Susceptibility to Fire (Case the Forest of Chettabah, Algeria)

Author's Details- [(1)]Megrerouche R., [(2)]Rached-Kanouni M.,[(3)]Amine Khodja A.E.M., [(4)]Alatou D.[1,2,4]Laboratory of development and valorization of plant genetic resources. Department of Biology and Vegetal Ecology, Faculty of Natural sciences and Life, Mentouri brothersUniversity, Constantine. [3]Forest Conservation, Constantine, Algeria-**Corresponding auteur:** Rached-Kanouni M.

Abstract

This work consists to evaluate the sensitivity of the Holm oak and Aleppo pine forestry vegetation against the fire in the region of Constantine (north-east Algerian). The shrub and herbaceous stratums are the most vulnerable and inflammables. The parameters analysis and the follow up of the foliage water content of the flammability and the combustibility is achieved during whole the year on the evergreen oak, Aleppo pine and a few number of secondary kinds of its floristic accompanying. The sensitivity of the foliage depend on the species, it is optimal during the summer. The time of flammability varies between 30 and 120 seconds in winter, even though the combustibility is between 40 and 500 seconds for the same periods. Theses variations allows to get noticed of the homogeneous groups for the litter, the bark and the other species like Asparagus acutifolium, Astragalus armatus Calycotome spinosa Ampelodesma mauritanicum, Cistus villosus, Pistacia lentiscus and Arbutus unedo. A classification of the different vegetables species is established according to studied parameters of the sensitivity degree. The air maximum temperature of the month is the hottest and is varied between (39-42°C). During the summer, the flammability is 60 seconds for Pinus halepensis and 20 seconds for Quercus ilex concerning the combustibility; it oscillates respectively between 200-400 seconds and 200-300 seconds for the two forestry species. The risk calculation by the CEMAGREF method is higher in the summer. The combustibility knowledge of the flammability is due to the foliage water content, linked to the species and the vegetable formation that are transposable for the vegetation map which allowed to class the planting by big flammability categories.

Keywords: *susceptibility to fire, Holm oak, Aleppo pine, water content, flammability, combustibility risk.*

Introduction

In the Mediterranean region more than 50.000 fires burn an estimated 600.000 - 800.000 hectares annually, about 1.5% of total Mediterranean woodlands (Meddour-Sahar & al., 2008b; FAO, 2007; FAO, 2010). Fires are particularly abundant in the northern rim of the Mediterranean, where France, Greece, Italy, Portugal and Spain contribute with a yearly average of 49.838 fires and 471.644 burned hectares (1980-2010) (Velez, 2000; FAO, 2012).

Causes of fire in Algeria are the result of high density of rural population (ranging from 40 to over 600 inhabitants per km^2 in the North Central region of the country), of growing demography, of rural exodus and countryside abandonment, of urban sprawl and increasing demand of building areas along the coast, of increasing production of home waste and of traditional forms of land use dominated by pastoralism (Vallejo, 2005; Bassi & Kettunen, 2007; Meddour-Sahar & Derridj, 2012).

In many cases the degradation of forested areas reflects a population accustomed to using forest as a free-for-all with scarce concern for forest preservation (Thirgood, 1981). This adds to an adverse climate, with recurring droughts and long, increasingly hot summers with prolonged, severe heat waves, such as in 2012. This scenario is rather similar to other M.E.N.A. countries' with similar climatic and productive features, where rural populations maintain excessively high pressure on wooded lands, overexploiting firewood and over-grazing (FAO, 2012 in Meddour-Sahar & *al.*, 2013).

In this work we investigated the outbreak of forest fires from characters of trees, shrubs and herbaceous and their behavior during the summer season when daytime temperatures exceed the threshold of 40°C. 35.000 ha of the Mediterranean landscape are reduced to ashes, where correspond to 3.500 fire starts per year. Burned area average between 23.000 ha and 55.000 ha per year between 1882-2001. Fires are frequent due to various causes such as careless smoking, neglect of farmers during the agricultural and forestry activities, reckless hunters and workers, and pyromaniacs.

