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Using photosynthetic capacity to understand the role of urban brownfields as a carbon sink

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ABSTRACT

Gas exchange measurements were used to calculate photosynthetic and carbon storage parameters of *Betula populifolia* Marsh. trees growing on a heavy metal contaminated brownfield in Jersey City, New Jersey. Urban green spaces are often subject to unique abiotic stresses such the urban heat island effect, altered hydrology, and polluted soils which can impair growth and carbon storage. Since carbon sequestration is a critical component of the response to climate change, it is important that we improve our understanding of the ability of urban green spaces to serve as carbon sinks. The study hypothesized that photosynthesis will be impaired by increasing soil metal load and increasing temperature. Two forested plots were selected to serve as the high metal load treatment while two others were a low metal load treatment. Measurements were made monthly from May to September 2014. The sites show a seasonal trend where dark respiration was lowest in July, which suggests the trees may have been less stressed during this month. V_{cmax}, which reflects maximum photosynthetic rates, peaked in August. Overall the study found no significant differences between the high and low metal load plots. This suggests metal load alone may not be the only factor affecting photosynthetic productivity in an urban context.

INTRODUCTION

- Urban trees in the continental US may have a gross C sequestration rate of 22.8 million tC/year and should be accounted for in global carbon budgets[1]
- Urban trees are subject to unique abiotic stressors, including 1) higher temperatures, 2) less water availability, and 3) polluted soils[2]
  - Carbon sequestration models should be parameterized with urban specific data to reflect these impacts[3]
- Future conditions predicted by climate change already exist in cities making urban environments an ideal microcosm to study potential ecological responses to climate change[2]

STUDY GOALS

- Compare the effects of soil metal load and temperature on three photosynthetic parameters used in carbon models
- We hypothesize higher metal load and higher temperature will
  - Decrease maximum carboxylation rates (V_{cmax})
  - Increase CO2 compensation point (Γ)
  - Increase mitochondrial respiration (R_{dark})

STUDY SITE

Figure 1: Plots of the interior forest of Liberty State Park (LSP) in Jersey City, New Jersey. An abandoned rail yard spontaneously colonized by early successional hardwood forest and several other vegetative assemblages.[4]

METHODS

Gas exchange measurements on *Betula populifolia* leaves from excised branched were used to calculate photosynthesis, transpiration rates, and related parameters.

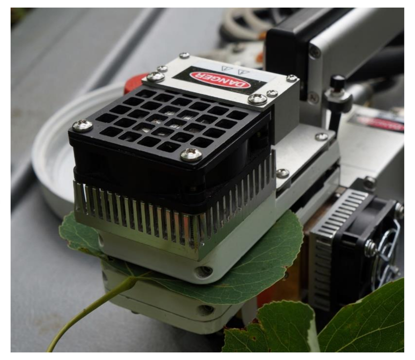
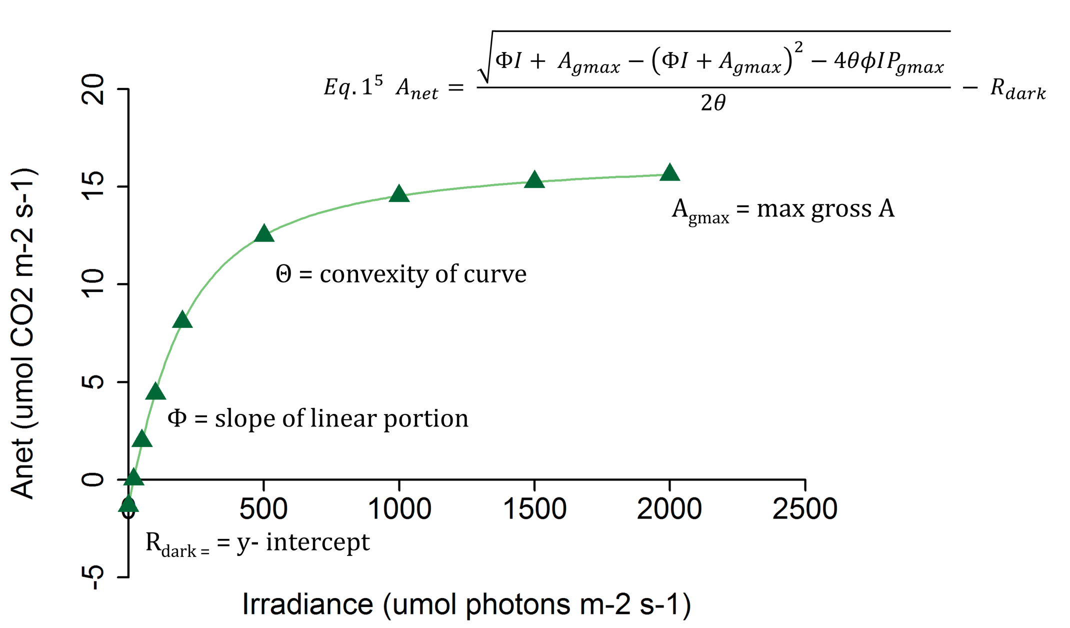


