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Increases in fire risk due to warmer summer temperatures and wildland urban interface changes do not necessarily lead to more fires

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ABSTRACT

Forest fire frequency in Mediterranean countries is expected to increase with land cover and climate changes as temperatures rise and rainfall patterns are altered. Although the cause of many Mediterranean fires remains poorly defined, most fires are of anthropogenic origin and are located in the wildland urban interface (WUI), so fire ignition risk depends on both weather and land cover characteristics. The objectives of this study were to quantify the overall trends in forest fire risk in the WUI of the Alpes-Maritimes department in SE France over a period of almost 50 years (about 1960–2009) and relate these to changes in land cover and temperature changes. Land cover for two contrasting reference catchments (236 km^2 and 289 km^2, respectively) was mapped from available aerial photographs. Changes in fire risk over time were estimated using statistical relationships defined for each type of WUI, where isolated and scattered housing present a greater risk than dense and very dense housing. Summer monthly temperatures and spring and summer precipitation were quantified over the same temporal period as land cover. Finally, trends in fire frequency and burned area were analyzed over a shorter 37 year period (1973–2009) due to the lack of available fire data before 1973. Fire risk associated with WUI expansion increased by about 18%–80% over the 1960–2009 period (depending on the catchment). Similarly, mean summer minimum and maximum monthly temperatures increased by 1.8 °C and 1.4 °C, respectively, over the same period. Summer rainfall appears to decrease over time since about the 1970's but remains highly variable. Land cover and weather changes both suggest an overall increase in fire risk. However, the number of fires and burned area have decreased significantly since about 1990. This paradoxical result is due to a change in fire-fighting strategy which reinforced the systematic extinction of fires in their early stages. Technical support in the form of improved radio communication and helicopters contributed greatly to reducing fire frequency and burned area. Surveillance and legal reforms included the introduction of field patrols and restricted access to forests during high risk periods. Although this has proven highly successful in the short term, the risk of fuel load accumulation over time remains a risk which might contribute to the development of mega-fires in extreme climatic conditions in the future.

Introduction

Each year, forest fires in Euro-Mediterranean countries burn hundreds of thousands of hectares (Martinez, Vega-Garcia, & Chuvieco, 2009). These fires cause or contribute to human deaths, severe property damage, and increased risks in soil erosion, runoff and downstream flooding. Repetitive fires may also contribute to soil degradation and biodiversity loss. Of the 30,000 to 60,000 fires that occur annually, it is estimated that more than 90% are of human origin (Martinez et al. 2009; Oliveira, Oehler, San-Miguel-Ayanz, Camia, & Pereira, 2012; San-Miguel-Ayanz, Moreno, & Camia, 2013). These ignitions are related to arson and a wide range of accidental causes which vary from one region to another. Factors such as land abandonment, socio-economic transformations in rural areas, persistence of fire producing traditional activities, negligence, landscape structure, land cover, population density, forest policy, greater recreational use of forests, and other human related factors all contribute to the frequency, size and spatial

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distribution of fires (Badia, Serra, & Modugno, 2011; Catry, Rego, Bação, & Moreira, 2009; Ganteaume & Jappiot, 2013; Martinez et al., 2009). Most authors agree that the wildland urban interface (WUI) plays a critical role in Euro Mediterranean forest fires (Catry et al., 2009; Chas-Amil, Touza, & García-Martínez, 2013; Lampin-Maillet et al., 2010), and there are fears that fire frequency and burned area will increase in the future as the WUI expands.

The WUI corresponds to the zone where housing and natural vegetation share a common space (Theobald & Romme, 2007). Although WUI categories vary from one author to another, they can include such variables as population density, housing density, number of houses, and neighborhood characteristics (Stewart, Radeloff, Hammer, & Hawbaker, 2007), and a combination of some form of housing density and vegetation continuity is frequently used to define categories (Bar-Massada, Stewart, Hammerc, Mockrin, & Radeloff, 2013; Chas-Amil et al., 2013; Lampin-Maillet et al., 2010). Due to the wide range in fire causes and vegetation characteristics, relationships between WUI categories and fire frequency or burned area tend to be site specific, where accidental causes and arson related fires can vary greatly from one area to another (Chas-Amil et al., 2013; Lampin-Maillet et al., 2010; Pezzatti, Zumbrunnen, Bürgi, Ambrosetti, & Conedera, 2013; Syphard et al., 2007). WUI fire analyses must therefore be site specific, even though the following tendencies are true for much of the Euro Mediterranean area: dense urban areas generally present high opportunities for fire ignition but low vegetation continuity and fire propagation, and as housing density decreases and vegetation continuity increases, there are fewer causes for fire ignition but greater risks of fire propagation. Hence, fire frequency may be greater in higher density areas, but fire size may increase as housing density decreases (Curt, Borgniet, & Bouillon, 2013). Fires in low density pastoral areas are frequently related to agricultural activities, especially traditional burning by shepherds to maintain grass cover, so intentional fire rates can be high (Chas-Amil et al., 2010; Nunes, 2012).

