DIMENSIONAL AND SCALE ANALYSIS IN FOREST FIRES MODELING

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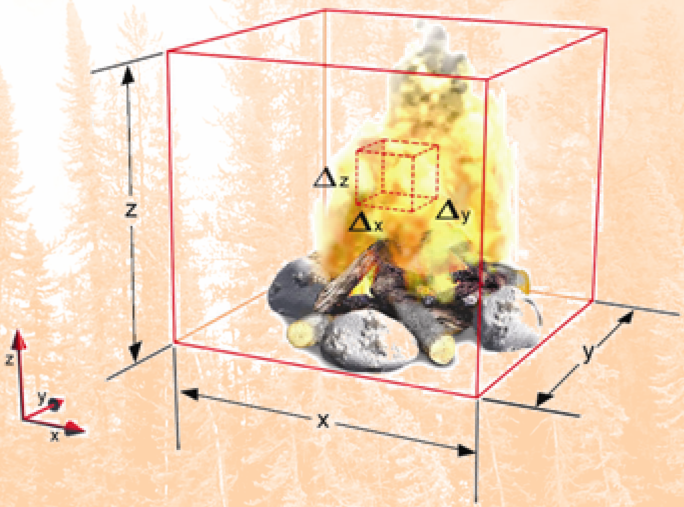


1. INTRODUCTION

- **Forest fires spread nonuniformly and nonsteady over nonhomogenous fuels**

- **Limitations to obtain data during real emergencies owing to technical, economical and safety constrains.**

- **Scale model experiments (lab and field) play an important role in forest fires research**

1. INTRODUCTION

- **Are Scale models able to provide significant information to the full-scale phenomena?**

Source: GRAF – Generalitat de Catalunya

The aim of this work is to discuss about the use of Dimensional and Scale Analysis in forest fires modeling

2. DIMENSIONAL AND SCALE ANALYSIS

GENERAL CONCEPTS

- **Dimensional Analysis**

  Any phenomenon can be described by a dimensionally homogenous equation containing the minimum characteristic variables

- **Dimensionless products π_i** →

  Selection / Formulation

  - Pi Theorem
  - Governing equations
  - Identification and equating of Energy, forces, and mass rates

- **Scale analysis – Scaling laws**

  Similarity theory states that dimensionless products have the same value in different scales

$$\pi_{i\,f} = \pi_{i\,m}$$

i=1, 2, ...
f: full-scale
m: model scale

Scaling laws → **Construct experimental model (or test)**

2. DIMENSIONAL AND SCALE ANALYSIS

FOREST FIRES MODELING

- **Application of dimensional analysis to forest fires**

  ↳ $> 30\ \pi_i$ → **Complete scaling is not possible**

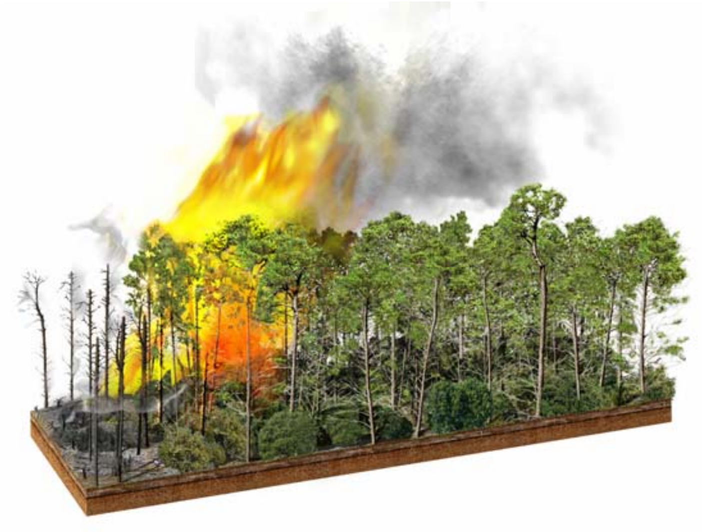
- **Hypothesis to omit some π_i groups**

  ↓

  Partial Scaling

- **Test hypothesis**

- **Different strategies for modeling**



FOREST FIRE MODELLING

- **Froude Modeling**

  Same ambient conditions in model scale and full-scale

  Re and Fr cannot be both retained

$$Re = \frac{L \cdot V \cdot \rho}{\mu} \qquad Fr = \frac{V^2}{g \cdot L}$$

$V \sim L^{-1}$ ≠ $V \sim L^{1/2}$ **Scaling contradiction** → **Omit Re or Fr**

L: Characteristic linear dimension

L_i: Linear dimensions

V: Velocity

Q: Heat flux

$L_i \sim L$

$V \sim L^{1/2}$

$Q \sim L^{3/2}$

FOREST FIRE MODELING

Advantages:

- The **generality of dimensional analysis** permits to use it without a **wide knowledge** on the phenomenon
- **Quantitative results** can be produced at an advantage of scale and cost.
- **Useful correlations** can be provided
- Some of the important **phenomena of large-scale** fire spread **can be captured**

Drawbacks:

- It is necessary to **know enough** about the phenomenon of interest **to identify the main variables** that control it
- It **doesn't exist standard definitions** for characteristic parameters
- **Scale effects** can be found and should be avoided
- **Data** from **different scales** are needed to test the modeling hypothesis

PREVIOUS WORK

- **Dimensional and scale analysis have demonstrated their potential in other fire research areas**

