Activity # 1- Assessing Horticultural Crop Suitability for the Queensland Murray Darling Basin Study Area

Case study I: Bioeconomic analysis of Southern Queensland sweet corn production

(1 August 2014 to 30 June 2016)

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Citation: Carey, D., Deuter, P., Zull, A., Taylor, H., White, N (2017) High Value Horticulture Value Chains for the Queensland Murray-Darling Basin Project: Activity 1 – Assessing Horticulture Crop Suitability for the Queensland Murray Darling Basin Study Area report. Queensland Government Department of Agriculture and Fisheries.

This publication has been compiled by David Carey of Agri-Science, Department of Agriculture and Fisheries.

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Case study I: Bioeconomic analysis of Southern Queensland sweet corn production

The gross value of Australian sweet corn production declined by 2.7per cent in 2013-14 compared to 2010-11, resulting in a production value of $83.5 million in 2013-14 according to Ausveg. Queensland production accounted for over 55 per cent of Australia's gross crop value in 2013-14. The number of sweet corn growers had decreased by 38 per cent since 2010-11, to 183 growers in 2013-14. Queensland is Australia's dominant producer of sweet corn.

(Ausveg statistics for corn)

Any sustainable growth in sweet corn production will depend on access to profitable export markets. Some increase in production for the domestic market is possible, though overproduction will rapidly occur. The fresh market sweet corn industry (domestic and export) like most vegetable industries, has a small number of large growers who produce 80-90 per cent of marketed product. Pre-packed cobs have a significant market share, with corn in husk making up the balance. There is also a small market for baby corn, though this product meets considerable competition from low labour cost imported product.

Southern Queensland supplies the market from spring to autumn, while New South Wales produces summer and autumn crops. Victoria, Tasmania and South Australia produce mainly summer crops, while North Queensland dominates winter production. The only other Australian production during winter is from the Ord in Western Australia. Large dominant suppliers operate in the fresh sweet corn market supplying chain stores directly as well as supplying some product to the central marketing system. There are a limited number of smaller growers who supply the central market system.

Irrigated cotton systems require break-crops within crop rotations to reduce soil borne pest and disease that affect cotton yields. It is not uncommon for maize (corn) to be used as a break crop. Maize is grown for livestock fodder and harvested once the plant has matured, whereas sweet corn is harvest at the milk stage. The production system for maize and sweet corn is very similar; it is the time of harvesting and the processing methods that are the main difference. Therefore, it may be possible to incorporate sweet corn production into irrigated cotton systems as a break crop, provided that it can be grown to a marketable standard for human consumption.

Bioeconomic crop analysis can be used to assess the viability of growing irrigated sweet corn within the Queensland Murray Darling Basin (QMDB) study area. In this example we start by comparing sweet corn production in the St George area of the QMDB study area to that of the Lockyer Valley; a nationally significant producer of sweet corn for the Australian domestic market. The sweet corn bioeconomic analysis will consider the impacts of heat stress on yields, gross margins and net profits across the QMDB study area.

To minimise the impact of excessive summer heat on marketable yields, a split-season production window (growing either side of peak summer heat) was investigated in the St George portion of the QMDB study area and compared to continuous summer production in the Lockyer Valley and Toowoomba region.

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1 Sweet corn bioeconomic model parameterisation

1.1 Bioeconomic parameter: heat stress

Sweet corn is produced commercially in many regions of Australia, with varying planting times due to climatic conditions (Wright et.al. 2005). In Queensland, one of the most critical yield constraints for sweet corn is heat stress events during the silking stage. Maximum daily temperatures above 35°C maximum for four consecutive days cause uneven pollination, resulting in "blanking" where not all kernels on the cob develop and fill; severely affected cobs are unmarketable. A review of historical weather records reveals that a primary constraint in the commercial production of sweet corn in the St George region will be biophysical -in this case heat stress. To investigate the potential yield impact of high summer temperatures experienced in parts of the QMDB study area team members have obtained, analysed and compared historical Bureau of Meteorology (BoM) maximum temperature data for the QMDB study area . This maximum temperature impact analysis is based on weekly crop plantings beginning each year on thel4th of August (harvested 25th October) through until the 16th of April (harvested 27th June) and compared to the current continuous summer plantings of sweet corn carried out in the Lockyer Valley. Due to higher summer temperatures in the St George region, two analyses have been undertaken: continuous planting and split season planting. The non-planting window in St George is between 2nd of October and 8th of January, based on the likelihood of plant heat stress during the crop silking period and the resulting economic impact of yield loss.

In conducting this yield impact analysis staff used the last 38 years of local BoM data 1977-2014 for both St George and the Lockyer Valley (BoM Gatton-UQ data).

In this analysis, a heat stress event is deemed to have occurred when there are four or more consecutive days 35°C during silking. Expert opinion and feedback reveals that such a heat stress event causes marketable yield loss from a market quality perspective.

1.2 Bioeconomic parameter: regional sweet corn gross margins

The variable crop production costs have been divided into pre-and post-heat stress events (see gross-margin3 in Table 6). The purpose of this is to apportion costs incurred by growers for both failed and successful crops. For example, if a heat stress event was to occur during silking and the crop is lost, the grower would still incur planting costs but not the harvesting or transportation costs. Likewise a proportion of other costs may be saved, such as irrigation costs, as no additional irrigation would be applied to the heat-stressed crop.

Compared to the sweet corn gross margin for the Lockyer Valley of $5443/ha in Table 6, St George gross margin is lower due to the additional transportation costs of moving packed sweet corn from St George to the Brisbane market ($30/pallet higher) and higher labour costs (increased from $27/hr to $30/hr), all other operations and prices have been kept constant between the St George and Lockyer Valley production systems in this analysis. The added input cost (transport and labour) decreases the gross margins for sweet corn in the St George region to $4566/ha.

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[3] Note these gross margins were generated in 2013, which are slightly different to those reported in Appendix 8: Annual AgMargins™ for 2016 and reported in Table 4 — Irrigated crop gross margins per hectare and per region.

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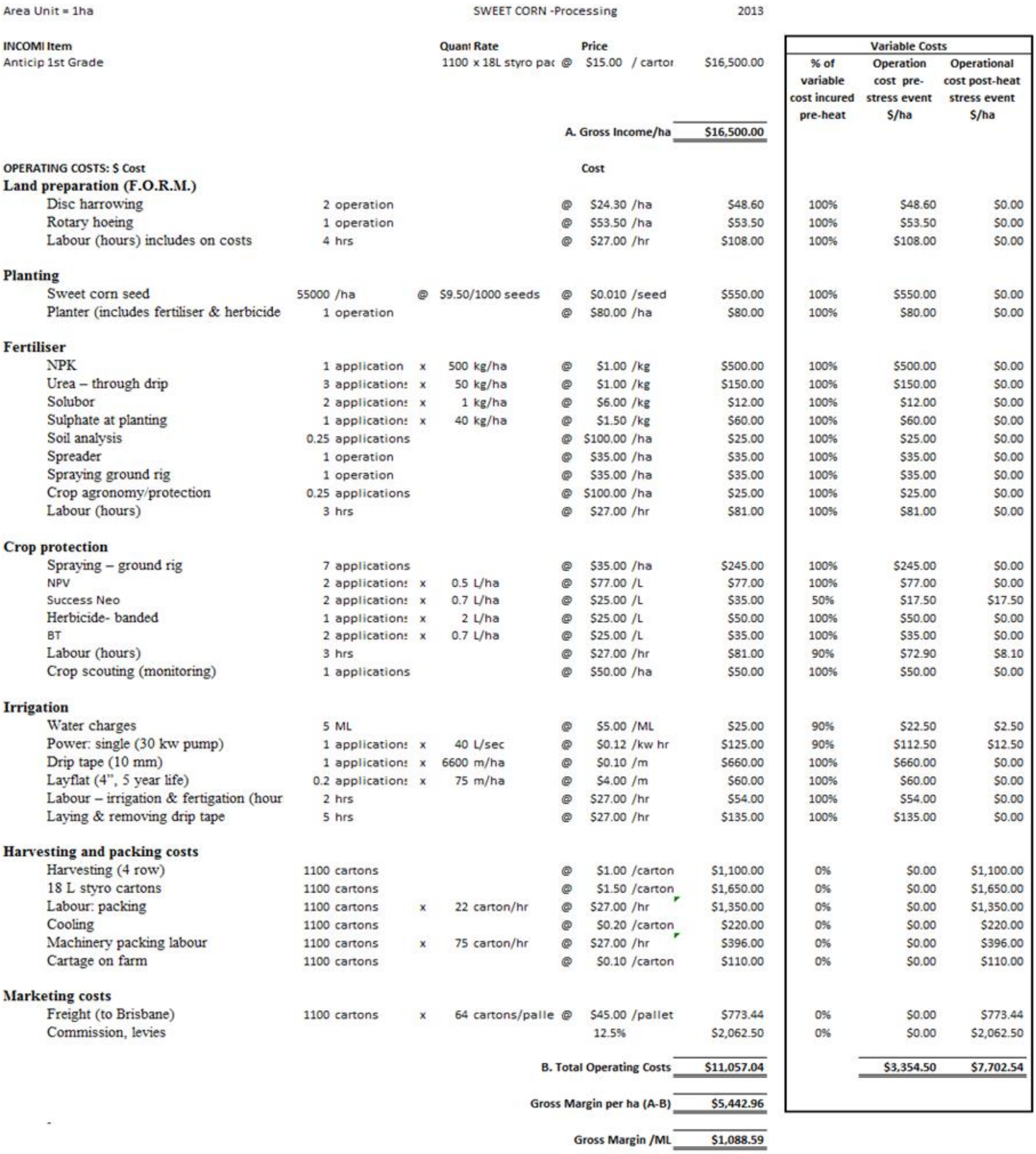
Table 6 - Example Gross Margin: irrigated sweet corn grown in the Lockyer Valley



