Measuring the Impact of Extinct Megafauna on Carbon Fluxes in Ponderosa Pine Forests

It is increasingly recognized that animals are not simply passive recipients of a world organized by powerful non-living forces such as climate, soil and fire. Instead they are key actors, exerting their own biological control on the composition and function of ecosystems across the world. It is likely that the importance of animals as agents of global change has been overlooked until recently because today we live in a world devoid of most of its megafauna (Sandom et al., 2014). Since the late Pleistocene, megafauna populations have been in a state of decline worldwide and today we have unequivocally entered the sixth mass extinction (Malhi et al., 2016). Both human and climatic reasons have been forwarded to explain the dramatic declines in megafauna populations, and whilst this has been the subject of intense debate (e.g. Johnson, 2002; Barnosky et al., 2004), there has been little conversation about the legacies of these lost ecosystem engineers across the world.

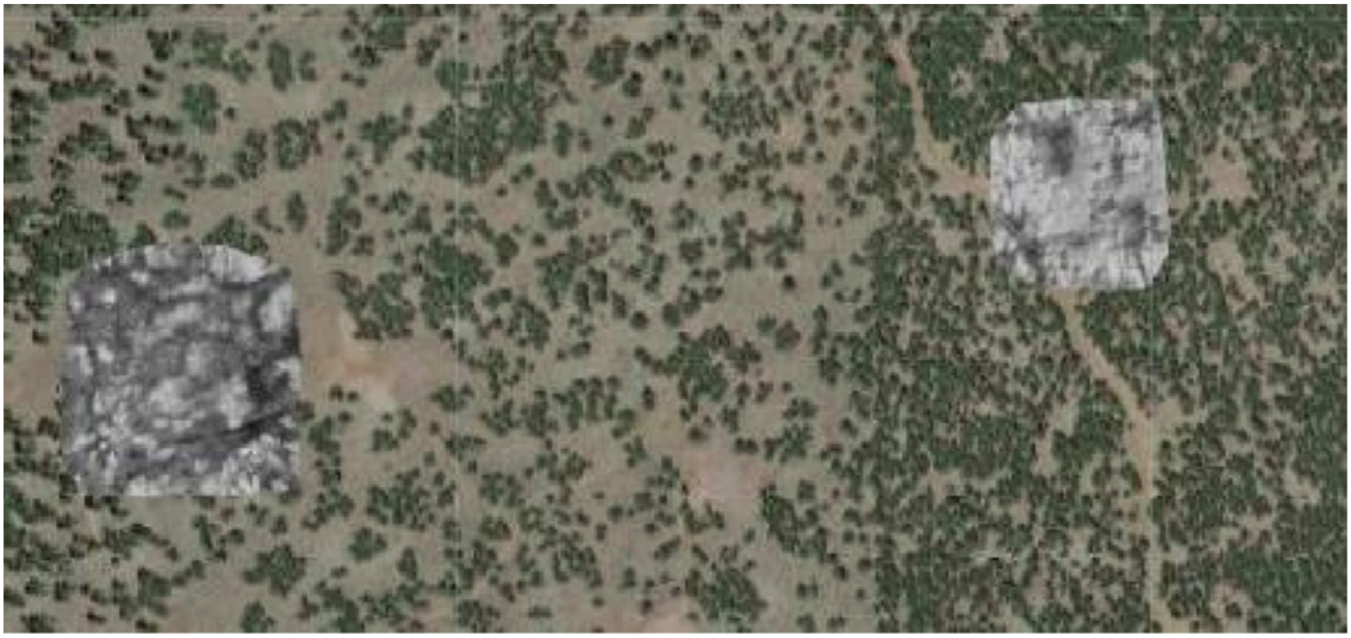

Figure 1: Normalized Difference Vegetation Index (NDVI) drone imagery for plots 2 (left) and 3 (right) (greyscale) overlaid on a Google maps image showing the forest thinning. Plot two is representative of a past landscape containing megaherbivores and without fire suppression.

In the present study, we aim to understand how past megafauna influenced carbon cycling in Ponderosa pine forests. Megaherbivores – by their sheer size – consume a vast amount of vegetation and cause widespread structural damage to woody plants. Walking in the footsteps of today's contemporary behemoths such as African elephants (*Loxodonta Africana*) provides a hint of what the USA's landscape may have resembled 10,000 years ago. Then, past megafauna such as the mammoth (*Mammuthus spp*), giant ground sloth (*Megatherium spp*) and glyptodon (*Glyptodon spp*) roamed the forests and grasslands of North America knocking over trees and trampling saplings as they went. The removal of dense forest stands by megaherbivores would have reduced competition between trees for resources, allowing more space for growth whilst also opening the understory to increased levels of light for photosynthesis on the ground. We hypothesize that this would increase the number of grazing animals present, facilitating a feedback process and boosting a number of key ecosystem services including seed dispersal, nutrient dispersal and carbon storage.

[1] Megafauna are defined here as all animals > 44.5kg.

[2] Megaherbivores are defined here as all herbivores >1000kg.

Our study is located in the Ponderosa pine forests surrounding Flagstaff, Arizona. Forest thinning in this region has been undertaken to reduce severe fire danger. We utilized this management strategy to mimic bygone behemoths. In three quarter hectare plots along a forest thinning chronosequence we measured carbon cycling fluxes between each of the major stocks of carbon in wood, leaf and soil. This allowed us to compare carbon-use efficiency (CUE) in forests representative of the late-Pleistocene and those defaunated today. We measured total net primary productivity (wood, fine roots and litter), total autotrophic respiration (wood, rhizosphere and canopy respiration) and large mammal herbivory (with camera traps and dung counts) over a two-year period. We found strong seasonality in all carbon cycling parameters and herbivory peaking during the warm, wet monsoon period. Forest thinning increased understory NPP, abundance of the three most abundant large herbivores in the region: mule deer (*Odocoileus heminous*), pronghorn (*Antilocapra americana*) and elk (*Cervus canadensis*), and small tree mortality. In the thinned stands, carbon was produced more efficiently CUE = 0.63 and 0.61) vs the unthinned stand (CUE = 0.39). These results confirmed our hypothesis that Ponderosa pine forests with bygone megaherbivores would have stored carbon more efficiently.

Figure 2: A herd of elk (*Cervus canadensis*) captured by a camera trap in plot 2.

The work presented here demonstrates the urgent need to incorporate animals as agents of change into our understanding of the Earth System. Modern science is currently grappling with the breakdown of both our climate and biodiversity systems. The collective impact of animals in altering the global carbon cycles links these crises, and thus offers limited hope. Under the growing conservation movement of rewilding, the practice of restoring biodiversity and their ecosystem services, animals can remove carbon dioxide from the atmosphere and partially mitigate anthropogenic greenhouse gas emissions. Where they are allowed to flourish, feedbacks within natural systems will help degraded landscapes bounce back over the coming century, increasing their contribution to ecological and climate stability.

Figure 3: Andrew Abraham and Chris Doughty take measurements of soil respiration using a PP Systems EGM-5 Portable CO_2 Gas Analyzer in one of their 0.25 ha plots near Flagstaff, Arizona.

PP Systems would like to thank and acknowledge Andrew J. Abraham and Christopher E. Doughty and Northern Arizona University's School of Informatics, Computing and Cyber Systems for providing the information contained in this application note.

To learn more about Doughty Lab's work:
https://www.cdoughty.org/

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If you would like to learn more about this application or speak with one of our experienced technical staff, please feel free to get in direct contact with us via any of the contact information listed below:

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