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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-03-07

Data collecting procedure

for modelling the behaviour of wildland fires (final)

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CONTENT LIST

SUMMARY

Data collecting procedures for modelling the behaviour of forest fires and the dispersion of the emitted smoke are presented.

These methodologies concern both laboratorial and field experiments, including some comments on measurements performed during wildland fires.

The document is focused on the type of data, obtained from lab or field experiments, that are needed to develop, to improve or to validate fire/smoke behaviour models.

Several EUFIRELAB teams involved in Unit 3 contributed to this Deliverable, which includes its annex (D-03-07_A01), describing their own experiments and expertise, or the input and output data of the models applied.

LIST OF ASSOCIATED DOCUMENTS

Name of the file	Title of the file	Content of the file
D-03-07_A01	Contributions from partners	Document fulfilled by partners with information concerning the general description of each model and the type of procedures used for collecting the data needed for the simulations.

1 INTRODUCTION AND SCOPE OF D-03-07

The main objective of D-03-07 is to describe the available procedures for collecting the data needed for modelling the behaviour of forest fires.

In this sense it complements:

- D-03-09 Behaviour modelling of wildland fires: final version of the State of the Art, and
- D-03-06 Behaviour models of wildland fire: third versions of the codes

Also, a close relation with following deliverables is achieved

- D-02-06 Methods for wildland fuel description and modelling: final version of the state of the art
- D-06-02 Decision support systems and tools: a state of the art
- D-07-01 Weather stations for lab and field experiments: the procedure of use
- D-07-11 Common methodologies for collecting data during laboratory fires
- D-07-12 Common methodologies for collecting data during outside fires, and
- D-07-13 Fire metrology: final version of the state of the art

The current document is focused on the different procedures used within the European fire behaviour modelling community to collect experimental data for models development, application, or validation, with the objective of identifying, defining and integrating common procedures.

According to the type and scale of fire behaviour models, different data collecting procedures are used.

The present document is divided into two main sections, according to whether these procedures are related to laboratory experiments or real scale measurements.

A third section briefly analyses some aspects related with performing measurements during wildfires.

The team from the University of Aveiro, in Portugal (P22, UAVR-DAO), coordinated the elaboration of the current document with contributions from partners P02 (EQUIPE FEUX), P12 (IST-DEM), P13 (ADAI), P18 (XG-CIFAL), P25 (UTAD) and P28 (CREAF).

2 LABORATORIAL DATA COLLECTING PROCEDURES

Several forest fire researchers have carried out laboratory fire experiments during many years as a common practice to study factors that influence forest fire behaviour and to test and develop forest fire behaviour models.

The main advantage of laboratorial experiments when comparing to real scale tests is the possible control over the parameters that directly influence the behaviour of fire and smoke.

Moreover, experiments can be reproduced under the same conditions. In this sense, almost all partners that contributed to the current version of this document use laboratorial data in the development, improvement or validation of their models.

This Deliverable mainly describes two laboratorial programs developed by ADAI in Portugal, and EQUIPE FEUX in Corsica.

2.1 ADAI LABORATORIAL PROCEDURES

This section describes the laboratorial protocol developed by the ADAI team in the Laboratory for Forest Fire Research (LEIF).

2.1.1 Laboratorial design

Figure 2-1 shows a combustion table used by ADAI in LEIF.

A complete description of the laboratory can be found in VIEGAS *et al*. (1998a).

This combustion table has 4 x 4 m^2, with a working surface of 2.9 x 2.9 m^2.

It has a surface plane that can be inclined, from 0º to 40º, in relation to the horizontal plane.

The table can also be tilted around the perpendicular axis to the fuel bed surface from 0 to 180º.

For simulating different wind conditions, a device consisting of three fans connected in parallel is used.

This device produces a homogeneous airflow above the table that is parallel to its surface.

This combustion table was used, for instance, to develop and evaluate the fire line rotation model (OLIVERAS, 2004).

The accuracy of fire emissions estimation is a critical issue when simulating smoke dispersion.

Therefore, in cooperation with ADAI team, UAVR was involved in fire emissions measurements at LAI (Industrial Aerodynamics Laboratory), in ADAI facilities.

These experiments were primarily designed to study the effect of chemical retardants on fire progression and fire emissions in the scope of the European project ERAS (EVG1-2001-00019).

An adequate apparatus for emissions measurements was built, which consisted in the construction of a stack in the top of the combustion table, with 1.2 x 2 m^2, used by ADAI for fire progression experiments (see figure 2-2), according to the requirements established by the Environmental Protection Agency (EPA) for measurements in industrial stacks.

In this combustion table, the weight loss is measured in a 0.77 x 0.24 m^2 area located at the centre of the apparatus using a high precision weighing-machine.

2.1.2 Fuel characteristIcs

The fuel bed should be chosen as a way of guaranteeing the best combustion properties for the table used and the optimum fuel load (for homogeneity of the fuel bed, fire line stability and flame length and height).

For example, for the combustion table shown in Figure 2-1, fuel bed was composed of dead needles of *Pinus pinaster*, with a fuel load of 0.6 kg.m^{-2} (dry basis).

Fuel moisture should be measured in each experiment. In this example an electronic balance was used with an infrared heat source.

A fuel sample of ca 1.000 g was introduced into the balance.

The sample was dried during 5 minutes at a temperature of 100 °C.

After that time the balance displays automatically the percentage of moisture content, referred to fresh weight.

For each test, three measures of moisture were made and the average value was used.

2.1.3 Fire line evolution

Reference tests of 1 m^2 with neither wind nor slope were done three times per day (morning, midday and evening) aiming to know the reference or basic rate of spread of the burns performed in that day.

Two series of tests were made: slope tests and wind tests.

Each test was replicated at least two times.

Single point ignitions were made in all the experiments.

Cotton threads were fixed parallel to the fire line at a given distance (for instance 10 cm or 20 cm), and the time to reach the threads registered and the spread velocity calculated as the derivative of distance by time.

Video and infrared cameras, as the ones shown on Figure 2-3, can be used as a support for monitoring the experiments. Infrared camera was connected to a TV screen in order to control the recording during the experiments and an observer followed the image to correct any distortion.

The cameras should be placed in an elevated plane because the angle of the optical axis (the axis between the table and the camera) cannot be very small in order to avoid aberration effects, and also to protect the equipment from the heat (OLIVERAS, 2004).

The infrared camera operates in a temperature range from -20 to 1200 °C, divided into 6 ranges.

For recording the experiments, the temperature range 250-750 °C was used, which allows to record only the fire line.

The four vertices of the combustion table were used as reference points and were recorded before and after each experiment.

Simultaneously to the ignition, the two cameras started to record the experiment.

In figure 2-4 there is a view of a burn with both cameras.

The monitoring technique used in this work has been accurately studied for many years by the ADAI team for minimizing the experimental errors.

The main objective of the technique is to reconstruct the real shape and dimensions from the image obtained with a camera.

Depending on the position, the focal distance and orientation to the plane object, there will be a distortion due to a linear effect of perspective.

To correct this effect, a mathematical algorithm has been developed by ADAI that displays an orthogonal image in all its points (GONÇALVES, 2000).

2.1.4 Fire emissions

As referred on topic 2.1.1, UAVR team performed fire emissions measurements on ADAI facilities.

The experimental procedures were conducted according to the EPA methods published in the Federal Register, vol. 42 n.160, 18^{th} of August 1977 (indicated in Table 2.1).

The main measured pollutants were particulate matter (PM), nitrogen oxides (NOx) and volatile organic compounds (VOC).

In addition, other parameters are measured, as the relative humidity and the molecular weight of oxygen (O_2), carbon dioxide (CO_2) and monoxide (CO).

In method 3A, a sample is continuously extracted from the effluent stream: a portion of the sample stream is conveyed to an instrumental analyser(s) for determination of O_2 and CO concentration(s).

Performance specifications and test procedures are followed to ensure reliable data.

In method 5 (see Figure 2-5), PM is isokinetically withdrawn from the source and collected on a glass fibber filter maintained at a temperature of 120 ± 14ºC.

The PM mass, which includes any material that condenses at or above the filtration temperature, is gravimetrically determined after the removal of un-combined water.

In method 7 (see Figure 2-6), a grab sample is collected in an evacuated flask containing a dilute sulphuric acid-hydrogen peroxide absorbing solution, and the nitrogen oxides, except nitrous oxide, are measured colorimetrically using the phenoldisulfonic acid (PDS) procedure.

To measure VOC (see Figure 2-7) a gas sample is extracted from the source through a heated sample line and glass fibber filter to a flame ionization analyzer (FIA).

Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

A series of essays were defined for different levels of fuel loads (straw) and retardant cover.

The information relating the equipment used is resumed in Table 2.2.

A more detailed description can be found on D-07-11.

2.2 EQUIPE FEUX LABORATORIAL PROCEDURES

This section describes the laboratorial protocol developed by the EQUIPE FEUX team to analyse the gas phase combustion of forest fuels.

Two devices were built up to propose a simple modelling for the gas phase combustion of forest fuels.

The first one was used to determine the composition of the gases released from the degradation of forest fuels and the second one was used to test the results of the modelling.

A complete description of these devices can be found in SIMEONI *et al.* (2006).

2.2.1 Analysis of the degradation gases

The tube furnace apparatus used as pyrolyser is shown in Figure 2-8.

It is made of a cylindrical furnace 43.5 cm long with an internal diameter of 6.5 cm.

The reactor inside is 86 cm long with an inner diameter of 5 cm.

Two thermocouples were used to record the temperature history in the furnace.

One was fixed on the inner surface of the furnace and the other was placed in the middle of the combustion boat.

Gases were collected into two balloons called the gas samplers, hereafter.

The combustion boat was kept outside of the furnace until the temperature of the furnace has reached the required value.

At the same time, air suction was switched on, the gas sampler was opened and nitrogen was injected to obtain an inert atmosphere in the device.

When the temperature was stable, the sample was introduced inside the furnace.

The injection of nitrogen was stopped, gas sampler was closed and the valve (8a on Figure 2-8) allowing the ejection of gases outside the apparatus was opened.

When the fuel reached the required temperature, gas sampling began.

Valve 8a was closed, a gas sampler was opened and nitrogen was injected into the reactor to fill the gas sampler with pyrolysis gases.

Then the gas sampler was directly attached to the gas chromatograph (Flame Ionization Detector and Thermal Conductivity Detector).

The sample was gone out the furnace and a load cell was used to obtain the mass loss.

2.2.2 Kinetic study of the oxidation of pyrolysis gases

Different reaction mechanisms (one detailed mechanism: 40 species, 322 steps and several skeletal mechanisms: 14-19 species, 22-58 steps) for the combustion of pyrolysis gases were compared.

Those mechanisms were tested with different mixture composition according to the literature.

The choice of the Perfectly Stirred Reactor (PSR) as a test environment allowed to test the mechanisms under a wide range of mixture gas composition and fuel/air equivalence ratio.

The calculations were performed with the PSR-code from the CHEMKIN II library.

The evolution of temperature and species mole fraction with a fuel/air equivalence ratio around unity (conditions encountered in wildland fires) was investigated.

Simulations to experimental data obtained with the PSR (Figure 2-9) were compared.

The gas mixture used (CH_4, CO_2 and CO) is representative of yield from high temperature wood pyrolysis and is considered as the fuel gas.

2.2.3 Time-varying, axisymmetric, diffusion flame

The experimental device is shown in Figure 2-10.

The bench of combustion was composed of a one square meter plate drilled at its centre.

A ten square centimetres insulator was included at this location to support the fuel.

It was positioned on a load cell in order to measure the fuel mass loss as a function of time.

An array of 11 thermocouples was positioned above the fuel bed along the flame axis.

The first thermocouple was placed 1 cm above the top of the support and the others were located 1 cm from each other.

The thermocouples used were mineral-insulated integrally metal-sheathed pre-welded type K (chromel-alumel) pairs of wire with an exposed junction.

At the exposed junctions the wires were 50 μm in diameter.

The load cell was chosen for its very short response time (0.2 s).

The uncertainty in temperature and mass measurements were respectively 0.5°C and 0.07 g.

The sampling frequency was 100 Hz.

A visual camera located on the side showed that the device effect on the hydrodynamics was negligible.

A second visual camera was placed above the flame in order to observe the regression of the flame basis.

The fuel beds were in the shape of a disk with a diameter of 3.5 cm, a depth of 0.5 mm and a mass of 1.5 g.

An automatic algorithm was developed in order to follow the flame height and the width of the flame basis (cameras 1 and 2 in Figure 2-10, respectively) as a function of time.

Images were first extracted from videos with a sampling rate of 0.5 Hz. For each image, the flame was segmented from the background by using selection criteria based on the RGB components.

Binary images results from this processing showed in white colour the segmented flame on the image plane.

Next, the flame height and the width of the flame basis were computed using the Cartesian coordinates of the white area in the image plane.

For the frontal view, the height of the flame corresponded to the height of the white area. In the case of top vision, the width of the flame basis was the average diameter of the white area.

2.2.4 Thermal degradation of ligno-cellulosic fuels

For a range of temperature, between 450 to 900 K, begins the pyrolysis process.

Pyrolysis breaks down the solid matrix into low molecular mass gases (volatiles), and carbonaceous char.

Under air the products are oxidized during the combustion step.

Biomass degradation is a very complex process of interdependent reactions due to the complex structure of fuels composed of numerous different monomers oligomers and polymers.

Representative species of the Corsican vegetation concerned by wildland fires were used.

Leaves and twigs of these fuels constituted these samples.

Lignocellulosic materials were determined by different gravimetric methods. Cellulose, Lignin (Klason) and Holocellulose according to normalized or published methods were obtained.

Details can be found in CANCELLIERI et *al.* (2005) and in Leroy et *al.* (2006).

The heat flow vs. temperature were recorded thanks to a power compensated DSC and the mass loss vs. temperature thanks to a TGA.

All the fuels and their components were thermally studied.

In order to predict the thermal behaviour of the biomass, one can emphasize a simple model based on the thermal behaviour of the different biopolymer affected with their percentage in the plant.

Results show that the energy release is a function of energies of all the components.

2.3 FIGURES

Figure 2-1: Combustion table.

Figure 2-2: Combustion table before (on the left) and after (on the right) the adaptation to emissions measurement.

