

# Wildland-Urban Interface Fire Risk Management: WARM project

David Caballero<sup>1</sup>

## Abstract

Forest fires in the wildland-urban interface is a growing problem in Europe as well as in the rest of the world. In the frame of WARM project (Wildland-Urban Area Fire Risk Management), a research activity of the 5<sup>th</sup> Framework Programme of the European Commission, the scales of the problem and factors identified are presented. According to the experience of past years, a consistent and comprehensive framework is explained in which several research activities are presented. Among them, the characterization of different house-vegetation patterns, the description of interface fuels, the modeling of fire behavior and the participation of water runoff and landslides are considered in the computing of settlement risk and vulnerability.

## Introduction

Most of the attention of natural resources protection management goes to the preservation of natural life, ensuring a sustainable and beneficial use for the society. Recently, there exists a growing demand for wildland as places where to live or to spend pleasant vacation periods. This phenomenon is more evident in the nearby of large urban agglomerations and cities. It is expected growing rates of occupation for the next years in wildland.

This situation leads to consider a new scenario of natural resources planning and management, that is where urban areas mixes with wildland grounds. This specific situation is commonly known as Wildland-Urban Interface (W-UI). It is defined as the line, area, or zone where structures and other human developments meet or intermingle with undeveloped wildland or vegetative fuels (United States Department of the Interior, 1995).

Wildland fire experts believe that the threat of massive fire damage to human lives, private property, and natural resources is increasing (Fischer and Arno, 1988) and the reasons for this are: 1. Human activity patterns have changed the landscapes over the past three decades. 2. Natural resources are too valuable to let fires burn uncontrolled. 3. Wildland fire fighting budgets are shrinking. 4. More people are escaping the cities into the wildland. 5. Wildland fire fighters are untrained and/or ill-equipped to fight structure fires. 6. Climatic conditions such as drought are like a match to volatile fuels (Chuvieco et.al, 1994).

W-UI areas present typical problems of cities management together with those found in wildland management. Besides, a specific set of problems arise as synergy and interaction between the two land uses. One of the most prominent problems

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<sup>1</sup> TECNOMA S.A. - TYPESA Group, Spain, davidcaballero@tecnoma.es

found in W-UI areas is the occurrence of wildfires. People inhabiting urban areas and residences amid the forests are barely aware about the destruction potential of forest fires, until they have been stroked by previous experiences (Cortner et al., 1990). Forest fires is something that citizens are not used to, but something that they are exposed to when populating W-UI areas. Foreign people (immigrants and tourists) usually do not care about wildland-urban forest fire risk (Goldammer, 1992; Thomas 1994)

It has been found that wildland-urban fire contingency is frequently associated to large fires and, in most of cases, to crown fires development (Alexander, 1988), as recent regrettable examples show (USA-Oakland Hill, 1991; Greece-Mt. Penteli, Athens 1995, 1998; Spain-Tarragona province 1994; South East France, 1995). In the other side, the presence of agglomerations of people, that frequently are tourists, do represent a potential risk itself in the probability of fire occurrence. Thus, urban areas are, frequently, sources of new wildland fires (Alcázar 1998).

Houses and structures are generally poorly protected against wildfires intensities and behavior, as forest fires strike structures from the outside. The production of flying embers is particularly dangerous as they fall in roofs and ignite accumulated dead biomass.

Post-fire effects, such as erosion, landslides and rainfall runoff, actually threaten structures. In some cases surface flow is multiplied several times because hydrophobic reaction of burned grounds. This entails great risk to structures placed downstream. Smoke is also a serious side-effect in cities and towns near wildland where recurrent fires occur (Eftichidis, 1990). Power lines are also affected and can collapse power distribution. Sometimes, power lines are origin of new fires and they difficult aerial traffic of fighting forces.

