Sugarcane production and climate change: Model projections for 2050

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SA Sugar Industry Agronomists' Association Symposium
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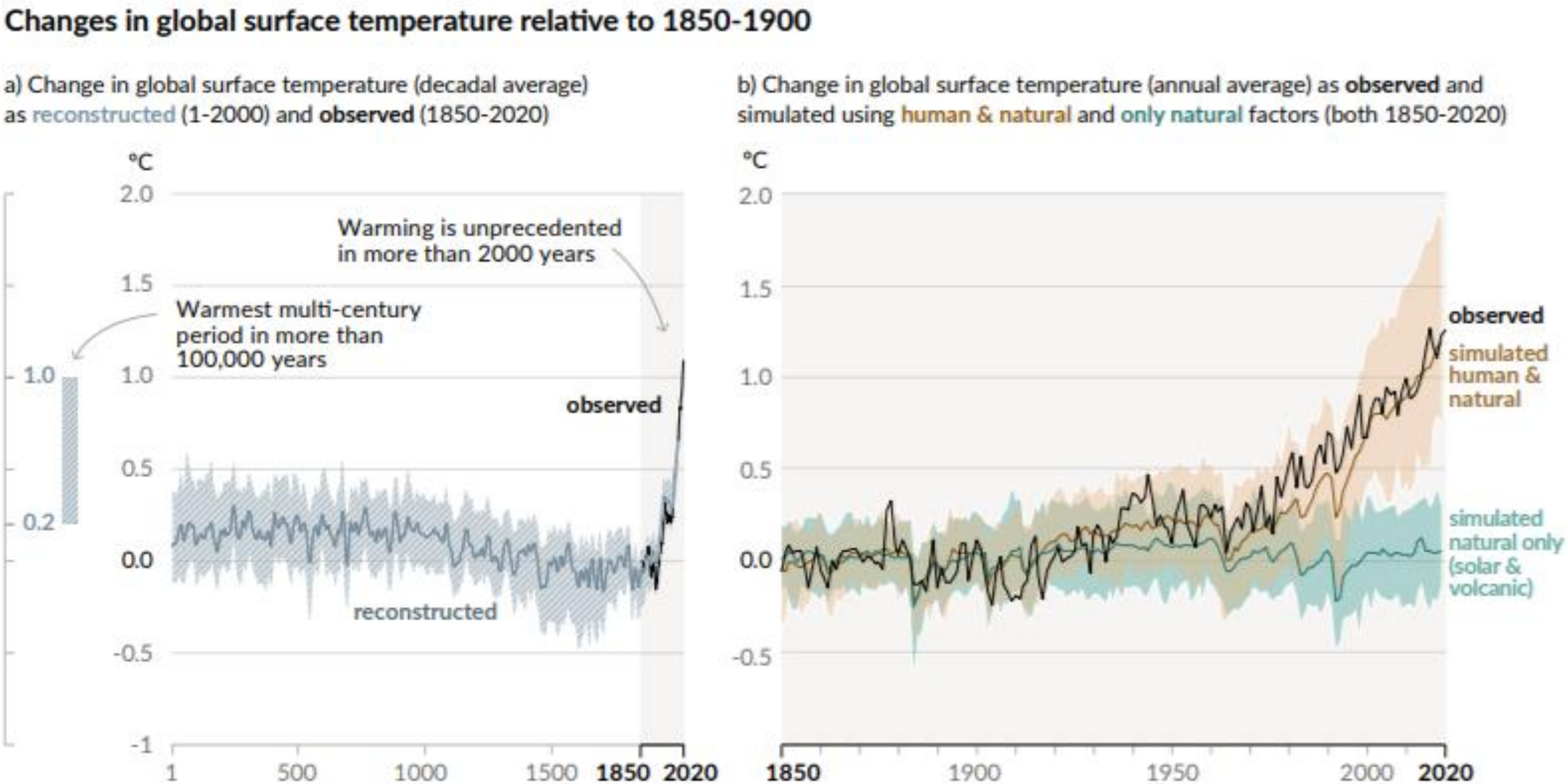
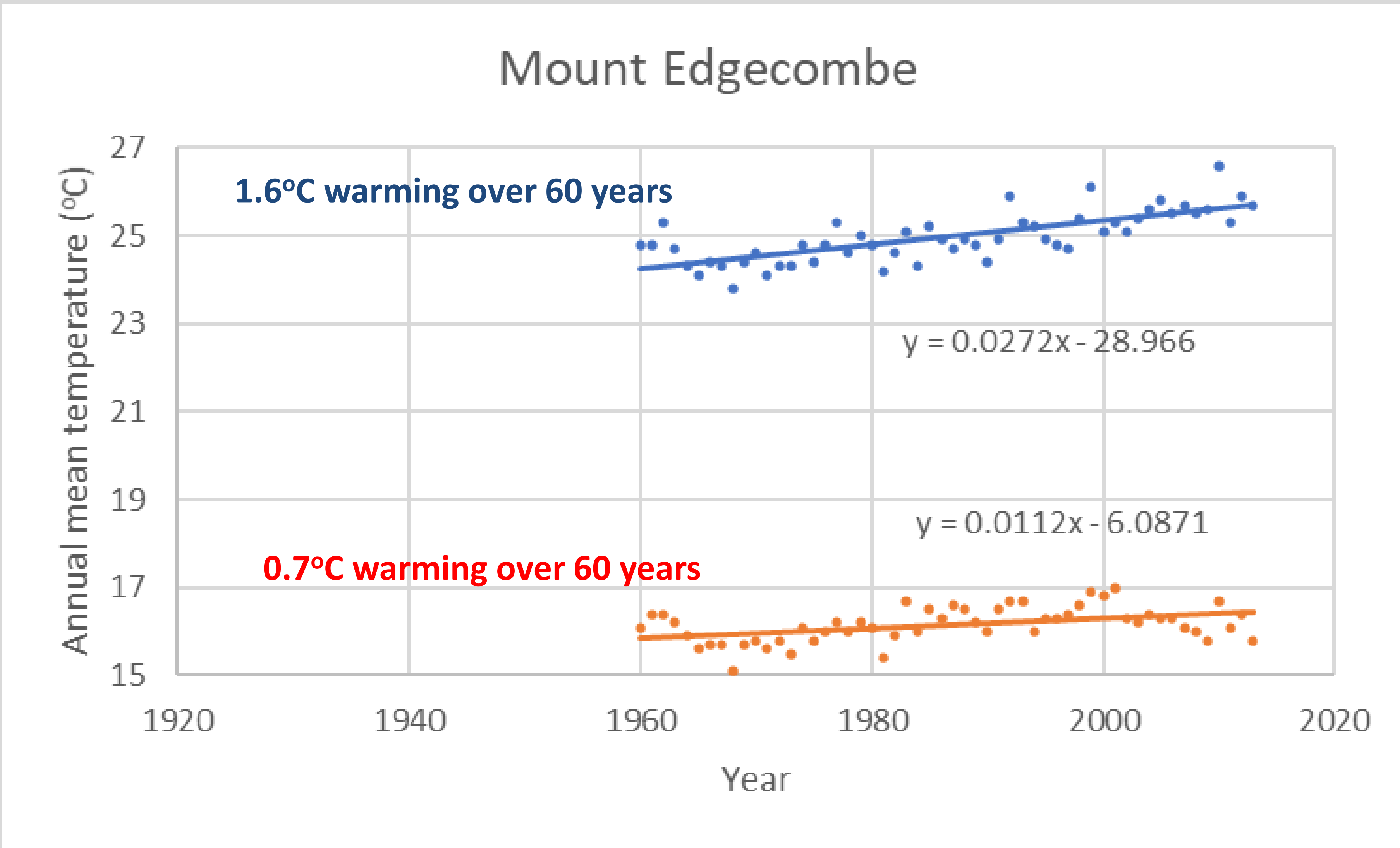
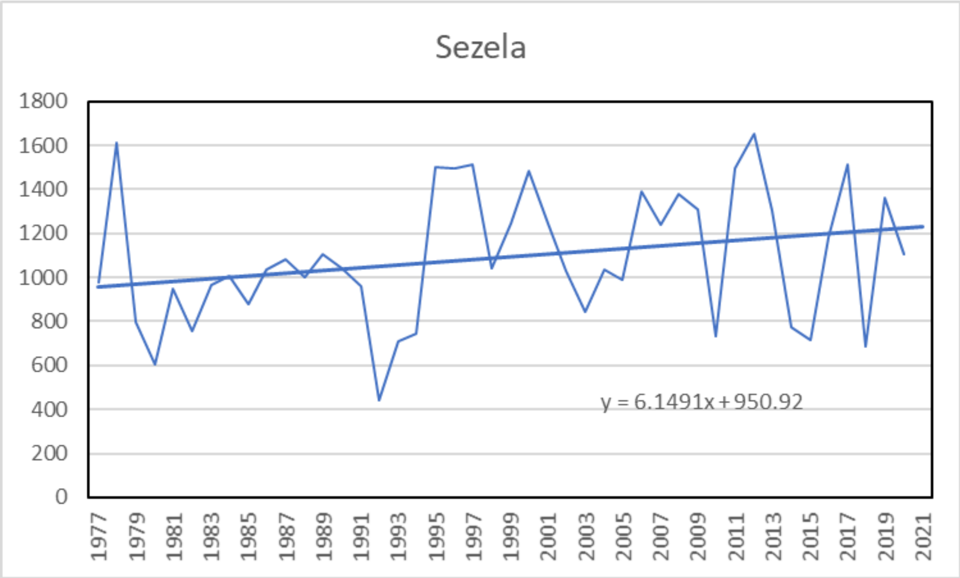


