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 alien plant species can increase fire hazard does not necessarily hold true, but very few works have been developed 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 two 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 study 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 are not 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 (3 cm), dark brown with a patent crest and beak, having two black winged seeds. Dehiscence occurs after tissue necrosis, allowing the release of the seeds (Marchante et al. 2008).

In order to characterize the fuel complex of plant communities dominated by each of the two target alien species, fuel samples were collected at nine different sampling sites for each species, reasonably representative of medium-mature development 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 most cases stands were monospecific, with no 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 by exposing the samples to 84°C 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 aerial 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 moisture scenarios established by Scott and Burgan (2005), with wind running upslope. Fuel characteristics and fire simulations were compared with other fuel complexes developed for Portugal by Fernandes et al. (2009). Fire simulations were performed using BehavePlus 5.0.5 software (Andrews 2014). The comparison of fuel characteristics and fire behavior was performed by averaging the fuel parameters of *H. sericea* fuel models and *A. dealbata* fuel models.

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 shrublands with high percentage 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 a 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 fuel characteristics for *H. sericea* and *A. dealbata* stands (n=14), compared to similar fuel models of native plant communities in Portugal. Fuel loads are in ton/ha. Fuel depth is in meters.

	A. dealbata	Broadleaf forest	*H. sericea*	Tall shrubs
1-h load	7.92	2.67	19.18	9.50
10-h load	1.86	1.27	0.05	2.50
100-h load	0.00	0.69	0.00	0.00
Live woody load	0.00	1.16	24.97	14.50
Herbaceous load	0.00	0.00	0.00	0.00
Fuel depth	0.02	0.15	1.61	1.05

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). The results obtained for the *A. dealbata* stand were not conclusive since there was no fire propagation.

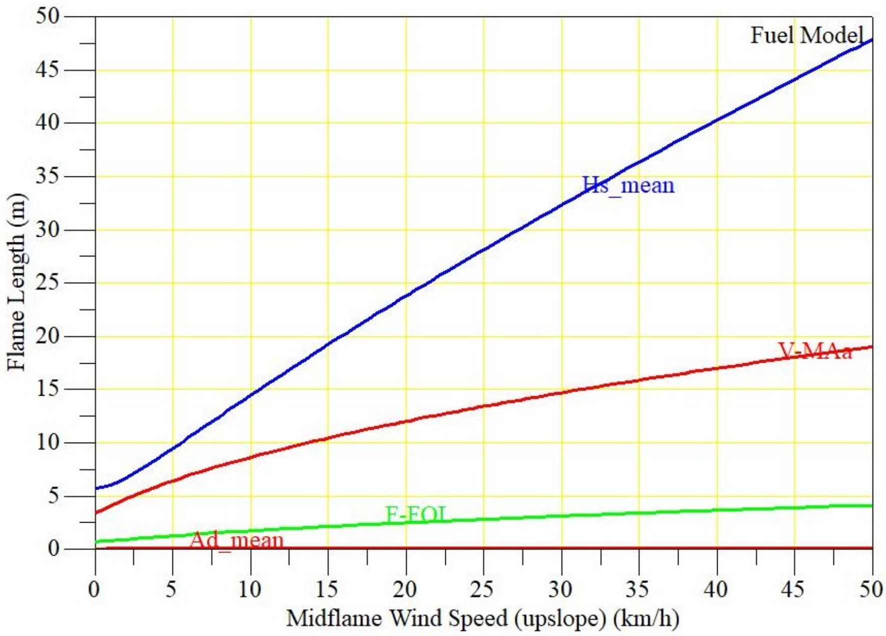

Fig. 1 – Results of fire behavior (Flame Length) simulated with BehavePlus 5.0.5 for the average *H. sericea* fuel model (Hs_mean), the tall shrubs fuel model (V-MAa), the broadleaves fuel model (F-FOL) and the average *A. dealbata* fuel model (Ad_mean). Simulations were performed using the D1L1 moisture 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 resulting from invasion 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 developed 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 an *A. dealbata* plot, 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, which directly determines the porosity of the fuel bed. On the other hand, the adopted sampling design may also have influenced our results, for not being representative of most plant communities dominated by these two invasive species.

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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 a research Group on Forest Ecology in 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 27 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.