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In Oregon, the EPA Calculates Nature's Worth Now and in the Future

by John P. Bolte, Robert B. McKane, Donald L. Phillips, Nathan H. Schumaker, Denis White, Allen Brookes, and David M. Olszyk

Eric Vance/EPA

A community along the Willamette River, in Oregon. Surrounding agricultural lands are protected under the state's urban growth boundary laws.

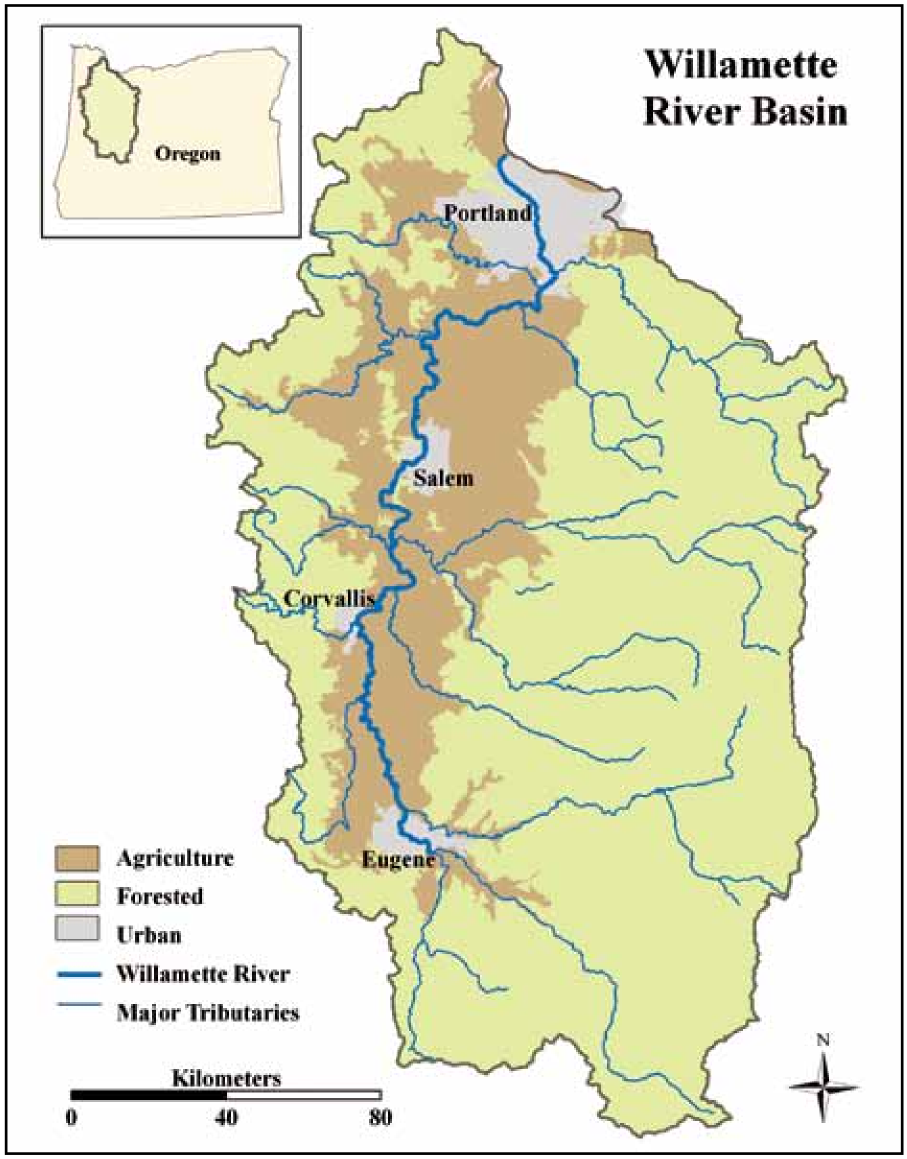
The Willamette River is the 13th largest river in the United States, and its 29,727 square kilometer basin supports a mosaic of agricultural, timber, and recreational resources as well as several growing urban centers and their water supplies. The Willamette River Basin (WRB) has a Mediterranean climate with dry summers and wet winters. The river drains the Coast Range on the west side of the basin, the Willamette Valley, and the Cascade Range to the east. The conifer forests that dominate the Coast Range and Cascade Range are among the most productive forests globally. They are economically and ecologically important for providing timber products, habitat for a diverse array of wildlife species, dependable supplies of clean water, and recreational opportunities. Rich alluvial soils in the broad valley bottom support a variety of high value agricultural crops such as grass seed, vegetables, fruits, nuts, and wine grapes. A small but increasing share of many of these crops are grown using organic farming methods. The Willamette River network supports a wide variety of native and exotic fish species. Several species of salmon native to the Pacific Northwest are listed under the Endangered Species Act.[1] These cold-water species are particularly sensitive to human activities—for example, stream channelization and removal of streamside trees—that can increase water temperatures above biological limits for survival. Efforts to mitigate excessive stream temperatures have resulted in the development of an ecosystem services marketplace for water cooling credits.[2] This marketplace provides payment to landowners and other stakeholders for restoration actions that reduce stream temperatures, for example, through restoration of riparian forests and wetlands that provide shade and inflow of cooling groundwater. Such actions also provide additional services such as improved aquatic habitat, flood control, and carbon sequestration. Similar marketplaces for greenhouse gas offsets, wetland mitigation, and other ecosystem services are also being developed.[3]