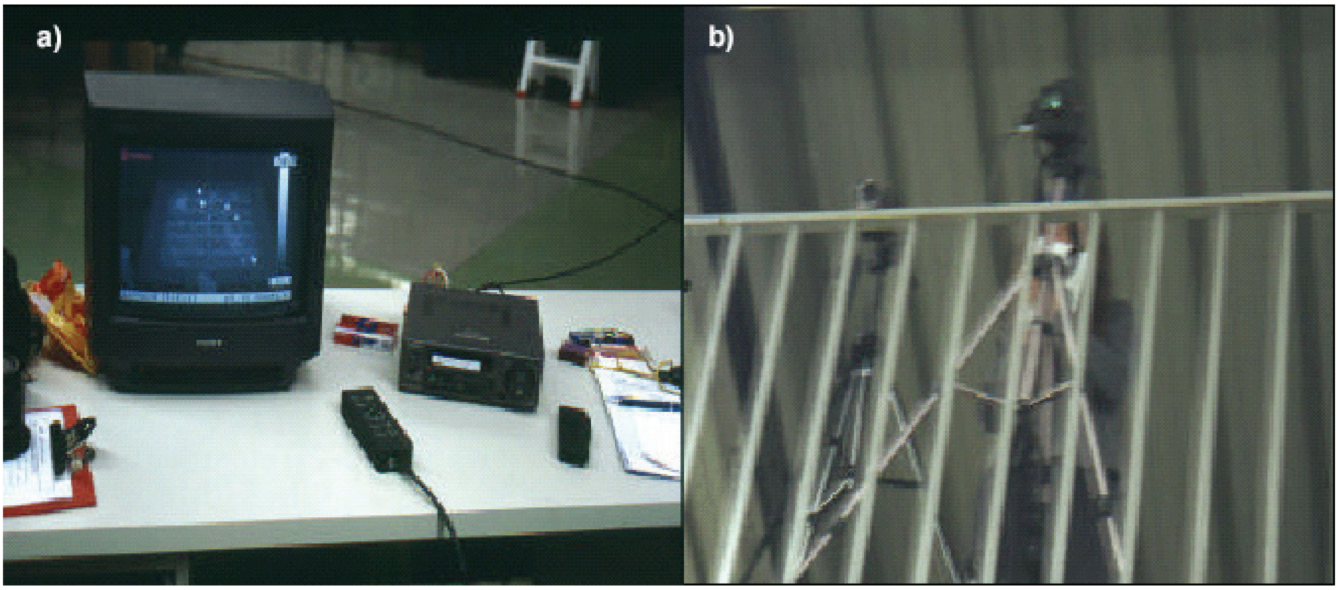

Figure 2-3 (a) TV screen and video recorder connected to the infrared camera
(b) view of the infrared and the video camera.

Figure 2-4: Image obtained with visual (left image) and infrared (right image) cameras.

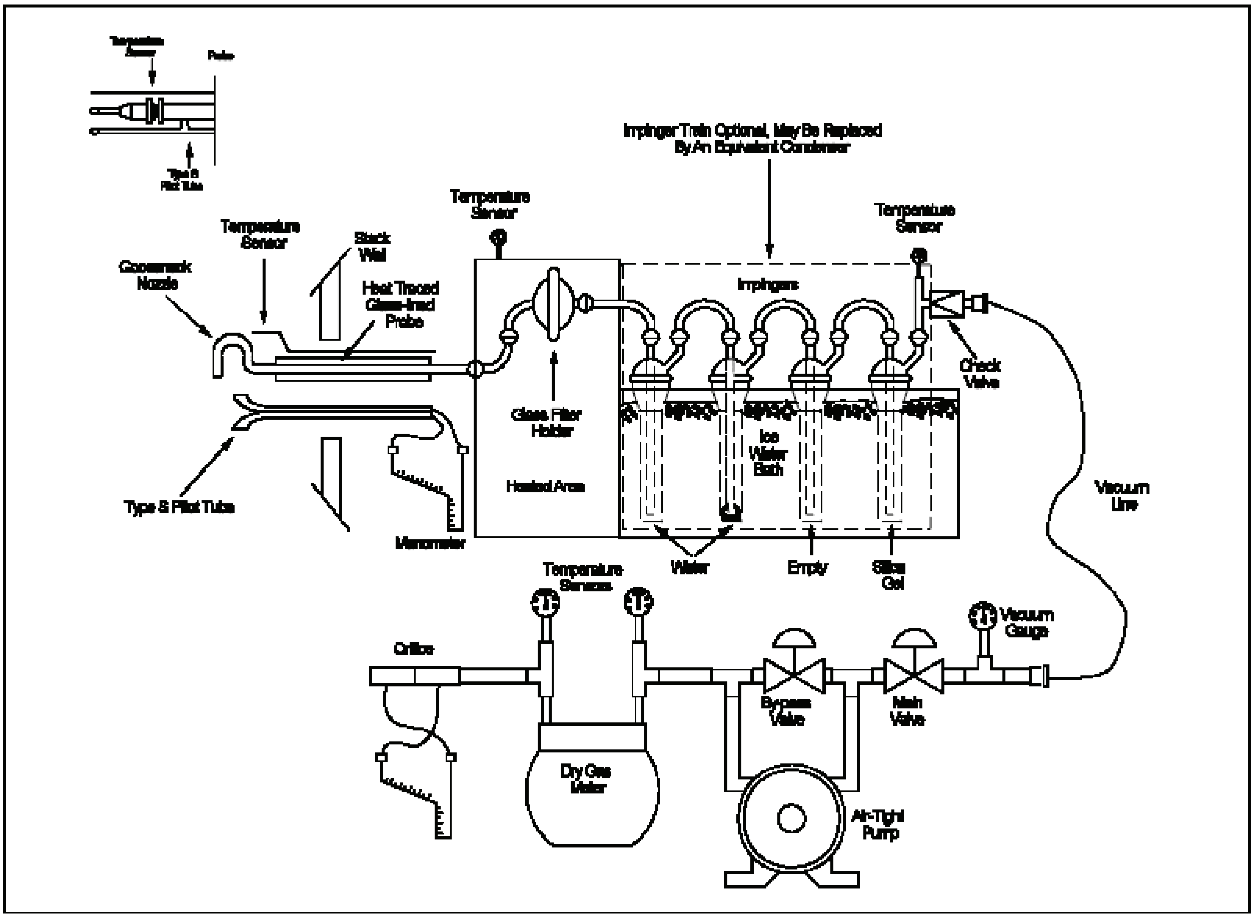

Figure 2-5: Method 5 scheme.

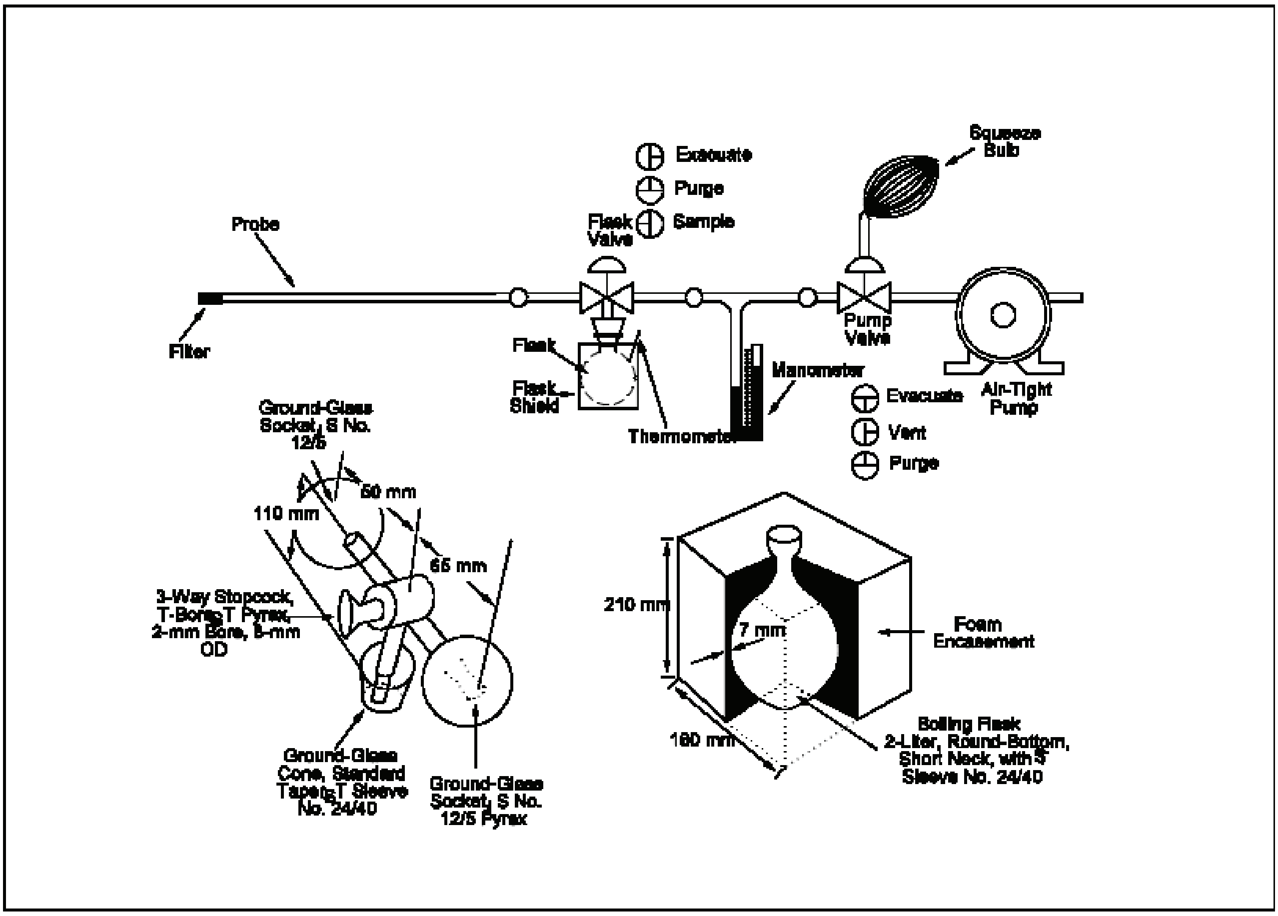

Figure 2-6: Method 7 scheme.

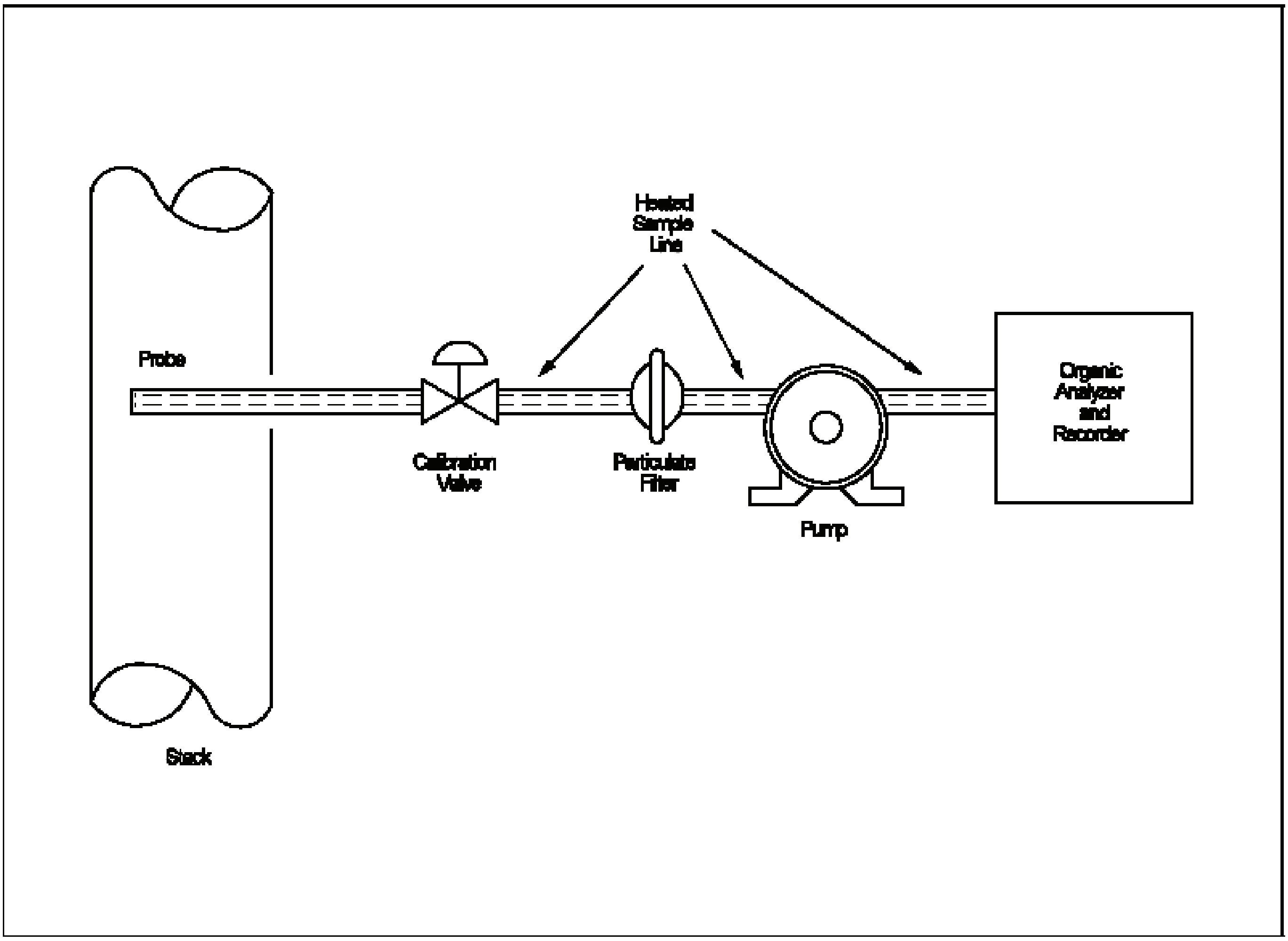

Figure 2-7: Method 25 A scheme.

