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Forest cover, carbon sequestration, and wildlife habitat: policy review and modeling of tradeoffs among land-use change scenarios

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ABSTRACT

Local and regional governments have developed climate action plans with significant implications for forests and wildlife. The effectiveness of climate mitigation through forest carbon sequestration depends on understanding the spatial and temporal dynamics of land-cover and land-use change (LCLUC). Few studies project future LCLUC effects on forest carbon sequestration, and even fewer examine the resulting consequences for forest connectivity and wildlife habitat. First, we asked what forest-relevant climate mitigation strategies have been identified in US state climate mitigation plans, and do they consider implications for wildlife habitat and forest connectivity? Second, for Wisconsin, a partially forested state, what are the effects of three future LCLUC scenarios on afforestation, forest loss, carbon sequestration and storage, forest connectivity, and wildlife habitat? The 35 US states with climate mitigation plans recommended woody biomass for biofuels or energy production (27 states), forest loss prevention (24 states), and afforestation (17 states). Most plans (24 states) anticipated positive wildlife impacts while 7 plans indicated potential negative wildlife impacts from biomass energy; only 3 plans anticipated tradeoffs among afforestation and energy production. A LCLUC model for Wisconsin revealed substantial local variation in potential afforestation and forest loss, carbon sequestration, and wildlife habitat across LCLUC scenarios that range from no change in current conditions (Static Forest) to maximum afforestation potential (All Forest). Projected increases in forest cover under the Dynamic Forest scenario equated to 0.41 TgC sequestered per year, or 1.3% of Wisconsin's emissions of 33 TgC per year. Potential increases in core forest area and connectivity would increase habitat for 60 forest-associated species of greatest conservation need, but may decrease habitat for 48 grassland-associated species of greatest conservation need. These results indicate the importance of synergistic evaluation of multiple policy goals and LCLUC scenarios to examine tradeoffs and spatial dynamics of climate change mitigation strategies.

1. Introduction

Forests provide diverse ecological, economic, and social benefits and services, including timber production, carbon sequestration and storage, scenic amenities, and wildlife habitat. International efforts to mitigate climate change through forest carbon sequestration and greenhouse gas emission reduction have captured scientific attention (Canadell and Raupach, 2008). Local and regional governments are

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increasingly moving forward with climate mitigation plans that may have important implications for forests. The effectiveness of proposed climate mitigation strategies for reducing atmospheric CO_2 concentrations depends on other land-cover and land-use change (LCLUC) drivers such as fragmentation, development, and agricultural conversion. However these relationships and the resulting patterns of forest loss and afforestation, carbon sequestration and storage, and wildlife habitat are not well understood (McKinley et al., 2011). We examined these issues through two approaches: a national policy review of US state climate mitigation plans, and a model of land-use change scenarios through 2051 for one state with forested and unforested landscapes.

The majority of US states have developed climate action plans that propose mitigation strategies with relevance for forest conservation and management. Climate change is a global issue, but forest-relevant mitigation strategies are often pursued at local to regional scales, with place-based implications for forest resources (Millar et al., 2007; Charnley et al., 2010). Simultaneous with trends toward globalization, trends toward devolution in environmental governance emphasize the role of state governments in environmental policy (Lester and Lombard, 1990). State governments have primary responsibility for private forest management and wildlife conservation (Dana and Fairfax, 1980). States may work independently to address state needs or react to opportunities created at federal or international levels.

Assessing the effectiveness of climate mitigation strategies that seek to avoid forest loss, reduce greenhouse gas emissions, and enhance carbon sequestration depends on understanding spatial and temporal dynamics of LCLUC, such as forest loss to agriculture or urban development as well as forest regeneration (Watson et al., 2000). Studies have estimated carbon sequestration potential based on historic land cover and current land use (Rhemtulla et al., 2009; Fissore et al., 2010), land ownership (Zheng et al., 2010; Failey and Dilling, 2010), or carbon tax or carbon credit price thresholds that reduce greenhouse gas emissions (Lippke and Perez-Garcia, 2008). These studies concluded that while there is substantial carbon sequestration potential for forests in the United States, that potential is unlikely to be achieved fully where the high value of row-crop agriculture and low price of carbon limit forest retention or gain. However relatively few studies consider how projections of future LCLUC may alter forest cover.

Estimating the impact of new mitigation strategies requires an analysis of additionality, or comparison with the counterfactual scenario in the absence of the intervention (Alig et al., 1997). Forest carbon is often analyzed as an aspatial resource, meaning that carbon sequestration is accounted for in total, independent of its spatial configuration. However LCLUC is driven by spatial processes with important implications for carbon sequestration patterns (de Jong, 2001). Analyses of additionality conducted for protected areas reveals that protecting forests with a low threat of forest loss results in minimal additional conservation gains (Andam et al., 2008; Byrd et al., 2009). Similarly, analysis of carbon mitigation policies must rely on future spatial projections of LCLUC, both to demonstrate additionality and to understand spatial and temporal dynamics of forest cover.

Forest loss, fragmentation, and gain have important implications for forest connectivity and wildlife habitat. Forest loss and fragmentation decrease the amount of habitat available for forest-associated species and can negatively impact area or edge sensitive species (Andren, 1994). Increases in core forest area and connectivity, and decreases in forest edge, can improve habitat conditions for many forest-associated wildlife species (Litvaitis, 1993). However, these changes may negatively impact habitat conditions for grassland-associated wildlife species, many of which have experienced marked population declines from 1960s to present concurrent with the loss of grassland in the eastern and central United States (Sauer et al., 2011).

We investigated potential synergies and tradeoffs among carbon sequestration, forest connectivity, and wildlife habitat among LCLUC scenarios. First, we asked what forest-relevant climate mitigation strategies have been identified in US state climate mitigation plans, and do they consider implications for wildlife habitat and forest connectivity? Second, what are the effects of three future LCLUC scenarios on afforestation, forest loss, carbon sequestration, forest connectivity, and wildlife habitat? We focus the scenario modeling on Wisconsin, a state with diverse ecological landscapes that span a gradient from forested to non-forested. We considered three LCLUC scenarios from no change in current conditions to maximum afforestation potential, and examined the resulting effects on carbon sequestration via afforestation and greenhouse gas emissions via forest loss. Finally, we examined the impacts of LCLUC scenarios on forest connectivity and wildlife habitat.

To answer these questions, we first review state government policies on forest-relevant climate change mitigation strategies and their consideration of wildlife habitat and spatial landscape dynamics (Section 2). We then model scenarios of land-use change to identify synergies and tradeoffs among land-cover change, carbon sequestration, and wildlife habitat across a diversity of ecological landscapes in Wisconsin (Section 3). Based on the policy review and land-use change model, we conclude with recommendations for developing and evaluating forest mitigation strategies (Section 4).

2. Review of forest-relevant state mitigation strategies

2.1. Methodology

We identified state Climate Action Plans or government reports (hereafter; plans) from an online database maintained by the Pew Center on Global Climate Change.[1] Based on these plans, we developed a list of mitigation strategies identified by state governments. We classified strategies according to their primary goal (carbon sequestration, emission reduction, combination of carbon sequestration and emission reduction, or program administration), and summarized forest-relevant strategies and recommendations. We also noted their consideration of wildlife impacts and spatial landscape dynamics such as forest connectivity and competition with alternate land uses.

[1] http://www.pewclimate.org/what_s_being_done/in_the_states/action_plan_map.cfm (accessed 03/31/11).