  (Hottel, 1959; de Ris, Kanury & Yuen, 1972; Quintiere, 1988; Thomas, 2000)

- **Some works using dimensional and/or scale analysis**

  - Thomas (1963) – **Model flames length**
  - Byram (1966) **– Formulate scaling laws for modeling mass fires**
  - Williams (1969) **– Partial scaling mass fires**
  - Lee (1972) – **Test scaling laws of Byram (1966) in smaller size models**
  - Emori and Saito (1982) – **Model a real fire to replicate its behavior**
  - Emori and Saito (1983, 1988) – **Formulate scaling laws for different models**
  - Nelson and Adkins (1988) – **Correlate data to model wind aided fires**
  - Raupauch (1990) – **Similarity analysis of the interaction of fire plume and wind**

METHODS

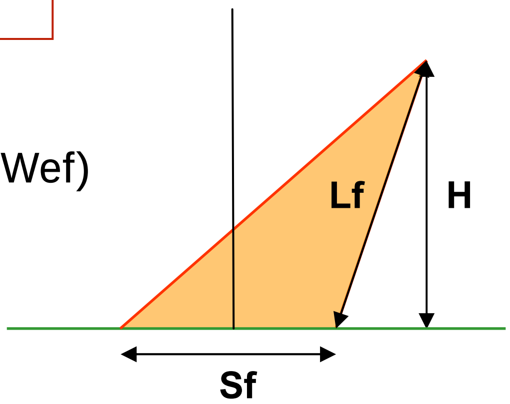
- **Dimensional and Scale analysis have been used for planning forest fires lab experiments**
- **Tests have been performed in geometrically similar fuel beds**
- **Tests specifications:**
  - No wind, no slope
  - Same fuel: Wheat straw
  - Dried fuel
  - Constant bulk density

Fuel bed width [x10^{-2} m]	Fuel bed height [x10^{-2} m]	Fuel load [kg/m^2]	Bulk density [kg/m^3]
25	2,0	0,15	7,5
50	4,0	0,30	7,5
100	8,0	0,60	7,5

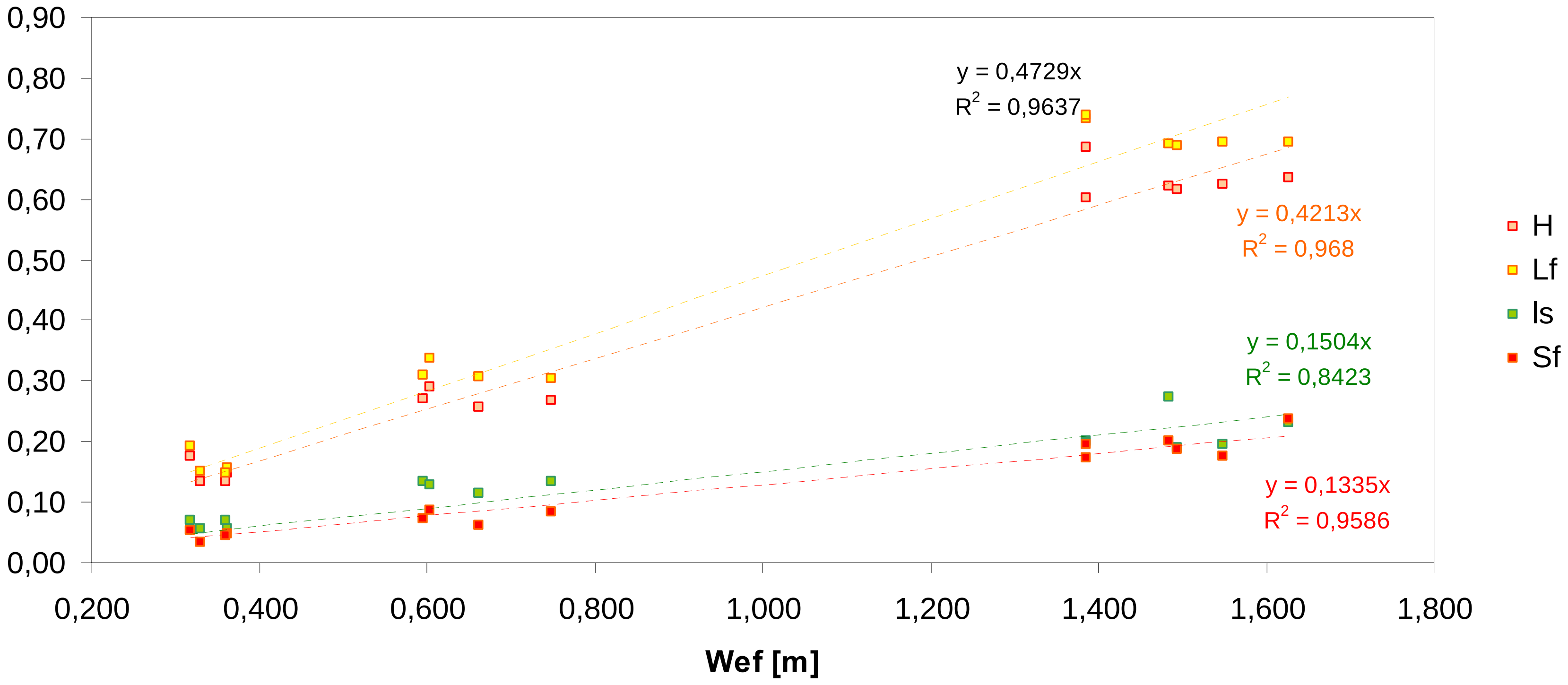
PRELIMINARY RESULTS AND DISCUSSION

H, Lf, Sf, ls ~ L

L (characteristic length scale) = Flames front length (Wef)

