



Final Report

On Farm Series | Cotton Research & Development Corporation

FINAL REPORT 2006

Part 1 - Summary Details

CRDC Project Number: CRC61 OR Cotton CRC Project Number:

Project Title: Development of a field method for measuring deep drainage potential

Project Commencement Date: 1 July 2004 **Project Completion Date:** 30 Jun 2006

CRDC Program: On-Farm **OR CRC Program:** - Please Select One -

Part 2 – Contact Details

Administrator: Ms. Luda Kuchieva
Organisation: The University of Sydney
Postal Address: Research Office A14, The University of Sydney. NSW 2006
Ph: (02) 9351 7903 **Fax:** (02) 9351 3256 **E-mail:** luda@reschols.usyd.edu.au

Principal Researcher: Budiman Minasny & Damien J. Field (*Researcher 2*)
Organisation: The University of Sydney
Postal Address: JRA McMillan Building A05. The University of Sydney
Ph: (02) 9036 9043 **Fax:** (02) 9351 3706 **E-mail:** budiman@acss.usyd.edu.au

Supervisor: Prof. Alex McBratney
Organisation: The University of Sydney
Postal Address: JRA McMillan Building A05. The University of Sydney
Ph: (02) 9351 3214 **Fax:** (02) 9351 3706 **E-mail:** Alex.McBratney@acss.usyd.edu.au

Signature of Research Provider Representative: _____

Part 3 – Final Report Guide (due 31 October 2006)

Background

The efficiency of surface irrigation is influenced by the water infiltration and drainage characteristics of the soil. Deep drainage is the downward flux of water below the depth to which plant roots can extract water. Excessive deep drainage can potentially lead to the development of shallow water tables and subsequent problems of secondary salinisation. In addition, drainage losses beyond the root zone are wasted resources. In the past, deep drainage has been neglected due to the belief that the heavy clay vertosols, on which a large proportion of irrigated cotton is grown, exhibits negligible water loss. However recent studies have highlighted the potential for appreciable drainage on the cracking clay. In order to enhance the efficiency of irrigation, the hydrological processes affecting soil water flow need to be understood and the rate of deep drainage need to be known.

Various methods have been proposed for measuring deep drainage. The direct methods are using lysimeter and also soil flux meters. There are also indirect methods based on soil-water balance, *Darcian* flux, and the use of water-borne tracers. These methods need specialised and expensive instrument, the measurement is quite tedious and require technical skill and can be expensive. Most of these methods are employed for research purposes. Under irrigated conditions, the rate of deep drainage can vary considerably over a field due to the spatial variation of the soil properties, uniformity and quantity of water application. Thus to quantify the rate of deep drainage considerable amount of samples are needed to adequately represent a field. There are also methods that estimate deep drainage based on modelling and inferring deep drainage from soil data, electromagnetic sensed data or environmental variables. Soil-water balance or salt balance model have been used extensively.

Many estimates have been given on the rate of deep drainage for irrigated cotton soil. These estimates are based on models that are simplification of reality which rely on many assumptions. Very few measurements have been actually made; this is mainly due to the high cost and the limited resources (e.g. lysimeter). *Thus a cheap and easy way to estimate the risk of deep drainage is needed urgently.*

Objectives

The aim of this project is to develop an easy and inexpensive method for measuring the risk of deep drainage potential. This method should require no specialised instruments and can be operated by growers, agronomists, industry development officers and everyone concern with environmental farming sustainability. The method should not be time consuming so that many measurements can be made within a field if necessary.

Objective 1. Is to develop a technique for measuring the deep drainage potential. The method has been developed and all field experiments to validate the method have been completed. The method and the results have been published as part of an Honours thesis by Ms Erin Trainer already supplied to the CRDC (see publications).

Objective 2. Conducting two workshops on the estimation of deep drainage potential. The method has been presented as a poster and a paper at the 13th Australian Cotton Conference, 2006. Negotiations need to be undertaken with the CRDC to organise a field-day, along with a protocol/fact-sheet, to demonstrate how the method can be implemented and the potential deep drainage calculated.

Methods

This project is primarily concerned with developing a technique for the estimation of subsurface (above groundwater table) hydraulic conductivity. Estimates of the subsurface hydraulic conductivity will allow for the maximum rate that water can pass through below the root zone to be established. A falling head borehole technique will be developed to achieve this objective. The method will make use of access tubes which growers have used to monitor soil water content using neutron probes or C-probes. The method will involve pouring a given amount of water into the access tube and monitoring the level that the water falls in the tube over time. This project will investigate the appropriate water level, time required and operational procedures of the approach being described. The treatment of the resulting data is based on the mathematical model developed by Phillip (1986, which forms a set of equations that can estimate the subsurface hydraulic conductivity. It is also expected that the use of the inexpensive and simple method offers a way of delineating the spatial variation of deep drainage in the field.

