Impacts of Forest Management on Regulating Services in Northern Forest Watersheds: Development of the Forest Ecosystem Services Toolkit

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Completion date:

- Water regulating services, unlike greenhouse gas mitigation and provisioning services, appear to be relatively resilient in the face of forest management
- Ecosystem services are as sensitive to social demand for services as they are to the system's ecological capacity to provide services; in some cases, they are more sensitive.

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http://www.nsrcforest.org
Project Summary

Forests and woodlands of the Northern Forest Region provide society with a variety of important ecosystem services – including wood and other forest products, cultural activities, and regulation of the human environment. These services often go unmeasured. Drawing on a wealth of existing scientific data, we created the Forest Ecosystem Services Toolkit (FEST) to begin the process of quantifying and visualizing the capacity of forests to provide these services. The FEST methodology is based on estimating the ecological capacity of an ecosystem to provide potential services (i.e. “supply”) and the use or hypothetical use of those services by people (i.e. “demand”).

We focused initial work on five ecosystem services: water flow regulation (flood regulation, drought mitigation), water quality regulation, forest growth regulation, greenhouse gas regulation, and the provision of woody biomass for energy and products. We found a clear tradeoff between harvesting intensity and the capacity of the forest to mitigate greenhouse gas emissions. In contrast, we found that regulation of water flow and water quality were relatively resilient in response to harvesting. With these results, FEST provides some initial estimates of the capacity of several sites in the Northern Forest to provide important ecosystem benefits to communities in the region. Our results also highlight the importance of understanding and quantifying social demand for ecosystem services in order to better quantify how forests and our management choices affect human well-being in our local, regional and global communities.
Background and Justification

- Ecosystems, including forests and woodlands, provide important services that confer multiple benefits that serve to increase human well-being.
- It is necessary that ecosystem services be quantified in detailed ways, to understand human dependency on forest systems, as well as to show how forest benefits to society are affected by land use and resource management decisions.
- Regulating services are those ecosystem services that benefit people by directly regulating the human environment (air and water quality, climate, flood frequency and damage, etc.)
- Most studies have focused on the impact of land cover change, such as deforestation, on the services provided in a landscape.
- Few studies have attempted to assess how services change when forests are managed under real-world silvicultural prescriptions.
Background and Justification

- Long-term ecological research (LTER) is an untapped resource to understand the capacity of forest ecosystems to provide multiple types of services
  - often spans decades (50+ years at Hubbard Brook)
  - includes parallel measures of an ecosystems vegetation, water, soils, air, wildlife, etc. over time and space
  - experiments incorporate management treatments at the scale of individual watersheds, making it possible to explore how management may affect groups of services together, and the tradeoffs that may occur due to management
Methods

• Initial FEST workshop held in October 2012
  – 25 attendees, ecological and social scientists
• Attendees were asked to brainstorm methods for estimating ecosystem services from LTER data.
  – Four categories of services: water flow regulation, water quality regulation, forest growth regulation, and greenhouse gas regulation.
• Attendees asked to identify appropriate methods and data for estimating both “supply” and “demand”.

[Diagram showing the relationship between external drivers, ecosystem service capacity, and service use by beneficiary population]
Methods

Long-term data acquired for three sites

- Hubbard Brook, Turkey Lakes, Neversink River Research Watershed
- Stream discharge, water chemistry and forest inventory data
- Climate data and bulk deposition inputs

Thresholds for water regulation services were calculated

- **Flood regulation**, based on flow capacity of dam infrastructure
- **Drought regulation**, based on municipal water withdrawal data
- **Water quality** thresholds based on legal drinking water standards.
Methods

Pollution remediation: ratio of outgoing (stream water) to incoming (rain water) nutrient pollution (N equivalents); if the ratio < 1, the watershed is reducing eutrophication potential of rainwater, which provides a benefit

Greenhouse gas regulation: total carbon in standing trees, storage in long-lived wood products, and use benefit from substitution of biomass for fossil fuels and products

Beneficiary survey:
How do people living near FEST study sites perceive and value different forest ecosystem services?
Sent to 2000 residents
Results/Project outcomes

FEST Knowledge Base
- Relational geodatabase
- 159 datasets
- 150+ R scripts for analysis and modeling

FEST 1.0 website
www.forestecoservices.net allows exploration of results from this project via:
- 31 interactive visualizations
- 4 main service pages
- 9 case studies
Results/Project outcomes

Comparison of treatment and reference watersheds at Hubbard Brook

Changes in water provision are greatest when forest is removed

Managed forests can regulate water quality and quantity

- Forest removal: entire catchment de-vegetated for 3 years
- Strip harvesting: entire catchment in 3 harvests spaced two years apart
- Whole tree harvesting: aboveground biomass removed from entire catchment
Results/Project outcomes

Multiple Site Comparison

We scaled the 10 service metrics to allow for comparison across sites and benefit types.

