

Estimation of Potential Losses from Ozone Damage to the Great Smoky Mountains National Park's Climate Regulation and Water Provision Services

Andrew Bingham



FEDERAL AGENCY EXPLORATIONS AND APPLICATIONS: CASE 14
National Park Service

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Andrew Bingham, National Park Service

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About This Document

This case is part of the Federal Resource Management and Ecosystem Services (FRMES) Guidebook created by the [National Ecosystem Services Partnership](#) (NESP). NESP, housed at the [Nicholas Institute for Environmental Policy Solutions](#), seeks to enhance collaboration within the ecosystem services community and to strengthen coordination of policy implementation and research at the national level. The FRMES Guidebook represents a collaborative effort by federal agencies and outside experts to develop a credible and feasible approach to incorporating ecosystem services into the decision-making processes of federal agencies.

Cases are written and approved by the author(s)' agency, but they have not been peer reviewed. They describe the decision-making context within which that agency is considering or testing an ecosystem services management framework, and they present approaches or innovations that the agency is using to incorporate ecosystem services into its planning and decision-making processes. Cases informed development of the FRMES Guidebook and could be of value to others embarking on ecosystem services planning and management efforts.

To read other federal agency explorations and applications of an ecosystem services management framework, visit www.nespguidebook.com.

CONTENTS

Motivation.....	2
Decision Context.....	2
Location.....	3
Key Players, Existing Resources, and Organizational Capacity	3
Analysis	3
Implications	4

Motivation

The mission of the National Park Service (NPS) explicitly recognizes the strong connection between natural landscapes and human well-being:

The National Park Service preserves unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world. (<http://www.nps.gov/aboutus/index.htm>)

The public generally appreciates the recreational, educational, and inspirational benefits provided by the national parks, but it may be less aware of the many other vital ecosystem services provided by parks—services that may be relevant to decisions regarding park management and protection. A benefit of applying an ecosystem services framework to decision making is to illuminate the less apparent ecosystem service tradeoffs associated with these decisions.

The NPS undertook a study to educate the public and NPS partner resource management and regulatory agencies about the importance to human well-being of two important services provided by Great Smoky Mountains National Park: climate stabilization (via changes in carbon sequestration potential) and water provision (via streamflow changes). Although national parks are among the most protected areas in the country, some threats to park ecosystems—such as air pollution—originate outside the jurisdiction of the NPS and can have detrimental effects on park resources. Integrating ecosystem service concepts, such as those evaluated in this study, into air quality management decisions provides a more complete picture of the effects of air pollution on people and communities. The NPS accordingly undertook this study to establish the foundation and provide context for measures that other state and federal agencies may undertake to improve air quality.

Decision Context

The National Park Service holds no regulatory authority with respect to air pollution control, yet it is charged in its Organic Act (16 U.S.C. § 1) with conserving resources unimpaired for future generations. It is therefore in the interest of the NPS to work cooperatively with regulators and other stakeholders to prevent or minimize air quality-related threats to national parks.

Ground-level ozone is a human-made pollutant that can damage vegetation and upset the water balance of forest ecosystems. Specifically, ozone damage to vegetation in forests can (1) reduce the potential for the ecosystem to remove carbon dioxide from the atmosphere through reduced tree growth and carbon accumulation, and (2) increase water loss through impairment of leaf stomata, which enhances evapotranspiration, increasing water use by the tree and thereby decreasing streamflow.

This study demonstrates to the regulators and other stakeholders the feasibility and importance of integrating these kinds of ecosystem service concepts into their program and policy analyses. The U.S. Environmental Protection Agency (EPA) is responsible for the development and enforcement of most atmospheric pollutant regulations as directed by the Clean Air Act and its amendments. The EPA sets ambient air standards for several pollutants of concern to the National Park Service, including ozone (O₃), sulfur oxides (SO_x), and nitrogen oxides (NO_x). A primary standard is set for human health protection and a secondary standard is set for environmental and ecosystem protection. Although to date all secondary

standards have been set equal to primary standards, the EPA makes explicit use of effects to ecosystem services in its discussions of secondary standards, as outlined in other case studies in this guidebook. These examples of effects on protected areas such as national parks can help inform regulatory and policy development and implementation.

