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

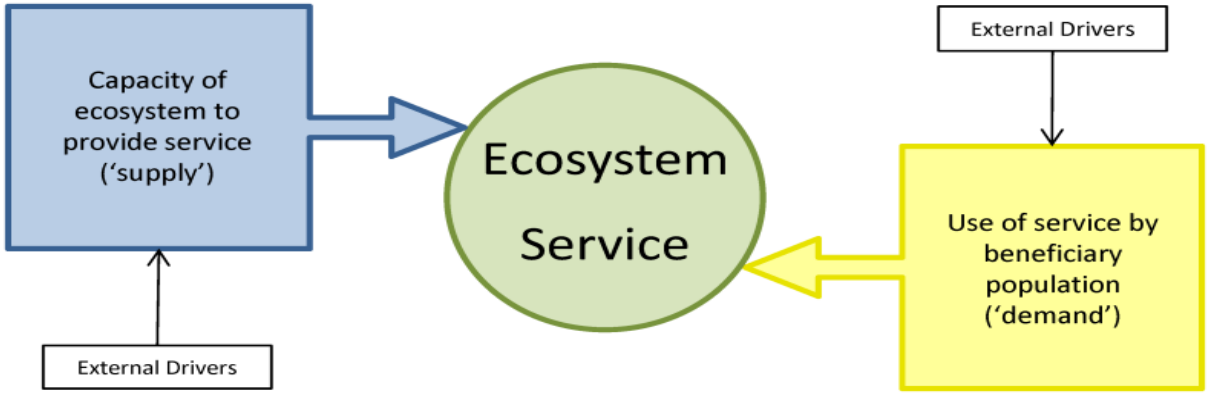
- Ecosystems, including forests and woodlands, provide important services that confer multiple benefits that serve to increase human well-being.
- It is necessary that ecosystem services be quantified in detailed ways, to understand human dependency on forest systems, as well as to show how forest benefits 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

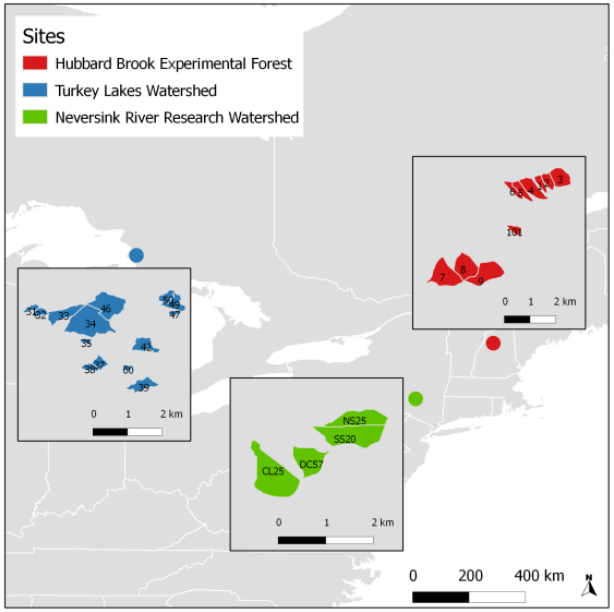
- Long-term ecological research (LTER) is an untapped resource to understand the capacity of forest ecosystems to provide multiple types of services
  - often spans decades (50+ years at Hubbard Brook)
  - includes parallel measures of an ecosystems vegetation, water, soils, air, wildlife, etc. over 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”.