In this context, this work focuses on knowledge of flammable materials namely forest vegetation consists of different strata. The study site is the forest of Chettabah (Ain-Smara, Constantine) made up of Aleppo pine and Holm oak. The sensitivity of vegetation to fire is defined by the flammability and combustibility; these two concepts characterize the risk presented vegetation towards the fire. This work aims to:

- Follow the kinetics of flammability and combustibility of certain species (Aleppo pine and Holm.
- Evaluation of the overall risk of fire.

Material and methods

The forest of Chettabah is located southwest of Constantine, it spreads over an area of 2398 hectares and consists of 410ha of forest of Aleppo pine, 898ha of green scrub oak, 930ha of young stands, it is also characterized by a very uneven with many ridgelines field and generally poor brown limestone soils type modal, organic matter in the lower horizons.

The altitudes of the forest vary between 652 m and 1104 m with exposure to East dominance, the average annual rainfall for the period 1995-2004 is 625 mm, the monthly distribution of rainfall during this decade (1995-2004) is irregular, the maximum rainfall is reached January and December (104.62-90.48 mm).While the two summer months (July and August) receive only small amounts (5.40- 3.95 mm), with a rainfall of HAPE kind, the minimum temperature of the coldest month (m) varies between 3.05 and 1.25°C between the extreme altitudes of the forest. The maximum temperature of the warmest month (M) is between 35 and 31.5°C, the dry season extends from May to October during 175 to 192 days while the wet season lasts about 185 days. Forest Chettabah overlaps bioclimatic atmosphere shared between the semi-arid to temperate in winter than at the lowest point and the average subhumid to cool winter at high altitude winter. A large plant grouping as the forest cannot be studied in its entirety, especially when it concerns hundreds of acres to be treated in detail. The choice has focused on the most representative sites of the forest (5 sites).

