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Analysis

The cost of climate change: Ecosystem services and wildland fires

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ABSTRACT

Little research has focused on the economic impact associated with climate-change induced wildland fire on natural ecosystems and the goods and services they provide. We examine changes in wildland fire patterns based on the U.S. Forest Service's MC1 dynamic global vegetation model from 2013 to 2115 under two pre-defined scenarios: a reference (i.e., business-as-usual) and a greenhouse gas mitigation policy scenario. We construct a habitat equivalency model under which fuels management activities, actions commonly undertaken to reduce the frequency and/or severity of wildland fire, are used to compensate for climate change-induced losses in ecosystem services on conservation lands in the contiguous U.S. resulting from wildland fire. The benefit of the greenhouse gas mitigation policy is equal to the difference in fuels management costs between the reference and policy scenarios. Results suggest present value ecosystem service benefits of greenhouse gas mitigation on the average of $3.5 billion (2005 dollars, assuming a three percent discount rate). Our analysis highlights the importance of considering loss of ecosystem services when evaluating the impacts of alternative greenhouse gas mitigation policies.

1. Introduction

Public and private lands managed for conservation purposes provide a variety of ecosystem services, including wildlife habitat, soils and sediment management, air and water quality, aesthetics and scenic resources, and recreational use (Krieger, 2001). Across the U.S., climate change is expected to increase the occurrence and size of wildland fire (Westerling et al., 2011; Stavros et al., 2014), which could lead to reductions in the ecosystem services provided by such lands. Greenhouse gas (GHG) mitigation is likely to result in fewer and/or less severe wildfires, thus providing potential economic benefits through the avoidance or reduction of ecosystem service losses from catastrophic fire. We estimate the cost of fuels management, land management activities designed to reduce the frequency and intensity of wildfires, required to compensate for climate change-induced losses in ecosystem services resulting from wildland fire. This avoided cost represents the benefit of climate change mitigation to ecosystem services on conservation lands.

We assess two pre-defined scenarios: a reference (REF) scenario corresponding to a global radiative forcing metric of 10 W/m^2 by the year 2100, and a global GHG mitigation policy (POL) scenario in which global radiative forcing is stabilized at 3.7 W/m^2 by the year 2100.[1] For both scenarios, results from MC1, a dynamic global vegetation model (Bachelet et al., 2001) using five different initializing conditions (Wind1, Wind13, Wind14, Wind26, and Wind28) of the IGSM-CAM[2] climate model (Monier et al., 2014) are analyzed. These initializations, each of which contains different climate conditions for the simulation, are designed to investigate the influence of natural variability in projecting climate change impacts. In this study, we evaluate the benefit of the POL scenario from 2013 through 2115.[3] This study is part of a national, multi-sector effort to quantify and monetize the potential benefits in the U.S. associated with global GHG mitigation.[4] For consistency with previous efforts, we present our results in 2005 dollars.

1.1. Climate Change Impacts on Wildland Fire

Research has demonstrated a strong link between increased fire and climate change (Aldersley et al., 2011; Marlon et al., 2008). There is general consensus that climate change is and will continue to be a primary driver of trends in wildland fires, outweighing even direct human influence on wildland fire patterns (Pechony and Shindell, 2010). Although fire is also naturally occurring, and in certain circumstances, essential to ecosystem health, climate change is predicted to leave ecosystems

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[1] See Paltsev et al. (2013) for a detailed discussion of the climate change scenarios used in this analysis.

[2] ISGM-CAM refers to the Integrated Global System Modeling-Community Atmosphere Model.

[3] This start year represents the first year of MC1 data for which actual, historical data were not available. Because the MC1 model runs through 2115, we also conducted our analysis through this year.

[4] See Waldhoff et al. (2014) for an overview of the Climate Change Impacts and Risk Analysis (CIRA) project. See Mills et al. (2014) for quantification of other categories of benefits related to changes in U.S. wildfire patterns.

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vulnerable to higher incidences of wildfire and reduce the capacity of some ecosystems to recover from such fires (Seidl et al., 2014). For example, warming trends are expected to result in increased lightning strikes (Romps et al., 2014); in the decade prior to 2013, lightning-caused fires burned 64% of the total acreage affected by wildland fire (NIFC).

Concurrently, other efforts are using various climate change scenarios to estimate the types of negative environmental impacts which may result from increasing wildfire (Litschert et al., 2014). To date, little work has been done to understand the economic impacts of unmitigated climate change on ecosystem services and the effect that emissions reductions would have in reducing those impacts. This paper aims to fill that knowledge gap by presenting and applying an approach that quantifies the fuels management costs necessary to avoid ecosystem losses due to climate change-induced wildland fire. Fuels management activities are routinely undertaken to change the amount, kind, and arrangement of fuel loads[5] in order to minimize the potential for catastrophic fire. Such activities include manual or mechanical vegetation removal and prescribed burning.

