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Technical Note TN 2.6.
Forensic study of a burnt hedgerow of *Cupressus arizonica* in Las Rozas (Madrid)

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Abstract	This Technical Note gathers the data obtained from a forensic study of a hedge burnt in Las Rozas municipality (Madrid). The comparison between the remaining fuels after the fire and a fuel sampling of the unburnt sections of the hedge shows the consumed fuel that contributed to the fire spread. The effects of the fire spread over the house have been also cataloged.

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1. Introduction

On July 3, 2020, a hedgerow of *Cupressus arizonica* ignited in Las Rozas municipality (Madrid), causing a fire spread that affected several plots in the wildland urban-interface of Las Matas neighbourhood. The incident was broadcast online and images and videos are available via twitter. On July 20, after getting in touch with the residents of one of the affected plots, a team composed by members of UPC and PCF went to San José del Pedrosillo street 38, to perform a forensic study of the fuel and the fire effects over the house and its surroundings (Figure 1).

The objectives of this activity were 1) to characterize the hedgerow as a fuel, gathering quantitative information of its moisture contents, loads and bulk densities, 2) to identify the portion of the hedgerow that contributed to the release of energy and 3) to analyse the effects of the fire on the building. Furthermore, data from previous fuel samplings carried out in the framework of the WUIVIEW project (Deliverable 2.1; Technical Note 2.2; Technical Note 2.3) allow comparing the fuel distribution along different shapes and ages of hedges of the *Cupressus* genus.

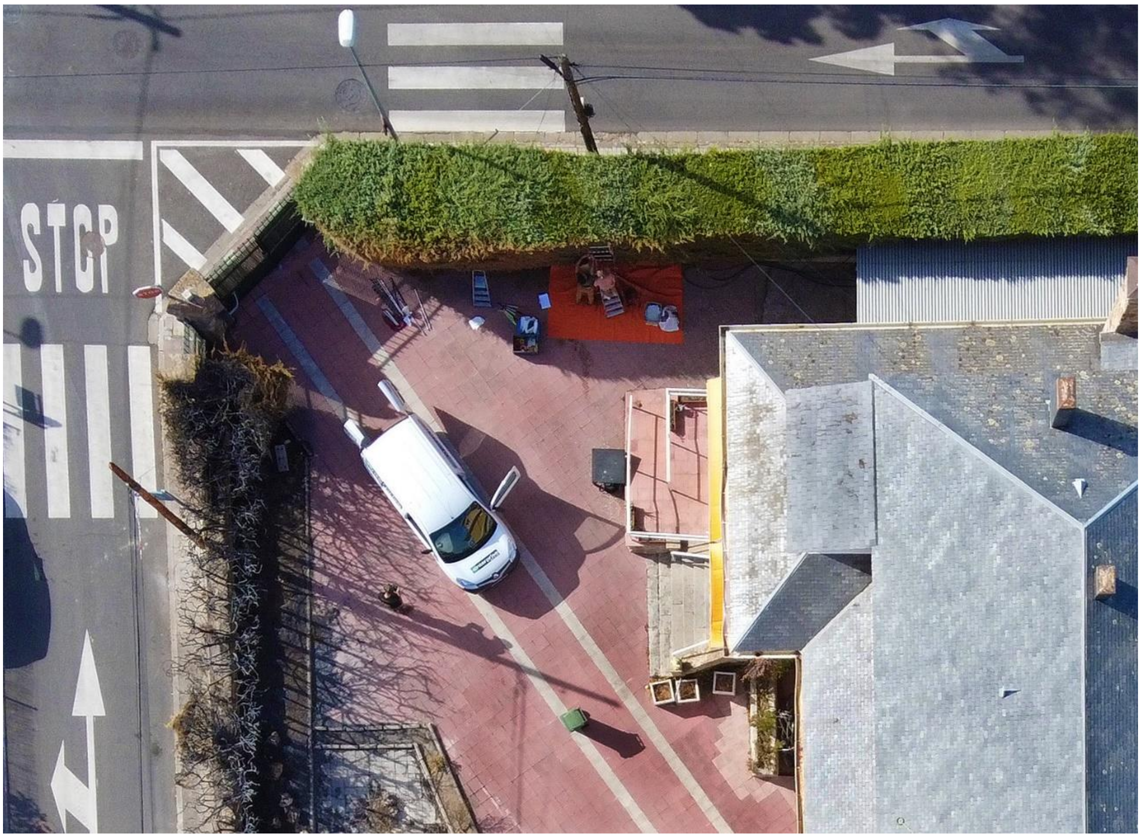

Figure 1. Aerial view of the studied plot

2. Methods

2.1. Hedge description

This hedgerow was located along the edge of several plots sited in San José del Pedrosillo St. and Primavera St. in Las Matas neighborhood (Las Rozas, Madrid; 30 T 424360.21 m E 4490392.26 m N). Following the public information from cadastre, the dwellings date from the year 1973; it is estimated that for the hedgerow dates from that time (approx. 45 years). The section of the hedgerow that burned followed the N-S axis (Primavera St.), while the one used for the fuel sampling followed the E-W axis (San José del Pedrosillo St.).

