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COASTAL FOREST ECOSYSTEM NEAR ROME

Researches in Castelporziano test site: ecophysiological studies on Mediterranean vegetation in a changing environment

Lina Fusaro · Elisabetta Salvatori · Simone Mereu · Valerio Silli · Alessandra Bernardini · Aleandro Tinelli · Fausto Manes

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Abstract Urbanization processes increased dramatically in the past century leading to the emission of large quantities of air pollutants over relatively small areas. The consequent high concentration of pollutants and particulate matter (PM) have clear detrimental effects not only on human health, but also on urban and peri-urban vegetation. In this context, the Castelporziano Presidential Estate, a protected natural area located at the southeastern edge of the large conurbation of Rome (Italy), represents an ideal site to study the interaction between vegetation and atmospheric pollutants. Here we present an overview of the international field campaigns carried out in Castelporziano during the past 20 years, and of the ongoing research activities aimed to understanding the role of the estate in the provision of ecosystem services to the Metropolitan area of Rome. The exposure and potential detrimental effects of air pollutants such as tropospheric ozone and PM on natural vegetation have been assessed, investigating also the potential capacity of vegetation to ameliorate air quality under Mediterranean climatic condition. The results show that a correct assessment of the Ecosystem Services (ESs) provided by Mediterranean vegetation must consider the functional strategies that different species adopt to cope with drought stress, including the species-specific response of stomatal conductance to atmospheric water pressure difference, as well as the length of the drought period and its inter annual variability. Our results highlight the need to adopt managements strategies to mainten and implement the ESs provided by the important peri-urban natural area of Castelporziano.

Keywords Ecosystem Services · Global change · Metropolitan area of Rome · Functional traits · Air pollution · Periurban forest

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L. Fusaro (✉) · E. Salvatori · V. Silli · A. Bernardini · F. Manes
Department of Environmental Biology, Sapienza University of Rome, P.le Aldo Moro 5, 00185 Rome, Italy
e-mail: lina.fusaro@uniroma1.it

S. Mereu
Department of Sciences for Nature and Environmental Resources, University of Sassari, Sassari, Italy

S. Mereu
Impacts on Agriculture, Forest, and Ecosystem Services (IAFES), Euro-Mediterranean Center on Climate Change (CMCC), Sassari, Italy

A. Tinelli
Tenuta Presidenziale di Castelporziano, via Pontina 690, 00128 Rome, Italy

1 Introduction

Natural and semi-natural ecosystems provide a wide range of free goods and services essential to support human welfare and quality of life through ecological processes and functions (Daily 1997). Ecosystem Services (ESs) are defined as "the benefits that human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997). ESs include supply of good quality water, removal of air and soil pollutants, soil formation, pollination. The role of urban forests in providing ESs has been demonstrated in many papers, considering both basic ecosystem functions (Pataki et al. 2011) and emerging services, such as offsetting carbon emission, removing air

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pollutants (Baumgardner et al. 2012; Manes et al. 2012, 2014), reducing noise, regulating the microclimate, and also offering areas for recreation and amenity. Collectively, they contribute to improve environmental and life quality as well as to sustainable urban development (Roy et al. 2012). The reduction of air pollution by urban trees has been recognized as a cost-effective component of pollution reduction strategies in several urban areas in the United States (Nowak et al. 2006, 2013; Morani et al. 2011), as well as in Beijing (Yang et al. 2005), Santiago de Chile (Escobedo and Nowak 2009), London (Tiwary et al. 2009), Toronto (Millward and Sabir 2011), and Barcelona (Baró et al. 2014). The urban forest can have a pivotal role in airborne pollutant abatement such as tropospheric ozone (O_3) and particulate matter (PM), with positive effects on public health (Manes et al. 2012; Nowak et al. 2013). In the Mediterranean area, very stable climatic conditions during summer (i.e. Azore's anticyclone) favor the formation of tropospheric O_3 and concentrations above a threshold of 40 ppb are frequently exceeded in cities and surrounding areas. Non stomatal O_3 removal strongly depends on the seasonal fluctuations in Leaf Area Index (Mills et al. 2011), while removal through stomatal uptake is strongly affected by other oxidative stresses as drought, high temperature and irradiance which have a concurrent impact on plant stomatal conductance (Anselmi et al. 2004). Understanding how stomatal closure is modulated by summer constrains is a key prerequisite to correctly estimate the uptake of pollutants (Emberson et al. 2000): under water limited conditions, stomata close to avoid damages and consequently reduce the species potential for stomatal pollutants uptake. Thus, environmental factors as water availability and VPD, that influence the stomatal behavior, play a key role on the provisioning of this important ESs.

More studies will be necessary, mostly in urban and periurban areas, to develop management plans and policies able to guarantee a positive balance of multiple services provided by urban forests. The Castelporziano Presidential Estate is a very important peri-urban forest located at the southeastern edge of the large conurbation of Rome. Being a protected area since 1951, Castelporziano is an interesting natural laboratory, where researches on climatology, ecology, geology and atmospheric sciences are carried out by international research groups. The co-presence of a typical Mediterranean climate, high biodiversity levels (Manes et al. 1997a) and its proximity to urban pollution sources, make the estate a favored site to study biosphere–atmosphere interactions. Similarly to other Mediterranean areas, the functionality of the ecosystems in Castelporziano are jeopardized by increasing anthropogenic pressures as climate change, urbanization and an increase in atmospheric concentration of pollutants (Manes et al. 2006).

