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Influence of fuel conditions on the occurrence, propagation and duration of wildland fires: A regional approach

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ABSTRACT

Wildfires affect Earth's surface every year. Fuels conditions influence fire occurrence and behavior; therefore, their characterization is important for fire risk studies. We analyzed vegetation conditions influencing fires occurrence, spread and duration in semiarid Argentina using satellite and complementary data. MODIS spectral data and GLC2000 map were the main inputs for this study. We analyzed pre-fire vegetation spectral responses of unburned areas and sites affected by fires of different sizes and durations nearby in space and time. Fire occurrence was more influenced by fuel load in shrublands, agriculture and steppes than in forests, where fuel status was most critical. Differences among burned and unburned sites were achieved in less time in shrublands and agriculture than in the steppes and forests due to fuel thickness, type and degradation state. Vegetation conditions also varied between fire sizes. Smaller fires were preceded by high fuel accumulation. From 300 ha burned fuel conditions were not related with fire spread probably due the influence of another variables. Fire duration was clearly influenced by pre-fire fuel quantity. Based on our results, we concluded that satellite data appears as a valuable tool to study fire occurrence and behavior, and to provide useful data for fire prevention.

1. Introduction

About one million square kilometers of forests, shrublands, grasslands, savannas and steppes are affected by uncontrolled fires worldwide every year (e.g. Goldammer, 2000, Krock, 2002). Although the onset of fires is often unpredictable, their evolution, development and severity is influenced by abiotic (weather, physical barriers or topography) (Bravo et al., 2010, Liu et al., 2014) and biotic factors (fuel moisture content, fuel type and quantity) that have different degrees of predictability (Chuvieco et al., 2003, Pyne et al., 1996). Noticeably, the onset of fires can affect some of these abiotic and biotic factors as it is the case of changes in vegetation cover and growth, opening the possibility for complex feedbacks in their dynamics (Irvine et al., 2007, Knorr et al., 2012).

Fuel characteristics are very important controls of fire behavior. Higher moisture contents and larger fractions of live biomass reduce the spread and intensity of fires (Burgan, 1979, Chuvieco et al., 1999). A large contribution of fine fuels encourages fire occurrence and spread, whereas a thick fuels favor fire duration and intensity (Tanskanen, 2007). Based on this background, the characterization of fuels is an important issue for fire hazard studies (e.g. Pyne et al., 1996). The most accurate way to analyze fuel status and quantity is through field measurements which are expensive and not plausible at large scales. To solve this, indirect estimates based on meteorological variables or satellite data become more appropriate (e.g. Chuvieco et al., 1999). In this sense, remote sensing allows obtaining global and periodic spectral data of earth's surface (Chuvieco and Kasischke, 2007, Justice and Dowty, 1994). In this way it is not only possible to detect wildfires (Chuvieco and Kasischke, 2007) but to assess vegetation conditions before their onset and after their retreat (Chuvieco et al., 2003, Crutzen and Andrade, 1990). Numerous studies of fuel status have been based on spectral information using vegetation or other indices to obtain indirect fire risk data (Bowman, 1989, Chuvieco, 1990, 2000, Hunt and Rock, 1989, Mbow et al., 2004). For instance, fuel moisture content has been the most extended estimator of potential fire occurrence and propagation. This variable is widely used for fire danger assessment (Viegas et al., 1992), and has a clear impact on the rate of fire spread (Nelson, 2001). Several indices like the

