Australian Government
Cotton Research and Development Corporation

FINAL REPORT

Part 1 - Summary Details

CRDC Project Number: **UNE 1603**

Project Title: Spatio-temporal visualisation of irrigated cotton root development in Eastern Australia.

Project Commencement Date: 1 Oct 2015 **Project Completion Date:** 30 Sept 2017

Part 2 – Contact Details

Administrator:	Libby Magann		
Organisation:	University of New England		
Postal Address:	Research Services		
	University of New England, Armidale, 2351		
Ph: 0267733875	**E-mail:**	emagann@une.edu.au	
Principal Researcher:	Brendan Griffiths		
Organisation:	UNE		
Postal Address:	Agronomy and Soil Science, ERS, 2351		
Ph: 0427 715990	**E-mail:**	bgriffi7@une.edu.au	
Researcher:	Dr Oliver knox		
Organisation:	UNE		
Postal Address:	Agronomy and Soil Science, ERS, 2351		
Ph: 0267 732946	**E-mail:**	oknox@une.edu.au	
Researcher:	**Jamie Barwick**		
Organisation:	UNE		
Postal Address:	Precision Agriculture Research Group, UNE		
Ph: 0428 694239	**E-mail:**	jbarwic2@une.edu.au	

Part 3 – Final Report

Background

1. Outline the background to the project.

This project has worked towards developing methods for assessing and improving understanding of below ground cotton agronomy through analysis of existing capacitance moisture probe data sets. Through the interrogation of the dataset investigated the authors have both spatially and temporally mapped the maximum depth of water extraction, and therefore the inferred maximum rooting depth, of cotton over the eastern Australian cotton growing regions. This has been achieved by analysis of the GIS positions of the network of 'Goanna telemetry' soil moisture probes over different years and across the cotton fields where their devices have been employed. The data set available consists of up to 720 sites, some operating for up to five years, are spread through all eastern Australian cotton growing regions. The derived map gives an overview of areas where rooting depth appears to be constrained, facilitating research efforts (within projects such as UNE 1403, 1601, 1504) to ground truth and investigate the causes of the inhibition of root development. It would seem from our investigations that soil structure is being compromised and soil porosity lost either due to rain shifting salts down through the profile and causing a band of structural collapse, which links in to irrigation recharge issues, or is due to the increased frequency of irrigation causing increased dispersion and general structural decline of the soils in question, thus reducing root penetration, and moisture infiltration.

Objectives

2. List the project objectives (from the application) and the extent to which these have been achieved.

The key aim of this project was to develop an improved understanding of the spatio-temporal distribution and extent to which cotton root development and general soil structural decline in the Eastern Australian irrigated cotton industry is occurring. This was achieved through analysis of the maximum depth of water extraction, and therefore the inferred maximum rooting depth, of cotton over the eastern Australian cotton growing regions. These maps have been generated from the analysis of the geo-located Goanna Telemetry soil moisture probes over different years and across the cotton fields where their devices have been employed. The maps provide an overview of areas where rooting depth appears to be constrained and also provide insight into areas where irrigation recharge is affected.

Approach

The approach proposed for this work is outlined in the following two project deliverables. Access to the capacitance probe data set was obtained with the permission and involvement of Goanna Telemetry and access to the Landsat imagery through resources available in project 4.17 (Geoscience Australia).

(i) Spatial and temporal map of cotton rooting depth across eastern irrigated cotton growing regions. Identifying and map, in space and time, the maximal depth of water extraction occurring under cotton within the regions covered by the Goanna Telemetry probes from their extensive capacitance probe data set.

(ii) Extract NDVI imagery from Geoscience Australia data base and overlay against the spatial rooting depth data developed in (i). Develop protocols that enable correlation and visualisation of the relationship between cotton root depth constraints and NDVA derived biomass.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related projects.

An interrogation of Goanna telemetry's recent years' capacitance probe data sets was conducted with the view of locating capacitance locations with minimal or no root development below a depth of 60cm in the soil profile. Earlier years, from 2012 – 2014 were investigated, however these were largely drought years and it was felt that these should not be included in the final investigation. Data from the 2015/2016 and the 2016/2017 have been the most complete and useful datasets to be used in the investigations.

A capacitance sensor uses an electronic current between two electrodes to measure the dielectric permittivity of the soil. The amount of moisture in the soil affects the frequency of the emitted current, which can be measured and converted into a measure of the total amount of moisture in the soil.

