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EUFIRELAB:

**Euro-Mediterranean Wildland Fire Laboratory,
a “wall-less” Laboratory
for Wildland Fire Sciences and Technologies
in the Euro-Mediterranean Region**

Deliverable D-02-02

**Physical, chemical and thermal characteristics of the
wildland fuel particles**

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SUMMARY

This document presents an inventory of the existing quantitative knowledge concerning fuel characteristics of particles. Methodologies and equipments have not been considered as they will be object of Deliverable D-02-03.

This document is divided into three main sections.

- the first includes the objective of this Deliverable and describes the sequence of steps which lead to its preparation.
- the second presents the state of the art in physical, chemical and thermal characteristics of the wildland fuel particles carried out by partner members: this was done through a questionnaire that surveyed members on their own pre-existing data.
 - the questionnaire itself, and
 - a summary of the responses (full responses of each research team are included in D-07-03_A);
- the third and final section of the deliverable presents an overview of the responses, presents some particular cases and draws some general trends, and outlines some conclusions.

LIST OF ASSOCIATED DOCUMENTS

| Name of the file | Title of the file | Content of the file |
|------------------|--|---|
| D-02-02_A | Physical, chemical and thermal characteristics of the wildland fuel particles: Answers from the partners | Full responses of each partner to the questionnaire |

1 INTRODUCTION

As it was already commented in Deliverable D-02-01, Physical, Chemical and Thermal properties of fuel particles are assessed at the level of the individual particle or element (leaf, spine, stalk, twig, branch, stem, etc.), or of compounded particles belonging to the same biological entity, e.g. the assemblage of leaves and small twigs of a given shrub species.

These properties have a direct effect on moisture relationships, heat transfer, ignition, and combustion.

Consequently, fuel particle characteristics contribute to the prediction of wildland fire intensity and severity, with all its consequences on suppression difficulty and human safety.

Characterisation of fuel particles is therefore required to interpret the results of flammability experiments in the laboratory and as an input to semi-empirical and physical fire behaviour models.

However, the natural variation and effect on fire behaviour of several properties (particle density, mineral content) are so low that they are usually kept constant in fire behaviour modelling.

Consequently, the interest in the evaluation of fuel properties is restricted to fire researchers.

The exception is fuel moisture content, critical to predict the potential for fire ignition and fire behaviour, but this property can be assessed at multiple levels (particle, bed, complex).

The methodology to produce the present deliverable was the following:

1.- A preliminary questionnaire was prepared by P010 and uploaded to the EUFIRELAB web site, and participants were requested not to fill out the questionnaire but to assist in refining the final version.

The questionnaire asked about the different characteristics that are measured, calculated or determined.

2.- After receiving and integrating the comments on improving the questionnaire, its final version was uploaded to the EUFIRELAB web site to be filled out.

3.- The concerned partners downloaded the questionnaire, filled out the relevant information and uploaded their contributions to the same folder in the web site.

4.- Based on these contributions, a draft was prepared and uploaded again for comments and suggestions.

5.- A final version was written, taking into account the feedback received from the interested partners.

Deliverable D-02-02 is divided into three main sections.

The first describes the sequence of steps which lead to its preparation.

The second includes the questionnaire used and a summary of the responses to it (full responses of each partner are included in Annex).

The third section includes some comments about the information collected and draws some conclusions.

2 THE STATE OF THE ART AMONG PARTNER MEMBERS

2.1 THE QUESTIONNAIRE USED TO SURVEY MEMBERS

2.1.1 Introduction

The questionnaire is divided into six tables:

Table 1.- Fuel Classes:

- 1.1.- State of the fuels
- 1.2.- Size class of the fuels

Table 2: Physical Characteristics:

- 2.1.- Measured parameters (Length, Width...)
- 2.2.- Calculated parameters (Surface, Volume...)

Table 3: Chemical Characteristics (Moisture content, Ash content...)

Table 4: Thermal Characteristics (Heat content, Thermal degradation...)

Table 5: Other Characteristics (Flammability...)

Table 6: Studied species

2.1.2 Questionnaire

- 1) In Table 1, 2, 3, 4 and 5, place an "X" on the appropriate column if you measure, calculate or determine that characteristic. If the information was already included in other deliverables, put the deliverable number in the last column.
- 2) In Table 6, list the species you have studied and give for each of them mean values or range of values (max-min) obtained of each concerned characteristic.

2.2 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|--------------|--|
| 1 | State | |
| 1.1 | live | |
| 1.2 | dead | |

| | | |
|----------|------------------------------|--|
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | |
| 2.2 | Fosberg and Deeming modified | |
| 2.3 | Other | |
| 2.4 | | |

| | |
|------|---------------------|
| Ref. | Observations |
|------|---------------------|

2.3 TABLE 2: PHYSICAL CHARACTERISTICS

| Ref. | Measured parameters | Data | Previous deliverable |
|--|---------------------|---|----------------------|
| 1.1 1.2 1.3 1.4 1.5 1.6 1.7 | Leaves | Length Width Thickness Diameter Mass Volume Other | |
| 1.8 1.9 1.10 1.11 1.12 1.13 1.14 | Needles | Length Width Thickness Diameter Mass Volume Other | |
| 1.15 1.16 1.17 1.18 1.19 1.20 1.21 | Twigs | Length Width Thickness Diameter Mass Volume Other | |
| 1.22 1.23 1.24 1.25 1.26 1.27 1.28 | Barks | Length Width Thickness Diameter Mass Volume Other | |
| 1.29 1.30 1.31 1.32 1.33 1.34 1.35 | Cones | Length Width Thickness Diameter Mass Volume Other | |
| 1.36 1.37 1.38 1.39 1.40 1.41 1.42 | Grasses | Length Width Thickness Diameter Mass Volume Other | |
| 1.43 1.44 1.45 1.46 1.47 1.48 1.49 | Other | Length Width Thickness Diameter Mass Volume Other | |

2 Calculated parameters

| | | Data | Previous deliverable |
|------|---------------------|--------------------------|----------------------|
| 2.1 | Surface | Leaves | |
| 2.2 | | Needles | |
| 2.3 | | Twigs | |
| 2.4 | | Other | |
| 2.5 | Volume | Leaves | |
| 2.6 | | Needles | |
| 2.7 | | Twigs | |
| 2.8 | | Other | |
| 2.9 | Ratios | Surface to volume | |
| 2.10 | | Mass to volume | |
| 2.11 | | Other | |
| 2.12 | Other | | |
| 2.13 | | | |
| Ref. | Observations | | |

2.4 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|-------------------------|---------|----------------------|
| 1 | Moisture content | | |
| 2 | Ash content | | |
| 3 | Chemical content | Element | Previous deliverable |
| 3.1 | | | |
| 3.2 | | | |
| 4 | Other characteristics | Data | Previous deliverable |
| 4.1. | | | |
| Ref. | Observations | | |

2.5 TABLE 4: THERMAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|----------------------------|------|----------------------|
| 1 | Thermal degradation | | |
| 2 | Heat content | | |
| 3 | Specific heat | | |
| 4 | Other | | |
| 5 | Other | | |
| Ref. | Observations | | |

2.6 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|---------------------|------|----------------------|
| 1 | Flammability | | |
| 2 | Other | | |
| 3 | Other | | |
| Ref. | Observations | | |

2.7 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|---------|---|--------------------------------|-----------------|----------------------|--------------------------|---------------------|----------------------|-----------------------|--------------|-------|
| | S/V ratio (m ² /m ³) | M/V ratio (Kg/m ³) | Ash content (%) | Moisture content (%) | Chemical composition (%) | Thermal degradation | Heat content (KJ/Kg) | Specific heat (KJ/Kg) | Flammability | Other |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

3 SUMMARY OF THE RESPONSES TO THE QUESTIONNAIRE

3.1 INTRODUCTION

Among the members that were solicited to contribute, 8 partners responded: P001, P009, P010, P013, P018, P025, P026 and P033.

The results below, based on these responses, are presented in terms of the partners who measure, calculate or determine the concerned characteristic (Tables 1, 2, 3, 4 and 5).

For the Table 6 the results are presented as an inventory of the existing knowledge concerning characteristics of the wildland fuel particles.

