Crop design for specific adaptation in variable dryland production environments

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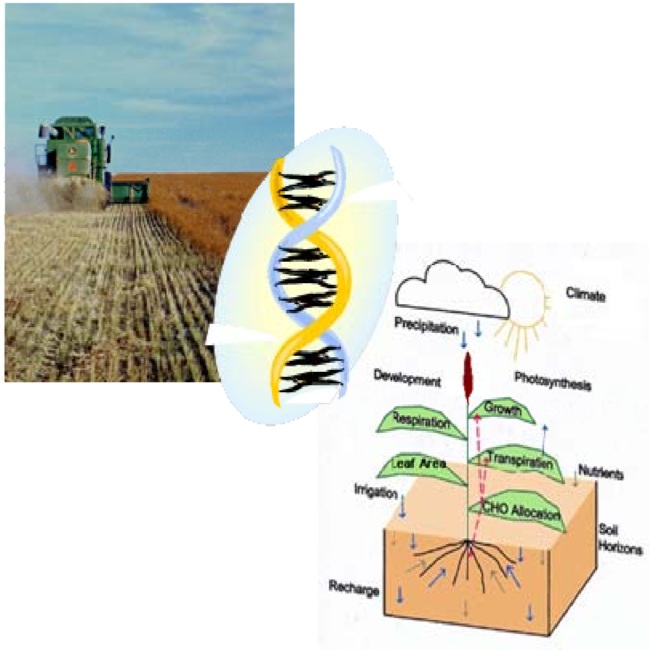


Working together with the Queensland Government

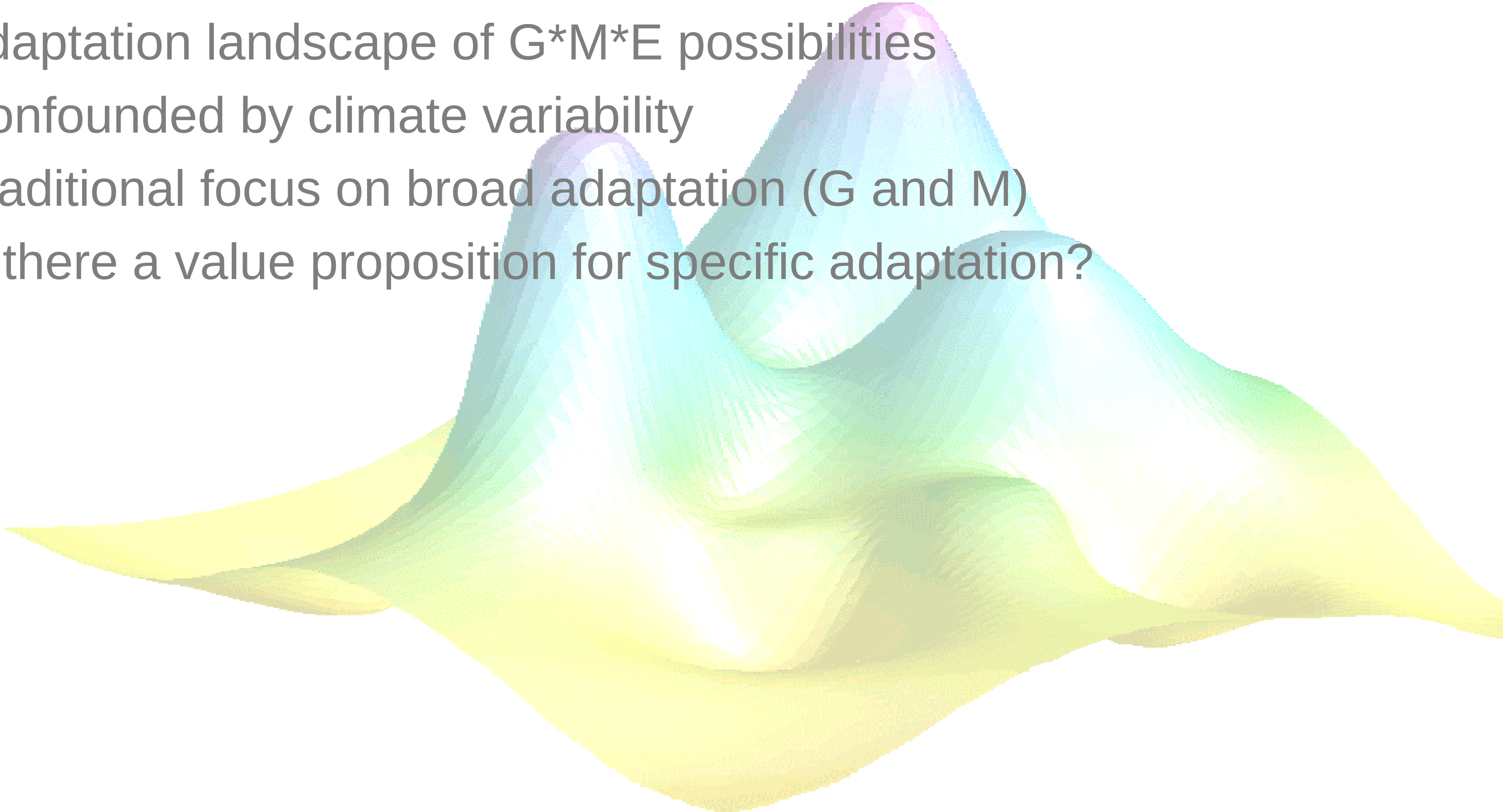
Centre for **Plant** Science

Overview

- Background – specific adaptation and G*M*E
- Case study – sorghum in Australia
  – production environment characterisation
- Simulating adaptation – the G*M*E adaptation landscape
- Simulating broad adaptation – the best overall G
- Simulating specific adaptation – the best local M and G
  – what value specific adaptation?
- Implications for advance

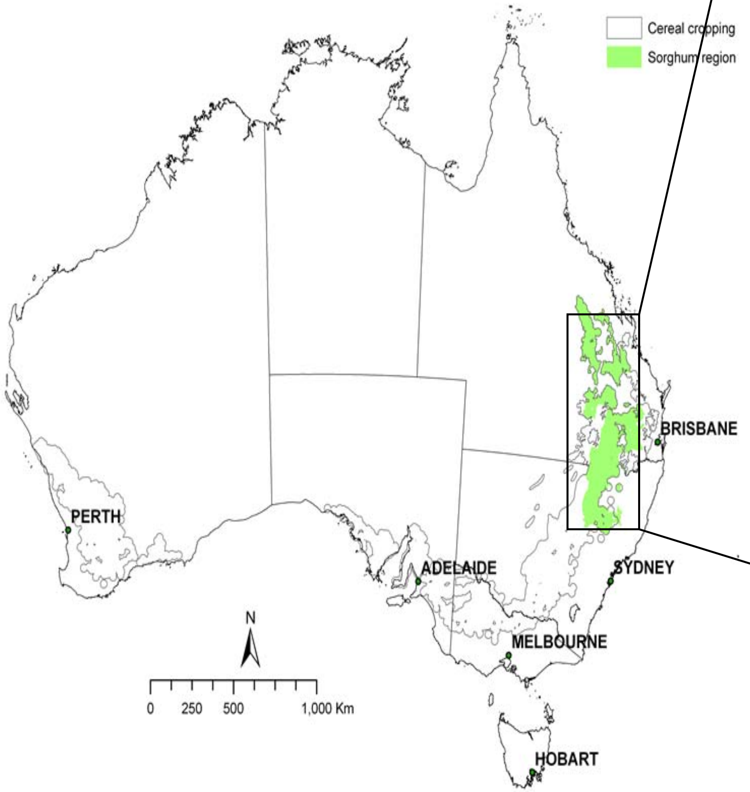
Background

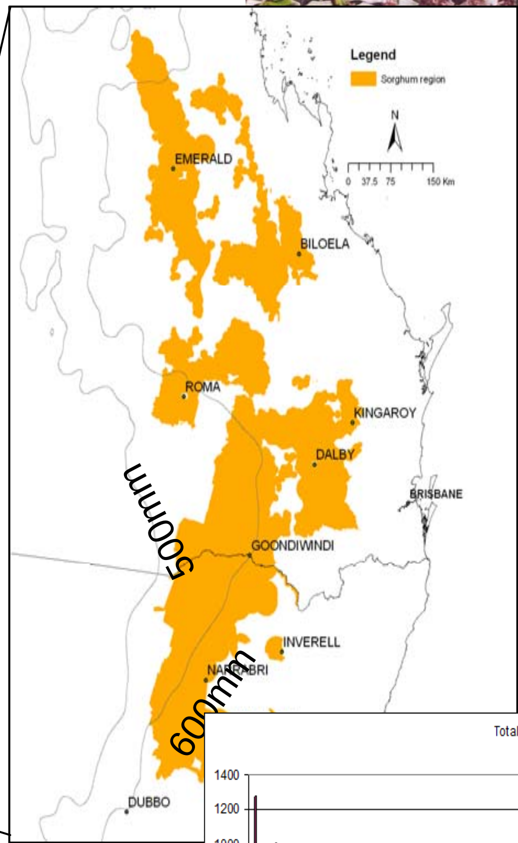
- Adaptation landscape of G*M*E possibilities
- Confounded by climate variability
- Traditional focus on broad adaptation (G and M)
- Is there a value proposition for specific adaptation?

