Fire Spread and the Wildland Urban Interface Problem

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Abstract

Forest fires in the wildland-urban interface are common in Europe, as population and human infrastructure facilities are disseminated throughout the forested zones, especially in the vicinity of large cities and tourist resorts. Within the European forest fire research project SPREAD, we address this particular risk situation together with fire spread characteristics. One of the goals is to identify exposed or vulnerable wildland-urban interface areas, produce fire risk maps and analyse fire spread phenomena that can create situations of risk for houses and structures. The present study investigates some real cases that occurred in Portugal. Furthermore it analyses the fire occurrence pattern in the wildland-urban interface of two fire prone areas in southeastern Switzerland (Ticino and Grison) and their characteristic settlement structures, as well as land use practices, and relates it to rural planning principles.

Introduction

The wildland-urban interface (WUI) can be considered to be a zone where the probability of fire occurrence (ignition and propagation) is by definition higher than in other zones such as plain rural zones or remote areas of poor accessibility. In the wildland-urban interface, are accumulated factors favouring fire ignition and propagation e.g. uncontrolled settlement processes reach into forest and/or brush zones, often resulting in settlement structures that are closely intertwined with patches that are rich in fuels. Equally important for assessing fire risk in the WUI are the building materials that are used. Flammable materials, such as wood products may considerably favour the spread of a fire through the wildland-urban interface, once a fire has started, whereas concrete and stony materials help stop fire propagation. Typically, the wildland-urban interface is an area of intense human professional as well as recreational activity. Unintentional and intentional fires are thus frequent. To master this situation, public authorities and professional fire fighting and management organisations need anticipatory planning instruments and decision support tools. Fire risk maps that assess the probability of fire occurrence, potential fire spread and damage potential (possible loss of houses and values) represent important means to this end. Equally important are means that allow the determination of vulnerability of structures in the WUI zone i.e. flammability and fire behaviour ('fire response') of building materials as proposed by the Structure Ignition Assessment Model (SIAM) by Cohen (1995) and Cohen and Saveland (1997). In this paper, a method of assessing fire risk associated to WUI and its application to two areas in Switzerland is presented together with some cases of fires involving WUI that occurred in Portugal during past years.

Analysis of the Wildland Urban Interface (WUI) and Fire Occurrence Patterns

To answer the question of whether fire ignition really clump in the wildland urban interface, land use patterns and potential fire areas are described and analysed along with the spatial pattern of fire ignition points in the Cantons of Ticino and Grison in Switzerland. Based on statistical comparisons of wildland fire ignition points against simulated (randomly distributed) points, extracted from potential fire occurrence areas (vegetated areas), and using the criteria of proximity distances to settlements and roads, we propose a hypothesis to explain the observed differences based on typical landscape structures. In a previous study, Koutsias et al (2002) observed a special spatial patterning of wildland fire ignition points in the canton of Grison, where human-caused fires tended to be found within the altitude ranges that correspond to inhabited and cultivated areas. Finally, we discuss the degree to which different rural planning approaches can influence fire occurrence patterns.

Land Use Patterns and the Derivation of Potential Fire Areas in Grison and Ticino

In the Canton of Grison, out of 7105 square kilometres, 1825 Km2 (i.e 26 %) are covered by forests, 114 Km2 (i.e_1.6%) are the acreage of settlements,, 2218 Km2 (i.e_31%) are agricultural land, while 2982 Km2 (i.e 42%) are covered by rock faces, perennial snow and glaciers, which represent the so- called unproductive land. Comparatively, in the Canton of Ticino, out of 2812 square kilometres, 1346 Km2 (i.e_48 %) are covered by forests (highest forest density in Switzerland), 128 Km2 (i.e_4.5%) are the acreage of settlements, 449 Km2 (i.e_16%) are agricultural land, while 891 Km2 (i.e_32%) are covered by unproductive land (Table 1).

