



Do ecosystem services have a biological cost?

Ozone and climate regulation by Norway spruce forests along an Alpine altitudinal transect in Trentino, northern Italy

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Scheme of the presentation

- Introduction
 - Ozone and impact on ecosystem services provided by forests
- The study on *Picea abies* along an altitudinal transect on Alps
 - Study design
 - Measurements of environmental and tree response variables
- Results
 - Environmental variables
 - Ozone removal
 - Relationship between ozone removal and
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- Discussion
 - Functional interpretation of monitoring data
 - Possible biological costs of removing ozone

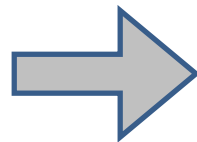


Introduction

Ecosystem services

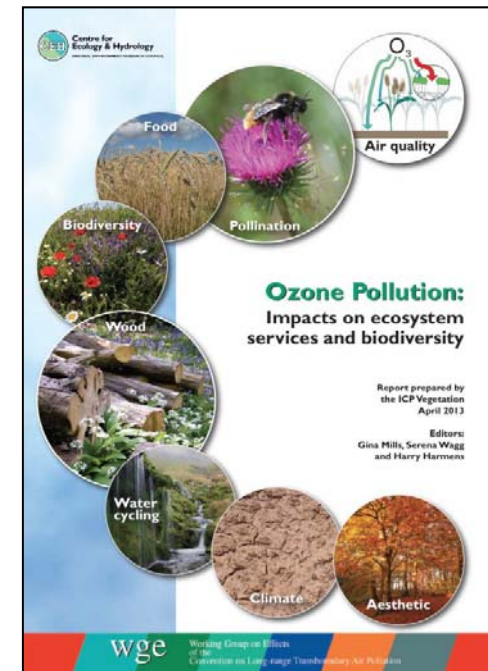
- Cultural
- Provisioning
- Supporting
- Regulating

Regulating services of forests



- Slope stability
- Water cycle regulation
- Carbon storage
- Climate regulation
- Air pollutant removal

Ecosystem services
benefits people obtain from ecosystems



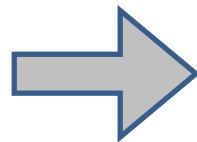
Mills et al., 2013

Introduction

Ecosystem services

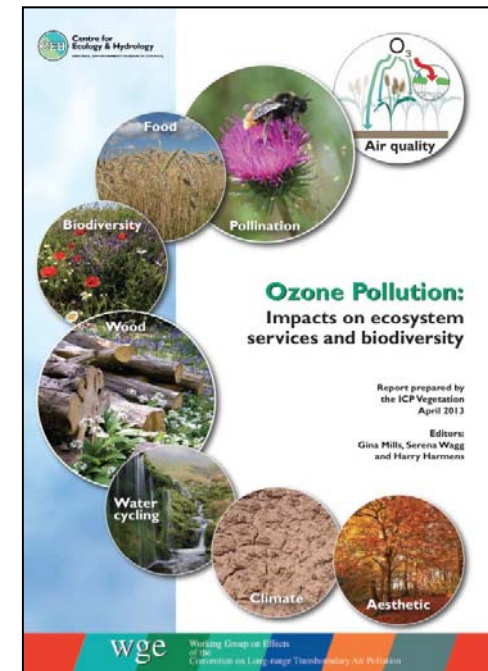
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Regulating services of forests



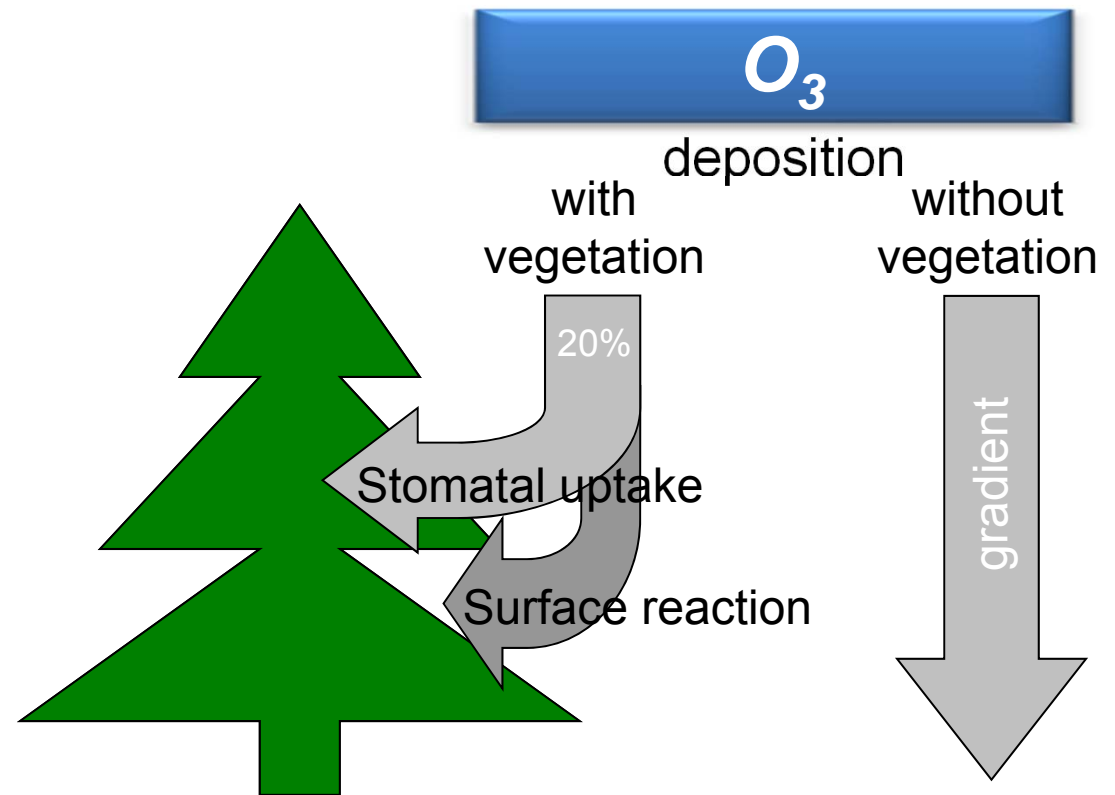
- Slope stability
- Water cycle regulation
- Carbon storage
- Climate regulation
- **Air pollutant removal**

Ecosystem services
benefits people obtain from ecosystems



Mills et al., 2013

- Ozone can potentially affect the vegetation:
 - phytotoxicity
 - high values
 - wide distribution in remote areas
- Forests may reduce ozone through stomatal and non-stomatal deposition



Aim of the study is to assess the size of ozone regulating services provided by forests:

- i) the portion of ozone removed by vegetation
- ii) if ozone removal may have a biological cost for plants

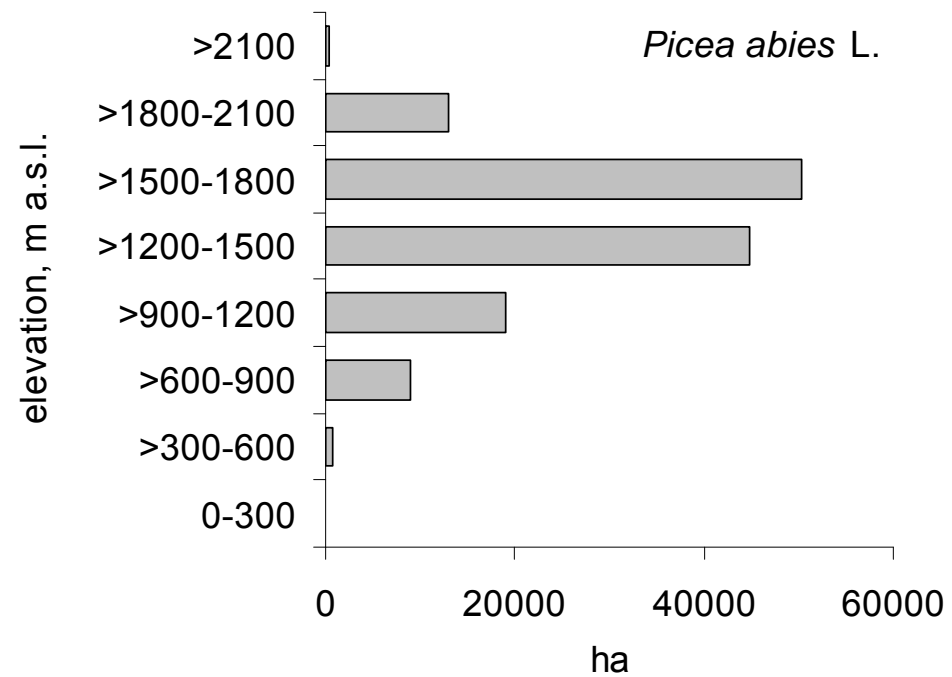
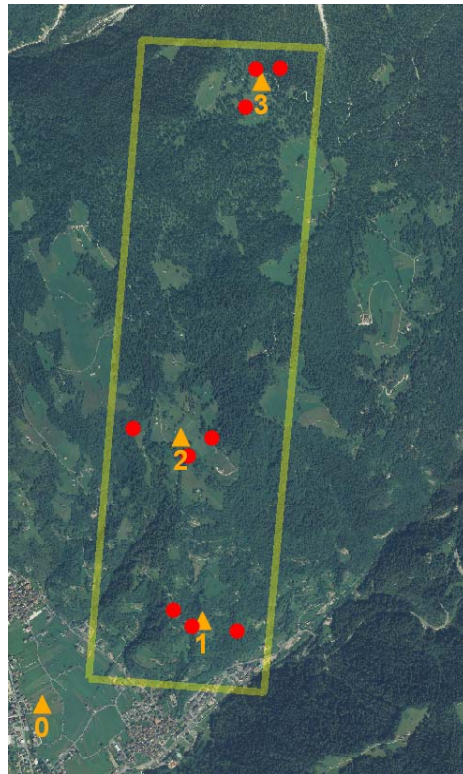
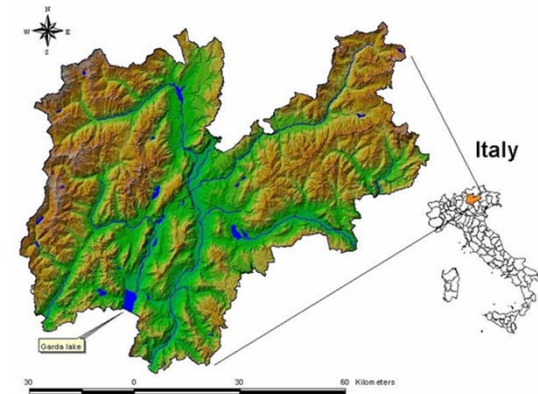
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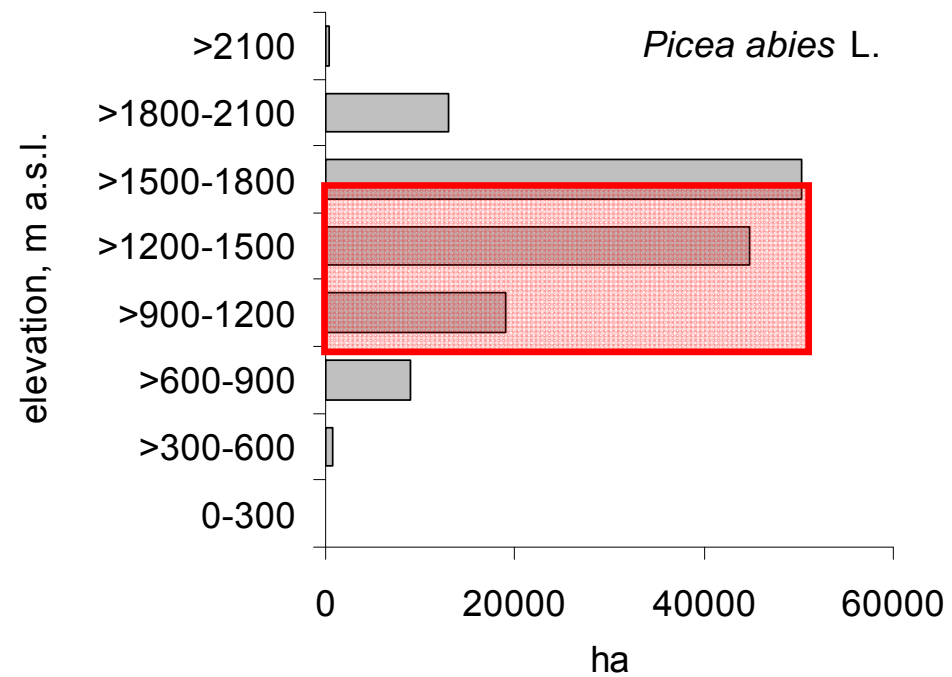
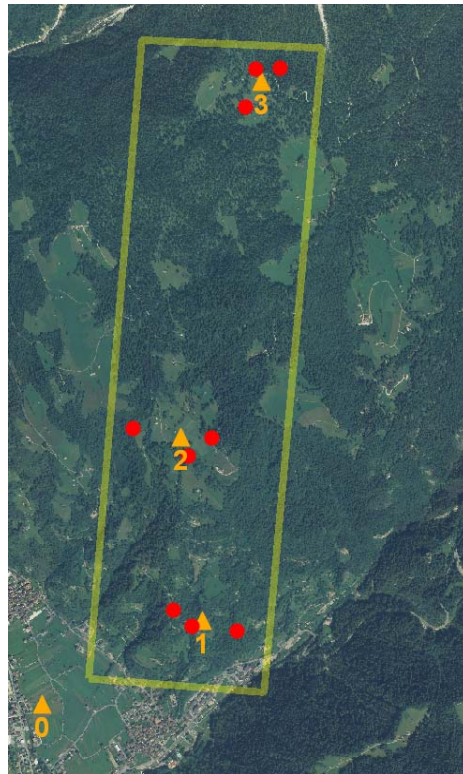
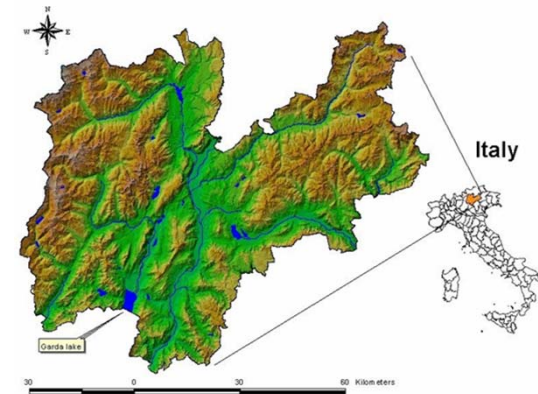
Study design