The full responses are included in Annex (D-02-02_A)

3.2 VARIABLE OR CHARACTERISTIC MEASURED OR CALCULATED

| Ref. | | Partners |
|----------|------------------------------|---|
| 1 | State | |
| 1.1 | live | P001,P009,P010,P013,P018,P025,P026,P033 |
| 1.2 | dead | P001,P009,P010,P013,P018,P025,P026,P033 |
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | P018,P010,P025 |
| 2.2 | Fosberg and Deeming modified | P001,P010,P013,P018,P025 |
| 2.3 | Other | Brown P033 Smaller size class |
| 2.4 | | <2,5 mm, < 3 mm P025 |
| 2.5 | | FCC system modified P026 |

3.3 TABLE 2: PHYSICAL CHARACTERISTICS

| Ref. | 1 | Measured parameters | Partners |
|------|----------------|------------------------|------------------------------------|
| 1.1 | Leaves | Length | P001, P010, P018 |
| 1.2 | | Width | P001, P010, P018 |
| 1.3 | | Thickness | P001, P010, P018, P025, P033 |
| 1.4 | | Diameter | P013, P018 |
| 1.5 | | Mass | P001, P010, P13, P018, P025, P033 |
| 1.6 | | Volume | P001, P013, P018, P025 |
| 1.8 | Needles | Length | P010, P018, P025 |
| 1.9 | | Width | P010, P018, P025 |
| 1.10 | | Thickness | P001, P010, P018, P025 |
| 1.11 | | Diameter | P001, P013, P018, P025, P033 |
| 1.12 | | Mass | P001, P010, P013, P018, P025, P033 |
| 1.13 | Volume | P001, P013, P018, P025 | |
| 1.15 | Twigs | Length | P010, P025 |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | P001, P010, P013, P018, P025, P033 |
| 1.19 | | Mass | P001, P010, P013, P018, P025, P033 |
| 1.20 | Volume | P001, P013, P018, P025 | |
| 1.22 | Barks | Length | P010 |
| 1.23 | | Width | P010 |
| 1.24 | | Thickness | P001, P010, P018, P033 |
| 1.25 | | Diameter | P001, P013 |
| 1.26 | | Mass | P001, P013, P018, P033 |
| 1.27 | Volume | P013 | |
| 1.29 | Cones | Length | P010 |
| 1.30 | | Width | P010 |
| 1.31 | | Thickness | P010 |
| 1.32 | | Diameter | P033 |
| 1.33 | | Mass | P010, P018, P033 |
| 1.34 | Volume | | |

| | | | |
|------|---|-------------------|------------------------|
| 1.36 | Grasses | Length | |
| 1.37 | | Width | |
| 1.38 | | Thickness | P033 |
| 1.39 | | Diameter | P025, P033 |
| 1.40 | | Mass | P013, P018, P025, P033 |
| 1.41 | | Volume | P013, P025 |
| 1.43 | Mosses | Length | |
| 1.44 | | Width | |
| 1.45 | | Thickness | P033 |
| 1.46 | | Diameter | |
| 1.47 | | Mass | P026, P033 |
| 1.48 | | Volume | |
| 1.50 | Single tree | Length | P009, P033 |
| 1.51 | | Width | P009 |
| 1.52 | | Thickness | |
| 1.53 | | Diameter | P009, P033 |
| 1.54 | | Mass | P009 |
| 1.55 | | Volume | P009, P033 |
| 1.56 | | Crown base height | P033 |
| 1.57 | Trunks, slash, litter, lichens, duff | Length | |
| 1.58 | | Width | |
| 1.59 | | Thickness | |
| 1.60 | | Diameter | |
| 1.61 | | Mass | P026 |
| 1.62 | | Volume | |

2 Calculated parameters

| | | Partners | |
|------|----------------|--------------------------|---|
| 2.1 | Surface | Leaves | P001, P018, P025 |
| 2.2 | | Needles | P001, P010, P018, P025 |
| 2.3 | | Twigs | P001, P018, P025 |
| 2.5 | Volume | Leaves | P001, P013, P018, P025 |
| 2.6 | | Needles | P001, P013, P018, P025 |
| 2.7 | | Twigs | P001, P013, P018, P025 |
| 2.9 | Ratios | Surface to volume | P001, P010, P013, P018, P025, P033 |
| 2.10 | | Mass to volume | P001, P009(individual tree), P018, P025 |
| 2.11 | | Surface to mass | P025 |

3.4 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Partners |
|------|-------------------------|--|
| 1 | Moisture content | P001, P009, P010, P013, P018, P025, P026, P033 |
| 2 | Ash content | P001, P018, P025 |
| 3 | Chemical content | P026 (duff) |

3.5 TABLE 4: THERMAL CHARACTERISTICS

| Ref. | | Partners |
|------|----------------------------|------------------|
| 1 | Thermal degradation | P001 |
| 2 | Heat content | P001, P010, P018 |
| 3 | Specific heat | |

3.6 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Partners |
|------|--|------------------------|
| 1 | Flammability | P001, P010, P013, P026 |
| 2 | Combustibility | P013 |
| 3 | Live fuel moisture content (Remote sensing) | P033 |

3.7 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|-----------------------------------|------------|-----|-------------|------------------|-------------|----------------------|--------------|---------------|---------------|------------------------|
| | S/V | M/V | Ash content | Moisture content | Chem. Comp. | Thermal degradation. | Heat content | Specific heat | Flam-mability | Moisture of extinction |
| <i>Abies alba</i> | X | | | X | | | | | | X |
| <i>Abies cephalonica</i> | | | | | | | | | X | |
| <i>Acacia dealbata</i> | | | | | | | | | X | |
| <i>Acacia longifolia</i> | X | | | | | | | | | |
| <i>Acacia melanoxylon</i> | | | | | | | | | X | |
| <i>Agrostis spp.</i> | X | | | | | | | | | |
| <i>Alnus subcordata</i> | | | | | | | | | X | |
| <i>Anthyllis cytisoides</i> | | | | X | | | X | | X | |
| <i>Arbutus unedo</i> | X | | | X | | | X | | X | |
| <i>Arctostaphylos uva-ursi</i> | | | | X | | | | | X | |
| <i>Atriplex halimus</i> | | | | X | | | X | | X | |
| <i>Betula celtiberica</i> | | | | | | | X | | | |
| <i>Brachypodium pinnatum</i> | | | | | | | | | X | |
| <i>Brachypodium ramosum</i> | | X | X | | | | X | | X | |
| <i>Brachypodium retusum</i> | | | | X | | | | | | |
| <i>Buxus sempervirens</i> | | | | X | | | X | | X | |
| <i>Calluna vulgaris</i> | | | | | | | | | | |
| <i>Calycotome spinosa</i> | | | | | | | | | X | |
| <i>Calycotome villosa</i> | | | | X | | | X | | X | |
| <i>Castanea sativa</i> | X | | | X | | | | | X | X |
| <i>Cedrus atlantica</i> | | | | | | | | | X | |
| <i>Chamaespartium tridentatum</i> | X | X | X | X | | | X | | X | |
| <i>Cistus albidus</i> | | | | X | | | X | | X | |
| <i>Cistus clusii</i> | X | X | | | | | | | | |
| <i>Cistus crispus</i> | | | | X | | | X | | X | |
| <i>Cistus ladanifer</i> | X | | | X | | | X | | X | |
| <i>Cistus laurifolius</i> | | | | X | | | X | | X | |
| <i>Cistus monspeliensis</i> | X | | | | | | | | X | |
| <i>Cistus salvifolius</i> | | | | X | | | X | | X | |
| <i>Cladina spp</i> | | | | X | | | | | X | |
| <i>Corema album</i> | X | | | | | | | | | |
| <i>Cupressus arizonica</i> | | | | | | | | | X | |
| <i>Cupressus sempervirens</i> | | | | | | | | | X | |
| <i>Cytisus scoparius</i> | | | | X | | | X | | X | |
| <i>Cytisus striatus</i> | | X | | | | | | | | |
| <i>Cytisus triflorus</i> | | | | | | | | | X | |
| <i>Daboecia cantabrica</i> | | X | | | | | | | | |
| <i>Diranum spp</i> | | | | X | | | | | X | |
| <i>Erica arborea</i> | X | X | | X | | | X | | X | |
| <i>Erica australis</i> | X | X | | X | | | X | | X | |
| <i>Erica ciliaris</i> | | | | X | | | X | | X | |
| <i>Erica multiflora</i> | | | | X | | | X | | X | |
| <i>Erica scoparia</i> | | | | X | | | X | | X | |
| <i>Erica umbellata</i> | X | X | X | X | | | X | | X | |
| <i>Eucalyptus camaldulensis</i> | | | | X | | | X | | X | |
| <i>Eucalyptus dalrympleana</i> | | | | | | | | | X | |
| <i>Eucalyptus globulus</i> | X | X | | X | | | X | | X | |
| <i>Eucalyptus macarthuri</i> | | | | | | | | | X | |
| <i>Genista falcata</i> | | | | X | | | X | | X | |
| <i>Genista scorpius</i> | | | | X | | | | | | |
| <i>Halimium alyssoides</i> | X | X | | X | | | X | | | |
| <i>Halimium ocymoides</i> | X | X | | | | | | | | |
| <i>Hylocomium splendens</i> | | | | X | | | | | X | |
| <i>Juniperus oxycedrus</i> | X | X | | X | | | | | | |
| <i>Juniperus sabina</i> | X | X | | | | | | | | |
| <i>Juniperus turbinata</i> | X | | | | | | | | | |
| <i>Larix decidua</i> | x | | | x | | | | | | X |
| <i>Lavandula stoechas</i> | | | | X | | | X | | X | |
| <i>Myrica faya</i> | X | | | | | | | | | |
| <i>Myrtus communis</i> | X | | | | | | | | | |
| <i>Olea europaea</i> | X | | | X | | | X | | X | |