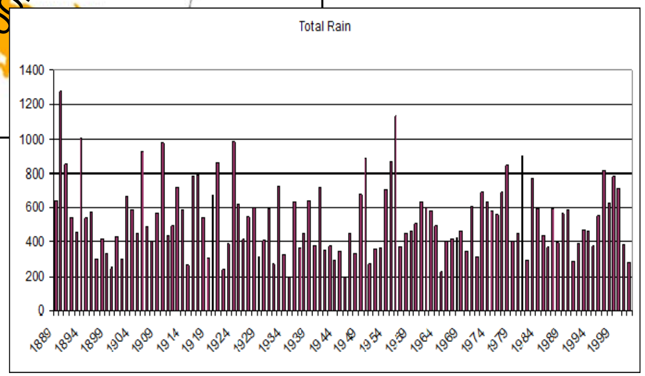


Case Study – Sorghum in Australia

- Major dryland grain row crop in NE Aust
- Summer crop system
- High climatic variability
- ~2 Mt grain from ~0.8 Mha

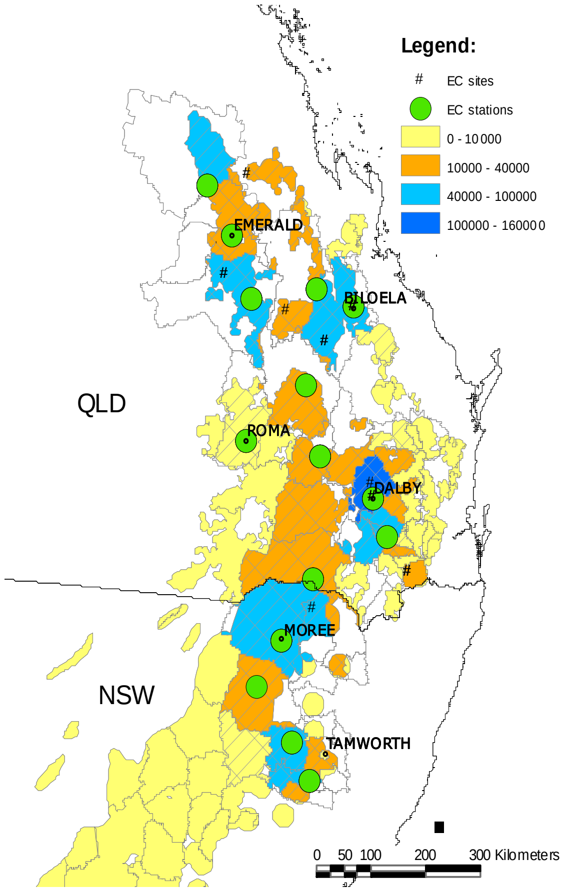






Environmental Characterisation

- historical climatic data
- local practice (G & M)
- local soils
- simulate crop life cycle stress patterns
- classify environments

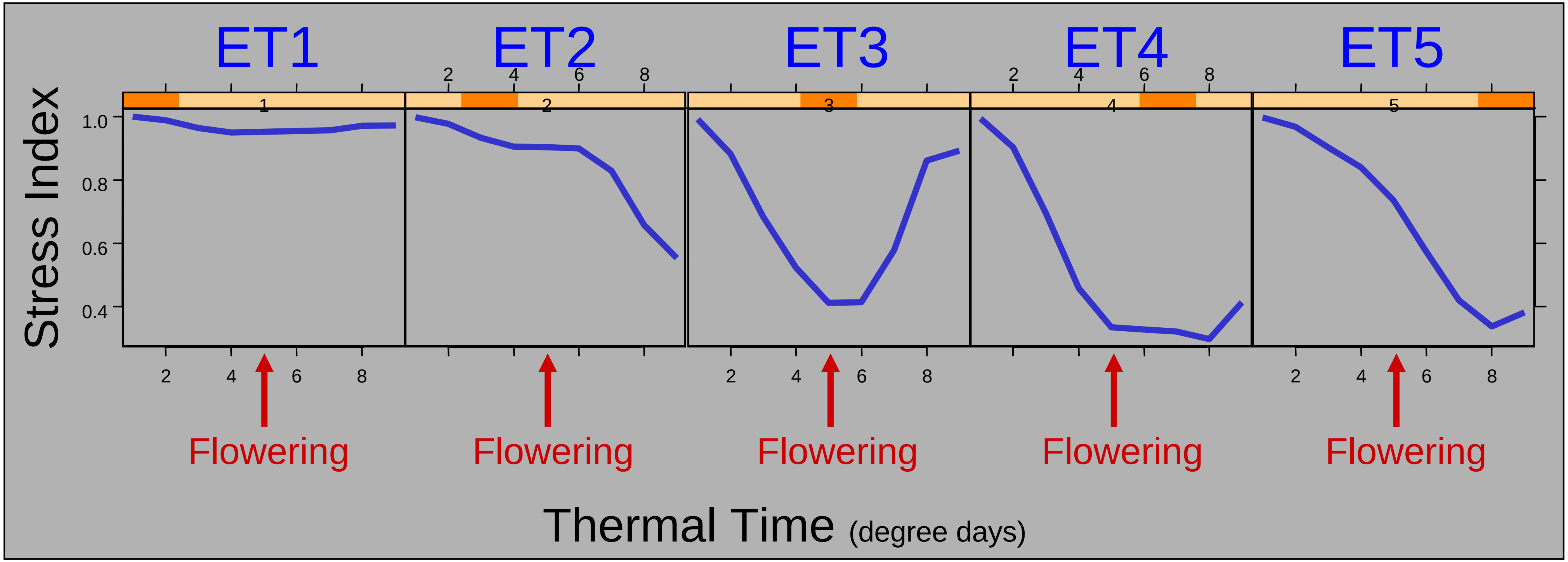


Location	Soil	Depth
Clermont	Black Earth	120
Clermont	Black Earth	80
Emerald	Black Earth	120
Emerald	Black Earth	80
Rolleston	Black Earth	120
Rolleston	Black Earth	80
Taroom	Gray Clay	150
Baralaba	Gray Clay	150
Biloela	Gray Clay	150
Dalby	Gray Clay	150
Dalby	Vertisol	180
Pittsworth	Gray Clay	150
Goondiwindi	Gray Clay	130
Goondiwindi	Red Clay	140
Miles	Gray Clay	150
Miles	Gray Clay	150
Roma	Black Earth	80
WeeWaa	Vertisol	150
Gunnedah	Vertisol	200
Moree	Vertisol	120
Quirindi	Vertisol	200