Fully randomized study on Norway spruce along an **altitudinal gradient** (900 - 1600 m a.s.l.) in Trentino, north Italy

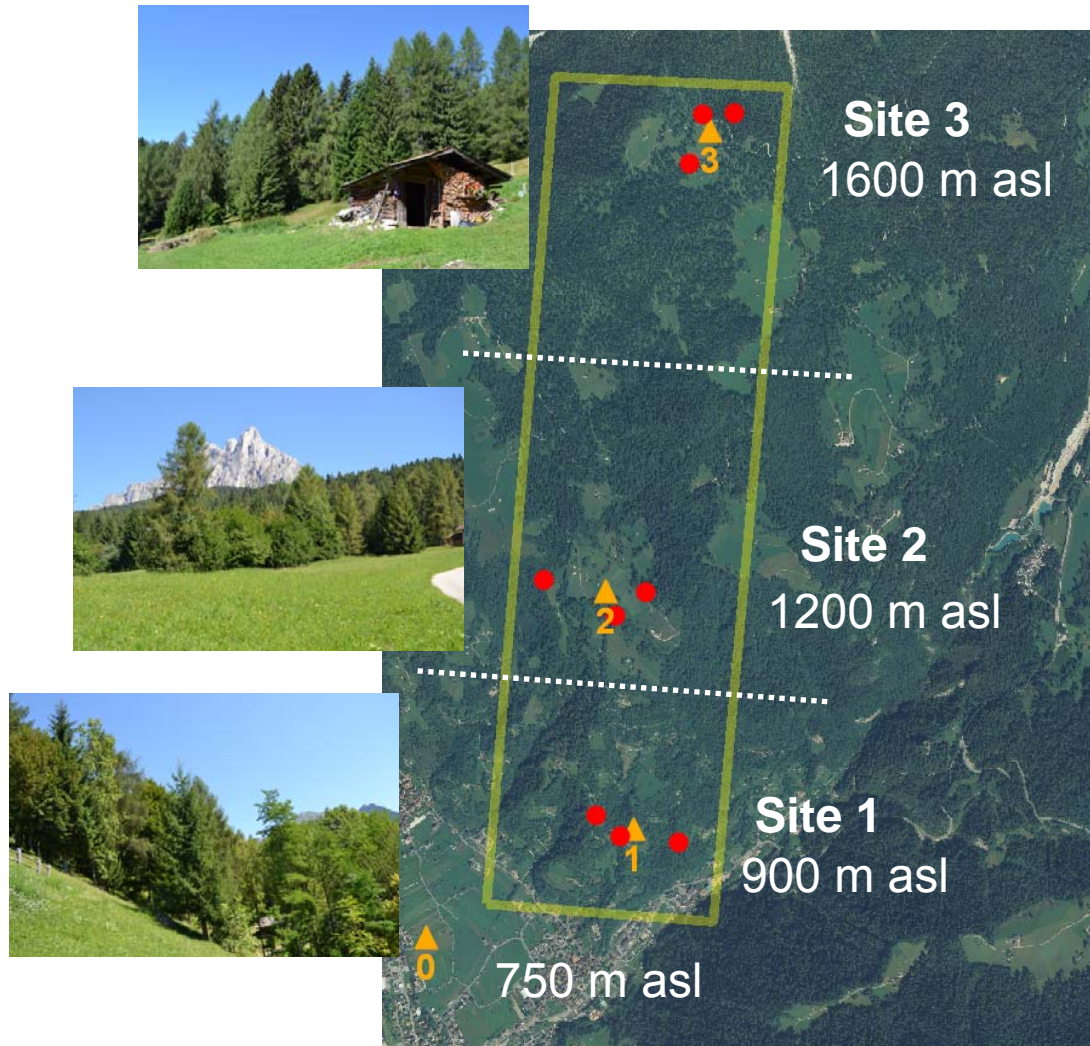


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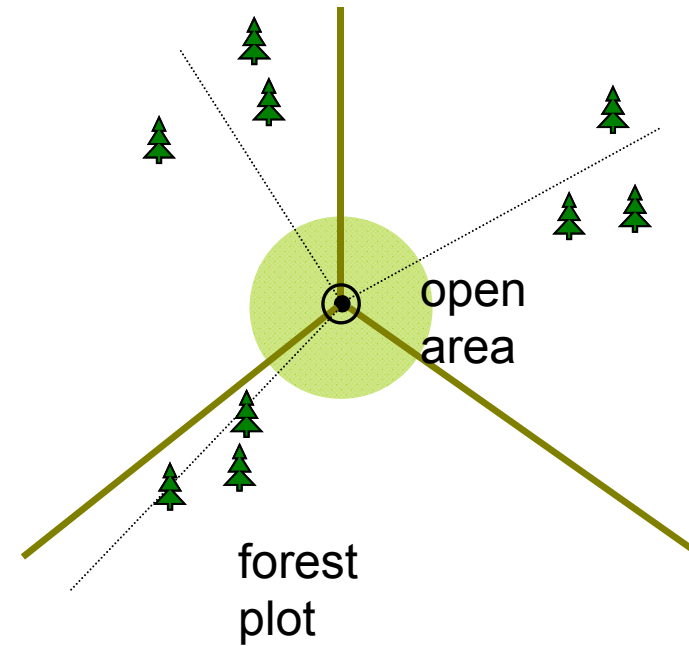


Study design

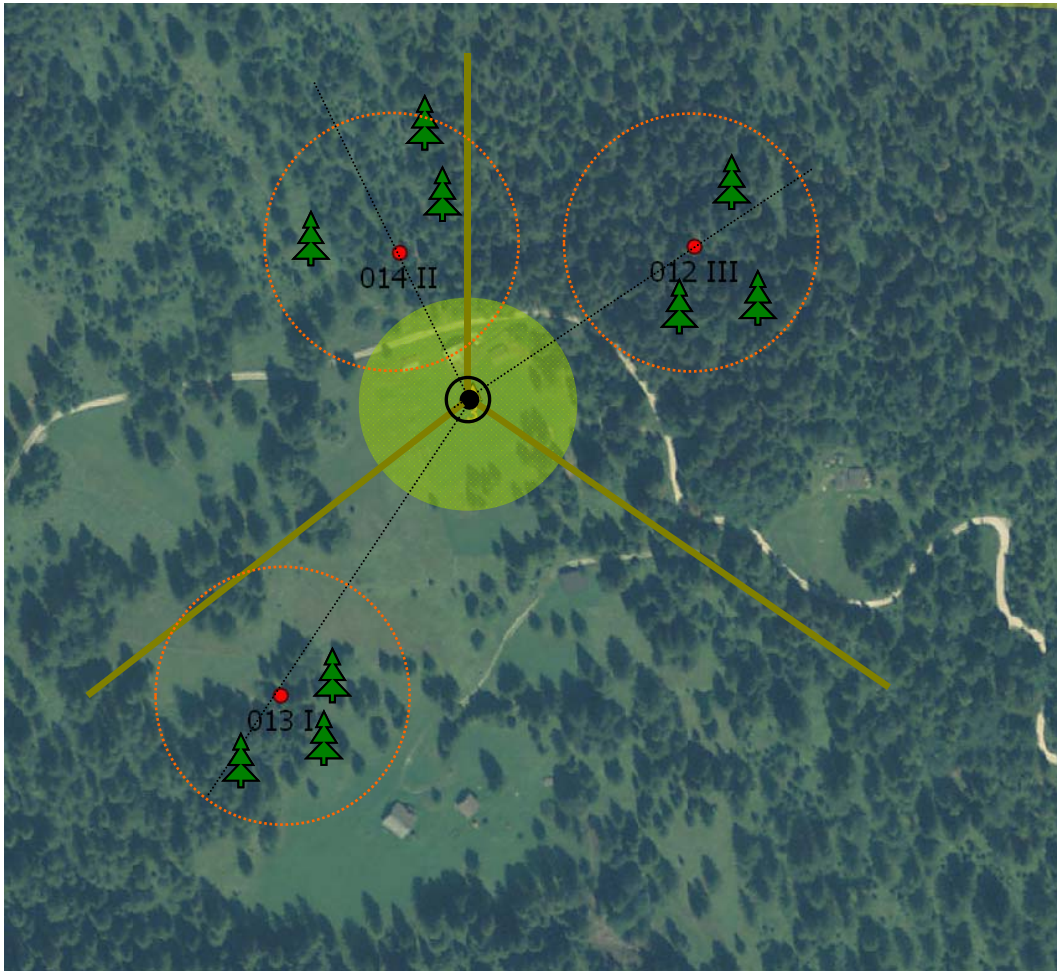


Statistical selection of:

