FAB five BIPOC researchers in climate change ecology – by Carlos Barreto

Climate change ecology is the study of the human-induced changes in the climate, and how these changes affect species at different ecological levels such as populations, communities, and ecosystems. This field of study investigates the effects of, among others, warming, altered precipitation regimes, and increase of CO_2 in the atmosphere on different species in terrestrial, marine, and fresh-water systems. Understanding how climate change factors will influence species in the (sometimes near) future will allow us to extrapolate these responses to the ecosystem level, make better predictions on how ecosystems will respond to climate change, and take actions while we can.

Although the field of ecology is undoubtedly important for our future, women of colour are still underrepresented, following a tendency seen in other STEM fields (AlShebli et al., 2018; Bernard and Cooperdock, 2018; Elliott et al., 1996; Evangelista et al., 2020; Hofstra et al., 2020; Tseng et al., 2020). Underrepresented groups like women of colour in STEM have been shown to produce higher rates of scientific novelty (as per the examples above), but their contributions are devalued (Hofstra et al., 2020), and this is a systemic issue in academia. Thus, this article aims to highlight the research of five excellent women researchers of colour. Yolima Carrillo, Erika Zavaleta, Asmeret Berhe, Astrid Caldas and Zoë Lindo are PhDs in different stages of their career who have made significant contributions to the field of climate change ecology through their research, teaching and/or policy. In no particular order:

Dr. Yolima Carrillo is a Colombian Senior Lecturer at Western Sydney University in Australia. Her

research focuses on the cycles of carbon and nutrients in terrestrial ecosystems, and how those cycles are affected by climate change factors like elevated CO_2, warming and water stress. Among her discoveries, Dr. Carrillo and collaborators determined that elevated CO_2 (especially under warming) produced grass roots that were longer and thinner, and this change could alter the availability of nitrogen in soils by slowing down the release of nitrogen from grasses. They also found that elevated CO_2 increased the degradation of dead roots (root litter decomposition) (Carrillo et al., 2014). In 2016, she and collaborators studied fungi that are associated with plant roots (mycorrhiza) and concluded that these fungi may help promote carbon storage in soils (Carrillo et al., 2016), which works as a climate change mitigation strategy. In another study, Dr. Carrillo and others concluded that elevated CO_2 when combined with warming negatively affected the carbon stocks in soils and how microbes use this carbon in soils as their source of energy (Carrillo et al., 2018).

Another researcher with important contributions to the responses of grassland ecosystems to climate change is **Dr. Erika Zavaleta**. Dr. Zavaleta is an American born with Bolivian and Indian parents. She is a Full Professor at the University of California Santa Cruz, and her research focuses on environmental changes, ecology, and ecosystems functions. In one of her studies, Dr. Zavaleta and collaborators tested the single and combined effects of warming, elevated CO_2, altered precipitation and addition of nitrogen on grasslands and concluded that these factors may have significant combined effects on both diversity and relative dominance of different plant types in grasslands, with consequences to nutrient cycling and net primary productivity (Zavaleta et al., 2003b). Specifically, elevated CO_2 and nitrogen deposition both reduced plant diversity, whereas elevated precipitation increased it, and warming did not have significant effects (Zavaleta et al., 2003a). Ultimately, her findings point to the need of combining global change factors when studying their effects since they can interact in varied ways, causing unexpected effects on plant diversity. In addition, Dr. Zavaleta also serves as the Faculty Director for the UCSC Doris Duke Conservation Scholars Program, which is a conservation leadership program supporting undergraduate students.

Although not directly working with plants, **Dr. Asmeret Berhe,** an Eritrean Full Professor of Biogeochemistry at the University of California Merced, investigates how climate change affects processes such as carbon and nitrogen cycling in soils, both essential nutrients for plants. In 2019, Dr. Behre summarized the changes soils and soil processes have been facing, who the drivers of these changes are, the role of humans in this story, and what the consequences of altered soils are to human wellbeing, biodiversity conservation and ecosystem processes (Berhe, 2019). But on top of the very important science that she and her diverse research group does, Dr. Berhe is also famous for her role in science communication and political ecology, both abilities she discussed in a document with the purpose of educating people on how to speak climate change to diverse audiences (Berhe, 2020). Specifically, in 2019 she delivered a TED talk on the role of soil and its use in maintaining the earth's climate that you can watch on YouTube. And last, but not least, she is a very active advocate for diversity, anti-racism and women in science, taking part in organizations such as ADVANCEGeo and 500 women scientists with the goal of making science open, more inclusive, and accessible.

Another woman working on the bridge between policy and research is **Dr. Astrid Caldas** from Brazil. She is a senior climate scientist with the Climate & Energy program at the Union of Concerned Scientists in Washington, DC, where she focuses on climate change adaptation with practical policy implications for ecosystems, the economy, and the society. Dr. Caldas is also a Research Associate affiliated to the Smithsonian Institute, where she reviewed the use of species traits (characteristics) of butterflies and moths to predict their responses to climate change, and concluded that the phenology (the study of the timing of the biological events) of butterflies and moths is a relevant source of information for resource management and conservation planning. For example, a longer growing season caused by warmer temperatures may also mean a second generation of an agricultural pest that advances its flight period (Caldas, 2014). Her latest contribution to climate change ecology was a study discussing how changes in climate are likely to intersect with COVID-19 outbreaks, pointing also to the compound risks that fall disproportionately on countries in the Global South (Phillips et al., 2020).

Last, but not least, is Canadian **Dr. Zoë Lindo**, whose parents immigrated to Canada from Scotland and Jamaica. Dr. Lindo is a Full Professor at The University of Western Ontario, where their research focuses on peatland biodiversity and ecosystem function relationships under a climate change perspective. Dr. Lindo is an expert on oribatid mites (spider-related tiny soil animals), and by investigating the effects of warming on these animals in a greenhouse experiment, they concluded that warming favours small-bodied organisms through higher reproduction rates and compositional shifts in soils (Lindo, 2015). In other words, smaller and asexual species of these mites were more abundant under warmed conditions. In the same study, Dr. Lindo concluded that saturated water table decreased the abundance (number of individuals) and richness (number of species) of oribatid mites, but elevated CO_2 did not have any apparent direct effect. By investigating the global change effects on plants, fungi, and other types of mites, Dr. Lindo is working towards building a link between comprehensive peatland soil food webs and global carbon budgets (Buchkowski and Lindo, 2020).

Lastly, BIPOC experience biases that affect their progress in academia (Wanelik et al., 2020), especially biases translated into microaggressions (Ro and Villarreal, 2019; Simatele, 2018). This issue becomes even more serious in the case of women of colour, since not only are they negatively affected for being women (McKinnon and O'Connell, 2020), but also for not being white — whether those biases have additive or synergistic effects remains an open question. Despite this negative experience in academia, it is undeniable that women of colour have significantly contributed to the study of climate change effects on several groups, from microbes to plants, from insects to mites, on nutrient cycling, and even on the coronavirus that causes COVID-19. Why our society might still ignore their voices is a question without any logical answer. Nonetheless, there is vast evidence that bias, discrimination, and harassment are among the causes of lack of diversity in STEM (Chaudhary and Berhe, 2020), including in soil sciences, one of the least diverse STEM fields (Berhe and Ghezzehei, 2020). It is past time we listen to women of colour in STEM, for everyone's benefit, when preparing to face a world that is changing for worse in accelerating never-seen rates. You can start by reading the advice presented in the articles cited in this piece, and particularly in the ones in Tseng et al. (2020), that summarizes strategies and support for BIPOC in the fields of ecology and evolutionary biology.

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