The unit consists of a probe that contains up to 10 sensors in 10cm increments to 1 meter depth (Image 1). This is placed into the soil in the field at the start of the crop life cycle. A control box sits on top of the probe above the ground and contains the circuitry required to generate the current and record the results. The box also contains a modem or radio that can communicate the results back to the server. A solar panel and battery provide the power for the unit. The probe remains in the soil for the life of the crop. At hourly time intervals the probe records the soil moisture and passes the data back to the database.

After both the 2015/2016 and 2016/17 cotton growing seasons the complete datasets of the Goanna telemetry capacitance probes was interrogated. The investigation involved the development of an algorithm to establish those locations/probes that were showing limited or no activity on those sensors below 60cm during the period from the 20th Jan until 1st June each year. This period was chosen to allow sufficient time for the cotton root system to reach full development in all of the cotton growing regions included in the investigation.

In terms of the interrogation of the data was expressed as **Deep Root Percent of Surface.** The product being the average daily movement for depths >= 60 and < 90 cm as a percentage of the average daily movement for depths >=10 and < 30 cm. Locations with a deep root percentage of surface of 15% or less were considered as 'constrained' and were drawn from the database to be included in the findings.

Outcomes

4. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The Goanna telemetry dataset for the 2015/2016 cotton season consisted of 253 irrigated field locations extending spatially from Emerald in the north to Darlington Point in the south. Of the 253 locations 103 showed inhibited root development or little or no moisture infiltration below a depth of 60 cm in the soil profile. The dataset for the 2016/17 year consisted of 719 irrigated field locations, again extending spatially from Emerald to Darlington point in the south. Of the 719 locations for the 2016/17 season 257 have shown inhibited root development or little or no moisture infiltration below a depth of 60 cm in the soil profile. These locations have been plotted in to Google Earth and ARC GIS to allow a clearer picture of whether these phenomena are appearing on a random basis or whether we have distinct soil type areas behaving in this manner. The mapping of this dataset has outlined some scatter in the occurrence of the outlined issues, but have shown two key growing areas with proportionately higher issues with root development / soil constraints, those being an area west of Goondiwindi in Qld, and an area around Hay in NSW in 2015/16, and in 2016/17 similar areas, and a further smaller cluster west of Narrabri. See attached files: **2016_2_constrained soils.kmz**.; **all_probe_locations.kmz**. ; **2017_constrained_soils.kmz.**

The investigation has been targeting a lack of root development or irrigation recharge issues in the lower portion of the soil profile (below 60 cm) and has broadly outlined two phenomena (subgroups) occurring within this dataset, those being 1. Locations showing little or no root development during the period being investigated (crop year period) and 2. Locations showing depleted root development, or poor or nil irrigation recharge to the portion of the profile investigated during the crop year period.

1. **Locations showing little or no root development below 60 cm**

It would seem that this phenomena is showing a distinct lack of root development and/or irrigation infiltration in of the portion of the soil profile below 60cm for the duration of the investigation (crop year period). The exact cause of these issues will be ground-truthed in further investigations, although broadly it seems that the issues are largely either related to increasing sodicity or increasing magnesium levels in the soil profile, creating dispersion or slaking at depth. In an example of this phenomena the soil profile graph is showing the field reaching refill on most irrigations indicating the same irrigation infiltration/recharge is being met on each irrigation (Fig 1).