Area Unit = 1ha					SWEET CORN -Processing	2013			
							Variable Costs		
INCOMI Item			**Quant Rate**		**Price**		**% of variable cost incured pre-heat**	**Operation cost pre-stress event $/ha**	**Operational cost post-heat stress event $/ha**
Anticip 1st Grade			1100 x 18L styro pac	@	$15.00 / cartor	$16,500.00			
					A. Gross Income/ha	**$16,500.00**			
OPERATING COSTS: $ Cost					**Cost**				
Land preparation (F.O.R.M.)									
Disc harrowing	2 operation			@	$24.30 /ha	$48.60	100%	$48.60	$0.00
Rotary hoeing	1 operation			@	$53.50 /ha	$53.50	100%	$53.50	$0.00
Labour (hours) includes on costs	4 hrs			@	$27.00 /hr	$108.00	100%	$108.00	$0.00
Planting									
Sweet corn seed	55000 /ha	@	$9.50/1000 seeds	@	$0.010 /seed	$550.00	100%	$550.00	$0.00
Planter (includes fertiliser & herbicide	1 operation			@	$80.00 /ha	$80.00	100%	$80.00	$0.00
Fertiliser									
NPK	1 application	x	500 kg/ha	@	$1.00 /kg	$500.00	100%	$500.00	$0.00
Urea – through drip	3 application:	x	50 kg/ha	@	$1.00 /kg	$150.00	100%	$150.00	$0.00
Solubor	2 application:	x	1 kg/ha	@	$6.00 /kg	$12.00	100%	$12.00	$0.00
Sulphate at planting	1 application:	x	40 kg/ha	@	$1.50 /kg	$60.00	100%	$60.00	$0.00
Soil analysis	0.25 applications			@	$100.00 /ha	$25.00	100%	$25.00	$0.00
Spreader	1 operation			@	$35.00 /ha	$35.00	100%	$35.00	$0.00
Spraying ground rig	1 operation			@	$35.00 /ha	$35.00	100%	$35.00	$0.00
Crop agronomy/protection	0.25 applications			@	$100.00 /ha	$25.00	100%	$25.00	$0.00
Labour (hours)	3 hrs			@	$27.00 /hr	$81.00	100%	$81.00	$0.00
Crop protection									
Spraying – ground rig	7 applications			@	$35.00 /ha	$245.00	100%	$245.00	$0.00
NPV	2 application:	x	0.5 L/ha	@	$77.00 /L	$77.00	100%	$77.00	$0.00
Success Neo	2 application:	x	0.7 L/ha	@	$25.00 /L	$35.00	50%	$17.50	$17.50
Herbicide- banded	1 application:	x	2 L/ha	@	$25.00 /L	$50.00	100%	$50.00	$0.00
BT	2 application:	x	0.7 L/ha	@	$25.00 /L	$35.00	100%	$35.00	$0.00
Labour (hours)	3 hrs			@	$27.00 /hr	$81.00	90%	$72.90	$8.10
Crop scouting (monitoring)	1 applications			@	$50.00 /ha	$50.00	100%	$50.00	$0.00
Irrigation									
Water charges	5 ML			@	$5.00 /ML	$25.00	90%	$22.50	$2.50
Power: single (30 kw pump)	1 application:	x	40 L/sec	@	$0.12 /kw hr	$125.00	90%	$112.50	$12.50
Drip tape (10 mm)	1 application:	x	6600 m/ha	@	$0.10 /m	$660.00	100%	$660.00	$0.00
Layflat (4", 5 year life)	0.2 application:	x	75 m/ha	@	$4.00 /m	$60.00	100%	$60.00	$0.00
Labour – irrigation & fertigation (hour	2 hrs			@	$27.00 /hr	$54.00	100%	$54.00	$0.00
Laying & removing drip tape	5 hrs			@	$27.00 /hr	$135.00	100%	$135.00	$0.00
Harvesting and packing costs									
Harvesting (4 row)	1100 cartons			@	$1.00 /carton	$1,100.00	0%	$0.00	$1,100.00
18 L styro cartons	1100 cartons			@	$1.50 /carton	$1,650.00	0%	$0.00	$1,650.00
Labour: packing	1100 cartons	x	22 carton/hr	@	$27.00 /hr	$1,350.00	0%	$0.00	$1,350.00
Cooling	1100 cartons			@	$0.20 /carton	$220.00	0%	$0.00	$220.00
Machinery packing labour	1100 cartons	x	75 carton/hr	@	$27.00 /hr	$396.00	0%	$0.00	$396.00
Cartage on farm	1100 cartons			@	$0.10 /carton	$110.00	0%	$0.00	$110.00
Marketing costs									
Freight (to Brisbane)	1100 cartons	x	64 cartons/palle	@	$45.00 /pallet	$773.44	0%	$0.00	$773.44
Commission, levies					12.5%	$2,062.50	0%	$0.00	$2,062.50
					B. Total Operating Costs	**$11,057.04**		**$3,354.50**	**$7,702.54**
					Gross Margin per ha (A-B)	**$5,442.96**			
-									
					Gross Margin /ML	**$1,088.59**			

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An economic sensitivity analysis was conducted on a sweet corn crop produced in the Lockyer Valley to identify what variables have the highest impact on gross margins: quantity (yield), price, costs, or water usage.

Table 7 - Sweet corn economic sensitivity analysis.

Based on Gatton gross margins (2013)	$/ha	Change %
Baseline net profit (no change)	$5,511	N.a.
10% Change in output quantity	$7,983	42.2%
10% Change in output price	$8,543	52.4%
10% Change in variable costs	$4,412	19.9%
10% Change in water usage	$5,496	0.3%
10% Change in power: single (30 kw p	$5,482	0.5%

The sensitivity analysis demonstrates that changes in sweet corn yield or price have the greatest impacts on gross margins. It is assumed that the price received for sweet corn would be similar for growers in the St George and Lockyer Valley regions. Therefore the greatest impact on the economic viability of sweet corn production in the St George region is likely to be decreases in yield due to heat stress events during silking.

1.3 Bioeconomic parameter: farm enterprise overhead costs

This bioeconomic analysis was developed based on a standardised farm enterprise area of 360 ha, with $500,000 of farm overheads allocated to the sweet corn crop ¬this equates to $1385/ha. These overheads were used to estimate net profits per hectare. Most fresh market sweet corn producers budget on achieving an average market price over the season, though daily and weekly returns fluctuate due to market demand, product quality and volume. In this bioeconomic regional comparison, the farm gate price used is constant throughout the season.

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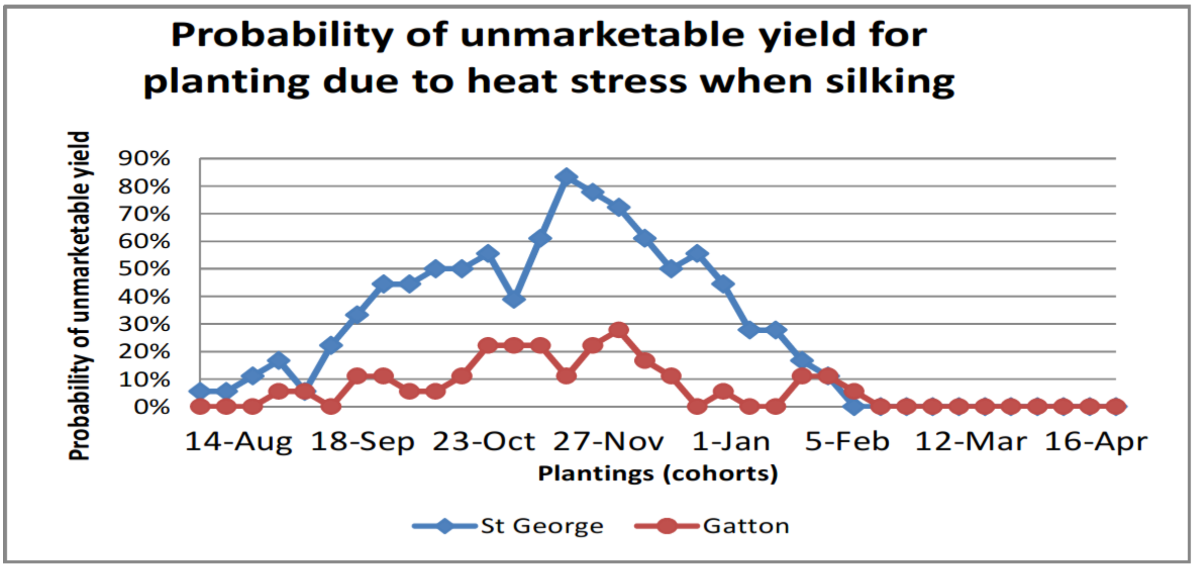
2 Sweet corn bioeconomic results for Gatton and St George

2.1 Bioeconomic results: heat stress on yields

Weather records indicate there is a far greater probability of heat stress events occurring in the St George region than in the Lockyer Valley (Figure 63). For example, using the 1997-2014 climate data the 15th planting (cohort) which was planted on the 20th of November and harvested on 31st of January only had a 22% likelihood of producing a marketable yield in St George compared to an 89% chance in the Lockyer Valley.

Figure 63 — Probability of sweet corn plantings (cohorts) having an unmarketable yield due to four or more consecutive days 35°C during silking at St George and Gatton.



