Australian Government

Cotton Research and Development Corporation

SUMMER SCHOLARSHIP REPORT: 2012-2013 SEASON

1.	**Project Title**	:	Potential contribution to soil carbon by cotton roots in minimum and maximum- tilled rotations
2.	**Proposed Start Date**	:	30th November 2012
	Proposed Cease Date	:	30th March 2013
3.	**Summer Scholar and University**	:	Camille Coleman, The University of Sydney
4.	**Organisation & Location for the project**	:	NSW DPI Australian Cotton Research Institute, Myall Vale
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Project Collaborators (Name and Organisation): Dr Daniel Tan, The University of Sydney

SUMMER SCHOLARSHIP REPORT

1. Executive Summary:

This summer scholarship project was undertaken by Camille Coleman. Camille is in her fourth and final year of Bachelor of Science in Agriculture at the University of Sydney and is majoring in agronomy. The scholarship commenced on the 30th November 2012, and was completed on 30 March 2013. The aim of this research was to outline the potential contribution of corn in rotation with cotton, in comparison to historical cotton and wheat rotations after minimum or maximum tillage. It tested the hypothesis that there is no difference in cotton root growth for cotton grown in a cotton monoculture, and after wheat and corn. The field experiment was conducted in Narrabri NSW, consisting of six treatments in a split plot design with four replicates. The experiment used minirhizotron, core break, root washing and plant mapping methods to measure cotton root growth and turnover during the 2012/2013 growing season. Cotton vegetative growth and potential carbon input by cotton roots was improved by including corn in rotation (cotton-corn-cotton) relative to historical cotton rotations.

2. Background:

Cotton (*Gossypium hirsutum*) is an important crop for Australia's agricultural industry. Australia is the fourth largest exporter in the world generating an excess of $2.5 billion in export revenue (Cotton Australia 2013). Hence, Australia is always encouraging research to improve both soil quality and cotton yield. Crop rotations have become increasingly important in the industry due to factors such as declining soil organic carbon and deteriorating soil physical properties. Until recently, Australia predominantly cropped cotton as a monoculture, using intensive tillage techniques together with a lack of organic inputs, which has steadily led to the decrease in soil organic carbon (Terry *et al* 2008). Further problems have also been associated with a low return rate of crop residues, including high growing season temperatures and excessive wet soils due to irrigation. Management practices aimed to reduce the decline in soil organic carbon include implementing minimum tillage and adding cereal and leguminous crops such as wheat (*Triticum aestivum*) and corn (*Zea mays*) (Hulugalle and Scott 2008), which may produce large amounts of crop residues when sown in rotation with cotton. Increasing soil carbon levels is a major priority for Australian farmers, as soil organic carbon is an excellent indicator of soil health. Good soil quality means productive land that may be maintained to increase farm profitability now and for future generations.

While there has been substantial research done on the impact of rotations on the above ground growth of cotton plants, there is however, little research done on the potential cotton root biomass and carbon below ground after a corn or wheat rotation. Cotton grown after corn may benefit from increased water availability, soil structure and better soil health due to corn providing increased amounts of organic matter in the top layers of soil, and corn extracting less water at lower depths than cotton (Holden *et al* 2008). Potential improvements to soil porosity and structure may be due to the natural high root mass of corn which increases the number of macropores in the soil, allowing for better soil drainage and water availability for cotton grown after a corn rotation. This experiment is built on past historical rotational experiments to determine whether there is a trend of higher cotton root growth after a corn rotation throughout the season, and whether cotton after corn has the ability to contribute to increased amounts of potential organic carbon, cotton root density, and cotton lint yield, compared with historical treatments, during the 2012/2013 growing season.

3. Aims and Objectives:

This project aimed to compare cotton root growth and yield in cotton monoculture and wheat and corn rotations. It tested the hypothesis that there is no difference in cotton root growth for cotton grown in a cotton monoculture, and after wheat and corn. Understanding cotton root growth and turnover will enhance the capability for primary industries to adopt more resilient and adaptive farming strategies and systems, and also encourage adaptive strategies to change initiatives and resource development. A better understanding of cotton root growth characteristics under monoculture and different rotations will provide growers with better crop water and nutrient management strategies.

4. Materials and Methods:

The experiment was conducted in a 7.5 ha flood irrigated Grey Vertosol field C1 (149º47'E, 30 º13'S), during the 2012/2013 growing season at the Australian Cotton Research Institute (ACRI), near Narrabri in NSW.

Past experiments conducted in field C1 started in 1985, trialling cotton monocultures, alongside cotton-wheat and cotton-vetch rotations. Corn was first introduced into the field in the summer of 2012 (Table 1). Following a winter fallow period, cotton (Sicot 71 BRF) monoculture was sown on October 25th 2012 after minimum or maximum tillage rotations. The field experiment consisted of six treatments in a split plot design with four replicates. The main plots consisted of the historical rotations: minimum tillage-wheat-cotton (MinWCott), minimum tillage cotton (MinCCott) and maximum tillage-cotton (MaxCCott) in a randomised complete block design (Table 2). Subplots were implemented in the 2011/2012 summer season, comprising of control historical treatments (main plot treatments), or with corn included in the rotation. After cotton was harvested, maximum and minimum tillage operations were completed to prepare for the next season. Maximum tillage involved slashing the cotton, followed by a disc plough up to 20 cm, chisel ploughing to 30 cm two times, and finally listering up. Minimum tillage involved slashing the cotton, followed by go devilling (disc-hiller), disturbing the soil to a depth of ~10-12 cm. The plots were 190 m long, with 24 rows, spaced in 1 m intervals. The wheat and corn stubble were retained as *in-situ* mulch into which the following cotton crop was sown.

Table 1. Chronology of treatments in experimental field C1.

		2010/2011	2011	2011/2012	2012	2012/2013
Treatment		**Summer**	**Winter**	**Summer**	**Winter**	**Summer**
1	**Minimum tillage-wheat-cotton**	Cotton	Wheat	Fallow	Fallow	Cotton
2	**Minimum tillage-wheat-corn**	Cotton	Wheat	Corn	Fallow	Cotton
3	**Maximum tillage-cotton-cotton**	Cotton	Cotton	Cotton	Fallow	Cotton
4	**Minimum tillage cotton-cotton**	Cotton	Cotton	Cotton	Fallow	Cotton
5	**Maximum tillage-cotton-corn**	Cotton	Cotton	Corn	Fallow	Cotton
6	**Minimum tillage cotton-corn**	Cotton	Cotton	Corn	Fallow	Cotton

Corn	Cotton	Fallow

Table 2. Split plot experimental design for field C1.

