C.R.D.C.

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Contents

Soils Research Priorities
(notes from a recent ACGRA meeting)

Dave Anthony & Harley Bligh

The ACGRA discussed what the goals, objectives and directions it should be following in terms of research into soils, tillage and engineering issues. It was felt that agronomy and soil-tillage-engineering issues should be amalgamated under a "farming systems" title that provided for a more multi-discipline approach to farming practices closely related to land preparation and soils issues.

Goal:
To develop cotton farming systems which produce sustained high yields of high quality cotton under irrigated and rain-fed situations in an environmentally and economically responsible manner.

Objectives:
- To identify farming practices which contribute to a soil resource which supports highly productive cotton on a sustained basis.
- To identify the key soil parameters which are responsible for soil physical, chemical and biological health.
- To encourage a multi-disciplinary approach to farming options with particular attention to the interaction between various agronomic factors eg. soil structure, weeds and disease.
- To identify the tools required by farmers to pursue the most desirable farming practices.

Limitations requiring research:
The group identified issues which it sees as significantly limiting successful farming systems:
Stubble handling - Machinepak development important
Pupae control measures
Weed control in minimum tillage systems and stubble retention farming including herbicides

Nutrition	-Nutripak development important
	- nutritional factors in minimum tillage and stubble-retained systems
	- nutritional factors in B.T. cotton fruiting patterns
Environmental work	- reducing sediment and pesticide run-off
	- stubble retention systems
Salinity work	- this need to be on-going and is seen as a very serious issue where prevention is the key
Equipment work	- guidance system work needs to be completed from listing through planting to cultivation
	- stubble handling techniques
Precision farming	- require more of a discussion paper from Prof. Alex McBratney on this issue

Collation of existing research:
The members raised a number of times the issue of collating and making accessible a database of existing research on farming system issues. This was seen as an essential step in identifying what research is further required and regarded as an important research project in itself. The ...pak system eg SOILpak and NUTRIpak was identified as a useful format for extending existing research.

Rotation crops and N fertilization

Ian Rochester

The CRC experiments have been closely monitored. N fertilizer rates have not differed greatly between treatments within each experiment, generally, the long fallow treatments have required less N than other treatments. The legume crops grown in these experiments have fixed little N and therefore, the N fertilizer requirement of those systems has not changed substantially. Soil and petiole analyses have confirmed that the correct rates of N were applied.

Surveys of commercial legume crops

During 1994 and 1995, legume crops which were grown in rotation with cotton were monitored throughout northern NSW. These included faba beans, soybeans, mung beans and peanuts grown for grain, as well as lablab which was green-manured. To estimate the net input of fixed N to the soil system, the amounts of N fixed by these crops and the amount of N exported from each field in harvested seed was determined for each crop.

In the faba bean crops, biomass and yields were closely correlated with water supply, with about 1 t grain/ha being produced for each irrigation during the drought year of 1994. The faba bean crops were well nodulated where the seed was inoculated with Rhizobia prior to planting. We observed a few poorly nodulated faba bean (and soybean) crops, which failed to fix N. We also observed that less N was fixed by faba bean crops which followed failed or over-fertilized cotton crops, as the faba beans used the residual fertilizer N, rather than fixing their own N, as this process consumes much energy. However, averaged over all crops, about 100 kg fixed N/ha was found in the faba bean shoots and seeds (range 33 to 250 kg fixed N/ha). The amount of N fixed was closely related to crop biomass.

Grain yields for commercial faba bean and soybean crops ranged from 0.8 to 4.4 t/ha. In a few instances, our N balance calculations indicated that less N was fixed by the crop than was removed in the grain (ie. the crop depleted soil N reserves). More commonly, the N fixed exceeded the N removed in seed by as much as 130 kg N/ha for faba bean and 175 kg N/ha for soybean (ie. the crops contributed to soil N). On average, we calculated that about 45 kg fixed N/ha were returned in the legume crop residues.

Faba bean crops have been surveyed in 1994-1996 in the Namoi, Macquarie and MacIntyre valleys. The amounts of N fixed are closely related to the crop biomass. In the smaller crops, most of the N fixed was removed in the grain. In the best crops, up to 250 kg N/ha were fixed, with up to 100 kg N/ha being removed in grain (up to 2.5 t/ha), so those crops added ~150 kg N/ha to the soil system.

Some commercial lablab and mungbean crops (dryland) have failed to fix any N where the crops were continually water stressed. Moderate amounts of N fixation (up to 100 kg N/ha) have been measured at other sites. Cowpeas, lablab (Koala and Rongai cvs) and peanuts have fixed up to 150 kg N/ha. Lablab and particularly cowpea may have weed suppressant properties. Forage legumes (including clovers, medics, vetches) have been grown in small plots at ACRI to evaluate DM production, N-fixation and potential weed problems.

Cropping systems experiments at ACRI

A number of cropping systems experiments have been initiated at ACRI. Green manured field pea and lablab have reduced the N fertilizer required by a following cotton crop to ~ 50 kg N/ha, grain legume (soybean and faba bean) to ~80 kg N/ha, compared with wheat or cotton which require ~150 kg N/ha.

The effect of previous crop on fertilizer N requirements

Cotton, soybean and lablab were grown under irrigation at the ACRI in the summer of 1994/95 to measure the inputs of N by these crops into these systems. The soybean grain was harvested while the lablab was green-manured. In the following summer, cotton was grown to determine how much fertilizer N was needed following the legume crops.

1. N fixation by the legume crops

We measured N fixation in the soybean and lablab crops and calculated crop N budgets on the basis of inputs of fixed N and the removal of N in seed (Table 1). Both cotton and soybean yielded well - between 100 and 245 kg N/ha was removed from these systems at harvest. Despite soybean fixing almost three times more N than the lablab (280 kg fixed N/ha compared with 110 kg N/ha), we estimate that only 35 kg N/ha was returned in the soybean residues, compared with lablab where the entire crop biomass was incorporated.

TABLE 1. Crop N Budgets

Crop	Yield	Crop DM (t/ha)	N Fixed (kg N/ha)	N Removed (kg N/ha)	N Balance* (kg N/ha)
Cotton	7.7 bales/ha	12.0	-	100	-100
Soybean	3.7 t/ha	12.1	280	245	+35
Lablab	-	5.3	110	0	+110

* N balance = (N fixed) - (N removed)

2. N fertilizer required by the following cotton crop

Prior to sowing the cotton crop in 1995 soil samples were collected an analysed for nitrate content. The N fertilizer requirement for each system was then estimated using the NRATE predictive model (Table 2). Anhydrous ammonia was applied at rates between 0 and 200 kg N/ha pre-sowing to allow us to determine the optimal N rate for each cropping system. Following a short fallow, the site was planted to cotton (Siokra V-15) and resown 8/11/95 as hail destroyed the first crop. At squaring, petiole samples were collected and analysed for nitrate to validate the NRATE predictions from soil nitrate data. Both the soil nitrate and petiole nitrate tests predicted substantially lower requirements for N fertilizer following the legumes compared with cotton following cotton.

TABLE 2. Prediction of N fertilizer required for optimum cotton yield based on pre-sowing soil nitrate or petiole nitrate at flowering.

Previous crop	N balance (Table 1) (kg/ha)	Soil nitrate * (ppm)	*(NFR) (kg N/ha)*	Petiole nitrate ** (ppm)	*(NFR) (kg N/ha)*	Actual NFR for optimum yield (kg N/ha)
Cotton	-100	2.6	*(150)*	5,800	*(160)*	160
Soybean	+35	7.3	*(110)*	11,600	*(130)*	100
Lablab	+110	14.0	*(60)*	14,500	*(80)*	60

* Measured to 30 cm in Sept (5 months after harvesting previous crop).
** Early flowering, 2 months after sowing.
NFR = predicted N Fertilizer Requirement

3. N responses observed with cotton following legume crops

Despite the delayed sowing, lint yields were quite respectable (Figure 1).

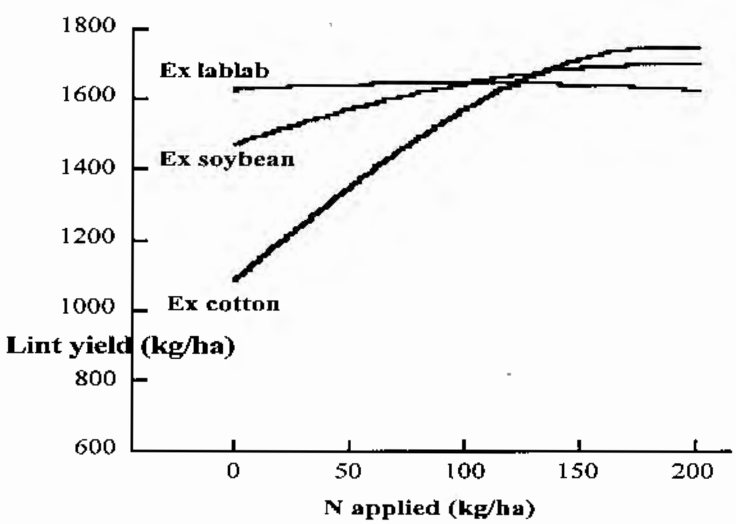

FIGURE 1. Response of cotton to fertilizer N, as affected by previous crops. Residual N fixed by the legume crops reduced the requirement for fertilizer N.

In each cropping system, maximum lint yields were ~1600 kg/ha (or 7 bales/ha). To produce the economically optimum lint yield, cotton following cotton required 160 kg N/ha, cotton following soybean 100 kg N/ha and cotton following lablab required 60 kg N/ha.

Despite mid-season measurements showing slightly better soil structure in the ex-legume systems, further analysis of the yield data indicated that the previous crop effects evident in Figure 1 were due almost entirely to the N status of the 3 systems; soil structure or crop pathogens did not significantly influence crop yield in this experiment. However, the benefits of legume crops may be more evident on poorer-structured soils.

The soil and petiole testing produced reliable estimates of the N fertilizer requirement of the cotton-cotton system for which it was devised. However, both tests tended to over-estimate the fertilizer required following legume crops. Apart from the N fixation measured in legume crops (Table 1) we have further determined that 25 to 30% of the N contained in the crop lies below ground. This represents an additional input of 30 to 75 kg N/ha for the faba bean crops we have sampled and 60 to 180 kg N/ha for the soybean crops. Because this input of legume-N is in an organic form, it is made available to the cotton crop as it is mineralized during the next growing season. The soil and petiole test calibrations are being improved to better predict the reduced need for N fertilizer following legume crops.

In the second experiment at ACRI, winter and summer growing species are being compared. Table 3 relates the soil nitrate levels measured in each cropping system prior to cotton sowing in 1996. The non-legume treatments required the most fertilizer N, the grain legumes substantially less and the green-manured legume treatments required only a small input of fertilizer N.

TABLE 3. N fertilizer requirements of cropping systems incorporating grain and green-manured legume crops.

Preceding crop	Soil nitrate - 4/7/96	NRATE recommendation
wheat	7	125
faba bean	9	110
field pea	17	65
cotton	2	150
soybean	11	100
lablab	20	50

The Use of the Carbon Management Index and Relationships Between $KMnO_4$ Oxidizable C and Soil Aggregate Stability

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Abstract

Twenty soil samples with clay contents <52% were collected from cotton producers in Eastern Australia and analyzed for total carbon (C_T), Labile C (C_L) by oxidation with 333 mM $KMnO_4$, and Walkley-Black C. The resulting 3 soil C pools can be used to initialize C cycling models. Data for C_T, C_L and non-labile C (C_{NL}) (C_T-C_L) from paired cropped and non-cropped (reference) soils was used to calculate a Carbon Management Index (CMI). The CMI of the cropped soils ranged from 34 to 96.

Cropping reduced the mean weight diameter (MWD) of the aggregates by an average of 25% with tension wetting. There was a significant linear correlation between MWD and both C_L and C_T with a stronger relationship with C_L.

CHEMICAL FRACTIONATION OF SOIL ORGANIC MATTER

In investigating the effect of management on Soil organic matter (SOM), it is important that appropriate measurements of SOM are made. To this end, changes in SOM can be measured as changes in total SOM, chemical fractions of SOM based on chemical groups through to specific compounds, physical fractions or combinations of these fractions.

One of the most common fractionations of SOM is based on differences in solubilities of organic constituents in acid and alkali. The complexity of these fractions means that they each contain a wide range of chemical forms, with very different turnover rates. These fractions are not conceptual pools, or related to their rate of turnover, but procedurally defined fractions, based largely on their solubility, and thus with limited value in studies of SOM dynamics.

Rather than assessing the chemical forms of SOM by fractionation techniques or techniques which analyse different functional groups, measurements of the rate of breakdown have been used to assess the quality of SOM. Most attempts to develop models of SOM turnover and relate SOM dynamics to soil fertility have involved the separation of carbon into a number of pools on the basis of their rate of turnover (Parton et al. 1989).

Modification and standardization of the $KMnO_4$ oxidation technique developed by Loginow et al. (1987) by Blair et al. (1995) has increased the precision and simplified the technique to use only one concentration of permanganate (333mM), thereby dividing soil carbon into labile (C_L) and non-labile (C_{NL}) carbon. These measurements of labile carbon have been used, in combination with similar data from a soil of an uncropped, reference area, to calculate a Carbon Management Index (CMI), as a measure of the relative sustainability of different agricultural systems (Blair et al. 1995). This index compares the changes that occur in the total and labile carbon as a result of the agricultural practice, with increased importance attached to changes in the labile, as opposed to the non-labile, component of the SOM.

Soil samples from a wide range of environments and cropping and pastoral systems have been analyzed using the above procedure. In the present study 11 cropped and 9 nearby uncultivated reference soils were collected from the irrigated cotton cropping areas of the MacIntyre, Gwydir and Macquarie valleys in N.S.W. and from the Emerald district in Queensland. The 20 soils included a wide variety of soil types ranging from Red-Brown Earths with low clay contents (20%) to Black Earth soils with 51% clay. The samples were collected from the 0-20 cm horizon and a subsample ground to < 0.5mm. Total carbon (C_T) was determined by catalytic combustion on a Carlo Erba NA1500 and labile carbon (C_L) by oxidation with 333mM $KMnO_4$ (Blair et al. 1995). Aggregates less than 4 mm were tension wetted and sieved through a nest of five sieves ranging from 2000 to 125 µm. The mean weight diameter (MWD) of the aggregates was calculated as the sum of the products of the mean size of 2 adjacent sieves (mm) and the weight (g) of soil on the smaller of the 2 sieves.

The 11 cropped soils had an average of 39% lower labile carbon content and 32% lower total carbon content than their corresponding reference soil.

Data for two contrasting soils from the 20 collected is presented in Table 1. In both soils there has been a reduction in C_T, hence the CPI's are less than 1.00. A reduction in both C_L and C_{NL} has contributed to this decline. In the Black Earth the reduction in C_L has been greater than C_{NL} thus resulting in a LI of 0.73. By contrast, in the Red Brown Earth the lability of C (L) has increased with cropping resulting in an LI > 1.

TABLE 1. Labile and non-labile C and Carbon Management Index from cotton cropped and adjacent non-cropped areas of Eastern Australia.

Cropping History (Years)	Labile C (C_L)	Non-Labile C (C_{NL})	Total C (C_T)	Carbon Pool Index (CPI)	Lability of C (L)	Lability Index (LI)	Carbon Management Index (CMI)
		mg/g					
Red Brown Earth							
0	1.95	9.76	11.71		0.20		
50	1.41	6.58	7.99	0.68	0.21	1.07	73
Black Earth							
0	3.19	10.61	13.80		0.30		
6	1.94	8.79	10.73	0.78	0.22	0.73	57

The 2 pool C fractionation procedure developed using $KMnO_4$ oxidation as outlined above has been extended to include 3 pools. This has been done to provide soil C pool data for incorporation into computer models of soil C such as the CENTURY model developed by Parton et al. (1989) and the Roth C-26 model of Coleman and Jenkinson (1995). All of these models presently use a series of conceptual soil C pools. Development of procedures to partition soil C pools into measurable units would greatly enhance the utility of these models.

The three C pools are measured as follows:

Labile C (C_L). This is determined by the $KMnO_4$ oxidation described earlier in this paper.
Less labile C (C_{LL}). This is determined as Walkley-Black acid dichromate oxidizable C minus C_L.
Intractable C (C_I). This is the C determined by difference between total C determined by catalytic combustion and Walkely-Black C.
Data from two contrasting soils from the 20 examined in this study is presented to demonstrate the effects of cropping on the three measured C pools (Table 2).

TABLE 2. The effect of cropping on the % distribution of C between soil pools in two contrasting soils.

Soil	Cropping History (years)	Labile C (C_L)	Less Labile C (C_{LL})	Intractable C (C_I)
		% of Total C (C_T)		
Red Brown Earth	0	18.5	71.3	10.2
	50	18.3	70.7	10.9
Black Earth	0	21.7	58.2	20.2
	6	17.3	61.2	21.5

Cropping did not result in any appreciable change in distribution of C between the three measured pools in the low clay (20%) Red Brown Earth soil (Table 2). In the high clay (46%) Black Earth soil the proportion of total C in the C_L pool decreased by 3.4% whilst increases of 3.0% and 1.3% were recorded in the C_{LL} and C_I pools respectively as a result of cropping. This increase in C_I as a result of cropping and the high C_I in this soil compared to the Red Brown Earth is most likely the result of clay protection of the organic matter.

SOIL CARBON FRACTIONS AND SOIL STRUCTURE.

SOM is critical in soil physical fertility through its role in maintaining aggregation of primary particles (sand, silt and clay) into microaggregates and macroaggregates (>250 um). The stability of aggregates relies on the binding agents involved, which are influenced by the soil carbon fractions.

In the soils collected in the present study cropping reduced MWD by an average of 25%. Under tension wetting, MWD was significantly larger in the reference, than for the corresponding cropped soil for 8 out of 9 of the reference soils. There was a significant relationship between MWD and both C_L and C_T, (Table 3) but no significant relationships with C_{NL}, C_{LL} or C_I. The relationship found in the present study is not as strong as many have found, but most researchers included only a single soil type or limited range of soils in their studies. However the fact that the correlation is significant shows that carbon, and particularly labile carbon, as determined by $KMnO_4$ oxidation, plays an important role in aggregate stability across the range of soils.

TABLE 3. Relationship between mean weight diameter of wet sieved aggregates and soil carbon fractions in 20 soils from cotton growing areas of E. Australia.

y	x	a	b	r^2
MWD	C_L	0.110	0.336	0.61**
MWD	C_T	0.085	0.056	0.46*
MWD	C_{NL}	0.098	0.066	0.41NS
MWD	C_{LL}	0.158	0.075	0.43NS
MWD	C_I	0.552	0.088	0.05NS

Because the cropped soils have lower organic carbon levels and are more weakly bound together (Tisdall and Oades, 1982) they are more prone to disruption from wetting. This study shows that for soils with lower clay contents, carbon compounds, and particularly the more labile fractions are more important in aggregate stability.

The $KMnO_4$ fractionation procedures outlined in this paper have proven to be useful indicators of the state and rate of change of systems when they have been incorporated into a Carbon Management Index. In low clay soils Labile C has been shown to be associated with soil aggregate stability. Combined use of neutral and acid $KMnO_4$ can be used to quantify 3 important C pools for use in computer models.

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Soil Structure

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Soil structure in a location at any one time reflects the soil ameliorative (eg. a high frequency of wet/dry cycles; maintenance of pore continuity; minimum tillage; encouraging beneficial soil biota) and degradative (eg. trafficking and tillage in wet soil; destruction of beneficial soil biota) practices which have been used at that location in the past. The effects of rotation crops on soil structure can be evaluated by measuring one or all of the following soil properties: soil strength; soil porosity and shrinkage; pore distribution and continuity; and dispersion.
The effects of rotations on soil structure can be measured after a short period of time or may become evident only after several years have passed. The short-term effects can be summarized as follows:

1. Continuous cotton degrades soil structure. Some exceptions to this rule do occur.
2. Crop growth duration appears to be directly related to soil structural amelioration.
3. In comparison with cereals, beneficial effects of legumes on soil structure are short-lived.

Long-term benefits of rotation crops include establishment of stable subsoil pores. Even in high strength, compacted soils these pores enable a cotton crop to minimize the effects of water shortage.

Pathology and VAM assessments of farming systems experiments

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WARREN
The severity of black root rot has been assessed at the Warren site in both November 1994 and November 1996.

The incidence of verticillium wilt was assessed at the Warren site in March 1995 and will be assessed again in March 1997.

VAM development was estimated at six weeks after planting in the 1994/95 season and samples have been taken for similar determinations in this current season.

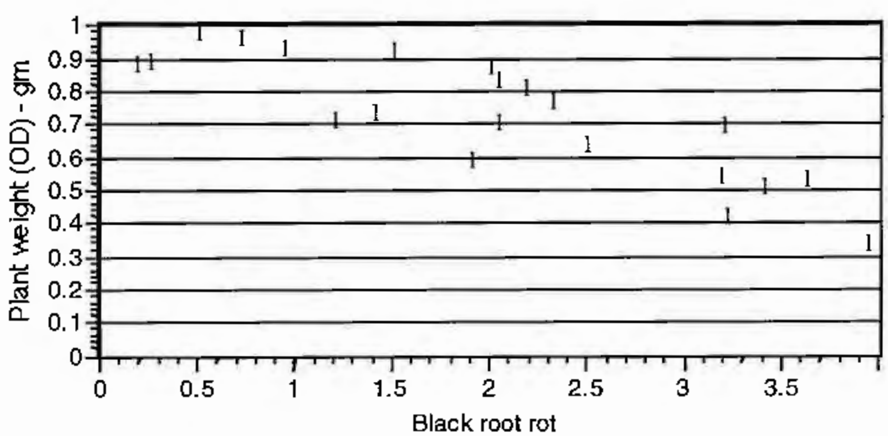
BEECHWORTH
Root browning caused by bacterial stunt and VAM development were assessed at six weeks after planting in the 1994/95 season and samples have been taken for similar determinations in this current season.

WARRA
It is difficult to get a good comparison between the treatments at Warra as there is no time when there is cotton in all plots. VAM development was estimated at six weeks after planting in the 1994/95 season and samples have been taken for similar determinations in this current season.

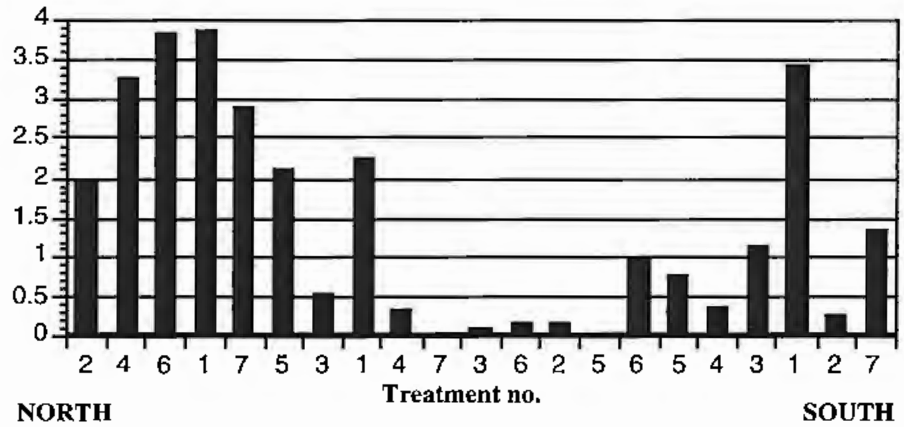
BLACK ROOT ROT AT THE WARREN FARMING SYSTEM SITE (See Figures)

The distribution of the disease in the field remains similar - however symptoms were more severe in the 1996 assessment for six of the seven treatments. This may be due in part to the ideal environmental conditions experienced so far in this current season as well as to the rotation treatments involved. The highest incidence of the disease occurs in those plots where cotton has been grown each season. The incidence of the disease has increased most in treatments "2" (+190%) and "3"(+327%) and declined in treatment "7"(-32%). Black root rot is assessed on a scale of '0' to '4' where '0' = healthy and '4' = 75-100% of the tap root blackened with few or no lateral roots remaining.

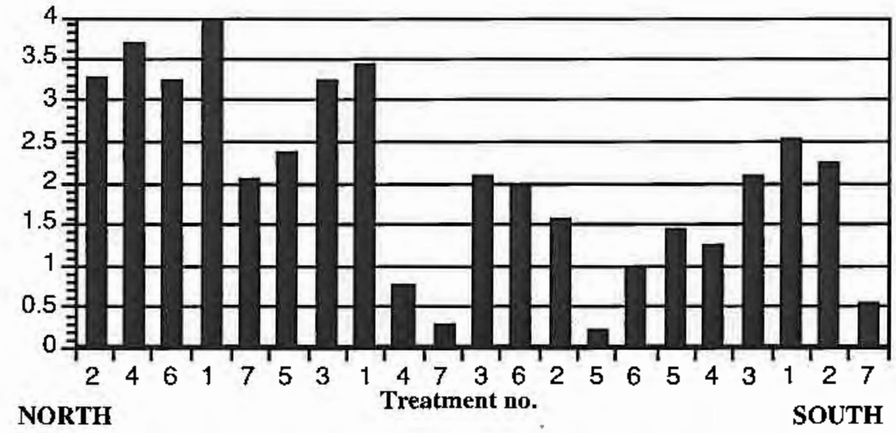
Plots were assessed along a transect centred 300metres from the head ditch. Treatments were as follows: 1 - cotton every season, 2, 3, 4, 5, 6 and 7 - cotton every second season with a bare fallow (2), field pea/summer fallow (3), wheat/summer fallow (4), High input wheat/summer fallow (5), wheat/legume (6) or wheat/legume + K & P fertilizer (7) - between crops



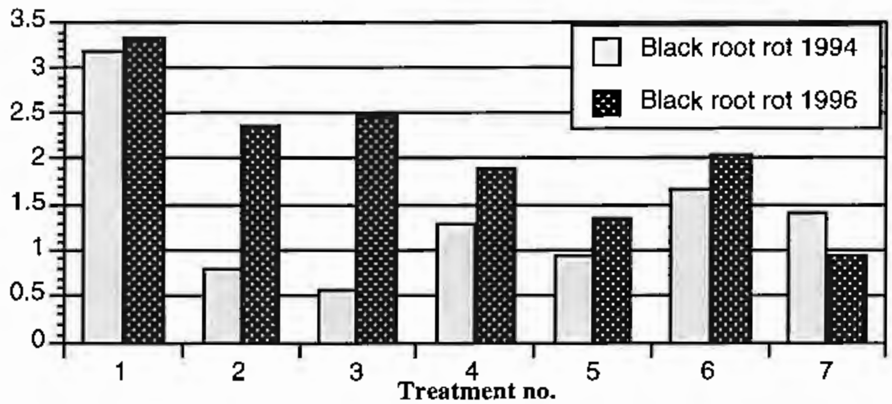
Relationship between Black root rot severity and plant weight at s after planting. Healthy plants were approx. 3 times the size of th severely affected plants (Warren Farming Systems - November



The incidence of black root rot of cotton in plots at the Auscott Warren field 13 Farming Systems trial site - NOVEMBER 1994



The incidence of black root rot of cotton in plots at the Auscott Warren field 13 Farming Systems trial site - NOVEMBER 1996



The mean incidence of Black root rot for each of the seven treatments in the Warren Farming Systems trial as assessed in 1994 qnd 1996.

Managing Weeds in Farming Systems

Graham Charles

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Background
Farming systems experiments are a core component of the CRC for Sustainable Cotton Production. Experiments are established on irrigated fields at 'Auscott' Warren, at 'Beechworth' Merah North, near Wee Waa, and on a non-irrigated field at 'Prospect' Warra, near Dalby. A large number of scientists are involved in monitoring various components of the systems, including soil characteristics, crop yields, water use, nutrition, disease incidence, and weed pressure.

Weed management is a constant problem in all farming systems, with infinite variations in weed spectrum and weed pressure. Weed problems are difficult to manage as they vary enormously between systems, between fields and within fields. Weed 'patchiness' is a normal but difficult to manage component of this problem. Ideally, different herbicides and rates are required in various parts of each field, to match weed occurrence. However, this is next to impossible to achieve with current technology. Weed problems also vary from year to year and season to season, making it difficult to predict the need for pre-emergent herbicides.

Weed pressure in a field may reflect an inadequacy in a farming system, but also may reflect historic events, invasion of weeds from other sources, or unfavourable conditions at a critical time which allowed weeds to establish and set seed. Weed control on the CRC systems experiments is further complicated by very close proximity of different crops, which sometimes limits herbicide options because of the high risk of drift to neighbouring plots.

CRC Results
Weed pressures over the three CRC sites are very different, both in weed species and in weed densities, with the greatest pressure at Beechworth, Merah North. Common factors over the three sites were the development of volunteer crops as important weeds, and the presence of high densities of sow thistle at all sites.

To allow a better understanding of the dynamics of weed populations on these sites, I've selected three systems from Beechworth: a continuous cotton system; a cotton/bare fallow rotation; and a cotton/wheat rotation. These systems are shown in figure 1, and the resulting weed pressures in figure 2. Thirty eight different weed species were identified at Beechworth over three seasons, although peach vine was by far the most numerous and most important, with densities as high as 28 seedlings per m^2 recorded. Peach vine is being controlled in cotton at Beechworth using Cotogard at planting and Gesagard at lay-by. In the 95/96 season, for example, Cotogard at 2.5 L/ha was applied at planting, and Gesagard at 2.5 L/ha was applied as a lay-by treatment.

