NEC11 – Final Project Report Attachment 4

Infield Spatial Variability of Surface Irrigated Cotton Yields

SC White and SR Raine

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IRRIGATION FUTURES

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1. Introduction

Anecdotal evidence suggests that there is significant infield yield variability within Australian cotton fields. In particular, the design and management of surface irrigation systems appears to have a substantial impact on crop moisture stress. Surface irrigation assessments conducted within the cotton industry have shown that traditional management practices favour allowing the irrigation to run for significantly longer than the furrow advance time to ensure that the bottom end of the field is well watered. However, this may result in waterlogging of the crop at the top end of the field, particularly on long furrows, due to the excessive period of crop inundation at the head ditch end of the field. The recent move towards increasing furrow flow rates and decreasing the period of irrigation application has reduced the potential for water logging but if not well targeted, this practice may result in under-watering at the tail end of the field. Hence, there is the potential for yields to significantly different between each end of surface irrigated fields with both the size and the nature (ie. either increased or decreased from one end to the other) of the variation a function of the system design and management practice.

Irrigation performance evaluations and optimisations are commonly conducted on a field by field basis for individual irrigation events throughout the season. The recent availability of satellite imagery has also raised interest in evaluating spatial variability in crop stress within cotton fields. However, the cost of satellite imagery acquisition has resulted in this method being used mainly by researchers or for catchment scale analyses and satellite imagery is rarely used at an individual field or farmer level to evaluate irrigation performance.

Many growers and harvest contractors now have yield monitors installed on cotton pickers and are therefore able to generate yield maps on a routine basis. However, the value of yield maps has been questioned as it is often difficult to identify appropriate responses to the observed variations. The advent of variable rate fertiliser technology has provided one notable application of yield monitor data. However, as water is a major source of crop stress, it seems reasonable to expect that the infield variations in crop yield should also be a function of the irrigation design and management practices. Hence, the objective of this work was to investigate the relationships between crop yield and surface irrigation field layout as an indicator of the impact of irrigation management practices.

2. Methodology

This study was conducted in two stages. A preliminary evaluation was conducted using yield monitor data collected during the 2004/05 and 2005/06 growing seasons from 50 fields randomly selected from the Darling Downs region. The second stage involved extending the study across another four cotton growing regions in Queensland by conducting a similar analysis for 25 randomly selected fields from each of the (a) Emerald, (b) Goondiwindi and southern Downs, (c) Mungindi and (d) St George areas over the same seasons. All data used in the study had been collected from commercial yield monitors and collated by DJAS Crop Data Pty Ltd. Data was used on the basis of anonymity for growers. Hence, DJAS Crop Data Pty Ltd removed all identifying details from the data and provided the individual maps only in final analysed form with each map and data set identified only by a unique number (Appendix 1).

The yield maps of the fields (Appendix 2) were plotted using a 20 m x 20 m grid. The average yield for each field was calculated along with the average yield in two zones (i.e. across the head ditch end and across the tail drain end) within the fields. For the Darling Downs fields, the infield zones extended across the entire field width and were 100 metres in length along the rows. A 10 metre buffer strip was omitted at the head ditch end to overcome yield monitor edge effects and a 50 metre buffer was excluded from the tail drain end to account for any water backing up into the field. For the fields from the other regions, the infield zones extended across the whole field width but the length was variable between sites and calculated as 1/5 of the row length. The same buffer strips (i.e. 10 metre head ditch end and 50 metre tail drain end) were imposed as in the Darling Downs fields. This difference in the size of the zone selection was chosen to account for differences in field length and would be expected to produce a more representative measure of the differences between field zones.

3. Results

Significant differences in cotton yields (e.g. Figure 1) were observed between the head ditch and tail drain end of most fields across all regions (Appendix 1). However, the nature of the difference between each end of the field varied greatly between individual sites (Table 1) with a maximum difference of 3.7 bales/ha (i.e. yield at tail drain end higher than head ditch end) to a minimum of -1.8 bales/ha (i.e. yield at tail drain end lower than head ditch end). There was no significant difference in the trends observed between the regions but the average difference ranged from 0.4 bales/ha for the Emerald region to approximately -0.2 bales/ha in the Goondiwindi and Mungindi regions (Table 1).

