# Operational tools for improving efficiency in wildfire risk reduction in EU landscapes (FIREfficient)

## Crown fire hazard assessment tool

**Dra. Míriam Piqué Nicolau**
**Head of Sustainable Forest Management Unit**
**Forest Science Centre of Catalonia (CTFC)**

**in collaboration with**
**Teresa Valor Ibars, Mario Beltrán Barba** **Asier Larrañaga Otxoa**
**(Forest Science Centre of Catalonia, CTFC)** **(GRAF-Forest Fire Fighting Department, DI)**

*Newcastle (UK), April 2015*

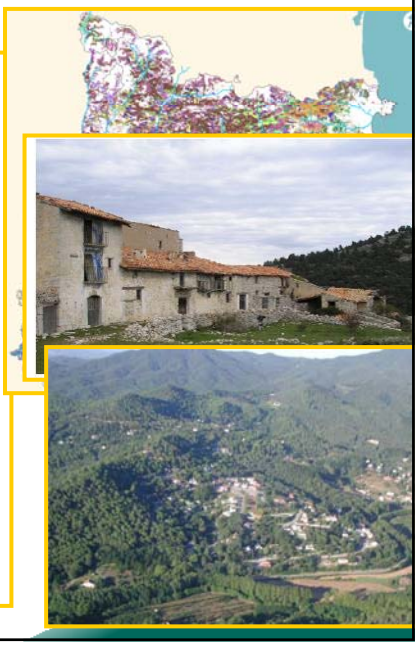
This project is co-funded by the European Union

www.ctfc.cat

## Forests in Catalonia: overview

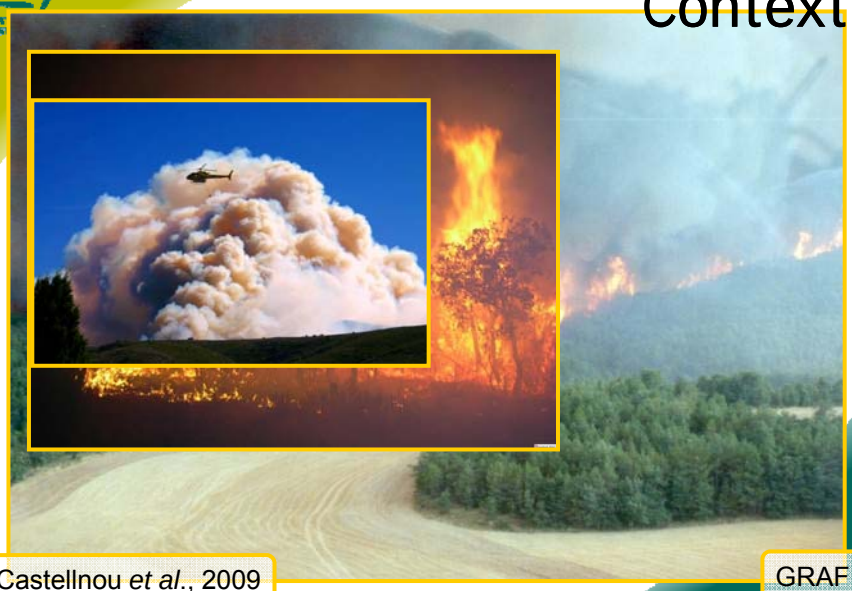
Catalonia (north – east Spain)

- Forest area: 2.055.000 ha (>64% of total area)
- Area covered by trees: 42% of total area
- 80% forest area, private owned (77% <25 ha)
- Great diversity of tree species, forest structures and silvicultural treatments
- Great increase of forest surface and biomass accumulation in the forests, during last decades (rural exodus/abandonment)
- Increasing risk of forest fires



**MCSC3, IFN2, IFN3, Eurostat**

# Context



Castellnou *et al.*, 2009

GRAF

www.ctfc.cat

# Forests in Catalonia: overview

| Species | Total (ha) | % pure stands | % mixed stands |
|---|---|---|---|
| *Pinus halepensis* | 294.363 | 69% | 31% |
| *Quercus ilex* | 223.062 | 54% | 46% |
| *Pinus sylvestris* | 221.874 | 65% | 35% |
| *Pinus nigra* | 127.313 | 48% | 52% |
| *Pinus uncinata* | 66.076 | 88% | 12% |
| *Quercus suber* | 60.980 | 46% | 54% |
| *Quercus pubescens* | 41.756 | 45% | 55% |
| *Pinus pinea* | 33.573 | 34% | 66% |
| *Quercus faginea* | 31.400 | 51% | 49% |
| *Fagus sylvatica* | 27.475 | 56% | 44% |
| | | | |
| Riparian forests | 24.686 | | |
| Productive plantations | 42.230 | | |
| Others | 123.306 | | |

Conifers: 61%

*Quercus* sp: 31%

Productive plantations: 3 %

Other broadleaves and riparian forests: 5 %

www.ctfc.cat

## Forests in Catalonia: overview

Young stands

www.ctfc.cat

## Forests in Catalonia: overview

High density, growth stagnation,
poor regeneration in mature stands

www.ctfc.cat

## Forests

Low management, lo

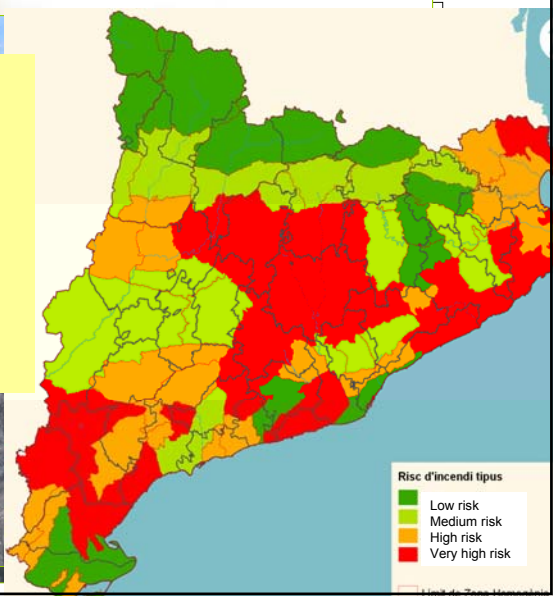
## Forests in Catalonia: overview

High fuel continuity (horizon

## Forests in Catalonia: overview

40% of surface very high risk of large wildfires
(red color)