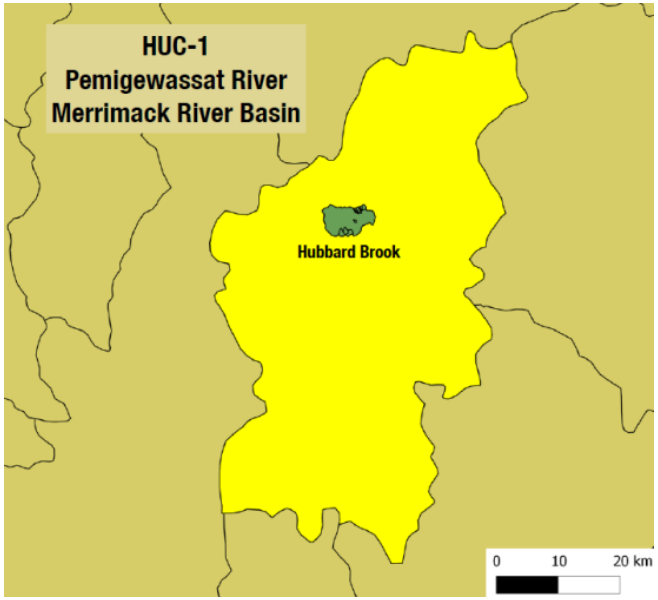


Methods



Long-term data acquired for three sites

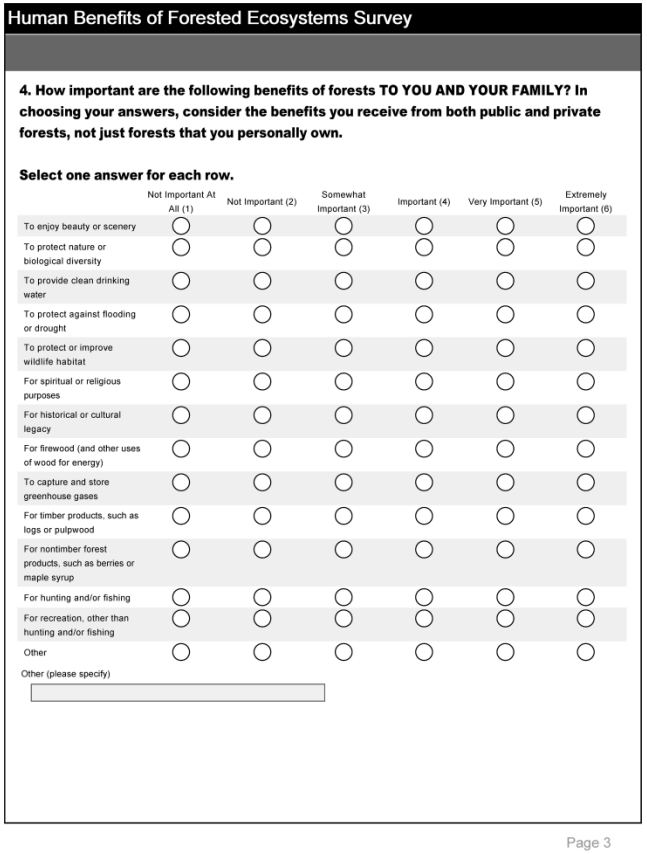
- Hubbard Brook, Turkey Lakes, Neversink River Research Watershed
- Stream discharge, water chemistry and forest inventory data
- Climate data and bulk deposition inputs



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



Human Benefits of Forested Ecosystems Survey

4. How important are the following benefits of forests TO YOU AND YOUR FAMILY? In choosing your answers, consider the benefits you receive from both public and private forests, not just forests that you personally own.

Select one answer for each row.

	Not Important At All (1)	Not Important (2)	Somewhat Important (3)	Important (4)	Very Important (5)	Extremely Important (6)
To enjoy beauty or scenery	○	○	○	○	○	○
To protect nature or biological diversity	○	○	○	○	○	○
To provide clean drinking water	○	○	○	○	○	○
To protect against flooding or drought	○	○	○	○	○	○
To protect or improve wildlife habitat	○	○	○	○	○	○
For spiritual or religious purposes	○	○	○	○	○	○
For historical or cultural legacy	○	○	○	○	○	○
For firewood (and other uses of wood for energy)	○	○	○	○	○	○
To capture and store greenhouse gases	○	○	○	○	○	○
For timber products, such as logs or pulpwood	○	○	○	○	○	○
For nontimber forest products, such as berries or maple syrup	○	○	○	○	○	○
For hunting and/or fishing	○	○	○	○	○	○
For recreation, other than hunting and/or fishing	○	○	○	○	○	○
Other	○	○	○	○	○	○

Other (please specify)

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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