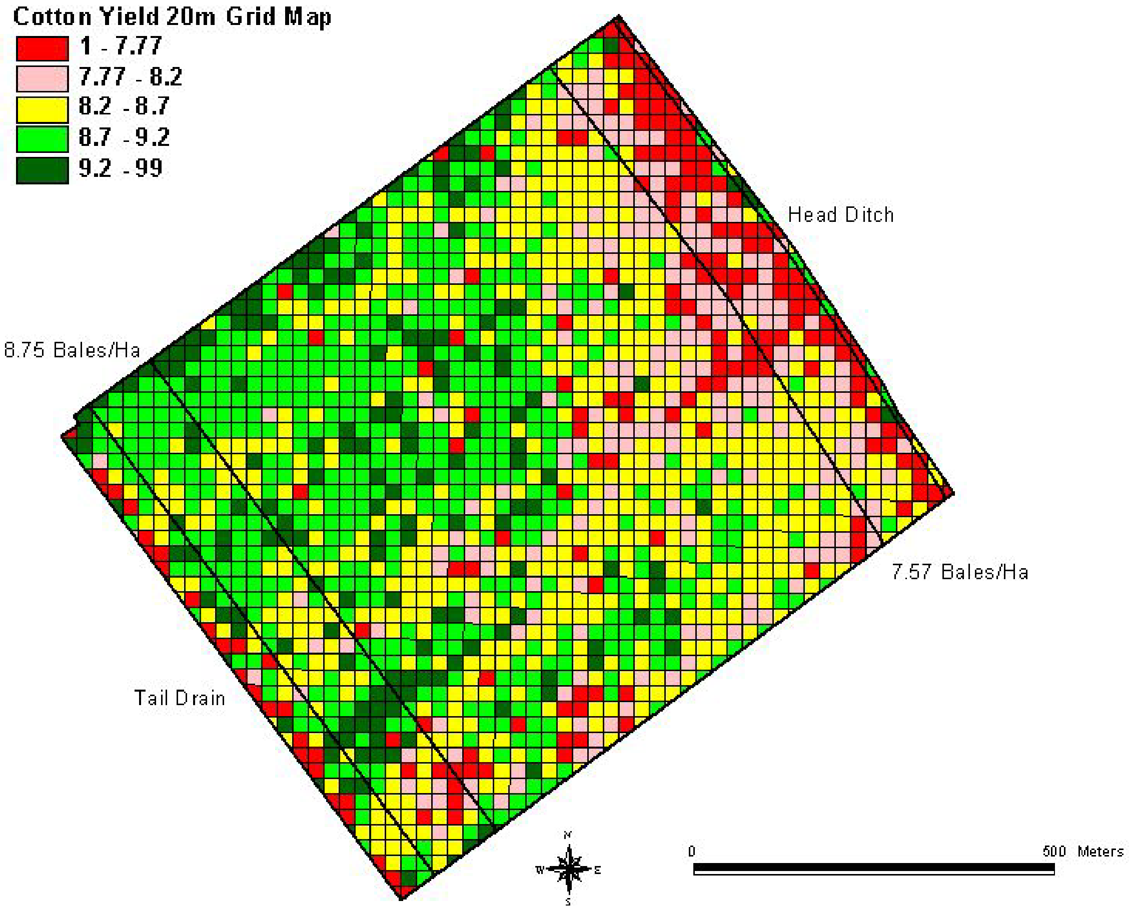


Figure 1. Example of a cotton yield map showing yield differences between the head and tail drain ends of a surface irrigated field

Table 1. Difference in cotton yield between the head ditch and tail drain ends of surface irrigated fields

Region	**n**	**Mean Difference (bales/ha)**	**Std. Deviation**	**Minimum Difference**	**Maximum Difference**
Darling_Downs	50	0.225	0.773	-1.84	1.84
Emerald	25	0.410	0.794	-0.68	1.60
Goondiwindi	25	-0.184	1.042	-1.54	3.72
St_George	25	0.383	0.843	-0.99	2.86
Mungindi	25	-0.209	1.065	-1.81	2.19

** positive values indicate that yield at tail drain end is higher than at head ditch end*

The frequency histogram of yield differences between the head ditch and tail drain ends of the fields are shown for both Darling Downs (Figure 2) and the other regions (Figure 3). The distribution appears to be log-normal positively skewed for the Darling Downs (Figure 2) but is not significantly different to a normal distribution for the other regions (Figure 3). This is consistent with observations for many physically measured irrigation related soil variables (e.g. sorptivity and hydraulic conductivity) which appear to be normally distributed at small scales (or with small sample numbers) but which tend to a positive skew with increasing scale and sample size (Sharma et al. 1983).

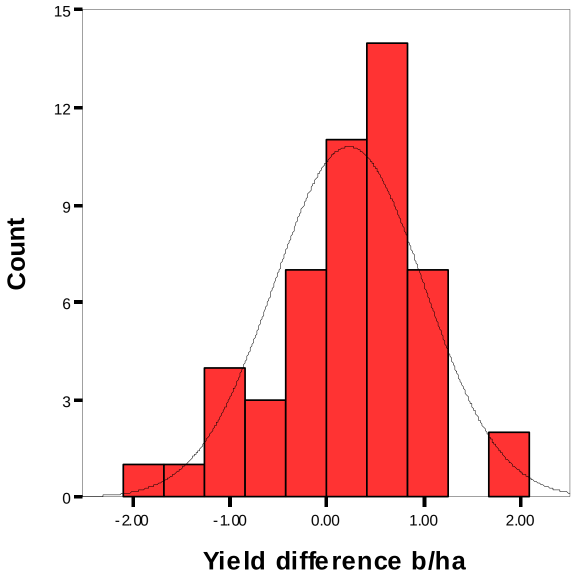


Figure 2. Frequency distribution of cotton yield differences between the head ditch and tail drain ends of fields within the Darling Downs region.