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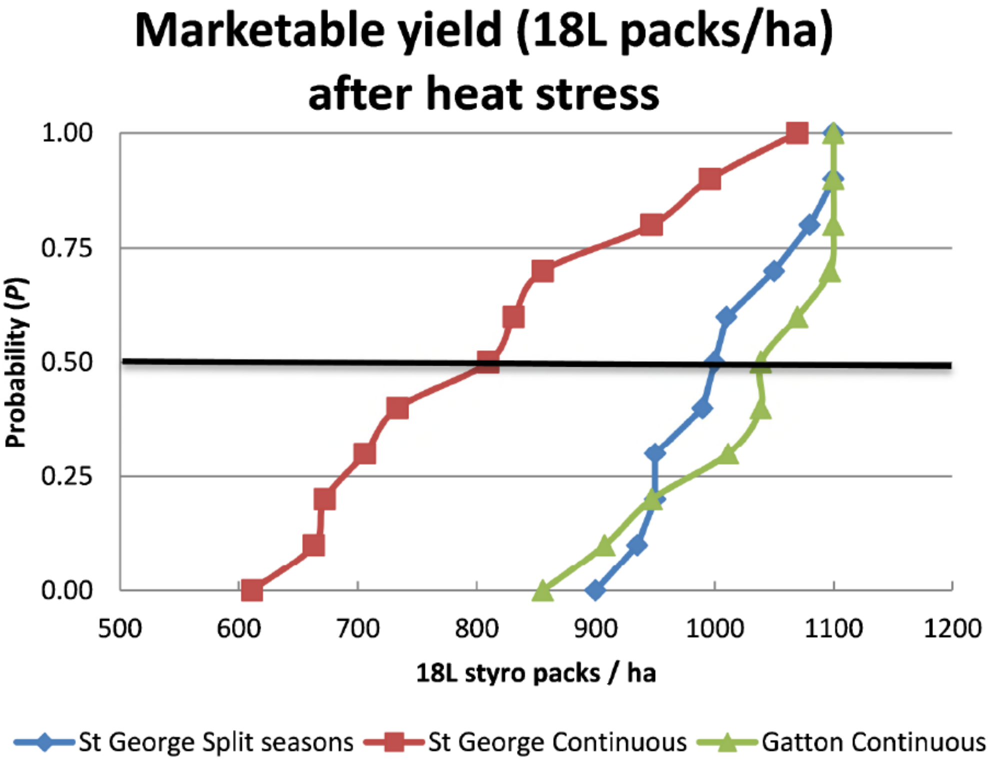
To understand the impact of heat stress on production in St George for both split and continuous season plantings, yields have been compared to the Lockyer Valley using cumulative distribution functions (CDF), see Figure 64.

Figure 64 — Sweet corn marketable yield probabilities for: Gatton continuous, St George continuous and St George split seasons (2007-2014). The expected value is the median (0.50) and the worst- and best-case scenarios are 0.00 and 1.00 respectively.



The expected yields (median P=0.5) for the Lockyer Valley, St George split season, and St George continuous season based on BoM temperature data (1997-2014) are estimated to have expected annual marketable yields of 1039, 1000, and 810 packages (18-litre styro) per hectare, respectively. The best-case scenario (P=1.0) resulted in similar yields for all three production systems of 1100, 1100, and 1069 styro packs per hectare, respectively. This occurred in 2007-08 when only one planting suffered marketable yield loss under continuous cropping in St George, and no marketable yield loss due to excessive heat at the plant silking stage would have occurred in the other production systems.

BoM temperature data (1997-2014) for the comparison production regions show the worst-case scenario (P=0.0) would result in annual yields of 856, 900, and 611 icepacks per hectare, respectively. This occurred in 1997-98 with 16 and 8 plantings suffering marketable yield loss with continuous cropping in St George and the Lockyer Valley, respectively. There is a 20% chance of St George producing higher yields with a split crop system compared to continuous cropping in the Lockyer Valley. This is because the Lockyer Valley is still exposed to some extreme high temperature events in the middle of summer in some years.

A cumulative distribution functions (CDF) has also been used to present both the expected gross margins and risk associated with the three production systems as a result of heat stress events, using the production input costs in Table 6 and the added transportation and labour costs for St George (Figure 65).

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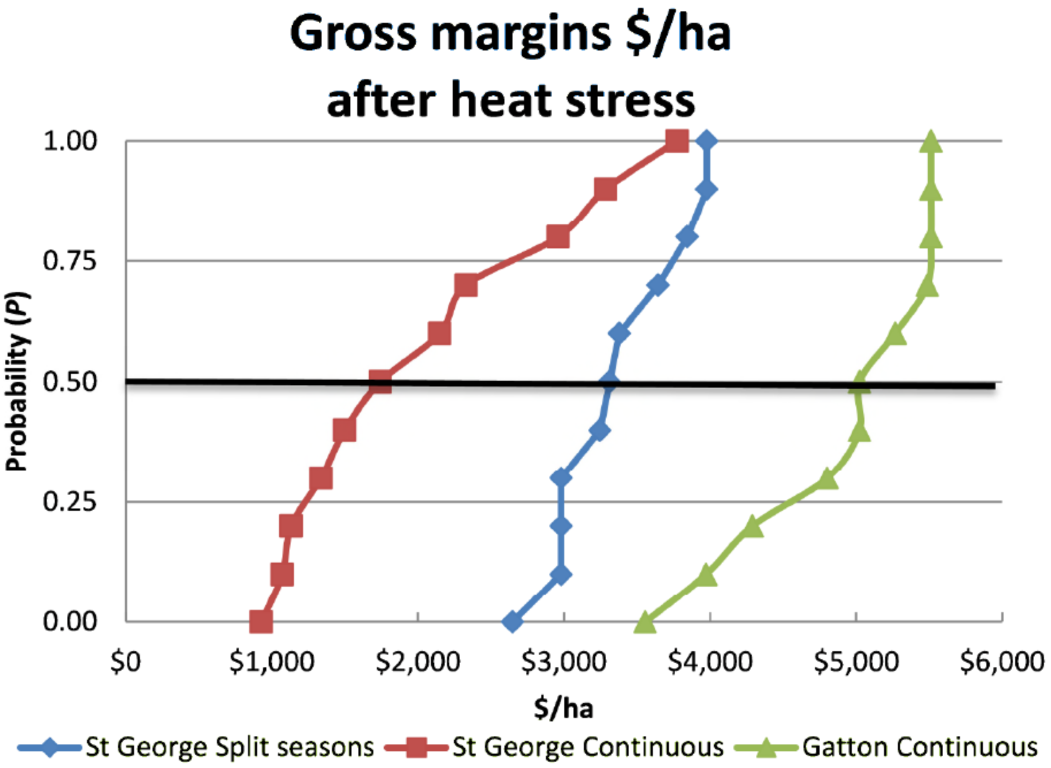
2.2 Bioeconomic results: heat stress on gross margins

Figure 65 — Sweet corn gross margins based on heat stress events (2007-2014) for: Gatton continuous, St George continuous and St George split seasons. The expected value is the median (0.50) and the worst- and best-case scenarios are 0.00 and 1.00 respectively.



The gross margins for the St George production systems are significantly lower than that offered in the Lockyer Valley. The expected return (P=0.5) for the Lockyer Valley crops is $5022/ha compared to $3312/ha and $1742/ha in the St George regions for the split and continuous production systems, respectively.

The expected (P=0.5) gross margins for all the production systems are lower than the gross margins reported for St George of $3977/ha and the Lockyer Valley $5511/ha (Table 6). This is to be expected as normal gross margins are based on successful crops while this analysis includes heat-stress events that impact marketable yield. The potential gross margins can be realised under the best-case scenario (P=1.0) due to low incidences of heat stress events in some years.

Under the worst-case scenario (P=0.0) the St George split system can produce higher marketable yields than the Lockyer Valley (Figure 64), but it still has a lower gross margins due to additional transportation and labour costs (Figure 65). Although the yield analysis indicated that there may be some advantage of the St George split-system over continuous summer production in the Lockyer Valley in poor years (20% of the time), gross margins indicate the Lockyer Valley has a clear comparative advantage (stochastic dominance) over the St George split window production system which is always dominant over the St George continuous cropping system (Figure 65).

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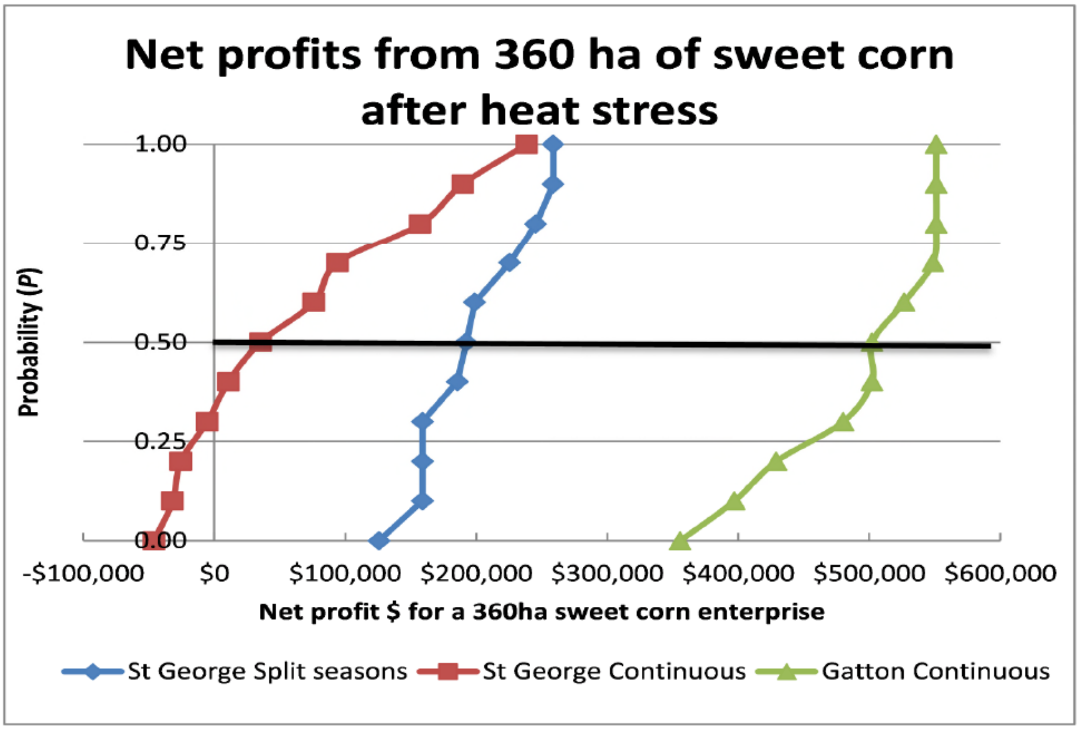
2.3 Bioeconomic results: heat stress on net profits

Gross margins are beneficial for short-term decisions as they help to determine which crop to plant using the same capital equipment; however, gross margins should not be used as a measure of profitability or used for long-term decisions such as capital investments or strategic planning. Net profits are a better tool to guide a farmer to determine the benefits and costs of adopting an alternative production system. The net profit analysis depicted below is based on a 360 ha enterprise with $50k of overheads allocated to this sweet corn enterprise (Figure 66).