(*Castellnou et al. 2010, Piqué et al. 2011)*




## Forests in Catalonia: overview

Dry periods and global change

www.ctfc.cat

## Main characteristics

- **Diverse forests with complex forest structure:**
  - ✓ Mixed forests
  - ✓ Different site conditions (climatology, geology, physiography)
- **Multifunctional forests:** timber and non timber production, biodiversity, landscape, environmental functions, etc.
- **Affected by perturbations (forest fires, mainly)**
- **Vulnerable to climate change and hydric stress**
- **Long history of uses, harvesting and human act**

*** COMPLEX FOREST MANAGEMENT**

## Wich is the challenge? How to manage this complexity? Some ideas ....

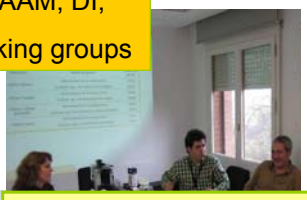
- "**Adaptative forest management**" and "**ecosystemic forest management**", for the management of complex and diverse forest ecosystems.
- Forest management **models and guidelines may vary**, depending on the stand characteristics and objectives and they may vary, also, through time.
- **"Multifuntional forest management",** based on the identification of **forest types** and their vocations, as a basis for prioritizing objectives and make them compatible
- Integration of **forest fire risk** in forest management and planning (forest fires main perturbation in Mediterranean ecosystems)

## ORGEST: Sustainable Forest Management Guidelines for Catalan Forests (2006-2015)

**Project Funded by the Center of Forest Ownership of the Catalan Government**

CPF, DAAM, DI,

15 working groups



FMG aim of:

a) increasing **growth,** vitality and timber production,

b) create **forests more resistant and resilient to** [illegible]

**Objectives of FMG**

- **Bridging** forest planning instruments at regional level with instruments at forest stand level

- **Ensuring ecological and socioeconomical value** of forests in actual context of global change

-**Giving technical information** for an efficient achieving of management objectives and **efficient resources allocation**

## Integration of wildfires in FMG

We have worked in the development of **tools for Fire risk assessment at stand level** (CFHC)
(to asses vulnerability of forest stands to generate crown fires)

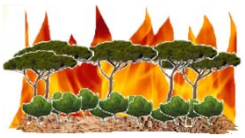
**As a basis for:**

- **Providing specific FMG** with the objective to reduce crown fires hazard, in areas specially susceptible to large wildfires.

- FMG are required to be **easy to implement**, **efficient** in terms of Large forest fires (LFF) risk reduction and **economically sustainable**.

# Background

## Types of fires in relation to the fuel involved in the propagation



Active crown fires

Passive crown fires

Surface fires

www.ctfc.cat

# Background

- Fire behaviour:
  - Meteorology
  - Topography
  - Fuel
- Four basic principles to modify fuel and create fire resistant forests:
  - Reducing surface fuel loads
  - Increasing height to crown base
  - Decreasing crown density
  - Keeping bigger trees to increase forest resilience

*Agee and Skinner, 2005*

www.ctfc.cat

# Methodology

## Integration of wildfires in FMG

**Crown fire hazard chart (CFHC) for main forest species in Catalonia**

**Expert opinion approach**

**Definition of fuel types, selection of silvicultural variables and threshold values**

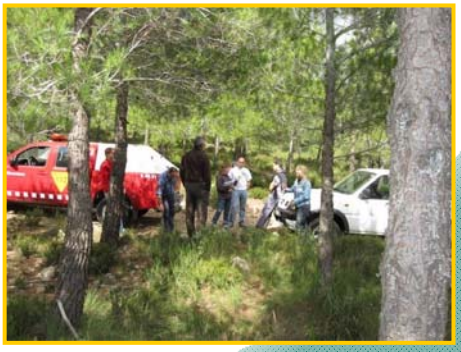
↓

**Design and development of CFHC**

↓

**Verification of CFHC in the field**

(Piqué *et al.*, 2011)



www.ctfc.cat

# Methodology

- Crown fire hazard chart for main forest species in Catalonia
  - Expert opinion approach

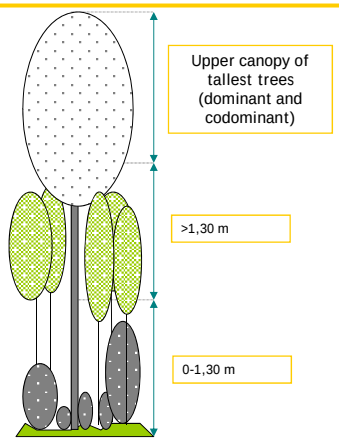
**Definition of fuel types, selection of silvicultural variables and threshold values**

| Questionnaire |
| --- |
| **1.** Indicate how you would design a CFHC with the limitations and assumptions explained before. In order to help you, dichotomic keys designed by Menning and Stephens (2007) and Farnestock (1974) are shown. |
| **2.** Key variables for characterizing stand's hazard to crown fires. At the stand scale, and considering only fuel: In which aspects you pay more attention to determine stand hazards to crown fire? |
| **3.** Indicate for each of the variables you mentioned in question 2, values or intervals associated with high, moderate or low hazard to crown fire. |

www.ctfc.cat

# Methodology

- Crown fire hazard chart for main forest species in Catalonia
  - Fuel type definitions




**AERIAL FUELS**
Aerial fuel layer containing crowns of the tallest trees (dominant and co-dominant).

**LADDER FUELS**
Low aerial fuels of height higher than 1.30 m which are not contained in the upper aerial fuel layer. Includes small trees, tall shrubs, fallen trees or lower parts of the tree canopy.