Protecting structures against fire in wildland is not an easy task, fire fighters must apply techniques to control forest fires, in such conditions all homes and structures can't be actively protected from fire. In case of active fire fighting, difficult decisions must be taken in the case that human lives, properties and wildland areas are at risk simultaneously (Goldammer 1992). Fire fighting techniques in structures are different from wildfire fighting. Specific dangerous situations are found in both cases (blow-out in forest fires and flash-over in buildings). This demands specific training, techniques and tools (Thomas, 1994). In W-UI areas, water supply is not always available in quantity as required for fighting purposes, as it happens in cities. Besides, access to structures in W-UI areas is difficult. Fighting forces spend too much time in accessing houses located in mid-slope in wildland (mountainous) areas. Frequently people has a one-way escape route

Forest fires in W-UI areas affects a variety of key actors, either as people suffering consequences or personnel implied in the prevention and fighting of wildfires. It has been identified the following key actors: Protection Agencies, home owners, land owners, government and banks and insurance companies. All of them have a role in the planning and management of W-UI areas under fire threat. It is well known that techniques aimed at controlling forest fuels in or around urban areas is not regularly applied in time, place and quantity as required to protect structures from wild fire intensity that such fuels generate.

Hence, the responsibility of fuel control practices and other passive defense techniques must be shared and coordinated between land managers and house owners. Within commuting distance of metropolitan areas, development point to erect relative expensive residences on medium-to large lots. House builders tend to leave as much native vegetation as possible to maintain and promote the rural effect that buyers seek. Also, building materials are commonly non fire-resistant and access roads are narrow and forming dangerous cul-de-sac. Implication of developers and homeowners is critical, which is why population in W-UI places must be aware of actual forest fire risks and of its consequences in their areas.

Wildland-urban fire protection must be planned at regional scale, but it has to be implemented locally. Currently number of information systems are apply to, either, urban planning and forest and wildland planning and management. This includes techniques of data capture using remote sensors, data geo-referencing, analysis and report. There exist a number of models to predict land uses changes, vegetation growth, forest fire progression and, also, detection and estimation of urban areas expansion.

In light of the above, defense planning against forest fires in W-UI areas is a multi-faceted challenge which requires a coordinated effort in identifying, measuring, analyzing and solving the different problems presented.

## **Wildland-urban interface defense assessment**

### ***Framework of the problem***

In light of the experience during 2003 fire campaign in Europe and according to the needs identified, several points have to be considered to provide a common understanding of the problem and a common working frame for the planning and management of this problem. Also, this will identify the research lines involved in the W-UI realm, left open for future research projects.

First, it is the need to have a common understanding of the geographical scope and meaning of "settlement". In this point, it should be clarified that the subject deals with groups of houses which could be defined as W-UI units. These not necessarily have to match with the classical definition of settlement, namely, a group of houses forming an structure with common services; instead, a broader definition has to be given and a preliminary classification of types.

In fact "settlement", or what hereafter will be referred also as W-UI Unit, is the geographical area of interest that include a group of houses which have spatial relationship with the existing vegetation, susceptible to burn.

A preliminary classification of these W-UI units can be given according to their house-vegetation structure. Thus, considering vegetation and house density and in the other hand the degree of clustering of both components, the following table is obtained:

**Table 1**—Wildland-urban interfaces according to house-vegetation patterns

		VEGETATION				
		SPARSE		DENSE		
		Uniform	Clustered	Uniform	Clustered	
HOUSE	SPARSE	Uniform	Not Considered	Not Considered	Sparse Intermix	Sparse Intermix
	SPARSE	Clustered	Not Considered	Not Considered	Clustered Intermix	Clustered Intermix
	DENSE	Uniform	Urban	Urban	Intermix	Occluded Urban Interface
	DENSE	Clustered	Urban	Urban	Urban Interface	Clustered Urban Interface

0. Urban. Dominated by housing occupation. Not considered.
1. Sparse Intermix - Typical structure in rural areas, self-protection plans are needed.
2. Clustered Intermix - Same as (1). Small clusters of few houses, isolated.
3. Intermix - Typical structure in high-value, tourist areas, physical plan, emergency plan and also self-defense plans are needed.
4. Urban Interface - A well-defined boundary exists between house-dominated and vegetation- dominated areas. Physical plan and emergency plan are needed.
5. Internal Urban Interface - Typical structure of large wildland parks inside cities, physical plan is needed to isolate fire and minimize effects on the surrounding houses.
6. Clustered Urban Interface - Same as (4). Urban Interface but in continuous groups.