Mediterranean areas continue to attract transient (tourists), temporary (secondary homes) and permanent (including retirees) residents for cultural, environmental, and climatic reasons (Benoit & Comeau, 2005; Serra, Pons, & Sauri, 2008). Migration from other European countries tends to favor Mediterranean areas (Brunetta & Rotondi, 1996), just as aging populations tend to migrate toward coastal zones when possible (Van Eetvelde & Antrop, 2004). In a study of Tavernes in the South of France, Van Eetvelde and Antrop (2004) found that urban expansion was concentrated along the coast, and arable land in foothills was progressively abandoned to the benefit of residential and secondary housing on traditional terraced foothills. These trends can also be observed in the Cannes-Nice area in the Alpes-Maritimes department of SE France, where urban development is concentrated along the coast, but where individual villas with swimming pools inland provide an alternative to seafront property. In addition, Moreira et al. (2011) cite several studies highlighting increased fire hazard as forest and shrub land replace agricultural and pastoral land. Therefore, the WUI behind the dense coastal urban area has evolved considerably over the past decades and is expected to continue to change (Roy, Fox, & Emsellem, 2014). This has had and will continue to have major implications for forest fire risk.

Climatic variables have long been known to affect fire frequency and burned area and the need for operational fire risk indices has led to considerable research on relationships between weather conditions and fire occurrence (Mölders, 2010; Moriondo et al., 2006; Sharples, McRae, Weber, & Gill, 2009). At finer temporal and spatial scales, temperature, rainfall, relative humidity, and wind speed have all proven to be related to fire risk in addition to soil and vegetation water contents (Baeza, De Luis, Raventos, & Escarre, 2002; Holsten, Dominic, Costa, & Kropp, 2013). At greater temporal and spatial scales, rainfall in both fire and off seasons has been proven important. Lower rainfall during fire season increases fire risk, but greater rainfall in the off season can also increase fire risk through increased biomass production (Ganteaume & Jappiot, 2013; Oliveira et al., 2012; Zumbrunnen, Bugmann, Conedera, & Bürgi, 2009). Maximum temperature and relative humidity have also been related to fire occurrence at the European scale (Oliveira et al., 2012). Mega fires are partially driven by extreme weather conditions and can often only be extinguished when conditions improve or when there is no more fuel to burn (Ganteaume & Jappiot, 2013; San-Miguel-Ayaz et al., 2013).

Climate change scenarios predict an increase in temperatures for the Euro-Mediterranean zone, and this might lead to a longer fire season and greater number of days with extreme fire danger, so there is good reason to believe fire hazard will increase significantly with climate change (ESPON, 2013; Moreira et al., 2011; Moriondo et al., 2006; Mouillot, Ratte, Joffre, Mouillot, & Rambal, 2005; Pausas, 2004; Theobald & Romme, 2007).

The objectives of this study are to estimate the land cover and temperature driven forest fire risk trends over a period of about 50 years (about 1960–2009) in the Alpes-Maritimes department in SE France and to compare fire risk to fire frequency and burned area (1973–2009).

Methods

Site description

The Alpes-Maritimes department is located in the extreme SE of France and possesses an extensive Mediterranean coastline and shared border with Italy. Total surface area is about 4300 km^2 and altitudes range from sea level to 3143 m. The coastal area is highly developed and forms an almost continuous narrow band of built area. The highland area is comprised mainly of wildland and more or less remote villages. Between these two extremes is an extensive band of intermingled built and forested area in which most of the WUI is concentrated. Due to the high urban pressure in the lowlands and steep slopes and shallow soils upland, there is virtually no agriculture in the department outside local olive production.

Mapping land cover for the entire department was beyond the scope of this paper, so two representative and contrasting catchments were selected for the study (Fig. 1). These are typical of the two major WUI land cover scenarios in the department: a catchment (Paillon) immediately upstream of a large city (Nice in this case) under intense urban pressure, and a catchment (Loup) subject to construction of individual villas and scattered housing in a more intermediate zone between the coastal area and mountainous hinterland. Neither the Paillon nor the Loup has any significant agricultural activity apart from occasional patches of olive groves, so both catchments can be considered natural or within some form of wildland urban interface. The northern limits of the reference catchments shown in Fig. 1 correspond roughly to the northern limit of much of the potential departmental WUI area, so the reference catchments cover about 20–30% of the departmental WUI area.

The Paillon river flows directly through the center of Nice and the catchment has a surface area of about 236 km^2 when measured just upstream of the main urban area (the densely urbanized part of the catchment was excluded because of its low fire risk). Urban pressure in the Paillon valley is high due to its proximity to Nice and the spatial confinement induced by local topography and the nearby sea, so it has undergone significant land cover change over time. Minimum and maximum altitudes are 0 m and 1495 m, respectively, with mean and median altitudes of 560 m and 528 m,