Model-projected climate-induced change in water use efficiency and irrigation requirements of sugarcane production in South Africa

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Background and objectives

- **Background**
  - Future climate change likely to **affect sugarcane production**, differently in different regions

Limitations:

- Different interpretations provided by GC

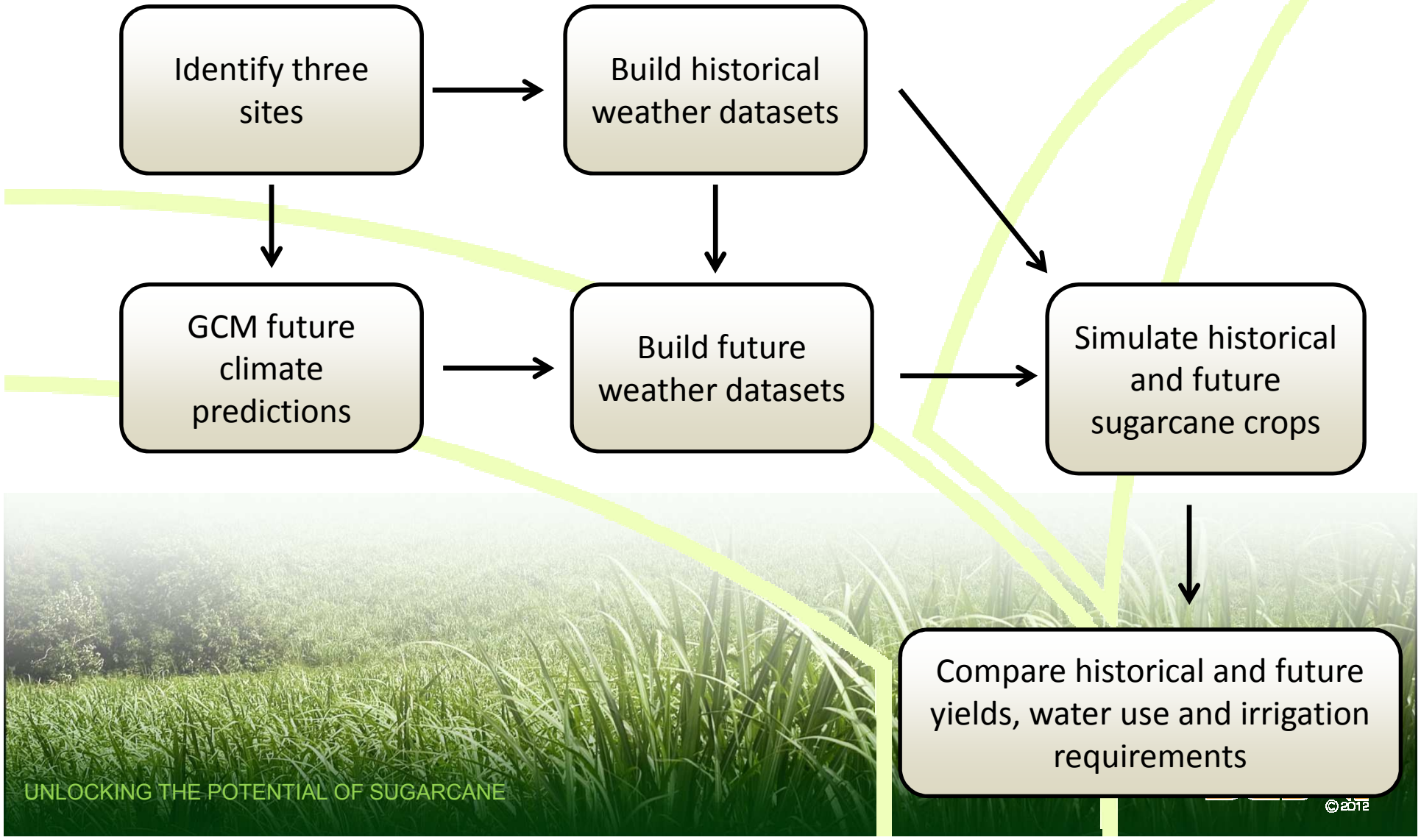
The Agricultural Model Intercomparison and Improvement Project (www.**AgMIP**.org) aims to characterise climate change impacts on agricultural production and enhance adaptation capacity:

- **Consistent (and widely inclusive) protocols** for all GCMs and crop models, at many sites.

Objectives

- **Estimate** (and explain!) **likely impacts of climate change on sugarcane yields, water use and irrigation demand** at three irrigated sugarcane production sites in South Africa.
- **Evaluate the methodology** used to link climate and crop models and conduct these analyses.