The assessment for planning will be focusing in the elaboration of:

- Physical plans, oriented to the execution of works
- Emergency plans, oriented to Civil Protection
- Self-protection plans, a tailored version of physical and emergency plans for isolated houses

W-UI Units are located in the landscape which has specific conditions and factors. A first analysis has to be done at landscape level, to provide planning strategies aimed at the prioritization of actions and quantification of the W-UI problem. Thus the assessment should include:

1. Identification of W-UI types, quantification
2. Potential causes of fires, fire origins
3. Fire fighting resources and infrastructures
4. Erosion, landslides and flood risk potential
5. Fire potential (intensity, spread rate)
6. Meteorological and wind most frequent, most adverse conditions
7. Ground accessibility through road network

For the point 1, a tool/method is needed to almost-automatically identify and quantify the different W-UI Unit classes in a certain territorial working area (TWA) according to the density of vegetation and houses and taking into account the cluster degree of houses and vegetation.

It has been observed that in the destruction of a house participate, first, the probability of fire reaching the house and, second, the probability that the fire destroys the house. To this it has to be considered a third probability or fact, the fire reaching and entering the settlement from the exterior.

Thus, it is required consider three scenarios:

EXT (X)	Fire propagating from outside the settlement and then entering it
SET (S)	Fire propagating inside the settlement
HOU (H)	Fire behavior in the lot and around the house, destroying properties

To this a new scenario has to be added, that specific of the Interface Zone (IFZ), which corresponds to the area of vegetation surrounding the settlement which potentially can drive fire to the vicinity of houses and evenly transport fire inside the settlement. This zone, which is a boundary between EXT and SET scenarios, is not present in all W-UI Unit types.

EXT (X) The fire external to the front is conditioned by the propagating factors, namely, forest fuel, topography and wind which corresponds to the immediate exterior of the settlement ("near zone", or 500 m. buffer around settlement boundary).

The fire can reach the settlement in two ways:

- A fire front approaching settlement boundary
- By firebrands flying inside settlement

Both phenomena do not automatically entail the propagation of the fire within the settlement and the destruction of houses.

SET (S) The fire propagates in the settlement thanks to the existing fuel, topography and wind conditions. To this we must add the unburnable structures which could act as barriers. But in the other hand we must consider again fire front propagation and firebrand production. The propagation inside the settlement is expected to occur through a non-uniform fuel pattern in a non-continuous flame front.

HOU (H) Fire behavior in the vicinity of the house is conditioned, mostly, by the presence of fuels and the wind. Radiation and convection are both related to the heating and destruction of the exterior house and properties outside, particularly when this entails flame contact. Also, sometimes this behaviors entails the fire entering or breaking into the house and destroying the house inside.

The above mentioned fire scenarios must be coupled with:

- Effective fire fighting operations, at the three levels (X, S and H)

- Civil protection (evacuation, confinement) and human behavior

The efficiency of these two set of operations can be helped or impeded by the infrastructures and local conditions at the three levels (X, S and H). In the end, our assessment has to point to the identification of:

- Potential destruction of settlement values
- Risk to human lives
- Destruction of properties in the lot, external to the house
- Destruction of the interior of the house, and thus the house itself

This assessment, that is the identification and quantification of factors that drive to these events, will have as outcome the measurement of vulnerability and risk associated to a settlement.

It is interesting to observe that these three scenarios, (X, S and H) happen normally in sequence one after the other, but in a real fire all of them can happen simultaneously in different points. Individual vulnerability of houses can be typified and sums to the total computation of settlement vulnerability and risk.

In light of this, in order to give a reasonably complete assessment, it is required to approach and solve the following questions:

In the EXT scenario:

- X1 Which meteorological and wind conditions are in average the most adverse for this settlement?
- X2 Which are the location and type the most likely sources of fire (starting points) or expected approaching fire fronts reaching this settlement?
- X3 How much is this settlement covered by nearby ground and aerial fire fighting forces?

In the SET scenario

- S1 How fire will reach and enter the settlement?
- S2 How fire could be effective and safely suppressed or controlled?
- S3 How fire will destroy settlement values (vegetation, infrastructures etc.)?
- S4 How fire should entail putting people at risk?

