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UNIVERSITY OF SOUTHERN QUEENSLAND

FACULTY OF ENGINEERING

Precision Agriculture in Sugar Cane: Preliminary Work

A joint effort by The University of Southern Queensland's
Faculty of Engineering and Incitec Ltd.

Report by:
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22/4/97

Contents

1. INTRODUCTION

Crop inputs such as soil ameliorants, fertilisers and water are currently applied on the basis of average values of nutrient status, soil moisture content, soil chemistry and soil structure across an entire field. There is evidence, however, that these parameters vary on a much smaller scale. For instance, soil maps of the Burdekin area show substantial soil type variations within fields, so that inputs calculated on the basis of field averages may not be appropriately scaled for sub-sections of the field. Several papers to the 1995 Australian Society of Sugar Cane Technologist Conference discussed the need for more precise specification of P and N fertilisers according to soil type and soil nutrient status (Johnson; Bramley, Wood and Cristaudo; Catchpoole and Keating). The overall conclusion was that much more precision was required to minimise off-farm impacts, waste of inputs and possible environmental degradation. In crops other than cane, such as cotton, it has been shown that applying fertilisers at the locally required rate reduces the cost of production (McBratney and Whelan, 1995). Simple estimates based on the potential halving of the amounts of soil ameliorants applied to fields in the Burdekin area suggest substantial cost savings are possible (David Cox, 1995, pers. comm.).

Crop yield results from the interaction between the crop, these inputs, and the local values of the soil and water parameters. It is apparent therefore that yield within a field will vary greatly over relatively small distances along the row. Only some of these parameters are within the control of the farmer. It is only recently that techniques have become available which allow yield to be measured and mapped with a resolution sufficient to make it possible to adjust inputs according to crop need instead of simply using averaged values. These techniques are being developed rapidly for the grain industries, but are just beginning to be investigated for cane.

This paper reports on the first known application of precision agriculture principles to sugar cane production. It is based on work conducted by the University of Southern Queensland, Faculty of Engineering and Surveying in association with Incitec Ltd. The work involved site specific sampling of soil under the direction of a yield map. Extensive laboratory analysis of the soil samples was then conducted to determine the level of nutrients and other elements. Analysis of these results against the respective yield measurement was carried out to determine the primary cause of the yield variations.

1.1. Aims/Objectives

The specific objectives of the work are:
(1) To collect soil samples site specifically, guided by a yield map and GPS technology.
(2) To analyse the soil sample and determine the factor/s affecting yield.

2. METHOD

2.1. Yield mapping

Yield mapping was carried out on DAVCO farming enterprise in the Burdekin North Queensland. Harvest of the field occurred over 18 days between 23rd of June, 1996 and 19th of August, 1996. The field is defined as Field 7a in farm plans and is approximately 117 ha in area.

The yield mapping of this field is the first of it kind for a sugar cane crop. The technology was developed at the University of Southern Queensland, Toowoomba. The yield mapping system uses differential GPS technology and a yield sensor fitted to the harvester.

2.2. Soil Sampling

Soil sampling was carried out at selected sites over the field. The sites were chosen to cover the full representation of the yield variation. From the yield map (page 10) six different yield intervals were definable. They were 60-80t/ha, 80-100t/ha, 100-120t/ha, 120-140t/ha, 140-160t/ha and 160-220t/ha. Two replicate sites were selected for each yield interval, making a total of twelve sampling sites. The selected sites are shown on the yield map.

Differential GPS technology was used to navigate to the selected positions. At these sites five samples were taken within a radius of 15m and mixed together to give a representative sample. The sampling method involved a coring tube and a Jackhammer. Samples were taken at a depth of 0-25cm and 25-50 on advice from Gary Ham, BSES, Burdekin.

The total of 24 samples (12 sites X 2 soil depths) were dried and sent to Incitec's soil laboratory in Brisbane. The top soil samples (0-25cm) were analysed for: Soil Colour (Munsell), Soil Texture, pH, Organic Carbon, Nitrate Nitrogen, Sulfur, Phosphorus (BSES), Phosphorus(Colwell), Potassium, Calcium, Magnesium, Sodium, Chloride, Electrical Conductivity, Copper, Zinc, Manganese, Iron and Boron. From these results the Cation Exchange Capacity, Calcium/Magnesium Ratio, ESP and Electrical Conductivity(se) were calculated.

