Concepts and ideas of assessing settlement fire vulnerability in the W-UI zone

D. Caballero, I. Beltrán
TYPSA, Spain

Introduction

For the last two years, many forested countries in the world, and particularly in Europe, have suffered the rage of a new and increasing natural-human phenomenon, that is the strike of forest fires onto populated settlements and housing areas. This new land use is the so-called Wildland-Urban Interface (hereinafter W-UI).

W-UI areas embrace both, the presence of vegetation and houses co-existing together and forming patterns. Vegetation is part of the surrounding natural environment, thus it is considered as an esthetical component in housing areas. But vegetation is also forest fuel. In this sense, vegetation, when present in more or less continuous areas, is commonly associated to the initiation and development of forest fires. In conclusion, and given these two aspects of vegetation, contact between houses and vegetation has to be studied in detail

W-UI is a multiform and complex scenario for forest fires. In fact this embraces the existence of vegetation which forms patterns; housing and infrastructure development, which also, form patterns;
and, finally, the presence of people which conditions fire fighting demand and operations. As it can be deduced, the inter-related house and vegetation patterns are associated to how the fire progression and house destruction happens, hence how it contributes to the settlement vulnerability.

The objective of this paper is to bring some ideas and questions about assessment of vulnerability of settlements in the event of forest fires in Europe, to present some approaches to identify and measure variables which could explain settlement vulnerability and, finally, to present some techniques to help in the identification, measurement and spatial analysis of such variables.

Background

Every year we learn about the events of forest fire affecting settlements in USA, Canada and Australia, among other countries. In them we have observed that frequently houses themselves are part of the fuel which initiates and propagates the fire, according to the sustained ignition of building materials used.

In our case in Europe we have similar situations, but in most of cases the factors and conditions for forest fire propagation in the settlements and of fire destroying partial or totally houses and other properties are different. These differences have to bee taken into account in the computation of houses and settlement vulnerability.

For example, we have observed that, as well as in other countries, our houses in the wildland are surrounded by vegetation and other fuels. This vegetation can be either, wild vegetation of the nearby or ornamental and hedges vegetation

Also, according to our experience, in European countries, houses are frequently destroyed by fire inside, that means, the fire manages to enter or to go breakthrough in the house and then initiate a fire which destroys partially or totally the building.

All these particularities are addressed by WARM project (Wildland-Urban Area Fire Risk Management), a research initiative co-funded by the European Commission under the V Framework Programme which objectives are:

- to characterise direct and indirect risks due to fires in the Wildland-Urban Interface (W-UI) in Europe,
- to provide a methodology and an information system, and
- to assess in the elaboration of rationalised, encompassed wildfire defence plans.

In this paper, some preliminary findings and approaches are presented to contribute to the knowledge in the subject and propose methods for the measure and control of factors directly involved in the propagation of fire and destruction of properties. In WARM project, W-UI problem is approached from different angles and at three different levels: landscape level, settlement level and house level, being the three of them inter-related. Settlement level is main focus of WARM project, for which the objective is to characterise risks and vulnerability, and obtain models out of observation and experimentation to be applied later in the planning and management procedures.

But the first difficulty has been to have a common and realistic understanding of the term "settlement", which varies from country to country and even within the same region.

Definitions of settlement

In order to have a common understanding of the term "settlement" a number of definitions have to be given. In this way, the selection of study cases, particularly the geographical extension, will be done consistently regardless the regions considered.

Settlement as group of lots

This is the typical formation with common infrastructures (roads), with small or no vegetation inside, formed by a number of neighbouring, small to medium-size lots. In this case we have a house-dominated area surrounded by vegetation and creating a definite boundary between both areas.

Settlement as area within administrative boundaries

In this case we refer to an administrative unit within a continuous intermix scenario for which boundaries between house-dominated and vegetation-dominated areas are not so well defined. It is frequently present in Mediterranean coast, showing a continuous land pattern in which vegetation is well represented hence the fire progresses within the settlement. In these cases, fighting and Civil protection operations are challenging in the

sense that decisions and criteria have to be applied for the defence of human lives, properties and natural environment simultaneously.