Figure 66 — Probable sweet corn annual net profit at St George and Gatton (2007-2014), under split and continuous seasons. The expected value is the median (0.50) while the worst and best-case scenarios are 0.00 and 1.00 respectively



Based on the input data used in this example, the expected net profit (P=0.5) from sweet corn in St George in a split production window system is estimated to be less than half of that in the Lockyer Valley, $192,320 and $502,220 respectively on a 360 ha enterprise. Continuous sweet corn summer cropping in St George is expected to result in only a $35,330 net profit, and there is a 32% likelihood of making a loss with this production system. Under the worst-case scenario (P=0.0) in this example, both continuous summer cropping in the Lockyer Valley and the St George split system result in a net profit: $355,600 and $125,830, respectively. Under the best-case scenario (P=1.0) there are significantly higher net profits for the Lockyer Valley than either the split or continuous systems in St George: $551,096, $258,801 and $238,486, respectively. It may be possible to improve the expected and worse-case scenario net-profits by making more targeted better informed planting decisions in years with a higher likelihood of heat stress events, i.e. in El Nino years.

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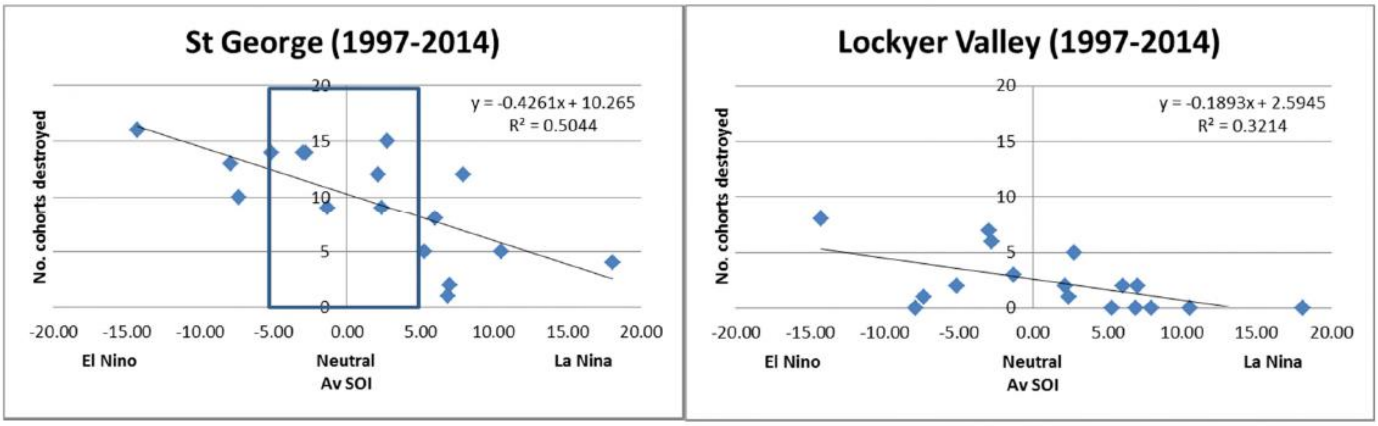
To investigate any correlation between the Southern Oscillation Index (SOI) and heat-stress events, the relevant data has been plotted for St George and the Lockyer Valley regions (Figure 67).

Figure 67 — Correlation between the Southern Oscillation Index (SOI) and the effect of heat-stress events on sweet corn marketable yield at St George and Gatton.



The linear regression and measure of dependence indicates that there is a correlation between the SOI and heat-stress events, especially in the St George region (R2=0.50).

When in the neutral phase (S01=±5), the SOI is a poor indicator of heat stress events. The results indicate that there is higher probability of heat-stress events during El Nino years than during La Nina years. This information may assist not only sweet corn growers in St George, but also in the Lockyer Valley. With this knowledge growers could decide to change to a split system production season during El Nino years.

Any new sweet corn production supplied to the domestic market via the central marketing system may well result in lower domestic sweet corn prices due to oversupply - reducing both the gross margins and net profits. As sweet corn economic returns are highly sensitive to decreases in farm gate prices, it is probable that St George sweet corn growers will not be able to compete on the domestic market with existing growers. Any new sweet corn production in the QMDB Study Area should be targeting international markets. Developing new international markets and supply chains for sweet corn may be beneficial to potential growers in the QMDB study area and existing suppliers in the Lockyer Valley and elsewhere. Quality sweet corn product exported from the QMDB study area could potentially assist existing Lockyer Valley producers and marketers by enhancing product volume and continuity of Australian supply to a targeted export market.

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3 GIS bioeconomic modelling of sweet corn across the QMDB

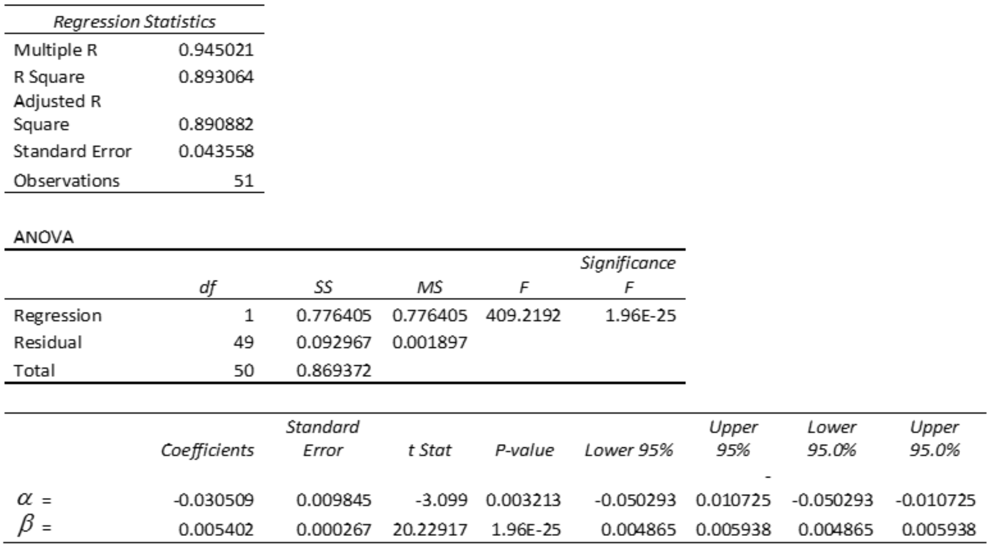
3.1 GIS bioeconomic: yield regression analysis

The previous bioeconomic analysis examines biophysical and economic information about growing sweet corn in the Lockyer Valley and in St George which is part of the QMDB study area. However there are vast areas between these two locations that may be suited to growing sweet corn. One method of addressing this would be to apply the previous detailed bioeconomic analysis which highlights the impact of high summer temperatures on marketable yield to other specific locations within the QMDB study areas; however, this would require substantial local site data. This site specific location based data would not cover all the QMDB study area. Members of the project team decided to use BoM gridded temperature data sets and regression analysis to generate a spatial map of potential sweet corn yields, gross margins and net profits, based on temperature records. This mapped spatial analysis visually indicates to individual growers whether developing a detailed bioeconomic model would be a worthwhile step in the crop choice decision making process. The first thing the team investigated was the use of a seasonal surrogate that correlates the probability of individual weekly plantings (cohorts) failing with respect to the frequency of daily heat-stress 35°C) events within a season. This will generate results which can be applied across southern Queensland. It is not practical to run the full bioeconomic model for all locations within the QMDB study area based on weekly plantings failing with respect to daily heat-stress 35°C). However the bioeconomic model we have estimates of the number of failed planting (cohorts) per season (1997-2014) in three productions systems: Lockyer Valley and St George using continuous and split season. By simply dividing these values with the number of total planting we may be able to derive the percentage of failed crops in each season and region. Therefore it may be possible to identify a correlation between the number of failed plantings estimated by the bioeconomic model and the total number of days 35°C within a season which can later be used in GIS analysis across the QMDB study area.