The subsoil samples (25-50cm) were analysed for: Soil Colour (Munsell), Soil Texture, pH, Sulfur, Phosphorus (BSES), Potassium, Calcium, Magnesium, Sodium, Electrical Conductivity and Potassium. From these results the Cation Exchange Capacity, Calcium/Magnesium Ratio, ESP and Electrical Conductivity(se) were also calculated.

3. RESULTS

3.1. Yield Map

See page 10. The grid size is 20 x 20m.

For analysis purposes the yield of the sample points was taken as the median of the yield range appropriate to that point. For example, Point One lies on the yield range 120-140t/ha. Therefore the yield is taken as 130t/ha.

3.2. Soil Analysis

A summary of the soil analysis results is given in Appendix A. The laboratory methods of analysis and calculation are given in Appendix B.

3.3. Regression

Simple linear regression was conducted for each soil variable versus yield.

3.3.1. Topsoil regression results (0-25cm)

Variable	R^2	F	Significance of relationship
pH	0.005	0.826	Not significant
Organic C	0.018	0.672	Not significant
Nitrate N	0.047	0.496	Not significant
Sulfur	0.272	0.082	Not significant
Phosphorus (BSES)	0.230	0.114	Not significant
Phosphorus (Colwell)	0.251	0.0966	Not significant
Potassium	0.000	0.936	Not significant
Calcium	0.008	0.778	Not significant
Magnesium	0.338	0.047	*Marginally significant*
Sodium	0.686	0.000	**Highly significant**
Chloride	0.535	0.007	**Highly significant**
Electrical Conductivity	0.636	0.002	**Highly significant**
Copper	0.150	0.213	Not significant
Zinc	0.232	0.112	Not significant
Manganese	0.049	0.488	Not significant
Iron	0.017	0.680	Not significant
Boron	0.003	0.862	Not significant
CEC	0.132	0.244	Not significant
ESP	0.320	0.055	*Marginally significant*
Ca/Mg Ratio	0.617	0.002	**Highly significant**
se	0.667	0.001	**Highly significant**

3.3.2. Subsoil regression results (25-50cm)

Variable	R^2	F	Significance of relationship
pH	0.565	0.004	**Highly significant**
Sulfur	0.396	0.028	**Significant**
Phosphorus (BSES)	0.690	0.001	**Highly significant**
Potassium	0.025	0.618	Not significant
Calcium	0.146	0.219	Not significant
Magnesium	0.755	0.000	**Highly significant**
Sodium	0.620	0.002	**Highly significant**
Electrical Conductivity	0.592	0.003	**Highly significant**
Potassium (nitric)	0.015	0.695	Not significant
CEC	0.722	0.000	**Highly significant**
ESP	0.469	0.014	**Significant**
Ca/Mg Ratio	0.448	0.017	**Significant**
se	0.591	0.003	**Highly significant**