| Species | S/V | M/V | Ash content | Moisture content | Chem. Comp. | Thermal degradation. | Heat content | Specific heat | Flam-mability | Moisture of extinction |
|-----------------------------------|-----|-----|-------------|------------------|-------------|----------------------|--------------|---------------|---------------|------------------------|
| <i>Phillyrea angustifolia</i> | X | | | X | | | X | | X | |
| <i>Phyllirea latifolia</i> | | | | | | | | | | |
| <i>Pinus eldarica</i> | X | X | X | | | X | | | X | |
| <i>Pinus halepensis</i> | X | X | X | X | | X | X | | X | |
| <i>Pinus mugo grex arborea</i> | | | | X | | | | | | X |
| <i>Pinus mugo grex prostrata</i> | X | | | X | | | | | | X |
| <i>Pinus pinaster</i> | X | X | X | X | | X | X | | X | |
| <i>Pinus pinea</i> | X | X | X | X | | X | X | | X | |
| <i>Pinus radiata</i> | | | | X | | | X | | X | |
| <i>Pistacia lentiscus</i> | X | | | | | | | | | |
| <i>Pleurozium shreberi</i> | | | | X | | | | | X | |
| <i>Polypodium sp./Genista sp.</i> | X | | | X | | | | | | X |
| <i>Pteridium aquilinum</i> | X | X | | X | | | X | | X | |
| <i>Quercus coccifera</i> | X | X | X | X | | X | X | | X | |
| <i>Quercus ilex</i> | X | X | X | X | | | X | | X | |
| <i>Quercus pubescens</i> | | | | | | | | | X | |
| <i>Quercus pyrenaica</i> | | | | X | | | X | | X | |
| <i>Quercus suber</i> | | | | X | | | X | | X | |
| <i>Rosmarinus officinalis</i> | X | X | | X | | | X | | X | |
| <i>Rubus idaeus</i> | | | | X | | | X | | X | |
| <i>Stauracanthus boivinii</i> | | | | X | | | X | | X | |
| <i>Stipa tenacissima</i> | | | | X | | | X | | X | |
| <i>Thymus vulgaris</i> | X | X | | X | | | X | | X | |
| <i>Ulex europaeus</i> | X | X | | X | | | X | | X | |
| <i>Ulex minor</i> | X | X | | X | | | X | | X | |
| <i>Ulex parviflorus</i> | | X | | X | | | X | | X | |

Tabl 6 cont.

4 COMMENTS AND CONCLUSIONS

4.1 FUEL CLASSES

4.1.1 State

All the partners carry out measurements on live and dead fuel.

The state of the fuels is particularly important as it is closely connected with moisture content.

The moisture content of dead material (litter, dead needles and leaves,..) varies fairly quickly according to the ambient conditions.

Nevertheless the moisture content of leaving material varies more slowly according to seasonal variations of the ambient.

4.1.2 Size class

Particle size categories are not standard across the world, which hinders comparability of fuel data and fire behaviour models.

Although it is generally agreed that fine fuels are those with diameters below 6 mm, this is not a universal rule.

Most of the partners (P001, P010, P013, P018 and P025) use the FOSBERG and DEEMING modified classification.

P033 uses the classification of BROWN, P026 the FCC system modified and P025 other.

4.2 PHYSICAL CHARACTERISTICS

Specific physical parameters characterise each fuel family.

These parameters are:

- either determined by direct measurements: measured parameters,
- or calculated and based on the above ones and some geometrical assumptions: calculated parameters.

Length, width, thickness or diameter, mass and volume belong to the first group.

Surface, volume and mass to volume or surface to volume ratios belong to the second group.

4.2.1 Measured parameters

Most partners measure these parameters on leaves, needles, and twigs. Some of them measure also barks, cones and grasses.

P033 and P026 are the partners who measure Mosses, and P009 and P033 take the measurements on individual trees.

P026 measures mass of trunk, slash, litter, lichens and duff as a whole.

4.2.2 Calculated parameters

Surface to volume ratio is an important input for some models of wildland fire behaviour.

So this parameter is calculated by most of the partners.

Mass to volume ratio is also determined by some of them, and P025 calculates surface to mass ratio.

4.3 CHEMICAL CHARACTERISTICS

4.3.1 Moisture content

As it has already been mentioned in Chapter 1 fuel moisture content is critical to predict the potential for fire ignition and fire behaviour.

Consequently all partners measure this characteristic.

4.3.2 Ash content

On the contrary, the ash content varies so slowly that we can consider that it is constant for a given fuel family.

This characteristic is only measured by P001, P018 and P025.

4.3.3 Chemical content

This characteristic is only considered by P026 who determines C; N; Ca, Mg, K, P content and pH on duff.

4.4 THERMAL CHARACTERISTICS

4.4.1 Thermal degradation

The only partner who measures this characteristic is P001.

4.4.2 Heat content

For a given fuel type, the first objective is to obtain a comprehensible measure of the potential thermal energy that can be released during the burning of the fuel.

The heat content of a species varies in accordance with location and collecting season.

So the second objective is to compare results:

- either of different fuel particles of the same species,
- or of the same fuel particles collected in different locations and/or seasons.

Heat content is determined by P001, P010 and P018.

4.5 OTHER CHARACTERISTICS

4.5.1 Flammability

In the studies we have carried out, "flammability" describes the time required until ignition of the fuel occurs (TRABAUD, 1976; DELABRAZE & VALETTE, 1974, VALETTE, 1990).

It is equivalent to the term "Ignitability" found in the Anglo-Saxon literature.

Flammability is determined by P001, P010, P013 and P026

4.5.2 Moisture of extinction and live fuel moisture content

Moisture of extinction is only measured by P033 and is not included in table 5, otherwise this parameter is included in table 6 as species studied data.

This partner also includes in "other characteristics" table, the estimation of live fuel moisture content with remote sensing methods.

4.6 STUDIED SPECIES

Table 6 is a summary of the existing data given by each Partner.

The document D02-02_A (Full responses of each Partner to the questionnaire) shows mean values and/or ranges of values for each parameter and species.

In some cases (Partners P001, P010 and P025) the table also contains data related to state and size class.

The total number of species is 87, 27 among them are trees and the rest are shrubs and grasses.

Trees with larger amount of data are *Pinus*, *Quercus* and *Eucalyptus*; in the case of shrubs, best known species are *Chamaespartium*, *Erica* and *Cistus*.

Thus, species like *Pinus halepensis*, *P. pinaster*, *P. pinea* and *Quercus coccifera* are those that have, overall, more studied parameters.

Forest ecosystems more affected by fires and with this kind of species, are also the ecosystems better studied from the point of view of physical, chemical and thermal characteristics of the particles.

The parameters better studied are moisture content, surface to volume ratio, and heat content.

The first and second ones are critical inputs in fire behaviour prediction models.

There are, also, data of flammability in most of the studied species.

On the other hand, the parameters less studied, and therefore with lacks of data in many species or even in all of them, are ash content, chemical composition, thermal degradation and specific heat.

A more detailed analysis, for all species as a whole, shows a lack of physical parameters data (S/V and M/V ratios) in many species that are plentiful in mediterranean ecosystems, like *Cistus* (*C.albidus*, *C. crispus*, *C.laurifolius*, *C.salvifolius*), *Erica* (*E. ciliaris*, *E.multiflora*, *E. scoparia*), *Quercus* (*Q.pubescens*, *Q.pyrenaica*, *Q.suber*), *Ulex* (*U.parviflorus*), *Calluna vulgaris*, *Cytisus sp.*, *Genista sp.*, *Lavandula sp.*, and *Thymus sp.* among others.

This fact is probably due to problems in data taking process.

4.7 CONCLUSIONS

As it has been shown, a large number of characteristics are measured and calculated for different species by some of the Consortium Partners.

With these collected data, we can come to the following conclusions :

1.- State and size class are basic parameters in order to study forest fuel particles, and they are studied by the whole of the Consortium Partners involved in this topic.

However, the existing diversity of criteria in the size classification requires future standardisation in order to develop common protocols.

2.- The majority of the Partners have studied the physical characteristics of leaves, needles and twigs.

Other particles, like barks, cones, grasses, mosses, trunks, slash, etc., are studied only by some Partners only and with less detail.

The outcome is that, currently, a large amount of S/V ratio data exists for many species in different state and size classes.

Nevertheless, data is lacking for some important species in Mediterranean ecosystems, a fact that future research should address.

3.- Apart from moisture content and, in some cases, ash content, the chemical characteristics are less studied.

Chemical composition data is lacking for all the studied species by the Partners.

4.- Thermal characteristics and flammability have been widely described by some of the research teams.

However, none of the Partners took measurements of specific heat, and therefore information of this property is not available.

In this sense, it is necessary to define the relative importance of this parameter in order to include it in future investigation lines.

5.- Data ranges provided by the Partners appear, for most of the studied species, representative enough to be used in the classification of those species in different states and size classes.

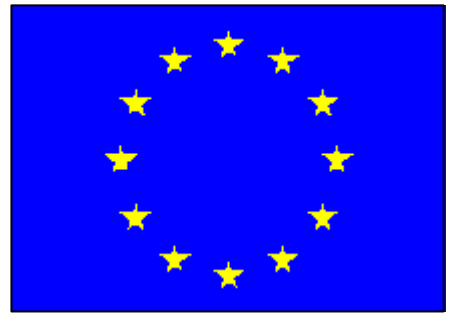
The models generated with such data can be considered as reliable enough, although a database to collect available and future information should be defined and created, in order to facilitate the data input process for fire behaviour modelling.