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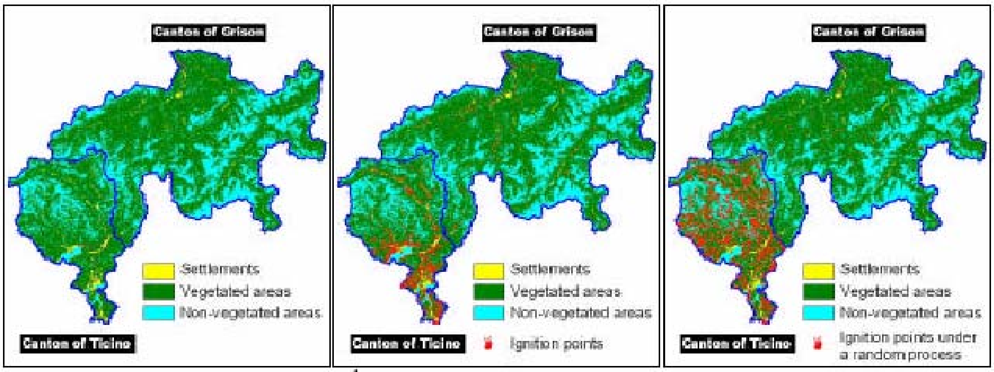
Table 1. Characteristics of the Swiss study areas (source: www.statistik.admin.ch/)

	Canton of Grison (GR)	Canton of Ticino (TI)
Total surface	7105 km^2	2812 km^2
Forests	1825 km^2 – 83% conifer species (mainly *Picea abies*) – 17% deciduous species (mainly *Fagus*)	1436 km^2 – 75 % deciduous forests (mainly *Castanea sativa* and Fagus – 25 % conifer species
Agriculture	2218 km^2	449 km^2
Settlements	114 km^2	128 km^2
Unproductive(*)	2982 km^2	891 km^2
Altitudes	250 – 4000 m.a.s.l.	200 – 3000 m.a.s.l.
Population	185,700	311,900
Density	26 persons/ km^2	111 persons/km^2
Main income	tourism (32%), public services (20%), construction industry (13%), industry (12%), …	tourism (24%), industry (19%), public services (18%), construction industry (9%), banking (7%), …
Main fire season	March, April (mainly human-caused fires, in total 75%) June – August (mainly natural fires, in total 25 %)	February, March (Winter fires) Mainly human fires (97%)

*) 'Unproductive land': Non-vegetated areas, rock faces, gravel, perennial snow and glaciers

In both Cantons, the schematic reclassification of the above scheme, using the criterion of potential (vegetated areas) and non-potential (non-vegetated land) areas 'hosting' a fire, is depicted in Figure 1. The classification category 'settlements' is preserved as a separate class in this reclassification scheme. Proximity distances to settlements and roads of wildland fire ignition points, as well as of the simulated random points, established inside the fire potential areas, were estimated for both Cantons. The hypothesis is that once fire ignition points clump in the WUI, and then their proximity distances should be different from those of random points. Under a random process there are no driving mechanisms to favour fire occurrence around specific spatial entities. Wildland fire ignition points as well as the simulated points under a random process are depicted in Figure 1.



a. b. c.

Figure 1. a. Reclassification of the land cover types to define potential and non-potential areas of hosting a fire, b. wildland fire ignition points extracted from the historical fire database, and c. points established under a random process inside the fire-potential areas.

Spatial Patterns of Fire Occurrence

Proximity distances to settlements and roads have been estimated to characterize the spatial arrangement of human-caused wildland fire ignition points and compare it with that of random points. Besides the mean and maximum values (Table 2) data histogram plots (Figure 2) have also been estimated for exploring the spatial pattern of wildland fire ignition points.

Table 2. Proximity distances to settlements and roads of fire ignition points and of points established under a random process inside "fire-potential" areas. Human-caused wildland fire events are distinguished into arson and negligence.

	Canton of Ticino		Canton of Grison	
	Settlements	Roads	Settlements	Roads
	Random Points			
mean	1148.38	140.88	1879.756	167.2708
max	5921.62	1162.16	7972.33	950.33
	All human-caused fires			
mean	379.5147	28.84667	820.2369	73.06363
max	3776.32	697.32	5257.44	807.77
	Arson			
mean	328.1818	24.16551	585.2383	42.68833
max	2288.7	285.04	1453.44	145.77
	Negligence			
mean	359.6667	26.16476	838.1247	72.76914
max	2712.59	309.23	5257.44	807.77

The statistical and graphical comparison of the data histogram plots reveals the following differences in the spatial pattern of fire occurrence:

- The mean proximity distance to settlements of the points established under a random process inside the fire potential areas (all vegetated areas that may host an ignition point) is 1148 m and 1879 m for Ticino and Grison respectively. In comparison, the mean proximity distance of all human- caused fires drops to 379 m and 820 m for Ticino and Grison respectively. This is clear evidence that human-caused fires accumulate near settlements, since the proximity distances are much smaller than those expected on the basis of chance.
- The mean proximity distance to roads of the randomly distributed points is 140 m and 167 m for Ticino and Grison respectively. In comparison the mean proximity distance of all human- caused fires drops to 28 m and 73 m for Ticino and Grison respectively. This again constitutes evidence that wildland fire ignition points tend to accumulate near roads, since the proximity distances are much smaller than those expected on the basis of chance.
- The above proximity distances to both settlements and roads for the human-caused fires, caused by arsonists, are even smaller. This finding may be explained by taking into account the behaviour of people who set fires on purpose; usually they prefer closer distances to roads so as to have better accessibility and escape quickly and easily.
- The proximity distances of the ignition points to both settlements and roads are smaller for Ticino compared with Grison. This may be explained by the fact that the spatial distributions of vegetated areas and settlements are different in these two regions. In Ticino, forests and settlements mix more compared with Grison. This creates more favourable conditions for starting a fire nearby due to higher probability.

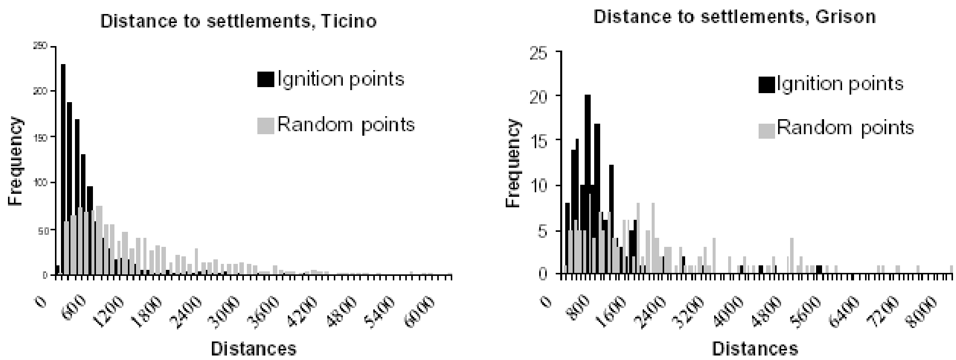


Figure 2. Data histogram plots of proximity distances to settlements in the Cantons of Ticino and Grison. The black histogram corresponds to human-caused wildland fire ignition points, while the grey histogram corresponds to random points established inside the fire-potential areas.

Settlement and Landscape Structures in Relation to Land Use Planning in the Cantons of Grison and Ticino

Land use planning in Switzerland is strictly settled by Federal legislation. In 1979 the Federal land use planning law (Bundesgesetz über die Raumplanung (RPG) vom 22. Juni 1979) was established for the whole of Switzerland, implementing a very clear differentiation between building and non- building zone s ever since. Building zones mainly contain settlements and industrial zones, whereas non- building zones comprise forested and agricultural zones, as well as protection zones. This has led to a fairly clear separation between settlements, industrial, agricultural as well as forested lands. The practical implementation of this federal land use planning law is left in the hands of the twenty-six (26) cantons of Switzerland. Every canton has its own cantonal legislation(1,2) that may vary in details. This is especially obvious for the Canton of Grison and the Canton of Ticino. Whereas the Canton of Grison clearly differentiates between settlement structures, agricultural land and forests (Figure 3), the Canton of Ticino shows a more intertwined structure (Figure 4) for forests and settlements. As has been shown in Table 2, the proximity of fires to settlements is clearly higher in Ticino than in Grison.