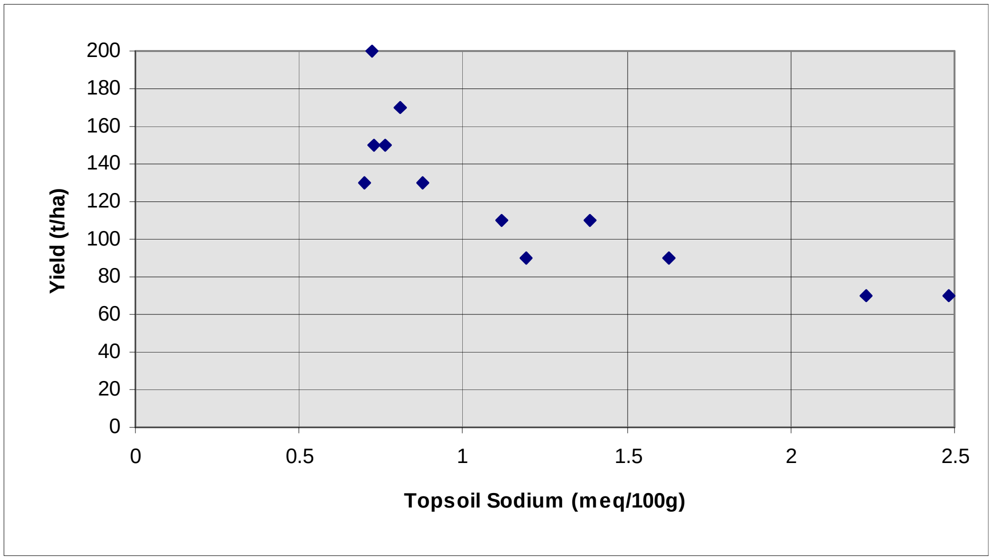


Figure 1. Relationship Between Topsoil Sodium and Yield

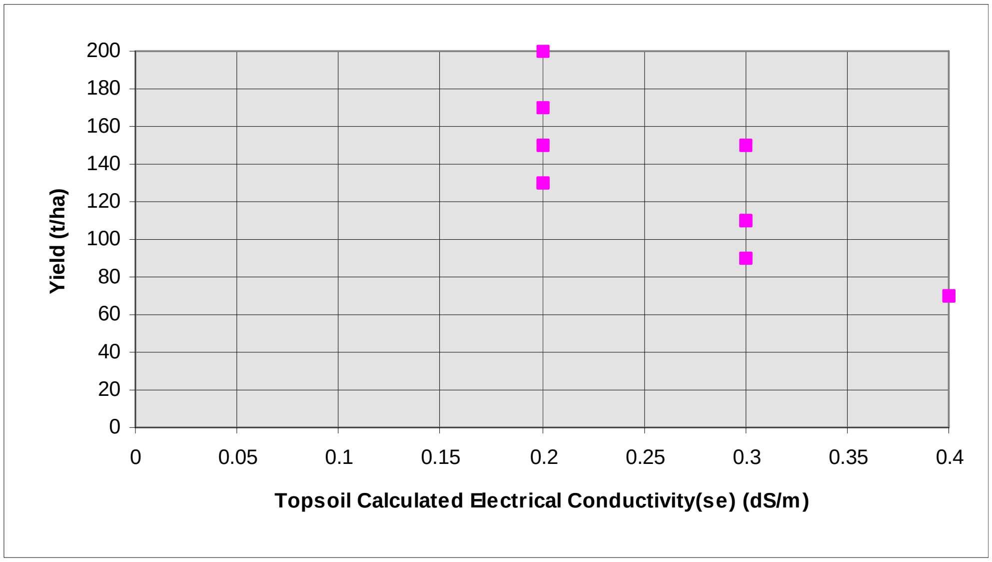


Figure 2. Relationship Between Topsoil Calculated Electrical Conductivity versus Yield

