WORKING PAPER

The Potential Role for Management of Public Lands in Greenhouse Gas Mitigation and Climate Policy

Lydia Olander
David Cooley
Christopher Galik

August 2010

Duke
NICHOLAS INSTITUTE
FOR ENVIRONMENTAL POLICY SOLUTIONS

NI WP 10-02

MITIGATION BEYOND THE CAP

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for more information please contact:

Nicholas Institute for Environmental Policy Solutions
Duke University
Box 90335
Durham, North Carolina 27708
919.613.8709
919.613.8712 fax
nicholasinstitute@duke.edu
nicholasinstitute.duke.edu

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Executive Summary

Management of forests, rangelands, and wetlands on public lands, including the restoration of degraded lands, has the potential to increase carbon sequestration or reduce GHG emissions beyond what is occurring today. While restoration is likely to bring positive co-benefits for wildlife, water quality and other ecosystem benefits; shifting management to maximize greenhouse gas benefits may lead to tradeoffs with the same ecosystem benefits as well as other uses, such as recreation, species protection, natural resource production, and adaptation to climate change. Public lands are managed for a range of specific uses (wilderness, timber, recreation), which may or may not coincide with management for GHG mitigation.

In this paper, we estimate a rough potential of enhanced GHG mitigation of approximately 100 million metric tons[1] (Mt) CO_2e per year on federal and state public lands. This estimate includes near-term sequestration generated from an elimination of timber harvests in public forests and improving management of some rangelands, but does not include reforestation and other rangeland management, where our data was insufficient, or the potentially significant (but highly uncertain) GHG mitigation opportunities related to wetland restoration or reduced emissions from wildfires. Given limited data on mitigation potential on public lands; uncertainties around climate-induced stress, such as increasing risks of forest fire; and the potential for leakage of land-use activities and their emissions to private lands, there is considerable uncertainty with this estimate.

A number of policy options have been proposed for shifting incentives to increase GHG mitigation on public lands. The first option includes **generating supplemental mitigation** on public lands for national accounting purposes. This would assist the U.S. in meeting goals negotiated in international agreements and is an extension of current policy. The U.S. currently uses GHG sinks from land use to offset the overall net emissions reported in the annual GHG inventory for our commitment to the United Nations Framework Convention on Climate Change. The second option is using GHG mitigation on public lands to help the Federal Government **achieve GHG neutrality**. Large existing land-use sinks may make this an ineffective incentive. The third option for mitigation on public lands is **supporting a private offsets market**. Public lands could be used to test and demonstrate new offsets protocols, or additional mitigation on public lands could be used as a reserve buffer to compensate for shortfalls in the private carbon market due to impermanence, lack of additionality, and/or leakage. This may benefit market development but is likely to come at a cost to other services. Also any reserve on public lands would likely be too small to support a federal offsets market of the scale incorporated in proposed federal legislation. The final policy option we explore is **allowing GHG mitigation on public lands to be sold in a private offsets market**, either by the overseeing agency or by private contractors. Federal agencies could use the proceeds or royalties from the sale of offsets to supplement their general budgets, or to generate targeted funding for management.

While there appears to be significant potential for additional GHG mitigation on public lands, the total potential will be tempered by consideration of the tradeoffs with other uses of public lands, the needs for climate change adaptation, and the effects on other ecosystem services.

Introduction

Public lands, which include federal and state lands, make up 37% of total U.S. land area and 29% of the nation's forests, grasslands, and cropland (Lubowski et al. 2006). Their current and potential contribution to ecosystem services production is substantial. Policies for mitigating climate change recently debated in the U.S. Congress have market and fund-based mechanisms to promote mitigation activities on private lands, but they have largely remained silent on the role of public lands (H.R. 2454, 2009; S. 1733, 2009;

[1] The term *ton* (abbreviated *t*) as used in this report refers to the metric ton (1 ton [or *tonne*] = 1,000 kg = 2,204.62 lbs). Hence, the abbreviation *Mt* refers to the megaton (1 million metric tons).

S. 2729, 2009; American Power Act, 2010). At the same time some federal agencies have moved forward to engage in carbon and other ecosystem services markets on public lands,[2] while others have held back. There are fundamental questions and debates under way regarding the role public lands should play in mitigating climate change and providing other ecosystem services. While some lawmakers have suggested that public lands could potentially use the carbon market to help with underfunded restoration projects, environmental groups have raised questions about such an approach, including issues of additionality and potential conflicts with multiple-use objectives.[3]

In this paper we explore and assess how government might enhance GHG mitigation on public lands. While the U.S. may not see a national cap-and-trade policy in the near term, it is still developing international commitments and is bound by the United Nations Framework Convention on Climate Change (UNFCCC),[4] and state and regional GHG programs may still move forward.[5] A voluntary carbon market also continues to move forward (Hamilton et al. 2009).

Management of forests and rangelands, wildfire management, and restoration of degraded lands and wetlands all have the potential to increase carbon sequestration or reduce GHG emissions beyond what is occurring today. However, it is important to keep in mind that these changes in management may lead to tradeoffs with other ecosystem services or climate change adaptation goals.[6] Management for increased carbon sequestration could also bring additional costs associated with addressing risk to carbon stocks, for example from fire or pest infestation.[7] Various federal and state agencies have different missions for the lands they manage (e.g., species protection vs. resource production) and oversee lands that are designated for specific uses (e.g., water quality vs. recreation).[8] We do not explore these various missions and mandates here, but they could ultimately affect the degree to which different lands are engaged in climate change mitigation activities.

In the assessment that follows, we (1) provide a rough estimate of additional GHG mitigation potential on federal and state public lands with relevant caveats and concerns (some of which are noted above), (2) highlight data gaps we face in assessing mitigation potential, and (3) outline several policy options for enhancing GHG mitigation on public lands, including:

- generating supplemental mitigation for national accounting purposes (an extension of current policy);
- using mitigation on public lands to help the Federal Government achieve GHG neutrality;
- using mitigation on public lands to support a private offsets market; and
- allowing mitigation on public lands to be sold in a private offsets market.

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[2] For example, the U.S. Fish and Wildlife Service has initiated several partnerships to participate in the voluntary carbon market. For more information see http://www.fws.gov/southeast/carbon/pdf/FWSTerrestrailCarbonFactSheet-partnerships.pdf.

[3] A report by the U.S. Forest Service indicates that external carbon funding could help address underfunded reforestation efforts (Goines and Nechodom 2009). However, six environmental groups recently sent a letter to Secretary of Agriculture Tom Vilsack and Secretary of the Interior Ken Salazar citing concerns with using private funding for carbon mitigation projects on public lands. A copy of the letter can be seen at http://wilderness.org/content/pr-climate-20100106 (accessed April 22, 2010).

[4] The U.S. has committed to reducing its GHG emissions by 17% below 2005 levels under the Copenhagen Accord. (U.S. Department of State 2010).

[5] These programs include the Regional Greenhouse Gas Initiative (RGGI), the Western Climate Initiative (WCI), and efforts to reduce GHG emissions in California under Assembly Bill 32 (AB32).

[6] For example, afforestation projects for GHG mitigation can result in decreased water yield (Jackson et al. 2005; Farley et al. 2005). This can have implications for both the provision of watershed ecosystem services and for adaptation to climate change, especially in arid regions or regions undergoing reductions in precipitation (Klein et al. 2007; Julius et al. 2008).

[7] For more information on the potential barriers to implementing mitigation projects on public lands, see Galik et al. (2010).

[8] For more information on the missions of the different land management agencies and the effects on their management activities, see Cody et al. (1995), General Accounting Office (1996), and Government Accountability Office (2009).

