

Flammability and Combustibility of *Cistus* Plant Groups in Tlemcen Region (Algeria)

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ABSTRACT

Since antiquity, fire has played a dual role in Mediterranean forests. On the one hand, it renews and enriches a natural ecosystem by ensuring its biological uplift from the point of view of plant diversity if its frequency is low and, on the other hand, it destroys the vitality of a vegetation cover if its frequency is high. The forest of the Tlemcen region is an integral part of this regime. Forest fires are characterized by several types (ground fires, surface fires, crown fires, etc.) depending on the nature and architecture of the forest. For this purpose flammability and combustibility as a function of the water content of plant species are a key factor, in determining susceptibility to forest fires during the spring season, which is the objective of our study for the prediction and prevention in the short and long terms. The methodology adopted is that of Valette and Moro modified by Hachmi and Essaghi and by Henaoui. Thirty-eight plant species underwent flammability and combustibility tests using an infrared burner to rank our forests on a scale of different indices (flammability, combustibility, intensity of combustion and water ratio) that will determine their states. The results show that 87% of the vegetation cover is highly flammable, 42% very combustible, 63% are represented by a high intensity of combustion and 42% are represented by a high water content. 50% of these plant species are characterized by high flammability, combustibility and burning intensity despite their high water content.

Key Words: Flammability; Combustibility; Fire; Water Content; Tlemcen (Algeria).

INTRODUCTION

The Mediterranean forests are subjected each year to a period of drought in summer. Lack of water due to limited or non-existent precipitation, low humidity and high temperatures with high evaporation requirements increase the risk of vegetation fires (Rambal and Hoff 1998). Fire has an important presence and its influence in these Mediterranean ecosystems, its damage mainly depend on the intensity of the fire and the frequency. Reconstruction of vegetation is slow and repetitive fires can seriously jeopardize re-vegetation (Francis and Thornes 1990, Ferran et al. 1992, Bautista et al. 1994, Moench and Fusaro 2003).

The flammability classification of forest species is an essential component of fuel hazard and fire risk assessment, which are important components of forest fire management planning (Le Houërou 1997, Trabaud 1976, Barney and Aldrich 1980).

The forest of the Tlemcen region is characterized by an important Mediterranean flora richness, about 500 plant species including endemic species (Henaoui 2012). These plant taxa are the result of the degradation of several plant structures (Zéen oak forest, cork oak and Thuya forests) which *Cistus* plant communities are part of this dynamic.

Our article synthesises two articles published in 2013 (Henaoui et al. 2013a, Henaoui et al. 2013b). The objective of our study is to estimate the degree of various flammability parameters as a function of the water content of their floristic cortège during the spring season in order to elucidate their sensitivity to fire. In order to better understand the problem, we asked a few questions:

- Do *Cistus* plant communities present an alarming fire risk?
- Does the spring season influence the degree of flammability and the combustibility of plant species in the Tlemcen and Traras mountains?

- How would be the reaction of the flammability parameters with respect to the water content of the studied plant taxa?
- How much will be the percentage of flammability and combustibility of the two mountain ranges biological material?
- Is there a relation between the studied three parameters of flammability (time of ignition, duration of combustion and intensity of combustion) according to the water content?
- What are the flammability parameters that mark each plant group according to its water content?
- Which strata are most sensitive to fire?

STUDY AREA

The study is located in the north-western part of Algeria. The study area is divided into two parts: one located in the mountains of Tlemcen and the other near the coast with rugged mountainous terrain (integral part of Traras Mountains). The stations choice mainly depends on the presence of pre-forest formations and shrubland. The area studied is located between 34° and 35°25' North and 0°55' and 2°30' West and covers a 9017.69 km² area. It is

limited geographically (Figure 1): To the north by the Mediterranean Sea, in the north-east by the wilaya of Aïn-Témouchent, to the east by the wilaya of Sidi-Bel-Abbès, to the west by Morocco. The stations of our study area are: Zarifet, Aïn-Fezza, Nedroma, Ghazaouet, Beni-Saf and Ouled-Mimoun (Figure 1). The bioclimate is the superior semi-arid (Henaoui 2013).

MATERIALS AND METHODS

In order to determine the sensitivity to fire of the vegetation formations of the study area (Tlemcen and Traras mountains), I adopted the method of the INRA of Avignon (Valette 1990, Moro 2004) and (Hachmi et al. 2011, Essaghi et al. 2017). The 38 plant species selected to quantify the flammability degree are listed in Table 1.