Historical (Subplots)	2011/2012	2012/2013	Tubes	Rep
Minimum Tillage/Continuous Cotton	Cotton	Cotton	1	1
	Corn	Cotton	2	
Maximum Tillage/Continuous Cotton	Cotton	Cotton	3	
	Corn	Cotton	4	
Minimum Tillage/Wheat-Cotton (standing stubble)	Fallow	Cotton	5	
	Corn	Cotton	6	
Minimum Tillage/Wheat-Cotton (standing stubble)	Fallow	Cotton	7	2
	Corn	Cotton	8	
Minimum Tillage/Continuous Cotton	Cotton	Cotton	9	
	Corn	Cotton	10	
Maximum Tillage/Continuous Cotton	Corn	Cotton	11	
	Cotton	Cotton	12	
Maximum Tillage/Continuous Cotton	Cotton	Cotton	13	3
	Corn	Cotton	14	
Minimum Tillage/Wheat-Cotton (standing stubble)	Fallow	Cotton	15	
	Corn	Cotton	16	
Minimum Tillage/Continuous Cotton	Cotton	Cotton	17	
	Corn	Cotton	18	
Minimum Tillage/Wheat-Cotton (standing stubble)	Fallow	Cotton	19	4
	Corn	Cotton	20	
Minimum Tillage/Continuous Cotton	Corn	Cotton	21	
	Cotton	Cotton	22	
Maximum Tillage/Continuous Cotton	Cotton	Cotton	23	
	Corn	Cotton	24	

Root growth was measured over the 2012/2013 summer using the following methods:

Core break method

Core break samples were taken at fortnightly intervals to observe surface root growth using a 10 cm diameter soil core. Soil cores were used for the surface 10 cm as minirhizotron measurements underestimate root growth within this depth. Each core was broken in half and the number of surface roots was counted (Figure 1). Subsamples of each replication were taken every fortnight for root washing and root biomass analysis.

Figure 1. Core break surface root counting

Figure 2. Root separation

Figure 3. WinRhizo® root scan

The subsamples taken from the core break method were soaked in a 2:1 solution of 10% sodium hexametaphosphate and 1 M sodium hydroxide in warm water, to disperse the soil. Once the roots were washed and collected using a sieve, the roots were stained in a 0.1% congo red solution in order to differentiate between live and dead roots. Roots were washed in absolute alcohol and live roots identified and separated from other organic material using tweezers (Figure 2). Root length was then determined using a WinRhizo ® scanning operation (Figure 3). The samples were then oven dried and weighed. Relative root length (root length/root weight) (mg/m) was calculated, and relationships between root weight and number analysed.

Minirhizotron

A minirhizotron was used to measure root growth and turnover to a depth of 1m using access tubes installed for each cotton treatment (Table 2) (Figure 4). Root growth from 0.1 to 1.0m depth was measured at 0.1m intervals using a 'Bartz' BTC-2 video microscope and I-CAP image capture system, to the left and right of each access tube every 2 weeks. The images (Figure 5) were then exported to Rootracker® software for analysis to estimate cotton root growth indices. The data for each orientation at each depth throughout the profile was calculated to assess root growth over a 360° plane of vision. Measurements included:

- Length and number of live roots at each measurement
- Number of roots which changed length
- Number and length of roots that died
- Number of new roots over time
- Net in root number and lengths.

Figure 4 .Data collection using minirhizotron

Figure 5. Mintill-Cotton-Corn 90 cm 20/02/2013. Cotton roots growing into macropores in soil

These measurements were used to calculate the following indices for individual depths and between times of measurement: (Hulugalle *et al*. 2009):

Net change in root carbon (g/m^2) = net change in root length × relative root length (mg/m) × root carbon concentration

Root carbon added to the soil (g/m^2) = length of roots which died × relative root length (mg/m) × root carbon concentration

Root carbon at the end of the season = sum of net changes in root carbon added between times of measurement in all depths (1)

Root carbon added to the soil during the season = sum of root carbon added to soil due to root death between times of measurement in all depths (2)

Root carbon which could be potentially added to soil organic carbon (3) = root carbon at the end of the season (1) + root carbon added to the soil during the season (2)

Plant mapping

Throughout the season, plant mapping was undertaken at weekly intervals. Plant mapping involved taking a metre stick into the field and placing it randomly along the apex of the bed. The number of plant stems, height, bolls and squares were counted and recorded every week. A dry biomass cut was conducted within the growing season. Fresh biomass of the plants cut was recorded (Figure 6), and a subsample removed from each sample and taken to the lab with a sample of bolls. The subsamples were weighed and dehydrated in paper bags (Figure 7). These samples were also weighed so the original mass and dry biomass per m^2 may be calculated.

Figure 6. Fresh biomass weighing of cotton plants in Field

Figure 7. Subsamples of cotton plants cut in field dehydrated in ovens

Analysis:

Statistical analysis was carried out using Genstat version 14. Root turnover was analysed with an analysis of variance (ANOVA) for a split plot design after $\log_e$ transformation. Root carbon indices were evaluated by multiple linear regression analysis.