**SURFACE FUELS**
Stratum up to not more than 1.30 m. Includes shrub, saplings, herbaceous fuel, branches, fallen trees, slash or lower parts of tree canopy.

www.ctfc.cat

# Methodology

- Crown fire hazard chart for main forest species in Catalonia

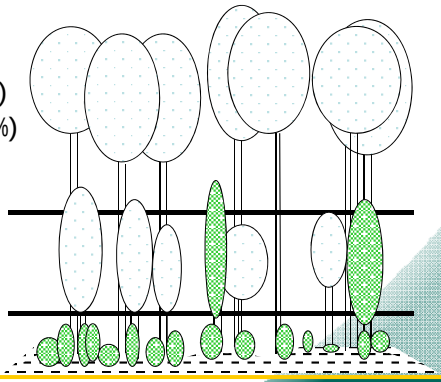
Structural/silvicultural variables selected by experts

Horizontal continuity:

- Percentage of aerial cover (%)
- Percentage of ladder cover (%)
- Percentage of surface cover (%)

Vertical continuity:

- Height of surface fuel (m)
- Distance between surface and ladder/aerial fuels (m)
- Distance between ladder and aerial fuels (m)



www.ctfc.cat

# Methodology

- Crown fire hazard chart for main forest species in Catalonia

Expert opinion approach

**Definition of fuel types, selection of silvicultural variables and threshold values**

↓

**Design and development of CFHC**

www.ctfc.cat

# Methodology

- Crown fire hazard chart for main forest species in Catalonia

Expert opinion approach

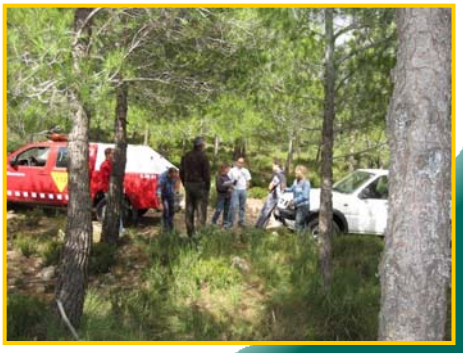
**Definition of fuel types, selection of silvicultural variables and threshold values**