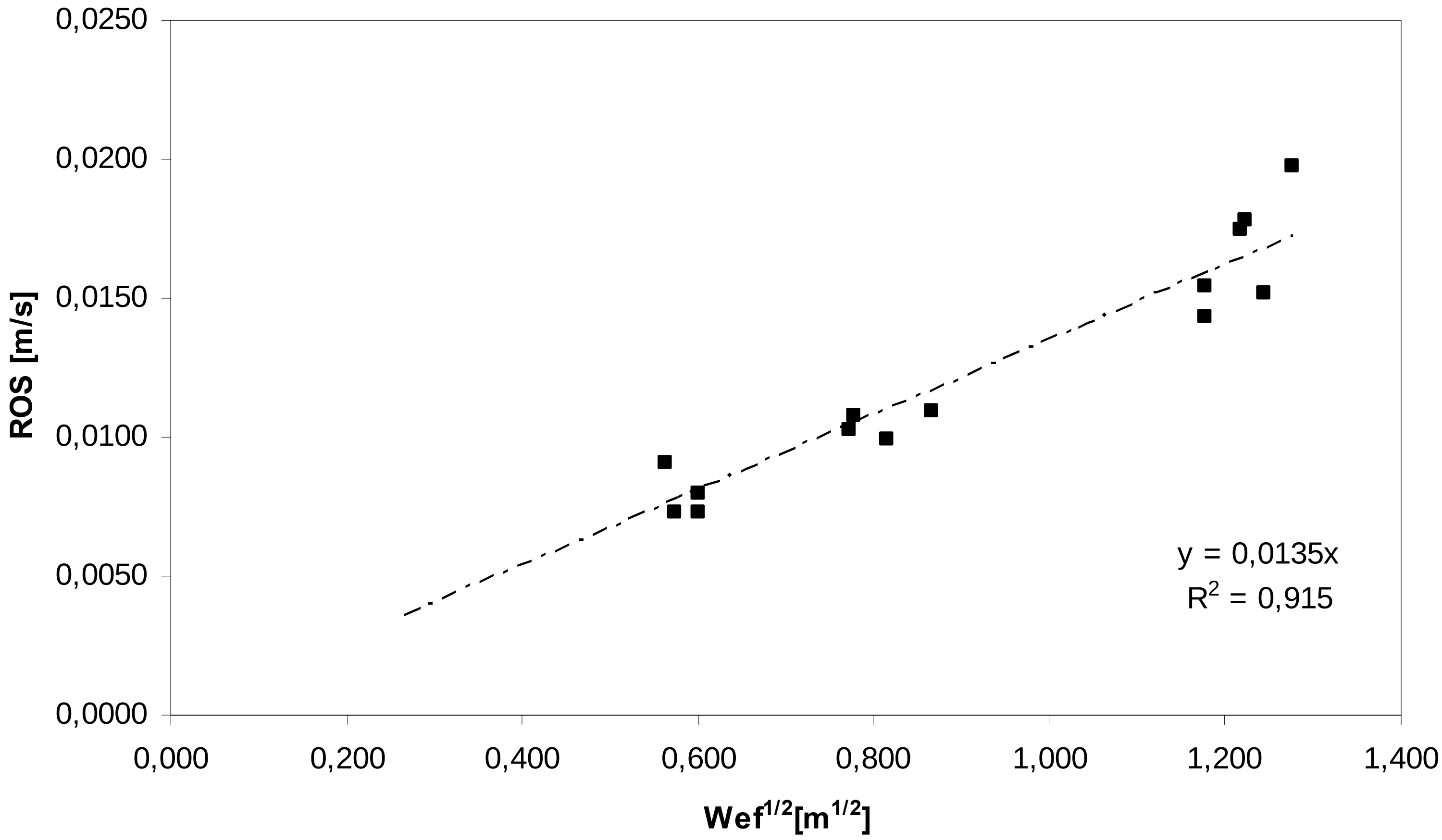


ls: Preheating fuel bed length



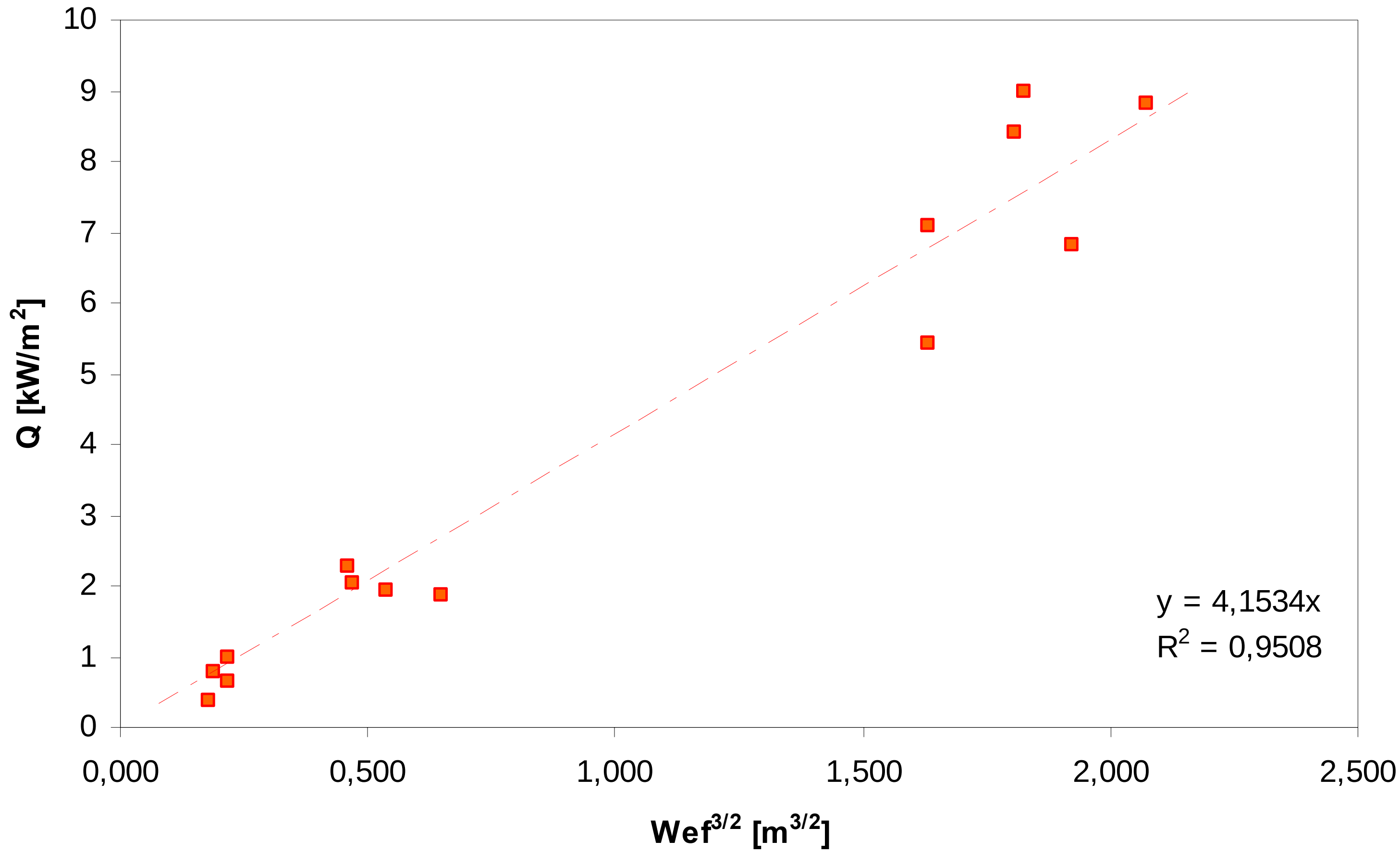
PRELIMINARY RESULTS AND DISCUSSION