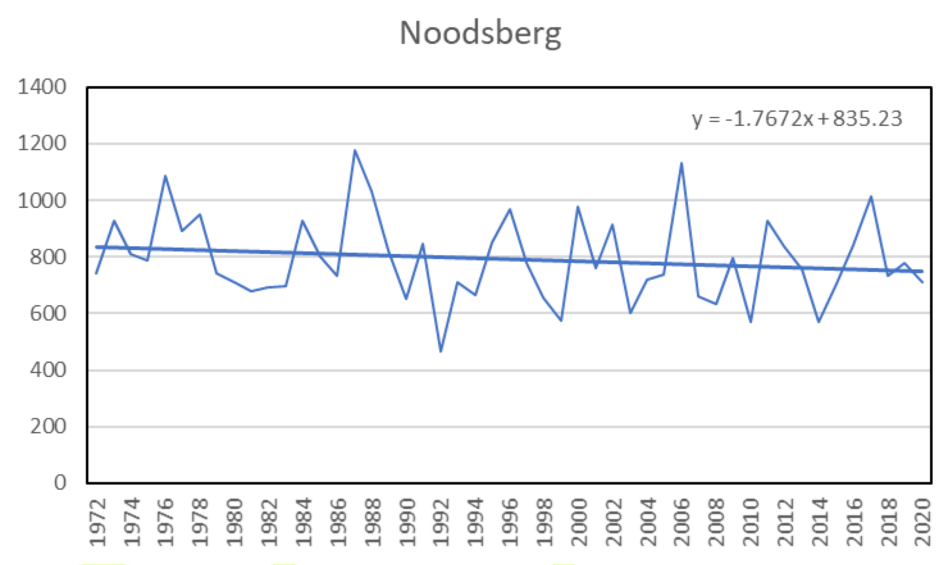
Figure SPM.1: History of global temperature change and causes of recent warming.

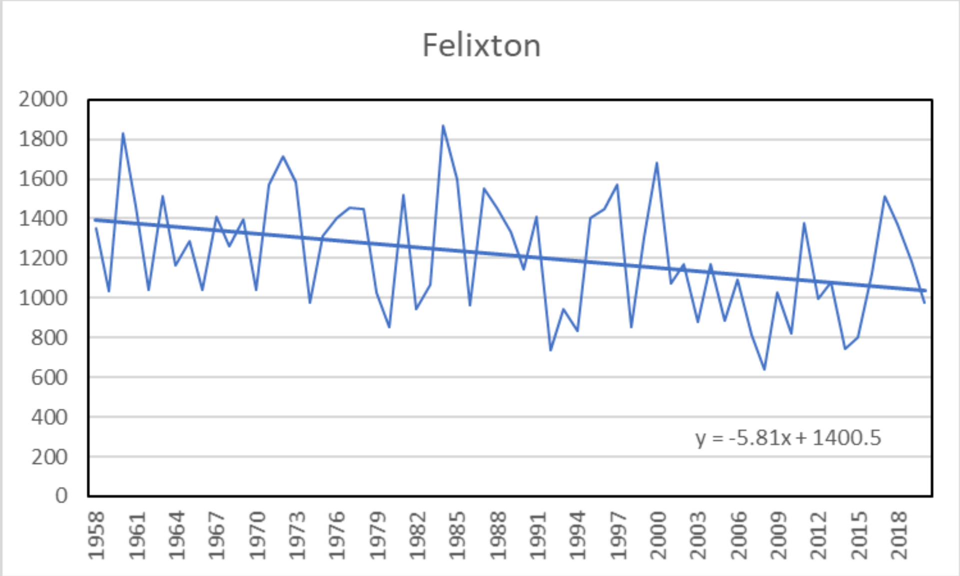


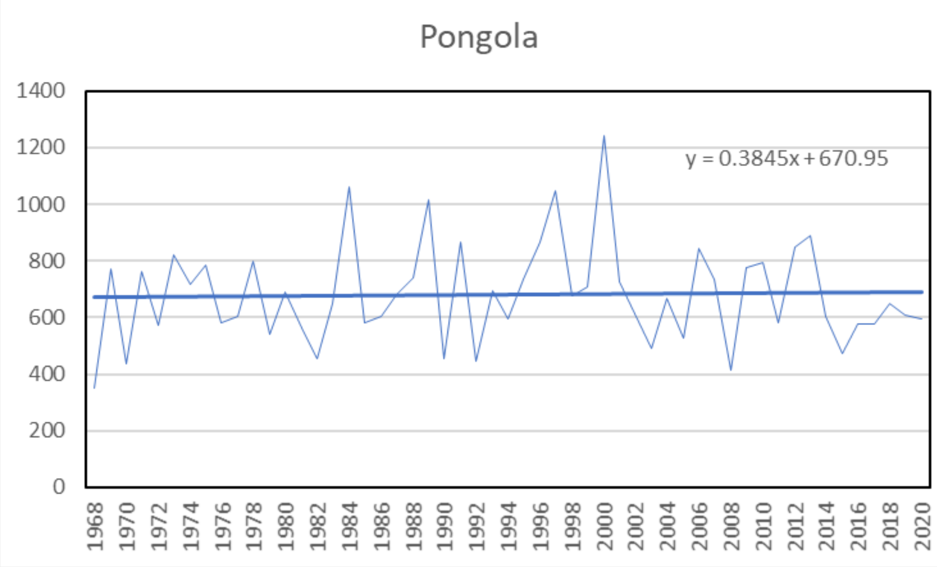
Mount Edgecombe
1.6°C warming over 60 years
y = 0.0272x - 28.966
y = 0.0112x - 6.0871
0.7°C warming over 60 years
Annual mean temperature (°C)
27
25
23
21
19
17
15
1920
1940
1960
1980
2000
2020
Year