- 3 + 1 sites (open area)
- 3 x 3 plot (forest)



Environmental variables



In each forest plot and open area, measurement at 2 m of:

Passive sampling:

- Ozone
- Nitrogen dioxide

Data logger:

- Temperature
- Relative humidity

Period: May - August 2013

Tree response variables



Tree health

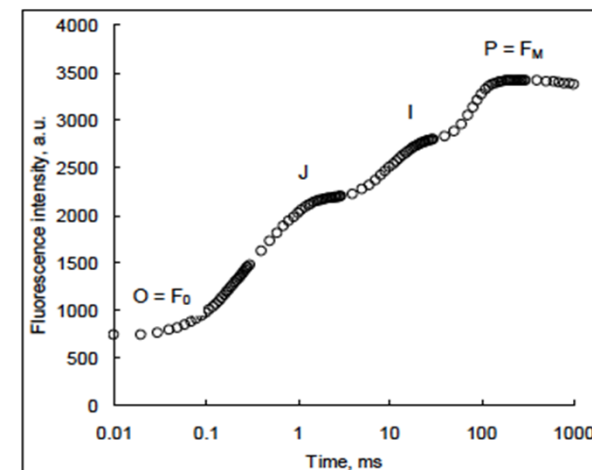
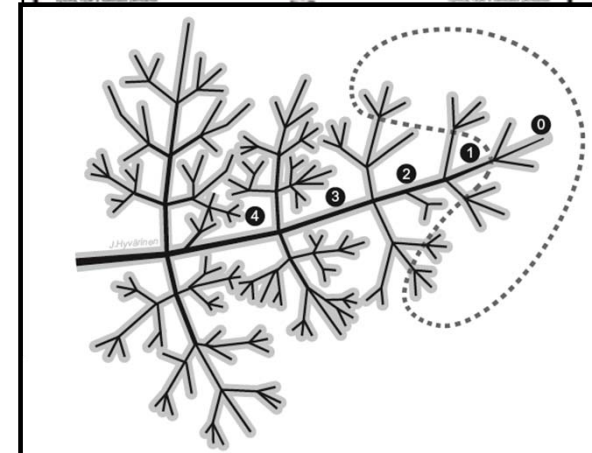
- Crown condition (n=27 trees)

Productivity

- Needle weight (n=9 trees, 900 needles per tree, C0)
- Shoot length (n=9 trees, 45 shoots per tree, C0)

Photosynthetic efficiency

- Chl a fluorescence (n=9 trees, 15 shoots per tree, C0 and C1)
- F_v/F_m = maximum quantum yield efficiency

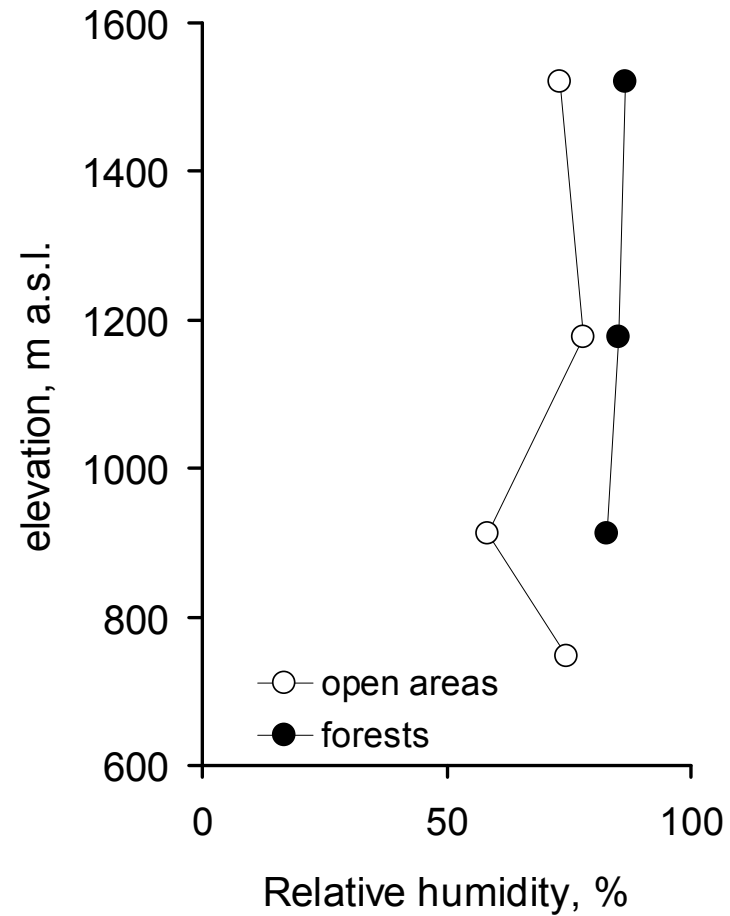
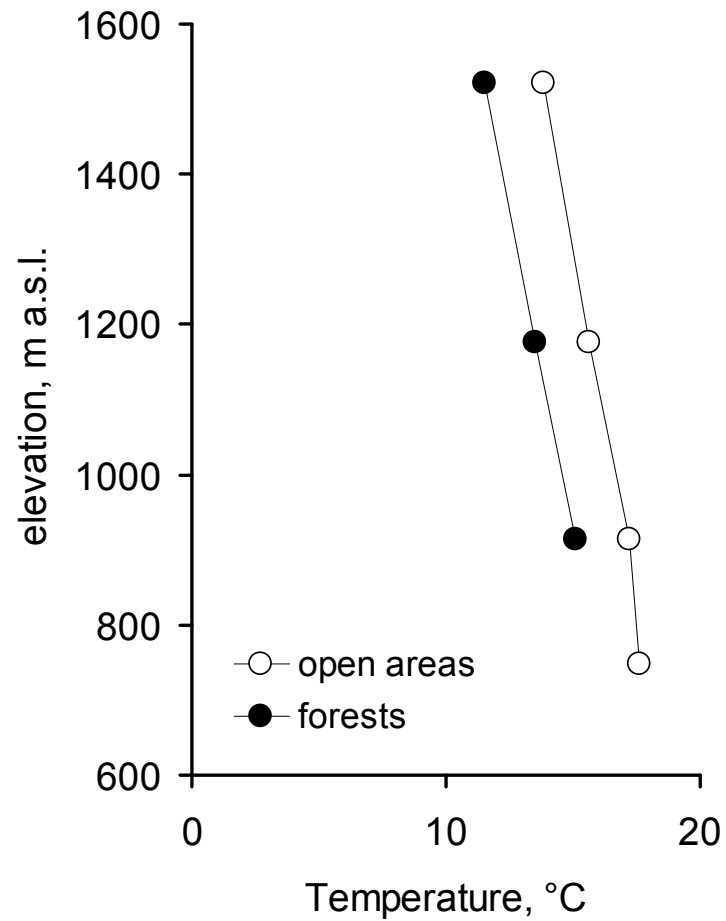


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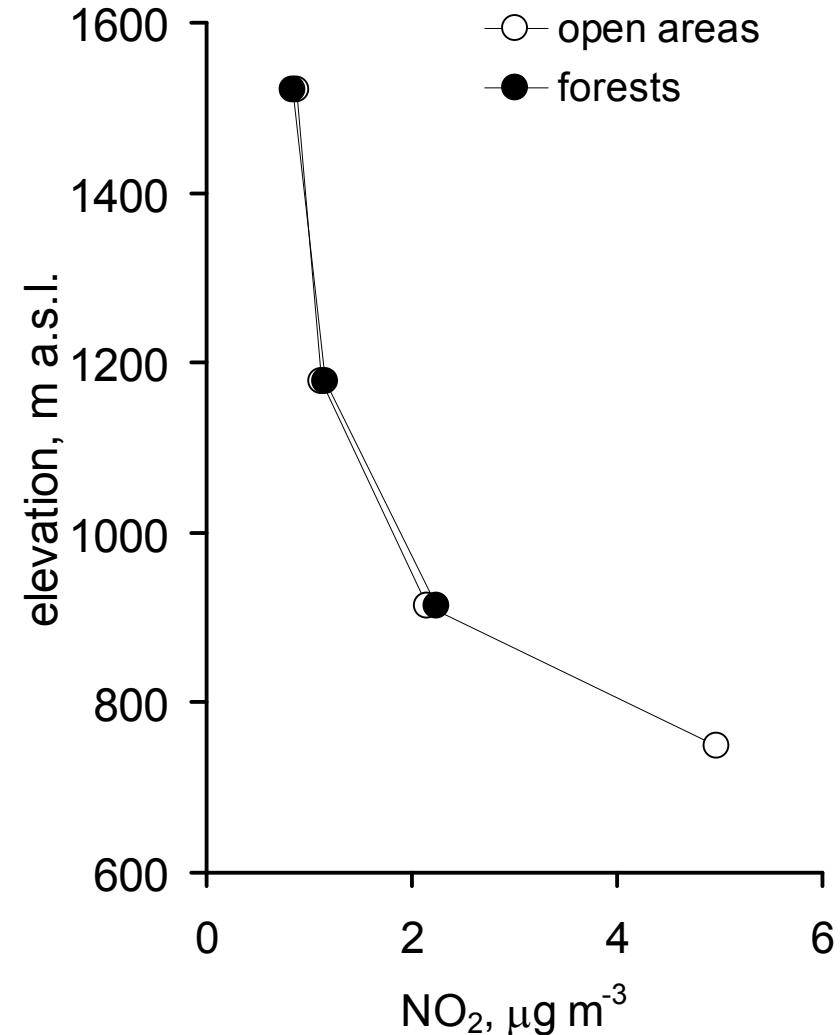


