Why Do We Care About ET?

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They are all around us: those crazy, vibrant water molecules yearning to break away from their liquid siblings and become free wanderers in the sea of atmosphere. All they need is the addition of a little energy and space in the air above, and they are off!

Thus, evaporation. It occurs from open water, from wet or moist soil, and as transpiration from stomata of plants. It is an age-old process that has pumped enormous quantities of water vapor from the oceans each year for millenia onto land masses in the form of rain or snow. A significant portion of this rain or snow in turn evaporates or transpires from the land surface and flows with the air masses to where the air cools below the saturation point so that the molecules condense and precipitate once again.

It Takes Energy

Just as evaporation of the water contained in a teapot requires the addition of energy, evapotranspiration (combined evaporation and transpiration, or ET) requires energy from the surrounding environment. Engineers and scientists make use of this energy requirement to estimate the rate of ET by measuring the energy consumed during the ET process. This energy is termed *latent heat*. Measured or estimated energy consumption is translated into an equivalent depth of ET over the land surface by dividing the latent heat by a constant that varies only slightly with temperature.

The significant energy requirement of ET helps place a cap on the amount of water that can evaporate from soil and vegetation surfaces, since there is a limited amount of energy at the land surface at any particular time. The amount of energy is governed by the amount of solar radiation, the amount of heat flowing from beneath the soil surface, and by the amount of heat that can be drawn out of the air as it passes over the surface. The heat exchange from passing air is a function of the temperature of the air relative to the surface, the velocity of the air, the "roughness" of the vegetation, and the dryness of the air. These impacts are often incorporated into "combination" equations, such as the widely used Penman-Monteith equation that uses weather measurements of solar radiation, air temperature, air humidity, and air movement to estimate ET rates.

ET is the second largest component of the hydrologic water balance, behind only precipitation. In desert areas of the Southwest, ET rates are so high that nearly as much water goes up into the atmosphere as falls from it. Globally, more than 50 percent of solar radiation is returned to the atmosphere through evaporation and transpiration. This return replenishes atmospheric moisture and leads to precipitation recycling. Yet ET is often the most difficult of the water balance variables to measure due to its wide spatial variation and invisibility.

Who Is Using It?

The irrigation engineering community was perhaps the first to push for more precise estimation of ET to help irrigated agriculture apply water more efficiently and to ensure that water supplies are adequate. Results of this push have been scientific-based (i.e., ET-based) irrigation scheduling programs for farm water management and standardized procedures for calculating ET requirements that have been published by the American Society of Civil Engineers and the United Nations Food and Agriculture Organization.

Today, irrigation engineers use daily ET rates to design and size irrigation conveyance, pumping, and application systems (such as sprinkler and drip), and seasonal ET volumes to size storage systems or ensure water supply for food production. They need ET information to monitor irrigation system performance (for example, the ratio of ET to diversions) and to assist farmers in irrigation scheduling.

Hydrologists covet estimates of ET over large land domains so that they can assess river basin and watershed water balances and estimate soil water storage and recharge (deep percolation) to groundwater systems. ET and infiltration are often the two large unknowns in a river basin or study area, so if ET can be determined, an improved estimate of the groundwater recharge term can be derived as a "residual." These watershed water balances are used to make critically important management decisions regarding current and future allocation of water supplies. Thus, uncertainties and measurement errors in major water components—particularly when measuring ET over natural vegetation and agricultural systems—have significant implications for those decisions. Historically, too much trust has been placed on somewhat loose numbers; our communities of technical professionals and water managers must tighten up their estimates in light of increasing competition for water in many river basins.

Groundwater modelers, who focus on the hydraulics of liquid water flowing through geologic strata, often wish for more accurate knowledge of rates, timing, and spatial distribution of ET, since this impacts both the extraction of groundwater used for irrigation and the surplus of soil water that can percolate through the strata and replenish the groundwater.

Civil engineers need to know ET rates and volumes and their variation in time in order to size water storage and conveyance structures (including for irrigation of landscapes and crops). Knowing the ET component of the water balance allows them to estimate sustainable yields of water from river basins under present and future land-use scenarios, and to optimize water management.

Agronomists and plant physiologists use precision measurements of the transpiration component of ET to estimate crop yields and to examine physiological behavior when soil water is in shortage. Shortage of soil moisture creates water stress in plants, which in turn causes the partial or complete closure of stomata. Stomatal closure, although critical to conserving life-sustaining water in plant tissue, also reduces the influx of carbon dioxide required for photosynthesis and the creation of biomass and reproductive seed. Happy, water-unstressed plants make for near-maximum levels of ET. Transpiration creates a flow of water from soil to roots and leaves that functions as a conduit for nutrient transport. Additionally, transpiration can help keep leaves somewhat cooled during hot periods and perhaps at temperatures more conducive to biological and enzymatic processes.

Ecologists study the relationships among precipitation, ET, and health of plant communities, including competition among species. Plant species can impact ET rates and create a sort of feedback between soil water and plant health. Deeper-rooted species have an advantage over shallow-rooted species by accessing water stored deep in the soil, thus increasing their water supply. Species that green up earlier in the growing season or nearer to the beginning of a wet season can convert available soil water reserves into ET sooner than their competition, helping them to dominate a landscape. Non-native species are often able to invade a biome because of this competitive edge.

River basin managers also care about ET from native plant species versus ET from invasive species, and should take riparian ET consumption into account when releasing reservoir flows. Native plants, while consuming valuable water, are generally desirable and require sustaining ET supply streams. Invasive species, on the other hand, sometimes consume precious water to the detriment of native plant systems.

Why We Must Care

Despite the interest in ET across many disciplines, ET quantification remains an imprecise science. Improvements in accuracy of data and new measurement techniques will have important and positive impacts in a number of scientific disciplines and in practical applications in engineering, agriculture, and water management. A number of court cases at local, state, and even U.S. Supreme Court levels, along with hydrologic issues related to endangered species management, are helping to move the science of quantifying ET forward.

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