after Chapman et al (2000) Aust J Agric Res

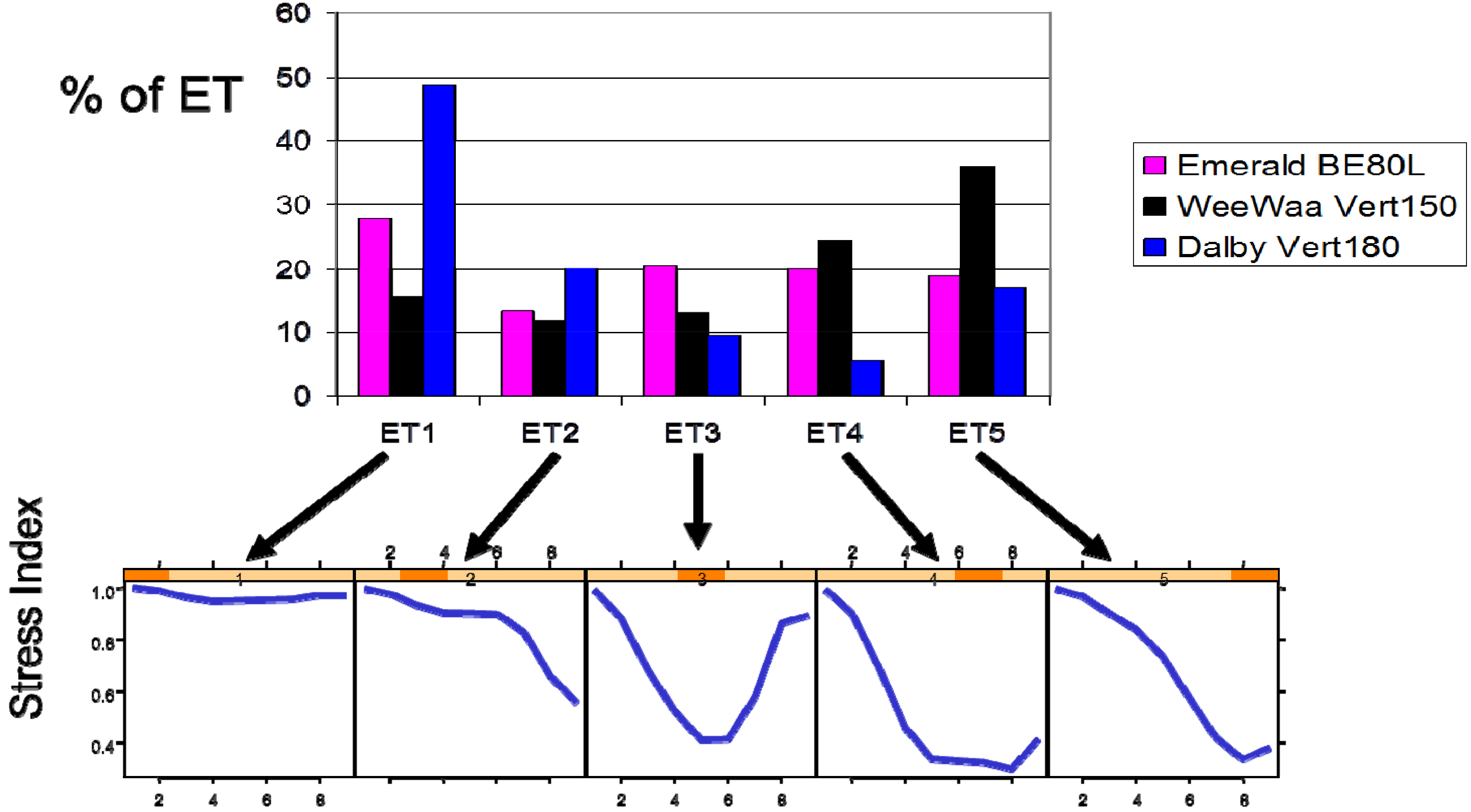
Environmental Characterisation

- Crop water stress patterns classified to derive 5 ETs



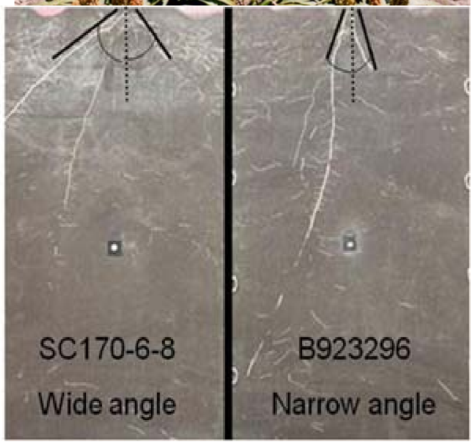
Environmental Characterisation

- Frequencies of Environment Types (ETs) experienced vary with location (for standard G and M)



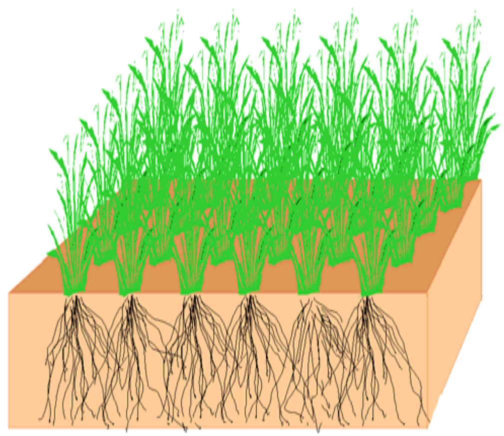
Simulating Adaptation

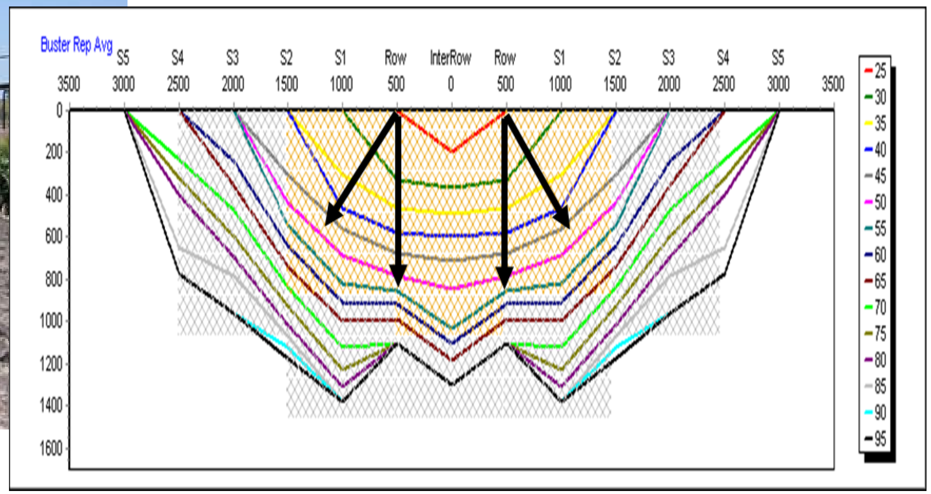
- Simulate range of G and M factors across production region
- Credible crop model for this (Hammer et al JXB 2010)
- M attributes
  - row configuration (3) (Whish et al CPS 2005)
  - density (4)
- G attributes
  - maturity (9) (Ravi Kumar et al FCR 2009)
  - tillering (9) (Kim et al Ann Bot 2010)
  - root system architecture (5) (Singh et al EJA 2012)
- E attributes
  - location, soil, (24) and historical climate (100+) (all ETs)
  - sowing date (3) and antecedent soil water (3)
- Computing architecture
  - approx 3 x 10^6 crop years



Simulating Adaptation – M attributes

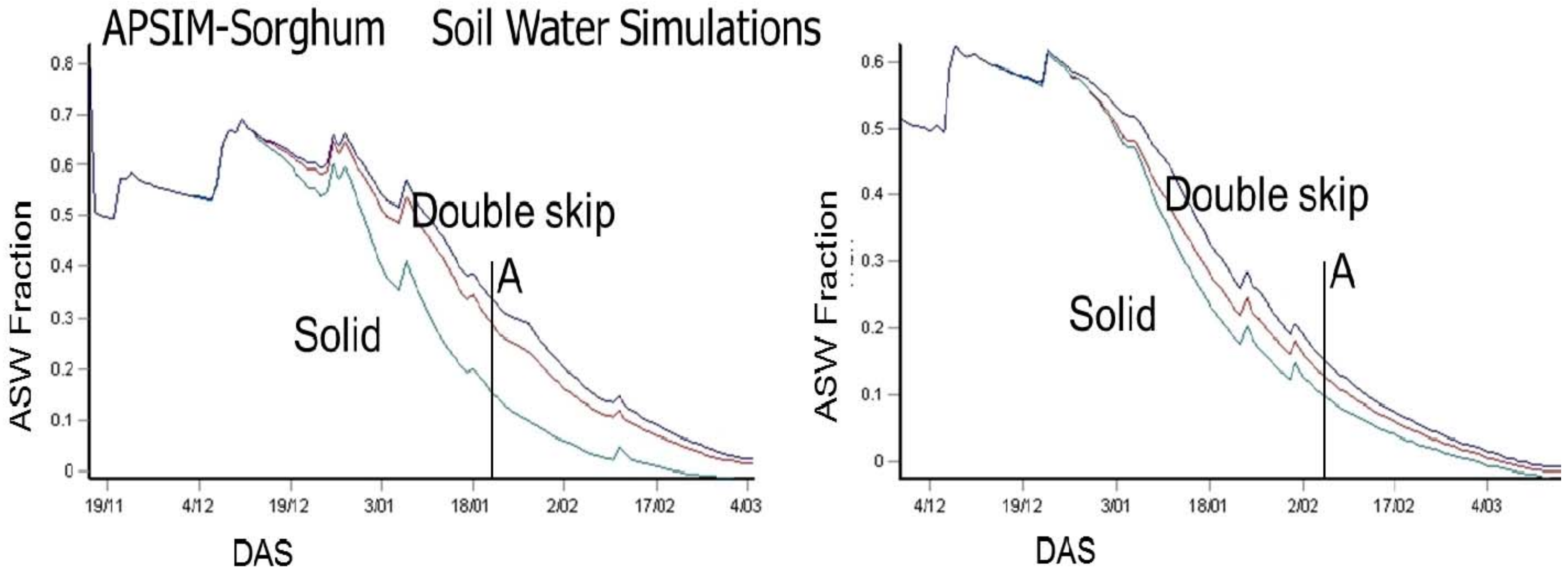
- Row configuration and density
  - Skip row water-saving systems – water demand and capture/supply
  - Density – canopy development and water demand



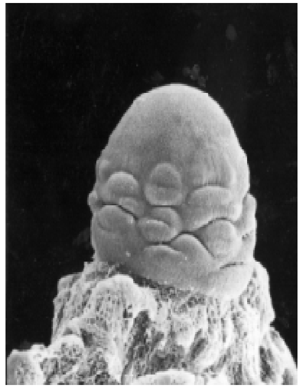


Simulating Adaptation – M attributes

- Row configuration and density
  - Manipulate total transpiration (extraction extent) and distribution in crop cycle