The procedure will be coupled with a program that will be made available in a user-friendly interface. The protocol being developed will enable anyone to use the proposed method, which is moving towards satisfying the second objective.

Results

The steps required to develop the protocol are presented in Figure (1), which include; a modifying a method to measure the subsurface hydraulic conductivity, the measurement and monitoring of the hydraulic conductivity, the design of the sampling scheme appropriate for a cotton growing system, the processing of the data through the interface and, the assessment of the leaching requirement towards and estimate of irrigation efficiency.

The falling-head lined-borehole technique (FHLBT)

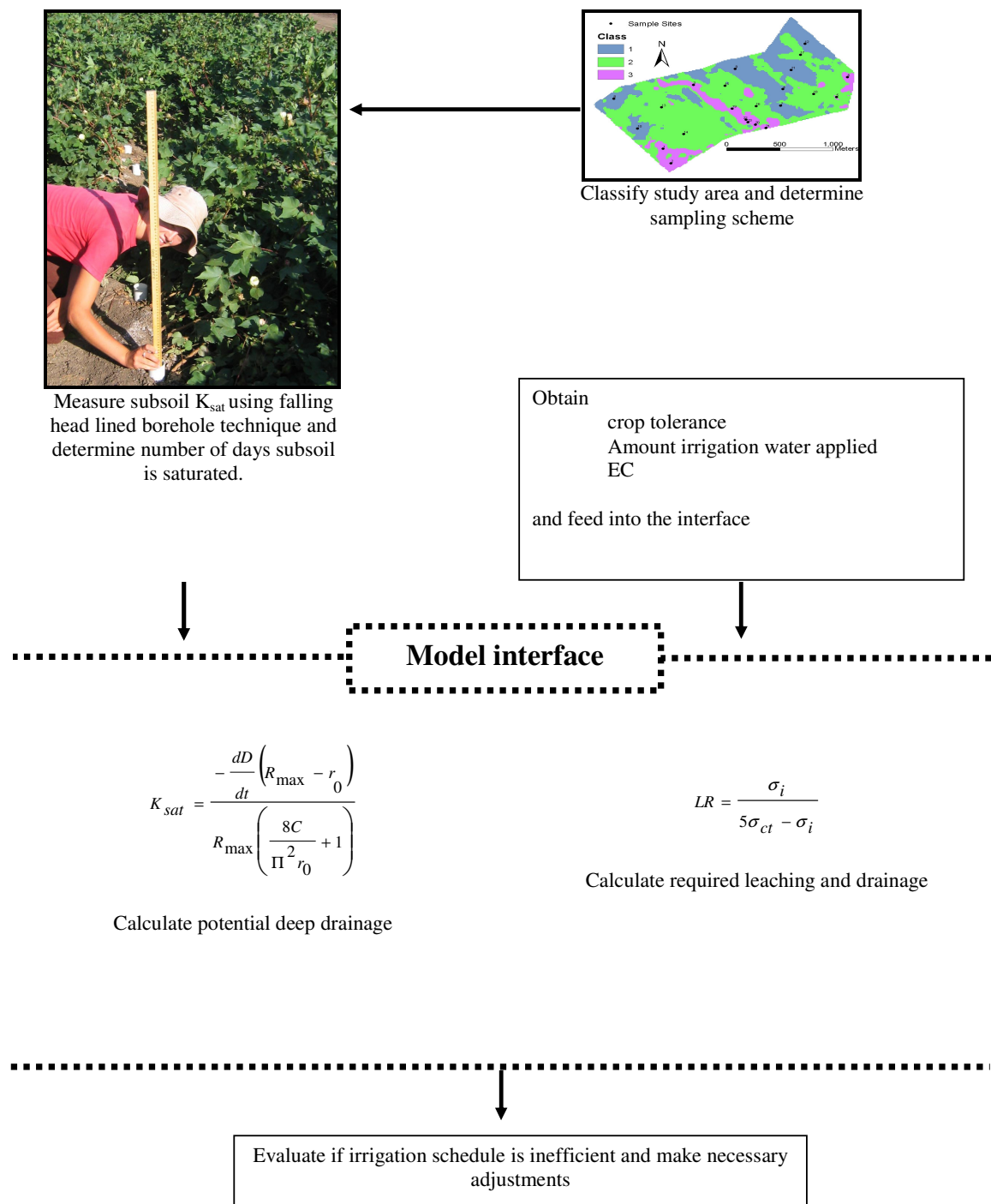
Early experimentation in this project was undertaken to determine what steps were required to further modify the falling-head lined-borehole technique for use in a cotton growing system. A major concern was the potential to develop a smeared base of the bore hole, impeding infiltration, if a hand auger is used. In this work it has been proven that araldite resin could be used to expose a fresh unsmeared soil surface at the base of the bore hole (Trainer, 2005). It was also demonstrated that is a push-tube or hydraulic ram was used to produce the borehole smearing was not a problem. During this experimentation it was also established that the PVC pipe use to line the borehole should bite approximately 2 cm into the soil at the base and a small amount of sand pored into the bore hole. The sand is added to prevent the soil surface from being disturbed when pouring in the water.

