

7. WaSSI Model Examines Drought Impacts on National Forests

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The WaSSI model has been expanded to the regional scale to predict future interactions between tree growth, water availability, and drought. WaSSI allows us to better assess the potential risks of drought to forest growth and carbon sequestration under future climate scenarios.

The 781,000 km² (193 million acre) United States National Forests and Grasslands system (NFs) provides important ecosystem services including clean water, timber, wildlife habitat, and recreation opportunities for the American public. Quantifying the historic impact of climate change and drought on ecosystem function at a national scale is essential to developing sound forest management and watershed restoration plans for the future.

PINEMAP has expanded the Water Supply Stress Index (WaSSI) hydrologic model to the regional scale in order to understand the broad consequences of pine forest management and climate change. We have incorporated new discoveries about the interactions of climate, atmospheric carbon dioxide (CO₂), and fertilization impacts on forest ecosystem services into WaSSI. A detailed description of WaSSI is available in the WaSSI Ecosystem Services Model User Guide (<http://www.forestthreats.org/research/tools/WaSSI>). The earlier version of the WaSSI model has been tested and successfully applied to geographical regions across the United States, and in Asia and Africa. WaSSI now covers more than 88,000 HUC-12 watersheds over the conterminous U.S. (CONUS). WaSSI predictions of historic water yield (Q) have been validated for 72 USGS gauged watersheds. In addition, WaSSI predicted evapotranspiration (ET) and gross primary productivity (GPP) have been compared to ET and GPP estimates derived by satellite data for 170 national forests and grasslands across the CONUS. Overall, the latest WaSSI model had the capability to reconstruct long-term water and carbon fluxes on a broad scale (Figure 7.1). More detailed model evaluation results will be published soon (Sun et al. 2015a, in press).

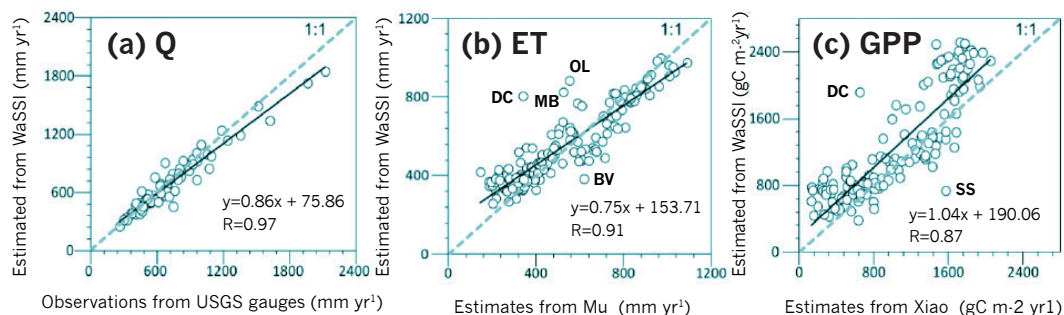


Figure 7.1. Comparisons of simulated multiyear mean annual Q, ET, and GPP by WaSSI against observed Q at USGS gauges. ET was estimated by Mu et al. (2010) and GPP estimated from Xiao et al. (2014), respectively. Note: Validation of Q was conducted at the corresponding watersheds monitored by USGS gauging stations (72 samples), while ET and GPP were scaled to the NF scale (170 samples). Dots with italic characters represent large discrepancies between ET or GPP modeled by WaSSI and other estimation methods. OL=Olympic National Forest; MB=Mt. Baker National Forest; DC=Deschutes National Forest; SS=Siuslaw National Forest; SK=Siskiyou National Forest; and BV=Butte Valley National Grassland.



Photo by Josh Cucinella.

We applied the previously validated WaSSI model to 170 National Forests and Grasslands in the conterminous US to examine how historic droughts have impacted forest water yield (Q) and gross primary productivity (GPP).

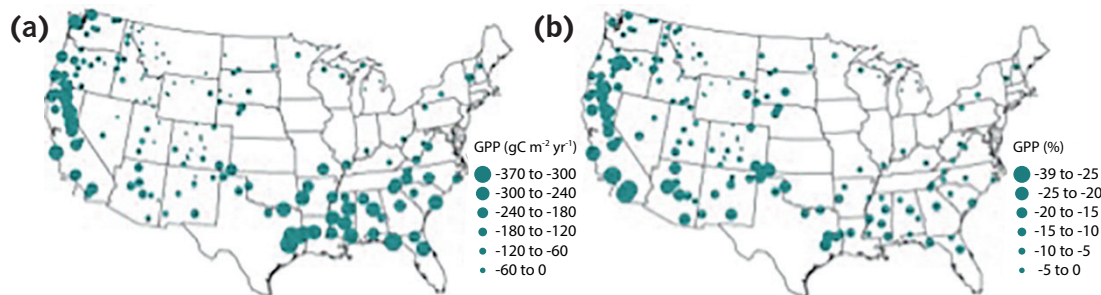


Figure 7.2. Deviations of (a) absolute values and (b) relative values of GPP for the top five drought years from the long-term (1962–2012) means in 170 National Forests and Grasslands.

We applied the previously validated WaSSI model to 170 National Forests and Grasslands in the conterminous US to examine how historic droughts have impacted forest water yield (Q) and gross primary productivity (GPP). For each NF, we identified the top five extreme drought years from 1962 through 2012, defined as the years with the smallest annual three-month Standardized Precipitation Index (SPI3). We found that both the extent of extreme droughts (the number of NFs affected) and total area affected by droughts have increased over the last decade. At the national level, the most extreme drought during the past decade occurred in 2002, resulting in a mean reduction of water yield by 32% and GPP by 20%. The top five droughts for the 170 individual NFs represented an average reduction in precipitation of 145 mm yr^{-1} (or 22%), causing reductions in ET by 29 mm yr^{-1} (or 8%), Q by 110 mm yr^{-1} (or 37%), and GPP by $65 \text{ gC m}^{-2} \text{yr}^{-1}$ (or 9%). The responses of the forest hydrology and productivity to droughts varied spatially due to different land-surface characteristics (e.g., baseline climate and vegetation) and drought severity at each NF. Figure 7.2 illustrates the magnitude of drought impacts on GPP in national forests. The detailed model evaluation results will be published in Sun et al. (2015b, in press).

This study provides a comprehensive benchmark assessment of likely drought impacts on the hydrology and productivity in national forests using consistent methods and datasets across the conterminous U.S. The study results will allow foresters to develop appropriate strategies to restore and protect ecosystem services under potential future increases in drought. We will use PINEMAP's Tier II and Tier III field experiment results to specifically validate WaSSI's ET and GPP model output predictions for loblolly pine stands, allowing us to examine impacts of climate change on forest productivity and water yield across the southeastern region for multiple global circulation models (GCMs) and emissions scenarios. As PINEMAP moves into the final year of funding, we will work with the PINEMAP Decision Support System team to incorporate WaSSI model results into the SouthEast Regional Climate Hub (SERCH) with an ongoing mission to maintain and increase working land (i.e., forest, rangeland, and grassland) productivity in the southeastern U.S. (<http://globalchange.ncsu.edu/serch/>).