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Short communication. Characterization of wildland-urban interfaces for fire prevention in the province of Valencia (Spain)

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Abstract

Aim of study: The present study is the first attempt to characterize and map wildland-urban interfaces (WUIs) in eastern Spain (province of Valencia) and its relationship with wildfire occurrence.

Area of study: The study area is located in eastern Spain in the province of Valencia. The area covers 246,426 ha and includes four administrative departments comprising 86 municipalities.

Material and methods: The methodology integrates housing density and vegetation aggregation for large-scale fire prevention using the WUImap® ARC GIS tool. A PLS model was developed to relate wildfire occurrence and WUI typologies.

Main results: The results show that 21% of housing can be considered as WUIs, highlighting the high degree of fire hazard in the study area. The PLS model shows that the 4 typologies outside of WUI present lower significance than most of WUI typologies. The types of WUI most related to fire occurrence (*Number of Fires* and *Area Burned*) are *Insolated* and *Scattered* housing with *Low* or *High vegetation aggregation*. The type *Insolated housing with low aggregation* presents the highest significance to explain wildfire occurrence.

Research highlights: A significant relationship between wildfire occurrence in the study area and WUI has been demonstrated. The obtained results verify the ability of *WUImap* tool in classifying large-scale administrative departments and its suitability for application to prioritize preventive actions in the Mediterranean areas.

Key words: housing density; PLS (Partial Least Squares) model; vegetation aggregation; WUImap.

Introduction

The transitional areas that lie between wildlands and urbanized spaces, generally defined as wildland–urban interfaces (WUI), represent an increasing risk factor in Mediterranean areas; these define a new scenario in forest fire fighting and prevention (Galiana *et al.*, 2011). New conflicts arise and environmental management of these areas is affected as a result of the changes occurring in the landscapes including fragmentation of habitats, the introduction of exotic species, and water supply difficulties (Radeloff *et al.*, 2005). The abandonment of rural areas in some Mediterranean regions increases the WUI problem because large areas of agricultural land, pasture and agroforestry systems are being replaced with forest and shrub vegetation (Ortega *et al.*, 2011), thus generating greater wildfire hazard and vulnerability in WUI areas (Lampin-Maillet *et al.*, 2010b). The demarcation of potentially hazardous areas with a high fire risk is essential for attaining special legal status, and WUIs require special attention because specific preventive measures may be needed (Montiel and Herrero, 2010). In addition, characterization of WUI could improve some important aspects of fire prevention (Lampin-Maillet *et al.*, 2010b): (1) Mapping WUIs is the first step in generating risk and vulnerability maps; (2) Characterizing WUI types helps to determine priority areas, which improves the cost-benefit relation for fire prevention measures, firefighting and evacuation plans; (3) WUI maps could be used as tools to help raise awareness amongst the inhabitants of WUIs about the risk of wildfire and the need for fire prevention measures.

Different definitions of WUI have been proposed: WUIs are defined as the line, area, or zone where

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infrastructure and other human developments meet or intermingle and blend with wildland and forested areas (Radeloff *et al.*, 2005). Thus, wildland-urban interfaces include the edges of large cities and small communities, areas where homes and other structures are intermixed with forests and other types of land use, as well as islands of undeveloped lands within urban areas (Caballero, 2004). These qualitative definitions have been completed with quantitative criteria regarding distance, buffers and vegetation aggregation (Lampin-Maillet *et al.*, 2010a,b).

The best method of decreasing the likelihood of homes being destroyed by fire in wildland-urban interface areas is to decrease the amount of flammable materials in the vicinity of houses (Winter *et al.*, 2002). This is taken into account in some European Mediterranean countries in legislation concerning the removal of shrubs and the reduction of horizontal and vertical continuity of forest stands around buildings and housings. However, in Spain such legislation only exists in some Autonomous Regions and territorial management, town planning and housing are the responsibility of Autonomous Regions and Municipalities. Forest Service is not usually responsible for land-management planning. Moreover, urban planning rarely takes forest fire risk into account. There is some conflict between land owners and the Public Administration as regards who is responsible for maintaining these areas free of vegetation. This conflict has mainly arisen because of the high cost of such maintenance. Moreover, housing development on forest land is often not well planned or uncontrolled, and therefore it is difficult to follow the actions established by law or proposed by authorities (www.firesmart-project.eu).