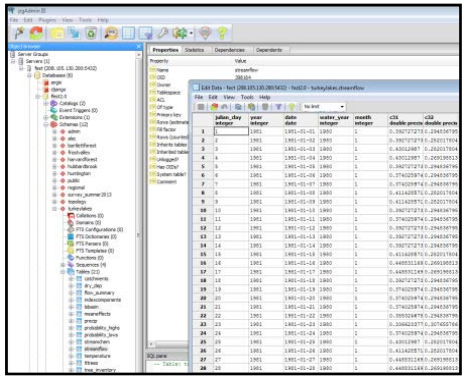
- Relational geodatabase
- 159 datasets
- 150+ R scripts for analysis and modeling

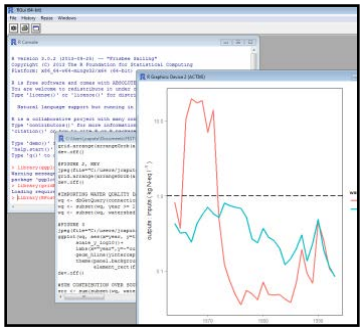
FEST 1.0 website

www.forestecoservices.net allows exploration of results from this project via:

- 31 interactive visualizations
- 4 main service pages
- 9 case studies

FEST Knowledge Base (PostgreSQL)





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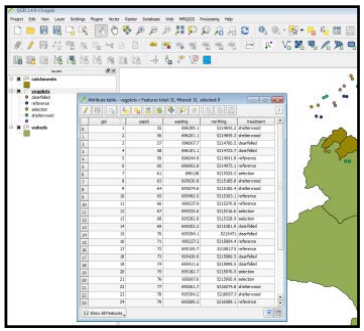
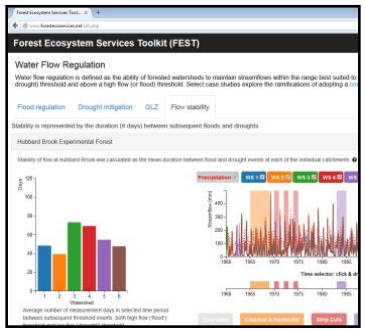