Basic Method

I improved upon the two previously mentioned methods of (Valette 1990, Moro 2004) and (Hachmi et al, 2011, Essaghi et al. 2017) by eliminating the frequency of inflammation used by these authors. Various parameters taken into consideration were: ignition delay, burning

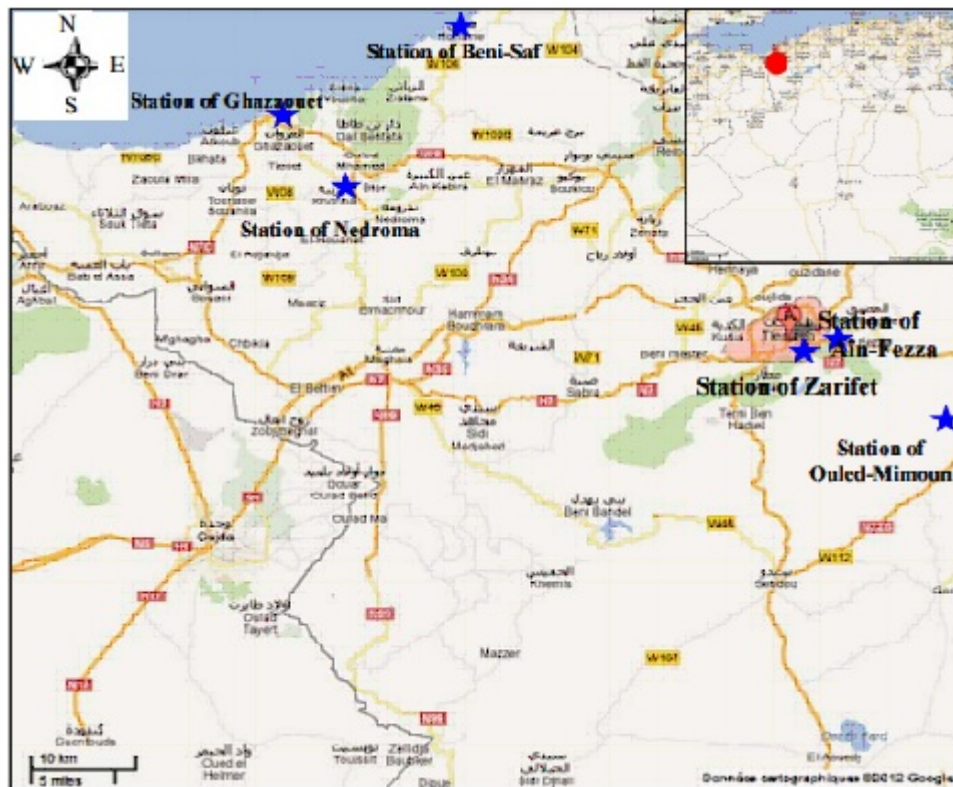


Figure 1. Location of study area (Henaoui 2013).

Table 1. Classification of plant species according to the flammability, combustibility, combustion intensity and water content. The classes are:

Flammability (Second): 1 (low) - ≥ 130 ; 2 (moderate) - $>65 < 130$; 3 (high) - ≤ 65 Combustibility (Second): 1 (low) - ≥ 102 ; 2 (moderate) - $>73 < 102$; 3 (high) - ≤ 73 Intensity of combustion (cm): 1 (Low) - ≤ 10 ; 2 (Average) - $>10 < 20$; 3 (High) - ≥ 20 Water content (%): 1 (low) - ≤ 50 ; 2 (Average) - $>50 < 65$; 3 (High) - ≥ 65

Scientific names	Family	Flammability	Combustibility	Combustion Intensity	Water Content
<i>Cistus ladaniferus</i> subsp. <i>africanus</i>	Cistaceae	3	3	3	3
<i>Cistus monspeliensis</i>	Cistaceae	3	3	3	3
<i>Ampelodesma mauritanicum</i>	Poaceae	3	3	3	1
<i>Arbutus unedo</i>	Ericaceae	3	2	3	2
<i>Asparagus albus</i>	Liliaceae	3	2	2	2
<i>Asparagus stipularis</i>	Liliaceae	3	2	3	2
<i>Calycotome intermedia</i>	Fabaceae	3	3	3	3
<i>Acacia cyanophylla</i>	Fabaceae	3	2	3	3
<i>Ceratonia siliqua</i>	Caesalpiniaceae	3	2	3	2
<i>Crataegus oxyacantha</i>	Rosaceae	3	3	2	2
<i>Cytisus triflorus</i>	Fabaceae	3	3	3	2
<i>Erica arborea</i>	Ericaceae	3	1	3	1
<i>Echium vulgare</i>	Boraginaceae	3	1	2	3
<i>Galium verum</i>	Rubiaceae	3	2	3	3
<i>Globularia alypum</i>	Globulariaceae	3	2	3	3
<i>Juniperus oxycedrus</i>	Cupressaceae	3	2	3	2
<i>Lavandula dentata</i>	Lamiaceae	3	1	1	3
<i>Lavandula stoechas</i>	Lamiaceae	3	3	3	1
<i>Olea europaea</i>	Oleaceae	3	3	3	2
<i>Phagnalons axatile</i>	Asteraceae	3	1	2	2
<i>Pinus halepensis</i>	Pinaceae	3	3	3	2
<i>Quercus faginea</i> subsp. <i>ilemceciensis</i>	Fagaceae	3	3	3	3
<i>Quercus suber</i>	Fagaceae	3	3	3	1
<i>Rhamnus alaternus</i>	Rhamnaceae	3	2	3	1
<i>Lonicera implexa</i>	Caprifoliaceae	3	1	2	3
<i>Prasium majus</i>	Lamiaceae	3	1	2	3
<i>Rosa canina</i>	Rosaceae	3	3	3	2
<i>Rubus ulmifolius</i>	Rosaceae	3	3	3	1
<i>Salvia verbenaca</i>	Lamiaceae	3	1	2	3
<i>Tetraclinis articulata</i>	Cupressaceae	3	3	3	2
<i>Thymus ciliatus</i> subsp. <i>coloratus</i>	Lamiaceae	3	1	2	2
<i>Ulex parviflorus</i>	Fabaceae	3	3	3	2
<i>Euphorbia helioscopiae</i>	Euphorbiaceae	3	2	2	3
<i>Ballota hirsuta</i>	Lamiaceae	2	1	2	3
<i>Chamaerops humilis</i> subsp. <i>argentea</i>	Palmaceae	2	3	3	1
<i>Daphne gnidium</i>	Thymeleaceae	2	3	3	2
<i>Withania frutescens</i>	Solanaceae	2	1	1	3
<i>Cistus salvifolius</i>	Cistaceae	1	3	1	3

