Research Profile

I am a PhD candidate in the School of Natural Sciences, Botany discipline at Trinity College Dublin, focusing on plant ecophysiology, sustainable agriculture, and environmental science. My research explores how plant diversity in grassland ecosystems can enhance agricultural sustainability while contributing to climate change mitigation.

My project, “Assessing the role of multi-species swards in mitigating carbon and greenhouse gas emissions from intensively managed grasslands in Ireland,” investigates how increasing plant diversity in pasture systems influences ecosystem function. Specifically, the research evaluates how multi-species grasslands can reduce greenhouse gas emissions, enhance soil carbon sequestration, and improve the resilience and sustainability of grassland-based livestock production systems.

This work is conducted under the supervision of Dr. Matthew Saunders (Discipline of Botany, School of Natural Sciences, Trinity College Dublin), Dr. Rachael Murphy (Teagasc Environment, Soils and Land Use Department and Teagasc Climate Centre), and Dr. Karl Richards (Teagasc Climate Centre). Through this collaboration, the project integrates expertise across plant ecology and ecophysiology, soil science, and agricultural climate research.

The outcomes of this research contribute to national and international efforts to develop climate-resilient agricultural systems that balance food production with environmental sustainability. It also advances interdisciplinary research on grassland ecosystems, biodiversity–ecosystem functioning relationships, and climate mitigation in agricultural landscapes.

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Research project summary

Irish agriculture faces the dual challenge of maintaining high productivity while reducing greenhouse gas emissions and nutrient losses to meet national and EU climate and water quality targets. Grass-based systems dominate Irish agriculture, with grasslands covering approximately 60% of the national land area and supporting the country’s globally significant beef and dairy sectors. These systems also represent the second-largest soil carbon reservoir after peatlands and wetlands.

However, around 95% of Irish grasslands are dominated by perennial ryegrass monocultures that rely heavily on nitrogen fertilizer inputs. While productive, such systems contribute significantly to agricultural greenhouse gas emissions, particularly nitrous oxide (N_2O) from livestock urine patches, as well as carbon dioxide (CO_2) exchanges between soils, vegetation, and the atmosphere. Intensive management can also increase risks of nutrient losses to water, biodiversity decline, and rising production costs.

Agriculture represents the largest source of greenhouse gas (GHG) emissions in Ireland, accounting for a substantial proportion of national emissions. Within this sector, methane (CH_4) from enteric fermentation in ruminant livestock is the dominant contributor. However, pasture-based systems also influence other important components of the greenhouse gas balance, including carbon dioxide (CO_2) through soil carbon sequestration and nitrous oxide (N_2O) through nitrogen cycling processes. Maximising CO_2 uptake while minimising N_2O emissions is therefore critical for improving the overall greenhouse gas balance and climate mitigation potential of grazing systems.

Understanding and quantifying both N_2O emissions and ecosystem carbon dynamics is therefore essential to accurately evaluate the net greenhouse gas balance of pasture systems and to inform the development of sustainable management strategies. Current greenhouse gas inventories often rely on generalized emission factors derived largely from monoculture systems and simplified assumptions, which overlook the spatial and temporal variability characteristic of grazed landscapes. In particular, these approaches often fail to account for emission "hot spots", such as urine deposition patches, and "hot moments", short periods of elevated emissions following events such as rainfall or fertilizer application. These localized and episodic processes can contribute disproportionately to total N_2O emissions, and their omission introduces uncertainty into emission estimates and constrains the development of effective mitigation strategies.

This research investigates multispecies swards (MSS) pastures that combine grasses, legumes, and herbs as a nature-based solution for developing more climate-resilient and environmentally sustainable grazing systems. The study is based on field-scale experiments conducted under managed grazing conditions, integrating plot measurements with ecosystem-scale monitoring. The project combines static chamber measurements of N_2O fluxes, unmanned aerial vehicle (UAV) mapping to characterise spatial vegetation patterns and urine patch distribution, and micrometeorological eddy covariance techniques to quantify ecosystem-level carbon exchange. In addition, soil processes are assessed through measurements of nitrogen dynamics and microbial activity to better understand the biogeochemical drivers of N_2O emissions. By integrating these approaches across multiple spatial scales from localized urine patches to whole-field carbon fluxes the monitoring framework captures key components of real grazing system dynamics, including plant functional diversity, soil nitrogen transformations, and ecosystem-level greenhouse gas exchange.

Key research components

- Ecosystem carbon balance: Eddy covariance measurements quantify net ecosystem carbon exchange at the field scale.
- Plot-scale emissions: Chamber techniques measure N_2O fluxes at the plot scale under controlled field experimental conditions, where nitrogen inputs such as fertilizer and simulated urine deposition are applied with defined timing and frequency to mimic grazing conditions.
- UAV mapping: High-resolution drone imagery identifies and maps urine and dung patches and their distribution across different grazed grasslands sward, this approach enabled accurate quantification of N_2O emissions by capturing the full spatial heterogeneity of urine-patch distribution as the hotspots of emissions, thereby improving field-scale estimates compared with the uniform distribution assumptions commonly used in current inventories.
- Flux upscaling emissions: Chamber measurements are combined with spatial data to estimate field-scale N_2O emissions.

Key Findings

- ✓ Improved emission estimation with UAV mapping: Using this approach, field-scale N_2O emission estimates were up to 30% lower than traditional chamber measurements, demonstrating that flux upscaling based on UAV-derived urine patch distribution provides a more realistic and precise assessment of emissions compared with uniform assumptions used in current inventories.
- ✓ Lower total emissions without compromising DM yield: Multispecies swards (MSS) reduced N_2O emissions by approximately 70% compared to perennial ryegrass (PRG) monocultures, while maintaining high dry matter productivity.
- ✓ Enhanced nitrogen uptake and use efficiency: MSS improved nitrogen uptake by up to 73% and increased nitrogen use efficiency (NUE) by 33% compared to PRG, reducing dependence on synthetic fertilizers.
- ✓ Reduced emission intensity: MSS decreased emission intensity by 60% relative to PRG, further highlighting their environmental benefits per unit of dry matter produced.
- ✓ Integrated carbon monitoring: MSS reduced carbon export by approximately 40% compared to PRG, highlighting their potential to enhance carbon sequestration in grasslands and supporting climate mitigation.
- ✓ Sustainable mitigation approach: Plant-diverse grasslands provide a practical and cost-effective pathway to reduce agricultural emissions while supporting productivity and farm resilience.

By combining biodiversity-based management with advanced spatial monitoring point source emissions and ecosystem scale carbon measurements, this research demonstrates that multispecies grasslands can simultaneously reduce greenhouse gas emissions and improve nutrient efficiency. The findings provide a strong scientific foundation for climate-smart grassland management that supports sustainable food production while reducing environmental impacts.

Figure 1. Measurement approaches for greenhouse gas emissions in Irish grasslands.

Static chambers used to measure soil nitrous oxide (N_2O) fluxes (**A**); eddy covariance systems measuring ecosystem-scale carbon dioxide (CO_2) exchange between the grassland ecosystem and the atmosphere (**B**); and UAV-based mapping used to detect and quantify urine patch distribution under grazing conditions (**C**).