10.1071/CP23057

Crop & Pasture Science

Supplementary Material

Profitable, low-emission nitrogen application strategies in Western Australian dryland cropping

C. d'Abbadie[A], *S. Kharel*[A], *R. Kingwell*[A,B,C,*], *and A. Abadi Ghadim*[A]

[A]Department of Primary Industries and Regional Development, Perth, WA, Australia.

[B]University of Western Australia, Perth, WA, Australia.

[C]Australian Export Grains Innovation Centre, Perth, WA, Australia.

[*]Correspondence to: R. Kingwell Department of Primary Industries and Regional Development, Perth, WA, Australia Email: ross.kingwell@aegic.org.au

Appendix 1

An overview of EVALUS

EVALUS is an economic simulation model designed to evaluate the biology and financial characteristics of land use sequences of broadacre production systems in Western Australia's agricultural region. Using a modified French and Schultz model, EVALUS estimates the potential yields of crops and pastures based on soil information and rainfall estimates for any chosen location. EVALUS calculates the potential yield based on Water Use Efficiency (WUE) and then adjusts the potential yields of crops and pastures based on land capability, soil pH, waterlogging, soil nutrient status, plant disease susceptibility, and heat and frost risks during flowering and grain filling.

Other models, such as Optlime and SYN (Select Your Nitrogen), are integrated into EVALUS to refine yield calculations. The model assumes a fixed stocking rate for self-replacing sheep flocks, and supplementary feeding increases or decreases depending on the rainfall. More information about EVALUS can be found in Kharel et al. (2022).

In EVALUS N is applied through MAP, Urea, or Flexi N, noting MAP’s other role in supplying phosphorus. Urea and Flexi N are the main fertiliser N sources, with Flexi N consisting of a blend of Urea, Ammonia, and Nitrate in a ratio of 50:25:25 respectively. By calculating the total N available from each source and employing emission factors from the National Inventory (2019), the overall emissions associated with use of N fertilisers are determined.

The crop rotation options chosen for each location in EVALUS are based on industry practice as reported in the Planfarm Benchmarks (2016 to 2020) and by Harries et al. (2015). Table A1 presents the crop rotations examined at each location for three different cropping frequencies: 100% cropping, 75% cropping, 50% cropping.

Table A1. Rotations[a] examined at each location for different cropping frequencies.

Location	Cropping Intensity of land use sequence		
	100%	75%	50%
Northampton	WWC	WWCP	WPPC
Moora	WBC	WBCP	WPPC
York	WBC	WBCP	WPPC
Katanning	WBC	WBCP	WPPC
Kojonup	WBC	WBCP	WPPC
Carnamah	WWC	WWCP	WPPC
Wongan Hills	WBC	WBCP	WPPC
Cunderdin	WBC	WBCP	WPPC
Corrigin	WBC	WBCP	WPPC
Ravensthorpe	WBC	WBCP	WPPC
Mullewa	WWC	WWCP	WPPC
Kalannie	WWC	WWCP	WPPC
Merredin	WWC	WWCP	WWPP
Hyden	WBC	WBCP	WBPP

[a] W = Wheat, B = Barley, C = Canola, P = Pasture

The SYN model

The Select Your Nitrogen (SYN) model originally was a large MS Excel spreadsheet that is now more readily available as “N Broadacre” – an iTunes app. SYN integrates multiple factors such as soil characteristics, rainfall, fertiliser type, and application timing to generate N response curves for crop yield and grain protein. N availability and rainfall are assessed on a weekly basis, for various soil types and locations. SYN incorporates the contribution of previous legume crops or pastures in determining N availability. Depending on the weekly rainfall, SYN simulates root growth, N movement through the soil profile, microbial activities and leaching, and finally calculates the total N available. By simulating these components, SYN projects N availability that subsequently affects final yield and protein of the grain or oilseed crop. For further description regarding the application of the SYN model, see Lemon (2007).

Appendix 2: Rainfall expectations and N Strategies

Rainfall expectations

When considering an N application strategy, the model assumes a farmer will decide which rainfall is expected during the growing season, after considering the known summer rainfall. The simulation considers three different scenarios:

a) Average rainfall

In this approach the farmer expects that each year will be an average weather-year where the amount of effective rainfall (i.e. pre-sowing and growing season rainfall) is the average recorded over the prior 30 years, based on site-specific SILO data (Queensland government 2022). Figure A2.1, shows an example of this approach where 350 mm average cumulative rainfall (the solid dark-blue line) contrasts against the 283 mm actual rainfall. In this example, the farmer expects a higher rainfall than actually occurs. The farmer is assumed to have zero confidence in the decile 5 rainfall forecast, instead relying on an historical average of observed rainfall.

b) Decile 5 projected rainfall

In this approach the farmer's rainfall expectation is based on rainfall to date, complemented by the subsequent projected decile 5 rainfall, as per DPIRD (2023) methodology. At the break of season, the farmer would sow and apply 30% of the N needed to match the decile 5 projection at time of sowing. In Figure A1, the yellow dotted line shows the actual cumulative rainfall up to the sowing date and a decile 5 projection onwards. In this case the farmer would apply N based on the 336 mm cumulative rainfall. Four weeks after sowing, the farmer would then consider the actual rainfall plus a subsequent decile 5 rainfall projection. At week 4 the farmer would put all the N needed, consistent with projected decile 5 rainfall.

In the example in Figure A2.1, the farmer would consider at week 4 the actual rainfall of 377mm and the subsequent decile 5 rainfall projection. Then at 8 weeks after sowing, the farmer would consider their tactical N decision based on actual rainfall up to week 8 plus the subsequent decile 5 rainfall projection. In Figure A2.1, by week 8 rainfall has not reached the decile 5 trajectory, and at week 8 the projected rainfall is 320mm. In this approach the farmer is assumed to have 100% confidence in the unfolding decile 5 rainfall forecast.

c) 50% Decile 5 projected – 50% Average rainfall

A third approach is where the farmer's rainfall expectation is based on an average of approaches (a) and (b) described above. In this approach (c) the farmer is assumed to have 50% confidence in the decile 5 rainfall forecast.

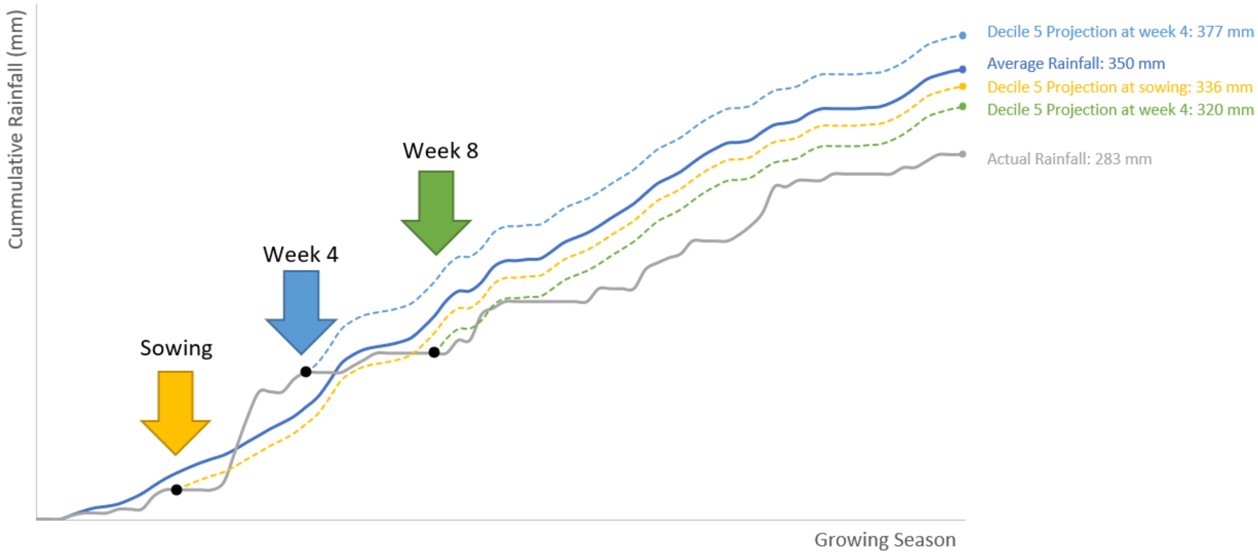


Figure A2.1. Projected decile 5 rainfall considering the rainfall to date.