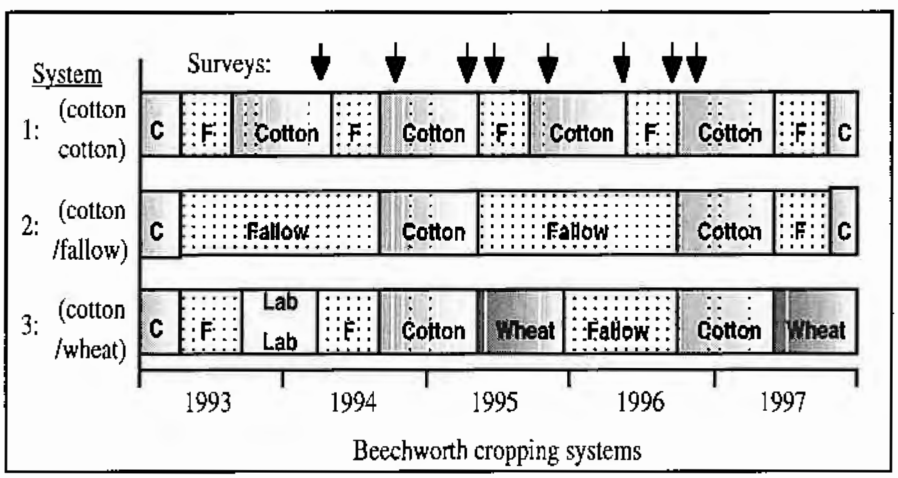

FIGURE 1. The crop rotations used in cropping systems: 1 - continuous cotton; 2 - cotton/fallow rotation; and 3 - cotton/wheat rotation.

Wild turnip was also present in the fallow of the cotton/wheat rotation at up to 7 seedlings per m^2. Overall, the continuous cotton system had the lowest average weed pressure, with comparatively low weed pressure on all but the last occasion. Nevertheless, it is significant that after three seasons of comparatively low weed numbers, this system does not have the lowest weed pressure in the current cotton season. There are a number of possible reasons for this result. It may be that the seed-bank of peach vine seed is so large at Beechworth that control over three seasons has not yet made an appreciable difference. Alternatively, it may be that peach vine seed is coming on to the field from an external source such as storage dams or supply channels. A third possibility is that even though the peach vine levels on the continuous cotton systems have been comparatively low, there may still be enough seed produced in this system each year to generate the numbers seen at the final observation.

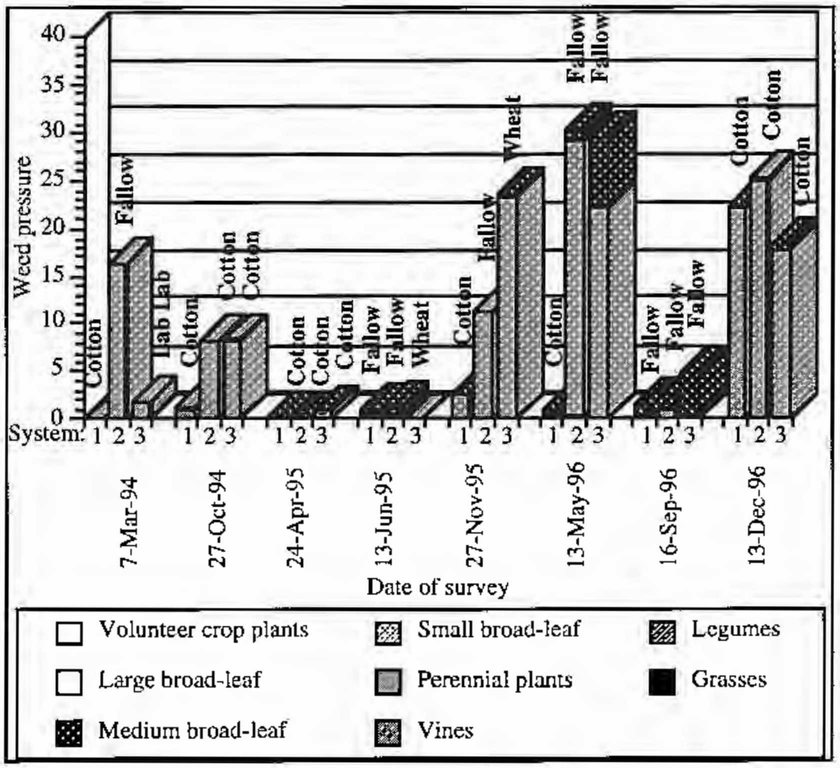

FIGURE 2. Weed pressure (small weed equivalents per m^2) on the Beechworth, Merah North, rotation experiment; the cropping systems are described in figure 1. The systems and dates of observation are indicated below the figure. Comparison of the systems can most accurately be made when all 3 are in the same cropping phase, as occurs on the 2nd, 3rd and final 2 observations.

Other work has shown that the levels observed, of 0.2 peach vine/m^2 in autumn, could have produced 158 seeds per m^2. This is more than sufficient to give the 22 peach vine seedlings per m^2 observed here at the final observation. A better understanding of the source of the peach vine problem may allow the development of more effective management solutions. Work over the next season should clarify the issue.

The comparative advantage of the continuous cotton system at Beechworth was not apparent at the other two sites (figure 3), although the large weed index on the continuous cotton at Auscott was largely due to a single occasion when the other two systems were in fallow. Also, the expected weed control advantage from a fallow component in a system is not apparent at this point. Possibly the advantage is being masked by the large seed-bank present in the soil. Similarly, although broad-leaf weeds have been almost impossible to control in the broad-leaf rotation crops, these weeds are not yet showing up as long-term problems.

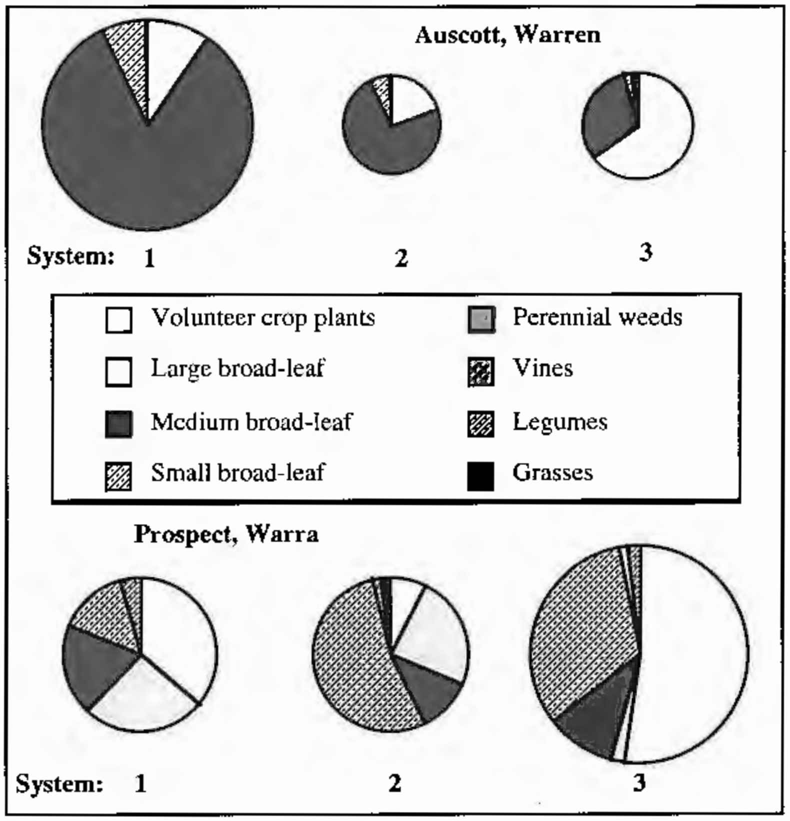

FIGURE 3. Weed pressure (small weed equivalents per m^2) on the Auscott, Warren and Prospect, Warra rotation experiments. The Auscott Warren systems were: 1 - continuous cotton; 2 - cotton/fallow rotation; 3 - cotton/wheat rotation. At Prospect Warra (the non-irrigated site), the systems were: 1 - cotton/fallow rotation; 2 - cotton/wheat rotation; 3 - cotton/wheat/fallow rotation.

Over the three sites, the data to this point have not indicated any major advantages or disadvantages for weed management on the various cropping systems. It seems that historic events and seasonal conditions are having a larger impact on weed populations than the cropping systems used. Data over the next couple of seasons should clarify this result.

Weed management is a constant problem in farming systems, with infinite variations in weed spectrum and pressure. Weed problems vary enormously between systems, between fields and within fields; weed 'patchiness' is normal but difficult to manage. Weed problems may reflect an inadequacy in a farming system, but also may reflect unfavourable conditions at a critical time, allowing weeds to establish.

Weeds pressures over the 3 CRC sites were very different, both in species and densities, with the greatest pressure at Beechworth. The common factors were the presence of high levels of sow thistle at all sites, and the development of volunteer crops as important weeds on all sites.

At Beechworth the continuous cotton plots had by far the lowest weed pressure, but this was not the case on the other two sites, although the large weed index on the continuous cotton treatment at Auscott was largely due to a single occasion when this was the only treatment in cotton.

Overall, the data reflects the difficulty in controlling broad-leaf weeds in broad-leaf crops, and the value of fallows for weed control.

Farming Systems Research - dryland cotton

Peter Carberry, Agricultural Production Systems Research Unit, CSIRO Tropical Agriculture
Mike Bange, Cotton Research Unit, CSIRO Plant Industry

CRDC Project (CSP67C): Improved cotton management through the application of cropping systems models

The Farming Systems Research (FSR) approach employed in this project is aimed at identifying opportunities for and resolving constraints to implementation of more profitable and sustainable dryland farming systems through participatory on-farm research where farmers, advisers, and researchers are part of the research team. The main areas of activity are:

Negotiation of grower and adviser involvement
Farmer groups working within the project are functioning on the Brigalow Flood Plains (2 groups), at Dalby, Brookstead, Goondiwindi, Moree, Edgeroi and Breeza. Group facilitators include Nevin Olm, Mike Lucy, Mick Castor, Chris Lehmann and agronomists from Primac and IAMA-Seed and Grain Sales (multiple groups).
Issues being addressed include fallow water storage, cotton water use efficiency, soil fertility management, row configuration, cropping sequence, soil water conservation and soil erosion.

Monitoring climate, soil and crop performance
More than 30 soils in the cotton growing regions from Capella to Breeza have been characterised for water holding capacity, bulk density, background fertility (OC%) and subsoil salinity.
A network of 20 automatic and manual weather stations (measuring rainfall, max/min/ground temperatures, radiation, relative humidity) are providing daily data for locations from Emerald to Croppa Creek.. These are additional to the existing network of Cotton CRC weather stations.
As part of negotiated on-farm trials, a number of cotton and other crops (wheat, barley, mungbean, chickpea, sorghum) have been monitored for each farmer group. Data on the pre-plant and post-harvest soil water and N status, and crop yield of each paddock are being collected.

Testing model capabilities
Through collaboration with Brian Hearn, the OZCOT cotton model has been extended to deal with skip row configurations and cool temperatures during establishment.
The APSIM systems model (incorporating OZCOT) has successfully predicted commercial dryland yields for cotton and other crops grown in a range of systems.

Example applications addressing industry issues
Issues that have been addressed through crop and soil monitoring include quantifying the water holding capacities of different soil types, the fate of early applied N fertilizer, the relative extraction of deep soil N by sorghum and cotton, soil water storage after heavy May 1996 rains, etc.
Issues that have been addressed through simulation include comparison of long versus short fallow cotton systems, the impact of different cotton planting dates, sorghum versus cotton production systems, cotton in rotation with mungbeans, cotton yield forecasting in January, etc.
On a number of occasions, simulation results concerning pressing issues have been undertaken for local consultants and growers on a request basis.

Machinery Development in the Cotton Industry

Murray Schoenfisch

Work is well under way with a new project that began this year. The first draft of a report titled "Machine-pac" is currently nearing completion, and will concentrate on the machinery currently available for stubble handling in the industry. This will be released in a loose leaf updatable format as information becomes available. Existing and new machinery is previewed, including pictures of the end product. Mulchers, slashers, and tillage equipment currently in use by producers are listed together with the rotation cycle used.

Two guidance systems are also in their final season of testing. The vision system will be commercialised by Case if final testing provides adequate results. A tactile system that will also steer the tractor is also ready for the market.

Future work involves the continued effort on guidance, pupae destruction, stubble handling, and other industry machinery requirements. Grower meetings will be held at suitable times throughout the season to concentrate attention especially on pupae destruction, with individual visits able to be arranged if required. Other expressions of interest by researchers or farmers are invited, whether in existing areas of concentration or new areas that need work.

Nutrient Removal and Balances

James Quinn.

Nutrient Removal
The uptake and removal of mineral nutrients from the soil is a important factor in sustainable cotton production systems. As part of the CRC Farming Systems Experiments, crop nutrient uptake and removal is being examined. However, A complete data set is available for the cotton crops of 1994/95, and we are continuing to analyse samples from later samplings.

From the two irrigated sites (Merah North and Warren) very similar results were obtained in nutrient removal. At these two irrigated sites, 95 kg N/ha, 22 kg P/ha and 32 kg K/ha were removed with each cotton crop. The average cotton lint yield at these sites was 7.7 b/ha at Merah North and 8.88 b/ha at Warren. About 38 kg N/ha, 4 kg P/ha and 23 kg K/ha were removed with the dryland cotton crop at Warra in 1994/95. The dryland crop was more vegetative than the irrigated crops.

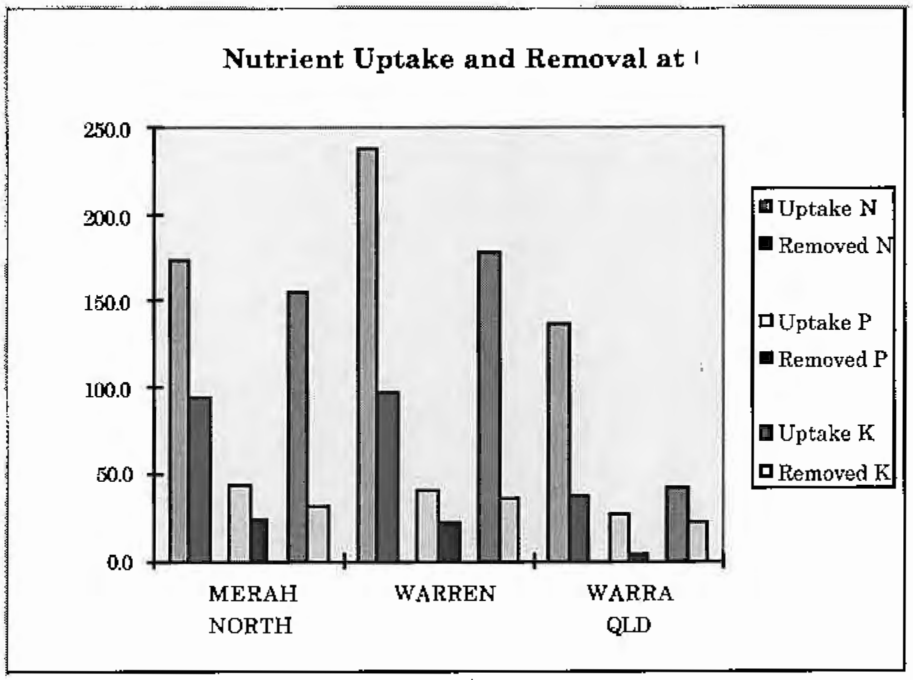

FIGURE 1:
Macronutrient Uptake and Removal at CRC Sites

Muaney and Stewart (1986), found that 53% of N, 58% of P and 26% of K taken up by the crop was removed from the field in seed cotton. At the CRC sites, similar proportions were whereby 55% of N, 52% of P and 21% of K taken up were removed. The percentage removal as proportion of nutrients accumulated by the crop in the dryland system was 27% of N, 16% of P and 54% of K were removed. Note the high percentage of removal of K in this production system.

The uptake and removal of minor nutrients in cotton seed and lint are shown in Table 1. Data is being collected to indicate the levels of nutrients removed from the CRC sites. Uptake from these sites from the 1994 is shown in the table below.

TABLE 1: Uptake of Micronutrients at CRC Sites 1994/95.

Element	Merah North	Warren	Warra
Ca	88 kg/ha	113 kg/ha	29 kg/ha
Mg	31	32	13
S	37	38	9
Cu	100 g/ha	64 g/ha	33 g/ha
Mn	242	296	72
Zn	104	220	43
Fe	2140	898	452

TABLE 2: Micronutrient Uptake and Removal in Cotton.

Element	Uptake (kg/100kg)	Removal (kg/100kg)
Ca	6.2 - 17.5	0.14
Mg	2 - 6.6	0.40
S	1.5 - 2.4	0.55
	(g/ha)	(g/ha)
Cu	20	1.3
Mn	450	29.3
Zn	60	5.8
Fe	600	29.3

Source - Hillocks, 1992.

Literature suggests that small amounts of Calcium, Magnesium and Sulphur are removed for cotton field, and micro nutrient removal rarely exceeds 30 g/100kg lint.

Nutrient Balances.
For a production system to be sustainable, it must not deplete the nutrient status of the soil. Nitrogen is an important input in the cotton production system regardless of the water situation. However, the removal of other major nutrients such as P and K has not been closely studied. The irrigated experiments at Merah North and Warren include treatments where the P and K removed in produce is replaced.

The amounts of P and K removed from these sites is shown above. Before the 1994 and 96 cotton crops were sown P and K fertiliser was incorporated. All legume crops were green manured so the nutrients removed from each system was solely from seed cotton. About 23 kg P/ha and 33 kg K/ha were replaced in fertiliser form (CK66) at the beginning of the 1996 season at both Warren and Merah North. However, before the 1994 cotton crop was sown at Warren, wheat was harvested in treatment 7 in 1993, nutrient replacement with this system was 53 kg N/ha, 25 kg P/ha and 73 kg K/ha. Poor growth of the legume crops has resulted in little N being returned to the soil within these treatments.

Quite a deal of study has been conducted into the rates of nitrogen needed for cotton in various systems. Environmental and cultural practices play an important role nitrogen management within a farm each farm unit. Factors such as previous rotation crop, climatic and soils all influence the fertiliser decision. The tables below show average rates of of nitrogen fertiliser application.

TABLE 3: Average nitrogen rates required for cotton following rotation crops.

Previous Crop	Nitrogen Fertilizer Rate (kg N/ha)
Cotton/Sorghum	130-160
Third Year Cotton	150-180
Soy Bean	60-100
Wheat	80-130
Fallow	60-100
Faba Bean	50-120

Factors that increase these rates:
- Long growing season
- Compacted soil.
- Heavy flat country

Factors that decrease these rates:
- River loam soils
- Short growing season
- Good soil structure

Source - Agfact P5.3.4 (1988)

Forum Discussion - Cropping Systems

Points raised:

Destruction of Heliothis pupae
- Pupae destruction critical to preserve Bt effectiveness
- Moisture retention, especially for dryland farming
- Cotton stubble plow-down time - need to monitor pupae numbers
- Lack of machinery options for pupae control without harming soil structure
- Degree of soil disturbance required? 10 cm or less, depending on soil conditions

Stubble management
- Stubble management and influence on C cycling
- Trash management related to soil loss
- Soil cover decreases erosion, especially wheat stubble left on the soil surface
- How important is soil OM in determining yields?
- What level of C needs to be returned to soil each year?
- Increase soil OM by maintaining crops in field, plant legume crop in wheat stubble?
- Soils of high clay content may not depend on OM for structural stability

Soil structure/compaction/tillage
- Cultivation and persistence of subsoil pores
- Tractor guidance systems - control compaction
- Dryland wheat often demonstrates worst soil compaction, c.f irrigated cotton
- Min-till has improved soil structure beyond that observed in some virgin soils
- Less weed incidence in min-till systems, but there control maybe more difficult
- Disease incidence increasing with permanent beds
- Increased adoption of conservation tillage

Agronomic issues
- Weed management
- Weed spectrum will change with farming practices, requiring different management practices
- Need for mechanical cultivation and herbicides for an effective weed management program
- Need for cropping alternatives for current systems
- Need to determine benefits/disadvantages of legume crops apart from N

Extension
- Improve efficiency of extension of research results to growers
- Growers may be uninformed of appropriate management options
- Growers need to be flexible in determining their cropping system options

NutriLOGIC - NUTRIpak - Development of the Package

Greg Constable

Concept: Computer-based decision support system to provide accurate *suggestions* with respect to fertilizer use and optimise crop performance by satisfying the nutritional requirements of cotton.

Inputs: Link to Entomologic, sowing date, soil and crop sampling dates, soil sampling depth, irrigation info, profile water in dryland, met data for crop physiological development stage and denitrification prediction.

Data input: Soil test data - NPK suggest rate, method, form, time of application
identify imbalances in other nutrients
allow for cross referencing between labs and extraction procedures
Petiole tests - NK suggest rates and methods of application - monitor trend over time
Plant tests - suggest action for next season's crop
Photos of deficiency / toxicity symptoms

Introducing NUTRIpak - the print companion to nutriLOGIC

Maris Rea & David Larsen

While 'nutriLOGIC' software is the main course in the nutrition menu for cotton production, NUTRIpak is an important side dish which will provide the industry with a companion print version of the latest information on cotton nutrition.

NUTRIpak will follow the successful SOILpak presentation i.e. information compiled in a ring binder and set out in a clear and logical fashion so that answers can quickly be found to a particular question using the contents page at the front and a cross referenced index at the back. The ring binder format gives the option to supply registered users with updates whenever new information comes along.

Dave Larsen started to put information together for NUTRIpak in 1994, but the task was sidelined because of the other responsibilites he faced in getting the CRC's Technology Resource Centre rolling. Although David's workload has not diminished the addition of an editorial officer position at the TRC provided technical support.

The topics to be covered by NUTRIpak flowed from discussions between Dave Larsen and Ian Rochester: a two part production was suggested with the first section offering "Quick Help" answers/advice to a range of common questions. Information proposed for this section may instead be incorporated into the relevant chapter(s).

A preliminary skeleton of the second section follows, listing major chapter headings and sub headings:

Soil Testing:
Taking the samples - Where to send them - Interpreting test results
Plant Testing:
Taking the sample - Where to send them - Interpreting test results
Fertiliser Application:
When, where & rate - Placement - Notes on chemistry & biology (*what's happening in the soil)* - Water run/aerial run urea - Foliar application - Table of spray applied nutrients *(nutrient sprays + insecticide sprays)*
Nutrition interactions:
Problems to be aware of: compaction - cut and fill - landform - soil structure *(gypsum, lime)*
Nutrients:
Background information .... macro & micro nutrients; Nutrient balances ... inputs & outgoings
Cropping systems:
Rotation - Frequency of cropping - VAM long fallow
The Future:
Precision farming ... yield maps etc

A special colour-key booklet for field use setting out nutrient deficiencies/damage will be an integral part of NUTRIpak

The challenge now is to finalise the 'skeleton' and continue preparing draft text - either by abstracting from current written material and checking the draft with an expert, or interviewing the expert(s) first and asking them to check/comment on the subsequent draft copy.

The active participation of those with knowledge of the various aspects to be covered should result in a lively, informative publication for **our target audience: GROWERS, CONSULTANTS, STUDENTS.**

Discussion points: Nutrition research

- need for more P, Zn and K work
- cost of soil/plant testing is high and related to poor adoption of this technology
- growers lack confidence in results and may be sceptical of recommendations
- growers lack experience in interpreting analytical results
- potential for improving tissue testing with NIR
- remote sensing may assist diagnosis of nutritional problems
- legume crops may improve nutrition of cotton (not just N)
- early season delays in growth not merely nutritional, but also reflects insect and herbicide damage
- late season problems (premature senescence) are related to nutritional stresses
- expression of Bt may be impaired by nutritional stress
- replacement of nutrients removed in produce must be considered in terms of sustainability
- dryland systems require close monitoring of nitrate leaching

ENVIRONMENTAL ISSUES - SALINITY

Irrigation Salinity

Tracey Willis

Excessive deep drainage is an environmental issue relevant to all cotton growing areas. Salinity is not evident in many cotton growing areas, so it may not be recognised as a potential problem. However it is important to look at the cause of salinity in order to prevent it. To ensure that the cotton industry remains sustainable we must determine whether deep drainage is excessive on each particular soil used for cotton production and then identify management practices to minimise deep drainage and prevent salinity.

In order to identify appropriate management practices for salinity prevention we must consider the factors that effect deep drainage. The three main factors effecting deep drainage are soil type, crop type and weather conditions. Deep drainage will generally be lower on heavier textured soils, where a crop is growing and taking up soil water and rainfall is below average. Conversely, deep drainage will generally be higher on light textured soils, under fallow where rainfall is above average. While the weather conditions cannot be managed, there is opportunity for crop and soil types to be managed in order to minimise deep drainage.

The management of different soil types to minimise deep drainage is achieved through the application of different irrigation practices. There is currently no research being conducted in this area. Research is required to assess the different types of irrigation practices that are feasible for cotton systems, the ability of these practices to minimise deep drainage on different soil types, and the effect of these practices on cotton yields.

Crop management practices to minimise deep drainage are being investigated in the Macquarie Valley, but research is needed in other cotton growing areas. The aim of the current project is to determine the amount of soil water remaining in the soil profile after the cotton season, and then to assess the ability of wheat and field peas to use this water, plus winter rainfall, in order to minimise deep drainage. The experiment is being conducted on a cracking clay (CRC Systems site, Auscott Warren) during 96/97. It will then be carried out on a red brown earth in 97/98. Similar research should also be carried out for a wider variety of crop species.

Understanding the salinity threat in the irrigated cotton growing areas of northern NSW. CRDC US22C

John Triantafilis[1,2] & Alex. B. McBratney[2]

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The project has three main objectives. These include: 1) the development and construction of a mobile EM sensing system (i.e. MESS) for rapid, repeatable soil salinity assessment on the field scale; 2) use salt/water balance models (i.e. SaLF) and scenario studies to assist in understanding the salinity threat on the broadscale, and; develop methods and techniques for carrying out broadscale EM34-3 surveys to identify areas of recharge and discharge. Each component requires data to be generated prior to the application of management strategies to prevent or minimise the impact of soil salinity.

Development and construction of a mobile EM sensing system

Soil salinity assessment is required on the field scale for a number of practical reasons. These include, the generation of information on the extent and spatial distribution of soil salinity, assessing the efficiency of irrigation/drainage and identifying the causes of soil salinity. In all cases, the resultant information generated provides data that can be used in identifying suitable management practices to help minimise the impact and spread of soil salinity. The collection of such data has in the last couple of years been improved significantly. Firstly, several remotely sensing instruments have been developed and are commercially available (eg. Geonics EM38 and EM31). These instruments operate using electromagnetic induction principles. The second development involves the mounting and mobilisation of such instruments onto small tractors, etc., for more rapid assessment.

As an example, the United States Salinity Laboratory developed their mobile EM sensing system (i.e. MESS) specifically for root zone soil salinity assessment on the field scale (Rhoades, 1992). The instruments mounted, include an EM38, a double set of insertion 4-electrodes (i.e. wenner array) and a global positioning system. The salt hopper, as it is otherwise known, is a stop and go vehicle capable of providing information on the spatial distribution of soil conductivity on a two dimensional grid. In addition, the data generated from the various instruments and from subsequent soil sampling can be used to construct depth specific salinity maps. Alternatively, the Department of Conservation and Land Management (Gunnedah) developed their mobile system using a small quadrunner with a GPS and EM31 mounted. The system was developed for on the go measurements for more rapid broadscale reconnaissance investigations.

The MESS currently being developed, with the assistance of the National Centre for Engineering in Agriculture (NCEA) at the University of Southern Queensland, will have similar features to those mentioned above. It is similar to that of the USSL, in that the tractor used by USSL to mount their instruments was recently purchased from the West Texas Lee Co. and imported from the U.S. At this point in time an EM38 and an EM31 will initially be mounted on the tractor along with a GPS and data loggers. It is anticipated that the MESS will be available for application in irrigated cotton growing fields for the 1997/98 season. The EM38 will be mounted in the rear of the vehicle and held in a fibreglass cylinder approximately 0.10 m above the ground. The EM31 will be mounted out the front as illustrated in Figure 1 and held approximately 1 m above the soil surface. The MESS will be capable of both 'on the go' as well as 'stop and go' modes of operation.

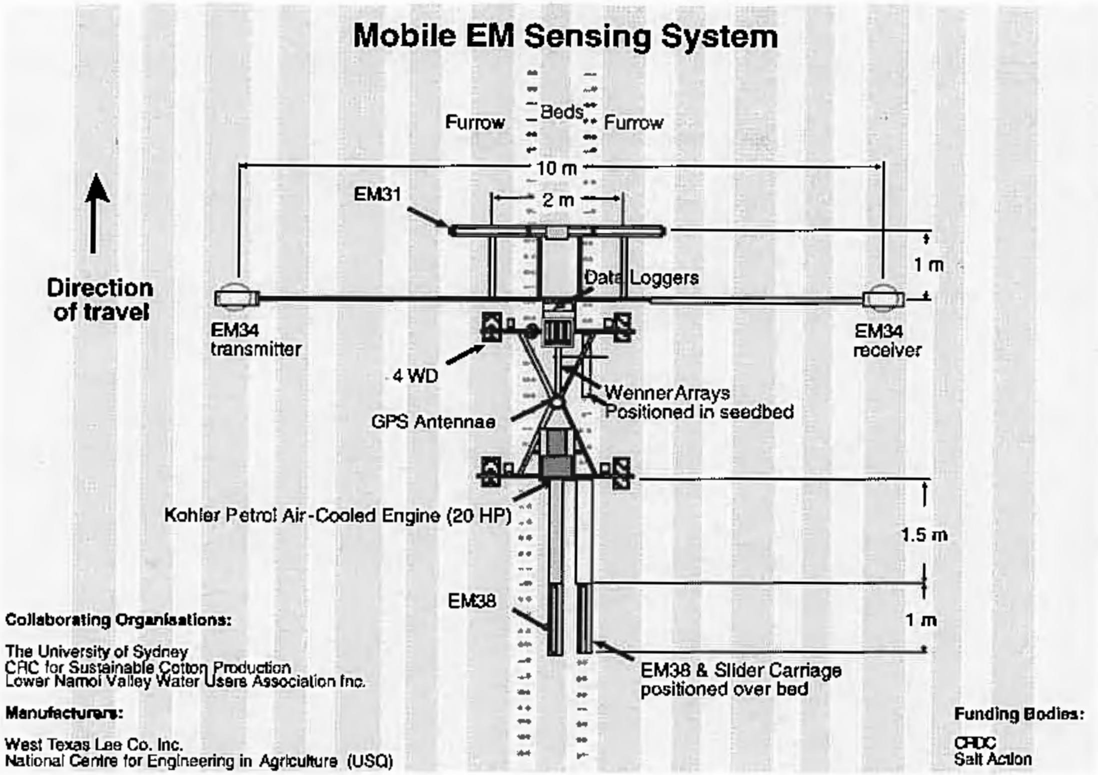

FIGURE 1. Schematic representation of the mobile EM sensing system to be developed.