Due to the different ground level between the streets and the plots, and also because of the different levels of insolation, the hedgerow presented differences between its different faces. The Figure 2 shows a sketch with its average shape. Notice that the sketch is based on the hedgerow of the San José del Pedrosillo St. because the other sections burned almost completely.

Like in other hedgerows previously sampled, the outer section was mainly composed by foliage, beyond which dead fine fuels are stored and/or trapped. However, unlike previous samplings, this hedgerow presented an inner section almost completely empty of fuels except for the thicker woody ones. This might be explained due to either its major size or the species; previous formed hedgerows sampled were made by *C. sempervirens* instead of *C. arizonica*.

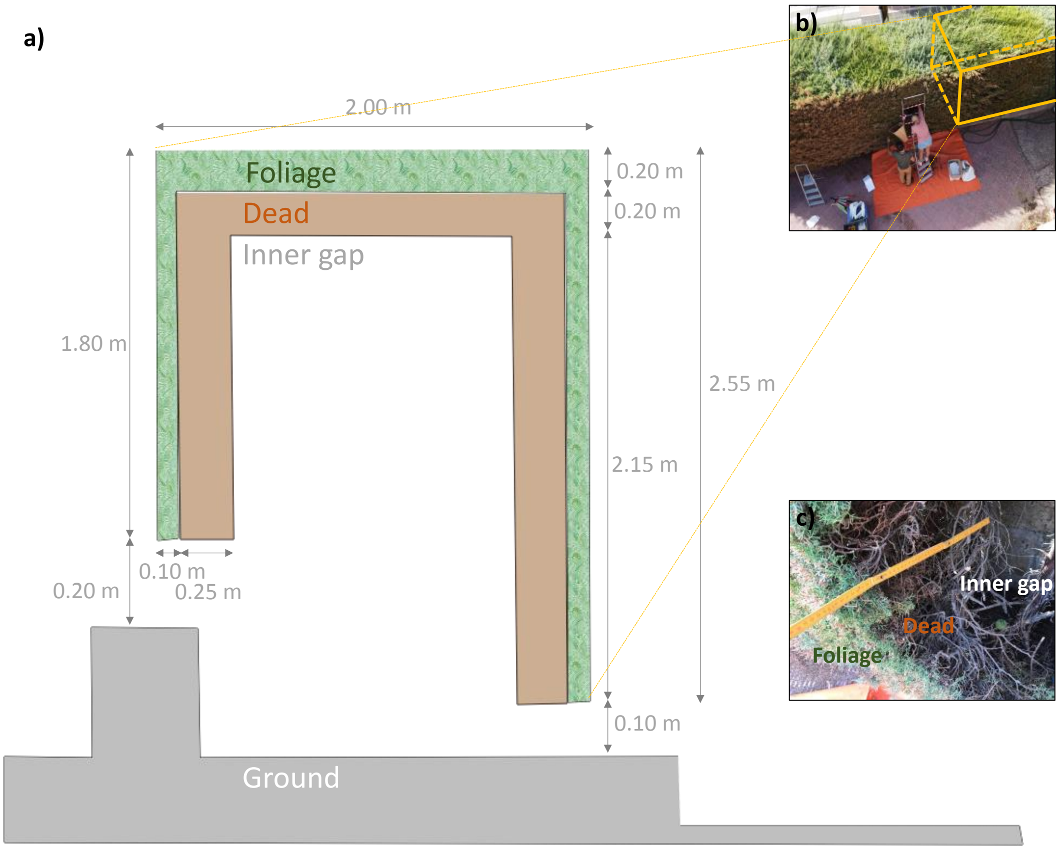

Figure 2. a) Sketch of one slice of the hedge. The foliage distribution is coloured in green while the dead materials are orange coloured. Woody tissues were distributed all allong the profile of the hedgerow, including the inner gap (See section "Living vegetation"); b) Aerial view of the hedge. The position of the slice is shown in yellow; c) Detail of a profile with the fuel distribution.

2.2. Vegetation sampling

2.2.1. Moisture

The fuel was collected at approximately the same hour at which the fire occurred (Figure 3). It was weighed *in situ*, stored in sealed cans, dried and weighed again to calculate its Fuel Moisture Content in dry basis (FMC_0). The weight was measured with a portable balance Mettler Toledo BL600 (0.1 g prec.). The samples were oven-dried for 24 hours at 90 degrees in a BINDER APT. line ED 720.

Figure 3. Sample collection for FMC_0 calculation.

