Anticipating Interactions Between Forest Management and Wildfire as Private Forestland Owners Adapt to Climate Change

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Abstract—Climate change will influence wildfire on private forest lands via two pathways: (1) changes in temperatures and precipitation will induce direct changes in wildfire likelihood and severity; and (2) changes in management by forest landowners seeking to adapt to climate change will result in shifts in species composition and harvest timing and intensity, which act as additional indirect influences on wildfire. We examined private forest landowners' management behavior in the context of climate change and wildfire, to anticipate how forest landowners in California, Oregon, and Washington (USA) are likely to adapt to climate change and how their adaptation could influence wildfire in the region. Drawing on fine-scaled panel data describing forest conditions, climate, wildfire, and private forest management, we estimated empirical models characterizing forestland owners harvest and replanting decisions in response to climate and wildfire variables. We used our empirical models to simulate forestland owners' future harvest and replanting decisions, and the likelihood and severity of future wildfires, as private forest landowners shift their management in response to changing climate. Our results suggest that climate change will induce moderate shifts away from Douglas-fir in favor of hardwoods and ponderosa pine, with associated increases in wildfire, particularly in the western Cascades.

Keywords: private forest landowners, climate change adaptation, wildfire

INTRODUCTION

A coupled human and natural systems (CHNS) approach to evaluating private management of fire-prone landscapes proposes a conceptual model in which forest landowners and managers respond to biophysical landscape conditions (e.g., vegetation, fuel conditions) and the existing fire regime via management actions, such as thinning, harvest, and replanting (e.g., Kline et al. 2016, 2017). These management actions alter biophysical characteristics and influence the fire regime that landowners and managers face in subsequent years (fig. 1). Both the human and biophysical systems also are influenced by exogenous factors, such as climate change, while landowners also are influenced by market forces, policies, and other socioeconomic factors.

A key reason for taking a coupled systems approach to wildfire and climate change, when private land is involved, is because human-caused disturbance is the primary source of tree mortality on private forest lands. In Washington, Oregon, and California, for example, harvesting accounts for between 71 and 87 percent of mortality on non-federal land, versus 5 to 16 percent on federal lands. Vegetation growth models typically presume some type of forest disturbance that links current and future landscapes, but these models often do not explicitly model forest management by landowners. As a result, analysts may

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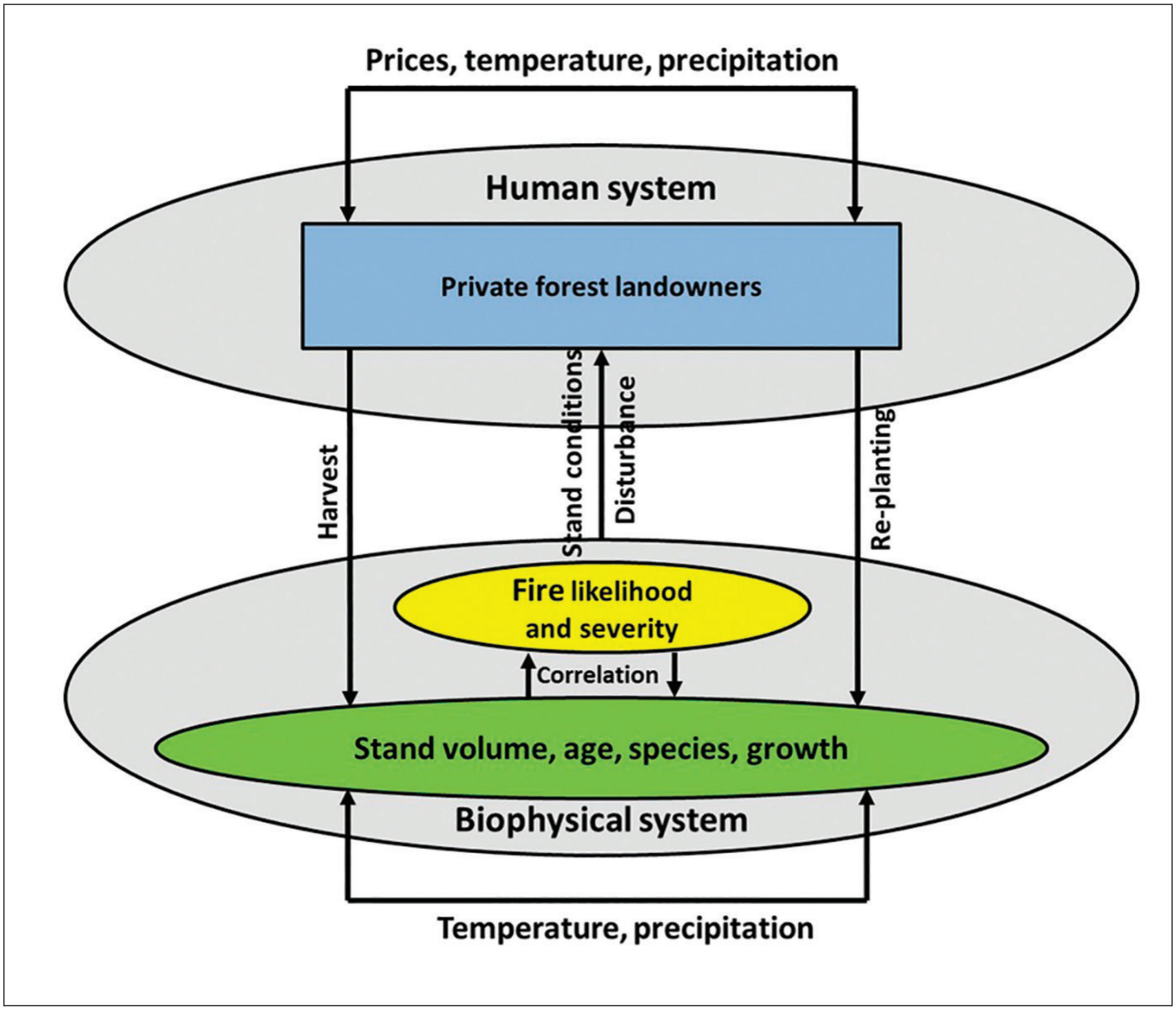