We started by using a linear regression:

$$w=a+Bx \qquad [1]$$

where w is the level of crop failure with respect to x being the number heat stress days within a season, and a is a constant. Using an analysis of variance (ANOVA) within Excel the following results were generated:



Regression Statistics	
Multiple R	0.945021
R Square	0.893064
Adjusted R Square	0.890882
Standard Error	0.043558
Observations	51

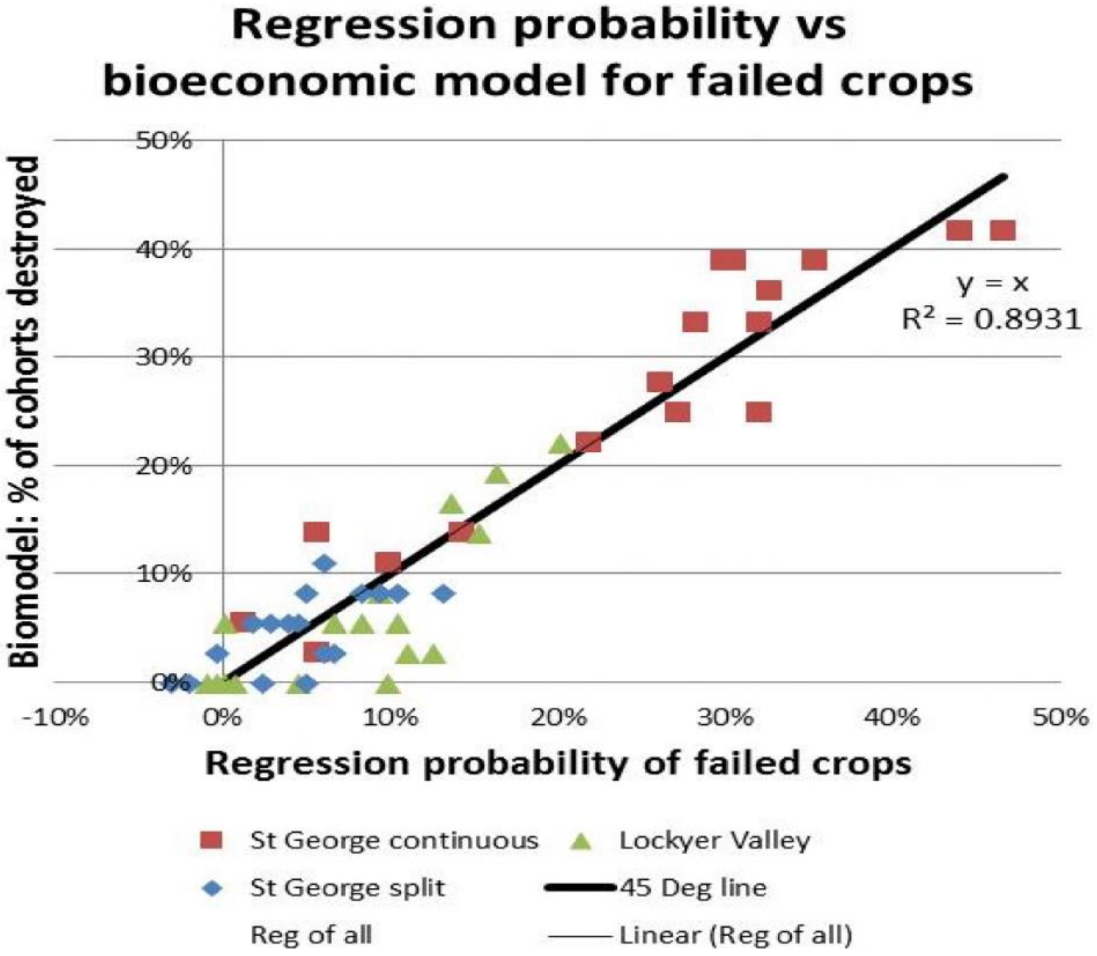
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.776405	0.776405	409.2192	1.96E-25
Residual	49	0.092967	0.001897		
Total	50	0.869372			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
α =	-0.030509	0.009845	-3.099	0.003213	-0.050293	- 0.010725	-0.050293	-0.010725
β =	0.005402	0.000267	20.22917	1.96E-25	0.004865	0.005938	0.004865	0.005938

The results indicate that for every day within a season that is 35°C there is a 0.005% increased probability of crop failure. The R^2 indicates that the regression estimates 89% of the information from the full bioeconomic model. Additionally, the constant (*a*) is close to the point of origin (zero). The following are the results from the bioeconomic model and the regression analysis (Figure 68).

Figure 68 - Illustrating the relationship of estimated seasonal failed sweet corn crops using the bioeconomic model (weekly planting cohorts and failure occurs when 4 days of 35°C during silking) against the total days in a season 35°C using a linear regression of (a =-0.0305 & B = 0.0054), for three production systems (1997-2014).



There is a clear correlation between the bioeconomic model results of failed crops and the regression analysis with respect to the total number of heat stress days in a season. The relationship between the two models fits neatly around the 45° line Y=X for all data across all production systems indicates that the regression model captures 89% of the information produced by the full bioeconomic model. This indicates that we can estimate seasonal sweet corn yields at a spatial scale across southern Queensland using GIS data as a function of the total number of days 35°C, for both continuous and split season production. Marketable yield without heat stress is given in Table 6 as 1100 (18L) styro packs (icepacks) per hectare. In a year were there is 20% crop failure the average yield for that year is estimated to be 880 18L styros/ha.

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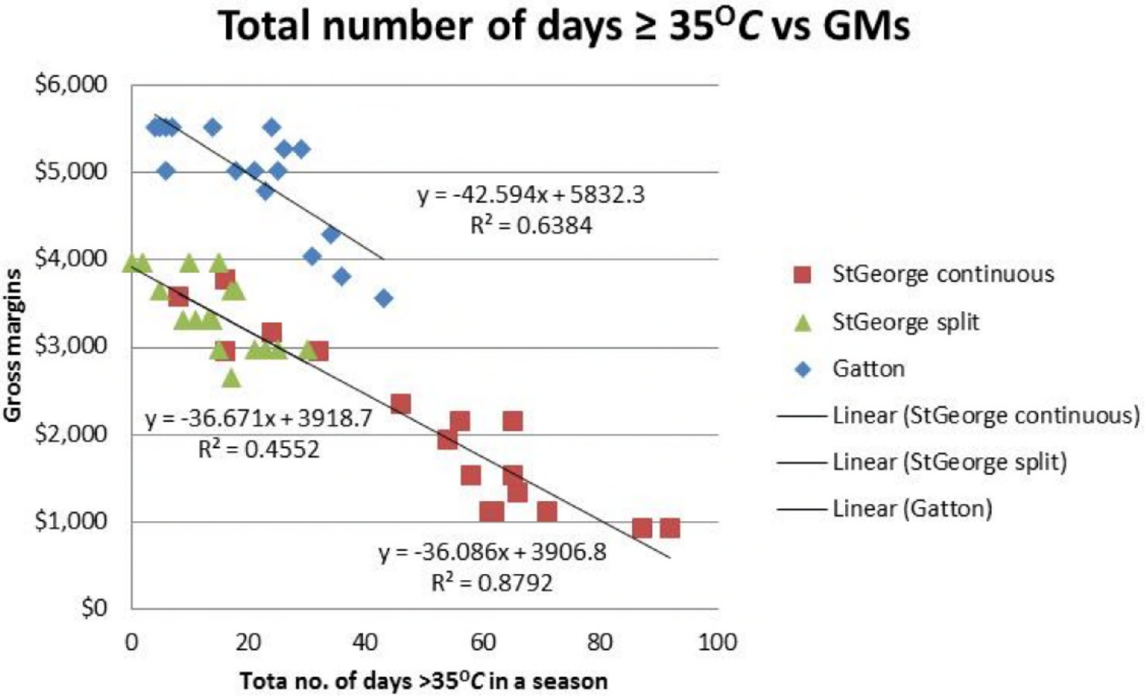
3.2 GIS bioeconomic: gross margin regression analysis

This information allows sweet corn yields to be estimated spatially and this means an ability to estimate sweet corn gross margins spatially for southern Queensland. This data was checked by investigating the relationship between the gross margins developed with the full bioeconomic model per season for each

Figure 69 - Plotting the bioeconomic modelled gross margins with respect to the total number of days 35°C within a season and production system (1997-2014).



There is a clear correlation between the bioeconomic gross margins and total number of days that are 35°C within a season and production system (1997¬2014). There is a negative correlation between gross margins and the total number of days in a season that are 35°C. The regression lines of the two St George production systems are similar with an intercept of 3919 and 3907 for split and continuous production, respectively. These figures are the regression estimate of gross margins when there are no heat stress events within a season. These results are very close to the actual gross margin of sweet corn in St George of $3977 and the gross margin intercept for the Lockyer Valley is $5833/ha compared to $5511/ha (Table 6). The slopes for the two St George production systems are also similar 36.37 and -36.09, indicating that for every heat stress day 35°C gross margins decrease by -$36/ha, while the data indicates Lockyer Valley gross margins decrease by -$43/ha per heat stress day.

This relationship between gross margins and the total number of days 35°C is better explained with continuous cropping in St George with an R^2 of 0.879. This means that if we know the total number of heat stress days in a season we can estimate gross margins with an almost 90% accuracy compared to the full bioeconomic model. The fits of the St George split season and the Lockyer Valley are lower (R^2 = 0.46 and 0.64 respectively) this to be expected as there are less heat stress days affecting yields and gross margins.