5. Results and Conclusions:

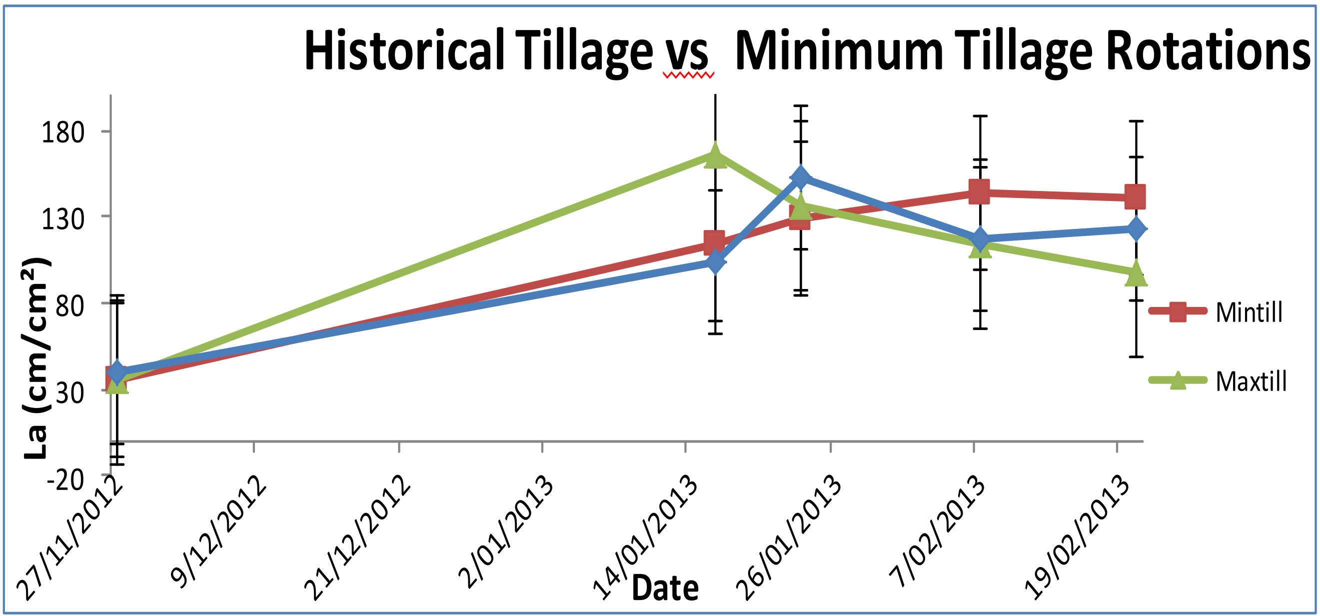

Figure 7. Cotton root length per unit area (cm/cm²) to a depth of 1 m for historical maximum tillage, minimum tillage and minimum tillage with wheat

Minimum tillage (Mintill) had a greater root area per unit length (La) than maximum tillage (Maxtill) to a depth of 1 m when averaged over the entire season (Figure 7). Cotton roots grown after a corn rotation had greater *($P<0.05$)* root length per unit area, than after cotton monoculture for the growing season (Figure 8).

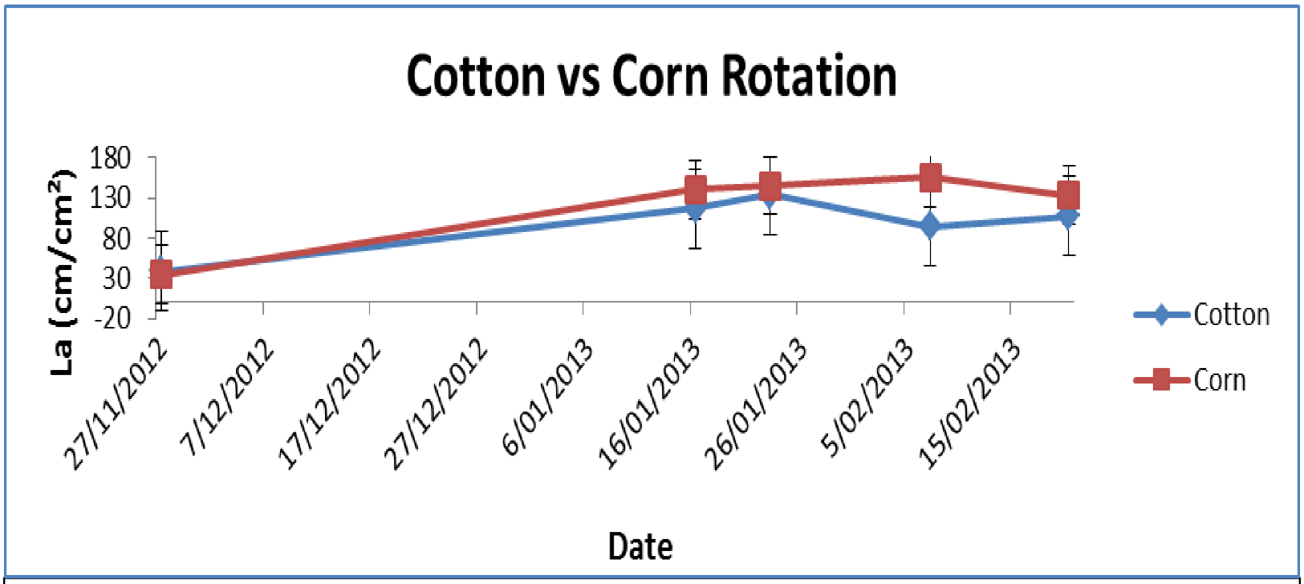

Figure 8. Cotton root length per unit area (cm/cm²) to a depth of 1 m for cotton monoculture and cotton in rotation with corn