Methodology overview



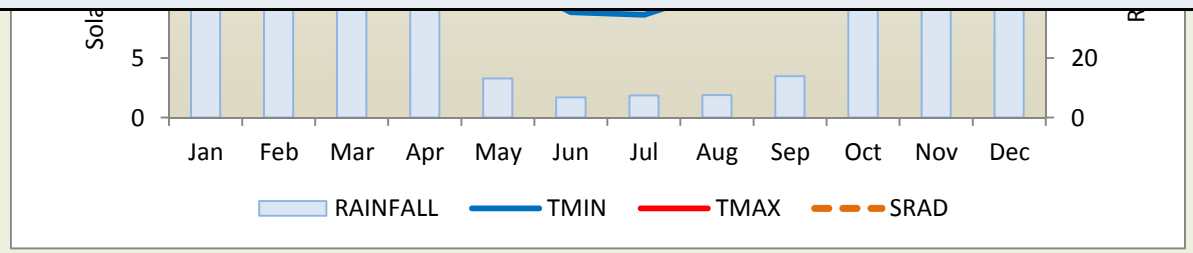
Sugarcane production sites

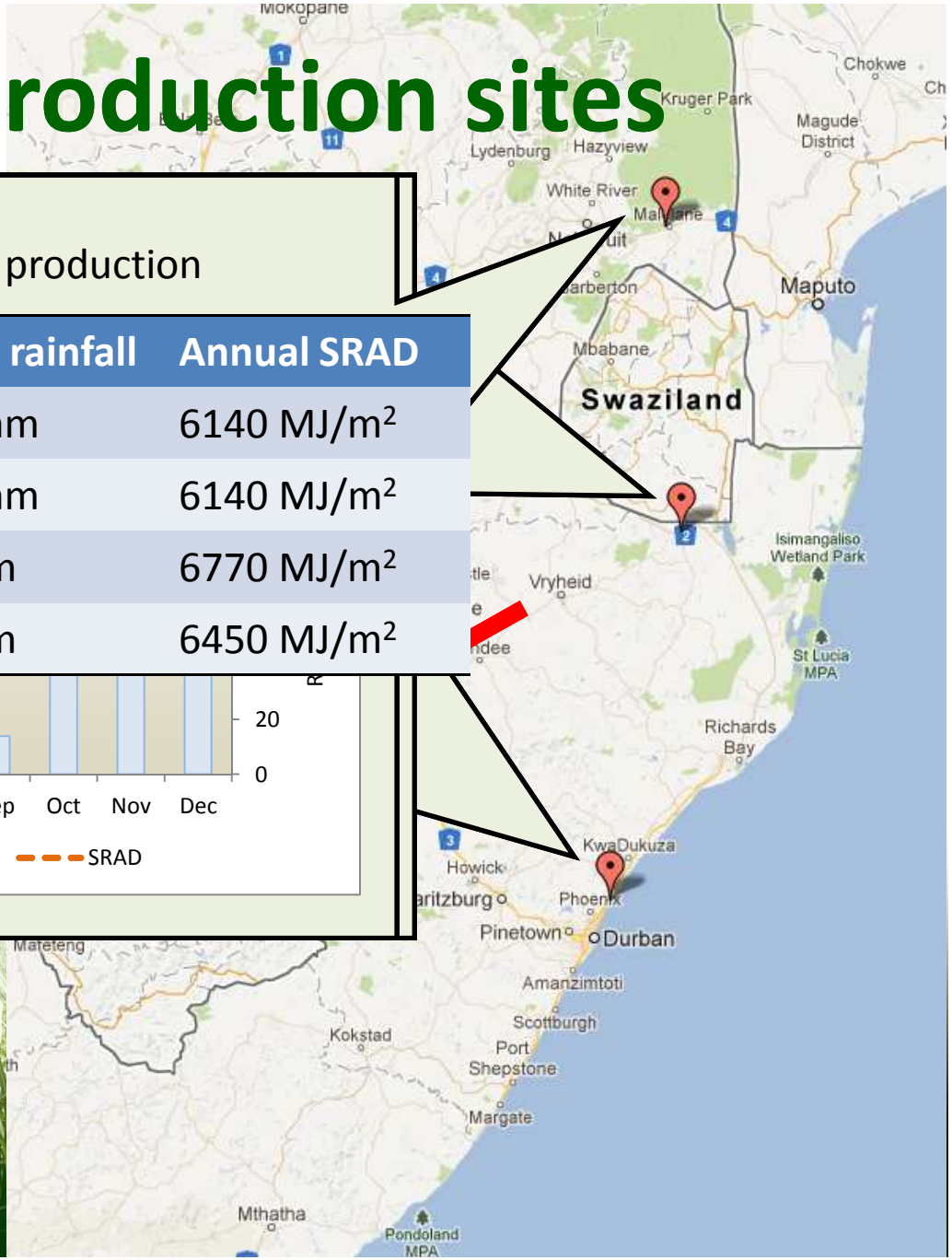
Malelane:

tential, irrigated production

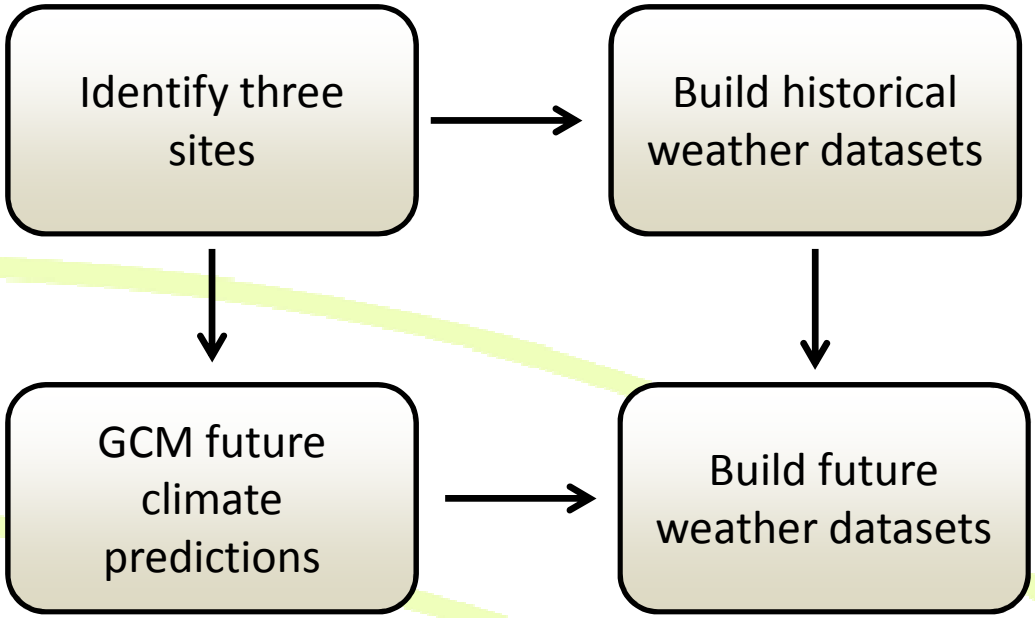
Identify three

Site	Irrigation	Annual rainfall	Annual SRAD
La Mercy	Rainfed	1000 mm	6140 MJ/m^2
La Mercy	Irrigated	1000 mm	6140 MJ/m^2
Malelane	Irrigated	560 mm	6770 MJ/m^2
Pongola	Irrigated	710 mm	6450 MJ/m^2