In the next 30 years, the human population in and around the WRB is anticipated to grow from 2.7 million to almost 4 million. The increasing population is a major, basin-wide driver that will increasingly limit the delivery of ecosystem services. The Willamette River Basin provides an excellent case study because it features diverse and highly valued resources providing numerous ecosystem services. These services are certain to be impacted by population growth, land use and land cover change, climate change, and other stressors. The Willamette River Basin provides services that are vital to society's well-being, yet these services are limited and often taken for granted as being free. The historical pattern of resource use in the WRB has often been one of boom and bust, with unsustainable management practices leading to severe downturns in major industries, such as the once thriving salmon fishery and forest products industries. Through our research, we are addressing the question, can methodologies be developed to quantify and value the WRB's ecosystem services, so this "natural capital" can be better accounted for in decisions that affect the supply of the goods and services upon which human well-being depends?

Ecosystem Services

Society is in the early stages of developing processes and methodologies to quantify and value the services provided by ecosystems. While today's technology and knowledge can help reduce the impacts humans have on ecosystems, they are unlikely to be deployed fully until ecosystem services cease to be perceived as free and limitless and their full value is taken into account. We may know the technological cost of providing clean drinking water and clean air, but we do not really know the value of lost or existing ecosystem services, which may perform the same functions more economically. Without this understanding, we can neither realistically determine the cost of pollution control regulations nor accurately calculate the economic benefits of ecosystem services.

In response to this critical need, the Environmental Protection Agency (EPA) initiated the Ecosystem Services Research Program (ESRP) in 2005 to conduct innovative ecological research that provides the information and methods needed by community planners, land managers, and other decision makers to (1) explore trade-offs in ecosystem goods and services resulting from alternative choices, and (2) quantify community and landscape sustainability trajectories to balance environmental, economic, and social criteria over timescales relevant to immediate needs and long-term (decades to centuries) planning goals.[4] Researchers are initially focusing on five geographic locations across the United States: the Willamette Basin, Tampa Bay, the coastal Carolinas, the Midwest, and the Southwest. These locations include a variety of ecosystem types, such as wetlands, agricultural lands, forests, and coral reefs, and span a variety of spatial scales and issues of concern.[4]



Connie Burdick

Major land use and land cover categories in the Willamette River Basin.

A central theme of these ESRP "place-based" studies is that ecosystem services are tightly linked, or "bundled," such that management decisions targeted for one service may have far-reaching positive or negative impacts on other services. Previously, under EPA's longstanding risk assessment paradigm, models typically were used to assess single or narrow sets of environmental endpoints.[5,6] For example, risk assessments concerning water or air quality traditionally have been treated as isolated issues by distinct program offices within EPA. Thus, EPA's Office of Air and Radiation and Office of Water are responsible for establishing independent criteria for regulating levels of mercury and other toxins in the nation's air and water to protect human health and the environment. Given the historical division of regulatory authorities and supporting research, it has often been difficult to predict how proposed standards for airborne emissions of a toxic substance might impact drinking water supplies or aquatic organisms many miles