Figure 3: LICOR 6400 portable photosynthesis system IRGA chamber with leaf.

Light curve procedure:

- Vary light levels, measure net photosynthesis (A_{net})
- Light ranged from 2000 to 0 µmol photons m^{-2} s^{-1}

Figure 4: Example light curve.



A/Ci curve procedure:

- Measured A_{net} as internal leaf CO_2 concentrations (C_i) varied
- Chamber CO_2 concentrations ranged from 20 to 1500 ppmv CO_2

Figure 5: Example A/Ci curve.

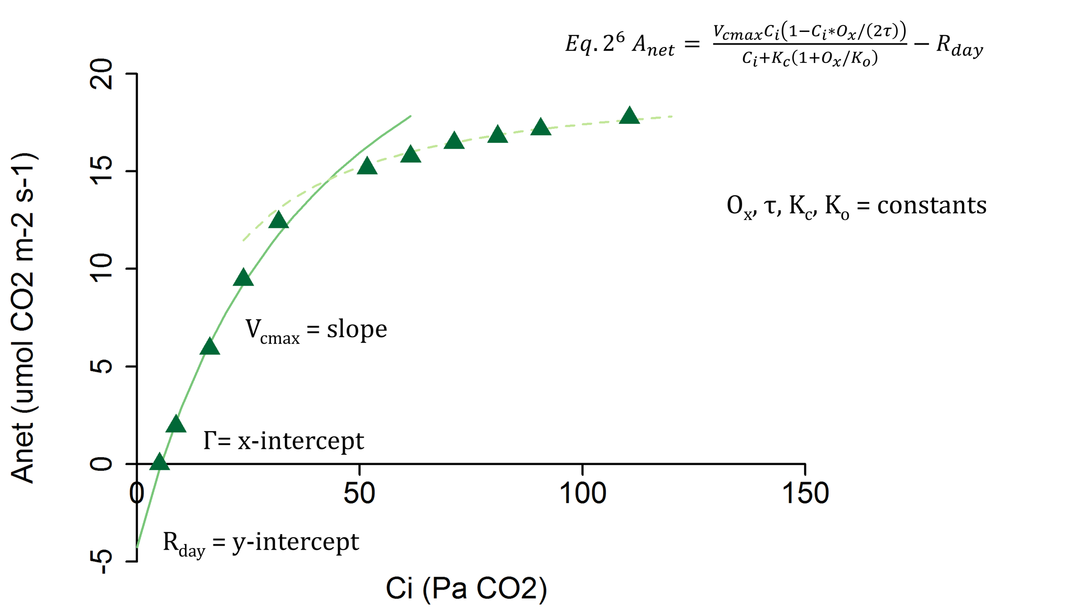


Table 1: Experimental design of study plots. Measurements were made monthly from May to September 2014. HML = High metal load. LML = Low Metal Load.