In the HOU scenario

- H1 How fire will behave in the lot and around the house?
- H2 Will the fire destroy properties outside and exterior of the house?
- H3 Will the fire enter the house and destroy it from inside?
- H4 Could the house constitute a safe shelter for people?
- H5 Which effective and safe fire fighting operations could be applied?

The assessment will be given in the form of maps and recommendations. The maps will be derived from the spatial analysis at settlement scale of the points mentioned above. Recommendations will be technical reports and protocols, and will point at:

In the EXT scenario

- Effective fuel management and vegetation structures in the exterior of the settlement
- Effective fire fighting operations (to avoid the fire entering the settlement)
- External accessibility and structures to help effective and safe fire fighting

In the SET scenario

- Fuel design and management to avoid adverse, sustained fire propagation
- Internal accessibility and structures to help fire fighting and Civil Protection operations
- Effective and safe fire fighting operations, to minimize fire propagation in the settlement
- Effective Civil Protection operations, to keep people safe in every moment

In the HOU scenario

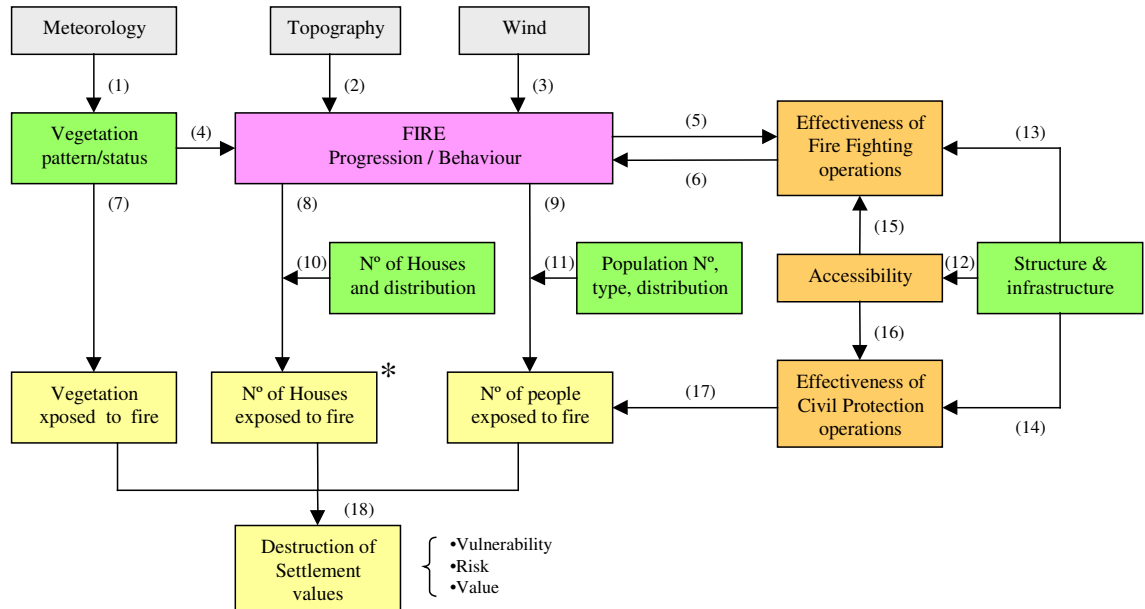
- Fuel (gardening) design and management to provide a safe place and minimize effect of fire on properties and house
- Design, location and protection of properties exposed outside the house
- Material, elements and their position/defense relative to potential sources of fire
- Identification and adaptation of house's weak points, through which fire could enter
- Effective and safe fire fighting operations
- Structure and infrastructure to help fire fighting safe and effectively
- Classification of house as “fire shelter”, or identification and adaptation of the required elements to be classified as it.

All the recommendations and the maps mentioned will constitute a preventive physical plan for settlement protection against forest fires. This should be complemented with an emergency plan oriented specifically to the protocols to follow in case of fire emergency, and should be directly pointing at the people inhabiting the settlement in such moment. Both documents, preventive physical plan and emergency plan, will constitute the General Plan of the settlement for its protection against forest fires.



