Increased aridity drives post-fire recovery of Mediterranean forests towards open shrublands

Mara Baudena[1,2], Victor M. Santana[3,4,5], M. Jaime Baeza[5,6], Susana Bautista[6], Maarten B. Eppinga[7], Lia Hemerik[8], Angeles Garcia Mayor[9], Francisco Rodriguez[10], Alejandro Valdecantos[6], V. Ramon Vallejo[3,5], Ana Vasques[4,11] and Max Rietkerk[12]

[1]Institute of Atmospheric Sciences and Climate, National Research Council, Turin 10133, Italy; [2]National Biodiversity Future Center, Palermo 90133, Italy; [3]Department of Evolutionary Biology, Ecology and Environmental Sciences, University of Barcelona, Ave Diagonal 643, 08028 Barcelona, Spain; [4]Department of Environment and Planning, Centre for Environmental and Marine Studies, University of Aveiro, 3810-193 Aveiro, Portugal; [5]CEAM Foundation (Mediterranean Center for Environmental Studies) Parque Tecnológico, C/ Charles Darwin 14, 46980 Paterna, Valencia, Spain; [6]Department of Ecology and IMEM, University of Alicante, Apdo. 99, 03080 Alicante, Spain; [7]Department of Geography, University of Zurich, 8057 Zurich, Switzerland; [8]Biometris, Mathematical and Statistical Methods, Wageningen University and Research, PO Box 16, 6700AA Wageningen, the Netherlands; [9]Department of Biodiversity, Ecology, and Evolution, Faculty of Biological Sciences, Complutense University of Madrid, Madrid, Spain; [10]Department of Applied Mathematics and IMEM, University of Alicante, Apdo. 99, 03080 Alicante, Spain; [11]Erasmus University College, Nieuwemarkt 1A, 3011 HP Rotterdam, the Netherlands; [12]Copernicus Institute of Sustainable Development, Utrecht University, PO Box 80115, 3508 TC Utrecht, the Netherlands

Corrigendum to *New Phytologist* **225** (2020), 1500–1515, doi: 10.1111/nph.16252.

Since its publication, the authors of Baudena *et al.* (2020) have identified an error for the set of parameter values representing flammability in Table 2. In this correction, the authors would also like to report that, when using the flammability values as originally published in Baudena *et al.* (2020; i.e. a factor 2 larger than those actually used in the simulations), the main results do not change qualitatively (see Supporting Information Figs S1, S2 to this correction).

Namely, when increased aridity was simulated as negatively affecting oak post-fire recovery and colonization rate, while positively affecting the community flammability, the authors observed that the forest state was resilient to the separate impact of fires and increased aridity. Yet, water stress could convert forests into open shrublands by hampering post-fire recovery and at the same time either increasing flammability or decreasing the oak forest colonization rate (or both). A tipping point (emerging from bistability of the open shrubland and forest state) was detected at intermediate levels of aridity (Fig. S1). In the 'short-term' run, that is a century, the authors observed again that the probability of a mixed successional community becoming an oak forest after 100 yr decreased drastically with increasing aridity (moving from bottom left to top right in Fig. S2, e.g. with flammability equal to 1.5 times the baseline value as published in table 2 in Baudena *et al.*, 2020). The main differences between the two parameter sets were that the effects of aridity were more dramatic in Figs S1 and S2, as their baseline flammability (given in table 2 in Baudena *et al.*, 2020) was twice as high as the baseline flammability that we actually used in figs 3 and 4 in Baudena *et al.* (2020) (as reported here in Table 2).

We apologize to our readers for this mistake.

Acknowledgements

The authors would like to kindly acknowledge Matilde Torrassa for finding the error in the original version of the paper.

ORCID

M. Jaime Baeza https://orcid.org/0000-0002-9739-0062
Mara Baudena https://orcid.org/0000-0002-6873-6466
Susana Bautista https://orcid.org/0000-0001-7175-7076
Maarten B. Eppinga https://orcid.org/0000-0002-1954-6324
Angeles Garcia Mayor https://orcid.org/0000-0001-8097-5315
Lia Hemerik https://orcid.org/0000-0002-6892-2840
Max Rietkerk https://orcid.org/0000-0002-2698-3848
Francisco Rodriguez https://orcid.org/0000-0002-0753-7826
Victor M. Santana https://orcid.org/0000-0002-6121-1747
Alejandro Valdecantos https://orcid.org/0000-0002-3761-3500
V. Ramon Vallejo https://orcid.org/0000-0002-6559-9451
Ana Vasques https://orcid.org/0000-0002-8697-8100

References

Baeza MJ, Raventos J, Escarre A, Vallejo VR. 2006. Fire risk and vegetation structural dynamics in Mediterranean shrubland. *Plant Ecology* 187: 189–201.

Baudena M, Santana VM, Baeza MJ, Bautista S, Eppinga MB, Hemerik L, Garcia Mayer A, Rodriguez F, Valdecantos A, Vallejo VR *et al.* 2020. Increased aridity drives post-fire recovery of Mediterranean forests towards open shrublands. *New Phytologist* 225: 1500–1515.

Caturla RN. 2002. *Efecte del foc i la recurrència d'incendis en camps abandonats dominats per Brachypodium retusum (Pers.) Beauv. a la Comunitat Valenciana.* PhD thesis, University of Alicante, Alicante, Spain.

