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WaSSI: A New Web-Based Tool Assesses Water Supply

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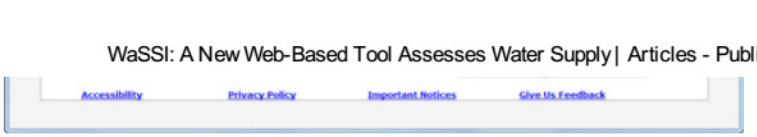
The U.S. Department of Agriculture (USDA) Forest Service manages more than 190 million acres (780,000 square kilometers) of national forest land, and understanding climate-change impacts on ecosystem services is a significant challenge for 21st-century Forest Service land managers.

Healthy forests provide several goods and services that benefit humans, called ecosystem services. Some important examples include water supply, wildlife habitat and carbon storage. Often these goods and services aren't traditionally valued; by managing national forests to sustain ecosystem services, the Forest Service encourages responsible decision making and long-term stewardship of the nation's natural resources.

Federal land managers collect site-specific inventory and monitoring data, but they may lack the expertise to examine and model potential future impacts due to climate change and other stressors. The Water Supply Stress Index (WaSSI) Ecosystem Services Model (*www.forestthreats.org/research/tools/WaSSI*) was developed to address this gap. Using this Web-based tool, land managers can visualize the effects of climate change, land-use/land-cover change, and water withdrawals on river flows, water-supply stress, and ecosystem productivity across the conterminous United States and Mexico.

The WaSSI Model

Climate-change impacts on water resources include increasing demand; increased drought, flooding or sea-level rise from increased climate variability; and degradation of water quality. With warmer air temperatures, evapotranspiration may increase and reduce available water in some areas. Climate change also may affect the timing of rainfall and may reduce snowfall or change the timing of snowmelt, an important source of drinking water for western areas.



The online WaSSI Ecosystem Services model helps assess and visualize the impacts of climate, land-use and population changes on ecosystem services across the United States.

More-frequent and intense rainstorms can impact water quality by moving more sediment, nutrients and pollutants to waterways. Land managers need tools to help them define and respond to threats and impacts from climate change on ecosystem services.

The WaSSI model is one such tool, featuring a water-balance and flow-routing model that's sensitive to changes in climate and land-use/land-cover types. WaSSI operates on a monthly time step and at a watershed scale. Its algorithms were developed using data from monitoring at Forest Service Experimental Forests, global eddy-flux measurements and national water-use assessments.

Using downscaled, monthly future climate scenarios from the most recent report of the Intergovernmental Panel on Climate Change, population projections and hypothetical changes in land use/land cover, WaSSI can help predict the effects of climate, population, and land-cover change on water resources and carbon fluxes during the next 100 years.

There are three integrated modules within WaSSI:

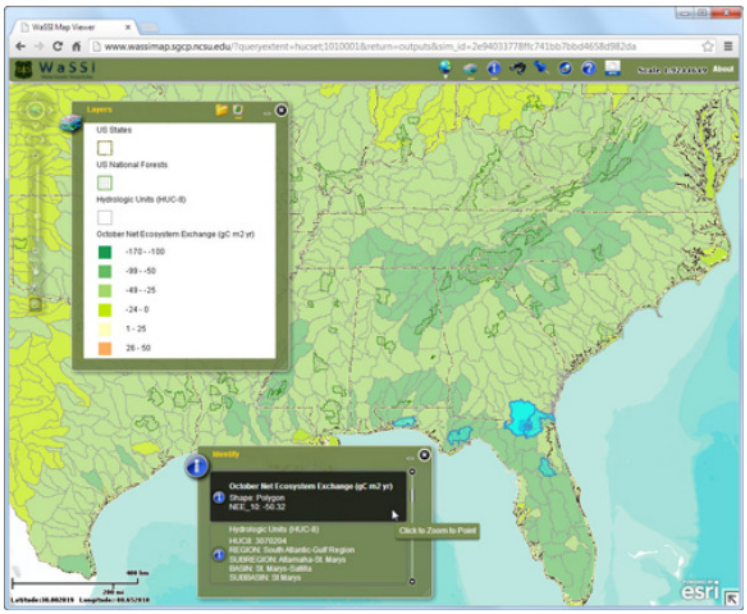
1. The Water Balance module estimates water use and evapotranspiration as well as water yield (i.e., runoff) from each watershed.

2. The Ecosystem Productivity module estimates carbon gains and losses in each watershed as functions of evapotranspiration.

3. The Water Supply and Demand module accumulates the water yield and flow through the river network according to topological relationships among adjacent watersheds. Consumptive water use by humans is subtracted from river flows, and water supply is compared to water demand to derive the WaSSI.

Online Tool and Map Viewer

The online WaSSI tool initially was only available for the southern United States at an annual time step. After integrating global eddy-flux measurements, flow routing, soil-water balance and county-level water-demand data, the current tool (version 2.0) was published online in 2012. Users can run simulations at the monthly time step for the conterminous United States, with an increased number of future climate scenarios available for assessing potential impacts.