N Strategies

EVALUS (Kharel et al. 2022) considers the water use efficiency (WUE) of a crop as affected by land capability and soil acidity. Then, drawing on the WUE and the farmer's rainfall expectations (as described above), the model considers the following N strategies:

(i) A fixed ratio

In this strategy N is applied according to a fixed ratio of the expected yield calculated as (*Y = WUE * Expected Rainfall*). The strategy involves applying 45 units of N per expected tonne of cereal and 70 units of N per expected tonne of canola. Figure A2.2 shows the yield relationship as $Y_{FR} = WUE * expected\ Rainfall$, with the fixed ratio relationship being used to specify the N applied (N_{FR}).

(ii) Agronomic target

This strategy seeks to apply sufficient N to maximise crop yield. Given the farmer's rainfall expectation and WUE, a yield-nitrogen response curve is generated by the SYN model, as shown in Figure A2.2. Higher rainfall and higher WUE shift the response curve upwards. From the curve, the maximum yield (Y_{max}) and associated N application (N_{max}) are identified. This strategy assumes that the N applied (N_{AT}) is 90% of the N level that maximises crop yield (N_{max}). The agronomic target is applied at each fertiliser decision point (i.e., at sowing, and 4 and 8 weeks after sowing).

(iii) Economic target

This strategy assumes N is applied to maximize the gross margin of crop production. As mentioned in strategy (ii), a yield-nitrogen response curve is derived from the WUE and the farmer's rainfall expectation at each tactical decision point (sowing, and 4 and 8 weeks after sowing). Gross margin (*GM*) is income (*I*) minus variable costs (*VC*):

$$GM = I - VC$$

Income is the yield (Y) multiplied by the price of the crop (P_c), while the variable costs are the amount of N applied multiplied by the price of N (P_n) combined with other variable costs (VC_{other}) that are not dependent on the amount of N applied.

$$GM = Y \,.\, P_c - N \,.\, P_n - VC_{other}$$

To maximize economic profit requires dGM/dN to equal 0. As the other variable costs do not depend on N, then dVC_{other}/dN is set to equal 0. The prices of N (P_n) and the crop (P_c) are considered constant. It follows then that:

$$dGM/dN = dY/dN \,.\, P_c - dN/dN \,.\, P_n - dVC_{other}/dN$$
$$0 = dY/dN \,.\, P_c - 1 \,.\, P_n - 0$$
$$P_n = dY/dN \,.\, P_c$$
$$dY/dN = P_n/\, P_c$$

To maximize economic profit requires determining the N applied such that the slope of the yield-nitrogen response curve (dY/dN) is equal to the ratio of the price of N to the price of the crop. This calculation occurs at each decision point. Figure A2.2 shows an example where the crop and N prices are set ($P_n/\, P_c$), and therefore the economic maximizing gross margin N rate is derived as (N_{ET}).

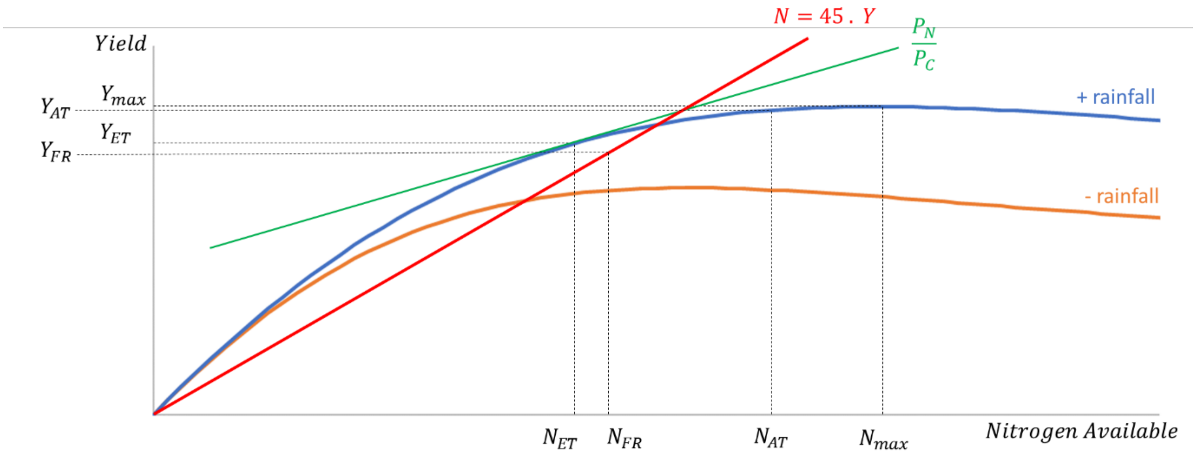
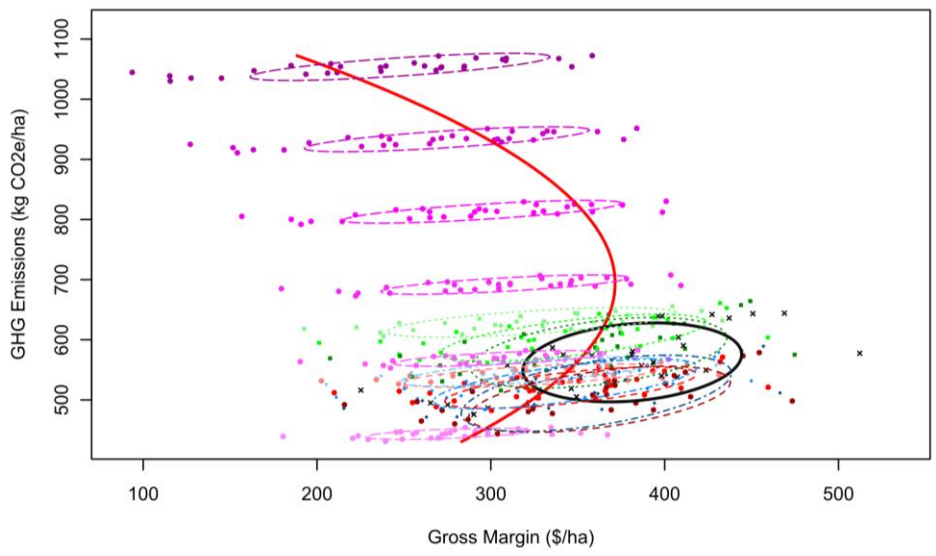
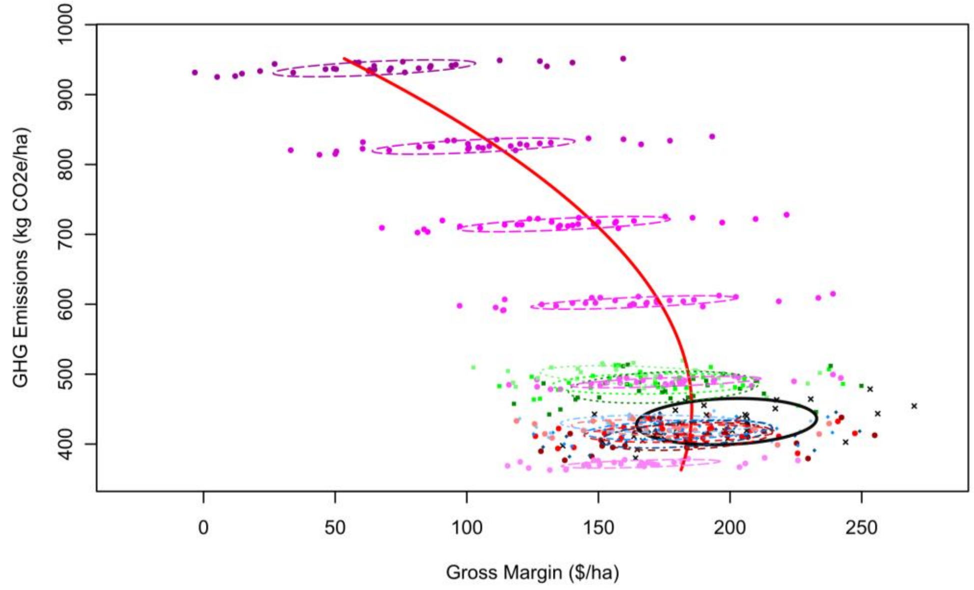


