Removal of greenhouse gases and pollutants in periurban Mediterranean forests described by the Aggregated Interpretation of the Energy balance and water dynamics for Ecosystem services assessment (AIRTREE) model

Silvano Fares[1] , Adriano Conte[1], Alessandro Alivernini[1]

[1] *Council for Agricultural Research and Economics- Research Centre for Forestry and Wood, Rome, Italy*

Introduction

Trees in urban areas remove carbon and pollutants from the atmosphere and provide many other ecosystem services (e.g. shading, reduction of heat island effect, recreational services). Modelling of these ecosystem services is a desirable tool for urban green management, since it can help urban planners to choose the best tree species in order to optimize the benefits for the citizens. Here we propose a novel multi-layer approach and process-based algorithms to investigate the physiological status of plants and the interaction with the urban atmosphere.

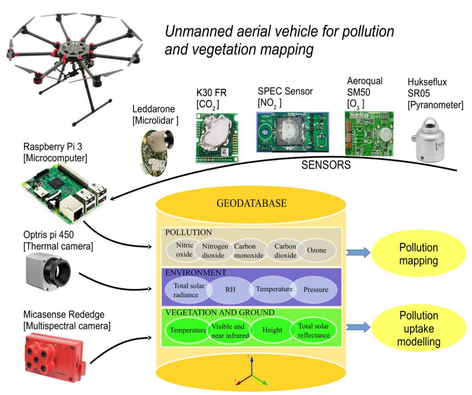
Model input

Parameters given by external atmospheric modeling systems or by a measurement station, when available

- wind (m s^{-1})
- air pressure (kPa)
- solar radiation (µmol photons m^{-2} s^{-1})
- air temperature (°C)
- atmospheric vapor pressure (kPa)

Parameters measured on site or derived by remote sensing

- carbon dioxide (ppm)
- volumetric water content (%)
- canopy area (m2)
- canopy depth (m) sampled wi (Vertex IV).
- leaf area index measured with
- BVOC Basal Emission Factors measured in-situ using cartridges with laboratory analysis via GC-MS.
- leaf width (mm)
- leaf length
- scattering a and PPFD
- Leaf IR em
- leaf clusteri
- canopy tota
- Ball-Berry c
- wilting poin
- velocity of c



Stomatal con velocity are n infrared gas-analyzer (Licor 6400, LICOR).

Model setup

Assessment of direct and scattering radiation for each layer (Bodin & Franklin 2012, Zhao & Qualls 2006)

Computation of the energy balance for each layer of the canopy (Lhomme 2012)