time and flame height, thus expressing flammability, combustibility and combustion intensity (the time in seconds was calculated by a multi-stop timer for ignition delay and duration of combustion; flame height was measured using a scale in centimeter). The water content is a primary factor as to whether or not it influences the other parameters mentioned above. A sample of 2 g of fresh material for each taxon was placed in an oven at 120°C for 24 hours). The samples were collected during the spring season (April and May 2013), a test consisting of three samples of each taxon (the aerial part: leaves, stems, twigs and buds, 10g for each, weighed with an electric scale “0.1 g”). This test was carried out using an infrared burner, the temperature at which the samples began to burn was measured with a multimeter temperature probe which corresponds to position 10 (850°C).

In order to have a flammability rating for each plant species, two elements are required: the average of ignition times and the frequency of ignition. For our case, we only took the first one because all the subjects present positive tests when using the classes coming from the following formula:

$$\text{Class Interval} = \frac{\text{maximum value} - \text{minimum value}}{\text{number of classes}}$$

Other parameters (combustibility, combustion intensity and moisture content) were also assigned a value using the same classification principle.

RESULTS AND DISCUSSION

Flammability and Combustibility

Figures 2 and 3 show that in our whole study area, plant cover is represented by 87% of highly flammable plant species and 42% of highly combustible plant taxa, the relationship between which is explained by the process of outbreak and the spread of forest fires.

Intensity of Combustion and Moisture Content

For the entire study area, (Figure 4) shows that 63% of plant species have the high intensity of combustion. At the same time, Figure 5 shows that there is a percentage of 42% of plant taxa with high water content. These results can be explained by the combination of the amount of evaporated water releasing oxygen with that of the air associated with other gases and the presence of the volatile organic compounds contained in the biological material which act in a manner or another on the high intensity of the combustion of plants.

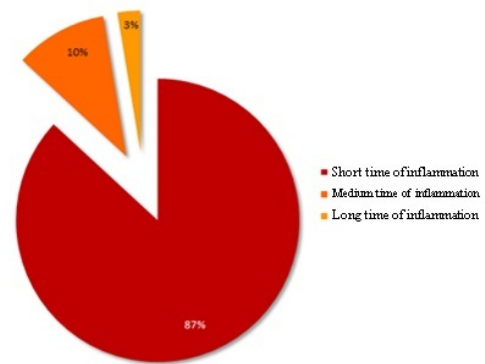


Figure 2. Flammability in the Study Area.

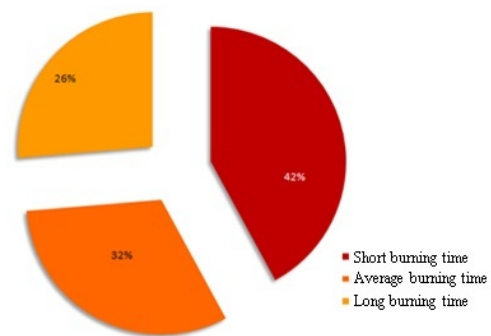


Figure 3. Combustibility in the Study Area.

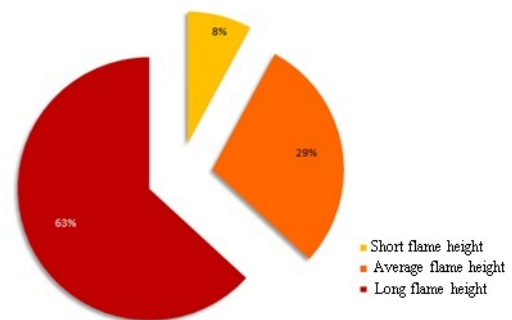


Figure 4. Intensity of combustion

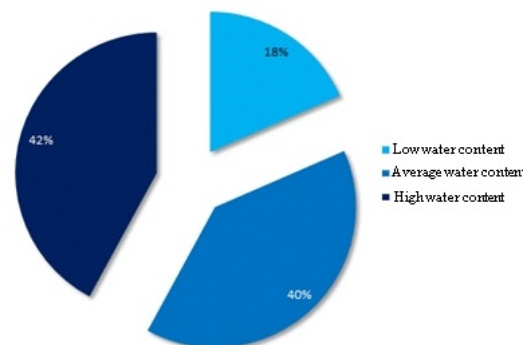


Figure 5. Water content

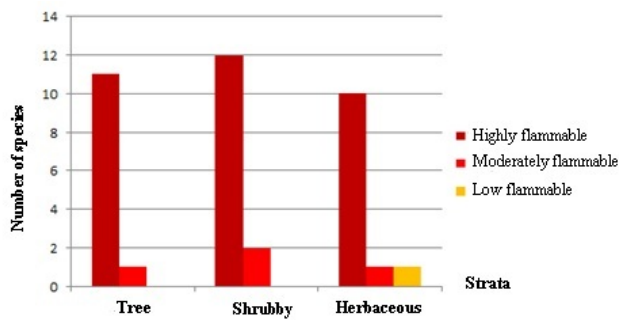


Figure 6. Flammability of the plant species according to the strata.

