

Supplementary materials

Ozone flux-based response functions for visible foliar injury and photosynthetic traits in a bioindicator species, *Viburnum lantana* L.

Elena Marra^{1,2}, Barbara Baesso Moura^{1,3*}, Elena Paoletti^{1,3}, Andrea Viviano¹, Jacopo Manzini^{1,4}, Ryoji Tanaka⁵, and Yasutomo Hoshika^{1,3}

1. *Institute of Research on Terrestrial Ecosystems (IRET), National Research Council of Italy (CNR), Via Madonna del Piano, I-50019 Sesto Fiorentino, Italy.*
2. *Department of Forest Bioeconomy and Technology (SLU), Swedish University of Agricultural Sciences, 907 36 Umeå, Sweden.*
3. *NBFC, National Biodiversity Future Center, Palermo 90133, Italy.*
4. *Department of Agricultural, Food, Environmental and Forestry Science and Technology (DAGRI), University of Florence, Piazzale delle Cascine, 18, 50144 Firenze, Italy.*
5. *Institute of Global Innovation Research, Tokyo University of Agriculture and Technology, Fuchu, Tokyo, 183-8509, Japan.*

*Corresponding author: Barbara Baesso Moura, E-mail: barbara.baessomoura@cnr.it

Method S1: Model functions of the stomatal conductance model

The response of stomatal conductance (g_s) to photosynthetic photon flux density (PPFD) is defined according to Hoshika et al. [49], as follows:

$$f_{light} = 1 - \exp(f_{light_a} \cdot PPFD) \quad (S1)$$

where f_{light_a} is a species-specific model parameter that determines the shape of the exponential relationship. The response of g_s to air temperature (T , °C), represented as f_{temp} , is characterized as follows:

$$f_{temp} = \left(\frac{T - T_{min}}{T_{opt} - T_{min}} \right) \left\{ \left(\frac{T_{max} - T}{T_{max} - T_{opt}} \right)^{\left(\frac{T_{max} - T_{opt}}{T_{opt} - T_{min}} \right)} \right\} \quad (S2)$$

where T_{min} , T_{opt} , and T_{max} represent the minimum, optimum, and maximum temperatures (°C) for g_s , respectively. The response of g_s to vapor pressure deficit (VPD, kPa), i.e., f_{VPD} , is expressed as follows:

$$f_{VPD} = \frac{(1 - f_{min}) \cdot (VPD_{min} - VPD)}{VPD_{min} - VPD_{max}} + f_{min} \quad (S3)$$

where VPD_{max} and VPD_{min} denote the thresholds of VPD for achieving full and minimum stomatal opening, respectively. If VPD exceeds VPD_{min} , f_{VPD} is set to f_{min} , whereas if VPD is below VPD_{max} , f_{VPD} is 1.

Table S1. Regression models evaluating the relation between Plant Injury Index (PII) and the physiological parameters (light-saturated net photosynthetic rate [A_{sat}], stomatal conductance [g_s], SPAD and maximum photochemical efficiency of PSII [F_v/F_m]) and the with two ozone exposure metrics: Phytotoxic Ozone Dose above a threshold of 1 nmol m⁻² s⁻¹ (POD₁) and Accumulated Ozone Exposure Over a Threshold of 40 ppb (AOT40). The table reports Residual Sum of Squares (RSS), coefficients of determination (R²), Akaike Information Criterion (AIC), p -values for each model. ‘***’ $p \leq 0.001$, ‘**’ $p \leq 0.01$, ‘*’ $p \leq 0.05$, ‘-’ > not significant, and critical levels (CLs) for PII, calculated considering the injury onset (PII = 0.1), and for the photosynthetic parameters derived as 4% reduction from the baseline value. Best models are highlighted in bold.

Variable	O ₃ index	Regression Type	Equation	RSS	R ²	AIC	p -value	CLs
PII	AOT40	Linear	$y = 0.12283x$	14.803	0.84	7.42	**	0.81
		Polynomial	$y = 0.01134x + 0.00255x^2$	7.108	0.92	3.02	**	4.42
	POD ₁	Linear	$y = 0.18463x$	24.128	0.74	10.35	*	0.54
		Polynomial	$y = -0.07532x + 0.01126x^2$	11.015	0.88	5.64	*	7.82
A_{sat}	AOT40	Linear	$y = 1 - 0.0154x$	0.203	0.86	-18.31	**	3.9
		Polynomial	$y = 1 - 0.02706x + 2.66288E^{-4}x^2$	0.119	0.92	-21.51	**	2.27
	POD₁	Linear	$y = 1 - 0.02576x$	0.086	0.94	-23.44	***	2.33
		Polynomial	$y = 1 - 0.03801x + 5.30245E^{-4}x^2$	0.057	0.96	-25.90	**	1.61
g_s	AOT40	Linear	$y = 1 - 0.01312x$	0.449	0.67	-13.56	*	4.57
		Polynomial	$y = 1 - 0.0311x + 4.10477E^{-4}x^2$	0.249	0.82	-17.10	*	1.31
	POD₁	Linear	$y = 1 - 0.02311x$	0.257	0.81	-16.89	**	2.60
		Polynomial	$y = 1 - 0.05072x + 0.0012x^2$	0.110	0.92	-22.02	**	1.22
F_v/F_m	AOT40	Linear	$y = 1 - 0.00109x$	0.017	0.27	-33.25	-	-
		Polynomial	$y = 1 - 0.00362x + 5.78085E^{-5}x^2$	0.013	0.44	-34.86	-	-
	POD ₁	Linear	$y = 1 - 0.00189x$	0.016	0.32	-33.64	-	-
		Polynomial	$y = 1 - 0.00618x + 1.85681E^{-4}x^2$	0.012	0.47	-35.17	-	-
SPAD	AOT40	Linear	$y = 1 + 0.00243x$	0.086	0.26	-23.44	-	-
		Polynomial	$y = 1 + 0.00281x - 8.56E^{-6}x^2$	0.086	0.27	-23.45	-	-
	POD ₁	Linear	$y = 1 + 0.00426x$	0.080	0.32	-23.89	-	-
		Polynomial	$y = 1 + 0.00499x - 3.16749E^{-5}x^2$	0.080	0.32	-23.90	-	-

Table S2. Sensitivity analysis of POD_1 at the FO_3X when AOT40 reached 12 ppm h following the field-observed critical level suggested by Gottardini et al. (2010), applying several stomatal closing scenarios due to additional environmental stress, such as drought.

Scenarios	POD_1 (mmol m^{-2}) when AOT40 reached 12 ppm h		
	AA	1.5×	2.0×
0% stomatal closure	15.2	10.7	8.6
10% stomatal closure	13.5	9.5	7.7
20% stomatal closure	11.7	8.4	6.8
30% stomatal closure	9.9	7.2	5.9
40% stomatal closure	8.1	6.6	5.0
50% stomatal closure	6.3	4.8	4.1