Sixty percent or more of the fields in the Darling Downs, Emerald and St George regions had a higher yield at the tail drain end of the field compared to the head ditch end (Table 2). In each of these regions, more than half of the fields had a yield difference of more than 0.25 bales/ha between these areas of the field while in Emerald, 28% of fields had a difference of more than 1 bale/ha. Goondiwindi and Mungindi had 28% and 40%, respectively, of fields with a higher yield at the tail drain end compared to the head ditch end. All regions except

Goondiwindi had approximately ⅓ of fields producing 0.5 bales/ha more at the tail drain end compared to the head ditch end.

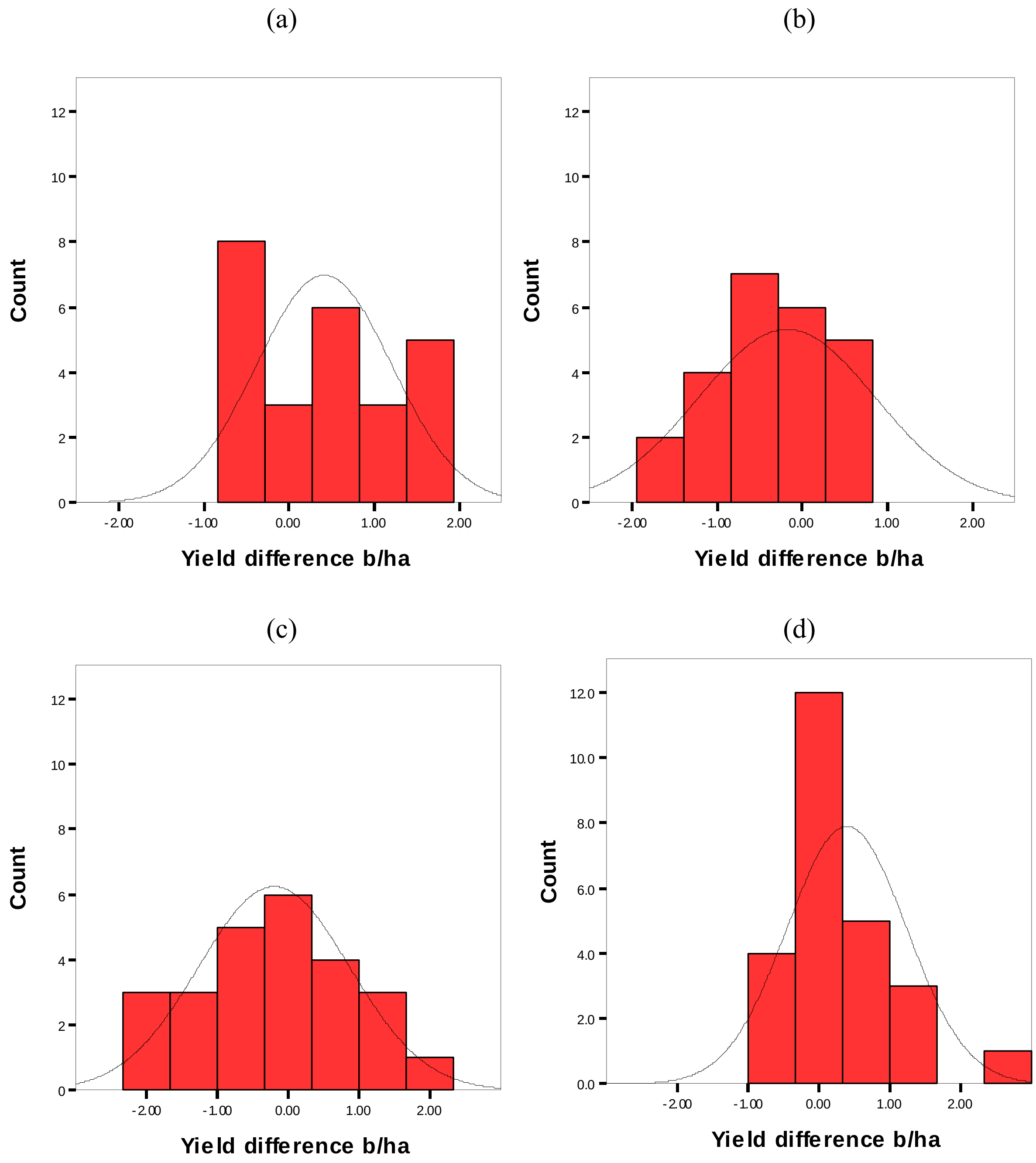


Figure 3. Frequency distributions of the yield differences between the head ditch and tail drain end of the field for the (a) Emerald, (b) Goondiwindi,

(c) Mungindi and (d) St George cotton growing regions.