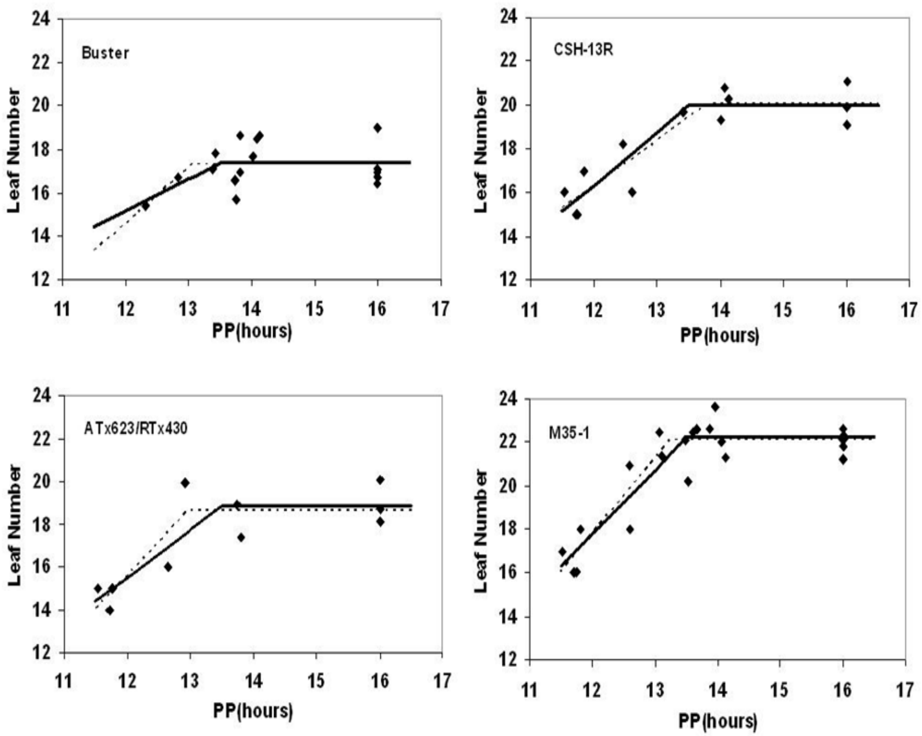


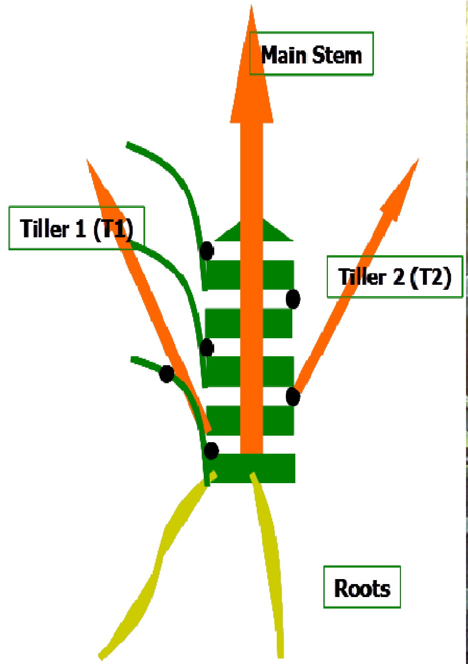
Whish et al (2005) Aust J Agric Res



Simulating Adaptation – G attributes

- Maturity and Tillering
  - Leaf number, canopy size and duration – water demand

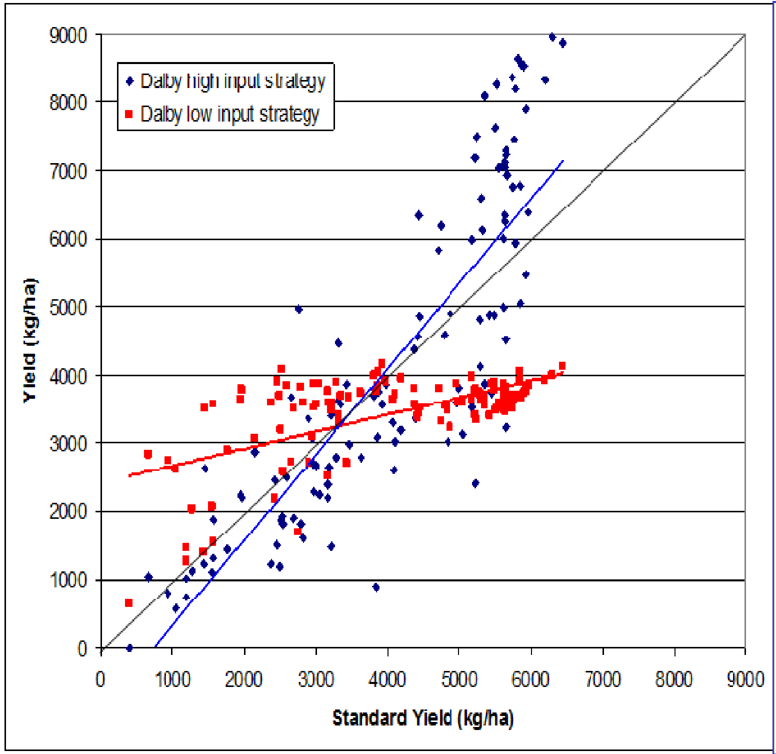




Ravi Kumar et al (2009) Field Crops Res; Kim et al (2010) Ann E

Simulating Adaptation – G and M attributes

- Maturity, Tillering, & Configuration effects



Standard strategy:

Medium cv.

5 pl/m^2

Solid

High input strategy:

Late cv.

12 pl/m^2

Solid

Low input strategy:

Medium cv.

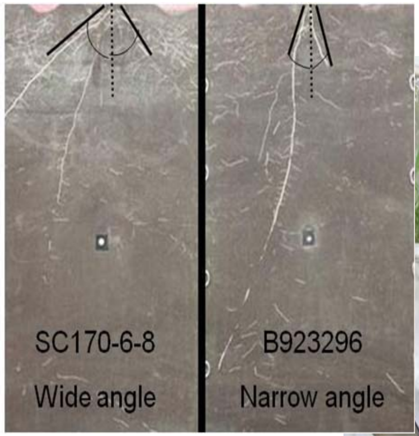
3 pl/m^2

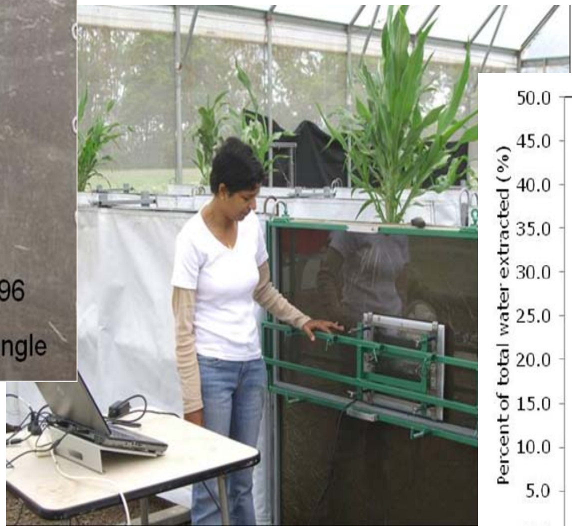
Single-skip

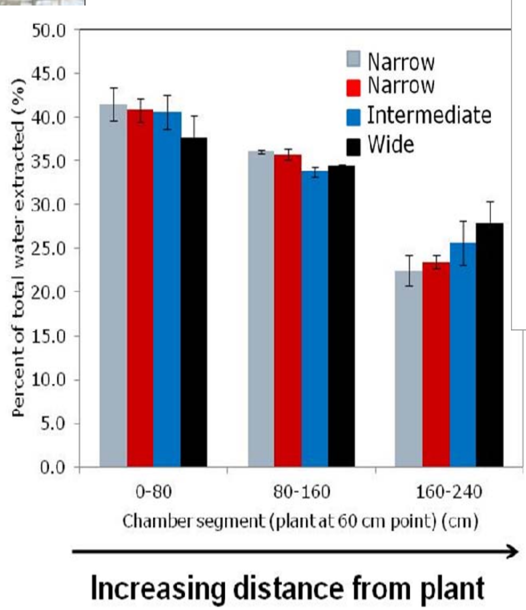
All: Dalby, 15 October plant, nitrogen not limiting, 1m rows, 240mm PAWC, 2/3 full