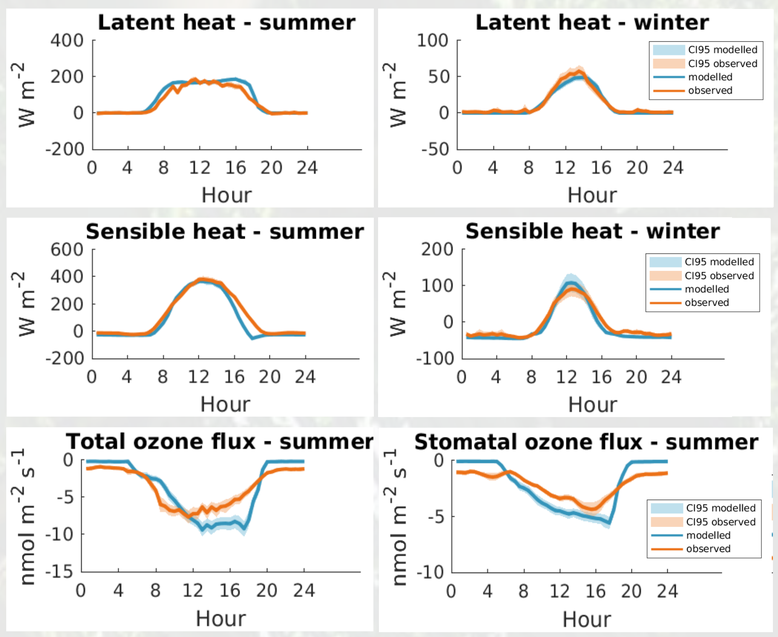
$$SW + LW = SH + LH$$

SW: Shortwave, LW: Longwave
SH: Sensible heat , LH: Latent heat

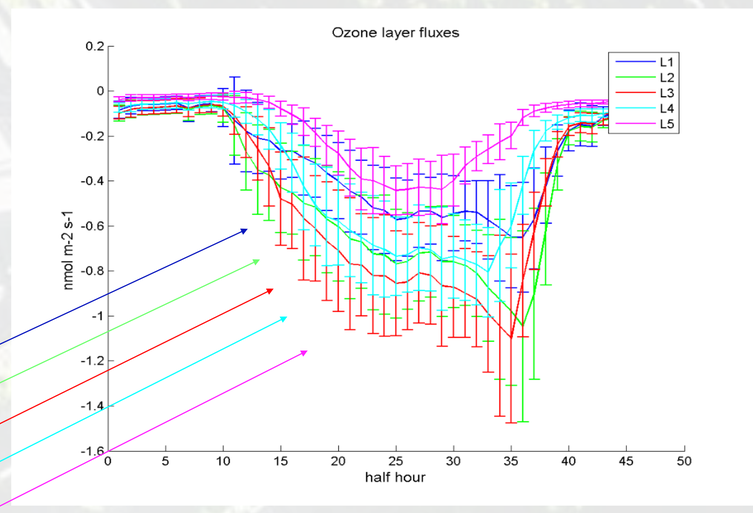
Analysis of photosynthetic flux density of a leaf and calculation of stomatal conductance. (Farquhar et al. 1980, Baldocchi 1994, Harley et al. 1992, Ball-Berry 1987)

Assessment of air pollutants deposition, VOC emission and carbon fluxes (Guenther et a. 2012)

Model run covering the year 2013



Pollutants are removed by vegetation through stomatal and non-stomatal pathways.
Quantification of stomatal aperture (G_{sto}) allows calculating the amount of pollutant entering leaves being destroyed in the intercellular spaces. Additional atmospheric models are used to quantify non-stomatal pollutant sinks: deposition to soils, leaf cuticles, and chemical removal by Volatile Organic Compounds (VOC) emitted by trees.



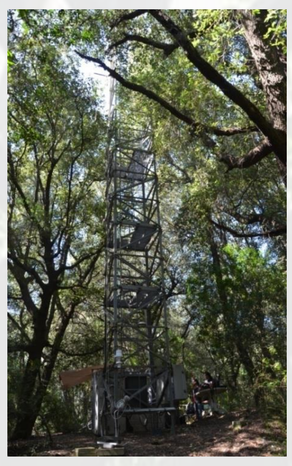
Multi-level deposition affected by the proportion of leaf biomass at each level

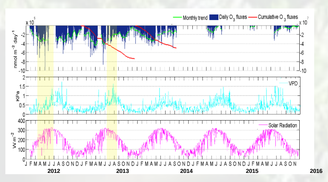
Model validation

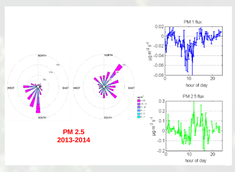
Test site

- Our test site is located in a Holm oak forest inside the Presidential Estate of Castelporziano, Rome, Italy.
- Climate is typically Mediterranean, characterized by high temperatures during summer periods, and a moderate cold stress during winter.

- CO2, O3, and BVOC Fluxes are calculated according to the Eddy Covariance technique on a 30 minute time interval (see Fares et al. 2014, 2016, 2018).