Altitudinal profile of T and RH concentration



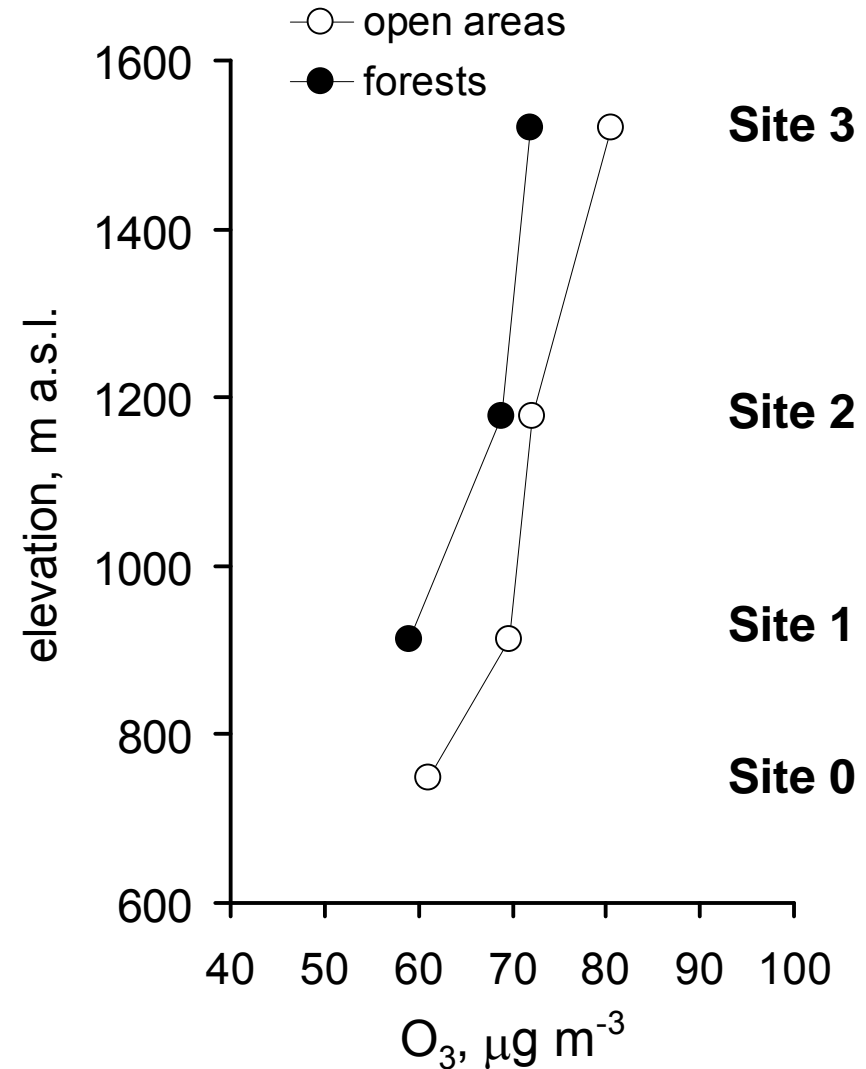
Altitudinal profile of NO₂ concentration

- Nitrogen dioxide concentration decreased with altitude, both inside and outside forests.
- Concentrations are very low (1.4 $\mu\text{g m}^{-3}$)

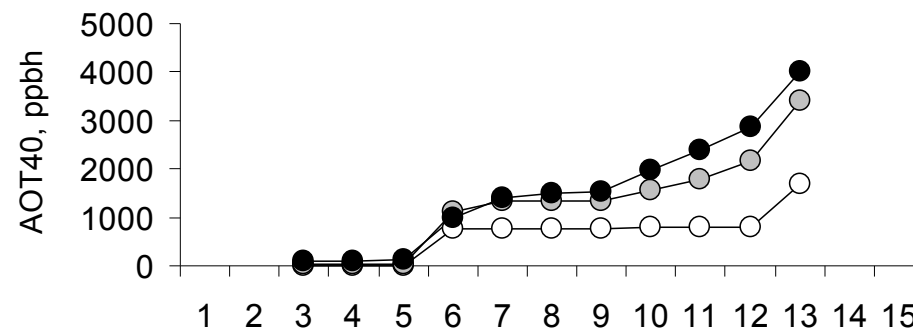
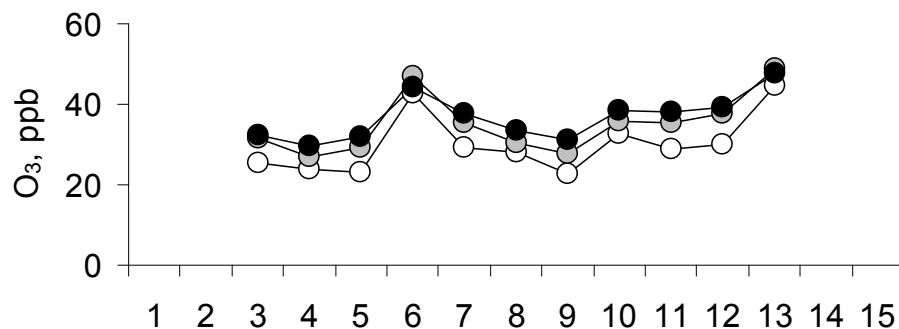


Altitudinal profile of ozone concentration

- Ozone concentration increased with altitude, both inside and outside forests.
- Lower ozone concentrations within the forest (64.8 $\mu\text{g m}^{-3}$) than in open areas (74.5 $\mu\text{g m}^{-3}$) ($P < 0.001$)

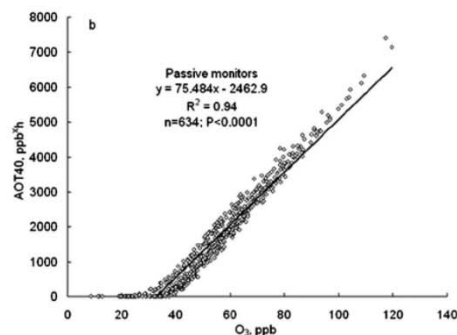
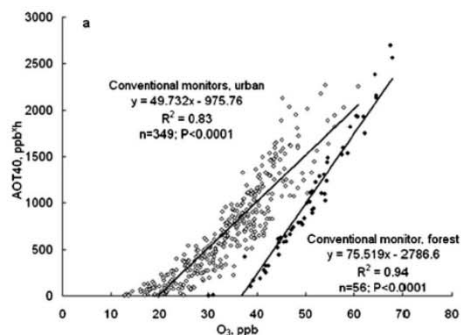


AOT40 estimation



Weekly ^{Week} O₃ concentration **➔** Weekly ^{Week} AOT40

$$\text{AOT40} = [\text{O}_3] \times 75.484 - 2462.9$$



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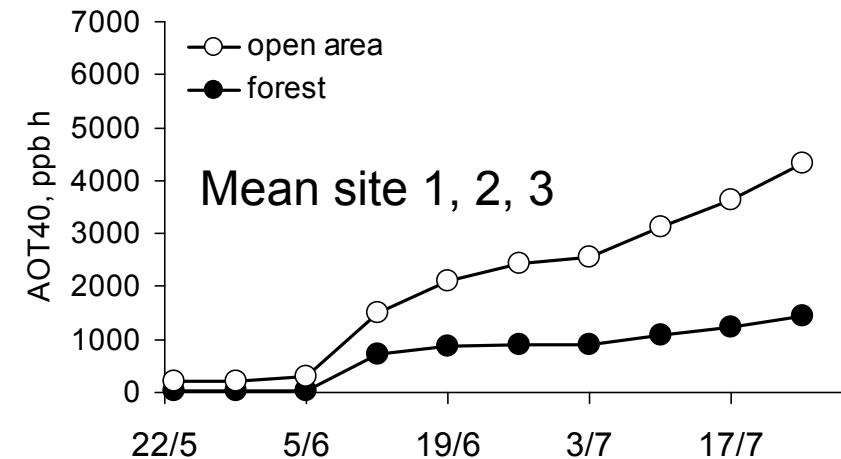
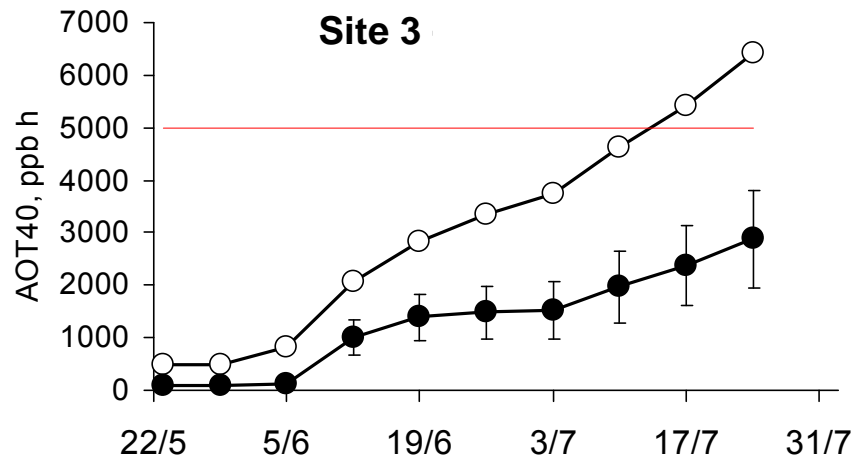
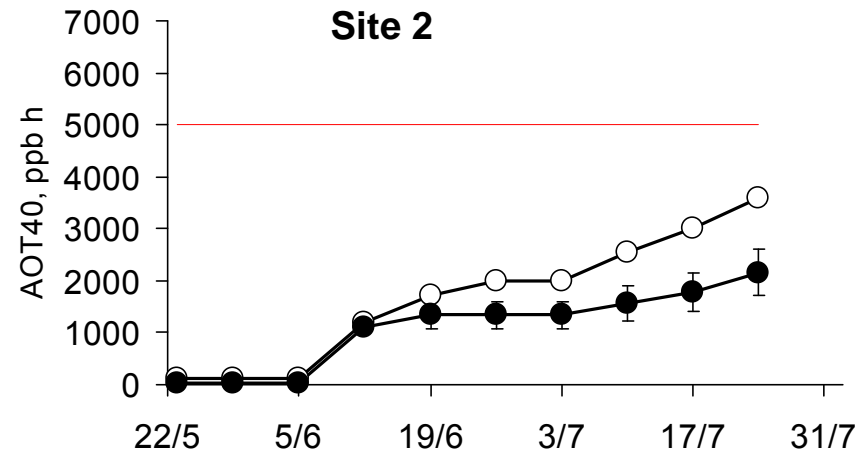
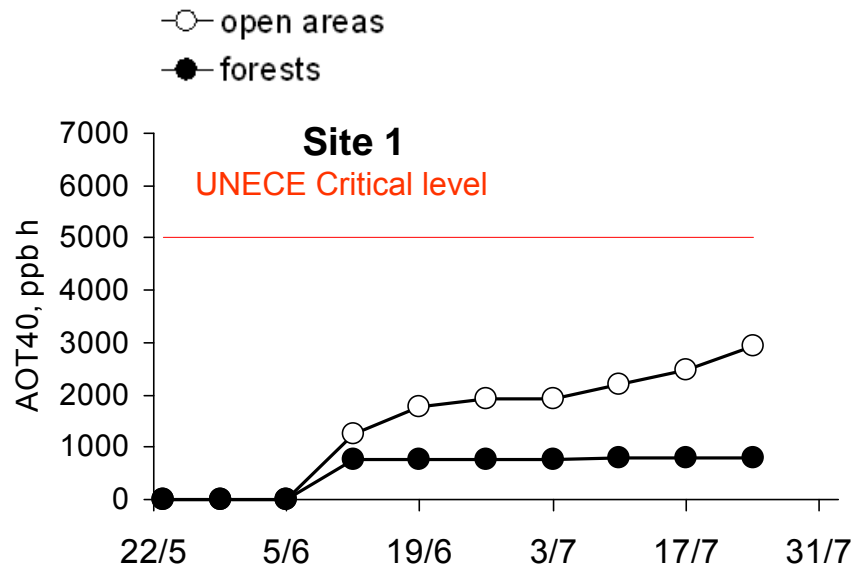
A simple linear model for estimating ozone AOT40 at forest sites from raw passive sampling data†