5 REFERENCES

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a “wall-less” Laboratory
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in the Euro-Mediterranean Region

Deliverable D-02-02_A

Physical, chemical and thermal characteristics of the
wildland fuel particles
Answer from the partners

Compiled by Carmen HERNANDO

May 2004

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1.1 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|------------------------------|---|
| 1 | State | |
| 1.1 | live | X |
| 1.2 | dead | X |
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | |
| 2.2 | Fosberg and Deeming modified | X |

1.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable | |
|----------|----------------------------|-------------|-----------------------------|-------------------|
| 1.1 | Leaves | Length | X | CF Firestar d6-01 |
| 1.2 | | Width | X | CF Firestar d6-02 |
| 1.3 | | Thickness | X | CF Firestar d6-03 |
| 1.4 | | Diameter | | |
| 1.5 | | Mass | X | CF Firestar d6-01 |
| 1.6 | | Volume | X | CF Firestar d6-02 |
| 1.7 | | Other | | |
| 1.8 | Needles | Length | | |
| 1.9 | | Width | | |
| 1.10 | | Thickness | X | CF Firestar d6-01 |
| 1.11 | | Diameter | X | CF Firestar d6-02 |
| 1.12 | | Mass | X | CF Firestar d6-03 |
| 1.13 | | Volume | X | CF Firestar d6-04 |
| 1.14 | | Other | | |
| 1.15 | Twigs | Length | | |
| 1.16 | | Width | | |
| 1.17 | | Thickness | | |
| 1.18 | | Diameter | X | CF Firestar d6-01 |
| 1.19 | | Mass | X | CF Firestar d6-02 |
| 1.20 | | Volume | X | CF Firestar d6-03 |
| 1.21 | | Other | | |
| 1.22 | Barks | Length | | |
| 1.23 | | Width | | |
| 1.24 | | Thickness | X | Ryan et al, 1993 |
| 1.25 | | Diameter | X | Ryan et al, 1993 |
| 1.26 | | Mass | | |
| 1.27 | | Volume | | |
| 1.28 | | Other | | |

| 2 | Calculated parameters | Data | Previous deliverable | |
|----------|------------------------------|--------------------------|-----------------------------|-------------------|
| 2.1 | Surface | Leaves | X | CF Firestar d6-01 |
| 2.2 | | Needles | X | CF Firestar d6-02 |
| 2.3 | | Twigs | X | CF Firestar d6-03 |
| 2.4 | | Other | | |
| 2.5 | Volume | Leaves | X | CF Firestar d6-01 |
| 2.6 | | Needles | X | CF Firestar d6-02 |
| 2.7 | | Twigs | X | CF Firestar d6-03 |
| 2.8 | | Other | | |
| 2.9 | Ratios | Surface to volume | X | CF Firestar d6-01 |
| 2.10 | | Mass to volume | X | CF Firestar d6-02 |
| 2.11 | | Other | | |

1.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|-------------------------|------|---|
| 1 | Moisture content | X | Moro C, annual report since 1990 (INRA-PIF) |
| 2 | Ash content | X | CF Firestar d6-03_A1 |

1.4 TABLE 4: THERMAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|----------------------------|------|----------------------|
| 5 | Thermal degradation | X | CF Firestar d6-03_A1 |
| 6 | Heat content | X | Doat & Valette, 1981 |
| 7 | Specific heat | | |

1.5 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|---------------------|------|----------------------|
| 8 | Flammability | X | Valette, 1990 |
| 9.1 | Other | | |
| 9.2 | Other | | |

1.6 TABLE 6: STUDIED SPECIES

| Species | fuel family | state | Parameters | | | | | | | | | |
|-----------------------|----------------------|-------|---|--------------------------------|--------------------|----------------------|----------------------|---------------------|----------------------|------------------------|-----------------------------------|--------|
| | | | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability (mark - in august -) | Others |
| Brachypodium ramosum | Grass | live | | 442 | 11,30 | | | | | 17638 | | |
| Pinus eldarica | Needles | dead | 5140 | 642 | 3,77 | | | | x | | | |
| Pinus halepensis | 2 mm < twigs < 6 mm | live | 1000 | 700 | | | | | | | | |
| Pinus halepensis | Needles | live | 6998 | 847 | 3,41 | | | | | 21130 | | |
| Pinus halepensis | Needles | dead | 6048 | 1.6.1.1.1.1 | 3,88 | | | | x | 22331 | | |
| Pinus halepensis | Needles | dead | 6167 | 706 | 3,61 | | | | x | | | |
| Pinus pinea | Needles | dead | 4271 | 554 | 4,46 | | | | x | | | |
| Pinus pinaster | Needles | dead | 2925 | 570 | 2,55 | | | | x | 21198 | | |
| Pinus pinaster | Needles | dead | 3061 | 568 | | | | | x | | | |
| Pinus pinaster | Needles | dead | 3017 | 652 | 2,45 | | | | x | | | |
| Pinus pinaster | Needles | dead | 3018 | 567 | 2,45 | | | | x | | | |
| Pinus pinaster | Needles | dead | 3007 | 490 | 1,16 | | | | x | | | |
| Quercus coccifera | 0 mm < twigs < 2 mm | live | 2780 | 900 | 3,88 | | | | x | 19212 | | |
| Quercus coccifera | 2 mm < twigs < 6 mm | live | 1070 | 930 | 3,89 | | | | x | 18943 | | |
| Quercus coccifera | Leaves | live | 5920 | 810 | 3,11 | | | | x | 19994 | | |
| Quercus ilex | 0 mm < twigs < 2 mm | live | 2490 | 878 | 5,23 | | | | | 18451 | | |
| Quercus ilex | 0 mm < twigs < 2 mm | live | 2450 | 935 | 0,00 | | | | | | | |
| Quercus ilex | 2 mm < twigs < 6 mm | live | 967 | 915 | 4,93 | | | | | 18246 | | |
| Quercus ilex | 2 mm < twigs < 6 mm | live | 959 | 970 | | | | | | | | |
| Quercus ilex | 6 mm < twigs < 25 mm | live | 412 | 924 | 3,97 | | | | | 18079 | | |
| Quercus ilex | 6 mm < twigs < 25 mm | live | 307 | 962 | | | | | | | | |
| Quercus ilex | Leaves | live | 4030 | 614 | 3,20 | | | | | 20055 | | |
| Quercus ilex | Leaves | live | 4050 | 571 | | | | | | | | |
| Brachypodium pinnatum | | | | | | | | | | | | 3 |
| Brachypodium ramosum | | | | | | | | | | | | 5 |
| Arbutus unedo | | | | | | | | | | 20869 | | 3 |
| Buxus sempervirens | | | | | | | | | | | | 2 |
| Calluna vulgaris | | | | | | | | | | | | 4 |
| Calycotoma spinosa | | | | | | | | | | | | 2 |
| Cistus albidus | | | | | | | | | | | | 2 |

| Species | fuel family | state | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability (mark - in august -) | Others |
|-------------------------|-------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|---|--------|
| Cistus montpellierensis | | | | | | | | | | | 3 | |
| Cistus salvaefolius | | | | | | | | | | | 1 | |
| Cytisus triflorus | | | | | | | | | | | 1 | |
| Erica arborea | | | | | | | | | 24058 | | 5 | |
| Erica scoparia | | | | | | | | | | | 5 | |
| Phyllirea latifolia | | | | | | | | | | | 5 | |
| Quercus coccifera | | | | | | | | | 19990 | | 4 | |
| Rosmarinus officinalis | | | | | | | | | | | 3 | |
| Thymus vulgaris | | | | | | | | | | | 5 | |
| Ulex parviflorus | | | | | | | | | 20902 | | 3 | |
| Abies cephalonica | | | | | | | | | | | 2 | |
| Acacia dealbata | | | | | | | | | | | 4 | |
| Acacia melanoxylon | | | | | | | | | | | 4 | |
| Alnus subcordata | | | | | | | | | | | 5 | |
| Castanea sativa | | | | | | | | | | | 5 | |
| Cedrus atlantica | | | | | | | | | | | 1 | |
| Cupressus arizonica | | | | | | | | | | | 1 | |
| Cupressus sempervirens | | | | | | | | | | | 2 | |
| Eucalyptus dalrympleana | | | | | | | | | | | 5 | |
| Eucalyptus Macarthuri | | | | | | | | | | | 5 | |
| Pinus halepensis | | | | | | | | | 22212 | | 4 | |
| Pinus pinaster | | | | | | | | | | | 3 | |
| Quercus ilex | | | | | | | | | 20279 | | 5 | |
| Quercus pubescens | | | | | | | | | | | 5 | |
| Quercus suber | | | | | | | | | | | 4 | |

2.1 TABLE 1: FUEL CLASSES

Ref.

| 1 | State | |
|-----|-------|---|
| 1.1 | live | X |
| 1.2 | dead | X |

Ref.

Observations

These data refer to complete individuals of 3 (n=71) and 9 (n=44) years old

2.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|------|---------------------|-----------|----------------------|
| 1.43 | Other | Length | X |
| 1.44 | | Width | X |
| 1.45 | | Thickness | |
| 1.46 | | Diameter | X |
| 1.47 | | Mass | X |
| 1.48 | | Volume | X |
| 1.49 | | Other | |

2

Calculated parameters

| | | Data | Previous deliverable |
|------|---------------|--------------------------|----------------------|
| 2.5 | Volume | Leaves | |
| 2.6 | | Needles | |
| 2.7 | | Twigs | |
| 2.8 | | Other individual | X |
| 2.9 | Ratios | Surface to volume | |
| 2.10 | | Mass to volume | X |
| 2.11 | | Other | |