Two important field experimental campaigns were held in Castelporziano in the past 20 years focusing on the interaction between vegetation and atmosphere. The first campaign characterized the type and amount of Volatile Organic Compounds (VOCs) emitted from the vegetation in the Mediterranean area (Biogenic Emissions in the Mediterranean Area, BEMA, 1997) and ten years later the European Union Network of Excellence on Atmospheric Chemistry (ACCENT) and the European Science Foundation programme on VOCs in the Biosphere–Atmosphere Interactions (VOCBAS), organized a field campaign to integrate the past experience of BEMA with concurrent measurements of BVOC emissions, CO_2 and H_2O fluxes from a Mediterranean maquis during the transition from favorable climatic conditions and high water availability (i.e. spring) to periods in which vegetation functions are limited by summer drought. Durnig the ACCENT-VOCBAS campaigns, ecophysiological monitoring activities were carried out in the same experimental site on three evergreen species, co-occurring in the maquis ecosystem: *Arbutus unedo* L., *Quercus ilex* L., and *Phillyrea latifolia* L. The interdisciplinary effort of the ACCENT-VOCBAS campaign pointed out some important advancement in plant-atmosphere interactions under Mediterranean climatic conditions (Fares et al. 2009): (1) The maquis ecosystem acted as a net sink for ozone and its deposition rates on vegetation were quite high. (2) Stomatal ozone uptake was strongly influenced by water availability and its contribution to total ozone fluxes decreased throughout the measuring period as the season became dryer (Gerosa et al. 2009). (3) Nocturnal stomatal uptake should not be ignored in order to give a better quantification of O_3 stomatal fluxes (Mereu et al. 2009). In order to deepen our knowledge of the interaction between vegetation and atmosphere and to give a contribution for the development of management plans aimed at the maintenance and improvement of ESs provided by the periurban vegetation of Rome, we merged results and some new data collected in the past 20 years. The objective is to provide an overview of the role that Castelporziano Estate has in the provision of ESs, with particular attention to O_3 removal by the vegetation and on the potential impacts of oxidative stresses on the vegetation of the Castelporziano Estate. Additionally, preliminary results are presented over the potential of the vegetation to remove PM.

2 Applied methods

All the experimental activities were carried out inside the Castelporziano Estate (41°41′54.56″N, 12°21′9.50″E), in several experimental sites. In the site named "Castello", the main tree species are *Quercus ilex*, *Phyllirea latifolia*, *Arbutus unedo*, *Laurus nobilis* L., *Pinus pinea* L., *Quercus* *suber* L. The site "Grotta di Piastra", located at 13 m a.s.l and 1.5 km from the seashore of the Thyrrenian sea, is covered almost prevalently by an even-aged evergreen Holm oak forest. An area characterized by sand dunes, 4–7 m high a.s.l., with mixed garrigue-type and maquis-type vegetation, was also included among considered experimental sites. "Figurone" experimental site, is forest co-dominated by the deciduous oaks *Quercus cerris* L. and *Quercus frainetto* L.

2.1 Analysis of climatic indices

Daily minimum, maximum and mean values of air temperature (°C) and total precipitation (mm) collected by the Castelporziano meteorological station of "Castello", were used to calculate several climatic indices for 1996–2011 period. This time interval was chosen for comparison with results obtained after the BEMA campaign. The Bagnouls-Gaussen's diagrams were used to describe the monthly averages of air temperatures and precipitation, and the length and intensity of the drought period, identified by the intersection (grey area) of the precipitation curve with the average temperatures. Using minimum and maximum monthly temperatures and precipitation, Monthly Cold Stress (MCS) and the Monthly Drought Stress (MDS) indices were calculated for two different time periods (1983–1995 and 1996–2011) following Fares et al. (2009).

2.2 Assessment of the O_3 exposure of vegetation: active biomonitoring activities

During the years 2008, 2009 and 2010 following the UNECE ICP Vegetation protocols (UNECE, 2008–2010), a biomonitoring activity was carried out. The response of the newly introduced *Phaseolus vulgaris* L. biomonitoring system, based on the O_3-sensitive (S156) and O_3-torelant (R123) genotypes (Burkey et al. 2005), was tested under Mediterranean climatic conditions. At the same time the O_3 concentration was continuously monitored with a photometric O_3 detector (Model 205, 2B Technologies, Boulder, CO, USA) inside the Castelporziano Presidential Estate. The exposure of vegetation to O_3 was assessed with AOT40 index, defined as the sum of the hourly mean O_3 concentration exceeding the threshold of 40 ppb over the period 1 April–30 September, considering only the daylight hours (global radiation >50 W m^{-2}).