Being one of the most forested cantons in Switzerland, it is difficult to establish an equally strict separation of the categories of settlements and forests. Figure 5 shows a typical rural utilisation plan (Zonenplan, Nutzungsplan) for the community of Malans in the Canton of Grison. Malans is situated in the Rhine valley where strong and very dry foehn winds may occur. However, taking the spatial arrangement into account it is very hard to imagine that a wildland fire would be carried into the settlements. When looking at Figure 4b, however, it is not hard to imagine, that this typical Ticino rustico house could be affected by a winter surface fire. To its advantage, it is built out of a stony material, which definitely does not favour fire ignition and thus matches the requirements of the SIAM Model by Cohen (1995), whose essence is quoted here: “The WUI fire problem can be examined on the premise that structure survival is the essence of the problem, and that structure ignition is the critical element for survival: homes that do not ignite do not burn. SIAM addresses the potential for structure ignitions rather than the potential for structure survival.”

1 Grison: Raumplanungsgesetz für den Kanton Graubünden vom 1. Januar 1988
2 Ticino: Legge di Applicazione della Legge Federale sulla Pianificazione delö Territorio (LALPT, 23 maggio 1990)

Figure 3 Typical settlement structures in Grison

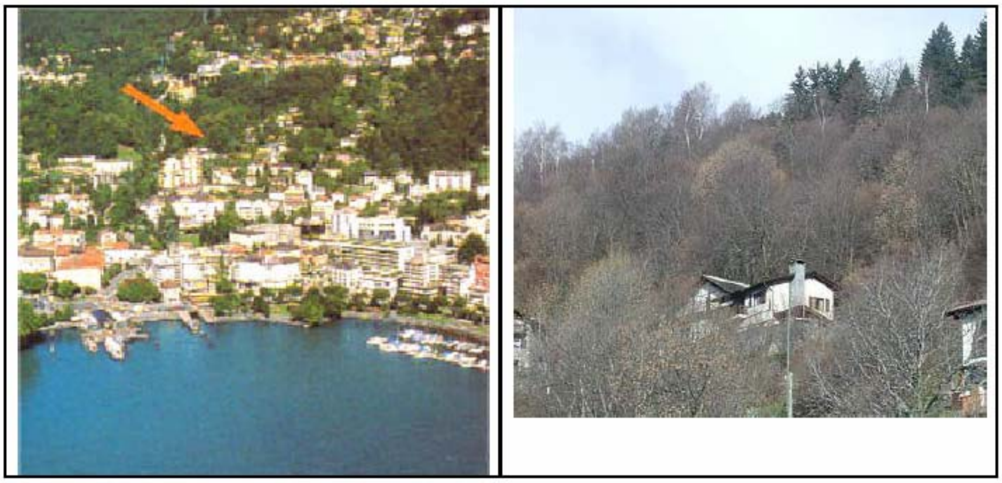


Figure 4 a and b : Typical settlement structures in Ticino

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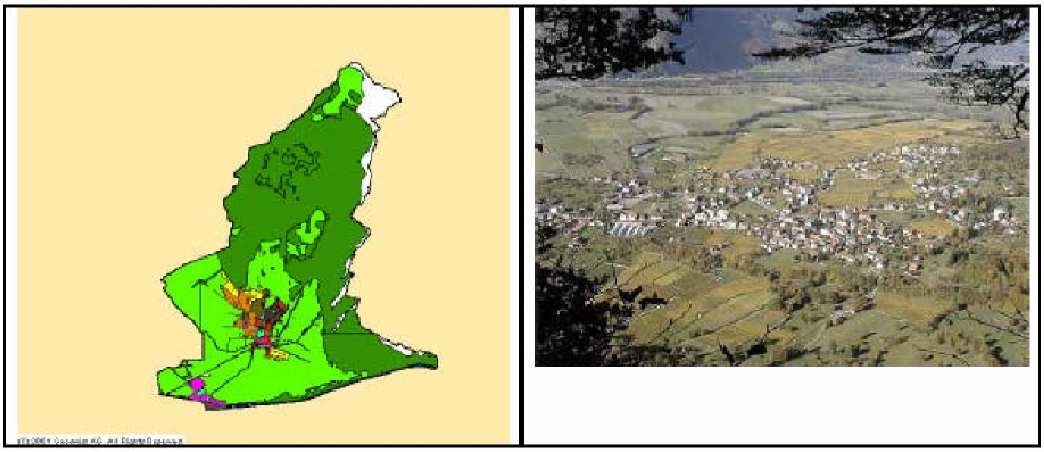

Figure 5 a and b: Land use plan and view of the community of Malans. The building areas are the red and yellow zones that represent the settlement, the light green is the agricultural area and the dark green zone represents the forested area. All zones together cover the total surface of the community of Malans.

