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Causasilty among wildfire, ENSO, timber harvest, and urban sprawl: The vector autoregression approach

Jianbang Gan *

Department of Forest Science, 2135 TAMU, Texas A&M University, College Station, TX 77843-2135, USA

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Abstract

This article demonstrates the applicability of vector autoregression (VAR) modeling in probing the causality relationships among wildfire, El Niño/Southern Oscillation (ENSO), timber harvest, and urban sprawl in the U.S. The VAR approach allows for the multi-directional, multi-faceted interactions among the variables concerned and enables us to portray the temporal impacts of ENSO, the volume of timber harvested, and urban sprawl on wildfire. The empirical analysis, though intended mainly for illustration, reveals that an individual factor may not affect wildfire activity (number of fires and area burned) when acting alone, but can significantly influence fire activity when coupled with other factors, and that wildfire activity has feedback effects on other variables. The impact of a change in ENSO, the volume of timber harvested, and urban population density on wildfire activity could last two decades with the most noticeable impact occurring in the initial 5–10 years. Though ENSO, timber harvest, and urban sprawl all Granger-cause wildfire activity, the impulse response functions show that wildfire activity is more responsive to urban population density than to the volume of timber harvested or ENSO. Thus, controlling urban sprawl represents another option for wildfire mitigation; and integrative wildfire management is essential.

Keywords: Wildfire activity; Wildfire mitigation; Vector autoregression; Granger causality; Impulse response function

1. Introduction

Fires are intrinsically and naturally coupled with forests. While fires play an important role in the dynamics of forest ecosystems, wildfires can pose severe threats to property, life, and the environment, engendering far-reaching costs and losses to society (Butry et al., 2001). The 122,827 wildfires that burned about 3.4 million ha in the U.S. in 2000 cost the federal government more than $1.36 billion in fire suppression alone (National Interagency Fire Center, 2003), even without accounting for the socioeconomic and environmental damages. Though the central tendency of wildfire activity (annual number of fires and annual area burned) has not dramatically changed over the past 40 years in the U.S. (Fig. 1), there is increasing concern about wildfires in recent years. As a result, efforts to mitigate wildfires,

* Tel.: +1 979 862 4392; fax: +1 979 845 6049.
E-mail address: j-gan@silva.tamu.edu.

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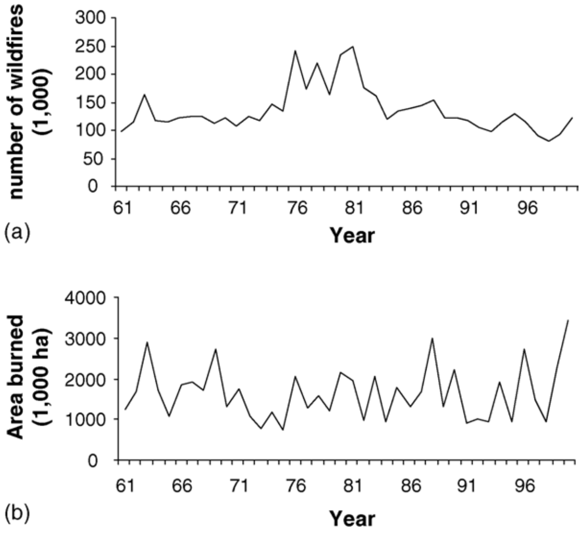

Fig. 1. (a) Annual number of wildfires in the U.S., 1961–2000; (b) annual area burned in the U.S., 1961–2000. (Source: National Interagency Fire Center, 2003).

including fire suppression and development of alternative fire mitigation policy such as the Healthy Forest Restoration Act, have been escalated. Alleviating the detrimental impact of wildfires requires effective fire management and prevention plans, which rely on our knowledge of the factors influencing wildfire activity.

Wildfires have been attributed to many factors, both human and natural causes. One of these factors is weather or climatic events such as El Niño/Southern Oscillation (ENSO). El Niño refers to an extensive warming of the upper ocean in the tropical eastern Pacific; the Southern Oscillation is a widespread interannual oscillation in sea-level pressure between the regions near northern Australia and in the central Pacific. El Niño and the Southern Oscillation are highly related; together they are referred to as ENSO. Though ENSO is mainly a tropical event, it affects global climate through atmospheric teleconnections (Ropelewski and Halpert, 1986; Wang et al., 1999). Climate changes resulting from ENSO events alter vegetation/fuel development and lightning occurrence, affecting wildfire risks. ENSO has been found to be more strongly and consistently correlated with area burned than with the number of fire incidences (Simard et al., 1985), particularly highly correlated with area burned in the U.S. at the regional level while the correlations vary across regions (Swetnam and Betancourt, 1990; Brenner, 1991; Chu et al., 2002). And switching from El Niño to La Niña conditions favors widespread fires (Kitzberger et al., 2001).

Timber harvest may also affect wildfire activity. On the one hand, timber harvest can play a critical role in mitigating forest fires (Dombeck, 2000). Harvest removes biomass/fuels from forestland and causes the fragmentation of fuel distribution, creating barriers to fire spreading. Road construction associated with logging operations can improve fire suppression capacity by creating access to previously isolated areas. On the other hand, logging slash and residues may be more susceptible to fire; machinery operation and human disturbances resulting from harvesting could increase the probability of fire occurrence. Altering forest structure, local microclimate, and fuel accumulation, logging may have a mixed effect on fire activity (Center for Water and Wildland Resources, 1996).

Urban sprawl has potential impacts on wildfires as well. In the U.S. over the past 50 years, urban sprawl has been characterized by low-density, discontinuous, and suburban style development (Brueckner, 2000; Carruthers and Ulfarsson, 2002). From 1960 to 1990, urban population density declined by more than 30% while the urban population increased by almost 50% (US Census Bureau, 1993). This has led to landscape fragmentation (Alig et al., 1999), increased fire suppression efforts (Irwin, 1987), and escalated human interventions with wildland (Plevel, 1997), adding to the complexity of wildfire mitigations (Keeley et al., 1999; Monroe, 2003). Recent studies report that wildfires are more likely to occur in proximity to urban areas (Pew and Larsen, 2001; Zhai et al., 2003), while urbanization has no significant impact on area burned (Prestemon et al., 2002) partially due to the increased fire suppression efforts and land fragmentation.

Other factors have also been linked to wildfires. Studies on fire behavior have identified that fuels, weather, and topography are related to fire spread and intensity (Rothermel, 1972; Rothermel and Philpot, 1973; Anderson, 1982). Forest fire history reveals that anthropogenic changes and the degree of stand/fuel development have an influence on wildfire occurrence (Weisberg and Swanson, 2003). Geographic location (latitude) explains most of the variability of human-caused wildfires in the eastern U.S. (Donoghue and Main, 1985). Past fires (Prestemon et al., 2002) and