Eric Vance/EPA

Controlled environment chambers at the EPA lab in Corvallis, Oregon, are used to study the effects of air pollutants and other stressors on native plant species. A variety of experimental data is needed to calibrate and verify the simulation models used to inform environmental decision making.

downstream from a particular airshed. The EPA established the ESRP to help formulate methods and models that consider broader sets of endpoints. Under this new paradigm, the ESRP is developing much more comprehensive assessments that quantify how multiple ecosystem services interact and respond in concert to environmental changes. A major goal is to assess how alternative climate and land use scenarios will simultaneously affect trade-offs in food and fiber production, regulation of water quality and quantity, reduction of greenhouse gases, and other services. Essential to this goal are highly integrated models that can be used to define policy and management strategies for entire ecosystems, not simply individual components of the ecosystem.[7]

Studying Ecosystem Services in the Willamette River Basin

We established the Willamette Ecosystem Services Project (WESP) in the Willamette River Basin in western Oregon to address the ESRP's local and national decision support objectives.[8] Our research includes monitoring, modeling and mapping, and analyzing how alternative-future scenarios impact ecosystem services and human health. We are developing analysis tools that support community decision making oriented around the provision of ecosystem services and that allow end users to explore different policies for land, water, and ecosystem management and to consider the resulting trade-offs in the production of ecosystem services. This effort is producing tools to help enable decisions that better account for the full value of ecosystem services in their present condition and as they may be altered in the future. We are developing a broadly applicable approach and the decision support tools for quantifying a variety of ecosystem services based on relevant local information, in this case, for Oregon's Willamette River Basin (WRB). Our overall goal is to conduct new research to characterize ecosystem services and to present this information in decision-relevant contexts.

The research we are conducting in the WRB is yielding answers to questions that need to be addressed nationwide, such as how to best assess, protect, and enhance ecosystem services. This necessarily requires a number of important considerations: engagement of clients and stakeholders to understand and incorporate their needs and decision processes; access to or development of common datasets necessary to inform ecosystem services assessments; access to or development of state of the art models capturing important drivers of ecosystem services dynamics; and development of robust, flexible, and extensible decision tools and frameworks allowing the exploration of impacts of alternative management strategies on the production of ecosystem services bundles. We focus on six key services of interest to EPA in the WRB that address the role of ecosystems in regulating stream water quality and quantity, biological sources of greenhouse gases, wildlife populations and habitat, fish populations and habitat, air quality, and production of food and fiber (e.g., lumber, pulpwood, and biofuels).

We have also identified a list of stressors or drivers in the WRB that are known to alter the provision of these services, such as climate change and land use and land cover management (land cover refers to vegetation type, for example, forests, agricultural crops, grasslands, etc.). Climate change is widely recognized as a critical global environmental problem. Rising temperatures, altered precipitation amounts and patterns, changes in accumulations and melting rates of mountain snowpack, and species range shifts all are resulting from climate change, and all have the potential to influence ecosystem services within the WRB. Land use and land cover management and modification significantly influence the extent to which ecosystems can provide the services on which humans depend. Population growth and economics remain the most significant drivers of land use and land cover change within the WRB.

SCENARIO	NARRATIVE
Status Quo	Continue existing growth management, forest management policies, and patterns of use
Smart Growth/ Carbon Offset Forestry	Emphasize protection of resource lands and compact growth in urban areas; forest management focuses on carbon sequestration on public lands, longer (80-year) rotations on private lands; afforestation of low-value agricultural lands in response to incentives for carbon sequestration
Unmanaged Growth/ Extractive Forestry	Relax restrictions on development on resource lands and rural lands near urban growth boundaries; some extractive uses allowed on public forest lands; private forest lands emphasize extractive uses, short (40-year) rotations

The authors and Richard Morin/*Solutions*

A demonstration of Envision for the Willamette River Basin developed three scenarios reflecting different forest management strategies.