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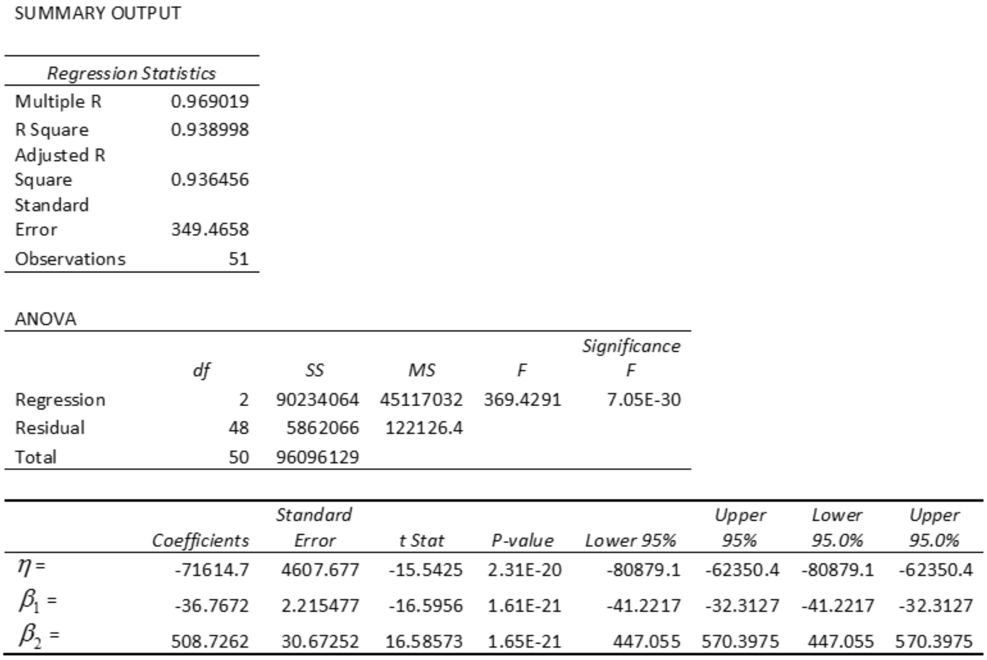
The slopes between all three production systems are similar; however, the Lockyer Valley is higher (different intercept) this is due to the lower cost of production in the Lockyer Value because of lower transportation costs to market and slightly lower labour costs. In other words, within southern Queensland, the further west sweet corn is produced the higher the transportation cost to market, the greater the chance of heat stress events 35°C, and potentially there are slightly higher labour costs. The above analysis confirms it should be possible to use a multi-regression analysis to estimate sweet corn gross margins in southern Queensland spatially based on the total number of heat stress days per season and the distance from the coast (measured in degrees longitudinally), being:

$$GM = N + B_1X_1 + B_2X_2$$ [2]

Where, B_1 is the coefficient with respect to total days in as season 35°C, and B_2 is the coefficient with respect to longitude[4]: Lockyer Valley = 152.0° and St George = 148.5°. Using an analysis of variance (ANOVA) within Excel the data generated the following results:

SUMMARY OUTPUT



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.969019
R Square	0.938998
Adjusted R Square	0.936456
Standard Error	349.4658
Observations	51

ANOVA

	df	SS	MS	F	Significance F
Regression	2	90234064	45117032	369.4291	7.05E-30
Residual	48	5862066	122126.4		
Total	50	96096129			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
η =	-71614.7	4607.677	-15.5425	2.31E-20	-80879.1	-62350.4	-80879.1	-62350.4
β_1 =	-36.7672	2.215477	-16.5956	1.61E-21	-41.2217	-32.3127	-41.2217	-32.3127
β_2 =	508.7262	30.67252	16.58573	1.65E-21	447.055	570.3975	447.055	570.3975

The adjusted R^2 of 0.94 indicates a strong correlation between gross margins with respect to days 35°C and longitude. To compare the full bioeconomic results with GIS-regression analysis, the two sets of results are graphed against each other (Figure 70). This indicates that we can estimate gross margins spatially across southern Queensland using the GIS-regression analysis with 94% accuracy of the full bioeconomic model.

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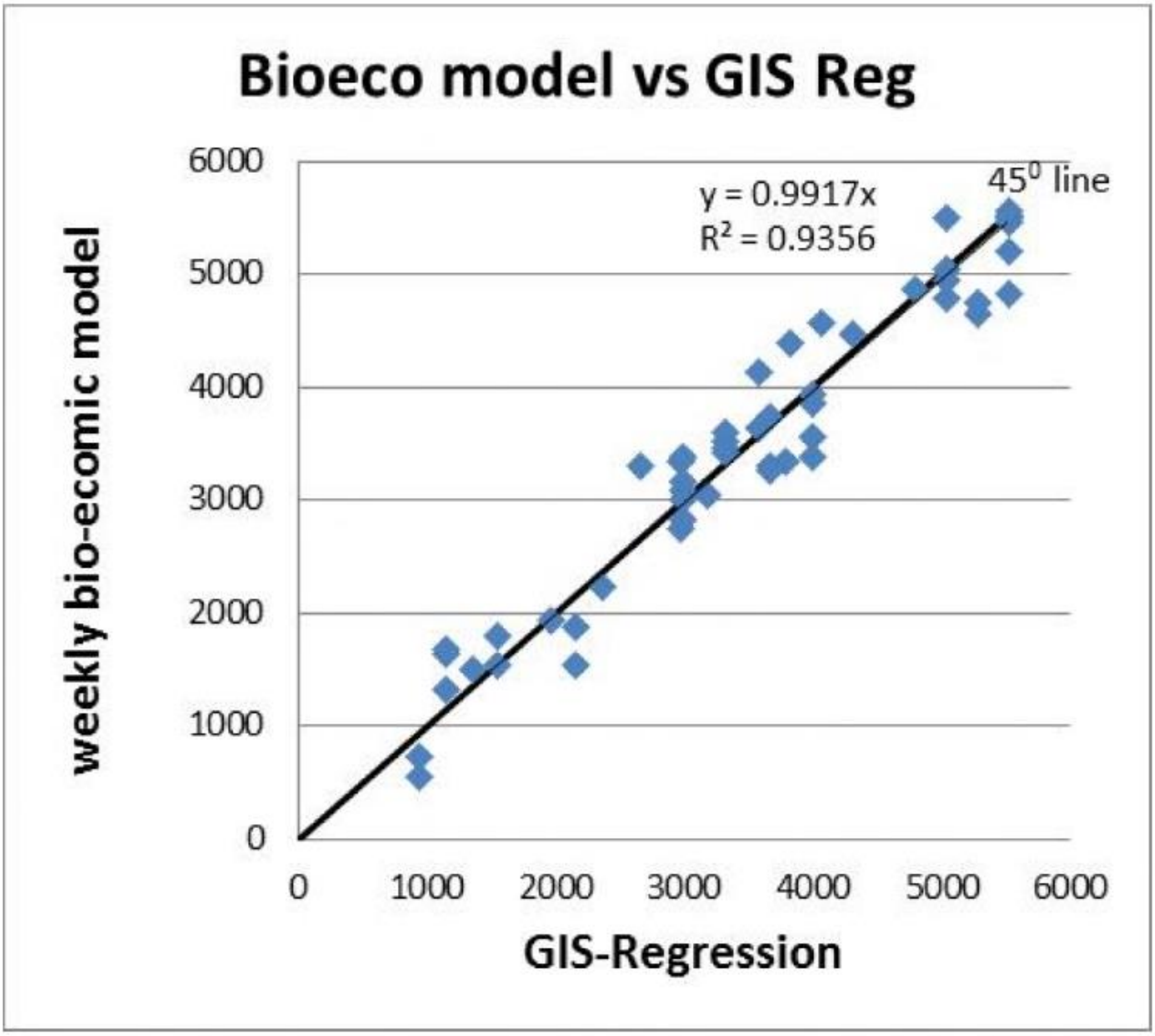
[4] Note: B_2 is expected to be a positive coefficient, due to the variable X_2 measurement as regions further west have a decreasing longitudinal value.

Figure 70 - Plotting the estimated gross margins with respect to the total number of days 35°C within a season and longitude (1997-2014).



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3.3 GIS bioeconomic: mapping heat stress days, gross margins and net profits across the QMDB

GIS-regression analysis estimates season averages for both continuous and split season production (Figure 71 to Figure 74):

1) Yields based on total days in a season 35°C identified by in Eq.1,
2) Gross margins based on total heat stress days and longitude estimated in Eq. 1 and Eq.2.
3) Net profits are based on a 360 ha enterprise with $50k of overheads allocated to the enterprise regionally