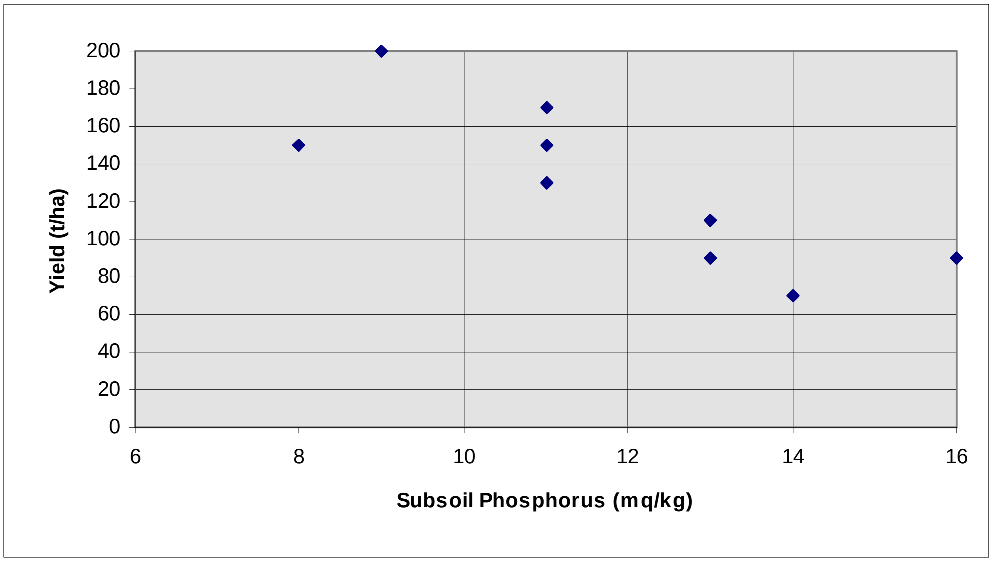


Figure 3 Relationship Between Subsoil Phosphorus and Yield

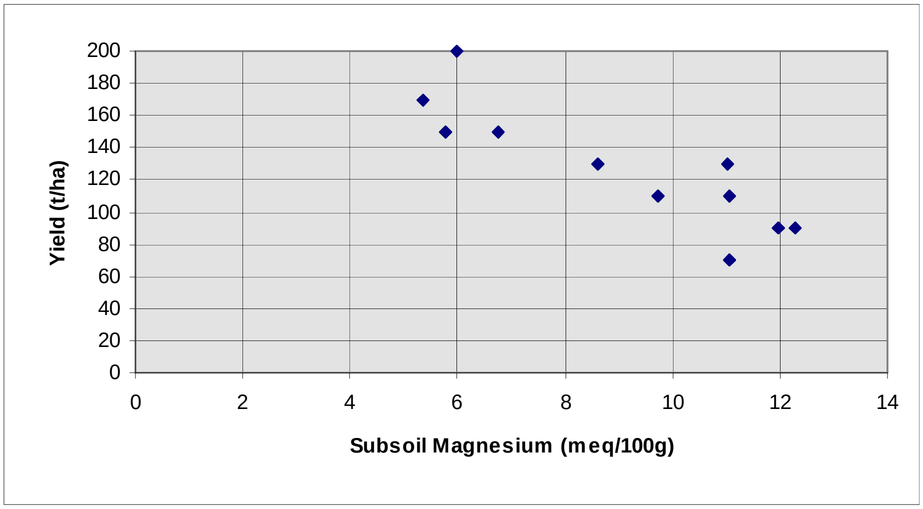


Figure 4 Relationship Between Subsoil Magnesium and Yield

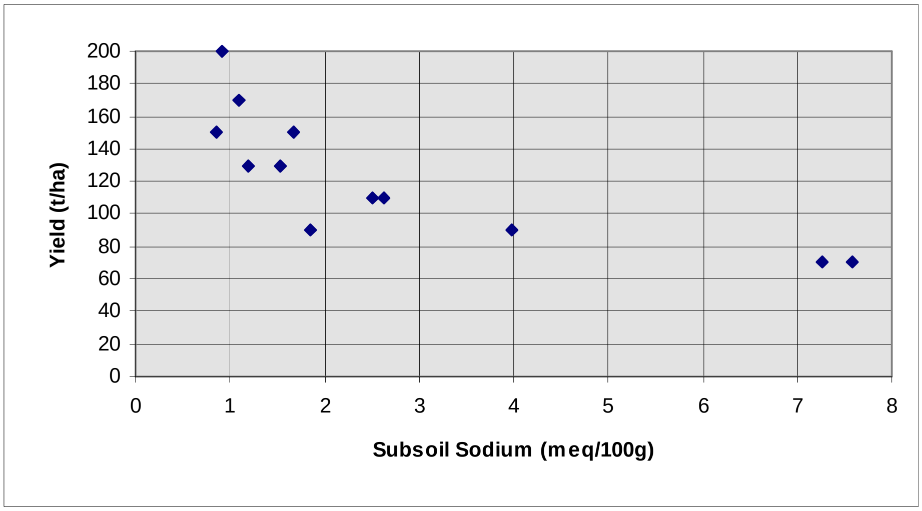