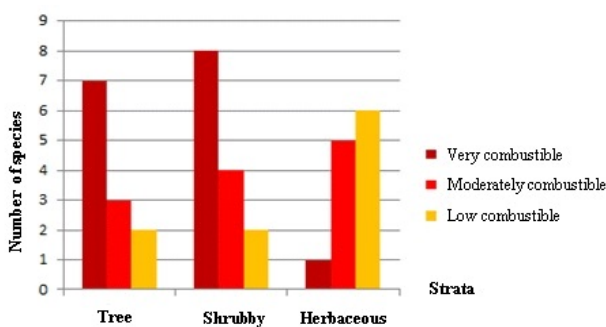


Figure 7. Combustibility of the plant species according to the strata.

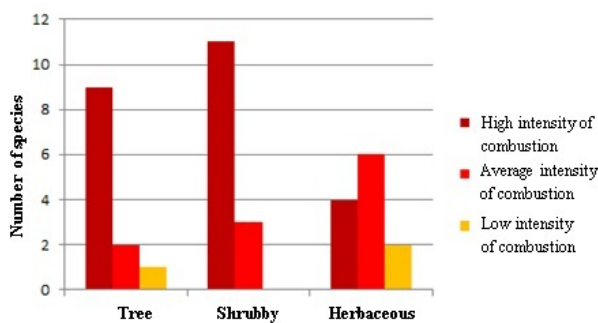


Figure 8. Intensity of combustion of plant species according to strata.

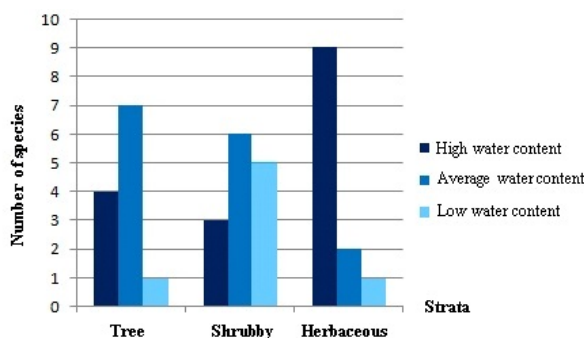


Figure 9. Water content of the plant species according to the strata.

Ranking

The flammability classification of forest species is an essential component of fuel hazard and fire risk assessment. They are important components of forest fire management planning (Le Houërou 1973, Trabaud 1976, Barney and Aldrich 1980). Louis Trabaud and Jean-François Galtié in their work on the evaluation of fire hazards have established a rating of the different species characterizing their predisposition to flammability and combustibility (Peyre 1991).

For our study area, the classification of plant species according to a score of each flammability parameter remains a fundamental step in order to better define the state of our forests (Table 1). We note that non-flammable plant species are: *Asphodelus microcarpus*, *Sedum acre*, *Urginea maritima* and *Smilax aspera*.

Classification of Flammability Parameters and Water Content According to Strata

Figure 6 shows that the three strata (tree, shrub and herbaceous) are dominated by highly flammable plants, moderately flammable taxa remain low in the three strata while low flammability species are located only in the herbaceous layer with a small amount.

Figure 7 shows that only the tree and shrub strata is dominated by highly combustible plants and a small amount of low combustible taxa against the herbaceous layer is dominated by taxa low combustible and a small amount of highly combustible plant species. The moderately combustible plant species are moderately represented for the three strata.

Figure 8 shows that the tree and shrub stratum is dominated by taxa with high combustion intensity whereas the herbaceous stratum is moderately represented by these plant species. The latter is dominated by medium-intensity combustion taxa with low representation for low-intensity plant species. Medium and low combustion intensity is poorly represented for the tree and shrub strata.

Figure 9 shows that high-water content taxa occur at the herbaceous stratum while they are moderately represented in the tree and shrub stratum. On the other hand, the medium-water content plant species are located at the tree and shrub stratum, whereas in the herbaceous layer they are weakly represented. The taxa, with low water content, are highly represented in the shrub stratum, whereas in the tree and herbaceous stratum they

are represented by small quantities. We can conclude that the tree stratum and the shrub layer remain the most vulnerable to fires in our study area.

Relationship Between Flammability and Moisture Content of Plant Species

The analysis of the flammability variations allows us to prioritize between species according to this criterion and to follow the evolution of the index of the risk of fires outbreak presented by the main species, taking into account their respective places in the different forest formations (Valette 1990).

