ECOSYSTEM SERVICES: A NEW NRS-FIA ANALYTICAL SCIENCE INITIATIVE

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Abstract—Forest ecosystem services (ES) are linked to sustaining human well-being. Recognizing an inappropriate economic valuation of ecosystem properties and processes, many ecologists, economists, and political scientists have pushed for an increasing awareness and appreciation of ES. Many definitions of ES include both direct and indirect benefits humans derive from ecosystem properties or processes. The Millennium Ecosystem Assessment (MA) typology classifies ES into four categories: provisioning, regulating, cultural, and supporting services; this framework enables linkages between Northern Research Station Forest Inventory and Analysis (NRS-FIA) research activities and specific services within MA categories.. A subset of those ES for which additional information is needed will be addressed in a proposed NRS-FIA ES science team.

Forest ecosystem services (ES) are linked to sustaining human well-being (Bonan 2008, Millennium Ecosystem Assessment 2005). By the mid to late 1990s, many lines of evidence suggested that the scope of human enterprise had grown large enough to begin seriously impairing ecological processes crucial to human existence. Acknowledged problems ranged from depleted fisheries to large-scale changes in climate due to the burning of fossil fuels. Many ecologists, economists, and political scientists recognized that these problems resulted from an inappropriate economic valuation of ecosystem properties and processes (Costanza and others 1997, Daily 1997). Consequently, researchers from across these fields pushed for an increasing awareness and appreciation of ES. They also called for development of valuation techniques that would better account for ES in economic decisions.

The phrase "ecosystem services" (or a variation thereof) has been independently defined several times (see definitions below) by ecological researchers and economists. From the perspective of raising public awareness, early and still widely cited definitions effectively capture the importance and pervasiveness of ES (Costanza and others 1997, Daily 1997, Millennium Ecosystem Assessment 2005). Broadly, these definitions characterize ES as the direct and indirect benefits humans derive from ecosystem properties or processes. This definition encompasses such widely varying phenomena as the aesthetic experiences natural areas provide to the importance of forest in acting as carbon sinks to buffer against climate change. Stated simply, ecosystem services are the benefits people obtain from ecosystems.

Given the wide variety of ecosystem properties and processes that qualify as ES, this definition is accompanied by a classification framework that helps clarify and highlight the types of benefits humans derive from ecosystems (de Groot and others 2002, Ekins 2003, Millennium Ecosystem Assessment 2005). One commonly cited typology was provided by the Millennium Ecosystem Assessment (MA). The MA recognized four types of ES: provisioning, regulating, cultural, and supporting (Table 1). Provisioning services refer to products (or "goods") people acquire from ecosystems, such as fiber and food. Regulating services stem from the regulation of

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Table 1.—Ecosystem services (ES) associated with forest ecosystems, adapted from a figure in Vernegaard and others (2010). Each service is assigned to a category in the ecosystem services classification framework presented in the Millennium Ecosystem Assessment (2005); see text for definitions of categories. Citations associating each service with forested ecosystems are numbered, with full references listed in the Literature Cited section. [1,2,3,4,5,6,7,8,9,10,11,12]One or more NRS-FIA product lines are associated with each ES.