Figure A.2: A sketch graph of the Nitrogen-yield relationship for the Fixed Rate (FR), Agronomic Target (AT) and economic target (ET) strategies.

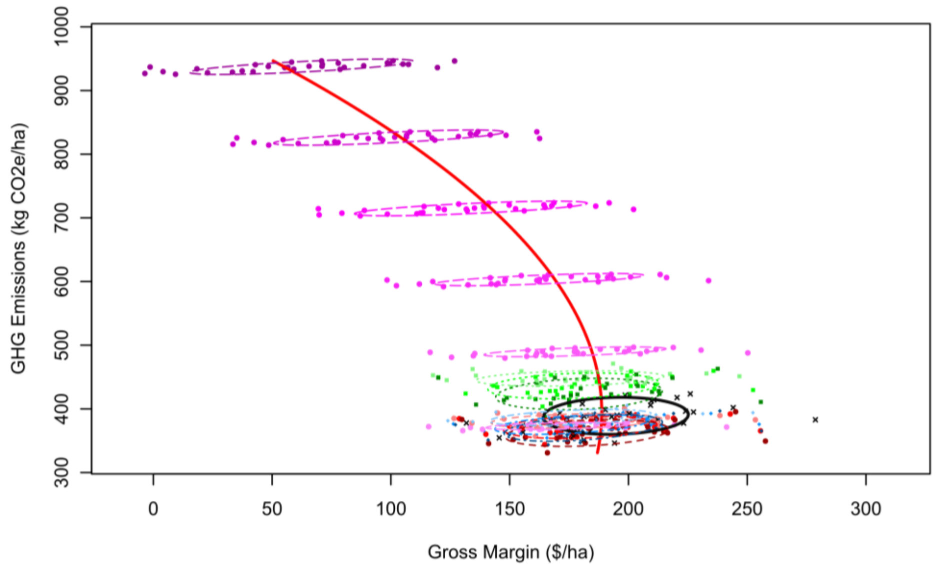
Appendix 3: Locations' N strategies' scope 1,2 and 3 emissions and gross margins for 30 randomised selections of weather-year and price sequences at 75% cropping land use sequences