Table 2. Summary of infield cotton yield analysis for each catchment

Region	**Darling Downs**	**Emerald**	**Goondiwindi**	**St George**	**Mungindi**
Total number of fields assessed	50	25	25	25	25
No. of fields where tail drain yield > head ditch	34	15	7	17	10
Proportion of fields where tail drain yield is greater than head ditch	68 %	60 %	28 %	60 %	40 %
Proportion of fields showing a tail drain > head ditch yield difference					
> 0.25 bale/ha	60 %	56 %	24 %	56 %	32 %
> 0.5 bale/ha	38 %	40 %	20 %	32 %	32 %
> 1 bale/ha	12 %	28 %	4 %	16 %	16 %

4. Discussion

This work assessed the yield variability between the head ditch and tail drain ends of 150 fields from across the Queensland cotton industry. Large spatial variations in yield were found between individual fields presumably due to the differences in design and irrigation management between locations and managers. However, across four regions (i.e. all except Goondiwindi) approximately ⅓ of the fields produced 0.5 bales/ha more at the tail drain end compared to the head ditch end. The majority of fields (≥60 %) in three regions (Darling Downs, Emerald, St George) showed higher yields at the tail drain end compared to the head ditch end of the field. The main mechanisms likely to be responsible for these differences are either waterlogging of the crop the upstream end of the field due to excessive inundation times or lower soil fertility at the head ditch end of the field. The most likely reasons for excessive periods of inundation are either inappropriately long furrows or a preference for running significant volumes of tailwater. However, possible reasons for lower soil fertility at the head ditch end of the field may be either exposure of sub-soils (with lower fertility or higher salinity levels) during land grading or the loss of mobile nutrients (e.g. nitrogen, sulphur) out of the root zone due to higher deep drainage losses in this area.

A substantial number for fields had higher yields at the head ditch end of the field compared to the tail drain. This effect was more prevalent in the Goondiwindi and Mungindi regions and is most likely associated with water shortages and/or a greater management culture in these regions of pulling furrow siphons earlier resulting in a slight under-irrigation of the tail end of the field.

The individual level of yield variability would also be expected to be influenced by the seasonal weather conditions. Data used in this analysis was acquired from the 2004/05 and 2005/06 seasons which had less than average rainfall during the crop growing period across most regions. If more rain had fallen the trends in yield variation due to irrigation performance would be expected to be smaller. In low rainfall years and under limited water conditions growers often adopt irrigation practices which conserve water such as increasing inflow and reducing over-irrigation at the head ditch end of the field. However, this may have the effect of under irrigating the tail end of the field as observed in the Goondiwindi and Mungindi regions. However, this effect could be due to differences in the soil characteristics, run lengths and/or inflow rates within each the field and region.

Without further information on the specific soils and irrigation performance it is impossible to identify relationships between the irrigation design and management practices and the trends in yield variation along the field length. However, it seems likely that the most significant factor influencing yield non-uniformity along the furrow length is water infiltration opportunity time which is a function furrow inflow rate, field length and irrigation application time.