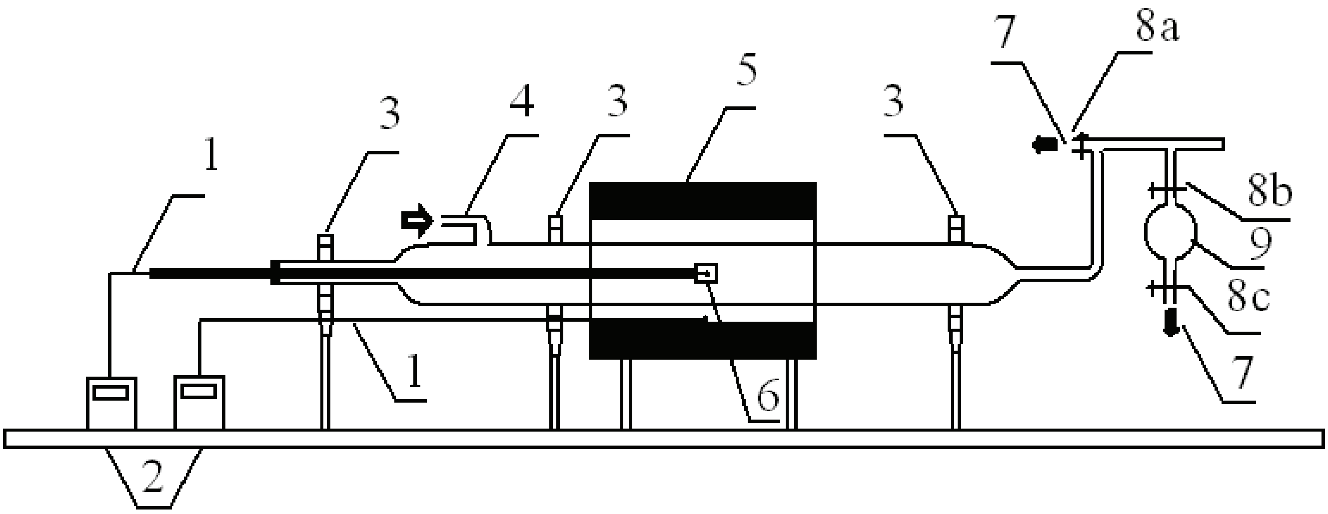

Figure 2-8: Schematic of the tube furnace
(1 thermocouple, 2 temperature controller, 3 bearing, 4 nitrogen injection, 5 electric furnace, 6 combustion boat, 7 air suction, 8a-c valves, 9 gas samplers)

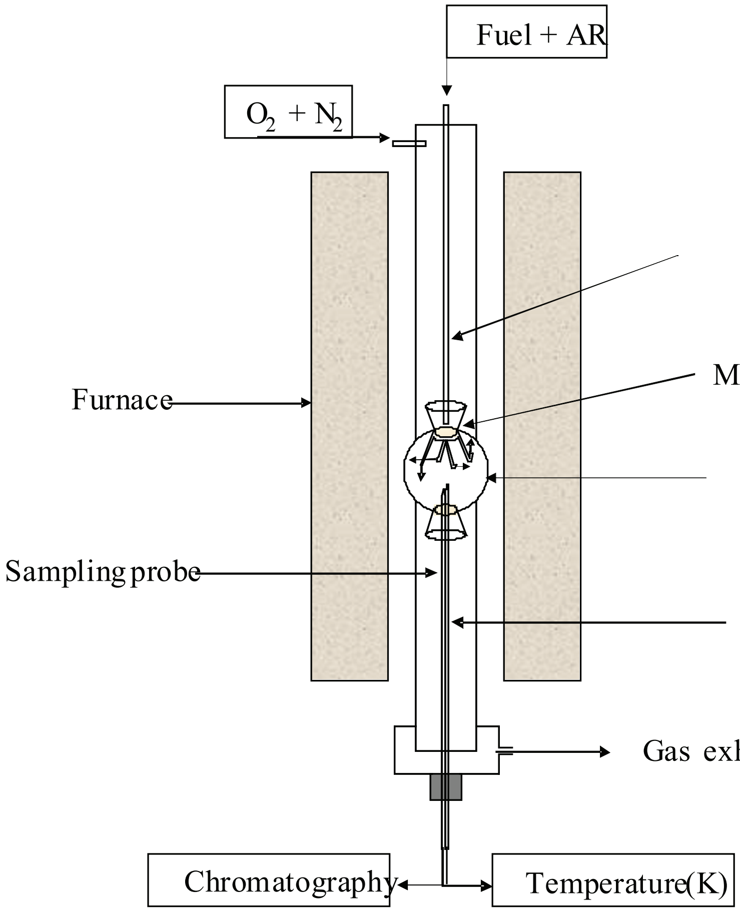

Figure 2-9: Sketch of the experimental Perfectly Stirred Reactor.

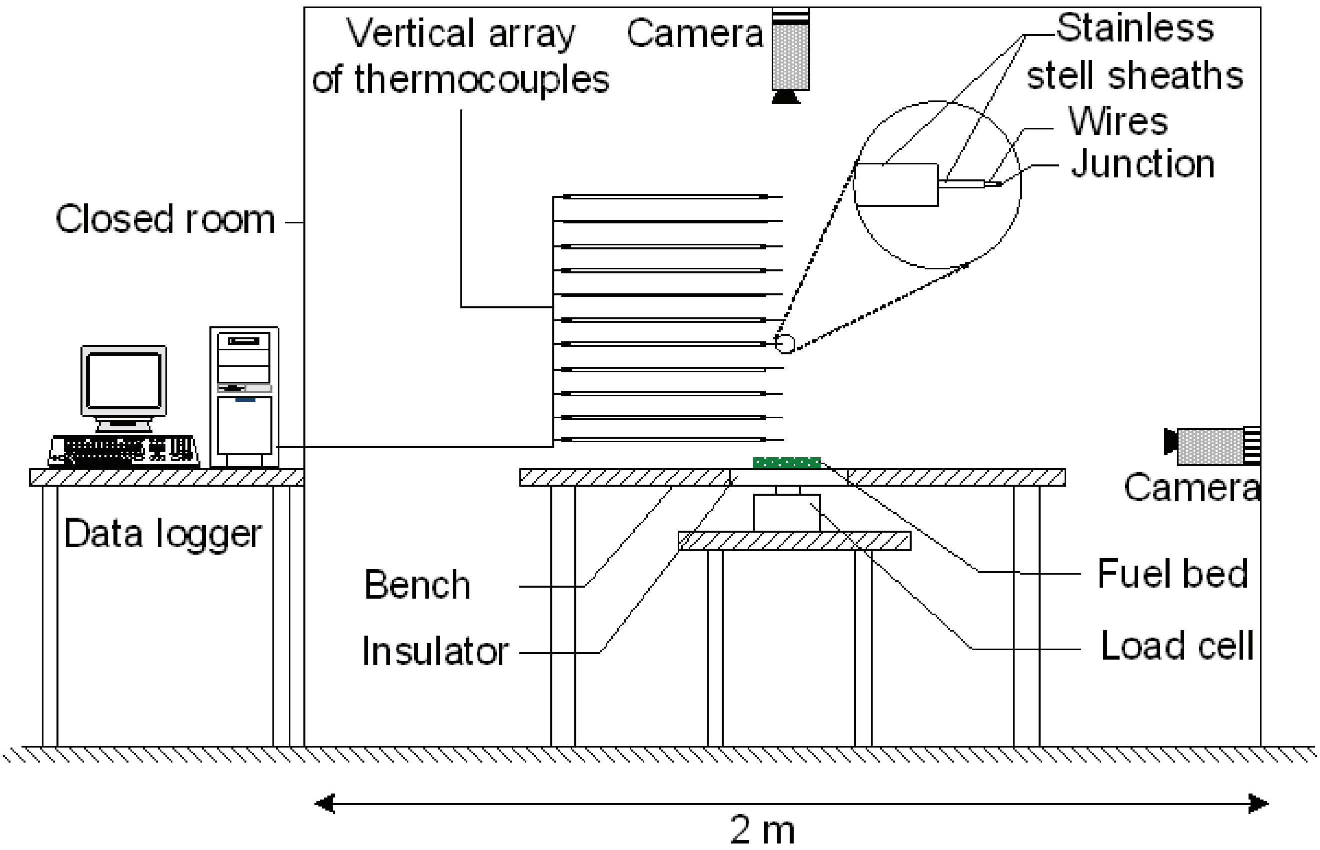

Figure 2-10: Sketch of the experimental apparatus.

2.4 TABLES

Table 2-1: Methods defined by EPA for measurements in stacks.

Parameter	EPA Method number
Number and location of sampling holes	1
Velocity and flow	2
Molecular Weight O_2, CO_2 e CO	3A
Relative Humidity	4
PM	5
NOx	7
VOC's	25 A

Table 2-2: Equipment used for smoke measurements in LAI facilities.

Parameter	Equipment
Molecular Composition	Analyser Hermann-Moritz-Trigaz 123 Tx
Flow, Humidity	Universal Stack Sampler, Andersen
PM	Universal Stack Sampler, Andersen
NO_X	NO_X sampling system, Andersen
VOC	Analyser Bernath Atomic Model 3006

3 FIELD DATA COLLECTING PROCEDURES

Real scale fire experiments constitute a usual practice to collect the necessary data to study the factors influencing forest fire behaviour and to test and validate forest fire behaviour models.

Commonly, accurate measuring of the variables influencing forest fire behaviour requires transporting and installing measurements devices in the field and locating them in appropriate places near the fire front, which makes difficult to obtain data in a real fire.

Notwithstanding these difficulties, wildfires are also a source of information and data, and some procedures used to acquire data in these adverse conditions are described in section 4.

Experimental field fires represent a valuable tool for understanding wildfires in its all extension: how it behaves, how it affects the environment or health, or how it can be efficiently extinguished.

Several issues regarding field experiments have to be taken into account when defining the location for carry on the experiments, namely terrain characteristics, fuel cover and others, and meteorological forecasts for selecting the most appropriate period.

3.1 REAL SCALE FIRE EXPERIMENTS – EXAMPLES

Several teams perform real scale fire experiments in Europe.

Portuguese (in Central and Northern Portugal), Galician and Corsican experiments are interesting examples of the kind of adopted procedures aiming to collect data to be used by the modellers community.

3.1.1 Galician fire experiments

Experimental fires have been done using Galician shrub lands that consist mainly of plants from family Ericaceous and others of genus Ulex and Chamaespartium.

About 125 Plots varying from 20 x 20 m to 200 x 300 m size with different aspects and slopes (steepness) have been burned in the last years.

A quadrangular or rectangular shape of the plot, oriented to the prevailing wind direction, has been used in most cases, but also hexagonal plots have been used to have better opportunities, for the ignition line, to be perpendicular to the wind direction (Figure 3-1).

The last set of experimental fires in shrublands has been carried out in the frame of the European Project FIRE-STAR (EVG1-CT2002-00041).

Twelve plots have been burned with size ranging from 20 x 20 to 80 x 100 m side.

3.1.2 Central Portugal (Gestosa) fire experiments

ADAI team has carried out Gestosa experimental burns since 1998 in the scope of various research projects funded by the European Union and by Portuguese Institutions, and always with a great number of participants from all Europe.

The study area (Figure 3-2) is located in Lousã, at Central Portugal (40º15'N, 8º10'W).

Experimental burning plots were established in the public lands that are owned by local communities but their management is under the jurisdiction of the Portuguese Forest Service.

The layout of the plots has been always designed taking into account the terrain configuration, safety conditions and the objectives of the teams involved in the experiments.

Since 1998, various dimensions and slopes of the burning plots have been tested.

During this period, values of area burned ranged between 0.1 and 1.8 ha, and slope varied from 11 to 32 º, allowing testing different conditions.

The plots are marked using GPS, and firebreaks are constructed in order to guarantee safety conditions.

In Figure 3-3, pictures of 2002 and 2003 burns, respectively, are shown.

The experiments are usually performed at the end of spring, during late May or early June, in order to have the burning conditions as close to those of the fire season as possible.

The weather is always very variable, and it has brought each year some difficulties in planning the burns.

Generally, mean temperature during the burns is around 20 ºC.

Different methods for fire ignition have been also tested.

These procedures include using a point or a line source, from one or more edges of the plots, and also linear ignition with pyrotechnic devices.

Water, foams and chemical retardants have been used for fire suppression efficiency assessment.

Also, explosive hoses filled with suppressant products have been used.

3.1.3 Northern Portugal fire experiments

Experimental fire activities in Northern Portugal vegetation types have been carried by UTAD since the 80's. (Figure 3-4)

The scientific objectives and experimental design have varied: a brief summary follows:

Experimental fires in maritime pine (*Pinus pinaster*) stands to study the effects of prescribed burning in the trees (e.g. BOTELHO *et al*., 1994).

Fires conducted in the dormant season. Plots usually 20x20 m.

The data obtained provided good documentation of low to moderate intensity fire characteristics, and have been used subsequently to test fire behaviour models.

Shrubland fires (mostly in the *Erica umbellatta-Pterospartium tridentatum* fuel type), with the objective of developing empirical fire behaviour models (FERNANDES, 2001).

Burns in late autumn to early spring.

Ignition line length varied between 20 and 100 m.

Shrubland fires (ignition line length up to 50 m) in the *Erica umbellatta - Pterospartium tridentatum* fuel type with the objective of developing empirical fire behaviour models and exploring within-fire variation (FERNANDES et al., 2000).

Burns in winter and early spring.

Hexagonal microplots of 1 m^2 were used as the sampling unit.

Shrubland fires (ignition line length between 20 and 120 m) in the *Erica australis - Pterospartium tridentatum* fuel type (VEGA *et al.*, 2006).

The objective was to provide data to test a physical fire behaviour model, but it also resulted in information respecting to the effect of terrain slope on fire rate of spread and within-fire variation in fire characteristics.

Burns in late spring.

Fire measurement by sections along the longitudinal axis of propagation.

Small (10-20 m side) surface fires of varying intensity (up to 4000 kW m^{-1}) in maritime pine stands, conducted from November to June (FERNANDES *et al*., 2002).

This was the most extensive (near 100 fires) burning program in Europe under a tree canopy.

The goal was to link the fire environment, the fire behaviour and the first order fire effects.

Empirical fire behaviour models were derived for ignition probability, rate of spread, flame dimensions, fireline intensity and fuel consumption.

As a result a complete prediction system was developed which originated decision support tools to prescribed fire and a sound database to test other fire models.

A high-intensity experimental fire in a maritime pine stand (2 ha size), conducted in July that included periods of crown fire (FERNANDES *et al*., 2004).

Ignition line length was near 40 m.

The objective was to produce data to test a physical fire behaviour model and to quantify the effect of prescribed burning on subsequent wildfire behaviour.

The burned area included 4 fuel ages (i.e. time since last prescribed fire), respectively 28 (stand age), 13, 3 and 2 years.

3.1.4 Corsican fire experiments

In Corsica, the experimental burn was carried out in the coastal region near Porto-Vecchio.

A complete description of this experiment can be found in SANTONI *et al.* (2006).

Situated on an uneven terrain, the plot was in the shape of a rectangle, 30 meters wide perpendicular to the slope with a north-western outlook on that side and 80 meters long parallel to the slope (cf. Figure 3-5).

The experimental protocol was elaborated to investigate the properties of the fire front, the environmental conditions and the effects of the head fire section ahead of it.

The different measuring structures and devices used are shown in Figure 3-6.