Measuring the sub-soil saturated hydraulic conductivity (K_{sat}) and calculating deep drainage

The experimentation has established that the monitoring of the hydraulic conductivity merely requires the user to measure the change in height of the water against the reference point in the cylinder using a ruler at least three times a day for the first 2 days. After this time the area of infiltration at the bottom of the tube should be saturated. Readings should then be done at least 5 times a day in order to establish the steady state infiltration, which is represented by a straight line (even gradient) in the plotted data. The slope (gradient) of line is then inserted into the appropriate field in the Potential and Deep Drainage Interface. To successfully calculate the deep drainage potential the number of days that the sub-soil is saturated needs to be established, because when the moisture content of the soil falls below saturation there is a rapid decline in the hydraulic conductivity and hence the deep drainage will effectively become negligible. Capacitance probes (C-Probes) are commonly used to monitor irrigation

scheduling in the cotton industry and this data proved useful in estimating the period of time which the sub-soil is saturated. Using this technology it is possible for the grower to determine the period of sub-soil saturation of which they include as data in the Potential and Deep Drainage Interface that has been developed (Trainer, 2005).

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



Sampling Scheme

Work was undertaken using a pasture soil and cultivated soil used for cotton production at the ACRI to estimate the number of boreholes required to give a good estimate of the subsurface hydraulic conductivity variability that characterises a cotton field. For these experiments it was suggested that a sample mean within 10 % of the population mean is considered adequate. Considering table 1 it was also determined that an 80 % confidence interval be appropriate resulting in some 30 boreholes needing to be in place to achieve this goal.

Table 1. Number of holes required to be within 10 % of the mean with 80 % or 90 % confidence.

Treatment	Number of samples used	80 % confidence	90 % confidence
Pasture	53	6	9
Cultivated	22	32	53

Work using Field 11 at Auscott proved useful in demonstrating that some prior knowledge of the field would benefit the sampling design for borehole placement. Information sourced from aerial photographs, EM surveys and yield maps have proven useful in identifying soil of different clay contents, prior streams giving rise to leaky soils, and areas prone to waterlogging. Processing data using statistical techniques, such as fuzzy k-means, the field can be divided into classes increasing the success for placing the sampling sites to capture the within field variability giving a better representation of deep drainage.

Validation of the method for estimating the potential deep drainage

Using the EM 31 and EM 38 soil survey data of Field 11 collected by Huckel (2001) the field was divided into 3 zones to capture the range of clay contents that characterise this field. Using the FHLBT it was possible to identify zone 3 which has been established as a comparatively leaky soil (Table 2), while zone 1 and 2 demonstrated deep drainage estimates expected for heavier clay soils.

Table 2. Summary of estimates of potential deep drainage occurring at Field 11, Auscott.

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

Leaching requirement

To prevent the build up of excess salts in the root zone a certain amount of water is required to pass below this zone and is defined as the leaching requirement. Incorporated into the Potential and Required Deep Drainage interface is a module that asks growers to estimate the amount of irrigation water applied over the growing season (mm), and estimate of the salinity of that irrigation water (dS/m), and the salt tolerance of the crops grown. Using this data estimates are made of the leaching requirement to maintain salt levels below the threshold of the least tolerant crop, which in a cotton growing system is more then likely the rotation crops incorporated between growing seasons. This is illustrated with the example in Table 3.

Table 3. Leaching and drainage requirement for cotton irrigated with 700 mm.