This paper joins an increasing number of other works exploring the role and potential of public land GHG mitigation. For example, initial assessments of mitigation potential have been completed at various scales, including national (Sundquist et al. 2009) and state (Goines and Nechodom 2009; Failey and Dilling 2010). The larger role of public lands in a low-carbon economy, including policy options for meeting both GHG mitigation and climate change adaptation concerns, is explored further in Galik et al. (2010), while Ruhl (forthcoming, 2010) provides an overview for how federal agencies might use a broader ecosystem services framework for managing its public lands. The assessment that follows builds on these previous works.

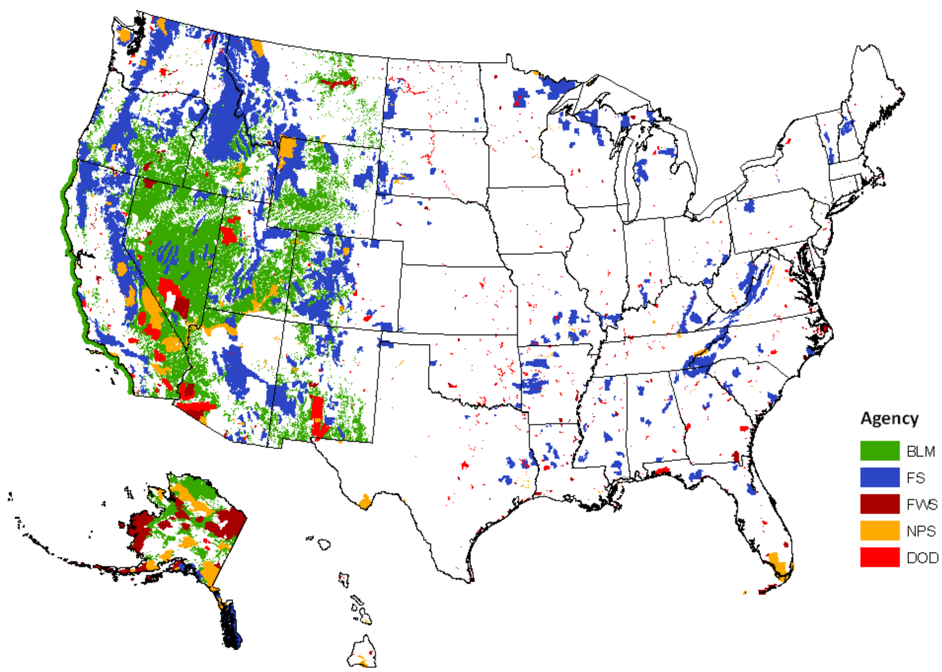
Potential GHG Mitigation Opportunities on Public Lands

The federal government is entrusted with roughly 635 million acres of land (28% of total land area) in a wide variety of land cover types (Lubowski et al. 2006). Most of this federal land is managed by five agencies: the Bureau of Land Management (BLM), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), and the Department of Defense (DOD). The majority of this land is located in the western U.S. (Figure 1). State and locally owned lands account for roughly 195 million acres (8.6% of total land area). These lands are distributed throughout the nation somewhat more evenly than federal lands, but still tend to be highly concentrated in the western U.S. (Lubowski et al. 2006). In addition, federal and state governments control a considerable amount of land (roughly 24 million acres)[9] in rights of way along public highways which could potentially be managed for GHG mitigation; however, this land will likely have other maintenance and management obligations as well. We do not consider the potential for GHG mitigation on rights of way in this assessment.[10]

[9] Federal and state governments control land in rights of way along public highways equal to roughly 24 million acres of land across all ownerships, assuming 4 million miles of public highways with an assumed 50-foot right-of-way. Source: Bureau of Transportation Statistics: http://www.bts.gov/publications/national_transportation_statistics/html/table_01_05.html, accessed April 22, 2010).

[10] By one calculation, the carbon storage from decommissioning and re-vegetating unneeded National Forest System roads is considerable once trees are fully grown: a total of 39.5–48.5 million metric tons CO_2e (Kerkvliet et al. 2010). This study did not, however, account for carbon emissions resulting from site preparation and planting.

Figure 1. Distribution of federal public land in the United States.



Source: http://www.nationalatlas.gov.

The magnitude of carbon mitigation opportunities on public lands depends on a number of factors. First, there are significant regulatory and other legal constraints. Some public land is ineligible or unsuitable for new management. This includes more than 100 million acres of designated wilderness (National Atlas of the U.S. 2006), where most management is restricted, and 58 million acres of roadless areas (66 Fed. Reg. 3245) where access to new management projects could be limited. In addition, most public lands are managed for multiple uses, such as natural resource production, recreation, and species or water source protection,[11] which will place inherent limits on managing lands to increase GHG mitigation. Second, mitigation potential varies greatly by land cover type and regional climate and biophysical conditions (e.g., soil type).

Acknowledging these constraints, we examine the opportunities for sequestration in public forestlands, rangelands, and wetlands, as well as opportunities for reducing emissions from wildfires through fuel reduction treatments. In discussing mitigation potential, we place particular focus on the amount of mitigation that is above and beyond that which would have been produced under a so-called baseline, or business-as-usual (BAU) condition.[12] These numbers are provided only for a sense of the order of magnitude, so that decision makers can have a sense of the scale of mitigation opportunities when they consider the tradeoffs inherent in any GHG policy on public lands. More research and analysis will be necessary to refine these estimates further.

[11] Most federal land management agencies, including the BLM and USFS, are required to manage public lands for multiple uses. For more information see the Federal Land Policy and Management Act (43 U.S.C. §§ 1701 et seq.) and the Multiple-Use Sustained-Yield Act (16 U.S.C. §§ 528 et seq.).

[12] GHG mitigation projects, including offsets projects, are typically required to provide mitigation benefits that are additional, or benefits that would not have otherwise occurred in the absence of the project. For more information on additionality requirements for carbon mitigation projects, see Box 2 below.

Forest lands

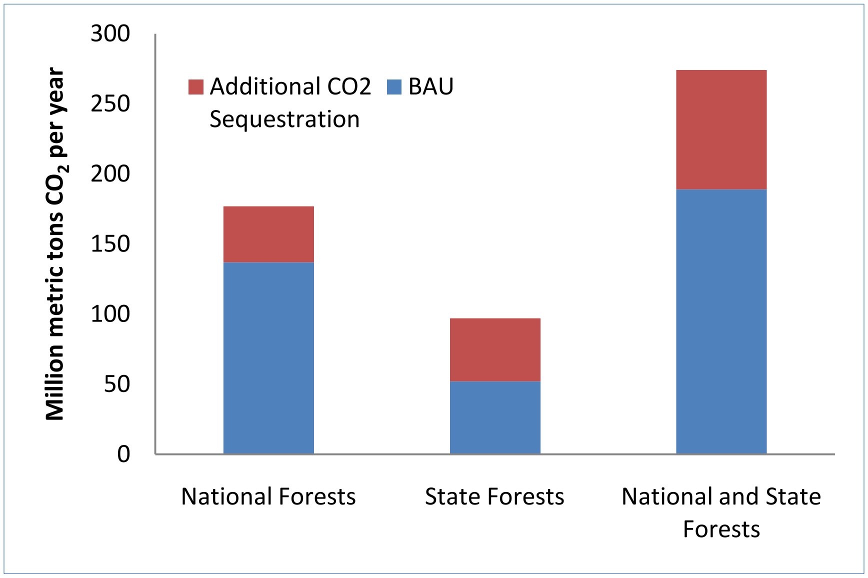
Across all agencies, the federal government manages approximately 248 million acres of forested land, or approximately one-third of all forested land in the U.S. (Smith et al. 2009). Of this, 109 million acres, or 44%, are timberlands, or forest land capable of and set aside for timber production (Lubowski et al. 2006). States and local governments manage an additional 70 million acres of forests, or around 9% of total forested land (Lubowski et al. 2006).

