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Future climate and fire interactions in the southeastern region of the United States

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ABSTRACT

Fire has a profound, though paradoxical influence on landscapes of the southeastern U.S.; it simultaneously maintains native biodiversity and ecosystem processes but also threatens silvicultural resources and human landscapes. Furthermore, since the majority of the southern landscape is heavily influenced by human activities, contemporary fire regimes are human managed disturbances within extant fire-dependent ecosystems. Though there is considerable uncertainty in climate projections for the southeastern U.S., climate change will likely impact both prescribed fire and wildfire. In this review, we synthesize climate change-fire interactions, discuss the impacts of uncertainty in a human-dominated landscape, and illuminate how both climate change projections and their uncertainties might impact our ability to manage forests in the Southeast. We define the Southeast region as consisting of the Gulf Coastal Plain, Lower Atlantic Coastal Plain, Piedmont and southern Appalachians and associated subregions. This region has the greatest area burned by prescribed fire, the highest number of wildfires in the continental U.S. and contains globally significant hotspots of biodiversity, much of which is dependent on frequent fire. The use of prescribed fire as a management tool depends on a suite of weather and fuel conditions which are affected by climate. Over the next five decades, general circulation models (GCMs) consistently predict air temperature to increase by 1.5–3 °C in the Southeast. Precipitation forecasts are more uncertain with respect to the mean; but, most models predict an increase in precipitation variability. Increases in the likelihood of severe droughts may increase wildfire occurrence while simultaneously limiting the implementation of prescribed burning by restricting the number of days within current prescription guidelines. While the Southeast has among the highest potential for C storage and sequestration, a reduction in C sequestration capacity due to increasing disturbances such as drought, insect infestations, hurricanes and fire, is possible. The potential for long-term shifts in forest composition from climate-altered fire regimes if coupled with an increased potential for wildfire occurrence could reduce quality and quantity of water released from forests at times when demand for high quality water will intensify for human use. Furthermore, any reduction in prescribed burning is likely to result in decreased biological diversity, particularly in the Coastal Plain, a global hotspot of biodiversity. Lastly, more future area burned by wildfire rather than prescribed fire has the potential to negatively influence regional air quality. Mitigating the negative effects of climate change-fire interactions would require actively exploiting favorable seasonal and inter-annual climate windows. Monitoring the type conversions of agricultural and fiber production forest will be critical for long-term projections of fire risk and watershed impacts of altered fire regimes.

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1. Introduction

In the Southeast U.S., fire both sustains many forest types and acts as a serious threat to others. Since the majority of the southern landscape is heavily influenced by human activities, even in natural areas, fire-dependent systems rely on the human application of prescribed fire, and fire-sensitive ecosystems rely on fire suppression. Changes in climate will likely add significant challenges to fire management in the near future by influencing prescribed fires and wildfires. This review synthesizes climate–fire interactions, presents projections for future climate, analyzes uncertainties

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associated with model projections, and sheds light on how those uncertainties might affect our ability to manage forests in the Southeast.

The Southeast encompasses several physiographic regions that have unique climate, vegetative composition, fire histories, fire regimes, and, consequently, current fire management. Overlain onto this complex physiography are future climate scenarios that will likely alter forest composition, species distributions, and associated fire regimes in different ways. We discuss climate–fire interactions in terms of their potential impacts on biodiversity, carbon storage, and water quality and quantity. We also discuss future fire management and potential means to manage forests under these uncertainties.

2. Physiographic region and forest types of the Southeast

We define the Southeast as consisting of the nine Level III Ecoregions shown in Fig. 1 (Omernik, 1987), that are broadly distributed across the Gulf and Lower Atlantic Coastal Plains, Piedmont and southern Appalachians. This area encompasses 96 million hectares, of which 53 million hectares is forested (Fig. 1, Table 1). The landscape is characterized by a complex arrangement of land cover, topography, and ownership. Within the forested land cover, there are extensive plantations of loblolly (*Pinus taeda* L.), longleaf (*Pinus palustris* Mill.) and slash pine (*Pinus elliottii* Engelm. var *elliotti*), and approximately one half of the region is covered in fire-dependent or fire-influenced ecosystems having a diversity of fire regimes (Drummond and Loveland, 2010). The Southeast has the greatest combined number and area of wildland fires in the U.S. (Melvin, 2012, Figs. 2 and 3).