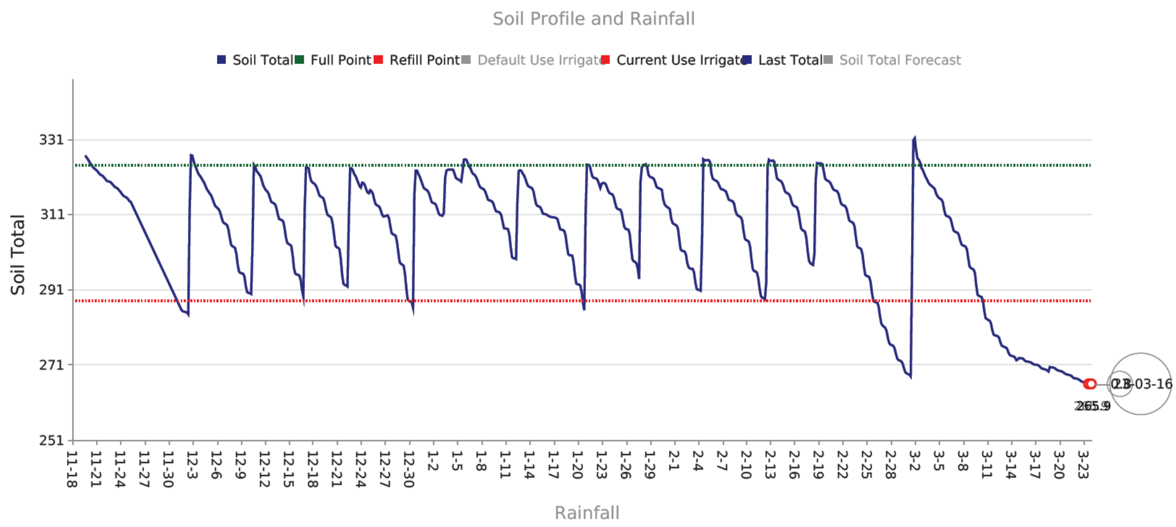

Fig 1. – Soil profile graph - Full point being met at each irrigation throughout the season.

In this instance when the individual capacitors in the soil profile are separated, as in a stack graph (Fig 2), there is no movement in capacitors below 60 cm indicating no root development or infiltration of irrigation moisture in to that part of the profile.

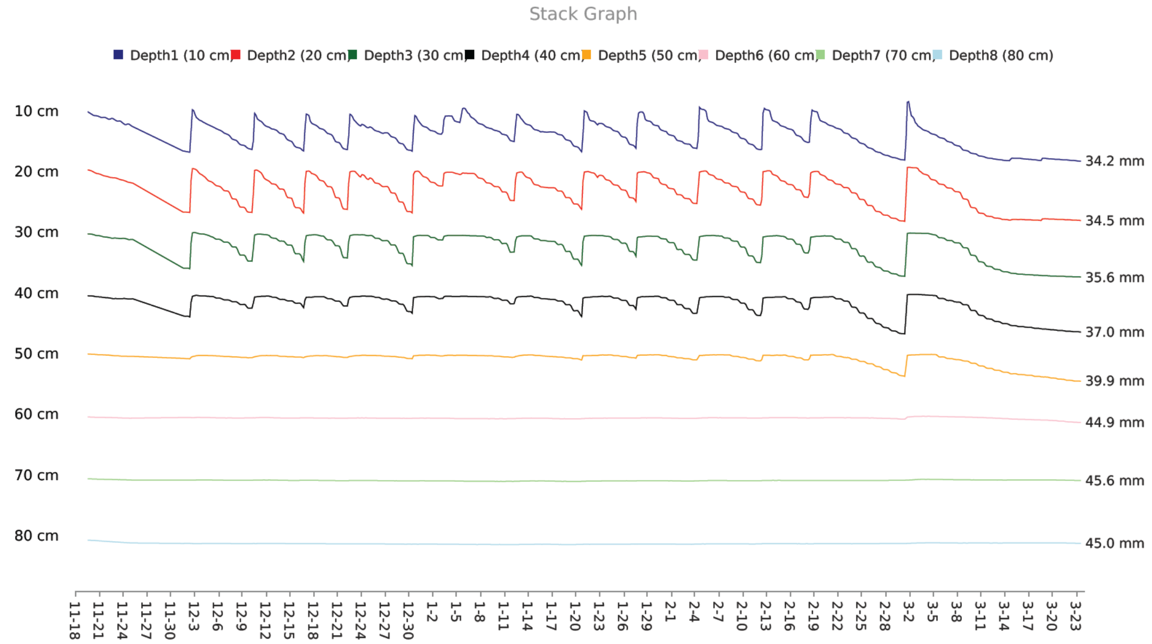

Fig 2. Stack graph – no root development or moisture infiltration during the growing period of the crop below 60cm (until the final irrigation).

2. **Locations showing depleted root development during the period being investigated.**

With respect to the second subgroup, it would seem that root development/moisture infiltration may occur in the profile deeper than 60cm earlier in the crop year period. However, with time and further irrigations the recorded recharge and root development is reduced to the point where there is either no or little development below 60cm. The exact cause of this phenomena is also to be the focus of further studies although it would seem that the cause is likely to be a function of increasing the frequency of irrigation on soil that could be deemed to be more 'fragile' in their structural and chemical makeup, and is related to issues largely caused by soil dispersion or slaking at depth.