Rainfall

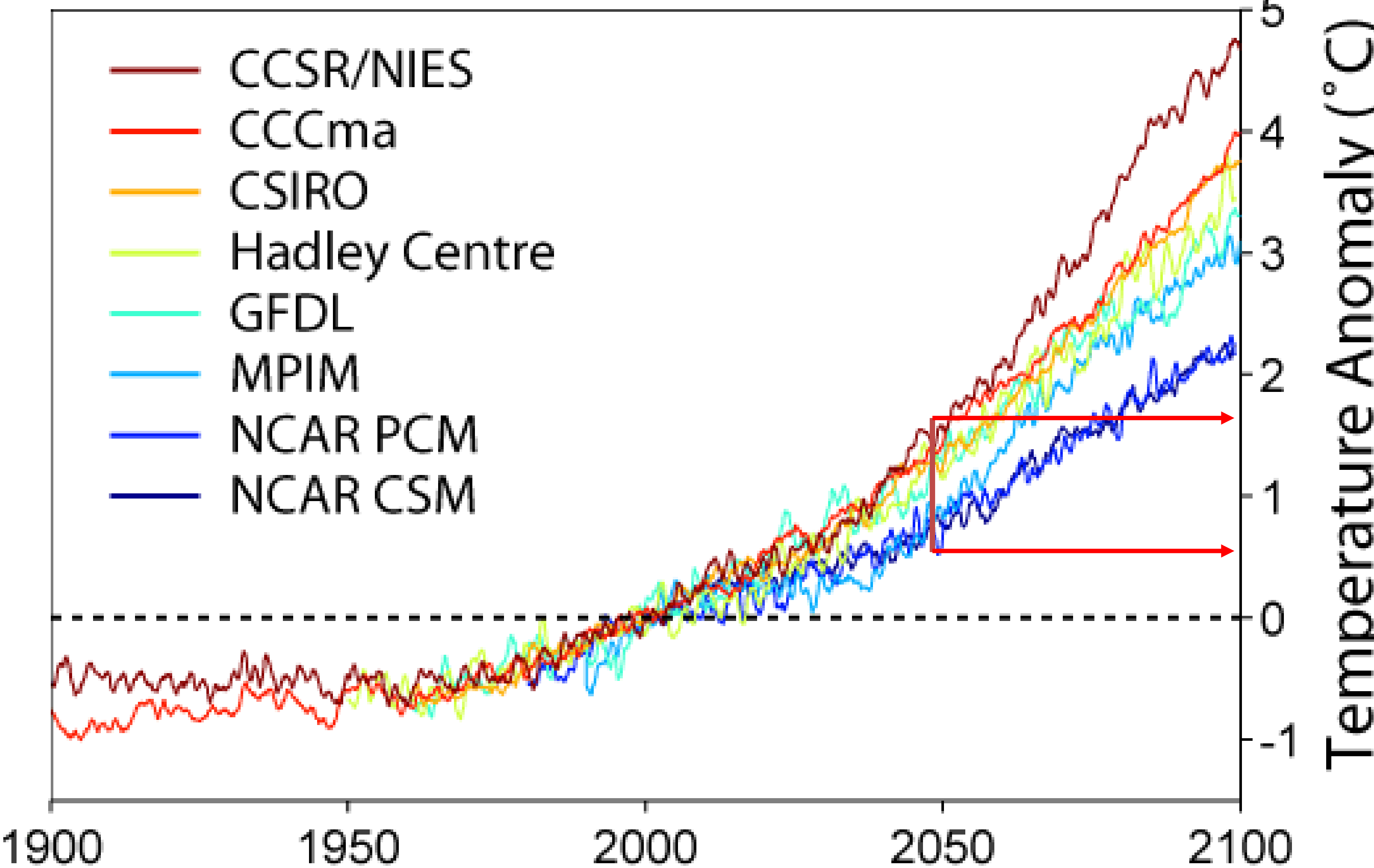

Sezela
y = 6.1491x + 950.92


Noodsberg
y = -1.7672x + 835.23


Felixton
y = -5.81x + 1400.5


Pongola
y = 0.3845x + 670.95

Global Warming Projections



IPCC report 2021
Projected changes for south-eastern Africa: 2050 vs 2000

Parameter	P25	Median	P75
Tmean (oC)	1.5	**1.7**	1.9
Tmin (oC)	1.6	**1.8**	2
Tmax (oC)	1.5	**1.8**	2
Frost days (d)	-1.8	**-1.2**	-0.9

Sugarcane physiology: Expected impacts

- Temperature increases below optimum
  - Accelerated canopy development - enhanced interception of solar radiation, increased evapotranspiration
  - Higher rates of potential leaf and stalk growth, reduced sucrose accumulation
  - Less frost damage
- Atmospheric CO_2 increase
  - Reduced stomatal conductance and improved water use efficiency
  - Little or no impact on photosynthesis
- Rainfall changes
  - Changed water status will impact crop growth and development
  - Rainfall totals and distribution will play role

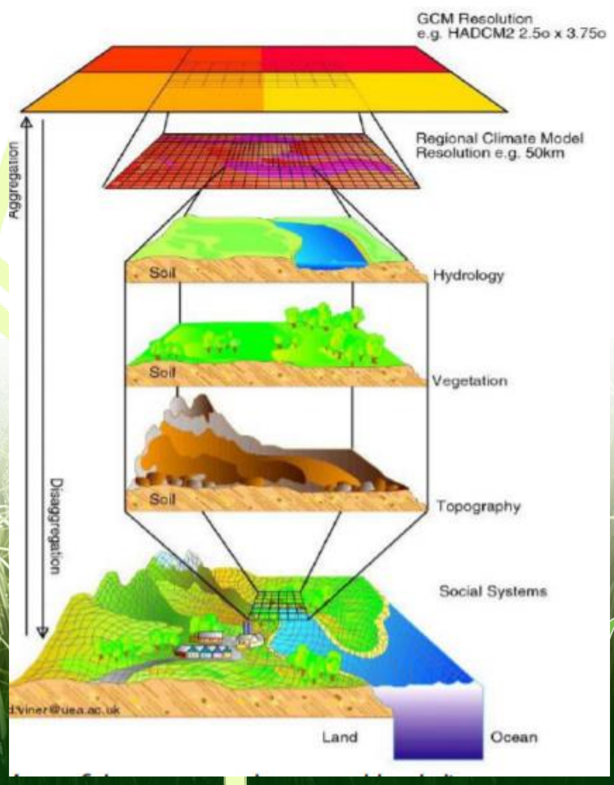
Presentation outline

- Background
  - Past and future climate change
  - Climate and sugarcane physiology
- Review of model projections to date
- SASRI climate change impact studies
  - Method and assumptions
  - Yield and water use impacts
  - Climatic suitable production areas in 2050
  - Impacts of reduced irrigation supply
- Adaptations
- Research needs
- Conclusions