Figure 5 Relationship Between Subsoil Sodium and Yield

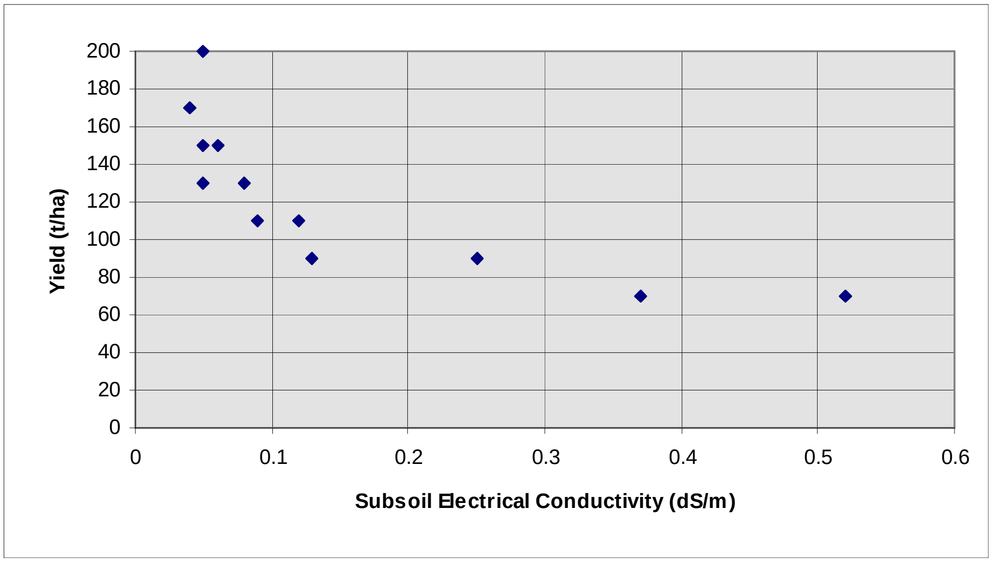


Figure 6 Relationship Between Subsoil Electrical Conductivity and Yield

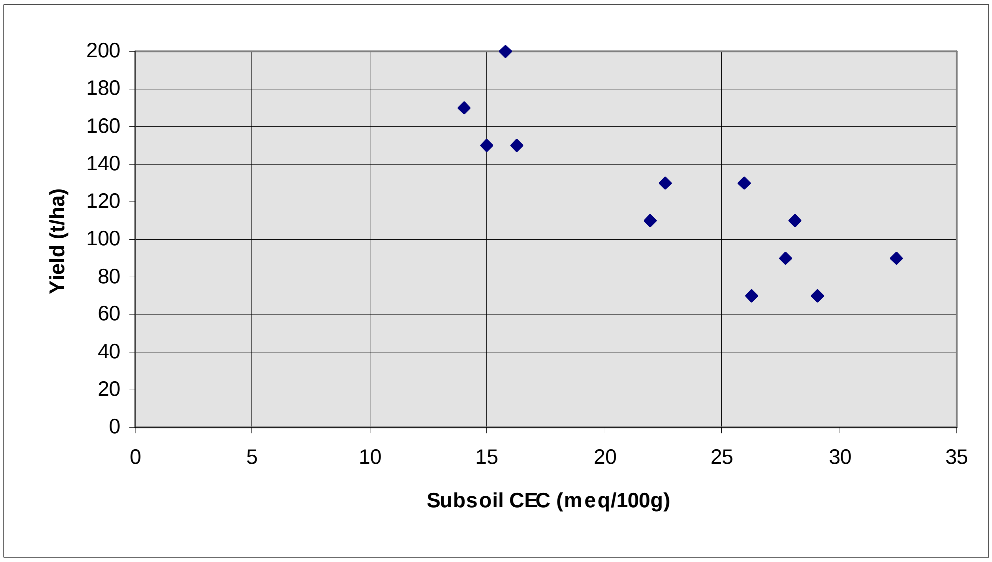
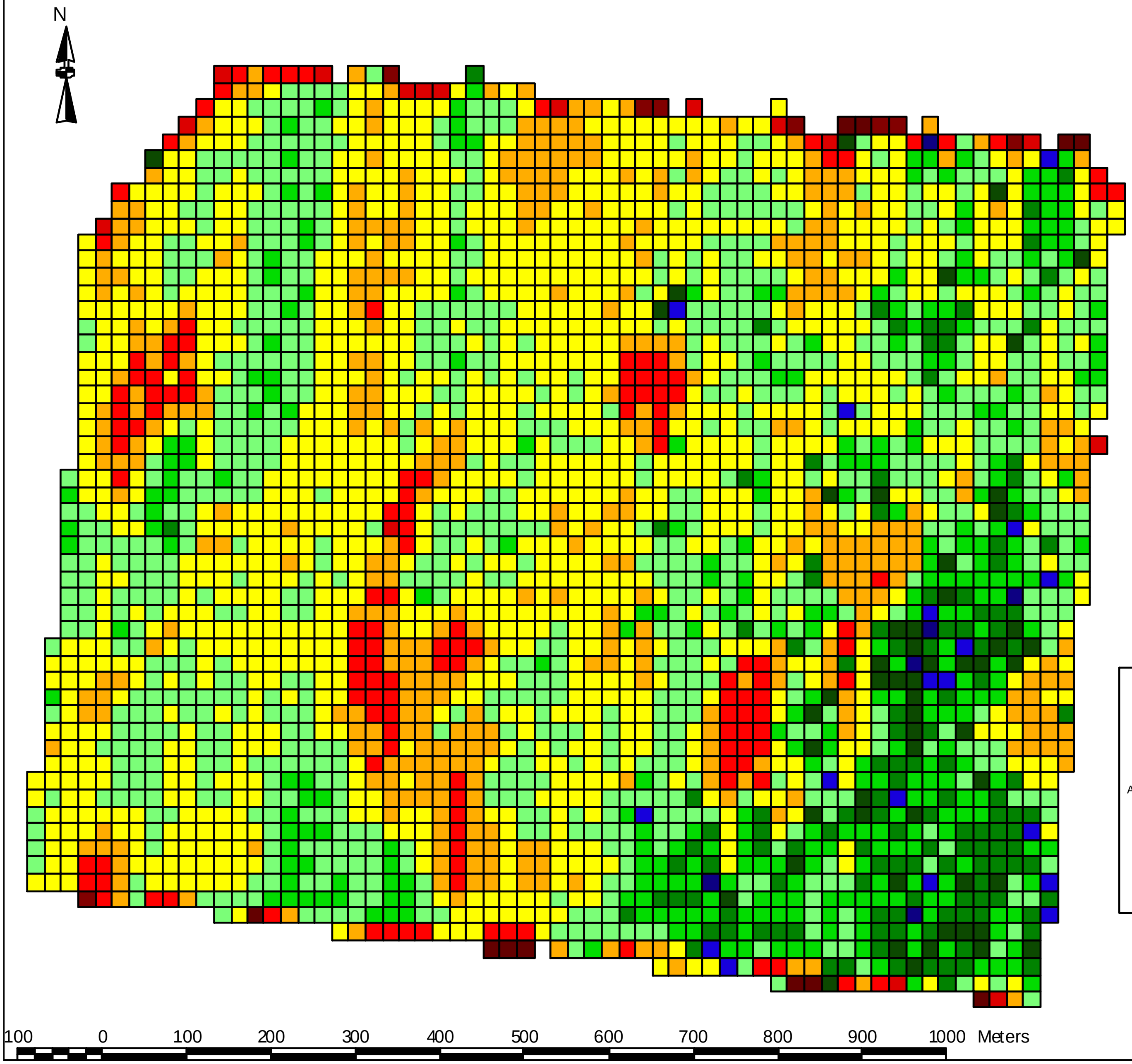