An Alternative-Futures/ Ecosystem Services Decision Platform: Envision

Central to WESP's goals is the development of a robust, decision-support platform for projecting future changes in ecosystem services in response to alternative decision scenarios. The Envision computing platform provides significant capabilities compared to other existing tools for assessing ecosystem services: (1) it is spatially explicit, supporting spatial models and tools for mapping dynamic changes in landscape characteristics; (2) it is temporally explicit, supporting assessments of current landscapes and trajectories of change; (3) it is a framework, supporting inclusion of a wide variety of models, decision tools, and datasets within an adaptable software architecture that allows rapid customization of applications to address specific needs and geographies; (4) it can be applied at any scale of analysis, from community-centric applications to regional assessments involving multiple communities and ecosystem types; (5) it provides direct support for capturing policies and management alternatives; and (6) it provides tools for decision support, including trade-off analyses, which compare results from alternative-future scenarios.[9]

Multi-agent models such as Envision simulate the actions of various "agents"—that is, individual persons, such as landowners and other citizens, or organizations and institutions, such as governments and businesses. Such models have emerged recently as a useful means for representing human behavior and decision making within complex environmental and socioeconomic settings.[10–16] Multi-agent modeling is a broad endeavor, relevant to many disciplines with interests in simulating the actions and interactions of adaptive agents in order to assess their effects on the system as a whole. In this context, Envision can be used to generate alternative-future scenarios that reflect possible choices of various decision makers and show how these choices interact and collectively impact a landscape's capacity to supply ecosystem services of interest. These scenarios can include a variety of environmental, social, and economic dimensions. Envision allows decisions to be defined interactively, with the intent of allowing different stakeholders to discuss and play out the consequences of their management choices, values, and preferences.[9]

The approach we use to apply Envision to any given location involves a series of steps. First, the ecosystem services of interest to the "consumers" of the analysis are identified. In the WRB, these services have been determined through a variety of consultations involving community planners and local, state, and federal land managers, considering both political interests and environmental and resource utilization interests. For this example, we focus on services related to the extraction, use, and monetary value of forest products, forest carbon dynamics, and habitat for endangered species such as spotted owls. Other applications may involve different ecosystem services, as Envision allows any number of services to be "plugged in" to a particular analysis. Second, we identify relevant simulation models to address the services of interest. For example, our WRB applications require models of forest ecosystem dynamics, land use change, human population growth, watershed hydrology, and storage of carbon within ecosystems. Third, we assemble relevant spatial datasets necessary to inform the above models and any decision alternatives incorporated in the analysis scenarios. About 30 attributes of the WRB landscape are used in our analysis, including land use and land cover types, forest stand age and structural type, soil productivity, population density, ownership classes, proximity to road and stream networks, urban growth boundaries, and similar datasets, based on both nationally and locally available sources.

Example Applications of Envision

Here we describe two Envision applications in the WRB that address different spatial scales: stakeholders and ecosystem services. In both cases, we use Envision to integrate: (1) maps of landscape characteristics necessary to determine ecosystem services of interest; (2) a set of computer models for assessing, using best available science, the production of the target services; (3) alternative-future scenarios capturing stakeholder-relevant choices and drivers of change; (4) a set of tools for visualizing production of ecosystem services under current and projected future conditions; and (5) analysis tools for examining trade-offs among multiple ecosystem services resulting from alternative decision scenarios.

Our first example application is a relatively fine-scale analysis focusing on forest ecosystem management in a 2,000 square kilometer forested landscape in the WRB's western Cascade Range. This application builds on the intensively studied H. J. Andrews Experimental Forest,[17] which is part of the National Science Foundation's Long Term Ecological Research network.[18] We are using Envision to explore the effects of alternative forest management practices and climate change on forest growth and timber production, carbon sequestration, greenhouse gases, stream water quality and quantity, and wildlife populations and habitat. Our objective is to quantify trade-offs among these forest ecosystem services in response to alternative land management scenarios, so that forest managers and policymakers can better assess costs and benefits associated with different levels of harvest, inclusion of conservation areas for wildlife protection, establishment of riparian "buffers" to protect stream water quality, and other actions. For example, we are using Envision and an associated plug-in model called VELMA to analyze changes in ecosystem services for the H. J. Andrews Experimental Forest in response to three alternative forest management scenarios spanning 2000 to 2070: (1) a present-day forest-cover scenario consisting of 60 percent previously harvested areas (since about 1950) and 40 percent old-growth (typically 200–500 years old); (2) an old-growth scenario reflecting historical presettlement conditions; and (3) a virtual, 100 percent clear-cut harvest of the entire H. J. Andrews site in 2000.[7,19,20] Preliminary results show that, in the short term, the 100 percent clear-cut harvest maximized timber production and stream flow but at the cost of decreased stream water quality (a ten-fold increase in stream nitrogen