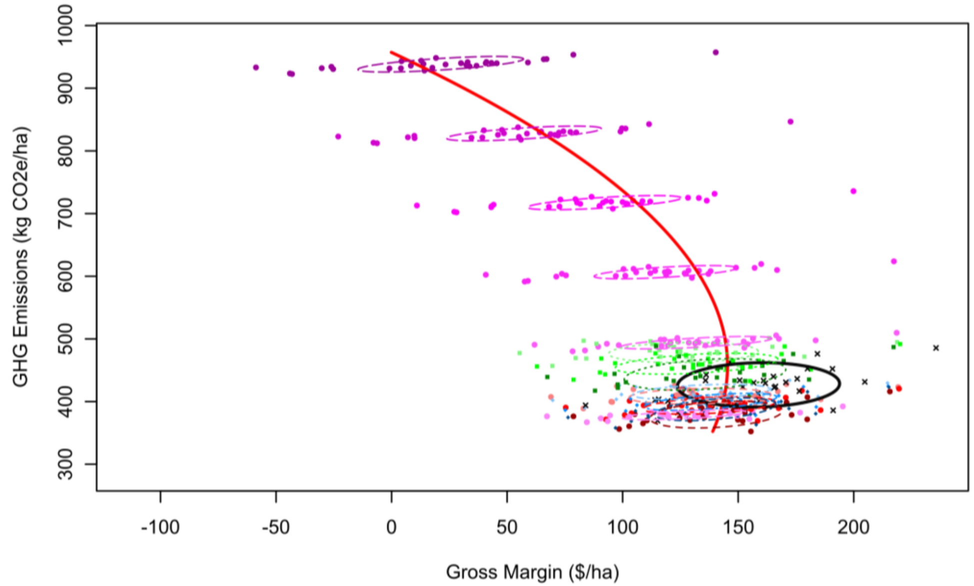
Carnamah



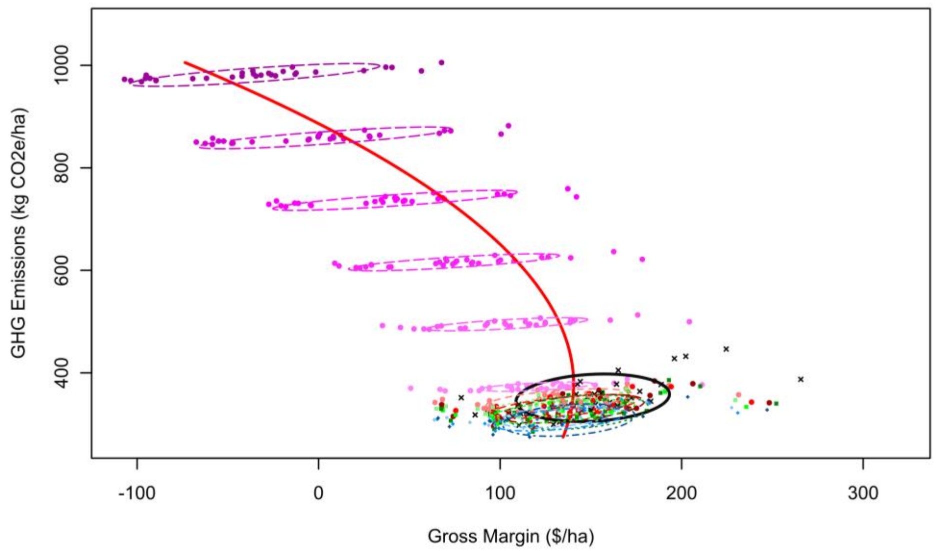
Corrigin



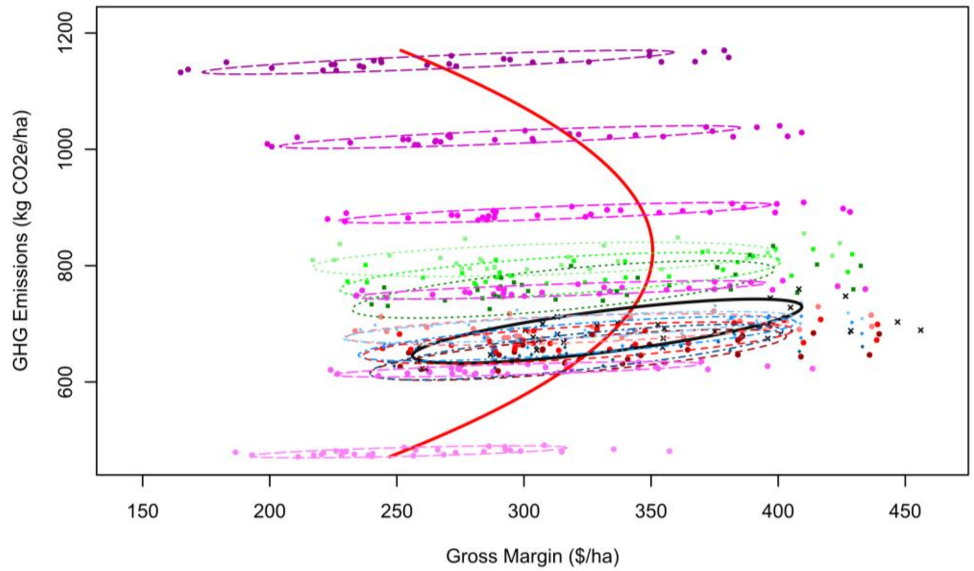
Cunderdin



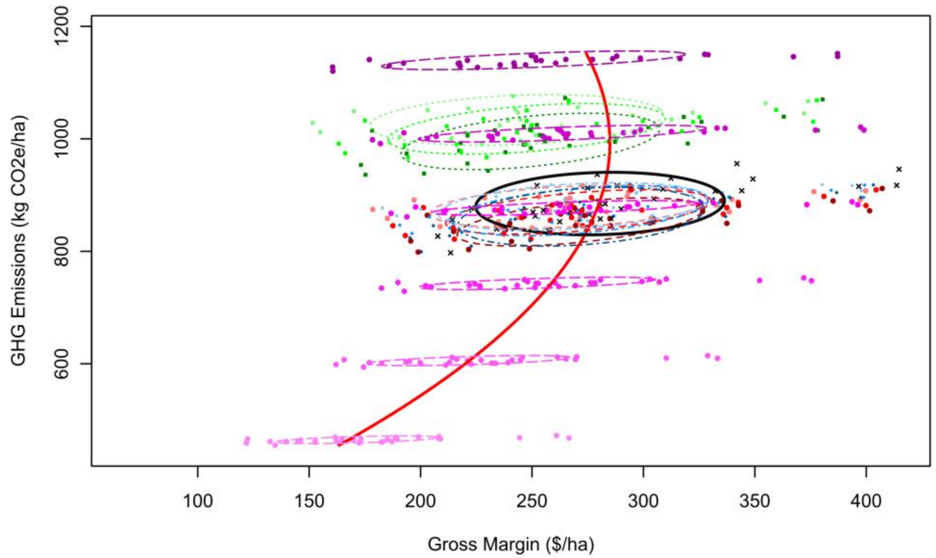
Hyden



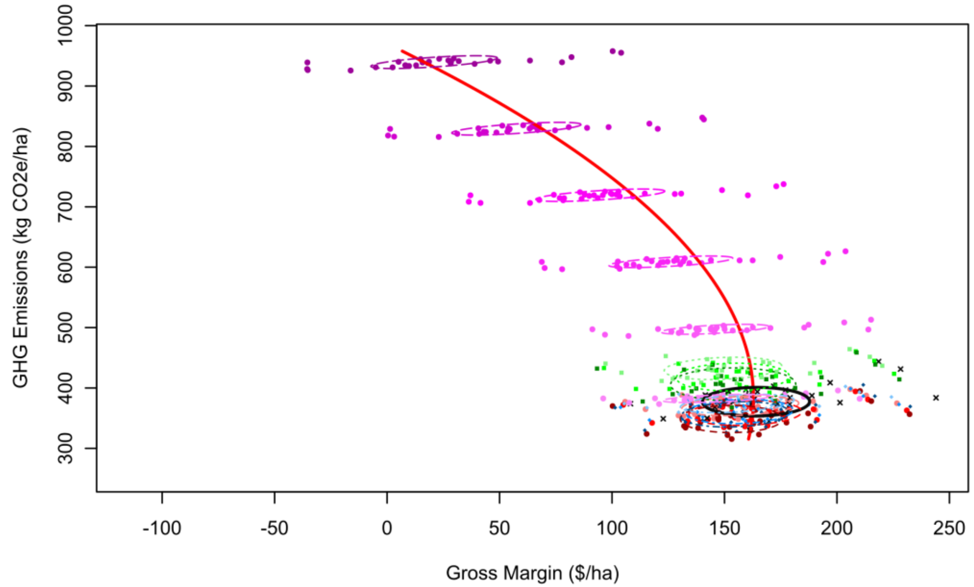
Kalannie



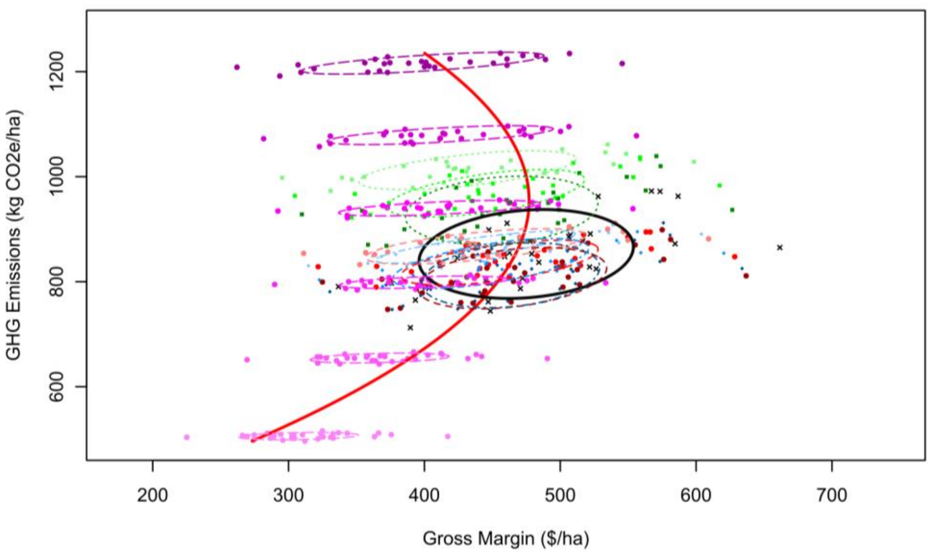
Katanning



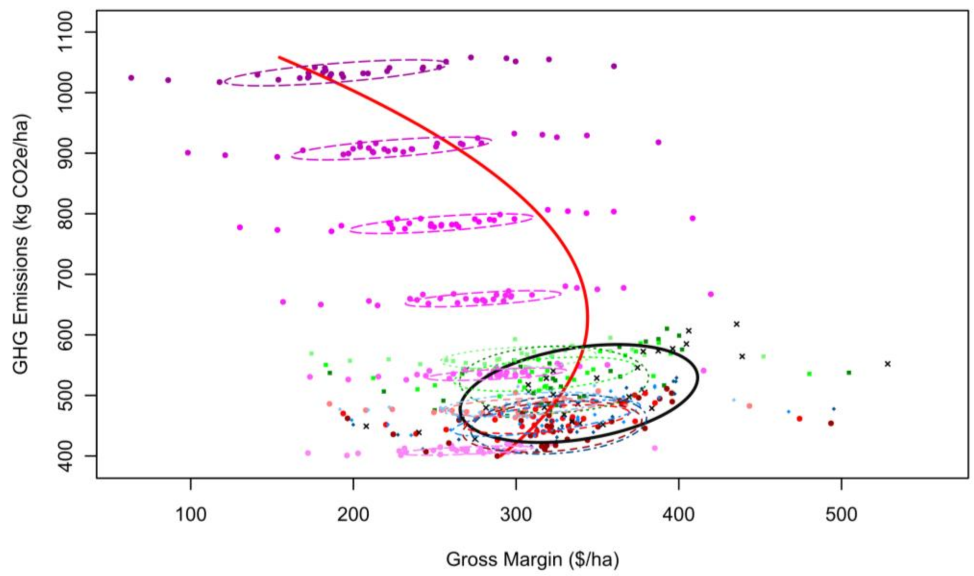