In this example (Fig 3), when the soil profile graph is investigated it becomes obvious that over time the irrigation events do not reach the refill point indicating depleted levels of irrigation recharge. When the stack graph (Fig 4) is observed it can then be seen that the moisture or irrigation infiltration issues are in the deeper portion of the profile.

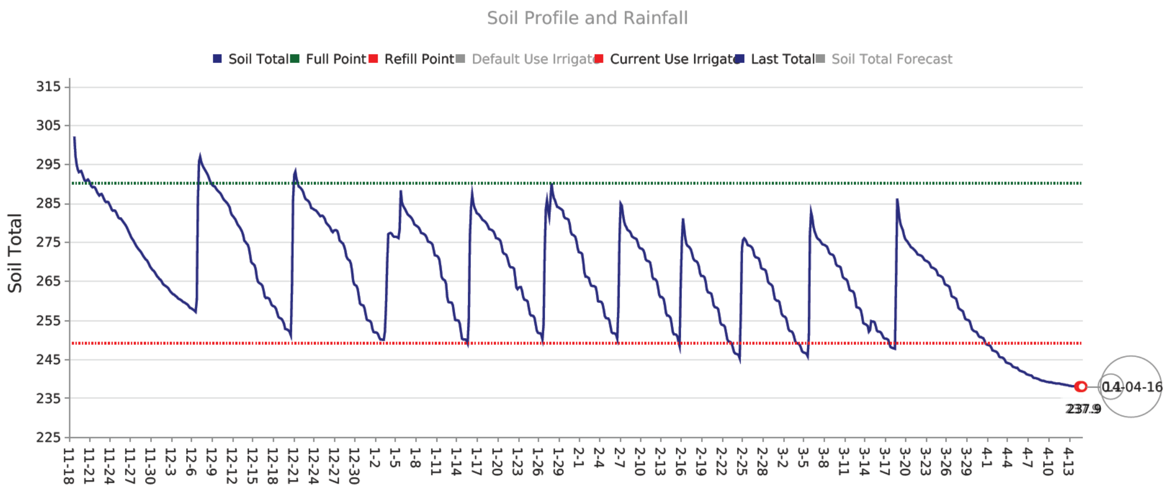

Fig 3. Soil profile graph – showing inability of irrigations to reach soil moisture full point over time.