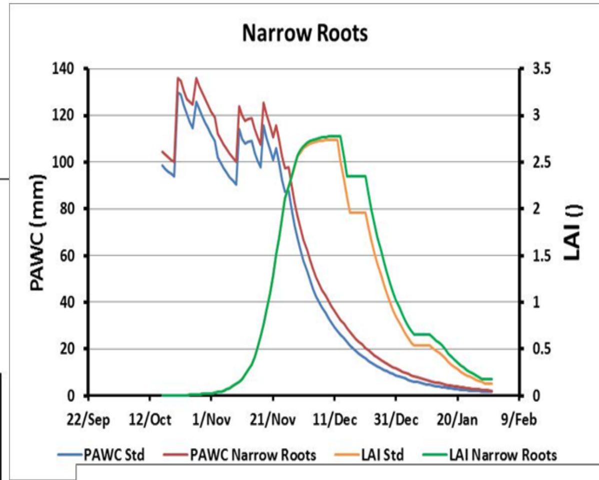
Simulating Adaptation – G attributes

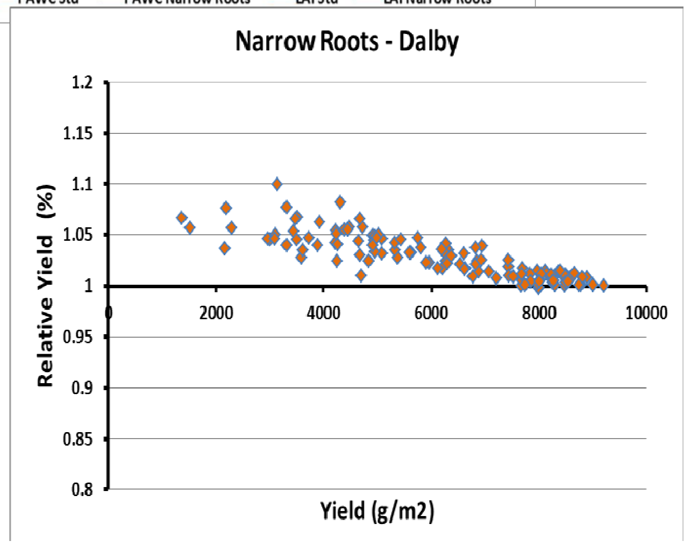
- Root system architecture
  - Root system distribution – extent of water capture and timing







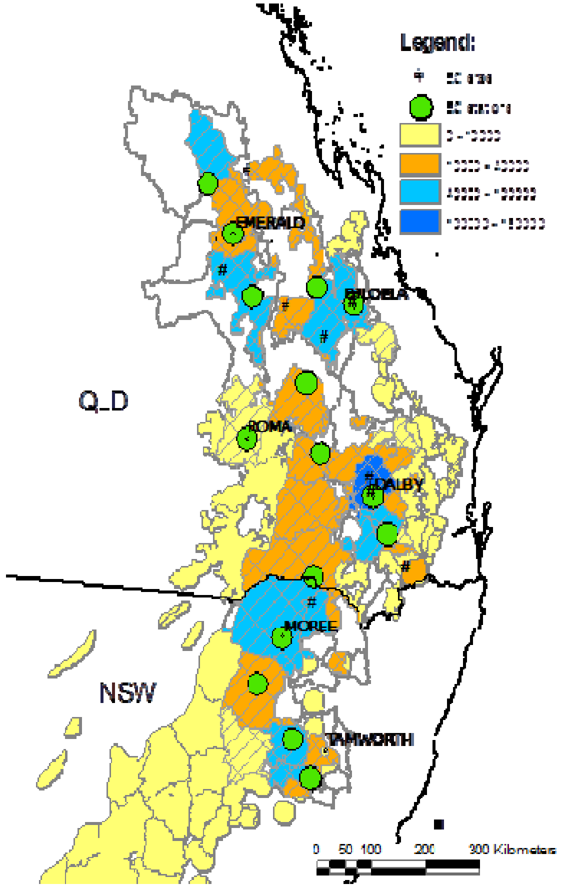




Singh et al (2011) Crop Sci; (2012) Eur J Agron

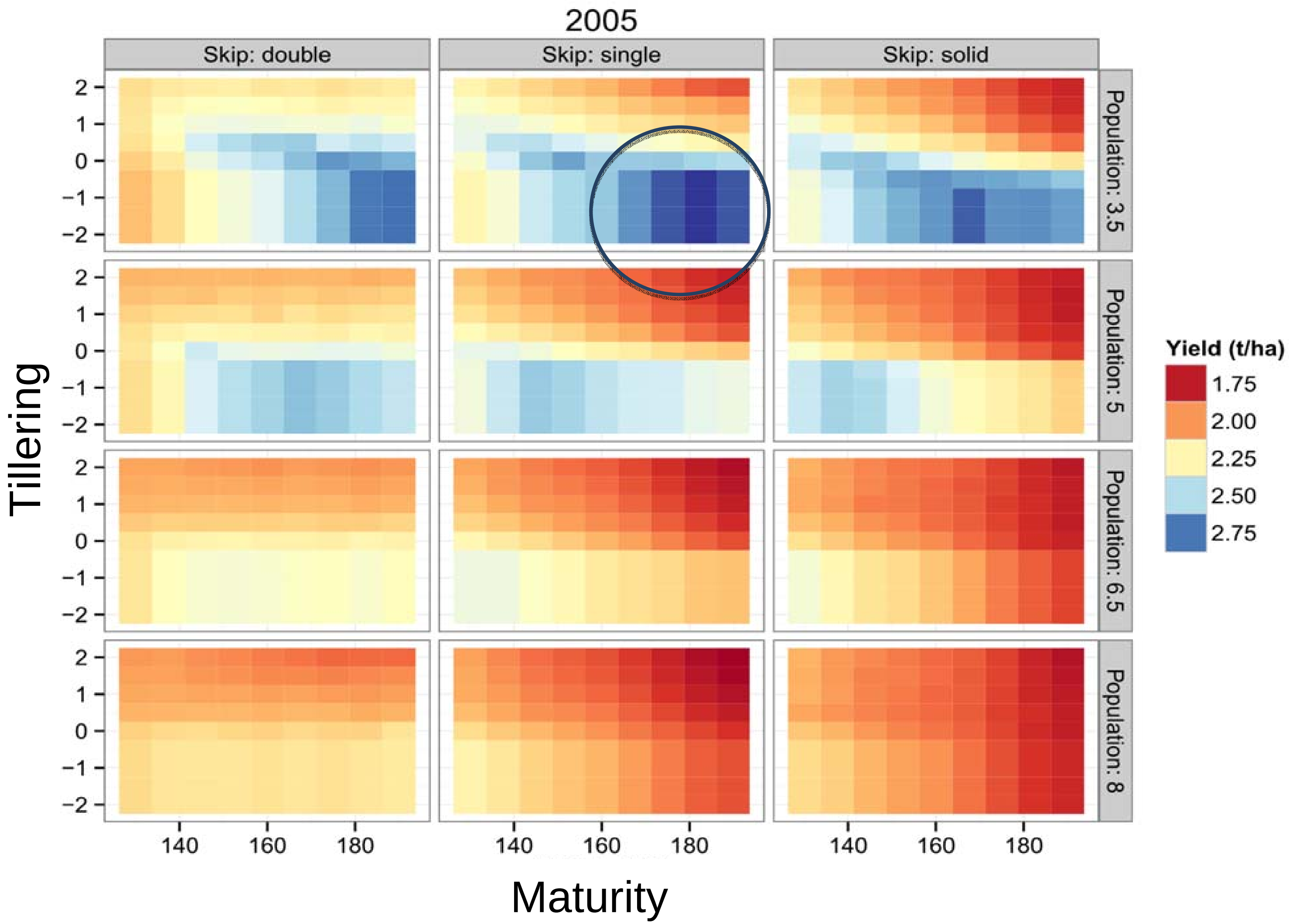
Simulating Adaptation – E attributes

- E attributes
  - Locations – long-term historical climate
  - Soils – relevant local cropping soils – depth, PAWC
  - Sowing date – uniform through local planting window
  - Antecedent soil water – 3 levels based on preliminary cropping system simulation of planting opportunities



