Calculating Water Use

Evaluating the Accuracy of Consumptive Use Estimates in Mountain Meadows

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Knowledge to Go Places

Water is a limited commodity in the western United States, and accurate estimates of water used in irrigation are necessary for administration of water in the region. In the upper Gunnison River Basin, Colorado State University professor of soil and crop sciences Dan Smith is researching forage water use.

Smith, with funding from the Agricultural Experiment Station and the Upper Gunnison River Water Conservancy District, is working with research scientist Joe Brummer of the Western Colorado Research Center and graduate student Darcy Temple to find a simple yet accurate method for determining the consumptive use of water in irrigated mountain meadows. "Consumptive use is the portion of the irrigation water applied to meadows that doesn't return to the stream system," Smith explains.

Accurate estimates of consumptive irrigation water use are essential for administration of water in Colorado and other western states because irrigation accounts for 80 to 90 percent of the region's total consumptive use. Colorado's allowable use under interstate compact agreements, like the Colorado River Compact, largely is attributable to irrigation. In addition, when irrigation water rights are changed to other uses, only the consumptive use can be transferred.

There are several methods for calculating consumptive use. All are based on measures of weather variables such as temperature, humidity, wind, and solar radiation. The most accurate methods require data for all four of these weather variables, so a complete (and more expensive) weather station is required to use these sophisticated methods. In addition to cost, the problem with these extensive data requirements is that conditions can vary greatly over short distances. Consequently, a single weather station provides estimates of water use that are applicable to only a small area. Simpler methods of estimating crop water use requiring only one or two weather variables are available, but they are less accurate and require local calibration.

Smith is testing the calculations made by different methods against data being collected in the field to find the most accurate and simplest method for computing consumptive use in mountain meadows. To collect field data, Smith and his team have installed nine lysimeters in representative irrigated meadows throughout the upper Gunnison River basin. The lysimeters look like large, square-sided buckets in which grass is growing. The water in the lysimeters is maintained at a level similar to that of the surrounding irrigated meadow by using a float valve attached to a supply reservoir. Water use is measured by changes in the level of water in the supply reservoir. Each of Smith's lysimeter sites also is equipped with a rain gauge and instruments for measuring weather variables.

One of the most popular methods of calculating consumptive use has been the Soil Conservation Service's (SCS) Blaney-Criddle method. The method has been a favorite because its only data requirement is average daily temperature, based on measurements of maximum and minimum daily temperatures. "In mountain meadows in the western United States, it is recognized that the SCS Blaney-Criddle method greatly underestimates water use unless crop coefficients are adjusted to meet local conditions," Smith says. However, even when these adjustments based on local methods are made, calculated values

of consumptive use and actual water use are poorly correlated. Using data collected in the mountain meadows, Smith tried to use alternative expressions of average daily temperature, such as the average of hourly temperatures throughout the day or just during the light period of each day, to calibrate the SCS Blaney-Criddle. The results of Smith's analysis indicate that water use is poorly correlated with average daily temperature regardless of the temperature expression used.

Smith and his co-workers were not completely surprised by these results. He notes that solar radiation is the best single weather variable that predicts consumptive water use. Fortunately, one lysimeter location was equipped with a complete weather station, so the group was able to conduct preliminary analyses to confirm the value of solar radiation as a predictor of crop water use. Radiation methods for estimating crop water use were investigated. One of these methods, called the Hargreaves method, which was developed in the 1970s but went relatively unnoticed until recently, looked promising because it was based on the use of temperature. But instead of using average daily temperature, this method relies on the difference between the maximum and minimum daily temperature.

"Looking back, the Hargreaves method should have been the first choice for these high-altitude environments," says Smith. "Days with radically different levels of solar radiation can have the same average temperature," Smith says. With one year of data collection remaining, Smith claims that the Hargreaves approach is producing much more accurate estimates of consumptive water use than the more conventional SCS Blaney-Criddle method.

Data requirements for the Hargreaves method are modest enough that Smith can imagine a day when the approach could be used over a wide range of conditions to monitor crop water use. The resulting data could then be used as a real-time inventory tool to aid Colorado officials in their efforts to monitor the state's compliance with interstate compacts.

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Forage Crops and Water Use

For the most part, environmental conditions determine the water use of plants, but different crops require different amounts of water even if they are grown under the same weather conditions. Forage crops, like hay, have low water requirements compared to most other crops. Forage crops are good crops for planting during drought or in naturally arid regions because they can be harvested at any growth stage. This means that the farmer can harvest forage crops early and escape drought-induced crop failures. Furthermore, established perennial forages will remain viable during drought periods only to re-initiate growth upon resumption of moisture from either rainfall or irrigation. Finally, seeding of annual forages is relatively inexpensive.

Forage crops have been grown in the dry, sunny Upper Gunnison River Basin since the 19th century, when farmers began using the mountain meadows to grow forage crops for draft animals. More recently, cattle have been raised in the mountain meadows. Mountain meadows supply the forage base for year-round livestock production in the Rocky Mountain region, and hay yields from mountain meadows average about 1.3 tons per acre.