Tableau 1. Characteristics of plots

Plots	**Characteristics**	
Plot 1	*Pinus halepensis*	
	Condition of vegetation: burned in 1996	
	Altitude	1018 m
	Acreage	6.60 ha
	Density	2600 tree / ha
	Vegetation	- The main species is *Pinus halepensis* (PA), the recovery is 73% The shrub layer includes: *Crataegus azarolus* (Aze) 0.53%, *Pistacia lentiscus* (Len) 1.03%, *Arbutus unedo* (Arb) 4.48%, *Phillyrea angustifolia* (P.ang) 0.64%, *Phillyrea media* (P.med) 5.88%, some trees of *Quercus ilex* (CV) 1.01%, the total recovery of 14%. - The shrubby stratum formed by *Ampelodesma mauritanica* (Dis) 0.31%, *Cistus villosus* (Cis) 0.42%, *Asphodelus sp, Asparagus acutifolius* (Asp) 0.061% *Calycotome spinosa* (Cal) 1.24, the total recovery is 2%. - The herbaceous layer covers about 80%. - Covering the floor litter is 80%.
Plot 2	*Pinus halepensis* + *Quercus ilex*	
	Condition of vegetation: burned in 1996	
	Altitude	992m
	Acreage	2.30 ha
	Density	1200 tree / ha (PA), 800 tree /ha (CV)
	Vegetation	- The main species is *Pinus halepensis* (PA) recovery is 35% + *Quercus ilex* (CV) recovery is 14%. - The shrub layer consists of *Arbutus unedo* (Arb) 2.16%, *Phillyrea angustifolia* (P.ang) 9.05%, *Phillyrea media* (P.med) 4.13%, *Crataegus azarolus* (Aze) 1.25% and the total recovery is 17%. - The shrubby stratum formed by *Ampelodesma mauritanica* (Dis) 2.56%, *Calycotome spinosa* (Cal) 1.42%, *Cistus villosus* (Cis) 2.76%, total recovery is 7%. - The herbaceous layer covers 35%. - Covering the floor litter is 70%.
Plot 3	Thicket Quercus ilex	
	Condition of vegetation: burned in 1996	
	Altitude	989m
	Acreage	6.72 ha
	Density	2100 tree / ha
	Vegetation	- The main essence is *Quercus ilex* (CV) recovery is 17%. - The shrub layer consists of: *Phillyrea angustifolia* (P.ang) 10.37%, *Pistacia lentiscus* (Len) 6.81%, *Phillyrea media* (P.med) 8%, some trees of *Pinus halepensis* (PA) 1.38 %, the total recovery is 27%. - The shrubby stratum formed by *Ampelodesma mauritanica* (Dis) 2.64%, *Cistus villosus* (Cis) 1.78%, Asphodelus sp, *Calycotome spinosa* (Cal) 2.16%, the total recovery of 7%. - The herbaceous layer covers 75%. - The recovery rate of the litter is about 60%.
Plot 4	Young forest of *Pinus halepensis*	
	Vegetation status: No fire	
	Altitude	621m
	Acreage	1.30 ha
	Vegetation	- *Pinus halepensis* (PA) recovery is 25%. - The shrub layer is constituted solely by *Juniperus oxycedrus* (Oxy) recovery is 8%. - The shrubby stratum formed by *Ampelodesma mauritanica* (Dis) 1.82%, *Astragalus* armatus (Ast) 0.35%, and the total recovery is 2%. - The recovery of the herbaceous layer is 90%. - Recovery rate of litter is de70%.
Plot 5	Garrigue of *Quercus ilex*	
	Vegetation status: No fire	
	Altitude	: 966m
	Acreage	15 ha
	Vegetation	- *Quercus ilex* (CV) recovery is 54%. - The shrub layer consists of: *Crataegus azarolus* (Aze) 1.28%, *Phillyrea angustifolia* (P.ang) 16.78%, *Juniperus oxycedrus* (Oxy) 16.85%, the total recovery is 35%. - The shrubby stratum formed by *Ampelodesma mauritanica* (Dis) 5.99%, *Asphodelus sp Calycotome spinosa* (Cal) 1.62%, *Asparagus acutifolius* (Asp) 1.7%, *Cistus villosus* (Cis) 4.14%, the total recovery is 13%. - 90% of the herbaceous layer - And finally 90% of the litter.

To evaluate the sensitivity of forest vegetation to fire, it was necessary to determine the duration of flammability and combustibility of the species in relation to their water content throughout the year (a sample is taken every month) and specially during the summer season (12 outputs on field). The plant material used is foliage species studied, the floristic composition of the PA and CV. The species studied correspond to Len, Arb, P.ang, P.med, Oxy, Aze, Cis, Dis, Ast, Asp, Cal. The bark (E) and litter (L) of the PA and CV are also analyzed.

The term combustibility is often confused with flammability but, according to Trabaud (1976), flammability in fact includes three components: ignitability, combustibility and sustainability. Ignitability indicates how easily the fuel ignites; combustibility refers to how plants burn after they have been ignited; sustainability registers the stability of the burning rate, i.e., how well the fuel continues to burn.

In laboratory, times of flammability and combustibility were measured using an infrared sear burner. The plant water content also determines the flammability and combustibility; it is calculated by the following formula:

$$WC = \frac{FW - DW}{W} \times 100$$

To assess the overall risk of the forest, we proceeded by extrapolating biovolumes obtained for the stations of studies to those of the forest. It is calculated by the method developed by Cemagref, it involves three steps:

1 - Evaluation of the combustibility index (CI) of the vegetation.

$$CI = 39 + 2.3BV\ (E_1 + E_2 - 7.18)$$

• BV: Biovolume of the vegetation

• E_1, E_2: are the notes of heat intensities (between 1 and 9) of the two dominant species; E_1 for high woody, E_2 for low woody.

