

Ozone Effects on Ecosystem Services at Great Smoky Mountains National Park



Introduction

Ground-level ozone (O₃) has long been known to be damaging to vegetation. Here, we have utilized the results from studies conducted in Great Smoky Mountains NP on the effects of ozone pollution on deciduous forest to estimate the effects to two ecosystem services: carbon sequestration and provision of drinking water.

Ozone Effects on Vegetation

Ozone is thought to damage vegetation through reduced photosynthesis and cellular damage, as well as reduced stomatal responsiveness. Reduced photosynthesis can lead to reductions in biomass accumulation while decreased stomatal responsiveness can result in increased stomatal and canopy conductance, leading to decreased soil moisture and stream flow.

Great Smoky Mountains National Park



Great Smoky Mountains National Park straddles the border of North Carolina and Tennessee in the Southeast USA and covers an area of 211,415 hectares. High levels of O₃ have been a concern at the park since the 1970's and can be twice the levels in nearby cities such as Knoxville or Atlanta.

Carbon Sequestration

The mean temperature on the Earth has been rising over the last century or so due to manmade emissions of several greenhouse gases, chief among them, carbon dioxide (CO₂), as well as due to land use change, especially the reduction of forested areas. Trees can act as a sink for CO₂ by fixing carbon (C) during photosynthesis and sequestering it as biomass.

A recent study found that in a high ozone year, stem growth in deciduous trees in the Southeast USA was reduced by around 40%, reducing forest carbon sequestration (McLaughlin, 2007a).

Results of Analysis

- Estimates of Aboveground Net Primary Production (ANPP) in Southeast USA deciduous forests range from a low of 446 g C m⁻² yr⁻¹ from modeling results to 860 g C m⁻² yr⁻¹ using tree growth measurements and allometric relationships.
- Deciduous forests in Great Smoky Mountains NP have the potential to sequester from 0.7 to 1.4 M t C yr⁻¹ in aboveground biomass.
- In a high ozone year, tree growth can be reduced by ~40%, resulting in potential carbon sequestration loss of about 500,000 – 960,000 t C yr⁻¹.
- This is the equivalent of the carbon emitted by about 360,000 – 690,000 cars per year.

Provision of Drinking Water

Forested areas are important sources of water used for extractive purposes such as municipal, agricultural and commercial use, as well as in-situ uses such as hydropower, transportation and recreation.

High levels of O₃ exposure can causes stomata to respond slowly to changes in water availability, resulting in increased levels of water use and loss by the tree. This in turn results in decreased soil moisture and reductions in stream baseflow. A modeling study of deciduous forest trees in the Southeast USA suggested that a 25% reduction of maximum daily O₃ levels can result in increases of baseflow by 62% during the dry Aug-Oct period and by 5% annually (McLaughlin, 2007b).

Results of Analysis

- USGS Stream Gauge 03497300 is located close to the park border and almost all water draining from within two watersheds passes this gauge.
- 25.7 M m³ of water originates within deciduous forest areas of Great Smoky Mountains NP within these watersheds and passes this gauge during the dry Aug-Oct period.
- Adding 62% to this amount reveals that streamflow originating in the deciduous area of these two watersheds is reduced by 15.8 M m³ due to O₃ damage.
- Over the deciduous area of the entire Great Smoky Mountains NP this is 109.6 M m³ of foregone baseflow.
- This is the same amount of water used by 498,000 downstream residents during an avg 3-month period.

Conclusions

Increasing the awareness of policymakers about how their decisions affect ecosystem services, including C sequestration and regulation of water quality and quantity, is crucial to preserving those ecosystem services and maintaining the well-being and health of humans and wildlife.

Our approach demonstrates a fast, straightforward and easily comprehensible method for estimating the effects of possible O₃ plant damage to ecosystem services. While this method may entail a greater degree of uncertainty and less precise estimates than a detailed study or process-based model might, the magnitude of the potential losses demonstrates the need for more research. Framing this link in a manner which is accessible to policy makers and the general public is a valuable method for translating these findings into metrics which are easily understood by decision-makers and is an important step towards communicating the effects air pollution can have on protected areas.

Information and References

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McLaughlin SB, Wullschleger SD, Sun G, Nosal M. 2007b. Interactive effects of ozone and climate on water use, soil moisture content and streamflow in a southern Appalachian forest in the USA. *New Phytologist* 174:125-136.