2.3 Assessment of gas exchanges between natural vegetation and the atmosphere

Daily courses of gas exchange at leaf level were performed during the summer in different years from year 2007 to 2012 using a CIRAS 2 (PP Systems, Hitchin, UK). The stored data were: net assimilation rates (Pn, µmolCO_2 m^{-2} s^{-1}); stomatal conductance to water vapor (gs, mmol m^{-2} s^{-1}), leaf transpiration rates (E, mmol m^{-2} s^{-1}). Substomatal to ambient CO_2 concentration ratio (Ci/Ca, adimensional) and the water use efficiency (WUE, Pn/E, µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}) were then calculated. For each species, the value of gs_{max} was estimated as the 95th percentile of all the valid stomatal conductance measurements (Gerosa et al. 2009). The sensivity of gs (gs_{sens}) to Vapour Pressure Difference (VPD, mbar) was derived from the angular coefficient of the linear relationship between gs and VPD. Using the equation derived from such linear part, we had also estimated the value of gs at different VPD (25 and 30 mbar).

2.4 Measurements of PM concentration above and below the canopy

In September 2012, PM concentration was measured in the location Torre Castello using a pre-existing fire tower to carry out simultaneous measurements of PM concentration below and above the canopy (about 5 and 35 meters of height). Concentrations of PM (2.5 and 10 µm fractions) were measured by two portable OPCs (Optical Particle Counters Analyzers mod. Aerocet 531, Metone - USA) for seven days and data were logged continuously every two minutes. In addition, meteorological parameters, air temperature/humidity and wind speed/direction were recorded simultaneously by a basic weather station (LaCrosse WS-2800). These measurements aimed at assessing the effects of vegetation on the distribution and concentration of this pollutant. Two days results are presented here, and change in PM concentration above (PM_{AB}) and below (PM_{BEL}) the canopy level, was calculated as.

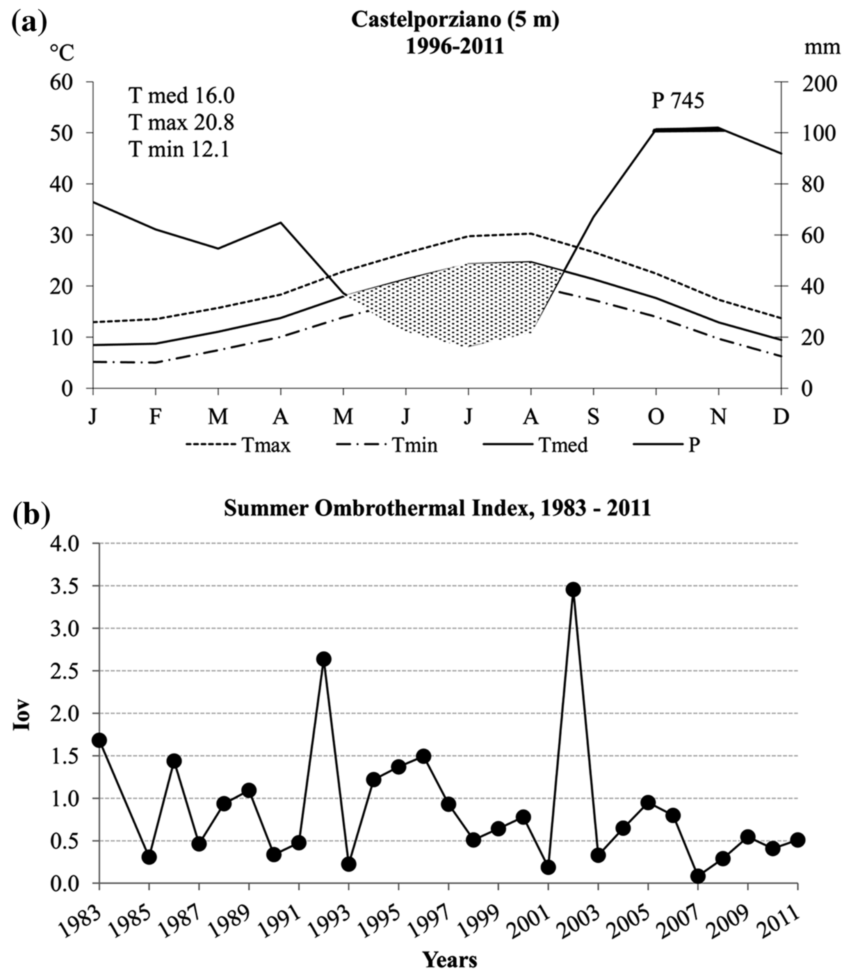
$$(PM_{AB} - PM_{BEL}) / \ PM_{AB}) \times 100 \qquad (1)$$

3 Results

3.1 Climatic conditions in the Castelporziano Estate

Bagnouls-Gaussen's diagram (Fig. 1a) for the period 1996–2011, showed that mean monthly temperatures of the site ranged between a minimum of 8.4 and a maximum of 24.7 °C. A maximal value of 30.3 °C reached in August and minimum of 5.0 °C in February without freezing events. Drought period started in May and ended in early September. Annual mean rainfall were 745 mm, rainfall events were concentrated in autumn, with low monthly rainfall in summer (<100 mm in the May–August period). Summer Ombrothermal Index (SOI) (Fig. 1b), showed a large interannual variability. Comparison of the Mitrakos' indices, MCS and MDS (Fig. 2a, b) for the periods