Marco Ferretti,^a Fabiana Cristofolini,^b Antonella Cristofori,^b Giacomo Gerosa^c and Elena Gottardini^b

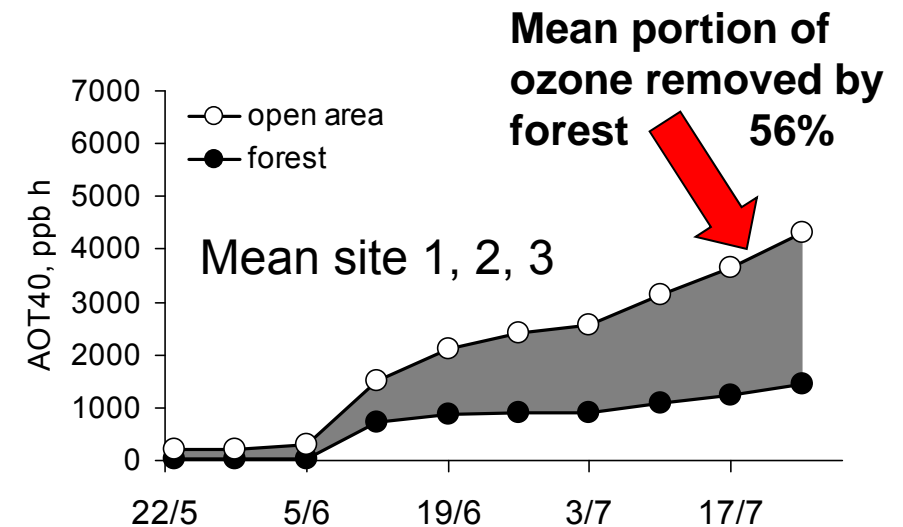
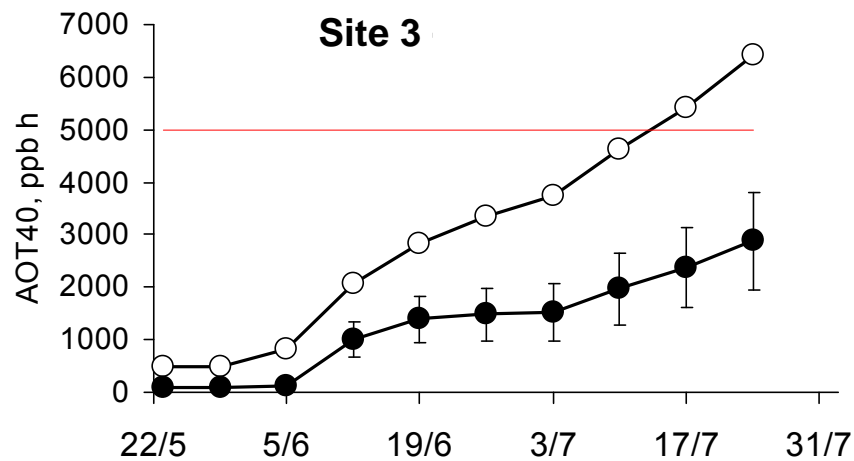
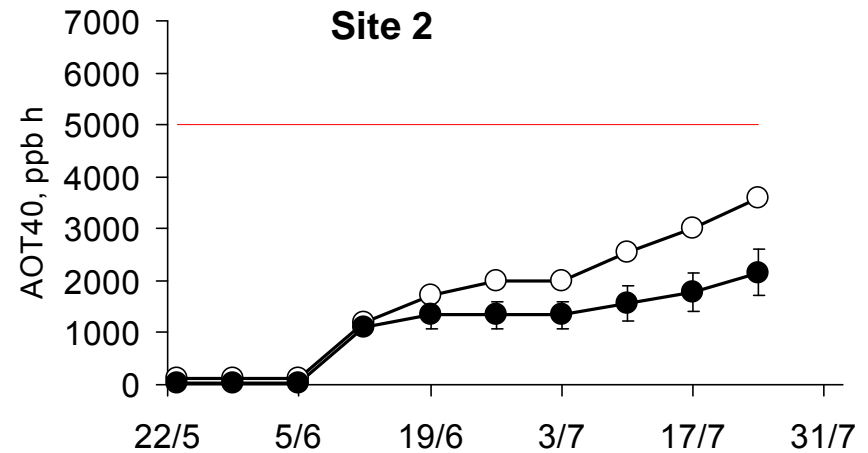
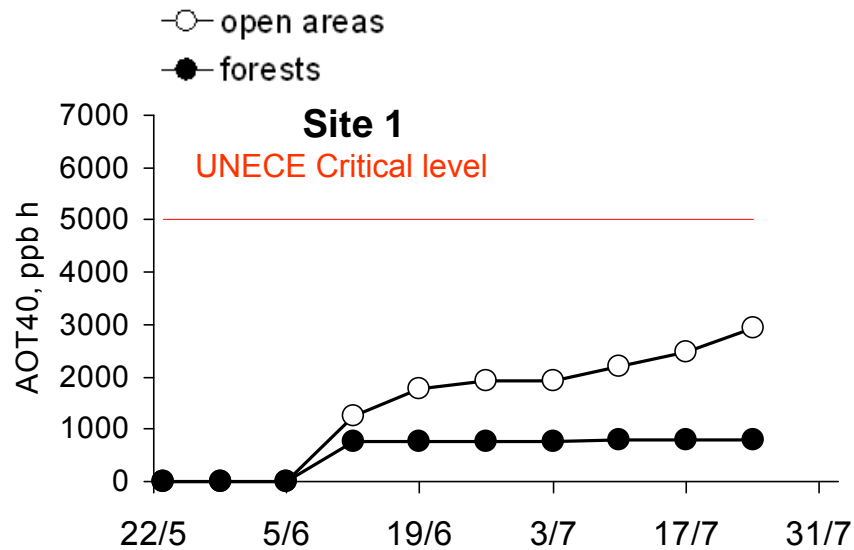
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PAPER

AOT40: differences between open areas and forest



AOT40: differences between open areas and forest

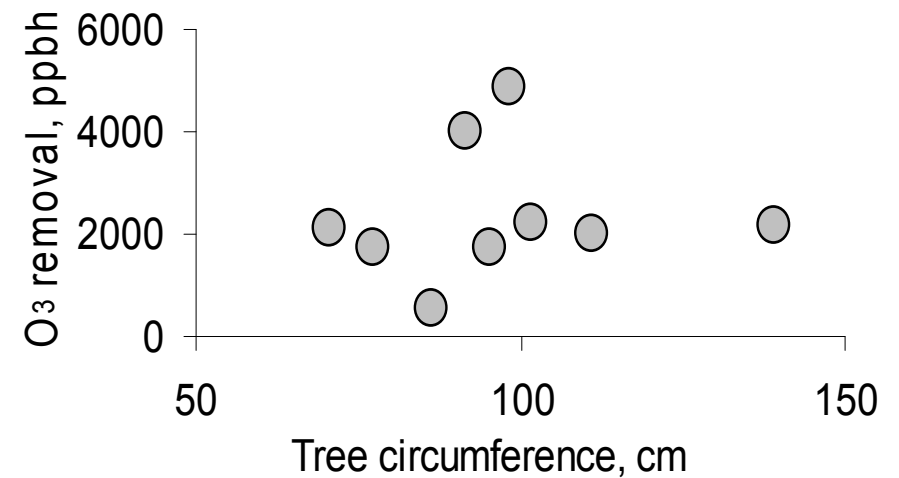
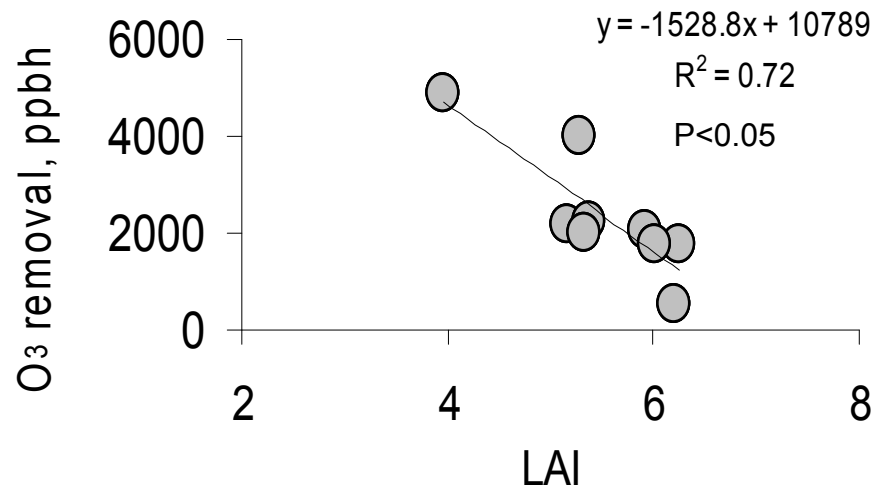
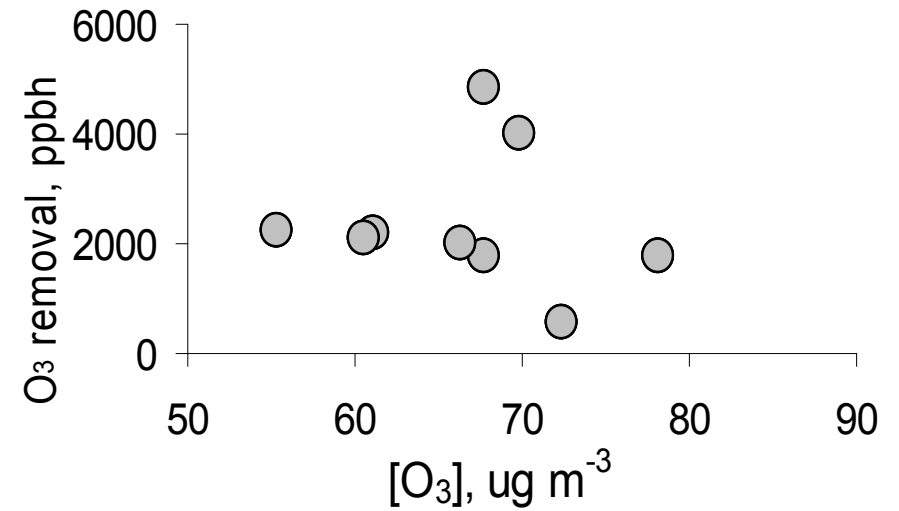
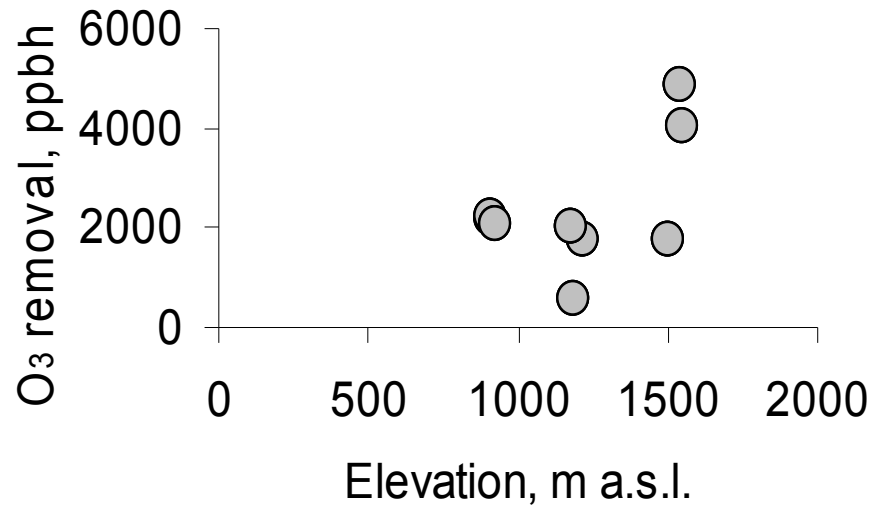


