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Fire hazard and plant invasions – the cases of *Hakea sericea* and *Acacia dealbata* in Portugal

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Introduction

Alien invasive plants are a major environmental concern in Portugal. These species originate direct (e.g. production loss) and indirect costs (e.g. ecosystem degradation) and, unlike other degradation processes (e.g. forest fires, soil erosion), their effects are in many cases nearly irreversible (Moreira et al. 2010). In Portugal, *Acacia dealbata* Link. and *Hakea sericea* Schrader are expanding as a result of the current fire regime (Marchante et al. 2014). Fire acts directly on the soil seed bank of *A. dealbata*, stimulating germination and resprouting (Lorenzo et al. 2010) and there is also evidence of a strong relationship between *H. sericea* and fire. This serotinous obligate seeder spreads wind-dispersed seeds through fire-triggered dehiscence (Esler et al. 2009), leading to new invasion foci.

Although it has been largely recognized that alien plant species can alter the fire regime in the regions where they become invasive (Brooks et al. 2004), there is a scarcity of scientific information on the fuel characteristics of these novel ecosystems. The initial hypothesis that the invasion by alien plant species is directly associated to an increase in fire hazard, does not necessarily hold true, but very few works were produced with this specific purpose. One of the works was developed by Van Wilgen and Richardson (1985) for *H. sericea* and *Acacia saligna in* South Africa. These authors concluded that fire in the native *fynbos* could be more intense than in areas invaded by the alien species. The present work presents preliminary results of fuel characterization and fire behavior in areas invaded by *H. sericea* and *A. dealbata*. These results were obtained in the frame of the ongoing project *Aliens & Flames*, aimed at studying the two-way relationships between fire and invasive alien plants.

Methods

The two studied alien species have been rapidly expanding over large areas of Central and Northern Portugal. *Acacia dealbata* is a tree up to 15 meters native to Southeast Australia and Tasmania. Seeds (4-5×2.5 mm in size) are numerous, hard-coated and dormant, and form extensive soil seed banks that can remain viable for decades. Although seeds and pods are not specifically adapted to wind dispersal, they may be transported by water and soil tillage. *Hakea sericea* is a shrub or tree up to 4 m, with irregular canopy. The fruits are woody follicles (around 30 mm in diameter), dark brown with a patent crest and beak, having two black winged seeds. Dehiscence occurs after tissue necrosis, allowing seeds dehiscence (Marchante et al. 2008).

In order to characterize the fuel complex of plant communities dominated by each of the two alien species, fuel samples were collected at nine different sampling sites (n=9) for each species, reasonably representative of intermediate-mature developmental stages. Sampling sites were all dominated by one of the two target species and were all located in Central Portugal in the region of Coimbra. In some cases stands were monospecific, with few native plant species contributing to the fuel complex. *Hakea sericea* stands were in general thick shrublands ranging between 1.5 to 4.5 m height, whereas *A. dealbata* stands had in general a clear separation between the canopy and the surface fuels layers, with trees up to 10 m height. In some sites we collected two fuel samples, so overall there were 14 fuel samples for each species. Fuel sampling followed standard methodology using 0.5x0.5m plots to collect dead material from the litter, duff and canopy layers, which was afterwards processed in the lab according to each fuel category (three time-lag classes, live herbaceous and live woody fuels) following the procedures of Deeming and Brown (1975). Dry weight was estimated after exposing the samples to 84ºC for 45 hours. Weight of 100 h downed dead material was estimated using the line intersect method (Van Wagner 1982). To estimate the dry weight of standing *H. sericea* individuals, we measured the diameters of four randomly chosen individuals and used the allometric relationships provided by Van Wilgen and Richardson (1985). In the case of *A. dealbata* stands, we considered litter and downed dead material but not the canopy biomass of the trees. In order to simulate fire behavior using the Rothermel model (Rothermel 1972) we adopted the values of surface-to-volume ratio, heat content and moisture of extinction presented by Van Wilgen and Richardson (1985) for *H. sericea* and by Fernandes (2009) for *A. dealbata*. Fire simulations were performed using the D1L1 moisture scenario (3, 4, 5, 30 and 60%

moisture for, 1h, 10h, 100h, live woody and live herbaceous fuels, respectively) established by Scott and Burgan (2005), with wind speed = 5km/h and slope = 0%. Fuel characteristics and simulated flame length were compared with equivalent fuel complexes developed for Portugal by Fernandes et al. (2009) using one-sample t-tests. Fire simulations were performed using BehavePlus 5.0.5 software (Andrews 2014).

Results

The two species presented remarkably distinct fuel characteristics. The *H. sericea* stands had a high fuel load particularly 1-h fuels and live woody fuels compared to the fuel model developed to characterize tall Atlantic shrublands (species with high proportion of dead foliage), developed for Portugal by Fernandes et al. (2009), (Table 1). The fuel complexes associated to *A. dealbata* stands showed complete absence of shrubs and herbaceous layer. The litter (L+F) layer is particularly compacted, with nearly 8 t ha^{-1}, concentrated in only 2 cm of fuel depth. This is strongly related to the very fine twice-compound leaves of *A. dealbata* that accumulate on the forest floor. This compact layer has the double effect of presenting very low porosity and therefore poor characteristics to propagate fire, but also it represents a barrier to plant propagules, which strongly reduces the chances of establishment of other plants.