## Settlement vulnerability, risk and value loss assessment

At settlement scale, defense planning assessment has to touch the following factors and considerations:



This point links with assessment at house level

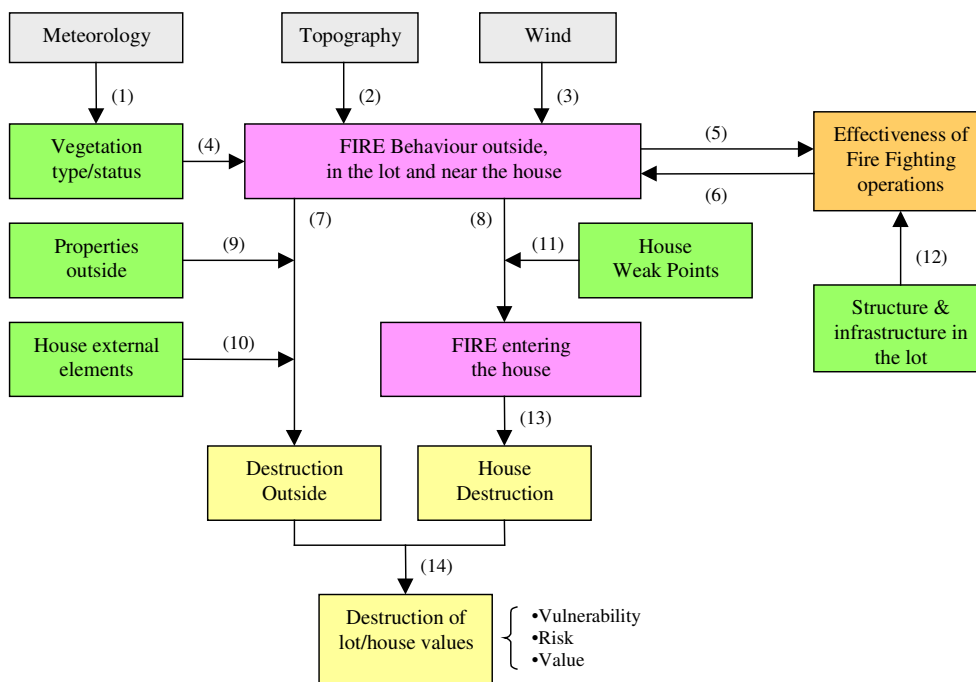
**Figure 1**—Assessment scheme at settlement level

- Vegetation patterns, understood as spatial distribution of burnable and non-burnable material, affecting fire behavior thus conditioning fire ignition and propagation inside the settlement. This accounts also for firebrand and smoke production and intrinsic properties, such as heat content, flammability or bulk load per volume unit. To the existing wildland fuels, specific to settlement fuel species have (4)
- Vegetation inside settlement as an intrinsic value (aesthetics, shadow etc.), with an associated monetary value, that could lead to destruction due to the fire front passing (7)
- The number and type of houses and the distribution within the settlement forms a pattern itself. When coupled with the fire front passing, a computation of the total house exposition to fire can be obtained. The evaluation of vulnerability, risk and values affected is done in more detail in the house vulnerability assessment (10)
- The people still present in the settlement while fire is progressing inside the settlement, can be coupled with the expected fire progression to compute the exposition of such people to fire and smoke. Number and type of people (mainly mobility) and human behavior has to be taken into account (11).

- The presence of specific infrastructures (such as, helispots, safe areas and shelters, including the houses that can be classified as such) can contribute to the effectiveness and safety of civil protection operations, such as evacuation, confinement and rescue (14).
- Civil protection operations will lead to the movement and/or protection of people potentially exposed to fire. This does not ensure, however, that all the people in the settlement will be kept under safe conditions. The remaining, exposing themselves (voluntarily or not) will account to the potential loss due to fire progression (threat to human lives) (17).
- Total accounting of vegetation loss, house and property loss (as comes from house level analysis) and threat to human lives will be synthesized in a unique, unified measurement of settlement vulnerability, risk and value at risk (18).

### ***Lot and house vulnerability, risk and value loss assessment***

At house-lot level the following points must be taken into consideration:



**Figure 2**—Assessment scheme at house-lot level

- Vegetation components in the lot, such as hedges, ornamental bushes and trees, affecting fire behavior thus conditioning fire ignition, propagation and heat release inside the lot. Intrinsic properties, such as heat content, flammability or bulk load per volume unit, of specific settlement fuel species has to be considered. 3D position, space occupation and species (characterized as

mentioned before) will be inputs for the assessment. Besides, vegetation inside the lot as an intrinsic value, with an associated monetary value, which has to be accounted in the total value of the lot (4).

