A User-friendly Method to Determine Deep Drainage and its Requirement in Cotton Soils.

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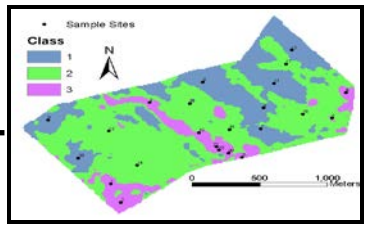
Overview

This paper describes a method that can be used by individual cotton growers and/or cotton consultants to estimate the potential deep drainage. To do this the initial work undertaken was to identify the minimum number of observations that need to be taken to in a cotton field to give a good estimate the potential deep drainage (Figure 1). Once the number of observations needed was known the next stage involved estimating the sub-soil hydraulic conductivity using the falling head lined-borehole technique (FHLBT). To calculate the potential deep drainage also requires an estimate of how many days the sub-soil is saturated for, which growers can determine by knowing the soil moisture after irrigation using their C-probe data (Figure 1). The data generated by the growers is managed by the user-friendly Potential and Required Deep Drainage Interface housed in Microsoft EXCEL. To make the estimate of potential deep drainage more meaningful growers are also asked about the quality of their irrigation water and the crops that are to be grown during the season. This information is used to by the Potential and Required Deep Drainage Interface to determine the leaching requirement that is needed to prevent excess salts build up in the sub-soil that may affect crop yield.

Some testing of the method has been conducted on Field 11 at Auscott Moree. This site was chosen as it is representative of the soil in the growing area, having heavy clays derived from alluvial material and less clayey and/or leaky soil traversing the field. Results showed a significant difference in the potential deep drainage occurring within Field 11, corresponding to soil with different soil clay contents and leaky areas.

Measure subsoil K_{sat} using falling head lined borehole technique and determine number of days subsoil is saturated.



Classify study area and determine sampling scheme

Obtain

crop tolerance
Amount irrigation water applied
EC

and feed into the interface

Model interface

$$K_{sat} = \frac{-\frac{dD}{dt}\left(R_{\max} - r_0\right)}{R_{\max}\left(\frac{8C}{\Pi^2 r_0} + 1\right)}$$

Calculate potential deep drainage

$$LR = \frac{\sigma_i}{5\sigma_{ct} - \sigma_i}$$

Calculate required leaching and drainage

Evaluate if irrigation schedule is inefficient and make necessary adjustments

Figure 1. Steps required for determining and comparing potential deep drainage and its requirement.

Potential Deep Drainage

As can be seen in Figure 1 there are a number of stages that the growers need to undertake in order to get an estimate of their potential deep drainage. These include the design which the growers want to use to sample their cotton field, the measurement of sub-soil hydraulic conductivity and monitoring of sub-soil saturation. The details of these stages are described as follows.

Sampling scheme

It is known that in cotton fields there can be a large amount of variation in water movement through the soil due to the presence of surface and sub-surface cracks. To account for this the growers need put in enough falling-head lined bore-holes to account for this variability. Work was conducted on pasture soil and cultivated soil used for cotton production at the ACRI. From these experiments it was found that for a cultivated site at least 30 bore-holes would need to be in place to get a good estimate of the variation (Trainer, 2005)

For growers to get the best information out of their potential deep drainage estimates it is also recommended that they have some prior knowledge about the field. This may be in the form of aerial photographs, EM surveys, yield maps, or soil surveys. This data has been used by members of the industry in the past to identify areas that have different clay contents resulting in different drainage rates, areas of the field traversed by prior streams resulting in leaky soils, and/or areas that are prone to waterlogging. Using appropriate statistical techniques the growers then have the opportunity to place the sampling sites in the field to capture the variability, which is illustrated in Figure 2, giving a better representation of the deep drainage.

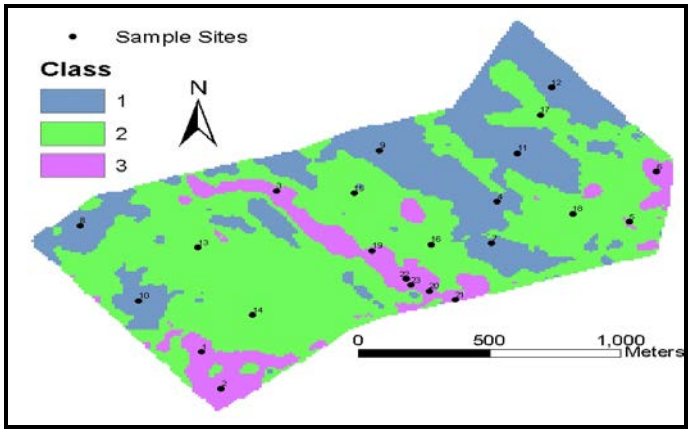


Figure 2. Soil class map of Field 11 at Auscott with 3 zones representing; Zone 1 medium to heavy clay, zone 2 medium clay, and zone 3 lighter then normal clay or potentially 'leaky' clay.