↓

**Design and development of CFHC**

↓

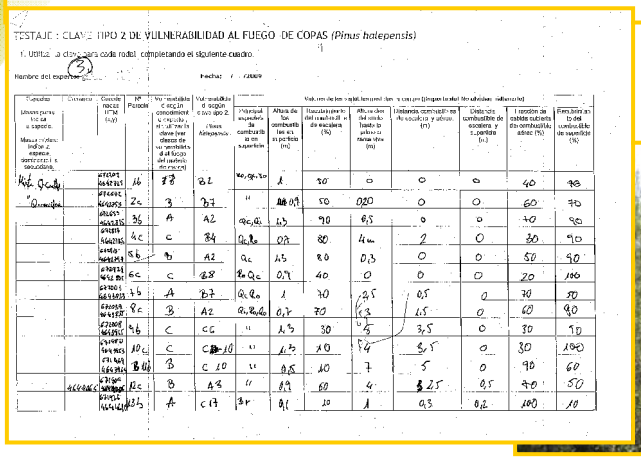
**Verification of CFHC in the field**



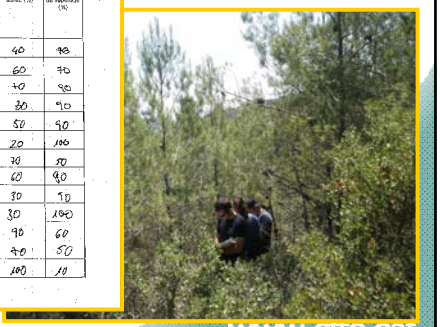
www.ctfc.cat

# Methodology

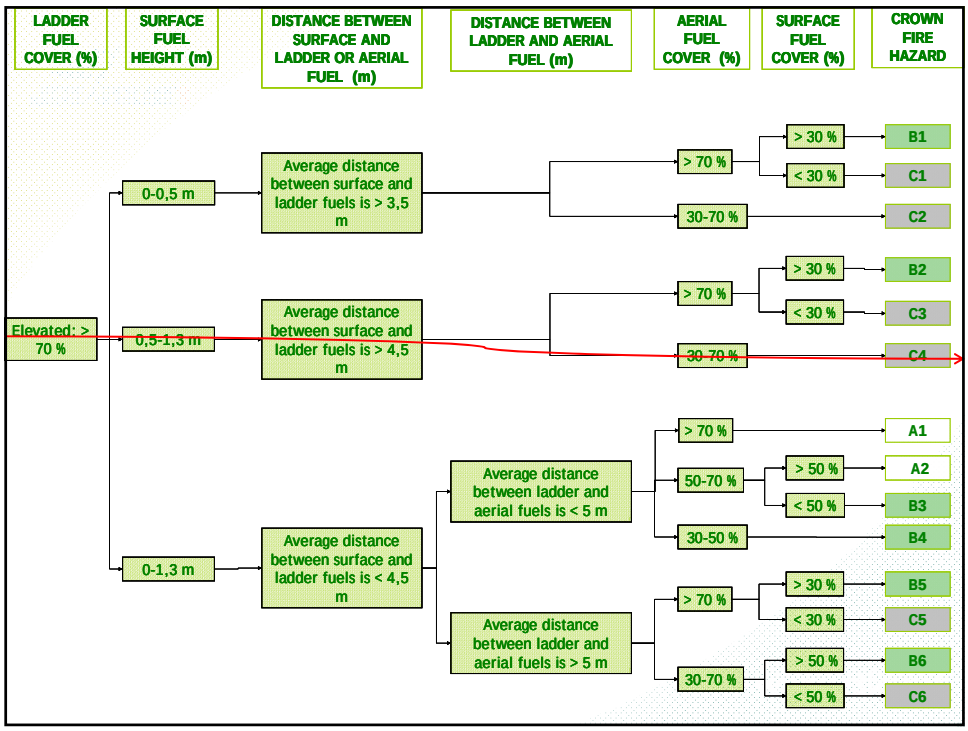
- Crown fire hazard chart for main forest species in Catalonia

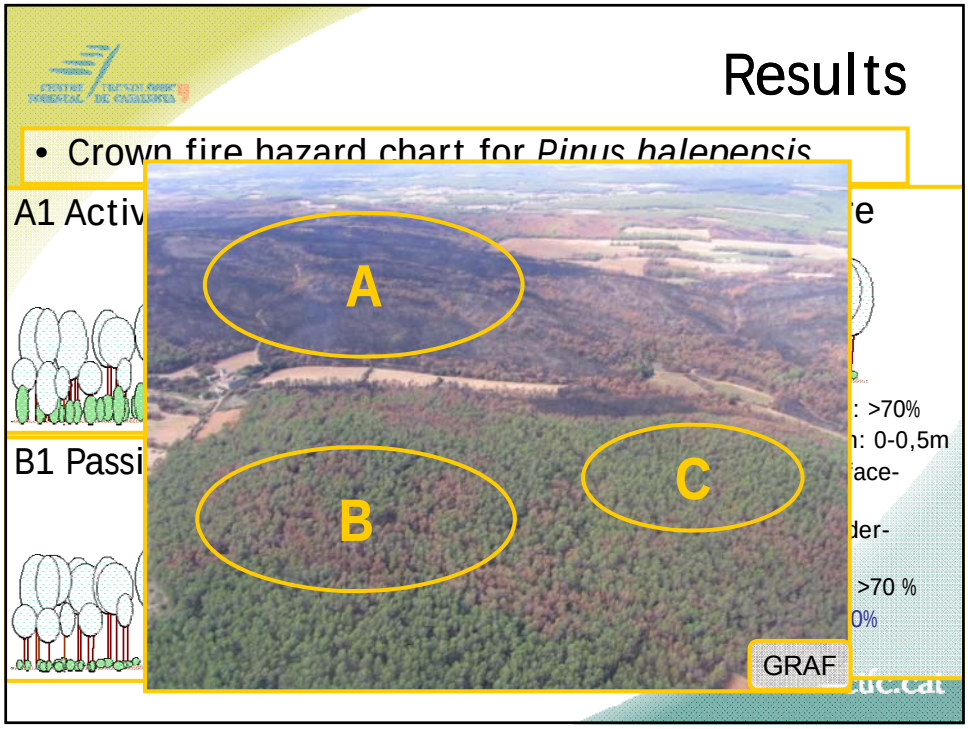


TESTAJE : CLAVE TIPO 2 DE VULNERABILIDAD AL FUEGO DE COPAS (*Pinus halepensis*)



www.ctfc.cat


LADDER FUEL COVER (%)
SURFACE FUEL HEIGHT (m)
DISTANCE BETWEEN SURFACE AND LADDER OR AERIAL FUEL (m)
DISTANCE BETWEEN LADDER AND AERIAL FUEL (m)
AERIAL FUEL COVER (%)
SURFACE FUEL COVER (%)
CROWN FIRE HAZARD
Elevated: > 70 %
0-0,5 m
0,5-1,3 m
0-1,3 m
Average distance between surface and ladder fuels is > 3,5 m
Average distance between surface and ladder fuels is > 4,5 m
Average distance between surface and ladder fuels is < 4,5 m
Average distance between ladder and aerial fuels is < 5 m
Average distance between ladder and aerial fuels is > 5 m
> 70 %
30-70 %
50-70 %
30-50 %
> 30 %
< 30 %
> 50 %
< 50 %
B1
C1
C2
B2
C3
C4
A1
A2
B3
B4
B5
C5
B6
C6


Results
• Crown fire hazard chart for Pinus halepensis
A1 Activ
B1 Passi
A
B
C
GRAF

# Methodology

- Crown fire hazard chart for main forest species in Catalonia
  - Expert opinion approach

**Definition of fuel types, selection of silvicultural variables and threshold values**

↓

**Design and development of CFHC**

↓

**Verification of CFHC in the field**

↓

**Integration of results for the elaboration of the silvicultural models**

www.ctfc.cat

# Results

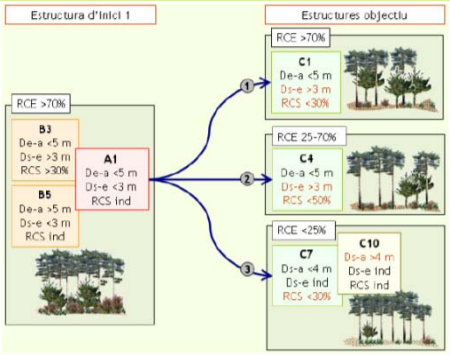
- Silvicultural models to reduce crown fire hazard
- TWO TYPES:
  - Definition of punctual treatments
    - Searching for C-structures
  - Long-term treatment planning
    - Keeping C-structures from establishment to regeneration

www.ctfc.cat

# Results

- Definition of punctual treatments

Boscos amb Fcc >70% i gran abundància d'un estrat dominat, subvol d'altra espècie o matollar alt.