- Is there a relationship between ozone removal and environmental/structural factors?

- Elevation
- Ozone concentration
- LAI
- Tree circumference



Ozone removal vs. environmental/structural factors



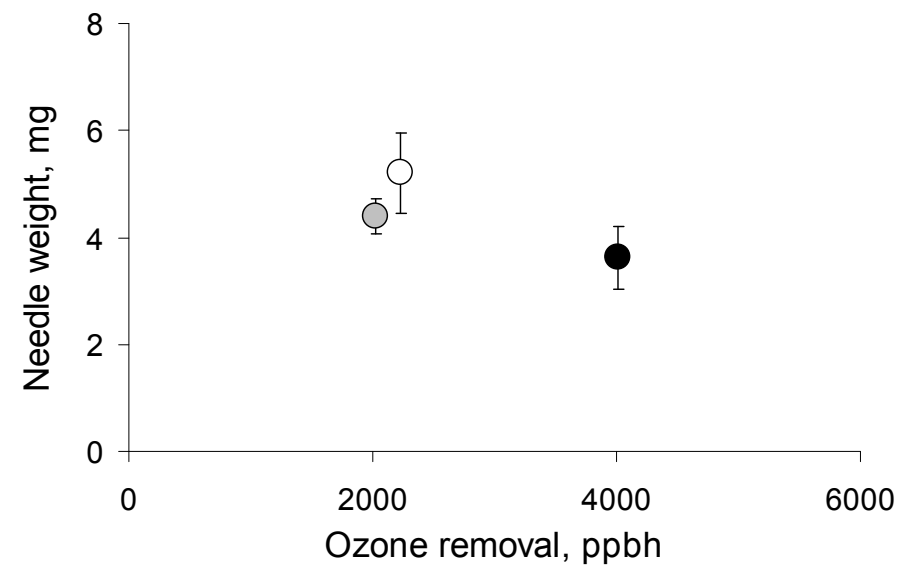
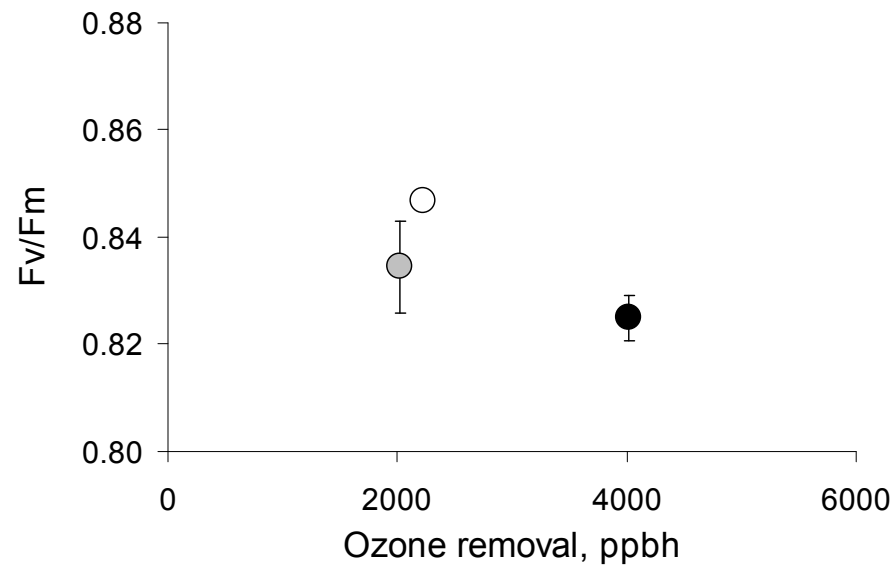
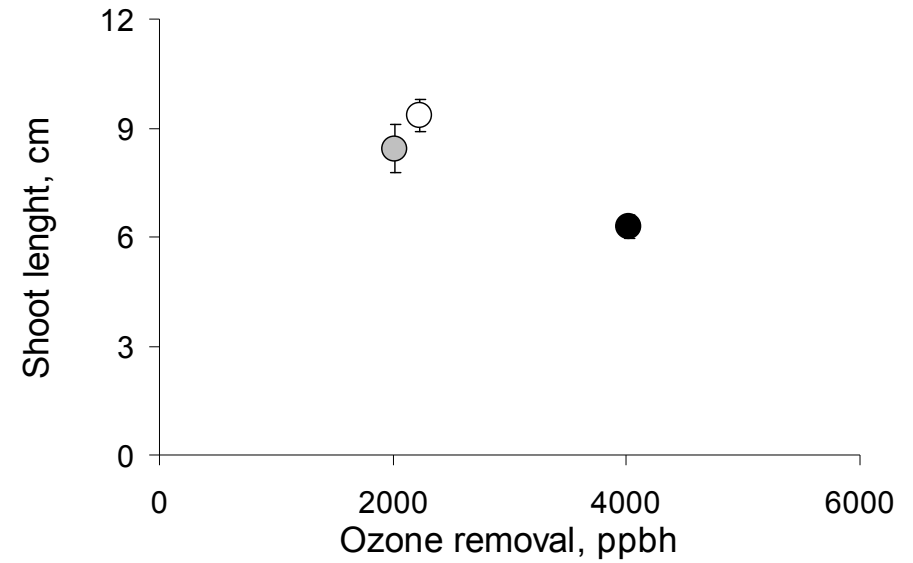
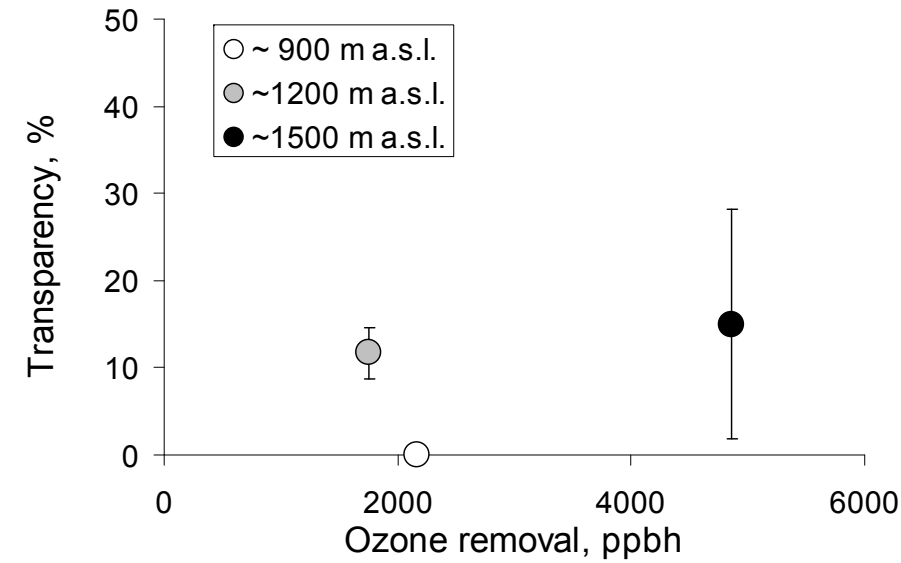
- Is there a biological “cost” for plants because of ozone removal?