- Locally developed fire behavior (radiation, convection, smoke) conditions fire fighting operations locally. Burning of other components and the house must be considered as well (5).
- Fire behavior inside the lot has destructive effects on the vegetation, understood as a value of the lot, the properties located outside the house, normally in the garden, and the external parts of the house (7).
- Fire behavior threatening house can derive, under certain circumstances, into the fire entering or breaking-through into the house (8).
- Properties outside the house, normally are exposed to the heat sources, hence entailing destruction and accounting for the total value loss of the lot (9).
- House external elements are commonly directly exposed to fire, such entailing different degrees of destruction, which derives into house value loss. Materials and their ease to be destroyed, 3D position relative to heat sources and value of such elements have to be considered (10).
- Weak points are those spots in the house structure that, according experience, fire enters or breaks through into the house, thus exposing interior to the ignition and destruction of properties inside or the house itself. Type and their relative 3D position to heat source has to be considered (11).
- Once fire is entering the house, it could entail the ignition and propagation of fire inside the house, even the total destruction of the building. This part fall in the domain of structural fires. Valuation of losses accounts here for the properties inside and the house itself (13).
- Total accounting of the lot and house vulnerability, risk and potential loss of values at risk is obtained by summing the losses in the exterior and interior of the house. This should be an input to the assessment at settlement level, thus accounting the total vulnerability, risk and values at risk of the settlement. To proceed, houses can be typified in a number of cases for which detailed assessment can be provided, and then extrapolate to the rest of the houses of the same type within the settlement (14).

## **WARM project**

### ***Description and objectives***

Fires in the W-UI/RA have been studied for decades in USA, Canada and Australia, among other countries. Looking at this experience, a number of research projects, co-funded by the European Commission, are now focusing into the reality of W-UI/RA fire management in Europe. Among them is WARM project (Wildland-Urban Area Fire Risk Management).

Within the context of WARM project, a scientific approach is proposed to complete a series of studies, experimentation activities and developments which will end up in a methodology and a computer-based Decision Support System in the aim that the resulting tool and protocols will assist wildland and urban planners to identify and solve forest fire risks to minimize losses and costs.

General objective of WARM project is to characterize direct and indirect risks due to fires in the wildland-urban interface (W-UI) in Europe and to provide a methodology and an information system to minimize losses of residences and other structures, while reducing social and environmental impact, throughout the assistance in the elaboration of rationalized, encompassed wildfire defense plans.

In this project, six countries participate with their experience and study cases, namely Spain, France, Italy, Greece, Slovak Republic and Czech Republic. These represent a significant number of cases hence a good sample of W-UI problem in Europe.

## Conclusions

In light of our activity in WARM project, a number of conclusions can be derived in regards to Wildland-Urban Interface in Europe:

- Forest fires in the W-UI in Europe is an emerging and growing problem, with social and economical consequences. In Europe, specially in Mediterranean countries, forest fires affect people, properties and natural environment. However, houses are affected but frequently they are not destroyed.
- W-UI problems has, at least, three different scales which must be approached in different ways, but consistently between them: landscape, settlement and house levels.
- Assessing settlement vulnerability to forest fires is a complex task that can be approached through the identification, measurement and spatial analysis of particular variables
- Settlement can be understood as a structure itself
- Settlement vulnerability is strongly based on house vulnerability, but also on fire progression within the settlement, accessibility and house exposition to fire
- House / vegetation densities and clustering degree are variables related to the progression of fire within the settlements. Each type demands different defense approaches.
- RS and GIS techniques can be applied to identify and measure relationships between vegetation and house distribution
- It is proposed to elaborate a danger index associated to such vegetation/house distributions
- Spatial integration of all the observed variables in synthetic maps help to identify which components have to be modified and which are the areas of higher vulnerability within a settlement.
- For each of the identified cases of settlement vulnerability, a set of good-practices and guide for self protection has to be produced and handled to people living in the settlement.

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