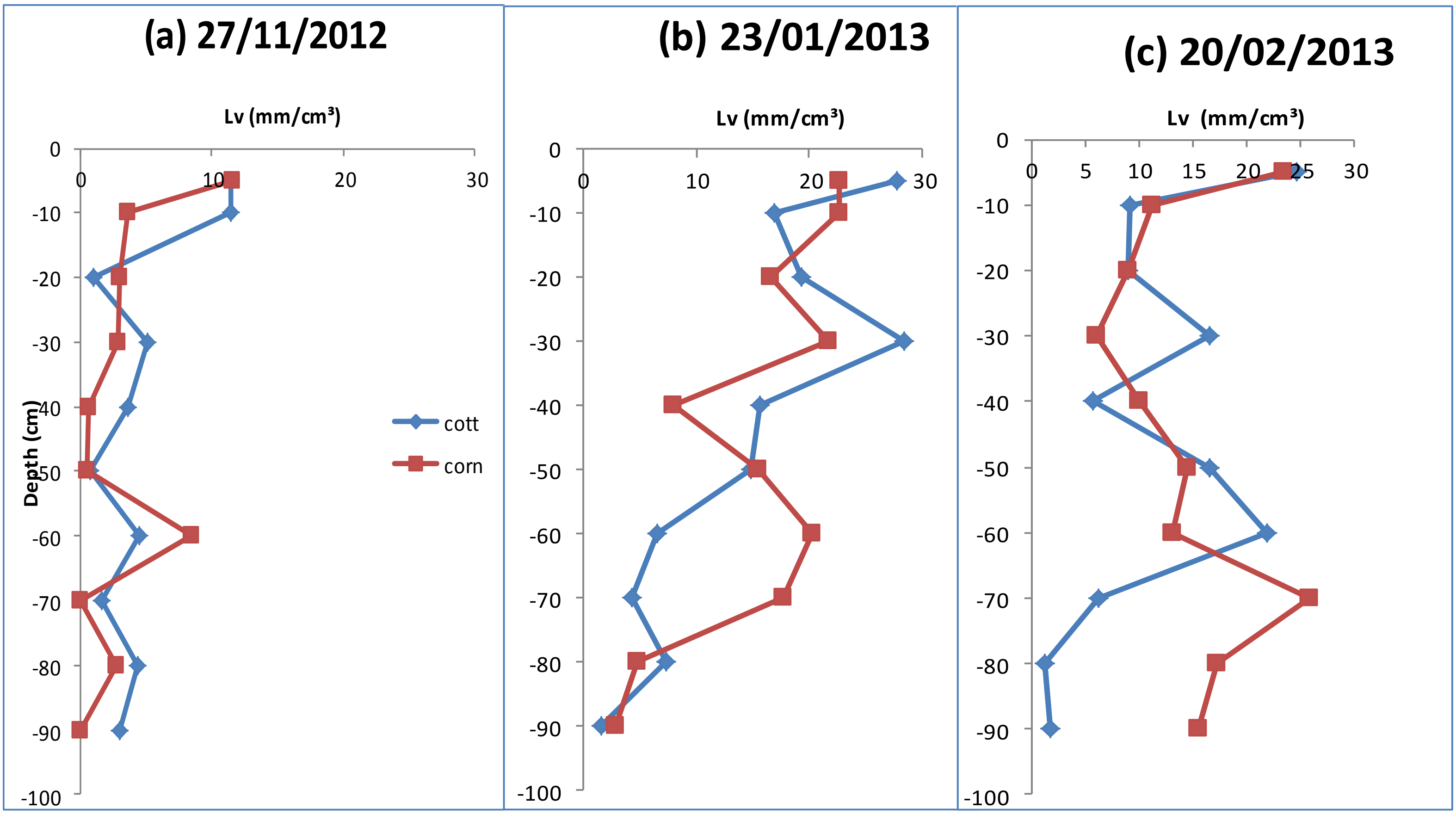

Figure 9. Cotton root length density (mm/cm³) for individual depth (cm) intervals after corn and in cotton monoculture at three respective dates (a) 27 November 2012, (b) 23 January 2013 and (c) 20 February 2013 during the season.

Root length density (Lv mm/cm³) was higher *($P<0.05$)* in cotton-corn rotations compared with cotton-cotton rotations (Figure 9). Although minimum tillage (Mintill) had consistent root length density over the growing season, maximum tillage (Maxtill) and minimum tillage wheat-cotton (MintillWC) had higher overall cotton root lengths (Figure 10). The higher cotton root length at lower depths may be due to previous corn roots better penetrating the soil and leaving behind macropores. It is beneficial for increased cotton rooting density as there will be more potential for the plants to have increased access to the uptake of ions and water. Factors affecting root density may affect plant size and thus yield.

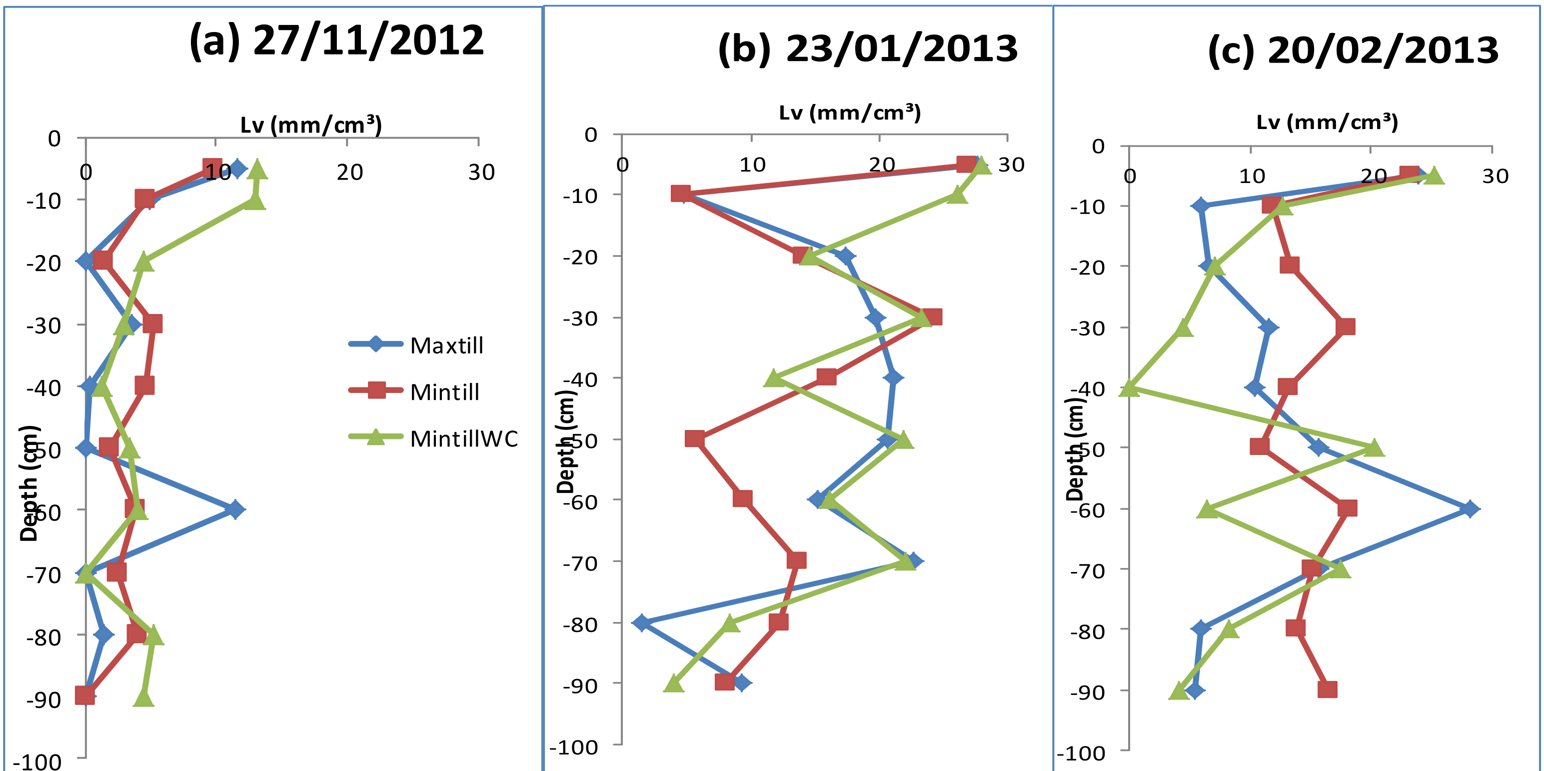

Figure 10. Cotton root length density (mm/cm³) for individual depth (mm) intervals for historical maximum tillage and minimum tillage systems with and without wheat at three respective dates (a) 27 November 2012, (b) 23 January 2013 and (c) 20 February 2013 during the season

