Graduate Research Plan Statement

Gas. A lighter. Soon, the rainforest was in flames. Thousand-year old trees crash to the ground. Hard-won indigenous land is replaced by soot and debris. The world is justifiably alarmed by the human-caused fires in the Amazon this summer and the intersecting effects of climate change and human land use on the highly biodiverse tropical ecosystems of South America. In addition to being home to many endemic species, the Amazon is an essential carbon sink, absorbing megatonnes of carbon dioxide each year, while the Andes are home to extensive yet vulnerable glaciers, which provide water to millions[1]. Meanwhile the combination of fires during drought and invasive grasses may cause the increasingly fragmented Amazon to reach a tipping point where it becomes a net carbon emitter and reduces rainfall through reduced moisture recycling[2].

Are these changes unprecedented, or are they only a few out of many transformative events in South American ecosystem history? How stable are Andean and Amazonian ecosystems over time, and how resilient were they to past climate and land use? How much are the supposedly pristine ecosystems of today the outcomes of past anthropogenic land use; was the 1491 Amazon a wilderness or garden? By studying how these ecosystems have changed in response to climatic or human forcings in the past, we can better predict how they might respond to future anthropogenic climate change. Paleoecological data is the only source offering comprehensive answers to questions about ecosystems' response to climate change and human disturbance at timescales beyond the instrumental record.

Background: For decades, palynologists have painstakingly amassed records of past vegetation dynamics in the Americas and studied vegetation responses to climate change, fire regime shifts, large mammal extinctions, and human impacts. Most of this work has been based on small sets of pollen cores collected from lakes, from one or a few different sites in an area, with limits placed by the twin difficulties of collecting many cores at once and the cultural and technological barriers to sharing data. Now, with the advent of big-data capabilities and a rapid cultural shift towards open data, paleoecology data is increasingly uploaded into community-curated data resources such as the Neotoma Paleoecology Database, an international hub for pollen cores, mammal fossils, diatom data, and more. **These data resources are enabling macro-scale studies of past ecosystem dynamics at continental to hemispheric scales[3].** Neotoma pollen data historically has been heavily weighted towards North American and European. However, over the last decade, the number of Neotoma pollen cores from the Northern Andes and the Amazon in the database has rapidly increased due to the re-emergence of the Latin American Pollen Database (LAPD). As of 2015, the LAPD had 1379 cores from 30 countries[4], and the North American Pollen Database (NAPD) has 1564 cores.

Intellectual Merit: The Latin American pollen cores recently added to the LAPD and the NAPD cores from North America would make possible a pole-to-pole analysis of climate-driven ecosystem dynamics since the Last Glacial Maximum (LGM) for the very first time. A continental analysis based on pollen data offers an exciting opportunity to determine if the broader analysis can **identify common climate-related ecosystem responses on different continents, as well as identify time periods where trends are more regional.**

First, I will complete a regional turnover analysis, which measures temporal change in community composition, for the Northern Andes and the Amazon respectively which now have enough pollen records to facilitate this project. These South American regions are key in studying global climate change, because of the carbon stored in the Amazon rainforest and increased warming caused by glacial retreat[1,2]. Once I complete a turnover analysis of South America, I will expand my analysis to North America.

My **research questions** are:

1. In the Northern Andes and the Amazon Rainforest, what are the temporal and spatial patterns of plant community turnover? Are patterns of community change governed by topographic position, climatic factors, human arrival, or other factors?
2. **What common patterns of plant turnover during the Holocene and Anthropocene do we see across the Western Hemisphere?** Can we link these patterns to known interhemispheric climate variations, e.g. the bipolar seesaw during millennial-scale climate change, when the Northern and Southern Hemispheres experienced opposite temperature trends? How do human arrival and population expansion affect patterns of turnover?

I am an excellent candidate to do this research, because I have worked closely with the Neotoma Database in my graduate studies. Last spring, I **performed a summary analysis of community turnover patterns in western North America, eastern North America, and Europe for the 2022 IPCC report**. For my PhD studies, I will be building upon these initial analyses for a full analysis of climate-driven community dynamics across the Americas. In my full analysis, I will spend more time examining individual pollen cores before calculating turnover, and I will focus significantly more on disentangling the drivers of turnover, rather than simply presenting the information as I did for the IPCC Report.

Methods: In this project, I am collaborating closely with leaders of Neotoma at UW-Madison (my advisor Dr. Jack Williams), the HOPE project in Bergen dedicated to studying human drivers of global ecosystem change (Drs. Suzette Flantua and Alistair Seddon), and specialists in tropical ecology at the University of Amsterdam (Dr. Henry Hooghiemstra). First, I will work with Dr. Flantua and others to upload records from the Northern Andes and the Amazon that are not yet in Neotoma. Using the *neotoma* R package, I will download South American pollen data from Neotoma and select sites based on high temporal resolution (records at least 1000 years long with a minimum of ten samples). I will create Bayesian age models for North and South American sites without good age models in R[5]. To ensure high data quality, I will set QA/QC rules and experiment with different metrics of community turnover. **After the turnover analyses are run, I will analyze the spatiotemporal patterns through mixed effects models with temperature, precipitation, human population size, etc. as predictor variables.** Using what I have learned from analyzing the Northern Andes and the Amazon, I will proceed to analyze North America and South America for equator-to-poles patterns of ecosystem turnover.

Broader Impacts: Over the course of my research, I will attend and present at the Latin American Congress of Biogeography. In addition, I will run a workshop on the Neotoma Paleoecology Database, training Latin American scientists on how to use the online interface and the *neotoma* R package to view and analyze data. **I will also expand the scope of Ice Age Mapper, an interactive mapping interface for North American pollen data that I am developing as part of an NSF-Geoinformatics grant under Jack Williams.** By creating a taxa list for Latin America, I will be able to add Central and South American cores to the visualization, which will expand the impact of the program and allow undergraduate students in Latin America to study taxa relevant to their landscapes. I also plan to **create an educational kit about pollen, past vegetation, and past climates**. I will work with the Master Naturalist program, which promotes understanding and stewardship of the natural environment through training a network of volunteers in the science and conservation of Wisconsin landscapes.

Citations: **1)** Rabatel, A. *et al. The Cryosphere*, (2013). **2)** Costa, M. H. & Pires, G. F. *International Journal of Climatology* (2010). **3)** Williams, J. W. *et al., Quaternary Research* (2018). **4)** Flantua, S. G. A. *et al. Review of Palaeobotany and Palynology* (2015). **5)** Wang, Y., Goring, S. J. & McGuire, J. L., *Sci Data* (2019).