Preliminary description of urban settlement typologies related to forest fire risk (WARM project)

Pascual, C[1]; García-Montero, L.G[1]; Manzanera J.A[1]; Arroyo-Méndez, L. A[1] Beltrán, I[2]; Caballero, D[2]
[1]IMIA Finca "El Encín" Apdo. 127. 28800 Alcalá de Henares. Madrid. Spain
[2] TECNOMA Isla Graciosa, 1. 28700- S.S. de los Reyes. Madrid, Spain

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Abstract

Forest fires originated in the vicinity of urban areas can inflict great damage specially when they are heavily inhabited. The EU research project ENV1-2001-00030 "Wildland-Urban Area Fire Risk Management" (WARM), which is integrated by 9 partners from 6 European countries, pursues to characterize direct and indirect risks due to fires in the WU-I in Europe and provide a methodology and information systems to assist in the elaboration of wildfire defence plans and minimize losses and environmental impact. A catalogue and a key for the classification of structures and assessment of their vulnerability to forest fires have been established. Finally, the procedure has been applied to a study-case area in Spain.

Introduction

Wild Urban Interface (WU-I) is commonly defined as "a geographic area where formerly urban structures, primarily homes, are built in immediate proximity to naturally occurring flammable fuels" (Summerfelt, 2001). FIREWISE (American Wildland Urban Interface Organization) also proposes WU-I as "the line, area or zone, where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels" (http://www.nifc.gov/fireinfo/glossary.html).

Wildland fires are inevitable natural events, but fires can inflict great damage and suffering when they occur in environments heavily inhabited by humans and their structures (Cleaves, 2001). The problem of wildfires in the WU-I has recently became of key importance in the Mediterranean basin countries due to the explosive growth of Wild Urban Interface areas and some major catastrophic events in the last decades. However, there is a lack of information regarding WU-I in Europe, about its real extent and characterization (Camia *et al*., 2002).

In such a peculiar scenario, Forest services and Management institutions must implement different fire control strategies, which should take into consideration the fact that human life, properties and wildland areas can be at risk simultaneously. (Goldammer 1992).

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methodology and information systems to assist in the elaboration of wildfire defence plans and minimize losses and environmental impact.

One of WARM's milestones is to establish a catalogue and key for structures and assessment of their vulnerability to forest fires. The present contribution describes the analysis of Spanish WU-I cases and their classification attending their risk to forest fires.

Methodology proposed

A test site located about 40km northwest of Madrid, in the southern slope of Sistema Central Mountains was selected. This study area is a square 30 x 30 km long which is inside a vast W-UI area with a high fire proliferation rate. Nine settlements were selected in order to elaborate a preliminary catalogue of WU-I risk situations.

A systematic inventory of W-UI situations in this area was carried out following common WARM project guide and forms (Beltran *et al.*, 2003). Two kinds of settlement components (*structural* and *modifiers*) were identified and characterised. The former consider three aspects: type of settlement, forest fuel and topography. On the other hand, the *modifiers* include: fire causes, historical fires, population density, road accessibility, forest fire defence forces availability and land use change.

In this inventory, a form was filled for each component. Firstly, a preliminary identification of the settlements and groups of houses was done by photo interpretation. In most cases, settlement boundaries were also digitalized. To arrange settlements according to their risk forest fires, several variables were taken into account, as building materials, occupation degree, type of vegetation surrounding the house, forest fuel, road accessibility and protection infrastructure. Whenever it was possible, the components topography, forest fuel, road accessibility and defence resources availability were characterized by aerial photo interpretation and digital maps analysis. On the other hand, for identifying the components type of vegetation surrounding the house, building materials, occupation degree and protection infrastructure, fieldwork and several visits to study area were done.

According to the inventory phase results, a methodology was proposed in order to classify the different WUI units of Madrid. This interface areas typology was based on the analysis of the three *Structural Components* studied (type of settlement, forest fuel and topography). Each of them was characterized as follows:

1) Type of settlement

This component was estimated from four sub-indexes: *Percentage of lots that were in touch with forest fuel, Vegetation just surrounding the house, Percentage of vulnerable lots and Security*

Sub-index 1: Percentage of lots in touch with natural vegetation

It was defined as number of lots in touch with forest fuel in the settlement over total number of lots in the settlement as percentage, and it was obtained by means of photo interpretation.

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Lots in touch with forest fuel were those lots that had at least one side in touch with forest fuels, either inside the settlement or in the boundary. When lots in the perimeter of the settlement were surrounded by a road, they were not considered to be in touch with forest fuel.

Lots not in touch with forest fuel (natural vegetation)
Lots in touch with forest fuels in a perimetral situation
Lots in touch with forest fuel inside the settlement

Values assigned to each kind of settlement for sub-index1 were:

Sub-index 1. Percentage of lots in touch with forest fuel
Value 1: interface (< 30%)
Value 2: medium interface (30-60%)
Value 3: interface/intermix (60-80%)
Value 4: intermix (> 80%)

Sub-index 2: Vegetation just surrounding the house
The quantification of this sub-index was carried out considering two factors from WARM Inventory Settlement forms: vegetation situation and distance to nearest wild vegetation.