Fig. 1 Bagnouls-Gaussen's diagram **(a)** and Summer Ombrothermal Index **(b)**, for the periods 1996–2011 and 1983–2011, respectively, derived from the meteorological data collected by the "Castello" meteo station. Monthly temperatures (°C) are shown as mean (*T*mean, solid line), maximum (*T*max, dotted line) and minimum (*T*min, dashed pattern). The sum of monthly rainfall (*P*, mm) is also reported



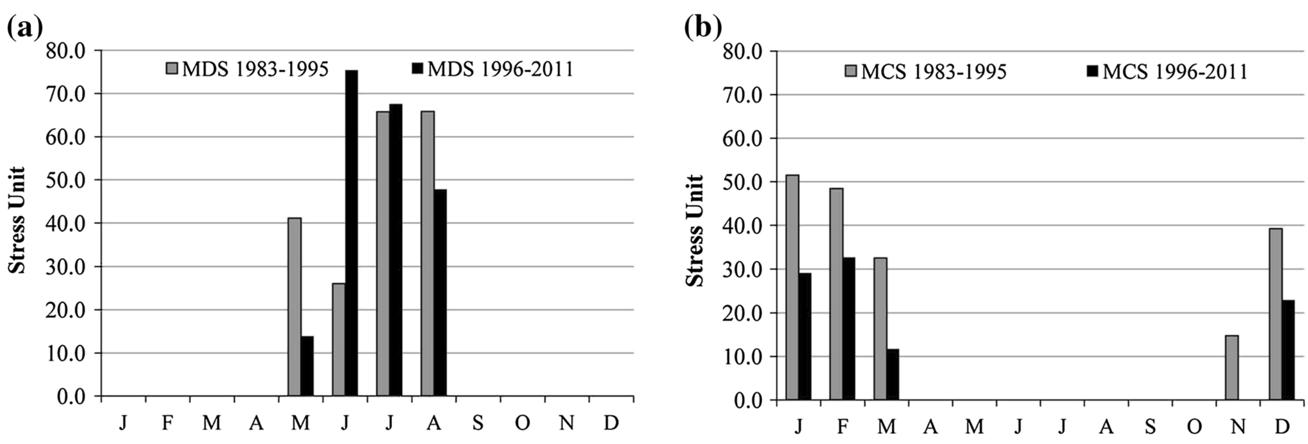


Fig. 2 Mitrakos diagrams (MCS, MDS) for the years 1983–1995 and 1996–2011 at Castelporziano Estate. The Mitrakos diagrams quantify monthly cold stress (MCS) and monthly drought stress (MDS) in stress units (0: no stress −100: highest stress level)

1983–1995 and 1996–2011, highlighted that significant changes over the two considered periods occurred: the MDS changed mostly in late spring, becoming higher in 1996–2011 interval, while MCS index varied largely among the two time period and in the 1996–2011 interval was lower than in 1983–1995.

3.2 Ozone exposure: from air concentration to stomatal fluxes perspective

Ambient ozone exposures expressed as AOT40 largely differ among the three considered years 2008, 2009, 2010 (Fig. 3a, d, g). In 2009 highest AOT40 was reached, when