From Figure 10, it can be seen that there is a large variation between the average ignition times and the water content of the studied plant taxa. In the degraded forests with *Quercus suber* and *Quercus faginea* (mounts of Tlemcen), there are plant species that are highly flammable despite their high water content (*Cistus ladaniferus* subsp. *ladaniferus*, *Cistus monspeliensis*, *Calycotome intermedia*, *Arbutus unedo* and *Lonicera implexa*). There are plant species that have a long delay

of inflammation and a high water content (the case of *Cistus salvifolius*). For the degraded forests with *Tetraclinis articulata* (Mountains Traras) there are plant species that have a short ignition delay and a high water content (*Tetraclinis articulata*, *Asparagus albus*, *Asparagus stipularis* and *Cistus monspeliensis*) while we have plant species that are less flammable despite their high water content (*Daphne gnidium* and *Ballota hirsuta*).

From these results it can be concluded that during the spring season, the water content is not the only factor that influences the degree of flammability parameters of plant taxa. Plant physiology is behaving as an element associated with the expressed water content by the composition of volatile organic compounds (VOC) which determines the phenomenon of outbreak of forest fires. To this end, some Mediterranean plants produce and emit volatiles that can be found in very high concentrations in the atmosphere, thus influencing strongly the risk of flammability of vegetation and promoting the spread of fire (Robles et al. 2003).

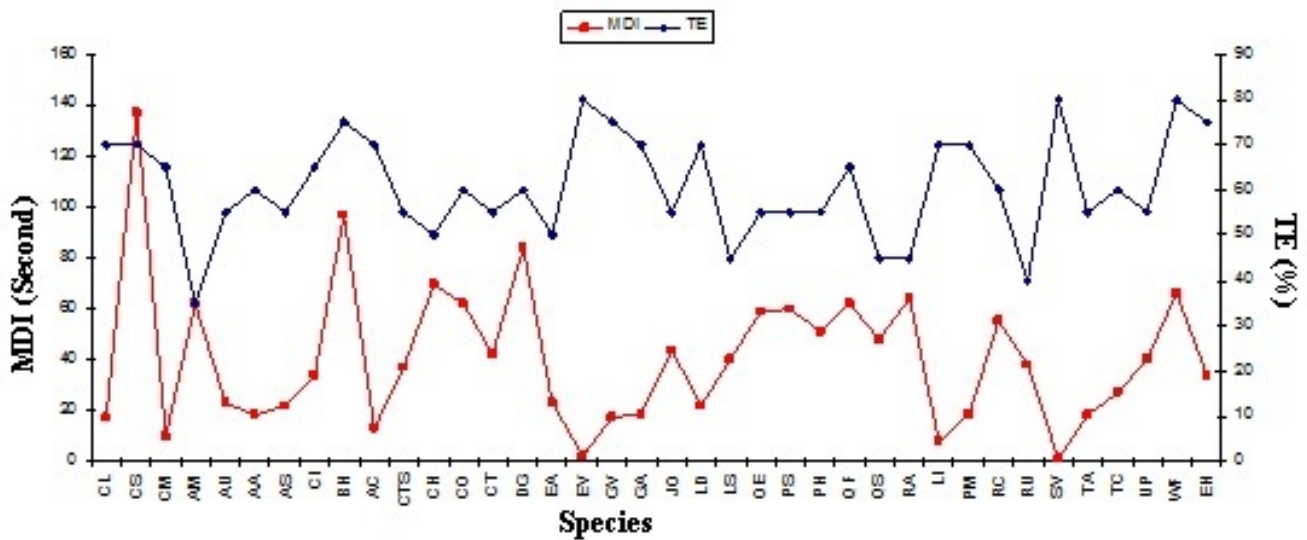


Figure 10. MDI variation "Mean time to ignition" according to TE (%) "Moisture content".

CL : *Cistus ladaniferus* subsp. *africanus*, CS : *Cistus salvifolius*, CM : *Cistus monspeliensis*, AM : *Ampelodesma mauritanicum*, AA : *Asparagus albus*, AS : *Asparagus stipularis*, CI : *Calycotome intermedia*, BH : *Ballota hirsuta*, AC : *Acacia cyanophylla*, CTS : *Ceratonia siliqua*, CH : *Chamaerops humilis* subsp. *argentea*, CO : *Crataegus oxyacantha*, CT : *Cytisus triflorus*, DG : *Daphne gnidium*, EA : *Erica arborea*, EV : *Echium vulgare*, GV : *Galium verum*, GA : *Globularia alypum*, JO : *Juniperus oxycedrus*, LD : *Lavandula dentata*, LS : *Lavandula stoechas*, OE : *Olea europaea*, PS : *Phagnalon saxatile*, PH : *Pinus halepensis*, QF : *Quercus faginea* subsp. *tlemceniensis*, QS : *Quercus suber*, RA : *Rhamnus alaternus*, LI : *Lonicera implexa*, PM : *Prasium majus*, RC : *Rosa canina*, RU : *Rubus ulmifolius*, SV : *Salvia verbenaca*, TA : *Tetraclinis articulata*, TC : *Thymus ciliatus* subsp. *coloratus*, UP : *Ulex parviflorus*, WF : *Withania frutescens*, EH : *Euphorbia helioscopiae*.

Table 2. Descriptive statistics.