Settlement as group of houses

Frequently associated to rural lands, a pattern is observed of sparse, isolated houses in large wildland, forest or agricultural lands, which also present limited ground accessibility. In these cases it is prescriptive a good planning oriented to self-defence.

Settlements as structures

For all of the previously presented cases, it is also interesting to note that a settlement can be understood as an structure itself in which persons, houses, infrastructures (roads) and vegetation are present. These can be considered as elements at risk (persons, houses), burnable materials (vegetation, other fuels) and unburnable materials (roads, safe areas, houses), thus reminding to actual structures (buildings) in the city. In this sense, the planning and management should take example of the structural fires, for which preventive measures are taken to avoid ignition, limit fire propagation and ensure structural stability; and installations and infrastructure for extinction and evacuation (access routes, water points etc.) are designed.

Settlement vulnerability

The main objective of the assessment on housing areas in the wildland is the settlement vulnerability estimation, which can be understood to be compound of:

- The potential of bringing fire fronts to the houses
- The sum of houses vulnerability exposed to fire
- The accessibility (lack of) of fighting forces
- The evacuation efficiency and existence of safe areas

As presented here, settlement vulnerability is directly linked to the vulnerability of each of the houses which belong to the settlement. That points to the need of characterisation of fire behaviour and house destruction potential at this detailed scale.

House vulnerability

The factors involved in the partial or total destruction of houses are numerous and complex. In Europe, particularly in Mediterranean countries, houses are not part of the fuel, instead frequently they are destroyed because the fire manages to be inside.
In these cases particular attention has to be paid to the hypothesis of fire entering the house:

- Radiation of close fuels breaking through "weak points"
- Fire, firebrands entering openings (windows ...)
- Fire leaking through roof and decks (destruction)

In light of the above, and schematically, the planning of settlement defence criteria has to point at two different aspects:

1. Preventive planning, which objectives are:

- To minimise or avoid consolidated fire progression within the settlement,
- To Minimise probability of sustained house ignition, and
- To Improve fighting operations (infrastructure).

2. Extinction operational, which objectives are:

- To control and suppression of the fire front,
- To control spot fires,
- To protect houses from ignition, and
- To improve and ensure safe civil protection operations (rescue and evacuation)

According to these objectives, it is proposed first to look at a number of variables which seem to be closely related to the settlement vulnerability, namely:

- Houses / vegetation density
- Clustering and intermix degree
- Exposition of houses to fire
- Ground accessibility

Houses / vegetation density

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:

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

1.- Urban. Dominated by housing occupation. Not considered.

2.- Sparse Intermix. Typical structure in rural areas, self-protection plans are needed.

3.- Clustered Intermix. Same as (1). Small clusters of few houses, isolated.

4.- Intermix. Typical structure in high-value, tourist areas, physical plan, emergency plan and also self-defence plans are needed.

5.- Urban Interface. A well-defined boundary exists between house-dominated and vegetation- dominated areas. Physical plan and emergency plan are needed.

6.- Occluded Urban Interface. Typical structure of large wildland parks inside cities, physical plan is needed to isolate fire and minimise effects on the surrounding houses.

7.- Clustered Urban Interface. Same as (4). Urban Interface but in continuous groups.

In every case, it seems that the clustering of houses s related to the possibility of fire to progress through the settlement. In this sense, it seems that the presence of relative large patches of vegetation between houses is a key factor entailing a sustained and destructive progression of a fire front. These internal patches, frequently, are abandoned, or just non-built lots which are bought for speculation.

Essentially, among others, two patterns have been identified as significant regarding differences of prevention and fire fighting demands, and are related to the grouping or "clustering" of houses and vegetation.

Thus, the **clustered formation** has well defined boundaries, the houses in the boundary are exposed to a potential fire, normally they present poor or no fire progression inside and normally common preventive measures and defence operations are taken for the whole settlement.

In the opposite, the **intermix formation** has not so-well defined boundaries and potentially all houses are exposed. Frequently they present a sustained progression of fire front and need of combined operations and self-protection.