Technical studies and guidelines regarding forest fire prevention practices are usually carried out at different scales: national, regional or local. Local data is crucial for effective forest fire prevention (Lampin-Maillet *et al.*, 2010b), and local studies will ensure the availability of good quality documentation on fire prevention and the application of known methods to ensure sound fire prevention practices. The Autonomous Region of Valencia is a good example of an area where WUIs have expanded as a result of counter-urbanization and development of second home dynamics (Galiana *et al.*, 2007). The increase in the number of WUIs has exacerbated the structural problem of wildfire in a region with high fire frequency and burned area (Pausas and Fernández-Muñoz, 2012). In this region, WUI preventive actions are focused at the housing level and on the development of preventive infrastructures and evacuation routes and tracks (www.firesmart-project.eu). Nevertheless, landscape and local studies are scarce (Galiana, 2007; Lampin-Maillet *et al.*, 2010b; Herrero *et al.*, 2012), and fire hazard assessment in WUIs requires adequate characterization of WUI at different scales.

The objectives of this study were: (1) Large-scale characterization of WUIs in the province of Valencia (eastern Spain), where previous studies have described an increase in the area of landscapes dominated by WUIs (Galiana *et al.*, 2007) and forest technical staff have detected an increase in the number of fires and emergency events in WUI areas (www.firesmart-project.eu). (2) Assessing relationships between fire occurrence (number of fires and areas affected by wildfires) and the presence or absence of WUI in the study area (3) Evaluating the WUI typologies more related to fire occurrence in order to determine priority areas for wildfire prevention.

Material and methods

Definition of WUI

This study follows the definition of WUI proposed by Lampin-Maillet *et al.* (2010b): (1) WUIs are composed of residential houses that are inhabited permanently, temporarily (2) Houses are located 200 m from forests or shrubland to consider an area where brush-clearing is partially required or spots fires occur, and (3) WUI are delineated by a radius of 100 m around the houses. This distance takes into acount the perimeter where in fuel reduction operations can be imposed on home owners. These distances have been proposed for European countries in the framework of different EU projects (www.eufirelab.org, www.fireparadox. org), but may be changed in local regulations to adapt to specific conditions.

Study area

The study area is located in eastern Spain in the province of Valencia (39° 12’ 53”-39° 50’ 21” N, 0° 11’ 13”-0° 59’ 67” W, Fig. 1). The area covers 246,426 ha and includes four administrative departments (*Fosa de Buñol*, *La Horta*, *El Camp de Turia* and *El Camp de Morvedre)* comprising 86 municipalities. Forestland