Figure 1—Coupled human and natural systems conceptual model of private forest landowners and their interactions with biophysical landscape features and wildfire, including climate influences (adapted from Kline et al. 2016, 2017).

miss opportunities for understanding the role that various biophysical and socioeconomic factors play in influencing landscape change.

We examined how private landowners might adapt to changing climate and what that would imply for future landscape change. We modeled three processes: (1) the timing and intensity of timber harvests; (2) the choice of tree-species replanted following harvest; and (3) what these landowner behaviors—in reaction to climate change and wildfire risk—could mean for future landscape conditions and disturbance. We also examined the influence of carbon pricing policies to mitigate climate change on these landscape changes.

METHODS

Study Area

Our study area included Washington, Oregon, and California, and our primary data were the Forest Inventory and Analysis (or FIA) data for these States. A key task was anticipating how private forest landowners' adaptation to climate change would influence future spatial distributions of forest species. Current distributions of species include the Douglas-fir forest type largely on the western portions of Washington and Oregon, interspersed with hardwoods, with ponderosa pine and other softwoods prevalent east of the Cascades, and extensive regions of hardwoods in portions of California, for example. Different species thrive in different locations and under different climatic conditions. If landowners are adapting to a changing climate, their post-harvest replanting choices conceivably would be influenced by expectations concerning the viable ranges of different species under those changing climatic conditions. A key difference in species viability is the juxtaposition of Douglas-fir, preferring moist conditions with moderate temperatures, versus hardwoods which tolerate warmer and drier conditions, for example. These differences in viability influence the profitability of growing different species under changing climatic conditions, and thus the choices that landowners are likely to make as they adapt.

Empirical Modeling

We used the historical FIA data to estimate four regression equations in a nested logit framework. One equation evaluated the likelihood that landowners elected to harvest via clear-cut or partial cut, or choose not to cut, between successive FIA inventories. For harvested plots, a second equation evaluated which species (or forest type) landowners chose to replant. For unharvested plots, a third equation evaluated the likelihood that the plot experienced natural disturbance, including wildfire. Lastly, for plots experiencing specifically wildfire, a fourth equation evaluated fire severity. Our analysis was based on the work of Hashida (2017). A complete description of our methods is provided in Hashida and Lewis (2017).

The specific variables that factored into each equation varied. Harvest was modeled as a function of current harvest revenue (prices, species, volume, age), as well as potential future yield—characterized as change in volume according to an expected growth curve, climate variables including expected future temperatures and precipitation, and disturbance likelihood. Similarly, post-harvest replanting was modeled as a function of potential future revenue, characterized by future timber prices, tree growth, site productivity, and expected future temperatures and precipitation. Natural disturbance and fire severity were modeled as functions of species, volume, and future temperatures and precipitation.

Additional data informs the modeled replanting choice set available to landowners who harvest, to account for spatial changes in the viability of different forest species in the future under climate change. We used "plant viability scores" developed by the USDA Forest Service (Crookston et al. 2010), combined with climate projections, to reflect the likelihood that future climate at any given location would be suitable for each species. Projections of future temperatures and precipitation under climate change, combined with plant viability scores, suggest a gradual reduction in the viable growing range of Douglas-fir, and gradual expansion of the viable growing range of ponderosa pine, for example, with shifts in viable ranges for other species as well.