2.2.2. Living vegetation

Two sites of the hedgerow were selected for the sampling of the living vegetation (Figure 3 & Figure 5). In each one of these sites, two incisions were made, centred 1 and 2 meters above the ground. The incisions were 0.5 meters wide per 0.5 meters high (0.25 m^2 of surface), and the depth was equal to the distance between the main stem of the hedgerow and the end of it (i.e. approx. half of the depth of the hedge).

The fuels extracted in these incisions were classified, oven-dried for 24 hours at 90 degrees in a BINDER APT. line ED 720 and weighed in a portable scale Mettler Toledo BL600 (0.1 g prec.).

The classification process divided the fuel by physiological state (in foliage, woody tissues and dead materials) and by diameter (0 to 3 mm, 3 to 6 mm, 6 to 10 mm and more than 10 mm).

For the bulk density calculations, the volumes differed between the different fuels: the foliage and the dead materials were located respectively on the outside and in the core of the hedge (See Figure 2), while the woody tissues were distributed along the whole volume of the hedgerow, including the inner gap.

Figure 4. Process of collecting the fuel in the upper incision. Notice that the most external foliage was withered as a consequence of the exposure to radiation. The left site was the closest to the fire.

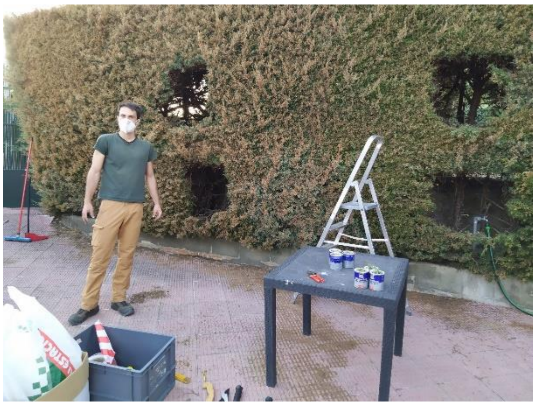

Figure 5. Four incisions were performed in the hedgerow (left and right sites) at one and two meters of height. Notice the tap and the hose in the bottom incision of the right site.

2.2.3. Burnt vegetation

To estimate the amount of fuel that contributed to the release of energy during the event, the remaining materials of four burnt trees were sampled. The sampling consisted of the measurement of the diameter of the remaining branches: all fuels of the same branch, which were thinner than the measured diameter, were burnt during the fire (Figure 6).

Figure 6. Measuring of the final diameter of the remaining branches.

2.3. Effects of the fire

The elements of the structure affected by the fire were identified through a visual inspection. Once identified, these elements were photographed to keep a record. The distance between them and the burned hedgerow was also measured.

3. Results

3.1. Fuel moisture

The Fuel Moisture Content of the different fuels that composed the hedgerow is shown in Table 1. As can be seen, the photosynthetic tissues (i.e. the foliage) presented the highest moisture content (127%), while the debris (miscellany containing all the fine dead fuels) had the lowest moisture content (6%). The woody tissues presented a moisture content around 84%, with the exception of the finer ones (34%). This could be explained by the misclassification in this class of woody thin fuels which were actually dead.

Table 1. Fuel Moisture Content in dry basis

Fuel	FMC_0
Foliage	127%
Debris	6%
Woody (0-3 mm)	34%
Woody (3-6 mm)	83%
Woody (6-10 mm)	85%

3.2. Fuel load and bulk density

The average fuel load of the hedgerow is presented in Table 2. This table shows the amount of fuel for each class, both at the top and the bottom incision and the average of all the values. The foliage and the thin woody tissues do not present large differences between both heights. The thicker fuels have a major presence at the bottom, as is expected in trees. The class of woody tissues with diameters larger than 10 mm poses an exception, with a bigger presence at the top than at the bottom. This can be explained because the main stem was left in place. Contrary to previous samples, here the average fuel load of the fine dead fuels (less than 3 mm) is larger at the top than at the bottom. Usually, when the fine dead fuels fall down, they are collected by the living woody tissues in the lower heights of the hedgerow. This situation was also seen here in the left site (1.47 kg of dead materials at the top versus 1.70 kg at the bottom). However, the presence of a water installation frequently manipulated hidden behind the right sampled site (See Figure 5) might have triggered the falling down of the fine dead materials stored at the bottom of this site, changing the expected situation and affecting the average value. This implied that the average values of Table 2 show a larger fuel load of these dead fine fuels at the upper sections, which does not correspond to normal conditions. Thus, using just the data from the left site for this class is recommended (1.70 kg instead of the averaged 1.01 kg).

Table 2. Average fuel loads of the hedgerow. Data in kilograms. Standard deviation in brackets.