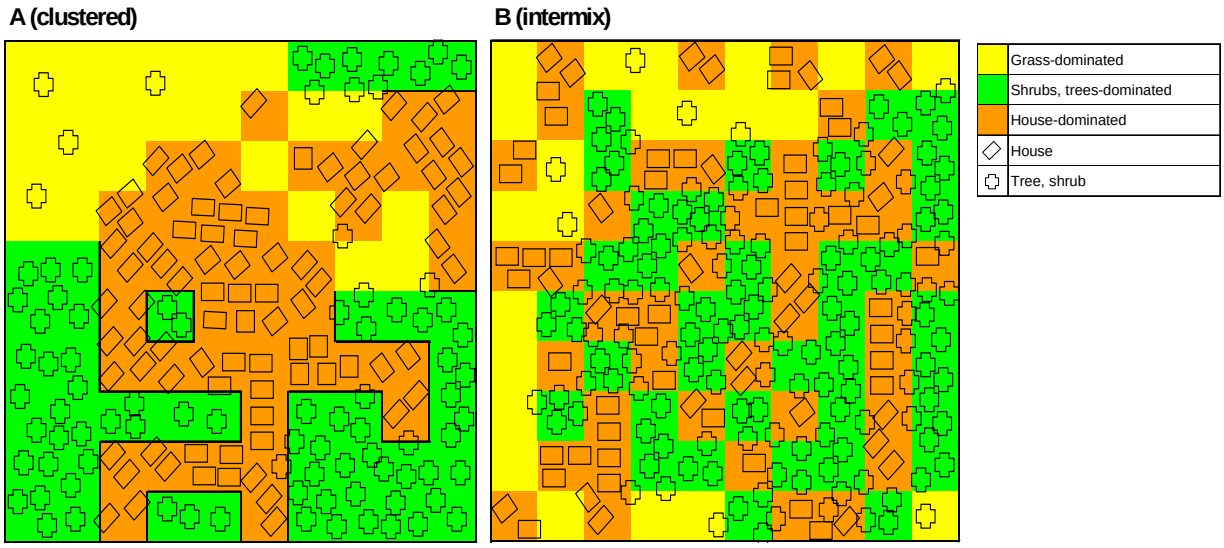
In our quest to identify and quantify such patterns, two main variables can explain clustering and vegetation/houses mixing, namely distances between houses in a settlement and Area with vegetation enclosed between houses. For both, Some Remote Sensing techniques and classification tools can help to identify and measure such variables, in particular E-Cognition software identifies and classifies geographical elements (objects) based on semantic rules (shape, texture, contextual) and helps to obtain spatial relationships between them (distance, neighbouring etc).

Out of the identification of vegetation-house patterns, a further analysis of the exposition to fire of settlements and house has to be performed. To do so, a new analytical approach is presented.

Exposition at settlement level

In order to measure the settlement potential exposition to fire, a portion of landscape is selected which includes the settlement (houses) and the surrounding vegetation. A square grid of a certain resolution (i.e. 25m) is used to identify if such position is dominated by houses, trees or shrubs (forest fuel) or bareland or short grass. A spatial

analysis procedure accounts for the grid-cell edges which are transition between one class or the other, and particularly the couples house-trees, house-grass and house-house. The total summing length of each couples explains the exposure (contact) of each pair of classes, and in particular F_{EXP} (houses exposed to forest fuel, which measures the potential exposure) F_{HBAR} (houses in contact with bareland) and F_{H-H} (houses in touch with other houses, which measures the degree of clustering).