Figure 7 Relationship Between Subsoil CEC and Yield

Yield Map

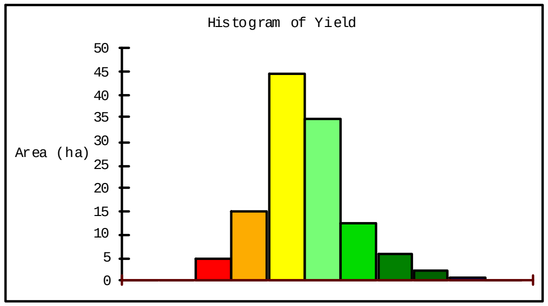
Field 7a 1996
DAVCO FARMING
Burdekin



Sugar Cane Yield (t/ha)

- 🟥 10 - 20
- 🟥 20.1 - 40
- 🟥 40.1 - 60
- 🟥 60.1 - 80
- 🟧 80.1 - 100
- 🟨 100.1 - 120
- 🟩 120.1 - 140
- 🟩 140.1 - 160
- 🟩 160.1 - 180
- 🟩 180.1 - 200
- 🟦 200.1 - 220
- 🟦 220.1 - 240

Total Yield: 14287.6 t
Average Yield: 122.6 t/ha



By Graeme Cox
16/10/1996

4. DISCUSSION

4.1. Yield map

The yield map (page 10) exhibited a significant level of spatial yield variation, from 60 to 200t/ha. This 300% plus variation is typical of yield differences found in other crop which have been yield mapped. The histogram of yield represents the area of the paddock covered by each yield range. It is interesting to note and also expected that the variation is normally distributed around the mean of 122.6t/ha.

The history of the field should be discussed to provide an insight into the cause of the yield variation. The field is situated in the newly developed Burdekin River Irrigation Area (BRIA) and has been in production for seven years. Prior to this it was laser leveled to improve irrigation and drainage. It is this levelling which has the caused the higher areas to be scalped of their top soil, exposing highly sodic subsoil. A cut/fill map has shown that these scalped areas occur in the same places shown by the lower yielding areas on the yield map. It is also interesting to note that the higher yielding area in the south eastern corner of the paddock was filled to provide the required gradient for furrow irrigation.

From this history the farmer expects the problem is due to the negative effect of sodicity on soil structure, and plans to rectify the problem with variable rate gypsum amelioration. The soil sampling provides evidence to support this line of action.