Figure 71

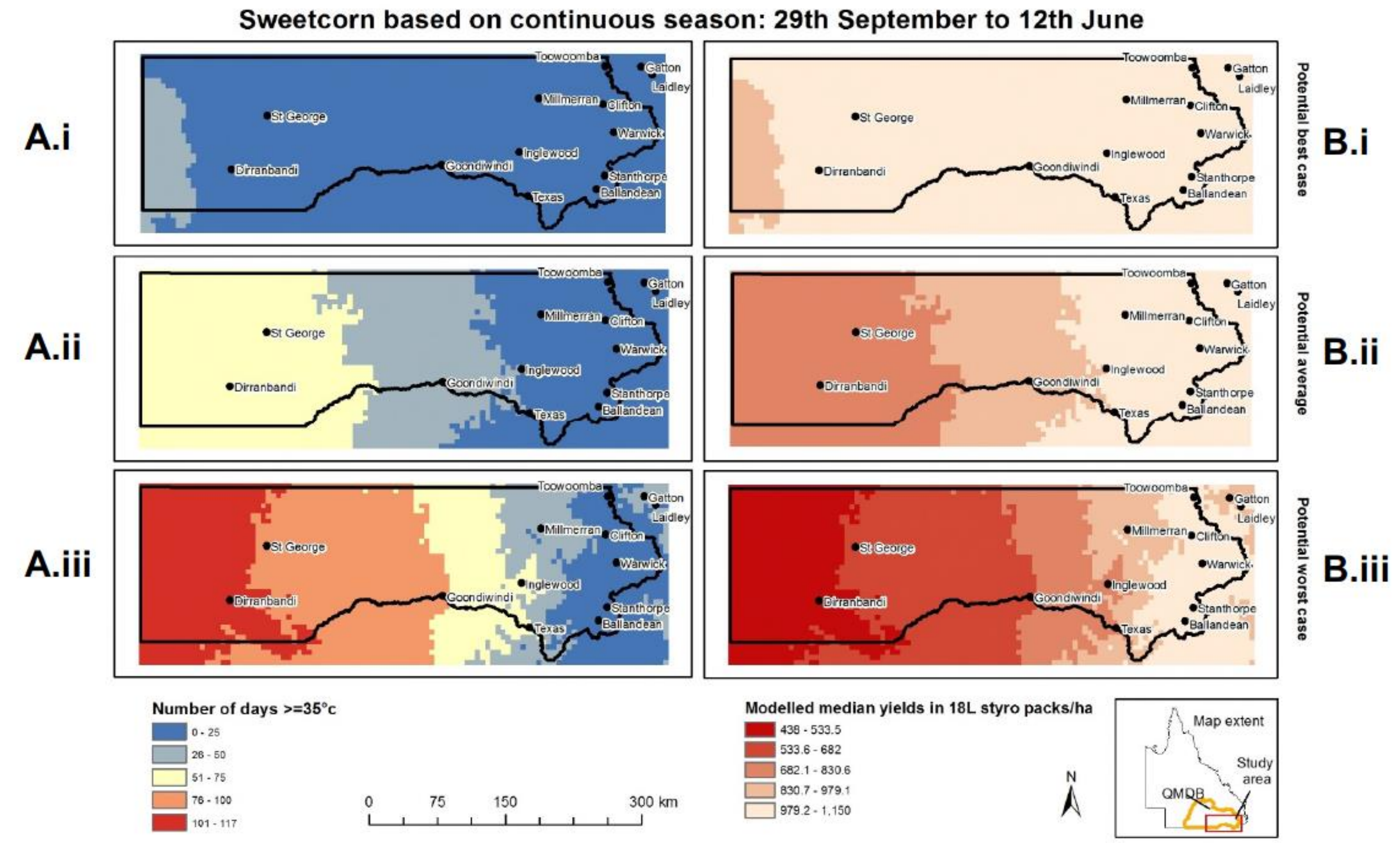

Figure 71 - Continuous sweet corn production from September 29th to June 12th, for (A) number of days ≥35oC and (B) modelled yields in 18L styro packs/ha for the potential (i) best-case, (ii) average, and (iii) worst-case scenarios using regression analysis Eq 1.

Figure 72

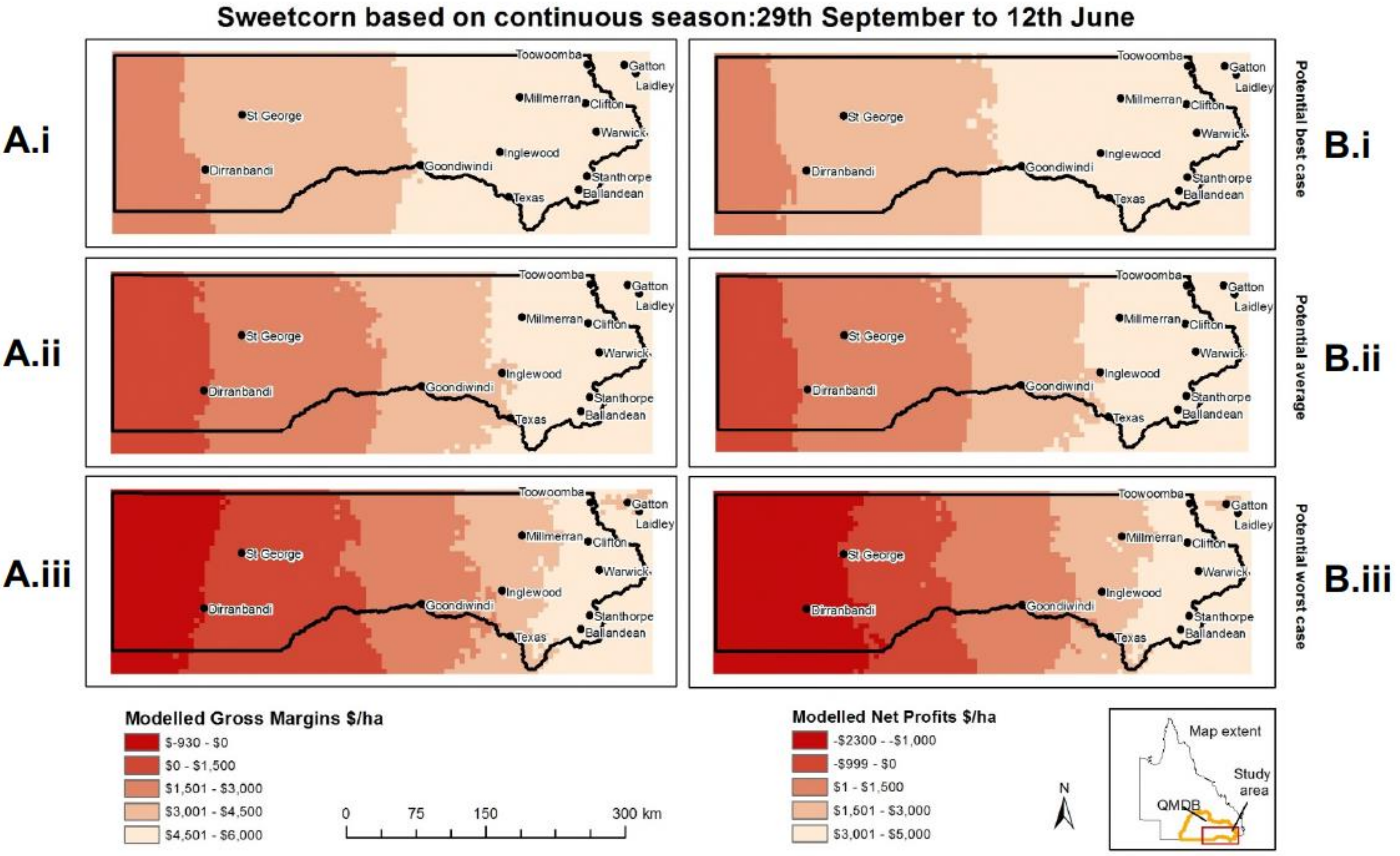

Figure 72 - Continuous sweet corn production from September 29th to June 12th, for (A) modelled gross margins $/ha and (B) modelled net profits $/ha for the potential (i) best-case, (ii) average, and (iii) worst-case scenarios using regression analysis Eq.2 and $1385/ha overheads.

Figure 73

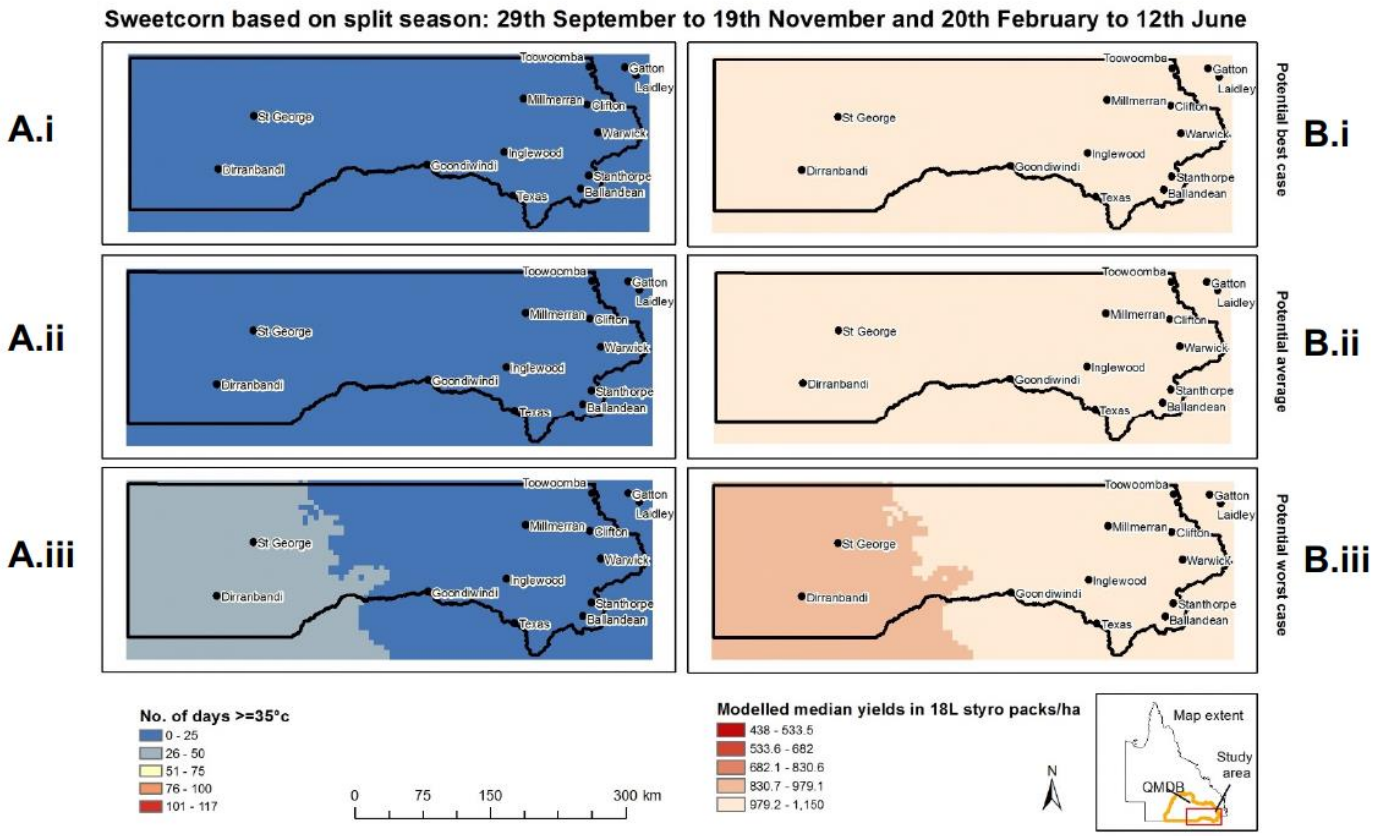

Figure 73 - Split season sweet corn production from September 29th to November 19th and February 20th to June 12th, for (A) number of days ≥35°C and (B) modelled yields in 18L styro packs/ha for the potential (i) best-case, (ii) average, and (iii) worst-case scenarios using regression analysis Eq.1