This framework can provide an additional tool for evaluating effects to park resources from changes to air quality in a number of management contexts. Ecosystem services frameworks are often used to evaluate tradeoffs inherent in alternative land use scenarios. Studies such as this one can help NPS, its partners, and the public better understand tradeoffs and costs associated when air pollution interacts with protected park ecosystems.

Location

This analysis is based on the deciduous forest ecosystems of Great Smoky Mountains National Park. The park, straddling the border of North Carolina and Tennessee, is the headwaters for 45 watersheds, and it protects more than half of the old-growth forest remaining in the eastern United States. The NPS chose this site for study because of observed damage to park resources from ozone pollution, which can sometimes reach levels higher than those in nearby urban areas such as Atlanta or Knoxville. The relatively large area of the park also suggests that the natural benefits it provides to nearby communities are likely substantial. Furthermore, by focusing on this site, the NPS was able to leverage existing site-specific studies quantifying the effects of ozone exposure on tree growth and streamflow and to take the next step toward translating these ecological effects into meaningful measures of changes in human well-being.

Key Players, Existing Resources, and Organizational Capacity

This analysis, undertaken by the National Park Service's Air Resources Division (ARD), is based on existing data and studies in the ecological scientific literature. The NPS as a whole and the ARD specifically have a strong commitment to developing an ecosystem services approach to highlight the positive contributions of protected areas to human well-being. NPS ARD staff have been building the skills and capacity needed to use ecosystem services frameworks to protect park resources from damaging air pollution.

Although no mandate requires this analysis, the NPS undertook it in recognition of the critical need for information on the implications of air quality management on protected landscapes and their associated ecosystem services. The NPS hopes to promote interest in further studies to better quantify the effects of air quality changes on ecosystem services. Subsequent studies may benefit from a broadened scope and additional primary data gathering and therefore would likely require additional funding and capacity, which might be obtained through partnerships with other experts (such as modelers), other agencies, academics, and other stakeholders.

Analysis

Using peer-reviewed studies conducted on similar ecosystems in and near Great Smoky Mountains National Park, the NPS estimated the potential loss from ozone damage to two ecosystem services: climate regulation (through the intermediate service of carbon sequestration) and water provisioning (through streamflow). These ecosystem functions benefit humans by helping to mitigate climate change

and all its negative impacts and by providing downstream beneficiaries with water for drinking and other household use, agriculture, recreation, and hydropower.

Quantified changes to the ecosystem due to air pollution have been translated into changes in the benefits humans receive from these same ecosystems. The study employs the following general methodology:

- Compare ecosystem services production at different ozone concentrations in order to estimate changes in that production at alternative ozone concentrations. Ozone levels to be compared were those used in peer-reviewed and published studies in and near the park.
- Using empirical values from existing studies, calculate effects over the scale of the entire park. This task was achievable because the data were from ecosystems in or near the park and because the studies aggregated individual species' responses to provide an estimate of the overall forest response.
- Identify meaningful indicators of the effects of these ecological changes on people and quantify the magnitude of those effects. Once estimates for carbon sequestration and streamflow reductions from ozone damage over the entire park were obtained, they were translated into tailpipe emissions and population served. These indicators were chosen due to their familiarity and importance to the general public and decision makers.

By quantifying the reduction in tree growth and streamflow due to ozone damage over the entire area of Great Smoky Mountains National Park, this analysis found that carbon sequestration losses in the park can reach 500,000–960,000 tons of carbon per year when ozone concentrations are at high levels. It also found that when ozone concentrations are raised by 25%, streamflow may be reduced by 109.6 million cubic meters during the dry months of August through October. Although rough, these estimates reveal the potential magnitude of the effects that air pollution can have on ecosystems and the services they provide.

Figure 1. Potential Magnitude of Air Pollution Effects on Ecosystem Services.