*Descripció de l'estructura d'inici*

Són boscos on el dosser principal es troba tancat i normalment hi ha una gran densitat. Tenen abundant vegetació que conforma un estrat de combustible d'escala amb gran recobriment (>70%) i que té continuïtat vertical amb el dosser principal. El recobriment del matollar d'alçada inferior a 1,3 m és indiferent, però també té continuïtat vertical amb la vegetació del combustible d'escala.

El fet de poder diferenciar un estrat de vegetació entre el matollar inferior a 1,3 m i l'inici de les capçades del dosser dominant implica que aquests boscos són més o menys adults i amb certa alçada, sobretot pel que fa al dosser de pins, que es troba ben desenvolupat.



# Results

- Long-term treatment planning

Estructura regularitzada. Torn de tallada físic. Tractaments per a reduir la vulnerabilitat estructural (aclarides, podes, estassades). Regeneració per aclarida successiva en dues fases.

*Paràmetres del Model*

| $H_0$ | Fcc | RM | AM | AC | Edat | Tractaments |
|---|---|---|---|---|---|---|
| <4,5 | - | - | - | - | <10 | No intervenir. |
| 4,5 - 13 | >70 | <30 | <1,3 | >1,3 | 10-30 | · Aclarida de plançoneda als 4,5 m d'$H_0$ (~10 anys), amb Fcc >70% i ABe <40%, amb estassada selectiva i poda baixa (fins 1,5 m) si és necessari. Les restes es redueixen i es disposen sobre el terra.<br>· Aclarida baixa als 9 m d'$H_0$ (~10 anys després), amb Fcc >70% i ABe <33%. Densitat final aprox. ~1.400 peus/ha. Estassada selectiva si és necessari. |
| 13 - 24 | >70 | Ind | <1,3 | >6 | 30-150 | · Aclarida baixa als 13 m d'$H_0$ (~10 anys després), amb Fcc >70% i ABe <33%. Estassada selectiva si és necessari.<br>· Aclarida baixa als 18,5 m d'$H_0$ (~30 anys després), amb Fcc >70% i ABe <33%. Densitat final aprox. ~430 peus/ha.<br>· Estassada selectiva quan l'AM sigui >1,3 m, només sobre el matollar que superi aquesta alçada. |
| >24 | - | - | - | - | ~150 | · Tallada disseminatòria amb ABe ~60%, deixant els arbres millor desenvolupats i més vitals.<br>· Tallada final ~10-15 anys després, amb regeneració aconseguida: almenys 5.000 peus/ha que superin 1,3 m d'alçada.<br>(Opcionalment: tallada arreu amb reserva d'uns 50 peus/ha, en funció de les condicions de la massa i del rodal). |

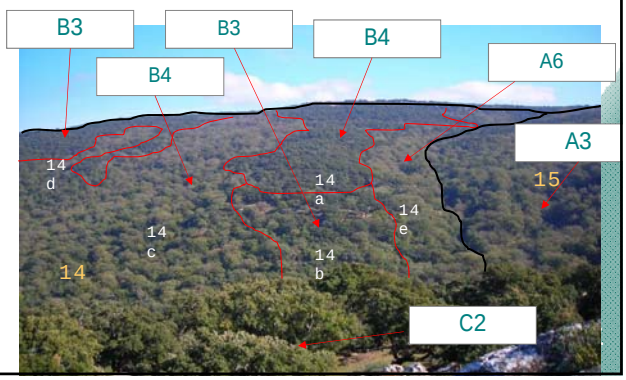
Fcc: Cobertura de l'estrat arbori dominant; RM: recobriment de matollar; AM: alçada de matollar; AC: Alçada de la base de capçades (primera branca viva).

*Modificacions al model*

Cas de Fcc <70%. Un dosser obert pot provocar que no es produeixi la mortalitat natural de les

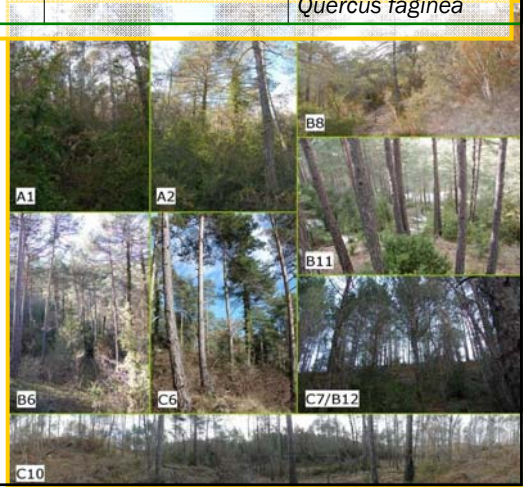
## Actual tools for forest managers and forest owners to support their decisions

-Tool for **assessing vulnerability** of forest stands to generate **crown fires**




## RESULTS: Crown fire hazard charts

| Type1 | Type 2 | Type 2.1 | Type 3 |
|---|---|---|---|
| *Pinus halepensis* | *Pinus sylvestris*<br>*Pinus nigra*<br>*Pinus uncinata*<br>*Pinus pinea*<br>*Pinus pinaster* | *Pinus pinea* y *Pinus pinaster with a substrate of pine-needle and leaf litter* | *Quercus suber*<br>*Quercus ilex ilex*<br>*Quercus ilex ballota*<br>*Quercus humilis*<br>*Quercus faginea* |




Piqué, M.; Castellnou, M.; Valor, T.; Pagés, J.; Larrañaga, A.; Miralles, M.; Cervera, T. 2011.