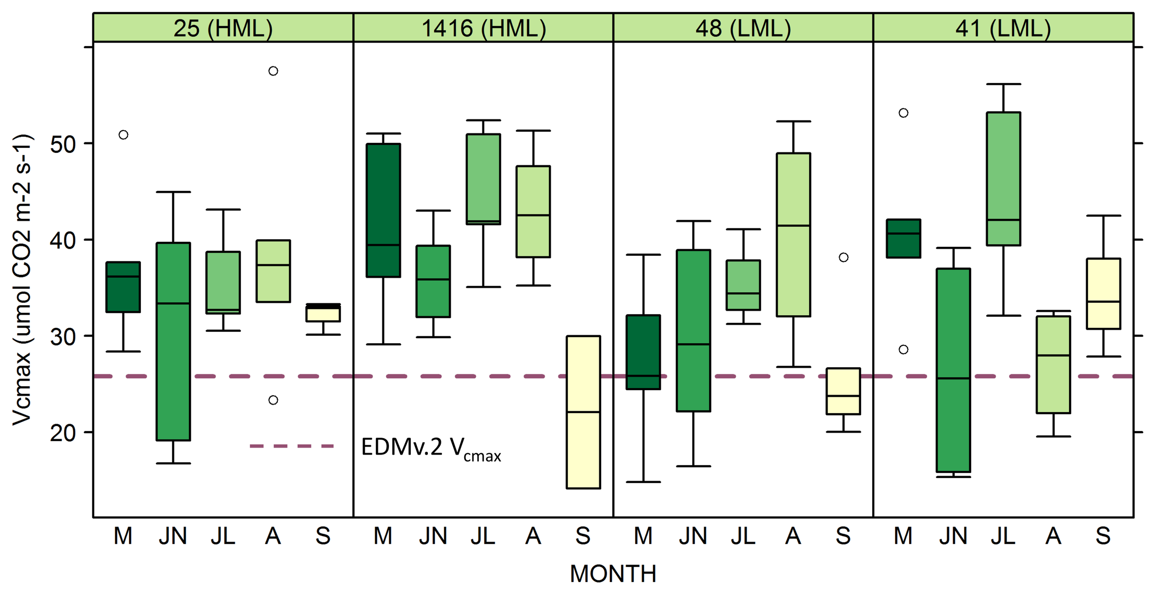
Plot	25	14/16	48	41
TML	4.31	3.56	1.56	0.85
Grouping	HML	HML	LML	LML
n (per month)	5	5	5	5

Ecosystem Demography Model v.2 (EDMv.2) [7]

Used equations from EDMv.2 to calculate an example of carbon model values for V_{cmax}, R_{dark}, and Γ