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Figure 74

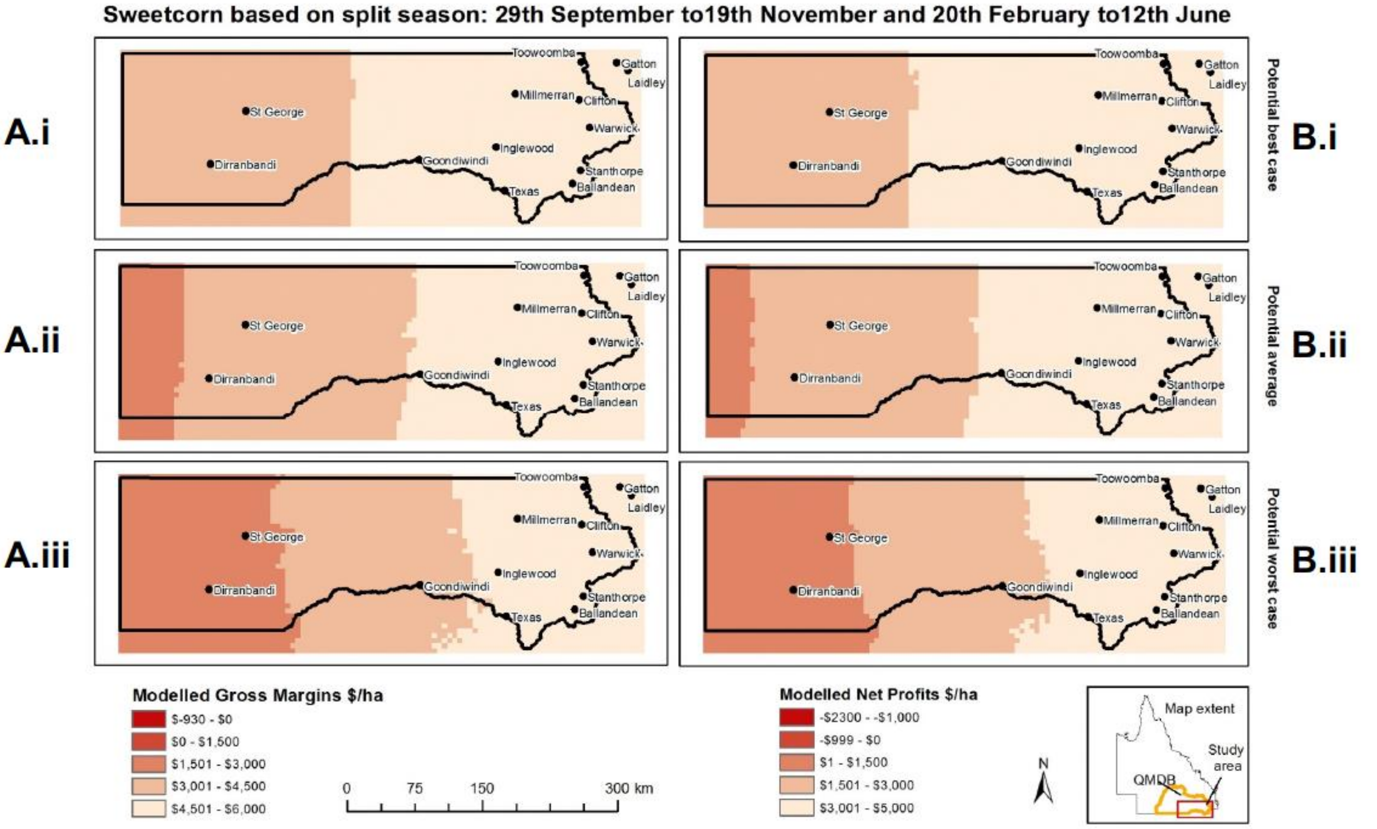

Figure 74 - Split season sweet corn production from September 29th to November 19th and February 20th to June 12th, for (A) modelled gross margins $/ha and (B) modelled net profits $/ha for the potential (i) best-case, (ii) average, and (iii) worst-case scenarios using regression analysis Eq.2 and $1385/ha overheads.

4 Discussion/Conclusion

To assess the viability of growing irrigated sweet corn within the Queensland Murray Darling Basin (QMDB) Study Area, team members started by comparing the production in the St George area of the QMDB to that of the Lockyer Valley; a significant current producer of sweet corn for the domestic market in Queensland and Australia. The two primary constraints in growing sweet corn in many parts of the QMDB are the distance to market (costal markets) and the frequency of heat stress days 35°C). Both of these factors have detrimental effects on the profitability of growing sweet corn in St George when compared to the Locker Valley. However, the impact of heat stress days in St George can be reduced by growing in split season windows, i.e. not growing at the hottest time of year. For St George this can lift the median yields (18L styro packs per ha) by 23%, gross margins by 90%, and net profits by 440% (Figure 64, Figure 65 and Figure 66). The Lockyer Valley typically does not use split-season planting for sweet corn, and as the projects focus is on the QMDB region staff did not investigate this any further. However, the results indicate that the Lockyer Valley may benefit from split season planting in at least 20% of the years; as can be seen from St George's modelled split season plantings which were able to attain higher yields under poorer conditions 20% of the time by reducing the impact of heat stress days, see Figure 66. However, this could come at the cost of reduced overall production in the years when there are few heat stress events.

The GIS-regression analysis indicates that for Gatton the median frequency of heat stress days 35°C) marginally decreased by implementing split-season, and likewise does not greatly improve yields, gross margins or net profits (Figure 71 and Figure 73). Whereas the St George region can reduce the effects of heat stress days 35°C) by about 70%, and resulted in similar yields and economic returns as described by the full bioeconomic model. More importantly, it may be possible for regions such as Texas and Inglewood to undertake continuous cropping in most years, with split season production windows used for crops grown in El Nino years. Growers in these regions may also benefit from having a shorter window of non-production, this can be further investigated using the full bioeconomic model.

Using GIS-regression analysis project economists were able to interpolate the effects of location and the frequency of heat stress days 35°C) across the QMDB. This GIS-regression analysis was able to achieve an accuracy of 89% for yields and 94% for gross margins and net profits, of the full bioeconomic model, under both the continuous (September 29th - June 12th) and split-season (September 29th —November 19th and February 20th — June 12th) production. This mapping will allow farmers to get a conceptual understanding of the frequency of heat stress days, expected (average) yields, gross margins and even net profits for their enterprise. The GIS regression analysis provides a visual indication of which regions across the QMDB would benefit most from either continuous or split-season sweet corn production. St George on "average" for example is expected to increase gross margins from $1500-3000/ha under continuous production to $3000-4500/ha under split-season production (Figure 72.A.ii and Figure 74.A.ii), this is consistent with Figure 65. Although the ranges of values in the map keys are broad, the maps provide finer scale information at the local scale. In Figure 72.A.ii, Inglewood for example is in the $3000-4500/ha gross margin range for continuous production, however it is also on the edge of $4500-6000/ha range, and is therefore estimated to have a gross margin of $4500/ha. The expected (average) gross margins ($/ha) east of Inglewood is similar for continuous and split-season production ($4500 -$6000/ha); whereas to the west there are clear advantages to split-season production (Figure 72.A.ii and Figure 74.A.ii). When looking at risk we need to also consider both the worst and best-case scenarios.

Scaling for Inglewood under the potential worst-case scenario (Figure 72.A.iii and Figure 74.A.iii) there can be significant differences in gross margins -$3500/ha vs $5000/ha, for continuous vs split season production; however, under the best-case scenarios (Figure 72.A.i and Figure 74.A.i) there are little difference between continuous and split-season production. Therefore it is up to the individual farmer to assess the benefits and risks of split vs continuous cropping. There may be reduced climatic risk factors for growers in this area to undertake continuous cropping.

If mapped results for sweet corn appear favourable to farmers compared to current returns, then they can use the full sweet-corn bioeconomic model with their personalised data, including climatic conditions, production, capital and overhead costs to investigate further. One may ask why the project team needed the full bioeconomic model when the team can estimate the yields and economic returns with -90% accuracy using the regression analysis. The latter is simply a rule-of-thumb based on the information obtained by the detailed analyses. That is, it is not possible to undertake the GIS-regression analysis without having the initial detailed bioeconomic model analysis.

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Both physiologically and economically it appears that sweet corn could be incorporated into irrigated cotton production systems, provided new processing infrastructure becomes available. Another alternative may be to export frozen sweet corn, again provided there sufficient economies of scale to develop an efficient supply chain to the world market.

The GIS analysis did not take into account the cost of land, water or other inputs across the QMDB region as these are highly variable. Therefore it is advisable for growers to first investigate the potential benefits of growing sweet corn using the full bioeconomic model and other industry information.

The results of this analysis indicated that there may be potential benefits to growing sweet corn in many parts of the QMDB study area; however, this must be compared to the opportunity cost of forgoing current returns and securing access to markets.

5 References

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