2.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | | |

2.4 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|---|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|
| | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
| <i>Brachypodium retusum</i> live 3 years-old | | | | 46,7 | | | | | | |
| <i>Brachypodium retusum</i> dead 3 years-old | | | | 16,3 | | | | | | |
| <i>Cistus albidus</i> 3 years-old | | | | 68,1 | | | | | | |
| <i>Cistus albidus</i> 9 years-old | | | | 40 | | | | | | |
| <i>Erica multiflora</i> 3 years-old | | | | 90,4 | | | | | | |
| <i>Genista scorpius</i> 9 years-old | | | | 30,6 | | | | | | |
| <i>Juniperus oxycedrus</i> 3 years-old | | | | 92,6 | | | | | | |
| <i>Pinus halepensis</i> 3 years-old (Needles) | | | | 122,2 | | | | | | |
| <i>Quercus coccifera</i> 9 years-old | | | | 58,7 | | | | | | |
| <i>Rosmarinus officinalis</i> 3 years-old | | | | 107,9 | | | | | | |
| <i>Rosmarinus officinalis</i> 9 years-old | | | | 87,1 | | | | | | |
| <i>Ulex parviflorus</i> 3 years-old | | 5,11 | | 72,9 | | | | | | |
| <i>Ulex parviflorus</i> dead 3 years-old | | | | 7,3 | | | | | | |
| <i>Ulex parviflorus</i> 9 years-old | | 9,59 | | 30,9 | | | | | | |
| <i>Ulex parviflorus</i> dead 9 years-old | | | | 7,6 | | | | | | |

3.1 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|------------------------------|---|
| 1 | State | |
| 1.1 | live | X |
| 1.2 | dead | X |
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | X |
| 2.2 | Fosberg and Deeming modified | X |
| 2.3 | | |
| 2.4 | Other | |

3.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|----------|----------------------------|-------------|-----------------------------|
| 1.1 | Leaves | Length | X |
| 1.2 | | Width | X |
| 1.3 | | Thickness | X |
| 1.4 | | Diameter | |
| 1.5 | | Mass | X |
| 1.6 | | Volume | |
| 1.7 | | Other | |
| 1.8 | Needles | Length | X |
| 1.9 | | Width | X |
| 1.10 | | Thickness | X |
| 1.11 | | Diameter | |
| 1.12 | | Mass | X |
| 1.13 | | Volume | |
| 1.14 | | Other | |
| 1.15 | Twigs | Length | X |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | X |
| 1.19 | | Mass | X |
| 1.20 | | Volume | |
| 1.21 | | Other | |
| 1.22 | Barks | Length | X |
| 1.23 | | Width | X |
| 1.24 | | Thickness | X |
| 1.25 | | Diameter | |
| 1.26 | | Mass | X |
| 1.27 | | Volume | |
| 1.28 | | Other | |
| 1.29 | Cones | Length | X |
| 1.30 | | Width | X |
| 1.31 | | Thickness | X |
| 1.32 | | Diameter | |
| 1.33 | | Mass | X |
| 1.34 | | Volume | |
| 1.35 | | Other | |

| 2 | | Calculated parameters | Data | Previous deliverable |
|------|-------------------------------|--------------------------|------|----------------------|
| 2.1 | Surface | Leaves | X | |
| 2.2 | | Needles | | |
| 2.3 | | Twigs | | |
| 2.4 | | Other | | |
| 2.5 | Volume | Leaves | | |
| 2.6 | | Needles | | |
| 2.7 | | Twigs | | |
| 2.8 | | Other | | |
| 2.9 | Ratios | Surface to volume | X | |
| 2.10 | | Mass to volume | | |
| 2.11 | | Other | | |
| Ref. | Observations | | | |
| 2.9 | Hernando <i>et al.</i> , 1955 | | | |

3.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | | |

3.4 TABLE 4: THERMAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|----------------------------|------|----------------------|
| 5 | Thermal degradation | | |
| 6 | Heat content | X | D-02-01 |
| 7 | Specific heat | | |

3.5 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|---------------------|------|----------------------|
| 8 | Flammability | X | D-02-01 |
| 8.1 | Other | | |
| 8.2 | Other | | |

| Ref. | Observations | | |
|------|---|--|--|
| 6&8 | Elvira L and Hernando C, 1989 Hernando C, 1989 | | |

3.6 TABLE 6: STUDIED SPECIES

| Species | Fuel family | State | Parameters | | | | | | | | | | |
|-----------------------------------|--------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|---------------------------|--------|--|
| | | | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability (Jul-Sep) | Others | |
| <i>Anthyllis cytisoides</i> | Leaves&twigs | Live | | | | X | | | | 18741 | | 0-5 | |
| <i>Arbutus unedo</i> | Leaves&twigs | Live | | | | X | | | | 21403 | | 2-4 | |
| <i>Arcostaphylos uva-ursi</i> | Leaves&twigs | Live | | | | X | | | | 21545 | | | |
| <i>Atriplex halimus</i> | Leaves&twigs | Live | | | | X | | | | 15376 | | 0-1 | |
| <i>Buxus sempervirens</i> | Leaves&twigs | Live | | | | X | | | | 21445 | | 1-2 | |
| <i>Calluna vulgaris</i> | Leaves&twigs | Live | | | | X | | | | 22504 | | 4-5 | |
| <i>Calycotome villosa</i> | Leaves&twigs | Live | | | | X | | | | 21005 | | 0-3 | |
| <i>Chamaespartium tridentatum</i> | Leaves&twigs | Live | | | | X | | | | 22341 | | 3-4 | |
| <i>Chamaespartium tridentatum</i> | Twigs:2-6mm | Live | | | | X | | | | 20220 | | 0 | |
| <i>Chamaespartium tridentatum</i> | Twigs:2-6mm | Dead | | | | X | | | | | | 2 | |
| <i>Chamaespartium tridentatum</i> | Twigs:6-25mm | Live | | | | X | | | | 19938 | | 0 | |
| <i>Cistus albidus</i> | Leaves&twigs | Live | | | | X | | | | 19515 | | 3 | |
| <i>Cistus crispus</i> | Leaves&twigs | Live | | | | X | | | | 18791 | | 3-4 | |
| <i>Cistus ladanifer</i> | Leaves&twigs | Live | | | | X | | | | 20974 | | 3-4 | |
| <i>Cistus laurifolius</i> | Leaves&twigs | Live | | | | X | | | | 20084 | | 0-2 | |
| <i>Cistus salvifolius</i> | Leaves&twigs | Live | | | | X | | | | 19201 | | 0-3 | |
| <i>Cytisus scoparius</i> | Leaves&twigs | Live | | | | X | | | | 21106 | | 2-4 | |
| <i>Erica arborea</i> | Leaves&twigs | Live | | | | X | | | | 23674 | | 4 | |
| <i>Erica arborea</i> | Leaves | Live | | | | X | | | | 23558 | | | |
| <i>Erica arborea</i> | Twigs:<2mm | Live | | | | X | | | | 22175 | | | |
| <i>Erica arborea</i> | Twigs:2-6mm | Live | | | | X | | | | 20571 | | | |
| <i>Erica arborea</i> | Twigs:6-25mm | Live | | | | X | | | | 20329 | | | |
| <i>Erica arborea</i> | Twigs:>25mm | Live | | | | X | | | | 20331 | | | |
| <i>Erica australis</i> | Leaves&twigs | Live | | | | X | | | | 24710 | | 3-5 | |
| <i>Erica australis</i> | Twigs: 2-6mm | Live | | | | X | | | | 19624 | | | |
| <i>Erica australis</i> | Twigs:6-25mm | Live | | | | X | | | | 19427 | | | |
| <i>Erica ciliaris</i> | Leaves&twigs | Live | | | | X | | | | 21612 | | | |
| <i>Erica multiflora</i> | Leaves&twigs | Live | | | | X | | | | 24120 | | 0-4 | |
| <i>Erica scoparia</i> | Leaves&twigs | Live | | | | X | | | | | | 4-5 | |

| Species | Fuel family | State | S/V ratio (m2/m3) | M/V ratio (kg/m3) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability (Jul-Sep) | Others |
|--------------------------|--------------|-------|-------------------|-------------------|--------------------|----------------------|----------------------|---------------------|----------------------|------------------------|------------------------|--------|
| Eucalyptus camaldulensis | Leaves&twigs | Live | | | | X | | | 20109 | | 5 | |
| Eucalyptus camaldulensis | Bark | Live | | | | X | | | 15823 | | 5 | |
| Eucalyptus globulus | Leaves&twigs | Live | | | | X | | | 22663 | | 5 | |
| Eucalyptus globulus | Leaves | Live | | | | X | | | 23458 | | 5 | |
| Eucalyptus globulus | Leaves | Dead | | | | X | | | 24062 | | 5 | |
| Eucalyptus globulus | Twigs: 2-6mm | Live | | | | X | | | 19717 | | 3 | |
| Eucalyptus globulus | Twigs: 2-6mm | Dead | | | | X | | | 19604 | | 3 | |
| Eucalyptus globulus | Bark | Live | | | | X | | | 18870 | | | |
| Genista falcata | Leaves&twigs | Live | | | | X | | | 21432 | | 5 | |
| Halimium alyssoides | Leaves&twigs | Live | | | | X | | | 19747 | | | |
| Junipres oxycedrus | Leaves&twigs | Live | | | | X | | | 22571 | | 0-3 | |
| Lavandula stoechas | Leaves&twigs | Live | | | | X | | | 20737 | | 3-5 | |
| Olea europaea | Leaves&twigs | Live | | | | X | | | 20746 | | 0-3 | |
| Phillyrea angustifolia | Leaves&twigs | Live | | | | X | | | 22851 | | 4-5 | |
| Pinus halepensis | Needles | Dead | 7973 | | | X | | | 22075 | | 5 | |
| Pinus halepensis | Twigs:0-2mm | Dead | | | | X | | | 20587 | | | |
| Pinus halepensis | Bark | Live | | | | X | | | 19469 | | | |
| Pinus pinaster | Needles | Live | | | | X | | | 21487 | | 3 | |
| Pinus pinaster | Needles | Dead | 4824 | | | X | | | 21302 | | 5 | |
| Pinus pinaster | Twigs:0-2mm | Dead | | | | X | | | 22071 | | 3 | |
| Pinus pinaster | Twigs:2-6mm | Dead | | | | X | | | 21374 | | 2-3 | |
| Pinus pinaster | Twigs:6-25mm | Dead | | | | X | | | 21030 | | | |
| Pinus pinaster | Bark | Live | | | | X | | | 20549 | | | |
| Pinus pinaster | Bark | Dead | | | | X | | | 21508 | | | |
| Pinus pinaster | Cone scales | Dead | | | | X | | | 20737 | | | |
| Pinus pinea | Needles | Dead | 5780 | | | X | | | 21800 | | 4-5 | |
| Pinus pinea | Twigs:0-2mm | Dead | | | | X | | | 20185 | | | |
| Pinus pinea | Bark | Live | | | | X | | | 20040 | | | |
| Pinus pinea | Cone scales | Dead | | | | X | | | 20151 | | | |
| Pinus radiata | Needles | Live | | | | X | | | 21419 | | | |
| Pinus radiata | Needles | Dead | | | | X | | | 22542 | | 5 | |
| Pinus radiata | Bark | Live | | | | X | | | 21583 | | | |
| Pinus radiata | Cone scales | Dead | | | | X | | | 20189 | | | |
| Pteridium aquilinum | Leaves | Live | | | | X | | | 19596 | | 0 | |
| Pteridium aquilinum | Leaves | Dead | | | | X | | | 19762 | | | |