Climate change impact research

Approach

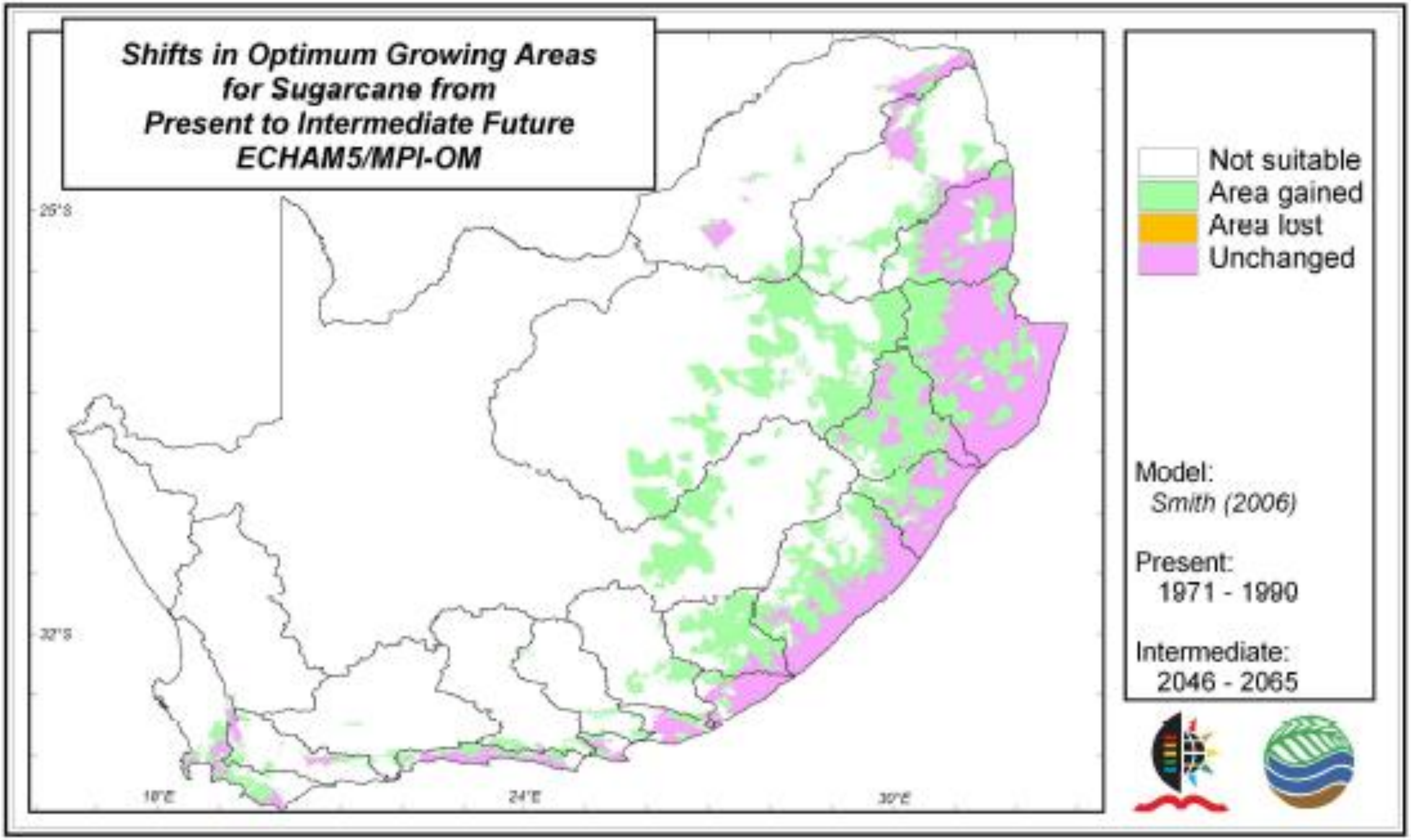
- Climate models (GCMs) project changes in climate at low temporal (500 km) and spatial (monthly) resolutions
- Downscale GCM climate projections to higher resolution weather data (20 km, daily)
- Crop model + projected weather data -> Crop growth and water balance
- Hydrological model + projected weather data -> runoff and water supply



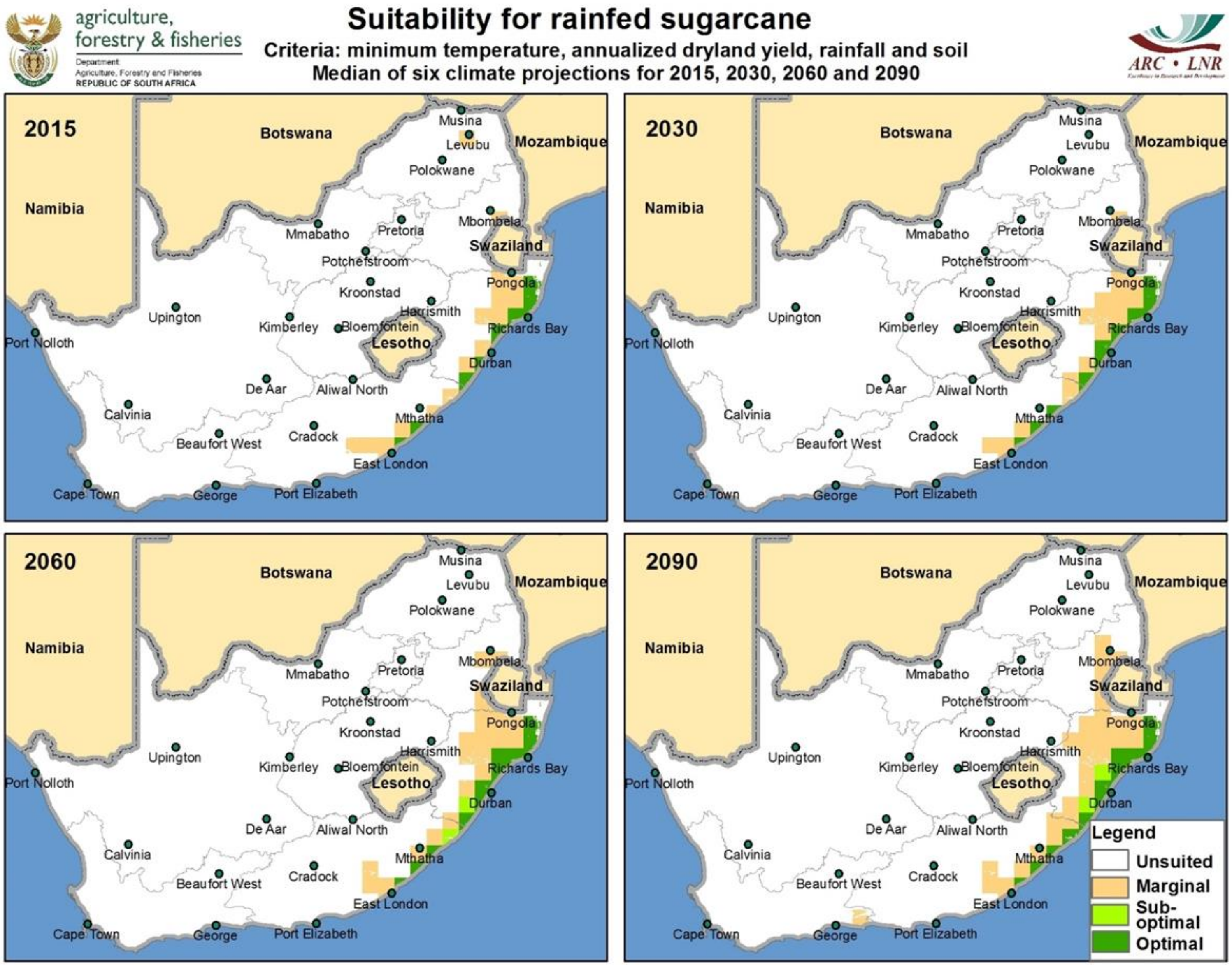
Yield and water use projections

Reference	Location	Period	GCM	Down scaling	Crop model	CO_2 effect	Yield change	CWU change	Irrigation change
Knox et al (2010)	Mhlume, Swaziland	2050s	HadCM3	Monthly delta	Canegro v3.1	Reduced CWU, on and off	+5-16%	+26%	+21%
Schulze and Kunz (2010)	SA	2050, 2090	MPI Echam5 et al		Smith model				+10-20%
Walker and Schulze (2010)	SA	Sensitivity analysis		Annual delta	APSIM-Sugar		+	+	+
Weepener et al (2015)	Eastern SA	2015, 2030, 2060, 2090	Six	Monthly delta	Thompson production function	No			
Jones et al (2015)	Malalane, Pongola	2085s	HadCM3 MPI Echam5 MIROC3.2	Monthly delta	Canegro v4.5	Reduced CWU Small + RUE effect	+10-12%	+11%	13%
Singels et al (2017)	Eastern SA	2050s	CSIROmk3.5 GFDLcm2.1 MPI Echam5	Empirical CSAG	Canegro v4.5_c2.2	Reduced CWU Zero RUE effect	+1-5%; +10-17%	+8-10%	+8-10%
Jones et al (2017)	Eastern SA	2050	Five	Monthly delta	Canegro v2.2	Reduced CWU	+8.7%		+7%

