Wildland-Urban Interface Virtual Essays Workbench
WUIVIEW
GA number 826522

PBD Virtual Lab WUIVIEW

Funded by European Union Civil Protection

Technical Note TN 2.2
Fuel load sampling of a *Cupressus sempervirens* hedge

WP - Task	WP2 – T2.1.	**Version** (1)	Final
File name	WUIVIEW_TN2.2	**Dissemination level** (2)	Internal
Programmed delivery date	31/07/2019	**Actual delivery date**	02/08/2019

Document coordinator	Alba Àgueda (UPC)
Contact	alba.agueda@upc.edu
Authors	Alba Àgueda (UPC), Juan Antonio Muñoz (UPC)
Reviewed by	Elsa Pastor (UPC)

Abstract	In this document, data from a destructive sampling of a *Cupressus sempervirens* hedgerow are shown, as well as the followed methodology. Measures of sizes and weights have been taken. With these data, moisture content, fuel load and bulk density have been calculated. Different fuel classes (state and diameter) have been taken into account.

(1) Draft / Final
(2) Public / Restricted / Internal

Table of Contents

1. Introduction

In this Technical Note we gather data on fuel load of a *Cupresus sempervirens* hedge through destructive sampling. We describe the methodology and report experimental results.

The general objective of this activity is to obtain quantitative information about this fuel structure because it has a high probability of being ignited in a wildfire scenario.

Data gathered here is needed to perform CFD preliminary simulations of pattern scenarios involving hedges. CFD models require the bulk density of the dry thermally-thin vegetation. Therefore, in order to determine this parameter, the fuel load of different size classes present in a known volume of a hedge fence has been determined.

2. Methods

2.1. Fence description

The fence is located in a small villa in the municipality of Vilanova de Segrià (Lleida, 41°42'5.62"N, 0°36'44.95"E), an agricultural area in the plain of Lleida. There is a wire fence surrounding the property together with a hedge fence of *C. sempervirens*. Trees in the area where the sampling was performed are about 25 years old, 3.6 m high and have a mean depth of 1 m (Figure 1). Sampling was performed during the morning of July 22, 2019.