Biomass removal has largest impact on greenhouse gas regulation.

Smaller impacts on water regulation services.

| CRB = Climate regulation benefit | BMS = Biomass production |
| PRM = Pollution removal benefit | FLD = Flood prevention |
| pH = pH regulation | DRT = Drought mitigation |
| SLF = Sulfate regulation | STB = Flow stability |
| CHL = Chloride regulation | NTR = Nitrate regulation |
Changes in GHG regulation depend on how harvested products are used

- Standing biomass declined after harvests, reducing the carbon storage in the forest.
- When biomass was used for long-lived wood products, this form of storage increased the value of GHG regulation.
- When wood products were used to substitute for more fossil fuel intensive products, the value of GHG regulation increased.
Implications and applications in the Northern Forest region

• Water regulating services of Northern Forest ecosystems are mostly resilient to forest management.
  – Removal of vegetation decreases pollution removal benefits
  – Flood prevention declines and drought mitigation increases (slightly)

• Allowing forest to regenerate is crucial for maintaining services

• Greenhouse gas regulation is sensitive to forest harvesting and how harvested biomass is used.
  – When biomass is used for long-lived wood products, harvesting can immediately increase the GHG regulation potential of a forest. When used to produce biofuels, GHG regulation decreases after-harvest

• Estimates of societal demand for benefits strongly shape these results, but are defined with significant uncertainty

• More information on beneficiaries of Northern Forest ecosystem services is needed to provide better estimates of benefits
Future directions

Next phase of FEST (funded by NYSERDA) is estimating how acidic deposition impacts ecosystem services in the Adirondacks, NY.

Forestry:
• We simulated growth of 20 sugar maple stands occurring on acidic and well-buffered sites, in order to understand how management and soil chemistry jointly determine long-term sustainability of northern hardwood forests and their ecosystem benefits.
Future directions

**Sport fisheries**

- We modeled likelihood of trout vs. other sport fish based on pH and whether or not the lake was stocked (trout).
- Benefit transfer data from Boyle (1999) was used to estimate the expected value of a freshwater fishing trip based on the fish species present.
- Approach can be used to estimate the potential economic damages to sport fisheries resulting from acidification...
- ... and the potential benefits of recovery.

![Graph showing expected value of fishing trips as a function of pH and stocking status](image)
List of products

• **FEST 1.0 website**: [www.forestecoservices.net](http://www.forestecoservices.net)

• **Peer-reviewed publications**
  - Beier, C.M., J.Caputo, and P. Groffman. In Press. Measuring ecosystem capacity to provide regulating services: forest removal and recovery at Hubbard Brook (USA). *Ecological Applications*.
  - Caputo, J., C.M. Beier, V.A. Luzadis, and P. M. Groffman. Under Review. Integrating beneficiaries into measurement of ecosystem services and tradeoffs associated with forest management at the Hubbard Brook Experimental Forest, USA. *Ecosystem Services*.

• **Conference presentations**
List of products

- **Conference presentations, cont.**

- **Theses**
List of products

• **Webinars**

• **Websites and databases**
  – All data associated with FEST (both raw and processed) is stored in the FEST Knowledge Base, a spatially-enabled PostgreSQL database housed on the FEST server. The database is remotely accessible from a database client, the R statistical and analysis platform, Quantum GIS, web applications, etc.
  – The FEST website ([http://www.forestecoservices.net](http://www.forestecoservices.net)) describes the project, provides additional information on the process, and hosts a wealth of interactive visualizations and case studies that summarize and analyze datasets directly from the FEST knowledge base.

• **Leveraged grants**
  – New York State Energy Research and Development Authority (NYSERDA), Accelerated Recovery and Environmental Economics of Mercury and Acidic Deposition (PON 2607) - $165,000.