Ecosystem Services 20 (2016) 104–112

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Examining the ecosystem service of nutrient removal in a coastal watershed

Chelsea E. Berg [a], Madeleine M. Mineau [b], Shannon H. Rogers [a,*]

[a] Center for the Environment, Plymouth State University, United States
[b] Earth Systems Research Center, University of New Hampshire, Durham, NH, USA

ARTICLE INFO

Article history:
Received 30 April 2015
Received in revised form
17 June 2016
Accepted 21 June 2016

Keywords:
Ecosystem service valuation
Nutrient retention
InVEST
Great Bay
Avoided cost analysis
FrAMES

ABSTRACT

Globally, managers are trying to prevent or halt the eutrophication of valuable estuaries and bays by reducing nutrient inputs, but justifying the cost of conservation or processing facility upgrades often proves challenging. We focus on a coastal watershed in Maine and New Hampshire struggling with the financial burdens of nitrogen pollution mandates due to the eutrophication of the Great Bay estuary. After creating two future watershed land cover scenarios comparing plausible extremes, we ran them through two models, the Natural Capital Project's InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) and a detailed hydrologic and biogeochemical river network model FrAMES (Framework for Aquatic Modeling of the Earth System). Through this work, we both evaluated and valued the ecosystem service of nitrogen retention. We find that both models provide numerical arguments for conservation efforts, and decision makers would benefit from using either an ecosystem services model or a biogeochemical model when dealing with complex issues like nutrient overenrichment. According to both our modeling results, modest watershed conservation efforts as defined by our expert stakeholders, ie: protecting wetlands and forests, could reduce the amount of total nitrogen entering the Great Bay estuary in the range of 3–28 metric tons per year.

1. Introduction

Human communities, on a local and global scale, depend on diverse natural systems for a variety of goods and services, also known as ecosystem services (ES) (Jacobs et al., 2013; Millennium Ecosystem Assessment, 2003). There is an international movement, ie: Intergovernmental Platform on Biodiversity and Ecosystem Services or Convention on Biological Diversity's Aichi targets, to incorporate ES into policies in order to holistically address human, economic, and environmental well-being (Neßhöver et al., 2013; President's Council of Advisors on Science and Technology, 2011; Russi et al., 2013). Due to this movement, academics and others have created a host of new decision-support tools to make quantifying ES easier for decision makers, and some tools have a built-in economic analysis function (Bagstad et al., 2013; Kareiva et al., 2011; Villa et al., 2014). The goal for the majority of ES tools is place-specific analysis to inform planning options (Grêt-Regamey et al., 2014), which can also potentially be accomplished with other tools that are not explicitly labeled as ES tools (Vigerstol and Aukema, 2011). Researchers and decision makers are looking for accessible methods with which to better understand and value ES. For this work, we chose one ES model and one model without the ES label: InVEST and FrAMES.

The Natural Capital Project's InVEST (Integrated Valuation of Environmental Services and Tradeoffs) modeling suite contains a spatial model focused on understanding the effect of land management trends by focusing on nutrient retention, specifically nitrogen (N) or phosphorus, in a specific geographic region (Kareiva et al., 2011). Using data on land use and land cover (LULC), nonpoint sources, precipitation, soil types, and slopes, InVEST predicts the annual biophysical contribution of landscapes in total nitrogen (TN) and then calculates a dollar value for the ES of N or phosphorus retention. Although there are an array of ES models available, we decided to use InVEST as the representative ES model because of its capacity to model N, the built-in economic evaluation, the published examples of other decision making uses, and its free “off the shelf” availability (Bassi et al., 2009; Hulse et al., 2004; Swetnam et al., 2011). As it is often recommended to natural resource decision makers as a viable option for gaining additional knowledge, it's touted user-friendliness was also attractive to us. Since this decision Bagstad et al. have compared or described 17 ES tools in an effort to discover ease of use (2013), however InVEST is still a recommended option for many, and we see strong value in investigating this tool.

* Correspondence to: Center for the Environment, Plymouth State University, MSC 63 17 High Street, Plymouth, NH 03264, United States.
E-mail address: shrogers@plymouth.edu (S.H. Rogers).

http://dx.doi.org/10.1016/j.ecoser.2016.06.007
2212-0416/

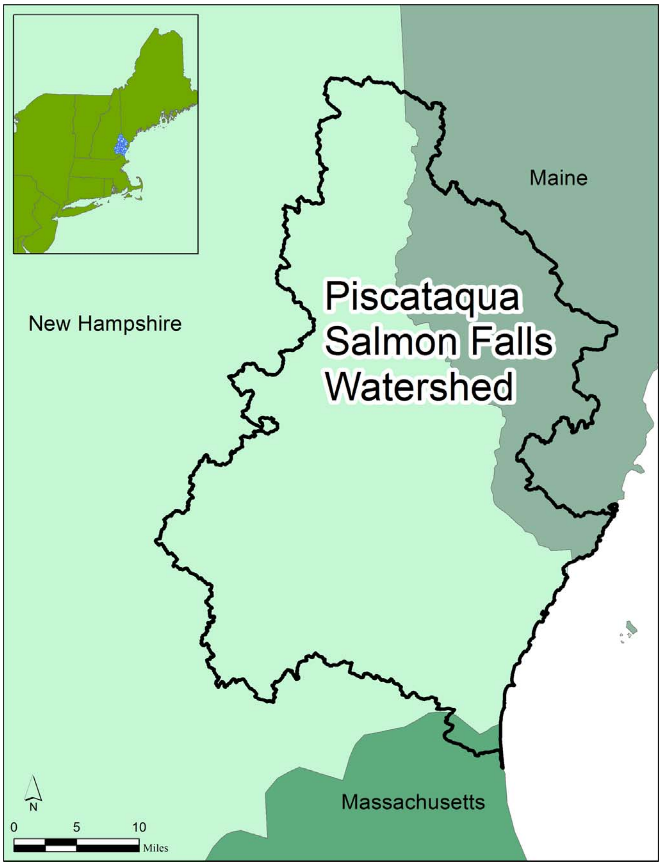

Fig. 1. Study location, the Piscataqua-Salmon Falls watershed (PSFW), in spatial context.