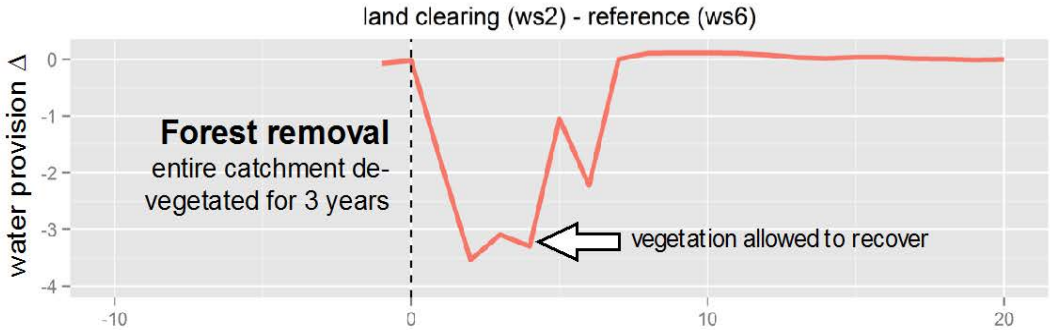
Quantum GIS



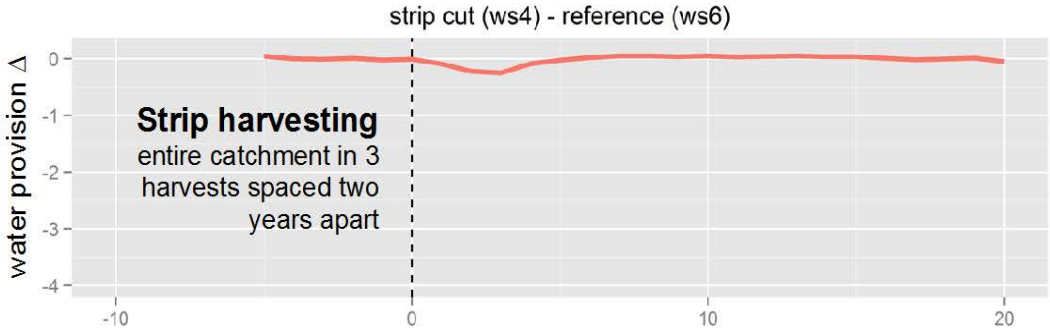
FEST Website

Results/Project outcomes

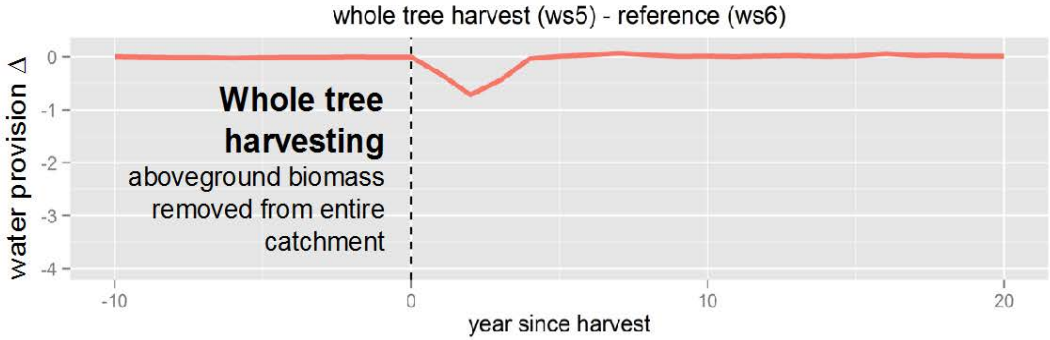
Comparison of treatment and reference watersheds at Hubbard Brook