Some Cases of Fires in WUI in Portugal

In Portugal, houses and dwellings are intermixed with the forest practically throughout the entire country; therefore the problem of fires in the WUI is very common and important in many aspects. In spite of the dangers associated with having a house in the middle of a forest, people enjoy having such. In the rural areas, houses are used as first residences and they may exist either in association with small villages or disseminated as isolated dwellings in the middle of agricultural or even forested areas. Some houses are used as a second residence and are occupied only during some periods of the year. If these periods of occupation coincide with the summer season – as is quite usual – protection against fires is better than when these houses are empty. In spite of the fact that the construction materials (brick, stone and ceramic roof tiles) are generally quite resistant to fire, every year many houses and structures are burnt by forest fires.

In many cases, industrial buildings or other structures related to agricultural activity are also mingled with the forest. The presence of dangerous materials is not uncommon in these situations, creating an even bigger concern to fire fighters.

The generalised abandonment of rural areas and agricultural activities created an extensive fire hazard even for houses that were once well protected against fire impact. Quite often, fire fighters are tied to protecting one or two houses and have to leave the main fire spreading freely. This is due to the fact that in many cases, people live in those houses and their lives and property are a major social concern for all. In the case of industrial buildings the labour places involved great additional pressure for fire fighters that sometimes risk their lives to save them. The characterization of this problem in Portugal is being made by the application of methodologies like the one that was presented above for the Swiss cantons. In order to gather more information about the impact of fire on houses and structures, a systematic study of past fires involving WUI problems or incidents is being carried out. Some cases are presented here as an illustration of the wide range of situations that can be found and to promote a reflection on the methods for approaching and dealing with them. Arganil (1987)

This was a very large fire, which occurred in September 1987 burning 12000 Ha and it is still the largest fire recorded in Portugal. This fire was studied in detail by Viegas *et al*. (1988). It occurred in a mountain area in the District of Coimbra in extreme fire danger conditions. During its very rapid spread at night it endangered many settlements in the middle of the forest. Given the difficulty fire fighters had of reaching these small villages they were left without protection from the outside. Fortunately, these villages were protected by a belt of agricultural fields that were cultivated by the few residents that lived in them. Mainly for this reason, the damages were not as large as they could have been. Even so, two persons lost their lives during the fire and some houses were destroyed. It was reported that in some villages the residents set counter-fires to protect themselves against the oncoming fire fronts. This action certainly aggravated the overall fire spread, but its effect has not been yet evaluated.

Figure 6: View of the settlement of Enxudro (Arganil) after the fire of 1987. The agricultural fields acted as a shield to protect the houses and their inhabitants.

Fire of Malveira/Guincho (2000)

This fire, which occurred in August 2000, started near Malveira (District of Lisbon) due to an accident relating with field cooking. It spread very rapidly endangering many houses, some of them of great material value. This fire caused a great impact due to its proximity to Lisbon and to the importance of the owners of some of the houses that were threatened.

It was verified that people wanted to have birds singing at their windows, but did not care to have their houses protected and their surroundings cleaned, in order to make them defensible. Trémoa (Miranda do Corvo 2001)

Figure 7: One of the many houses that were destroyed during the quick fire advance at Malveira/Guincho in 2000.

In the following case, which occurred in September 2001 a fire of 114Ha endangered the small village of Póvoa. This case is relevant for the following fact: two fire trucks that were trying to protect the village were burnt due to difficulties with the terrain and the quick advance of the fire. Fortunately, there were no human losses.

Figure 8: Aerial view of the village of Póvoa that was threatened by a forest fire. The site where two fire trucks were burned-over is indicated in the figure. The main fire was coming from the top to the bottom of the photo.

Conclusions

Fires in the interface create particular problems for fire fighters and the Civil Protection authorities. Rural planning should take into consideration fire risk in the deployment of houses and structures inside or near the forest. Pressure from the politicians, the public and the media when facing this problem may create a great burden for decision makers and lead fire spread in the forest itself, with all its consequences, to second place. Methods of assessing fire risk and the analysis of study cases contribute to a better understanding of this problem and will certainly help solve it.

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