Response indicators:

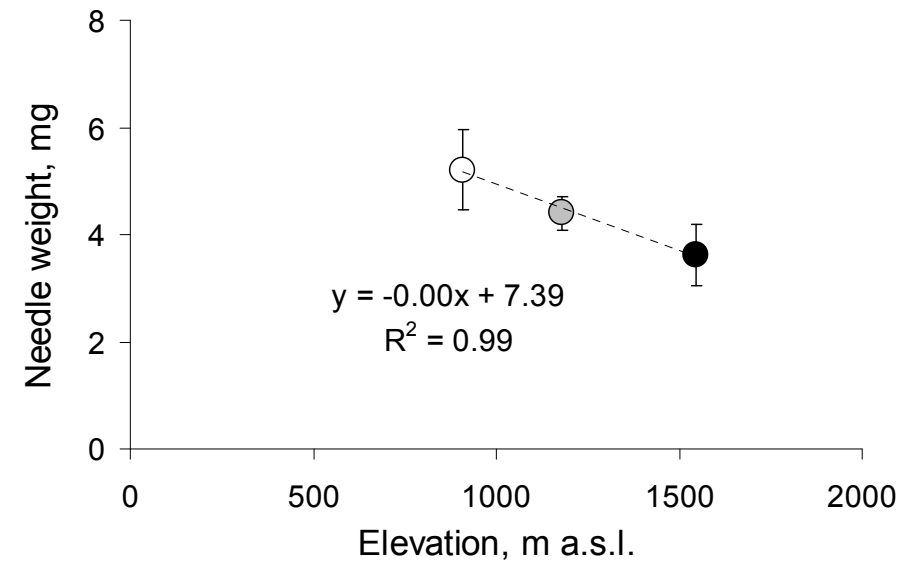
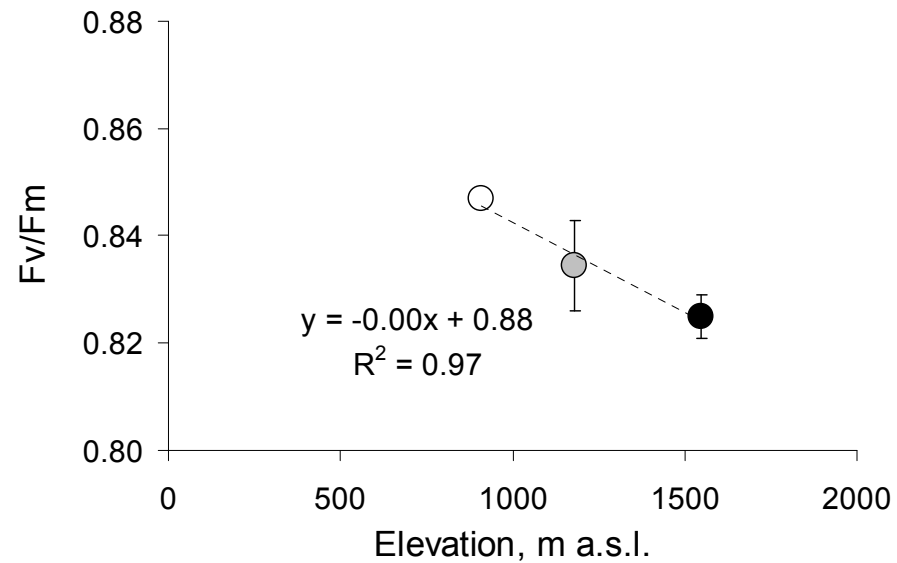
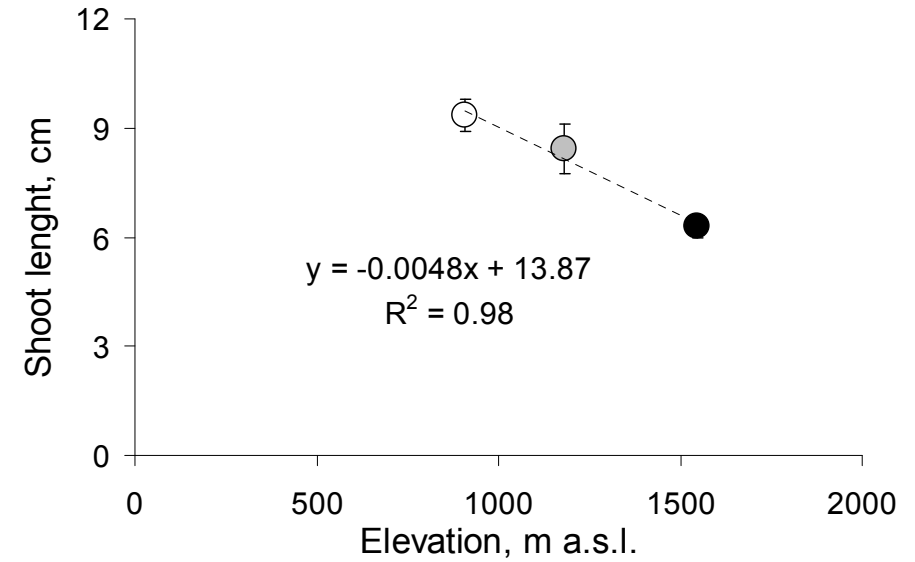
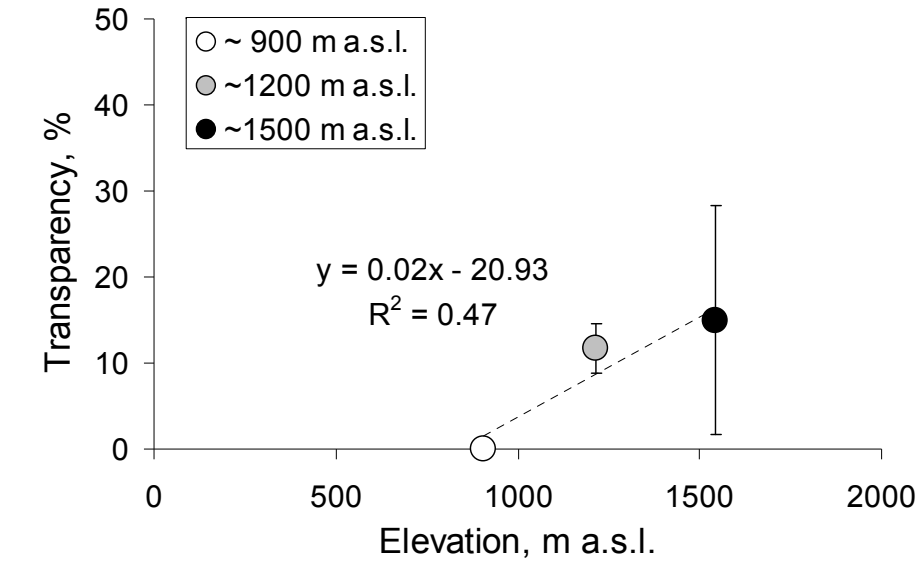
- Transparencency
- Shoot lenght, needle wheight
- Chlorophyll fluorescence



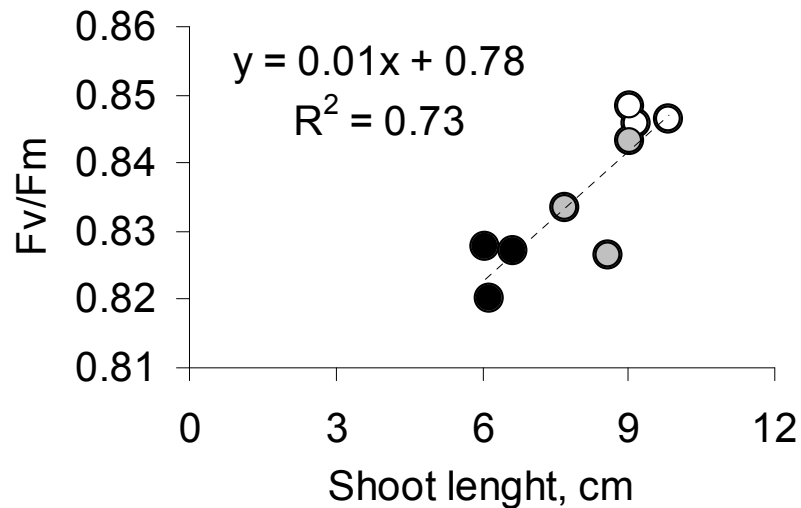
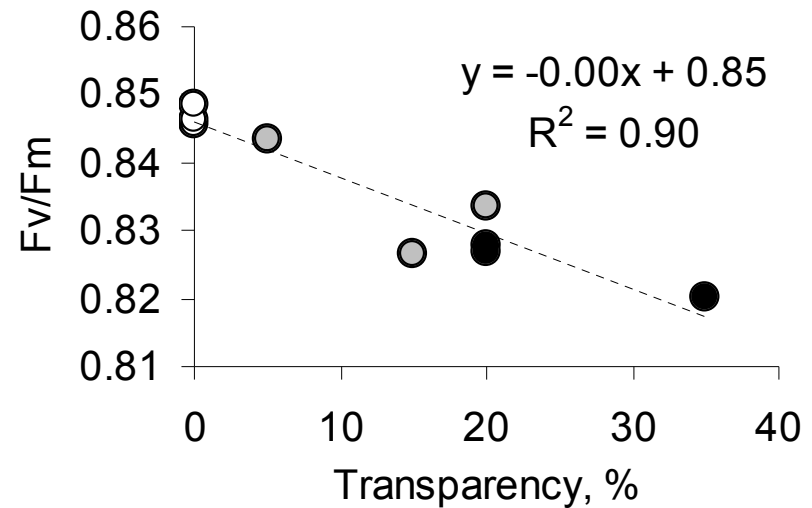
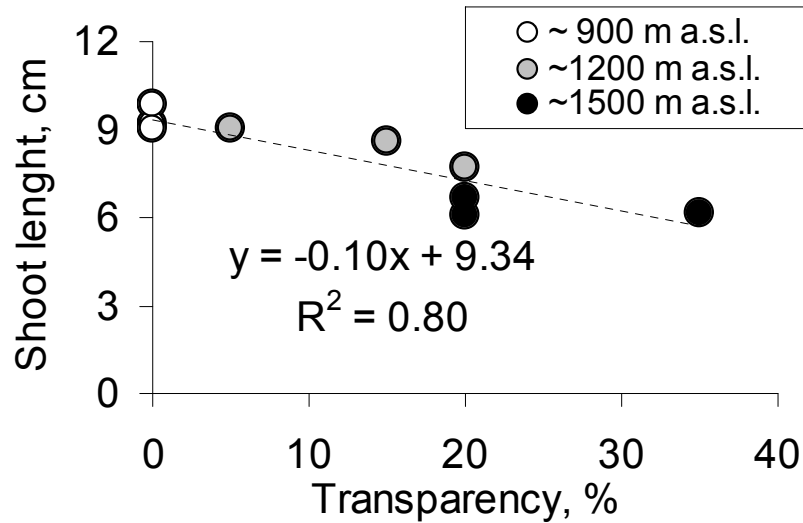
Ozone removal vs. tree responses