3.1.5 Figures

Figure 3-1: Burning plots layouts in Galician fire experiments.

Figure 3-2: Geographical location of Gestosa field experiments and aerial view of the plots burned in the years of 1998 to 2001.

Figure 3-3: Burning plot with linear ignition pattern in year 2002 (left image) and high intensity fire (due to high winds) in year 2003 (right image).

Figure 3-4: Examples of UTAD's experimental fires. Summer (July 2002) fire in a *Pinus pinaster* stand, soon after ignition in 13-year old fuels. Spring (May 2003) fire in *Erica australis – Pterospartium tridentatum* shrubland.

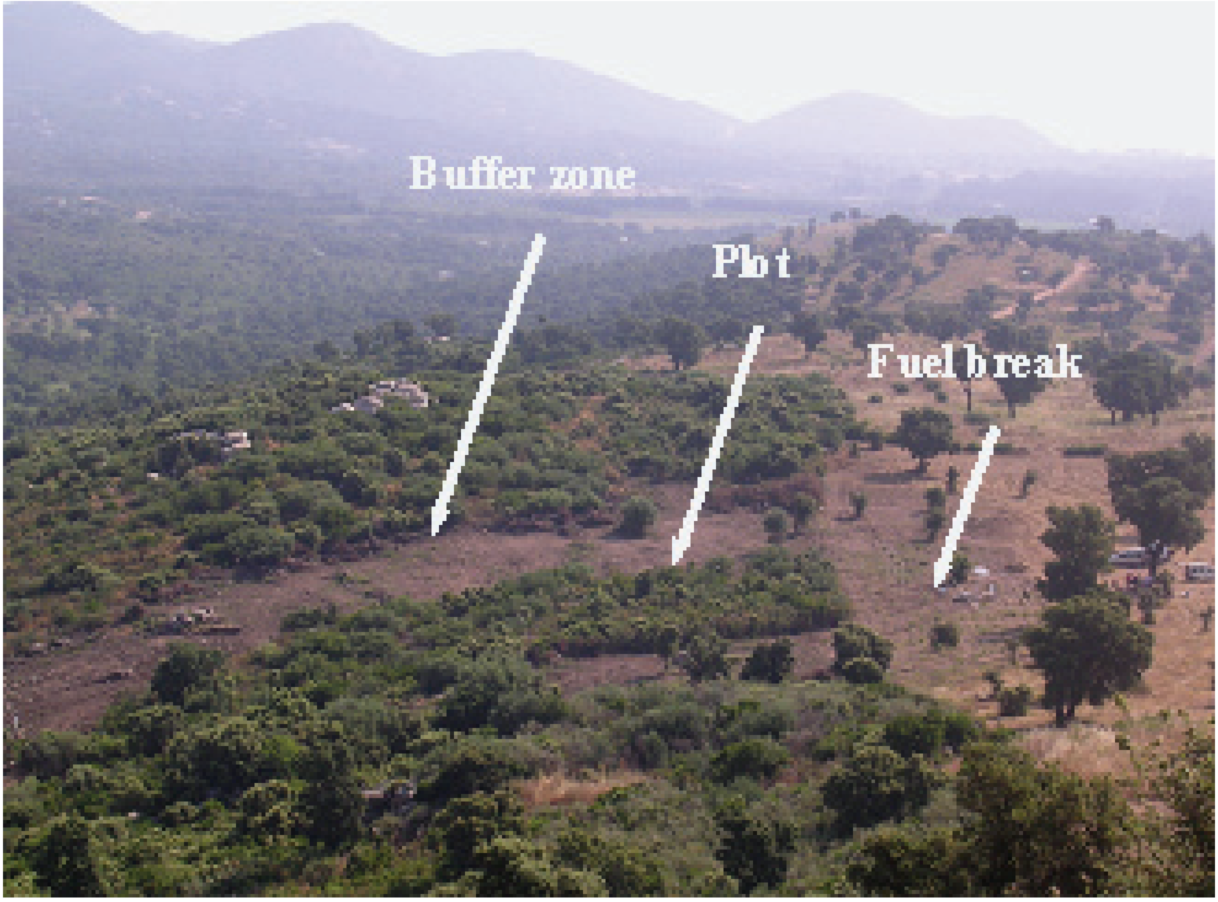

Figure 3-5: General view of the selected plot.

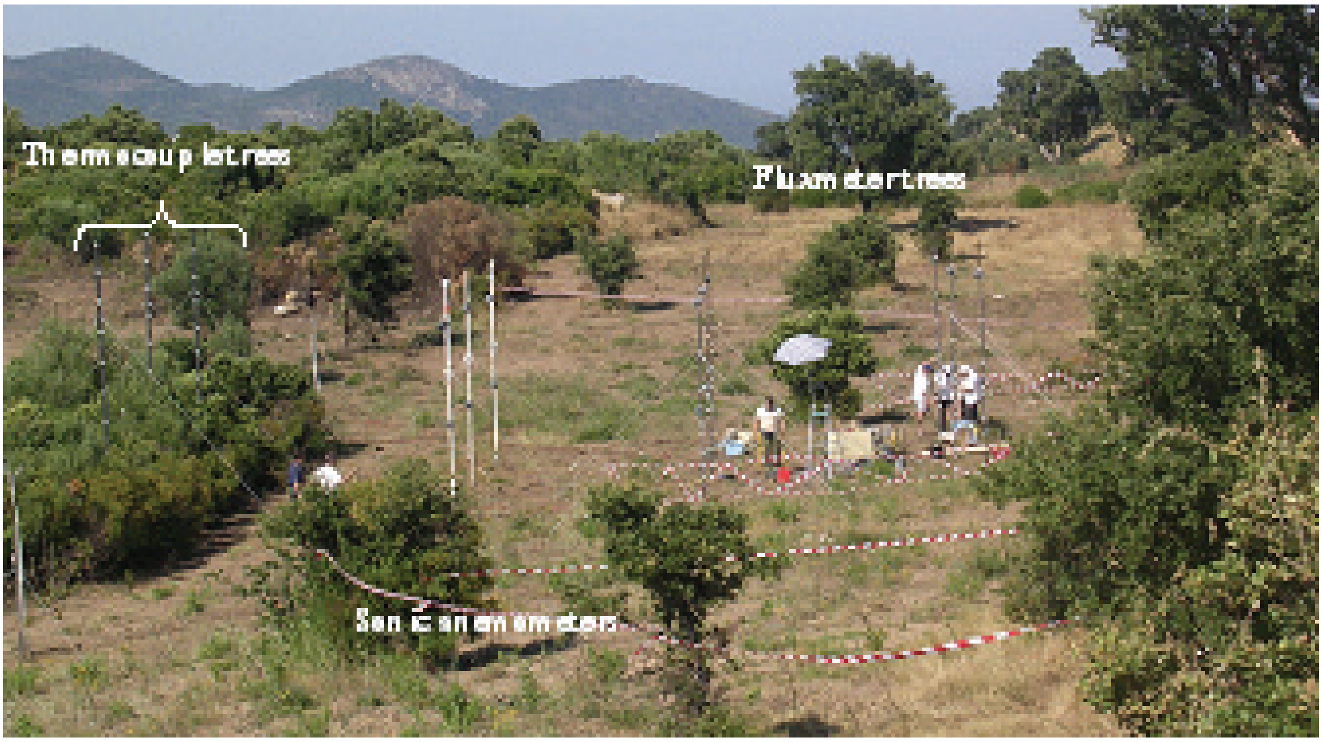

Figure 3-6: Schema of the plot, with measuring devices.

3.2 FIRE AND SMOKE BEHAVIOUR MODELLING

Fire experiments are essential for the collection of data during real scale fires, which are used by numerical models of fire behaviour as input information needed for running the simulation or as validation data needed for evaluating model performance.

These data are related with the characterization of the terrain, the fuel, the meteorological conditions or the fire itself.

In the scope of smoke modelling, fire experiments are also a unique opportunity for testing models.

3.2.1 Terrain characteristics

Plots layout and extension depend on:

- the objectives of the experiments,
- the type and size of the vegetation and
- the compromise between the size of the plot required to simulate a wildfire and the size needed to ensure topographic and fuel homogeneity inside the plot.

Although different sizes and shapes have been used in different studies (see section 3.1), most fire experiments use quadrangular or rectangular plots of varying sizes, usually in the 10x10 to 100x100 meters range (FERNANDES *et al*., 2003).

In fact, a particular attention is devoted to slope when organizing a field fire experiment.

Several partners pointed out topography (see Annex A) as an important input data in both fire and smoke modelling.

According to FERNANDES *et al*. (2003), the terrain slope should be as much as possible constant on each plot.

In the Corsican fire experiments, a Digital Elevation model was designed in order to integrate data into a Geographic Information System (GIS) thanks to a Leica tachometer.

3.2.2 Fuel characteristics

Deliverable D-02-01 produced under EUFIRELAB gives a state of the art on the available methods for wildland fuel description and modelling.

It comprises an extended list of references from fuel particle level to landscape level.

It also includes examples of site and country-specific fuel modelling methods throughout Europe, covering different countries (ALLGÖWER *et al*., 2004).

Two main approaches are possible for fuel sampling.

The first considers the acquisition and measurement of average values for the plot concerning the fire environment and behaviour; in this strategy, the most common one, the fire is represented by a single value for each meaningful variable.

In the second procedure, individual measurements are collected that describe and take advantage of the fire internal variability (FERNANDES *et al*., 2003).

The scale of fuel description depends on the sampling strategy.

Average fuel descriptors will be estimated for each sampling unit (the macroplot, i.e., the entire plot; the microplot; the sub-plot) by non-destructive methods.

A combination of line transects sampling, quadrate sampling, visual estimates and tree measurement methods are to be used.

For instance in Galician fire experiments, vegetation cover and height and litter depth are measured across the major axis of the plot in two transect lines.

Post-burn biomass is determined from material collected in a random sample of quadrates with 2 x 2 m size, selected within the plot; another set of quadrates, similar to those inside the plot, can be selected in the surrounding vegetation near the plot to determine the pre-burn shrubs, herbaceous and litter biomass, avoiding fuel heterogeneity inside the burning plot.

Fuel load, distribution of fuel families (solid particles of vegetation with common properties concerning the physical and chemical processes involved in the fire) and fuel consumption can be calculated from these quadrates data.

Also, allometric relationships between several shrubland biometrical parameters (cover, height, basal stem diameter, stem density and age) and shrub biomass can be used in order to estimate the pre-fire fuel load.

In order to guarantee representativity, samples for fuel moisture content determination should be collected immediately before ignition in several sections randomly selected along the plot.

These locations should combine different shading conditions, wind exposition, and shrubs aspects and heights.

The number of samples for each fuel family (or each cluster of fuel families) of dead fuels and live fuels should range, respectively, from 3 to 5 and from 1 to 3.

Replication of the sampling procedure after the fire is not necessary, unless the fire duration exceeds one hour (FERNANDES *et al*., 2003).

Fuel moisture has to be sampled for each particle family, as well as the other physical and chemical parameters required by the model (mass-to-volume ratio, surface-to-volume ratio).

Fuel samples have to be tightly sealed in adequate containers, which should prevent moisture exchanges after collection in order to calculate the percentage of moisture content on a dry weight basis (taking into account the condensation onto the jars).

The preferred method of determining the moisture content of the samples is the use of a forced-air drying oven.

In Portugal, the vegetation cover of Gestosa is a continuous shrubland with some isolated *Pinus pinaster* trees.

There are three dominant species: *Erica australis*, *Erica umbellata* and *Chamaespartium tridentatum*, corresponding to 85% of the total percentage cover.

The characterization of the vegetation cover is made using destructive and non-destructive sampling.

At least once a week fuel samples are collected in order to evaluate moisture content during three months prior to the experiments (VIEGAS *et al*., 1998b).

To map vegetation in Corsica, a quadrat method was used and the terrain was divided in 90 quadrats of 25 m².

In each quadrat, the location of each species and their heights were defined.

Vegetation was classified in a flora and also in strata: upper shrub layer (> 2 m), lower shrub layer (< 2 m) and herbaceous layer.

The data coming from site survey within a GIS was integrated.

Polygonal vector layers for the three strata were defined. In addition to spatial data, attribute data were also stored in tables that contain descriptive fields (species, minimum/maximum dimensions, recovery rate…).

Pre-burn conditions were measured: moisture content for each species and meteorological conditions.

3.2.3 Meteorological conditions

Various meteorological parameters are monitored during experimental fires in order to obtain input data for both fire progression and smoke dispersion models (see Annex A).

Deliverable D-07-01 analysed in detail this topic. In particular, a description of the protocols used for meteorological data collection is made, as also recommendations for improving meteorological measurements during experimental fires.

Additionally, deliverable D-07-08 can provide some useful complementary information on data acquisition and logging systems.

During experimental field fires, the use of mobile automatic meteorological stations is a common procedure for the real time measurement of meteorological conditions (see left picture on Figure 3-7).

Also, fixed masts (usually 10 m height) are used (central picture on Figure 3-7).

Shielded thermo-hygrometers are used for the measurement of temperature and humidity. Its location should prevent the direct exposition to solar radiation and a free air circulation.

This equipment should be placed at 1.8 to 2 m height (when considering open grasslands, bush vegetation, or low-density forests).

A 1 s time-step is a feasible value, but a 1 min average (calculated using instantaneous measurements made every 1, 2 or 5 seconds) is usually sufficient for modelling purposes.

In Corsica, weather parameters were recorded during the fire by a meteorological station but particular attention was given to the wind field in the vicinity of the plot thanks to the three two-dimensional sonic-anemometers (cf. Figure 3-6).

The advantage of those anemometers lies in their sampling frequency of 1 Hz, which allows coping with possible quick changes of wind field.

Due to the effect of vegetation on wind speed, the following recommendations should be taken into account (CARRERA and FOX, 2003):

- Wind speed simultaneously measured at different heights for the same point in order to define the wind speed profile.
- If just one height is available, measurements should be done at 30 to 50 cm above the highest stratum of vegetation that will be completely burned, which corresponds roughly to the mid-height of the flames.

Except in closed micro-scale conditions, temporal variability in wind speed and direction can be extremely important due to both thermal (advection) and mechanical (surface roughness) air motions and turbulences.

A low time-step value, from 1 to 2 s, should be used in order to guarantee representativeness of the data acquired.

According to CARRERA and FOX (2003), for a 1 s time-step the combination of a wind vane and anemometer does not react sufficiently quick to measure wind characteristics accurately.

If the wind vane and anemometer are on the same axis, both react too slowly to bursts of wind.

If the wind vane and anemometer are on separate axes, the wind vane reacts more slowly than the anemometer and there is a lag between direction and wind speed recorded.