**http://ags.ctfc.cat/?p=649**

## Example for *Pinus sylvestris*

Crown fire hazard charts for *P. sylvestris*
– Total of 31 types of forest structures

– Ranked as:
- A (high vulnerability to active crown fire), 5 types A
- B (moderate, passive crown fire), 14 types B
- C (low, surface fire), 12 types C


## Definition of treatments

*Boscos amb Fcc >70%*
*RCE >70%*
*Estructures A1, B3 i B5*

MODEL Ps15
ESTRUCTURA INICI1

- Information about the types of forest structures (A, B or C) serves us to:

1) Identify **stand crown fire hazard**

2) To orientate forest management to **create fire resistant structures** that facilitate fire extinction tasks

3) **Provide managers with numerical** data to help in fuel management decision making processes

El fet de poder diferenciar un estrat de vegetació entre el matollar inferior a 1,3 m i l'inici de les capçades del dosser dominant implica que aquests boscos són més o menys adults i amb certa alçada, sobretot pel que fa al dosser de pins, que es troba ben desenvolupat.

w.ctfc.cat

## Integration of fire risk: promoting forest structures resistant to crown fires that facilitate fire fighting

To **increase resistant of forest to LFF**, we suggest following principles:

- Treatments to **reduce forest fuel should be in strategic areas** facing the prevention and suppression of forest fires at the mountain scale.

- Treatments should cause **changes in forest structure** and **influence fire behaviour** in the desired way.

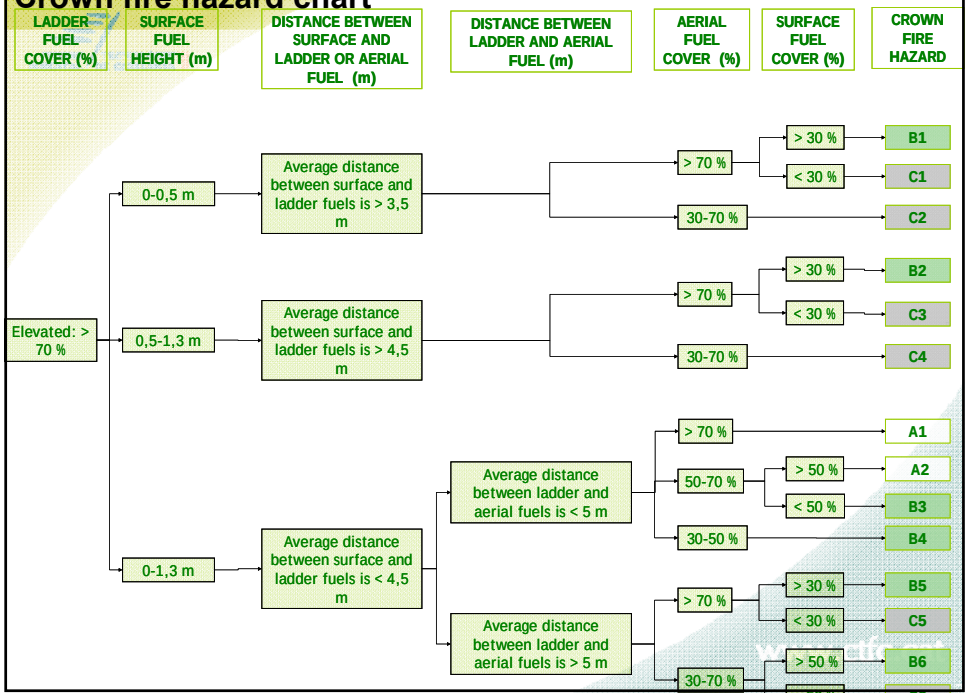
- Treatments should take into account the **natural dynamics** and are based in adaptive management.

- Minimal intervention treatments, **low cost** and its **effect should last a** maximum time.

### What are the target forest structures?

www.ctfc.cat

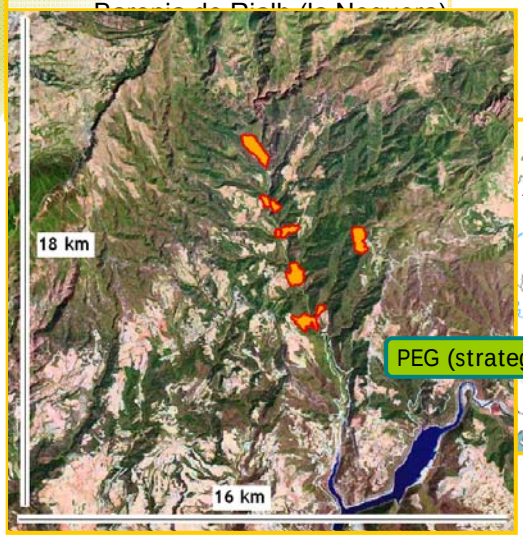
## Crown fire hazard chart



# Example of application

**Silvicultural guidelines and treatments to reduce forest stand vulnerability to crown fires**

- Basin of Rialb river (Prepirenees)