ROS ~ $L^{1/2}$ (L = Wef: Flames front length)



PRELIMINARY RESULTS AND DISCUSSION

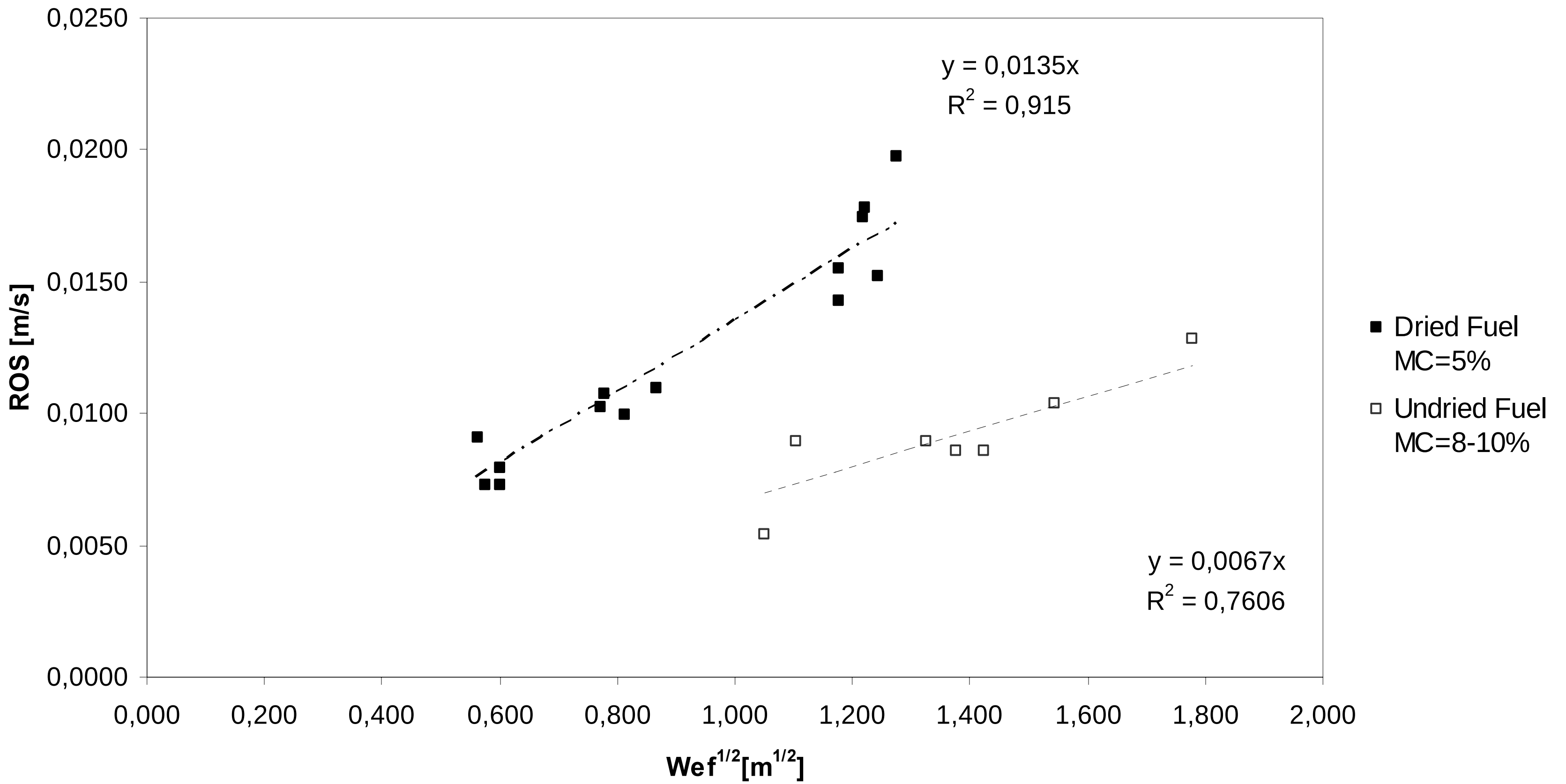
$Q \sim L^{3/2}$ (L = Wef: Flames front length)