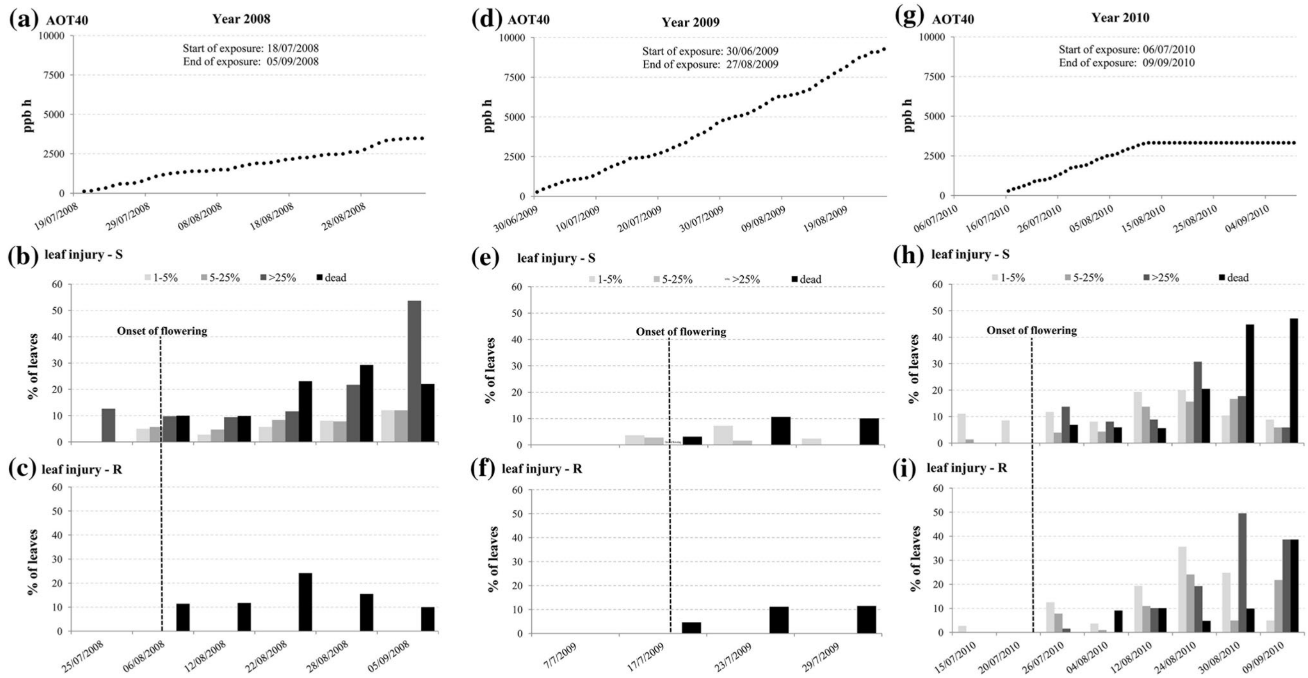


Fig. 3 AOT40 (ppb h) and leaf injury (% of injured leaves respect to the total number of leaves per plant) detected on the S and R bean genotypes during the years 2008 (**a**, **b**, **c**), 2009 (**d**, **e**, **f**) and 2010 (**g**, **h**, **i**). The date when 50 % or more plants had flowers (onset of flowering) is also indicated

Table 1 Summary of O_3 and temperature peaks during the study period of the years 2008, 2009 and 2010

	2008	2009	2010
(a) O_3 mean	Number of hours		
$O_3 > 60$ ppb	32	263	236
$O_3 > 80$ ppb	*	3	11
(b) *T*max	Number of days		
$T > 30$ °C	35	46	49

It is evident that the 2008 growing season was characterized by milder climatic conditions and fewer photochemical pollution episodes than the following years. (a) Number of daylight hours with O_3 mean concentrations higher than 60 and 80 ppb; (b) Number of days with maximum air temperatures higher than 30 °C

higher number of days with air temperature above 30 °C (Table 1) was detected. A difference in visible injury between the two beans lines was evident in 2008 (Fig. 3b, c), and the pod yield in the S clone was also affected (developed pod ratio S156/R123 = 0.86). During the year 2009 (Fig. 3e, f), instead, the extent of leaf injury and the production of developed pod (S156/R123 = 3.46) were not directly related to AOT40 (ICP Vegetation, 2010). In 2010, leaf injury was observed also in the R genotype (Fig. 3i), and production of developed pod was similar between genotypes (S156/R123 = 1.12). It is worth to notice that in 2010 plants have grown less than in the previous years: mean number of trifoliate leaves at flowering was 8.5 and 5.3 in the S and R genotypes, respectively, while at same phenological phase, plants had a mean of 47.8 (S) and 32.6 (R) leaves in 2009, and 42.1 (S) 28.5 (R) leaves in 2008.

3.3 Stomata response to vapor pressure difference (VPD)

The relations between VPD and stomatal conductance (gs) are reported in Fig. 4 for three co-existing evergreen maquis species (*Q. ilex*, *P. latifolia* and *A. unedo*) and one deciduous broadleaved, *Quercus cerris* L. Until 20 mbar (Fig. 4a) in *Q. ilex* (Qi) gs was almost around his maximum value (205.9 mmol m^2 s^{-1}). Respect to this maximum value, at 25 and 30 mbar gs decreases by about −40 and −76 % (Table 2). *P. latifolia* (Pl) has the highest gs_{max} compared to the other evergreen species (240.26 mmol m^2 s^{-1}) and the reduction of gs between this value and those measured at 25 and 30 mbar is −35 and −57 % (Fig. 4b). In *A. unedo* (Au) for the same VPD steps, the amount of gs reduction is −54 and −77 %, and also is interesting to notice that at 20 mbar the gs decreases of almost 20 % (Fig. 4c). Turkey oak had the highest gs compared to evergreen species (378 mmol m^2 s^{-1}) where gs sensitivity to VPD was similar to Au (Fig. 4d).

3.4 Interaction between vegetation and airborne particulate concentration

Measures of $PM_{2.5}$ and PM_{10} concentration were carried out above and below the canopy in a mixed Mediterranean