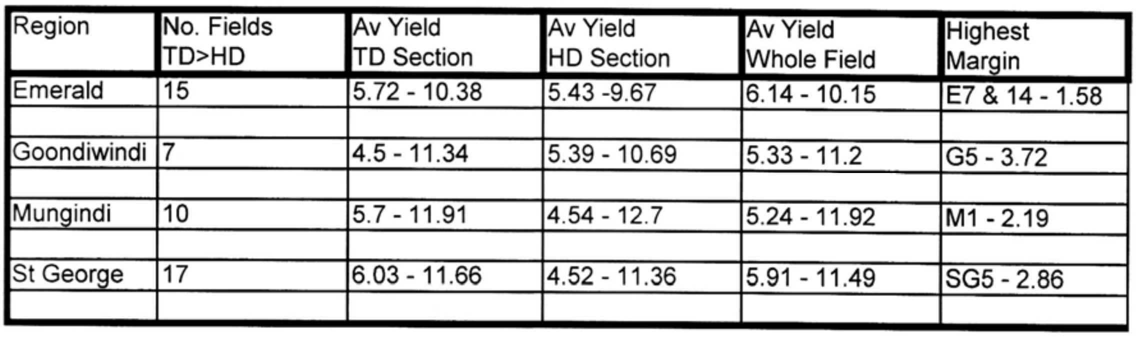
5. Conclusions

Significant variations in cotton yield have been found between the head ditch end and tail drain end of surface irrigated fields across five major cotton growing regions of Queensland. It seems reasonable to assume that a substantial proportion of these differences are related to irrigation design and/or management practices. In approximately ⅓ of the fields evaluated, there was a 0.5 bales/ha higher yield at the tail drain end compared to the head ditch end. This difference is most likely a result of irrigation induced waterlogging of the crop at the head ditch end of the field due to either excessively long furrows (for the flow rates used) or running tail water for too long. However, a substantial number of individual fields (particularly in the Goondiwindi and Mungindi regions) produced a higher yield at the head ditch end compared to the tail drain end. This is most likely associated with growers attempting to maximise water use efficiency by pulling siphons early and under-irrigating the tail end of the field.

6. References

Sharma, M. L., Barron, R. J. W., and De Boer, E. S. (1983). "Spatial structure and variability of infiltration parameters." *Advances in Infiltration, Proceedings of the National Conference.*, Chicago, IL, USA, 113-121. BN-0-916150-58-5.

<u>Appendix 1:</u> Tabulated Yield Data for Individual Fields in Each Catchment



Region	No. Fields TD>HD	Av Yield TD Section	Av Yield HD Section	Av Yield Whole Field	Highest Margin
Emerald	15	5.72 - 10.38	5.43 -9.67	6.14 - 10.15	E7 & 14 - 1.58
Goondiwindi	7	4.5 - 11.34	5.39 - 10.69	5.33 - 11.2	G5 - 3.72
Mungindi	10	5.7 - 11.91	4.54 - 12.7	5.24 - 11.92	M1 - 2.19
St George	17	6.03 - 11.66	4.52 - 11.36	5.91 - 11.49	SG5 - 2.86

REGION	HECTARES	FIELD CODE	ROW LENGTH 1 Meters	ROW LENGTH 2 Meters	1/5 PORTION Lengths (m)	AV YIELD Bales/Ha	HD AV YIELD Bales/Ha	TD AV YIELD Bales/Ha	YLD DIFFERENCE BALES/HA
Emerald	43.3	E1	510	423	73	9.74	9.54	9.7	0.16
	43.3	E2	510	423	73	9.69	9.44	9.87	0.43
	35.3	E3	212	425	30	9.66	9.01	9.41	0.4
	36.8	E4	604	762	109	8.58	8.07	8.74	0.67
	58	E5	620	615	111	8.7	8.6	9.07	0.47
	57.3	E6	790	790	146	6.72	6.03	7.54	1.51
	57.3	E7	790	790	146	7.3	6.4	8	1.6
	49.3	E8	903	881	164	6.31	5.43	6.93	1.5
	43	E9	306	561	50	9.96	9.38	10.31	0.93
	56.9	E10	640	631	114	9.51	8.82	10.19	1.37
	58.7	E11	820	306	50	10.15	9.67	10.38	0.71
	48.7	E12	602	362	60	9.32	8.76	9.83	1.07
	42.5	E13	1104	852	158	8.25	7.38	8.9	1.52
	30.1	E14	962	874	163	6.99	5.93	7.51	1.58
	62.8	E15	555	1487	85	8.66	8.49	8.77	0.28
	69.1	E16	460	179	24	6.45	6.65	5.97	0.68
	68	E17	460	179	24	6.75	7.12	6.52	0.6
	58	E18	620	615	111	8.09	8.42	8.38	0.04
	56	E19	886	878	164	6.14	6.26	5.72	0.54
	49.3	E20	903	881	164	8.16	8.1	7.58	0.52
	51.6	E21	557	557	99	8.63	8.72	8.42	0.3
	38.1	E22	547	710	97	8.46	8.49	8.36	0.13
	35.2	E23	1064	852	158	7.23	7.26	6.95	0.31
	38.2	E24	580	464	81	8.63	8.9	8.42	0.48
	20.2	E25	242	140	16	8.53	8.8	8.45	0.35