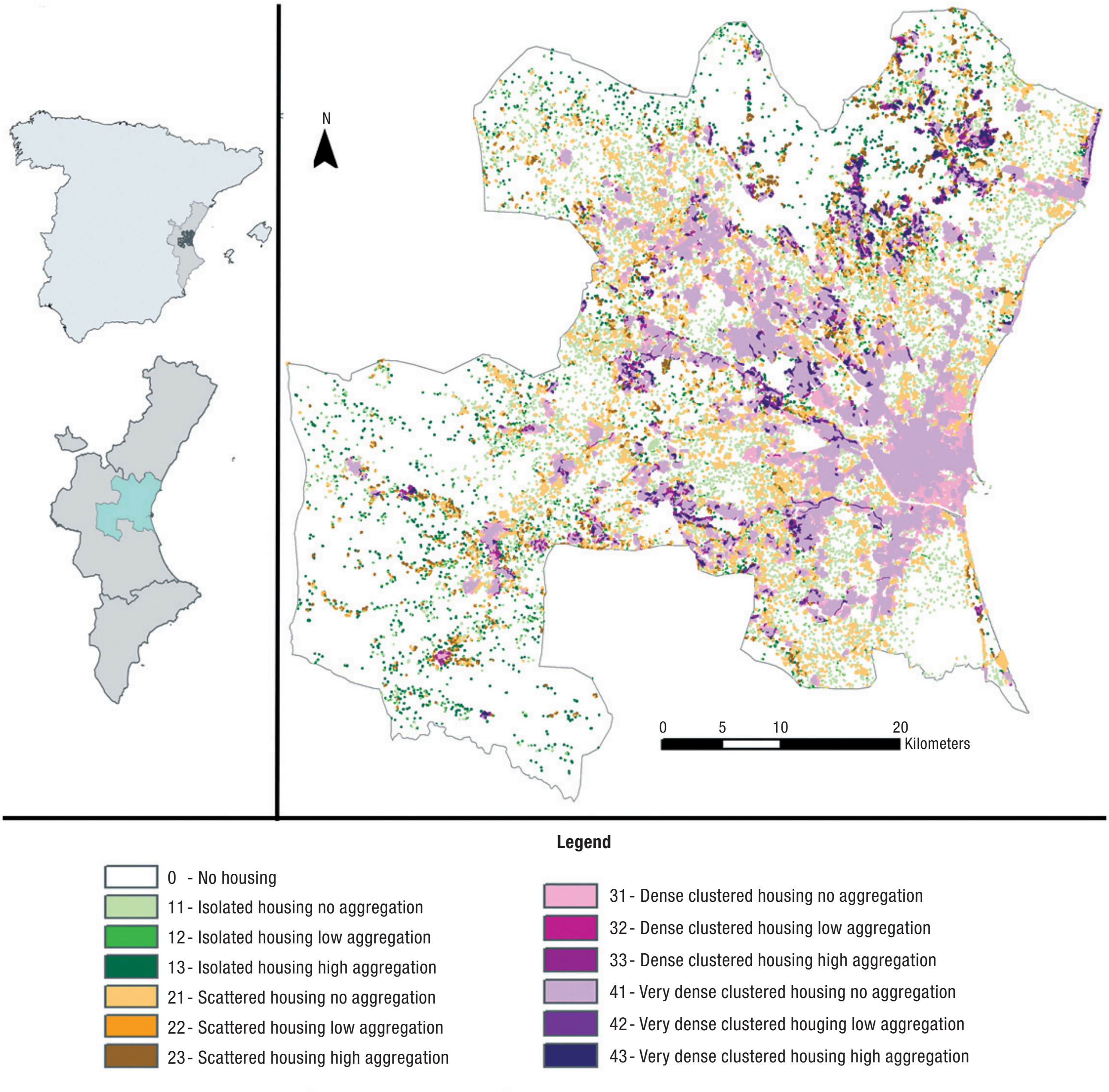

Figure 1. Study area and classification of WUI types using WUImap®. Types 11, 21, 31 and 41 (no aggregation) refer to housing outside the WUI.

(forest and shrubs) represents 44% of this area (109,253 ha), urban areas (including the metropolitan area of the city of Valencia) represent 14% (34,065 ha) and agricultural land represents 34% (83,572 ha). Other types of use prevail in the rest of the area (8%). The study area was selected for the following reasons: (i) it represents a particularly fire-prone area with high wildfire frequency and extensive areas of burned land (Pausas and Fernández-Muñoz, 2012), and (ii) it includes a high level of housing and isolated houses beside forest land (Galiana *et al.*, 2007).

Data

Characterization and mapping of the WUI was based on land cover information extracted from SIOSE map (www.siose.es, National Geographical Institute IGN). This map was generated using different sources of geographical information: Spot 5 multi-spectral 2.5-m pan-sharpened image captured in 2005 complemented by two images from LANDSAT5 TM (2005) and two orthophotos (PNOA 2004 and 2006, 0.5 m spatial resolution, www.ign.es/PNOA/). The conceptual geodata model of the SIOSE map was constructed according to ISO19101 (Geographic Information- Reference Mode). Arc GIS 9.3® was used to analyse the geographical data.