One study estimates the baseline, business-as-usual (BAU) carbon sequestration rates in national forests at about 137 million metric tons (Mt) CO_2e per year between 2010 and 2050; state and other public forests average carbon sequestration of 52 MtCO_2e per year over the same period (Depro et al. 2008). Since this represents BAU, however, the carbon sequestered would probably not be considered additional mitigation. There are a number of ways to increase sequestration on public timberlands beyond BAU, including changing harvest patterns or modifying management practices. The reduction of harvest activity may hold significant potential for sequestering additional carbon in the coming decades. One study in particular found that if timber harvests were stopped in all national forests, these forest lands could sequester an average of nearly 40 MtCO_2e per year above BAU between 2010 and 2050; state and other public lands could sequester an average of 45 MtCO_2e over the same period by curtailing harvesting (Depro et al. 2008). The total potential forest carbon sequestration for all federal, state, and other public lands could generate additional mitigation of approximately 85 MtCO_2e per year (Figure 2).

It is important to recognize the limitations of these estimates from the study by Depro et al., which examined only three harvest scenarios: baseline (BAU), elimination of harvest, and an increase in harvest to the levels of the late 1980's. More research is needed to determine more fully the types of forest management (as well as the relative intensity) with the greatest potential for GHG mitigation. There is a particular need for studies examining the GHG benefits of different levels of harvest, rather than complete elimination of harvest, as well as analyses of the costs of the various options. This information would allow policymakers and land managers to more completely weigh GHG benefits against other demands and objectives of the management of public forests and improve insights into the cost-effectiveness of the options.

Other studies counterbalance the results of Depro et al. by finding relatively lower overall GHG mitigation potential from public forests, largely by assuming slower growth rates, which may be more appropriate for aging public forests. Examining public timberland with these assumptions, Adams et al. (2010) estimate fewer GHG mitigation benefits from reduced harvest as compared to Depro et al.. Looking specifically at national forests in California, Goines and Nechodom (2009) find that the slower growth of aging trees and increased emissions from wildfires in the BAU scenario could cause those forests eventually to become net sources of GHGs over time. The authors identify management scenarios that could achieve higher rates of carbon sequestration, but they note that these must be balanced with other resource objectives.

Figure 2. Potential average annual business-as-usual (BAU) CO_2 sequestration and additional sequestration ($MtCO_2$) from eliminating timber harvests in national, state, and other public forests between 2010 and 2050.

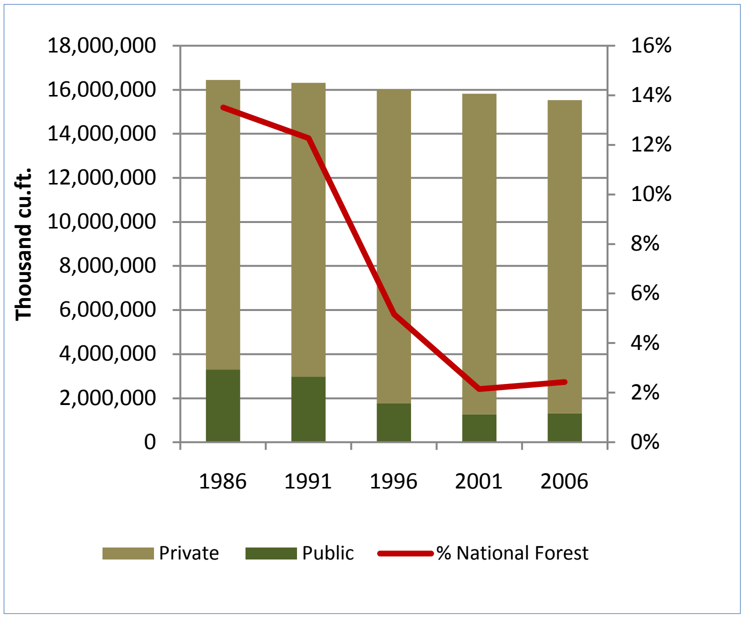


Source: Depro et al. 2008.

Significant leakage is also likely to be associated with reduced harvest activity on public lands, thus reducing the net sequestration benefits. Figure 3 shows that, while the percentage of timber harvests in National Forests has declined markedly since the late 1980s, overall timber production has decreased only slightly, with harvests on private lands increasing to meet demand. It is quite possible that the carbon emissions avoided by reduction or elimination of timber harvests on public lands could be substantially offset by increased harvest on private lands or overseas (Wear and Murray 2004; Murray et al. 2004).

Reforestation, involving the planting of trees in cleared areas or other disturbed areas with poor tree growth, represents another potentially significant mitigation opportunity for public lands. If the land in question is reforesting naturally or is already scheduled to be actively reforested, the carbon stored as part of the reforestation process could be non-additional to BAU. In contrast, if the land is degraded and growing back poorly, with low density or slow growth, and reforestation could help increase forest carbon stocks or the rate at which they accrue, some or all of the stored carbon could be considered additional. Even planned reforestation projects might be considered additional in some situations, particularly where carbon financing could address a shortage of funds needed to conduct the work (Goines and Nechodom 2009).

Figure 3. Timber harvest on public and private land in the U.S.



Source: Powell et al. 1993; Waddell et al. 1989; Smith et al. 2009.

Assessment of reforestation potential here was not possible due to limited available data. Although the U.S. Forest Service tracks some measures of the need for reforestation in the National Forest System, the GAO (2005) found their data insufficient and unreliable for quantifying the acreage and the locations of lands in need of reforestation. Indeed, while the most recent assessment of reforestation need reports that nearly 900,000 acres were in need of reforestation on Forest Service lands (U.S. Forest Service 2004), other data sources suggest the number could be much higher, since in 2008 wildfires burned nearly 4 million acres of federal lands (National Interagency Fire Center 2008) and insects and disease caused nearly 9 million acres of tree mortality on Forest Service lands (U.S. Forest Service 2009).

For these reasons we did not have sufficient data to accurately estimate the GHG mitigation potential for reforestation. To accurately estimate the GHG mitigation potential for reforestation, it is necessary to know specifically which forests were impacted by disturbance, the severity of the impact, the carbon density of those forests, how likely these forests are to re-grow sufficiently on their own (i.e., under BAU without reforestation), and which reforestation projects are already scheduled, sufficiently funded, and likely to move forward. Such an analysis is beyond the scope of this paper; more research will be needed to assess this potentially significant source of additional GHG mitigation on public lands.

Fire management

In principle, removing smaller fuels from forests prevents them from contributing to and intensifying natural wildfires. With estimated average emissions from wildfires on public lands of roughly 140 million metric tons CO_2 per year,[13] a reduction in the frequency, extent, and severity of wildfires would seem to bring significant GHG benefits. However, uncertainty remains over the net long-term GHG benefits of wildfire fuel reduction treatments, such as prescribed burning or mechanical thinning. The debate centers

[13] Data from the National Interagency Fire Center (2008) shows that wildfires on federal public lands burned an average of 60% of all acres burned by wildfires in the U.S. between 2005 and 2007. By multiplying this percentage by the total U.S. wildfire emissions from the same period (EPA 2009a), we can roughly estimate the average emissions from wildfires on public lands at 142 million metric tons CO_2 per year, with significant annual variability. However, one recent study found that estimates of GHG emissions from wildfires may be overstated, because quick re-growth of early successional vegetation offset declines in productivity after even severe fires (Meigs et al. 2009).

on whether the initial GHG emissions from the treatments or the increased risk of future catastrophic fire outweigh any emissions reductions from reduced extent and severity of wildfires. Studies examining this issue have found significant regional variability. For example, studies in relatively drier, more fire-prone landscapes, such as parts of California and Arizona, have found that fuel reduction treatments tend to result in more carbon stored on the landscape over the long term (Hurteau et al. 2008; Hurteau and North 2009; Dore et al. 2010).