Variable	Observations	Observations with missing data	Observations without missing data	Minimum	Maximum	Average	Standard deviation
MDI	38	0	38	1.000	137.000	40.658	28.178
MDC	38	0	38	29.000	161.000	81.368	32.790
MHF	38	0	38	9.000	56.000	23.474	9.622
TE	38	0	38	35.000	80.000	60.789	11.362

MDI :Average time of ignition (second) ; MDC : Average duration of combustion (second) ; MHF : Average flame heights (cm) ; TE : The water content (%).

Statistical treatment "Factor Analysis"

To make our data more explanatory, we performed a factor analysis with XLSTAT 2010 (www.xlstat.com). The statistical treatment gave us the following results:

The first results are the simple descriptive statistics of the selected variables (Table 2) and then the correlation matrix for these variables (Table 3). Some correlations are important (0.514 for the average flame height (MHF) and the water content (TE), -0.444 for the average ignition delay (MDI) and the average combustion times (MDC), -0.433 for MDC and MHF). The standardized Cronbach alpha is then calculated. Its value here is -2.701.

Table 3. Correlation Matrix [Pearson (n)].

Variables	MDI	MDC	MHF	TE
MDI	1	-0.444	-0.077	-0.189
MDC	-0.444	1	-0.433	0.318
MHF	-0.077	-0.433	1	-0.514
TE	-0.189	0.318	-0.514	1

Table 4. Own values and inertia rate (Figure 11)

	F1	F2	F3
Own values	1.612	1.027	0.014
Variability (%)	40.308	25.674	0.354
% accrued	40.308	65.982	66.337

The eigenvalues from the factor analysis are displayed in Table 4. We note that with three factors, 66.337% of the variability of the initial data is retained.

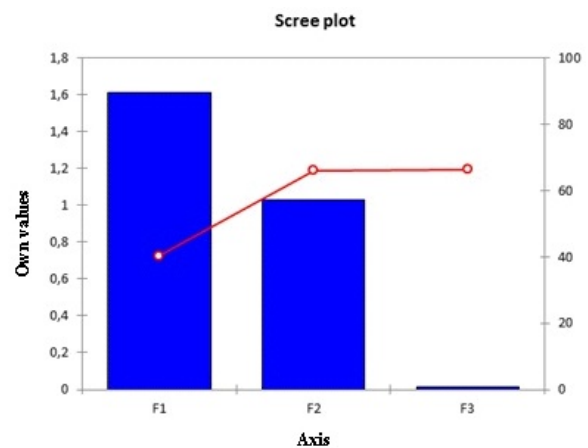


Figure 11. Own values.

Results after Varimax Rotation

Tables 5 and 6 show that the first factor is strongly related to MDI, MHF and TE. The second factor is related to MDI. From these results, it can be deduced that the plant species which have high coordinates on the first factor are highly combustible taxa with a high water content while plant species that have high coordinates on the second factor are highly flammable taxa (see Figure 12). Table 7 lists the coordinates of the individuals on the factor axes after the Varimax rotation.

Table 5. Percentage of variance after Varimax rotation.

	D1	D2
Variability (%)	37.233	28.594
% accrued	37.233	65.826

Table 6. Factorial coordinates after Varimax rotation.

	D1	D2
MDI	0.017	0.944
MDC	-0.470	-0.459
MHF	0.996	-0.094
TE	-0.526	-0.183

The values in bold correspond for each observation to the factor for which the square cosine is the largest.

Table 7. Coordinates of observations after Varimax rotation.

	Abbreviation	D1	D2
<i>Cistus ladaniferus</i>	CL	-0.445	-0.725
<i>Cistus salvifolius</i>	CS	-1.078	3.282
<i>Cistus monspeliensis</i>	CM	-0.046	-1.036
<i>Ampelodesma mauritanicum</i>	AM	1.146	0.778
<i>Arbutus unedo</i>	AU	-0.120	-0.537
<i>Asparagus albus</i>	AA	-0.654	-0.721
<i>Asparagus stipularis</i>	AS	0.090	-0.614
<i>Calycotome intermedia</i>	CI	3.392	-0.358
<i>Ballota hirsuta</i>	BH	-0.665	1.742
<i>Acacia cyanophylla</i>	AC	-0.452	-0.915
<i>Ceratonia siliqua</i>	CTS	1.306	-0.248
<i>Chamaerops humilis</i>	CH	0.249	1.005
<i>Crataegus oxyacantha</i>	CO	-0.614	0.808
<i>Cytisus triflorus</i>	CT	-0.264	0.103
<i>Daphne gnidium</i>	DG	-0.011	1.490
<i>Erica arborea</i>	EA	-0.103	-0.716
<i>Echium vulgare</i>	EV	-0.686	-1.329
<i>Galium verum</i>	GV	0.194	-0.805
<i>Globularia alypum</i>	GA	1.145	-0.801
<i>Juniperus oxycedrus</i>	JO	-0.262	0.206
<i>Lavandula dentata</i>	LD	-1.574	-0.580
<i>Lavandula stoechas</i>	LS	0.356	-0.036
<i>Olea europaea</i>	OE	1.788	0.577
<i>Phagnalon saxatile</i>	PS	-0.488	0.460
<i>Pinus halepensis</i>	PH	0.501	0.373
<i>Quercus faginea</i>	QF	-0.718	0.833
<i>Quercus suber</i>	QS	1.109	0.279
<i>Rhamnus alaternus</i>	RA	0.545	0.745
<i>Lonicera implexa</i>	LI	-0.992	-1.071
<i>Prasium majus</i>	PM	-1.154	-0.786
<i>Rosa canina</i>	RC	0.101	0.501
<i>Rubus ulmifolius</i>	RU	1.176	-0.061
<i>Salvia verbenaca</i>	SV	-1.010	-1.298
<i>Tetraclinis articulata</i>	TA	0.279	-0.691
<i>Thymus ciliatus</i>	TC	-0.514	-0.456
<i>Ulex parviflorus</i>	UP	0.993	-0.058
<i>Withania frutescens</i>	WF	-1.406	0.805
<i>Euphorbia helioscopiae</i>	EH	-1.115	-0.144

