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Tracking the Effects of Climate Change Along an Elevational Gradient

Direct and Indirect Consequences of Climate Change on Net Ecosystem

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Abstract

Despite the multitude of studies examining the effects of climate change, few have addressed both the direct and indirect consequences of global warming on ecosystem level carbon dynamics. Given the integral role ecosystems play in regulating carbon levels in earth's atmosphere it is imperative to understand how ecosystems are being affected by climate change induced factors, including warming and biodiversity loss. In this study we hypothesized: (I.) Net Ecosystem Exchange (NEE) would be significantly affected by both warming and species removal treatments, thus altering the carbon relationships present in the area. (II.) NEE measured along an elevational gradient would significantly differ via elevation, in addition to being driven by both plant community dynamics, and a suite of abiotic factors. Consistent with our hypothesis, we found NEE was affected by experimental removal of dominant plant species, but was not strongly influenced by warming manipulations. In addition, we found an overall negative NEE pattern across our measured gradient, suggesting this ecosystem acts as a overall carbon sink.

Key Words: Climate Change, Net Ecosystem Exchange, Global Warming, Elevational Gradient, Carbon Dynamics, Community Composition, Plant Traits.

Introduction

Global warming, driven by anthropogenic greenhouse gas emissions has been predicted to increase global temperatures by 2-4 Celsius by 2090 (IPCC 2014). The predicted rate of warming is explicitly linked to the the level of carbon present in

earth's atmosphere at a given time (Bonan et al. 2002). Climate change driven warming has both direct and indirect consequences for ecosystem level carbon dynamics (Oleson 2000, Poulter et al. 2011, Lal 2004). Warming soil including soil moisture and respiration (Ehrenfeld 2010). Additionally, warming can alter plant communities, indirectly influencing carbon dynamics (Lavorel 2002). Plants that are more responsive to warming often exhibit traits differences that affect carbon dynamics such as faster decomposition rates of their litter (Bardget et al. 2010). Although the largest terrestrial reserves of carbon capable of atmospheric exchange reside in the soil, little is known how these carbon caches are reacting to warming under climate change via shifts in community composition and soil dynamics.

The effects of climate change will be especially evident in high latitude and montane ecosystems (IPCC 2014). These systems often support diverse plant and belowground communities, and typically harbor substantial carbon reserves, thus providing an ideal system for studying ecosystem carbon dynamics in response to warming (Niu et al. 2013). Additionally, studying various communities and their subsequent carbon dynamics across an elevational gradient provides a unique opportunity to examine the effects of warming across a space affected by varying climate and temperature regimes.

Due to the integral role terrestrial carbon reserves play in regulating the amount of carbon present in the atmosphere, it is imperative that the influence of climate change on ecosystem carbon dynamics. Additionally, this research yield insight regarding the function of montane ecosystems in response to shifts in biodiversity, and warming.

Methods

Study Site and Experimental Setup

Experimental treatments were previously established at both high and low elevation sites, specifically Almont Triangle and Paradise Divide in the Gunnison River Valley, Colorado in 2013. At each of these experimental sites a 2x2 factorial warming (W) x Plant Species Removal (SR) experiment was instituted. Each site contains a sample size of eight replicates per treatment, with a total of 32 plots at each site. Open-Top Chambers (OTCs) were utilized to simulate warming, and preliminary results from our chambers demonstrate an average increase of 3 degrees Celsius in air temperature during the day, and 0.5 degrees at night (Leadley et al. 1993). Dominant species were also identified at each site, and removed from a quarter of the total plots. Warming and Removal treatments were also crossed in an attempt to disentangle the direct and indirect effects of warming on the subsequent carbon dynamics at each site.

In addition to the experimental sites, we established an observational gradient spanning over 1,000m with twelve distinct sites across the gradient.

In order to access carbon dynamics within each site a modified Net Ecosystem Exchange (NEE) chamber will be utilized to quantify a number of carbon cycling processes. The chamber is equipped with a PAR sensor, thermometer, and a CO₂/sensor. The sensor will make 4-5 consecutive measurements spanning 1,000 PAR to dark, with 2-3 levels of meshing to vary PAR between full sun and dark. The full light treatment allows a measurement of net photosynthesis, and the opaque,

full-dark cloth effectively stops photosynthesis, allowing a measurement of net respiration. This will create a light response curve for NEE at each treatment replicate, and allow for the calculation of dark respiration, and GPP. These tests will allow analysis of carbon flux at each site, and assess whether the communities present are absorbing or releasing more carbon as a result of the treatment variables.