Elevation vs. tree responses



Relationship among tree responses



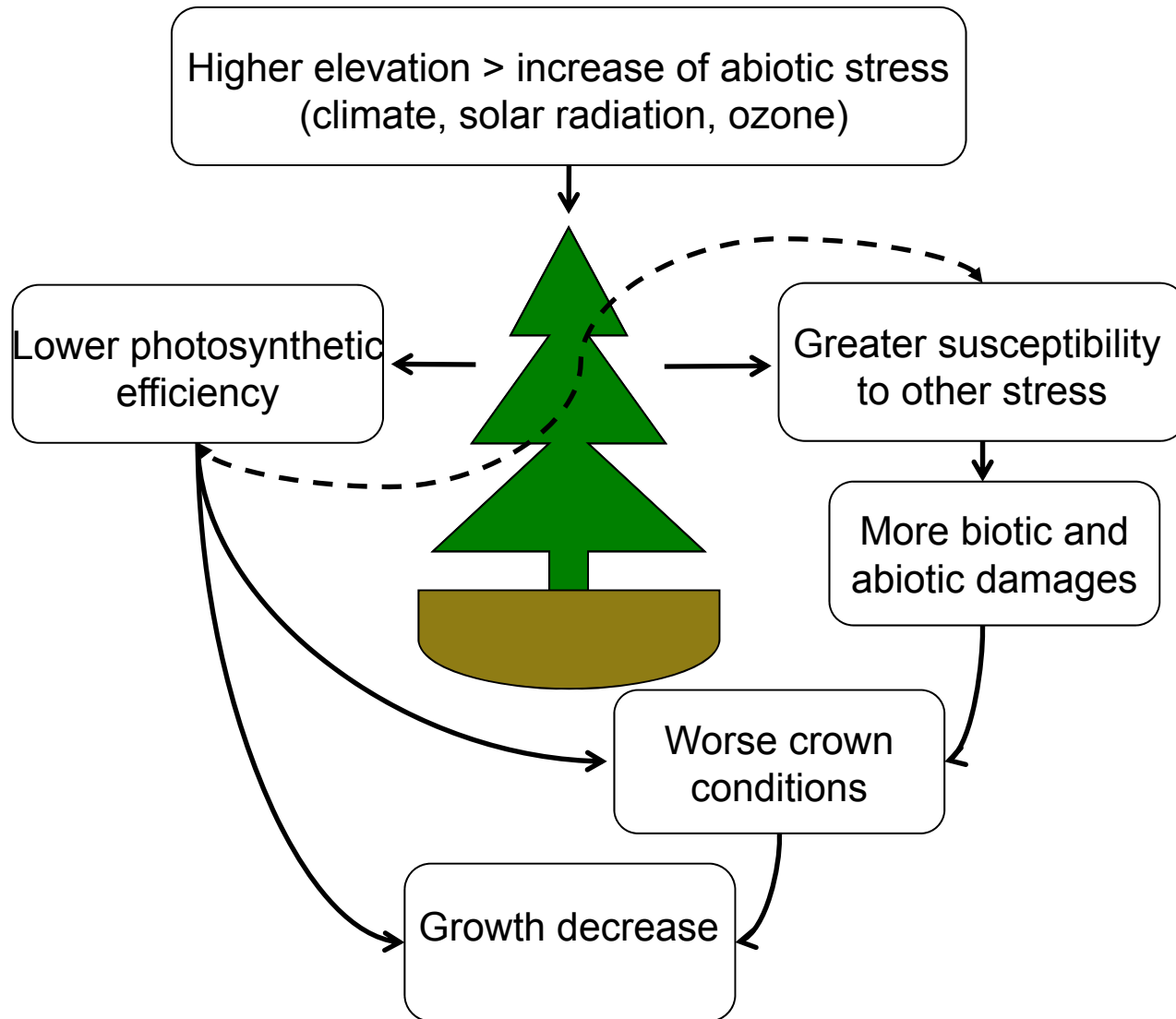
Nested within such a superimposed effect of the elevation, the various response indicators were related to each other

Scheme of the presentation

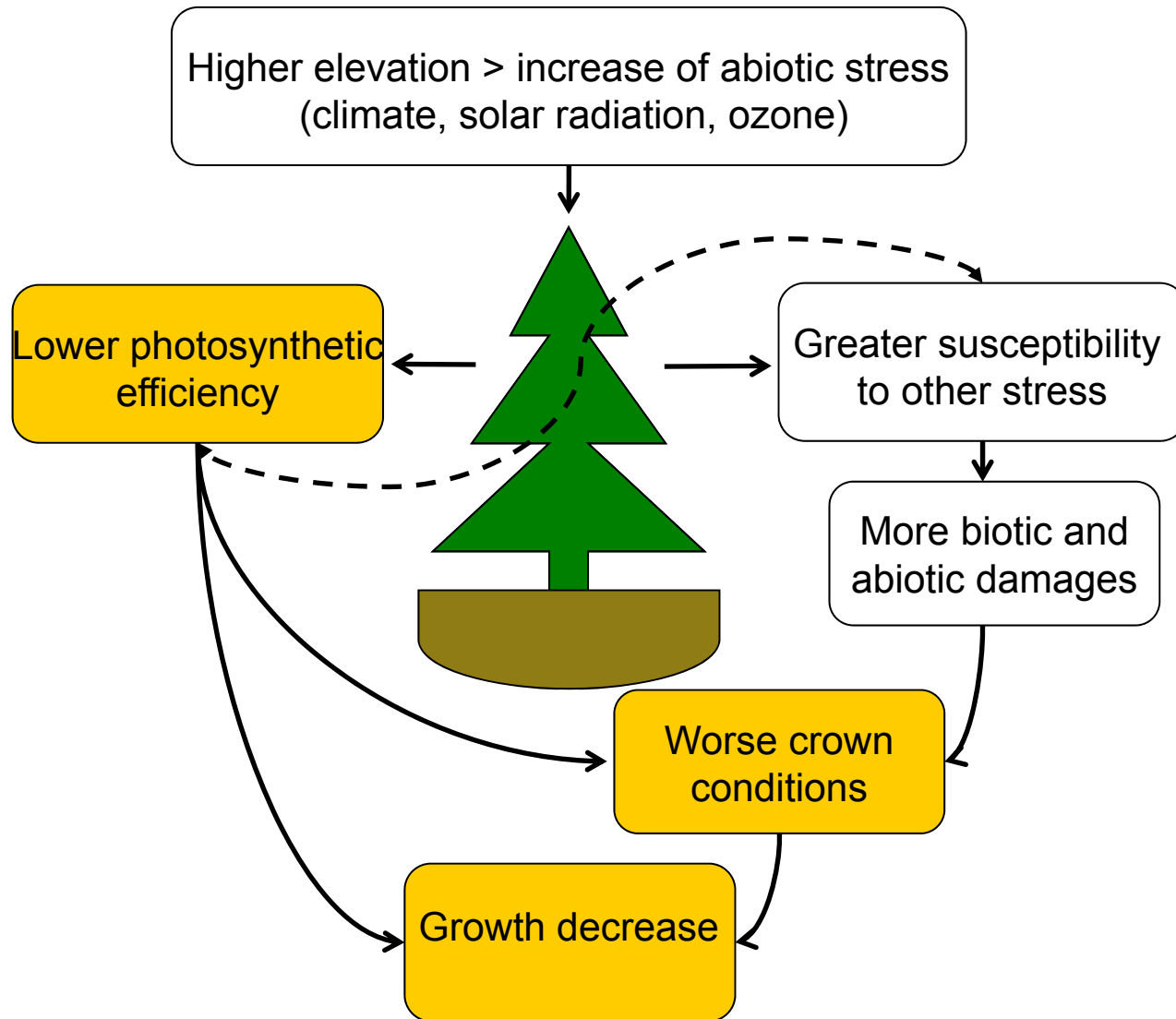
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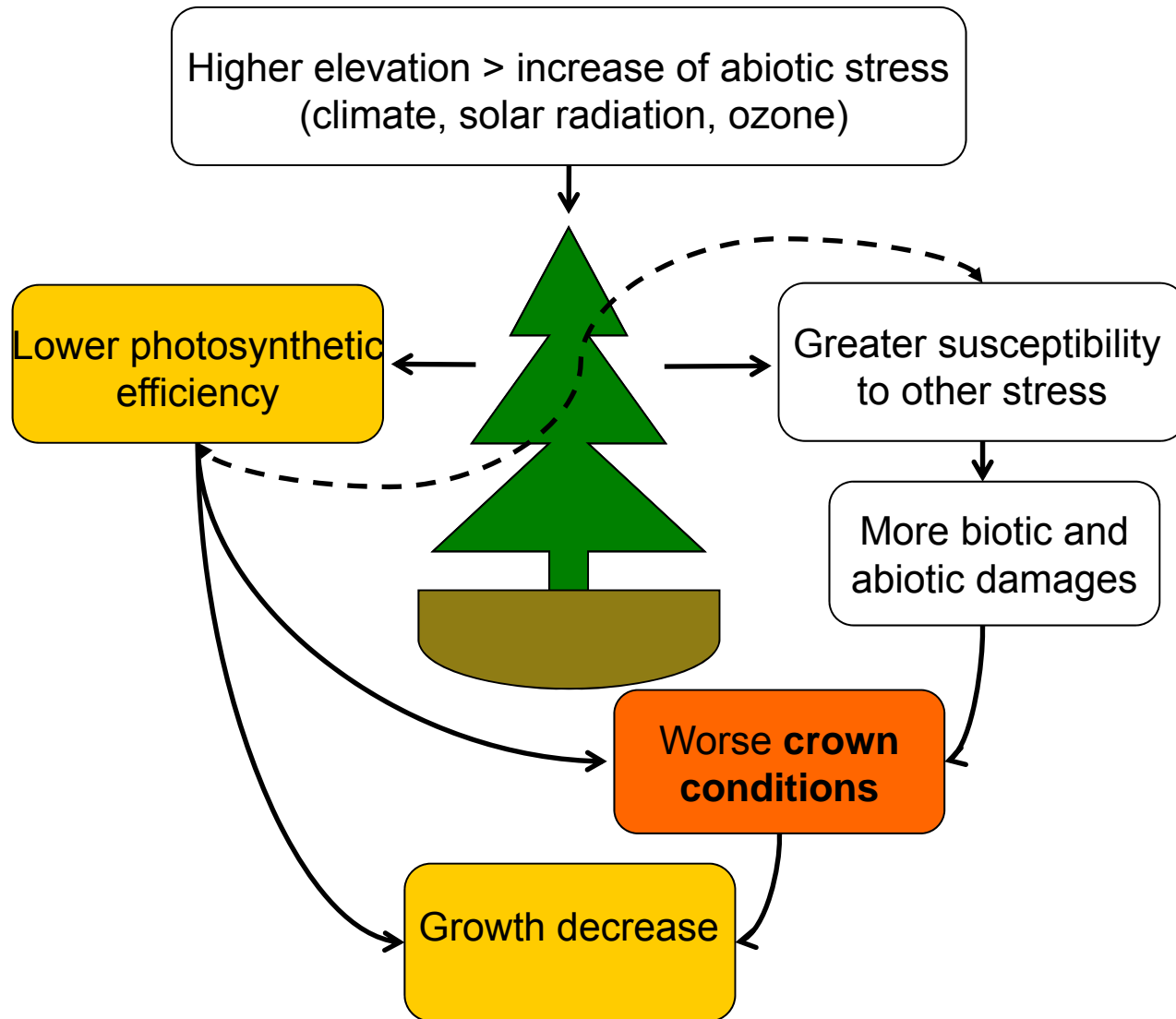
Functional interpretation of monitoring data



Functional interpretation of monitoring data



Functional interpretation of monitoring data



Possible biological costs of removing ozone

- Vegetation provides ecosystem services → ozone removal
- Ozone removal resulted:
 - slightly dependent on elevation and on ozone concentration
 - slightly associated to lower productivity and photosynthetic activity, and higher crown transparency
- Thus, ozone removal seems to have a slight (if any) “biological cost”
- Plants are able to play an important role in regulating services - like ozone removal - also where environmental conditions are more stressful
- Side findings: data suggest a possible functional interpretation of forest health monitoring data

Acknowledgments

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