Methodology summary



Methodology: historical ("baseline") and future weather data

- Baseline: 1980-2010, [CO2
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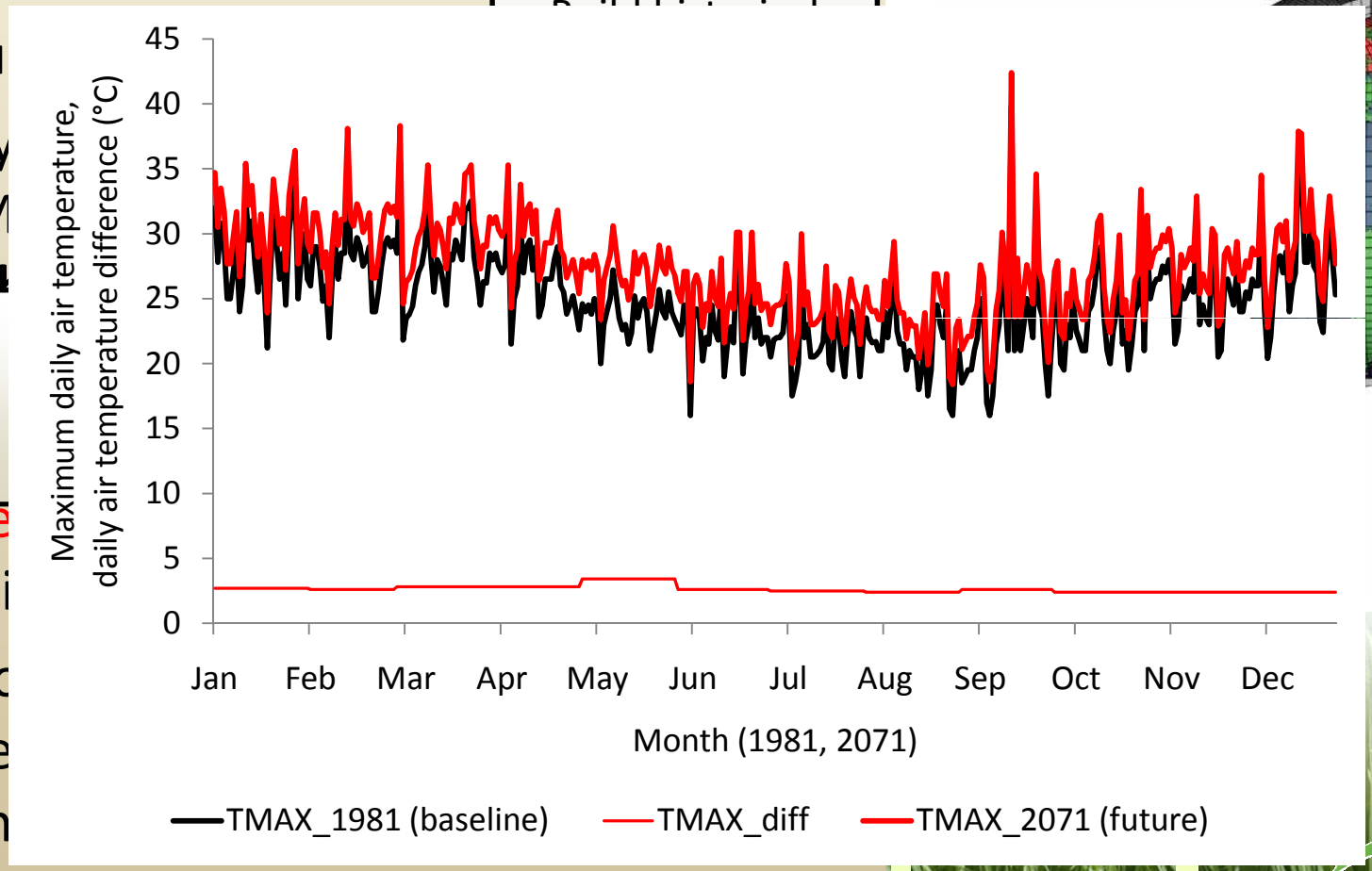
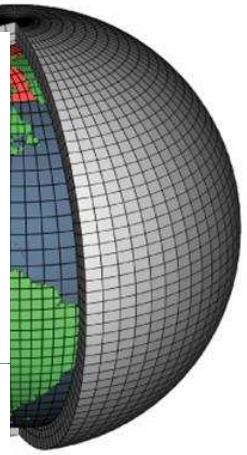
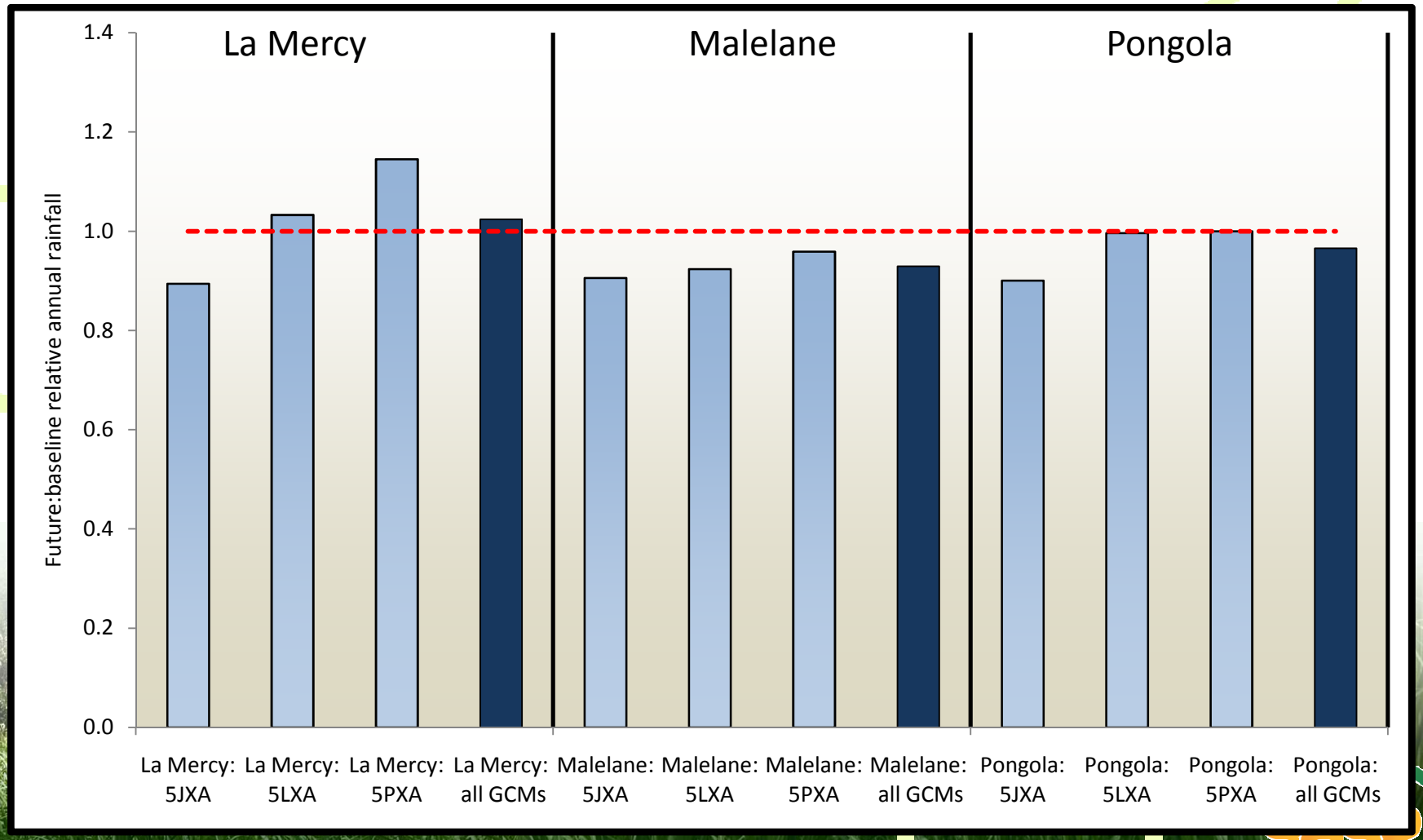
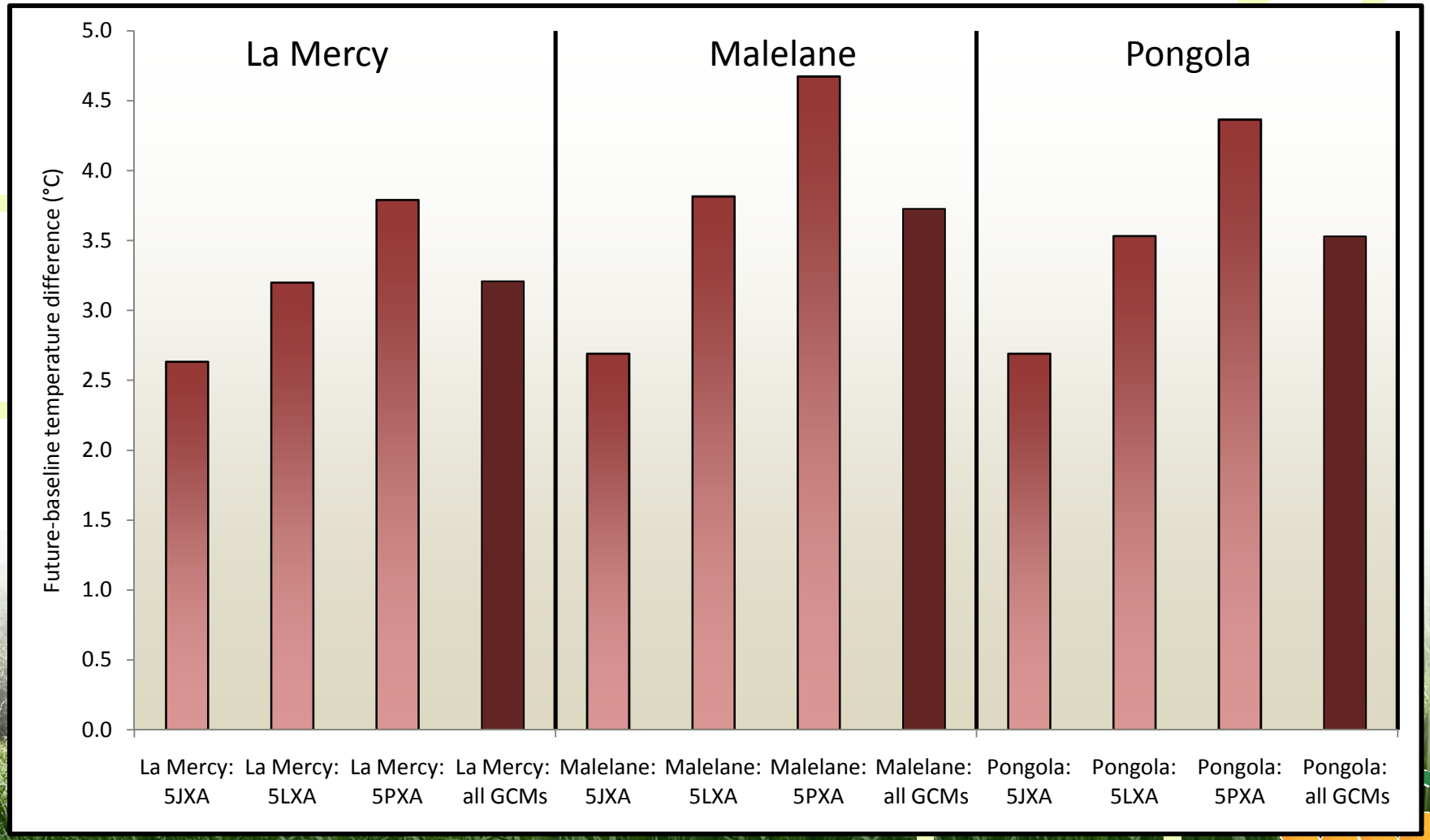