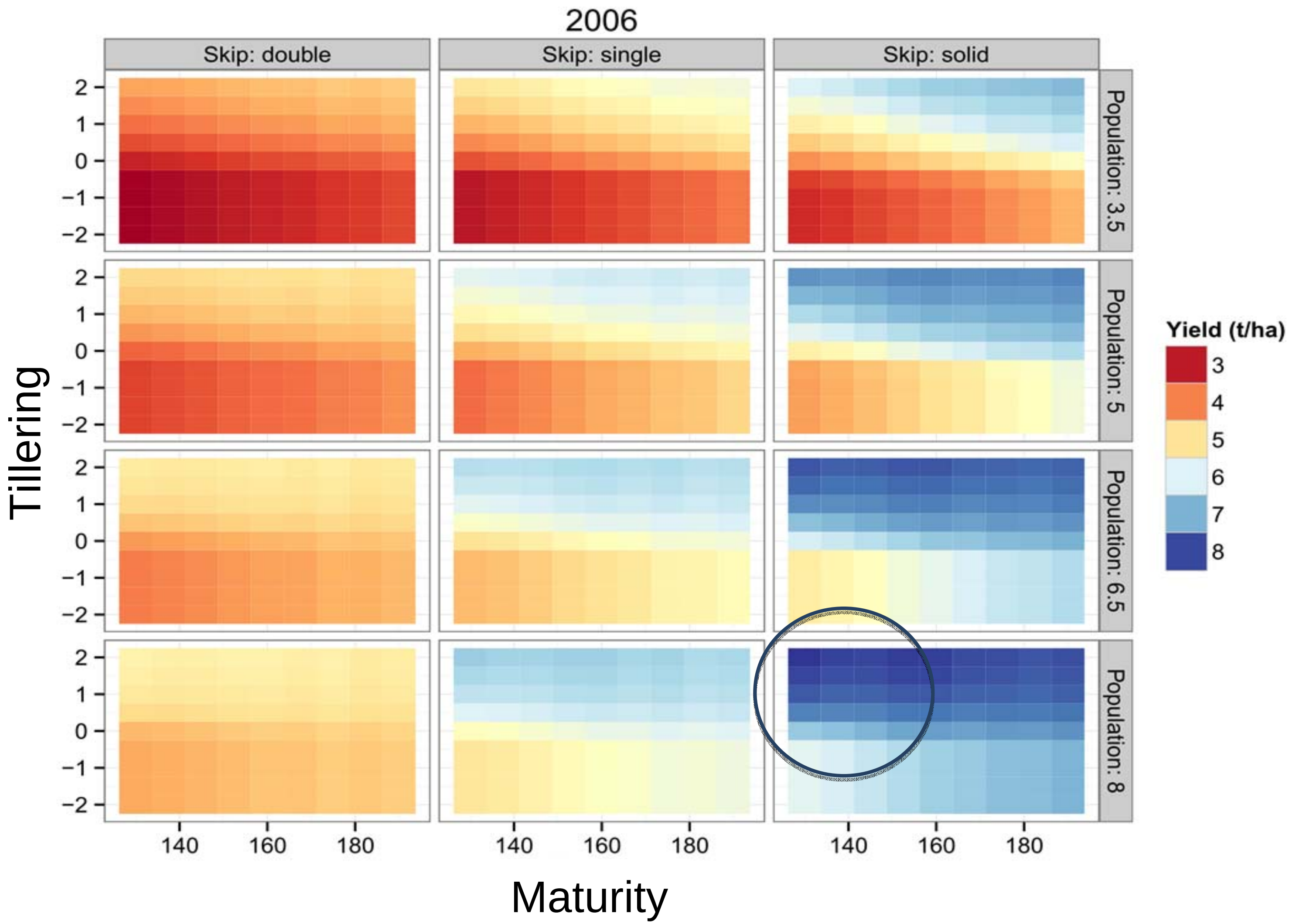
- Simulation
  - Simulate the landscape of GxMxE possibilities
  - Approx 3 x 10^6 crop years
  - Consider average yield over all E for standard M used in breeding trials – broad adaptation
  - Consider specific adaptation – add M effect and G*M effect within sub-regions

Simulating Adaptation – the GxMxE landscape



Yield response at Emerald – specific sowing date, soil water, root angle

Simulating Adaptation – the GxMxE landscape

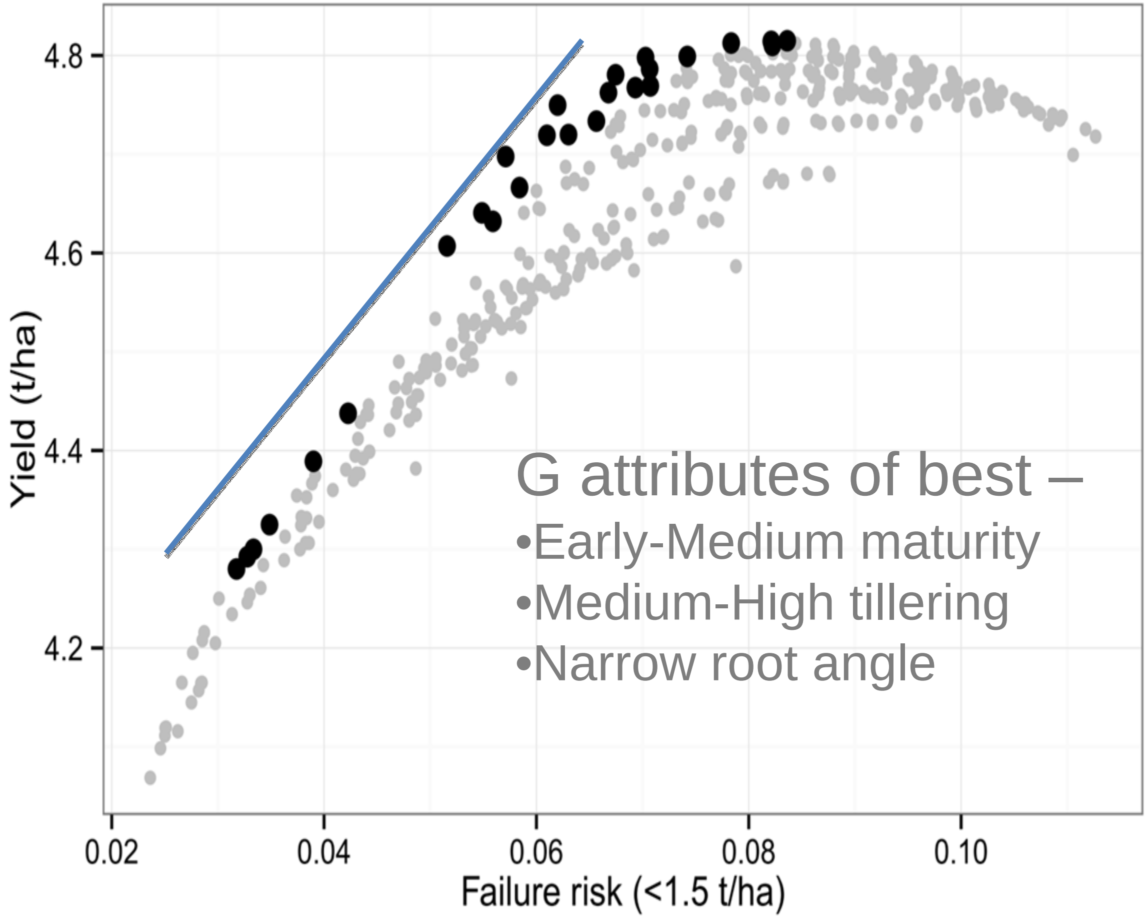


Yield response at Emerald – specific sowing date, soil water, root angle

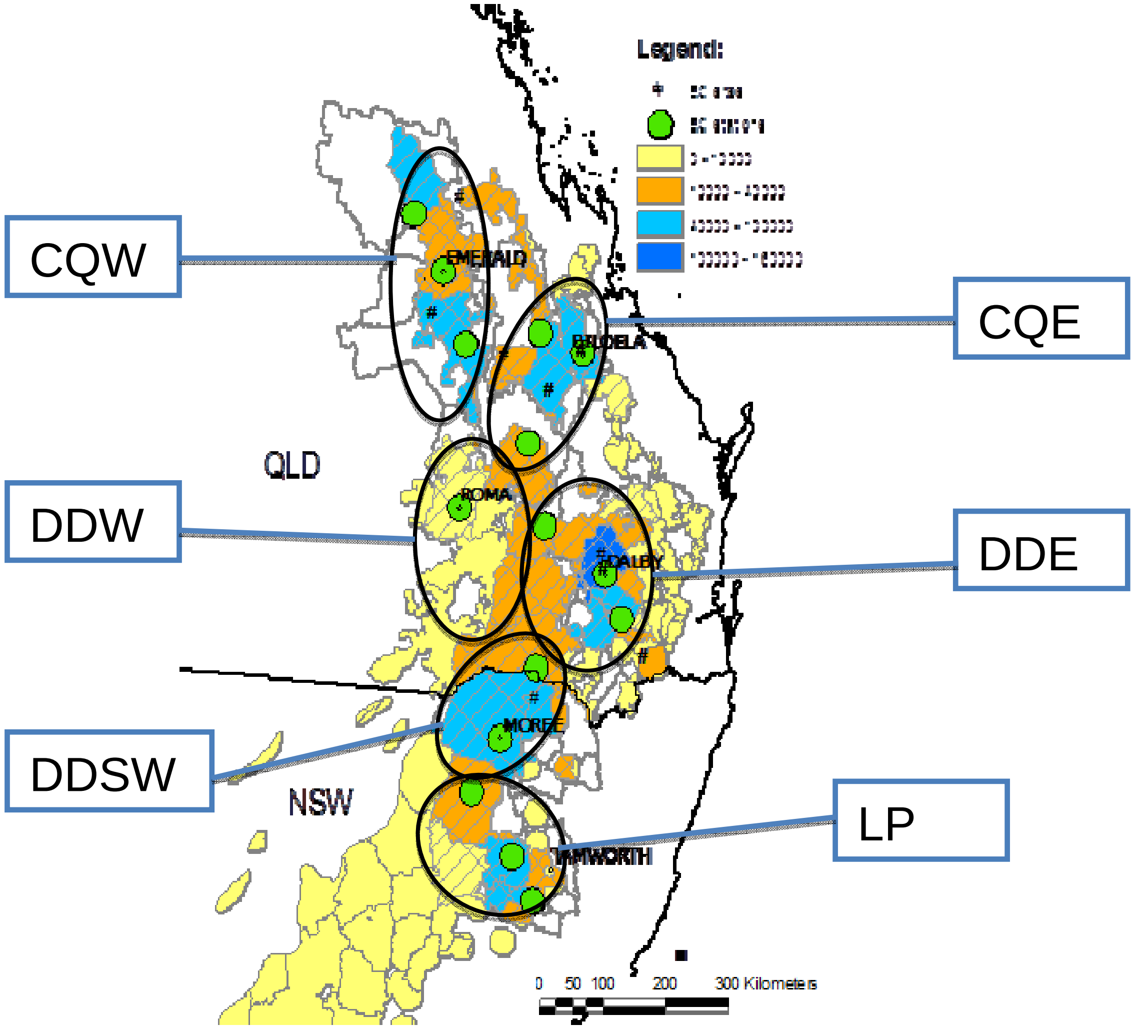
Simulating Broad Adaptation – technology frontier

- What is the best G over all E given standard M (solid planting at 5 plants m^{-2})?