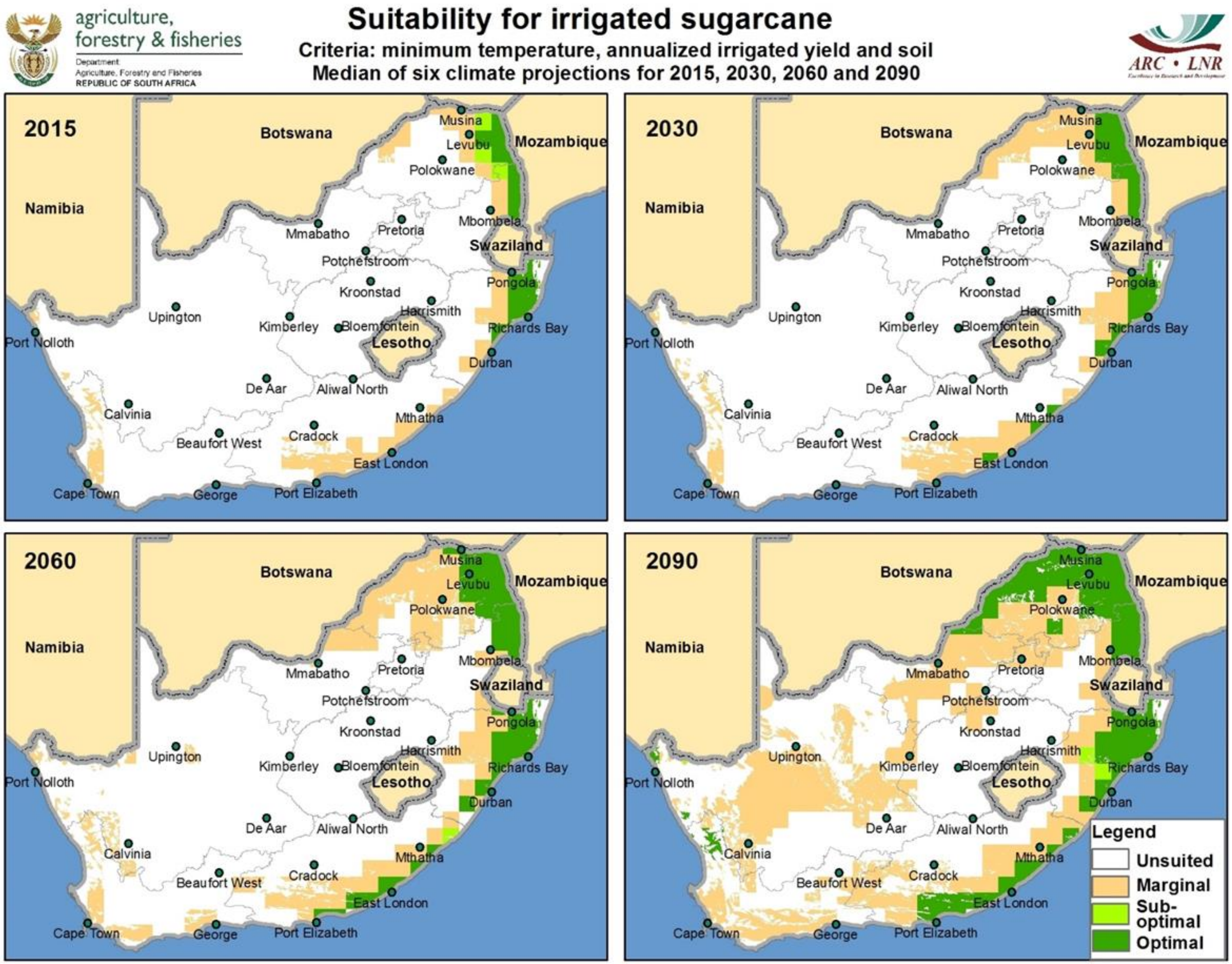
Schulze & Kunz, 2010



Weepener et al., 2015



Weepener et al., 2015



SASRI climate change projects

- SASRI project 08RE14: **Yields and water use** of sugarcane and **energy-cane** around 2050 in different regions
- SASRI project 11CM06: Explored production **adaptation options** for coping with expected climate change: harvest age, row spacing, drought tolerance.
- SASRI project 15SD3E: WRC funded project with UFS looking at expected impacts of climate change on the **water footprint** of sugarcane production.

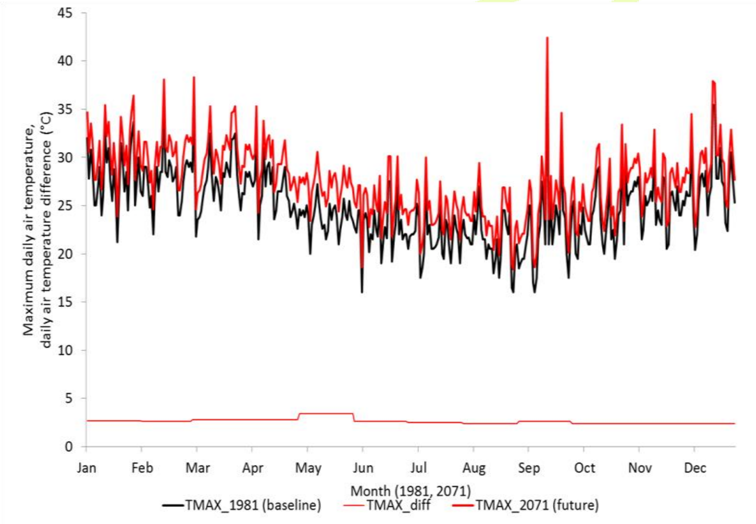
Publications

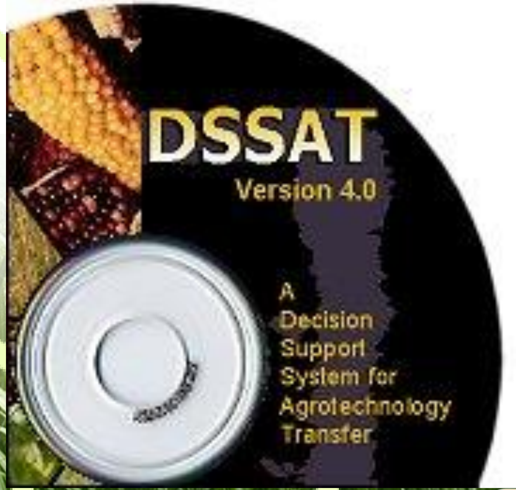
- Singels, A., Jones, M. Marin, F., Ruane, A.C. and Thorburn, P. 2014. Predicting climate change impacts on sugarcane production at sites in Australia, Brazil and South Africa using the Canegro model. Sugar Tech 16(4): 347-355 (also published in Int. Sugar J. 115: 874-881)
- Jones, M.R., Singels, A. and Ruane, A. 2015. Simulated impacts of climate change on water use and yield of irrigated sugarcane in South Africa. Agric. Systems 139: 260–270
- Singels, A., Jones, M.R. and Lumsden T.G. 2018. Sugarcane productivity and water use in South Africa under a future climate: what can we expect? Proc. S. Afr. Sug. Technol. Ass. 91: 57-61
- Singels, A., Jones, M.R., Lumsden, T.G. 2019. Potential for sugarcane production under current and future climates in South Africa: Sugar and ethanol yields, and crop water use. Proceedings of the International Society of Sugar Cane Technologists 30: 1123–1130.