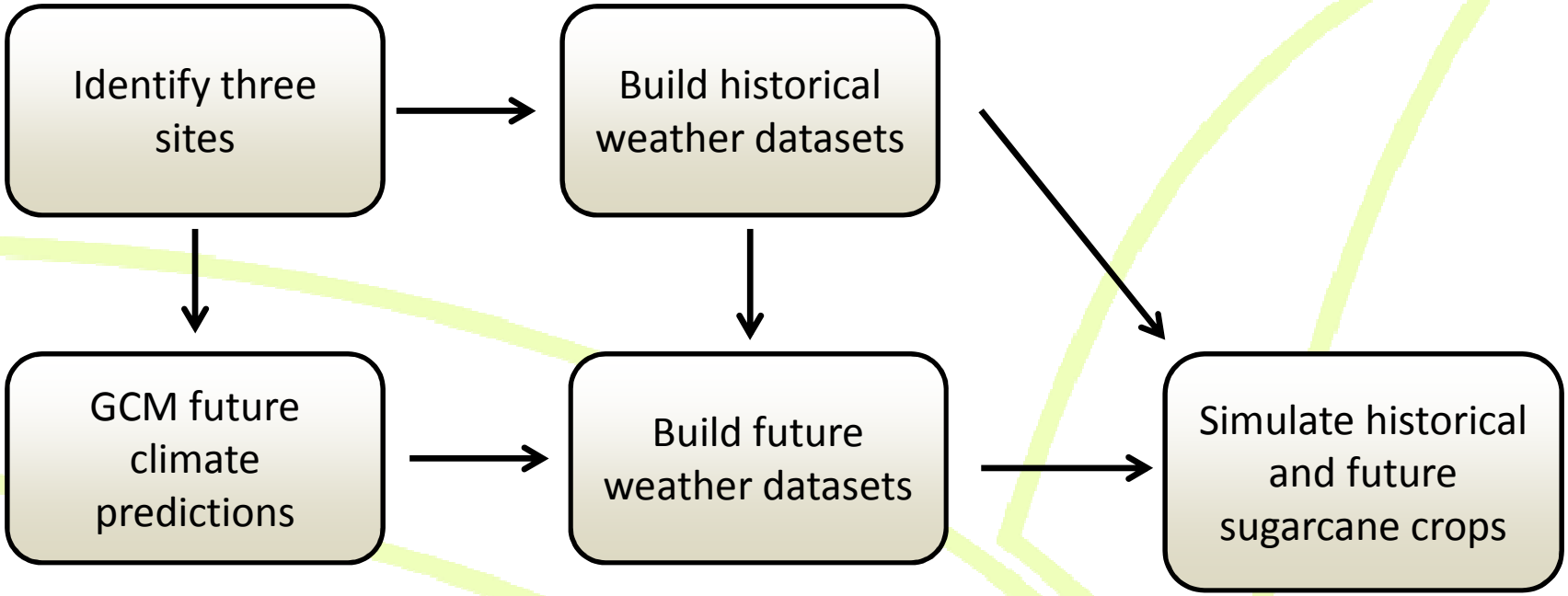
Expected rainfall changes



Expected temperature changes

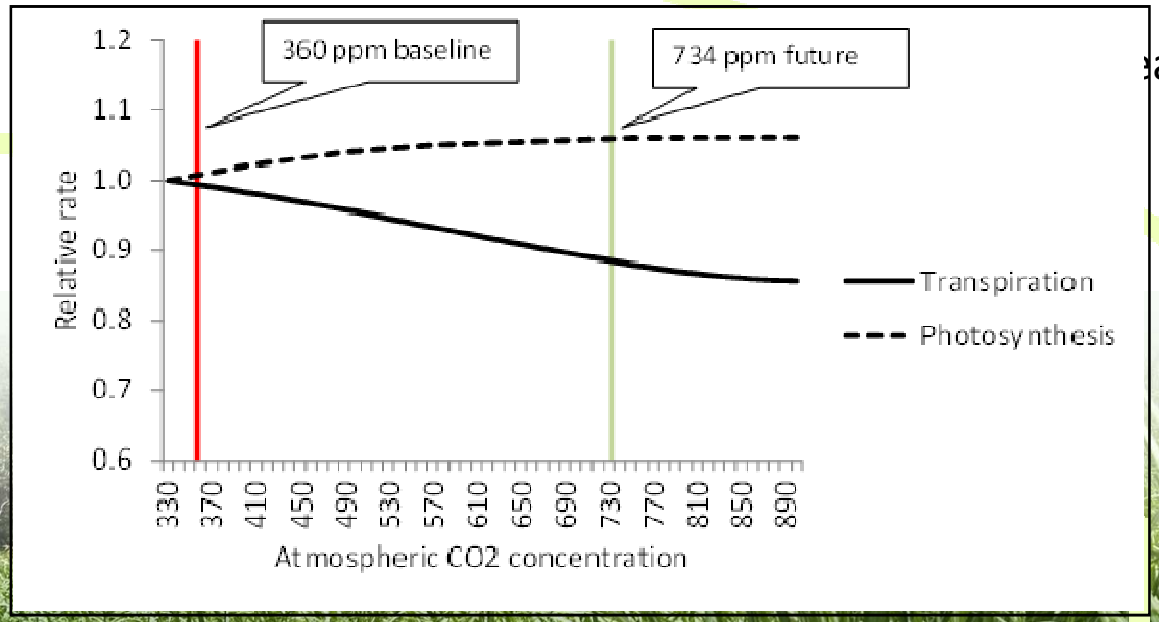


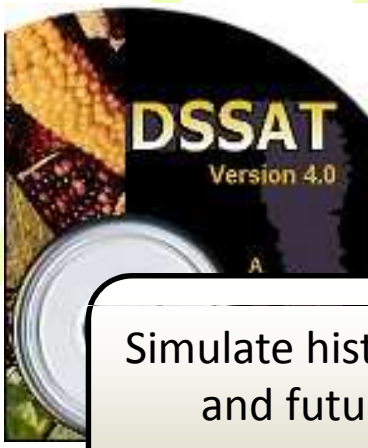
Methodology summary



Methods: crop simulations with DSSAT-Canegro

- Main features:
  - Radiation use efficiency and soil water deficit approach
  - **CO_2 sensitivity:** transpiration and photosynthesis
  - **Temperature sensitivity:** photosynthesis, maintenance respiration, biomass partitioning, germination and emergence, tillering, leaf appearance, root elongation…