Changes in water provision are greatest when forest is removed



Managed forests can regulate water quality and quantity



Results/Project outcomes

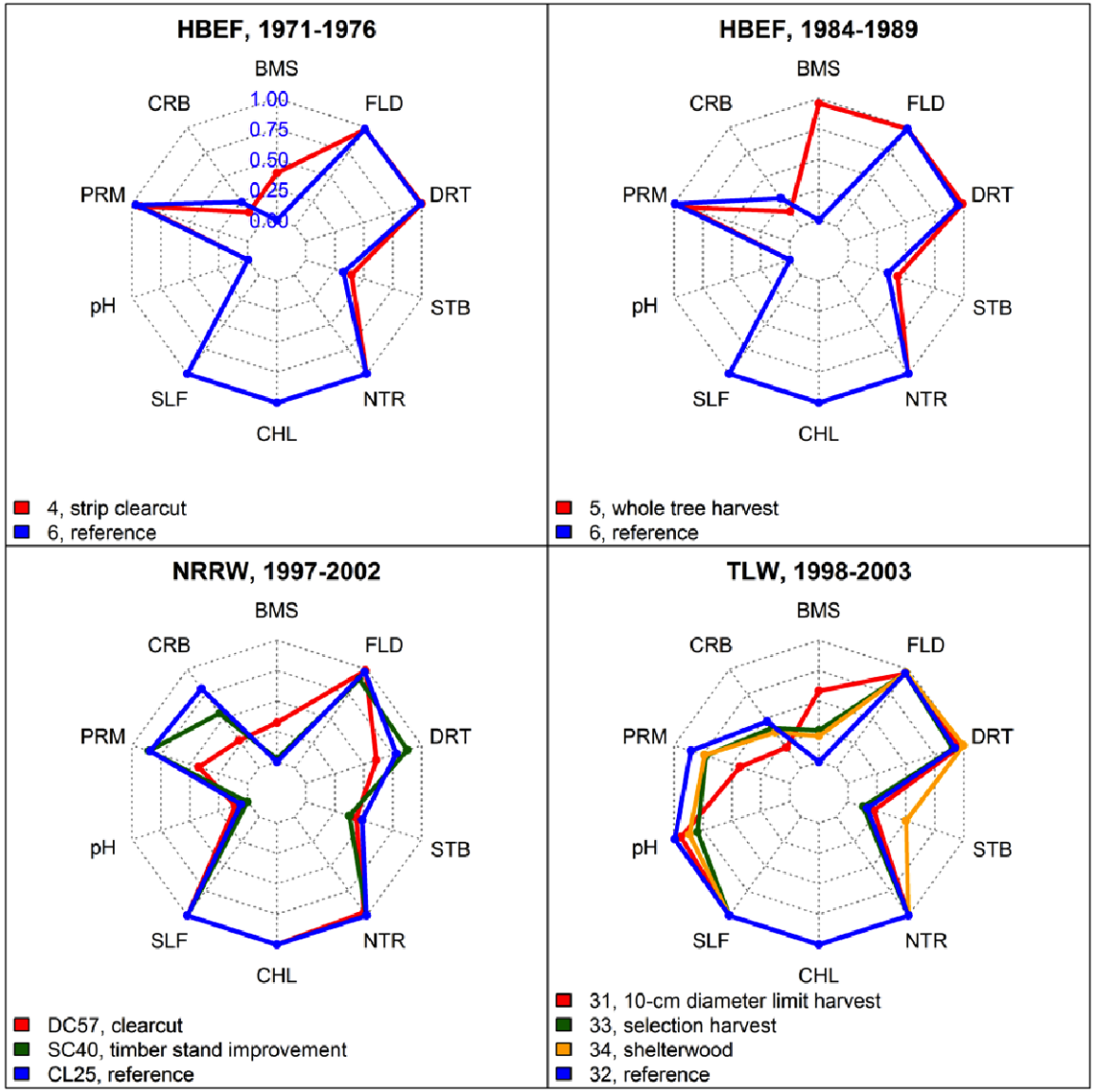
Multiple Site Comparison

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

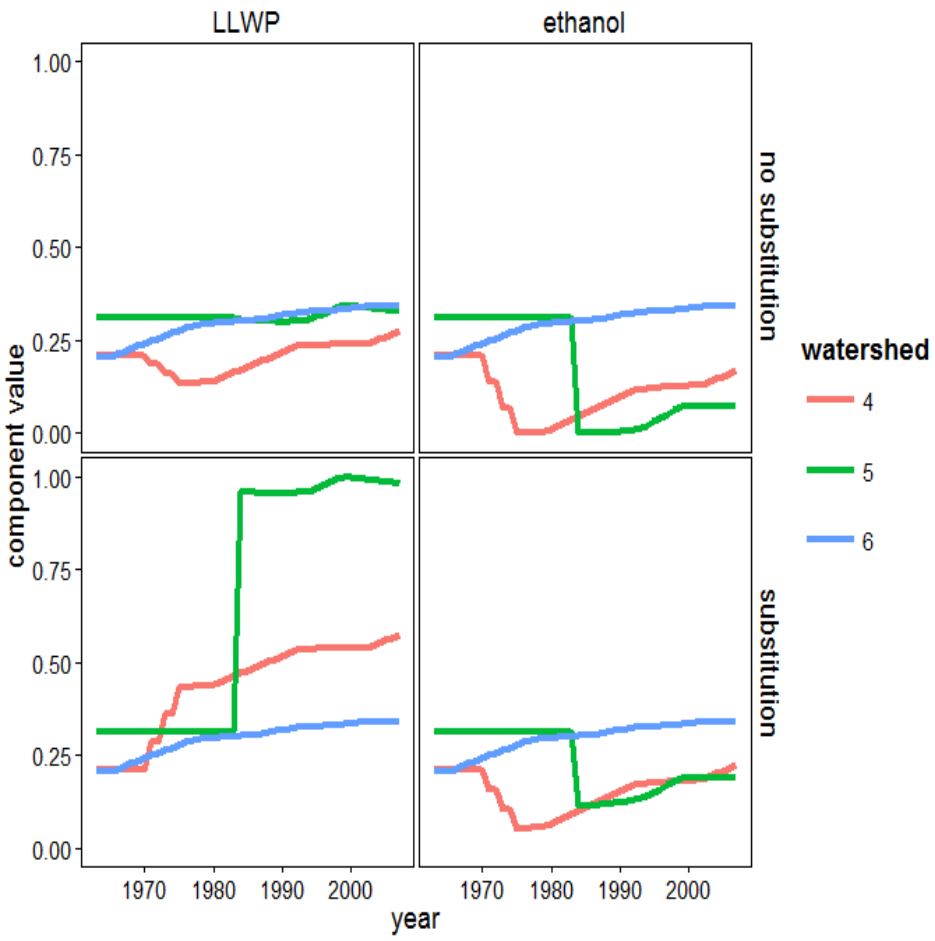
CRB = Climate regulation benefit	**BMS = Biomass production**
PRM = Pollution removal benefit	**FLD = Flood prevention**
pH = pH regulation	**DRT = Drought mitigation**
SLF = Sulfate regulation	**STB = Flow stability**
CHL = Chloride regulation	**NTR = Nitrate regulation**