RESULTS & DISCUSSION

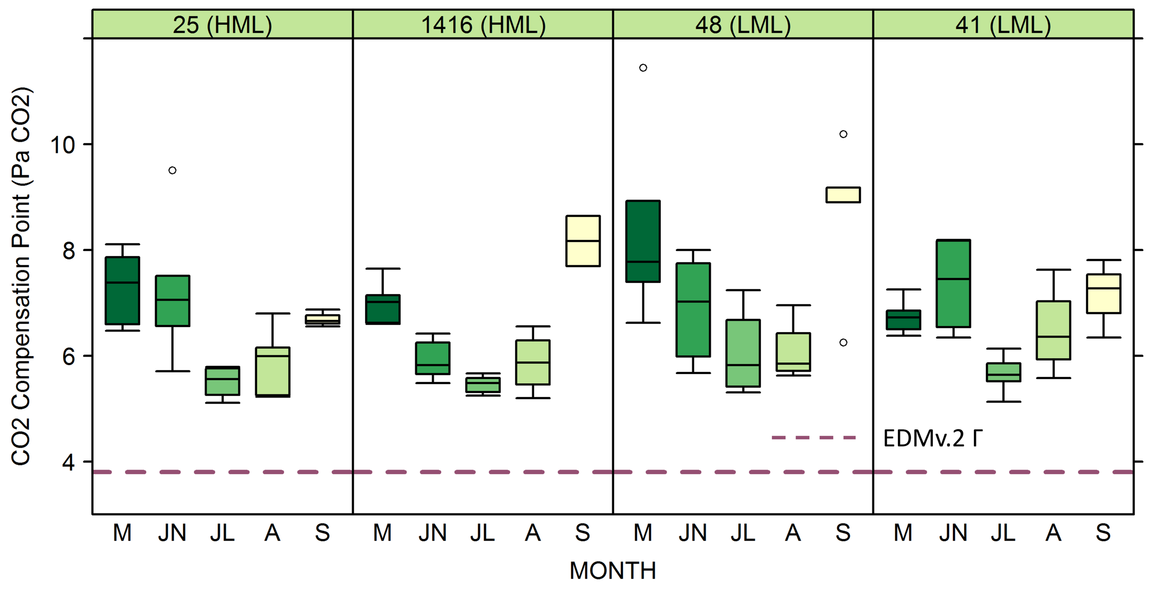
Figure 6: V_{cmax} boxplot grouped by site and month.



V_{cmax} = rate at which CO_2 binds to Rubisco, controls photosynthesis rate at and below ambient CO_2. Significantly:

- higher in Plot 14/16 than in 48
- higher in July than in June and September

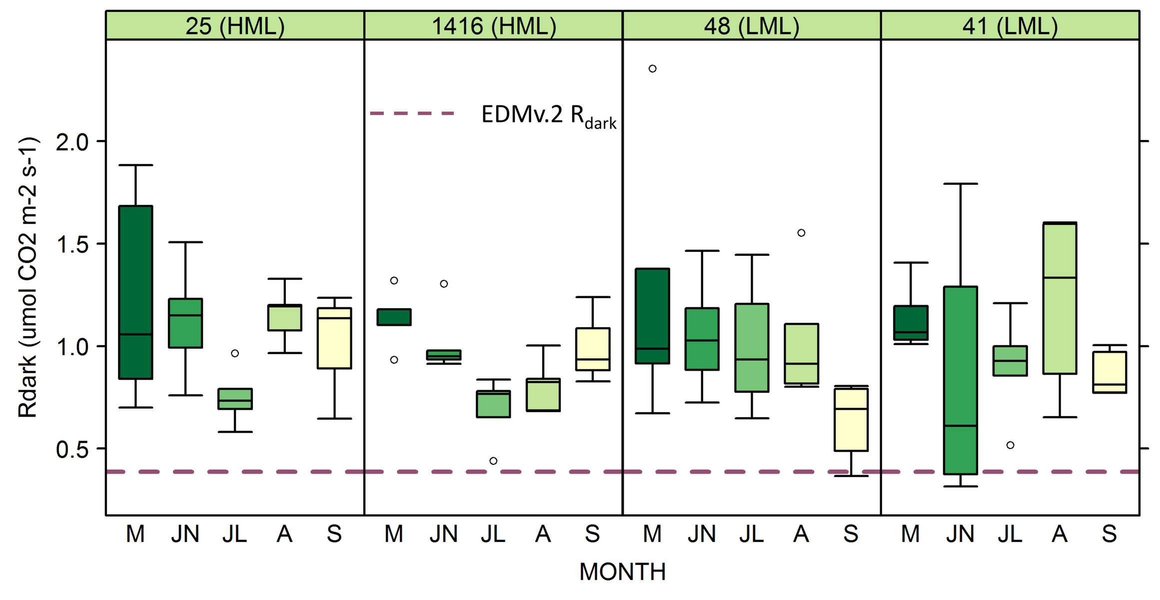
Figure 7: Γ boxplot grouped by site and month.