To avoid these errors, the use of instruments capable of a fast reaction to simultaneous wind speed and direction is necessary.

This equipment can be of two types:

- 1, 2 or 3 dimension mechanical anemometers with weak inertia and propellers oriented at a 90° angle in order to calculate the wind speed and direction from vectors.
- Expensive and sophisticated sonic anemometers (as the one shown in Figure 3-7, right-side image, used in Galician experiments).

The location of the instruments, schematically represented in Figure 3-8, depends on the number of sensors available, and the size and configuration of the experimental burn plot.

The equipment should be placed at the windward side of the plot in order to avoid interferences from the air circulations induced by heat.

However, other locations can be tested if these disturbing phenomena are going to be analysed. Instrumentation for a large (100 x 100) forested plot (tree height > 15 m) would be located roughly 150-200 m upwind of the initial burn line.

For a small (10 m x 20 m) bush plot (bush height < 1 m) on a steep slope, instruments should be located roughly 15 m upwind of fire ignition line (CARRERA and FOX, 2003).

If possible, instruments should be located on both sides of the burn plot.

Two stations located upwind can be used for larger plots.

Wind speed and direction near the fire front can be measured laterally on either side of the plot.

Also, hand-held instruments allow to be moved along the plot as the fire front progresses.

During Gestosa fire experiments, both UAVR and ADAI teams use meteorological stations for data measurement and storage at different heights and locations, providing an accurate description of meteorological data in time and space.

These data is used as input in DISPERFIRE model in order to relate wind behaviour with air pollutants measured concentrations.

3.2.4 Fire line evolution

A usual methodology for determining the rates of fire spread consists on measuring the time needed for fire front to reach pre-placed labelled iron posts located in two rows along the plot and the same number of wooden stakes placed in both sides of the plot that divide the run of the fire in several segments.

Figure 3-9 illustrates this kind of approach.

The rise in temperature during the fire is usually monitored using thermocouple probes located at regular intervals along the central axis of the plot.

In each point 2 thermocouple probes can be placed at two different heights, one at litter surface level and the other at 30 cm bellow the top of the shrub strata.

In Figure 3;10, 30 m long K type chromel/alumel thermocouples (0.1 mm wires, 1 mm diameter inconel sheath) used in Galician experiments are presented.

Temperatures can be recorded using data loggers.

A 1 s time-step is indicated in order to guarantee an accurate description of fire behaviour.

Visual estimates of flame position, length and depth and spotting activity is usually a difficult task because of the great quantity of smoke produced, that hampers the flames observations.

The study of the duration of the rising temperatures produced by flames moving along the aligned thermocouple probes helps to assess the flame depth.

The height of shrubs and posts can be used as reference for flame height measurements (see Figure 3-11).

Also, video images recorded with hand held cameras, at both sides of the plot, by operators walking parallel to the fire front displacement provide an excellent method for post-fire analysis of fire spread.

In Gestosa fire experiments, also a top view given by cameras embarked in a helicopter allows to systematically localise the fire front progression.

In order to catch the fire line evolution, both visible and infrared video cameras, as shown by comparison in Figure 3-11, should be placed at fixed positions that allow that all the fire evolution can be recorded.

For converting the images of the experiments from analogical format (8 mm or VHS) to digital (AVI), a video capture card can be used.

Videos can be processed using an image capture program (as Pinnacle Studio PCTV Plus), as done by ADAI team.

The captured photo frames, correspondent to fixed intervals of time (usually every 15 s), can be used to reconstruct the evolution of the fire line (for example, using the MicroStation program).

From each photo frame, the contour of the fire line can be drawn by hand, and then applied the macro which contains the mathematical algorithm for correcting the perspective effect.

For the data analysis, a computer program in Java language was developed.

The program, called Fire Analysis, reads the experimental data from text files and calculates the evolution of the fire perimeter, the rotation of the fire line and displays a graphic to follow the calculations.

Figure 3-12 shows an example of the program (OLIVERAS, 2004).

In Corsican fire experiments, and with regard to the properties of the fire front, “characterisation lines” were elaborated to determine the fire front shape and velocity.

Each line consists of six sensors (fuse breaking at 300°C and a resistor) provided by a 12 V direct power supply.

Second structures, called “thermocouple trees” (cf. Figure 3-6), are structures of six meters high built in order to study the temperature in the fire plume.

They were placed in the upper part of the plot, inside the vegetation.

Each “thermocouple tree” was equipped with 10 thermocouples positioned from 0.6 to 6 meters.

The thermocouples used in these experiments were pre-welded K-type with an ungrounded protected junction.

They were 15 cm long with sheaths of 250 μm and were chosen since they constituted a compromise between their robustness and their rapidity.

To study the effects of the head fire section, nine masts each one supporting two devices containing two radiant and convective heat flux sensors (Captec®) were placed in the fuel break (cf. Figure 3-6).

The posts were positioned in three lines located at a distance of 5, 10 and 15 m from the top of the parcel, in order to investigate the heat flux variation along distance.

The sensors were connected to a data logger except the cameras and the weather station.

Two video cameras were located on the sides to investigate the flame shape (cf. Figure 3-13a).

An infrared camera (cf. Figure 3-13b) and a video camera were used to film the fire font reaching the thermocouple trees in a frontal view and a remote video camera served to localise the fire front advance.

The measurement of radiation and convection is of great interest to improve and validate modelling approaches.

A device was designed to record heat transfers in the fire. Its detailed description can be found in SILVANI and MORANDINI (2006).

The sensor consists on the association of two heat flux sensors Medtherm® with a K-type thermocouple facing the fire front.

One of the heat flux-sensor characterized the radiant heat flux whereas the second one measures the total heat flux.

The thermocouple provides the external temperature of the gas mixture surrounding the sensor.

Two T-type thermocouples measure the operating temperature of each heat flux sensor, which has to be lower than 300°C.

A photograph of the device is presented in Figure 3-14.

The heat flux sensors and the thermocouple are fixed on the same face of an insulated support.

They are plugged on the power-supplied data logger and this last is buried 30 cm under the ground surface.

The electric cables from sensors to the data logger go through a vertical steel tube carrying the sensors support.

The heat flux sensors are water-cooled with a flow rate of 2 litres per minute.

The cooling pipes also pass by the thermally insulated steel tube and are connected to a pump.

The two flux-meters are designed for measuring total and radiant heat fluxes over a large range, i.e., up to 200 $kW.m^{-2}$.

This new sensor must offer a large set of advantages by facilitating the instrumentation of experimental fires and enhancing the relevancy of data gained on such experiments.

It allows investigating the fire spread over larger parcels of solid fuel (shrub lands or forest).

This feature is extremely important because fire is a scale dependant process and for a better relevancy, experimental studies must be performed at a convenient scale.

The device is also intrusive and it can enter into contact with flame.

This is a fundamental advance in comparison with non-intrusive heat flux sensors since it will allow identifying the dominant heat transfer mechanism during fire spread.

Finally, the device is reusable.

Out of the change of cooling pipe after multiple uses, sensors are thermally protected, even in intense fire.

The integrity of each sensor and the relevancy of measured heat fluxes are controlled through the time evolution of their operating temperature.

3.2.5 Atmospheric emissions

The measurement of fire emissions during field experiments is a common procedure for calculating emission factors used as inputs for smoke dispersion models.

The UAVR team has applied for several years in Gestosa a technique for the measurement of volatile organic compounds (VOC) emissions, which consists on sampling smoke into Tedlar bags using an appropriate pumping device, as shown in Figure 3-15.

Samples are then kept in a cool and dark environment.

Subsequent laboratorial analyses consist in submitting the samples to a gas chromatography with a flame ionisation detector (FID) (see deliverable D-07-03).

This technique allows sampling smoke during different fire stages (flaming and smouldering), enabling to determine specific emissions for different burning conditions.

Also the effect of retardants application on the characteristics of smoke can be analysed.

In Corsican experiments, two original devices to collect volatiles and smoke were used.

Thanks to air sampling pumps, atmosphere samples were taken into cartridges filled with an adsorbent and into tedlar bags.

Analyses were performed at the laboratory by gas chromatography one day after the field experiment.

Samples were thermally desorbed from the cartridges in the GC column coupled to a MS detector.

The aim is to characterize the risks related to the toxicity of smoke in actual conditions.

Benzene, Toluene and Xylene (BTX) are highly toxic compounds that are quantified in the smoke sampled during the fire.

Quantification of such compounds was done with an external calibration using commercial mixtures of BTX.

The sampling device consists of a portable air sampling pump linked to a pyrex cartridge filled with an adsorbent.

The pump flow rate was 150 $mL.m^{-1}$.

A gas volume (2.25 l) passes through the cartridge and the molecules present in the gas phase are trapped.

The sampling zone was located at the end of the plot on the fuel break so as to analyse the atmosphere’s composition 30 m away from the fire zone.

A thermocouple was used to measure the temperature during the sampling.

The cartridges were rapidly brought to the laboratory and analysed in order to avoid further oxidation. A full description of this part can be found in BARBONI *et al.* (2005).

3.2.6 Air quality

Air pollutants concentration values measured in a given location are used to validate the results of smoke dispersion models.

In the field, distinct techniques and equipment are usually applied in order to perform the measurements of different pollutants.

As an example, Table 3-1 summarises the measuring techniques and equipments used by UAVR team during Gestosa fire experiments for air quality data monitoring (MIRANDA and BORREGO, 2002; MIRANDA *et al.*, 2005).

Usually, the pollutants monitored are carbon monoxide (CO), nitrogen dioxide (NO_2), nitrogen oxide (NO) and particles with an aerodynamic diameter minor than 2.5 and 10 µm (PM2.5 and PM10, respectively).

The equipment and methods used were described in more detail on deliverable D-07-03.

In Figure 3-16, an example of a mobile laboratory used by UAVR team during Gestosa experiments for air quality and meteorological data acquisition is shown.

The location of the mobile laboratories should be, as much as possible, in the proximity and downwind of the burning plots in order to have a good representation of smoke dispersion.

Taking into account the instability of the wind direction and the extension of the plots this constitutes, however, a critical decision, which has to be taken prior to the experiments.

The selection of the most appropriate spot for placing the equipment should be based on the analysis of meteorological forecasts and historical wind direction data, always guaranteeing the best operational and safety conditions of personnel and equipment.

Also, the rise of the plume caused by the intense heat produced by fire, especially under calm winds, is a disadvantageous situation for the measurement of air quality degradation as a result of vegetation burning.

The results of passive sampling can also be used to validate models results.

Passive samplers (PS) (see Figure 3-17) can be used for both individual exposure assessment and air quality monitoring, with the great advantage of being portable and easy to use.

Subsequent samples analyses are performed in laboratory under controlled conditions.

NO_2 and sulphur dioxide (SO_2) hourly concentrations can be sampled using this technique, as also shown in Table 3-1.

In this case, a grid of samplers should be defined, according to the local dominant winds, in order to obtain, in conjunction with the mobile laboratories, a representative spatial coverage of pollutants dispersion.

The grid of NO_2 and SO_2 samplers defined in Gestosa 2002 can be shown as an example for locating the equipment in terrain.

This grid, which was defined according to the local dominant winds, consisted basically on two rows of PS placed at the top of the experimental field.

A high-resolution spatial coverage, with replicates in each location, of pollutants dispersion was obtained using this method.

In Figure 3-18, the location of the two lines of PS is presented:

- the first one, closer to the burning area, in which the samplers were replaced one or two times a day (temporary fixed samplers - TFS); and
- the other one with the devices that were sampling during all day (permanent fixed samplers - PFS), aiming to evaluate the influence of the burned plots characteristics on air pollutants concentration values.

In between the rows the mobile laboratories were located.

Various firemen and members of the research-team (see Figure 3-19) carried a mobile PS during the experiments in order to estimate the human exposure to NO_2 and SO_2.

Instead of having cumulative values of smoke exposure, corresponding to the period during which the sampling was performed, a detailed evolution with time of air pollutants concentrations in the breathing area can be obtained using portable equipment indicated for personal exposure assessment (REINHARDT *et al.*, 2001; REINHARDT and OTTMAR, 2004).

3.2.7 Figures

Figure 3-7: Meteorological mast (10 m height), mobile automatic meteorological station and ultrasonic anemometer.

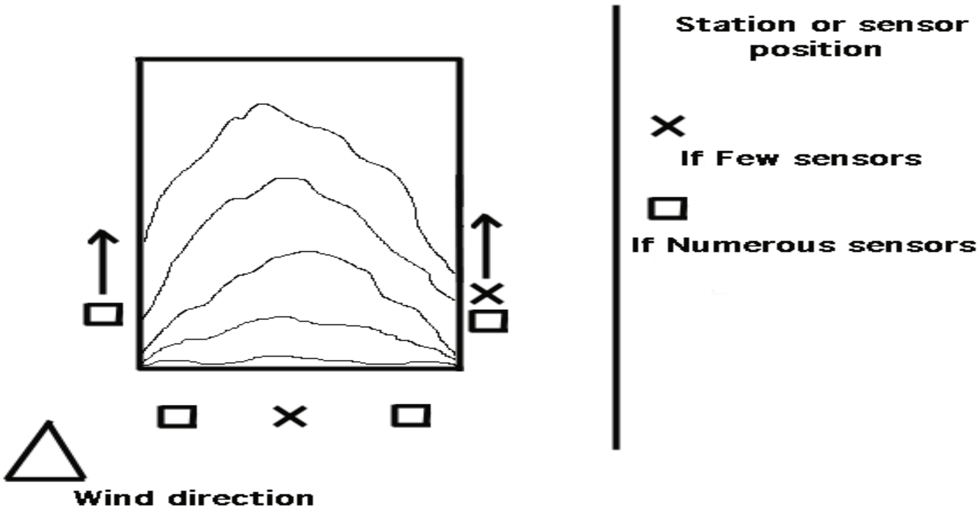

Figure 3-8: Instrument locations around the burn plot (Carrera and Fox, 2003).

