ARC • LNR

Implications of
Climate Change
for Crop Production

Harold Weepener
Christien Engelbrecht
Dr Mitsuru Tsubo
Dr Johan Malherbe

11 November2014

Photo: Johan Malherbe

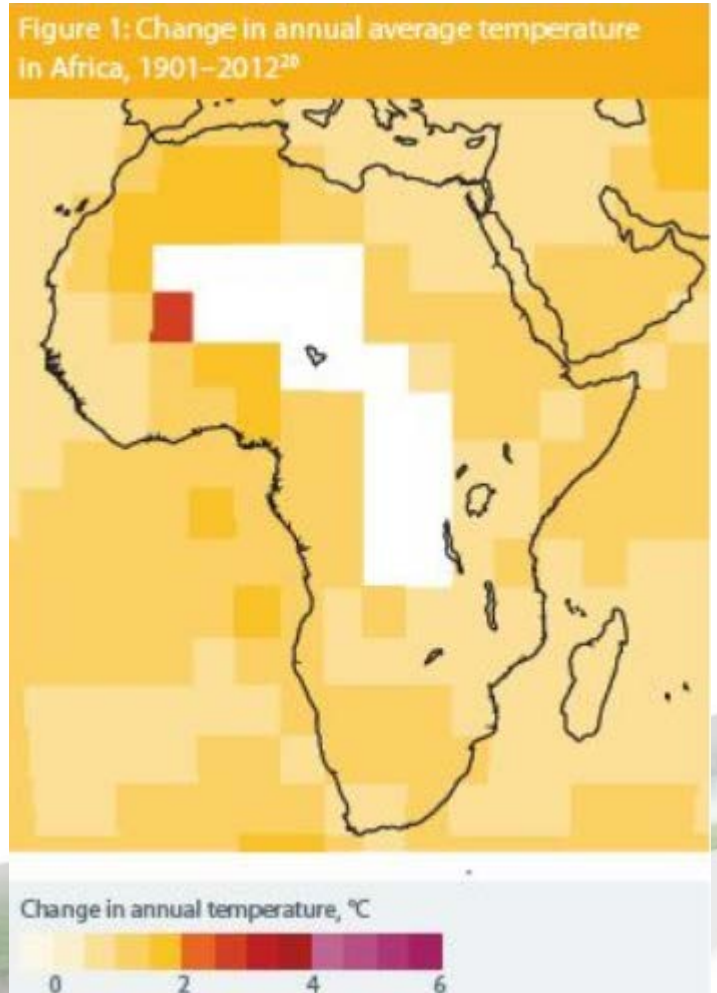
Acknowledgements

- Department of Agriculture, Forestry and Fisheries (DAFF) Directorate: Climate Change and Disaster Management (CCDM) for funding
- Council for Scientific and Industrial Research (CSIR) Climate Studies, Modelling and Environmental Health group for making climate projection data available.

ARC • LNR
Excellence in Research and Development

Observed trends

- **Observed trends indicate increased temperatures (0.5 – 2 ºC) over much of Africa with variable trends (IPCC – AR 5)**
- **Uncertainty due to data scarceness underlines the importance of having accurate weather observation networks**