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0140-1963/

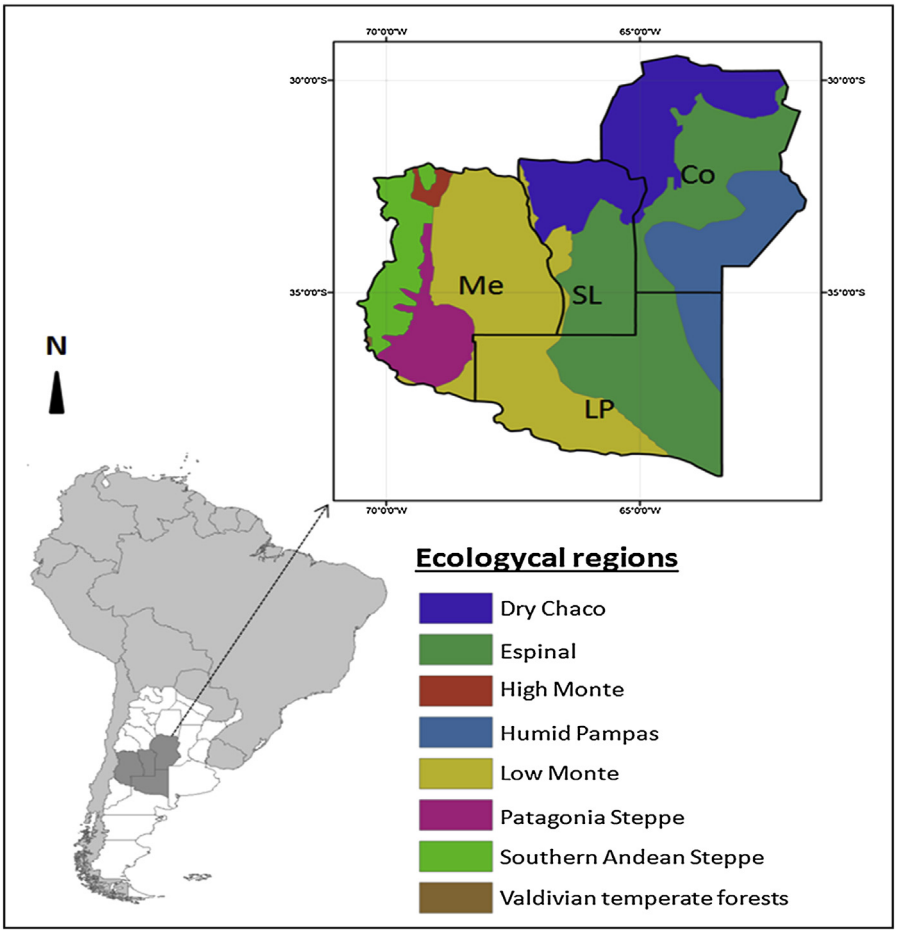

Fig. 1. Location of the study area (dark gray), which includes the provinces of Cordoba (Co), La Pampa (LP), Mendoza (Me), San Luis (SL) and detail ecological regions delimited by Olson et al., 2001.

Normalized Difference Vegetation Index -NDVI- (Rouse et al., 1974), Enhanced Vegetation Index -EVI- (Huete et al., 2002), Normalized Difference Infrared Index -NDII- (Hunt and Rock, 1989), Normalized Difference Water Index -NDWI- (Gao, 1996), among others, show a strong correlations with field measurements of fuel moisture content (Yebra et al., 2007).

In Argentina, wildfires affect a large area every year. From 2000 to 2012, more than 12,000 fires were reported every year, burning 1.3 million hectares on average (PNEF 2000–2012). While the causes of wildfires in this region are commonly unreported (~40%), most of them are attributed to the ignition by humans (~50%) (PNEF 2000–2012). The unpredictability of fires caused by humans as well as limited information on fire occurrence, behavior and environmental factors, hinder their understanding. Although the central semiarid region of Argentina is highly affected by wildfires, fires studies are scarce and field data are poor (e.g. Cabrera and Willink, 1973, Di Bella et al., 2006). Previous studies have focused on analyzing and characterizing fire events and how their spatial distribution is associated with latitude, vegetation types, land use and meteorological conditions (e.g. Di Bella et al., 2011; Fischer et al., 2012). The main objective of this paper is to address the relation between fuel conditions and fire occurrence, size and duration. This information would be relevant to apply adequate management practices to the fire control, prevention and mitigation at a regional scale.

To address our main goal we used a hotspot database to detect fire events location, their occurrence date, size and duration, satellite data of medium spatial resolution, from which we obtained vegetation indices and algorithms evaluating their temporal evolution; and a land cover/land use map. This information allows not only assessing vegetation conditions before fire occurs, but also it allows us to cover large areas with an advantage in data acquisition homogeneity.

2. Materials and methods

2.1. Study area

The study area extends over 530,000 km^2 and covers four provinces in central Argentina: Cordoba, La Pampa, Mendoza and San Luis (Fig. 1). This region is severely affected by fires every year (Fischer et al., 2012). Spatial and temporal distribution of fires is related with a significant rainfall gradient from east to west decisive in land use and land cover types (Fischer et al., 2012). Rainfall varies from 800 to 200 mm in east-west sense per year. In the east there is a significant surface under agriculture with the predominance of extensive crops (*i.e.* soybean, wheat, corn, sunflower). In the center, annual rainfall is lower than in the east, and the area is dominated by: shrublands, grasslands and several forests mainly characterized by xerophytic adaptations (Burkart, 1999, Cabrera and Willink, 1973). The predominant natural vegetation shows the production peak during the spring-summer season (September–March). Husbandry is the main land use. The western area is characterized by water deficits during most of year; hence the use