Daskalakou EN, Thanos CA. 1996. Aleppo pine (*Pinus halepensis*) postfire regeneration: the role of canopy and soil seed banks. *International Journal of Wildland Fire* 6: 59–66.

Lloret F, Pausas JG, Vilà M. 2003. Responses of Mediterranean plant species to different fire frequencies in Garraf Natural Park (Catalonia, Spain): field observations and modelling predictions. *Plant Ecology* **167**: 223–235.

Martínez-Sánchez JJ, Ferrandis P, de la Sheras J, Herranz JM. 1999. Effect of burnt wood removal on the natural regeneration of *Pinus halepensis* after fire in a pine forest in Tus valley (SE Spain). *Forest Ecology and Management* **123**: 1–10.

Moya-Delgado S. 2017. *Dinámica temporal del esfuerzo reproductivo post-fuego de tres especies germinadoras obligadas.* Masters thesis, University of Alicante, Alicante, Spain.

Panaïotis C, Carcaillet C, M'Hamedi M. 1997. Determination of the natural mortality age of an holm oak (*Quercus ilex* L.) stand in Corsica (Mediterranean Island). *Acta Oecologica* **18**: 519–530.

Pausas JG. 1999b. Mediterranean vegetation dynamics: modelling problems and functional types. *Plant Ecology* **140**: 27–39.

Pausas JG, Ouadah N, Ferran A, Gimeno T, Vallejo R. 2003. Fire severity and seedling establishment in *Pinus halepensis* woodlands, eastern Iberian Peninsula. *Plant Ecology* **169**: 205–213.

Raevel V, Violle C, Munoz F. 2012. Mechanisms of ecological succession: insights from plant functional strategies. *Oikos* **121**: 1761–1770.

Roy J, Sonie L. 1992. Germination and population dynamics of *Cistus* species in relation to fire. *Journal of Applied Ecology* **29**: 647–655.

Santana VM, Alday JG, Baeza MJ. 2014. Effects of fire regime shift in Mediterranean Basin ecosystems: changes in soil seed bank composition among functional types. *Plant Ecology* **215**: 555–566.

Santana VM, Baeza MJ, Maestre FT. 2012. Seedling establishment along post-fire succession in Mediterranean shrublands dominated by obligate seeders. *Acta Oecologica* **39**: 51–60.

Key words: alternative stable states, climate change, forest fires, increased aridity, Mediterranean shrubland, resprouters, seeders, stochastic dynamical model.

Author for correspondence:
Mara Baudena
Email: m.baudena@isac.cnr.it

Supporting Information

Additional Supporting Information may be found online in the Supporting Information section at the end of the article.

Fig. S1 Plant composition under the 48 aridity scenarios in the long-term experiments.

Fig. S2 Probability distribution of the oak cover and the shrubs + grass cover in the short term runs.

Please note: Wiley is not responsible for the content or functionality of any Supporting Information supplied by the authors. Any queries (other than missing material) should be directed to the *New Phytologist* Central Office.

Corrected Table 2

Table 2 List of symbols, names, values, units and their source for the parameters and functions used in Eqn 1.

		Values in use for							
Symbol	Interpretation	Q ($i=1$)	P ($i=2$)	R ($i=3$)	U ($i=4$)	C ($i=5$)	B ($i=6$)	Units	Sources[†]
c_i	Colonization rate	0.047	0.053	0.045	0.067	0.11	0.22	yr^{-1}	a
m_i	Mortality rate = *1/average life time*	1/400	1/125	1/50	1/25	1/15	1/40	yr^{-1}	b
r_i	Fraction of space maintained after fire	0.9	0	0	0	0	0.4	–	c
l_i	Flammability (i.e. the inverse of fire average return times if entire plot is covered by one plant type)	**1/800**	**1/40**	**1/30**	**1/20**	**1/20**	**1/20**	yr^{-1}	d
α_i	Colonization of seeders after fires	0	See Eqn 2				0	yr^{-1}	–
γ_i	Post-fire seed germination and seedling establishment	–	0.040	0.0016	0.0029	0.00078	–	–	e
S_i	Seed production and storage in the seed bank	–	See Notes S1				–	–	–
C	Conversion parameter	–	0.014				–	yr^{-1}	f

B, *B. retusum*; C, *Cistus* spp.; P, *P. halepensis*; Q, *Quercus* spp.; R, *R. officinalis*; U, *U. parviflorus*. (It includes the correct values for the flammability parameters (in bold) used in Baudena *et al*., 2020.)

[†]Sources: [a]Optimization of the parameters with the successional data (c_{1-5}) and with fire data (c_6). [b]Roy & Sonie (1992), Panaïotis *et al*. (1997), Pausas (1999b), Caturla (2002), Lloret *et al*. (2003), Baeza *et al*. (2006), Raevel *et al*. (2012), Moya-Delgado (2017). [c]r_1, expert estimation; r_6, optimized from fire site data. [d]Expert estimation. [e]Daskalakou & Thanos (1996), Martínez-Sánchez *et al*. (1999), Pausas *et al*. (2003), Santana *et al*. (2012, 2014). [f]Calibration with fire data.