ES category	Ecosystem services	Relevant citations	FIA product lines
Provisioning	wood products – timber, biomass/ biofuel, fuelwood	[1-10]	timber products output (TPO), biomass, economics
	biodiversity – genetic information, pharmaceuticals	[1-5, 8, 10-12]	Criteria & indicators (C&I) – biodiversity, Northern Forest Futures Project (NFFP), National Sustainability Report
	food – wildlife, nuts, berries, etc.	[1-4, 6, 8, 9]	nontimber forest products (NTFP)
	clean air	[2-5, 8]	ozone, lichens
	clean water	[1-3, 5-12]	water quality – Great Lakes Restoration Initiative (GLRI), NFFP
Regulating	climate regulation – carbon sequestration	[1-4, 6, 7, 9-12]	carbon
	air quality regulation – sequestration of pollutants	[2-5, 8]	ozone
	water regulation – flood control, erosion control, maintenance of water quality	[1-12]	water quantity – NFFP
	regulation of disease and pests	[2, 6, 12]	forest health
Cultural	aesthetic	[2-4, 6, 8, 10]	National Woodland Owner Survey (NWOS), urban
	spiritual/religious	[1-4, 10]	tribal
	recreational	[1-8, 11]	NWOS, NFFP
	educational	[2, 5]	NRS-FIA Techniques Team 1, New York Research Map (RMAP) of tree species distribution (Riemann et al. 2014)
	historical	[1, 2]	Trend analyses, historical map of woodland density (Liknes et al. 2013)
Supporting	biodiversity maintenance – promotes ecosystem resistance, resilience, productivity	[1-5, 8, 10, 12]	Wildlife and fish habitats, landscape structure and function, fragmentation
	nutrient cycling	[2, 3, 8]	soils, carbon, down woody
	soil formation	[2-5]	soils
	primary production	[2, 4]	soils, forest site productivity

[1] Millennium Ecosystem Assessment 2005
[2] Vernegaard and others 2010
[3] Chiabai and others 2011
[4] Cóndor and others 2008
[5] Gaodi and others 2010
[6] Nasi and others 2002
[7] Notman and others 2006
[8] Pattanayak and Butry 2003
[9] Smail and Lewis 2009
[10] Watson 2008
[11] Ghani, n.d.
[12] Myers 1997

ecological processes and include, for example, climate regulation and disease control. Cultural services refer to intangible benefits people derive from their natural surroundings, e.g., spiritual experiences and aesthetic vistas. Supporting ecosystems services make all other types of services possible. They are fundamental processes, such as primary productivity, that allow for the existence and persistence of ecosystems.

ASSESSING FOREST ES WITH FIA

A complex combination of factors affects the extent to which forest ES are realized; some of these factors include the forest characteristics of composition, structure, spatial pattern, and cultural context (Matthews and others 2014). The Forest Inventory and Analysis (FIA) program produces and distributes a wealth of data, information, and knowledge on these forest characteristics. FIA has evolved from a timber survey to a forest inventory and is moving toward a treed-lands inventory that can address a broad array of forest ES.

Each forest resource can be associated with one or more ES. Consider the ES associated with wildlife, for example. One could make a strong case for including wildlife in all four of the ES categories listed in Table 1: (1) Provisioning – food/meat; (2) Regulating - regulation of disease and pests, e.g., bird controls on forest insect pests; (3) Cultural Services – recreation: birding, hunting, etc.; and (4) Supporting Services – maintenance of biodiversity. And, additional wildlife supporting services could be added to this list: pollination, seed dispersal, and scavenging.

FIA provides indicators or proxies for important ecosystem processes or end products. For example, with regards to sustaining wildlife populations, the end product could be viewed as the number of individuals of a particular wildlife species supported within a given forest. Using only forest inventory data sets and habitat models, we cannot estimate actual populations of wildlife. However, such data sets can be used to assess the suitability of wildlife habitat and estimate trends in suitable habitat abundance, thereby defining the upper potential for wildlife population numbers (i.e., carrying capacity).

NORTHERN RESEARCH STATIONFIA ES SCIENCE TEAM

ES provides a framework or structure for understanding and linking Northern Research Station (NRS) FIA activities. The authors adopted the ES classification system outlined by the MA for use by the NRS-FIA Ecosystem Services Science Team. The mission statement proposed for this Science Team is to: use scientific methods and research to produce data, information, and knowledge that informs wise management decisions about forest ecosystem services in the midwestern and northeastern United States of the Northern Research Station.

The NRS-FIA ES Science Team – established by the authors of this paper, is intended to facilitate collaboration and product delivery of forest ES research and reporting. The ES Science Team would leverage existing experience and expertise of NRS-FIA staff and would include cooperators from other Forest Service research units and other agencies and organizations. This team is prioritizing research projects and products, based on the following context.