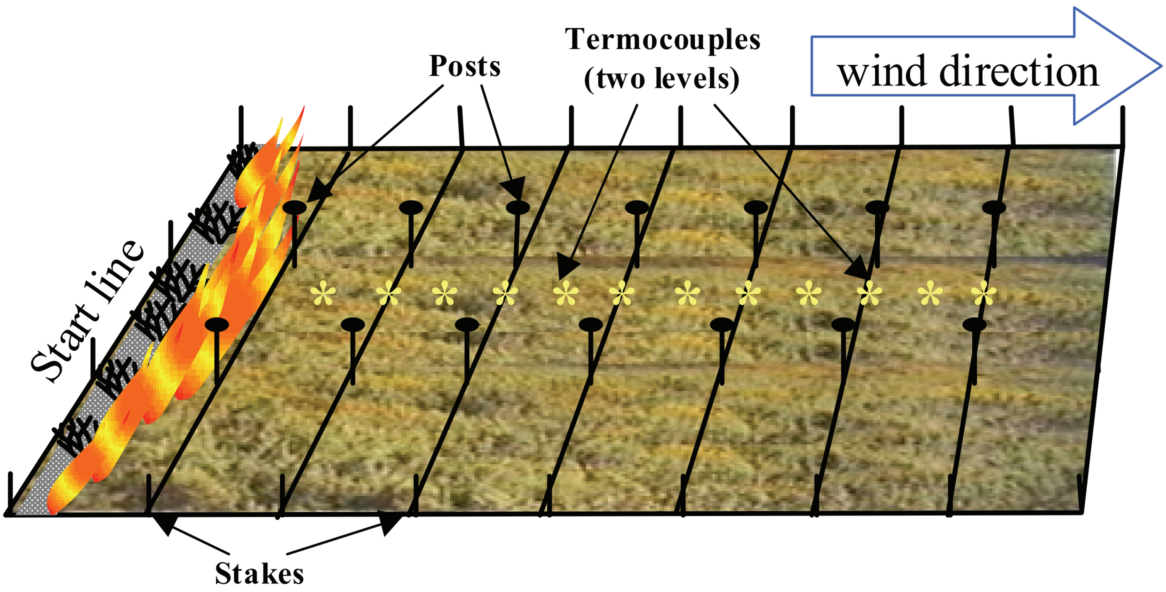

Figure 3-9: Typical layout for fire progression measurement.

Figure 3-10: Temperature data measuring and acquisition equipment.

Figure 3-11: Fire progression during Galician experiments registered using a visual (left image) and an infrared (right image) camera.

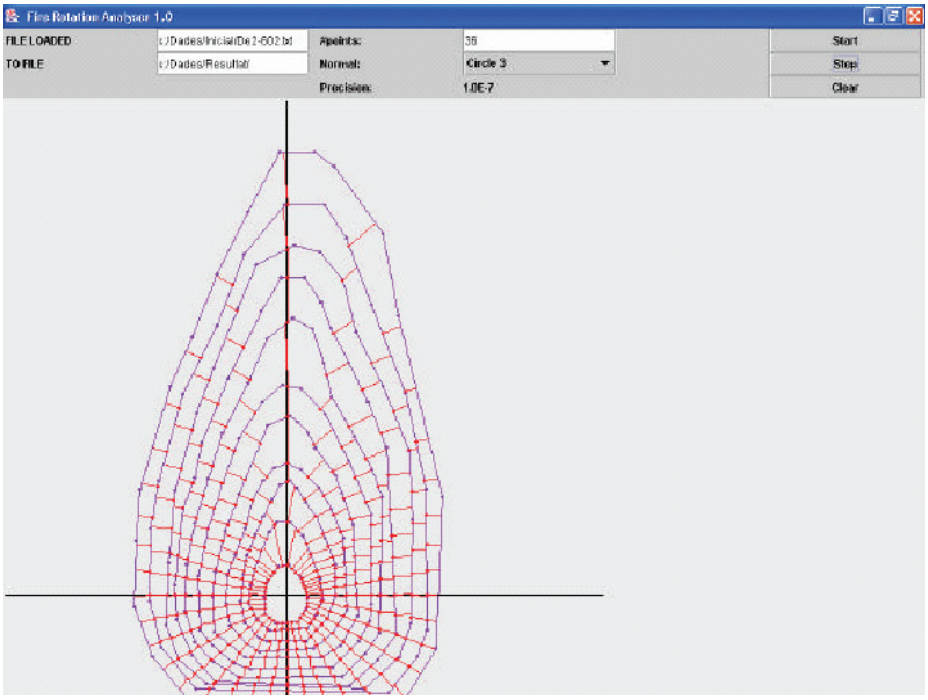

Figure 3-12: Screen of the Fire Rotation Analyser Program. Red points correspond to radial points and red lines correspond to the propagation vector of that point to the next perimeter.

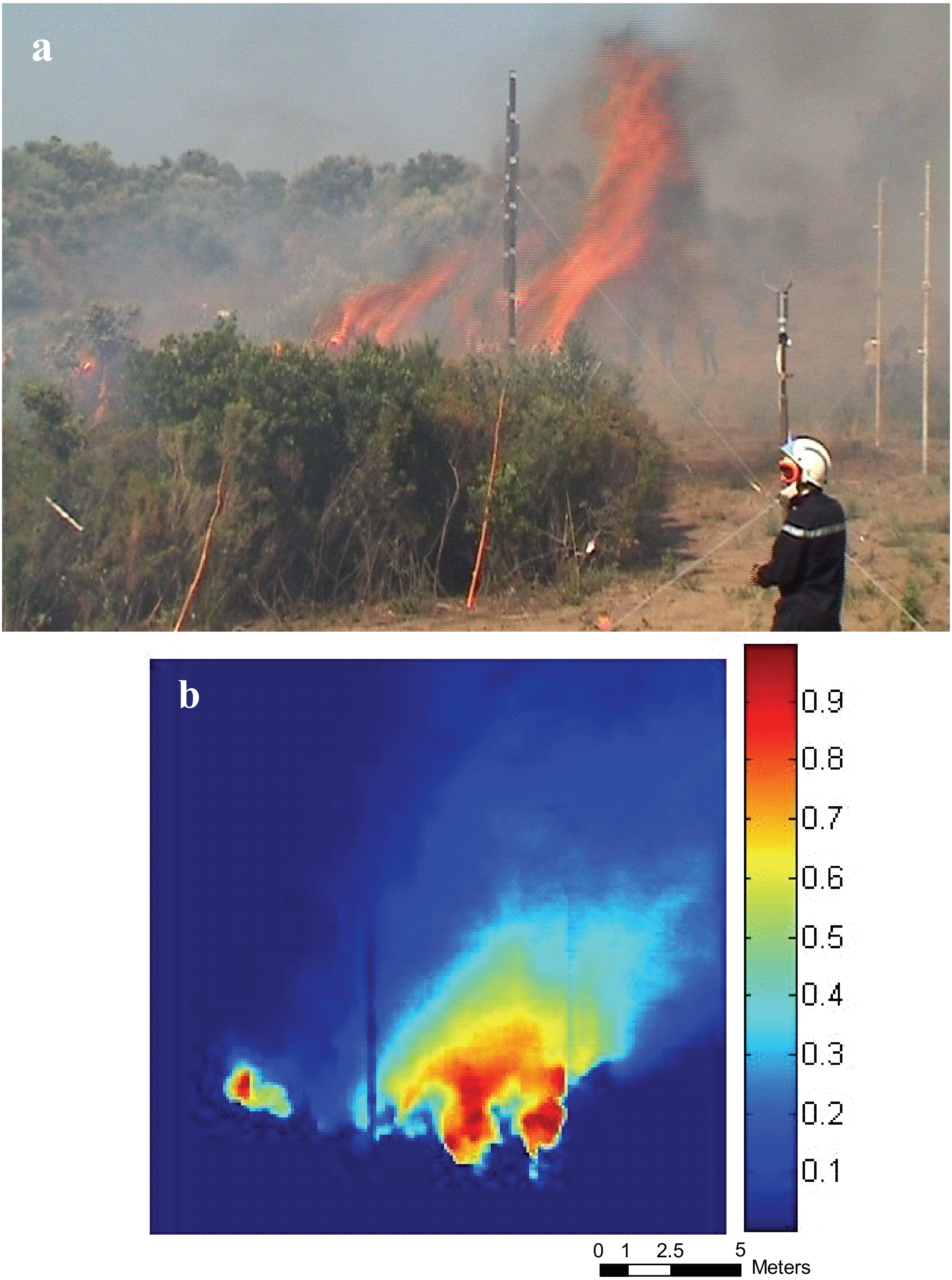

Figure 3-13: Fire front: a) visible lateral view b) infrared frontal view

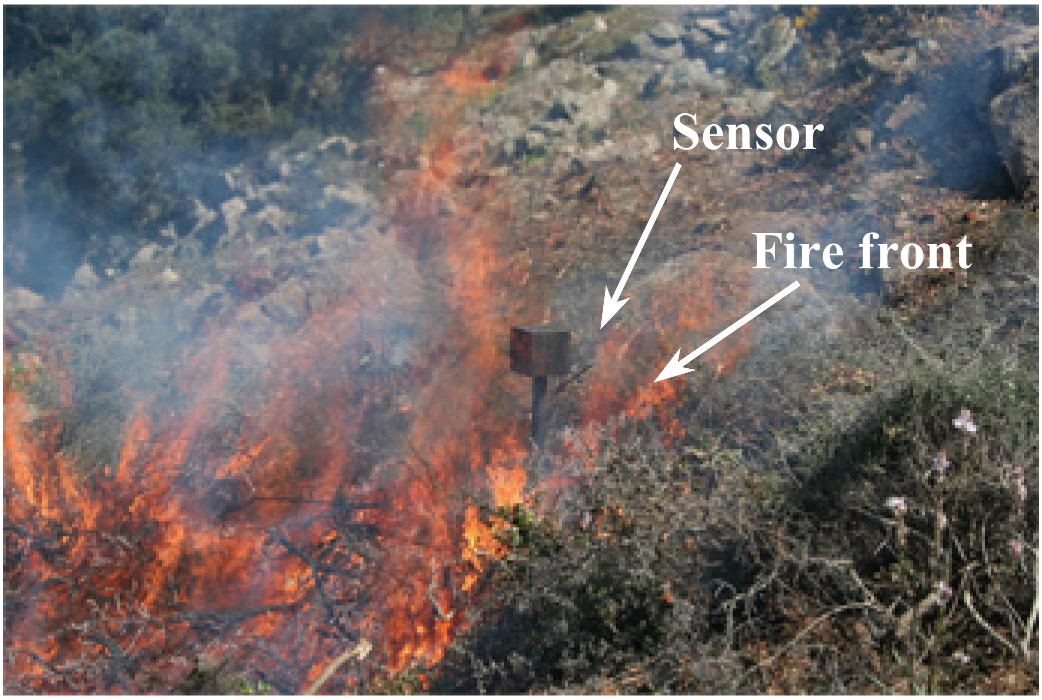

Figure 3-14: Intrusive heat flux sensor.

Figure 3-15: Smoke sampling technique during smouldering phase.

Figure 3-16: Mobile laboratory used by UAVR team during Gestosa experiments for air quality and meteorological data acquisition.

Figure 3-17: Photograph of a passive sampler used in Gestosa fire experiments.

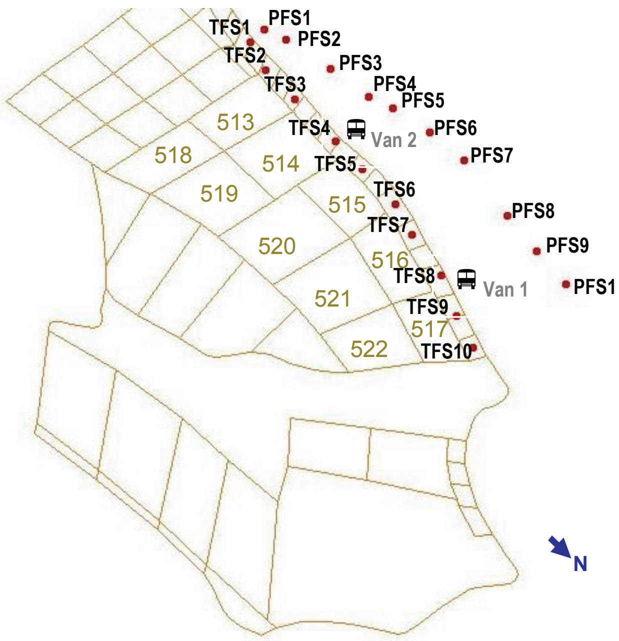

Figure 3-18: Global representation of Gestosa-2002 study area, with location of PS and mobile laboratories.

Figure 3-19: Example of an ADAI team member carrying a PS for personal exposure estimation.

3.2.8 Tables

Table 3-1: Air pollutant measurement techniques during Gestosa experiments.

Pollutant	Technique	Equipment	Type of data
NO_x (NO, NO_2)	Automatic equipment, Van 2	Environment AC31MTM	Continuous measurement: 1 min average
CO	Automatic equipment, Van 2	Environment CO11M	Continuous measurement: 1 min average
Particulate matter: PM_{10}, $PM_{2.5}$	Automatic equipment, Van 2, Van 1	Environment MP101M	Continuous measurement: 15 min average
NO_2, SO_2	Passive samplers	Radiello	Variable sampling period: 1 h average

4 WILDFIRES COLLECTING PROCEDURES

Although the laboratorial experiments have great advantages related to the control over the parameters that directly influence the behaviour of fire and the reproductability of results under the same conditions, the ultimate objective of fire behaviour modelling is to predict wildfire behaviour.

Therefore, wildfires observation is a precious and essential tool to understand the phenomena involved during fire propagation under conditions in which the fire becomes in fact a real problem.

This is the case of severe meteorological conditions such as high temperatures, low fuel moisture and high wind speeds.

Also the available fuel for combustion is different during the fire season, which is an important question since dead fine fuels originate high rates of spread and sudden changes in fire behaviour.

Although experimental field fires represent a valuable tool for understanding wildfires, fire propagation under these extreme conditions is not usually studied since there would be no safety conditions and the impacts in the ecosystem would be considerable.

4.1 MOBILE FIRE DETECTION AND MONITORING

The CEIF (ADAI) team members have a special authorization from the Portuguese National Fire Department to go to fires during the fire season.

During years of field work, some extreme fire behaviour cases where observed such as fire eruptions (Viegas, 2005), long distance spotting and crown fires (see Figure 4-1).

During the years of 2003 and 2004 the CEIF (ADAI) team was involved in a project called COTEC that had a component of mobile fire detection and monitoring.

During the project, the wildfire observation was also used for image sending to the Management and Coordination Centre allowing decision support.

For that purpose an all-terrain vehicle was developed, which works like a mobile watchtower.

It incorporates a video camera, a meteorological station, digital maps, GPS and video recorder.

It also has Internet access allowing the image broadcasting (see figure 4-2).

Forest fires are selected by proximity and probability of interesting phenomena to happen.

Usually a fire is more likely to produce such phenomena when it’s burning for several days meaning that different zones in the perimeter are burning without fire fighting allowing observing wildfire propagation without external influence.