The values in bold correspond for each observation to the factor for which the square cosine is the largest.

The dendrogram (Figure 13) clearly shows how the algorithm proceeds to group the plant species of the plant groups (in the study area according to the flammability parameters and the water content) and then the sub-groups. Finally, the algorithm gradually regrouped all the observations.

Coordinates of the variables (Axes D1 and D2: 65,83%) after Varimax rotation

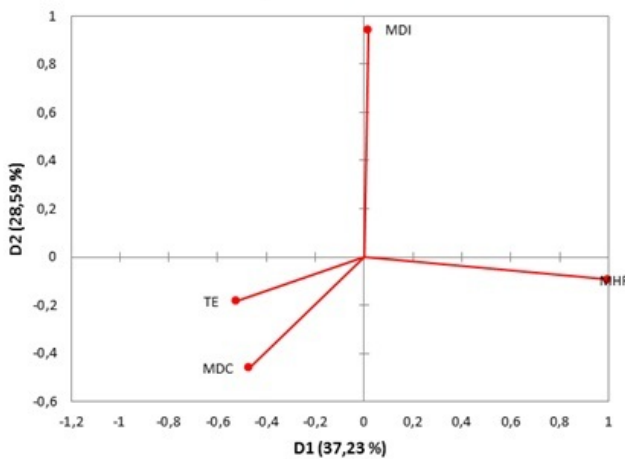


Figure 12. Position of the variables on F1 and F2 axes.

Dendrogram

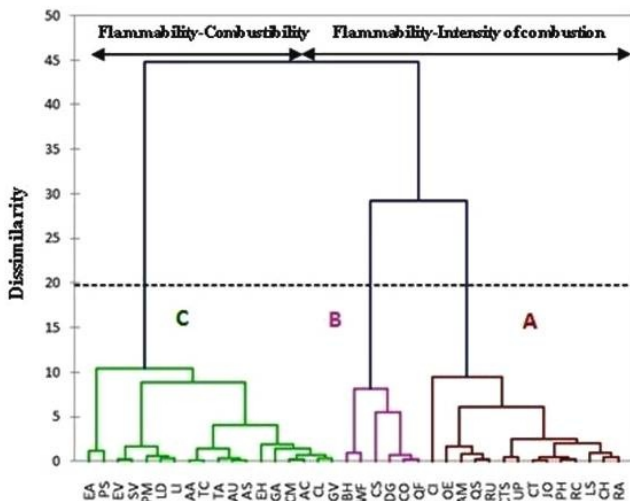


Figure 13. The dendrogram of plant species.

The dashed line represents the truncation and makes it possible to visualize that three homogeneous groups have been identified. The first group is more homogeneous than the third group (the dendrogram is flatter for the first group). The second group includes the *Quercus faginea subsp. tlemceniensis* taxa grouping.

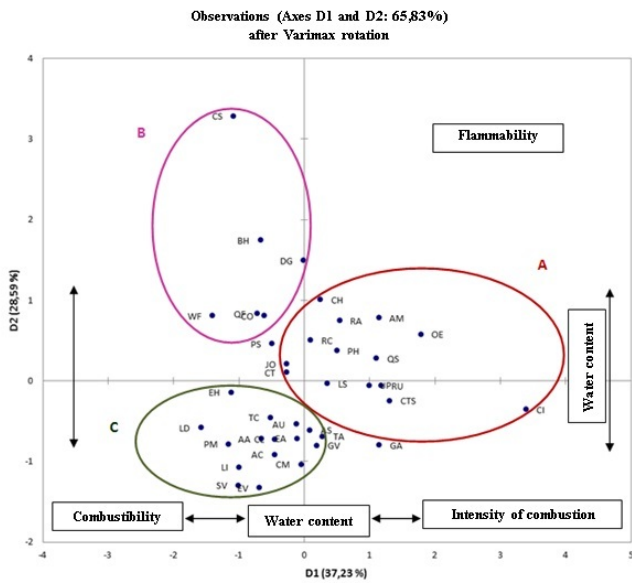


Figure 14. The factorial map “plant species” (Axis 1 and 2).

The factorial map (Figure 14) groups the plant species of the study area into 3 nuclei (A, B and C) according to the studied flammability parameters. Each nucleus corresponds to a plant group (A: *Quercus suber* grouping, B: *Quercus faginea subsp. tlemceniensis* grouping and C: *Tetraclinis articulata* grouping).