Factor 2.1.- Vegetation situation
The six vegetation situations that appear in the forms were grouped into two, according to their risk for forest propagation. On the one hand, *no vegetation*, *pruning vegetation*, *garden*, *lawn* and *orchard* (codes 0, 3, 4, 5, 6) were considered lots with low fire risk vegetation. On the other hand, *wild light* and *wild strong* situations (codes 1 and 2) constitute lots with high-risk value.

Thus, values assigned to each settlement considering this factor were:

Factor 2.1. Vegetation situation
Value 1: < 25% of lots with low fire risk vegetation
Value 2: > 25% of lots with low fire risk vegetation

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Factor 2.2.- Distance to nearest wild vegetation
Two groups were considered:

- Wild vegetation is < 2 meters from building
- Wild vegetation is >2 meters from building

Value assigned to each settlement attending to this factor was:

2.2. Distance to nearest wild vegetation
Value 1: > 60% of lots have wild vegetation at least 2 meters away from construction
Value 2: < 60% of lots have wild vegetation at least 2 metres away from construction

Factors 2.1. and 2.2. (Vegetation situation and Distance to nearest wild vegetation) were integrated in order to get the risk value for sub index 2 (*Vegetation just surrounding the house*)

The integration matrix was as follows:

Sub-index 2. Vegetation just surrounding the house	2.1. Vegetation situation	2.2. Distance to nearest vegetation
1	1	1
2	1	2
2	2	1
3	2	2

Fig. 2.- *Garden with high fire risk*

Fig. 3.- *Carefully kept garden with low risk*

Sub-index 3: Percentage of vulnerable lots
This sub-index is based on building materials and houses state of preservation. Lots were considered vulnerable when existed any of the following situations:

Vulnerable Lots
More than 80% made of wood or other burnable materials.
A significant part (40-80%) of building is made out with flammable materials.
Poor or deficient construction.
Prefabricated.

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Fig 4.- Examples of vulnerable lots

Values were assigned to sub-index 3 as follows:

Sub-index 3. Percentage of vulnerable lots
Value 1: < 20% are vulnerable lots
Value 2: > 20% are vulnerable lots

Sub-index 4: Security

The quantification of this sub-index was based on three factors that also came from WARM Inventory Settlement forms. These factors were: Factor 4.1. Protection infrastructures, Factor 4.2. Accessibility to the lot, Factor 4.3. Use.

Factor 4.1.- Protection infrastructures

This factor was evaluated in field inventory. The values for this factor were:

4.1. Protection Infrastructure
Value 1: Protection infrastructures are present
Value 2: Protection infrastructures are not present

Fig 5. - Protection infrastructure

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Factor 4.2. - Accessibility to the lot
Accessibility to the lot was grouped into two possible situations.

4.2. Accessibility to the lot
Value 1: Optimum
Value 2: With non paved roads and mechanised trails

Factor 4.3.- Use
This factor was related with houses occupational level (Code E). This factor considered two level of houses occupation:

4.3. Use
Value 1: > 50% of lots are permanently occupied
Value 2: < 50% of lots are permanently occupied

"Security" Sub-index came from the final integration of Factor 4.1, Factor 4.2 and Factor 4.3. as is presented in the following table.

Sub-index 4. Security	4.1. Protection infrastructures	4.2. Accessibility	4.3. Use
1	1	1	1
2	1	1	2
2	1	2	1
2	1	2	2
2	2	1	1
3	2	1	2
3	2	2	1
3	2	2	2

At this point, the 4 sub-indexes previously calculated, had to be integrated to get the structural component "Type of settlement". The objective was to ascribe each settlement into 4 types o categories: from type 1 (low WU-I forest fire risk) up to 4 (highest WU-I forest fire risk). The applied methodology involved to assign a "sub-index vector" to each settlement, so vectors had as components the respective four sub-index values obtained before. All vectors were ranked in ascending way, and reclassified keeping in mind that sub-indexes were not equally weighted. Sub-index 1.-Percentage of lots in touch with forest fuel was the most important and Sub-index 4.- Security the least.

2) Forest Fuel component
In order to typify forest fuel near settlements, the following variables were taken into account: On the one hand, 3 propagation groups were considered: Grass dominated, Shrubs dominated and Litter or slash dominated. At the same time, a combination of cover (%) and height of vegetation was also taking into consideration. The thresholds for cover and height classes were the followings:

Sparse cover (SC)	< 40%
Dense cover (DC)	40% - 75%
Very dense cover (VDC)	> 75%
Low height (LH) < 1,5m	

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High height (HH) >1,5m

Beside 3 fire type groups were distinguished according to WARM project forms:

	FIRE TYPE
1	Fresh, leafy shrubs, large % of life, green material, less prone to burn
2	Sclerophyill Mediterranean-like evergreen shrubs, able to burn well with wind
3	Fine leafed or thorny shrubs, such as cured brush, often very dry, with large % of dead flash or explosive fire behaviour with wind

Matrix combination for forest fuel variables is the next one:

		FIRE TYPE		
		1	2	3
Propagation group Density (%Cover) &	Grass/ Shrubs/ Litter (SC[1])	x	x	1
	Shrubs (DC & LH)	1	2	2
	Shrubs (DC & HH)	1	3	3
	Shrubs (VDC & LH)	2	3	4
	Shrubs (VDC & HH)	2	4	4

[1]Sparse cover (SC) < 40%; Dense cover (DC) 40% - 75%; Very Dense Cover (VDC) <75%, Low height (LH) < 1,5m; High height (HH) > 1,5m.