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REGION	HECTARES	FIELD CODE	ROW LENGTH 1 Meters	ROW LENGTH 2 Meters	1/5 PORTION Lengths (m)	AV YIELD Bales/Ha	HD AV YIELD Bales/Ha	TD AV YIELD Bales/Ha	YLD DIFFERENCE BALES/HA
Goondiwindi	132.1	G1	909	909	170	8.36	8.28	8.58	0.3
Sth Downs	32.2	G2	419	426	72	9.62	9.17	9.83	0.66
	22.9	G3	525	438	76	9.65	9.5	9.7	0.2
	41.4	G4	724	700	128	7.5	7.03	7.76	0.73
	44.5	G5	374	931	63	8.53	5.45	9.17	3.72
	20.7	G6	584	718	105	11.2	10.69	11.34	0.65
	36.8	G7	718	714	131	9.1	8.4	9.15	0.75
	26.7	G8	395	284	45	8.25	8.47	8.17	0.3
	49	G9	385	645	65	7.38	7.47	6.02	1.45
	31.7	G10	568	626	102	7.99	8.57	7.38	1.19
	40	G11	493	561	87	6.6	7.6	6.06	1.54
	36.9	G12	309	703	50	5.33	5.39	4.5	0.89
	40.5	G13	688	669	122	7.08	7.57	6.68	0.89
	34.5	G14	917	348	58	7.57	8.01	7.18	0.83
	32.3	G15	720	720	132	9.16	9.05	8.75	0.3
	79.1	G16	725	725	133	8.71	9.19	8.44	0.75
	51.3	G17	627	674	113	7.72	8.01	7.51	0.5
	68.1	G18	905	888	166	8.62	8.8	8.17	0.63
	59.6	G19	862	865	160	8.07	8.72	7.98	0.74
	29.6	G20	890	900	166	8.6	8.62	8.48	0.14
	44.3	G21	900	900	168	8.52	8.48	8.4	0.08
	36.8	G22	1099	753	139	8.55	9.08	8.2	0.88
	24.4	G23	585	718	105	6.67	6.8	6.71	0.09
	74.3	G24	900	900	168	8.73	9.02	8.75	0.27
	54	G25	740	748	136	8.88	8.91	8.76	0.15

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Mungindi	49.2	M1	370	530	62	8.72	7.41	9.6	2.19
	63	M2	600	595	107	7.35	6.49	7.55	1.06
	57.4	M3	643	740	117	11.86	11.69	11.91	0.22
	19.8	M4	500	493	87	11.38	10.94	11.54	0.6
	33.7	M5	282	410	44	10.03	9.82	9.98	0.16
	67.8	M6	726	729	133	8.97	8.26	8.94	0.68
	65.6	M7	1013	684	125	8.18	7.6	8.44	0.84
	50.2	M8	555	550	98	5.24	4.54	5.7	1.16
	39.3	M9	234	935	35	7.78	7.14	8.14	1
	85.7	M10	935	925	173	7.72	7.68	8.19	0.51
	17.8	M11	490	586	86	7.72	7.79	7.34	0.45
	18.9	M12	668	371	62	6.73	6.95	6.54	0.41
	30.4	M13	740	873	136	7.33	7.25	7.02	0.23
	40.2	M14	650	657	118	7.8	7.66	7.65	0.01
	70.6	M15	453	554	79	10.29	10.85	10.38	0.47
	56.9	M16	696	706	127	11.92	12.7	10.89	1.81
	36.6	M17	583	566	101	9.76	10.05	9.05	1
	45.2	M18	529	580	94	10.03	10.05	9.83	0.22
	39.3	M19	573	557	99	11.24	11.72	10.81	0.91
	32.5	M20	203	573	29	11.49	11.82	11.49	0.33
	32	M21	582	438	76	9.14	9.2	7.86	1.34
	58	M22	502	497	87	8.03	8.59	7.06	1.53
	53.8	M23	976	328	54	8.87	9.27	7.74	1.53
	52	M24	395	642	67	9.02	9.56	7.85	1.71
	74	M25	369	907	62	8.55	9.42	7.72	1.7