Kojonup



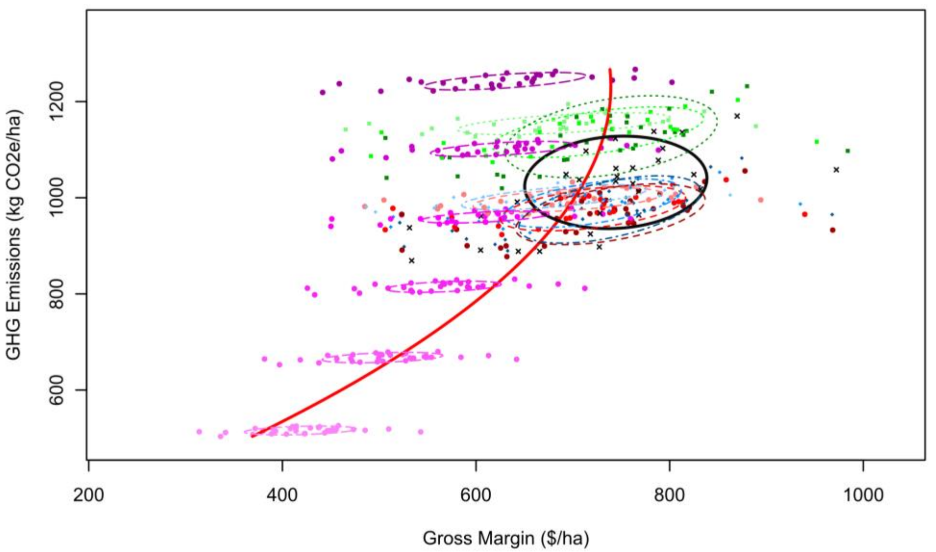
Merredin



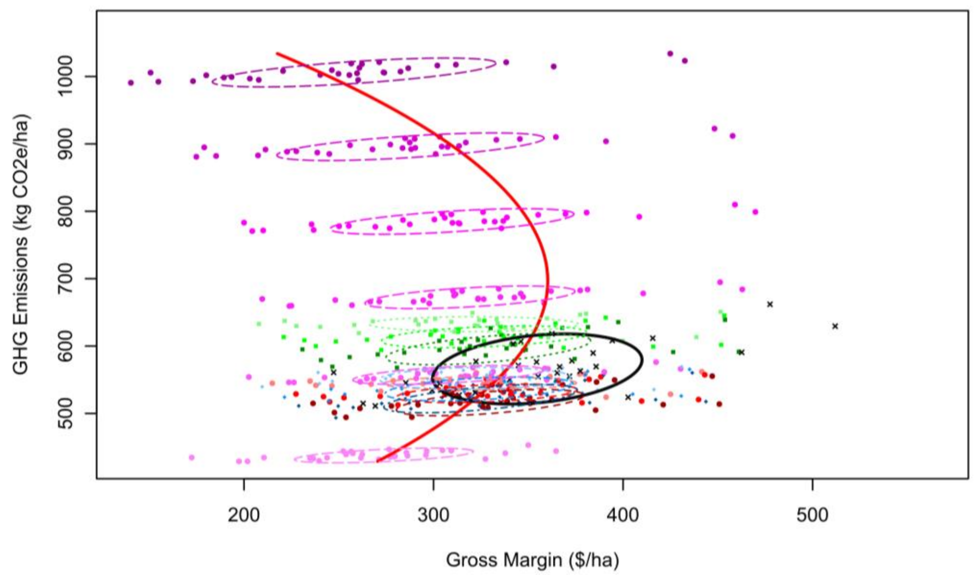
Moora



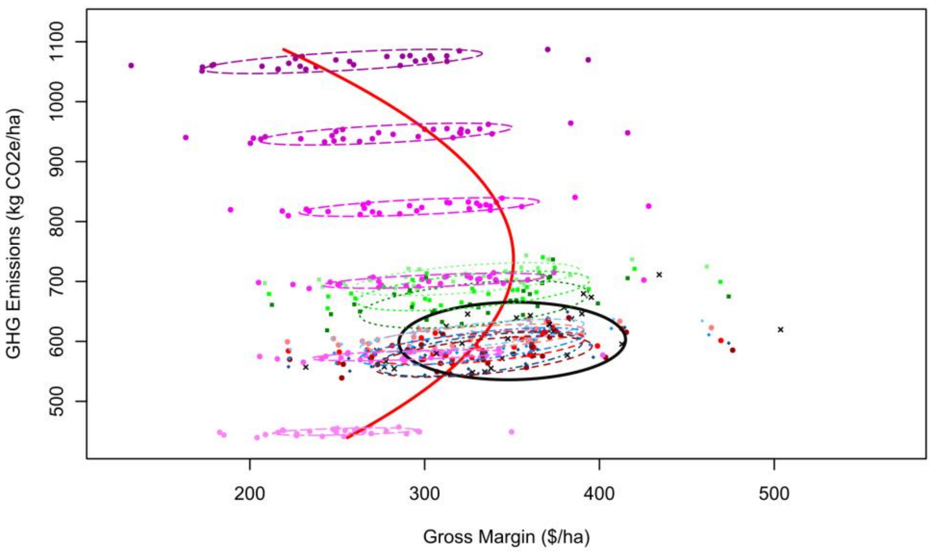
Mullewa



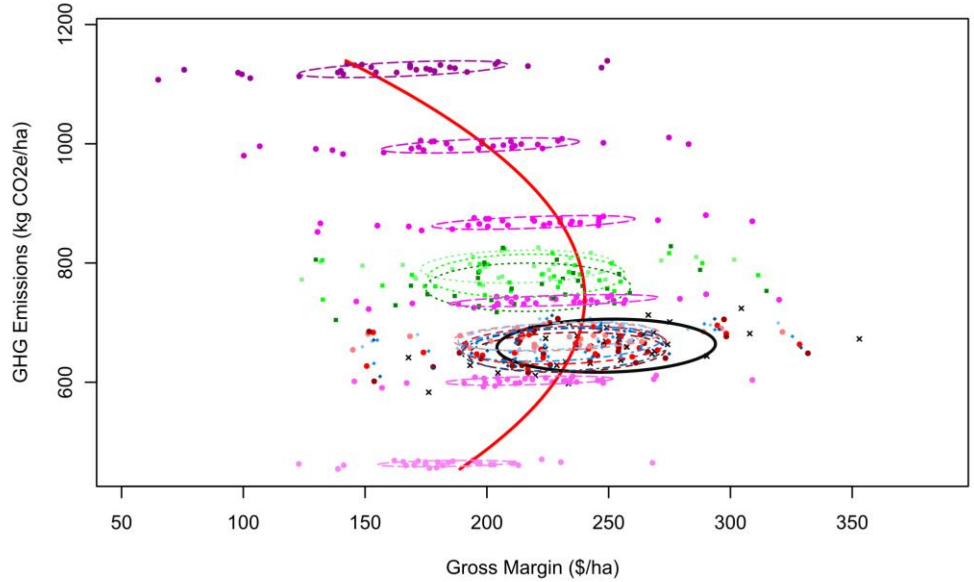
Northampton



Ravensthorpe

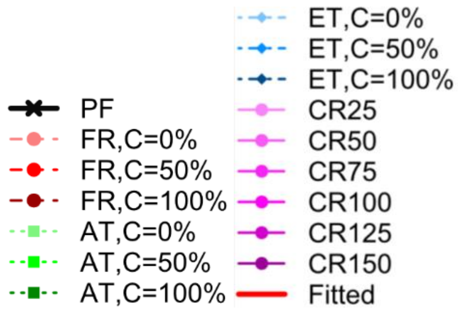


Wongan Hills

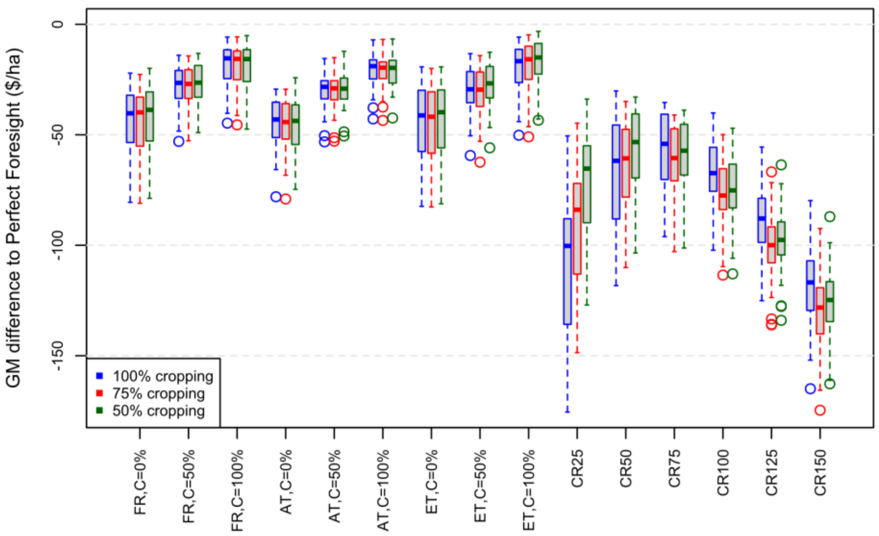


York