1.2. Economic Impacts of Wildland Fire

Historical efforts to assess the impacts of wildland fire have primarily focused on readily available metrics, such as the number of acres burned, the number of lost structures, the number of responding personnel, the costs of fire suppression and response, and in some cases, the value of lost timber. This information, however, provides only a partial view of the total economic impacts of wildland fire because it does not take into account the long-term impacts of wildland fire on affected watersheds and ecosystems. For example, the Western Forestry Leadership Coalition (WFLC) estimates the true cost of past fires in the western U.S. to be between two to thirty times the cost of suppression (WFLC, 2010).[6] A San Diego State University study estimated the total economic impact of the 2003 wildland fires in San Diego County at $2.45 billion, of which suppression costs accounted for less than two percent of total costs (Rahn, 2009).[7]

Little research has focused on the economic impact associated with wildland fire on natural ecosystems and the goods and services they provide. Changes in such ecological systems as a result of high intensity, catastrophic wildfires can interrupt and/or diminish both market and non-market ecosystem services from the time of the fire through full recovery of the system to its baseline (or pre-fire) condition. While market-based goods and services can be monetized relatively directly, non-market services are often referenced only qualitatively when discussing the potential economic impact of wildland fire. Our analysis assesses how climate change-driven changes in wildfires affect the non-market services provided by ecosystems.

In considering the multiple streams of benefits or services flowing from an ecosystem, estimating economic impacts can either involve a service-by-service analysis or a proxy analysis. In a service-by-service approach, categories of benefits associated with an ecosystem are deconstructed and quantitatively or qualitatively assessed individually. Assessing each potential category of benefit requires constructing a unique framework and developing appropriate inputs. While this approach has been carried out in the context of forest fires (Batker et al., 2013), it is resource intensive, requiring detailed, case-specific research and the development of large volumes of data. Instead, we use a proxy method in which a single metric, or a collection of a few metrics, serves as a 'proxy,' representative of a broader set of services provided by a particular ecosystem. We employ live vegetative cover as the proxy to reflect the overall bundle of services provided by an ecosystem.

The remainder of this paper is organized into three parts. In Section 2, we review the MC1 model which we rely upon to understand changes in the pattern of vegetation and wildland fire due to climate change. We also briefly describe the habitat equivalency analysis (HEA) framework. This is followed by a detailed discussion of data and methods. Section 3 presents our analytic results and Section 4 concludes with areas of uncertainty.

2. Data and Methods

2.1. MC1 Dynamic Global Vegetation Model

The MC1 model is a dynamic vegetation model developed by the U.S. Forest Service (USFS) that simulates ecosystem biogeochemical processes and changes in ecosystem structure to facilitate projections about how potential vegetation may change in response to different disturbances. The MC1 model has been used in a number of applications, including assessing potential climate change effects on vegetation and faunal species (Halofsky et al., 2013; King et al., 2013; Mills et al., 2014). For this analysis, we rely on outputs generated by MC1 model runs conducted under a previous effort and provided for use in this economic analysis (see Mills et al., 2014 for a description of the approach used to prepare and run the MC1 model). The MC1 model divides the contiguous U.S. into 3256 grid cells, where each cell is roughly 50 km by 50 km in size, equivalent to approximately 2500 km^2 (or 617,763 acres).[8] Outputs for a wide-range of variables are generated for each grid cell for each year from 2000 through 2115. For this study, we rely on outputs for seven variables, including the year of the fire. The remaining variables are introduced as they are used in the calculations in the Methodology section that follows. Because the model only allows one value per variable per year, the MC1 model limits each cell to no more than one fire in any given year. In cases where fire may be more frequent (i.e., a cell may experience more than one fire in a single year) this assumption may underestimate fire frequency and/or the total number of acres burned.[9] We further assume that the area burned within each cell is an independent fire. That is, if two adjoining cells both have a noted fraction burned, we assume these burned areas are from separate fire events.

2.2. Overview of Habitat Equivalency Analysis

In the context of environmental damage liability regimes, habitat equivalency analysis (HEA) is one well-accepted technique for determining appropriate compensation for the loss of ecosystem services (U.S. DOI, 2008; EU, 2008; NOAA, 1995). The basic premise of HEA is that the public can be compensated for past and expected future losses in ecosystem services through the provision of additional and equivalent services in the future (Roach and Wade, 2006). These "compensatory" services are in addition to actions taken to restore the resource to its baseline condition (in this case, the pre-fire condition), since simply restoring the resource to its baseline condition after an extended period of time will not make the public whole. These compensatory services are provided through restoration activities selected based on their efficiency at replacing the lost services. The proper scale of compensatory

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[5] Fuel can include any type of flammable material, for example trees, brushes, and grass. Fuel load describes the amount of flammable material within a specific area (i.e., tons per acre).

[6] The Oregon Department of Forestry follows the concept of "cost plus loss," in which the full accounting of losses from a wildland fire in forested ecosystems is equal to timber and ecosystem values in addition to suppression expenditures (ODF, 2014).

[7] Other cost categories included economic impacts to infrastructure, natural areas, businesses, and the community (i.e., recreation impacts, human and health services, and public assistance).

[8] Because the grid cells are aligned with latitude and longitude lines, there is some variability in cell area. These differences were factored into the analysis when calculating the number of acres of land burned.

[9] The effect of this underestimation in the model is not simple. While the burned area may be greater and associated with increased losses in ecosystem services, more frequent fire may also result in younger baseline ages and shorter recovery times.