Field Capacity Probability

Introduction A temporal assessment of risk is the second aspect of the drainflow risk decision tree – "is the time of year when I propose using the product inherently risky?" In order to inform this question the probability of medium to heavy soils being at field capacity for each week of the year was calculated using the MORECS model as a measure of the potential temporal risk that may arise from drainflow.

Approach The work of Smith and Trafford (1976) stands as a seminal text on land drainage statistics and the approach adopted looked to build on this approach with the field capacity estimation being undertaken using the MORECS (Met Office Rainfall and Evaporation Calculation System) model (Thompson *et al*., 1981; Hough *et al*., 1995). Field capacity occurs when the soil holds the maximum amount of water it can hold against gravity. A return to field capacity, when the soil moisture deficit is zero, normally occurs during autumn or early winter, whilst it ends in spring when evapotranspiration exceeds rainfall. Estimation of the number of days that a soil is at Field Capacity is notoriously difficult to derive. A soil can fluctuate in and out of field capacity for a few days or weeks, whilst some wet areas can be at field capacity all year round (for example, north western parts of England), whilst some dry areas during extreme years may never reach field capacity.

MORECS daily soil moisture deficit data for the 1961-2010 time period has been used to calculate the probability that a soil under specific crops are at field capacity for a specific day/week. Fifty years of data has been included in the calculations covering the time period 1961 to 2010. MORECS assumes 3 classes of soils in their calculations according to available water content namely, low, medium and high. A medium soil has been assumed for this work, as this includes the majority of soil types that cereals and oil seed rape are grown on (see Table 1).

Table 1: Summary of the soil type in each available water content class (after Hough *et al*., 1995)

Available Water Content Class	Soil Type
Low	Coarse sand, Loamy coarse sand, Coarse sandy loam
Medium	Loamy sand, Sand, Loamy fine sand, Fine sand, Sandy loam, Fine sandy loam, Loam, Silty loam, Silt loam, Clay loam, Sandy clay loam, Silty clay loam, Sandy clay, Silty clay, Clay.
High	Loamy very fine sand, Very fine sand, Very fine sandy loam, Peat, Loamy peat, Peaty loam.

In order to define a probability of Field Capacity from daily MORECS data, it is first necessary to state how Field Capacity is defined by Soil Moisture Deficit estimates. Francis (1981) and Smith and Trafford (1976) highlight the difficulties in estimating the date of ending of field capacity, suggesting that this is ‘by far the most subjective of the data based on the soil moisture balance, and should be treated with caution’ (Francis, 1981, p3).

Field capacity is not defined within MORECS, so it is assumed to be at field capacity if the soil moisture deficit is less than 5mm. Note that the probabilities are calculated based on the threshold alone, and there is no consideration of whether the threshold is in a drying sequence. This removes the subjectivity of defining a sequence, and is not required since individual year abnormalities are smoothed in the fifty year statistics.

Although there is no published work supporting the use of the 5mm threshold using MORECS data, a number of studies have used this threshold. For example, a soil moisture deficit of less than 5mm has been used to define field capacity in determination of legal cases involving run-off of pollution by the Environment Agency (Met Office Rural Environment Team, Pers. Comm., 2010). The 5mm MORECS threshold has also been used in a Defra Project, which assesses the duration of Field Capacity Days for the Agricultural Land Classification (Defra, 2010). A published method for defining the start and end dates using the 5mm threshold is also provided by Francis (1981) to describe the climate of agriculture areas in Scotland. Francis defined the date of ending field capacity as ’the starting day of the first drying sequence that reached a soil moisture deficit of 5 mm or more’. Francis (1981) defines the return to field capacity as a drying period.

MORECS Model MORECS is designed to provide estimates of weekly and monthly evapotranspiration, soil moisture deficit, and excess rainfall based on a complex Penman Monteith equation. It uses daily observations from 130 synoptic stations as input into the model. The output is in the form of daily, weekly or monthly averages over a 40km x 40km grid covering Great Britain. Although MORECS is run operationally at a 40 km by 40km resolution, the model is scalable. Therefore if site specific input data are available, the output of MORECS can be used at a field scale.

MORECS uses a modified version of the Penman-Monteith equation to calculate both potential and actual evapo-transpiration. In the latter case, the bulk surface resistance is modified according to the magnitude of the soil moisture deficit. MORECS assumes that soil moisture deficit depends only the cumulative balance between rainfall and evaporation once deficit conditions exist. Day time and night time calculations are performed separately, with daily mean values of wind and temperature adjusted empirically according to which period is being considered.

The Penman Monteith equation provides a rational, physically-based means of calculating water loss from any surface. The equation is,

$$\lambda E = \frac{\Delta (R_N - G) + \rho C_p (e_s - e)/r_a}{\Delta + \gamma(1 + r_s/r_a)}$$

Where,

E = rate of water loss (kg m^{-2} s^{-1})
Δ = rate of change of saturated vapour pressure with temperature (mb K^{-1})
R_N = net radiation (W m^{-2}) (+ve downwards)
G = soil heat flux (W m^{-2}) (+ve downwards)
ρ = air density (kg m^{-3})
C_p = specific heat of air at constant temperature (1005 J kg^{-1})
e_s = saturation vapour pressure at screen temperature (mb)
e = screen vapour pressure (mb)
λ = latent heat of vaporisation (~ 2465000 J kg^{-1})
γ = psycromic constant (0.66 for temperature in Celsius)
r_s = bulk surface resistance (s m^{-1})
r_a = bulk aerodynamic resistance (s m^{-1})

A full description if MORECS is available in The Meteorological Office Hydrological Memorandum No. 45 (Thompson *et al.*, 1981).

MORECS output has been verified against some 25 station years of neutron probe soil moisture deficit data and found to provide generally acceptable values of soil moisture deficit (Thompson *et al.*, 1981).

References

Defra, 2010. The impact of climate change on the suitability of soils for agriculture as defined by the Agricultural Land Classification. Defra R&D Report No. SP1104

Francis, P.E. 1981. The climate of the agricultural areas of Scotland. Climatological Memorandum No 108., Meteorological Office.

Hough, M., Palmer, S., Weir, A., Lee, M. and Barrie, I., 1995. The Meteorological Office Rainfall And Evaporation Calculation System: MORECS version 2.0. An update to Hydrological Memorandum 45.

Smith, L.P. and Trafford, B.D. 1976. Climate and Drainage, Technical Bulletin 34, Ministry of Agriculture, Fisheries and Food, London.

Thompson, N., Barrie, I. and Ayles, M. 1981. The Meteorological Office Rainfall and Evaporation Calculation System MORECS, Hydrological Memorandum No 45, Met Office Bracknell.