PRELIMINARY RESULTS AND DISCUSSION

Undried fuel

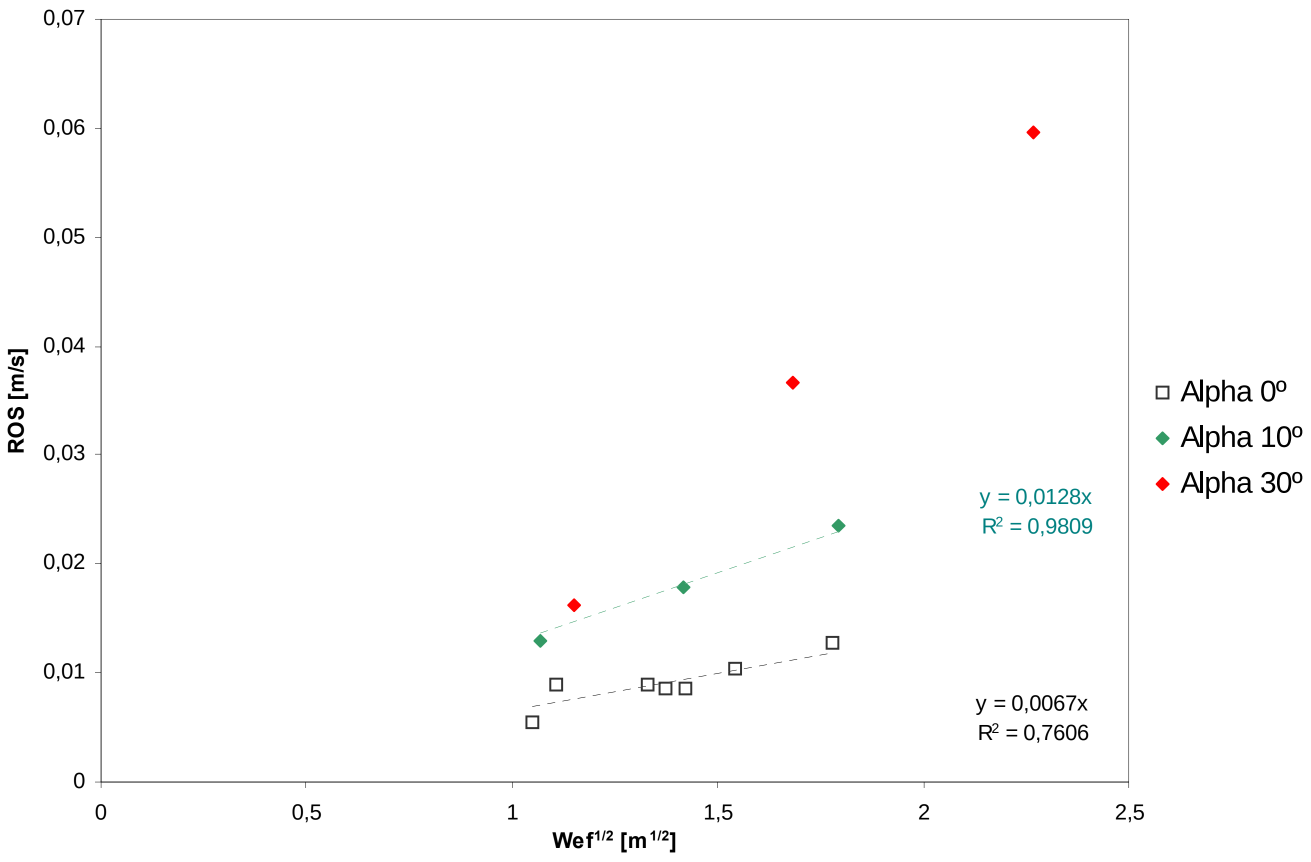
ROS ~ $L^{1/2}$ (L = Wef: Flames front length)