| Species | Fuel family | State | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability (Jul-Sep) | Others |
|------------------------|--------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|---------------------------|--------|
| Quercus coccifera | Leaves&twigs | Live | | | | X | | | 20285 | | 0-3 | |
| Quercus coccifera | Leaves | Live | | | | X | | | 19679 | | | |
| Quercus coccifera | Twigs:0-2mm | Live | | | | X | | | 19545 | | | |
| Quercus coccifera | Twigs:2-6mm | Live | | | | X | | | 19051 | | | |
| Quercus coccifera | Twigs:6-25mm | Live | | | | X | | | 18254 | | | |
| Quercus ilex | Leaves&twigs | Live | | | | X | | | 19950 | | 5 | |
| Quercus ilex | Leaves | Live | | | | X | | | 19697 | | | |
| Quercus ilex | Twigs:0-2mm | Live | | | | X | | | 18448 | | | |
| Quercus ilex | Twigs:2-6mm | Live | | | | X | | | 18243 | | | |
| Quercus ilex | Twigs:6-25mm | Live | | | | X | | | 18075 | | | |
| Quercus pyrenaica | Leaves | Live | | | | X | | | 20013 | | | |
| Quercus pyrenaica | Leaves | Dead | | | | X | | | 18824 | | | |
| Quercus pyrenaica | Twigs | Dead | | | | X | | | 19669 | | | |
| Quercus suber | Leaves&twigs | Live | | | | X | | | 20457 | | 2-4 | |
| Rosmarinus officinalis | Leaves&twigs | Live | | | | X | | | 22669 | | 3-4 | |
| Rosmarinus officinalis | Leaves | Live | | | | X | | | 22090 | | | |
| Rosmarinus officinalis | Twigs:0-2mm | Live | | | | X | | | 19997 | | | |
| Rosmarinus officinalis | Twigs:2-6mm | Live | | | | X | | | 19770 | | | |
| Rosmarinus officinalis | Twigs:6-25mm | Live | | | | X | | | 19812 | | | |
| Rubus idaeus | Leaves&twigs | Live | | | | X | | | 17133 | | 0-5 | |
| Stauracanthus boivinii | Leaves&twigs | Live | | | | X | | | 21441 | | 3-4 | |
| Stipa tenacissima | Grasses | Dead | | | | X | | | 19955 | | 5 | |
| Thymus vulgaris | Leaves&twigs | Live | | | | X | | | 20876 | | 4 | |
| Ulex europaeus | Leaves&twigs | Live | | | | X | | | 20647 | | 3 | |
| Ulex minor | Leaves&twigs | Live | | | | X | | | 20712 | | | |
| Ulex parviflorus | Leaves&twigs | Live | | | | X | | | 21072 | | 3-4 | |

4.1 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|------------------------------|---|
| 1 | State | |
| 1.1 | live | X |
| 1.2 | dead | X |
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | |
| 2.2 | Fosberg and Deeming modified | X |
| 2.3 | | |
| 2.4 | Other | |

4.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|----------|----------------------------|-------------|-----------------------------|
| 1.1 | Leaves | Length | |
| 1.2 | | Width | |
| 1.3 | | Thickness | |
| 1.4 | | Diameter | X |
| 1.5 | | Mass | X |
| 1.6 | | Volume | X |
| 1.7 | | Other | |
| 1.8 | Needles | Length | |
| 1.9 | | Width | |
| 1.10 | | Thickness | |
| 1.11 | | Diameter | X |
| 1.12 | | Mass | X |
| 1.13 | | Volume | X |
| 1.14 | Other | | |
| 1.15 | Twigs | Length | |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | X |
| 1.19 | | Mass | X |
| 1.20 | | Volume | X |
| 1.21 | Other | | |
| 1.22 | Barks | Length | |
| 1.23 | | Width | |
| 1.24 | | Thickness | |
| 1.25 | | Diameter | X |
| 1.26 | | Mass | X |
| 1.27 | | Volume | X |
| 1.28 | Other | | |
| 1.36 | Grasses | Length | |
| 1.37 | | Width | |
| 1.38 | | Thickness | |
| 1.39 | | Diameter | |
| 1.40 | | Mass | X |
| 1.41 | | Volume | X |
| 1.42 | Other | | |

| 2 | | Calculated parameters | Data | Previous deliverable |
|------|---------------|--------------------------|------|----------------------|
| 2.5 | Volume | Leaves | X | |
| 2.6 | | Needles | X | |
| 2.7 | | Twigs | X | |
| 2.8 | | Other | | |
| 2.9 | Ratios | Surface to volume | X | |
| 2.10 | | Mass to volume | | |
| 2.11 | | Other | | |

4.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | | |

4.4 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|----------------------|------|----------------------|
| 8 | Flammability | X | |
| 8.1 | Other combustibility | X | |
| 8.2 | Other | | |

4.5 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|-----------------------------------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|
| | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
| <i>Chamaespartium tridentatum</i> | | x | | x | | | | | | x |
| <i>Erica australis</i> | | x | | x | | | | | | x |
| <i>Erica umbellata</i> | | x | | x | | | | | | x |
| <i>Pinus pinaster</i> | x | x | | x | | | | | | x |
| <i>Eucalyptus globulus</i> | | x | | x | | | | | | x |
| <i>Ulex sp</i> | | x | | x | | | | | | |

5.1 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|--------------|---|
| 1 | State | |
| 1.1 | live | X |
| 1.2 | dead | X |

| | | |
|----------|------------------------------|---|
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | X |
| 2.2 | Fosberg and Deeming modified | X |
| 2.3 | | |
| 2.4 | Other | |

5.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|----------|----------------------------|-------------|-----------------------------|
| 1.1 | Leaves | Length | X |
| 1.2 | | Width | X |
| 1.3 | | Thickness | X |
| 1.4 | | Diameter | X |
| 1.5 | | Mass | X |
| 1.6 | | Volume | X |
| 1.7 | | Other | |
| 1.8 | Needles | Length | X |
| 1.9 | | Width | X |
| 1.10 | | Thickness | X |
| 1.11 | | Diameter | X |
| 1.12 | | Mass | X |
| 1.13 | | Volume | X |
| 1.14 | | Other | |
| 1.15 | Twigs | Length | |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | X |
| 1.19 | | Mass | X |
| 1.20 | | Volume | X |
| 1.21 | | Other | |
| 1.22 | Barks | Length | |
| 1.23 | | Width | |
| 1.24 | | Thickness | X |
| 1.25 | | Diameter | |
| 1.26 | | Mass | X |
| 1.27 | | Volume | |
| 1.28 | | Other | |
| 1.29 | Cones | Length | |
| 1.30 | | Width | |
| 1.31 | | Thickness | |
| 1.32 | | Diameter | |
| 1.33 | | Mass | X |
| 1.34 | | Volume | |
| 1.35 | | Other | |

| | | | |
|------|----------------|-----------|---|
| 1.36 | Grasses | Length | |
| 1.37 | | Width | |
| 1.38 | | Thickness | |
| 1.39 | | Diameter | |
| 1.40 | | Mass | X |
| 1.41 | | Volume | |
| 1.42 | | Other | |
| 1.43 | Other | Length | X |
| 1.44 | | Width | X |
| 1.45 | | Thickness | |
| 1.46 | | Diameter | X |
| 1.47 | | Mass | X |
| 1.48 | | Volume | X |
| 1.49 | | Other | |

| 2 | | Calculated parameters | Data | Previous deliverable |
|----------|---|------------------------------|------|----------------------|
| 2.1 | Surface | Leaves | X | |
| 2.2 | | Needles | X | |
| 2.3 | | Twigs | X | |
| 2.4 | | Other | | |
| 2.5 | Volume | Leaves | X | |
| 2.6 | | Needles | X | |
| 2.7 | | Twigs | X | |
| 2.8 | | Other: individual | X | |
| 2.9 | Ratios | Surface to volume | X | |
| 2.10 | | Mass to volume | X | |
| 2.11 | | Other | | |
| 2.12 | Other | | | |
| 2.13 | | | | |
| Ref. | Observations | | | |
| | Barks and cones are measured when they appear as part of the litter layer | | | |