Characterization and mapping fire occurrence was based on BDIF database (Ministry of Agriculture and Environment of Spain). Number of fires and areas affected by wildfires were grouped using the studied municipalities (n = 86) in order to analyze spatial distribution of fires during the period 1985-2010.

Method for mapping WUIs

The WUIs were mapped using the method proposed by Lampin-Maillet *et al.* (2010a) and implemented by WUImap® ARC GIS 9.3 tool (http://fireintuition.efi.int/products/wuimap.fire). This method integrates housing density and vegetation aggregation for fire prevention. The method involves three steps:

(1) The configuration of houses was quantitatively defined and classified into four types of configuration: *isolated, scattered, dense* or *very dense*, according to the method developed by Lampin-Maillet *et al.* (2009).

(2) The vegetation structure was characterized and mapped to emphasize its horizontal continuity, to produce three types of aggregation: *high, low and zero*. In this study, the aggregation metrics were calculated using a spatial resolution of 25 m; a value of *100* was assigned for forest vegetation and a value of *0* for agricultural land and no vegetation, for each pixel of 2.5 m (spatial resolution of the SIOSE map). The output vegetation map was classified as follows: *High aggregation* = forest vegetation; *Low aggregation* = transition forest/agricultural uses; and *Zero aggregation* = without forest vegetation.

(3) The *WUImap tool* maps the intersections between the four types of housing and three types of aggregation, thus characterizing 12 types of WUI.

Statistical analysis: relationship between wildfire occurrence and WUIs

Partial Least Square (PLS) multiple regression model (NIPALS algorithm) was used to explore the correlation between wildfire occurrence (dependent variables: *Number of Fires* and *Area Burned*) and areas occupied by WUI typologies (independent variables: 12 types of WUI) in analyzed municipalities (n = 86). Factors were selected using Q^2 Stone-Geiser statistic and the importance of WUI typology to fit the model was evaluated using VIP statistic (*Variance Importance in Projection*). According to criteria established by Esposito *et al.* (2010), VIP values higher than 0.8 for independent variables (WUIs) are considered as the most significant to fit the model and to explain dependent variables (Number of fires and Area burned).

Results and discussion

The WUI characterization in the study area is shown in Fig. 1. The intersections between urban and vegetation types generated by the *WUImap tool* characterized 12 typologies (96366 ha, 39% of total area) in the study area (Fig. 1). More than 21% of areas involving urban land use are in contact with forest vegetation (8 types of WUI and 4 types outside of WUI). Classification of urban areas is consistent with orthophotographs, and the house density was correctly classified. The aggregation method also showed good agreement with orthophotographs and the SIOSE map, and it correctly detected differences between forest land (*High aggregation*) and mixed land use (*Low aggregation*). A gradient of WUI from the coast (East) to the mountains (West) was observed (Fig. 1). The expansion of counter-urbanization from the city of Valencia in recent years has generated an increase in WUI zones associated with a high fire hazard (Galiana *et al.*, 2007). This process, which has also been observed in other countries, generates high fire hazard and ecological, goods and human losses (Radeloff *et al.*, 2005).

The analysis of BDIF database for studied municipalities (n = 86) during 1985-2010 period (Fig. 2) shows a high number of fires and areas affected by wildfires (Pausas and Fernández-Muñoz, 2012). Data from WUI map (Fig. 1) and Fire occurrence map (Fig. 2) were related using a PLS regression model ($R^2Y = 0.57$, $R^2X = 0.80$, 2 Components, Q^2 Stone-Geiser = 0.34). Results (Fig. 3) shows that the 4 typologies outside of WUI (11, 21, 31, 41) present low significance (VIP < 0.8) and lower values of VIP than most of WUI typologies. The types of WUI most related to fire occurrence (*Number of Fires* and *Area Burned*) are *Insolated*