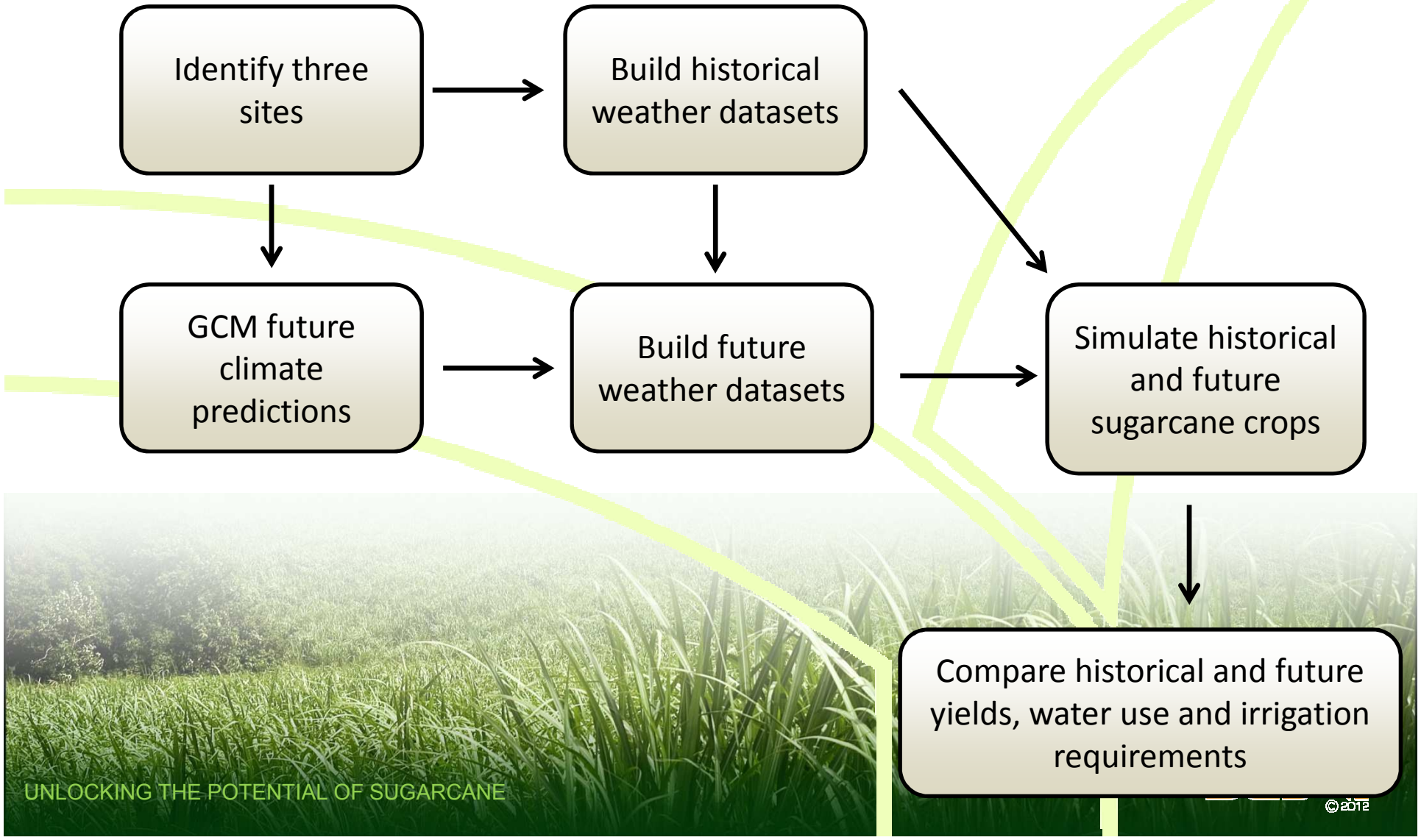


Simulate historical and future sugarcane crops

Simulation settings summary

Factor	Settings
Soil water holding capacity (WHC)	120 mm
Sugarcane variety	NCo376
Irrigation System	Overhead sprinkler, 100% efficiency, irrigation when required.
Start dates	1 April, 1 October; 1980-2009 (30 crops x 2 per site and weather data set)
Crop type	Ratoon

Methodology summary



Methodology: analyses

- Tools: MySQL DB and Excel
- Water use efficiency (t/ha/mm):