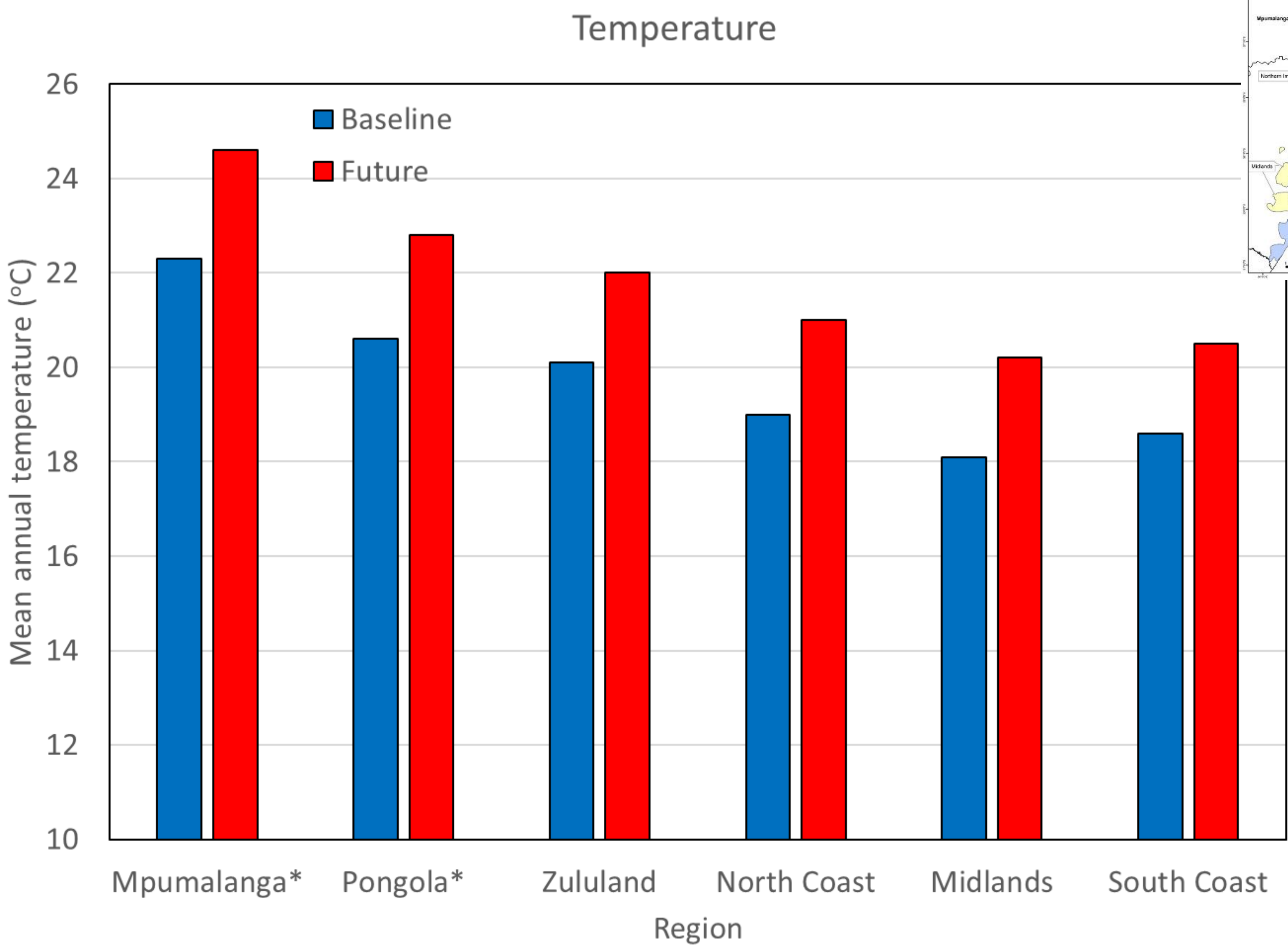
Singels, A., Lumsden, T., Jones, M.R., Patton, A., Ngxaliwe, S., Hoffman N. 2017. Past and future crop productivity and water use of sugarcane in South Africa. South African Sugarcane Research Institute, Mount Edgecombe. p58. ISBN 978-0-6399083-9-7

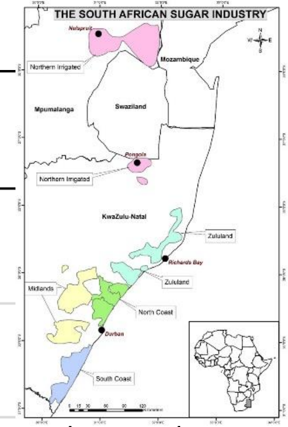
Methodology

- Weather data generation
  - 3 GCMs
  - Empirically downscaled to 1 986 agro-climatic zones in eastern South Africa
  - Downscaling method assumes no change in length and frequency of dry and wet spells
  - Baseline: 1971-1990
  - Future: 2046-2065
- Crop modelling
  - DSSAT-Canegro model: Refined simulation of high temperature effects, tillering, photosynthesis, respiration and water stress response (Jones & Singels, 2019, Eur J Agron)
  - Current typical management inputs
  - Ideal nutrient and no weed, pest and disease effects
  - Adequate irrigation water



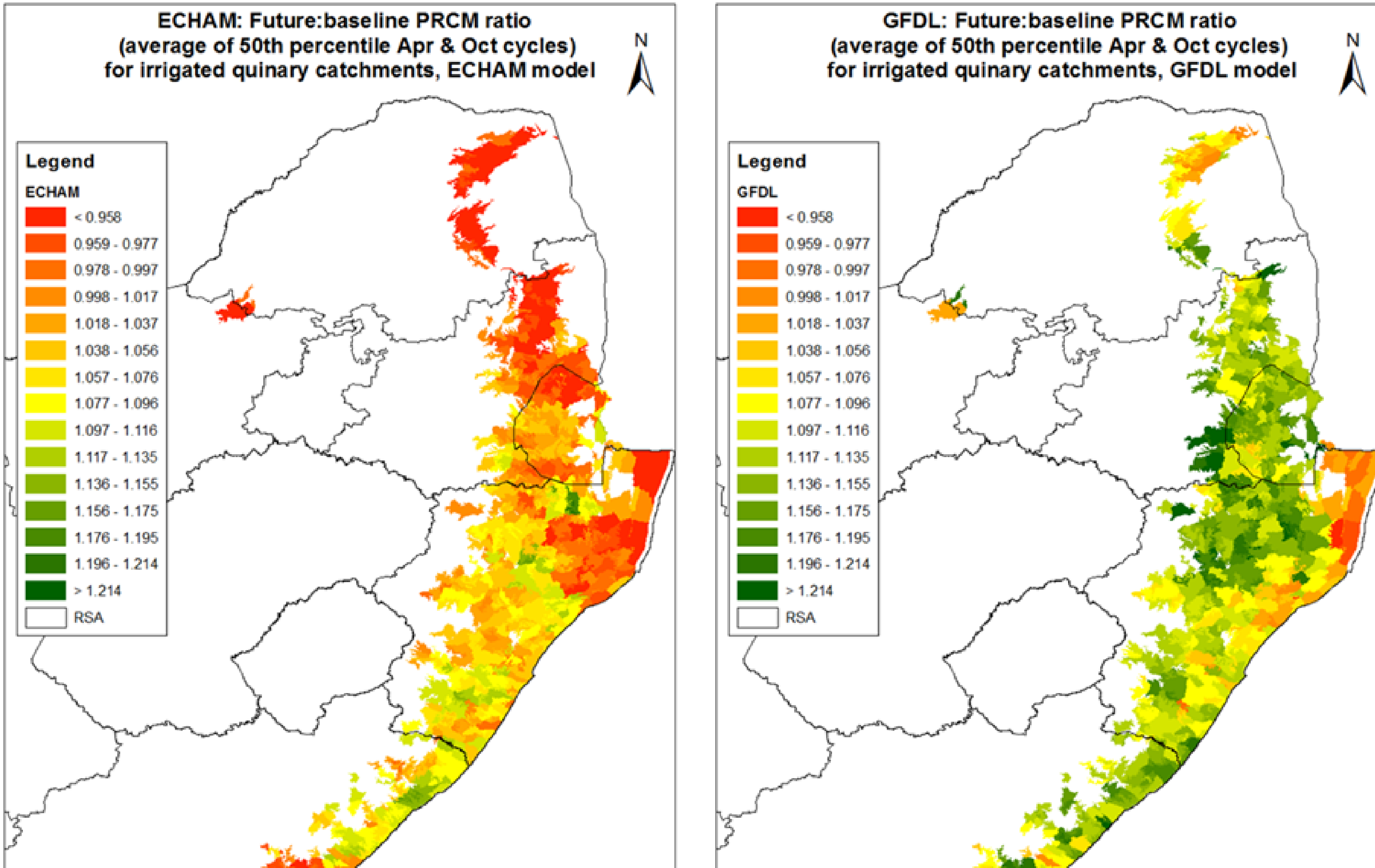






Singels et al., 2019. Potential for sugarcane production under current and future climates in South Africa: Sugar and ethanol yields, and crop water use. Proceedings of the International Society of Sugar Cane Technologists 30: 1123–1130.