Measuring the sub-soil K_{sat}: The falling-head lined-borehole technique (FHLBT)

To set up the falling-head lined-borehole procedure the grower makes a cylindrical hole to the desired measurement depth either using a hand auger or a push tube/hydraulic ram. Usually the depth chosen is just below the root zone for the crop being grown but, if there is a known constricting layer (e.g. compacted layer) measurements should be taken at this depth. If a hand auger is used the nature of the clay soil used for cotton production will result in the development of a smeared surface, which will impede water infiltration. To overcome this araldite resin is prepared and poured down the hole (Figure 3). A square of Hessian cloth is then inserted into the hole, making sure there is a good contact between the Hessian and resin. Once the araldite has hardened the Hessian cloth is pulled carefully from the hole, exposing a fresh soil surface. Visual inspection of the soil adhered to the resin should

Figure 3. Treating the hole with araldite using the Hessian and twine method.

indicated if smeared surface is not removed and further treatment is necessary. A plastic pipe of equivalent diameter to the hole is now inserted biting approximately 2 cm into the soil at the base of the hole. Sand is then poured into the hole to prevent the destruction of the soil surface when pouring water into the hole. To ensure consistency of measurement a reference point is marked on the pipe and the depth from this point to the top of the sand is noted. The hole is then filled with water and the initial height of water it noted. The change in height of the water is determined by inserting a ruler to the water surface and the value height being recorded against the reference point. As a guide it has been found that the change in height of the water in the hole should be measured 3 times a day, at approximately 3 hours apart, for the first 2 days. By this time the area of interest should be fully saturated. On the final day 5 measurements should be taken at approximately 2 hours apart to obtain the steady-state infiltration. The reading times presented here are a guide and should be modified depending on the rate at which water is actually infiltrating at steady-state. This data is then entered

into the appropriate section of the Potential and Required Deep Drainage Interface where the K_{sat} is calculated using the model developed by Philip (1993).

Calculating potential deep drainage

To calculate the potential deep drainage the grower also needs to know the number of days that the sub-soil is saturated. This is because when the moisture content of the soil falls below saturation there is a rapid decline in hydraulic conductivity and hence the deep drainage occurring is negligible (Trainer, 2005). Capacitance probes (C-probes) are commonly used to monitor irrigation scheduling in the cotton industry and this data is useful in estimating the period of time for which the sub-soil is saturated. After each of the irrigations over a season the growers can use their C-probe data to estimate the period of time that the sub-soil is saturated which they then enter into the Potential and Required Deep Drainage Interface and now the potential deep drainage can be calculated.

Estimates of potential deep drainage at Field 11, Auscott

Using the EM 31 and EM 38 soil survey of Field 11 collected by Huckel (2001) the field was divided into 3 zones, which represented a range in sub-soil textures that are found in the field. One of the zones represents areas of lower then average clay content which Stannard and Kelly (1968) identified as prior streams that traverse the field and are often described as comparatively leaky soils (Figure 2). In Table 1 t can be seen that the estimates of potential deep drainage that zone 3 exhibited the greatest, which coincides with soils of lesser clay or prior streams, while zone 2 with heavy clay sub-soils demonstrated less potential deep drainage (Trainer 2005).

Table 1. Summary of estimates of potential deep occurring at Field 11, Auscott, from Trainer (2005)

Class	Sub-soil clay	Potential Deep Drainage mm/season
1	Medium to heavy	39
2	Medium	19
3	Lighter/leaky	450

Leaching Requirement and Drainage

According to Richards (1954) the leaching requirement is defined by the minimum fraction of applied irrigation water which must pass below the bottom of the root zone to prevent the reduction of crop growth, or maintain a specific level of salinity. To calculate the leaching requirement in the Potential and Required Deep Drainage Interface growers are asked how much water is applied over the irrigation season (mm), an estimate of the salinity (EC) of the irrigation water (dS/m), what is the salt tolerance of the crop to be currently or to be grown in the future? The drainage requirement is then calculated using the estimates made of the leaching requirement and the amount of irrigation water applied over the growing season, which is described by Trainer (2005). This can be illustrated by the following example; the leaching requirement for cotton is presented in Table 2 which has a salinity tolerance of 7.7 dS/m for a 10% yield loss. In Narrabri there are two sources from which irrigation water can be obtained: bore water (4 dS/m) and the Namoi River (1.1 dS/m, March 2004). Remembering that the leaching requirement is that fraction of water required to leach through the profile the actual drainage required must also take into account the volume of irrigation water that is applied, which is also presented in Table 2.

Table 2. Leaching and drainage requirement for cotton irrigated with 700mm.

Water source	Leaching requirement	Drainage requirement (mm)
Narrabri Bore Water	0.12	81.2
Namoi	0.03	20.6
Gwydir	0.006	4.4

It should be remembered that cotton is more often then not grown in rotation with other crops. This is recognised in the Potential and Required Deep Drainage Interface and, growers are asked to identify what crop has the lowest salinity tolerance. It is this crop that will be used to determine the lower limit for the drainage requirement. Once determined the drainage required can be compared to the estimate of deep drainage allowing the grower to identify if too much or too little irrigation water is being applied.

Conclusions

A method for the in-filed measurement of sub-soil K_{sat} using the falling-head lined bore-hole technique was developed to be suitable for Vertosols of the cotton growing region of NW NSW. From the K_{sat} data and period of sub-soil saturation the potential deep drainage was successfully measured. The procedure was tested on Field 11 at Auscott, which had been divided into 3 zones representing soil of different textures and the presence of prior streams. The potential deep drainage results showed significant differences between the zones and in particular demonstrated that zone 3 is a relatively "leaky area", which coincides with the less clayey alluvial deposits. To make the estimate of potential deep drainage more meaningful a procedure was also developed to estimate the drainage required to prevent the build up of salts in the sub-soil that may reduce crop yield. Once determined the drainage required can be compared to the estimate of deep drainage allowing the grower to identify if too much or too little irrigation water is being applied. These calculations are housed in the user-friendly Potential and Required Deep Drainage Interface managed by Microsoft EXCEL available to the industry.

References

Trainer, E. 2005. A method for the simple and rapid determination of deep drainage and its requirements. Honours Thesis. The University of Sydney.

Philip, J. R. 1993. Approximate analysis of falling-head lined borehole permeameter. Water Resources Research. 29. 3763-3768.