4.2. Soil Sampling

GPS technology was easily used to navigate to the required soil sampling sites. The five metre accuracy of the Differential GPS system was well within the requirement to position within the 20 x 20m resolution of the yield map.

4.3. Regression

4.3.1. Topsoil

Of the top soil parameters analysed, Sodium, Chloride, Electrical Conductivity, Ca/Mg Ratio and Calculated Electrical Conductivity (se) were significantly correlated with crop yield ($F<0.01$). Magnesium and ESP were marginally correlated with yield (approx. $F=0.05$). Of these variables the best linear correlation came from Sodium and Calculated Electrical Conductivity (se), accounting for 69% and 67% of the variation respectively. Obviously these two variables are strongly related. The results for these two variables are plotted against yield in Figures 1 and 2.

The strong negative correlation with sodium is expected. The relationship between Sodium and the Electrical Conductivity (measured and calculated) is obvious and therefore it too exhibits a strong negative correlation with yield. The high negative Chloride correlation is related to the inability of the high sodic soils to leach the chloride from the topsoil. The only positive correlation with yield was found with the Ca/Mg ratio due to the positive effect of Ca on the sodic soil.

Figure 1 indicates a nonlinear relationship between sodium and yield. It appears the that the crop is insensitive to sodium levels below 1 meq/100g. However at levels higher than this the yield drops off dramatically.

4.3.2. Subsoil

Of the subsoil variables measured most were significantly correlated with yield. They were: pH, Sulphur, Phosphorus, Magnesium, Sodium, Electrical conductivity, CEC, ESP, Ca/Mg Ratio and Calculated Electrical Conductivity (se). The noncorrelated variables were Potassium, Calcium and Potassium(nitric).

The strong correlation of yield with most of the variables is due to the interdependence between them. This interdependence is primarily due to the leaching nature of the soil. The highly sodic soils allow less infiltration and therefore less leaching, resulting in higher concentrations of the measured parameters.

Again the correlation with sodium is strong, accounting for 62% of the yield variation and the relationship to yield does not appear to be linear (Figure 5). Surprisingly the best correlation was found with Magnesium, accounting for 75% of the yield variation. This negative correlation is shown in Figure 4.

An interesting correlation is the negative relationship of Phosphorus with yield (Figure 3). This could be due to a build up of residual Phosphorus in lower yielding areas after uniform application. This result would indicate that variable rate application of this input could take advantage of this factor and save on input costs.

4.4. Final Discussion

The choice to sample at two levels (0-25cm and 25-50cm) on advice from BSES agronomist Gary Ham was proved correct with higher correlations in the 25-50cm range. Sodium correlations were expected to be better at the deeper sample interval, but were approximately the same as in the higher interval.

If the soil sampling was conducted randomly across this field and compared with the average yield of the field, then the data would be rather useless due to the variability in yield and soil parameters measured. It is obvious therefore that individual or mixed soil samples should not be used to make blanket field recommendation for crop inputs. This maybe a reason for the general distrust of farmers towards soil analysis results. The use of yield maps can greatly improve sampling strategies and in doing so provide a great deal more agronomic information on which to base recommendations.

5. CONCLUSION

Yield mapping was conducted on a 117 ha sugar cane field in the Burdekin. The map exhibited yield variations of greater than 300%. A soil sampling strategy was implemented to determine the cause the yield variation, although high sodium levels were suspected. DGPS was used to navigate to twelve points in the field, representing a range of yield levels. Soil samples were taken at two depths. The soil samples were then analysed for various parameters.

Linear regression of the soil parameters against yield indicated that 69% of the yield variation can be accounted for by the Sodium levels. Surprisingly though, Subsoil Magnesium levels produced a stronger relationship accounting for 76% alone.

From this work we have shown that yield maps can be used to guide soil sampling to improve agronomic analysis.

6. REFERENCES

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McBratney A B, and Whelan B M, 1995, "The potential for site specific management of cotton farming systems"; CRC for Sustainable Cotton Production, Discussion Paper No 1.