Forest fires occur over a wide range of scales from <10 ha to 250,000+ ha; but, accurate estimates of the area burned annually are difficult to calculate due to the short duration and/or small scale of many prescribed fires that limit detection by remote sensing. Nonetheless, in 2010, there were 522,000 ha of lands managed by state and federal agencies in the Southeast reported to have been burned, though this is a small fraction of the total area burned since federal lands represent less than 8% of the region (National Interagency Coordinating Center, 2010; Melvin, 2012). The Southeast also conducts more prescribed burns than the rest of the country combined, with most of these fires occurring in the Coastal Plain and Piedmont sub-regions (Melvin, 2012). Therefore discussions of climate–fire interactions in the Southeast must include the effects on prescribed fire as well as wildfire.

The majority of the region is covered by ecosystems that tend to burn with low intensity surface fires; though there are notable exceptions (see below). Fires can recur at time scales ranging from annually (e.g., longleaf pine woodlands) to more than a century (e.g., Appalachian mountain coves and swamps); and have differing cascading ecosystem responses depending fire intensity (the amount of energy produced by the fire) and severity (a function of energy release) (Neary et al., 2005). There are four main natural forest types that occur in the region: upland pines; mixed pine and hardwoods; upland hardwoods; and swamps and forested wetlands. The pine forests in the Southeast can be divided into two subtypes that require different fire regimes that are either low intensity surface fires or intense, stand replacement fires. Forests requiring the former are much more prevalent than those requiring the latter. Within the surface fire regimes, frequency, or fire return interval, varies among forest subtypes though all occur over relatively short periods with a maximum interval of 5–10 years. Fire management in the extensive pine plantations of the region ranges from frequent surface fire regimes to the more common management without prescribed fire.

2.1. Piedmont and Coastal Plain forest types

Longleaf pine forests were the once the dominant forest type in the Coastal Plain (≈37 million ha, Frost, 1993) until widespread conversion to pine plantations, agriculture and other land uses occurred in the 20th century. Longleaf woodlands are some of the most frequently burned ecosystems in the world, with the

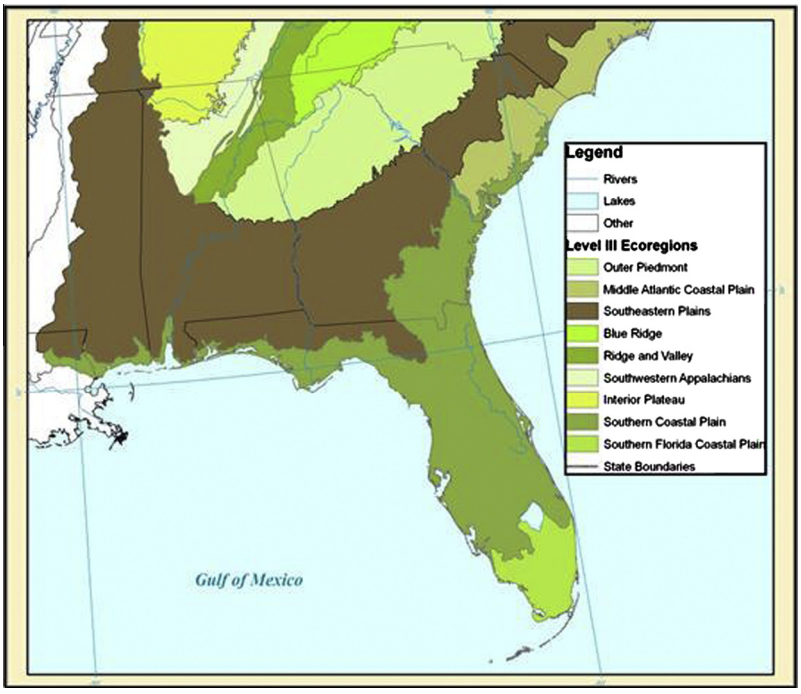

Fig. 1. Ecoregions discussed in the section on the southeastern U.S. (Bailey, 1995, http://www.fs.fed.us/land/ecosysmgmt/).

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