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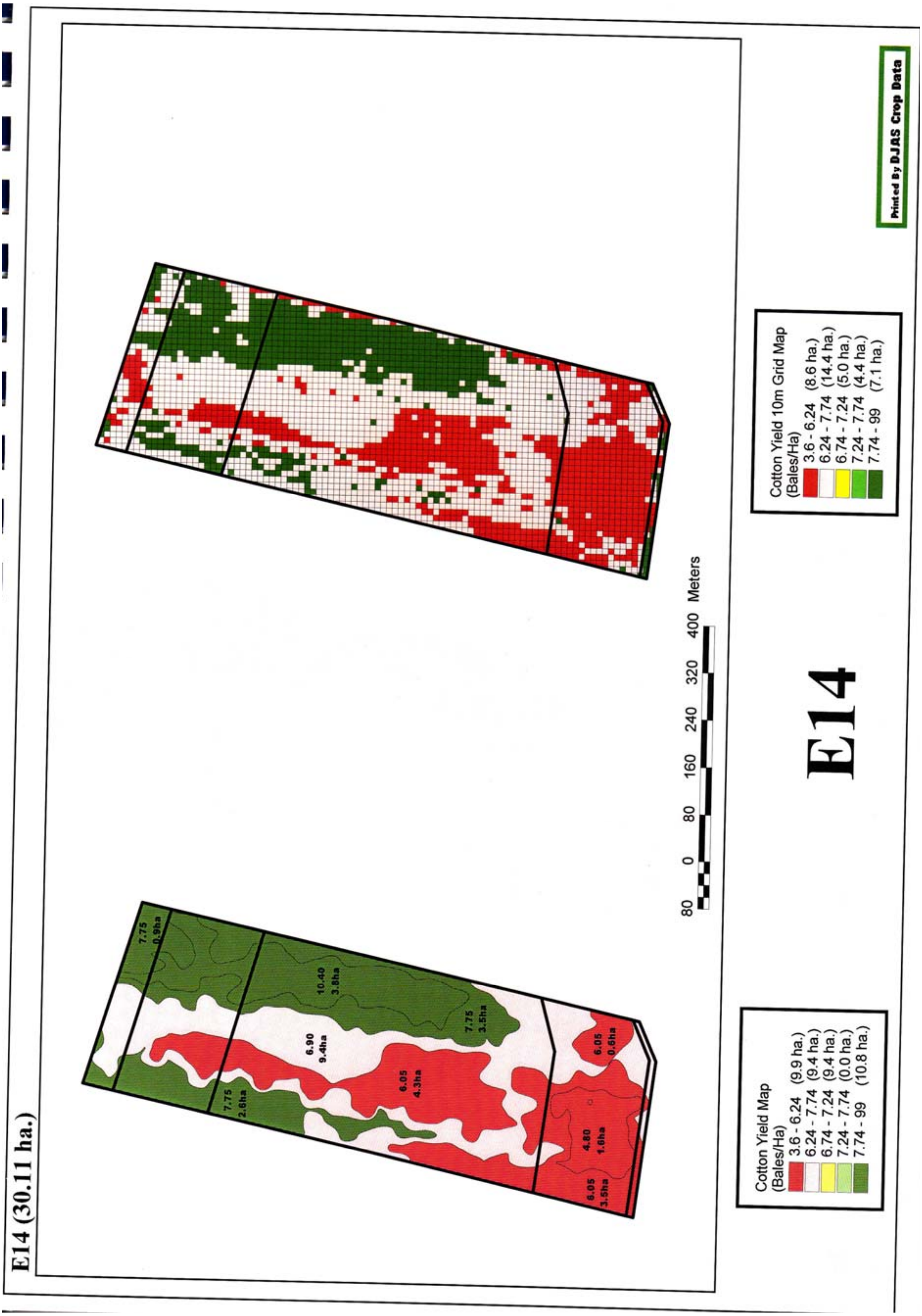
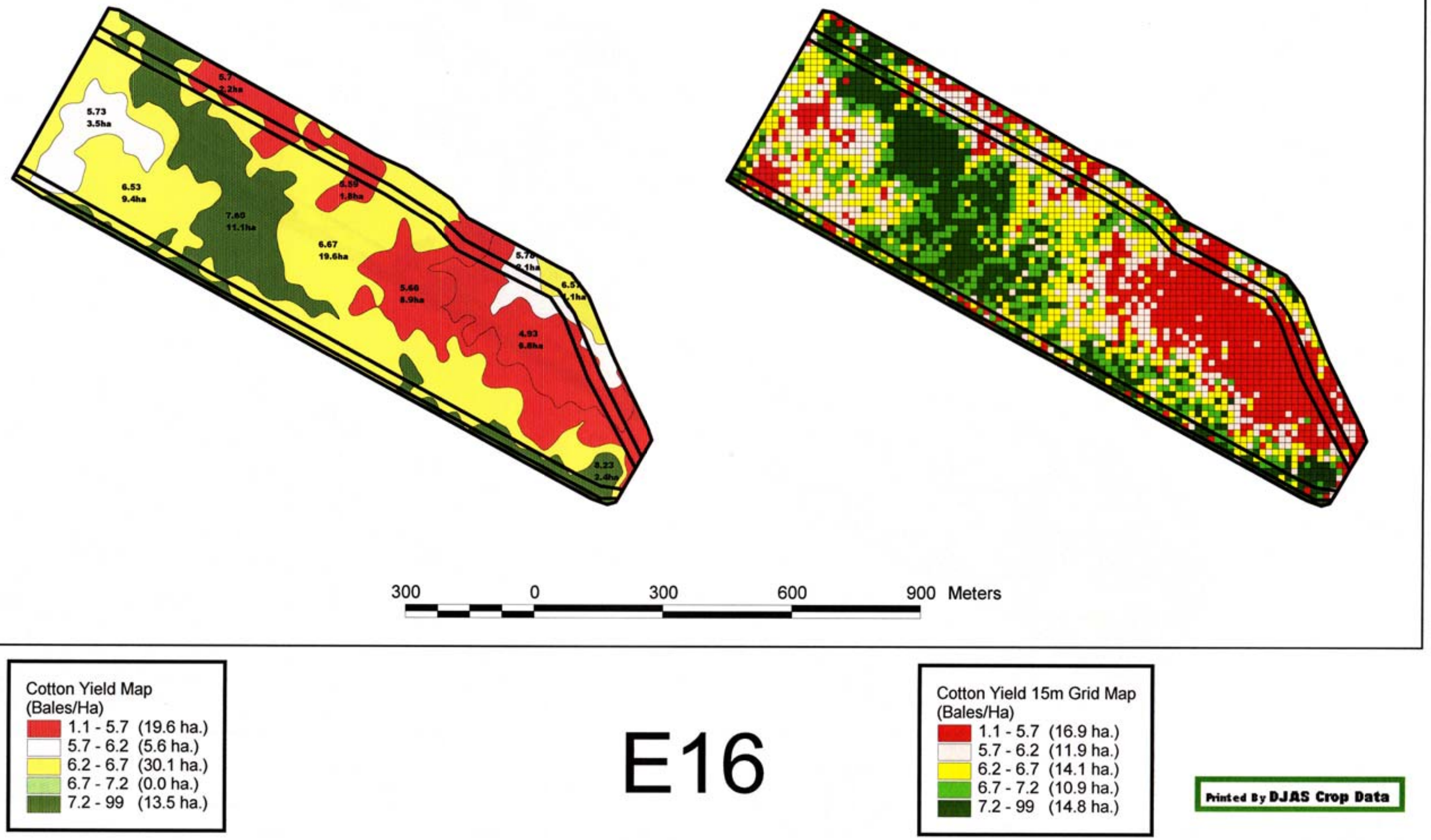
REGION	HECTARES	FIELD CODE	ROW LENGTH 1 Meters	ROW LENGTH 2 Meters	1/5 PORTION Lengths (m)	AV YIELD Bales/Ha	HD AV YIELD Bales/Ha	TD AV YIELD Bales/Ha	YLD DIFFERENCE BALES/HA
St George		SG1	656	873	119	9.9	9.68	9.96	0.28
		SG2	800	1006	148	9.19	8.88	9.2	0.32
		SG3	356	746	60	8.88	8.15	9.7	1.55
		SG4	290	978	46	8.87	8.01	9.62	1.61
		SG5	336	518	55	5.91	4.52	7.38	2.86
		SG6	714	587	105	10.02	9.87	10.23	0.36
	82.5	SG7	950	839	156	10.67	9.48	11.14	1.66
	84.8	SG8	712	707	129	10.88	10.89	11.11	0.22
	50.4	SG9	746	746	137	10.78	10.4	11.07	0.67
	38.3	SG10	755	751	138	11.25	10.57	11.41	0.84
	35	SG11	1118	1122	212	11	10.9	11.2	0.3
	104.7	SG12	864	1123	161	11.49	11.36	11.66	0.3
	104.5	SG13	1045	827	153	10.44	10.23	10.43	0.2
	165.2	SG14	851	858	158	8.18	8.12	8.28	0.16
	168	SG15	866	878	161	8.88	8.77	9.02	0.25