$$WUE = \frac{Yield}{ET}$$

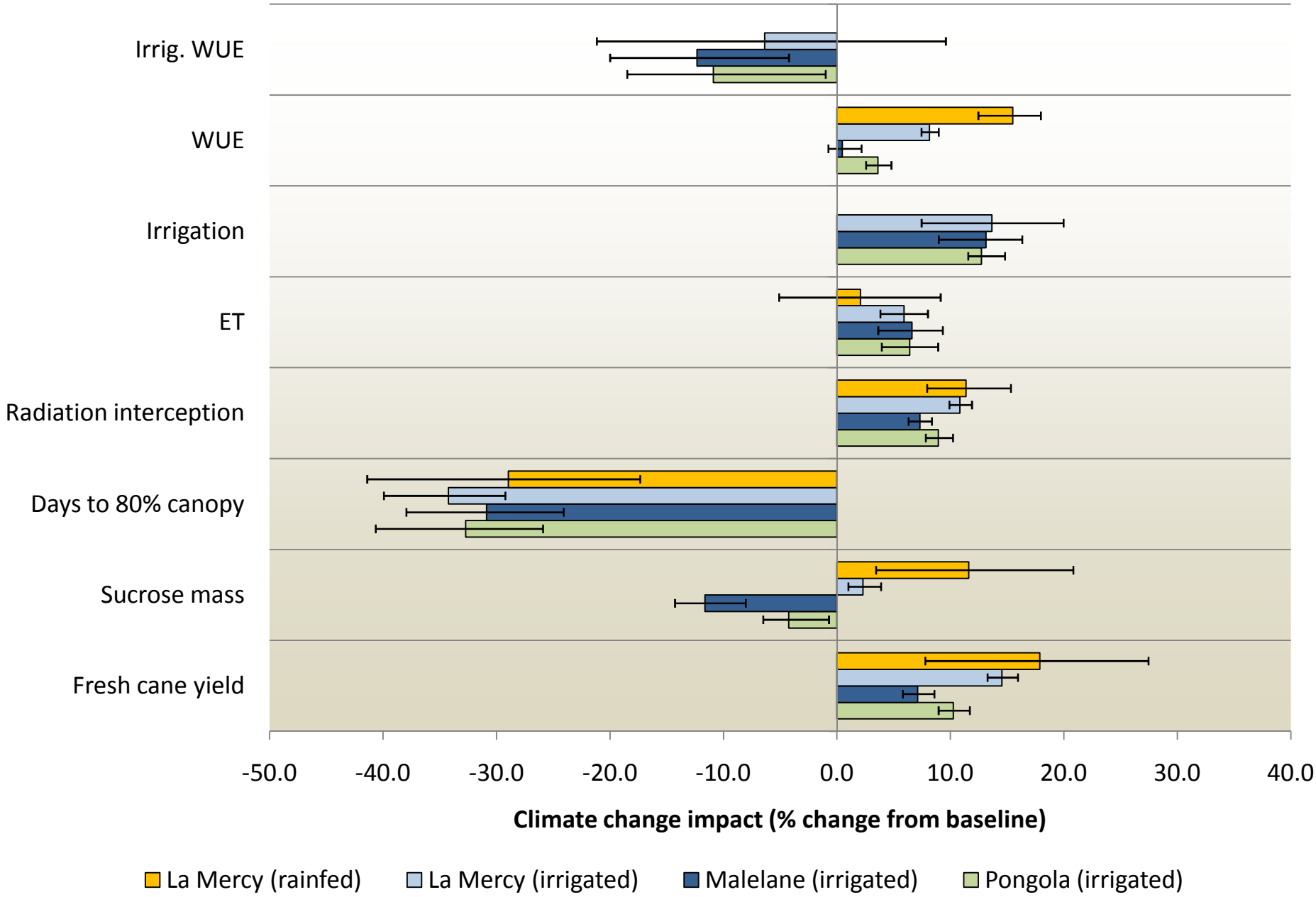
- Irrigation water use efficiency (t/ha/mm):

$$IWUE = \frac{Yield_{irrig} - Yield_{rainfed}}{Irrig}$$

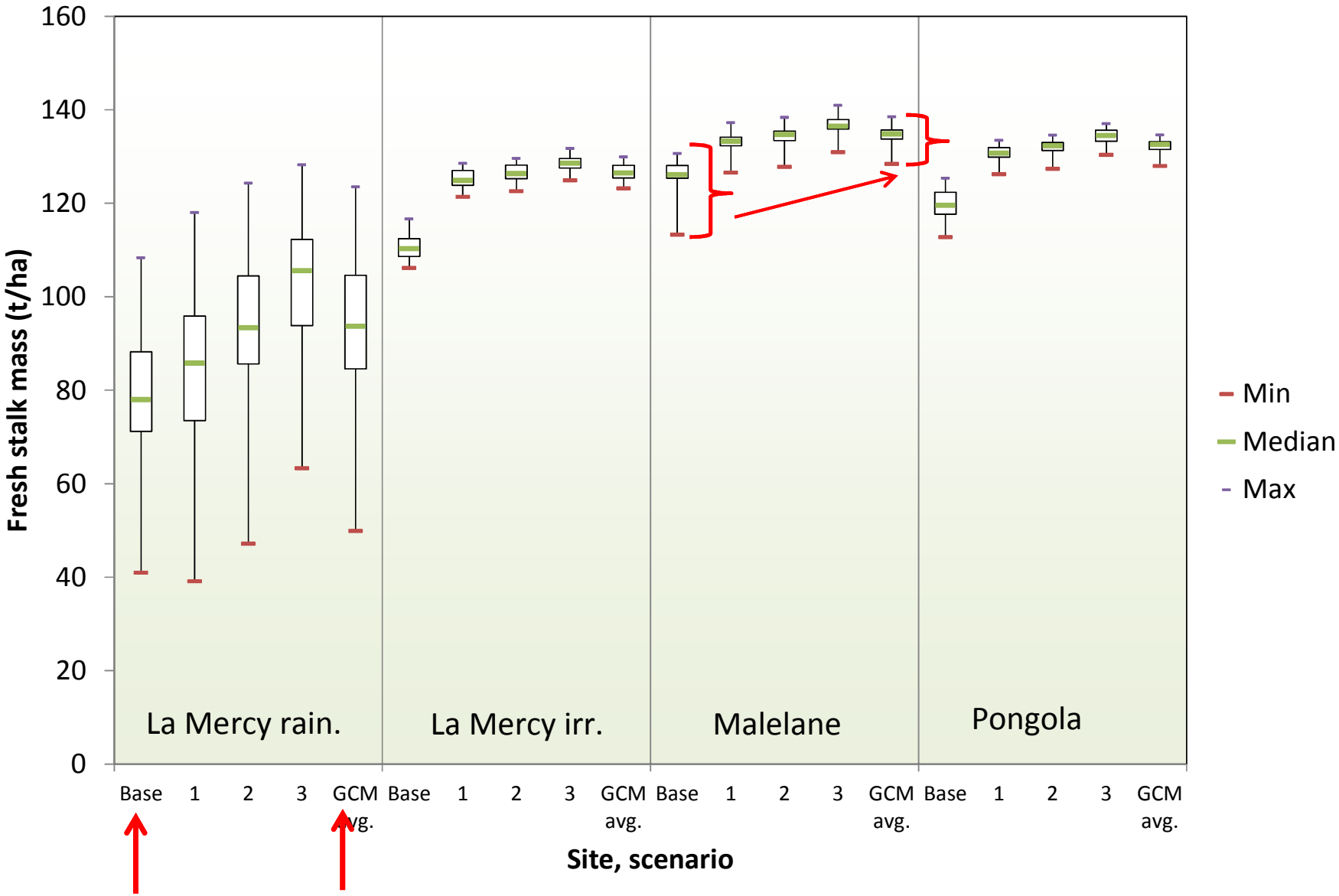
Compare historical and future yields, water use and irrigation requirements