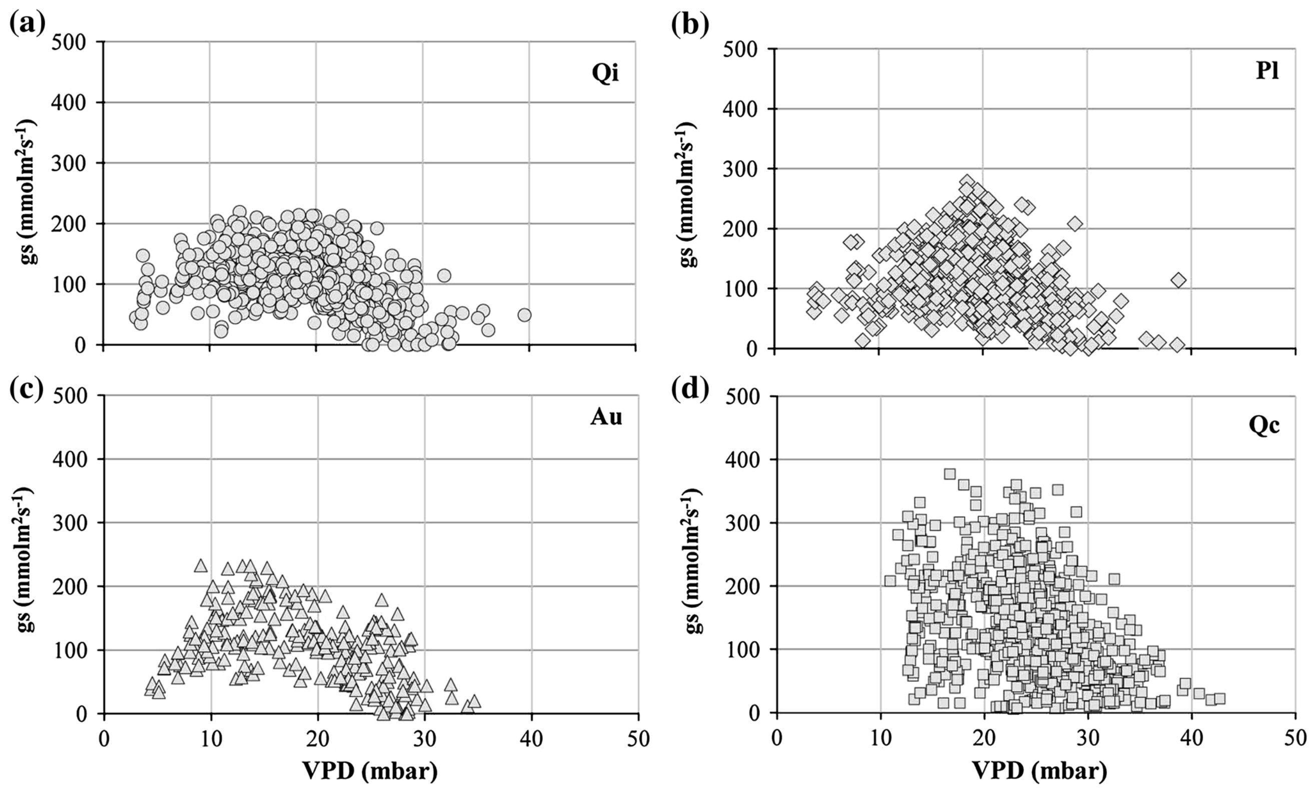


Fig. 4 Relationship between stomatal conductance (gs, mmol m^2 s^{-1}) and VPD (mbar) for the three studied species: Qi (*Q. ilex*), *Pl* (*P. latifolia*) and Au (*A. unedo*) and Qc (*Q. cerris*). The ecophysiological measurements were carried out between 2007 and 2012 in four different sites inside Castelporziano Estate

Table 2 Overview of different parameters: maximum value of stomatal conductance (gs_{max}), gs calculated for two different VPD values (gs_{25}, gs_{30}), and stomatal sensitivity to VPD changes (gs_{sens}) calculated for Qi (*Q. ilex*), Pl (*P. latifolia*), Au (*A. unedo*), and Qc (*Q. cerris*)

Parameters	*Q.ilex*	*P.latifolia*	*A.unedo*	*Q.cerris*
gs_{sens}	−0.071	−0.058	−0.051	−0.056
gs_{max}	205.9	240.26	230.4	378
gs_{25}	122.51	156.18	104.19	172.13
gs_{30}	49.21	102.54	52.09	114.89

forest pointed out that during the nighttime and the first hours of the morning there were different concentrations of PM below and above the canopy. During the day, concentrations of PM were similar or slightly different above and below the canopy with PM values around 2–3 μgm^{-3} for $PM_{2.5}$ and 8–10 μgm^{-3} for PM_{10} (Fig. 5a, b). Before dawn (between 5:00 am and 6:30 am) above the canopy, peaks of $PM_{2.5}$ (up to 30 μgm^{-3}) and PM_{10} (55 μgm^{-3}) concentration were observed. Instead below the canopy in the early morning (between 6:00 and 7:30), 30 min or 1 h late respect above canopy, peaks of $PM_{2.5}$ (up to 10 μgm^{-3}) and PM_{10} (20 μgm^{-3}) were measured. The percentage of average abatement, due to the green, ranged from about 25 % to over 75 % both for $PM_{2.5}$ and PM_{10} (Fig. 6a, b). Negative values of abatement are related to rapid changes in micro-meteorological conditions (in particular in wind direction and velocity) and to intermittent sources of PM existing within the park (as service vehicles, green maintenance activities).