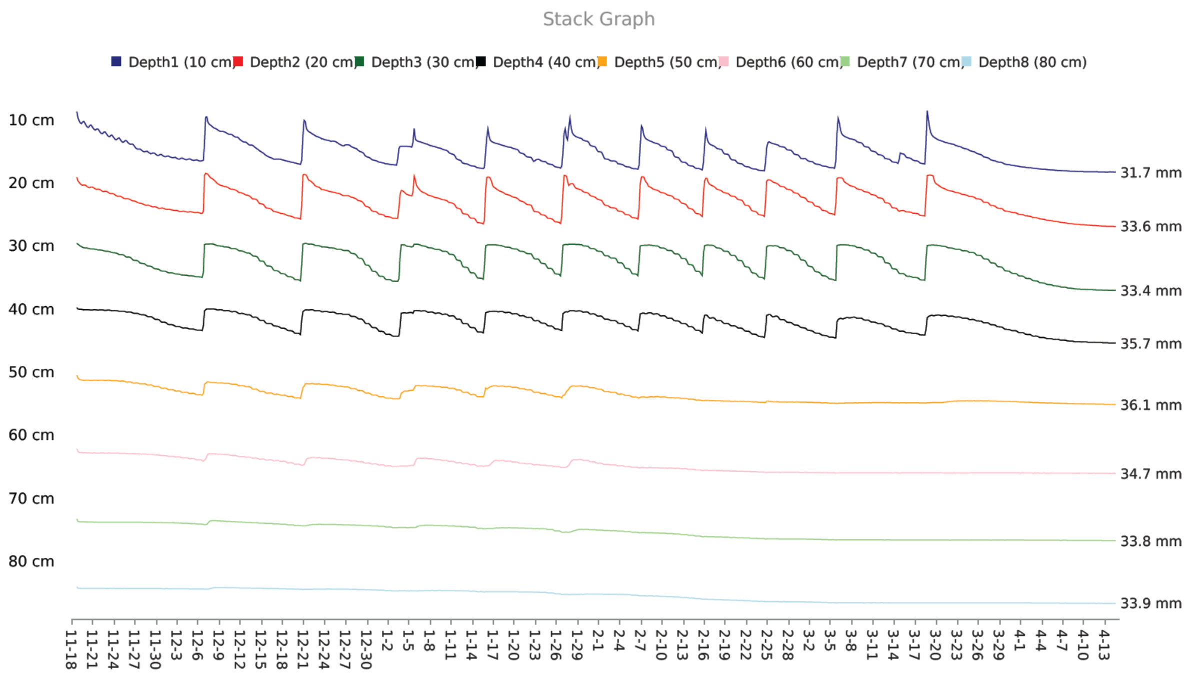

Fig **4.** Stack graph – outlining decreased irrigation recharge over time at depth.

Further observations

Our observations have also identified other issues not covered by our initial interrogation. An example of this is included in Fig 6, and 7. In this situation it is observed that the refill point is not reached after several irrigations as can be seen in Fig 6., however the key difference to that outlined in subgroup 2 is that the recharge issues are in fact higher in the profile as can be seen in Fig 7. Again, the exact cause would need to be the focus of further investigations although it seems that increasing the frequency of irrigation, and scheduling on irrigation deficits below 45 mm PAW may cause a loss in air filled pore space resulting in lower levels of moisture infiltration, and in fact a reduction in soil water holding capacity. In some instances it seems that if irrigations are resumed at refill points at or above the previously set refill points the ability to reach the soil full point is regained, whilst in others it is not. This may indicate that there are several mechanisms involved in the cause of this phenomena, although it does appear as if this issue is very common within the overall dataset.

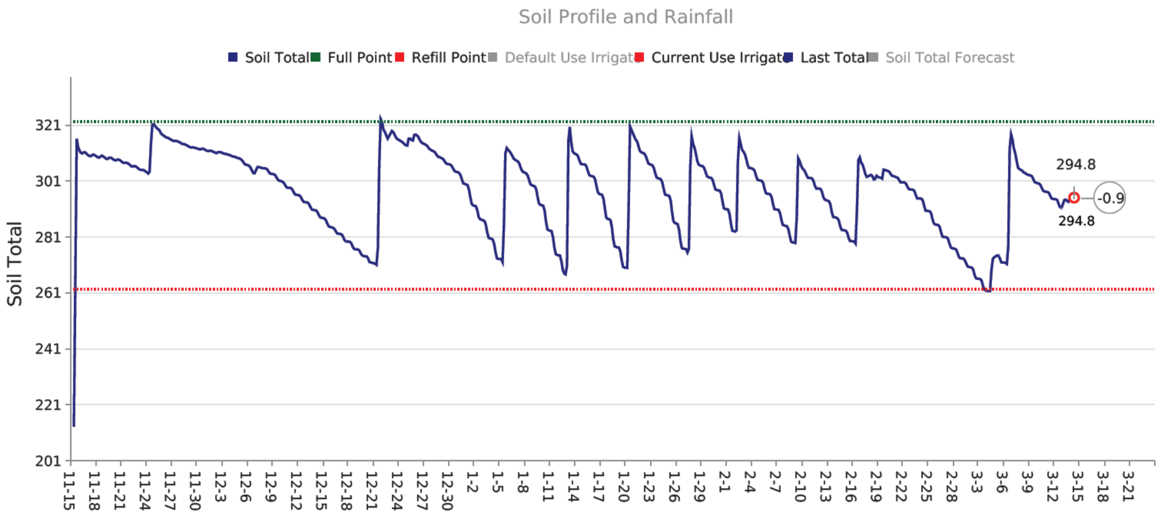

Fig 6. Soil profile graph outlining an inability to reach soil water full point due to very low irrigation deficit.