There was no difference between any of the carbon indices between the treatments. Cotton roots in minimum tillage with corn rotation contributed more carbon to the soil, and lost the least carbon throughout the season (Figure 11 and 12). All minimum tillage systems have lost almost no carbon during the growing season, while maximum tillage systems have lost a quarter of their total carbon in roots (Figure 13). There was a general trend that minimum tillage rotations provided a higher root carbon contribution than maximum tillage rotations. Minimum till rotations were more beneficial than maximum till as carbon in the crop stubble was left to return to the soil. Root carbon and root density in the soil were highest in cotton based rotations which included corn, presumably due to the higher corn residue biomass added to the soil and the ability of corn roots to create macropores into which new cotton roots can follow downwards. Cotton grown in rotation with corn and wheat may improve soil organic carbon and soil health.

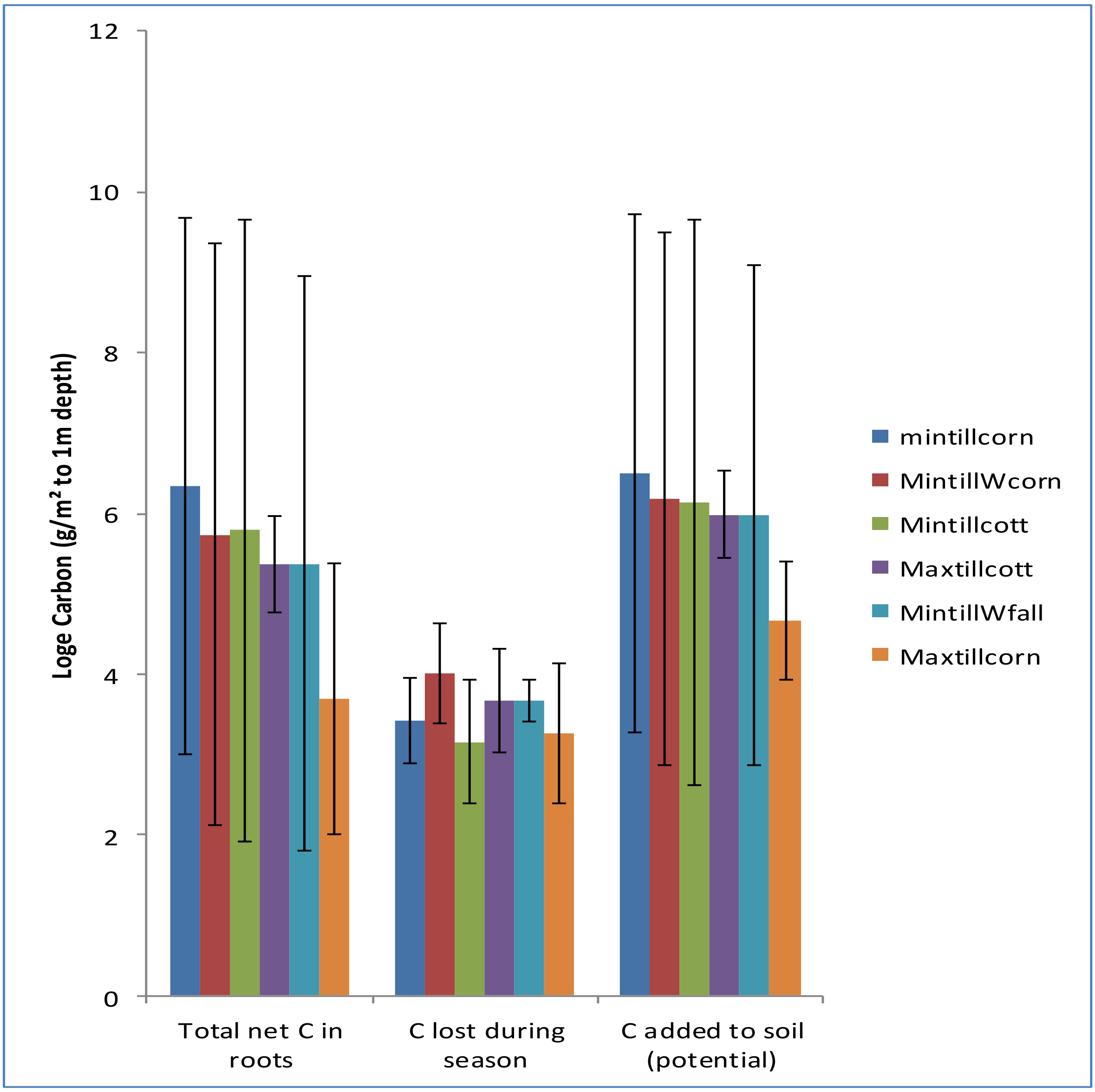