Understanding the salinity threat using scenario studies (SaLF)

On the broader scale, data is similarly required to determine the potential salinity threat. In particular soil information is necessary to establish baseline data, for decision making on environmental protection and allow for monitoring agriculturally-induced environmental impacts. In addition, this information can be used with soil/water balance models, using scenario studies, to determine where soil salinity may occur. In areas highlighted by such studies through the generation of maps, more detailed investigations can be carried out with management strategies implemented to reduce the perceived threat

At present the necessary data required by the Sodium SaLF model (Ian Gordon, Dept. of Nat. Res. Qld) for validation and hence application to the soil of the lower MacIntyre, Gwydir and Namoi valleys, is currently being generated at the University of Sydney (Mohammed Faruque). The soil in these valleys was previously collected as part of a quantitative inventory of irrigated-cotton (Dr Inakwu Odeh, The Uni. of Syd.). The improved SaLF model and the soil samples will then be in a number of different scenarios to identify areas where soil salinity may occur as a result of differing water quality application due to a reduction in soil quality etc.

As an illustration the Edgeroi data set (McGarry et al., 1989) was used as an example. In figure 2, the result of irrigating with a 'theoretically' very high EC water (i.e. 7 dS/m) to the soil in lower lying areas of the landscape is shown. In the first map, the leaching fraction increased from approximately 40 mm/yr on the application of 700 mm of Namoi river or bore water (results not shown) as compared to about 150 mm/yr using the high salinity water in the irrigated areas. This is a reduction in irrigation efficiency of approximately 25 % (i.e. almost a quarter of the water drains beyond the rootzone and is unavailable for plant transpiration). Added to this is the marked increase in soil salinity within the rootzone to above 6 dS/m as compared to less than 1 dS/m using the River and Bore water, at steady state, as illustrated by the figure on the right. This level of salinity is nearing the critical limits of tolerance for cotton (i.e. 7.7 dS/m) and exceeds the thresholds of many other crops used in rotation with irrigated cotton production. It must be remembered that the example cited here is a worst case scenario, however, decreases in water quality will lead to increases in salt build up within the rootzone.

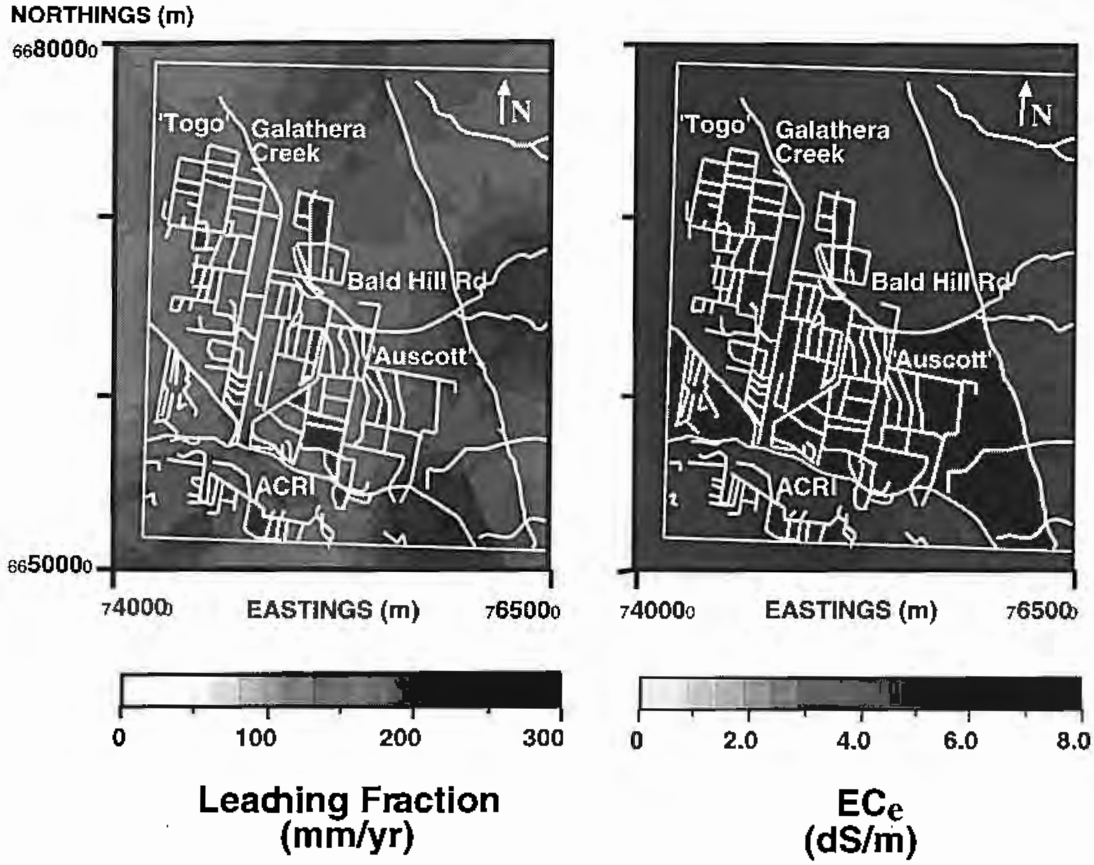

FIGURE 2. Leaching fraction and ECe scenario result of hiEC water applied to the cotton growing areas of the Edgeroi soil data base.

Broadscale EM34-3 surveys: identifying areas of potential salinity threat

Unlike the EM38 and EM31, the EM34-3 consists of two independent coils that are connected via a flexible cord. As the name implies the instrument can be used at three fixed coil configurations. The intercoil spacing can be varied by the user(s) and is measured electronically so that the receiver operator determines the effective depth of penetration by fixing the coils to either 10, 20 or 40 m. The theoretical depth of penetration of the instrument in the horizontal mode of operation at these intercoil spacings are 7.5, 15 and 30 m respectively.

Previously, the instrument has been used for a wide and varied number of practical applications. Potts (1990), for example, describes its use by the Rural Water Commission of Victoria to determine areas where shallow sand aquifers containing good quality water for irrigation purposes exist. With respect to delineation of soil salinity assessment Williams and Baker (1982) first used the EM34-3 to provide a rapid method for reconnaissance surveys of EC_a which could provide an indication of sites which may be hazardous with respect to salinity in an area approximately 10,000 km^2 in the mid-Lachlan valley, NSW.

Similarly, Williams and Arunin (1990) were able to infer from a number of EM measurements, recharge and discharge zones in an area severely affected by secondary salinisation in Thailand. Most recently, Cook *et al.*, (1989) attempted to derive calibration procedures so that the EM34-3 could be used to estimate groundwater recharge rates in a semi-arid area of South Australia.

In the lower Namoi valley and subsequently in the lower Gwydir and Macintyre valleys similar studies will be undertaken to delineate areas of potential salinity concern using broadscale EM34-3 surveys. Soil sampling to depths of up to 15 m will provide data for calibration of the instrument, with subsequent mapping using geostatistical techniques used to delineate areas of large salt stores as well as provide data for recharge/discharge studies using chloride-mass balance models. It is envisaged that 1 to 5 km sampling intervals will be adopted in these investigations.

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Towards quantitative irrigation water quality guidelines for sustainable cotton production

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The widespread use of surface water for irrigation of cotton is resulting in rising water tables through increased recharge to groundwater. One strategy to manage shallow water tables is the conjunctive use of surface and groundwater for irrigation. As salinity and sodicity are the key water quality parameters determining the suitability of groundwater for irrigation of cotton (Shaw and Gordon, 1994), an accurate prediction of the likely impact of altering irrigation water quality on soil leaching, soil salinity and thus crop yield is required.

Leaching controls salt accumulation in the root zone and the extent of downward salt mobilisation. As the salinity of irrigation water increases the greater the leaching required to maintain root zone salinity at levels not toxic to cotton. The addition of saline water will also increase the exchangeable sodium percentage (ESP) of the soil surface. As ESP increases, the rate of water infiltration into the soil surface will decrease, hence reducing the amount of leaching.

Therefore it is important to have good predictions of salt leaching in soils, particularly the slowly permeable Vertisols on which cotton production is concentrated, for reliable irrigation suitability assessments. A knowledge of the potential salt accumulation under irrigation is also important in determining the likely impact on crop production and long term sustainability of irrigation and management practices.

One of the earliest models developed to quantify irrigation water quality with prediction of leaching flux under "steady state" conditions, is the USSL (United States Salinity Laboratory, 1954) model of mass balance. The USSL is also the steady state solution to the SODICS model (Thorburn et al., 1990). The SODICS model is a transient salt mass balance model developed specifically for slowly permeable soils and provides information on predicted steady state chloride profiles and the estimated time for the profile to reach equilibrium under the current management practices and water quality. A salinity model was developed by Shaw (1996) to predict root zone salinity under rainfall. The model SaLF was developed from data of 889 non irrigated sites based on the relationship between soil leaching and hydraulic conductivity (K). The soil properties chosen to represent K were clay content, clay mineralogy (CEC / Clay % Ratio, CCR) and exchangeable sodium percentage (ESP). The underlying assumption of this model (SaLF) was that, "if the ESP-EC-rainfall equilibrium established for the non-irrigated sites is below the threshold level for maximum K, there will be a linear increase in leaching for an increase in electrolyte concentration above this level".

More recent research has developed a non-linear relationship between increasing electrolyte concentration and leaching fraction. This project has utilised SaLF with the model of Suarez (1981) to develop the model Sodium SaLF (SS) which accounts for irrigation water quality compositions where the ESP of the soil will be changed. The model of Suarez allows the sodium adsorption ratio (SAR) of drainage water, hence the ESP of the soil, to be simply and accurately calculated from a derived equation and a table accounting for the ionic strength and HCO_3/Ca ratio in the irrigation water.

Historically water quality criteria for irrigation have been developed for a specific region where local soils, environmental conditions and management practices have been influential in developing suitability limits. These guidelines tend to be overly conservative and cannot be satisfactorily extrapolated to different regions.

This paper presents results from data collected from the Lockyer Valley and Darling Downs and makes comparisons between SODICS, USSL and SS models in the development of a quantitative approach to irrigation water assessment.

Methodology

Soil and water sampling was undertaken on 37 key sites selected within cotton growing regions in central New South Wales and southern Queensland (Figure 1). Sites were selected where groundwater provided a significant proportion of the irrigation supply to allow monitoring of the impact of marginal quality waters on soil properties, salinity and sodium levels. Samples were collected from non-irrigated, short-term and long-term irrigation paddocks from each site. A detailed history of irrigation and management practices on each of the paddocks was collected from farmers, consultants and regional agronomists. This information was collated to provide data on the total amount of water (hence sodium and total salts) applied to each paddock that was sampled as part of the project.

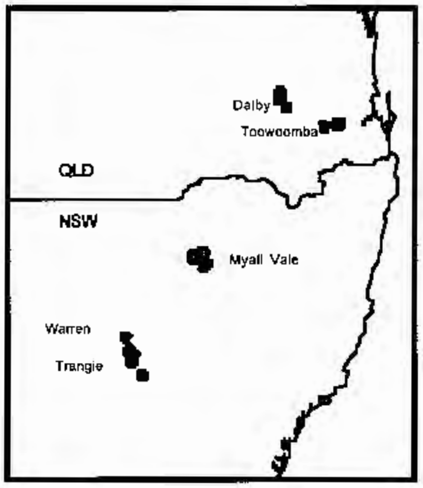

FIGURE 1. Location of soil and water sampling

Laboratory analysis of samples provided the data to run Sodium SaLF, SODICS and the USSL models. The models were selected as they can be applied to data routinely collected during soil surveys and water testing and require no detailed soil physical measurements. The minimum data set required to run all models includes, soil chloride, particle size analysis, cation exchange capacity, sodium and 15 bar moisture content and water salinity, chloride concentration, sodium, magnesium and bicarbonate levels.

From the models calculations of leaching fraction at the bottom of the root zone was converted to average root zone salinity using a relationship derived by Rhoades (1983) as follows:

$$EC_{se,\ avg.} = (EC_{iw}/2.2)/\ LF_{avg.} \qquad \text{Eq. 1}$$

where: $EC_{se,\ avg}$ is the averaged root zone electrical conductivity of soil saturation extract, EC_{iw} is the electrical conductivity of irrigation water and LF_{avg} is the average leaching fraction of the root zone and

$$LF_{avg.} = (\ 0.976\ LF_{bottom} + 0.022\ )^{0.625} \qquad \text{Eq. 2}$$

where LF_{bottom} is the leaching flux at the bottom of the root zone.

Results & Discussion

Data collected from field sites was used to estimate the leaching fraction under the various irrigation conditions. These leaching fraction estimates were then used to calculate the average root zone salinity and leaching flux for each treatment using equations 1 and 2. Leaching flux and average root zone salinity estimates from the three models tested are presented in Table 1.

Under steady state conditions there is a general agreement of estimated leaching fluxes between the SODICS and the USSL model (Table 1). This is to be expected as the USSL model can be shown to be a special case of the SODICS model when steady state chloride levels have been reached. Therefore, under conditions where steady state exists, the USSL provides similar accuracy compared to SODICS but requiring less input parameters.

For the highly saline sodic waters on the Darling Downs site the Sodium SaLF model gave a better estimate of salinity than the SODICS and USSL models. The SODICS model has indicated that steady state has not been reached for this particular site where irrigation has only been applied for a few years.

TABLE 1. Predicted leaching flux and average root zone salinity from soil and water data collected from sites in the Lockyer Valley and the Darling Downs.

Site	Bore water quality		Estimated Leaching Flux (mm/yr)			Estimated salinity (dS/m)			Measured (dS/m)
	EC (dS/m)	Volume (mm/yr)	SS	USSL	Sodics	SS	USSL	Sodics	
Darling Downs	4.06	355	15	52	41	3.7	2.0	2.2	5.1
Namoi Valley	0.34	556	8	5	5	0.7	0.7	0.7	2.1
Macquarie Valley	0.42	740	170	279	617	0.3	0.2	0.1	0.7

Cotton growth is considered to be affected by salinity once a threshold of electrical conductivity of the soil saturation extract (EC_{se}) of 7.7 dS/m has been exceeded. Estimates of average root zone salinity (Table 1) show a fair agreement between calculated and measured salinity for the SS, SODICS and USSL models, particularly under steady state conditions.

The Australian Water Quality Guidelines (1992) provide general criteria which suggest that waters with salinity levels (EC) greater than 2.3 dS/m are "not suitable for irrigation water under ordinary conditions". Results presented the Darling Downs in Table 1 indicate that long term cotton production is feasible with irrigation water salinity levels in excess of commonly accepted criteria. The new approach of Sodium SaLF takes into account both soil properties and water properties when estimating leaching fluxes and soil salinity.

Full statistical analysis has not been completed for data presented in this paper, but results highlight the relativity between the various approaches to estimation of leaching flux under irrigation.

Tables 1 and 2 as well as Figure 2 and 3 shown in the appendices give an example of the spatial versatility of the Sodium SaLF model. Table 2 indicates the differences in soils and irrigation practices across a property with regard to salinity. Figures 2 and 3 in the appendices are an example of broad scale application of the Sodium SalF model to the Macquarie soils map using GIS to give what if scenarios in relation to root zone salinity and irrigation water quality.

TABLE 2. Predicted leaching flux and average root zone salinity from soil and water data collected from one property.

Site	EC (dS/m)	Volume (mm/yr)	Estimated Leaching Flux (mm/yr)	Estimated salinity (dS/m)
Paddock 1	0.045	714	179	0.3
Paddock 2	0.045	845	211	0.3
Paddock 3	0.045	780	13	1

Conclusions:

Results from this project highlight the fact that irrigation of cotton can be sustained with water quality considered to be unsuitable under "traditional" water quality criteria. A more logical approach would be an assessment of water quality for a particular soil type. A soil properties based approach such as the Sodium SaLF model could provide a mechanism to rapidly assess the suitability of any water source for irrigation on a particular soil type. Further improvements to the SaLF model as indicated in this paper would make a more robust methodology for assessing water quality impacts on soil leaching and soil salinity. This approach also has important ramifications for assessing the viability of salinity management options such as conjunctive use strategies.

Acknowledgments
This research was financially supported by the CRC for Sustainable Cotton Production. The authors would also like to thank the property owners who provided information, access to their fields for sampling, and collaboration in this research project.

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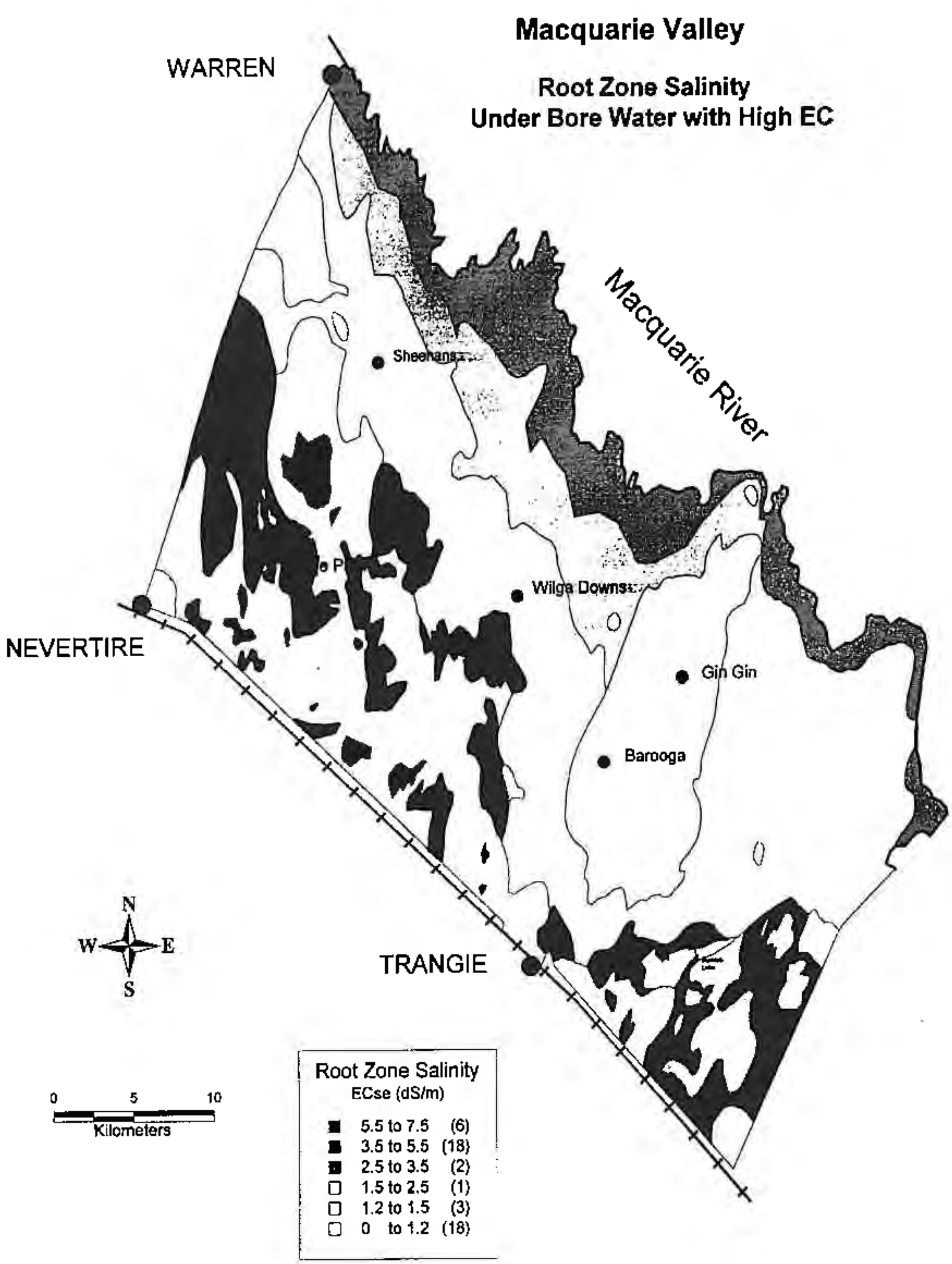
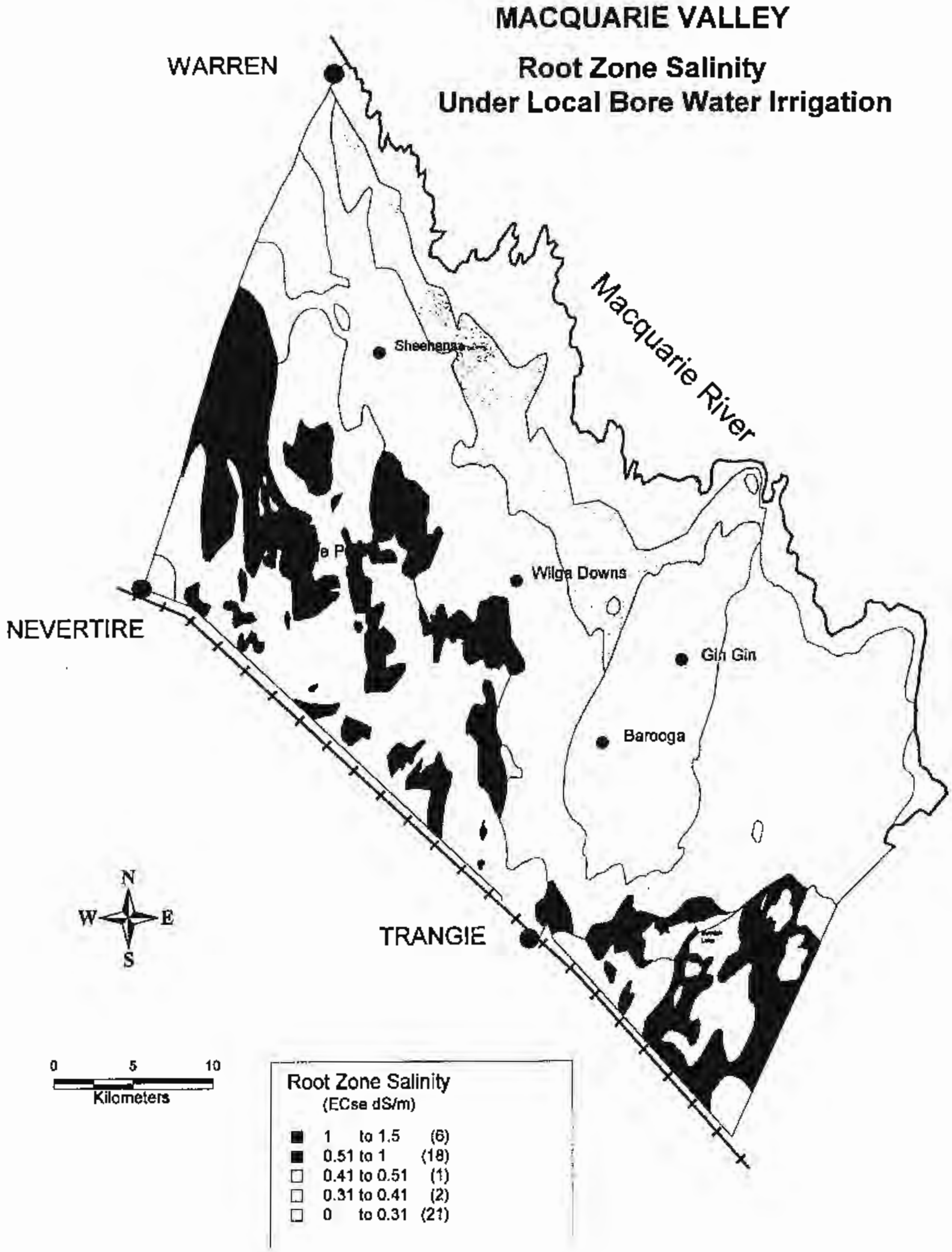

Macquarie Valley
Root Zone Salinity
Under Bore Water with High EC
WARREN
Macquarie River
Sheehans
Wilga Downs
Gin Gin
Barooga
NEVERTIRE
TRANGIE
N
W
E
S
0
5
10
Kilometers
Root Zone Salinity
ECse (dS/m)
5.5 to 7.5 (6)
3.5 to 5.5 (18)
2.5 to 3.5 (2)
1.5 to 2.5 (1)
1.2 to 1.5 (3)
0 to 1.2 (18)



Discussion points: salinity

- Dust has high OM content and high in N and P
- Densification has good and bad features. Seepage is slowed, but permanent pores are maintained
- Cation concentrations at depth may be altered, leading more unstable soil

ENVIRONMENTAL ISSUES - EROSION

Runoff And Soil Loss From Dryland Cotton Rotations

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Introduction
Runoff and soil erosion from dryland cotton fields is of major concern. Dryland cotton provides little cover and soil protection from raindrop impact. Skip row configurations further exacerbate these problems. Crop rotations, including wheat and sorghum, can provide stubble cover to protect the soil. Controlled traffic layouts and minimal tillage will also assist in increasing infiltration and reducing runoff. Automated runoff and soil loss measuring equipment has been installed to measure these responses.

Results and Discussion
Cotton was planted in T1-T5, T8 and T9, and sorghum in T6 on 16 January. Sorghum was harvested on 15 May, and cotton on 4 July. Wheat was planted in T7 on 16 May, and harvested on 18 October. Soil water (10-80cm) in January was 255mm (T4), 275mm (T1,3 and 8), and 290mm (T5-7). Estimated soil water in September was 240mm (T7), 270mm (T4), 300mm (T1,3 and 8), and 320mm (T6). All runoff events from January, 1996 to October, 1996 are summarised below.

	9/1/96 Rain=125mm I_{30}=53mm/hr			30/9/96 Rain=40mm I_{30}=27mm/hr			9/10/96 Rain=62mm I_{30}=29mm/hr			19/10/96 Rain=34mm I_{30}=25mm/hr		
Plot	Cover (%)	Run-off (mm)	Soil Loss (t/ha)	Cover (%)	Run-off (mm)	Soil Loss (t/ha)	Cover (%)	Run-off (mm)	Soil Loss (t/ha)	Cover (%)	Run-off (mm)	Soil Loss (t/ha)
T1 WT	12	47	4.22	10	4	0.20	10	8	0.10	10	0	0.00
T1 non	12	24	1.95	10	8	0.41	10	14	0.18	10	3	0.07
T3 WT	21	21	3.21	13	0	0.00	13	0	0.00	13	0	0.00
T4 WT	20	57	3.37	9	1	0.02	9	1	0.02	9	0	0.00
T4 non	20	33	2.21	9	0	0.00	9	10	0.15	9	0	0.00
T5 WT	15	62	6.09	13	4	0.20	13	4	0.06	13	0	0.00
T6 WT	14	45	4.58	51	0	0.00	51	25	0.10	51	0	0.00
T7 WT	1	35	3.07	63	0	0.00	63	0	0.00	63	0	0.00
T8 WT	17	37	3.61	9	1	0.06	9	0	0.00	9	0	0.00
T8 non	17	26	3.54	9	1	0.04	9	5	0.08	9	2	0.04

Generally, treatments with drier soils and higher cover infiltrated more before runoff commenced, and had higher infiltration rates (lower runoff peaks). Soil loss in January was approximately 100 kg/ha/mm of runoff but reduced to 20-40 kg/ha/mm in September/October due to lower rainfall intensities. Suspended soil loss was 70-90% of total soil loss. This implies that most bed load is being deposited in the furrows, and not moving along the furrow.

Conclusion
Soil erosion is a major issue for dryland cotton, but soil cover reduces soil loss and increases infiltration. Soil loss is dominated by runoff amount, but soil cover reduces sediment concentration. Controlled traffic layouts can provide runoff and erosion control.

Future Research
In future we will sample runoff and sediment for nutrients and pesticides to increase our understanding of processes, the management options to reduce sediment and chemical losses, and the on-farm and off-farm implications. Insect control has been an issue in past seasons due to nearby irrigated crops. Three treatments were planted to INGARD cotton on 25 October, and two on 13 December.

MARK SILBURN - See proceedings from 1995 meeting.

Ped fabric studies and subsoil densification in cracking clays used for cotton production

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The fabrics of cracking clay soils used for cotton production are routinely described using the techniques for field soil structure description outlined in the SOILpakb manual. SOILpakb states, along with other structural indicators, that a proliferation of shiny ped faces indicates good soil structure whereas compacted, poorly structured cracking clay soils generally have dull faces. Given that shiny ped faces often indicate the presence of clay coatings formed by structural instability and clay translocation, the interpretation of soil fabric for cotton growing has been unclear due to the lack of information regarding:

* firstly, what do the different fabrics represent in terms of soil stability and land management? and
* if shiny fabrics are due to clay translocation then is this process the cause of deep subsoil densification that has been previously observed in a cotton field in the Macquarie?

Results

SEM examination of the shiny undulating ped surface fabrics demonstrated that these were comprised of clay coatings usually very thin (but up to 1mm in some deep subsoils) and covering all of the ped surfaces examined. SEM examination of the rough ped surfaces (these were always dull) showed that these surfaces were also covered by very thin clay coatings.

Factors that affect ped fabric include:

1) ped surface wetness - when the soil is wet these surfaces can appear shiny but when dry the same surface can appear dull.
2) the nature of the incident light is important for ped fabric determination. For example, on sunny days ped fabrics are more likely to appear lustrous as compared to cloudy days when the incident (natural) light is more diffuse in nature (a small penlight torch is very useful for determining ped fabric lustre on cloudy days).
3) the angles of incidence and of observance of the incident light off the ped surface. The shallower these angles the greater the likelihood of the surface appearing shiny.
4) condition of the soil pit (regarding wetness) and definition of the soil's structure. The soil in pits dug in cotton soils were usually much wetter than those dug in adjacent undisturbed sites. It was noted that the surfaces on soil materials dissected from the walls of cotton soil pits immediately after pit exhumation were apparently not always separated into large intact peds but rather had surfaces resulting from fracturing across large peds. The fabrics of these exhumed materials often appeared rougher than pits in the adjacent undisturbed sites. However, after a day or two of drying, the inherent soil structure on the side of the pit was more clearly evident and larger intact peds with shiny fabrics were able to be easily separated from the rest of the soil materials.