Annual rainfall around 2050



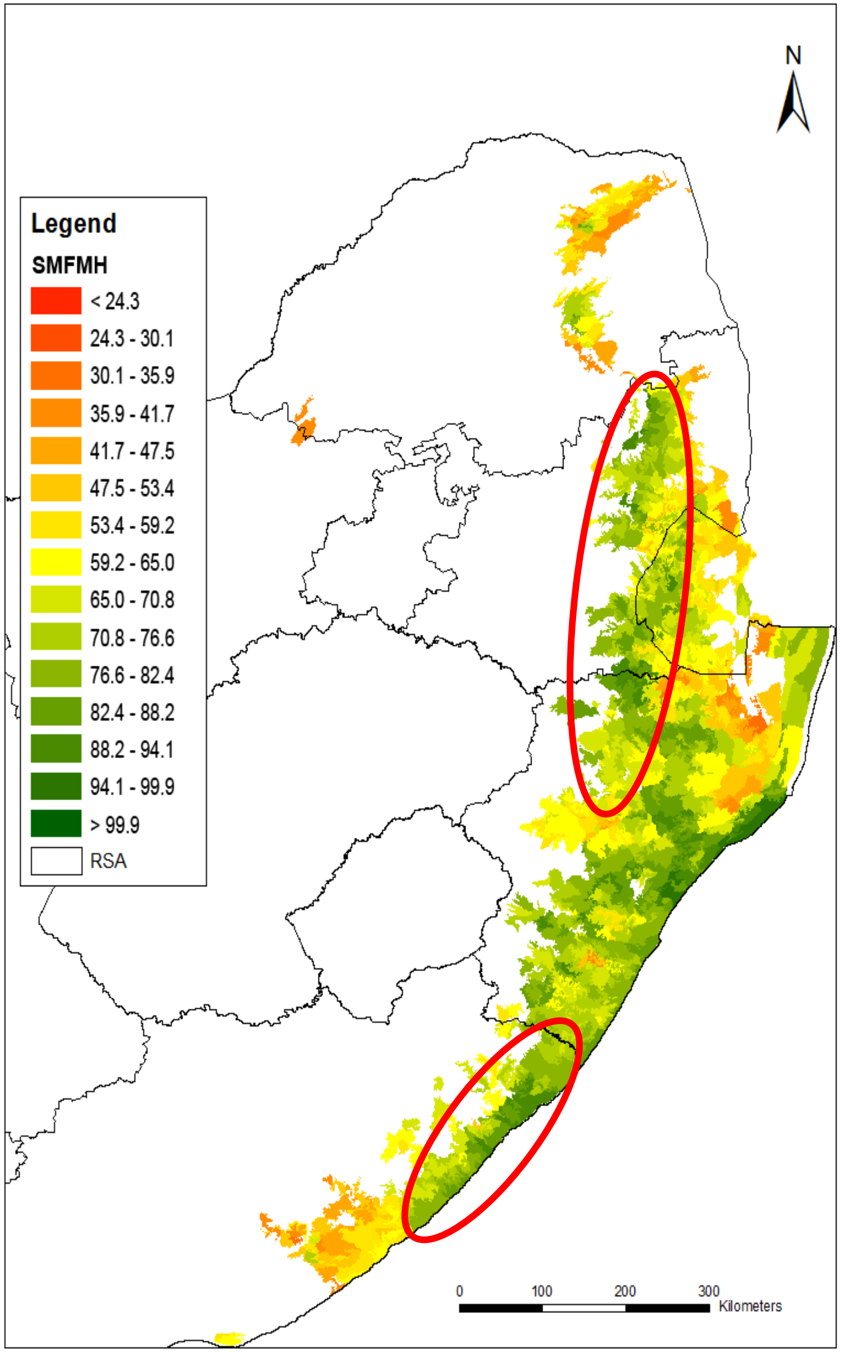
Singels A, et al. 2018. Sugarcane productivity and water use in South Africa under a future climate: What can we expect? Proc. S. Afr. Sug. Technol. Ass. 91: 57-61

2050 dryland production

Region	Cane yield	
	LTM (t/ha/an)	Δ (%)
Zululand	77	+13
North Coast	80	+17
Midlands	76	+19
South Coast	80	+15