Figure 11. Log_e carbon (g/m²) potential contribution summary

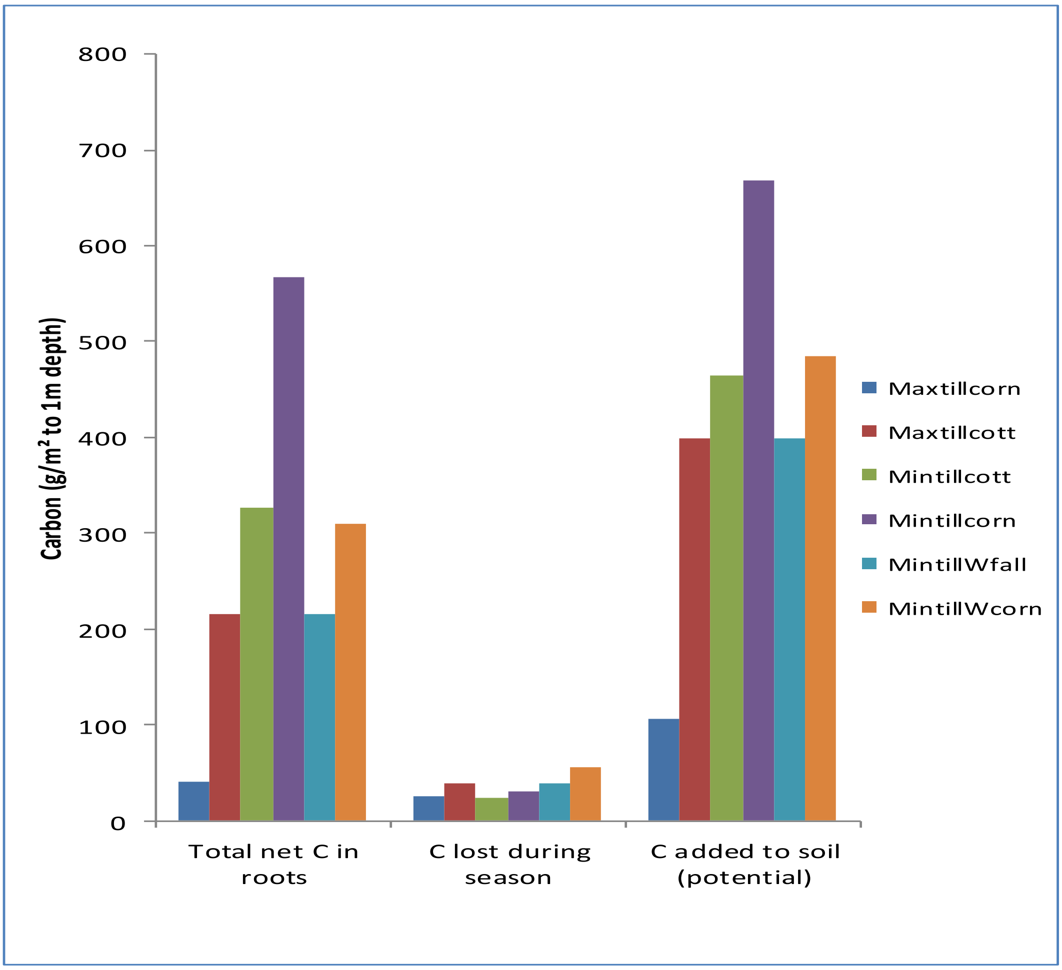

Figure 12. Back transformation values of potential carbon (g/m²) contribution

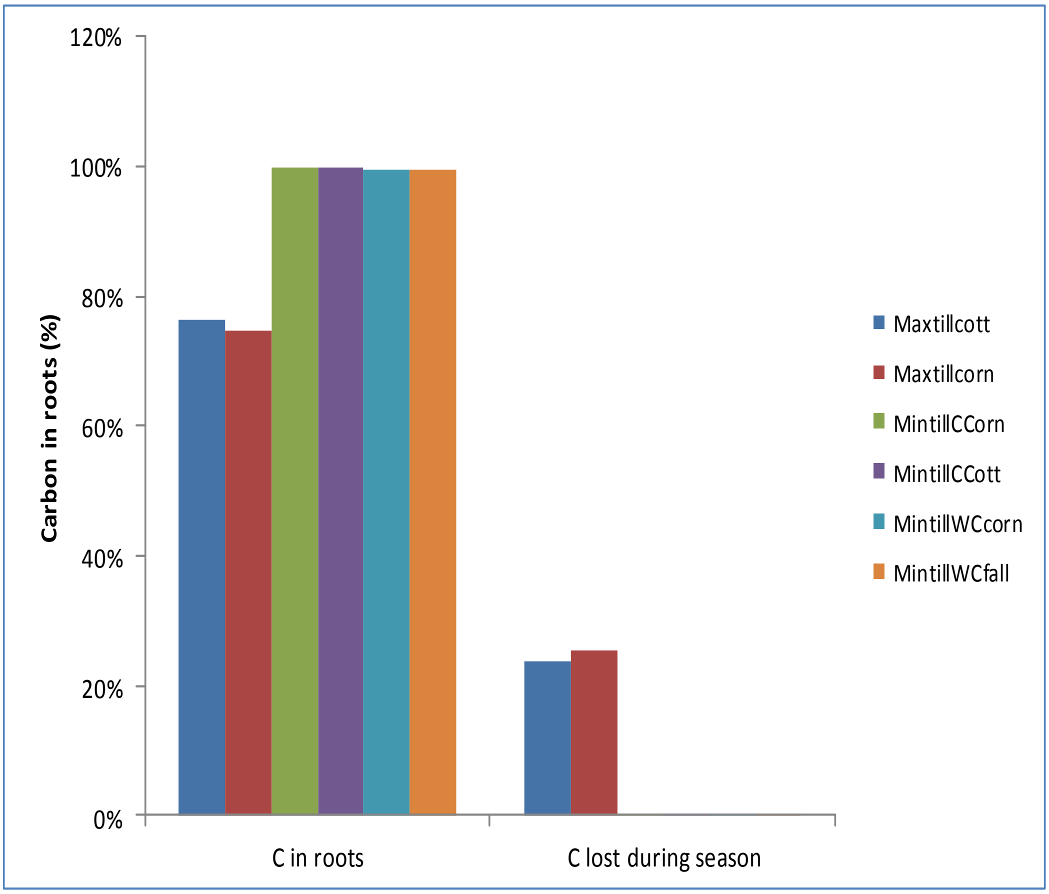

Figure 13. Percentage of carbon remaining in the root system and lost during the season.

Maximum tillage continuous cotton (MaxtillCCcott) had the lowest plant height throughout the season, compared with minimum tillage wheat-fallow (MintillWCfall) which consistently had the tallest plants over the season (Image 14). Minimum tillage wheat-fallow had a higher number of squares and bolls compared with the other treatments throughout the growing season (Figure 15 and 16). The total live root counts using the core break method in the top 10 cm of soil were higher for the maximum tillage continuous cotton rotation (MaxCC-cott) (Figure 17). There was an interaction between the plant growth parameters, which may be confirmed once data analyses have been completed. When corn was sown into either of the cotton monoculture treatments, an improvement in cotton yield and root biomass occurred.