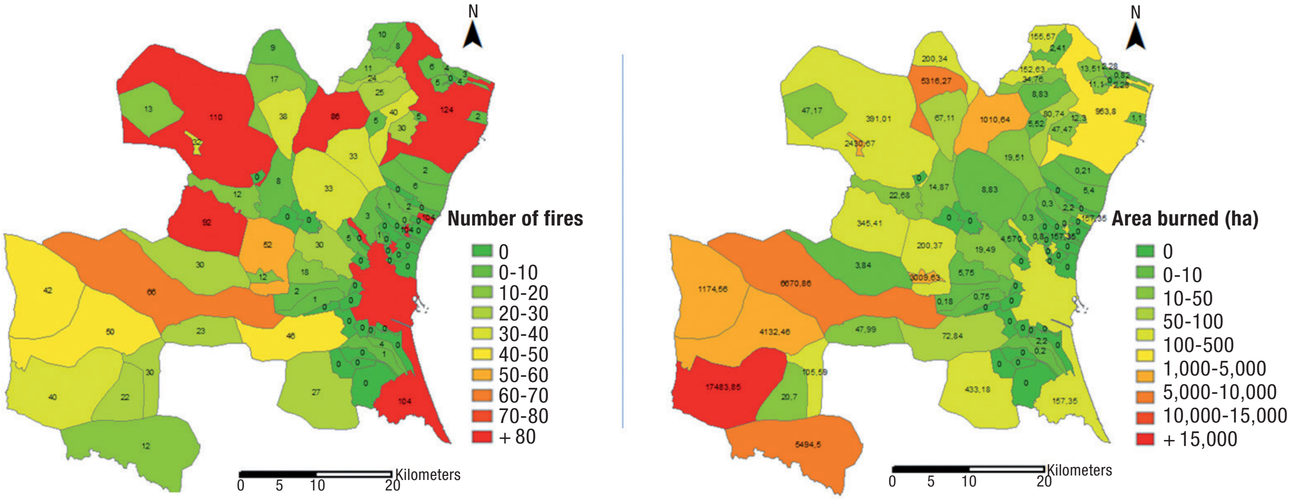

Figure 2. Fire occurrence map (*Number of Fires* and *Area Burned*) in studied area (period 1985-2010) grouped by municipalities (n = 86).

and *Scattered* housing with *Low* or *High vegetation aggregation* (types 12, 13, 22, 23 and 32, Fig. 1 and Fig. 3). The type 12 (*Insolated housing with low aggregation*) presents the highest VIP (Fig. 3) corresponding to mixed agrarian uses (agriculture, pastures, agroforestry and forest systems) in contact with insolated houses. Results agree well with detected spatial pattern of vulnerability to wildfires at the forest agriculture interface in Spain (Ortega *et al.*, 2012). Therefore these areas must be prioritized to develop fire prevention measures in order to minimize the two assessed problems: (1) High level of wildfire risk according to fire regime in the area (Fig. 2) and (2) High vulnerability of insolated and scattered houses in contact with forest vegetation (Fig. 1 and Fig. 3). Results confirm the serious risk of wildfire detected in study area in relation to WUIs (Galiana *et al.*, 2007; Herrero, 2012). The obtained results verify the ability of *WUImap* tool in classifying large-scale administrative departments (Lampin-Maillet *et al.*, 2010a) and its suitability for application to prioritize preventive action in Mediterranean areas.

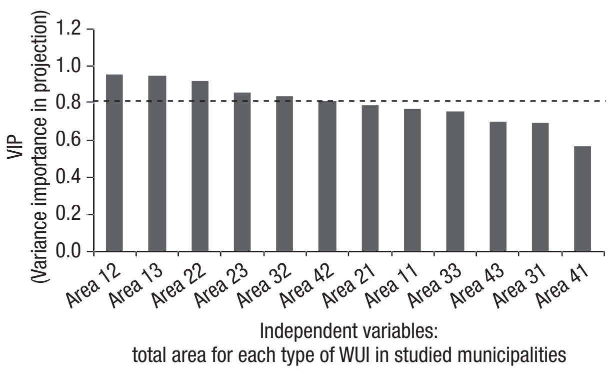

Figure 3. VIP values (Variance importance in projection) for PLS developed model ($R^2Y = 0.57$, 2 Components, n = 86) are shown. Types of WUI above dot line (VIP = 0.8) are the most significant areas correlated to the number of fires and area burned (dependent variables).

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