Water Source	Leaching Requirement	Drainage Requirement
Narrabri Bore Water	0.12	81.2
Namoi	0.03	20.6
Gwydir	0.006	4.4

The calculations are housed in the user-friendly Potential and Required Deep Drainage Interface managed by Microsoft EXCEL available to the industry

Outcomes

The project has successfully;

- Developed a protocol that can be used to assess the potential deep drainage on a cotton farm
- Demonstrated the importance of strategically placing sampling sites to capture the within field soil variability, increasing the opportunity for a better representation of the potential deep drainage.
- Developed a user-friendly interface in commonly available software to calculate the potential deep drainage.
- Incorporated a module into the Potential and Required Deep Drainage software to determine the drainage required to avoid subsoil salinisation.

1. Please describe any:-

- a) Not applicable
- b) The novel approach developed is clearly outlined in Figure 1.and
- c) Not applicable

Conclusion

A major issue facing the cotton industry is to achieve its long-term environmental outcomes of increasing water use efficiency. The Cotton Research and Development Corporation have demonstrated a strong commitment to supporting research and extension in this area. The development of a protocol to measure the Potential and Required Deep Drainage allows growers to assess the risk of deep drainage on their enterprises and to move towards a more efficient use of their irrigation water which forms one component towards increasing the water use efficiency on cotton farms.

Extension Opportunities

2. Detail a plan for the activities or other steps that may be taken:

Negotiations need to be held with the CRDC to organise a demonstration day for the training of extension staff and other interested parties. Members from the research team undertake other teaching and training activities in the Narrabri area in late February and this may be an opportune time for holding a workshop on the use of the Falling Head Lined-Bore Hole technique to measure deep drainage.. .

8. A. List the publications arising from the research project and/or a publication plan.

Trainer E. 2005. A Method for the Simple and Rapid Determination of Deep Drainage and Its Requirement. Honours Thesis. The University of Sydney.

Trainer E., Minasny B., Field D., McBratney A. 2006. A user-friendly method to determine deep drainage and its requirement in cotton soils. 13th Australian Cotton Conference, Broadbeach Queensland, 8-10th August.

Trainer E., Minasny B., Field D., McBratney A. 2006 A quick and cost-effective method of estimating potential deep drainage. Poster Presentation. 13th Australian Cotton Conference, Broadbeach Queensland, 8-10th August.

B. Have you developed any online resources and what is the website address?

Not applicable

Part 4 – Final Report Executive Summary

The Cotton Research and Development Corporation have demonstrated a strong commitment to supporting research in water use efficiency across the industry. One component of water use in irrigation is the identification of the risk of water being wasted through deep drainage, which is defined as the rate of water that is lost below the depth of plant roots. The cotton industry also recognises that excessive deep drainage can also potentially lead to the development of shallow water tables often blamed for root zone salinisation affecting crop performance. There are many methods that exist to estimate the deep drainage however they need specialised and expensive instrumentation and, the measurement is often tedious requiring highly specialised skills. With this in mind the CRDC supported this project with the charge to develop a cheap and easy protocol to estimate the risk of deep drainage. The method should not require any specialised equipment, should not be time consuming, and can be operated by growers and IDO's within the industry.

The initial work involved the successful completion of experiments that determined the minimum number of observations that need to be taken to in a cotton field to give a good estimate the potential deep drainage and the implementation of a modified sub-soil hydraulic conductivity using the falling head lined-borehole technique (FHLBT) appropriate for a cotton growing system. The readily available Microsoft EXCEL was chosen as the platform to develop the user-friendly interface for managing the data to estimate the potential and required deep drainage. Testing of the method was conducted on Field 11 at Auscott Moree, which was chosen as this site is representative of the soil in the cotton growing area, having heavy clays derived from alluvial material and less clayey and/or leaky soil traversing the field. Results showed that the method could successfully identify the significant difference in the potential deep drainage occurring within Field 11, corresponding to soil with different



soil clay contents and leaky areas. To make the estimate of potential deep drainage more meaningful the Potential and Required Deep Drainage Interface incorporates a leaching requirement that is needed to prevent excess salts build up in the sub-soil that may affect crop.

The main outcomes to benefit the cotton industry are:

- the Development of a protocol that can be used to assess the potential deep drainage on a cotton farm
- demonstrating the importance of strategically placing sampling sites to capture the within field soil variability, which will increase the opportunity for a better representation of the potential deep drainage.
- the development of a user-friendly interface in commonly available software to calculate the potential deep drainage.
- and the incorporation a module into the Potential and Required Deep Drainage software to allow growers to determine the drainage required to avoid subsoil salinisation that could potentially reduce crop performance.