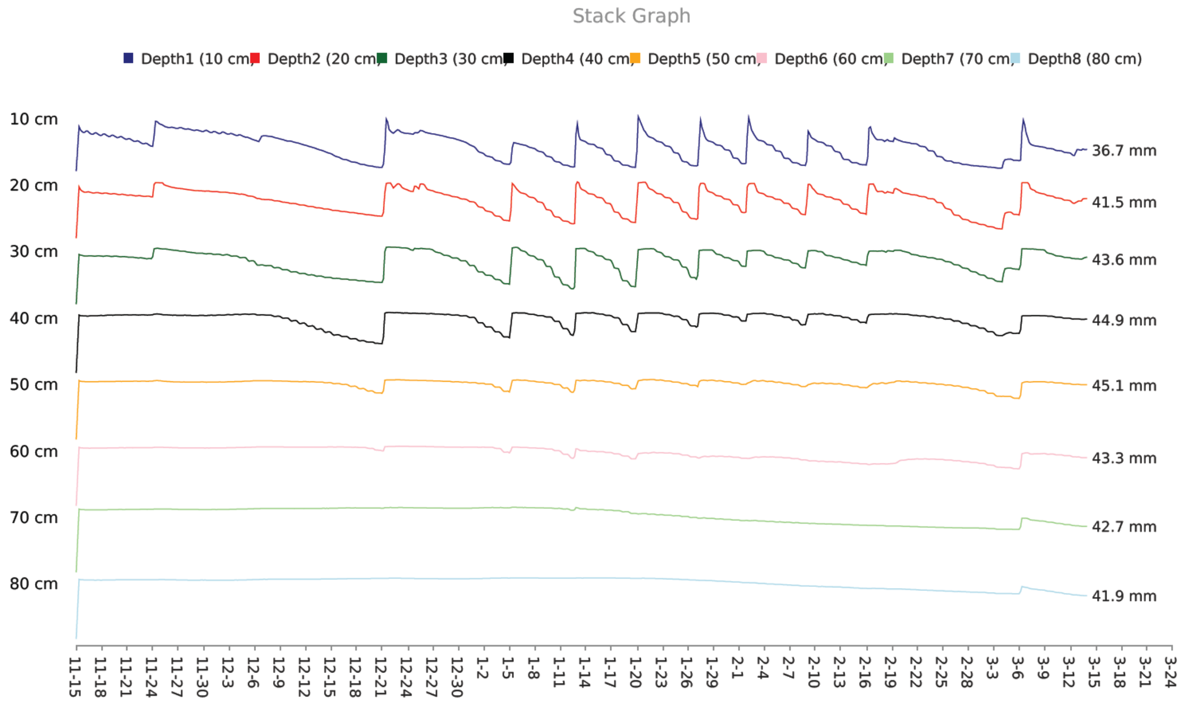

Fig 7. Stack graph showing inability of the soil to reach full irrigation recharge at 10, 20, 30, 40 and 50cm indicating a loss of soil porosity in the upper part of the profile.

NDVI Imagery and relationship to plant root development / crop biomass

The research group gained NDVI imagery through Geoscience Australia to investigate relationships to crop biomass at constrained and unconstrained sites (that had been determined through the investigation). There was unfortunately no relationships between the imagery and soil/plant root constraints in the scope of this study, largely due to the geographic spread of this investigation. However, these relationships will continue to be investigated in future studies as the mechanisms behind constraints to plant root development, at field level, are investigated.

5. Please report on any:-

a) Feedback forms used and what the results were
b) The highlights for participants or key learnings achieved
c) The number of people participating and any comments on level of participation

To date this project has been used at 1 pilot workshop conducted at Dalby in August 2017 co-ordinated by Annabelle Kings of Cotton info. The day was attended by 45 growers and agronomists and the information presented was well received. See attached extension material prepared for delivery of project material.

Budget

6. Describe how the project's budget was spent in comparison with the application budget. Outline any changes and provide justification.

Budget has been spent in accordance with the application budget,

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

In this investigation we have identified that approximately 30% of the sites in both years investigated are showing issues at depth with respects to root development and / or irrigation infiltration. There was broadly, two phenomena that have been identified in this study, those being; 1. Locations showing little or no root development during the period being investigated (crop year period) and/or 2. Locations showing depleted root development, or poor or nil irrigation recharge to the portion of the profile investigated during the crop year period. Further to our investigations it would seem that soil structure is being compromised and soil porosity lost either due to rain shifting salts down through the profile and causing a band of structural collapse, which links in to irrigation recharge issues, or is due to the increased frequency of irrigation causing increased dispersion and general structural decline of the soils in question, thus reducing root penetration, and moisture infiltration.

This study has identified spatially and temporally the extent to which these constraints to the production of cotton are an issue at an industry level. The findings of this study will allow the authors to focus future research efforts to investigate in more detail the causal factors behind the mechanisms identified. This research will also follow on to more detailed investigations as to how the mechanisms identified in this study are affecting plant root development and moisture infiltration again both spatially and temporally at field level .