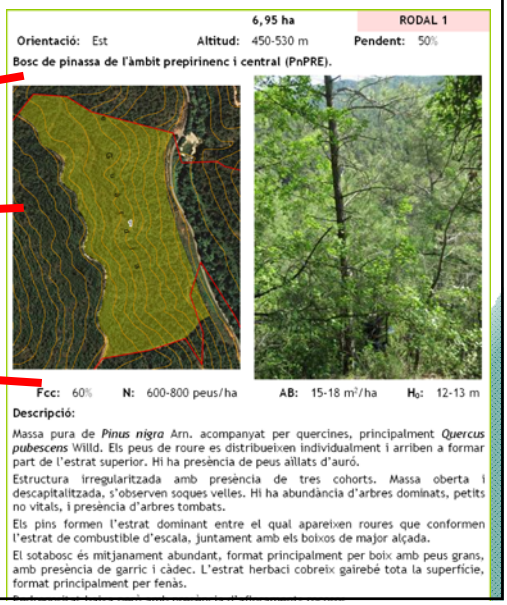

**Strategic points of Management:**

- Create resistant forest structures to crown fires
- Create forest structures that can alter forest fire propagation, and facilitate extinction tasks

PEG (strategic point) GRAF, CPF

www.ctfc.cat

- Forest type
- Forest stand structure (variables N, G, Dm, Do, Hm, Ho)
- Crown fire hazard classification


6,95 ha RODAL 1

Orientació: Est Altitud: 450-530 m Pendent: 50%

Bosc de pinassa de l'àmbit prepirinenc i central (PnPRE).

Fcc: 60% N: 600-800 peus/ha AB: 15-18 m²/ha $H_0$: 12-13 m

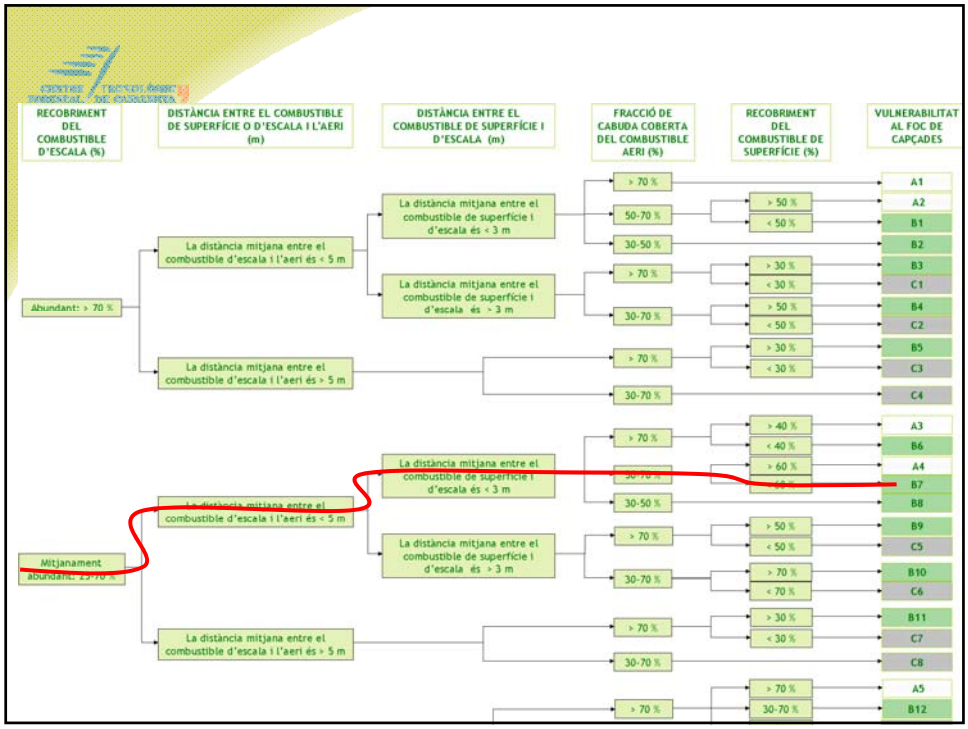
Descripció:

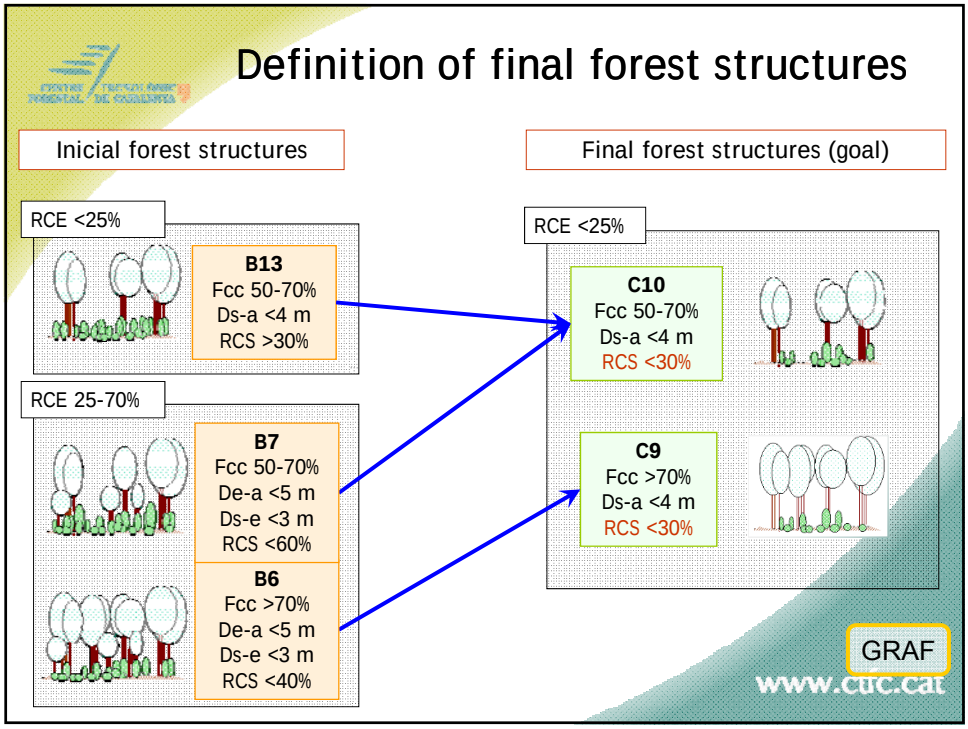
Massa pura de *Pinus nigra* Arn. acompanyat per quercines, principalment *Quercus pubescens* Willd. Els peus de roure es distribueixen individualment i arriben a formar part de l'estrat superior. Hi ha presència de peus aïllats d'auró.