(1) Interpretation of axis 1: eigenvalue: 1.612, inertia rate: 40.308% (see Extended Data Table 4)

- The positive side of the axis 1 includes taxa of rings A and B (*Quercus faginea*, *Quercus suber*, *Rosa Canina*, *Juniperus oxycedrus*, *Crataegus oxyacantha*, *Cytisus triflorus* and *Ampelodema mauritanicum*) expressing and the flammability parameter is related to plant communities *Quercus suber* and *Quercus faginea*.

- The negative side of the axis 1 groups the plant species of rings A and C (*Calycotome intermedia*, *Lavandula stoechas*, *Ceratonia siliqua*, *Tetraclinis articulata*, *Cistus monspeliensis*, *Lavandula dentata*, *Asparagus albus*, *Ulex parviflorus* and *Asparagus stipularis*), reflecting that the intensity of combustion parameter and

that of combustibility influenced by the water content are related to the plant groups of *Quercus suber* and *Tetraclinis articulata*. For this purpose, Trabaud (1976) describes a trend where leaves with a lower percentage of water burn easily, while leaves with high leaf hydration rarely lit. Even if this was true for most species, an exception was found in the case of *Quercus pubescens*, which rapidly flared even at a high hydration level. The dependence of flammability on the water condition of plants and leaves is therefore also linked to other environmental factors, the life history and ecophysiology of the plant. Some species are more flammable than others at the same water content (Massari and Leopaldi 1998).

(2) Interpretation of axis 2: eigenvalue: 1.027, inertia rate: 65.982% (Table 4)

- The positive side of the axis 2 includes taxa of the three rings A, B and C (*Daphne gnidium*, *Quercus suber*, *Ampelodema mauritanicum*, *chamaerops*, *Ulex parviflorus*, *Olea europaea*, *Pinus halepensis*, *Lavandula stoechas*, *Rosa Canina*, *Ceratonia siliqua*, *Tetraclinis articulata*, *Asparagus stipularis*, *gallium verum* and *Calycotome intermedia*), which expresses the flammability parameter and the combustion intensity influenced by the water content are linked to the plant communities of the entire study area.

- The negative side of the axis 2 contains plant species of the three rings A, B and C (*Juniperus oxycedrus*, *Cytisus triflorus*, *Quercus faginea*, *Crataegus oxyacantha*, *Cistus salvifolius*, *Tetraclinis articulata*, *Thymus ciliatus*, *Lavandula dentata*, *Cistus monspeliensis* and *Asparagus albus*), thus indicating that the flammability parameter and that of the combustibility influenced by the water content are linked to the plant groups of the entire study area. In this regard, Valette (1990, 1974) and Schaffhauser (2008) specify that the combustibility of plant formations on the north side of the Mediterranean is assessed on the basis of specific flammability.

Notes

(1) Following the interpretation of axis 1 and 2 of the plant species factorial map (Figure 14), we find that the flammability parameters of the three plant groups in the study area are chained from the relationship point of view (flammability with combustibility, combustibility with combustion intensity and flammability with combustion intensity) which water content enters as an influencing parameter.

(2) One can also notice that the further away from Tlemcen mountains to Traras mountains the more flammability and combustibility of taxa increase and the further away the mountains of Traras to the mountains of Tlemcen the more flammability and the combustion intensity of increase.

CONCLUSION

The Tlemcen region is represented by different degraded forests (*Quercus faginea* subsp. *tlemceniensis*, *Quercus suber* and *Tetraclinis articulata*).

These plant formations occupy important areas based on: *Cistus ladaniferus* subsp. *africanus*, *Cistus salviifolius* and *Cistus monspeliensis*.

For the entire study area, plant species that have a short inflammation delay and short or long burning duration are: *Erica arborea*, *Arbutus unedo*, *Ceratonia siliqua*, *Lavandula stoechas*, *Ulex parviflorus*, *Thymus ciliatus* subsp. *coloratus*, *Lonicera implexa*, *Cytisus triflorus*, *Juniperus oxycedrus*, *Quercus faginea* subsp. *tlemceniensis*, *Quercus suber*, *Pinus halepensis*, *Cistus ladaniferus* subsp. *africanus*, *Calycotome intermedia*, *Crataegus oxyacantha*, *Cistus monspeliensis*, *lavandula dentata*, *Globularia alypum*, *Galium verum*, *Asparagus stipularis*, *Asparagus albus*, *Tetraclinis articulata*, *Olea europaea* and *Chamaerops humilis* subsp. *argentea*. The latter remain extremely sensitive to fire characterizing *Quercus suber*, *Quercus faginea* subsp. *tlemceniensis* and *Tetraclinis articulata* degraded forests from the mountains of Tlemcen and the mountains of Traras respectively.

There is an irregularity between the flammability and the water content of the plant species in the study area because each plant taxon is characterized by its own values. The tree stratum and the shrub stratum remain the most sensitive to fire throughout our study area.

Factor analysis of flammability parameters as a function of watercontent clearly shows that the *Cistus*-based plant groups in the study area are highly vulnerable and fire-sensitive.

It would be desirable to control forest fires and avoid their recurrence; because too close frequencies destroy plant diversity and distant frequencies enriches the phylogenetic potential.

The management of the forest against devastating fires results in the setting up of combustible cuttings in the field (Duche and Rigolot 2000).

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