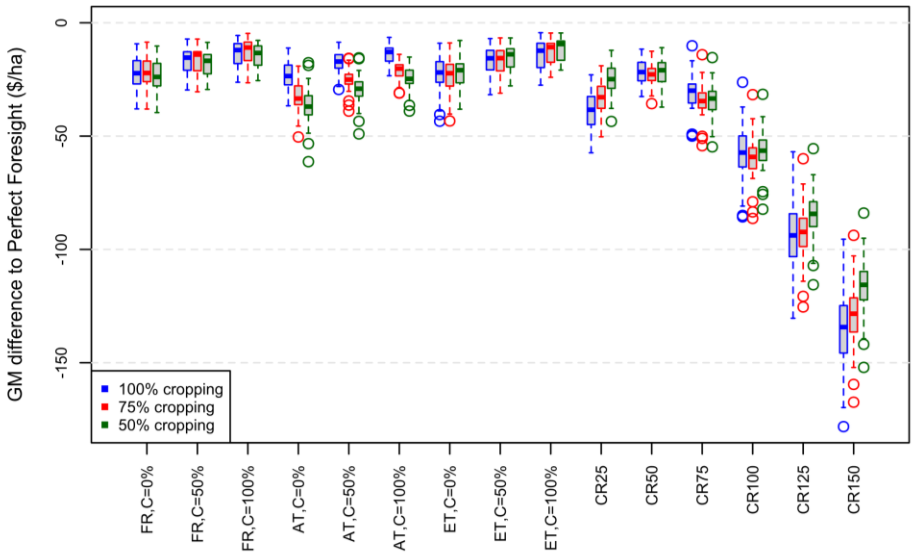
FR: Fixed Ratio, AT: Agronomic Target, ET: Economic Target, CR: Constant Rate, C: Confidence in decile 5 forecast, PF: Perfect Foresight



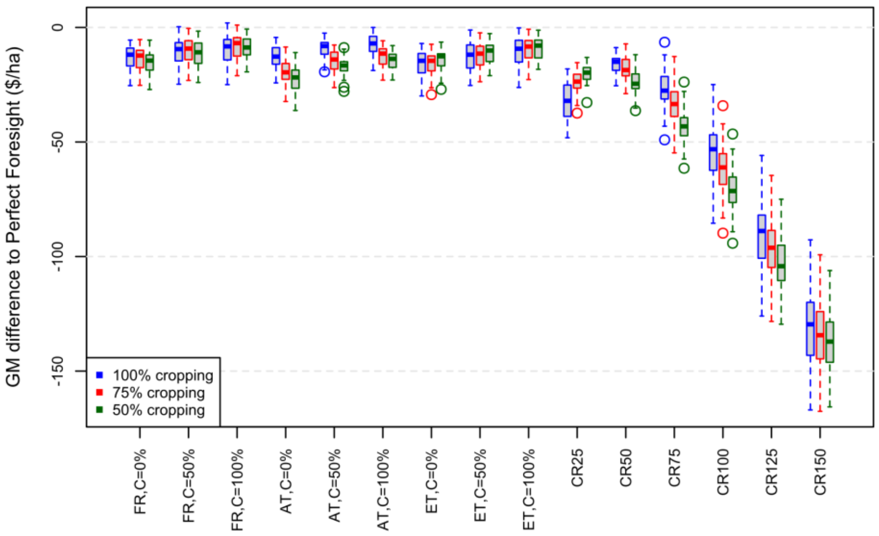
Appendix 4: Locations' N strategies' gross margins for 30 randomised selections of weather-year and price sequences compared against perfect foresight