SOILpak states that, along with other structural indicators, compacted poorly structured cracking clay soils generally have dull faces whereas well structured cracking clay soils have a proliferation of shiny faces. This was not uniformly observed in this project however. For example, at the CRC for Sustainable Cotton Production rotational trial site located near Dalby the reverse occurred: here the native site had a rough fabric and the cultivated site, although having a much denser structure, also had a proliferation of shiny ped surfaces.

Importantly, the results indicate that a dull ped fabric in these soils can not be taken to indicate that that soil has not experienced clay accumulation as a result of soil instability in the form of clay dispersion. Indeed, the highly sensitive scanning electron microscopy technique used in this study for detecting clay coatings in soils clearly shows that clay movement is a common natural process in these soils whether cultivated or not. All undulating ped faces examined were clay coated whether shiny or not. In these cracking clay soils lustre is a direct result of the roughness of the underlying coated soil ped surface rather than being an indicator of soil instability and clay translocation.

Deep subsoil densification cracking clay soils used for cotton production
Replicated paired site trials were established with soil density, particle size analysis and scanning electron micromorphology being determined in successive layers down to 205 cm depth. As is usual, the bulk density of the cultivated soil clods in the surface layer(s) at both sites were less than that for the native soils due to the effects of cultivation.

At the Macquarie site it was very clear that considerable deep subsoil densification has occurred below the cultivation layer down to the 200 cm depth. The compaction was particularly severe in the 130-145 cm layer where a dry bulk density increase of 11% occurred. The trends in bulk density with depth suggest that the densification may have extended below the deepest sampling depth (ie. 200 cm).

The similarity in the particles size analysis versus soil depth relationships for cultivated and native soils at this site clearly indicates that the main reason for the densification in all soil layers was compaction (induced by vehicles) rather than by translocated clay plugging existing pore space as induced by clay translocation from surface layers and irrigation water. The relationship between the % clay of individual soil clods as compared to the bulk density of that clod for the 130-145 cm layer, demonstrates that compaction is the main cause of subsoil densification even more clearly. It is apparent from this data that the cultivated soil clods had higher bulk densities at any given clay content. Therefore, the densification in this layer was not due to clay translocation.

This result might seem contradictory with the results mentioned in earlier, namely, that scanning electron microscopy of samples from all of sites indicated the presence of clay coatings on all ped faces other than those affected by stress (e.g. slickensides). However, it should be stressed that clay coatings were ubiquitous on the peds surfaces of the native soils as well the cultivated soils. Thus, clay translocation is a process that is occurring naturally in these soils. The % clay content data for these soils clearly indicates that the suggestion of McKenzie et al. (1991) that enhanced clay translocation in these soils as a result of soil instability could be responsible for the observed deep subsoil densification is not tenable.

Pilliga site subsoil densification
At the Pilliga site it was evident that deep subsoil densification has occurred in the 30 - 85 cm and 130 -145 cm depth layers, but only resulting in a dry bulk density increase of 2% at the lower layer. The similarity in the particles size analysis versus soil depth relationships for cultivated and native soils at this site clearly indicates that the main reason for the deep subsoil densification at this site (as at the Macquarie site) is compaction by vehicles with high axle loads (Sohne, 1958; Danfors, 1974) rather than by clay translocation from surface layers and irrigation water.

Conclusions
This study has extended the results of previous research on cracking clays to show that the past practices used in long-term irrigated cotton growing have resulted in substantial deep subsoil densification down to depths of 200 cm and that such deep subsoil densification is likely to be widespread in the irrigated cracking clay soils used for cotton production. The peculiar structure of these cracking clay soils may contribute to making these soils very susceptible to deep subsoil compaction under some soil moisture conditions.

This project has also identified that the cause of the deep subsoil densification in irrigated cracking clay soils used for cotton production is vehicular compaction rather than clay translocation as has been previously suspected. Although some of the changes associated with deep subsoil compaction may actually be beneficial, overseas experience overwhelmingly suggests that deep subsoil compaction is irreversible and almost permanently detrimental to crop yields. These results indicate that the present trends and recommendations towards the use of lower axle loads and permanent bed systems in cotton production in Australia (McKenzie 1995; Anthony and Schoenfisch 1995) are appropriate for these soils.

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Discussion points: Erosion

- Dust has high OM content and high in N and P
- Densification has good and bad features. Seepage is slowed, but permanent pores are maintained
- Cation concentrations at depth may be altered, leading more unstable soil

ENVIRONMENTAL ISSUES - POLLUTION

Best management practices manual for cotton growers

Allan Williams

A manual is being prepared to provide cotton growers with information regarding the best practices to adopt in cotton farming. The manual will cover areas such as application of pesticides, farm design, integrated pest management and soil and water management.

Summary of best management practices for soil and water management.

Soil management:
Best management practices to minimise erosion
Crop stubble is not to be burnt if the field is to be sown back to cotton, unless;
wet soil conditions will cause unacceptable degradation in the hills or beds
the field is to be relevelled and other methods of stubble removal will interfere with relevelling
disease control is required and cannot be achieved any other way
In-crop cultivation will be used only where absolutely necessary for weed control and drainage
Soil OM must be monitored and crop rotations and minimum tillage practices used to maintain or increase OM
Minimum tillage farming systems must be adopted which maximise the retention of surface cover

Water management:
Best management practices to minimise the amount of runoff water
Always schedule irrigation using soil moisture monitoring techniques
Maximum tail water runoff from a field is to be 15% of water applied
Use weather forecasts to assist irrigation planning
Irrigation must be delayed if a storm is imminent
Cease irrigation at the onset of a storm
These points are discussed at length in the draft versions previously published for discussion

Fate and transport of pesticides and their containment on cotton farms

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Three years of research on environmental issues related to pesticides funded by the CRDC and the Cotton CRC (Kimber, Ahmad and Kennedy, 1994; Kimber and Kennedy, 1995a; Southan and Kennedy, 1995; Feng and Kennedy, 1997; Kimber, Southan, Ahmad and Kennedy 1995b; Lee, Skerritt and Kennedy, 1995a; Lee *et al.,* 1995b; Van Zwieten *at al.,* 1995a; 1995b; Harris and Kernnedy, 1996; Lee *et al.,* 1997) was too little to prevent serious problems developing during 1994-196 related to pollution by Helix and endosulfan. The evidence suggests that contamination of gin trash fed to stock and aerial drift onto pasture were the operative risk factors. Too often, up till now, research has reacted to the problem rather than actively prevented it developing. One can debate who was to blame for these problems, but lessons should be learnt and a case can now be made that effective environmental protection is within reach as a result of the research.

Neither of these problems was related to soils but the continuing contamination of the rivers with pesticides (mainly endosulfan) clearly is. We have suggested that most of the river contamination is from soil erosion, because of the predominance of endosulfan sulphate in river water. Most sulphate is formed from endosulfan in soil by microorganisms and we have never observed significant sulphate formation in pure water, although any biota present may cause sulphate formation. There is ample evidence available now to prove that soil erosion on cotton farms is a key risk factor. If use of endosulfan recedes because of Ingard cotton, erosion of soils with bound herbicides or insecticides cotrolling pests other than *Heliothis* will remain a problem.

Why is a measure of optimism about the future justified? In managing pesticide use to reduce pollution, there are three logical steps (Harris and Kennedy, 1996):

Minimise pesticide input;
Contain the pesticide to the application site; and,
Select for use pesticides with minimal environmental impact.

The introduction of Ingard cotton this year has potential to minimise pesticide input, particularly of endosulfan. On the other hand, herbicides will become an issue of greater significance, particularly if transgenic cotton cultivars with resistance to herbicides are introduced (Charles, Constable and Kennedy, 1995). Research on containment will involve careful study of the binding properties of individual chemicals to various media and the possibility of applying technological solutions such as flocculants (Hugo, Caldwell and Kennedy, 1996). The selection of better pesticides also requires that rigorous laboratory and field tests be developed to generate data able to predict risk factors (see Table1) and environmental benefits. High quality protocols for field tests have been established by the research (drift and volatilisation, half-lives and degradation, rainfall simulation and erosion, runoff in irrigations and storms).

Thus, key best practices required for environmentally responsible cotton production will be:

- complete environmental assessments of farm chemicals, with a shift in focus to herbicides. This was not done with Helix, producing a perilous situation,
- the application of test protocols for new chemicals in the field to identify risk factors. The Commonwealth EPA, the National Registration Authority, the CRDC and the cotton industry at large should now insist on this testing,

- better methods of management of soil erosion and runoff management. More research is needed to understand the relationship between soil erosion and pesticide transport but some direct conclusions about the need to minimise erosion can already be made.

Table 1 indicates the parameters that tests need to measure. Once developed, the tests would involve measurement of rates of dissipation from several standard soils selected for their relevance to the cotton industry, in runoff water and on foliage, the kinetics and equilibrium values for adsorption and desorption from standard soils, partitioning to organic matter (Eadsforth, 1986), adsorption and desorption with soil additives (cotton trash, plant residues and straw, charcoal, flocculants, etc.) and the capacity for containment, etc.), various physical (volatility) and chemical parameters (solubility, pH) related to fate and transport and testing in standardised microcosms designed to measure rates of degradation and biodegradation and the potential for remediation of soil, water and plant residues. The methods developed will be compared with other procedures (e.g. see OPPTS Test Guidelines, 1996) but emphasis will be placed on innovative methods that are convenient and rapid to use (e.g. chromatography on thin layers of soil, measurement of partitioning by HPLC (Eadsforth, 1986), distribution through polymeric membranes, etc.) Such data is normally requested by the EPA and the NRA for registration purposes, but it is often from studies carried out by chemical companies, obtained under conditions poorly relevant to Australian conditions.

TABLE 1: Properties Of Chemicals & Environmental Risk Factors

Property	Parameter measured	Possible risk factor(s) assessed
Mobility	Volatility (Pa), Henry's constant	Damage to non-targets in air
Mobility	Solubility in water (g L^{-1})	Leaching, runoff potential
Mobility	Binding soil/sediments (g kg^{-1})	Runoff potential to rivers
Partitioning/hydrophobicity	Octanol-water K_{ow}, K_{oc}	Bioaccumulation in produce
Partitioning	Adsorption, deadsorption (K_D)	Release from runoff sediments
Partitioning	Binding K_D to media	Inability for containment
Persistence, dissipation	Half-life (days) in soil	Accumulation in environment
Persistence, dissipation	Half-life (days) in water	Transport in runoff
Persistence, dissipation	Half-life (days) on foliage	Transport in trash
Persistence, degradation	Ultraviolet degradation (sec^{-1})	Potential for accumulation
Persistence, degradation	Chemical hydrolysis (sec^{-1})	Potential for accumulation
Persistence, degradation	Effect of pH	Potential for accumulation
Persistence, degradation	Rate of biodegradation (sec^{-1})	Potential for accumulation

The normal sequence of examination for each new chemical, once the set of tests has been established, would be:

A primary literature search for key physical and chemical data, using the STN network. This involves commercial databases (Chemical Abstracts) that are hand-indexed from around 1966 with up to 50-100 keywords, so that searching is extremely thorough (e.g. a recent search using STN for a review prepared for Sandoz on quinalphos yielded over 1200 references (papers comprehensively indexed from 1966), compared to about 20 using a normal library computer search (papers with limited keywords from 1990 only). A typical STN search, using an academic discount of 80% available to the Cotton CRC at the University of Sydney, involving downloading of say 100 full abstracts and other details of papers, would cost about $300-1000, depending on the database accessed an assessment of whether there are gaps in this data set for estimation of risk factors for the chemical, or whether the data is adequate for field conditions in the Australian cotton industry using both technical grade, analytical grade and formulation grade chemicals obtained from the manufacturer, to complete the set of standard laboratory tests using defined procedures and standard sets of soils used for cotton growing input of all available data (literature and laboratory tests) into a computer program designed to estimate environmental risk factors and to rate the chemical by comparison with other chemicals used in the cotton industry output of a graphical nature indicating the degree of risk and sensible precautions needed to achieve best practice standards minimising the risk a final experimental component, not included in this project, would involve field validation of the predicted risk factors, derived from a data set obtained in field trials. Currently, such field trials are being conducted for the insecticides Intrepid and Cascade (using expertise developed studying endosulfan) and the herbicide Staple, funded by the chemical manufacturers seeking registration for these chemicals (Cyanamid and DuPont).

In future, new tests will be designed to include rapid measurement of all parameters needed for EPA assessment (see *Cotton Pesticides in Perspective,* Kennedy *et al., 1997*) of environmental fate and will be detailed in a Cotton CRC (hard-copy and computer) manual. Chromatographic techniques (gas, liquid, thin-layer) will be exploited in development of the manual as far as possible, with the aim of rapid production of objective data. Where possible, the gathering of this data will be facilitated by using immunoassays developed in previous work of the CRC Subprogram 1.1 (e.g. diuron, Alice Lee, see Lee *et al.,* 1994, 1995, 1996) and in current work (pyrithiobac, Shuo Wang). Immunoassays allow approximately ten times the rate of analysis that the traditional methods of gas or liquid chromatography provide (Kennedy *et al.,* 1997).

As part of the Manual detailing the outcomes, a computer program (relational database with data processing) will be developed, accepting all the data generated in the tests and accessing other available information (e.g. using direct access to the Pesticide Database), in order to provide an objective assessment of the test data and to generate a hazard rating and best practice recommendations related to mode of application, formulation, etc. This computer program will be developed in close liaison with other research workers in the CRC involved in Program 1 (directed by Alex McBratney), integrated pest management and the introduction of transgenic cotton (e.g. Gary Fitt, Neil Forrester, etc.), with assistance from the CRC Director or coordination to other CRC Programs. It will also be aligned to the Best Practices Manual for Cotton Growers (Anon., 1996).

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Control Of Erosion And Run-Off Of Sediment Bound Endosulfan Residues From An Irrigated Cotton Field Using A Polyacrylamide Flocculant

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The production of cotton in Australia is an intensive process that is heavily dependent on the use of pesticides for pest control. In particular, the control of *Helicoverpa spp.* relies on the use of the insecticide, endosulfan. The intensive nature of production also means that irrigations to the crop are frequent and the run-off from such irrigations often contains large loadings of eroded sediment. Endosulfan has long been associated with this sediment fraction. It is proposed that the control of this sediment run-off during irrigation could possibly reduce the run-off losses of endosulfan. Various erosion control measures, both physical (for example, stubble retention) and chemical (the use of a flocculant), may be employed to control this sediment run-off.

In this study, polyacrylamide, an anionic synthetic flocculant was applied to irrigation water prior to the water moving onto the field. The field was freshly cultivated and the soil was highly erodible. Erosion and pesticide movement under three levels of polymer application (0, 1 and 3 mg/L polyacrylamide) was studied. Mean sediment concentrations of 8, 5.8 and 1.8 g/l were recorded for 0, 1 and 3 mg/L treatments respectively. The effect of traffic compaction on erosion was also studied, with compacted furrows exhibiting lower erosion than the non-compacted furrows. The trial was conducted later in the cotton season, long after the application of endosulfan had ceased and the degradation product, endosulfan sulfate, was the major chemical species present in the run-off. A further analysis of this data will be discussed.

The Potential Impact of Precision Agriculture

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Through the ages, agricultural production systems have benefited from the incorporation of technological advances primarily developed for other industries. The industrial age brought mechanisation and synthesised fertilisers, the technological age offered genetic engineering and now the information age brings the potential for Precision Agriculture. With the advent of tools such as the differential Global Positioning System (dGPS), Geographical Information Systems (GIS), and miniaturised computer components, agricultural enterprises are now capable of gathering more comprehensive data on production variability in both space and time. The desire (and ability) to monitor and respond to such variation on a fine-scale is the goal of Precision Agriculture.

This desire has both an economical and environmental basis. Matching inputs to crop and soil requirements as they vary within a field should improve the efficiency of resource use and minimise adverse environmental impact. At present, monitoring and mapping the spatial variation in small-grain crop yields is receiving much publicity in Australia. Yield mapping is only one component of a Precision Agriculture system and small-grains is not the only enterprise to embrace the ideas. Crop yield monitors are also available for potato, peanut and forage harvesters and are under development for cotton, sugarcane and a range of horticultural crops.

The Precision Agriculture philosophy may be eventually applied to the spectrum of agricultural industries, for both quantity and quality control.

A Precision Agriculture System

There are 5 components to consider in the development of a Precision Agriculture system.

Spatial referencing
Gathering data on the pattern of variation in crop and soil parameters across a field requires an accurate knowledge of the position at which samples are taken. The dGPS network enables this information to be swiftly obtained with an accuracy here in Australia of approximately +/- 1 metre.

Crop & soil monitoring
Influential factors effecting crop yield, along with the crop yield itself, must be monitored at a fine-scale. Measuring soil factors such as texture, nutrient concentrations, pH etc. at present remains reliant on systematic manual soil sampling and analysis in the laboratory. Research is underway worldwide into real-time analytical soil sensors that will eventually automate the sampling and analysis procedures in the field.

Pest and disease dispersal along with crop growth indicators such as water stress can be successfully monitored using aerial or satellite photography in conjunction with crop scouting. In Australia two types of real-time small-grain yield sensor, measuring either volumetric or mass flow, are available from five manufacturers. This number will possibly double by 1998.

The total number of grain yield monitors operating in the country is below 200 at present. In the USA it is estimated by the manufacturers that between 5,000 and 10,000 units are operating, half with dGPS capability.

Spatial prediction & mapping
To produce a map of variation in soil, crop or disease factors that represents an entire field it is necessary to estimate values for unsampled locations. Various methods may be used for these predictions based on the values at the sampled locations. The most suitable methods for the various factors continues to be debated and the techniques refined.

Decision support
The degree of spatial variability found in a field will determine whether unique treatment is warranted in certain parts. Correlation analysis between the variation in crop yield and the measured factors influencing crop yield can be used to formulate agronomically suitable treatment strategies.

Differential action
To deal with spatial variability, operations such as fertiliser, lime and pesticide application, tillage, sowing rate etc. may be varied in real-time across a field. A treatment map can be constructed to guide rate control mechanisms in the field. Here in Australia there are presently three systems on the market that can integrate these operations and the number will continue to rise. The controller hardware is also available.

System Development
These components are at different stages of development and implementation. The technology required to gather detailed data leads the agricultural science of deciphering and applying the information it contains.

Technology
Ground positioning using dGPS receivers is well advanced and continues to increase in precision. Competition among an expanding number of GPS companies in Australia should also begin to reduce unit costs.

Crop yield monitors are considered very accurate at measuring the bulk yield of an entire field however less is known about the accuracy of the monitoring systems at the 1-2 metre level where individual yield measurements are matched with dGPS position. This contributes to uncertainty in the industry over the detail yield maps should attempt to display

Variable-rate controlling equipment is also well advanced with feed-forward times being reduced and rate changes becoming much smoother. Technological answers are less abundant in the search for information on what may be causing the observed yield variation. Data is required on the same scale as yield data (ie. every 1-2m). This will eventually require sensors that either externally scan or invasively measure soil attributes as they pass in the field.

Agronomic Research
Here lies the greatest information gap. Scientists and commercial entities both in Australia and internationally are actively researching the causes of, and treatments for, the observed yield variation.

It is evident that cotton lint & seed yield can vary widely within a field and that the spatial pattern of this variation may change over time (Figure 1). This is even evident in the 1996/97 season cotton crop where irrigation usually mediates the significant environmental parameter of soil moisture.

Identifying a significantly yield limiting factor in one year may have limited bearing on the next growing season if its influence is considered singularly. Yield, soil, pest and environment variability data will have to be collected for a number of years (possibly up to 10 in highly variable environments) to adequately characterise and model this interaction. In this manner a map of yield potential for a field may be constructed and then used each year in conjunction with early season environmental indicators and crop response models to guide differential actions.

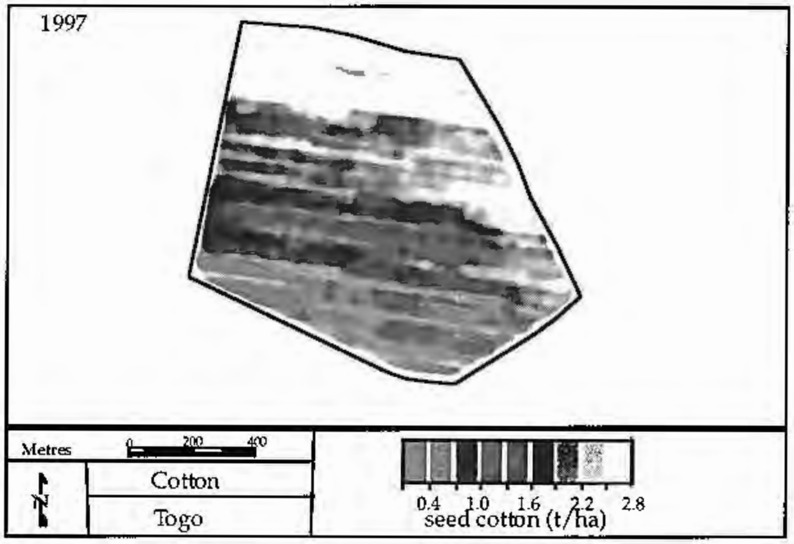

FIGURE 1. Cotton yield for 1997, 'Togo', Narrabri.

Establishing a baseline understanding of the variability in yield potential within a field becomes essential if the most significant soil-based contributors to variability are shown to be difficult to manipulate. Soil factors such as clay content and organic matter levels are known to contribute to nutrient availability and moisture storage capacity of the soil. They are also extremely difficult or impractical to amend in the short-term.

Our research has shown that the spatial variability in these two factors overwhelmingly affects the variation in sorghum yield in one northern NSW field. Intuitively, factors contributing to variability in the soil moisture regime will be important in the majority of cereal growing regions in Australia. The more easily adjusted soil factors such as available nutrient levels and pH will also be important in many areas. However if the more rigid factors are going to limit yield then it would seem prudent to allow these to govern the application rates of any ameliorants in the field.

Precision Agriculture is not about treating a field to produce a uniform yield unless the potential is uniform. Its potential will be only be realised by acknowledging diversity in yield potential and environmental conditions when formulating field management operations.

Economics

The potential value of Precision Agriculture can best be displayed in a gross margin map for a wheat crop (Figure 2). Uniform field treatment costs have been deducted from variable gross profit (yield x price). The 1996 wheat harvest produced a gross profit range between $A0/ha and $A560/ha at a mean of $A295/ha. Mean gross profit could have been increased with some form of differential treatment.

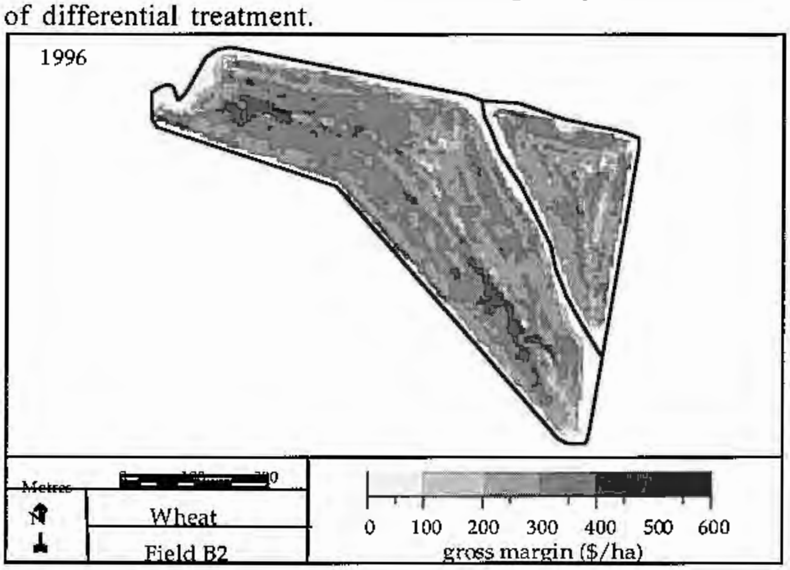

FIGURE 2. Gross margin map for wheat 1996, 'Marinya', Biniguy, NSW.

Determining and attempting to manage variability in yield potentials will obviously raise the variable costs associated with sampling and amelioration. Estimates from the USA place this figure between $A12/ha and $A21/ha depending on the sampling detail. In Australia the projected cost would be between $A12/ha and $A63/ha due to greater unit sampling and analysis costs.

However, the economics of improved environmental stewardship does not easily fit the standard accounting paradigm. The allocation of monetary value to environmental gain is a fledgling science. Payments for positive actions or fines for deleterious actions could be accommodated, but at present Australia has no such remunerative or punitive legislation in place. It is apparent that Europe and the USA are moving in this direction.

Risk Assessment
The improved production information gathered using Precision Agriculture techniques also provides an ideal tool for risk assessment in potentially poor growing seasons. For example, well documented areas of low yield potential may be removed from production or have their inputs reduced to minimise potential financial losses. Such assessments would form part of the decision-support system, so that management actions may be used to disperse or lower production or capital risks across a whole farm.

Education
As with the introduction of all new approaches to crop production, education plays a pivotal role in its widespread adoption. Within the farming community, the main source of Precision Agriculture information has been the marketeers of technology, and not agricultural systems managers or recognised educational bodies. The main reason for this being the as yet minimal agronomic research being performed here in Australia. It is vital that the technology is utilised in an efficient systems approach that is suitable for the Australian environment. This type of 'high tech' approach will probably see the advent of skilled consultants catering for a number of enterprises. Tertiary education will be required to train such people.

Politics
There is still not as yet a strong Precision Agriculture movement in Australia, driven by the economic-environmental imperative, as in the US and Europe. We anticipate legislation such as the 1996 US Farm Bill to expedite research and development.

Conclusions
Information is an economic necessity in any productive industry. The technology is now becoming available to monitor agricultural input/output at an increasingly detailed level. At present, it is necessary to gather data on output to characterise the variability that may be expected over space and time. Understanding the causes will be more difficult at this scale and require committed research from the agricultural industry and improvements in soil sampling and analysis technology. Ultimately these will be available but the impact of Precision Agriculture in Australia will depend on ensuring only suitable techniques are adopted within a fertile research, educational and political framework.

Acknowledgments
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Discussion points - Precision Farming

- Yield monitors being developed overseas
- Is technical input from Australian industries required?
- Problems with interpretation, cannot imply cause and effect (eg influence of insect damage)
- Problems with management (more or less inputs on good or bad areas?
- Fund agronomic interpretation research by RDC's

Soil Carbon Fractions As Indicators Of The Sustainability Of Cotton Cropping Systems

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The development of sustainable cotton cropping systems requires the identification, monitoring and management of those soil properties whose variability significantly affect the stability and resilience of cotton cropping systems. Soil organic matter status is one such property known to have significant effects on the structure and fertility of the soils on which cotton production occurs. This has been emphasised in earlier reports (Blair, 1993; Macleod, 1993; Hulugalle, 1993). This project is therefore carried out to:

(i) develop techniques for assessing the current state and rate of change of organic carbon and nutrients on soils used in cotton production
(ii) determine the suitability of carbon and nutrient balances as indicators of sustainable cotton production
(iii) determine strategies to optimise the management and utilisation of crop residues in cotton cropping systems.

RESEARCH PLAN

1. Technique development

Soil organic matter changes in soil are gradual such that small changes are difficult to detect by conventional methods. The popular Walkley-Black procedure has not shown any relationship to organic matter dynamics. Advanced techniques such as NMR and isotope labelling are not easily accessible for routine monitoring. There is thus a need for the development of simple, accurate and sensitive measures which could be used for regular monitoring purposes. The technique employed in this project simulates the oxidative action of soil microbes by using dilute solutions of potassium permanganate to breakdown the readily decomposable organic compound known as labile carbon. The difference between the total organic carbon and the labile carbon gives the nonlabile carbon which is that component of soil organic matter that is likely to remain in the soil for relatively long periods.

Using the amounts of labile and nonlabile carbon in cotton soils, monitoring indices can be developed (Blair *et al.,* 1995) which have direct relevance to organic matter dynamics under cotton cropping systems.

(a) Carbon Pool Index (CPI): This expresses the amount of total organic carbon in a given cropped soil as a proportion of the total organic carbon in a reference soil of the same type. This is a result of the fact that losses of carbon from a soil with a large pool size is of less consequence than the loss of the same amount of carbon from a soil already depleted of carbon. Similarly, a soil already depleted of carbon is harder to rehabilitate as compared to a soil with a large carbon pool. Thus, a carbon pool index is derived as:

$$\text{CPI} = \frac{\text{Sample total carbon (mg.g}^{-1}\text{)}}{\text{Reference total carbon (mg.g}^{-1}\text{)}}$$

(b) The loss of labile carbon is of greater consequence than the loss of nonlabile carbon. To account for this, a carbon Lability Index is calculated (Blair *et al.*, 1995) as follows:

$$\text{Lability of carbon} = \frac{\text{Labile carbon in sample (mg.g}^{-1}\text{)}}{\text{Nonlabile carbon in same sample (mg.g}^{-1}\text{)}}$$

$$\text{Lability Index (LI)} = \frac{\text{Lability of carbon in sample}}{\text{Lability of carbon in reference soil}}$$

(c) The Carbon Management Index (CMI) can then be calculated as:

$$\text{CMI (\%)} = \text{CPI} \times \text{LI} \times 100$$

2. Cotton Soil Survey

Analyses carried out on sixty-five soil samples collected from different cotton growing regions, including native and cropped sites, in New South Wales and Queensland have shown a parabolic relationship between length of cropping and the CPI and CMI (Figure 1).