5.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | X | |

5.4 TABLE 4: THERMAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|----------------------------|------|----------------------|
| 5 | Thermal degradation | | |
| 6 | Heat content | X | |

| | |
|------|--|
| Ref. | Observations |
| | Heat content determined is the high heat value |

5.5 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|---------------------------------------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|
| | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
| <i>Ulex europaeus</i> | 8088 | 679 - 774 | | | | | 20533 | | | |
| <i>Ulex minor</i> | | 780 - 854 | | | | | 20227 | | | |
| <i>Chamaespartium tridentatum</i> | 4632 | 669 - 669 | | | | | 21827 | | | |
| <i>Erica australis</i> | 6724 | 432 - 831 | | | | | | | | |
| <i>Erica umbellata</i> | | 362 - 888 | | | | | 22341 | | | |
| <i>Calluna vulgaris</i> | | 626 - 718 | | | | | 21414 | | | |
| <i>Daboecia cantabrica</i> | | 605 - 693 | | | | | | | | |
| <i>Halimium alyssoides</i> | | 582 - 729 | | | | | | | | |
| <i>Cistus clusii</i> | 1391 | 879 - 985 | | | | | | | | |
| <i>Rosmarinus officinalis</i> | 1111 | 639 - 693 | | | | | | | | |
| <i>Thymus vulgaris</i> | 2561 | 693 - 693 | | | | | | | | |
| <i>Eucalyptus globulus</i> | | 720 - 784 | | | | | 23943 - 20321 | | | |
| <i>Juniperus oxycedrus</i> | 10210 | 808 - 752 | | | | | | | | |
| <i>Juniperus sabina</i> | 1121 | 786 - 787 | | | | | | | | |
| <i>Pteridium aquilinum</i> | 9662 | 411 - 427 | | | | | 18613 - 18162 | | | |
| <i>Pinus pinaster</i> | | | | | | | 21593 - 20950 | | | |
| <i>Pinus radiata</i> | | | | | | | 21159 - 20502 | | | |
| <i>Betula celtiberica</i> | | | | | | | 20969 - 20600 | | | |
| <i>Rubus sp.</i> | | | | | | | 19039 | | | |
| <i>Cytisus scoparius</i> | | | | | | | 20540 | | | |

6 CONTRIBUTION UTAD-DF (VILA-REAL) P025

6.1 TABLE 1: FUEL CLASSES

Ref.

| | | | |
|----------|------------------------------|---------------------------|---|
| 1 | State | | |
| 1.1 | live | | X |
| 1.2 | dead | | X |
| 2 | Size class | | |
| 2.1 | Fosberg and Deeming | | X |
| 2.2 | Fosberg and Deeming modified | | X |
| 2.3 | Other | Smaller size class:<2.5mm | X |
| 2.4 | | Smaller size class:<3.0mm | X |

6.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|----------|----------------------------|-------------|-----------------------------|
| 1.1 | Leaves | Length | |
| 1.2 | | Width | |
| 1.3 | | Thickness | X |
| 1.4 | | Diameter | |
| 1.5 | | Mass | X |
| 1.6 | | Volume | X |
| 1.7 | | Other | |
| 1.8 | Needles | Length | X |
| 1.9 | | Width | X |
| 1.10 | | Thickness | X |
| 1.11 | | Diameter | X |
| 1.12 | | Mass | X |
| 1.13 | | Volume | X |
| 1.14 | | Other | |
| 1.15 | Twigs | Length | X |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | X |
| 1.19 | | Mass | X |
| 1.20 | | Volume | X |
| 1.21 | | Other | |
| 1.36 | Grasses | Length | |
| 1.37 | | Width | |
| 1.38 | | Thickness | |
| 1.39 | | Diameter | X |
| 1.40 | | Mass | X |
| 1.41 | | Volume | X |
| 1.42 | | Other | |

| 2 | | Calculated parameters | Data | Previous deliverable |
|------|----------------|--------------------------|------|----------------------|
| 2.1 | Surface | Leaves | X | |
| 2.2 | | Needles | X | |
| 2.3 | | Twigs | X | |
| 2.4 | | Other | | |
| 2.5 | Volume | Leaves | X | |
| 2.6 | | Needles | X | |
| 2.7 | | Twigs | X | |
| 2.8 | | Other | | |
| 2.9 | Ratios | Surface to volume | X | |
| 2.10 | | Mass to volume | X | |
| 2.11 | | Surface to mass | X | |

6.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | X | |

6.4 TABLE 6: STUDIED SPECIES

| Species | Fuel family | State | Parameters | | | | | | | | | | | |
|----------------------------|----------------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|--|--|
| | | | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others | | |
| Acacia longifolia | Leaves | live | 7080 | | | | | | | | | | | |
| Acacia longifolia | 0-6 mm twigs | live | 1865 | | | | | | | | | | | |
| Agrostis spp. | 0-6 mm twigs | dead | 8000 | | | | | | | | | | | |
| Arbutus unedo | Leaves | live | 4500 | | | | | | | | | | | |
| Arbutus unedo | 0-6 mm twigs | live | 1900 | | | | | | | | | | | |
| Calluna vulgaris | 2-6 mm twigs | live | 1000 | 227 | | | | | | | | | | |
| Calluna vulgaris | Leaves + <2 mm twigs | live | 9560 | | | | X | | | | | | | |
| Calluna vulgaris | Leaves + <6 mm twigs | live | 8810 | 440 | | | | | | | | | | |
| Chamaespartium tridentatum | 2-6 mm twigs | live | 9600 | 765 | | | X | | | | | | | |
| Chamaespartium tridentatum | Leaves + <2 mm twigs | live | 4710 | 613 | 1.62 | | X | | | | | | | |
| Chamaespartium tridentatum | Leaves + <2 mm twigs | dead | | 489 | | | X | | | | | | | |
| Chamaespartium tridentatum | Leaves + <6 mm twigs | live | 4260 | 640 | | | | | | | | | | |
| Cistus ladanifer | Leaves | live | 4550 | | | | X | | | | | | | |
| Cistus ladanifer | Leaves | dead | | | | | X | | | | | | | |
| Cistus ladanifer | Leaves + <6 mm twigs | live | 1800 | | | | X | | | | | | | |
| Cistus monspeliensis | 0-6 mm twigs | live | 2600 | | | | | | | | | | | |
| Cistus monspeliensis | Leaves | live | 3500 | | | | | | | | | | | |
| Corema album | Leaves | live | 9469 | | | | | | | | | | | |
| Corema album | 0-6 mm twigs | live | 1969 | | | | | | | | | | | |
| Corema album | 0-6 mm twigs | dead | 2970 | | | | | | | | | | | |
| Cytisus striatus | Leaves + <2 mm twigs | live | | 696 | | | X | | | | | | | |
| Cytisus striatus | Leaves + <2 mm twigs | dead | | 379 | | | X | | | | | | | |
| Erica arborea | 0-6 mm twigs | live | 4500 | | | | | | | | | | | |
| Erica arborea | Leaves | live | 13000 | | | | | | | | | | | |
| Erica arborea | Leaves + <2 mm twigs | live | 7200 | 253 | | | X | | | | | | | |
| Erica arborea | Leaves + <2 mm twigs | dead | 9200 | 324 | | | X | | | | | | | |
| Erica arborea | Leaves + <6 mm twigs | live | 6690 | 500 | | | | | | | | | | |
| Erica australis | 2-6 mm twigs | live | 9300 | 782 | | | X | | | | | | | |
| Erica australis | 2-6 mm twigs | dead | | 856 | | | X | | | | | | | |
| Erica australis | 6-25 mm twigs | dead | | 844 | | | | | | | | | | |
| Erica australis | Leaves + <2 mm twigs | live | 7950 | 434 | | | X | | | | | | | |
| Erica australis | Leaves + <2 mm twigs | dead | | 364 | | | X | | | | | | | |
| Erica australis | Leaves + <6 mm twigs | live | 6330 | 580 | | | | | | | | | | |

