Application of the WEPP Model to Simulate the Water Balance of a Forested Watershed, Interior US Pacific Northwest

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Quantification of water balance of forest ecosystems is needed to advance sound forest management practices and to ensure long-term sustainability. Models are widely used as cost-effective tools in forest hydrological assessments. The Water Erosion Prediction Project (WEPP) model is a physically-based hydrology and erosion prediction technology that has been widely applied. Studies assessing the adequacy and ability of WEPP in simulating the water balance and the individual hydrologic processes under forest conditions are still lacking, likely because of the difficulty in obtaining the field data over long time periods. A comprehensive investigation of cumulative environmental effects of forest management activities has been conducted at the Mica Creek Experimental Watershed (MCEW) located in northern Idaho, USA (Figure 1). Daily streamflow was monitored at subwatershed outlets. Sap-flux-based transpiration was measured in an unharvested subwatershed, and soil water content was monitored throughout the area. Meteorology data were collected at a USDA NRCS SNOTEL station and at four weather stations across the watershed.

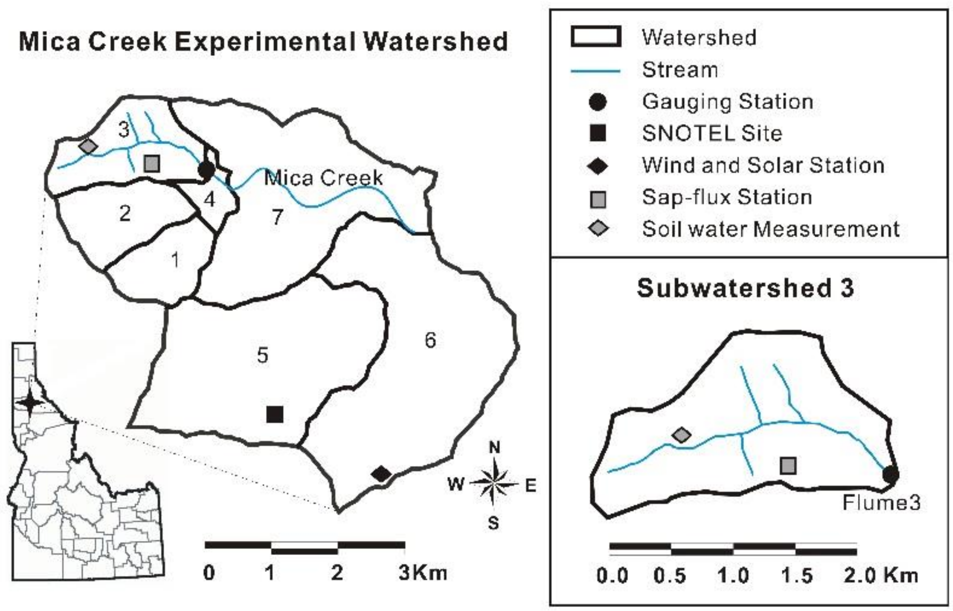

Figure 1. Location of Mica Creek Experimental Watershed study site.

The purpose of this study was to assess the performance of the WEPP watershed model in simulating water balance. The specific objectives were: (i) to present the major components of the observed water balance, including streamflow, plant transpiration, and transient soil water

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content; and (ii) to evaluate the suitability of WEPP in simulating these hydrologic processes. WEPP v2012.8 was applied to subwatershed 3 at the MCEW. Simulations were conducted for two periods, 1992–2003 for calibration, and 2004–2013 for verification. WEPP-simulated streamflow values were agreeable with field observations (Figure 2). Generally, simulated streamflow peaks resulting from snowmelt were overpredicted compared to those observed during spring time, and low flows were underpredicted during the summer time. Over the entire simulation period, the Nash-Sutcliffe model efficiency ranged from 0.24 to 0.75, averaging 0.54, and deviation of runoff volume varied from −19% to 37%, averaging 8%, indicating underpredicted streamflow. The annual average simulated versus observed streamflow was in close agreement with a coefficient of determination (R^2) of 0.88. For the whole simulation period, the contributions of surface runoff, subsurface lateral flow, and baseflow to streamflow were 4%, 79%, and 26% of the total simulated streamflow of 542 mm, respectively. The annual average evapotranspiration was 746 mm or 52% of average annual precipitation (Table 1). Without accounting for tree water storage, WEPP could not properly simulate temporal dynamics of plant transpiration, in particular for the drying period in summer. Future efforts should be devoted to assessing the influence of snowmelt timing on stream flow and including tree water storage in estimation of plant transpiration and soil water dynamics.

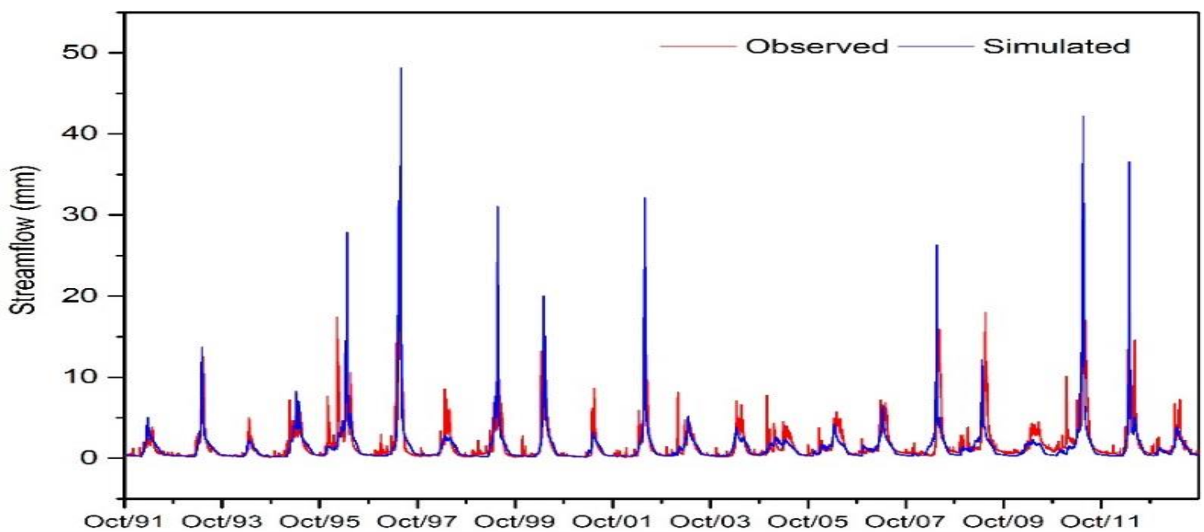

Figure 2. Comparison of observed and simulated streamflow from 1992 to 2013.

Table 1. Simulated annual water balance for calibration and verification periods.

Simulation periods	*P**	*ET*	*D*	*SW*	*GW*	Q_{surf}	Q_{lat}	Q_b	*BFI* (%)
	(mm)								
Calibration (1992–2003)	1450	763	128	12.4	−0.1	31	430	129	28
Verification (2004–2013)	1451	730	157	−12.9	0.0	17	422	157	32
Overall (1992–2013)	1450	746	143	−0.5	−0.1	24	426	143	30

**P*-precipitation; *ET*-evapotranspiration; *D*-deep percolation from soil profile; *SW* and *GW* - yearly change in soil water and ground water, respectively, calculated as the last day's value minus the first day's; Q_{surf}-surface runoff; Q_{lat}-subsurface lateral flow; Q_b-baseflow from groundwater storage; and *BFI*-baseflow index (baseflow in percent streamflow). The sum of Q_{surf}, Q_{lat}, and Q_b is the total streamflow.