Sampling Design

Net Ecosystem Exchange was measured at each distinct plot within the experimental manipulations for a total of 64 measurements at the high and low sites. Each observational site was sampled a total of five times, for a total of 60 measurements across the gradient.

In addition to NEE measurements, plant communities were surveyed both in early and late system at all sites, soil moisture was measured, and both above and below-ground plant traits were collected.

Statistical Analyses

In order to best analyze relationships present in our data we utilized a structural equation model to examine both the direct and indirect effects of our treatments on measured response variables. A Principal Component Analysis (PCA) was also used to examine traits means within each plot. Community level trait means were measured for each site, both for Specific Leaf Area (SLA) as well as Specific Root Length. These values were then applied to the SEM, and the best fitting axis was extracted in order to explain the most variation.

Results

In regards to our experimental manipulations we found significant direct effects of species removal on Net Ecosystem Exchange (**Figure 1**). Structural Equation Modeling also revealed significant correlations between site and LAI, and site and trait values (**Figure 1**). Warming exhibited no significant affect on overall Net Ecosystem Exchange, in opposition to our hypothesis.

Leaf Area Index (LAI) was found to be significantly correlated with Net Ecosystem along our observational gradient ($p=0.01$ **Figure 2.**). Also, NEE as a function of elevation was found to be marginally significant (0.10 **Figure 3.**).

Discussion

Understanding Ecosystem Level carbon dynamics is essential in order to better understand the implications of climate change, and ideally improve existing predictive models of uncertainty regarding ecosystem function. Through experimental manipulation and observational analysis we found during peak season, a gradient within the West Elk Mountains exhibited an overall negative value of Net Ecosystem Exchange, thus making it a net carbon sink. In addition, we discovered the effect of plant traits had the most significant affect on NEE within our experimental sites. Species removal was shown to be correlated with NEE, but warming had no significant effect.

Elevation played a significant role in determining the rate of NEE, and can be explained by a number of factors. Biomass, as measured by Leaf Area Index was strongly correlated (negatively) with NEE. The more biomass present in a system,

the more carbon was drawn from the atmosphere. Water stress is much more prevalent at low elevation sites, thus limiting biomass production. In addition, high elevation sites exhibit fast-growing species traits in order to cope with the shortness of the growing season, also affecting biomass present at these sites. Due to these factors it is the mid-elevation sites that dominate biomass production, driving down rates of NEE, and defining the unimodal shape of the curve (**Figure 3.**). As levels of carbon increase in our atmosphere it is imperative we continue to examine Ecosystem Level Carbon dynamics in order to better predict future climates.