Results

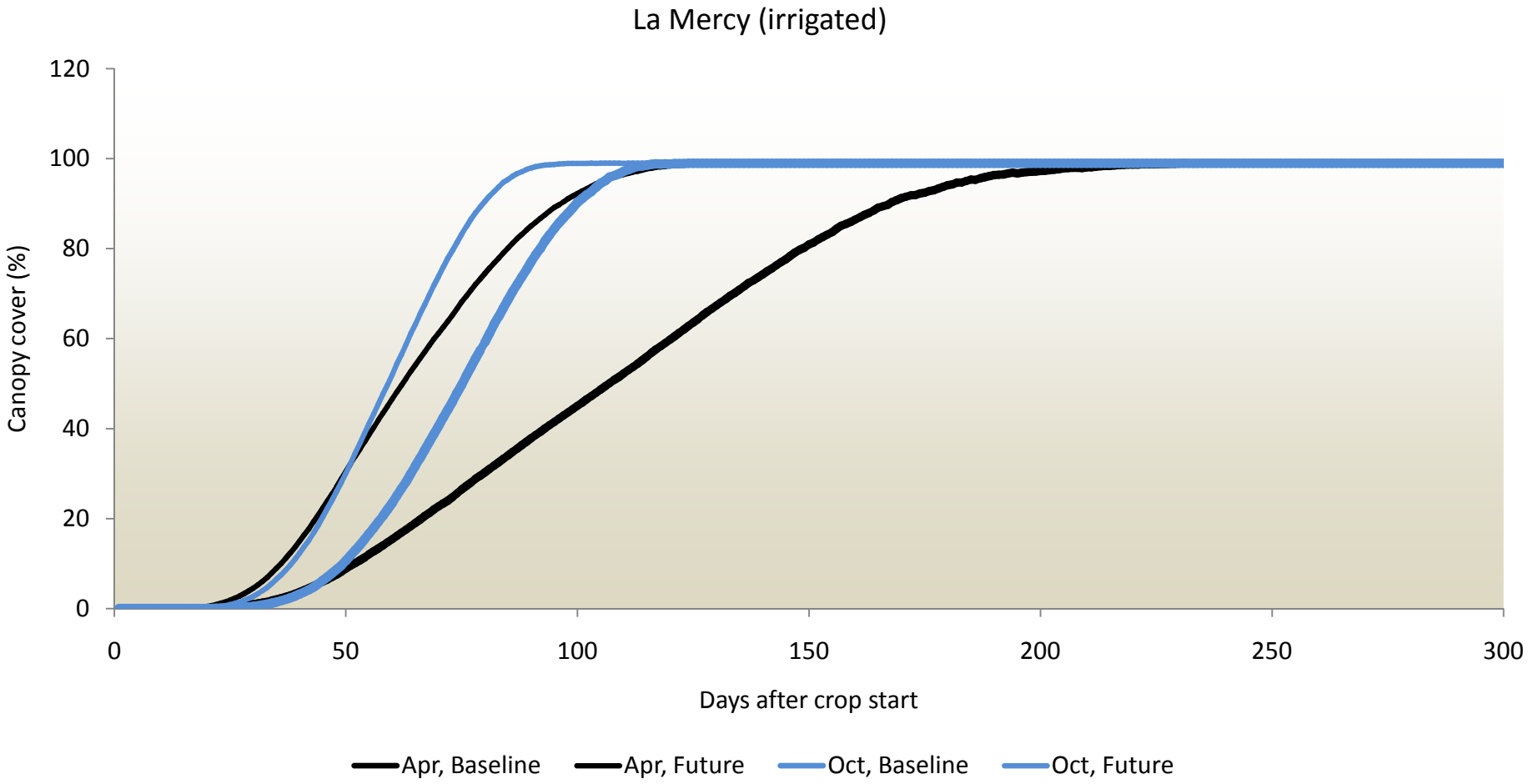
- Metrics
  - Yield responses
  - Phenological development (canopy cover)
  - Water use, irrigation demand and efficiencies
- Dimensions
  - Spatial / environmental (+GCM) variation
  - Seasonal (+GCM) variation
  - Crop cycle variation


Irrig. WUE
WUE
Irrigation
ET
Radiation interception
Days to 80% canopy
Sucrose mass
Fresh cane yield
-50.0
-40.0
-30.0
-20.0
-10.0
0.0
10.0
20.0
30.0
40.0
Climate change impact (% change from baseline)
La Mercy (rainfed)
La Mercy (irrigated)
Malelane (irrigated)
Pongola (irrigated)

Seasonal variability



Crop cycle variability



Insights

- Main findings
  - Accelerated canopy development due to **increased heat units** and exceeding **base temperature threshold** in autumn crops
  - Leads to increased interception of radiation and increased transpiration, increased cane yields
  - Higher irrigation demands (but higher cane yields)
  - ET and transpiration increased due to increased evaporative demand and canopy cover, despite inhibiting effect of elevated CO_2
  - Climate change impacts are **more favourable for currently lower-potential areas** and vice-versa.

Methodology issues

- **Un-capped temperature response** in DSSAT-Canegro model
- Temperature sensitivity of **maintenance respiration** → decreased sucrose accumulation.
- Downscaling method:
  - what if seasonal and inter-annual **variability (e.g. rainfall) change in future?** → additional downscaling methods
  - Solar radiation? Relative humidity? Windspeed?

Practical conclusions

- **Demand for irrigation water will increase** in future
  - Greater irrigation water supply / efficiency improvements required
  - Higher-capacity hardware required
- Yields will increase, but **sucrose yields might decrease**
  - Ripener use, varieties, season length, harvest age?

Future work

- Use all GCMs and time periods, more downscaling methods
- Refine and compare crop models and use APSIM and Canegro, possibly Casupro and Aquacrop
- Simulate more sites (regional studies)

Acknowledgements

- AgMIP (methods)
- Phillemon Sithole and Shenay Harisunker (baseline weather data preparation)