Our non-ES labeled model, FrAMES (Framework for Aquatic Modeling of the Earth System), also spatially evaluates N, specifically the loading to river networks and in-stream processing of dissolved inorganic nitrogen (DIN). FrAMES is a spatially distributed hydrology and biogeochemical river network model that was developed at the University of New Hampshire (UNH) and locally adapted to New England watersheds. Although it is not described with ES language, the model does provide information on aquatic nitrogen removal, which is an ES, at varying spatial and temporal scales. It also accounts for seasonal variation and in-stream DIN dynamics. It could be helpful for local decision makers if presented with ES language (Smart et al., 2012).

We used the two different models for the Piscataqua-Salmon Falls watershed (PSFW) that flows into the Great Bay Estuary (GBE) on the coast of New Hampshire and Maine (Fig. 1). Water body managers around the world are dealing with the challenge of nutrient overenrichment related to population increase. In that way, the PSFW is relevant to nutrient impaired coastal water bodies all over the Globe struggling with the impacts of increasing human populations in sensitive coastal areas. Within the PSFW, the GBE, along with the majority of the Northeast's estuaries influenced from the flow of nutrients downstream, is deteriorating into a state of anthropogenic nutrient overenrichment called eutrophication (Lee et al., 2004; Piscataqua Region Estuaries Partnership, 2013; Vitousek et al., 1997). With increased population density driving land cover and land use changes, GBE is one of the six “hot spots” of poor water quality in New England (Office of Research and Development and Office of Water, 2012). Like most coupled human and natural systems, the primary cause of this decline is debated due to imperfectly understood interactions and drivers of change, but studies point to increased levels of nitrogen (N) as the main driver (Howarth, 2008; Liu et al., 2007; Odell et al., 2006).

Human activities increase the flow of N from land through fertilizer application, air pollution, and point sources like wastewater treatment plants (Driscoll et al., 2003; Vitousek et al., 1997). As shown in Fig. 2, eighteen publicly owned treatment works (POTWs), point sources of N from human wastewater, release about twenty million gallons a day of processed effluent into the GBE, its tributaries, or into the tidally relevant waters (Spalding, 2012). Upgrading the POTWs to the limits of technology represents an immense potential financial cost to local ratepayers, estimated at 354 million dollars (Kessler, 2010). Several organizations and community members are interested in approaching the issue from an alternative perspective, specifically land conservation (Rogers et al., 2014; Vanasse Hangen Brustlin, Inc., 2014).

Land conservation has the potential to remove N from the Great Bay because natural landscapes retain nutrients. For example, New York City, Boston, and other international areas have shown that allocating resources towards conservation efforts or green infrastructure can significantly reduce nutrient levels and provide a cost savings over wastewater treatment or water filtration plant upgrades because natural landscapes retain nutrients (Daily and Ellison, 2002, pp. 61–85; Foran et al., 2000; Grolleau and McCann, 2012; National Research Council, 2005). In other cases, integrated management plans provide the most effective strategy to reduce N (Driscoll et al., 2003; Lowrance et al., 1997; Mitsch et al., 2001). Talberth et al. (2013) tested avoided cost methods in Portland, Maine, for the Sebago Lake Watershed by running six future landscape scenarios through a mapping software to look at infrastructure options and costs over 20 years under different discount rates. By investing in green infrastructure such as riparian buffers, culvert upgrades, reforestation, and conservation easements, Portland found that they could save up to 71% of the cost of a new drinking water filtration plant. In a similar effort, we wanted to evaluate the potential of alternative management, specifically conservation easements and reforestation, to avoid or offset some of the costs of proposed POTW upgrades in the PSFW.

In order to accomplish this goal, we needed to first know the range of potential N loading and retention efficiencies from both extremes of conservation and development futures. Future scenario generation is commonly used in the ecosystem services field (Alcamo, 2008; Cook et al., 2014). As described in detail in a previous publication, we queried a variety of expert stakeholders representing various sectors, build future land cover scenarios, and simulated the impacts of both conservation efforts and increased development on N loads from each tributary (Berg et al., 2015). Again, the ultimate goal of this study was to investigate the amount of nitrogen removed and costs avoided of non-point source N management compared to point source management using two stakeholder-driven future land cover scenarios. We hypothesized that like the Sebago example, an alternative management plan would allow the Great Bay municipalities to avoid part of the proposed cost associated with upgrading 18 POTWs to the best available technology by reducing the non-point source pollution load through conservation.

2. Methods

2.1. Scenario generation

In order to evaluate potential future N loads to the GBE, we needed to decide how LULC change could occur over our study area. Specifically, we were interested in discovering the full range of N retention between a very conservation focused future vs a development focused future. As part of the scenario generation,