availability are evaluated, the Penman-Monteith equation or more complex multi-layered energy balance equations should be used, since changes in vegetation characteristics can be more directly and readily incorporated into the calculations for aerodynamic and surface resistances. Where specific documentation of ET is required for small areas, direct measurements must usually be made using micrometeorological methods including the Bowen ratio and eddy correlation methods or soil water balance methods including lysimeters and direct soil profile measurement. Various precautions that must be exercised when measuring ET have been discussed in the relevant sections of this chapter.

Generally, as one progresses from the K_c ET_0 approach to the direct Penman-Monteith approach, the quantity of data required increases, the required calculation timestep decreases, and the requirement for representativeness and accuracy of data increases. It is difficult to apply the direct Penman-Monteith equation using historical data from standard weather stations, since the historical weather data reflect ET flux densities of the weather measurement surface. When applied to some other vegetation type, the direct Penman-Monteith may over or under predict, since the effect of feedback mechanisms between ET and vapor content and temperature of the boundary layer are not reflected in the data.

Energy balance methods, including the combination equation (Penman-Monteith equation) and energy balance equation (Equation 4.96), are generally more dependable and consistent in estimating ET as compared to direct aerodynamic methods (for example Equation 4.90), since the inclusion of energy availability in the former equations places an upper limit on ET estimates. In addition, instrumentation requirements are often less rigorous and demanding.

The K_c ET_0 procedure can sometimes be the best overall approach to estimating ET since the use of ET_0 provides a measure of general energy available for evapotranspiration, and the K_c coefficient can incorporate a wide assortment of physiological and environmental factors affecting ET rate, including plant density, soil evaporation, and effects of small stand size. This implicit incorporation makes the K_c ET_0 approach robust in application and fairly transferrable to other climates, regions, and time periods. Physiological and environmental factors need to be explicitly identified and incorporated during direct application of the Penman-Monteith and other directly applied boundary layer equations, making these approaches usually more data intensive. However, application of the direct Penman-Monteith equation can often serve as a valuable check on validity of K_c values and can in some instances be used to develop K_c's for new types or variations of vegetation.

Usually, calculations made using the Penman-Monteith equation on a 24-hr basis are sufficient for hydrologic studies. Under most conditions, 24-hr estimates of ET_0 calculated using the Penman-Monteith equation for 24-hr timesteps provide estimates of total 24-hr ET_0 which are within 5 to 10 percent of 24-hr sums made using hourly timesteps for any given day, with differences varying randomly, depending on the general proportions of daytime to nighttime wind speeds and daylengths (Allen et al., 1994b). Results are similar for calculations made using the direct Penman-Monteith equation. The exception is for situations where the stomatal conductance functions (g()) or stability corrections are to be applied. In these situations, calculations should be made on an hourly or shorter basis. Calculations of ET_0 on a monthly basis are generally equivalent to those made on a 24-hr basis and summed over the month (Jensen et al., 1990; Allen et al., 1994b).

Energy balance methods must generally use hourly or shorter time steps since measurements of surface temperature, which are highly correlated with solar radiation, are involved, and since corrections for stability are generally employed, especially under conditions of moisture stress.

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