a) *b)*

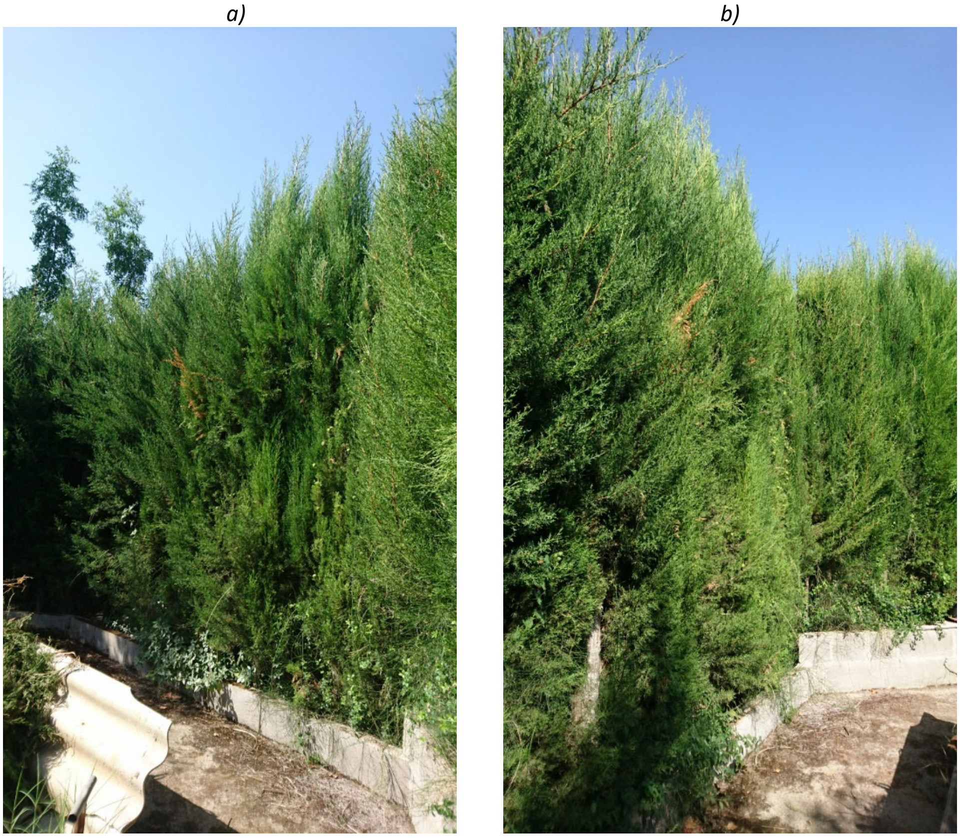

Figure 1. Hedge fence to be sampled

2.2. Vegetation sampling at the field

Destructive sampling was performed in a section of the *C. sempervirens* hedge. A tubing structure and pieces of thread (Figure 2) were used to define two volumes (i.e. prisms) of interest. They were centred at 1 m and 2 m height above ground level (a.g.l.), respectively. The prisms had surfaces parallel to the hedgerow of 0.5 m x 0.5 m, and a depth (dimension across de hedge) of 0.8 m, representing a total volume of 0.2 m^3. A sketch of the sampling volumes with respect to the ground is shown in Figure 3.

Figure 2. Tubing structure used to define the volumes of interest. 0.5 x 0.5 m² surface delimited by the vertical tubes and the green threads.

The sampling was done using pruning shears. Two people cutting were located at both sides of the fence. All the fuel present in the volumes was removed and collected in four bags: two bags for the fuel sampled at each side of the hedge, one for every volume. Tree stems with diameter ≥14 mm were not cut and left in-situ (only 4 samples representing stems were removed to determine wood density afterwards). Their dimensions were also tallied.

Fuel samples were also taken for moisture content analysis and collected in sealed cans (see Figure 4b). Three types of samples (around 40 g in wet weight each) were gathered per prism: live foliage, live roundwood, and dead roundwood, and three replicates per type of sample were taken (18 samples in total).

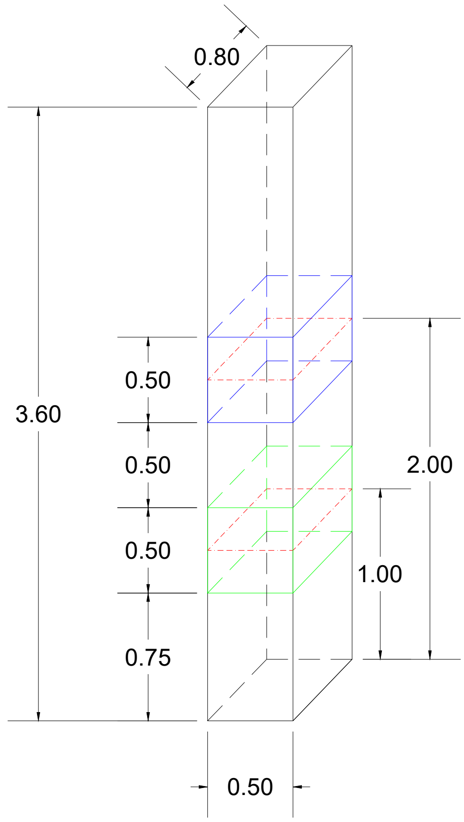

Figure 3. Sketch showing the position and dimensions of the sampling volumes. Lower volume in green and upper volume in blue. Red contours indicate the central plane of every volume. The whole dimension of the hedge section under study is depicted in black.

2.3. Laboratory measurements

Fuel sampled was transported to CERTEC laboratory in four bags and classified the day after the sampling according to whether it was live or dead fuel, and also according to the following size classes: foliage (only for live fuel), roundwood of diameter <3 mm, roundwood 3–6 mm in diameter, roundwood 6–10 mm in diameter and roundwood 10-14 mm. After classification, fuel samples were weighted (Sartorius BL600), oven-dried (BINDER APT. line ED 720) at 90°C for 40 h (Figure 4a), and once again weighted to have a rough estimate of fuel moisture (M). Note that this moisture content was not the real one because samples were kept for about 30 h in non-sealed bags before being oven-dried (see Annex 1 for complete details).

The 18 fuel moisture samples were weighted (Mettler Toledo PB153-S/FACT), oven-dried for 24h (BINDER APT. line ED 720) at 90°C, and then weighted again (the time between sampling and oven drying was kept as short as possible).

To estimate the dry weight of the tree stems wider than 14 mm, the four samples of roundwood fuel were oven-dried (BINDER APT. line ED 720) 72 hours at 90°, weighted (Mettler Toledo PB153-S/FACT) and measured in length and diameter (3 measurements at three different points –top, middle, bottom- of the sample).

a) *b)*

Figure 4. a) Fuel separated in different classes before oven-drying; b) Fuel moisture content sampling

3. Results

3.1. Wood density

As mentioned above, all stems with diameter wider than 14 mm were left in-situ. The sampled volume at the bottom had 7 of these stems, with an average diameter of 4.78 cm (s.d. 2.00), while the top volume had 14 stems, with a lower average diameter (2.58 cm, s.d. 1.55). These results are in line with the common structure of treated hedgerows.