Estructura irregularitzada amb presència de tres cohorts. Massa oberta i descapitalitzada, s'observen soques velles. Hi ha abundància d'arbres dominats, petits no vitals, i presència d'arbres tombats.

Els pins formen l'estrat dominant entre el qual apareixen roures que conformen l'estrat de combustible d'escala, juntament amb els boixos de major alçada.

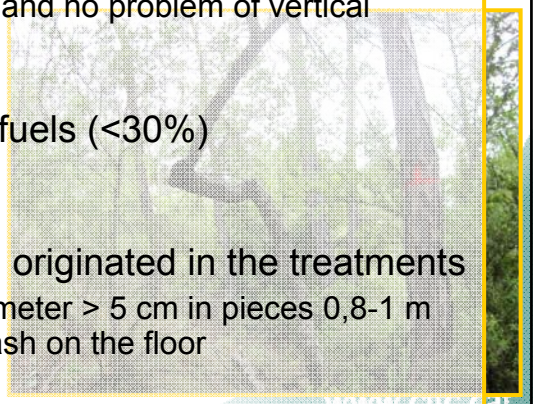
El sotabosc és mitjanament abundant, format principalment per boix amb peus grans, amb presència de garric i càdec. L'estrat herbaci cobreix gairebé tota la superfície, format principalment per fenàs.


RECOBRIMENT DEL COMBUSTIBLE D'ESCALA (%)
DISTÀNCIA ENTRE EL COMBUSTIBLE DE SUPERFÍCIE O D'ESCALA I L'AERI (m)
DISTÀNCIA ENTRE EL COMBUSTIBLE DE SUPERFÍCIE I D'ESCALA (m)
FRACCIÓ DE CABUDA COBERTA DEL COMBUSTIBLE AERI (%)
RECOBRIMENT DEL COMBUSTIBLE DE SUPERFÍCIE (%)
VULNERABILITAT AL FOC DE CAPÇADES
Abundant: > 70 %
Mitjanament abundant: 25-70 %
La distància mitjana entre el combustible d'escala i l'aeri és < 5 m
La distància mitjana entre el combustible d'escala i l'aeri és > 5 m
La distància mitjana entre el combustible de superfície i d'escala és < 3 m
La distància mitjana entre el combustible de superfície i d'escala és > 3 m
> 70 %
50-70 %
30-50 %
30-70 %
> 50 %
< 50 %
> 30 %
< 30 %
> 40 %
< 40 %
> 60 %
< 60 %
< 70 %
A1
A2
B1
B2
B3
C1
B4
C2
B5
C3
C4
A3
B6
A4
B7
B8
B9
C5
B10
C6
B11
C7
C8
A5
B12


Definition of final forest structures
Inicial forest structures
Final forest structures (goal)
RCE <25%
B13
Fcc 50-70%
Ds-a <4 m
RCS >30%
RCE 25-70%
B7
Fcc 50-70%
De-a <5 m
Ds-e <3 m
RCS <60%
B6
Fcc >70%
De-a <5 m
Ds-e <3 m
RCS <40%
RCE <25%
C10
Fcc 50-70%
Ds-a <4 m
RCS <30%
C9
Fcc >70%
Ds-a <4 m
RCS <30%
GRAF
www.ctfc.cat

## Definition of treatments

- Reduction of ladder fuels (<25%)
  - Eliminate urderstory superior to 1,3 m
  - Eliminate dominant trees with crowns in contact.
  - Keep small trees (priority *Quercus* sp.), where there is no other trees around and no problem of vertical continuity
- Reduction of surface fuels (<30%)
  - Selective clearings
- Management of slash originated in the treatments
  - Cut the slash with diameter > 5 cm in pieces 0,8-1 m long. Distribute the slash on the floor
  - Prescribed burning





**"Lesson learned"**

Implication of forest sector (forest owners, forest managers, firefighters, administration, researchers, industry) in the process

**"Challenges"**

Implementation, Divulgation, Demonstration, Capacity Building and specialization, Forest valorisation, Forest policy

## ORGEST Publications

**FMG** for most important forest types in Catalonia, covering the **87% of the forest surface** (pure and mixed forests): 13 books published

**Tools for practical diagnosis of forest stands**

**Forest Management Guidelines + Code of good practices**

http://ags.ctfc.cat/?p=649

www.ctfc.cat

## Thank you for your attention

**Contact:**

**miriam.pique@ctfc.cat**

**Acknowledgments:**

Centre de la Propietat Forestal of Departament de Medi Ambient i Habitatge de la Generalitat de Catalunya.

Marc Castellnou, Marta Miralles, Asier Larrañaga (UT GRAF, DI)

Firefficient project