PRELIMINARY RESULTS AND DISCUSSION

Undried fuel + slope

ROS ~ $L^{1/2}$ (L = Wef: Flames front length)



PRELIMINARY RESULTS AND DISCUSSION

Undried fuel + slope

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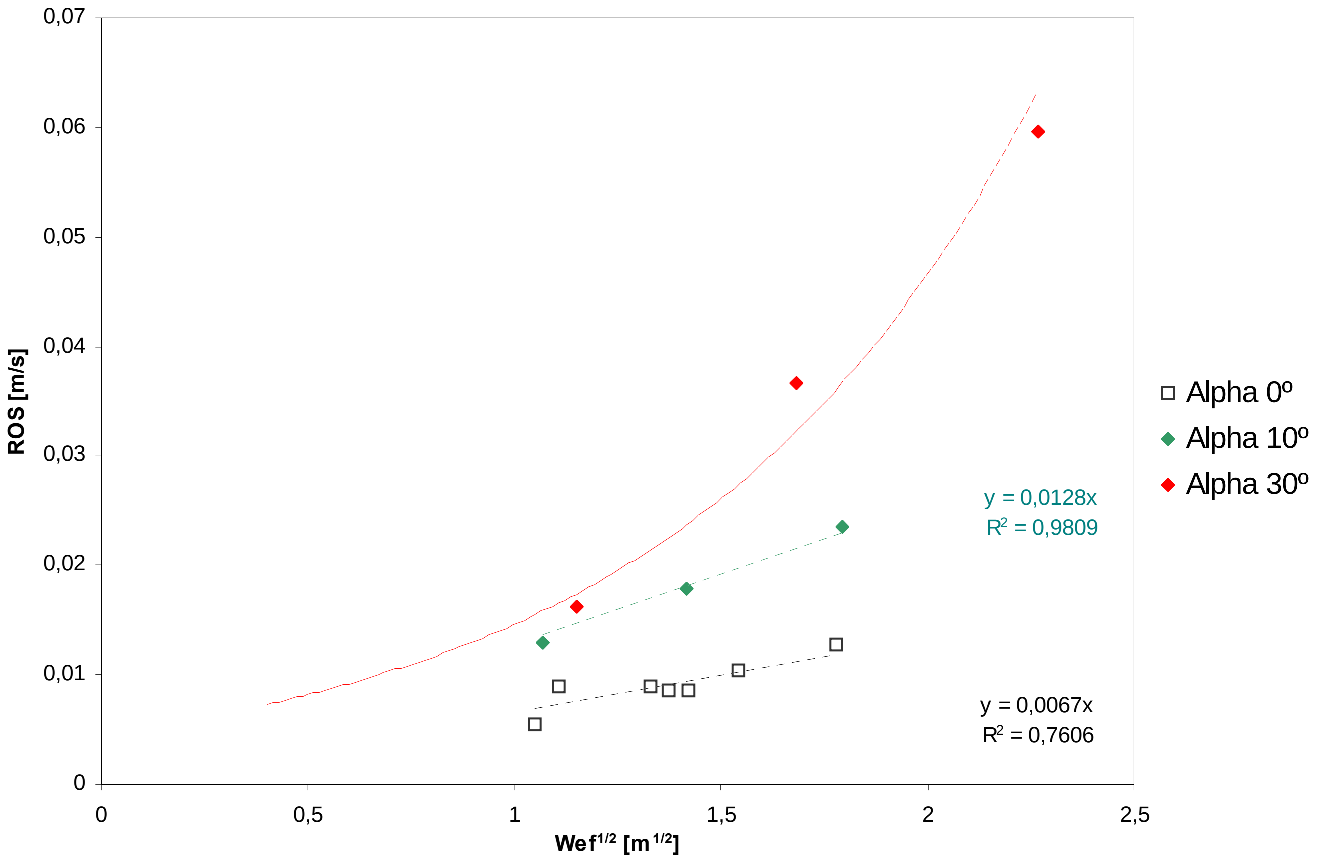
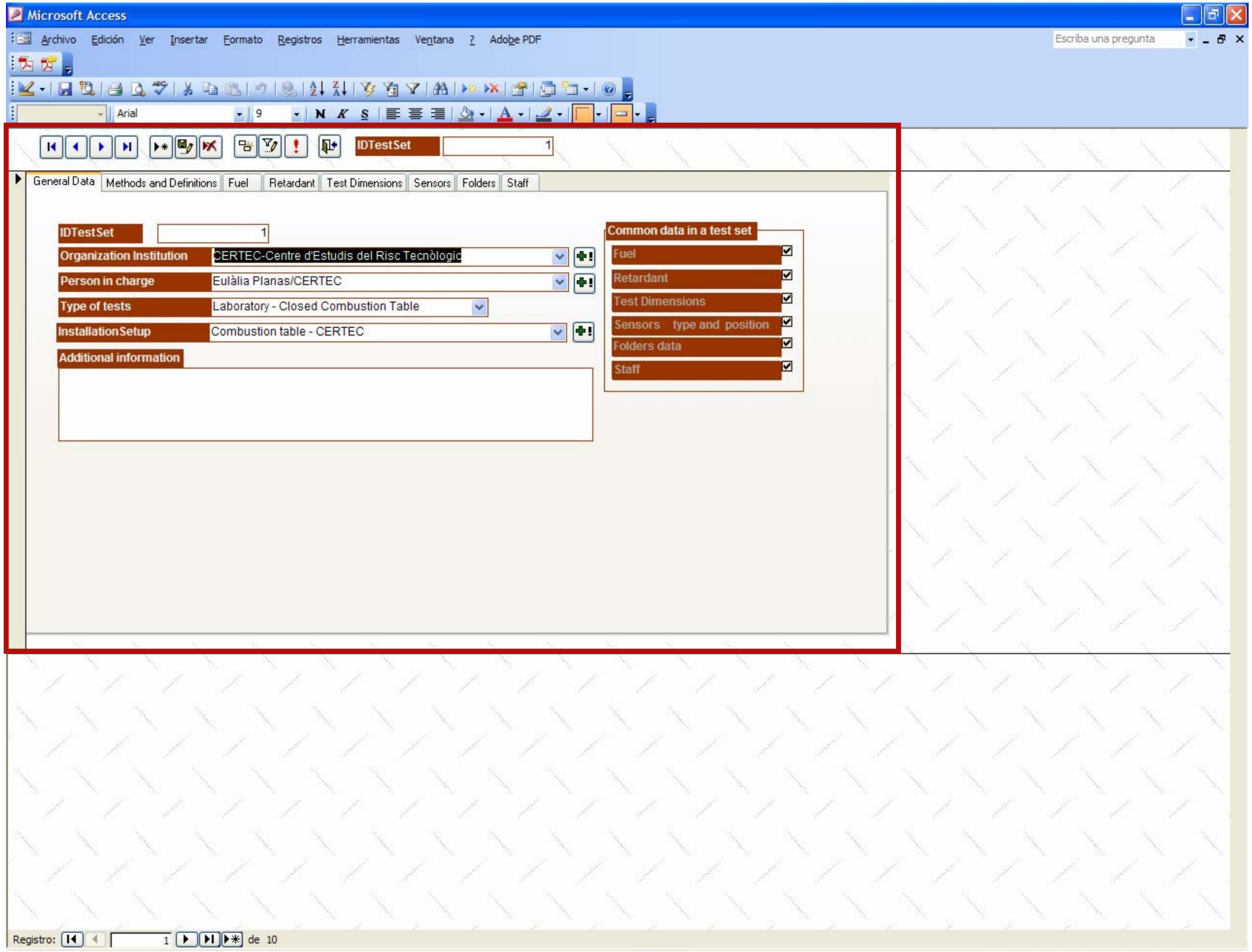