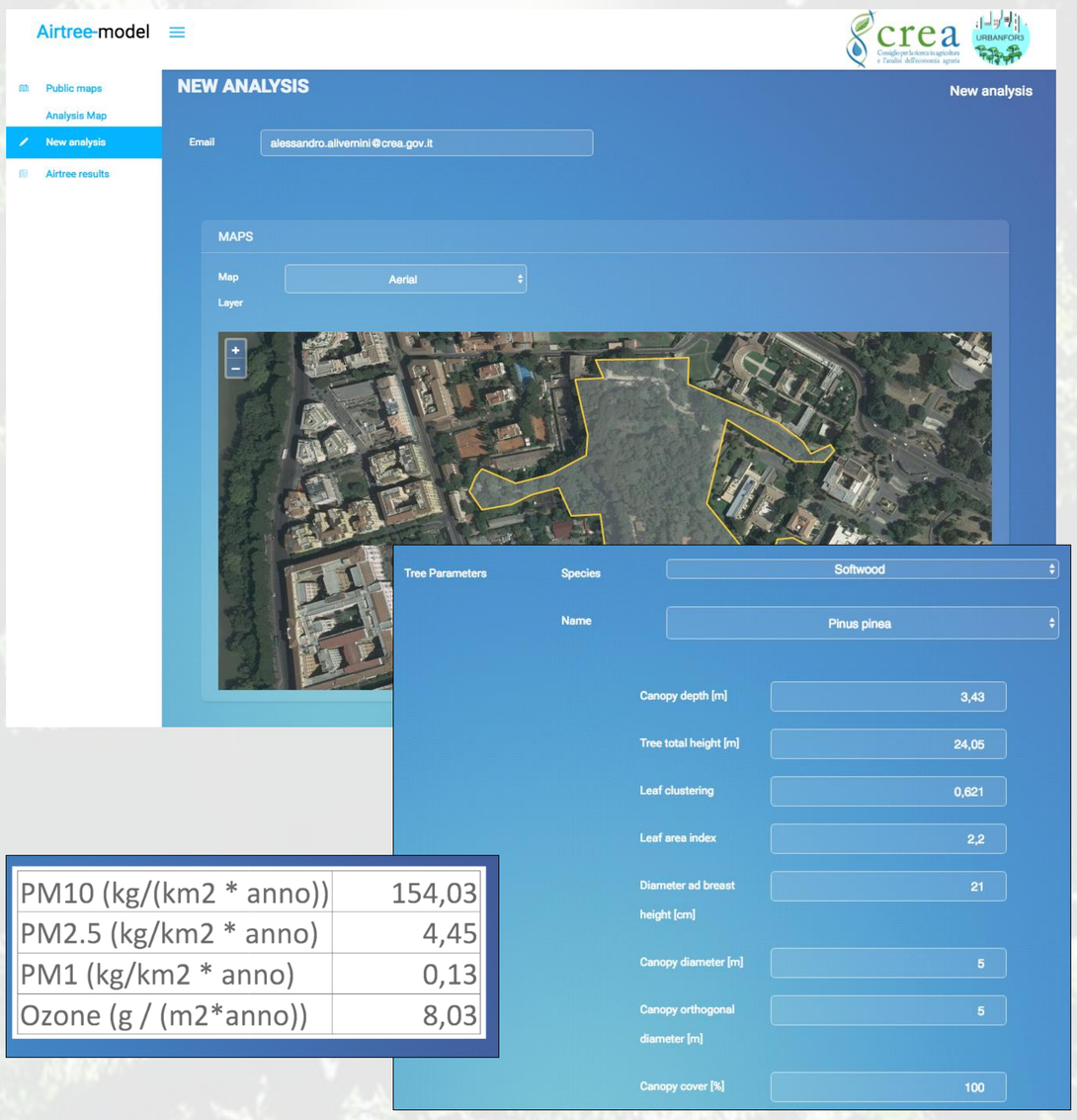
Canopy fluxes

Wind Direction and Sonic Temperature	Gill Windmaster
CO_2 and H_2O	LI-7000/7200, LICOR
O_3	NOOA

5-heights gradient measurements

O_3	49i, Thermo Scientific
CO_2 and H_2O	LI-840, LICOR

AIRTREE in WebGis: on-line decision support system for urban forestry - www.air-tree.org



PM10 (kg/(km2 * anno))	154,03
PM2.5 (kg/km2 * anno)	4,45
PM1 (kg/km2 * anno)	0,13
Ozone (g / (m2*anno))	8,03

Conclusion

- The first component of a model to assess the ecosystem services offered by urban trees has been developed and validated for CO_2 and O_3 sequestration.
- In the near future, the model will be tested for other main gaseous pollutants: nitrogen oxides (NO_x), particulate matter (PM) , and anthropogenic VOC.
- Further developments will involve using remote sensing techniques to estimate canopy metrics and volumetric water content of soils.

Contact: silvano.fares@crea.gov.it

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