The representative sizes, weights and densities of the four samples of roundwood are shown in Table 1. The average density was 571.26 kg/m^3 (dry basis) in agreement with common values used for *Cupressus sempervirens* (460-640 kg/m^3)[1].

Table 1. Dimensions, geometry, weight and density for four dry samples of roundwood of Cupressus sempervirens.

	Sample 1	Sample 2	Sample 3	Sample 4
Length (cm)	22.00	16.75	26.35	22.05
Avrg. diameter (cm)	1.55	1.46	1.94	1.77
Dry Mass (g)	24.722	17.705	42.463	28.116
Section (cm^2)	1.90	1.68	2.95	2.46
Volume (cm^3)	41.71	28.17	77.75	54.32
Density (kg/m^3)	592.76	628.47	546.15	517.65

Assuming that the length of these stems is equal to the height of the prism (i.e. 0.5 m) and the diameter is constant, the upper sampled volume had 2.80 kg of ≥ 14 mm stems, while the 1 m a.g.l. prism had 4.14 kg.

3.2. Fuel moisture

Fuel moisture content values obtained from samples specifically collected to compute this variable are shown in Table 2. As expected, live fuel (foliage and roundwood samples) has high percentages of moisture. Dead roundwood samples were very dry, with moisture values lower than 30% (dry basis). Moisture differences between both prisms were very small.

Table 2. Fuel moisture content determined on a dry basis.

Sampled Volume	Classification	Replicate	Dry mass (kg)	Moisture (%)	Mean moisture (%)
@ 1 m	Live foliage	1	11.371	173	160
		2	7.636	147	
		3	-	-	
	Live roundwood	1	19.494	101	101
		2	15.328	110	
		3	12.739	94	

[1] Bolza, Eleanor, and William G. Keating. "African timbers-the properties, uses and characteristics of 700 species." *African timbers-the properties, uses and characteristics of 700 species.* (1972).

	Dead roundwood	1	24.059	11	13
		2	19.947	11	
		3	15.732	16	
@ 2 m	Live foliage	1	14.257	159	164
		2	17.069	171	
		3	11.93	153	
		4	26.367	174	
	Live roundwood	1	19.337	125	118
		2	20.362	133	
		3	22.466	95	
	Dead roundwood	1	19.276	11	13
		2	12.817	11	
		3	15.165	16	

3.3. Fuel load

The mass of the fuel sampled in each prism is shown in Figure 5, as well as the average mass of both prisms. Stems >14mm are not included here. Dead fraction <3mm in diameter (D3) has the highest average presence, closely followed by foliage (LF). It is worth to note that the dead fraction <3mm clusters all dead fuels with diameter lower than 3 mm, including dead foliage. In live fuels, a distinction is done between foliage and roundwood with diameter lower than 3 mm (LW3). Regarding all those fuels with diameter greater than 3mm, live fuels have a larger presence than dead fuels. Note that, while dead fuels are mainly present in the core of the sampled prisms, foliage is only present in the boundary of the hedgerow: during the sampling it was observed that the hedge had to portions (one in each side of the hedge) of depth of about 0.07-0.1 m of live fuel (outer volume). The rest of the sampled volume (depth 0.6-0.66 m) consisted basically of dead foliage and dead roundwood (core volume). Live roundwood was distributed throughout the whole hedge volume.

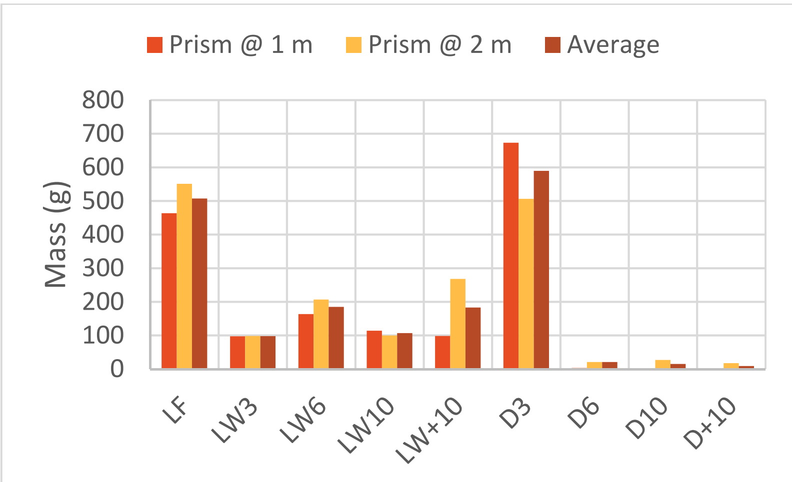

Figure 5. Mass of fuel classes sampled according to height (1 m/2 m) and average mass per class. L: live; F: foliage; W: roundwood; D: dead; 3: diameter < 3 mm; 6: diameter 3-6 mm; 10: diameter 6-10 mm; +10: diameter 10-14 mm. Stems left in the sampling location (> 14 mm) are not considered.