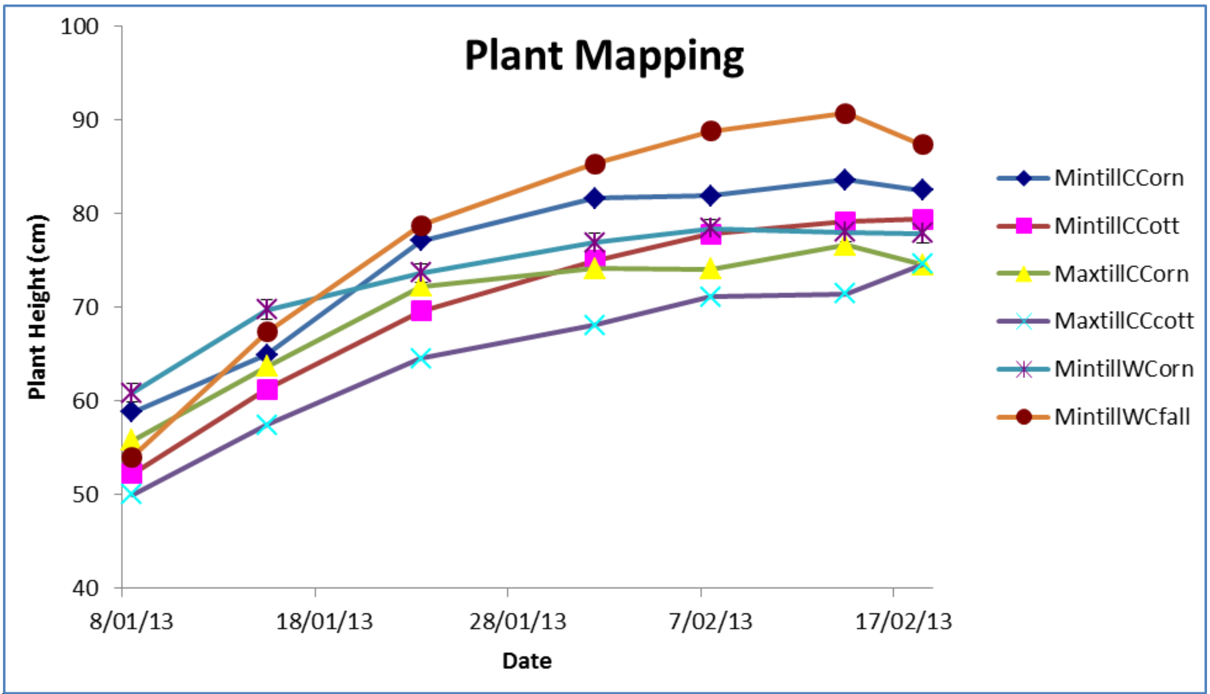

Figure 14. Plant height (cm) during the season

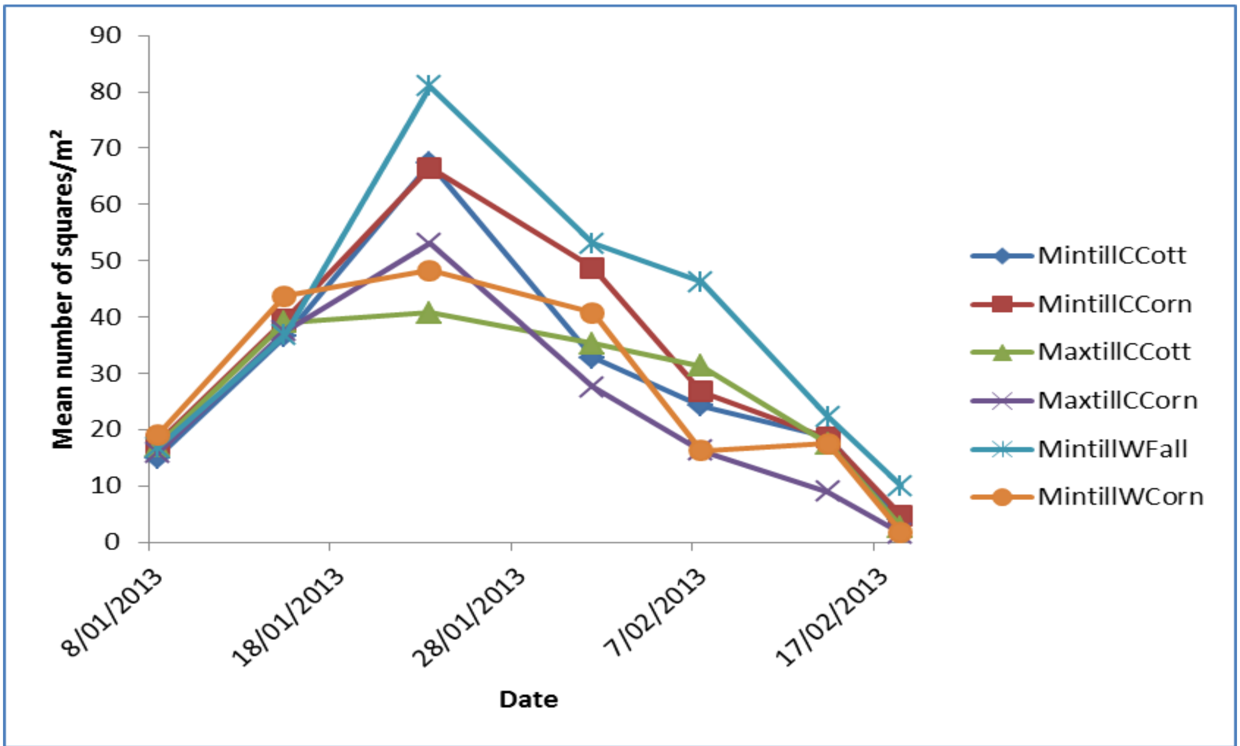

Figure 15. Mean number of squares/m² during the season

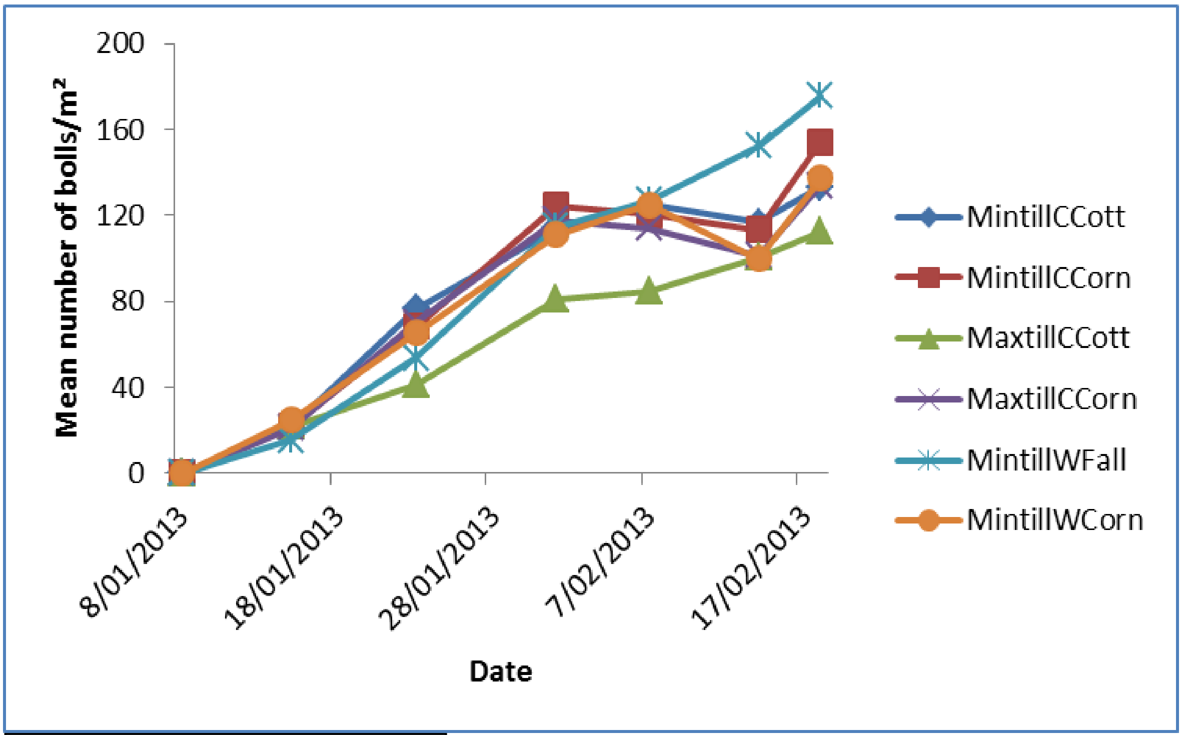

Figure 16. Mean number of bolls/m²

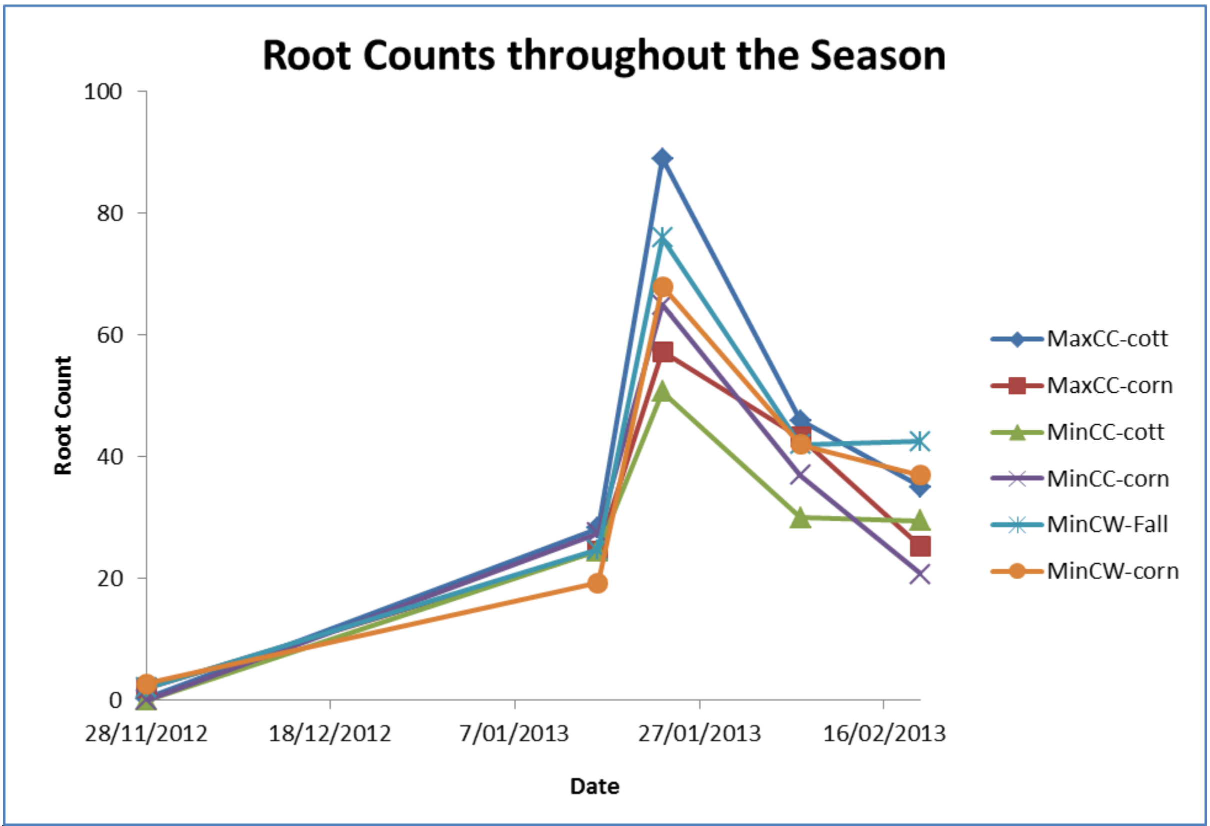

Figure 17. Root counts from core break method throughout the season.

6. Future Research:

Future research should focus on the investigation of root systems of cotton to enhance the capacity of the industry to adopt resilient and adaptive farming systems. By improving human resource development and capacity by supporting initiatives, this will encourage the climate change adaption. As there is little underground study done on carbon root biomass and carbon contribution after a corn rotation, this investigation will contribute to the information available to farmers to increase their cotton yield per ha, by shifting from historical practices, and implementing a rotation system, while producing a more sustainable growing environment and still maintaining profitability.

Longer experimental periods are required for this experiment to show a long term trend of total carbon changes in the soil. There is an increasing need for more knowledge about the effect of crop rotations with corn, detailing the potential input of corn to carbon contribution and overall plant biomass.

7. Presentations and Public Relations:

An oral presentation was presented on the 1st March 2013 at ACRI and a thesis proposal was presented on the 15th of March to academics of the Faculty of Agriculture and Environment at the University of Sydney.

8. Reference List:

Cotton Australia (2013) The Economics of Cotton in Australia. <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-economics-of-cotton-in-australia> Accessed 13/03/2013

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Hulugalle NR, Scott F (2008) A review of the changes in soil quality and profitability accomplished by sowing rotation crops after cotton in Australian Vertosols from 1970 to 2006. *Australian Journal of Soil Research* **46**, 173-190

Hulugalle NR, Weaver TB, Finlay LA, Luelf NW, Tan DKY (2009) Potential contribution by cotton roots to soil carbon stocks in irrigated Vertosols. *Australian Journal of Soil Research* **47**, 243-252.

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