Appendices

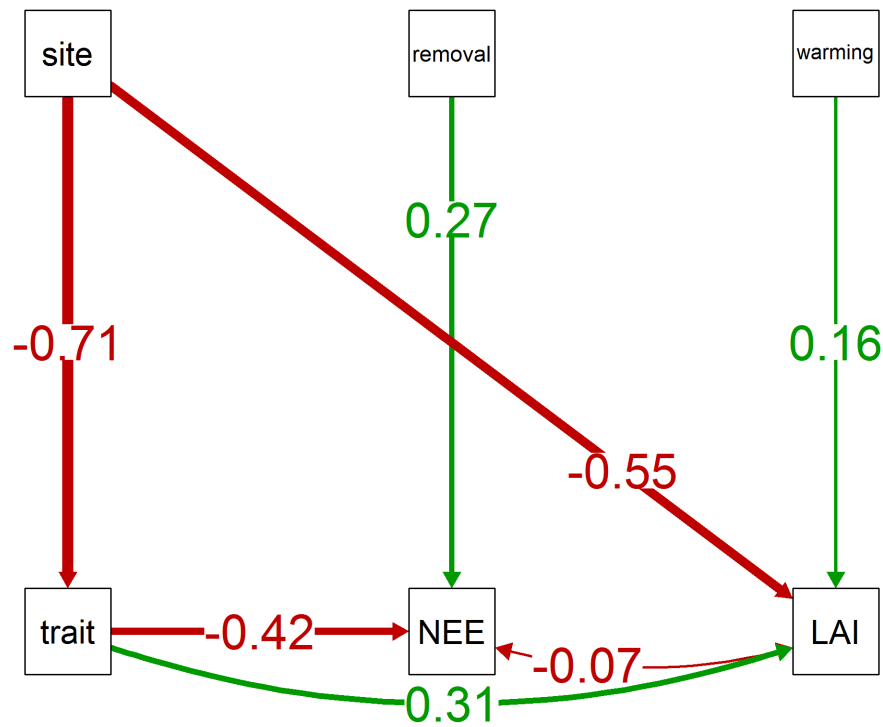


Figure. 1. Structural Equation Model of the Experimental Sites: Strong Relationships Present Between Site, Trait Values, and NEE.

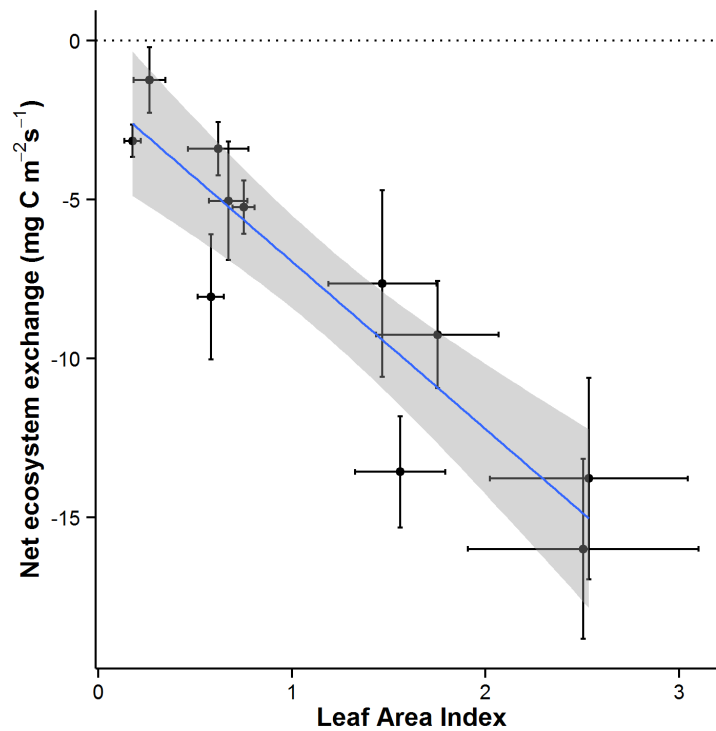
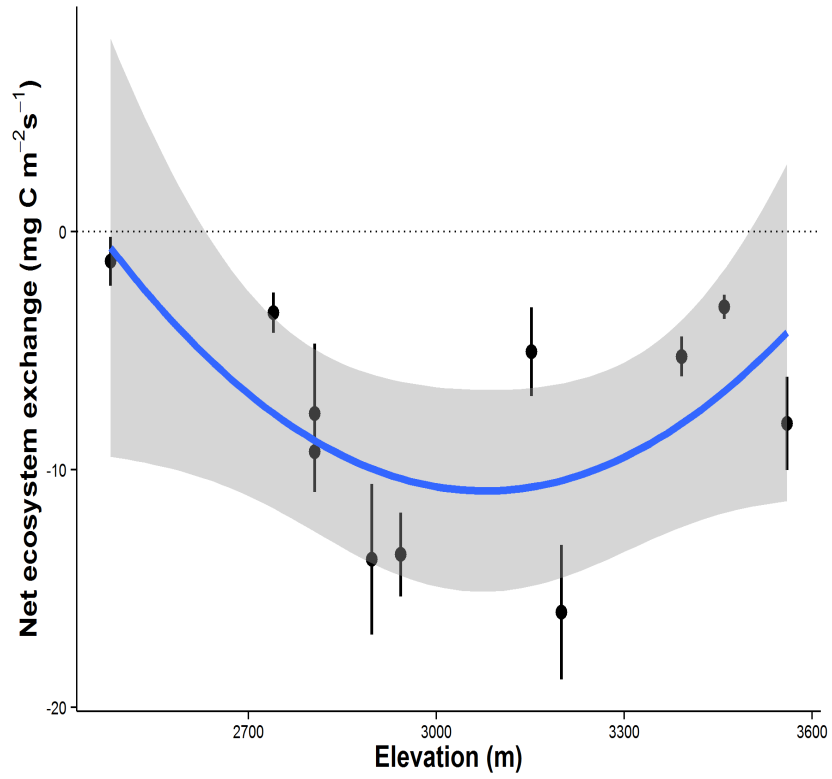


