An eco-hydrological modeling framework for assessing trade-offs among ecosystem services in response to alternative land use and climate scenarios

Scientists, policymakers, community planners and others have discussed ecosystem services for decades. However, society is still in the early stages of developing methodologies to quantify and value the services provided by ecosystems. For example, the U.S. Environmental Protection Agency recently established the Sustainable and Healthy Communities Research Program to address such questions as, can methodologies be developed to quantify and value of 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? 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. We developed the VELMA (Visualizing Ecosystems for Land Management Assessments) eco-hydrologic modeling framework to help address this emerging risk assessment objective. Here we describe a proof-of-concept application of VELMA to the H.J. Andrews Experimental Forest, a forested 64 km² basin and Long Term Ecological Research site in the western Cascade Range of Oregon, USA. VELMA is a spatially-distributed eco-hydrologic model that links a land surface hydrologic model with a terrestrial biogeochemistry model for simulating the integrated responses of vegetation, soil, and water resources to interacting stressors. We used the model to simulate the effects of three different land use scenarios (100% old-growth, 100% clearcut harvest, and present-day land cover consisting of 45% old-growth and 55% harvested) on changes in five ecosystem services: timber production, carbon sequestration, greenhouse gas regulation, water quantity, and water quality. Compared to the old-growth simulation, over a 60-year period the clearcut simulation reduced total ecosystem carbon stocks (-40%), and initially increased total stream discharge (+28%), stream nitrogen export (>300%), and total CO₂ and N₂O radiative forcing (>200%). The simulation for present-day land cover resulted in intermediate values, although closer to old growth than to the clearcut simulation, in most cases. Ongoing work is focused on incorporating VELMA within a flexible decision support platform (Envision) that integrates a wide variety of models, decision tools, and datasets for evaluating economic, social and environmental trade-offs associated with alternative decision scenarios. This framework will be used to address questions about the sustainability of natural capital vital to local and regional economies, initially in the Pacific Northwest and Central Great Plains. For example, can those factors that have the greatest potential to improve future trajectories of ecosystem services and human well-being be identified? What green and grey infrastructure improvements, carbon and nitrogen management practices, and growth and development policies can most effectively be managed to attain a sustainable and desirable future?