Study	ANPP g C m ⁻² yr ⁻¹	GSMNP t yr ⁻¹	Is 40% of (t)	Difference (t)	Equal to cars yr ⁻¹
Busing (2005)	860	1,437,760	2,396,266	958,506	688,686
Curtis <i>et al.</i> (2002)	446	745,629	1,242,714	497,085	357,156

Deciduous in GSMNP (m²): 1.67 billion

Avg Car Emissions yr⁻¹ (t C): 1.4

In addition to quantifying resource losses, this analysis transferred these losses to other metrics in order to make the information more understandable and relevant for policy makers and the general public. The 500,000–960,000 tons of annual carbon sequestration loss is equivalent to the amount of carbon emitted by approximately 360,000 to 690,000 automobiles per year. Approximately 109.6 million cubic meters of reduced streamflow is equivalent to the amount of water used by some 500,000 local residents during a three-month period. These findings help illuminate the important contributions that ecosystems without ozone damage make to human well-being and highlight the need to mitigate pollutant source emissions.

Implications

This analysis is the first step in illustrating how underappreciated benefits that protected lands provide to people and communities are threatened by air pollution. Ideally, it will provide additional justification for

reducing pollution emissions that lead to high levels of ozone as well as promote additional research on the effects of air pollution on ecosystem services.

The purpose of translating the loss of carbon sequestration in terms of automobile emissions and the reduction of streamflow to impacts on a variety of municipal water users was to articulate for policy makers and the public two of the services provided by an ecosystem in the absence of ozone pollution. The NPS may examine other ecosystem services and consider other benefit-relevant indicators to communicate this information as part of future studies. The ability to translate the detrimental effects of air pollution on park resources into tangible effects on people is crucial to demonstrating that sound air quality management has numerous anthropic benefits.

Monetizing changes to ecosystem services is not always appropriate or necessary. Because NPS is not focused on balancing multiple uses in the same manner as some other federal agencies, it thinks that monetization would not be an appropriate approach. Articulating benefits derived from protected ecosystems can be more informative for decision makers and stakeholders, though monetization could be undertaken in a subsequent analysis, for example, by evaluating carbon change using social cost of carbon values. Uncertainty in monetary estimates as well as unfamiliarity in translating aggregate monetary damages to a personally meaningful value also inhibits the value of monetization for conveying the extent of damages to non-experts. However, in many cases, the use of benefit-relevant indicators (such as water consumption in this analysis) or other metrics (such as tailpipe emissions) can be not only more appropriate, but also more powerful in conveying the various ways that air pollution impacts on an ecosystem can personally affect those who depend on the resources that a park provides.

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About the National Ecosystem Services Partnership

The National Ecosystem Services Partnership (NESP) engages both public and private individuals and organizations to enhance collaboration within the ecosystem services community and to strengthen coordination of policy and market implementation and research at the national level. The partnership is an initiative of Duke University's Nicholas Institute for Environmental Policy Solutions and was developed with support from the U.S. Environmental Protection Agency and with donations of expertise and time from many public and private institutions. The partnership is led by Lydia Olander, director of the Ecosystem Services Program at the Nicholas Institute, and draws on the expertise of federal agency staff, academics, NGO leaders, and ecosystem services management practitioners.

About the Nicholas Institute for Environmental Policy Solutions

Established in 2005, the Nicholas Institute for Environmental Policy Solutions at Duke University improves environmental policymaking worldwide through objective, fact-based research in the areas of climate change, the economics of limiting carbon pollution, emerging environmental markets, oceans governance and coastal management, and freshwater management. The Nicholas Institute is part of Duke University and its wider community of world-class scholars. This unique resource allows the Nicholas Institute's team of economists, scientists, lawyers, and policy experts not only to deliver timely, credible analyses to a wide variety of decision makers, but also to convene decision makers to reach a shared understanding of this century's most pressing environmental problems.

For more information about the
Federal Resources Management and Ecosystem Services Guidebook,
visit www.nespguidebook.com.

For more information, please contact:

Lydia Olander
E-mail: Lydia.olander@duke.edu
Phone: 919-613-9713
Web: <http://bit.ly/1zCpSnt>

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