Table 1 - Average (±SE) fuel characteristics and simulated flame length (moisture scenario D1L1, wind speed = 5km/h, slope = 0%) for *H. sericea* and *A. dealbata* stands (n=9), compared to reference fuel models of native plant communities in Portugal. Fuel loads are in ton/ha. Fuel depth and flame length are in meters. Significance of one-sample t-tests is indicated by an asterisk.

	A. dealbata	Broadleaf forest	*H. sericea*	Tall shrubland
1-h load	7.59±1.25*	2.67	17.85±5.15	9.50
10-h load	2.10±0.53	1.27	0.04±0.04*	2.50
100-h load	0.00	0.69	0.00	0.00
Live woody load	0.00	1.16	27.32±7.43	14.50
Herbaceous load	0.00	0.00	0.00	0.00
Fuel depth	0.02±0.00*	0.15	1.69±0.33	1.05
Flame length	0.00	1.20	6.22±1.64	5.90

The results obtained with the fire simulations were consistent with the fuel characteristics. The fuel complex dominated by *H. sericea* presented the highest flammability followed by the shrubland model, whereas the broadleaf model showed the lowest flammability (Fig. 1) and there was no fire propagation in the *A. dealbata* stand.

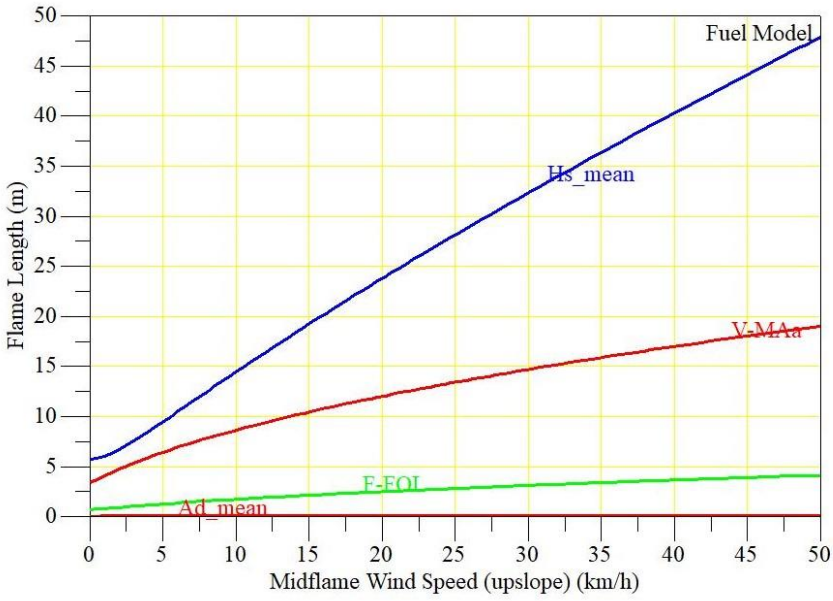

Fig. 1 – Results of fire behavior (Flame length) simulated with BehavePlus 5.0.5 for the average *H. sericea* fuel model (Hs_mean), the tall shrubland fuel model (V-MAa), the broadleaves fuel model (F-FOL) and the average *A. dealbata* fuel model (Ad_mean). Simulations were performed using the D1L1 moisture scenario (very low dead-fuel moisture) and a 30% slope (wind running upslope).

Discussion

These preliminary results suggest that generalizations about the higher fire hazard of plant communities in areas invaded by alien woody species may not necessary hold true. While areas invaded by *H. sericea* seem to present high fire hazard, because of the high fuel loads of 1 h fuels and the vertical continuity of these plant formations, plant communities dominated by *A. dealbata* may on the contrary represent low fire hazard in mature stands, mostly because of the absence of shrubs in the understorey and the strongly compacted litter fuel bed. Preliminary field experiments (not part of this study) in plots dominated by each of the two species, were consistent with the fuel data. While in *H. sericea* plots flame lengths have reached 3 m, there was strong difficulty in burning the litter floor of *A. dealbata* stands, for similar environmental conditions. Nonetheless, the absence of fire propagation using Rothermel-based fire simulations may reflect some of the shortcomings of this system, which is known to be very sensitive to fuel depth and to the porosity of the fuel bed. Our results for *H. sericea* are apparently contradictory to those of Van Wilgen and Richardson (1985) who obtained a higher fire hazard in native shrublands of South Africa.

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Presenter's bio:

Joaquim S. Silva holds a BSc. and a PhD in Forestry, both awarded by the University of Lisbon. He works at the College of Agriculture of the Polytechnic Institute of Coimbra in Portugal, currently teaching several subjects on fire ecology and fire management. His main research interests are within the domains of fire ecology and invasion ecology. He leads the Forest Ecology Group at the Centre for Functional Ecology, at the University of Coimbra. He is/was the leader of four research projects, two of which are still ongoing. He has authored 28 research papers in journals indexed in the Web of Science, mainly in the fields of invasion ecology and fire ecology. He has also authored more than one hundred non-indexed publications, including conference papers, book chapters and technical reports. He was editor of six books and the book series Árvores e Florestas de Portugal (Trees and Forests of Portugal). He has integrated the two Commissions nominated by the Portuguese Parliament that investigated the catastrophic 2017 fires in Portugal and currently is a member of the Observatório Técnico Independente that assists the Portuguese Parliament in the matter of forest fires.