These fuel values (1 to 4) were weighted by the percent of perimeter in touch with each fuel type (obtaining the so called "*Contact-fuel value"*) and also by percent of area within a 500m buffer ring, obtaining the "*Near- fuel value*".

"*Fuel final value*" is equal to "*Contact-Fuel value*" whenever it is greater or equal to "*Near-fuel value*". In case of being smaller, "*Fuel final value*" will be equal to "*Contact-Fuel value*" plus 1.

3) Topography

Topography was classified into two groups

Low topography (type1) <25%

High topography (type 2) >25%

Once structural components (Type of settlement, Forest fuel and Topography) were calculated, the target was to integrate them into a final risk index for each settlement. Firstly, Forest fuel and Topography were considered. These two defined final fuel value named "*Fuel (topography)"* that was equal fuel value when Topography is "type 1", and it was increased in one unit when Topography is "type2"

Final integration to get a risk value for each settlement was:

		Type of settlement			
		4	3	2	1
Fuel (topography)	4	3	3	2	2
	3	3	3	2	2
	2	2	2	2	1
	1	2	1	1	1

Methodology application for Spanish area

The above methodology was applied in nine settlements allocated within the Spanish study area (El Ramiro, Reajo el Roble, San Muriel, Valdencina, Los Linos, El Berrocal, Los Palacios, Vista Real and Sierra Bonita). Settlement selection was carried out considering every possible situation that could be fond in Spanish region. Gathering data was done between July - October 2003, including field work, photointerpretation and lab work.

Types of settlement results obtained for each settlement are the followings:

	Subindex 1 % Lots in touch with nat. veg.	Subindex 2 Vegetation surrounding the house	Subindex 3 % Vulnerable lots	Subindex 4 Security	*Type of settlement*
El Ramiro	3	3	2	3	**4**
Reajo	3	2	1	1	**3**
San Muriel	3	1	2	2	**3**
Valdencina	3	1	1	1	**2**
Los Linos	2	2	2	2	**2**
El Berrocal	2	1	2	2	**2**
Los Palacios	1	3	1	2	**1**
Vista Real	1	2	1	3	**1**
Sierra Bonita	1	2	1	2	**1**

Regarding *Forest Fuel* component, next table shows values for each settlement:

	Near-fuel value	Contact-fuel value	*Forest fuel*
El Ramiro	2	2	**2**
Reajo	1	2	**2**
Vista Real	2	1	**2**
San Muriel	1	1	**1**
Los Linos	1	1	**1**
Valdencina	1	1	**1**
El Berrocal	1	1	**1**
Los Palacios	1	1	**1**
Sierra Bonita	1	1	**1**

Finally, *Topography* component values are the followings:

	Topography
El Ramiro	**2**
Reajo	**2**
Vista Real	**1**
San Muriel	**1**
Los Linos	**2**
Valdencina	**1**
El Berrocal	**1**
Los Palacios	**2**
Sierra Bonita	**1**

As it has been explain above, first step for final integration involved *Forest fuel* and *Topography* components:

	Forest fuel	*Topography*	Fuel (Topography)
El Ramiro	2	2	**3**
Reajo el Roble	2	2	**3**
Vista Real	2	2	**3**
San Muriel	1	1	**1**
Los Linos	1	2	**2**
Valdencina	1	1	**1**
El Berrocal	1	1	**1**
Los Palacios	1	1	**1**
Sierra Bonita	1	1	**1**

Finally, last integration included *Type of settlement* and Fuel (Topography). It was carried out as follows:

	Type of settlement	Fuel (Topography)	**FINAL VALUE**
El Ramiro	4	5	**3**
Reajo el Roble	3	4	**3**
Vista Real	1	2	**2**
San Muriel	3	1	**1**
Los Linos	2	3	**2**
Valdencina	2	2	**1**
El Berrocal	2	2	**1**
Los Palacios	1	1	**1**
Sierra Bonita	1	1	**1**

As it is shown above, final risk value is ranked between 1 an 3. A final risk value of 3 would mean the highest risk, whereas value 1 would mean the lowest one. Regarding Spanish area, some settlements were assigned to high risk levels (Ramiro), while others were classified as low risk ones (Sierra Bonita). Nevertheless, the predominant risk value was 1, 50% of settlement were classify as low dangerous.

Conclusion

A methodology for classify Wildland Urban Interface units according to its fire risk level has been performed. The procedure developed has been applied to a Spanish area, obtaining 3 different risk levels. This paper has been taken as a starting point of a method that it should be applied to other European Mediterranean situations in WARM project context. During this European validation other conditions might be found. Therefore, the number of risk levels and components are expected to increase or change in future.

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