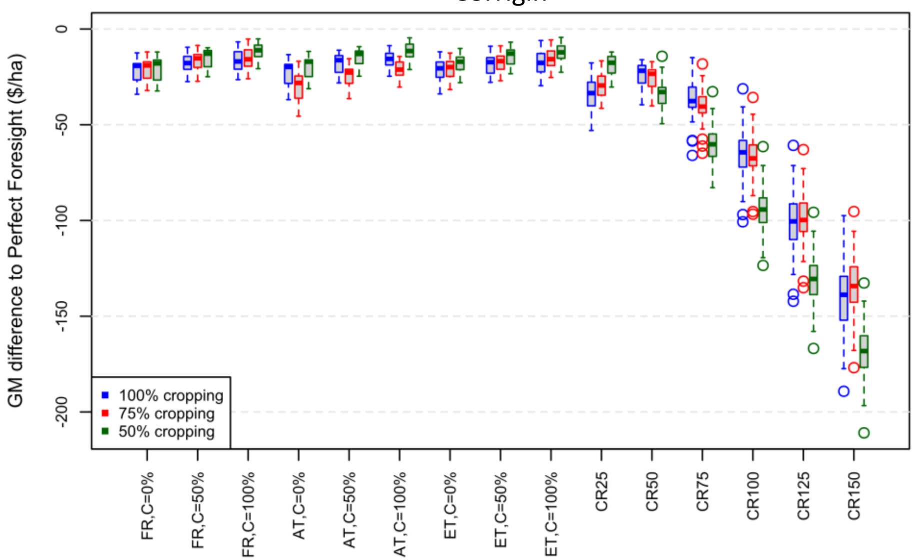
Carnamah



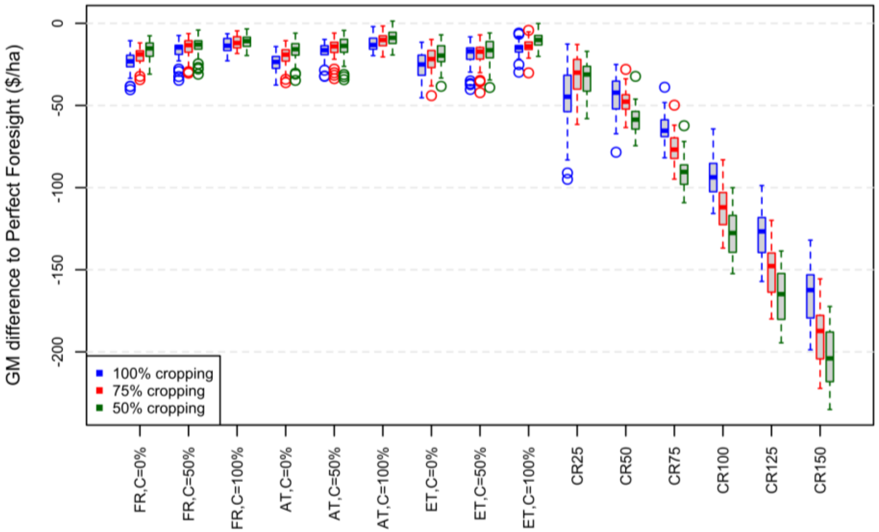
Corrigin



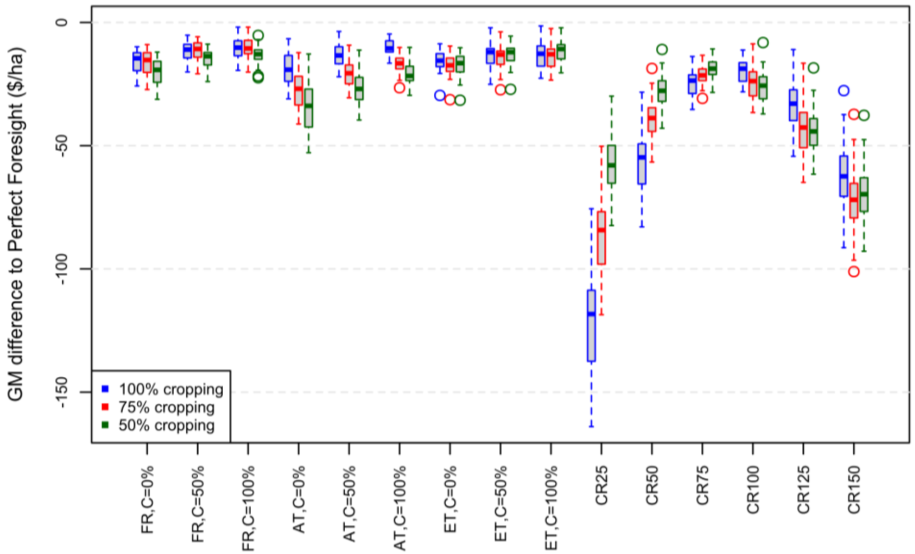
Cunderdin



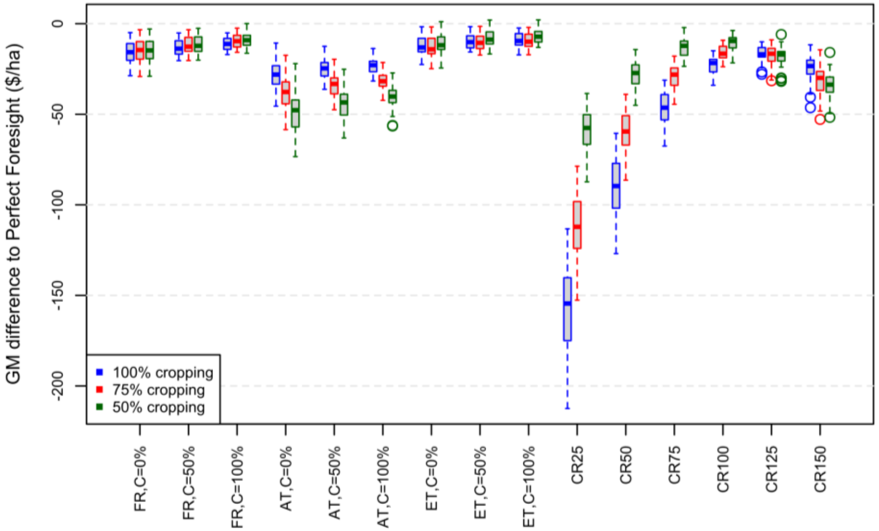
Hyden



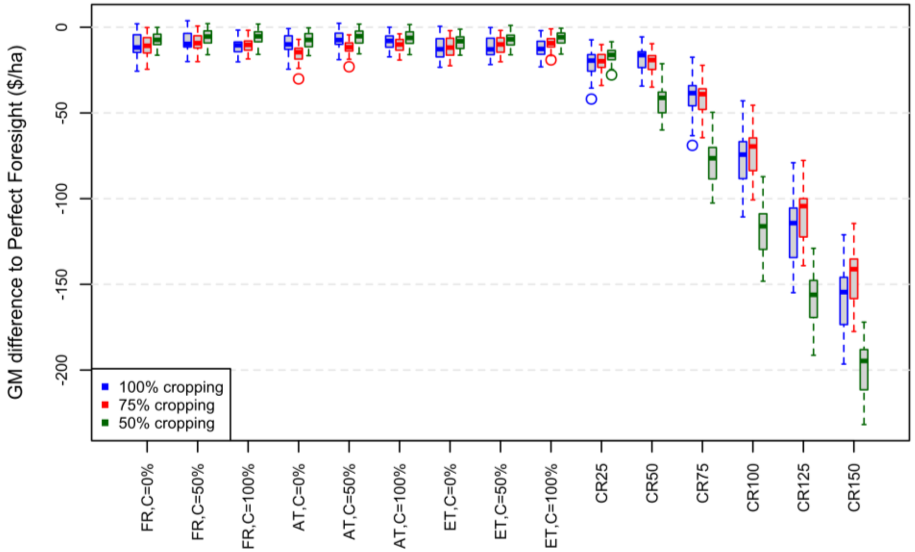
Kalannie



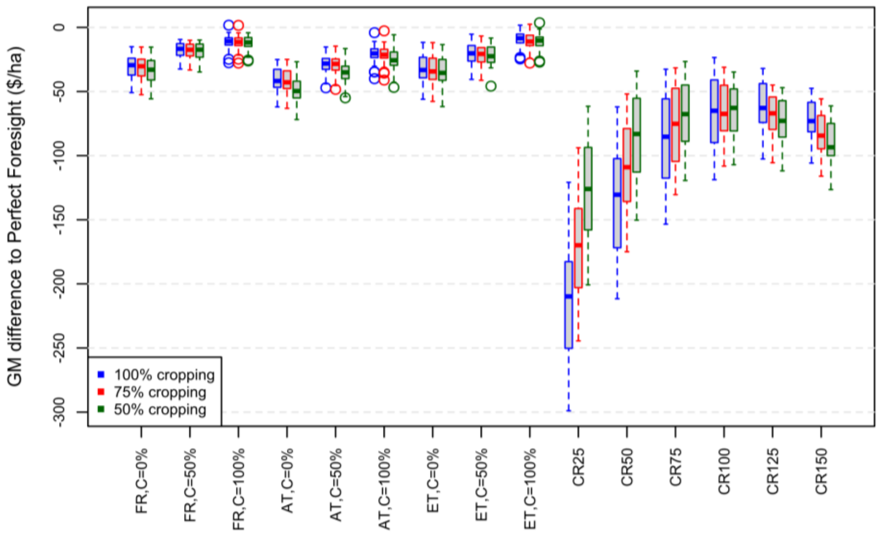
Katanning



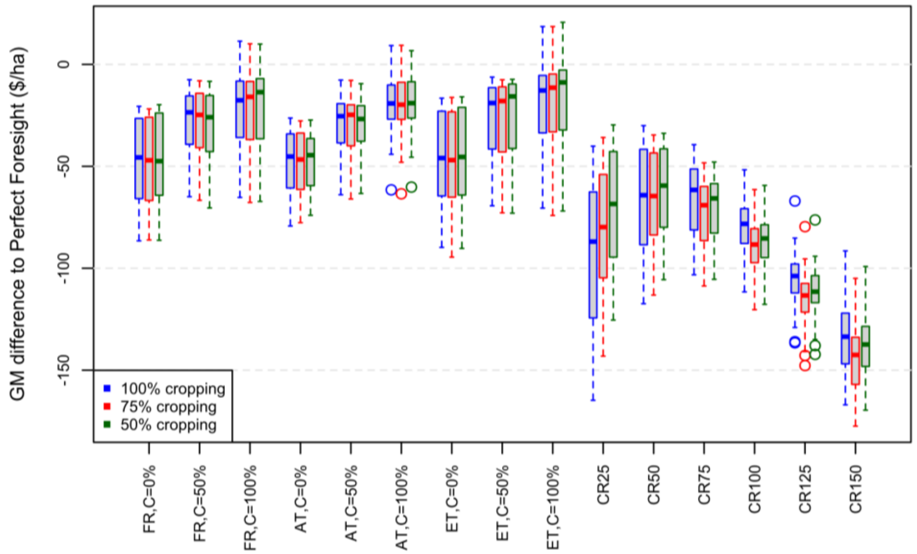