All the team members carry personal protection equipment (PPE) and respect standard safety procedures in the proximity of fire such as always leaving the car working and facing an exit, always check before parking the car if the planned escaping route it’s not a dead end and planning the position of each team member inside the vehicle in case of an emergency runaway.

Figure 4-1: Fire eruption observed by the CEIF team during a real fire, Sertã, Central Portugal (18-Aug-2003).

Figure 4-2: Mobile detection vehicle used during the COTEC project.

4.2 IMAGE RECORDING

The equipment used for image recording of the fire line evolution is usually composed of video cameras.

An infrared video camera is also an option for image recording with the great advantage of easier spotting detection.

However, the tough conditions of operation in terms of heat, dirt and bumping (due to bad access roads) bring a great risk of damaging such expensive equipment and so it is not usually carried during wildfire observation.

4.3 TERRAIN CHARACTERISTICS

The terrain characteristics assessment can be made either by GPS or using maps.

The last option requires less field work and therefore less time but it is not so accurate.

When possible it's always preferable to assess the terrain altimetry using the GPS.

4.4 FUEL CHARACTERIZATION

The fuel characterization can be made still during the fire propagation by either image capture or simply by taking notes or after the fire by analysing unburned nearby areas with apparent similar fuel conditions.

The first option is naturally more accurate and, if possible, should be the one selected.

Both the terrain characteristics assessment and the fuel characterization can be made after the fire but especially in the fuel characterization it is recommendable to make it:

- either during the wildfire propagation
- or during the following days in order to obtain precise information.

4.5 METEOROLOGICAL CONDITIONS

Regarding the meteorological conditions they can be obtained in the local using a portable meteorological station.

This information can be afterwards completed and compared with the information of nearby fixed meteorological stations taking into account the difference in height between measurements.

4.6 LOGISTICS

During wildfire observation it's impossible to tell when an interesting phenomenon is going to take place.

So, besides the knowledge on forest fire behaviour necessary for this activity, a close attention to the fire progression is needed.

Given the nature of this activity, when some interesting fire behaviour is recorded, it's almost inevitable coming back to where the event took place either for collecting new data or for confirming data collected during the event.

Also the logistic aspects need to be account for.

As it is impossible to know a priori when and how long an interesting fire behaviour will take place, energy supplies for field communications, cell phones, GPS devices, cameras and all the remaining equipment should be provided and managed in order to last during all the wildfire observation.

5 LAST COMMENTS

The current document presents some of the procedures, concerning both laboratorial and field experiments, commonly applied in the acquisition of the data needed for fire and smoke behaviour modelling.

The broad range of experimental situations makes difficult to define a single protocol with a universally accepted standard instrumentation.

Although the instruments and protocols have to be adapted to the specificity of each situation, a global effort should be made in order to reach an agreement about the most appropriate ones under specific conditions.

In particular, the constraints and limitations of each model, as also the data needed for running the simulations need to be clearly defined prior to the experiments in order to guarantee that the data measured are really the data needed.

Some aspects to be carefully defined are, for instance, the parameters to be measured (e.g., the flames height, the air humidity, the air pollutants concentration), the location where the measuring devices should be placed and the temporal and spatial resolution of the measurements.

One can conclude that the communication between modellers and experimentalists should be strengthen in order to improve the overall goal of this work that is the understanding of the behaviour of fires in their overall scales.

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EUFIRELAB

EVR1-CT-2002-40028

D-03-07-A

http://www.eufirelab.org

EUFIRELAB:

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

Deliverable D-03-07_A

Data collecting procedure for modelling the behaviour of wildland fires (final) Questionnaire to the partners

Ana I. MIRANDA, Jorge H. AMORIM, Joana VALENTE, Helena MARTINS, Pedro CUIÑAS, Paulo FERNANDES, Eric LEONI, José M. MENDES-LOPES, Frédéric MORANDINI, Imma OLIVERAS, Josep PIÑOL, Luis M. RIBEIRO, Carlos G. ROSSA, Paul-Antoine SANTONI, Albert SIMEONI, João VENTURA, Domingos X. VIEGAS

December 2006

CONTENT LIST

INTRODUCTORY COMMENTS

The main objective of D-03-07 is to describe the available procedures for collecting the data needed for modelling the behaviour of forest fires.

The current document constitutes the Annex to the referred deliverable.

In this sense it complements D-03-09 (Behaviour Modelling of Wildland Fires: final version of the State of the Art) and D-03-06 (Behaviour models of wildland fire: third versions of the codes).

It does not intend to elaborate a detailed description on each model (this is the objective of the previous referred deliverables), but to identify the main input and output variables that can be obtained by measurements at lab and field scales for performing the simulations and validating the results.

1 FIREANALYTIC

1.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	EQUIPE FEUX
PARTNER NUMBER	P002
FULL NAME OF THE INSTITUTION	SPE UMR CNRS 6134 – UNIVERSITE DE CORSE
CONTACT PERSON(S)	A. SIMEONI
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1.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		FIREANALYTIC
FULL NAME (if existent)		
VERSION		1.1
APPLICATION FIELD		LABORATORY AND FIELD SCALE
CONTACT	**INSTITUTION(S)**	LABORATOIRE SCIENCES POUR L'ENVIRONNEMENT – UMR CNRS 6134
	CONTACT PERSON(S)	J.H. BALBI, J.L. ROSSI AND T. MARCELLI
	E-MAIL ADDRESS(ES)	balbi@univ-corse.fr ; rossi@univ-corse.fr ; marcellii@univ-corse.fr
	URL	http://spe.univ-corse.fr

1.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

1.3.1 Input data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Moisture content	Oven	Drying 24 hours a sample of the fuel bed
Fuel load	Weighing device	Weighting of dried fuel samples
Slope	Adjustable plate	Given value
Wind speed	No wind in laboratory	
Ambient air temperature	Thermohygrometer	Mean value during the experiment
Vegetation distribution	Made in laboratory in function of the needs	Given value

1.3.2 Input data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Moisture content	Oven Thermobalance	Drying 24 hours a sample of the fuel bed Used directly in the field just before the burning to adjust the moisture contents if necessary
Fuel load	Balance	Weighing a dried sample cut in a similar parcel
Slope	GPS and Tachometer	Punctual recording in the field and interpolated Digital Elevation Model put in a GIS
Wind speed	Sonic anemometers weather station	Mean wind on the parcel
Ambient air temperature	Weather Station	Mean value during the burning
Vegetation distribution	Field investigation and GIS	Quadrat method in the field and insertion in a GIS to obtain polygonal vector layers

1.3.3 Output data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Rate of fire spread	Thermocouples	Time lag between the signals of two consecutives thermocouples located at the top of the fuel bed
Geometry of the fire front	Visible and IR cameras	Digital processing
Temperature of the fuel layer	Thermocouples	Arrays of thermocouples

1.3.4 Output data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Rate of fire spread	Characterization lines	Thermal fuses and resistors put on the ground: time lag between the destruction of 2 fuses
Geometry of the fire front	Visual camera and IR camera: (flame height, flame tilt angle) Characterization lines (position of the fire front)	Digital processing Thermal fuses and resistors put on the ground: interpolation of the fire front thanks to the destruction times of the fuses combined with video analysis
Temperature of the fuel layer	Thermocouples	Thermocouple rods to obtain the temperature distribution in the fuel layer Thermocouples put on the ground

2 IST-DEM

2.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	IST – DEM
PARTNER NUMBER	P012
FULL NAME OF THE INSTITUTION	INSTITUTO SUPERIOR TÉCNICO
CONTACT PERSON(S)	JOÃO VENTURA / JOSÉ MIGUEL MENDES-LOPES
E-MAIL ADDRESS(ES)	**VENTURA@IST.UTL.PT / MENDESLOPES@IST.UTL.PT**

2.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		-
FULL NAME (if existent)		-
VERSION		-
APPLICATION FIELD		1 – SUBMODEL FOR CONVECTIVE HEAT TRANSFER COEFFICIENT BETWEEN GAS AND UNBURNED FUEL INSIDE FUEL BEDS AND SHRUBS 2 – SUBMODEL FOR PRESSURE LOSS INSIDE FUEL BEDS AND SHRUBS
CONTACT	**INSTITUTION(S)**	INSTITUTO SUPERIOR TÉCNICO
	CONTACT PERSON(S)	JOÃO VENTURA / JOSÉ MIGUEL MENDES-LOPES
	E-MAIL ADDRESS(ES)	VENTURA@IST.UTL.PT / MENDESLOPES@IST.UTL.PT
	URL	-

2.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

2.3.1 Input data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Air temperature	D-07-01, D-07-03	D-07-01, D-07-03
Air humidity	D-07-01,D-07-03	D-07-01,D-07-03
Wind speed	D-07-01,D-07-03	D-07-01,D-07-03
Fuel temperature (experiments with combustion)	D-07-01,D-07-03	D-07-01,D-07-03
Fuel moisture content	D-07-03	D-07-03
Fuel temperature (experiments to determine the convective heat transfer coefficient)	K thermocouples and CAMPBELL CR10 data logger (D-07-08)	Several pairs of thermocouples, each pair with one thermocouple inserted in the fuel particle (virtually at its surface) and the other in the air very near (≈2.0mm) the fuel particle. Experiment run in transient conditions (hot air heatin up cold fuel)
Pressure drop	Micromanometer	Pressure taps along the wind tunnel that contains the fuel bed or shrubs

2.3.2 Output data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Fuel temperature	D-07-01,D-07-03 ,D-07-08	D-07-01,D-07-03 ,D-07-08
Flame temperature	D-07-01,D-07-03 ,D-07-08	D-07-01,D-07-03 ,D-07-08
Flame geometry	D-07-03	D-07-03
Rate of spread	D-07-03	D-07-03
Convective heat transfer coefficient h	(see input data)	h computed from the temperature-time curves of each pair of thermocouples
Pressure drop per unit length	(see input data)	Δp computed directly from the pressure measurements

3 FIRESTATION

3.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	ADAI
PARTNER NUMBER	P013
FULL NAME OF THE INSTITUTION	ASSOCIAÇÃO PARA O DESENVOLVIMENTO DA AERODINÂMICA INDUSTRIAL
CONTACT PERSON(S)	DOMINGOS X VIEGAS; LUIS MARIO RIBEIRO
E-MAIL ADDRESS(ES)	XAVIER.VIEGAS@DEM.UC.PT; LUIS.MARIO@ADAI.PT

3.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		FIRESTATION
FULL NAME (if existent)		
VERSION		
APPLICATION FIELD		FIRE SPREAD AND WIND FIEL SIMULATION OVER COMPLEX TOPOGRAPHY
CONTACT	**INSTITUTION(S)**	ADAI
	CONTACT PERSON(S)	DOMINGOS X VIEGAS; LUIS MARIO RIBEIRO
	E-MAIL ADDRESS(ES)	XAVIER.VIEGAS@DEM.UC.PT; LUIS.MARIO@ADAI.PT
	URL	

3.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

3.3.1 Input data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Topography (slope, orientation)	Digital Elevation Model	All data derived from digital maps
Fuel maps		Fuel maps derived from aerial photos and/or satellite image, based on fuel complex photoguide (D-02-01)

3.3.2 Input data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Fuel models	D-02-01	D-02-01, D-03-02
Wind speed and direction	D-07-01, D-06-02	Data collected from wind stations at 6m
Simulated wind field (input for fire spread simulation)	D-03-02, D-06-02	Wind field simulated based on data collected in meteo stations

3.3.3 Output data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Fire Spread characteristics: - Rate of Spread - Fire growth - Fire line intensity - Flame length - Energy released	D-03-02, D-06-02	Spatial and temporal simulation. Fire Behaviour as proposed by Rothermel (1972); All fire characteristics mapped with GIS based software (D-06-02)
3d wind field over complex topography	D-03-02 D-06-02	Nuatmos model - The code solves for a divergence free flow field, based on an initial solution obtained by spatial interpolation from the meteorological stations.
Fire Weather Index (FWI) and sub-indices (FFMC, DMC, DC, ISI, BUI)	D-03-02, D-06-02	Computed after Van Wagner (1987)

4 XG-CIFAL

4.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	XG-CIFAL
PARTNER NUMBER	P018
FULL NAME OF THE INSTITUTION	CENTRO DE INVESTIGACIONS FORESTAIS E AMBIENTAIS DE LOURIZAN. CONSELLERÍA DE MEDIO AMBIENTE. XUNTA DE GALICIA.
CONTACT PERSON(S)	JOSÉ ANTONIO VEGA / PEDRO CUIÑAS
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4.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		
FULL NAME (if existent)		
VERSION		
APPLICATION FIELD		EMPIRICAL MODEL OF FOREST FIRE BEHAVIOUR. (FIRE RATE OF SPREAD AND FLAME LENGTH)
CONTACT	**INSTITUTION(S)**	CENTRO DE INVESTIGACIONS FORESTAIS E AMBIENTAIS DE LOURIZAN. CONSELLERÍA DE MEDIO AMBIENTE. XUNTA DE GALICIA.
	CONTACT PERSON(S)	JOSÉ ANTONIO VEGA / PEDRO CUIÑAS
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	URL	

4.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

4.3.1 Input data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Air temperature	Thermometers, Thermocouples, automatic weather station D07-01, D07-03	Time-step measurements: 1minute D07-01, D07-03
Air humidity	Psychrometer, automatic weather station. D07-01, D07-03	Time-step measurements: 1minute D07-01, D07-03
Solar radiation	Automatic weather station. D07-01, D07-03	Time-step measurements: 1minute D07-01, D07-03
Wind speed and direction	Stand alone ultrasonic anemometers. Automatic weather station D07-01, D07-03	Time step from 1 second to 0ne minute. Measurements at 6 meters height and fuel levels. D07-01, D07-03
Barometric pressure	Automatic weather station D07-01, D07-03	Time-step measurements: 1minute D07-01, D07-03
Fuel load by size classes and fuel condition (live or dead)	D-02-01, D-02-02	Line intersect method, double sampling methods, Destructive sampling of fuels D-02-01, D-02-02
Fuel moisture content	Ovens with forced ventilation D-02-01, D-02-02, D-07-03	Sampling of all important fuel classes and sizes, (by strata) just before ignition D-02-01, D-02-02, D-07-03
Fuel layers height	D-02-01	Extensive inventory of ground and surface fuels on each plot before experimental fires
Fuel packing ratio (compactness or volume fraction)	D-02-01, D-02-02	This is a calculated variable from particle density and fuel layer height. D-02-01
Fuel particles surface to volume ratio	D-02-01, D-07-03	Geometrical methods
Slope	D-07-01	

4.3.2 Output data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Soil and fuel Temperature	Type K inconel shielded (1 mm diameter) Thermocouples D-07-03	Data acquisition time-step: 1 second D-07-03
Flame temperature	Type K inconel shielded (1 mm diameter) Thermocouples D-07-03	Data acquisition time-step: 1 second D-07-03
Flame geometry	Photographic, cameras, video cameras, and infrared camera. D-07-03	Visual estimates and images comparison with pre-placed posts
Forward rate of spread of the fire	Video cameras, and infrared camera. D-07-03	Measuring time the fire reaches consecutives posts pre-placed perpendicularly to the fire front. D07-03
Fuel consumption	D-02-01	Fuel inventories D-02-01

5 DISPERFIRE

5.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	UAVR
PARTNER NUMBER	P022
FULL NAME OF THE INSTITUTION	UNIVERSITY OF AVEIRO
CONTACT PERSON(S)	ANA ISABEL MIRANDA
E-MAIL ADDRESS(ES)	AICM@DAO.UA.PT

5.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		DISPERFIRE
FULL NAME (if existent)		
VERSION		
APPLICATION FIELD		SMOKE DISPERSION SIMULATION AT COMPLEX TOPOGRAPHY (LOCAL SCALE)
CONTACT	**INSTITUTION(S)**	UNIVERSITY OF AVEIRO
	CONTACT PERSON(S)	ANA ISABEL MIRANDA
	E-MAIL ADDRESS(ES)	AICM@DAO.UA.PT
	URL	WWW.DAO.UA.PT/GEMAC

5.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

5.3.1 Input data, laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Fuel maps		Fuel maps derived from aerial photos and/or satellite image, based on fuel complex photoguide
Emission factors (NOx, PM_{10} and $PM_{2.5}$).	D-07-11 Molecular Composition: Hermann-Moritz-Trigaz 123 Tx Analyser; Flow, Humidity and PM: Andersen Universal Stack Sampler, NOx: Andersen sampling system; VOC: Analyser Bernath Atomic Model 3006	D-07-11 EPA methods published in the Federal Register, vol. 42 n.160, 18th of August 1977.