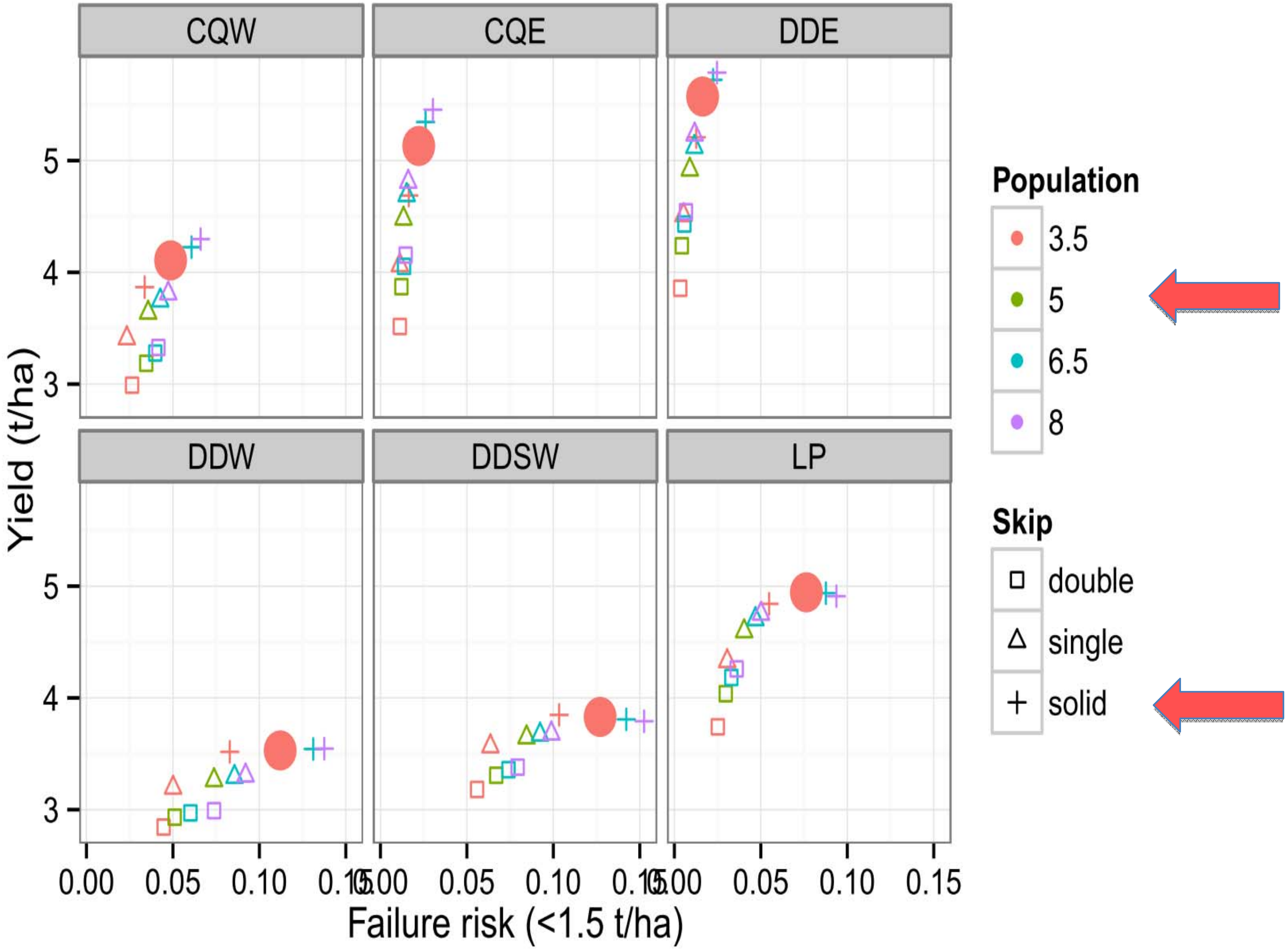
Consider Average Yield-Risk trade-off



Simulating Specific Adaptation – sub-regions



Simulating Specific Adaptation – global G, global

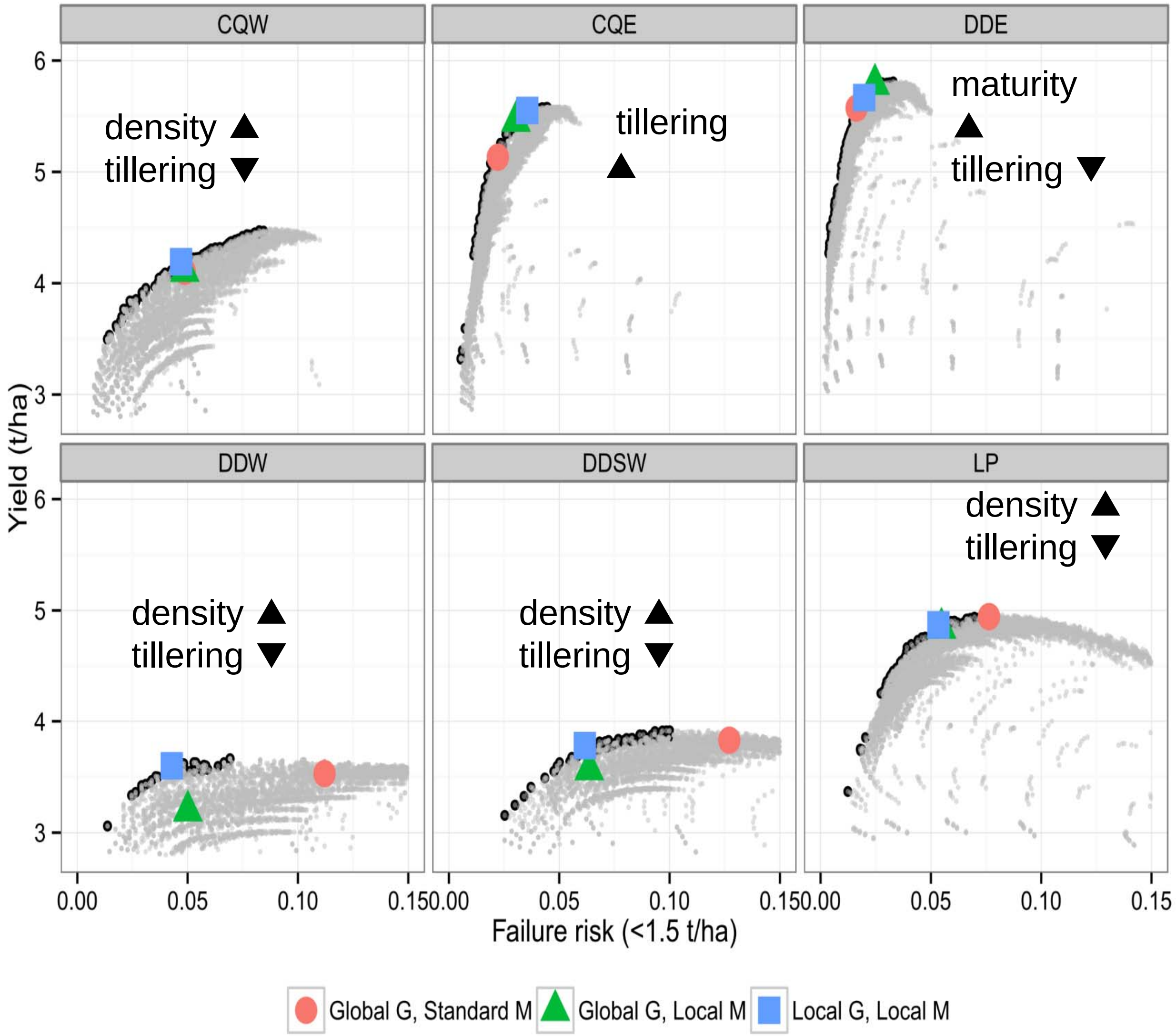


Simulating Specific Adaptation – global G, local M

Simulating Specific Adaptation – local G, local M

Significant shift in technology frontier associated with specific adaptation in some sub-regions