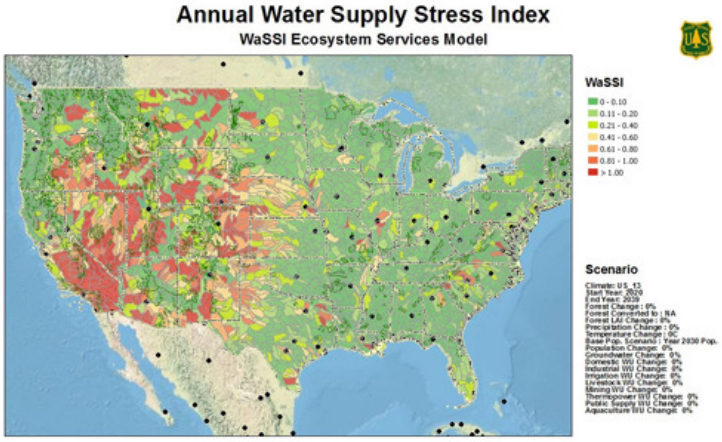
The WaSSI Map Viewer displays outputs from a user-defined model scenario and provides custom tools for visualizing, exporting and querying Web-map layers.

Resource managers, educators, researchers, non-government organizations, and the general public can simulate and graph global-change scenarios; visualize simulation results with an ArcGIS-based map viewer; and assess the effects of multiple stresses on water and carbon cycling at local, regional and continental scales.

The general WaSSI workflow is to select a region of interest, view potential model inputs (watershed or ZIP Code), develop a simulation scenario and view model outputs. Users choose the United States or Mexico and then a watershed, ZIP Code or grid cell (for Mexico). Watersheds are listed by number or name, and the Map Viewer also can be used to zoom and pan to help find watersheds.

Users then explore WaSSI model inputs for specific watersheds, including climate projections, groundwater withdrawal, land cover, leaf-area index, population projections and water use. Using the Input Viewer, these data can be displayed as charts and downloaded as image or text files.

WaSSI's Simulation Tool helps users define climate, land cover, water-use scenarios and time period (in years) of the model run. Tool tips for each setting explain possible values and how user choices influence model outputs. After the simulation is complete, outputs again are available as charts and text files.



A sample WaSSI output shows the potential effects of climate and population change for 2020-2039.

Simulation results are dynamically linked with the Map Viewer and made available in seconds. The WaSSI Map Viewer was developed using Esri's ArcGIS Server 10.0 and Adobe's FlexBuilder 3.0, and it includes all the standard Web-mapping navigation tools and layer lists, along with custom tools that identify attributes, export printable map templates, and provide navigation and interpretation help and metadata.

WaSSI outputs available in the Map Viewer are grouped by the three modules, and each model output is displayed as mean annual or mean monthly values, based on the user's scenario definitions and averaged over the selected time period.

Water Balance layers include precipitation, temperature, snow-water equivalent, soil moisture, potential evapotranspiration, actual evapotranspiration and runoff. Ecosystem Productivity layers include gross ecosystem productivity, ecosystem respiration and net ecosystem exchange. Water Supply and Demand layers (available only for the United States) include total water demand, net water demand (accounting for return flows), groundwater supply, surface-water supply, total water supply and WaSSI value—greater than 1 indicates potential stress on the water supply.

Users can parameterize scenarios and explore the impacts of different changes in climate, land use and population on all model outputs separately or in conjunction. Ancillary layers are included to enhance custom map products that can be created and exported for use in reports or project documentation.

WaSSI Model Applications

The WaSSI model has been successfully used in climate-change assessments in the eastern United States and for examining the nexus of water and energy at a national scale. Most recently, the WaSSI model is being applied as part of the "Forests to Faucets" project, a national-scale effort to locate lands important for surface drinking water, understand the roles that national forests play in protecting water supply, and identify the extent to which some of these forests may be threatened by human and environmental stressors.

At a research site in North Carolina's Piedmont region, scientists from the Eastern Forest Environmental Threat Assessment Center study water quantity and quality to support forest watershed management.

WaSSI model results at the sub-watershed scale are included in the Forests to Faucets project for several national forests in the southern region. Estimates of actual evapotranspiration and runoff inform managers about water resources needed for ecosystem functioning vs. what's available for public supply and consumption as well as increase public awareness about the importance of national forests as providers and protectors of water.

In addition, WaSSI can be used to evaluate tradeoffs among management strategies that influence multiple ecosystem services, such as carbon and water. Managing an ecosystem to increase carbon sequestration, such as bioenergy development, may reduce river flow and, in some cases, cause water-supply concerns for human use through the complex interactions of water and carbon cycles at multiple scales.

WaSSI model results also can be used to support regional- and landscape-scale planning processes. The Template for Assessing Climate Change Impacts and Management Options (TACCIMO) is another interactive, Web-based tool that delivers credible and concise climate-change science needed to assess, manage and monitor forest resources.

TACCIMO supports national forests in the Southern and Pacific Southwest Regions through land- and resource-management plan-revision processes, using peer-reviewed literature and model results such as those from WaSSI as trusted information sources. Together, scientists and managers identify potential impacts of climate change and appropriate management options, consider current management capabilities, reconcile them with scientific findings, and validate or modify management direction.

Forest Service Researchers continue to refine and apply the WaSSI model worldwide. Key components such as reservoirs, inter-basin transfers, groundwater availability and ecological flows will be included in the next version.

In addition, an online version is being developed that will be used in ecosystem-service assessment efforts for Rwanda and Burundi in eastern Africa. This GIS-based tool for quantifying human impacts on the natural environment demonstrated its value for the Forest Service as the agency strives to sustainably manage national forests and the ecosystem services they provide.

Authors' Note: *Readers are encouraged to consult the following references for example applications of the WaSSI Ecosystem Services model: Averyt et al. 2011, Lockaby et al. 2011, Marion et al. 2013, Tavernia et al. 2013. For more information on how WaSSI operates, please consult the user guide at* www.wassimap.sgcp.ncsu.edu/help/wassiuserguide.pdf.

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