| Species | Fuel family | State | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
|------------------------|----------------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|
| Erica umbellata | 2-6 mm twigs | live | 1180 | 788 | | X | | | | | | |
| Erica umbellata | Leaves + <2 mm twigs | live | 1010 | 318 | 2.39 | X | | | | | | |
| Erica umbellata | Leaves + <2 mm twigs | dead | | 244 | | X | | | | | | |
| Erica umbellata | Leaves + <6 mm twigs | live | 8680 | 490 | | | | | | | | |
| Eucalyptus globulus | Leaves | dead | 5690 | 650 | | | | | | | | |
| Halimium alyssoides | Leaves + <2 mm twigs | live | | 261 | | | | | | | | |
| Halimium ocymoides | 2-6 mm twigs | live | 1380 | 750 | | | | | | | | |
| Halimium ocymoides | Leaves + <2 mm twigs | live | 4780 | 278 | | | | | | | | |
| Halimium ocymoides | Leaves + <2 mm twigs | dead | | 453 | | | | | | | | |
| Halimium ocymoides | Leaves + <6 mm twigs | live | 4440 | 470 | | | | | | | | |
| Juniperus turbinata | Leaves | live | 5634 | | | | | | | | | |
| Juniperus turbinata | 0-6 mm twigs | live | 2145 | | | | | | | | | |
| Juniperus turbinata | 0-6 mm twigs | dead | 5238 | | | | | | | | | |
| Myrica faya | Leaves | live | 6349 | | | | | | | | | |
| Myrica faya | 0-6 mm twigs | live | 1435 | | | | | | | | | |
| Myrica faya | 0-6 mm twigs | dead | 1961 | | | | | | | | | |
| Myrtus communis | 0-6 mm twigs | live | 2100 | | | | | | | | | |
| Myrtus communis | Leaves | live | 6500 | | | | | | | | | |
| Olea europaea | 0-6 mm twigs | live | 2400 | | | | | | | | | |
| Olea europaea | Leaves | live | 6000 | | | | | | | | | |
| Phillyrea angustifolia | 0-6 mm twigs | live | 2200 | | | | | | | | | |
| Phillyrea angustifolia | Leaves | live | 7500 | | | | | | | | | |
| Pinus halepensis | Needles | dead | 8740 | 790 | | | | | | | | |
| Pinus pinaster | Needles | dead | 4990 | 660 | | X | | | | | | |
| Pinus pinea | Needles | dead | 6470 | 690 | | | | | | | | |
| Pistacia lentiscus | 0-6 mm twigs | live | 1800 | | | | | | | | | |
| Pistacia lentiscus | Leaves | live | 6000 | | | | | | | | | |
| Pteridium aquilinum | Leaves + <6 mm twigs | live | 9400 | 300 | | X | | | | | | |
| Pteridium aquilinum | Leaves + <6 mm twigs | dead | | | | X | | | | | | |
| Quercus coccifera | Leaves | live | 6000 | | | | | | | | | |
| Quercus coccifera | 0-6 mm twigs | live | 2100 | | | | | | | | | |
| Rosmarinus officinalis | 0-2 mm twigs | live | 3760 | 680 | | | | | | | | |
| Rosmarinus officinalis | 0-6 mm twigs | live | 2200 | | | | | | | | | |
| Rosmarinus officinalis | Leaves | live | 5500 | | | | | | | | | |
| Rosmarinus officinalis | Leaves + <2 mm twigs | live | 4860 | 540 | | | | | | | | |

| Species | Fuel family | State | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
|----------------|----------------------|-------|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|--------|
| Ulex europaeus | Leaves + <2 mm twigs | live | | 651 | | X | | | | | | |
| Ulex europaeus | Leaves + <2 mm twigs | dead | | 356 | | X | | | | | | |
| Ulex minor | Leaves + <2 mm twigs | live | | 474 | | X | | | | | | |
| Ulex minor | Leaves + <2 mm twigs | dead | | 317 | | X | | | | | | |
| Ulex minor | Leaves + <6 mm twigs | live | 5540 | | | | | | | | | |

7.1 TABLE 1: FUEL CLASSES

| Ref. | | | |
|----------|------------------------------|---|---|
| 1 | State | | |
| 1.1 | live | | X |
| 1.2 | dead | | X |
| 2 | Size class | | |
| 2.1 | Fosberg and Deeming | | |
| 2.2 | Fosberg and Deeming modified | | |
| 2.3 | Other | FCC system (Sandberg et al 2001) modified | X |
| 2.4 | | | |

7.2 TABLE 2: PHYSICAL CHARACTERISTICS

| Ref. | Observations |
|------|---|
| | Cones, bark, twigs etc combined to "litter" class |
| | Following fuel class (measured by mass): trunks, slash, litter, mosses, lichens, duff |

7.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|-------------------------|-----------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | | |
| | | Element | Previous deliverable |
| 3 | Chemical content | C,N | |
| 3.1 | | Ca, Mg, K | |
| 3.2 | | K, P | |
| 3.3 | | pH | |
| 3.4 | | | |

7.4 TABLE 5: OTHER CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|---------------------|------|----------------------|
| 8 | Flammability | X | |
| 9.1 | Other | | |
| 9.2 | Other | | |

7.5 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|----------------------|---|--------------------------------|--------------------|----------------------|----------------------|---------------------|----------------------|------------------------|--------------|--------|
| | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Others |
| Pleurozium shreberi | | | | X | | | | | | X |
| Hylocomium splendens | | | | X | | | | | | X |
| Cladina spp | | | | X | | | | | | X |
| Diranum spp | | | | X | | | | | | X |
| "Duff" | | | | X | X | | | | | X |

8.1 TABLE 1: FUEL CLASSES

Ref.

| | | |
|----------|--------------|---|
| 1 | State | |
| 1.1 | live | X |
| 1.2 | dead | X |

| | | |
|----------|------------------------------|--|
| 2 | Size class | |
| 2.1 | Fosberg and Deeming | Modified method according to Brown et al. for the use within Rothermel's mathematical fire spread model, http://www.geo.unizh.ch/gis/research/edmg/fire/papers/minerve/fuel.pdf |
| 2.2 | Fosberg and Deeming modified | |
| 2.3 | Other | |
| 2.4 | | |

8.2 TABLE 2: PHYSICAL CHARACTERISTICS

Ref.

| 1 | Measured parameters | Data | Previous deliverable |
|----------|----------------------------|-------------|-----------------------------|
| 1.1 | Leaves | Length | |
| 1.2 | | Width | |
| 1.3 | | Thickness | X |
| 1.4 | | Diameter | |
| 1.5 | | Mass | X |
| 1.6 | | Volume | |
| 1.7 | | Other | |
| 1.8 | Needles | Length | |
| 1.9 | | Width | |
| 1.10 | | Thickness | |
| 1.11 | | Diameter | X |
| 1.12 | | Mass | X |
| 1.13 | | Volume | |
| 1.14 | | Other | |
| 1.15 | Twigs | Length | |
| 1.16 | | Width | |
| 1.17 | | Thickness | |
| 1.18 | | Diameter | X |
| 1.19 | | Mass | X |
| 1.20 | | Volume | |
| 1.21 | | Other | |
| 1.22 | Barks | Length | |
| 1.23 | | Width | |
| 1.24 | | Thickness | X |
| 1.25 | | Diameter | |
| 1.26 | | Mass | X |
| 1.27 | | Volume | |
| 1.28 | | Other | |
| 1.29 | Cones | Length | |
| 1.30 | | Width | |
| 1.31 | | Thickness | |
| 1.32 | | Diameter | X |
| 1.33 | | Mass | X |
| 1.34 | | Volume | |
| 1.35 | | Other | |

| | | | |
|------|---------------------|-----------------------------|---|
| 1.36 | Grasses | Length | |
| 1.37 | | Width | |
| 1.38 | | Thickness | X |
| 1.39 | | Diameter | X |
| 1.40 | | Mass | X |
| 1.41 | | Volume | |
| 1.42 | | Other | |
| 1.43 | Mosses | Length | |
| 1.44 | | Width | |
| 1.45 | | Thickness | X |
| 1.46 | | Diameter | |
| 1.47 | | Mass | X |
| 1.48 | | Volume | |
| 1.49 | | Other | |
| 1.50 | Single trees | Length (Heigh) | X |
| 1.51 | | Width | |
| 1.52 | | Thickness | |
| 1.53 | | Diameter | X |
| 1.54 | | Mass | |
| 1.55 | | Volume | X |
| 1.56 | | Height of the base of crown | X |

| 2 Calculated parameters | | Data | Previous deliverable |
|--------------------------------|----------------|--------------------------|----------------------|
| 2.1 | Surface | Leaves | |
| 2.2 | | Needles | |
| 2.3 | | Twigs | |
| 2.4 | | Other | |
| 2.5 | Volume | Leaves | |
| 2.6 | | Needles | |
| 2.7 | | Twigs | |
| 2.8 | | Other | |
| 2.9 | Ratios | Surface to volume | X |
| 2.10 | | Mass to volume | |
| 2.11 | | Other | |

8.3 TABLE 3: CHEMICAL CHARACTERISTICS

| Ref. | | Data | Previous deliverable |
|----------|-------------------------|------|----------------------|
| 1 | Moisture content | X | |
| 2 | Ash content | | |

8.4 TABLE 5: OTHER CHARACTERISTICS

| Observations | |
|---------------------|---|
| 9.1 | <p>Ceccato, P., Flasse, S. and Gregoire, J. M. (2002), Designing a spectral index to estimate vegetation water content from remote sensing data - Part 2. Validation and applications. Remote Sensing of Environment, 82(2-3), 198-207.</p> |
| 9.2 | <p>Carlson, J. D. and Burgan, R. E. (2003), Review of users' needs in operational fire danger estimation: the Oklahoma example. International Journal of Remote Sensing, 24(8), 1601-1620.</p> |

8.5 TABLE 6: STUDIED SPECIES

| Species | Parameters | | | | | | | | | |
|---|--|-----------------------------------|--------------------------|----------------------------|-------------------------|------------------------|----------------------------|------------------------------|--------------|------------------------------|
| | S/V ratio (m ² /m ³) | M/V ratio (kg/m ³) | Ash content (g/hg) | Moisture content (%) | Chemical composition | Thermal degradation | Heat content (kJ/kg) | Specific heat (J/K/kg) | Flammability | Moisture of extinction |
| Larix decidua | 7809 | | | x | | | | | | 35,99 |
| Pinus mugo grex arborea (Mountain Pine) | 6499 | | | x | | | | | | 36,50 |
| Pinus mugo grex prostrata | 4764 | | | x | | | | | | 44,12 |
| Abies alba | 7215 | | | x | | | | | | 32,00 |
| Polypodium sp. and Genista sp. | 10851 | | | x | | | | | | 16,00 |
| Castanea sativa | 10383 | | | x | | | | | | 18,00 |