5.2 Meteorological data

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For estimating the production capacity of a region, the prevailing weather conditions are of major importance, a fact that has been made patently clear in the preceding chapters. In this section the relevant variables are treated in a schematic way. For a more detailed treatment of the processes involved, the reader is referred to textbooks on the subject (cf. Grace, 1983; Monteith, 1973).

Weather data are collected at weather stations, run mostly by the meteorological service of a country. Very often these services are not in the first place, or not at all, concerned with the use of their data in the field of agro – meteorology. Good contacts with the local service should promote cooperation, especially if the agro – meteorologist or agronomist is able to clearly explain his needs.

Weather data reported by the meteo stations should never be taken at face value, but should be judged using common sense and, if possible, the instrumentation and the method of collecting the data should be checked by the user.

5.2.1 Radiation

Solar energy is the primary source of energy for all terrestrial life. It is trapped by the green pigments of the plant and converted into chemical energy in the process of assimilation (Section 2.1). For the calculation of (potential) assimilation and (potential) evapotranspiration a reasonably accurate estimate of solar radiation is indispensable. Total global radiation received at the earth's surface may be measured by solarimeters, which provide accurate data on daily totals of global radiation. Unfortunately, such data are rather scarce and often use must be made of records on sunshine duration. For conversion of these data, Angströms equation may be used (Section 3.1). As is explained there, the coefficients applied are location specific, so if, even for a limited period of time, data on both measured radiation and sunshine duration are available, it may be worthwile to derive a specific equation.

If sunshine duration is also not available, it may be possible to obtain a first approximation of sunshine duration from the degree of cloudiness as estimated by an observer several times a day. It should be realized that especially for strongly fluctuating conditions such estimates may not be very accurate, but for the purposes of the present approach they may be useful. The average cloudiness weighted according to time can then be set equal to the fraction overcast as defined in Section 2.1, and Tables 1 and 2 can be used directly.

5.2.2 Air temperature

In general daily maximum and minimum air temperature are recorded at screen height. For the present approach, the arithmetic average of the two may serve as a reasonable estimate of the mean temperature sensed by the vegetation. This is due to the fact that most of the temperature – dependent relations in the model are essentially linear in the relevant range. If, however, maximum or minimum temperature are outside the linear range, a more accurate value of the dependent variable may be obtained by averageing hourly values. If hourly temperature values are not available they can be estimated from minimum and maximum temperature by a procedure developed by de Wit et al. (1978), which calculates a daily temperature regime from measured minimum and maximum temperature under the assumption of a sinusoidal daily wave.

5.2.3 Air humidity

Many different types of instruments are used to determine the humidity of the atmosphere, but many of these are either not very good or easily misused. The actual concentration of moisture in the air is given by either absolute humidity, which is the mass of water vapour per unit volume of air, W_w, or by the specific humidity, the mass of water per unit mass of the moist air.

In agro – meteorology, air humidity is either expressed by the dew point, T_d, the vapour pressure of the atmosphere, e_a, the relative humidity, h_r, or the wet bulb temperature, T_w. Without going into the details of measurement, relations between the various variables are presented here.

The dew point of a volume of air with temperature T_a and vapour pressure e_a is the temperature at which e_a would be the saturated vapour pressure. The relation between e_a and T_d may be approximated by the expression:

$$e_a = 6.11 \times e^{(17.4 \times T_d/(T_d+239))} \qquad (81)$$

with T_d expressed in °C and e_a in mbar.

The vapour pressure e_a (mbar) is often measured directly. It can also be deduced from the absolute humidity by applying the ideal gas law, which gives the expression:

$$e_a = T_k/0.217 \times W_w \qquad (82)$$

where

T_k is absolute temperature (K), equal to T_a + 273
W_w is absolute humidity in kg m^{-3}

The relative humidity of the air is the ratio between the actual vapour pressure of the air and the saturated vapour pressure at air temperature, e_s. The latter, expressed in mbar, may be approximated by:

$$e_s = 6.11 \times e^{(17.4 \times T_a/(T_a + 239))} \tag{83}$$

The wet bulb temperature, T_w, is the temperature of a wet surface exposed to atmospheric conditions, but shielded from radiation. As a result of evaporation of the water, the temperature of the wet bulb will be lower than air temperature (Section 3.1) and the temperature difference is a measure of air humidity:

$$e_a = e_w - \gamma(T_a - T_w) \tag{84}$$

where

e_w is saturated vapour pressure at wet bulb temperature (mbar), equal to $e_w = 6.11 \times e^{(17.4 \times T_w/(T_w + 239))}$

γ is psychrometer constant (mbar °C^{-1}) (= 0.66)

5.2.4 Wind speed

Wind speed is recorded with integrating anemometers and very often these are read once daily, so that total daily wind run is obtained. As a rule of thumb it may be assumed that the wind speed during the day is twice that at night (de Wit et al., 1978).

If wind speed is not measured at the standard heigth of 200 cm, as required in the Penman equation (Section 3.1), the wind speed at 200 cm may be calculated, assuming a logarithmic wind profile. If wind speed was measured at a height H, the equation reads:

$$U_{200} = U_H \cdot \ln(200/z_o)/\ln(H/z_o) \tag{85}$$

with z_o the roughness length of the surface. As most meteorological observations are carried out over a short green grass cover, z_o may be approximated as 2 cm. The equation then reduces to:

$$U_{200} = 4.61\ U_H/\ln(H/2.) \tag{86}$$

5.2.5 Precipitation

A rain gauge, to record the amount of rainfall is probably the most widely spread meteorological instrument in use and consequently rainfall data are generally available in much higher density than any of the other variables. The accuracy of the measurements depends very much on the type of rain gauge used, its position and the prevailing wind. Variations of not less than 15% are common. Generally, daily values of precipitation are available, which for the present approach is sufficiently detailed. It should be realized, however, that proper estimation of, in particular, surface run-off requires greater detail, as rainfall intensity is the determining factor. To obtain such data a self-recording rain gauge is necessary, of which not many are in operation. If run-off plays an important role it may therefore be necessary to measure that component of the water balance directly and to introduce it in the model as a forcing variable.

5.2.6 Potential (evapo)transpiration

As has been discussed in preceding chapters, a reasonably accurate estimate of potential (evapo)transpiration is obtained by application of the Penman equation, or the Penman-Monteith equation. Application of that equation requires, however, availability of such data as total global radiation and wind speed, which are not always available. In some situations data may be available from a so-called evaporation pan, a container with water, from which the daily water loss is determined. Various types of such evaporation pans exist, and are in operation around the world. One of the earliest types was the so-called BPI sunken pan, which was lowered into the soil, with its rim approximately at surface level; it produced reasonable results. For unknown reasons that type was largely abolished in favour of the Class A pan, which is set up at some height above the soil surface. This type, in particular, reacts differently from an extended water layer because exchange of heat may also take place through the pan walls, and because there is influence from the rim, as the water surface is generally some - variable - distance below the rim. An additional disadvantage is that the presence of such a body of water, especially in not well-guarded situations, invites attention from men and animals, so that not all the changes in water level are due to atmospheric processes. However, despite these disadvantages, if only pan-evaporation data are available they may be applied as a first approximation of the evaporative demand by multiplying the reading by a factor of 0.7.