Research Plan – Visiting Graduate Research Student Program

Applicant: Laíla Arnauth
Home Institution: Federal University of Rio de Janeiro (UFRJ)
Host Institution: University of Regina
Supervisor in Canada: Dr. Mark Vanderwel

Research Title: Diversity or Identity: Functional and Phylogenetic Contributions to Biomass Production in Restored Forests

1. Introduction

Tropical forest restoration is increasingly recognized as a vital strategy for climate change mitigation, particularly through its role in sequestering atmospheric carbon. However, defining the most effective approaches to maximize ecosystem functions such as biomass accumulation remains a challenge. One key question is whether restoration outcomes are better optimized by selecting fast-growing, high-yielding species or by fostering diverse species assemblages that may enhance functional complementarity and ecosystem stability over time.

While biodiversity-ecosystem functioning (BEF) relationships are well documented in natural ecosystems, their applicability to restored forests, especially in early successional stages, remains insufficiently understood. Restoration sites often differ substantially in structure, composition, and management history, which complicates generalizations about the drivers of ecosystem functioning.

My master's research aims to investigate how different dimensions of biodiversity – namely species richness, phylogenetic diversity, and functional diversity – relate to aboveground carbon accumulation in restoration plantings of the Atlantic Forest. By disentangling the contributions of taxonomic, phylogenetic, and functional diversity, the study seeks to clarify whether ecosystem functioning in restoration is driven more by the presence of dominant traits (mass-ratio hypothesis) or by the complementarity among species (niche differentiation). This understanding can provide important insights for improving restoration planning and aligning it with global climate and biodiversity goals.

2. Research Objectives

- To evaluate the relative importance of species richness, functional diversity (FD), and phylogenetic diversity (PD) in explaining variation in aboveground biomass across Atlantic Forest restoration sites.
- To investigate the potential decoupling and interactive effects between functional and phylogenetic diversity on ecosystem functioning.
- To understand how key functional traits influence carbon accumulation in restored forests.

3. Methodology

This research draws on vegetation surveys and trait data collected from multiple Atlantic Forest restoration sites in Brazil to investigate how different biodiversity dimensions influence aboveground biomass accumulation. The study is structured in two

complementary analytical components, corresponding to the two main chapters of my master's thesis.

In the first chapter, I evaluate the relationship between phylogenetic diversity and aboveground biomass across a wide set of restoration sites. Phylogenetic structure is quantified using metrics such as sesPD and sesMPD, based on species composition and abundance data. I apply linear mixed-effects models to examine how these metrics relate to aboveground biomass while accounting for random variation among sites. In addition, I use Principal Coordinates of Phylogenetic Structure (PCPS) to explore how phylogenetic composition varies across the restoration sites and whether it correlates with productivity gradients. Additionally, I will apply Structural Equation Modeling (SEM) to identify direct and indirect effects among biodiversity metrics and ecosystem functioning.

In the second chapter, I focus on two restoration sites for which functional trait data is available. The selected traits – including specific leaf area (SLA), leaf dry matter content (LDMC), leaf nitrogen and phosphorus content, and wood density – represent key ecological strategies related to growth, resource use, and structural investment. I integrate species richness, functional diversity (e.g., Functional Dispersion, Functional Richness), and phylogenetic diversity into mixed-effects models to assess their relative influence on biomass production. This approach also allows me to examine whether functional and phylogenetic diversity exert independent or overlapping effects on ecosystem functioning.

During the research visit, I aim to strengthen my analytical skills by collaborating with researchers at the Forest Dynamics Lab. Depending on ongoing projects, I also hope to explore the potential for incorporating remote sensing or landscape-level data into future analyses, expanding the spatial scale and applicability of my findings.

4. Preliminary Results

Preliminary analyses conducted across multiple Atlantic Forest restoration sites indicate that species richness is more strongly associated with aboveground carbon accumulation than phylogenetic diversity. This suggests that simply incorporating a wider range of species, regardless of their evolutionary relatedness, may be more effective in enhancing ecosystem functioning than selecting species based on phylogenetic breadth alone.

The presence of fast-growing, phylogenetically clustered species, particularly species from the Fabaceae family, which are often selected in restoration plantations for their fast growth, did not consistently translate into higher biomass accumulation. This challenges the assumption that restoration strategies based on a few high-performing species will necessarily lead to better carbon outcomes. Instead, it points toward the importance of community-level interactions and the possibility that functional redundancy or environmental filtering may be influencing the observed patterns.

These findings highlight the need to further explore the relationship between phylogenetic and functional diversity in shaping restoration trajectories. In particular, they raise critical questions about the degree to which phylogenetic diversity captures ecologically meaningful trait variation in restoration contexts, and whether functional and phylogenetic dimensions operate independently or interactively in driving ecosystem processes such as carbon storage.

To address these gaps, the next steps in the research include the calculation of functional diversity metrics (such as Functional Dispersion and community-weighted means) for the two restoration sites with available trait data. These metrics will be integrated into models alongside species richness and phylogenetic diversity to test their relative contributions to biomass accumulation.

In addition, I plan to apply Structural Equation Modeling (SEM) to evaluate the direct and indirect effects among biodiversity components and carbon accumulation. Finally, I will formally assess the degree of coupling or decoupling between functional and phylogenetic diversity, which will help clarify whether these dimensions' capture overlapping or distinct aspects of community structure. Together, these analyses are expected to shed light on the mechanisms underpinning biodiversity–ecosystem functioning relationships in tropical forest restoration.

5. Objectives of the Research Visit

- To participate in academic discussions and technical exchanges with the Forest Dynamics Lab team.
- To improve my methodological and analytical approaches to biodiversity and ecosystem functioning, particularly through novel statistical tools and conceptual frameworks.
- To explore the potential integration of remote sensing and landscape-scale data into restoration ecology analyses.
- To establish collaborative relationships that may lead to future research partnerships.

6. Expected Outcomes

- Refinement of my master's dissertation based on expanded analyses and theoretical contributions developed during the visit.
- Strengthened scientific foundation and enhanced ability to apply multivariate and integrative approaches in ecological research.
- Improved academic writing skills in English, particularly in the context of scientific communication and publication.
- Greater international collaboration and academic exchange in the fields of forest restoration and biodiversity-ecosystem functioning research.

7. Timeline and Work Plan

- **Month 1-2:** Literature review, discussion of methodologies, potential lab integration.
- **Month 3-4:** Data analysis (PD, FD, SEM); refinement of statistical models.
- **Month 5-6:** Manuscript preparation, feedback sessions, possible collaboration on side projects.

8. Relevance of the Visit

This research visit will enhance the academic quality of my MSc dissertation and contribute to my long-term goal of pursuing a PhD in ecosystem functioning and restoration. Collaborating with Dr. Vanderwel's lab, with its strong expertise in forest

dynamics, biodiversity, and remote sensing, represents an invaluable opportunity to expand my scientific network and skillset.

Rio de Janeiro, June 11, 2025

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