Γ = internal CO_2 concentration when A_{net} and respiration are equal. Higher Γ values are associated with stress. Significantly:

- higher at Plot 48 than 25 and 14/16
- higher in September than July

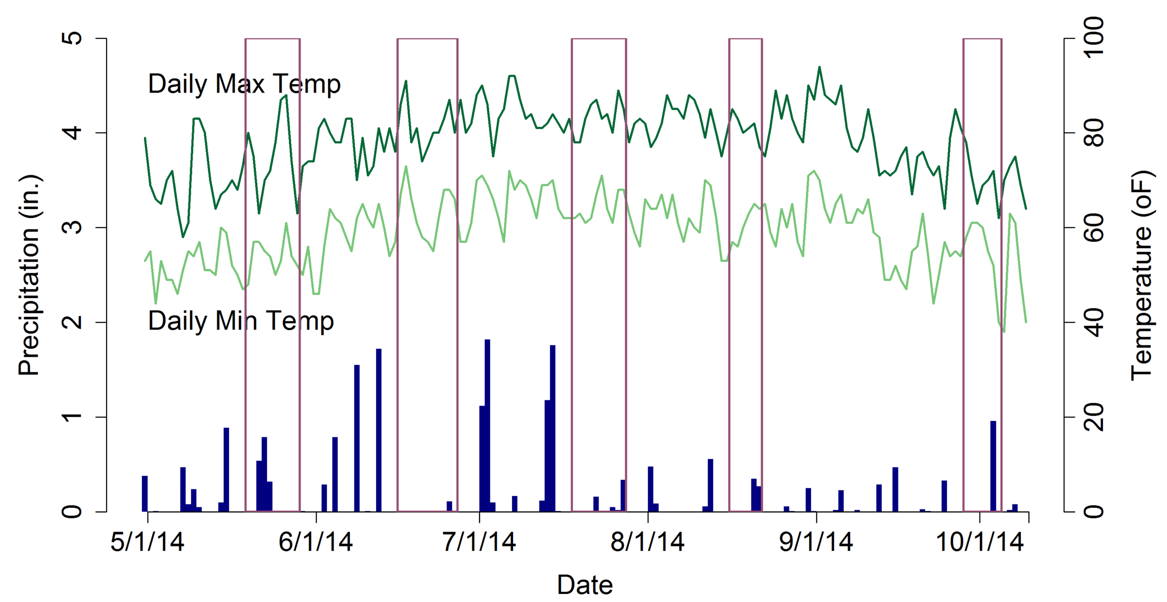
Figure 8: R_{dark} boxplot by site and month



R_{dark} = CO_2 released by cellular respiration for growth and maintenance. Higher rates are associated with stress. Significantly:

- higher in May than in September and July

Figure 9: Daily precipitation (blue bars) with max and min temperatures from May 1, 2014 to October 10, 2014. Boxes indicate measurement days. Weather data from Liberty Science Center weather station, Jersey City. [8]



Overall, 2014 had a mild growing season.

- Difficult to draw conclusions about role of temperature
- T_{max} = 94ºF on 9/2/14
- July: hottest and wettest, T_{mean} = 76ºF, P_{Jul} = 6.85 in.
- August: driest, P_{Aug} = 2.13 in.

Prior work with tree rings found high metal load plots had lower growth rates.[9] Failure to reject initial hypotheses suggests:

- other conditions may more strongly influence growth
- photosynthetic rates at HML plots could be overcompensating to provide energy for maintenance

Plot 48 results opposite of initial hypotheses.

- Consistent with visisbly poor condition of trees at plot
- Potentially caused by Hurricane Sandy damage

The EDMv.2 carbon model parameterizations:

- are comparable for V_{cmax}
- underestimate Γ and R_{dark}

Future research will:

- collect a second season of data in 2015
- characterize other edaphic conditions at the site

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