Other studies in relatively wetter forests of the Pacific Northwest and the Northern Rocky Mountains have found that fuel reduction treatments are often counterproductive to carbon storage goals. Although reductions in fuels can lead to reductions in fire severity, these studies find that the carbon removed in fuel reduction treatments tend to be greater than the amount of carbon lost to wildfire emissions (Mitchell et al. 2009; Reinhardt and Holsinger 2010). In some cases, even when accounting for biomass energy produced from removed fuels, it would take decades for the project to produce net positive GHG benefits (Mitchell et al. 2009). Nevertheless, although fuel reduction treatments may result in net positive GHG emissions in some forests, many experts suggest that they may still be necessary, since other options such as wildfire exclusion are not sustainable solutions, especially in the western states where fire suppression can eventually put forest carbon stocks at greater risk for catastrophic loss (Reinhardt and Holsinger 2010).

While more research will be necessary to determine the net carbon balance of fuel reduction treatments, the research conducted to date has demonstrated that the GHG mitigation benefits of such treatments will vary regionally. Furthermore, the potential for fuel reduction treatments to provide net GHG benefits may change over time, as many sources predict that wildfires will increase in frequency and extent under climate change, especially in the western United States (Westerling et al. 2006; IPCC 2007a; Kirilenko and Sedjo 2007).[14] While there may be important reasons to move forward with fuel reduction programs, their application for GHG mitigation would need to be applied differently for each region and forest type.

Rangelands

The primary activities for sequestering carbon on rangelands include improved management of livestock grazing and the restoration of degraded lands. The Bureau of Land Management and the U.S. Forest Service oversee more than 250 million acres of rangeland, including 189 million acres of grazing allotments (BLM 2009; NILS 2006). As centralized data is not available on the current livestock management practices or the quality of the rangelands administered by federal agencies, it was not possible for us to fully determine the potential for enhanced mitigation.

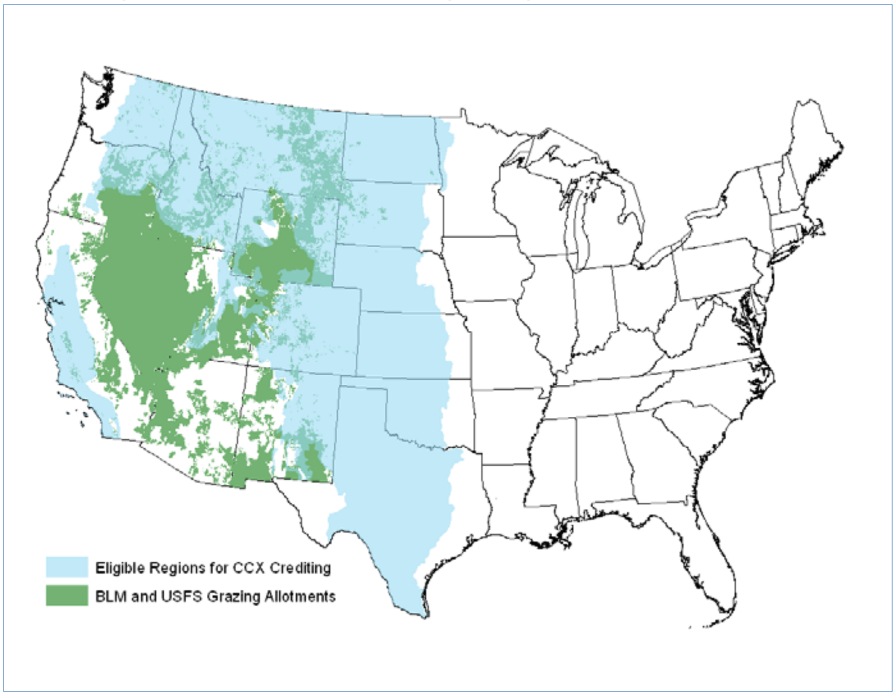
However, we were able to generate a rough estimate of soil carbon sequestration potential from improved rangeland management. Estimates from the literature for soil carbon sequestration rates from rangelands range between 0.26 and 1.10 tCO_2 per hectare per year (Schuman et al. 2002; Derner and Schuman 2007; Follett and Reed 2010). The soil sequestration rates used for crediting in the Chicago Climate Exchange (CCX) offset protocol for rangeland soil carbon sequestration range between 0.29 and 0.79 tCO_2 per hectare per year (Chicago Climate Exchange 2009), which is generally similar to, and in some cases more conservative than, the rates found in the literature. Because the CCX protocol accounts for regional variability in sequestration rates, we use those rates to calculate soil carbon sequestration for improved management of federal rangelands, which includes restrictions on the duration and intensity of grazing activity allowed to ensure a net increase in soil carbon stocks.

In the protocol, sequestration rates vary by USDA Land Resource Regions, which we aligned with data obtained from the BLM and USFS (NILS 2009) showing the locations of public grazing allotments

[14] Fire is not the only threat to forest carbon that could increase under climate change; several studies suggest that increasing temperatures could exacerbate pine beetle outbreaks in many parts of the U.S., leading to increased tree mortality and reversals of carbon sequestration benefits (Gan 2003; Waring et al. 2009).

(Figure 4). This overlay indicates that roughly one-third of public grazing allotments are located in Land Resource Regions eligible for CCX credits.[15] If we assume all public grazing lands in the eligible areas could benefit from improved management as defined by the CCX protocol, the total potential carbon sequestration for rangelands is approximately 16.6 $MtCO_2$ per year.[16] While this may overestimate potential from improved rangeland management, it does not include other mitigation opportunities, such as rangeland restoration or methane emission reductions from keeping herds in pasture for shorter times and moving them to feeding operations more quickly (McCarl and Schneider 2001).[17]

Figure 4. Federal public rangeland eligible for CCX crediting. Areas in blue are USDA Land Resource Regions eligible for CCX crediting. Areas in green are BLM and USFS grazing allotments.



Source: USDA Major Land Resource Area 2002; National Integrated Land System 2006.

Wetlands

The federal government manages 72 million acres of wetlands, slightly over half of which are in Alaska (Table 1). These lands are fairly evenly split across many agencies, including BLM, USFS, FWS, DOD, and NPS, all of which have different management objectives. We can say little about the aggregate mitigation potential of wetlands, given insufficient data on the type and expanse of federal wetlands in need of restoration, and uncertainties around the potential for methane and nitrous oxide emissions to counteract the GHG benefits of restoration efforts (Bridgham et al. 2006).[18,19]

[15] The Chicago Climate Exchange protocol for rangeland carbon sequestration confines eligibility for rangeland projects to Land Resource Regions that exhibit long-term annual average precipitation between 13” and 40”.

[16] State and local governments manage 40 million acres of grazing land (Lubowski et al. 2006). Because we lack data on the spatial distributions of these lands, we are unable to make similar estimates on the sequestration potential of state and local rangelands.