Al Levno/USFS PNW-OSU Forest Science Data Bank

The northern spotted owl is native to the Pacific Northwest and depends on old-growth forests for its survival. It is listed as a threatened species under the Endangered Species Act.

levels relative to the old growth scenario); 50 percent lower ecosystem carbon storage; and a more than 100-fold increase in the production of greenhouse gases, such as nitrous oxide and carbon dioxide. Negative effects of clear-cutting on water quality and greenhouse gases diminished within ten years of harvest. However, carbon storage remained close to 50 percent of old-growth values throughout the 70-year simulation, as carbon gains in regrowing trees were balanced by net losses of soil carbon associated with decomposition processes. The present-day forest-cover scenario represents a compromise between the old-growth and 100 percent clear-cut scenarios, providing sustainable rates of timber production over the next 70 years, while maintaining other ecosystem services closer to those for old growth.[7]

Al Levno/USFS PNW-OSU Forest Science Data Bank

Rain and snow falling in the Cascade Range are the main sources of water for Portland and other communities in the Willamette River Basin. If current warming trends continue, snow is likely to melt earlier in the spring. This would deplete already low water supplies during the dry Northwest summers.

Our second example application of Envision is at the scale of the entire Willamette River Basin and focuses on the effects of alternative scenarios of population growth and land use on ecosystem services during the next 50 years (2010–2060). This example addresses a variety of management choices with particular emphasis on policy decisions governing urban growth boundaries and forest management practices. Because urban expansion and increasing use of forest resources by an expanding human population will have a major impact on forest growth and management decisions, dynamic simulation models representing the interaction of these processes and policies were "plugged in" to the Envision platform. Policy decisions governing urban growth boundaries and forest management practices are captured through alternative policy options represented in Envision's policy framework. These options can be combined in various ways into a set of alternative-future scenarios. In this example, we develop three scenarios (see Table) reflecting three distinct sets of management strategies for both urban development and forest management. These scenarios are used by Envision to project future landscape trajectories and resulting changes in ecosystem goods and services, including valuation of services in economic terms. Outputs from the analysis include dynamic maps showing a variety of landscape characteristics, graphs showing summaries of ecosystem services generated by the landscape, and trade-off analyses comparing relative gains and losses of ecosystem services across different scenarios.

Additional WESP Activities

The preceding examples represent just two of many activities being undertaken by WESP to quantify ecosystem services in the Willamette River Basin. Other activities include the development of models to assess population dynamics of salmonids (the family of fish that includes salmon and trout) in response to changes in stream flow, stream temperature, and other habitat variables;[21] assessments of the ecosystem services associated with urban forests using the iTree model;[22] application of the VELMA eco-hydrologic model for quantifying the interactive effects of land use and climate change on trade-offs among multiple ecosystem services in landscapes having complex mosaics of agriculture, wetland, forest, and other land cover types;[7,19,20] evaluation of the population dynamics of endangered species in the WRB under alternative forest management plans using HEXSIM, a spatially explicit, individual-based model designed for simulating terrestrial wildlife population dynamics in response to multiple, interacting stressors;[23] and the characterization of private, industrial forest management strategies under current and potential future conditions reflecting a carbon-offset forest management approach.[24]

Summary

The EPA's Willamette Ecosystem Services Project is developing a variety of tools and approaches for quantifying ecosystem services and informing the decision making that affects these services. Central to our approach is the use of alternative-future scenarios to capture the interactive effects of management choices and other drivers of landscape change, so that trade-offs in ecosystem services of interest to communities, land managers, and other stakeholders can be evaluated. We employ an alternative-futures decision framework and toolkit, Envision, to integrate spatial data describing landscapes; models representing biophysical and sociocultural processes within landscapes; policy sets reflecting decision alternatives of interest to stakeholders; and evaluative models for measuring trajectories of landscape performance. We have successfully prototyped applications of this approach for the Willamette River Basin. These applications combine scenarios of human population growth and forest management strategies affecting vital ecosystem services: provision of forest products, carbon sequestration, regulation of water quality and quantity, maintenance of wildlife populations and habitat, and the capacity of the landscape to support further population growth. Work currently under way is developing additional models and assessment tools for fish and terrestrial population dynamics, hydrological and biogeochemical processes, and valuation of ecosystem services in monetary and nonmonetary terms. Our ultimate goal is to better assist decision makers in balancing environmental, economic, social, and institutional criteria over timescales relevant to immediate needs and long-term planning goals.