5.3.2 Input data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Topography	Digital Elevation Model	Data derived from digital maps
Wind speed and direction	D-07-01, D-06-02	Data collected from wind stations
Emission factors (NOx, PM_{10} and $PM_{2.5}$).		Data is obtained from Database of Forest Fires Emission Factors. -Miranda, A.I.; Borrego, C.; Sousa, M., Valente, J., Barbosa, P. and Carvalho, A. (2005) Model of Forest Fire Emissions to the Atmosphere. Deliverable D252 of SPREAD Project. - Miranda, A.I.; Borrego, C.; Santos, P.; Sousa, M. and Valente, J. (2004) - Database of Forest Fire Emission Factors. Deliverable D251 of SPREAD Project.

5.3.3 Output data, laboratory scale

None

5.3.4 Output data, field scale

Variable and/or **property**	**Equipment**	**Methodology**
Wind speed and direction over complex terrain.	D-07-01	Data collected from wind stations
Air Quality. 3D concentration fields (NOx, PM_{10} and $PM_{2.5}$).	D-03-02, D-07-13	Data collected with air quality analysers placed in mobile laboratories.

6 DISPERFIRESTATION

6.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	ADAI + UAVR
PARTNER NUMBER	P013 + P022
FULL NAME OF THE INSTITUTION	ASSOCIAÇÃO PARA O DESENVOLVIMENTO DA AERODINÂMICA INDUSTRIAL + UNIVERSIDADE DE AVEIRO
CONTACT PERSON(S)	DOMINGOS X VIEGAS; ANA ISABEL MIRANDA
E-MAIL ADDRESS(ES)	XAVIER.VIEGAS@DEM.UC.PT; AICM@DAO.UA.PT

6.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		DISPERFIRESTATION
FULL NAME (if existent)		
VERSION		
APPLICATION FIELD		FIRE SPREAD, WIND FIELD AND AIR QUALITY SIMULATION OVER COMPLEX TOPOGRAPHY
CONTACT	**INSTITUTION(S)**	ADAI, UAVR
	CONTACT PERSON(S)	DOMINGOS X VIEGAS; ANA ISABEL MIRANDA
	E-MAIL ADDRESS(ES)	XAVIER.VIEGAS@DEM.UC.PT; AICM@DAO.UA.PT
	URL	WWW.DAO.UA.PT/GEMAC

6.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

6.3.1 Input data, Laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Emission factors (NOx, PM_{10} and $PM_{2.5}$).	D-07-11 Molecular Composition: Hermann-Moritz-Trigaz 123 Tx Analyser; Flow, Humidity and PM: Andersen Universal Stack Sampler, NOx: Andersen sampling system; VOC: Analyser Bernath Atomic Model 3006	D-07-11 EPA methods published in the Federal Register, vol. 42 n.160, 18th of August 1977.

6.3.2 Input data, Field scale

Variable and/or **property**	**Equipment**	**Methodology**
Topography (slope, orientation)	Digital Elevation Model	Data derived from digital maps
Fuel maps		Fuel maps derived from aerial photos and/or satellite image, based on fuel complex photoguide (D-02-01)
Fuel models	D-02-01	D-02-01, D-03-02
Wind speed and direction	D-07-01, D-06-02	Data collected from wind stations
Emission factors (NOx, PM_{10} and $PM_{2.5}$).		Data is obtained from Database of Forest Fires Emission Factors. -Miranda, A.I.; Borrego, C.; Sousa, M., Valente, J., Barbosa, P. and Carvalho, A. (2005) Model of Forest Fire Emissions to the Atmosphere. Deliverable D252 of SPREAD Project. - Miranda, A.I.; Borrego, C.; Santos, P.; Sousa, M. and Valente, J. (2004) - Database of Forest Fire Emission Factors. Deliverable D251 of SPREAD Project.

6.3.3 Output data, Laboratory scale

None

6.3.4 Output data, Field scale

Variable and/or **property** (3)	**Equipment**	**Methodology**
Fire Spread characteristics: - Rate of Spread - Fire growth - Fire line intensity - Flame length - Energy released	D-03-02, D-06-02	Spatial and temporal simulation. Fire Behaviour as proposed by Rothermel (1972); All fire characteristics mapped with GIS based software (D-06-02)
3D wind field over complex topography	D-03-02, D-06-02	Nuatmos model - The code solves for a divergence free flow field, based on an initial solution obtained by spatial interpolation from the meteorological stations.
Fire Weather Index (FWI) and sub-indices (FFMC, DMC, DC, ISI, BUI)	D-03-02, D-06-02	Computed after Van Wagner (1987)
Air Quality. 3D concentration fields (NOx, PM_{10} and $PM_{2.5}$).	D-03-02, D-07-13	Data collected from air quality analysers placed in mobile laboratories
Visibility. 2D deciview fields	D-03-02	

7 AIRFIRE

7.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	UAVR
PARTNER NUMBER	P022
FULL NAME OF THE INSTITUTION	UNIVERSITY OF AVEIRO
CONTACT PERSON(S)	ANA ISABEL MIRANDA
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7.2 GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		AIRFIRE
FULL NAME (if existent)		
VERSION		
APPLICATION FIELD		Wildfire modelling: progression, smoke dispersion, photochemical modelling
CONTACT	**INSTITUTION(S)**	UNIVERSITY OF AVEIRO
	CONTACT PERSON(S)	ANA ISABEL MIRANDA
	E-MAIL ADDRESS(ES)	AICM@DAO.UA.PT
	URL	HTTP://WWW.DAO.UA.PT/GEMAC/

7.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

7.3.1 Input data, Laboratory scale

Variable and/or **property**	**Equipment**	**Methodology**
Air pollutants emissions: forest fires	D-07-11 Molecular Composition: Hermann-Moritz-Trigaz 123 Tx Analyser; Flow, Humidity and PM: Andersen Universal Stack Sampler, NOx: Andersen sampling system; VOC: Analyser Bernath Atomic Model 3006	D-07-11 EPA methods published in the Federal Register, vol. 42 n.160, 18th of August 1977.

7.3.2 Input data, Field scale

Variable and/or **property**	**Equipment**	**Methodology**
Topography		Digital terrain data
Land use		Corine Land Cover Database
Meteorology		- Meteorological field campaigns; - University of Wyoming website: http://weather.uwyo.edu/upperair/sounding.html - National meteorological agencies
Burnt areas		Forestry agencies
Fuel characteristics		Trabaud, L.; Christensen, N. and Gill, A. – Historical biogeography of fire in temperate and Mediterranean ecosystems. In Crutzen, P. and Goldammer, J. – Fire in the environment. The ecological, atmospheric, and climate importance of vegetation fires. Chicester, England: John Wiley & Sons, 1993, p. 277-295.
Air pollutants emissions: traffic, industry, biogenics		- POLAR2 database; - National emission inventories (NIR)
Air pollutants emissions: forest fires		Calculated based on fuel characteristics and emission factors. -Miranda, A.I.; Borrego, C.; Sousa, M., Valente, J., Barbosa, P. and Carvalho, A. (2005) Model of Forest Fire Emissions to the Atmosphere. Deliverable D252 of SPREAD Project. - Miranda, A.I.; Borrego, C.; Santos, P.; Sousa, M. and Valente, J. (2004) - Database of Forest Fire Emission Factors. Deliverable D251 of SPREAD Project.

7.3.3 Output data, Laboratory scale

None

7.3.4 Output data, Field scale

Variable and/or **property**	**Equipment**	**Methodology**
Meteorology		- Meteorological field campaigns - University of Wyoming website: http://weather.uwyo.edu/upperair/sounding.html -National meteorological agencies
Air quality		- Environmental agencies - Air quality field campaigns

8 PIROPINUS

8.1 PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	UTAD-DF
PARTNER NUMBER	P025
FULL NAME OF THE INSTITUTION	UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO
CONTACT PERSON(S)	PAULO FERNANDES, CARLOS LOUREIRO, HERMÍNIO BOTELHO
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8.2 TABLE 23. GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		PIROPINUS
FULL NAME (if existent)		
VERSION		1.3
APPLICATION FIELD		PREDICTION OF FIRE BEHAVIOUR AND EFFECTS FOR PRESCRIBED BURNING PLANNING AND EVALUATION IN MARITIME PINE STANDS
CONTACT	**INSTITUTION(S)**	UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO
	CONTACT PERSON(S)	PAULO FERNANDES
	E-MAIL ADDRESS(ES)	PFERN@UTAD.PT
	URL	HTTP://HOME.UTAD.PT/~FLORESTA/LAB_FOG_FL.HTML

8.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

8.3.1 Input data, Laboratory scale

None

8.3.2 Input data, Field scale

* Model development, ** Model development and application, *** Model application

Variable and/or **property**	**Equipment**	**Methodology**
Air temperature	Thermometer** Automatic weather station*	Continuous measurement at 1-s intervals
Propagation mode (backfire or headfire)	n.a.	n.a.
Nº days since last rainfall >0.5 mm	Automatic weather station*	
Fuel-complex type (litter, litter+shrubs, litter+grass/ferns)	n.a.	Visual evaluation
Windspeed at 2m height	Anemometers** Automatic weather station*	Continuous measurement at 1-s intervals, in-stand at 1.7-m height
Understory vegetation height	D-02-01	Line transect sampling, or random point sampling scheme **
Understory vegetation cover	D-02-01	Line transect sampling** Visual estimation ***
Surface fuel load	D-02-01	Random or systematic destructive quadrat sampling of various sizes* Estimation with models***
Dead fuel moisture content (surface fuels or duff)	D-02-01	Destructive sampling* Several indirect methods using field data or fire weather indexes ***
Slope	Clinometers**	Measurement **
Live crown base height		Measurement **
Tree height		Measurement **
Tree density	n.a.	Counting
Tree diameter at breast height		Measurement **

8.3.3 Output data, Laboratory scale

None

8.3.4 Output data, Field scale

Variable and/or **property**	**Equipment**	**Methodology**
Probability of sustained fire spread	n.a.	Classification after visual observation
Probability of marginal fire spread	n.a.	Classification after visual observation
Rate of fire spread	Chronometer, photographic camera, video camera	Imagery analysis, visual estimation timing against pre-placed poles or pre-existing references
Flame height	Photographic camera, video camera	Imagery analysis, visual estimation against pre-placed poles or pre-existing references
Flame length	n.a.	Calculated from flame height by trigonometry
Flame tilt angle	Photographic camera, video camera	Imagery analysis, visual estimation against pre-placed poles or pre-existing references
Fireline intensity	n.a.	Calculated after Byram (1959)
Relative fuel consumption by fuel layer (surface litter, upper duff, shrubs)	D-02-01	Random or systematic destructive quadrat sampling of various sizes
Scorch height		Measurement
Crown scorch ratio	n.a.	Calculated
Probability of mortality	n.a.	Classification (dead or alive) after visual observation
Post-burn fuel accumulation	D-02-01	Random or systematic destructive quadrat sampling of various sizes

9 FIREREGIME

9.1 TABLE 25. PARTNER IDENTIFICATION.

PARTNER IDENTIFICATION	
TEAM ACRONYM	CREAF
PARTNER NUMBER	P028
FULL NAME OF THE INSTITUTION	CENTER FOR ECOLOGICAL RESEARCH AND FOREST APPLICATIONS
CONTACT PERSON(S)	JOSEP PIÑOL
E-MAIL ADDRESS(ES)	JOSEP.PINOL@UAB.ES

9.2 TABLE 26. GENERAL INFORMATION USED FOR MODEL IDENTIFICATION.

MODEL GENERAL DESCRIPTION		
ACRONYM		FIREREGIME
FULL NAME (if existent)		
VERSION		1.0
APPLICATION FIELD		REGIONAL FIRE REGIME
CONTACT	**INSTITUTION(S)**	CREAF
	CONTACT PERSON(S)	JOSEP PIÑOL
	E-MAIL ADDRESS(ES)	JOSEP.PINOL@UAB.ES
	URL	HTTP://WWW.CREAF.UAB.ES/JPINOL/FIREREGIME_OLD

9.3 DESCRIPTION OF THE DATA COLLECTING PROCEDURES.

9.3.1 Input data, Laboratory scale

No Input required – the model parameters are fitted by calibration against wildfires statistical data

9.3.2 Input data, Field scale

No Input required – the model parameters are fitted by calibration against wildfires statistical data

9.3.3 Output data, Laboratory scale

None

9.3.4 Output data, Field scale

Variable and/or **property** (3)	**Equipment**	**Methodology**
Number of fires per year and per 1000 km^2		Statistics of fire agencies
Area burnt per year and per 1000 km^2		Statistics of fire agencies
Distribution of number of fires per size classes		Statistics of fire agencies
Distribution of the area burnt per size classes		Statistics of fire agencies