[17] The province of Alberta, Canada has developed an offset protocol that quantifies the emissions reductions resulting from improved efficiency in the lifecycle of cattle (Alberta Environment 2009).

[18] The level of nitrous oxide emissions, another potent GHG, from wetlands is seen as insignificant compared to fluxes of carbon and methane, though nitrous oxide emissions can be increased somewhat in the presence of nitrogen pollution (Smith et al. 1983; Bridgham et al. 2006).

It is worth noting that some types of tidal wetlands will have lower methane emissions, potentially leading to net positive GHG benefits from restoration (Philip Williams & Associates, Ltd. 2009). Estimates of average annual soil sequestration rates in U.S. tidal wetlands are around 0.9 tons CO_2e per acre per year, though these rates can be highly regionally variable, with estimates for U.S. tidal wetlands ranging from 0.08 tons per acre per year in a mangrove site in Florida to nearly 7 tons per acre per year in a National Wildlife Refuge in Louisiana (Chmura et al. 2003). With high-end mitigation potentials that could dwarf other mitigation options (such as ozone-depleting substances) and the significant potential for synergies with other restoration objectives, such as water quality or wildlife habitat in some cases, federal wetlands could be part of a future mitigation portfolio. It will face the usual additionality question of what level of restoration is already planned by the managing agencies, but also must consider regulatory commitments; 14 states have set goals for wetland restoration on public lands (Thomas 2008). If these goals are accompanied by funding for specific restoration projects, then the mitigation resulting from these specific projects would be considered non-additional. However, these goals are typically not legally binding and are often underfunded or unfunded (Philip William and Associates, Ltd. 2009).

Table 1. Acreage of federal public wetlands by wetland type. Note that Estuarine and Marine wetlands are the tidal wetlands described above.

	Total federal public lands *1,000 acres*		
Wetland Type	**Contiguous states & HI**	**Alaska**	**Total U.S.**
Estuarine and Marine Deepwater	5,769	1,220	6,989
Estuarine and Marine Wetland	1,549	449	1,998
Freshwater Emergent Wetland	5,154	19,481	24,635
Freshwater Forested/Shrub Wetland	7,714	11,782	19,496
Freshwater Pond	334	914	1,248
Lake	11,339	4,154	15,493
Riverine	68	30	98
Other	781	1,223	2,004
Total	**32,708**	**39,253**	**71,961**

Source: National Wetland Inventory (U.S. Fish and Wildlife Service 2009).

Summary of GHG mitigation opportunities on public lands

The estimates of GHG mitigation potential presented here should be viewed as rough approximations; analysis of mitigation potential on public lands is difficult at a national scale due to data limitations and high regional variability. We estimate potential sequestration in public forests of up to 85 $MtCO_2$e per year resulting from the cessation of timber harvests on public lands. This estimate could be tempered, however, by accounting for risks of leakage through increased timber production on private lands or reversals from increases in wildfires or pest infestations. We lack data to analyze mitigation potential from reduced (rather than eliminated) timber harvests, as well as potentially significant sequestration opportunities from reforestation projects.

[19] Some studies have suggested that lakes and wetlands in Alaska are becoming major sources of methane emissions under climate change due to melting permafrost (Sitch et al. 2007; Walter et al. 2007). Therefore, while there may be opportunities for carbon sequestration through wetland restoration on public lands, these may be dwarfed by increased emissions of methane, a gas with 25 times more warming potential than CO_2 (IPCC 2007b). On a national level these wetland emissions will likely reduce our expected terrestrial sink affecting our ability to achieve our UNFCCC commitments and any other national goals. However, increasing mitigation and reducing net GHG contributions through land management where possible can on net still contribute and help counteract this trend.

Our estimate of federal rangeland mitigation potential of 16.6 $MtCO_2e$ per year only covers around two-thirds of federal rangelands, as the CCX methodology only covers part of the U.S. We also assumed that all of these lands would benefit from improved management. However, we lacked the data necessary to estimate mitigation potential from other rangeland projects, such as restoration or improved livestock and waste management. We were also unable to assess state or locally owned rangelands.

We similarly lack data to provide estimates of mitigation potential from wetland restoration and wildfire fuel reduction treatments. Because these project types can result in increased GHG emissions, more analysis will be necessary to determine the full GHG accounting of these approaches.

For what we were able to estimate, mitigation potential was split roughly evenly between federal and state lands, with mitigation potentials of 55 $MtCO_2e$ and 45 $MtCO_2e$ per year, respectively, for the period between 2010 and 2050. Although we present mitigation potential as an annual rate, it may be more appropriate in future analyses to explore the total amount of storage that can be maintained long-term, given that maturing forests will experience declining growth rates and many landscapes could face increased risk of disturbance under climate change. In sum, estimates of GHG mitigation potential from public lands are highly uncertainty due to critical information gaps and analytical limitations. Research is needed to meaningfully inform policy deliberations on managing public lands for GHG mitigation.

Policy Options

U.S. public lands can achieve enhanced GHG mitigation through a variety of management activities. While the question remains whether public lands management should be shifted to enhance mitigation, a number of ideas for how these lands could participate in climate change mitigation programs have circulated during discussion of national climate policy. These include:

- generating supplemental GHG mitigation for **national accounting** purposes under the UNFCCC through management shifts on public lands, which is an extension of existing policy
- using GHG mitigation on public lands as part of a strategy to help the Federal Government achieve **GHG neutrality**
- using GHG mitigation on public lands to **support a private carbon market**
- allowing GHG mitigation generated on public lands to be **sold in private carbon markets**, either by overseeing agencies or private contractors

We discuss each of these options below.

National accounting

Under the UNFCCC, the United States is committed to report annually on the nation's GHG emissions and sinks (United Nations 1992). In 2007, the total U.S. GHG emissions were 7.2 billion tons CO_2e. However, the total land-use sink reduces that number by 1.1 billion tons, resulting in net emissions of 6.1 billion tons (EPA 2009a). The EPA GHG inventory does not separate the land-use sink into public and private lands, but it is clear that public lands play an important role.

At the COP-15 meeting in Copenhagen, President Obama made a nonbinding pledge to reduce U.S. GHG emissions to 17% below 2005 levels by 2020 (U.S. Department of State 2010). Land management could be instrumental in meeting such an emissions reductions target. If land-based mitigation is accepted under the international agreement, mitigation on public lands will likely be used to help meet the emissions reduction target.

Current policy tracks land-based mitigation in the U.S., but does not apply significant incentives or programs designed to generate additional mitigation. If it is in the U.S. interest to generate supplemental mitigation, perhaps to achieve a new nonbinding pledge or binding agreement, shifts in management of public lands could increase the current land-use sink by at most 10%, using our rough estimate of mitigation potential. However, as discussed above, multiple-use mandates for land management agencies may significantly limit the overall amount of mitigation that could be achieved on public lands.

If the U.S. implements a national cap-and-trade policy, additional funding to support mitigation on public lands could come from a portion of the allowance allocation (see Box 1) or other fees. Such funding could be used to help address the reforestation backlog for the U.S. Forest Service. Funding could be used to purchase land in need of restoration, expanding the total area of public lands, increasing mitigation capacity, and potentially avoiding land-use change that could result in net GHG emissions.

As federal and state lands are currently included in national GHG accounting (EPA 2009a), any mitigation on these lands used to offset emissions from regulated entities under a cap-and-trade policy could not be used to meet national targets, since there would be no net reduction in emissions. However, if mitigation on these lands were involved in a carbon market and any credits received were retired, rather than used to offset emissions of regulated entities, the reductions could count for the national account.