DB FOC – Data base on forest fire lab and field experiments



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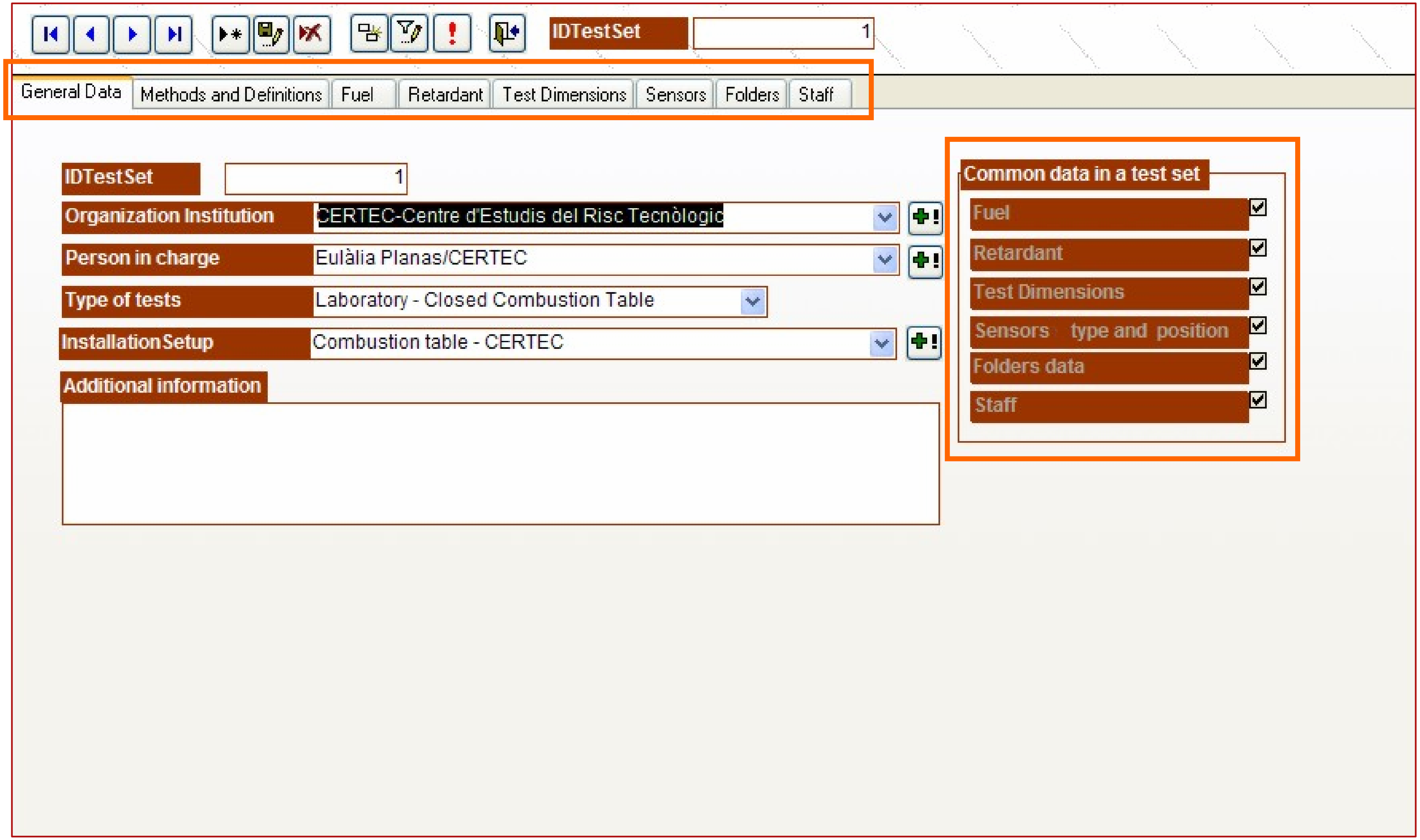
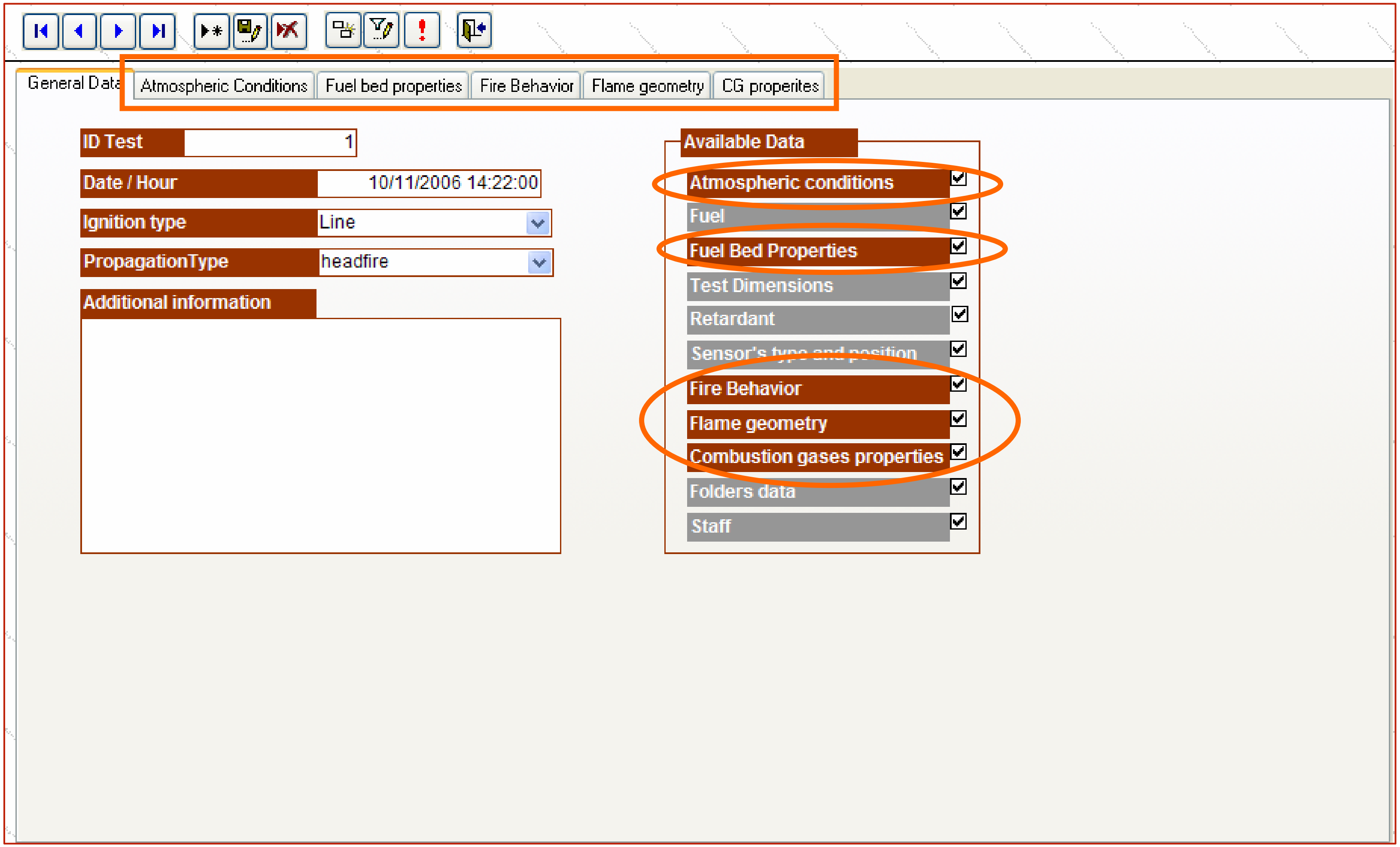


4. DATA BASE – DB FOC

DB FOC – Data base on forest fire lab and field experiments



5. CONCLUSIONS

- Dimensional and scale analysis seem to be very useful tools in forest fire modeling
- Data from different scales are essential for the assessment of forest fires models.
- Data base DBFOC has been developed to collect and manage field and lab data
- Next step… other conditions in lab and field assessment of scaling laws

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