractions are targeted by N-mining microbes and which taxa are producing the enzymes that mobilize N and release volatile nitrogen in those fractions.

Further reading:

Cotrufo, M. F.; Wallenstein, M. D.; Boot, C. M.; Denef, K.; Paul, E., The Microbial Efficiency- Matrix Stabilization (MEMS) framework integrates plant litter decomposition with soil organic matter stabilization: do labile plant inputs form stable soil organic matter? *Global Change Biology* 2013, 19 (4), 988-995.

Further details:

Please add project/institutional contact details including a link to the application website if applicable

Environmental Processes Lab Website: www.ryanmushinski.com