The overall strategy of increasing mitigation on public lands for national accounting purposes seems to be a useful extension of current policy, especially where costs of shifting management are low. However, in some cases, supplemental mitigation would require a shift in policy that would allow federal and state agencies to adjust priorities and funding for land management.

Box 1. Carbon markets, offsets, and supplemental funding.

Carbon markets have emerged in the U.S. in recent years to enable trading of emissions reduction or enhanced sequestration projects. Trades in carbon markets can be used by regulated entities to meet compliance with a mandatory cap-and-trade system, or trades can be voluntary, where individuals or businesses seek to offset their personal carbon footprints.

A **cap-and-trade system** places a limit on the total amount of GHG emissions regulated entities can emit, and allowances for each ton of CO_2e emissions are then either auctioned or distributed to regulated entities. The allowance can be traded amongst entities, and each entity can either buy allowances in order to have enough for compliance or sell allowances to other entities if it has more than it needs.

In addition to emission allowances, some cap-and-trade programs allow unregulated entities to sell **carbon offsets** from emissions reduction or sequestration projects to regulated entities. An offset allows a regulated entity to emit another ton of CO_2e, because an additional ton was sequestered or avoided through the offset project.

Some federal climate legislation proposals have also included **supplemental funding** for mitigation projects. These projects could include emissions reduction or sequestration projects on public or private lands, but the mitigation generated by the projects would not be used to offset emissions from regulated entities. Rather, the mitigation from these projects would add to the emissions reductions accomplished through the cap-and-trade program.

GHG neutrality

In addition to using mitigation on public lands to help achieve a national target as described above, it could also be used to help achieve a domestic goal, such as GHG neutrality for the Federal Government. Because GHG neutrality for the Federal Government would also contribute to national accounting goals, these options are not mutually exclusive. If, however, public lands mitigation is used to offset emissions from regulated entities, then it could not be used to help achieve either of these goals. Within the federal government, climate mitigation strategies have so far largely been focused on energy conservation.[20] However, new policy now requires reporting of GHG sequestration and emissions from federal land management activities (Executive Order 13514, 2009). Here we consider the possibility that the Federal Government chooses to go beyond reporting and consider management of public lands along with its energy efficiency programs to do a complete net accounting of all GHG impacts as a potential means for achieving GHG objectives.

For energy and transportation, the U.S. Department of Energy (2008) reports that Federal Government emissions were roughly 153 $MtCO_2e$ in 2006. Determining emissions from land use is more complicated, as the U.S. GHG inventory does not separate out public lands from private.[21] The inventory of U.S. GHG emissions shows that agriculture and forest lands result in annual net sequestration of nearly 1.1 billion tons CO_2e (EPA 2009a).[22] If even 14% of the net land-use sink was due to land use on federal public lands (which account for 28% of total U.S. land area), the federal government would already be effectively GHG neutral. For this reason, a federal GHG neutrality goal may not provide any additional incentive for increased mitigation on public lands.

Supporting a private carbon market

Implementation of a national cap-and-trade policy would create the largest carbon market in the U.S. and would likely include land use through an offsets program and perhaps through supplemental mitigation programs (Box 1).[23] While a federal program is not yet in place, a number of state (California), regional (RGGI, WCI) and private (CCX, VCS, ACR) carbon market initiatives are moving forward. In most of these programs, emission reduction and sequestration from land use is or likely will be included among eligible mitigation activities.

There are, however, a number of obstacles to developing an offsets program for forests and agriculture on private or public lands. These include (1) developing viable, acceptable, and scientifically founded methodologies and protocols where needed; and (2) addressing environmental integrity risks, such as permanence, leakage, additionality, and scientific uncertainty (see Box 2 for an explanation of these terms). By helping to address these hurdles, public lands could help support private carbon market development or function.

One way that public lands could help support carbon market function is to provide a testing ground for the development and demonstration of project protocols, which are used for the measurement, monitoring, verification, and reporting of GHG mitigation projects. Because testing protocols could involve costs in the form of lost production that comes with a shift in management or in the costs inherent in implementing the protocol (i.e., measurement costs, verification fees, etc.), public lands could facilitate protocol development and demonstration either by bearing these costs directly or by incorporating protocol testing and evaluation into existing management activities. Protocol testing on public lands or by public agencies could also help to avoid proprietary data or confidentiality issues. Nevertheless, it is likely that offset project developers would prefer to carry out testing activities on private lands, as any eventual project stemming from protocol evaluation and implementation may be more easily transitioned into a future carbon market. Private landowner experience with offset protocol implementation would also be helpful in generating feedback over the on-the-ground workability of measurement, monitoring,

[20] See for example section 431 of the Energy Independence and Security Act of 2007 (42 U.S.C. §§ 17001 et seq.), which specifies energy reduction goals for federal buildings, and Executive Order 13423 (2007), which sets energy intensity reduction goals for all federal agencies.

[21] However, the underlying data sources used to compile the U.S. GHG inventory do include information on ownership, so future analyses could estimate government emissions from land use more accurately.

[22] It is important to note that climate change will likely result in increased GHG emissions from wildfires and melting permafrost, potentially reducing the national GHG sink.

[23] Assuming 2 billion tons per year of offsets and $15/ton CO_2, the value of the carbon market could be $30 billion per year. By comparison, the annual market value of corn and soybeans in 2007 was $40 billion and $20 billion, respectively (USDA 2009).

verification, and reporting procedures, as well as in increasing exposure of offsets as an emerging investment opportunity.

> **Box 2.** Common criteria for GHG mitigation activities.
>
> **Additional** – Achieving *additionality* requires that mitigation activities reduce emissions or sequester more carbon than business as usual. If the management activity and resultant mitigation would have occurred anyway, even in the absence of the mitigation policy or program, it is not considered additional.
>
> **Accounting for Leakage –** *Leakage* refers to the possibility that changes in land management practices motivated by the mitigation policy or program could drive changes in land management outside of the boundaries of the intended change. For example, reducing or eliminating timber harvests in National Forests could lead to increased timber harvests on private lands. Leakage can reduce the overall mitigation benefits.
>
> **Managing for Permanence Risks –** *Permanence* usually is used in the context of sequestration projects and refers to the possibility that mitigation actions can be (intentionally or unintentionally) reversed due to events such as forest fires, droughts, pest infestations, or harvest.
>
> **Accounting for Uncertainty** – *Uncertainty* is inherent in the measurement and monitoring of mitigation activities because all of the quantification tools—measurement technology, modeling tools, and calibration and reference data—contain different levels of uncertainty.

Mitigation on public lands could also be used to alleviate integrity risks with private markets by acting as a buffer to cover the inherent environmental integrity risks in an offsets market. A common approach to address these integrity issues is to discount projects based on the risks they hold in each of these areas. Such discounting can significantly affect the financial feasibility of an offset project, however, which could affect overall participation, especially for a new program. Furthermore, it can be seen as unfair to penalize private landowners for some integrity issues, such as leakage, over which they do not have any control. Using mitigation on public lands as a buffer could help avoid these problems by allowing discounts to be reduced or eliminated for program startup or even longer-term.

Using a public buffer to back permanence or reversal risks in private market offset projects could reduce administratively difficult issues regarding changes in ownership and responsibility for sequestration projects over long periods.[24] Additionality is a particularly vexing issue when starting an offsets program and trying to recognize previously initiated good behavior (i.e., early actors). Compensating for a certain level of non-additional projects with new mitigation achieved on public lands would be one possibility. For uncertainty in methods and measurement or leakage, a public lands buffer could be used to correct for errors after the fact, allowing less conservative discounting, while providing some assurance that the atmospheric impact would be addressed.