Simulations

Using these estimated equations, we simulated landowners' future harvest and replanting choices under climate change using down-scaled (1 km resolution) climate data for representative concentration pathway (RCP) 8.5 from the National Center for Atmospheric Research's (NCAR), Community Climate System Model (CCSM) (Wang et al. 2012). The RCP-8.5 scenario is a business as usual scenario that anticipates a 5 degree Celsius increase in average global temperature through 2100. This is expected to result in warmer and drier conditions for most of the western portions of Oregon, Washington, and northern California; and warmer and wetter conditions for eastern portions of those States.

Simulation steps involved: (1) estimating harvest as either clear-cut, partial cut, or no cut; then (2) for harvested plots, estimating the replanted species choice; and then (3) in the no-cut cases, estimating the incidence of natural disturbance; and finally (4) in the case of wildfire, estimating fire severity. These outcomes were then used to update forest attributes, which were then combined with climate projections to inform simulation of the next time period. Tree growth models estimated for each forest type enable updating of tree volumes at each simulation step. We repeated the simulation process through 2100. The result of these simulations was a set of predicted outcomes determined by interactions between landowners' harvest and replanting choices, and the biophysical factors of tree growth, climate change, and natural disturbance.

RESULTS

Forest Types and Natural Disturbance

Our simulations anticipate reductions in Douglas-fir on private forest land in the prime coastal Douglas-fir regions of Oregon and Washington, largely due to the warmer and drier conditions anticipated under RCP-8.5. Our simulations also anticipate increases in ponderosa pine for California, and increases in hardwoods for Oregon and Washington. Hardwoods, in particular, are projected to become a prevalent re-planting choice by 2090, largely due to their viability in the warmer temperatures anticipated. This is notable from a profitability standpoint, since hardwoods tend not to earn as much revenue for private forest landowners compared to other forest types, but under current climate projections would appear to offer greater viability in the future. The extent of all of these landscape changes are fairly subtle, even under the fairly pessimistic RCP-8.5 climate scenario. Because harvesting and replanting tend to occur infrequently, we can expect that adaptation could be a fairly slow process.

Our simulations also anticipate changes in natural disturbance. Recalling the warmer and drier conditions expected for coastal Oregon under RCP-8.5, for example, our projections anticipate elevated disturbance incidences throughout much of western Oregon and northeastern California. Changes in both climate and species choices also are expected to induce changes in harvest choices. For example, our simulations anticipate reduced prevalence of clear-cutting in much of Oregon and Washington, and higher prevalence of clear-cutting in northern California.

The spatial distributions of expected forest type changes suggest fairly dramatic declines of Douglas-fir in coastal Oregon and Washington from 10 to 25 percent, with those declines coming in favor of hardwood expansion. Our simulations also anticipate modest hardwood declines in California, with increases in ponderosa pine. These shifts in forest type could include increased natural disturbance, since FIA data indicate that hardwoods tend to have a higher incidence of natural disturbance than Douglas-fir. We would expect that this increased natural disturbance incidence would be exacerbated by the drier conditions expected under climate change.

Carbon Policy Interactions

An advantage of explicitly modeling landowner behavior when anticipating landscape change under climate change is that it enables simultaneously accounting for the influence of socioeconomic and other factors on landscape change. To demonstrate this, we used our model to examine the combined influence of climate change and carbon pricing on landowners' adaptation responses. Carbon pricing is a policy approach to mitigating climate change by providing payments to forest landowners who alter management of their forest lands in ways that store additional carbon above and beyond what would be stored based on their past management.

We found that implementation of carbon pricing would likely induce faster landscape changes in line with those that would occur under climate change alone. Specifically, with carbon pricing we would see even faster declines in Douglas-fir in coastal Oregon and coastal Washington, for example, and more rapid increases in hardwoods. Although carbon uptake for Douglas-fir typically exceeds that of hardwoods, the difference in total carbon absorbed (?) is negligible in young stands. Moreover, hardwoods exceed Douglas-fir in carbon uptake on low site-class plots, enabling landowners to earn greater carbon payments with hardwoods if carbon prices rise sufficiently. These factors cause the revenue premium of Douglas-fir over hardwood to decline as carbon prices rise, adding to the incentive some private forest landowners may have to shift from Douglas-fir to hardwoods under climate change.

CONCLUSIONS

Our empirical analysis of private forest landowners' harvest and replanting choices under climate change suggests that landowners will alter their harvest and replanting choices, resulting in shifts away from Douglas-fir toward hardwoods in Oregon and Washington; and expansion of ponderosa pine in California at the expense of hardwoods there. Resulting landscape changes could effect changes in natural disturbance regimes, including wildfire, beyond those induced by climate change alone. Accounting for the manner in which private landowners are likely to adapt to climate change helps to improve landscape analysis, by enabling additional analyses of the influence of socioeconomic factors, including policy effects. It is important to remember that landowners are always adapting, whether to climate, prices, policies, or some other factor that happens to be changing. When landscapes involve private landowners, we cannot fully understand how and why a landscape might be changing without examining the factors motivating landowners to manage in the ways they do.

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