Food, water and energy resources – the rule of three

A team of researchers from the Northwest Region of the United States, led by co-Principal Investigators Drs Jennifer Adam, Jan Boll, Stephen Katz, Dustin McLarty and Julie Padowski, are working on a novel project focusing on the interactions between water, food and energy resource management to enable people and institutions to more effectively adapt to global change.

Rapid population growth, economic development and the associated impacts of climate change are altering vital water, energy and agricultural resources in important ways. These three resources are not only critical to our global society, they are linked by complex, interdependent relationships. This interlinked triptych is known as the food-energy-water (FEW) nexus. The connections within the FEW nexus must be carefully managed to withstand environmental and societal change to ensure the continued security of FEW resources. A team from the Northwest Region of the United States is working to identify and examine effective strategies to develop our understanding of these relationships and to balance the benefits between FEW sectors in a bid to predict and enhance the resilience of these systems for sustainable growth.

OVERVIEW OF STUDY DOMAIN AND PROJECT GOALS

The team’s research focuses on the Columbia River Basin (CRB), one of the most highly managed basins in the US. Hydropower from the CRB contributes 77% of the energy generated in the US. In the CRB, the competition for limited surface water resources to sustain irrigated agriculture, hydropower generation, and in-stream flow requirements for endangered fish populations applies indicates the challenges within the FEW nexus. This individual example is characteristic of the global challenges in this area.

Research needs to consider where and why strong FEW system interdependencies occur

In each sector is affected by the capacity of the other sectors to weather and even capitalise on external biophysical and economic disturbances. By understanding the characteristics of the FEW nexus, the research team hopes to be able to predict how FEW dynamics will impact the economic, political, social, and environmental resilience of the whole CRB system. This in turn will help to identify the types of technological advancements, institutional adaptations and/or legislative requirements most appropriate for responding to change.

The team’s work focuses on the idea that coordinated management of storage systems across the three sectors can increase FEW system resilience. This involves looking at not only physical storages, such as surface water reservoirs, but exploring how non-physical storages can improve FEW management. Non-physical storages, such as water markets, help redistribute resources from areas of low-value use to high-value use in times of shortage. The overall aim of the project is to develop, evaluate and apply a framework to understand FEW linkages, quantify innovative solutions, remove barriers to adoption of these solutions and increase system-wide resilience on a global scale.

THE FOUR STAGES OF THE PROJECT: Develop a theoretical foundation to characterise FEW system resilience. Assessment of resilience is generally performed for a single system, such as the resilience of an ecosystem to land use change. When researching the FEW “system of systems”, resilience assessment must be broadened to consider multiple resource sectors (for example irrigated agriculture, fish flows, flood protection, and hydropower generation). However, a management action to benefit one sector may be at the expense of the others due to their tightly-interacting nature. Therefore, within this phase, the team explores metrics that are best able to capture resilience of the FEW system as a whole, which will form the basis of a “FEW Resilience Calculator”. This theoretical framework is tested both specific to the CRB and to its ability to be generalised to other regions and the globe.

Integrate computer-based modelling systems to capture FEW system interactions in a quantitative system dynamics model.

By integrating and refining existing modelling platforms, the team is able to combine a deep understanding of each of the food, energy, and water sectors into a single framework to simulate the production and management of FEW resources. This
Your initial case studies of the Columbia and Yakima rivers will both provide temperate examples of the problems and solutions. What kind of issues in model outputs would you expect to see in, for example, a tropical river system? The methodology developed as part of the ColumbiaFEW project is applicable to other regions of the world, although the models would need to be tailored to accommodate the differences that may occur in and among the institutions that manage natural resources. In the tropics, in particular, tools that help plan for climate change adaptation are especially important. These regions are already showing signs of increased floods and droughts, as well as infrastructure damage due to climate change. Crops are anticipated to be more negatively impacted by warming, and in many cases there is a lack of infrastructure for example through irrigation systems that allow these regions to buffer the impact of shifts in climate patterns. The conflicting demands between allocating river water for hydropower production versus water for irrigated agriculture are global challenges that exist in temperate and tropical climates alike.

Can the model be applied to marine systems which have similar demands for FEW such as fisheries? The modelling tools and data outputs we are producing are already incorporating fresh water and anadromous (species that use both fresh and marine water such as salmon, sturgeon and lamprey) fish species. Protection of the environment for many of these endangered species is a component of the solutions that we are currently exploring. We are also quantifying the discharge of water and nutrients to marine environments that impact these ecosystems. More generally, the approach that we are developing starts with critical analysis of multi-sector management, with a focus on developing solutions across these multi-sector systems. Once developed, the frameworks can be applied to different systems where the sectors themselves are quite different, but the frictions across sectors are at least as complex, particularly in coastal ocean systems.

What do you envisage will present the greatest barriers to success of this project? The greatest challenge our team has encountered is the vast breadth of issues that come under the purview of FEW in the basin, particularly given how incredibly complex this basin is with respect to hydrology, climate, agriculture, and water resources management. To make this scope more tractable, our team has identified unique case studies focused on specific elements that have strong influence on FEW resources, e.g., a specific innovation that has high potential to alleviate conflicts, or a specific industry in which innovation would greatly improve efficiencies across multiple sectors. As we develop more case studies, a general and holistic understanding of the FEW nexus and its potential solutions will emerge.

Will the models be able to accurately quantify metrics for FEW resilience, e.g., actual levels of precipitation which may trigger flooding? The “original” behind the ColumbiaFEW project is a set of sophisticated computer models that represent the mechanisms that govern how the FEW system responds to global change and more local changes in management. Therefore, there is a degree of realism in our model predictions that would not otherwise be possible. Even the best models, however, have inherent limitations and may not give exact answers to some very specific questions. To address this, we explore solutions that remain robust despite known limitations and uncertainties in the model and the data that are used to drive it. For example, if a specific solution shows optimal results across the FEW nexus for a large set of future climate conditions, we know that this is a solution that we should bring to our stakeholders for more intense scrutiny and analysis.

If the framework outputs are able to inform changes to the Columbia River Treaty, do you think this model has an application on global treaties, decisions and legislation? Absolutely. While we do not intend to develop new policy alternatives, we can quantify the regional-scale impacts to proposed changes in national or even global policy. It is critical that regional-scale models be used in addition to larger-scale models, because such regional-scale models can capture the realism of how resources are managed. Without this realism, there is a large potential for unintended consequences.

Your research focuses on how water interacts with food and energy production, and how people can respond and adapt to global change. Your current project aims to increase regional-to-global scale resilience in Food-Energy-Water systems through coordinated management of water and energy storage and through technological and institutional innovations.

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COLLABORATORS For a full list of team members please visit https://fewstorage.wsu.edu/people/

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