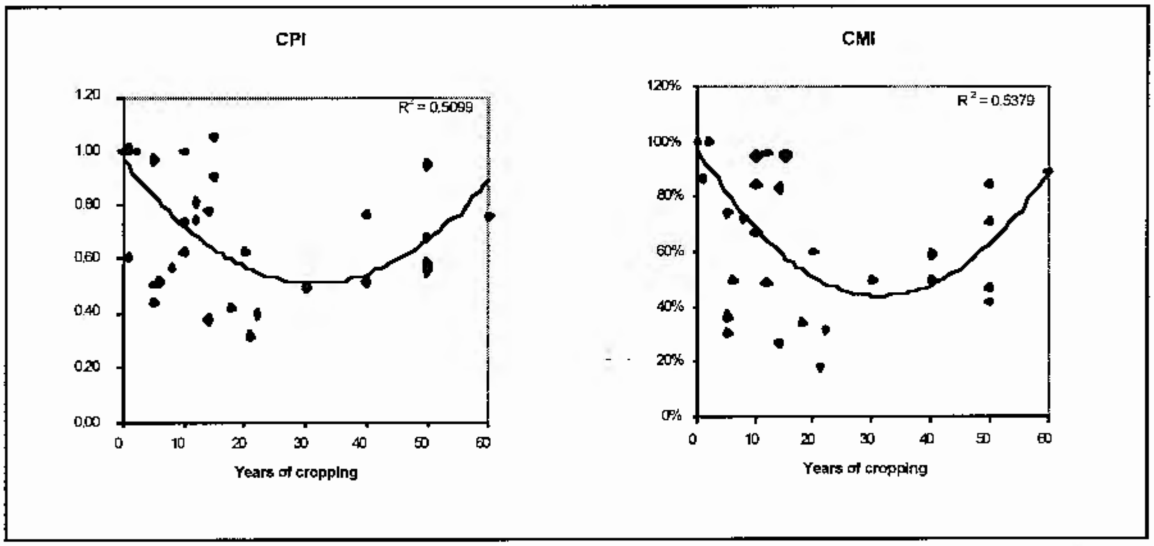
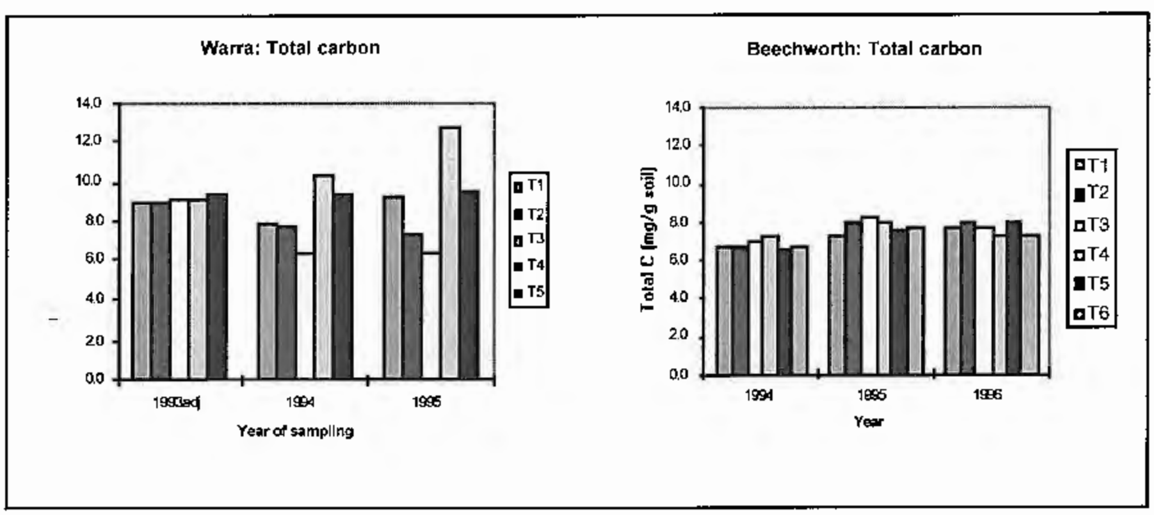


FIGURE 1: Carbon Management Index as affected by length of cropping

A nutrient omission trial conducted in the glasshouse provided results which necessitated a field response trial in two sites in the Namoi Valley; Kilmarnock and Togo Station. Although initial differences in growth rate between treatments were observed, the final yields of cotton did not show any significant difference between the treatments compared. An examination of the chemical composition of the water used for irrigation in the two sites showed some data that will necessitate regular monitoring of the chemical composition of irrigation water.

3. Residue Management Experiments in the Field

Long-term CRC Rotation Experiments: A wide range of rotation treatments have been set up in irrigated and dryland cotton growing sites by the CRC for Sustainable Cotton Production. These rotation treatments for two sites, Beechworth and Warra are shown in Table 2. Samples collected in 1993, 1994, 1995 and 1996 have been analysed for total carbon, total N, $^{13}C/^{12}C$ ratio, available P (Colwell) and available S (KCl-40). Some results are shown in figure 2. The overall changes in the C/N ratio, inorganic P and available sulfur are shown in figure 3.



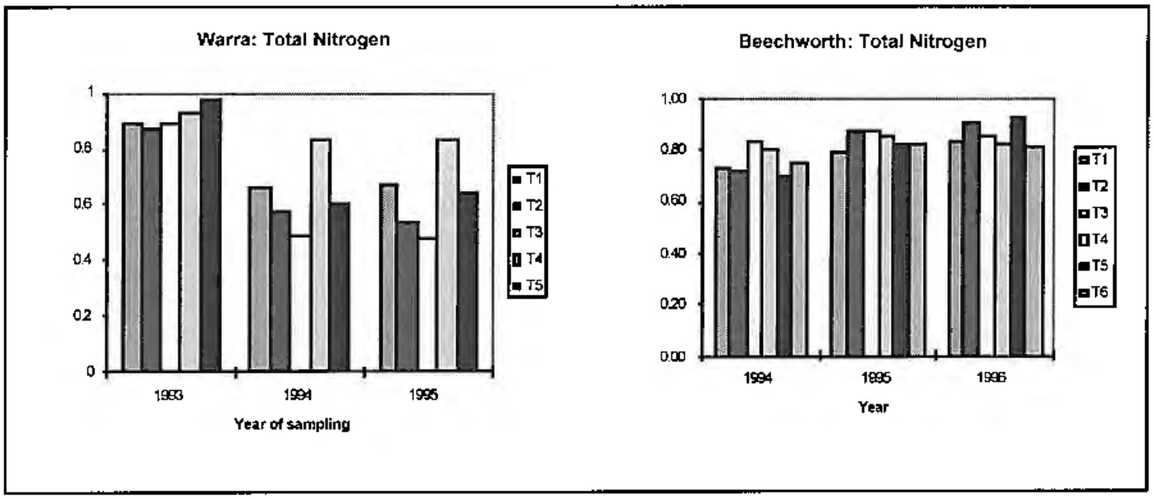
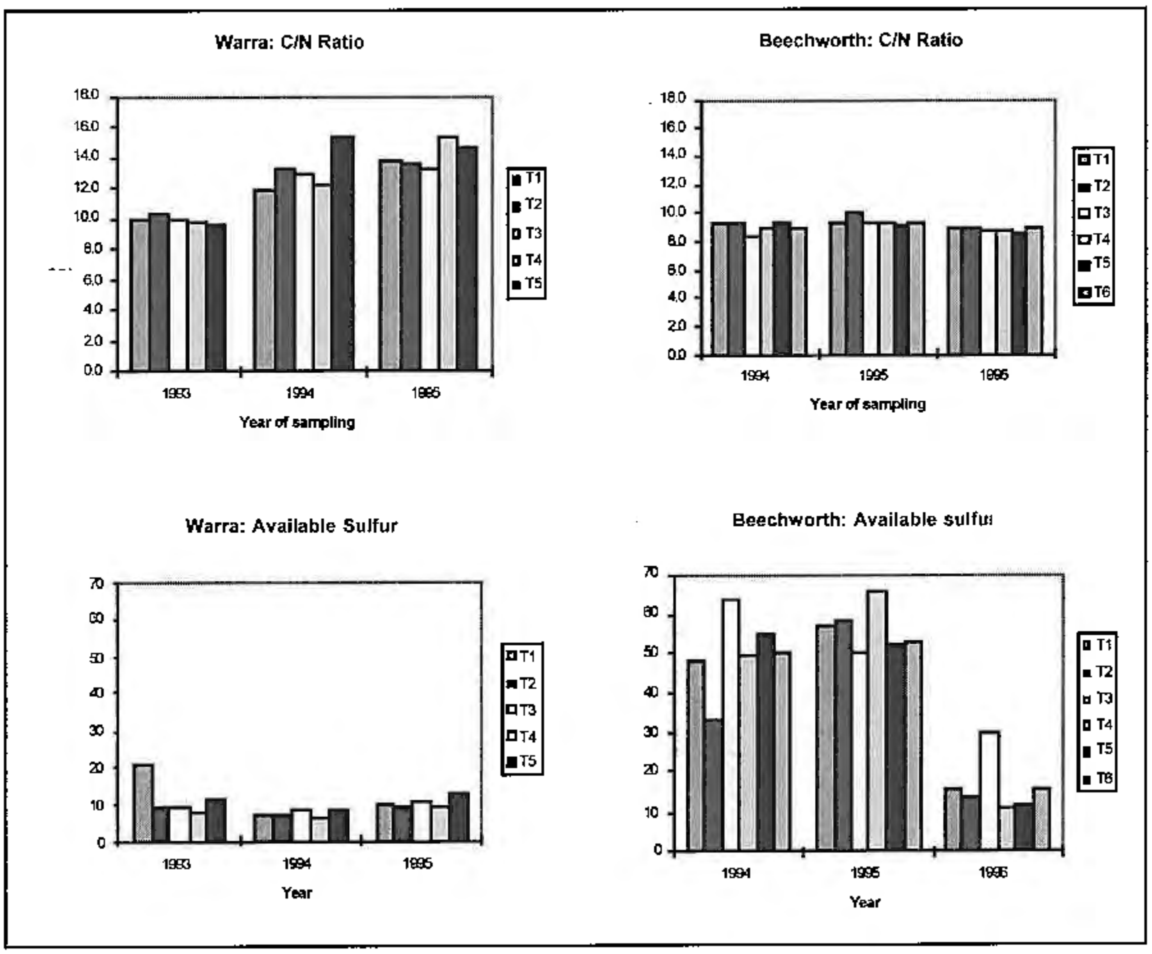


FIGURE 2. Changes in total carbon and total N in three years of cotton rotations

Soil samples from Warra in 1993 were collected to a depth of 0 - 10 cm while the subsequent samples were to a depth of 0 - 30 cm. For comparison purposes, the carbon values obtained from the depth of 0 - 10 cm were adjusted to correspond to a depth of 0 - 30 cm (Dalal and Mayer, 1986).



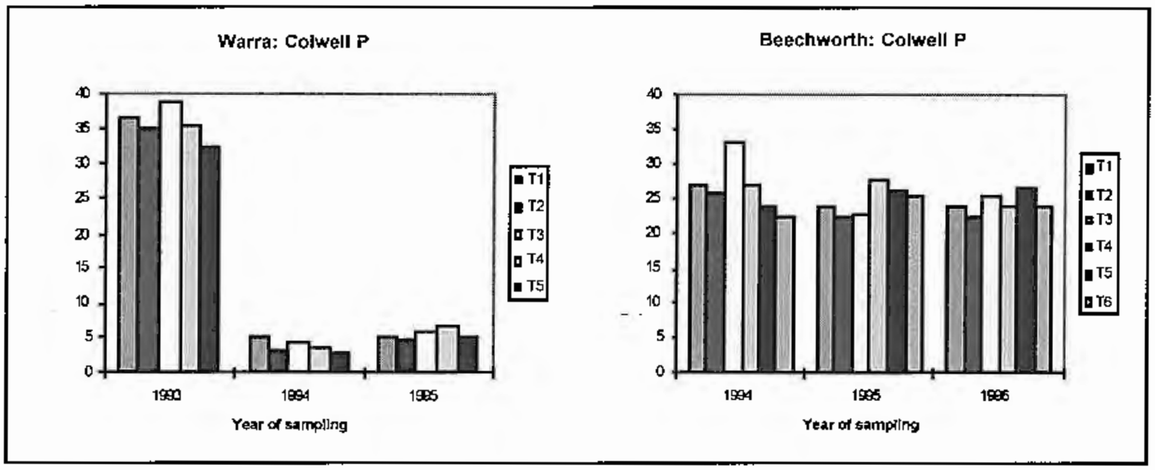


FIGURE 3. Changes in C/N ratio, available S and available P during three years of cotton rotations

Further analysis for labile carbon, nonlabile carbon and the determination of carbon pool and carbon management indices are in progress. Results obtained so far for Warra samples during the period 1993 - 1994 are shown in table 1.

TABLE 1. Changes in soil carbon fractions under cotton rotations at Warra.

		C_T (mg.g^{-1})	C_L (mg.g^{-1})	C_{NL} (mg.g^{-1})	L	LI	CPI	CMI (%)
T1	1993	8.97	1.62	7.35	0.22	0.57	0.12	6.76
	1994	7.87	1.15	6.72	0.17	0.44	0.10	4.60
T2	1993	8.97	1.72	7.25	0.24	0.61	0.12	7.28
	1994	7.76	0.84	6.92	0.12	0.31	0.10	3.22
T3	1993	9.07	1.41	7.66	0.18	0.47	0.12	5.71
	1994	6.36	0.78	5.58	0.14	0.36	0.08	3.04
T4	1993	9.13	1.84	7.29	0.25	0.65	0.12	7.88
	1994	10.3	1.52	8.78	0.17	0.44	0.14	6.10
T5	1993	9.33	1.19	8.14	0.15	0.37	0.12	4.66
	1994	9.41	0.96	8.45	0.11	0.29	0.13	3.65
Ref.	1993	75	21	54	0.39	1	1	100

TABLE 2: Rotation Treatments at Beechworth and Warra

BEECHWORTH

	SUM 92/93	WIN 93	SUM 93/94	WIN 94	SUM 94/95	WIN 95	SUM 95/96	WIN 96	SUM 96/97
T1	Cotton		Cotton	Fallow	Cotton	Fallow	Cotton	Fallow	Cotton
T2	Cotton	P	Cotton	F. Bean	Cotton	F. Bean	Fallow	F.bean	Cotton
T3	Cotton	R	Fallow	Fallow	Cotton	Fallow	Fallow	Fallow	Cotton
T4	Cotton	E	Lablab	F.Bean	Cotton	Wheat	W.stub	Fallow	Cotton
T5	Cotton	P	Lablab	fallow	Cotton	Fallow	lablab	Fallow	Cotton
T6	Cotton		Lablab	P+K	Cotton	Fallow	Lablab	P+K	Cotton

WARRA

	SUM 92/93	WIN 93	SUM 93/94	WIN 94	SUM 94/95	WIN 95	SUM 95/96	WIN 96	SUM 96/97
T1	Cotton	Fallow	Fallow	Fallow	Cotton	Fallow	Fallow	Fallow	Cotton
T2	Cotton	Fallow	Sorgh	Fallow	Cotton	Fallow	Sorgh	Fallow	Cotton
T3	Cotton	Barley	Fallow	Fallow	Cotton	Wheat	Fallow	Fallow	Cotton
T4	Cotton	Barley	Fallow	Chkpea	Fallow	Fallow	Cotton	Wheat	Fallow
T5	Cotton	Fallow	Fallow	Wheat	Fallow	Fallow	Cotton	Wheat	Fallow

Stubble Management Experiment (Rochester, *pers comm.*): This will examine the changes in soil carbon fractions in a three-year residue management experiment conducted by Ian Rochester at the ACRI (1991 - 1993). The experiment compared the effects of incorporating and burning of cotton residues on the subsequent cotton yield and some soil properties. The soil analyses are in progress.

4. Relating Soil Carbon Fraction to other Organic Matter Measurements
This aspect of the project will help to explain what constituents of the soil organic matter are present in the labile and nonlabile carbon fractions. The following techniques will be employed.

Spectroscopic Techniques
- Near Infrared Reflectance (NIR)
- Nuclear Magnetic Resonance (NMR)

Wet Chemical Techniques
- Humic substances, HA/FA ratio, E4/E6 ratio
- Total and Labile Polysaccharides
- Water soluble phenolic compounds
- Litter and Humic Compounds

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Spatial variability of selected soil properties describing soil degradation in the lower Gwydir valley

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Abstract. Degradation of soil structure in some areas of Australia is in part due to the influence of irrigation on the equilibrium of physico-chemical constitution of the soil which in turn results in structural instability. The resulting disequilibrium may lead to structural instability. This study is aimed at analysing the salient topsoil (0-10 cm) properties (related to soil structural stability) that indicate potential or actual degradation of the irrigated-cotton soil of the lower Gwydir valley. A specific objective was to determine broad-based spacial variability of these properties (electrical conductivity (EC) Sodium Adsorption Ratio (SAR) and Dispersion Index(DI)) that enable derivation of potential gypsum requirement in the valley. Following field sampling and laboratory analysis, a geostatistical technique of kriging was applied to predict these properties into a fine-grid mesh. The spacial variability of these properties were represented on their respective prediction maps which show variable patterns of SAR, EC and DI in the valley. Through a set of expert rules an index of probable gypsum requirement that is indicative of the broad-based variation of gypsum needed to ameliorate potential structural instability and consequently soil degradation across the region, was determined and displayed in a map. The pattern of gypsum requirements indicates that areas with the most probable requirements roughly coincide with the most intensively cultivated areas of the valley.

The need for soil information for the cotton-growing region of eastern Australia cannot be overemphasised. The spatial distribution of soil properties important for sustainable cotton production needs to be elucidated to enable targeting of the problem areas for better management and amelioration. This paper focuses on results of spatial analysis on selected soil properties in the lower Gwydir valley. Further analysis of interactions among soil properties for decisions regarding the need to apply gypsum or not, to ameliorate potentially dispersible soil types in the valley was carried out.

Gypsum is the most common soil structural ameliorating agent for alkaline soils (Abbott and McKenzie, 1996). It works in the following ways: firstly by increasing the EC of the soil, which in contrast to high sodicity, promotes structural stability even under medium soil sodicity. Secondly the calcium ion in gypsum is exchanged for sodium ions at clay exchange sites while the latter are flushed past the root zone.

Most soil properties vary continuously in space as a result of differential pedological processes (Bouma and Finke, 1993). It is expected that soil properties which can lead to potential or actual soil degradation, for example SAR and EC, may exhibit spatial variability across the valley. This invariably means that gypsum requirement may also vary in correspondence to the variability expressed by the soil properties.

Metbods

This project is a part of a wider project covering 3 valleys: the Macintyre, the Gwydir and the Namoi. A prior study (Odeh and McBratney, 1994) had determined the number of sampling sites required for each valley. Based on the sampling strategy, 153 sites were sampled in the lower Gwydir valley. The samples were analysed in the laboratory, determining the salient soil properties. Geostatistical models for spatial prediction was used to predict the values of soil properties to locations where samples were taken in the field. This resulted in soil properties prediction maps indicating spatial variability across the valley.

Further analysis of interactions between the important soil properties determining potential soil dipersibility was carried out based on threshold values above or below which soil structural degradation may occur. The rule guiding this analysis was based on the expert knowledge (McKenzie et al., 1995) listed as:

IF EC<4 dS/m **AND** SAR>3 **OR** DI>8, **THEN** SOIL STRUCTURE IS SUSCEPTIBLE TO DEGRADATION, THEREFORE MAY REQUIRE GYPSUM APPLICATION.

These nominal values were transformed into its indicator variable and then interpolated using ordinary kriging to produce maps of probabilities that gypsum application is required.

Results and discussion

Salinity as expressed by electrical conductivity

The spatial distribution of topsoil EC (0-10 cm) across the lower Gwydir valley is shown in Fig. 1. The whole region exhibit relatively low salinity at this depth, particularly in the western half of the sampling region meaning soils in these areas will be susceptible to instability even at low sodicity. There is a definite increase in salinity from west to east, which is very inconsistent with the trends of salt formation across Australia as outlined by Hubble et al., (1983). Generally, one would expect salinity to increase as one moves in the western direction because of decreased precipitation and increased evaporation with increasing distance in this direction.

Sodium adsorption ratio (SAR)

The spatial variation of SAR across the lower Gwydir valley for the topsoil (0-10 cm depth) is shown (Fig. 2). Sodicity values are particularly low in areas just west and south-west of Moree , However, there are problem areas north east of Moree, south-west of Garah and south-east of Bullarah. There appears to be no systematic patterns of SAR variation in the valley. The patterns of variation in SAR may be explained by different parent material and, perhaps more so by land use.

Dispersion Index

The map of the indicator transform of the DI at 0-10 cm depth is shown in Fig. 3. Spatial variation in DI, expected to correspond to EC and especially SAR, across the valley, is generally not the case. The only exception is a small area south-east of Bullarah that has high SAR corresponding to high index of dispersion. Generally, the most probable dispersive soil types occur just east and south-east of Moree and north of Ashley. The main reason for these highly probable dispersive soil types is perhaps due to their low salinity which causes relatively moderate sodic soil types to disperse.

Spatial variation of the probable gypsum requirement

The spatially variable probable gypsum requirement for the region were found in general to correspond to the values in the SAR, EC and DI maps, as shown in Fig. 4. Probable gypsum requirements for the topsoil were found to be low ($P < 0.3$) in the far western, central and lower-southern regions. These areas had low EC (<1.3 dS/m), moderate SAR (2-3) and low dispersion probabilities ($P < 0.4$) when referring back to the corresponding areas in the soil property maps. These regions are predominantly stable at present and the benefits as a result of gypsum application would be minimal. However, requirements are substantially higher in the lower middle to upper southern regions (P>0.6-0.8), the northern (P>0.8) and to a lesser extent the eastern regions, corresponding to higher relative SAR values, lower relative EC values and higher likelihood of dispersion. The application of gypsum to these unstable areas would potentially improve soil structure.

Conclusions

The values of the primary soil parameters: SAR, EC and dispersion index, were found to be highly variable throughout the lower Gwydir valley. The gypsum requirement is equally variable in correspondence to variation of the primary soil parameters. Most areas with a high probability of gypsum requirement in the topsoil are in the east of the valley, while there are extensive stable regions of low sodicity in the central and west sections of the valley. The areas south-west of Moree and north of Ashley particularly are of high probable gypsum requirement. These areas coincide with intensively cultivated portion of the valley. More work is ongoing to relate these findings to landuse patterns in the valley.

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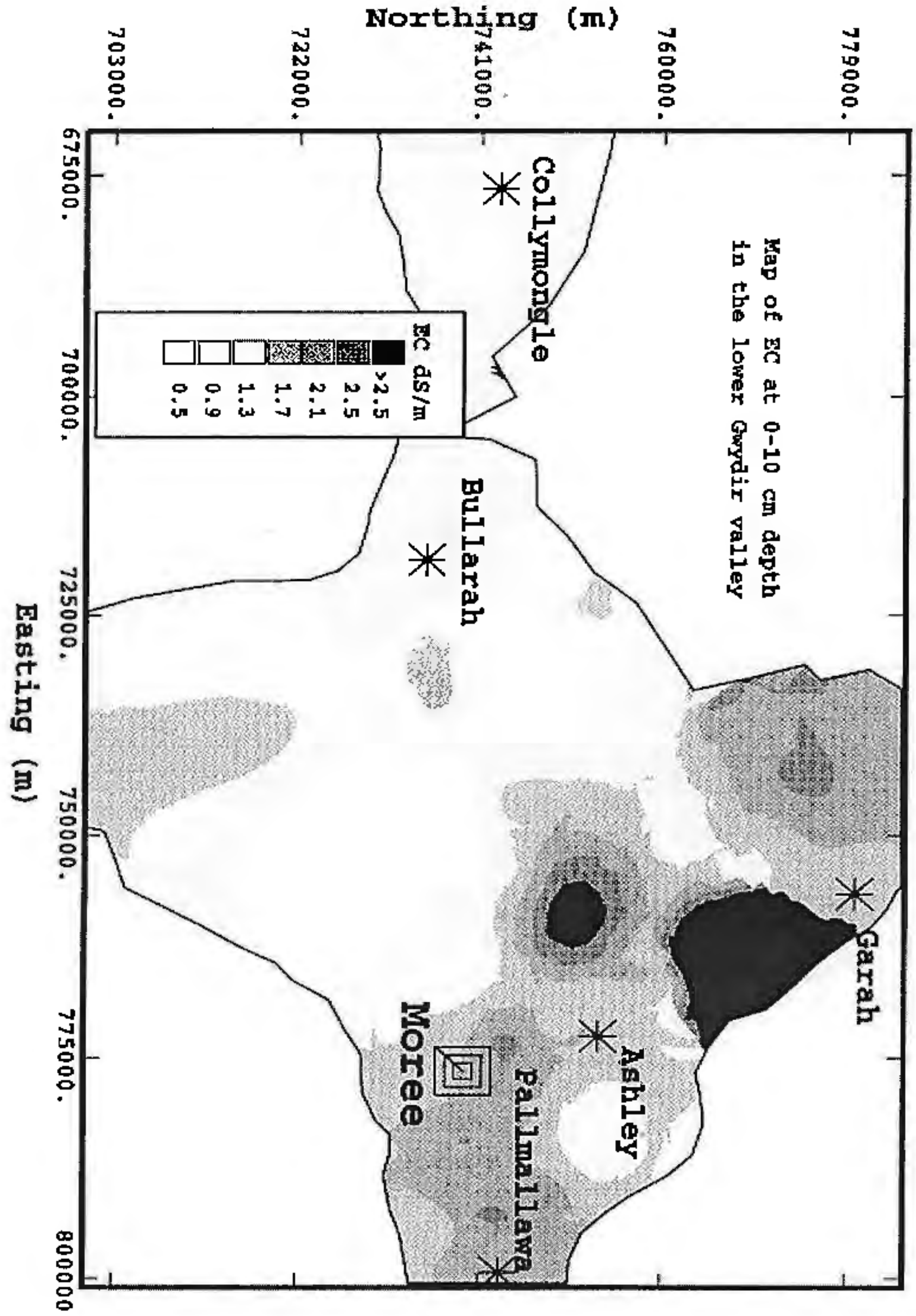
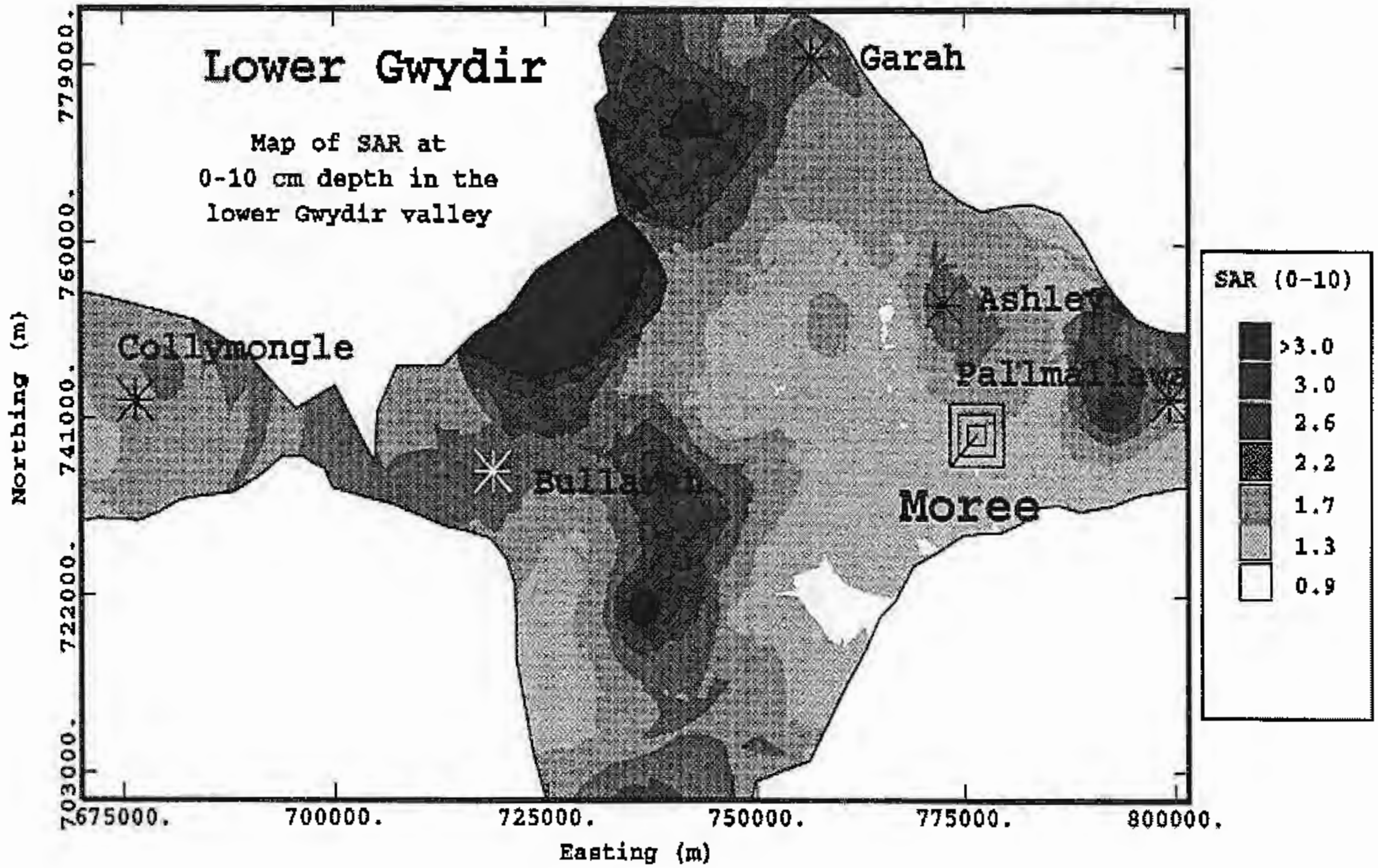


FIGURE 1.



Lower Gwydir
Map of SAR at
0-10 cm depth in the
lower Gwydir valley
Garah
Collymongle
Ashley
Pallmallawa
Moree
SAR (0-10)
>3.0
3.0
2.6
2.2
1.7
1.3
0.9
Northing (m)
703000.
722000.
741000.
760000.
779000.
Easting (m)
675000.
700000.
725000.
750000.
775000.
800000.

FIGURE 2.