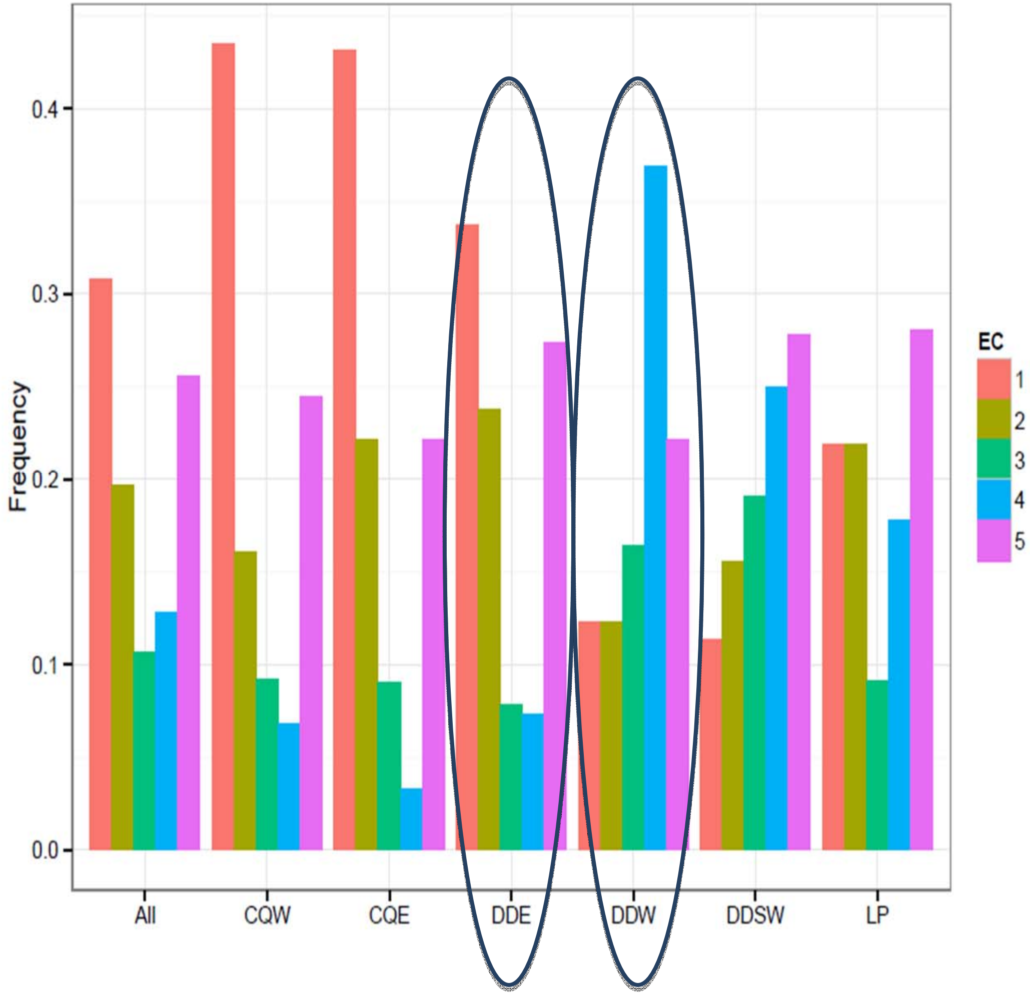
Consistent with mix of ETs within sub-regions ……

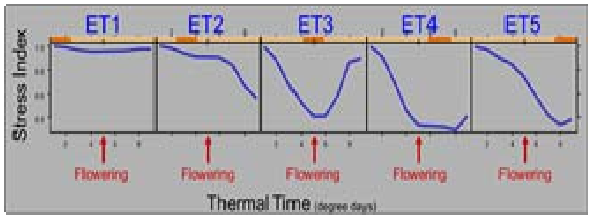


Simulating Specific Adaptation – ET effect

Mix of ETs within sub-regions underpins specific adaptation ……

but also restricts its extent!

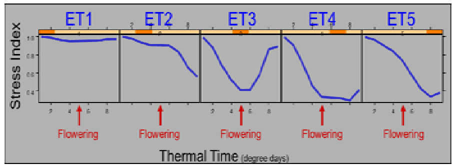


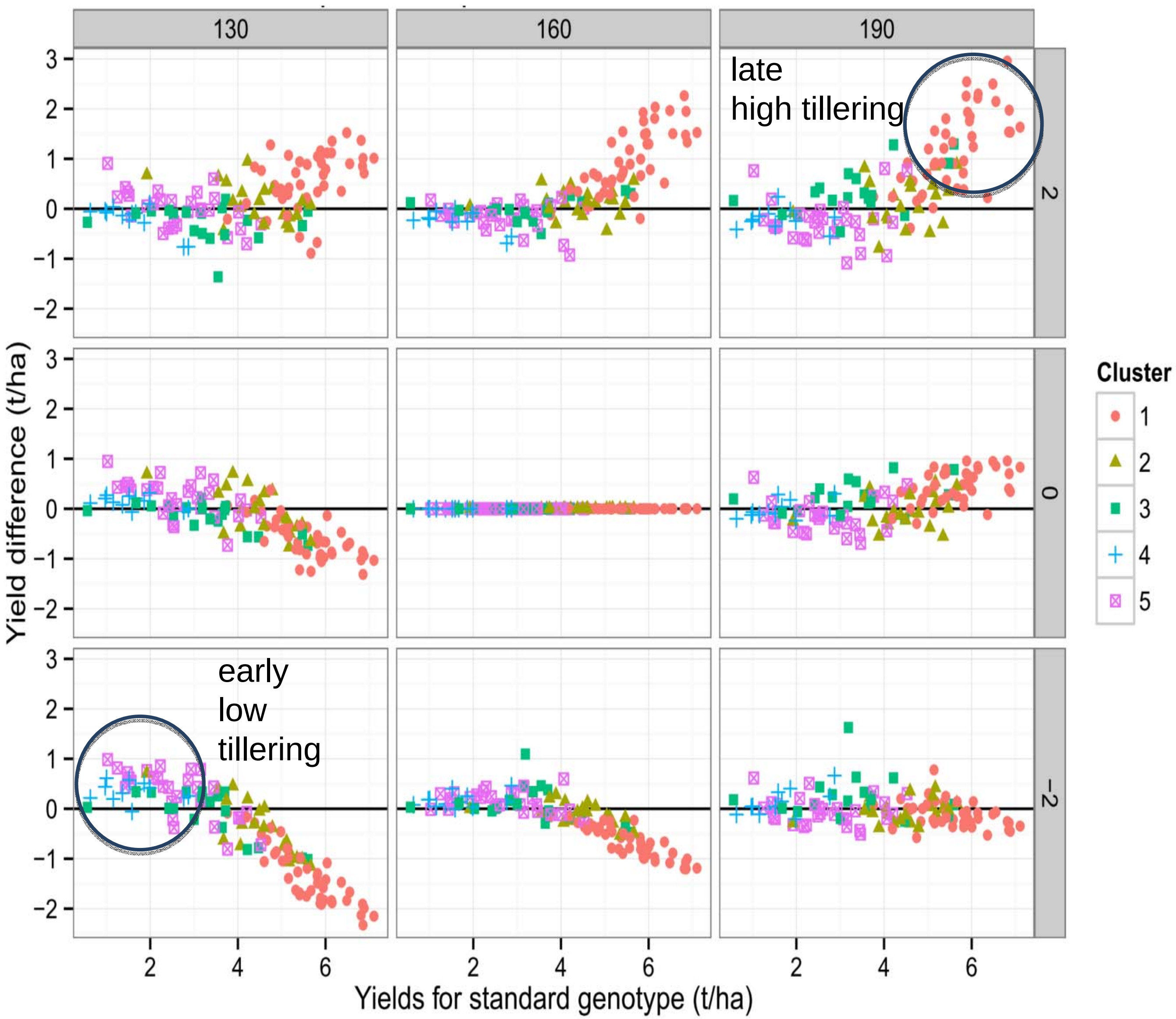


Simulating Specific Adaptation – ET effect?

Emerald (CQW) yield difference by maturity and tillering clustered by ET

Significant opportunity if have better advance indicator of ET than location alone





Implications

- Specific adaptation can increase yield and reduce risk
- M, G and G*M all contribute
- Potential benefit vs cost? – market value dependency
- Value varies among sub-regions for sorghum in Australia depending on mix of ETs
- High likely value of better advance indicators of ET than location – soil water content; sowing time; ENSO ??

"if you don't really understand it, you can't model it, but……
if you don't model it, you can't really understand it !"

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