The fuel bulk density calculated for every prism and the dry mass distribution (percentage) are shown in Table 3, together with values averaging both sampled volumes. Dead fine roundwood (<3mm) is the most predominant fraction in the used classification, and has almost the same average amount of fuel than the sum of the fine live fuels (35% *vs.* 35.5%). The rest of the fractions have a much lower presence. Average bulk densities regarding overall burnable (i.e. live and dead particles) fuels are for dead fuels 3.12 kg/m^3 and for live fuels 5.33 kg/m^3.

Table 3. Bulk density (in kg/m^3) and distribution (in percentage) of dry mass in the different classes (L: live; F: foliage; W: roundwood; D: dead; 3: diameter < 3 mm; 6: diameter 3-6 mm; 10: diameter 6-10 mm; +10: diameter 10-14 mm). Distribution has been calculated not taking into account stems with diameter >14mm. Bulk densities have been calculated assuming that all fuels are uniformly distributed all along the prism.

Prism		LF	LW3	LW6	LW10	LW+10	D3	D6	D10	D+10
@ 1 m	Bulk density (kg/m3)	2,32	0,49	0,82	0,57	0,34	3,37	0,02	0,00	0,00
	Mass distribution	28,7%	6,0%	10,1%	7,1%	6,1%	41,7%	0,2%	0,0%	0,0%
@ 2 m	Bulk density (kg/m3)	2,76	0,49	1,03	0,50	1,34	2,53	0,10	0,14	0,09
	Mass Distribution	30,7%	5,5%	11,5%	5,5%	14,9%	28,2%	1,2%	1,5%	1,0%
Average	Bulk density (kg/m3)	2,54	0,49	0,93	0,53	0,84	2,95	0,06	0,07	0,04
	Mass distribution	29,7%	5,8%	10,8%	6,3%	10,5%	35,0%	0,7%	0,8%	0,5%

Due to the particular arrangement of fuels observed during the fuel sampling (i.e. dead fuels mainly present in the core of the sampled volumes with and external boundary of green fuels), bulk densities have also been calculated considering a discretization of the sampled prisms between a “core volume” and an “outer volume” (Figure 6).

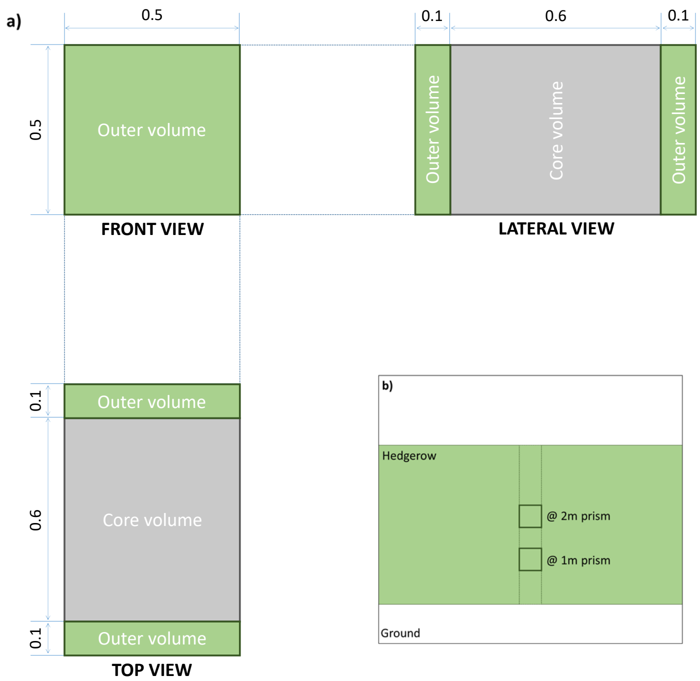

Figure 6. a) Sketch of the sampled prisms in the Cupressus sempervirens hedgerow. Foliage (LF) was concentrated in the outer volume. Dead fuels (D) were mainly present in the core volume, while live roundwood (LW) was distributed all along the prism (outer and core volumes). b) Sketch of the front view of the hedgerow. Dark green squares depict the sampled prisms.