The definition of ES is comprehensive, and includes many disciplines, existing efforts, and topics already covered by major research initiatives: i.e., timber, biomass/biofuel, fuelwood (provisioning service), and carbon accounting (regulating service). Table 1 includes a crosswalk between ES and FIA research activities. This framework reveals that the full breadth of NRS-FIA research activities is included within ES, including the traditional notion of both “goods” and “services.” The framework highlights current successes in addressing some ES via well-established FIA “product lines”, while revealing emerging opportunities for better serving other ES. We emphasize ES topics that are less well represented by existing FIA research efforts, e.g., water, wildlife, fish, nontimber forest products, and those ES associated with landscape pattern (fragmentation) and land use/land cover dynamics. Examples from two specific projects are described below.

Example of Potential ES Study – "Monitoring Past Trends, Current Conditions, and Future Projections of Habitats for Forest-associated Wildlife Species"

The goal of this project is to integrate wildlife species-habitat relationships with forest inventory data and geospatial data sets to inventory, monitor, and manage forest wildlife habitat condition across northeastern and midwestern forests of NRS. We presume that 1) the FIA database (FIADB; http://apps.fs.fed.us/fiadb-downloads/datamart.html) provides a wealth of data, information, and knowledge that can be used to inform estimates of habitat abundance; 2) species-habitat relationships, like those provided by U.S. Geological Survey (USGS) Gap Analysis Program (GAP) provide a means for associating many wildlife species with specific habitat characteristics; 3) the national vegetation classification (NVC) system provides a consistent system for GAP and other species-habitat relationships, such as NatureServe Explorer and the NatureServe Northeastern Terrestrial Wildlife Habitat Classification; 4) the addition of NVC attributes to FIADB will enable consistent linkage between FIA and databases such as GAP; and 5) new attributes and techniques are needed to establish such linkages and producing estimates of habitat abundance. This ES project is designed to address these needs.

Example of Potential ES Study – "Estimating and mapping change in both land use and land cover."

The objective of this study is to develop and implement tabular and geospatial products that include attributes of both forest cover and forest use. Land use and land cover are terms often used interchangeably. Although they may be identical in some places and at some times, they differ substantially in others. Remote sensing-based maps, like the USGS National Land Cover Database (NLCD), typically are considered to portray land cover, while FIA data typically are described as representing land use. Both characterizations are oversimplifications—representing a false dichotomy—of actual definitions, thereby discouraging more comprehensive understanding and integration of various information products. The FIA image-based change estimation (ICE) project, conducted in partnership with the Forest Service Remote Sensing Applications Center (RSAC), is designed to produce statistical estimates of change in both land use and land cover. ICE requires manual photo-interpretation of aerial imagery (NAIP) in the vicinity of FIA plot locations. Concurrently, FIA and RSAC are collaborating on a project to model geospatial data sets of 1) tree canopy cover, 2) forest cover, 3) forest use, and 4) subcategories of FIA forest land (timberland, reserved forest, other forest).

CONCLUSION

The FIA program already assesses many benefits that people obtain from forest ecosystems, including provisioning, regulating, cultural, and supporting services. The MA ES framework provides a comprehensive approach for describing FIA research activities and product lines; these relationships are presented in Table 1. The NRS-FIA's proposed ES Science Team is poised to better understand those ES that have been so far inadequately studied.

LITERATURE CITED

Bonan, G.B. 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science. 320(5882): 1444-1449.

Chiabai, A.; Travisi, C.; Markandya, A.; Ding, H.; Nunes, P.L.D. 2011. Economic assessment of forest ecosystem services losses: cost of policy inaction. Environmental and Resource Economics. 50(3): 405-445.

Cóndor, R.D.; Scarelli, A.; Valentini, R. 2008. Assessing multiple forest ecosystem services: a multicriteria approach. In: Annual Conference of the European Forest Institute; 15-20 December 2008; Palazzo del Popolo, Centro dei Congressi, Orvieto, Italy.

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; et al.. 1997. The value of the world's ecosystem services and natural capital. Nature. 387(6630): 253-260.