2 - Evaluation of the combustibility weighted index (CWI).

$$CMI = 1/ST\ x\ (S_1\ x\ CI_1 + S_2\ x\ CI_2 + S_3\ x\ CI_3 + ...)$$

• ST: Total area of several plant formations, respectively, each occupying a surface S_1, S_2, S_3 ..... and having an combustibility index own IC1, IC2, IC3, ...

3 - Average annual Risk Assessment (AAR)

$$AAR = 0.1\ x\ CMI - 3$$

Results and Discussion

For all species studied, the change in the flammability and combustibility time is function of the water content which is directly dependent on the period of analysis. If we take as an example the month of July, the average percentage of the water content is 29% to Asp, 33% for Len and CV, 36% for P.ang, while from 1 to 5% E.PA, E.CV and L.PA and the CV. In the same month, the species show a remarkable sensitivity to fire (Figure 1).

Flammability of CV, Asp, E.PA, L.PA and the E. CV is between 15 and 20 seconds. The combustibility is between 150 and 300 seconds; these results are obtained for other species showing high temperatures (43°C) during the month of July. The flammability varies between 37-40 seconds for P.med, Dis, P.ang, Cal, E.CV and from 43-58 seconds to Aze, Cis, Len and PA. The combustibility time for these species is between of 168-600s (Figure 2).

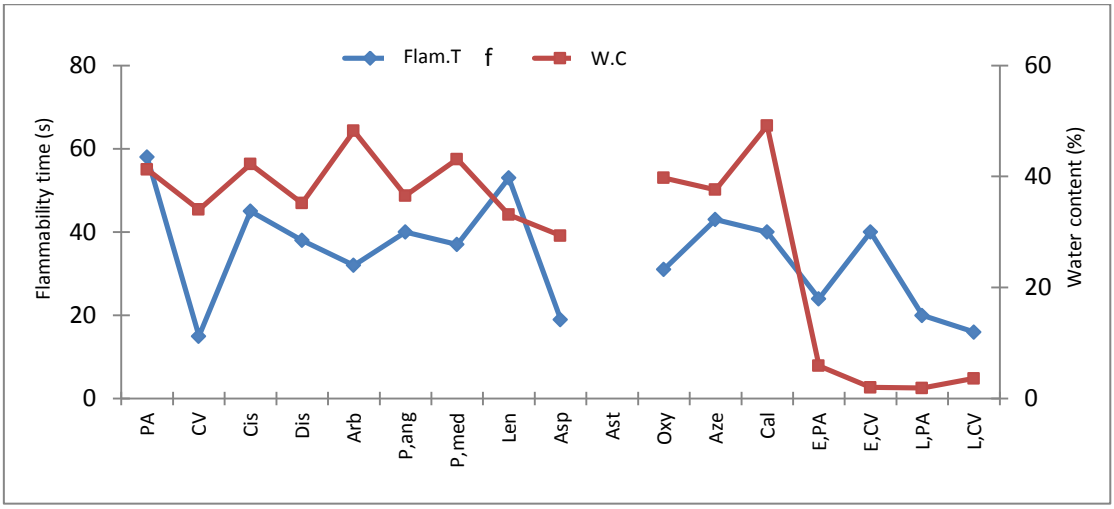

Figure 1.Variation of the flammability time and water content of the plant species (July)