The bulk densities of the fuels in the outer volume are shown in Table 4 and Table 5 shows the fuel bulk density of the core volume. Note that dead fuels are not present in the outer volume. Considering this discretization of the sampled volumes, it can be observed how average overall dead fuel density in the core volume is 4.16 kg/m^3, 1.33 times higher than the value obtained without discretising the sampled volume. In addition, average overall live fuel density in the outer volume is 13.02 kg/m^3, 2.44 times higher that without considering discretization.

*Table 4. Bulk density (in kg/m^3) of the different fuel classes in the **outer volume** (L: live; F: foliage; W: roundwood; 3: diameter < 3 mm; 6: diameter 3-6 mm; 10: diameter 6-10 mm; +10: diameter 10-14 mm).*

Bulk density in the outer volume (kg/m3)					
Prism	LF	LW3	LW6	LW10	LW+10
@ 1 m	9,27	0,49	0,82	0,57	0,49
@ 2 m	11,02	0,49	1,03	0,50	1,34
Average	10,15	0,49	0,93	0,53	0,92

*Table 5. Bulk density (in kg/m^3) of the different fuel classes in the **core volume** classes (L: live; W: roundwood; D: dead; 3: diameter < 3 mm; 6: diameter 3-6 mm; 10: diameter 6-10 mm; +10: diameter 10-14 mm).*

Bulk density in the core volume (kg/m3)								
Prism	LW3	LW6	LW10	LW+10	D3	D6	D10	D+10
@ 1 m	0,49	0,82	0,57	0,49	4,49	0,02	0,00	0,00
@ 2 m	0,49	1,03	0,50	1,34	3,37	0,14	0,18	0,12
Average	0,49	0,93	0,53	0,92	3,93	0,08	0,09	0,06

4. Conclusions

The destructive sampling performed on a hedge of *C. sempervirens* has shown that the thinest (0-3 mm) dead fraction represents about 35% (28.2% and 41.7%) of the total mass available to burn, closely followed by foliage (29.7%), which is instead concentrated in a smaller volume around the boundaries of the hedge. The distribution of lower diameter fractions (0-3 mm) of dead and live fuels is predominant in this vegetation structure, rising up to 70% (76.5% and 64.4%) of the total mass available to burn.

We have also observed that differences between prisms sampled at two different heights are small. However, note that fine dead fuels are more concentrated in the bottom sections of the tree, suggesting that once they die and fall down, can accumulate not only in mulch beds under the tree canopy base but also in the bottom part of the tree. This situation could help fire transition from surface to the hedgerow.

The sampled hedge is illustrative of a parcel in which non intensive clipping nor particular watering regime has been applied. Pattern hedge scenarios gathered in D5.1 do not necessarily respond to this characterization. Therefore, more hedges need to be sampled to get representative data for simulation purposes.

5. Annex 1

Moisture values from Table 6 are those obtained after classifying and drying the whole amount of fuel sampled. However, since these fuel samples were oven dried 30 h after the destructive sampling and kept in non-sealed bags, they do not refer to the real moisture content. Live fuel (foliage and roundwood) moisture content presents lower values than those obtained in Table 2. This is probably because these class fractions were getting dried during the 30 hours between sampling and drying. Initially, values referred to the dead class fractions were quite variable, ranging from 12% to 94%. This is not in agreement with the values shown in Table 2, which are very low (13%). This was probably because some roundwood branches considered as dead fuel during the classification step, might have been alive in fact. To fix this, all those sub-samples classified as dead fuels with moisture contents higher than expected for dead fuels, were considered as live fuels in Table 6.

Table 6. Moisture content (dry basis) according to different size classes, after clasiffy the whole amount of fuel sampled. Delay between sample collection and weighing lead into lower values than in Table 2. All those values modified after restructuring the dead-alive roundwood fuel classification are in brackets.

		@ 1 m a.g.l.	@ 2 m a.g.l.
Living/Dead	**Classification**	**Weighted mean moisture (%)**	**Weighted mean moisture (%)**
Living	Foliage	111%	134%
	Roundwood < 3 mm	65%	66%
	Roundwood 3-6 mm	(64%)	(82%)
	Roundwood 6-10 mm	(84%)	(94%)
	Roundwood 10-14 mm	(117%)	(144%)
Dead	Roundwood < 3 mm	18%	17%
	Roundwood 3-6 mm	(15%)	(19%)
	Roundwood 6-10 mm	(-)	(12%)
	Roundwood 10-14 mm	(-)	(12%)