4 Discussion

The results of the different experimental activities carried out in the Castelporziano test site suggest that this area is exposed to multiple stress factors, that are known to affect vegetation functionality and gas exchange with the atmosphere through their influence on stomatal conductance. Elaboration of meteorological data showed that the climate of the site is typically Mediterranean (Blasi 1994). Relative to the previously published climatic diagram Manes et al. (1997a, b, c) the temperature range and the mean annual precipitation remain almost constant among the two considered period (1983–1995 and 1996–2011). The large variability in the SOI, which is used to separate Mediterranean climates from temperate ones (without summertime

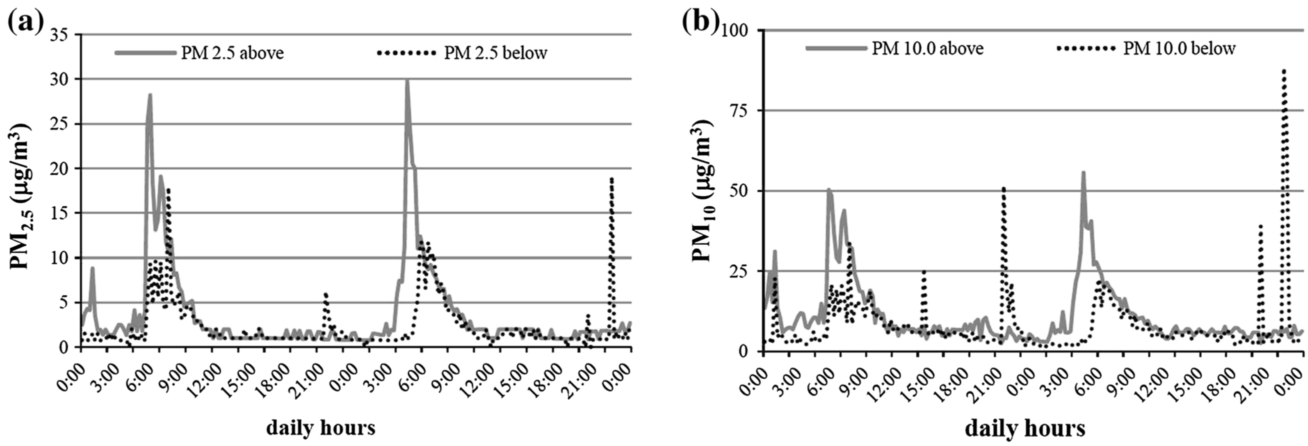


Fig. 5 Concentration of $PM_{2.5}$ **(a)** and PM_{10} **(b)** above and below the canopy in two selected days chosen as exemplificative trend of the experimental campaign (μgm^{-3})

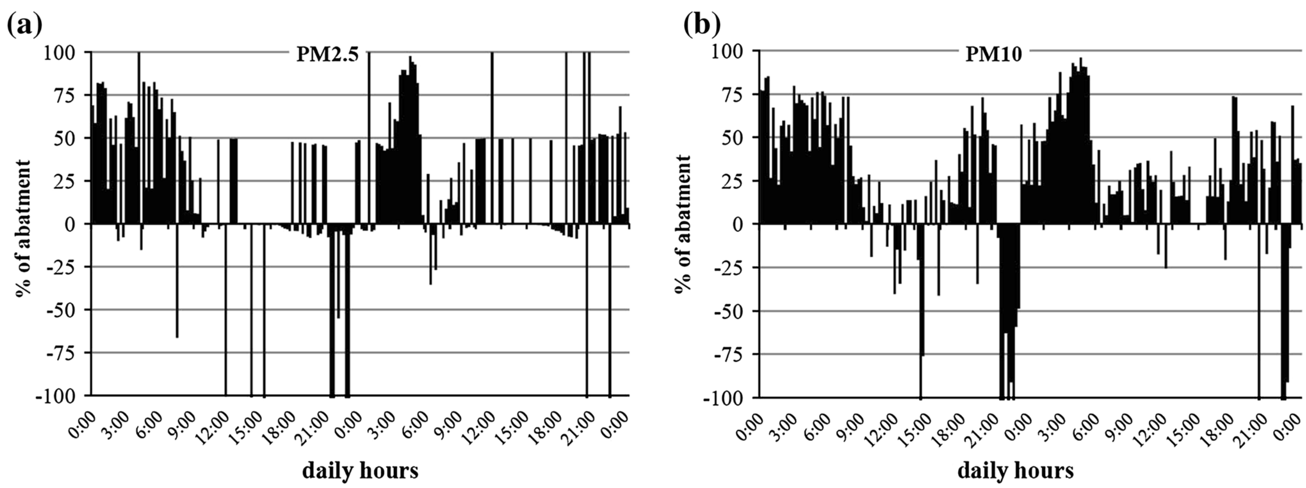


Fig. 6 Percentage difference between above and below the canopy for $PM_{2.5}$ **(a)** and PM_{10} **(b)** concentration