	143.5	SG16	848	823	153	9	8.54	9.14	0.6
	165.3	SG17	865	860	160	8.17	7.78	8.48	0.7
	91.3	SG18	920	915	171	8.81	8.94	8.89	0.05
	123.5	SG19	890	906	166	8.48	8.63	8.35	0.28
	123.5	SG20	710	855	130	7.75	8.23	7.48	0.75
		SG21	645	779	117	9.14	9.42	8.88	0.54
	64.3	SG22	1015	888	166	6.44	6.41	6.03	0.38
	41.6	SG23	888	798	148	7.54	7.57	7.43	0.14
	58.4	SG24	924	733	135	7.62	7.36	7.18	0.18
	91.8	SG25	984	996	185	10.69	11.07	10.08	0.99

Appendix 2. Individual Yield Maps of the Fields Analysed in Each Catchment



E16 (68.64 ha.)


5.7
2.2ha
5.73
3.5ha
6.53
9.4ha
7.60
11.1ha
5.59
1.8ha
6.67
19.6ha
5.60
8.9ha
4.93
8.8ha
8.23
2.4ha
300
0
300
600
900 Meters
Cotton Yield Map
(Bales/Ha)
1.1 - 5.7 (19.6 ha.)
5.7 - 6.2 (5.6 ha.)
6.2 - 6.7 (30.1 ha.)
6.7 - 7.2 (0.0 ha.)
7.2 - 99 (13.5 ha.)
E16
Cotton Yield 15m Grid Map
(Bales/Ha)
1.1 - 5.7 (16.9 ha.)
5.7 - 6.2 (11.9 ha.)
6.2 - 6.7 (14.1 ha.)
6.7 - 7.2 (10.9 ha.)
7.2 - 99 (14.8 ha.)
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