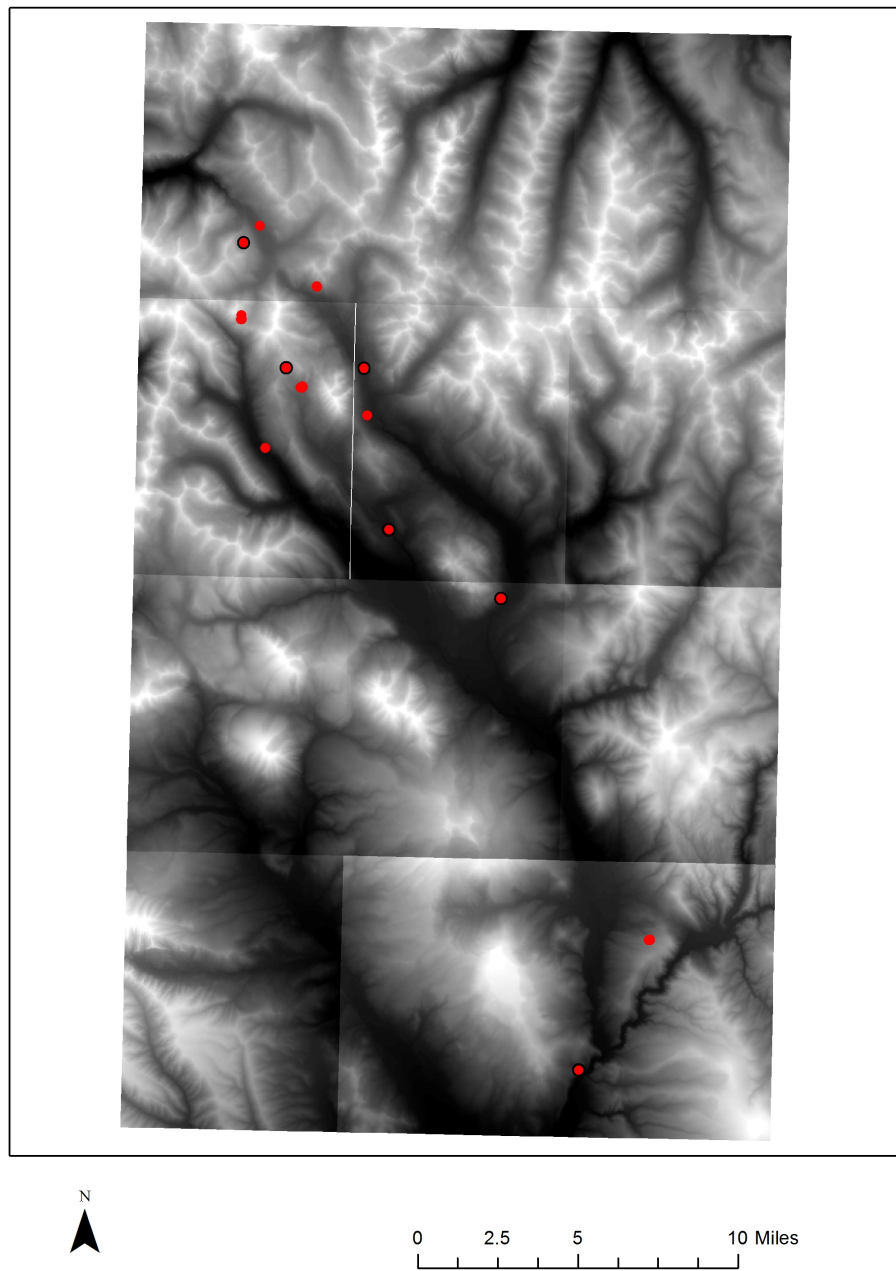
Figure. 2. Leaf Area Index Significantly Correlated with Net Ecosystem Exchange
($p=0.01$)



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178 **Figure 3.** Net Ecosystem Exchange is Affected by Elevation (p=0.10)

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181 **Figure 4.** Aerial Overview of All Sites

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