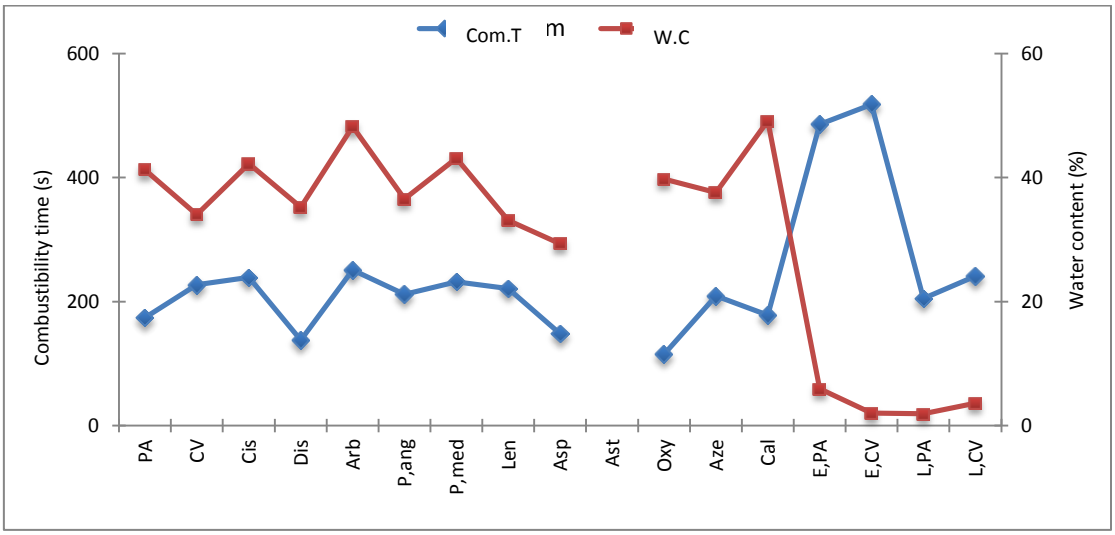

Figure 2. Variation of the combustibility time of and water content of the plant species (July)

The fire behavior of the two main tree species CV and PA is different, it is the CV leaves that ignite very quickly, so that the needles of the PA resistant to flame advantage (sips resin), but produce then a sudden release of terpenes which together with ambient air gas mixture which ignites at a stroke, producing flames of several tens of meters.
By examining the curves in Figure 3 and 4, we can say that the L.CV bark caught fire 77 seconds then what is consumed at 665 seconds and L.PA caught fire 68 seconds then what is consumed to 681 seconds. The chemical composition also plays an important role in the flammability and combustibility of a species. The essential oils of some plants by activating influence combustion flame, case *Cistus* and *Rosmarinus* are of species susceptible to the action of fire. Figures 3 and 4 also show that Cis has 83 seconds to ignite and 307 seconds to burn. Len and Cal are a group of highly combustible species.

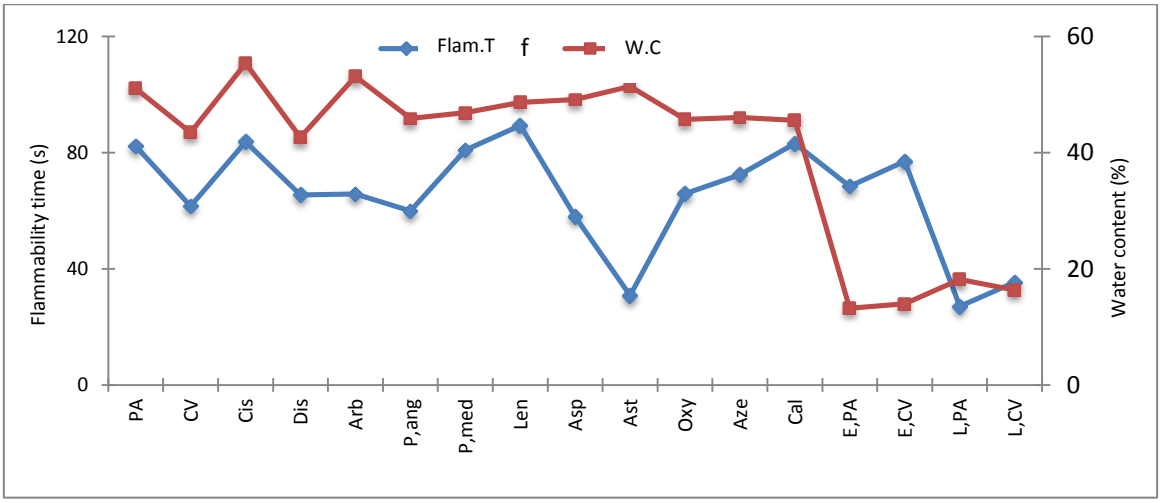

Figure 3. Average annual change of the plant species (flammability time and water content).