water deficit), highlights that the functional activity of vegetation and accordingly, its capacity to provide ESs, is subjected to large interannual variations. The provisioning of ESs can be predicted through the functional traits of species Díaz et al. (2013). Here, the difference in stomatal sensitivity to VPD highlights very well the different behaviour between co-existing evergreen maquis species, and between the latter and the deciduous oak *Q. cerris* (Qc, Turkey oak). Turkey oak has a different gs sensitivity to VPD, and also a different water use strategy compared to evergreen species. The maximum gs measured is 378 mmol m^2 s^{-1}, and the sensitivity of stomatal conductance to the increase in VPD is similar to that of *A. unedo*. It is interesting to highlight that the ranking of stomatal closure threshold in the considered species follows the sclerophylly degree order: *P.latifolia* > *Q.ilex* > *A. unedo* > *Q. cerris*. The high sclerophyll level is known to confer resistance to drought stress (Manes et al. 1997c; Anselmi et al. 2004); accordingly *P. latifolia* is capable to maintain high transpiration rates for a given value of VPD, compared to the other three species. The interspecific difference in the stomatal response to key environmental factor as VPD, could have a great influence on the potentials for O_3 removal, and it must be taken into account to evaluate the provision of regulating ESs at ecosystem level in the Mediterranean area. Indeed the seasonal trend of stomatal conductance at leaf or at canopy level is used to quantify O_3 removal by stomatal flux (Fares et al. 2010) but it should be reminded that vegetation spatial distribution, abundance and phenology are also important parameters affecting the magnitude and efficiency of O_3 removal (Manes et al. 2012). Furthermore, it has been shown that the magnitude and efficiency of O_3 removal from the vegetation differs greatly among tree functional groups (i.e. evergreen broadleaves, deciduous broadleaves and conifers) because of the large differences in physiological responses to environmental condition and stress responses. Manes et al. (2006) have shown that the responsiveness of stomata to environmental factors differed among the oaks species; therefore in order to have an accurate ozone risk assessment in a natural mixed forest context, structural and functional biodiversity should be considered. In Castelporziano Estate it is essential to account for the different vegetation types, since evergreen broadleaves, deciduous broadleaves, *Pinus pinea* L. plantations and maquis vegetation are all present (Manes et al. 1997b). As stomatal O_3 fluxes are know to have an effect on stomatal conductance itself, also the species specific sensibility to O_3 should be considered. At his regard, in the last ten years, biomonitoring activities has been trying to deal with dose–response function to achieve more accurate calculations of O_3 fluxes (Manes et al. 2003).

Despite chambers studies (Flowers et al. 2007) have found clear relationship between O_3 exposure, leaf injury, and yield of the S156 and R123 bean genotypes, the results of the three years pilot study here presented suggest that, under typical Mediterranean summer condition, their O_3 response is affected by environmental factors, as also reported by Elagöz and Manning (2005) and Salvatori et al. (2013). In particular, high air temperature seems to have acted as a confounding factor during the growing seasons 2009 and 2010. Further studies are therefore needed to better investigate the applicability of the snap bean biomonitornig system under the Mediterranean climatic condition. On the Mediterranean ecosystems, a big open issue concerns the suitability of the AOT40 and similar cumulative indexes in representing the O_3 uptake. The poor performance of this index (Fares et al. 2010) is due to the fact that O_3 uptake does not depend only on O_3 concentration. Several resistance components belonging to the deposition pathway of O_3 from the atmosphere to plant tissue and soil (Emberson et al. 2000; Massman 2004). VPD and soil water availability as driving force of the stomatal conductance behavior (Manes et al. 2007) and more in general seasonal environmental conditions, can influence the O_3 uptake by vegetation. In Mediterranean climatic condition, it is very important to consider that vegetation functionality strongly depends on the severity and length of the drought period, interannual variability in precipitations and stress which can occur in winter (Manes et al. 2003). The complexity of interaction between each of these factors makes the O_3 dose responses of plants very "noisy" as showed by Ball et al. 1998.

Vegetation has also a key role in PM removal. Our results showed a difference in PM concentration above and below the canopy. The percentage of change in PM concentration above and below the canopy, can be up to 75 %. Further the observed trend could be due to dynamic of air pollutants transport between city of Rome and Castelporziano Estate. Indeed the pollutant has been emitted during the day by the activities occurring in the Metropolitan area of Rome, then transported over Castelporziano Estate in the nighttime, by inversion of breeze currents from N-NE (Fares et al. 2009, 2014), and deposited over the vegetation when the Planetary Boundary Layer is closer to the ground (Seidel et al. 2010) and air turbulence is low, as it happens during nighttime.

5 General consideration and research perspective

Due to Mediterranean climatic condition and the proximity with the Metropolitan area of Rome, the vegetation inside the Castelporziano Estate is exposed to several stressors of both natural and anthropogenic origin as drought, or O_3 and PM. The capacity to provide ESs such as air pollution removal largely depends on the stomatal responsiveness to environmental factors. This key parameter largely differs among the investigated species, and we argue that the stomatal conductance sensitivity to VPD should be included in the list of functional traits commonly used to assess ESs. In conclusion we draw the attention on the pivotal role that the functional biodiversity in terms of vegetation growing in the Castelporziano Estate could have in improving the air quality of the neighbouring Metropolitan area of Rome, because the species-specific responses to environmental factors allow the stable provision of ESs over different seasonal environmental condition. The maintenance of ESs provided by vegetation is becoming an important issue for the future. The European Strategy toward 2020 aims to achieve the key objective "to halt the loss of biodiversity and the degradation of ES, and to restore them if possible". Combining monitoring activities with further field research could build a positive feedback between environmental policy and green management in large metropolitan areas. Monitoring the effects of abiotic stresses on vegetation functionality is fundamental to understand dynamic processes at individual and ecosystem level, to promote timely interventions and prevent loss of biodiversity and ESs provided by the vegetation.

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