Daily, G. 1997. Introduction: What are ecosystem services? In: Daily, G., ed. Nature's services: societal dependencies on natural ecosystems. Washington, DC: Island Press: 1-10.

de Groot, R.S.; Wilson, M.A.; Boumans, R.M.J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics. 41(3): 393-408.

Ekins, P. 2003. Identifying critical natural capital: Conclusions about critical natural capital. Ecological Economics. 44(2–3): 277-292.

Gaodi, X.; Wenhua, L.; Yu, X.; Biao, Z.; Chunxia, L.; Kai, A.; Jixing, W.; Kang, X.; Jinzeng, W. 2010. Forest ecosystem services and their values in Beijing. Chinese Geographical Science. 20: 51-58.

Ghani, A.N.A. N.d. Economic valuation of forest ecosystem services in Malaysia. (online powerpoint). Available http://www.jst.go.jp/asts/asts_m/files/0311pdf/09_Seminar_ASTS_Penang_10-14_March_2006_Awang_Noor.pdf. (Accessed January 2011).

Liknes, Greg C.; Nelson, Mark D.; Kaisershot, Daniel J. 2013. Net change in forest density, 1873-2001. Using historical maps to monitor long-term forest trends. RMAP-NRS-4. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 12 p.

Matthews, S.; Iverson, L.; Peters, M.; Prasad, A.; Subburayalu, S. 2014. Assessing and comparing risk to climate changes among forested locations: implications for ecosystem services. Landscape Ecology. 29(2): 213-228.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

Myers, N. 1997. The world's forests and their ecosystem services. In: Daily,G., ed. Nature's services: societal dependencies on natural ecosystems. Washington, DC: Island Press: 215-235.

Nasi, R.; Wunder, S.; Campos, J.J. 2002. Forest ecosystem services: can they pay our way out of deforestation? Report for Global Environment Facility. Bogor, Indonesia: CIFOR for the Global Environmental Facility (GEF). 33. Available http://www.cifor.org/library/1199/forest-ecosystem-services-can-they-pay-our-way-out-of-deforestation/. (Accessed January 2011).

Notman, E.; Langer, L.; Crow, T.; Mercer, E.; Calizon, T.; Haines, T.; Greene, J.; Brown, T.; Bergstrom, J.; Loomis, J.; Hayes, J.; Call, J. 2006. State of knowledge: ecosystem services from forests. Unpublished white paper: U.S. Forest Service. 56. Available http://www.fs.fed.us/ecosystemservices/pdf/state-of-knowledge.pdf. (Accessed January 2011).

Pattanayak, S.K.; Butry, D.T. 2003. Forest ecosystem services as production inputs. In: Sills, E.O.; Abt, K.L., eds. Forest in a market economy. Boston: Kluwer Academic Publishers: 361-378.

Smail, R.A.; Lewis, D.J. 2009. Forest-land conversion, ecosystem services, and economic issues for policy: a review. Gen. Tech. Rep. PNW-GTR-797. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 40 p.

Riemann, Rachel I.; Wilson, Barry T.; Lister, Andrew J.; Cook, Oren; Crane-Murdoch, Sierra. 2014. Modeled distributions of 12 tree species in New York. Research Map NRS-5. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [map; ~ 1:3,900,000].

Vernegaard, L.; Burne, M.; Clish, H.; Connolly, K.E.; Finton, A.D.; et al. 2010. Forest futures visioning process recommendations of the technical steering committee: final report. Boston: Massachusetts Department of Conservation and Recreation. 171. Available http://archives.lib.state.ma.us/bitstream/handle/2452/50079/ocn649854362.pdf?sequence=1&isAllowed=y. (Accessed 4 February 2015).

Watson, B. 2008. Forest ecosystem services and sustainable community development. Denver, CO: The Rocky Mountain Land Use Institute. 9 p. Available http://www.law.du.edu/images/uploads/rmlui/rmlui-sustainable-ForestEcosystemServices.pdf. (Accessed January 2011).