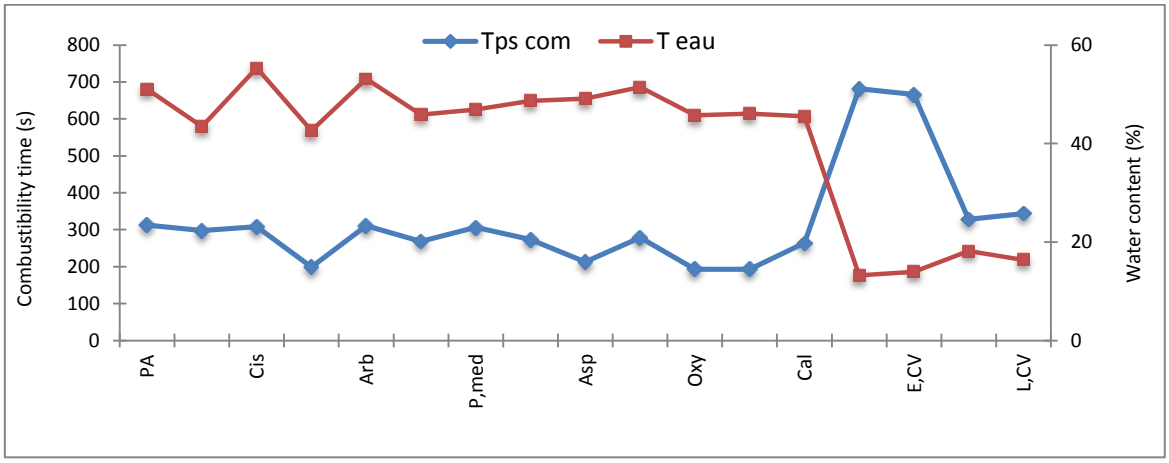

Figure 4. Average annual change of the plant species (combustibility time and water content).

The results of the analysis of variance test to a classification criterion used to compare the means of each variable (ignition time, time combustibility, water contents) for all species and 12 outputs (table 2), show that there are very highly significant differences.

Table 2. ANOVA analysis

Variables	F	P
Flammability time	18.12	0.000***
Combustibility time	172.28	0.000***
Water content	113.19	0.000***

The results of the multivariate analysis (MANOVA) are given in Table 3, the examination of the results shows that there are also very highly significant differences when comparing the average of the three variables for the 12 release dates and all species.

Table 3. MANOVA analysis

Tests	F	P
Wilk‘s	96.981	0.000***
Lawley-hotelling	3000.043	0.000***
Fillai’s	36.615	0.000***

Conclusion

Samples are slow to ignite with increasing water content, as well, high water content reduces the time during which the flame persists. The contents of the highest water are observed in Cal, Cis and Arb, with a percentage of between 56.52% and 52.84%, while the lowest values were recorded to L.CV and L.PA. So we can say that the bark and litter of CV and PA have the lowest flammability time, for against their combustibility is longer. For other species it is variable during the year and follows the same kinetics. Knowledge of flammability parameters, combustibility and the water content of the plants used to calculate the risk of outbreak of fires and can be transposed on a cartographic support to identify the sensitivity levels in a forest.

Our flammability and combustibility studies lead to better information on heat loads and the role of each species in the kindling. It specifies the influence of stand structures on the spread of fire, so the silvicultural interventions expected.

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