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7. APPENDICES

Appendix 7.1 Soil Analysis Results
Appendix 7.2 Method of Soil Analysis and Calculations

7.1. Appendix A - Soil analysis results

		Soil sample results (0-25cm)															
Point	Yield	pH	Organic C	Nitrate N	Sulfur	Phosphoru	Phosphoru	Potassium	Calcium	Magnesium	Sodium	Chloride	Electrical C	Copper	Zinc	Manganes	Iron
po No.	t/ha	(1:5 Water)	%C	mg/kg	mg/kg	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	mg/kg	dS/m	mg/kg	mg/kg	mg/kg	mg/kg
1	130	7	1	6	5	18	9	0.35	12.04	8.76	0.7	15	0.05	1.8	0.3	15	33
2	110	7.9	1	0.7	3	24	4	0.32	14.02	9.83	1.12	15	0.06	1.4	0.1	9	17
3	150	8.3	1	35.9	2	31	6	0.28	12.04	6.59	0.73	15	0.06	1.2	0.3	9	13
4	90	7.5	0.9	0.7	4	17	6	0.45	18.17	11.52	1.19	35	0.06	1.7	0.3	14	30
5	110	7.5	0.8	0.9	5	21	13	0.41	14.77	9.98	1.39	40	0.07	1.9	0.4	13	32
6	130	7.2	1.5	0.6	5	20	12	0.37	11.33	6.9	0.88	30	0.05	1.8	0.6	28	29
7	70	7.4	1.1	0.4	8	10	4	0.2	5.95	6.65	2.23	75	0.08	1.4	0.3	23	21
8	70	7.6	1.1	0.5	5	9	3	0.17	4.97	6.43	2.48	90	0.1	1.2	0.4	19	20
9	90	7.7	1.4	0.7	6	14	4	0.32	8.98	8.81	1.63	40	0.06	1.1	0.7	18	14
10	200	7.4	0.9	0.4	3	16	8	0.21	6.49	3.53	0.72	20	0.04	0.9	0.7	22	22
11	170	8.2	1.5	0.4	3	64	11	0.38	9.72	6.22	0.81	20	0.05	1	0.7	21	14
12	150	6.9	1.5	0.3	7	11	7	0.26	6.59	4.73	0.76	25	0.05	1.2	1	40	21

Continued

					Soil sample results (25-50cm)												
Boron	CEC	ESP	Ca/Mg Rat	se	pH	Sulfur	Phosphoru	Potassium	Calcium	Magnesium	Sodium	Electrical C	Potassium	CEC	Ca/Mg Rat	ESP	se
mg/kg	meq/100g			dS/m	(1:5 Water	mg/kg	mg/kg	meq/100g	meq/100g	meq/100g	meq/100g	dS/m	meq/100g	meq/100g			dS/m
0.69	21.86	3.2	1.37	0.2	6.8	4	11	0.38	12.99	11.03	1.54	0.05	2.43	25.95	1.18	5.93	0.2
0.77	25.3	4.43	1.43	0.3	8.1	3	13	0.26	9.28	9.73	2.63	0.09	2.32	21.91	0.95	12	0.4
0.73	19.65	3.71	1.83	0.3	7.9	5	11	0.19	7.3	5.79	1.67	0.06	2.45	14.96	1.26	11.16	0.4
0.77	31.34	3.8	1.58	0.3	7.5	4	13	0.46	17.84	12.27	1.85	0.13	2.91	32.43	1.45	5.7	0.6
0.94	26.56	5.23	1.48	0.3	7.3	2	13	0.39	14.18	11.06	2.51	0.12	2.72	28.15	1.28	8.92	0.5
0.77	19.49	4.51	1.64	0.2	6.9	4	11	0.38	12.36	8.61	1.19	0.08	3.2	22.55	1.44	5.28	0.4
1.45	15.04	14.83	0.89	0.4	8.7	6	14	0.29	7.62	11.07	7.26	0.37	3.11	26.25	0.69	27.66	1.7
0.03	14.06	17.64	0.77	0.4	9	4	14	0.26	10.16	11.07	7.58	0.52	3.09	29.08	0.92	26.07	2.3
1.48	19.75	8.25	1.02	0.3	8.8	3	16	0.3	11.47	11.96	3.99	0.25	3.85	27.73	0.96	14.39	1.1
0.57	10.96	6.57	1.84	0.2	6.8	10	9	0.31	8.54	5.98	0.92	0.05	3.75	15.76	1.43	5.84	0.2
1.45	17.14	4.73	1.56	0.2	7	6	11	0.28	7.28	5.34	1.09	0.04	3.14	14	1.36	7.79	0.2
0.64	12.35	6.15	1.39	0.2	6.3	10	8	0.3	8.3	6.76	0.85	0.05	3.12	16.22	1.23	5.24	0.2

7.2. Appendix B - Method of Soil Analysis and Calculations