<u>Potential new areas</u>
<u>(future cane yield > 60 t/ha/an)</u>

- High lying areas in KZN and Mpumalanga
- Northern coastal Eastern Cape

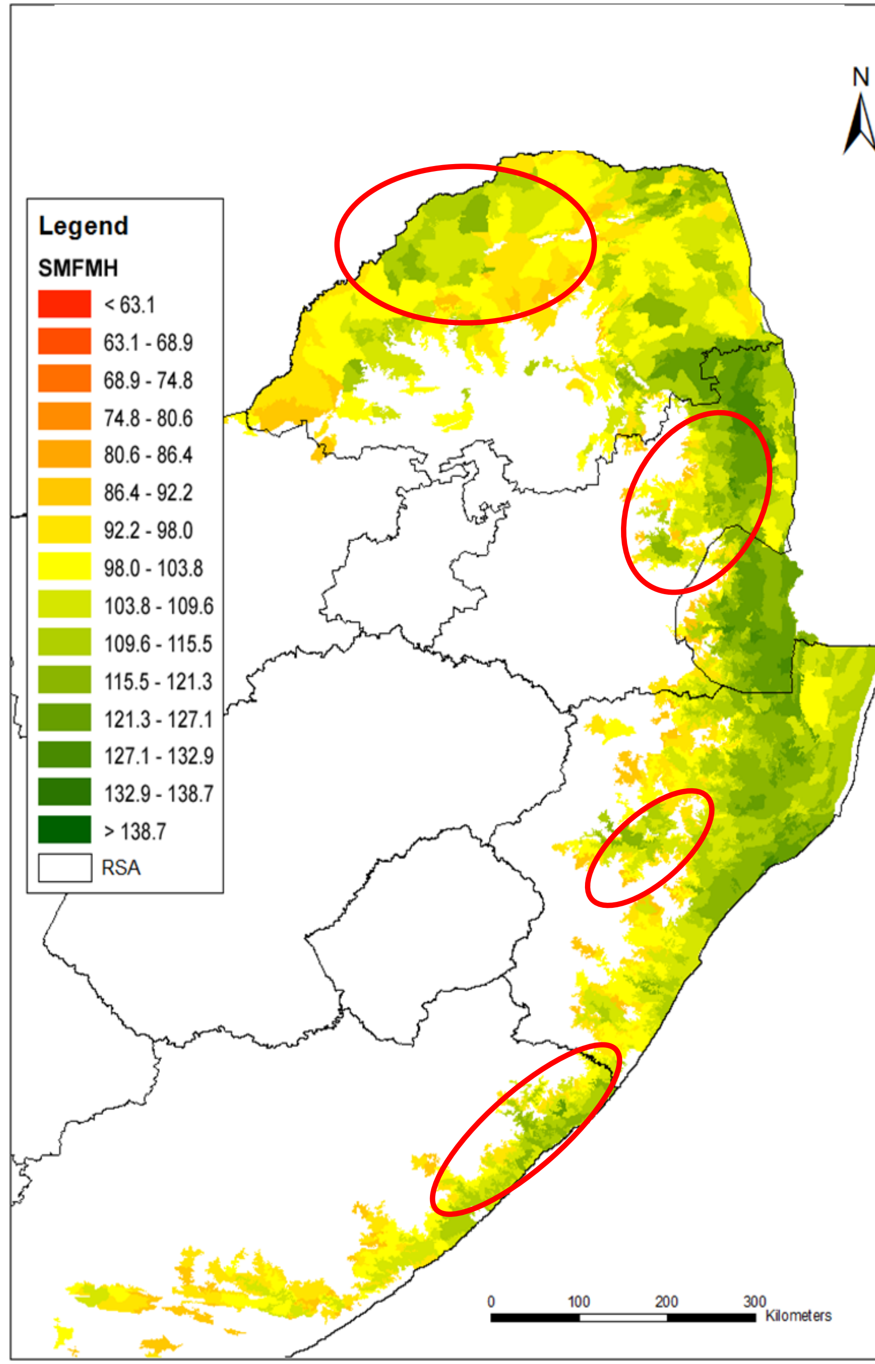


2050 irrigated production

Region	Cane yield		
	LTM (t/ha/an)	Δ (%)	(m
Mpumalanga	142	0.7	1
Pongola	139	5.3	1
Zululand	132	5.4	1
North Coast	139	9.8	1
Midlands	128	17.0	1
South Coast	132	13.4	1

<u>Potential new areas (future cane yield > 90 t/ha/an)</u>

- Northern Limpopo
- High lying areas in Mpumalanga and KZN
- North-eastern Eastern Cape



Climate, water supply and mulching: Predicted impacts for Malalane

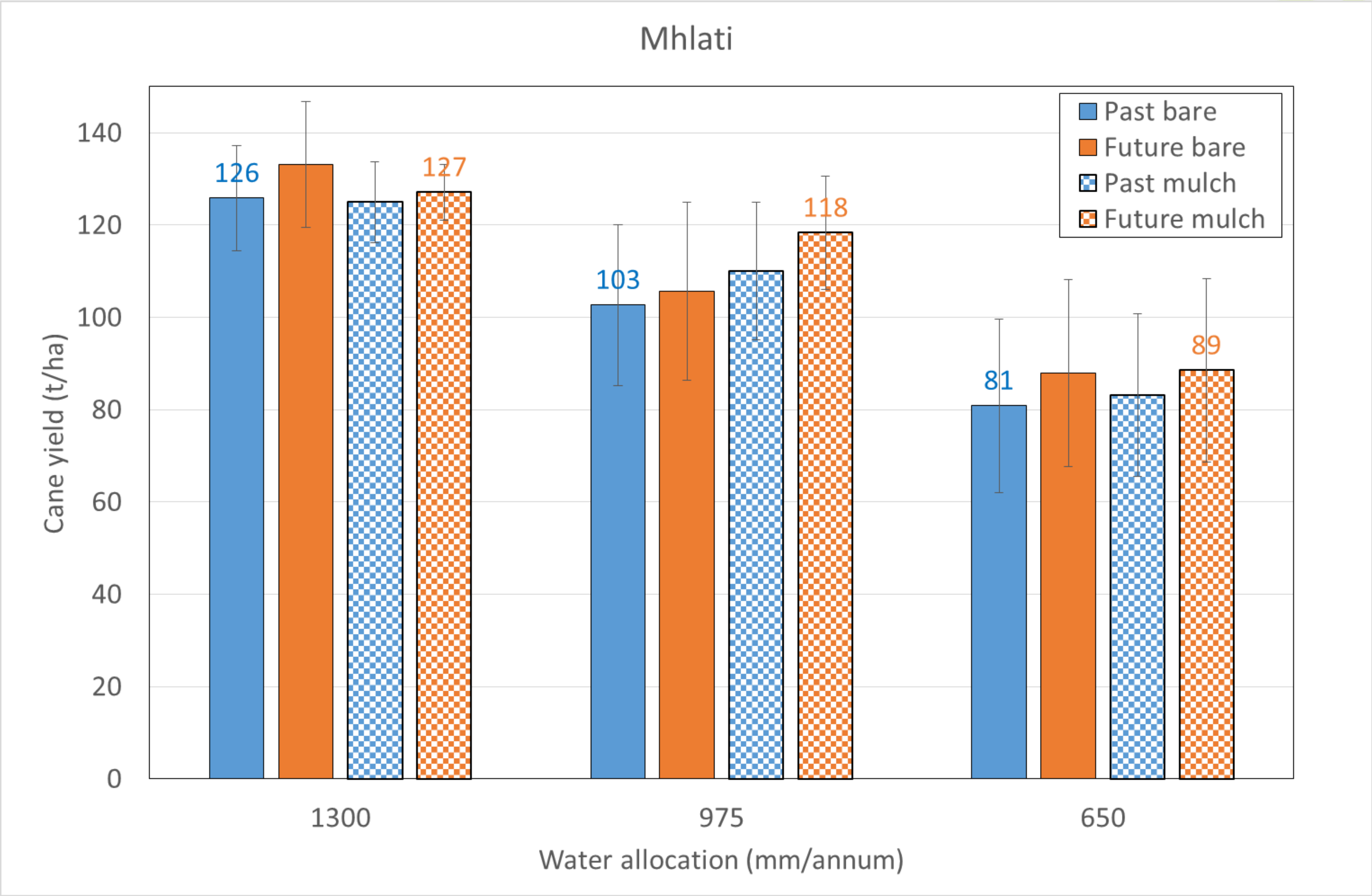
- Climate scenarios
  - Future: Weather data for 2041-2070 from 16 GCMs:
    - Downscaled using monthly Delta method
  - Baseline: Past weather data for 1981-2010
- Water allocation scenarios: 50, 75 and 100% of 1300 mm distributed according to LTM crop demand
- Mulching scenario: Bare soil (burnt cane), crop residue cover

- MyCanesim® model
  - 12 month crops started in April and October
  - Soil: Available water holding capacity of 75 mm AWC
  - Irrigation settings
    - Overhead irrigation: 26 mm X 4d
    - Pro rata scheduling rule ADL =45 mm

MY CANESIM®

Singels et al., 2018. Climate change and irrigated sugarcane production in South Africa: Threats, opportunities and uncertainties. SANCID symposium held from 13 -15 November 2018, Witrivier, Mpumalanga

Predicted yield impacts: Climate, water supply and mulching



Dryland adaptations

- Reduced harvest age could increase annualized yields
- Wider rows (1.8 m) could increase returns in some areas (reduced planting costs)
- Drought tolerance (increased sensitivity to drought stress with conservative water use) desirable in stressed environments (low rainfall and low potential soil)
- Soil mulching increases yields slightly in most areas

Jones MR and Singels A (2017). Climate change impacts and adaptation in sugarcane in South Africa. SASRI research report, SASRI, Mount Edgecombe.

Future research needs

- Update downscaled climate scenarios
- Apply water supply scenarios in projections
- Account for changes in pest, disease and weed impacts
- Explore economically viable adaptation options

Conclusions

- Present marginal (thermal) areas stand to benefit from medium term climate change
- Present high potential areas will benefit little
- Adaptations will be required to exploit benefits and mitigate negative effects
  - Harvest age, maturity management
  - Water management: Increase water use efficiency
  - Cultivar choice: Drought tolerance
  - Plant health management
- Research required for improved projections, feasibility studies, and exploring adaptation options

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