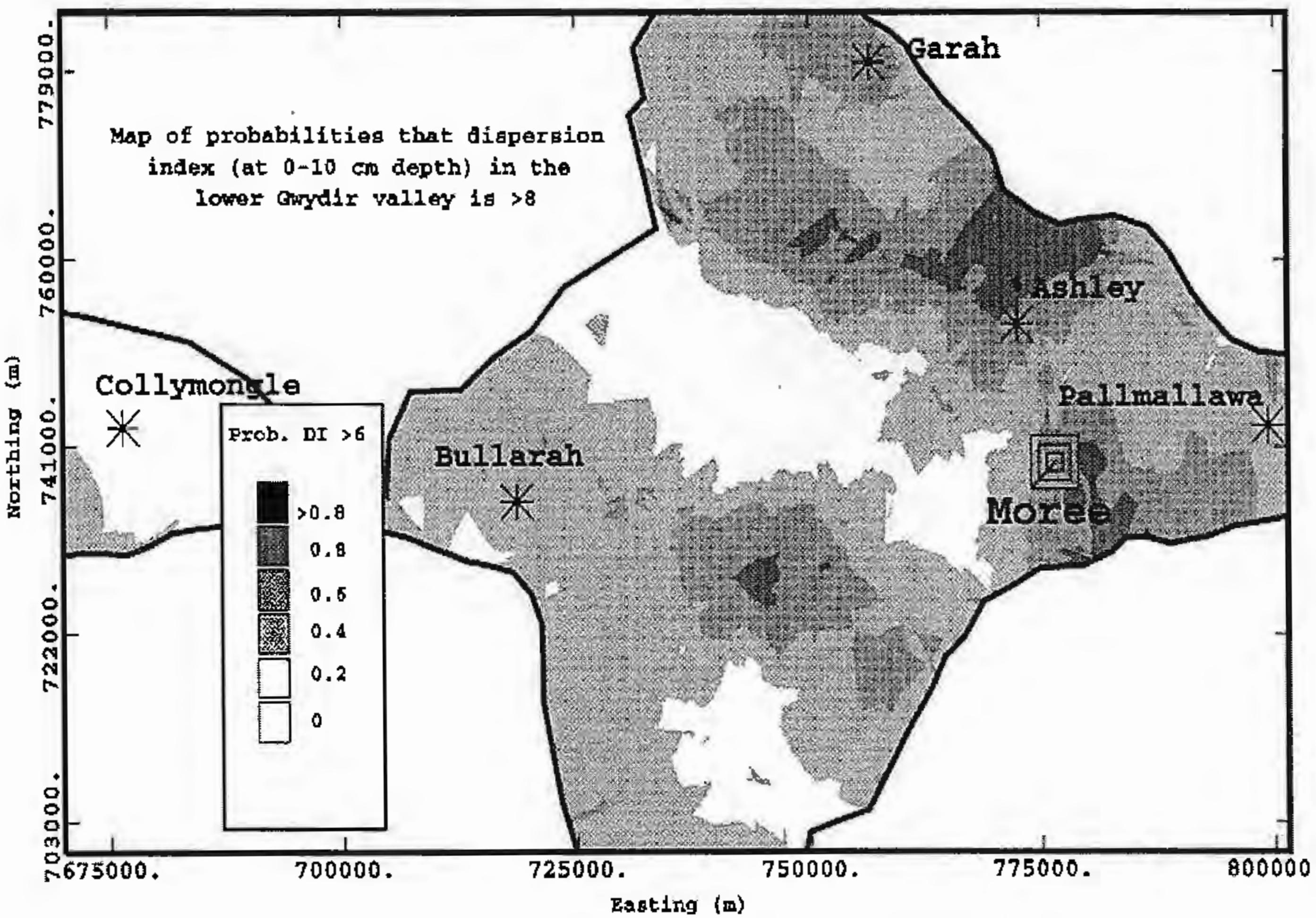
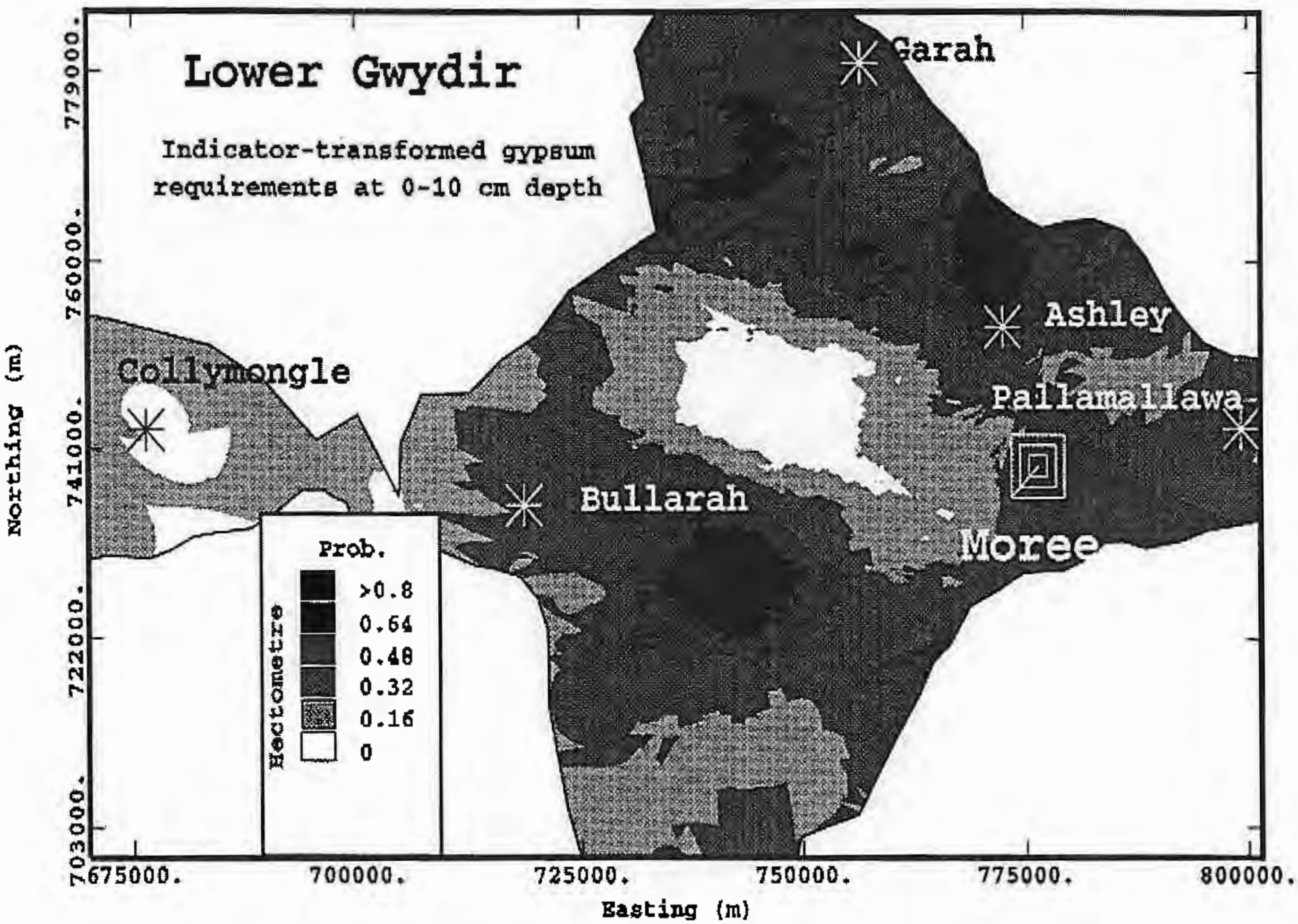

Map of probabilities that dispersion index (at 0-10 cm depth) in the lower Gwydir valley is >8
Prob. DI >6
>0.8
0.8
0.6
0.4
0.2
0
Garah
Ashley
Pallmallawa
Collymongle
Bullarah
Moree
Northing (m)
703000.
722000.
741000.
760000.
779000.
Easting (m)
675000.
700000.
725000.
750000.
775000.
800000.

FIGURE 3.



Lower Gwydir
Indicator-transformed gypsum
requirements at 0-10 cm depth
Garah
Ashley
Collymongle
Pallamallawa
Bullarah
Moree
Prob.
>0.8
0.64
0.48
0.32
0.16
0
Hectometre
Northing (m)
703000.
722000.
741000.
760000.
779000.
Easting (m)
675000.
700000.
725000.
750000.
775000.
800000.

FIGURE 4.

Soil Quality Assessment in the Lower MacIntyre Valley NSW

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Abstract: Previous soil quality research (Acton & Gregorich, 1995) has identified a number of chemical, physical and biological attributes which are indicators of soil quality. This study focuses on using soil chemical and physical properties obtained from a baseline study in the lower MacIntyre valley, to determine which properties are critical for soil quality assessment in the irrigated cotton growing regions of northern New South Wales and southern Queensland. The purpose of this paper is to report on preliminary work to develop a model that could quantify the various attributes of soil quality and from it, derive one or more indexes for simulation and prediction. The use of such a model, especially the determination of interaction and weighting of these indicators, will provide valuable information for the long-term sustainable management of irrigated cotton soil in the valley.

Introduction

Soil quality is seen as a composite measure of both a soil's ability to function and how well it functions, relative to a specific use (Gregorich et al., 1994). It follows that the quality of any soil depends in part on the soils natural or inherent composition (inherent soil quality), soil formation factors (parent material, topography, climate) and also changes related to human use and management (dynamic soil quality) (Gregorich et al., 1994). Formally, soil quality may be defined as: 'the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health' (Doran & Parkin, 1994).

Deriving a Soil Quality Index

Although 'soil quality' may be defined, a set of basic indicators of soil quality have not been previously specified largely due to the difficulty in defining and identifying what soil quality represents and how it can be measured (Doran & Parkin 1994). This is further complicated by the ability to express individual attributes and the relationship they have to each other in a meaningful way. A mathematical relationship or model that could quantify the various attributes of soil quality and from it, derive one or more indexes for simulation and prediction, could provide valuable information for the long-term sustainable management of irrigated cotton soil in the valley. Parr and others (1992) have broadly expressed this relationship as follows:

$$SQI = f(BD, SP, MI, EF, PP, FQ, H, ER) \quad (1)$$

where S	QI = Soil Quality Index	BD = Biodiversity	SP = Soil Properties
	MI = Management Inputs	EF = Environmental Factors	
	PP = Potential Productivity	FQ = Food Quality/Safety	
	H = Health (animal/human)	E = Erodibility	

This model is slightly modified to more closely represent Doran and Parkin's (1994) definition and clarify some of the attributes. For example, 'soil properties' may be better described as pedodiversity and erodibility, along with other degradation processes, will be included within many of the other broad groupings. Equation (1) becomes:

$$SQI = f(BD, PD, M, EQ, PP, FQ, H) \quad (2)$$

where	BD = Biodiversity	PD = Pedodiversity
	M = Management	EQ = Environmental Quality
	PP = Potential Productivity	FQ = Food & Fibre Quality/Safety
	H = Health (animal/human)	

Figure 1 shows the relationship between each element. This paper deals with resolving the portion of the index in terms of physical and chemical soil properties (pedodiversity), and how they influence and are influenced by, management inputs and environmental quality.

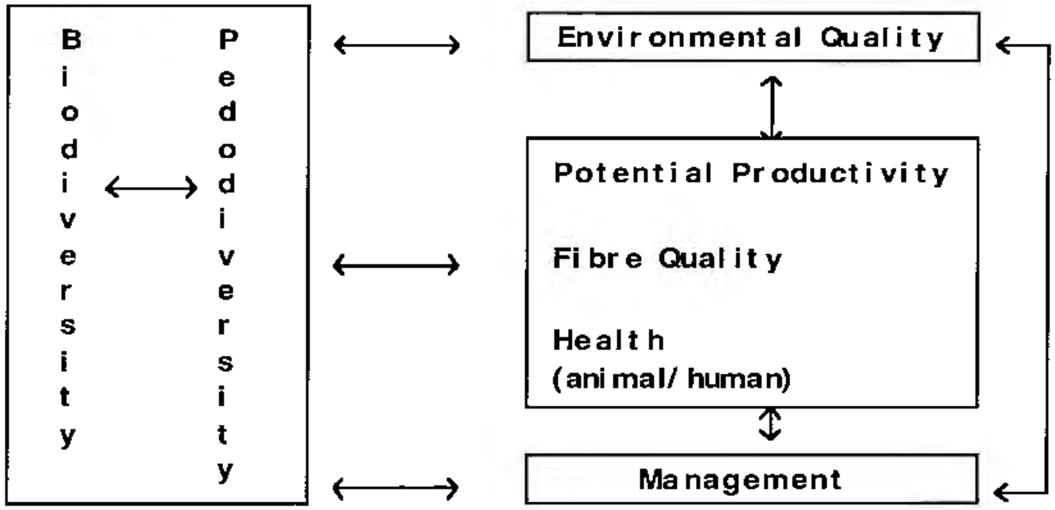

FIGURE 1 Components and relationships of a Soil Quality Index (SQI) after Parr al., 1992.

Resolving a SQI for the lower MacIntyre valley

Previous soil quality research (Acton & Gregorich, 1995: Gregorich et al., 1994; Doran et al., in press) has focused on the pedodiversity/biodiversity/management and productivity ends of Parr and others (1992) model. The aim is to establish a minimum data-set of chemical, physical and biological attributes which are indicators of soil quality. The limitation of the minimum data-set approach is indicator selection for one area may not be as appropriate for other areas. Lists of suitable indicators also run the risk of neglecting what they are attempting to measure - the impact of (in this case) agriculture on soil properties. The impact on these properties is as much a factor of the individual property as how a particular activity will affect the soil processes which determine a soil property. To overcome this, the choice of attributes for study in this paper was determined by dominant processes affecting cotton production in the lower MacIntyre valley. By focusing on processes, the work derives a limited SQI from selected physio-chemical components of the soil. The index is expressed as follows:

SQI = f(Sa, Sd, Ssd, Ns) (3)

where Sa = Salinisation
Sd = Sodification
Ssd = Soil Structural Decline
Ns = Nutrient Supply

and Sa = f(ECe, Leaching fraction, Permeability, Ground water quality, Ground water depth)
Sd = f(ESP, SAR, pH, Clay)
Ssd = f(OC, N. C:N, Texture, Bulk density, Salinity/Sodicity)
Ns = f(OC, N, C:N, CEC, TEB, Texture, Clay mineralogy)

At each stage the attribute is quantified and expert knowledge is used to derive threshold (optimum) values. In this case the study utilised the data collected for the baseline survey of the lower MacIntyre valley. Actual (measured) values are then differentiated from threshold values. This could be expressed in several ways, for example:

$$SQI_p = \min(TH_j - AC_j); 1 \leq j \leq p \quad (4)$$

$$SQI_p = \mathrm{mean}(TH_j - AC_j); \quad 1 \leq j \leq p \quad (5)$$

$$SQI_p = \prod_{j=1}^{p} TH_j - AC_j \quad (6)$$

where SQI_p = Soil Quality Index for each attribute p
TH_j = Threshold values
AC_j = Actual values

To solve equation (3) the steps described above are repeated for each attribute in each part of the equation, then a cumulative SQI for valley under present conditions is developed using rules describing the interaction between each attribute. For instance IF Sa is >x AND Sd is < x THEN Ssd is y ELSE Ssd is z, and so on.

Conclusions

The study describes a simplified soil quality index which focuses on the physio-chemical attributes involved in four soil processes: salinisation, sodification, soil structural decline and nutrient supply. The purpose of deriving an index is to identify the underlying causes of the estimated SQI for the valley. Is the estimated SQI explained by land use, management practice, and/or natural variation (geology/climate)? Once we can go some way to explain the reasons for some of the variability we see within the valley, we can identify problem areas and potential problem areas both for production and environmental protection. By considering the original sampled sites as 'reference' sites, we can also use the index to monitor the long-term changes in the valley. However, in order to truly asses soil 'quality' within the irrigated cotton growing areas, all the components of Parr and others (1992) model must be included. This means the simple model and rules developed here would be expanded to incorporate the results of other industry based research projects on biodiversity, pedodiversity, environmental quality, productivity and management inputs.

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Surface–active fauna in irrigated cotton managed with Envirofeast® at ACRI

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Abstract

Main trends for surface–active fauna sampled using pitfall traps during the 1995–96 season in unsprayed irrigated cotton managed with Envirofeast® at the Australian Cotton Research Institute (ACRI) are presented. Block 16 has been a demonstration field for Envirofeast® IPM for the last three consecutive growing seasons, and aspects of the field design and location that may have influenced populations of surface–active predators are outlined.

Predacious ants belonging to the *Iridomyrmex vicinus* group were the dominant species collected in the cotton, especially during stages I and II. Catches of these morpho–species were highly significant in comparison to all other field sites sampled, which perhaps suggests that the combined effects of insecticides and cultivation are the principal factors causing their mortality in irrigated cotton fields. Workers of this group were also frequently observed foraging in the tops of the cotton canopy during stages II and III. The lucerne strips proved to be a very favourable refuge for another predacious ant species, *Rhytidoponera metallica*. This species appears to be very sensitive to waterlogging, and with the heavy rains in late December–early January and over generous 14 day irrigation interval in stages II and III, workers were rarely cited foraging in the cotton. Ant species diversity and surface–activity in block 16 was at least equal (often greater) to that observed in first season, unsprayed plots at Doreen and significantly greater than all other conventional cotton fields sampled during this project.

Catches of the beneficial predacious earwig, *Labidura truncata*, in the cotton of block 16 were the most numerous of all cotton fields sampled during the last three growing seasons. This species was rarely caught in the lucerne strips and burrows located in the centre of the raised beds during stages II and III commonly contained females with large numbers of young. Surface–active beetles with a reported predatory feeding habit were rare throughout the growing season in both the cotton and lucerne. The principal factors thought to have contributed to these very small catches were: (1) the very small size of the cotton plots and lucerne strips, (2) the poor surface–cover provided in the cotton plots by three years of consecutive cotton–winter fallow, and (3) the close proximity of this field to adjoining insecticide field trials and commercially sprayed cotton. Catches of total spiders were particularly promising in the lucerne strips, and further research on this predator group is recommended. Springtail species diversity in the cotton was the greatest of all cotton fields sampled, and this may best explained by the three year absence of any conventional insecticides.

Checklists of species and their associated feeding habits or functional groups for block 16 are given for ants, earwigs, beetles, and springtails. It was concluded that block 16 for the 1995–96 season was not a suitable field to properly assess the effectiveness of lucerne strips and the Envirofeast® food spray in promoting populations of surface–active predators.

Introduction

Increased community pressure to decrease the use of synthetic insecticides and increasing resistance in *Helicoverpa armigera* to most of the key insecticide groups is placing greater emphasis on the development of true IPM systems. One recently–developed technology that endeavours to assist in the development of IPM is the exploitation of beneficial canopy predators and parasites using Envirofeast® technology (use of lucerne strips for conservation of beneficials, regular application of Envirofeast® food spray, and determination of predator / prey ratios). Considerable interest has been generated in this new IPM technology. In this five minute talk, I plan to present a brief overview of the preliminary results (first available dataset) for soil predators collected in unsprayed cotton managed with Envirofeast® during the 1995–96 season at the Australian Cotton Research Institute (ACRI).

Materials and Methods
Fieldwork during the 1995–96 season was conducted in a small demonstration field of approximately 1.03 ha in size (block 16) at the ACRI, which is located approximately 30 km west of Narrabri (30°13'S, 149°47'E). For a third consecutive season, cotton was planted into 1 m beds at a seeding rate of 15 kg / ha, fertilised with 120 N kg / ha in the form of anhydrous ammonia, and managed with the aid of regular applications of Envirofeast®. Strips of lucerne (4 rows wide) had also been growing (between cotton plots) continuously for approximately three years, and during each growing season, 2 rows were slashed every 4 weeks to keep the foliage young and lush. Minimum tillage had been practised during the three years, and no within–season herbicide was applied during the 1995–96 season. It was not however, possible to guarantee adequate protection from the occurrence of insecticide drift, because a commercially owned cotton field, located within 200 m of the western side of block 16, was conventionally sprayed by aircraft throughout the 1995–96 growing season. In addition, field plots involving intensive insecticide field trials (insecticides generally applied with ground–rig) for spider mites were also being conducted across the main road on the southern side of block 16.

A total of 16 pitfall traps were installed during late November and ten 3–day trapping periods were conducted during the months of December, January and February of the 1995–96 growing season (see fig. 1).

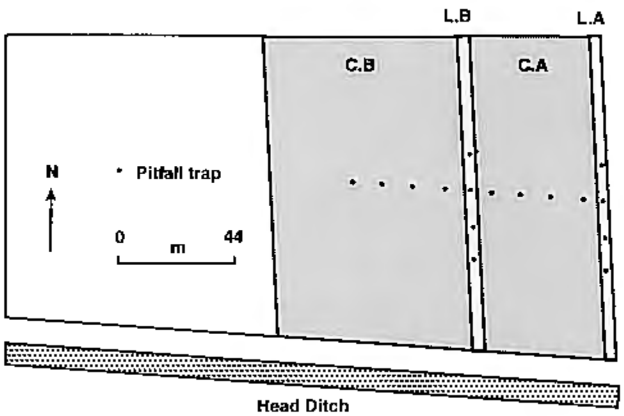

FIGURE 1: Field plan of block 16 at the ACRI for the 1995–96 season

Results and discussion
ANTS
A total of fourteen morpho–species, representing 4 subfamilies and 5 genera, were collected in block 16 during the 1995–96 season (see table 1). Ants belonging to the *Iridomyrmex vicinus* group were both the most observed and frequently caught ant species in pitfall traps in the two cotton plots (see fig. 2). These ant species have been observed by the author and others (Murray, person. comm.) to be particularly active during stage I on small cotton seedlings (up to 6 node stage), and were often observed during stages II and III to be actively searching in the tops of the cotton canopy (cotton rows located towards the tail drain end and adjacent to the lucerne strips), especially during the later afternoon hours. Because the catches of *Iridomyrmex vicinus* group spp. collected in block 16 far exceeded those from any other field site sampled during this three year baseline study, it is likely that insecticides and cultivation have greater detrimental effects on the abundance and survival of these morpho–ant species in cotton fields than irrigation.

Throughout the growing season, exceptionally large catches of *Rhytidoponera metallica* sp. were collected in the lucerne plots, whilst the catches collected in the cotton were significantly less (see table 1). *Rhytidoponera metallica* sp was observed to be very sensitive to waterlogging at the 1995–96 Namoi valley Bt field trial ('Doreen'), and generally appears to be less common in fields with at least a moderate history of conventional, irrigated cotton. In first season, unsprayed plots at Doreen, this species was the most frequently caught in well–drained areas but completely absent for the whole season where prolonged waterlogging had occurred during watering–up. It is therefore likely that *Rhytidoponera metallica* chose to remain in the lucerne (see fig. 2) because of the comparatively less effective drainage that occurred in the cotton plots after the substantial rains received in late December–early January and the over generous 14 day irrigation interval used towards the end of stage II and during stage III.

TABLE 1: Ant species and their functional groups collected in pitfall traps in block 16 at ACRI (total means for season ± SEM; relative percentage given in brackets)

Functional group	Sub–family	Taxa	Morpho–species (Rel. abundance)		
			Cotton	Lucerne	Total
Dominant Dolicherinae	Dolicherinae	*Iridomyrmex vicinus* group spp.**	4 (**48.9**)	5 (16.6)	5
Subordinate Camponotinae	Formicinae	*Camponotus consobrinus* sp.	1 (<1)	0	1
Cryptic species	Myrmicinae	*Solenopsis* sp.	1 (<1)	0	1
Opportunists	Ponerinae	*Rhytidoponera metallica* sp.**	1 (9.34)	1 (**57.0**)	1
Generalised Myrmicines	Myrmicinae	*Pheidole* spp.	5 (**41.2**)	4 (**26.4**)	6
	TOTAL morpho–species		12	10	14
	Total Dominant Dolicherinae / trap / day		1.7±.34	0.6±.25	
	Total *Rhytidoponera metallica* / trap / day		.24±.06	2.05±.21	
	Total Generalised Myrmicines / trap / day		1.4±.19	.95±.47	
	MEAN PREDATOR ants / trap / day for SEASON		1.92±.34	2.65±.30	

** ant species likely to have greatest impact on cotton insect pests

Large catches (> 2 / trap / day) of *Pheidole* ants (see generalised myrmicines in table 1) were also observed in both the cotton and lucerne plots during stage I and cotton only during stage II. In African cotton, *Pheidole* ant spp. have been reported as predators of *Helicoverpa* spp. larvae (see Reed, 1965), and Room (1979) also assumed that *Pheidole* spp. served as predators of *Helicoverpa* spp. eggs and larvae in Namoi valley cotton crops. In grassland habitats of NSW, *Pheidole* spp. are however generally reknown for their seed harvesting activities, and so the author has opted to temporally exclude this group of ants from those species classified with a predatory feeding habit until further feeding and observational studies in cotton are conducted.

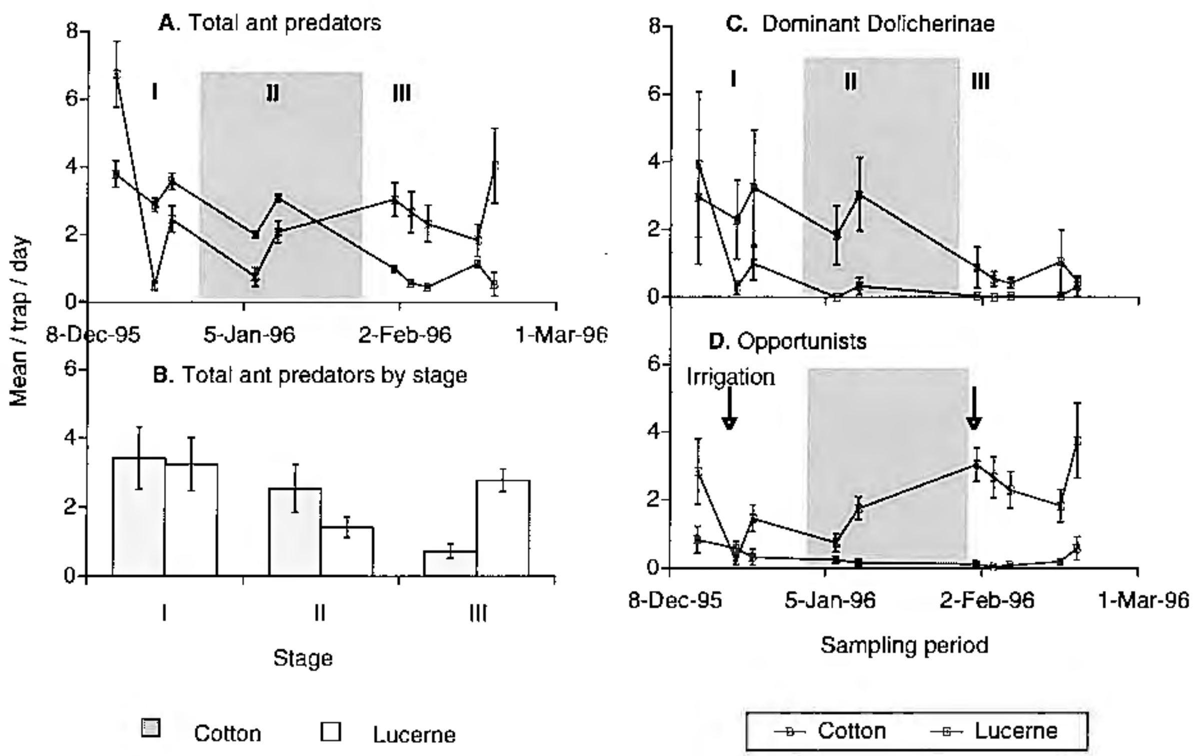

FIGURE 2: 1995–96 seasonal abundance of predatory ants collected in pitfalls from irrigated cotton managed with Envirofeast® at the ACRI

EARWIGS

The two earwig species, *Labidura truncata* (common brown earwig) and *Nala lividipes* (black field earwig), commonly found in NSW and QLD cotton fields, were both collected in pitfall traps operated in block 16 during the 1995–96 season. Catches of *Labidura truncata* collected in the cotton plots during stage I (see fig. 3), were the most numerous of all field sites sampled during this three year study. *Labidura truncata* is a cosmopolitan beneficial earwig species that prefers to inhabit cultivated row crops that (i) are frequently irrigated, (ii) are often inhabited by lepidopterous and wireworm larvae, (iii) have reduced natural enemy populations, and (iv) have been in production for some years. This species was uncommon in pitfall catches collected in the lucerne, and burrows located in the centre of the raised beds during stages II and III commonly contained females with large numbers of young. In Australian field crops, *Labidura truncata* has been reported to consume the following insect pests of cotton: *Helicoverpa* spp. larvae and pupae (Room, 1979; Donaldson & Ironside, 1982), false wireworms (Donaldson & Ironside, 1982), cutworms, armyworms and aphids (Allsopp & Lloyd, 1982).

TABLE 2: Pitfall trap catches of earwigs in block 16 at ACRI (total catch means for season ± SEM; relative percentage given in brackets)

Feeding habit	Family Sub-family	Taxa	Mean catch / trap / day (Rel. abundance)	
			Cotton	Lucerne
	Labiduridae			
Beneficial predator	Labidurinae	*Labidura truncata*	1.0 ± .11 (**68.1**)	0.05 ± .02 (21.15)
Scavenger–pest–predator	Nalíinae	*Nala lividipes*	0.10 ± .02 (7.1)	0.16 ± .03 (73.1)
		Indet. immatures	0.37 ± .07 (5.8)	0.01 ± .01 (24.9)

Nala lividipes has a smaller body size and at night is particularly active on the wing and attracted to lights. Catches of this species in pitfall traps during the 1995–96 season were very small and it is possible that significantly greater catches may have been collected had light traps been used. *Nala lividipes* is thought to have varied feeding habits in field crops, with reports of it acting either as a (i) scavenger feeding on decaying organic matter; (ii) plant feeder consuming germinating seeds, seedling stems below and above the ground or adventitious roots of maize or sorghum (Simpson, 1989); or (iii) a facultative predator of hemipteran and lepidopteran insect pests (Situmorang and Gabriel, 1988a & b; Kapuge et al., 1987; De Barro, 1990). Whilst the majority of literature published on this earwig species in Australian arable field crops during the 1970's and 1980's reported its role as either a serious or occasional pest, the finding that *Nala lividipes* feeds voraciously on eggs and larvae of the corn borer, *Ostrinia furnacalis*, and some other major corn insect pests (including *Helicoverpa armigera* larvae and pupae) (Situmorang and Gabriel, 1988a) deserves recognition. Since Simpson and Robertson (1993) also found that *Nala lividipes* failed to survive on germinated cotton seedlings, the author has tentatively considered this species as a generalist predator in irrigated cotton (at least after crop establishment in stage I, and throughout stages II and III) until further feeding and observational studies are conducted.