To use carbon sequestered or emissions avoided on public lands as a buffer, land managers would need to generate additional mitigation, which would then be placed in a reserve buffer that could be drawn upon to compensate for shortfalls in the carbon market(s) due to integrity problems. While the use of public lands mitigation as a buffer may provide multiple benefits for market development, there are limitations that need to be considered. First, as noted before, focusing management of public lands on enhancing

[24] Some have argued that mitigation projects on federal public lands lack permanence because land managers cannot manage certain parcels of land a certain way in perpetuity. While this is true, for public land mitigation to act as a buffer for private offsets projects, only the overall amount of mitigation would have to be maintained, not the management of particular parcels.

GHG mitigation can result in significant tradeoffs for other uses and benefits from public lands, including water quantity (Jackson et al. 2005; Farley et al. 2005) and biodiversity (Nelson et al. 2008). Second, because there are increasingly uncertain risks of leakage and reversal for carbon stored on public lands, it may not be a sound policy to use these lands for a buffer. Third, proposed national cap-and-trade policies include a domestic offsets program with up to 1 billion metric tons per year, a majority of which would come from land use. Although variable, several existing GHG protocols use set-asides or buffers of approximately 20%[25] to address risk (including one or more of the following risks: leakage, reversals, and measurement uncertainty). Using this percentage as a single point estimate of potential buffer size, a 1 billion metric ton market would require approximately 200Mt of buffer per year. Our rough estimates suggest that public lands could at best provide coverage for part of this market (federal lands alone would at most provide ~50Mt). Thus a public lands buffer may not be sufficient to cover a large national program, but could perhaps play a partial role or work for smaller state or regional programs. Furthermore, it is important to avoid moral hazard issues, meaning that some incentive should be provided for individual offset project developers to minimize risks of reversal; otherwise the government could be incentivizing riskier projects by assuming responsibility for reversals.

Participating in a private carbon market
Finally, it is possible that additional mitigation generated on public lands could be sold in private carbon markets, potentially generating funding for public lands management in the process. The idea of selling mitigation from public lands has already received some support in Congress. Sen. Wyden, chairman of the Energy and Natural Resources subcommittee on Public Lands and Forests, has stated that he will push for inclusion of public lands in a federal offsets program (Straub 2009). However, several environmental groups have raised questions about allowing offset projects on public lands, stating that projects could interfere with existing management mandates and require land managers to spend time and scarce resources on monitoring and verification.[26] Opponents to offsets from public lands also point out that the use of federal funds to generate offsets could result in competition with private offsets developers, potentially discouraging investment by the private sector. Moreover, USDA Forest Service Chief Tidwell has questioned the role of the federal government as both a seller and regulator of offsets (Straub 2009.) The net effects of offsets from public lands on the private offsets market, however, will clearly depend on the size of the market; if the market is large enough, competition from projects on public lands would likely not be an important issue. Again using our rough estimate, public lands may supply at most 10% of a 1 billion-ton domestic offsets market from H.R. 2454.[27]

The cost-effectiveness and potential for net revenue from offset projects on public lands will depend on the market price of carbon. The EPA has suggested that carbon prices for a national cap-and-trade program could be \$15/ton CO_2e in the early years (EPA 2009b). Combining this price with the GHG mitigation benefits estimated above, we provide a back-of-the-envelope estimate of the costs and potential carbon revenue from offsets on public lands:

- GHG mitigation revenue generated by ceasing timber harvests on all public lands would average \$1.3 billion per year, which compares favorably with revenue from timber harvests on all state and federal public lands in 2005 of approximately \$800–\$900 million (Depro et al. 2008).[28]

[25] Note that some protocols include buffers that may be compounded (e.g., separate additive buffers for leakage, reversal risk, uncertainty, etc.), increasing total set-aside above 20% (See, e.g., Galik et al. 2009).
[26] To see a letter from the environmental NGOs to USDA and the Department of Interior, visit http://wilderness.org/content/pr-climate-20100106.
[27] EPA analyses of H.R. 2454 and the American Power Act have suggested that initial offsets supply could fall short of the binding limit (EPA 2009b; EPA 2010). Furthermore, some of the most recent proposals before Congress have suggested reducing the total number offsets allowed for compliance. In both cases, public lands would be able to supply a higher percentage of the domestic offsets supply.
[28] Revenue from ceasing timber harvests in National Forests is \$595 million per year for the period 2010–2050. The potential revenue from state and other public lands is \$668 million per year for the same time period.

However, these estimates do not include discounts to address the risk of impermanence or the potential for leakage, which can vary substantially by region and forest type (Murray et al. 2004).

- The cost of rangeland carbon sequestration projects has been found to vary substantially by soil (de Steiguer 2008) and project type (Campbell et al. 2004), ranging between $1 and $37 per ton CO_2e sequestered. In most cases, however, project costs were less than $5 per ton of CO_2e sequestered, which could make many projects economically viable.

- Data is scarce on the costs of wetland restoration for carbon sequestration, but one study found that the cost of restoring wetlands can outweigh the potential carbon revenues in many cases (Hansen 2009). However, cost estimates vary widely depending on wetland type and location.[29]

Should public lands be eligible for participation in private carbon markets, managers of federal and state lands could have a coordinated top down approach for engaging in carbon markets, where they act as an aggregator, the conduit for funding to public lands and the seller of mitigation to private markets. One approach would be to establish a revolving fund where initial seed funds from the agencies or from a climate program could be used to support management changes on federal lands or purchase new lands for mitigation.[30] Land managers could also pursue new, additional, or alternative management objectives that increase GHG sequestration without necessarily increasing costs.[31] Once such mitigation practices have been instituted, land managers could then quantify the mitigation generated on these lands using an accepted protocol and sell the mitigation produced through the coordinating agency into the carbon market. The revenue would refill the revolving fund to continue supporting management for sequestration or emissions reduction on public lands, and if profitable, may be sufficient to support general operating budgets and other management activities.

Alternatively, individual agencies and parts of agencies could develop projects for sale in the carbon markets. This is the model currently being used by the USFWS in its partnership with The Conservation Fund's Go Zero program. In this program donations to The Conservation Fund from individuals or businesses for the purposes of offsetting carbon emissions are used to reforest and restore National Wildlife Refuges (NWRs).[32] The revenue from the carbon market helps pay for restoration that the agency would have had to finance in other ways.

If the overseeing agencies or managers of public lands choose not to develop offsets projects themselves, they could allow projects to be developed by private contractors. For this scenario to work, however, ownership for the carbon and liability for reversals would have to be worked out. In the simplest case, the mitigation project developer could lease the right to sequester carbon and sell offsets from the project on public lands. Similar arrangements are already being made through individual contracts or memorandums of agreement. A partnership between the Forest Service and the National Forest Foundation allows interested individuals to contribute funds that are then used either to reforest existing Forest Service lands

[29] The median cost of wetland restoration ranges from $803 per acre in the Mississippi alluvial valley to $1,907 per acre in the central valley of California. At the estimated rates of carbon sequestration for these regions, a carbon price of $15/ton, and a discount rate of 3%, it would take 12 years to earn enough money through carbon financing to repay restoration costs for projects in the Mississippi alluvial valley; the net present value of projects in the central valley of California is low enough that they would never earn enough money through carbon financing to repay restoration costs.
[30] A potential model for this is the Knuston-Vandenberg Act (16 U.S.C. §§ 576-576b), by which the Secretary of Agriculture can collect funds from the sale of national forest timber to fund reforestation and restoration projects.
[31] However, changes in the management of public lands could alter what is considered additional. If an agency begins managing its lands specifically for the purpose of increasing GHG mitigation, the resulting mitigation might then be considered non-additional and therefore ineligible for offsets. Offsets would only be allowed from GHG mitigation occurring above and beyond that which is produced from existing and planned management activities. Given limited funds for land acquisition, offsets that allow for the purchase of new public land would likely more easily be seen as additional.
[32] For more information on The Conservation Fund's Go Zero program, see http://www.conservationfund.org/gozero.