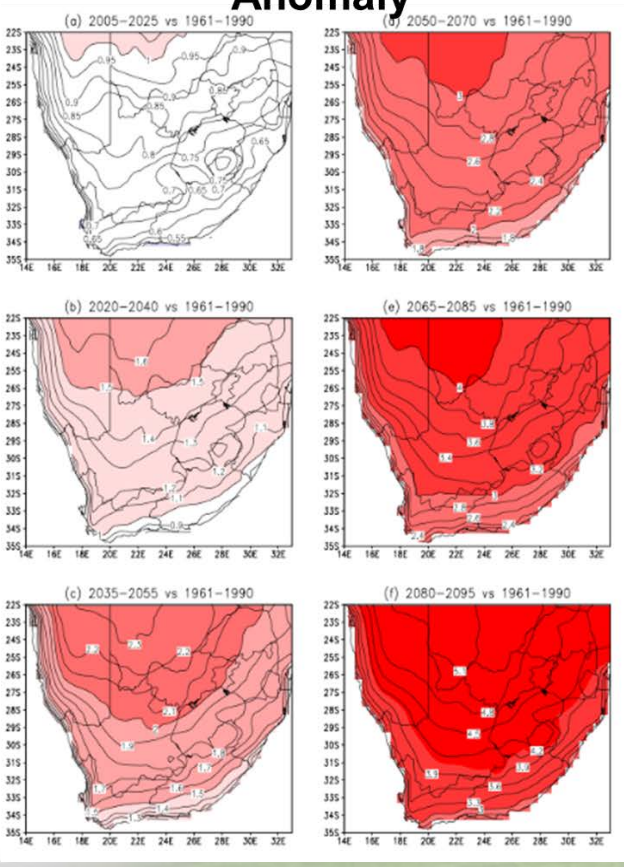


ARC • LNR
Excellence in Research and Development

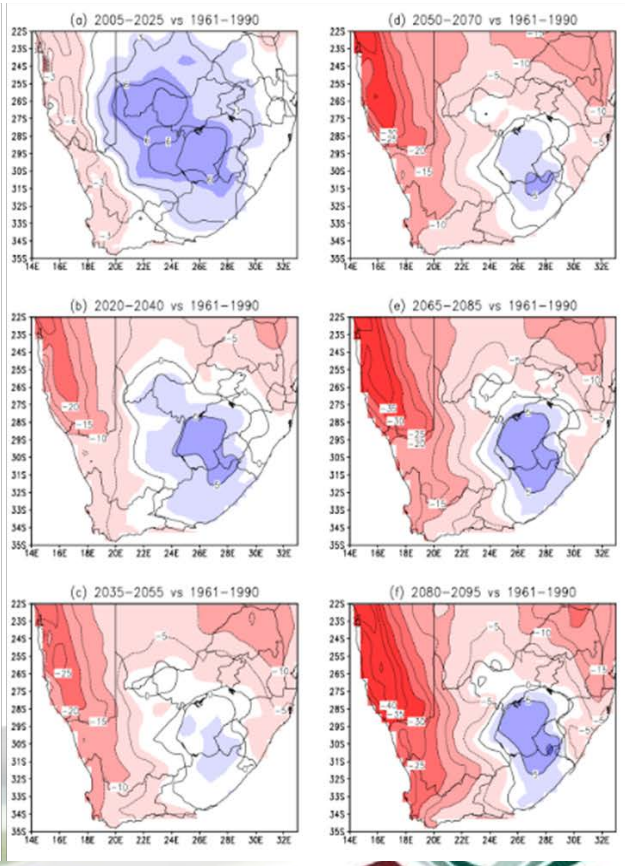
What are the implications for Agriculture in South Africa?

- **Projections based on Climate simulations of the Conformal Cubic Atmospheric Model based on Sea Surface Temperatures and Sea Ice data as simulated by 6 coupled Global Climate Models, A2 ("business as usual" scenario)**