Kojonup



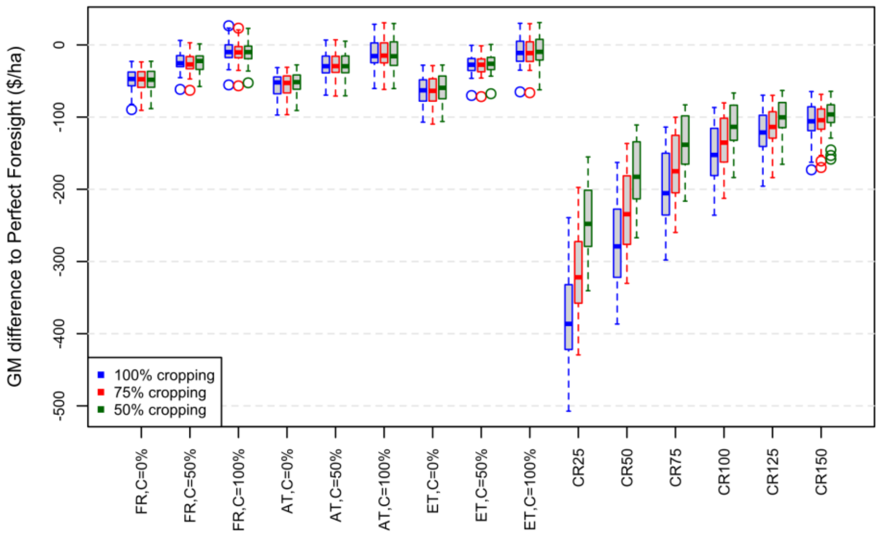
Merredin



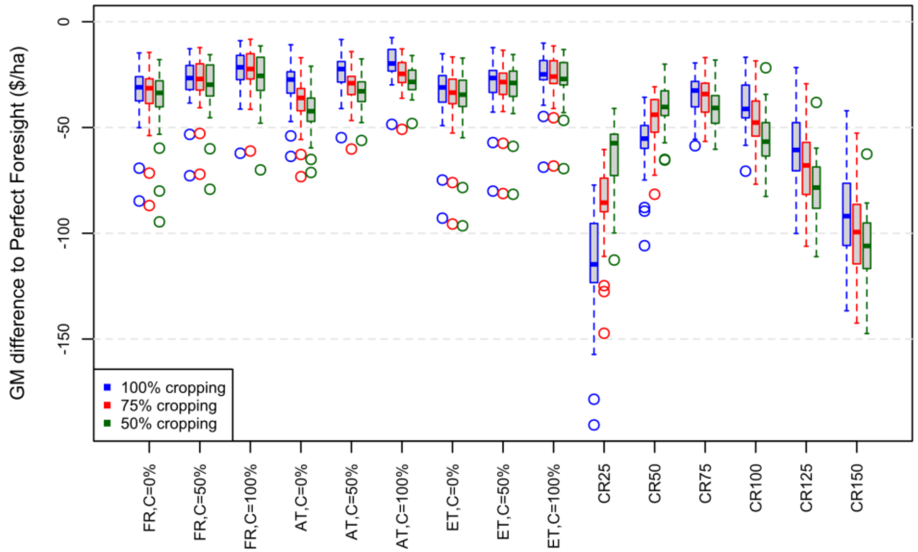
Moora



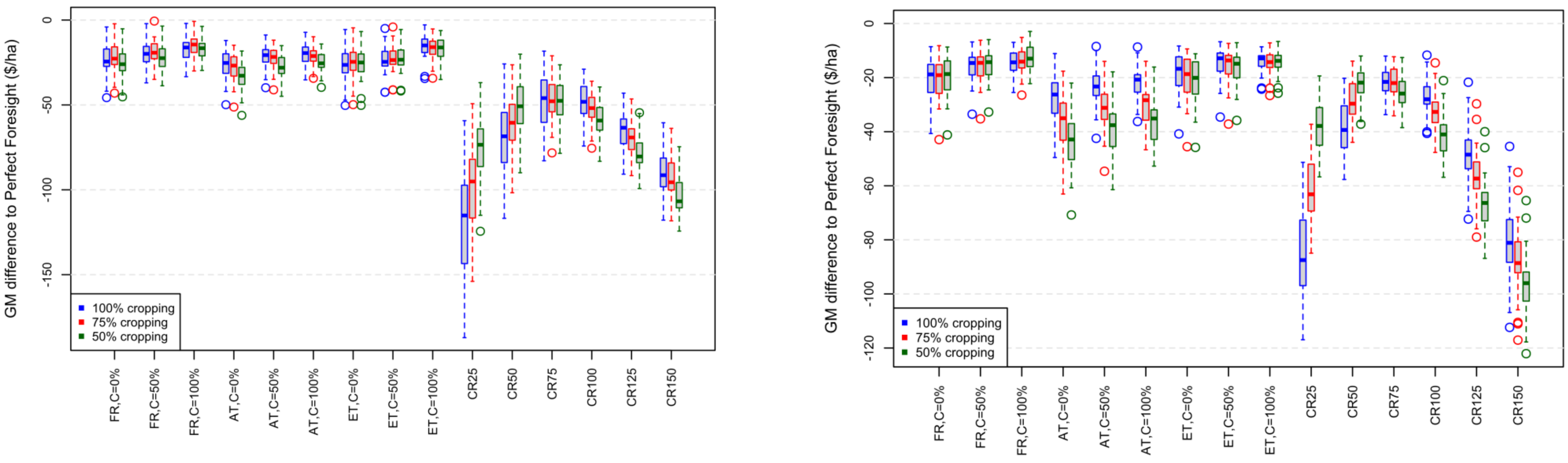
Mullewa



Northampton



Ravensthorpe



Wongan Hills

York

FR: Fixed Ratio, AT: Agronomic Target, ET: Economic Target, CR: Constant Rate, C: Confidence in decile 5 forecast