		Top	Bottom	AVERAGE
Foliage		0.36 (±0.04)	0.40 (±0.08)	0.38 (±0.06)
Woody	**ø<3mm**	0.13 (±0.03)	0.14 (±0.03)	0.14 (±0.03)
	3<ø<6mm	0.20 (±0.06)	0.26 (±0.10)	0.23 (±0.08)
	6<ø<10mm	0.16 (±0.05)	0.28 (±0.09)	0.22 (±0.09)
	ø>10mm	0.30 (±0.15)	0.15 (±0.02)	0.22 (±0.12)
Dead	**ø<3mm**	1.13 (±0.47)	1.01 (±0.98)	1.07 (±0.63)
	3<ø<6mm	0.04 (±0.04)	0.09 (±0.01)	0.07 (±0.04)
	6<ø<10mm	0.00 (±0.00)	0.07 (±0.03)	0.04 (±0.05)
	ø>10mm	0.00 (±0.00)	0.03 (±0.01)	0.02 (±0.02)

These fuel load data have been divided by the proper volume to obtain the bulk densities of these classes in the hedgerow (Table 3). The larger bulk densities were given by the fine dead materials (18.54 kg·m^{-3}), closely followed by the foliage (15.57 kg·m^{-3}). The woody tissues presented a very low density (around 1 kg·m^{-3}each class). The presence of foliage and fine dead materials (very dense) at the outside part of the hedge, but just woody tissues (low density) in the inner volume, suggests a structure where the air can easily flow inside the hedgerow but can hardly flow through its boundaries. Furthermore, observations in the field showed the presence of withered foliage damaged by the exposure to the radiation from the fire (Figure 4). Both previous facts suggest that hedges could present a high resistance against radiation at the first stages (when the radiation cannot reach the more flammable dead materials, hindered by the green and wet foliage), but is highly sensitive to convection once the flame impingements the hedgerow, with plenty availability of fine dead fuels and ease for oxygen supply because of the presence of the inner gap. Like in the fuel load, the bulk density of the fine dead fuels at the bottom is lower than what is expected in normal conditions. Because of this, we suggest to use not the average but the value obtained in the left site (therefore, 28.31 kg·m^{-3} instead of 16.48 kg·m^{-3}).

Table 3. Average bulk densities in the hedgerow. Data in kilograms per cubic meter. Standard deviation in brackets.

		Top	Bottom	AVERAGE
Foliage		15.73 (±4.00)	15.41 (±2.91)	15.57 (±2.86)
Woody	**ø<3mm**	0.52 (±0.04)	0.67 (±0.06)	0.60 (±0.10)
	3<ø<6mm	0.78 (±0.10)	1.21 (±0.31)	0.99 (±0.31)
	6<ø<10mm	0.64 (±0.11)	1.30 (±0.26)	0.97 (±0.41)
	ø>10mm	1.14 (±0.41)	0.70 (±0.00)	0.92 (±0.35)
Dead	**ø<3mm**	20.59 (±11.35)	16.48 (±16.72)	18.54 (±11.91)
	3<ø<6mm	0.76 (±0.77)	1.45 (±0.04)	1.10 (±0.60)
	6<ø<10mm	0.00 (±0.00)	1.11 (±0.37)	0.56 (±0.68)
	ø>10mm	0.00 (±0.00)	0.48 (±0.05)	0.24 (±0.28)

3.3. Fuel consumption

A total of 109 measurements were taken of the remaining branches of four trees of the hedgerow burned during the fire. These branches had an average diameter of 0.93 cm, with a standard deviation of 0.32 mm. These data imply that the branches around one centimetre of diameter are charred but not completely burned, and can be assumed to not contribute to the combustion.

Following the fuel load data distribution set in the previous section, excluding the fuels with diameters larger than 1 cm implies that it is the 90% of the fuel load that contributes to the fire, while the remaining 10% charred in place.

3.4. Effects of the fire

Awning: it remained unfolded during the fire. The section 11 meters far from the hedge was scorched, but not the section at 13.5 meters.

PVC Gutter: both sections (11 and 13.5 meters far from the hedge) warped. This deformation was light at the background, but severe at the closets section.

Windows: just one window cracked (but did not break) at 13.5 m from the hedge. The area of the window that cracked was not sheltered behind the awning. Other windows closer to the fire remained unbreak.

Figure 7. Effects of the fire over the elements of the house.

4. Conclusions

Once again, the role of the hedgerows during a fire event in the WUI brings out its importance as an element that acts as a source of heat and as a driving element, linking plots and spreading the fire with alacrity. The data gathered in this study provide a better understanding on how the heat interacts with this gardening element during a combustion process and allow to study the evolution of its flammability and hazard along its growth and artificial shapes, by comparison with the previous samplings performed in the framework of this same project. The recorded effects of the fire over the surroundings, both ornamental vegetation and structures, will allow to validate our current models.