Results/Project outcomes

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

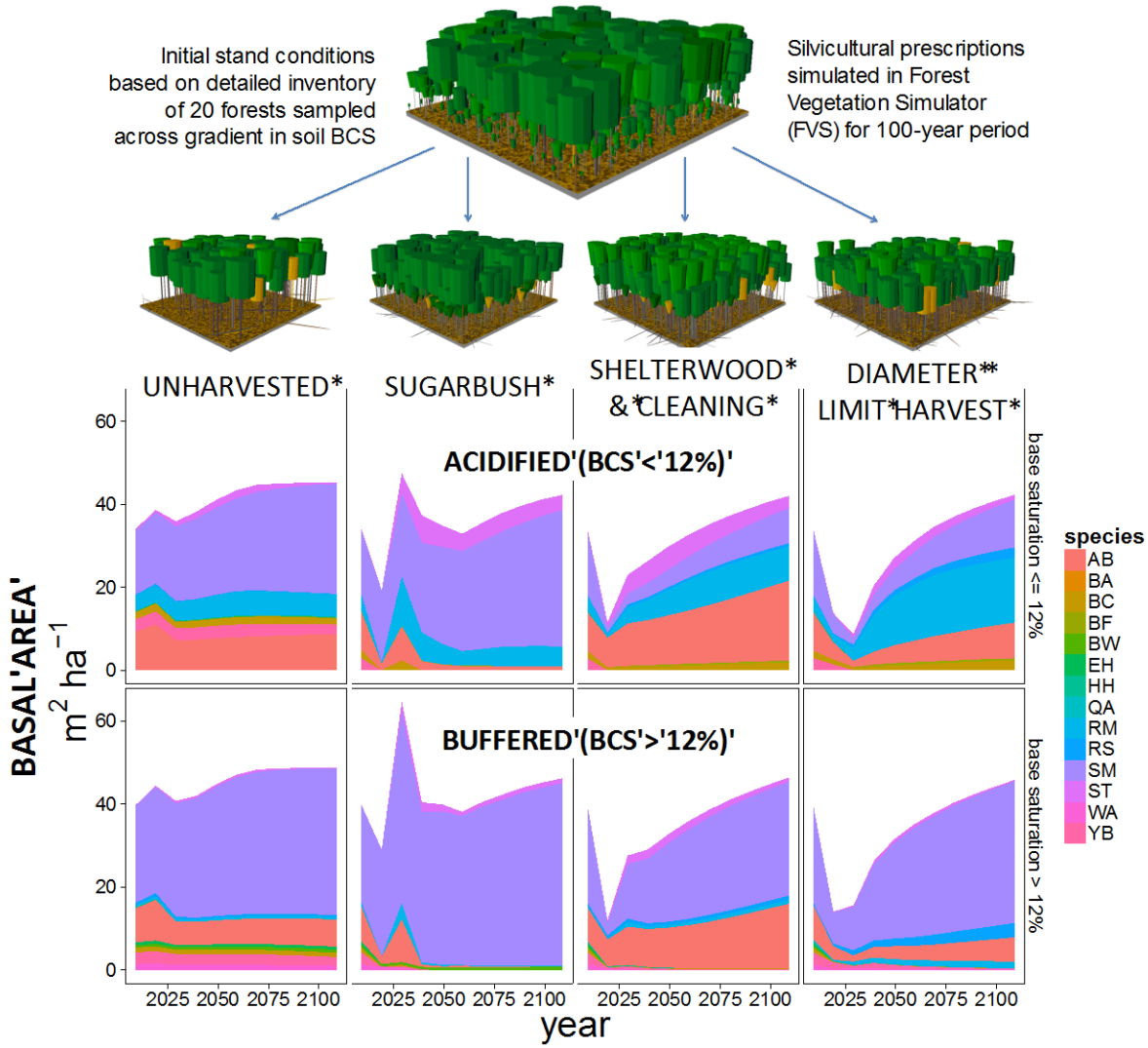
- Water regulating services of Northern Forest ecosystems are mostly resilient to forest management.
  - Removal of vegetation decreases pollution removal benefits
  - Flood prevention declines and drought mitigation increases (slightly)
- Allowing forest to regenerate is crucial for maintaining services
- 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