BEETLES

Relative abundance (see fig. 4) and diversity (< 15 % of the total species identified in irrigated cotton collected; see table 3) of surface–active beetles were particularly disappointing in both the cotton plots and lucerne strips throughout the season in block 16. For stage I in the cotton plots, a single scavenger beetle species, *Anthicus australis*, accounted for 80 % of the total beetle catch. Surface–active beetles with a 'reported' generalist predator feeding habit never exceeded a daily catch per trap of 0.4 (see fig. 4), and so the potential predatory activity contributed by these beetles was likely to be very minimal. A total of only five generalist ground beetle predators were collected in the cotton, all of which were rare, and individually constituted less than 5 % of the total seasonal catch for beetles collected in the cotton. *Chlaenius australis* (Carabid: 16 mm) was the only generalist predator collected in the cotton with a body length greater than 5 mm, whilst only a further two species, *Geoscaptus laevissimus* (Carabid: 25 mm) and *Threocephalus* sp. (Staphylinid: 14 mm), of this body length class were collected in the lucerne plots. 92 % and 63 % of the total seasonal catches of surface–active beetles collected in the cotton and lucerne, respectively, had a body length less than 5 mm. The potentially important Carabid beetle, *Calosoma schayeri*, was completely absent from all pitfall catches collected in block 16, and this may, in part, be due to the virtual absence of *Helicoverpa* spp. larvae and the occurrence of insecticide drift from the adjoining commercially owned cotton field.

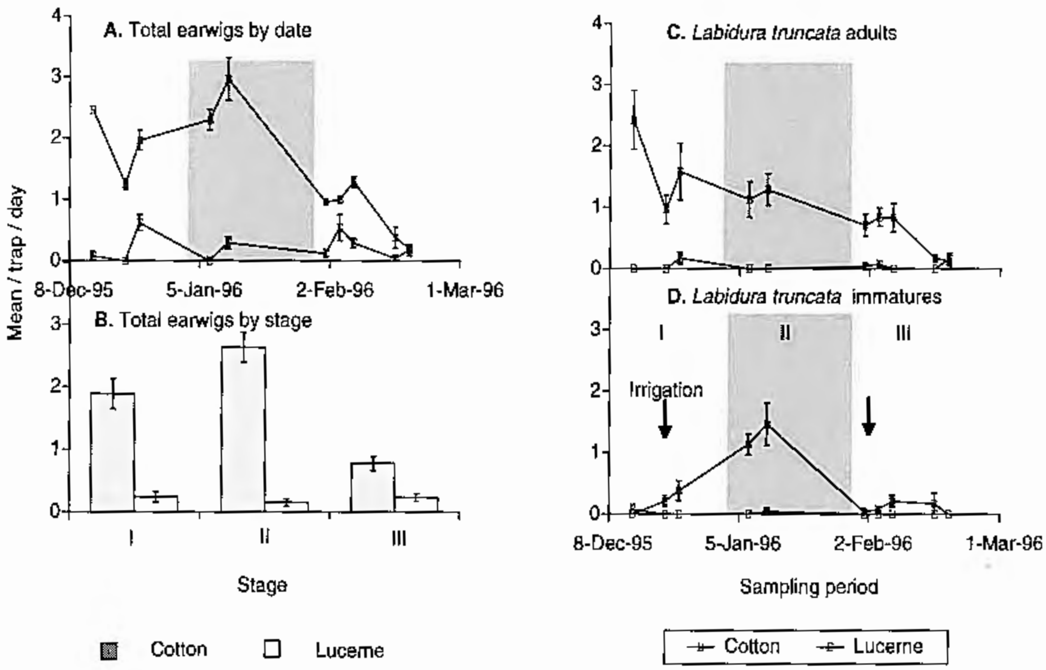

FIGURE 3: 1995–96 seasonal abundance of earwigs collected in pitfalls from irrigated cotton managed with Envirofeast® at the ACRI

Catches of adult Elaterid beetles (*Agrypnus variabilis*) were significantly greater in the lucerne plots, but on a per trap per day abundance they were not likely to be of any consequence. Because of the very small size of block 16 and its close proximity to aerial insecticide spraying regimes it is difficult to draw any genuine conclusions from these 1995–96 data on the effectiveness of lucerne strips and/or Envirofeast® in promoting populations of beneficial surface-active predacious beetles (principally Carabids and Staphylinids). The seasons data does, however, highlight the likely sensitivity of this natural enemy group to conventional insecticides applied to neighbouring fields and potential importance of habitat manipulation for the conservation of beneficial predators. The practice of consecutive cotton with a autumn–winter fallow is a further factor that may also do little to encourage and maintain populations of predacious surface-active ground beetles.

TABLE 3: Feeding habits of adult surface–active beetles collected in pitfall traps in block 16 at ACRI (species listed were > 1 % of total seasonal catch for ground beetles; relative percentage given in brackets; & total means for season ± SEM).

Feeding habit	Family / Sub–family or tribe	Genera–Species	Species (Rel. abundance) Cotton	Luceme	Total
Generalist predators	Carabidae				
	Callistini	*Chlaenius australis*	1 (1.3)	1 (4.1)	1
	Lebiini	*Microlestodes macleayi*	1 (1.3)	0	1
	Scaritini	*Geoscaptus laevissimus*	0	1 (8.2)	1
	Staphylinidae				
	Aleocharinae	Unidentified sp.	0	1 (2.1)	1
	Paederinae	*Astenus* sp.	1 (1.3)	0	1
		Scopaeus sp.	0	1 (2.1)	1
	Staphylininae	*Philonthus subcingulatus*	1 (1.8)	1 (2.7)	1
		Quedius sp.	0	1 (4.1)	1
		Thyreocephalus sp.	0	1 (2.7)	1
		Zeteotomus sp.	1 (1.8)	1 (2.1)	1
	MEAN Generalist Predators / trap / day for SEASON		0.12±.02	0.18±.03	
Scavengers	Anthicidae				
	Anthicinae	*Anthicus australis*	1 **(49.3)**	1 (2.05)	1
		Anthicus hesperi	0	1 (2.1)	1
	Tenebrionidae				
	Opatrini	*Mesomorphus* sp.	0	1 (1.4)	1
	MEAN scavengers / trap / day for SEASON		0.5±.10	.05±.02	
Fungivores	Corylophidae				
	Parmulinae	Unidentified sp.	0	1 (3.4)	
	Sericoderinae	*Sericoderus* sp.	1 **(9.2)**	1 **(15.1)**	1
	Lathridiidae				
	Corticariinae	*Corticaria japonica*	0	1 (2.7)	1
	Languriidae				
	Cryptophilinae	*Cryptophilus integer*	1 (7.0)	1 (2.7)	1
	Staphylinidae				
	Tachyporinae	*Sepidophilus* sp.	1 **(11.8)**	1 **(13.0)**	1
	MEAN Fungivores / trap / day for SEASON		.28±.05	.24±.04	
Saprophages	Staphylinidae				
	Oxytelinae	*Anotylus* sp.	1 (1.3)	2 (4.79)	2
	MEAN Saprophages / trap / day for SEASON		.023±.01	.023±.01	
Phytophages in soil	Elateridae				
	Agrypininae	*Agrypnus variabilis*	0	1 **(17.1)**	1
	MEAN Phytophages / trap / day for SEASON		0.02±.01	0.10±.02	
	TOTAL SPECIES (> 1% of total catch)		10	19	**20**
	MEAN BEETLES / TRAP / DAY for SEASON		0.95±.1	0.61±.1	

SPIDERS

Whilst time did not allow for spiders to be identified to the taxonomic levels of family–genera–species, the catches of total spiders collected throughout the growing season in the lucerne strips were potentially significant (see fig. 5). The significance of lucerne strips as a refuge for spiders deserves further research, especially in terms of obtaining seasonal estimates of their population densities in the lucerne and corresponding dispersal into adjoining irrigated cotton. Much taxonomic and ecological work is also required on spiders in Australian cotton, since their potential impact on pest species has received limited attention in the past (Room, 1979; Bishop, 1980 & 1981; Bishop & Blood, 1981). At the 1995–96 Bt field trial conducted at Doreen, spiders were an abundant group of soil surface predators that were observed to be significantly more numerous in unsprayed fields during stage III.

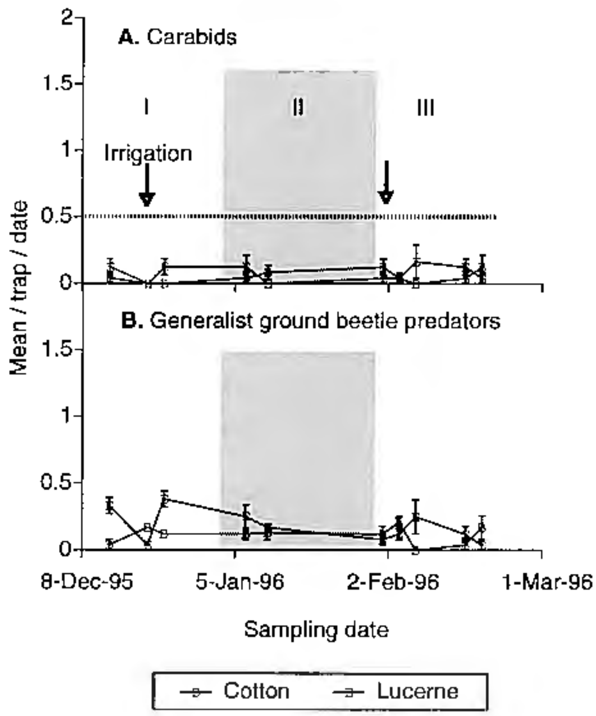

FIGURE 4: 1995–96 seasonal abundance of predatory ground beetles collected in pitfalls from irrigated cotton managed with Envirofeast® at the ACRI

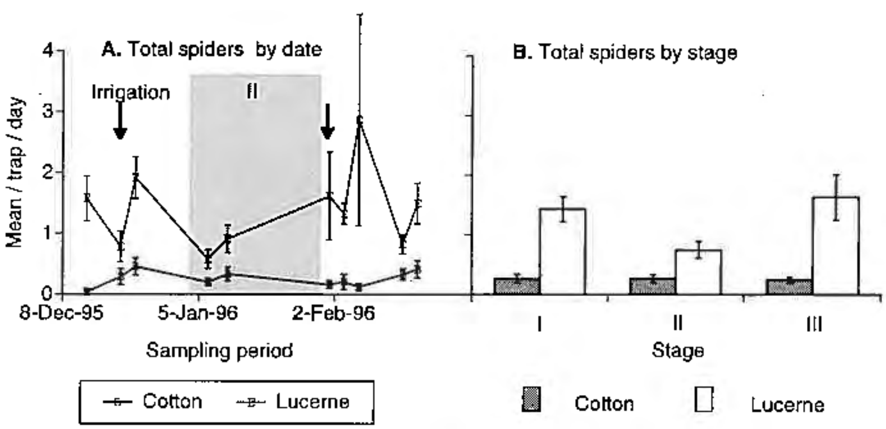

FIGURE 5: 1995–96 seasonal abundance of total spiders collected in pitfalls from irrigated cotton managed with Envirofeast® at the ACRI

SPRINGTAILS

Springtail species diversity in block 16 was the greatest of all field sites (several new species recorded) sampled during this baseline research project, and a checklist of the more common species identified during the 1995–96 season is given in table 4. Daily catches of springtails in the cotton throughout the season were however, generally less than those observed at other field sites. This may, in part, reflect the scarcity of available organic residues typical of consecutive cotton fields and the significant abundances of predatory ants and earwigs. Springtail species belonging to the 'hemiedaphic fungal feeders & saprophages' functional group clearly dominated the pitfall catches in the cotton plots, and this was predominantly due to the presence of a single species, *Proisotoma minuta*.

TABLE 4: Feeding habits of springtails collected in pitfall traps in block 16 at ACRI (species listed were > 1 % of total seasonal catch for springtails; relative percentage is given in brackets; & total means for season ± SEM)

Functional group	Taxon	Genera–Species	Species (Rel. abundance)		
			Cotton	Lucerne	Total
Hemiedaphic predators of nematodes & bacteria	Brachystomellidae				
	Brachystomella	*Brachystomella platensis*	1 (5.2)	1 (11.1)	1
Hemiedaphic fungal feeders & saprophages	Isotomidae				
	Cryptopygus	*Cryptophygus thermophilus*	1 (1.9)	0	1
	Proisotoma	*Proistoma minuta*	1 (**49.0**)	0	1
	Entomobryidae				
	Lepidocyrtus	*Lepidocyrtus (Ascocyrtus) kukea*	1 (1.3)	0	1
	Sminthuridae				
	Sphaeridia	*Sphaeridia boettgeri*	1 (1.5)	1 (**45.6**)	1
Euedaphic fungal feeders & saprophages	Isotomidae				
	Folsomides	*Folsomides parvulus*	1 (5.3)	1 (2.3)	1
Epigaeic phytophages	Entomobryidae				
	Lepidobrya	*Lepidobrya* sp.	1 (**17.7**)	0	1
	Sminthuridae				
	Fasciosminthurus	*Fasciosminthurus* sp.	1 (2.4)	1 (**29.7**)	1
Hemiedaphic external digesters	Neanuridae				
	Pseudachorutes	*Pseudachorutes* sp. cf. *longisetis*	1 (3.27)	1 (6.9)	1
	TOTAL SPECIES (> 1 %)		9	5	9
	MEAN COLLEMBOLA / TRAP / DAY for SEASON		3.4± 0.7	45.4± 8.1	

EARTHWORMS

Two earthworm species that have not previously been observed by the author in cotton fields, were observed in passing in the cotton plots of block 16 during the 1995–96 season. The first species, *Aporrectodea rosea* (also called *Eisenia rosea*), is an exotic species found in Australia that has a worldwide distribution and has been recorded to survive in other cultivated field crops. Trails of the second species were commonly observed in the moist furrows the day after a irrigation or heavy rainfall event, and so it was assumed that this large native earthworm (approx. 150 mm long) crawled along the above–ground surface of the furrows during the night. The exact identification of this species is yet to be confirmed, but it may be *Heteroprodrilus mediterreus* (myall worm) or *Perionyx excavatus* (big blue worm).

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Use of high MW polyacrylamides (PAM) as soil conditioner in fnrrow irrigated cotton fields - effectiveness and breakdown

Anne Refsgaard

Slaking and dispersion associated with furrow irrigation may lead to soil erosion, surface sealing and reduced infiltration. The aim of this project is to find out whether the use of high molecular weight polyacrylamide (PAM) application in irrigation water can reduce the effects of slaking and dispersion by improving soil structure. PAM shows ability to hold soil particles together in sandy soils (Zhang & Miller, 1996; Malik & Letey, 1991) but little is known about its efficacy in clayey soils. Soil from the CRC Farming Systems Experiments near Warren and Narrabri have been sampled and will be tested for soil strength and infiltration rate with and without PAM and other soil conditioners e.g. gypsum.

Experiments have shown the need for application of PAM in every irrigation to maintain the effect (McCutchan et al., 1993; Malik et al., 1991; Zhang & Miller, 1996; Levy et al., 1992), probably because of a high breakdown rate of the PAM molecule. In this project the breakdown rate is measured in a simple viscosity test of two PAM solutions, one covered and one exposed to daylight. The exposed solution lost most of its viscosity after a week while the unexposed was almost unaffected suggesting that photo-oxidation is an important and rapid process. The breakdown products is being determined by electrophoresis and gel chromatography. Further research should be done on PAM before commercial use in the soil. Hopefully the results from this project will delineate the effectiveness of PAM as a soil conditioner.

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Aggregation of particles in Vertisols

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Aggregates are the results of the soil constituents being grouped together through some interactions and therefore show responses in accordance with these interactions. Aggregation in cropped soil controls various properties such as water infiltration, aeration, drainage and crop establishment. Crop performance depends on the presence of aggregates of soil particles that have an integrity which enables them to remain stable when wetted. For irrigated cotton using raised beds (especially those using poor water quality) this instability may lead to poor seedling vigour, loss of nitrogen and poor efficient use of water. For dryland cotton without raised beds, structural instability may cause seedling death or poor vigour due to crusting and/or waterlogging and poor water storage efficiency. Thus a description of aggregation of particles is fundamental to the concept of structure for the growing of cotton.

The description of the interactions between soil particles has resulted in the development of the concepts and models which describe a hierarchical system of aggregation, which has defined the boundary between macroaggregates and microaggregates (Edwards and Bremner, 1967; Tisdall and Oades, 1982; Oades and Waters, 1991). This distinction between macroaggregates and microaggregates has helped in understanding how aggregate hierarchies influence the function and behaviour of the soil. There is no universal classification for the size of aggregated features (Tippkötter, 1994). The boundary between macroaggregates and microaggregates is often arbitrarily defined as size ranges, by the energy used to cause their breakdown, and their associations with bonding agents. The mechanisms involved in microaggregate formation and stability are also unclear. This is especially true for the Vertisols. Thus, to appreciate the interaction between primary particles forming aggregates and its possible implications, research was initiated to: (1) identify suitable separation techniques to prepare microaggregates for morphological study; (2) to describe the nature, size and relationship of microaggregates in a 3 dimensional aspect using Scanning Electron Microscopy (SEM) and (3) to further describe the relationships between microaggregates by their identification in thin section.

Separation Techniques
If a slaked aggregate for the cracking clays used for cotton production is observed using SEM we see evidence of an aggregate hierarchy. These slaked aggregates consist of smaller aggregates. To adequately characterise microaggregates by SEM they must first be liberated from the soil with minimal disruption of their integrity and surface morphology. To accomplish this a suite of separation techniques were examined for their effectiveness for liberating microaggregates. These included: aggregate slaking in water; aggregate slaking in methanol; modified end-over-end shaking; water shaking (shaking table); modified wet sieving and ultrasonic agitation. To prepare the liberated microaggregates for SEM a standard microaggregate separation and washing technique was developed. This is a gentle method developed to prevent the reaggregation and coating of microaggregates with dispersed clay on drying. Observation of microaggregates produced from the separation techniques showed no evidence of dispersed clay coating or reaggregation. The standard microaggregate separation and washing technique was successful in preventing reaggregation and coating of aggregate material on drying. It was found that the aggregate slaking in water and aggregate slaking in methanol did not supply enough energy to liberate the microaggregates. The modified end-over-end shaking, water shaking (shaking table) and modified wet sieving interfered with the surface morphology producing rounded aggregates. The ultrasonic agitation effectively separated the microaggregates with little interference of surface morphology.

Microaggregate Morphology and Relationships, a 3 and 2 Dimensional Interpretation
To describe the nature and size of microaggregates and their relationship in the aggregate hierarchy, a description of the soil fabric is necessary. Thus to fully appreciate the nature of the

microaggregates, initially the fabric units must be described at the sub-microscopic (SEM) level. The clustered microaggregates were approximately 10–50 μm in diameter. Generally they exhibited a spherical morphology although elongated examples were observed. The fracturing of the aggregates by the ultrasonic agitation dislodged a few microaggregates from the surface leaving cavities. Strong orientation of clay around cavities was identified when fracture faces of the aggregates were observed. The size of the cavities appears to match that of the microaggregates described earlier. The strong orientation of the clay suggests that the clay acts as a bridge between the microaggregates and other discrete particles. The 3 dimensional reality is that the aggregates consist of microaggregates 10–50 μm in diameter that are randomly distributed throughout the larger aggregates. These microaggregates are surrounded (coated) with a thin layer of oriented clay.

To further understand the spatial relationship of the microaggregates and their persistence throughout the soil description at the microscopic level (light microscopy) is necessary. At the microscopic level, with the use of thin sections, the nature and size of the microaggregates in Vertisols are not readily determined as no concept exists which allows them to be distinguished within a clay matrix. To develop this concept previous observations at the submicroscopic level will facilitate the conceptualisation of the 2 dimensional image observed in thin section. The development of the conceptual model will be summarised here, a comprehensive description is given in a paper by D. J. Field *et al* (1996) in the proceedings for the 10th International Working Meeting on Soil Micromorphology (Moscow, 1996). If a section was cut through the microaggregates and oriented clay as described earlier the following features would be observed. The strong orientation of the clay coats and their circular (ring) type nature would appear as strongly anisotropic (bright) zones that are continuous and circular in nature. The less well oriented internal nature of the microaggregates would appear as weakly anisotropic (dull) to isotropic (black) areas within the strongly anisotropic circular areas that is the oriented clay. Simplistically, Figure (1) represents the observed features. The shaded areas represent the microaggregates and the concentric rings the oriented clay. These features are observed in thin section, thus a new conceptual model has been developed to identify the microaggregates in thin section.

Implications for cotton production

The research thus far has opened up new possibilities for the measurement and interpretation of the function and behaviour of the Vertisols used for cotton production. The implications discussed here are merely concepts regarding the interpretation of the system and remain to be proven by future work in this project.

The oriented clay, its constituents and spatial relationship with the microaggregates discussed earlier may have important implications regarding the stability of the water–stable aggregates they form. This oriented clay may act as a bridge between the microaggregates holding the system together. Further the oriented clay, if a certain chemical status is meet (eg. highly sodic), may also act as planes of weakness which may result in the breakdown of the water–stable aggregate.

The identification of the coating clay and spatial relationship of the microaggregates has important implications for developing concepts to explain the diffusion of solutes in the cracking clays. This relates to the change in chemical status of the oriented clay that may affect the stability of the water–stable aggregate. Consider figure (1), the arrows represent the pathways that may be used by solutes (eg. Ca^{2+}, Na^{+}) as they diffuse through the water–stable aggregate. The varying thickness of the arrows represent the differences in rates of diffusion that may be encountered. It is safe to assume that the potential for exchange of solutes on the surface for water stable aggregates is quite high. It also appears logical that the strongly oriented clay would influence the flow paths for solutes into the water–stable aggregate, and from these flow paths the possible entry of solutes into the microaggregates. The limiting step for exchange and spatial distribution of solutes within the water–stable aggregate is the distribution and interconnection of oriented clay within the water-stable aggregate and the rate of diffusion along the oriented clay and possibly into the microaggregates.

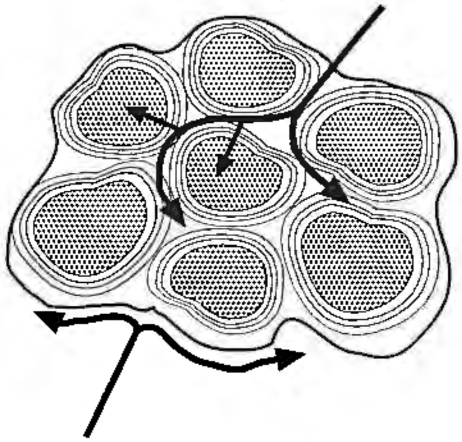

FIGURE 1: Schematic of a water–stable aggregate containing microaggregates (shaded areas) and strongly oriented clay (concentric rings). The arrows indicate the possible pathways for diffusion of solutes into and through the aggregate.

This has implications for the short and long term management of the system. The question can be raised, are growers managing the whole water–stable aggregate or just the oriented clay through additions of ameliorants. Work by David McKenzie (formerly of NSW Agriculture) indicated that when gypsum and lime were added to ameliorate an irrigated grey soil, gypsum improved structural stability much more quickly than ground limestone (lime). However, after about 3 years the lime proved to be more beneficial than gypsum. The gypsum, which remains moderately soluble as pH increases, increased the electrolyte concentration and replaced exchangeable sodium with calcium. The high solubility though apparently resulted in the leaching of native calcium carbonate, thus reducing its beneficial electrolyte effect at the surface. Added lime is less soluble than gypsum under these pH conditions. Thus, the residence time of lime at a particular position in the profile is much longer. Because the limitations of diffusion of solutes described earlier, the longer residence time of the lime may allow greater diffusion of Ca^{2+} into the oriented clay of the water–stable aggregate saturating the exchange sites and increasing the stability. This topic obviously requires further attention.

Work by researchers on the contribution of organic constituents to structural stability has been fraught with contradiction (Murray and Quirk, 1990). Recent ideas regarding the role of organics have highlighted the importance of the spatial distribution with the system. The spatial distribution of the organics within the system also effects the accessibility to microbial attack. The microaggregates and oriented clay may protect organics form microbial attack. Increasing evidence suggests that the products and enzymes produced from attack by the microbial biomass in the soil effects the stability of the soil system. Identification of the fabric here may assist those researching the role of organics, enabling them to relate the organic constituents to the structure of the system.

Research is moving towards a philosophy of placing the most appropriate material at the most efficacious place within the soil structure and pore space (Quirk, 1978). To complete this task a fundamental understanding of the interaction of soil particles is necessary.

Future Work

Future research will involve the following: experimentation to determine the response of the microaggregates and strongly oriented clay to various moisture regimes, the use of microanalysis to target the composition of the microaggregates and oriented clay, and the saturation of water–stable aggregates with salt saturated solutions to determine the affect diffusion has on the spatial distribution of solutes.

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Development and Application of Immunoassays for Cotton Pesticides

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Abstract: Immunoassay methods of analysis for pesticides have been increasingly used in environmental application over the last 10-15 years as a consequence of their advantages of sensitivity, specificity and cost over alternative procedures. A number of immunoassays based on ELISA have already been prepared and/or validated for use by the Cotton CRC for studies on the environmental fate of pesticides (e.g. endosulfan, diuron, DDE, pyrethroids, parathion). New immunoassays for the insect growth regulator family of benzoylphenylureas are currently being developed and should soon be available. This assay will be used for environmental studies that may be instrumental in the introduction of members of this class of chemicals (with many positive features) for use in the cotton industry.

Transgenic cottons expressing the crystal protein toxin from the bacterium, *Bacillus thuringiensis* (Bt) have progressed to the field testing stage and will soon become part of the Australian cotton production system in 1997. The use of Bt cotton will significantly reduce the requirement for endosulfan to control *Helicoverpa*. However, other chemicals will still be required. Benzoyphenylurea insecticides may possibly be used in association with trangenic cotton.

Benzoyphenylurea pesticides have many desirable features and potential for use in Australian cotton, information regarding their environmental fate is of importance. In order to obtain this information, a large number of samples should be analysed. But the classical methods of benzoylphenylurea pesticide analysis by GC or HPLC are very expensive and tedious, although they are of adequate sensitivity. Improved analytical methods are needed so that a large number of samples can be inexpensively analysed within a short period of time. Because immunoassay for pesticide analysis is simple, rapid, precise, cost effective, and adaptable to laboratory or field effect, it has been proved to be the best choice for the analysis of the large number of samples. Since first used in 1971, immunochemical methods have been rapidly gained acceptance as analytical techniques for pesticide residue analysis. Therefore a study is being undertaken to develop simple immunoassays for the benzoylphenylurea IGRs.

Development of ELISA for Benzoylphenylurea IGRs

The five benzoylphenylureas chlorfluazuron, diflubenzuron, flufenoxuron, lufenuron and teflubenzuron are structurally very closely related, exhibited common aromatic-urea group (Figure 1). Low molecular weight compounds such as these, which are not inherently immunogenic but are capable of functioning as antigens in the presence of specific antibodies, are described as haptens. To produce antisera against them it is necessary to link the parent molecule, or a structural analogue, to a carrier protein. If the hapten-protein conjugate is used to immunise a vertebrate, the resulting antiserum may contain antibodies which bind to the hapten portion of the conjugate and to the hapten in isolation. Thus it is possible to devise a competition ELISA which can detect and quantify the parent hapten molecule in solution.

The orientation of the hapten relative to the carrier protein is an important factor in determining the specificity of antibody-hapten binding. The region of the hapten molecule which is distal to the point of attachment to the protein will be most exposed to the immune response, resulting in preferential recognition of this region. This potentially offers the opportunity to design a hapten-protein conjugate for production of ether a generic assay, for detection of a range of analogues, or a compound specific assay with low levels of cross-reaction to related compounds. In the case of the benzoylphenylureas pesticides, we have exploited this principle to produce antisera designed to detect the class of benzoyphenylurea and selectively diflubenzuron.

In order to achieve this aim, two approaches have been tried by 1. making a derivative in which the aniline-urea motifs of benzoylphenylurea compounds are preserved and are distal to the point of coupling. This derivative would provide an aromatic-urea group which is common in the benzoylphenylurea and is possible to be a broad-specificity assay for the class of benzoylphenylurea pesticides. 2. making a derivative coupled through the other end, ie the ring that has the difluro- on it. These haptens will result in a selective assay for diflubenzuron. In some cases, coupling through the middle of the molecule can result in sensitive assay, although in general, through ends of molecule sometimes provide better assay. So in this study, another approach through middle of molecule will also be tried.

In the first year of this project, three haptens have been synthesised (Figure 2) and ovalbumin (OA) and keystone limpet haemacyanin (KLH) conjugates are being used to immunise rabbits, and the resulting polyclonal antisera will be tested by a binding assay on microtitre plates coated with the hapten-OA or hapten-KLH conjugates (indirect ELISA). Those antisera showing the highest levels of binding will be selected for further characterisation, using competition ELISA tests to measure the sensitivity of detection of the parent benzoylphenylurea pesticides.

It is intended to extend this technology to the immunoassay of herbicides used in the cotton industry.