	(A) Clustered	(B) Intermix
Area total	100	100
Area house	40	40
Area Vegetation	37	37
Area grass	23	23
Length total	400	400
Lenght House	160	160
Length Vegetation	148	148
Length Grass	92	92
Length Exposed (House-Tree)	35	79
Length House-Grass	25	30
Length House-House	45	17
Factor LExp/LHou	0.22	0.49

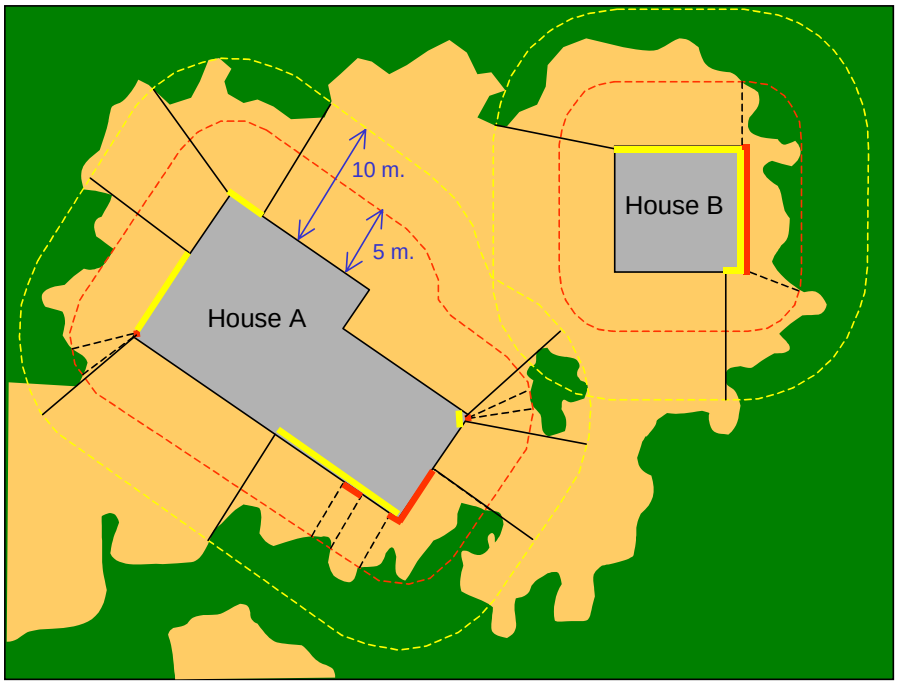
It is interesting to note that, for the same number of cells occupied by houses (40), vegetation (37) and bareland (23), the case of intermix formation the total house exposure to vegetation (79) is more than the double than in the clustered case (35). Also, note that the house-house total length is significant larger. Dividing the total exposed length by the total length of house-dominated cells, we obtain a factor, the **Interface Specific Length** (λ_e) explaining the total demand (vulnerability) of fire fighting defence in case all the vegetation was burning.

Exposition at house level

At house level, the objective is to look for the distances between the immediate fuels and the elements of house, and the house itself, exposed to flame contact (0-2 m.), flame radiation-convection (2-10 m.) and spotting (more than 10 m.). According to this criteria, and making use of the buffers at such distances of the house, a computation of

total house length exposed to vegetation at such given distances is obtained. Particularly interesting is in the case that within such lengths an opening or a weak point is present, places through where fire could manage to enter and ignite the house inside.

This analysis is based on finer data about the position of burning elements and house elements exposed to fire, and specific and detailed inventory has to be performed. This finned analysis can be repeated for all houses in a settlement, thus accounting of all exposed lengths and giving a more accurate value for settlement vulnerability.



Conclusions

Summing up, a number of conclusions can be obtained from the experience in the design and application of the presented method:

- 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 defence 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
- Specific Interface Length is a proposed measurement to explain the amount of length exposed to fire in a settlement per total area covered by houses.
- This measure can be combined with the analysis of weak points in houses to improve efficiency in the design of passive measures to protect houses
- Ground accessibility participates in fighting and evacuation operations. It weights house vulnerability in the computation of settlement vulnerability
- 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.

Further analysis should point to the incorporation of monetary value to the damaged properties and aesthetic elements (particularly vegetation). At settlement level, new elements have to be incorporated to the vulnerability accounting, such as ground accessibility and the presence of other infrastructures. Besides, at house level, a three-dimensional approach has to be designed and applied in the inventory and modelling of fire behaviour and its consequences on the degree of house destruction.