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References

1. Endangered Species Act [online]. www.nwr.noaa.gov/ESA-Salmon-Listings.
2. Oregon Department of Environmental Quality—Water Quality Trading [online]. www.deq.state.or.us/wq/trading/faqs.htm.
3. Willamette Partnership: Ecosystem Services Markets [online]. willamettepartnership.org/about-markets.
4. EPA: Ecosystem Services Research Program (ESRP). www.epa.gov/ecology.
5. National Research Council (NRC). *Risk Assessment in the Federal Government: Managing the Process* (National Research Council, National Academy Press, Washington DC, 1983).
6. Norton, SB et al. A framework for ecological risk assessment at the EPA. *Environmental Toxicology and Chemistry* 11, 1163–1672 (1992).
7. McKane, RB et al. An integrated eco-hydrologic modeling framework for assessing the effects of interacting stressors on multiple ecosystem services. The Ecological Society of America 95th Annual Meeting, Pittsburgh, PA, August 1–6, 2010.
8. EPA: Ecosystem Services Research Program [online]. www.epa.gov/ecology/pdfs/ESRP-Fact-Sheet-Overview.pdf.
9. Bolte, JP, Hulse, DW, Gregory, SV & Smith, C. Modeling biocomplexity—actors, landscapes and alternative futures. *Environmental Modeling and Software* 22, 570–579 (2007).
10. Levin, SA. Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1, 431–436 (1998).
11. Ostrom, E. A behavioral approach to the rational choice theory of collective action. *American Political Science Review* 92, 1–22 (1998).
12. Jager, W, Janssen, MA, De Vries, HJM, De Greef, J & Vlek, CAJ. Behaviour in commons dilemmas: *Homo economicus* and *Homo psychologicus* in an ecological-economic model. *Ecological Economics* 35, 357–380 (2000).
13. Janssen, MA & Jager, W. The human actor in ecological-economic models. *Ecological Economics* 35, 307–310 (2000).
14. Holling, CS. Understanding the complexity of economic, ecological and social systems. *Ecosystems* 4, 390–405 (2001).
15. Beisner, BE, Haydon, D & Cuddington, KL. Alternative stable states in ecology. *Frontiers in Ecology and the Environment* 1, 376–382 (2003).
16. Parker, DC, Manson, SM, Janssen, MA, Hoffmann, MA & Deadman, P. Multi-agent systems for the simulation of land-use and land-cover change: A review. *Annals of the Association of American Geographers* 93, 314–337 (2003).
17. H. J. Andrews Experimental Forest [online]. andrewsforest.oregonstate.edu.
18. National Science Foundation: Long-Term Ecological Research (LTER) network [online]. www.lternet.edu.
19. Abdelnour, A, Stieglitz, M, Pan, F & McKane, RB. Catchment hydrological responses to forest harvest amount and spatial pattern. *Water Resources Research* (in press).
20. Abdelnour, A, McKane, RB, Stieglitz, M, Pan, F & Cheng, Y. Effects of Fire and Harvest on Carbon and Nitrogen Dynamics in a Pacific Northwest Forest Catchment. *Water Resources Research* (under review).
21. Rashleigh, B. A spatially structured modeling approach to represent ecosystem services provided by fish in stream networks. Internal Report, US EPA, ORD (2009).
22. Nowak, DJ & Crane, DE. In *Integrated Tools for Natural Resources Inventories in the 21st Century* (Hansen M & Burk T, eds) The urban forest effects (UFORE) model: Quantifying urban forest structure and function (USDA Forest Service General Technical Report NC-212, Washington DC, 2000).
23. Schumaker, NH, Ernst, T, White, D & Haggerty, P. Projecting wildlife responses to alternative future landscapes in Oregon's Willamette Basin. *Ecological Applications* 14, 381–400 (2004).
24. Phillips, DL, Beedlow, PA, Ernst, T & Burdick, C. Carbon Offset Forestry Analogs for the Willamette River Basin, Oregon, USA: Implications for Ecosystem Services. *Mitigation and Adaptation Strategies for Global Change* (under review).