Figure 1. Structures of benzoyphenylurea compounds

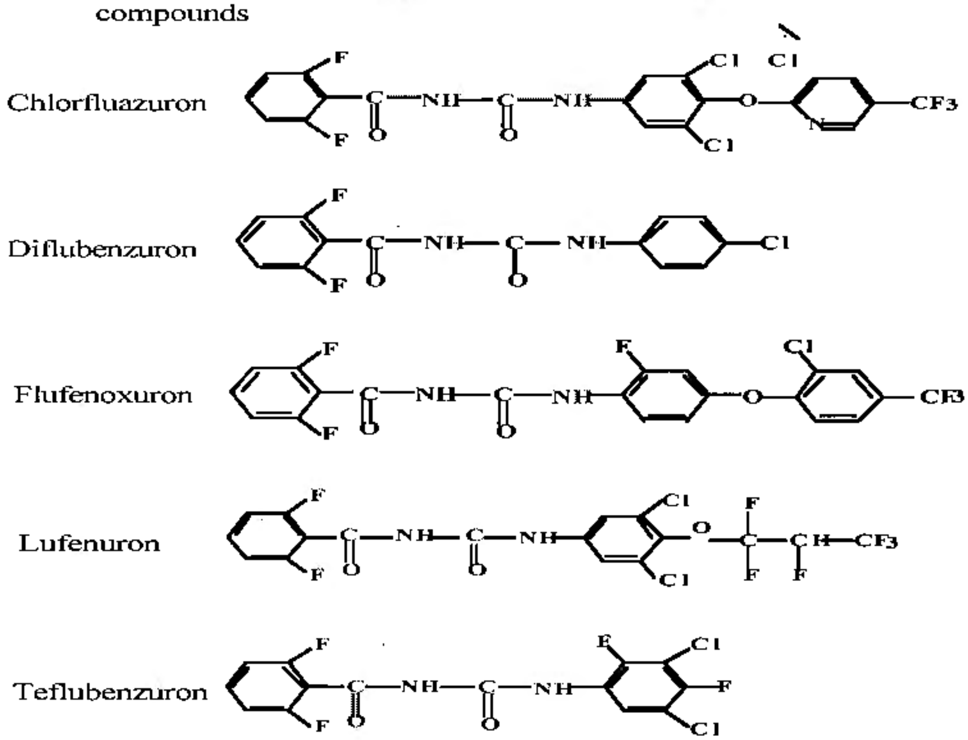
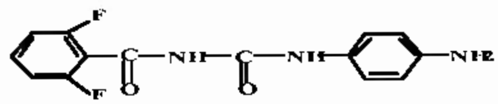
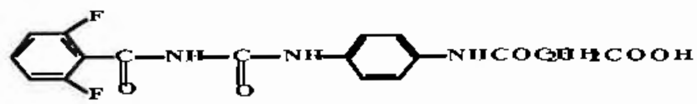


Figure 2 Structures of Haptens

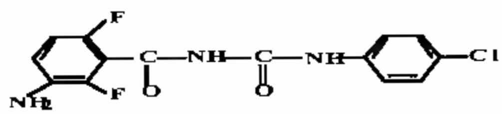
Hapten 1



Hapten 2



Hapten 3



The Effect of Waterlogging During Boll Development on the Nutrition of Cotton

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CRC for Sustainable Cotton Production
Department of Agronomy and Soil Science, University of New England, Armidale, NSW 2351

Introduction

Reports of premature senescence of cotton in Australia have become more apparent over recent years. Plants suffering from premature senescence have reddening of the upper leaves and petioles during peak boll fill, consistent with symptoms of late season potassium (K) deficiency of cotton. On severely affected plants leaves drop prematurely, stopping boll development and consequently reducing yield and quality.

Some cotton soils have been found to be inherently low in exchangeable K (<0.4 meq K/100g), and a response to K applications would be expected K (Harden 1994). However, cotton grown on soils apparently containing adequate levels of exchangeable K have been reported to suffer premature senescence. Symptoms usually occur on high yielding crops that have experienced some form of physiological stress, such as extended periods of waterlogging and/or cool weather conditions during peak boll fill when K requirements are highest.

Potassium uptake is also affected by competition with the cations Mg, Na and Ca. Competition from these cations may induce K deficiency, particularly during recovery from waterlogging.

This paper examines the effect extended periods of waterlogging during mid-flower and peak boll development on the uptake and translocation of nutrients.

Methods

The trial was conducted in the glasshouse to allow conditions to be controlled. The soil used in the experiment was a cracking grey clay (vertisol), typical of the soils of the Namoi Valley. Waterlogging was imposed for seven days either during mid-flowering or during peak boll development. Plants were harvested pre- and post-waterlogging to assess the effect of waterlogging on dry weights and nutrient uptake.

Results

- Root activity declines during the period of boll development when demand for K is high (Figure 1). This is exacerbated by waterlogging during this period.
- The reduction in root activity from waterlogging significantly reduces the uptake of K. Conversely, waterlogging increases the passive uptake of Na (Table 1).
- During recovery from waterlogging K flux to the tops is not fully restored. However, the flux of Mg to the tops significantly increases, indicating a preferential uptake of Mg (Table 1).
- Waterlogging also reduces the uptake of anions, particularly P (Table 1 and Figure 2).
- Under waterlogging a considerable amount of K and P is translocated from the leaves, stems and roots to the developing fruit, to compensate for reduced uptake (Figures 2 and 3).

Conclusions

Premature senescence of cotton is a complex problem, particularly on soils apparently high in available K. Results from this trial indicate that both potassium and phosphorus may be involved in premature senescence of cotton.

Root activity declines during the period of boll development when both K and P are in high demand, and a physiological stress such as waterlogging during this period can significantly reduce the uptake of these ions. Na can to some extent substitute for K in cotton when K supply is inadequate (Joham and Amin, 1965). However, under extreme K deficiencies Na cannot fully compensate for reduced K levels.

Considerable amounts of K and P are translocated to developing fruit, and if the deficiency is severe, visual reddening may appear on the upper leaves, resulting in lower photosynthetic activity. At present there is no diagnostic test that will accurately predict whether premature senescence may be a problem on high K soils. Current recommendations are to encourage strong root growth by avoiding compaction and avoiding waterlogging during boll development through good irrigation management.

Acknowledgments
This project was funded by the Cooperative Research Centre for Sustainable Cotton Production. Thanks goes to Michael Crestani and Leanne Lisle for their technical support.

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Joham, H.E. and Amin, J.V. (1965). Role of sodium in the potassium nutrition of cotton. *Soil Science*,

, 220-226.

TABLE 1 The effect of waterlogging on percentage change in flux of ions to cotton tops

nutrient	Period	% Change in Flux to Tops WL1	WL2
Potassium	WL period + 6d recovery	- 20	
	19 d period after WL	- 22	-48
Sodium	WL period + 6d recovery	+321	
	19 d period after WL	+65	+360
Magnesium	WL period + 6d recovery	-65	
	19 d period after WL	+16	-64
Phosphorus	WL period + 6d recovery	-98	
	19 d period after WL	+10	-100

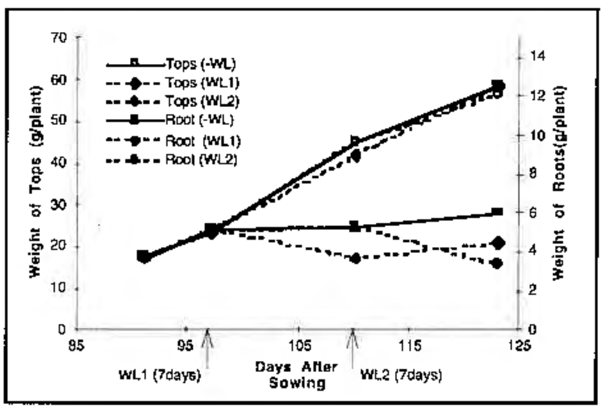

FIGURE 1 The effect of waterlogging on cotton tops androot weights

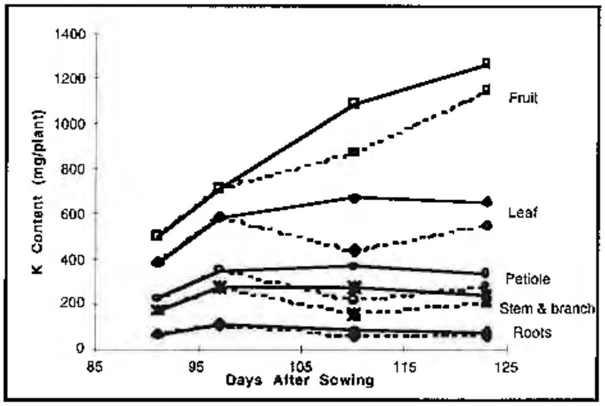

FIGURE 2 The effect of waterlogging during mid-flower on the cumulative uptake and distribution of potassium. Solid lines = control; Dashed = waterlogged.

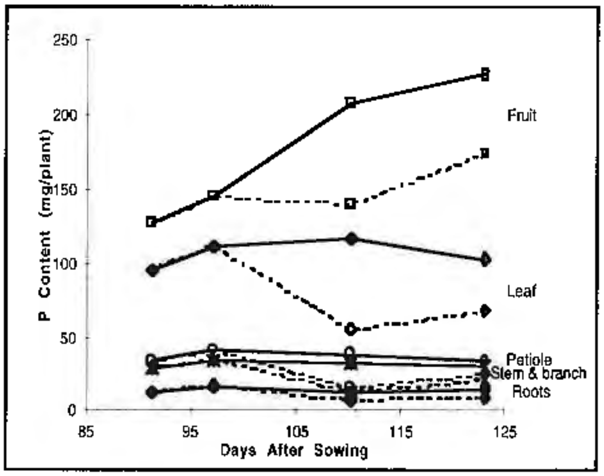

FIGURE 3 The effect of waterlogging during mid-flower on the cumulative uptake and distribution of phosphorus. Solid lines = control; Dashed = waterlogged.

Manipulation of soil micro-organisms to improve cotton production

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Germinating cotton seed and cotton plant roots exudate a wide variety of substances into the immediately surrounding soil environment, known as spermosphere or rhizosphere. These substances can attract and support the growth of the soil microorganisms. The influence of the various components of exudates on soil microorganisms is largely non-specific; therefore, the plants cannot selectively attract and support only beneficial microbes to the exclusion of the deleterious microbes and pathogens. However, in certain cases, the composition of the rhizosphere microflora can be manipulated via exudates. For example, in the development of MAR cotton cultivars, the hypothesis was that cotton has the genetic potential to alter its natural symbiotic microflora on its seed and root surfaces and in tissues; the change is accomplished by genetic alteration of the components of exudates to render them unfavourable for pathogens but favourable for microflora that compete with the pathogens.

Another way to manipulate the rhizosphere microflora is introducing beneficial bacteria into the rhizosphere. CRDC project DAN96C has selected several bacterial strains which can control soil-borne pathogens. Introduction of these strains on to planting seed reduced seedling diseases and increased seed cotton yield. The performance of the strains was consistent over two cotton growing seasons, and in different fields. Results from pot experiments show that some bacterial strains have the potential to control Verticillium and Fusarium wilts.

The development of SOLICON - a soil structure evaluation system using image analysis

Libby Roesner, Tony Koppi, Alex McBratney & Bob Farrell

Introduction:

The purpose of this work is to develop a technique for standard quantitative soil structural assessment using image analysis. The degradation of soil structure from cotton farming practices leads to poor root growth and reduced yields. An evaluation of soil structure can indicate the potential of the soil to produce a crop. Soil structure however is extremely difficult to quantify. In the past, quantitative evaluation of soil structure has been limited to scientific research and has not been accessible to the agronomists or consultants who would greatly benefit from it. These field workers have had to use qualitative visual estimates from soil pits. Modified techniques and an enhanced computer interface has brought quantitative assessment using the image analysis system "SOLICON" closer to field workers.

What is SOLICON?

The word SOLICON is derived from two Latin words, *sol*, meaning soil and *icon* meaning image. The original SOLICON[i] was an imaging system used for analysis of vertical soil sections. It has been developed further in order enable horizontal soil sections to be analysed and classified. Using this new system, SOLICON 2, images of soil collected from the field can be measured and classified in relation to a library of pre-determined structures. It has been successfully applied to field trial images to distinguish between management treatments.

The SOLICON 2 procedure:

This computer aided system involves the collection, processing, analysis and classification of images that represent the field condition of the soil pore network. There are four main steps involved:

1. Visualising the pore network

A variety of dying and staining methods are available to highlight and expose the soil pore network. A resin impregnation technique[ii] was found to be the best for highlighting soil macropores. Other cheaper and simpler techniques including the use of acrylic paint have been tested but the images do not depict the structure so well. Images may be obtained from both vertical and horizontal sections of soil using the resin impregnation technique.

2. Obtaining a binary image

Photographs are taken of the exposed soil structure surface under UV lights in order to obtain the best contrast between pores and solid soil. These photographs are simply scanned into a computer to obtain a digital image. Alternatively a video camera could be used to capture images directly onto the computer. The digital image must be made binary, (just black and white) this is done using a technique called segmentation.

3. Image analysis

The binary image has to be analysed in order to determine the state of the soil structure. This involves measuring structural attributes from the images. That is, quantifying the pixel (picture element) patterns seen in the image. Different attributes are used for horizontal and vertical sections. Vertical assessment involves one-dimensional assessment across rows of the image to assess the structural changes with depth. Horizontal assessment on the other hand involves two-dimensional assessment of the entire soil section.

4. Classification

The two-dimensional structural attributes measured during horizontal analysis can be used to classify the images. Classes may be defined for various purposes by using the relevant structure attributes. Attributes must be chosen that best distinguish the structural condition/s to be identified. Fuzzy classification gives degree of membership of each image to a class. This enables soil images to be allocated to agronomically relevant structural classes.

Latest developments:

Database collected - about 200 images

A collection of image samples were taken from two depths under a wide variety of management regimes together with a range of physical measurements related to soil structure such as bulk density and air permeability. The purpose of collecting this library of images is to determine the variation of structural conditions that exist in cotton growing areas of NSW and QLD. The image samples were impregnated using a polyester resin with a UV dye and hand-ground to expose a single section of the horizontal structure. Digital images (2000 × 2000 pixels) representing a 200 mm square of soil were produced from these samples. A survey of the field cropping histories for the past seven years was also collected from growers for each of the fields sampled. The database of images is important as it is used to define the soil classes to be used in the SOLICON 2 structure classification.

Image segmentation - an automated procedure

An automated segmentation procedure for turning colour images into black and white has been developed that uses the combination of several filters and a simple fuzzy classification to define areas of 'pore' and 'solid' in the image. The image segmentation procedure is a major area of development enabling standardised analysis so that all images will be treated equally.

Using appropriate horizontal attributes

In the past structural attributes have been measured from the individual pores seen in a binary image. This method is erroneous and biased as pores seen in a two-dimensional cross-section of the soil represent a network of voids within the soil and not individual features. The method of measuring these images therefore has to be based on a model that uses attributes that represent the whole pore network. In other words, attributes that look at the local region of pore space rather than discrete pores. An improved set of structural attributes have been developed[iii] that measure global estimates of the pore and solid network. They are described briefly below:

Porosity: Measures the volume proportion of pores per unit soil.
Surface area: Measures the boundary area of the pore and solid interface per unit volume of soil.
Solid star area: Measures the equivalent diameter of the size of solid area that can be measured in eight directions from each solid pixel. The mean solid star area gives an average size estimate of soil aggregates.
Pore sieve: Measures the equivalent diameter of octagon the fit inside the pore network. The mean gives an average size of pores. The distribution of the pore sieve relates to the pore size distribution.
Pore star shape factor: The local shape of pores relative to a sphere.
Wetting distance: The distance into aggregates required to saturate 90 % of the solid soil.
Macropore potential: The proportion of the soil that is pore or within 3 mm of a pore and hence the best environment for roots (in a heavy cracking clay).
Anaerobic risk: The proportion of the soil that is further than 10 mm from a pore and therefore has a high risk of being anaerobic when the soil is wet and therefore not suitable for plant roots.
Pore Genus: The connectivity of the pore phase. The larger the genus the more "loops" of pore space exist in the image.

Each attribute measures something about the nature of the pores or solids as defined by the binary image. This is important as it is the attributes that form the basis of the classification. The classification depends on the attributes that we measure on the images, so, it's important that they distinguish between the different structural types. The attributes however can have their limitations when used in isolation. The importance of using several attributes to distinguish between different structures is highlighted in Figure 1. The two images in Figure 1, both have identical porosity's, surface areas and pore sizes, these attributes alone therefore will not distinguish between these two structures. In this case the pore star shape is likely to be of greatest importance in discriminating these images. This illustrates why it is important to select the best combination of attributes to both relate to the physical properties that we are trying to represent and distinguish between different structures.

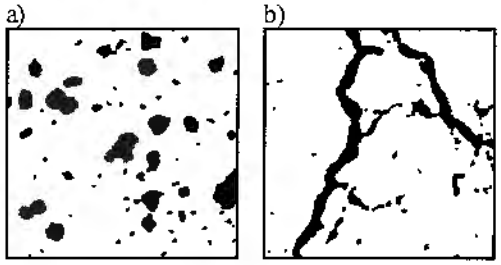

FIGURE 1 - Two images highlighting the importance of using the appropriate combination of structure attributes to discriminate between images. Images *a)* and *b)* have identical porosity's *(0.125 mm^3mm^{-3})*, surface areas *(0.672 mm^2mm^{-3})* and pore sizes *(0.761 mm)*. A fourth attribute, the mean pore star shape factor *(0.77 for a) and 0.38 for b))*, is required to discriminate between these two images.

Update SOLICON 2 soil structure classification
A classification system is being developed to assess soil images and evaluate their status against a library of images whose management history is known. An initial classification was set up by identifying structural classes from the database of images that was collected. The classes were defined by an expert according to what images related to major differences in physical structure. Ten different structures were defined from a visual assessment of the images. A sample image representing each structural type is given in Figure 2 below.

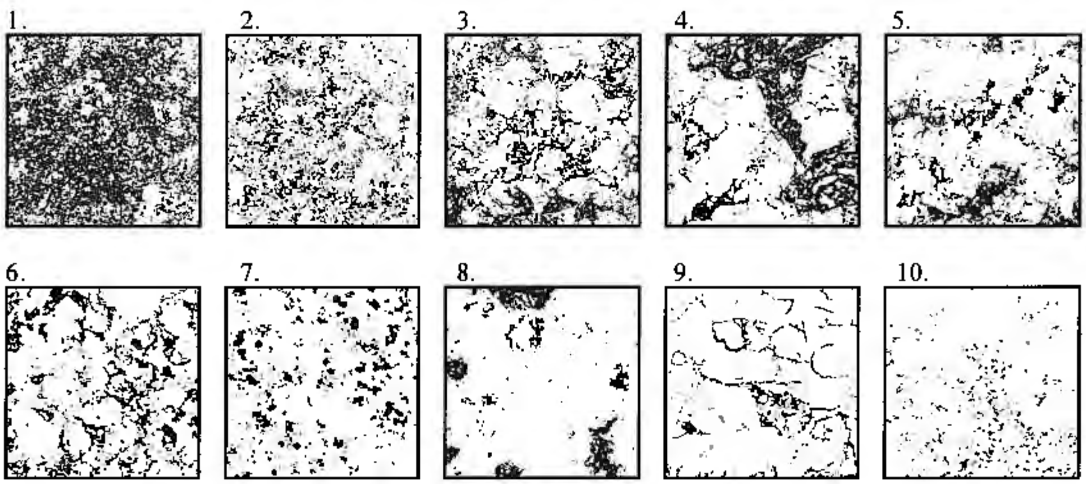

FIGURE 2 - Ten structural classes showing the variation in soil structure

The classification was set up by selecting the horizontal attributes that best highlight the differences between structures. A range of images in each visual class were then measured using these attributes. The mean and variation of the attributes for each structural type is used to define each class. Fuzzy classification is used to give unknown images a membership value to each class. The variation in structure over the database ranged enormously and some images were difficult to classify. Low memberships infer that either there are not enough classes or that the attributes do not distinguish between them. The quality of the classification system is dependant on the quality of the binary images and the ability of the attributes to distinguish between classes. By measuring and comparing these attributes on an unknown image and comparing the results to those defined by the classification the structure of the unknown can be identified.

Menu driven SOLICON 2
The user interface of SOLICON 2 has been updated to a menu driven system that makes it easier to operate. The one application, "SOLICON 2", can now open and segment colour or grey-scale images and turn them into binary images which can be printed. Vertical and horizontal attributes can be measured from the binary images and the data output in the form of text, graphs and/or images can be printed directly from the application or saved to file. The classification output from the horizontal analysis can also printed or saved to file.

Status:

The SOLICON 2 soil structure evaluation system has been developed in order to enable horizontal soil sections to be analysed and classified. Using this new system, horizontal images of soil collected in the field can be measured to determine the proportion of pore, the interactive area between pores and solids, and the size distribution, shape and connectivity of the pore and solid phases of the soil. These attributes are what define the classes of pre-determined structures. The classification system can then be used to identify unknowns according to these pre-determined structures and relate them to management practices. Further modifying and testing of the classification system will complete the final piece in the jigsaw puzzle of quantitative soil evaluation using image analysis.

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Managing the hydrological cycle in relation to cotton

Janelle Douglas, Donald MacLeod, Richard Faulkner

A major problem facing the Australian cotton industry is the availability of water and the impact of the industry on downstream water quality and quantity. Inefficient irrigation practices can lead to problems such as salinity, waterlogging, and the movement of soil, nutrients and agricultural chemicals off-farm. The aim of this research is to examine the hydrology of cotton soils and quantify components of the water balance in order to improve water-use efficiency. From these results, the potential threat of soil salinity under irrigated cotton will be evaluated using the SODICS model. The results from the first season's work are from ACRI on a typical grey clay; slope was 1 in 1176.

The change in soil water storage (ΔS) is described by:
ΔS = (Rain + irrig.) - (runoff + evaptrans. + deep drainage)

The quantity and intensity of rainfall was measured, as was the quantity of water applied at the head ditch and runoff at the tail drain. Evapotranspiration was also measured. Drainage below the root zone was measured by assessing the change in water storage in that zone. Tensiometers were used to determine hydraulic gradients and direction of water movement. Under saturated conditions, downward movement was estimated from hydraulic conductivity measure with a well permeameter. Changes in soil water storage were measured directly with a neutron probe during the season.

The measured components of the soil water balance are present below. Only 2 irrigations were monitored fully, when there was no rain over the test period (4 days after irrigation). At irrigation 4, the soil was moist prior to irrigation and some water leaked from an adjacent furrow, increasing the runoff measurement and confusing the ΔS results.

	Irrig mm	Run off mm	Et mm	Drainage mm	ΔS mm	Calculated ΔS mm
Irrig 2	94	2.4	22.9	2.04	65.1	66.7
Irrig 4	82	6.4	10.0	1.02	55.9	64.6

From these results, irrigation application efficiency can be calculated. It is ratio of water available to the plant divided by the volume of water applied. The irrigation application efficiencies of the two irrigations above are 95 and 90% respectively.

We have developed an accurate means of quantifying the components of the soil water balance in irrigated cotton. This data suggests that drainage from heavy grey soils is a small component of the soil water balance. The study will continue on different cotton soils in the next 2 seasons in the Gwydir valley. Salt levels in the irrigation water will also be monitored, to determine the amount of salt entering the system. This will aid our assessment of the future threat of salinity on cotton soils given their hydrology and water management.

Improving Extension

Bruce Pyke
Cotton Research & Development Corporation, Narrabri

Extension initiatives

- **Extension network.** Both CRDC and the CRC are supporting extension officer positions at Warren, Gunnedah, Moree and Emerald. The network also includes the State Department extension agronomists who work on cotton and is complimented by CRC technical officers at Myall Vale and Dalby as well as others eg. Murray Schoenfisch. The network is coordinated via a CRC extension committee (Geoff McIntyre, Gus Shaw and Bruce Pyke) and now has a dedicated National Extension Coordinator (Dallas Gibb) whose role it will be to develop and implement major national issues more quickly. While the priority national issue is currently IPM, the new structure of the extension network will also allow other important issues to be dealt with more effectively at the same time if that is required. Some of the delivery methods being employed by the extension network team members include:

    - Regional R & D validation and demonstration trials
    - Small regional group meetings and Focus groups for major issues
    - Organisation and coordination for general field days and special meetings eg. IPM support groups
    - Preparation of special publications and Research Reviews
    - Monthly newsletters to local growers and consultants (Cotton Tales)
    - Compilation of regional trial booklets

    The whole cotton extension team now meets at an annual workshop to review programs and initiatives and to set or readjust priorities for extension over the next 12 months. This is an important process for developing and improving the extension network. However, more effort may need to be directed towards giving researchers and extension workers more opportunities to interact.

- **Best practice manual.** The LWRRDC/CRDC/MDBC joint pesticides program has studied the fate of pesticides on cotton farms, particularly in soil and water. Based on this program, best management practice (BMP) guidelines are being developed to minimise the impact of pesticides on the riverine and general environment. At present ACGRA (Allan Williams) is the driver of this project. The joint pesticides program funding will finish in July 1997 and it will fall upon the cotton industry to carry the development of BMP further. CRDC is establishing an BMP program that will continue funding in this area. The major technical resource for soils and water BMP will be Cotton SOILpak-3. While it is envisaged that ACGRA and Cotton Australia field staff will be more closely associated with the regional adaptation, development and adoption of BMPs, there is a clear role for the extension network to assist with demonstration and promotion of some of the technical aspects of the components of BMPs.

- **SOILpak.** Plans are underway to review SOILpak to produce Cotton SOILpak-3 and a revised draft should be ready for comment in about 12 months. The revised manual will contain links with the BMP manual and companion manuals such as NUTRIpak and ENTOpak.

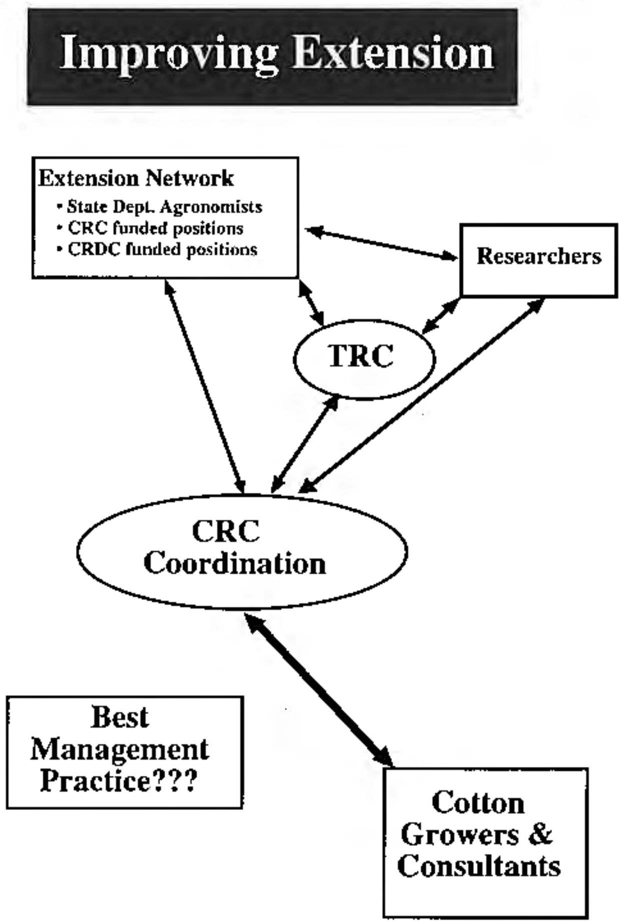
- **TRC activities.** The CRC's Technology Resource Centre has compiled all the available extension literature on cotton and makes this available on request to the industry. It also develops information both written for general distribution to the industry and for its cotton web page. The TRC has set up a complete industry mailing list and has the capability to send short messages and information to growers and consultants by fax stream. Researchers are encouraged to make use of the TRC when they wish to communicate with the industry.

- **Farming systems program.** The farming systems program coordinators are playing an important role in keeping relevant information up to the researchers who are involved in the three farming systems trial sites.

- **General comments.** The extension network and TRC should not be seen by researchers as separate entities that will automatically take the results of their research to the industry. Extension requirements and initiatives should be considered at an early stage in most research projects and it is also important for researchers to discuss these needs with extension agronomists at an early stage.

Researchers who have identified extension needs for their results or who wish to explore those needs are encouraged to contact Dallas Gibb at ACRI and/or Bruce Pyke at CRDC.

Soils Workshop



Biloela/Theodore
- **1 QDPI (April)**

Emerald
- **1 CRDC**

Downs
- **3 QDPI**
- **1 CRC**

Extension Network
- **CRC Committee + National Coordinator***

Goondiwindi
- **1 QDPI**

Gunnedah
- **1 CRDC**

Moree
- **1 CRC**
- **1 NSW Ag.**

Narrabri
- **1 CRC**
- **1 CRDC***
- **1 NSW Ag.?**

+

TRC
- **5 CRC**

Improving Extension *Soils Workshop*

Extension Network 1996/97

- **National priority - IPM**

- **Regional soils, tillage, nutrition extension:**

  - Emerald .... ID of nutrition issues

  - Downs...................Reduced tillage
    ....Bed vs furrow trafficking
    ....N management, budgeting, bulk density

  - Gwydir/MacIntyre......Salt action, long fallow disorder

  - Upper Namoi............Pupae busting, stubble management,
    ....rotation crops, NPK, lime/gypsum

  - Warren....................Nutrition: N, lime/gypsum, Zn, P, K
    ....Farming Systems coord.

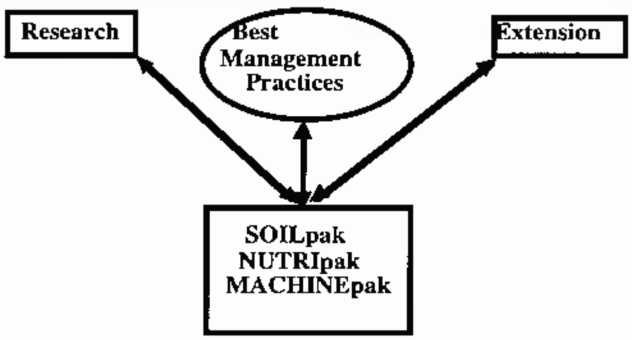
  - ACRI
    ...Farming Systems.....Coordination, newsletter

    ...TRC....................Web page, NUTRIpak
    ....Research Reviews:
    - Rotations (? John M)
    - Stubble management (Murray S.)
    - Pupae control (BP, MS)

    ....SOILpak

Major Issues

- **Early ID & Planning of extension**
- **Developing the Extension Network**
- **Links between researchers and extension network**
  - **national priority issues**
  - **regional adaptation**
  - **publications (research ↔ extension)**



Discussion points:

- Agribusiness is having an increasingly important role in extension
- Machinery dealers provide very little technical input
- The number of extension workers to cope with increasing number of growers
- The increasing complexity of research and technology (IPM etc)
- Extension workers need to be included in technical reports to growers (coauthors)
- Cottontales
- Use of packages developed from outside cotton industry

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