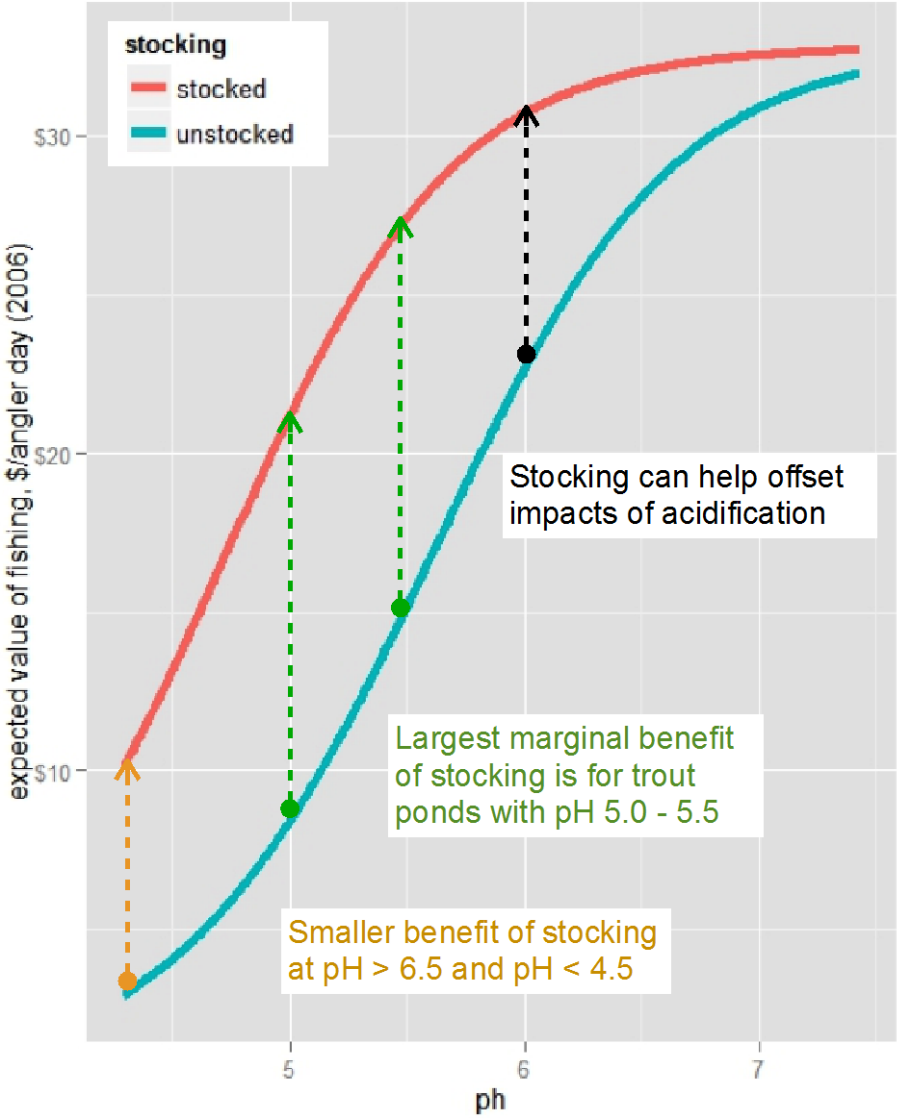
Next phase of FEST (funded by NYSERDA) is estimating how acidic deposition impacts ecosystem services in the Adirondacks, NY.