or to acquire and afforest new lands for incorporation into the National Forest system.[33] This model does not allow for participating individuals to claim ownership for stored carbon, only to offset personal emissions in a voluntary setting. A different approach is being pursued by the Fish and Wildlife Service on NWR lands, in which outside entities are able to reserve sequestered carbon for later reporting or marketing.[34] As is the case with the Forest Service-National Forest Foundation model, NWR-affiliated projects can consist of either restoration work on already-owned NWR lands or the purchase and restoration of additional lands and subsequent transition to the NWR system.[35] For example, the Trust for Public Land has donated more than 6,770 acres to the Tensas River National Wildlife Reserve in Louisiana, but it retained the rights to the carbon from reforested trees to help finance the project (Morrow 2007). If either of these two general models is to be used in an expanding offsets market, rules for the development of offsets on public land by private contractors issued at the agency, interagency, or congressional level could help facilitate private-actor involvement.

Although most projects in the voluntary market are governed by some sort of contract or agreement spelling out specific project requirements and obligations, rules regarding liability for noncompliance in a mandatory market could be significantly more onerous. Liability for reversals would likely be held by private contractors, despite their limited influence on the management of public lands immediately surrounding the project. This could subject the project to reversal risk that would be difficult to mitigate. Nevertheless, these reversal risks could potentially be estimated and reflected in discounts on offsets generated from these lands. Land management agencies would also need to clearly identify their exposure to liability before deciding if they wish—or are even able—to move forward with offsets projects.

Conclusions

Given limited available information, we estimate that roughly 50 $MtCO_2e$ of additional GHG mitigation can be generated each year from both federal and state lands (totaling around 100 $MtCO_2e$ each year), in the next few decades, through shifting management. In our estimate most of this comes from an estimate of stopping timber harvest from one study. There are a number of other activities that could potentially contribute lesser amounts of mitigation on public lands, but we do not have enough information to include them. It is also important to note that this estimate does not account for competing uses of lands that could limit availability of land for mitigation activities.

While 100 $MtCO_2e$ each year would be a significant contribution from public lands, more than total emissions from U.S. land use (42.9 $MMTCO_2e$ in 2007; EPA), it seems small compared to the scale of the private domestic offsets market proposed in recent cap-and-trade legislation (1,000 $MtCO_2e$ per year; H.R. 2454, 2009).

In the process of estimating the potential GHG mitigation from projects on federal and state public lands, we identify several gaps in available data and information that should be addressed. Areas for additional research include:

1. disaggregating the EPA GHG inventory, which currently aggregates public and private lands, to fully determine the GHG flux from public lands alone;
2. examining GHG benefits from afforestation and reforestation projects and from reducing (rather than simply eliminating) timber harvests on public lands, as well as the implications for leakage to private lands;

[33] See Modification No.1 to Master Memorandum of Understanding No. 1993-SU-11130000-035 between the National Forest Foundation and U.S. Forest Service, Washington Office. July 25, 2007. Retrieved June 2, 2009, from http://www.fs.fed.us/ecosystemservices/pdf/NFF_MOU_aug2007.pdf.
[34] This program is also facilitated through a partnership between the Fish and Wildlife Service and The Conservation Fund, but it is distinct from the Go Zero program.
[35] See, e.g., http://www.fws.gov/southeast/carbon/ (Retrieved June 1, 2009); http://www.gocarbonzero.org/gozero (Retrieved June 1, 2009).

3. improving research on GHG impacts and reversal risk of natural disturbances, such as fire, pest infestation, disease, wind, and drought;
4. continuing research to determine more accurately net GHG fluxes from improved management and restoration of public rangelands, wetlands, and fire-prone systems, as well as the types of projects in these ecosystems that will yield net positive GHG benefits;
5. understanding the co-benefits and tradeoffs of managing for GHG mitigation; and
6. understanding the effects of projected changes in temperature, precipitation, and atmospheric CO_2 concentrations under climate change on ecosystem productivity and carbon storage.

Managing public lands to enhance GHG mitigation where other uses are enhanced or maintained (e.g., improved rangeland management, wetland restoration, reforestation, acquisition of new land) seems a straightforward approach for public land managers, especially where costs of shifting management are low or compensated. Such management of public lands could simultaneously meet existing mandates while assisting in the achievement of national commitments under international agreements. However, to increase GHG mitigation in other situations federal and state agencies would likely need to see support for these types of activities through policy adjustments and in many cases new funding strategies.

Existing executive and proposed legislative actions designed to achieve GHG reductions in the federal government have focused on energy efficiency and have not yet explicitly included management goals for increasing GHG mitigation on public lands. That said, a federal GHG neutrality objective (which would include public lands) is unlikely to provide strong incentive for additional mitigation as federal lands may already provide a large enough sink to offset federal government emissions. As such, objectives designed to enhance mitigation on public lands would need to be developed independently of or in addition to a federal GHG neutrality target.

The government could provide support to a private carbon market where investment may be inefficiently allocated by the private sector, such as the testing and demonstration of new offsets protocols. Government support could also serve to reduce transaction costs, increasing market efficiency and liquidity, for example by using public lands as a buffer to reduce environmental integrity discounts with offset projects. However, shifting management on public lands to support private carbon market function raises a number of concerns. There are questions about whether public resources should be used to support the development of a private market. Are there tradeoffs with enhancing mitigation that would negatively impact other public uses of these lands, other ecosystem services, or opportunities for climate adaptation? There is also a question about scale. If the market is large, public lands could only provide minimal support for the new market. Overall, it seems like public lands could only provide a small level of market support and should probably only do so in cases where mitigation created positive co-benefits for other public uses.

Public lands could also participate directly in private carbon markets through federally established revolving funds, development of individual projects, or by allowing federal contractors to engage. In light of the multiple other objectives for which public lands are managed, we suggest that when engaging in the carbon (or other ecosystem service) markets, government agencies entrusted to manage public lands carefully consider whether a project creates positive co-benefits or at the very least has no negative impact on other public uses or objectives. While carbon (and other emerging) markets could help support improved management on public lands (e.g., restoration), some are concerned that the supply of GHG mitigation from public lands could harm private market engagement by undercutting involvement of private lands that are sometimes under greater pressure for development or conversion to other uses. If the carbon market is sufficiently large, the contribution and competition from public lands may be relatively insignificant. However, significant involvement of public lands could have considerable effects on smaller or regional markets with more localized buyers.

Perhaps emerging carbon markets, along with other ecosystem services markets, will provide new ways to consider and finance the multiple-use mandates of federal lands, particularly for those lands now focused on natural resource production. We provide several policy frameworks that could encourage ecosystem management on public lands in the context of GHG mitigation. However, it is critical that public lands management not be driven completely by markets for an individual ecosystem service, because maximization of a single service may compete with other important uses of public lands and the services they provide.

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for more information please contact:

Nicholas Institute for Environmental Policy Solutions
Duke University
Box 90335
Durham, North Carolina 27708
919.613.8709
919.613.8712 fax
nicholasinstitute@duke.edu
nicholasinstitute.duke.edu