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



Estimated value of sport-fishing (2006 USD) as a function of lake pH and stocking (of trout)

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

ADIRONDACK LAKES SURVEY CORPORATION
www.adirondacklakessurvey.org

List of products

- FEST 1.0 website: 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.*
  - Caputo, J., C.M. Beier, P.M. Groffman, D.A. Burns, F.D. Beall, P.W. Hazlett, and T.E. Yorks. In Preparation (ex. Completion, 1 April 2015). Effects of harvesting forests for bioenergy on water and climate regulation services provided by forested watersheds in northeastern North America.
- Conference presentations
  - Caputo, J., C.M. Beier, P.M. Groffman, D.A. Burns, F.D. Beall, P.W. Hazlett, and T.E. Yorks. Using the Forest Ecosystem Services Toolkit (FEST) to assess the implications of biomass harvesting on ecosystem services. ACES 2014: A Community on Ecosystem Services, Linking Science, Practice, and Decision Making. 8-12 December 2014. Washington, D.C. *Poster.*
  - Caputo, J. C.M. Beier, F.D. Beall, and F.W. Hazlett. Development of a Forest Ecosystem Services Toolkit (FEST) to estimate impacts of biomass harvesting on ecosystem services. Long Term Ecological Research at the Turkey Lakes Watershed: 35th Anniversary of Interdisciplinary, Cooperative Research. 19-20 November 2014. Great Lakes Forestry Centre. Sault Ste. Marie, Ontario.
  - Beier, C., J. Caputo, and P. Groffman. Assessing the societal benefits of healthy forest ecosystems with the Forest Ecosystem Services Toolkit (FEST). New York State Energy Research and Development Authority (NYSERDA): Environmental Monitoring, Evaluation, and Protection (EMEP) in New York, Linking Science and Policy. 6-7 November 2013. Albany, NY.

List of products

- Conference presentations, cont.
  - Caputo, J., C. Beier, and P. Groffman. Assessing changes in regulating services after biomass removal in the Hubbard Brook Experimental Forest, using the Forest Ecosystem Services Toolkit (FEST). New York State Energy Research and Development Authority (NYSERDA): Environmental Monitoring, Evaluation, and Protection (EMEP) in New York, Linking Science and Policy. 6-7 November 2013. Albany, NY. *Poster.*
  - Beier, C., J. Caputo, and P. Groffman. Assessing the ecosystem service of water provision from northern forest watersheds using the Forest Ecosystem Services Toolkit (FEST). American Water Resources Association (AWRA) 2013 Summer Specialty Conference: Healthy Forests = Healthy Waters. 27-28 June 2013. Hartford, CT.
  - Caputo, J., C. Beier, and P. Groffman. Assessing water regulation services of northern forest watersheds using the Forest Ecosystem Services Toolkit (FEST). Northeastern Ecosystem Research Cooperative (NERC) 2013 Conference. 19-20 March 2013. Saratoga Springs, NY. *Poster.*
  - Beier, C.M. and J. Caputo. Impacts of forest management on regulating services in northern forest watersheds: development of the Forest Ecosystem Services Toolkit (FEST). FEST Workshop 2012. 11 October 2012. Cary Institute of Ecosystem Studies. Millbrook, NY.
  - Beier, C.M. Ecosystem services assessment and the Forest Ecosystem Services Toolkit. Hubbard Brook Committee of Scientists Meeting: Wood Bioenergy in the Northern Hardwood Forest. 5 October 2011. Cary Institute of Ecosystem Studies. Millbrook, NY.
- Theses
  - Caputo, J. 2014. Understanding and assessing the sustainability of woody biomass production in the northeastern United States. Ph.D. Dissertation. SUNY College of Environmental Science and Forestry. 247 p.

List of products

- Webinars
  - Beier, C.M. and J. Caputo. Forests, services, and society: using the Forest Ecosystem Services Toolkit (FEST) to measure how northern forest watersheds support human well-being. USDA Forest Service Northern States Research Cooperative (NSRC) Webinar. 28 May 2014.
- 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) 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.