Average Temperature Anomaly



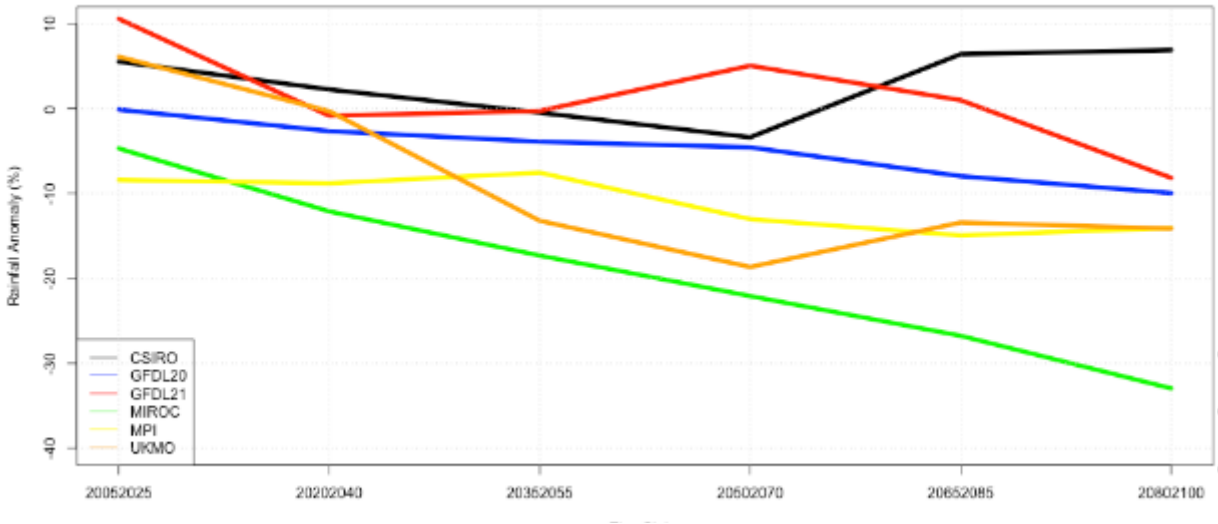
Rainfall Anomaly



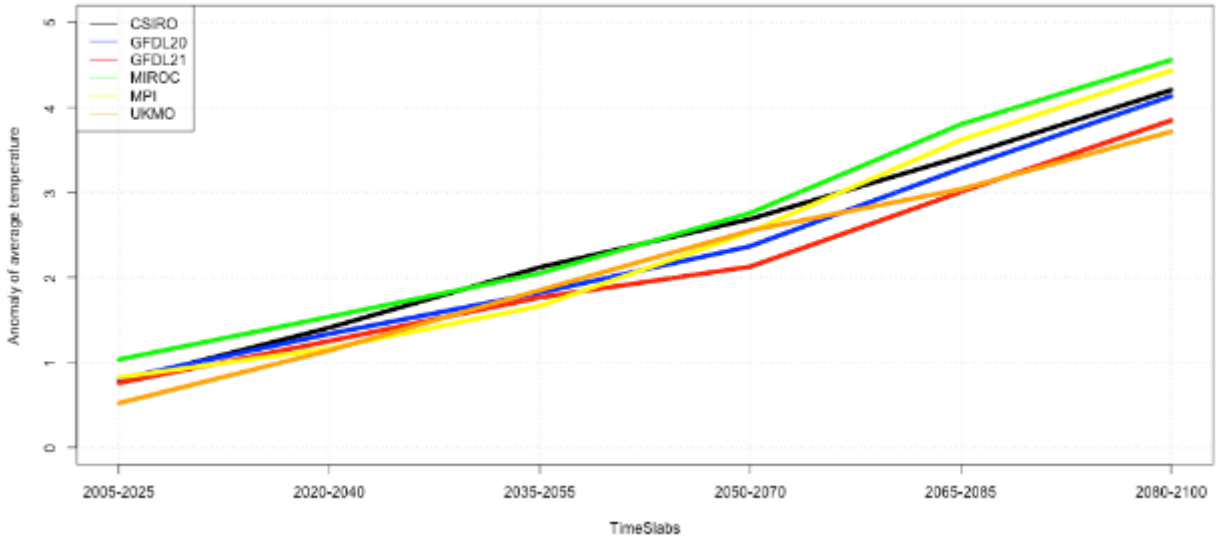
GFDL-CM2.0 [The version 2.0 CGCM of the Geophysical Fluid Dynamics Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA) in the United States]
GFDL- CM2.1 [The version 2.1 CGCM of the Geophysical Fluid Dynamics Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA) in the United States]
ECHAM5/MPI-Ocean Model [The CGCM from MPI in Germany]
UKMO-HadCM3 (The Met Office Third Hadley Centre Coupled Ocean-Atmosphere GCM - United Kingdom)
MIROC3.2-medres (Model for Interdisciplinary Research on Climate 3.2, medium resolution version, of the Japanese Agency for Marine-Earth Science and Technology)
CSIRO Mark3.0 (The version 3.0 CGCM of the Commonwealth Scientific and Industrial Research Organisation in Australia)

Range of possible outcomes

Rainfall



Temperature



CSIRO Mark3.5 from Australia
GFDL-CM2.0 from NOAA
GFDL-CM2.1 from NOAA
MIROC3.2-medres from JAMSTEC
MPI - Ocean Model from Germany
UKMO-HadCM3 from the United Kingdom

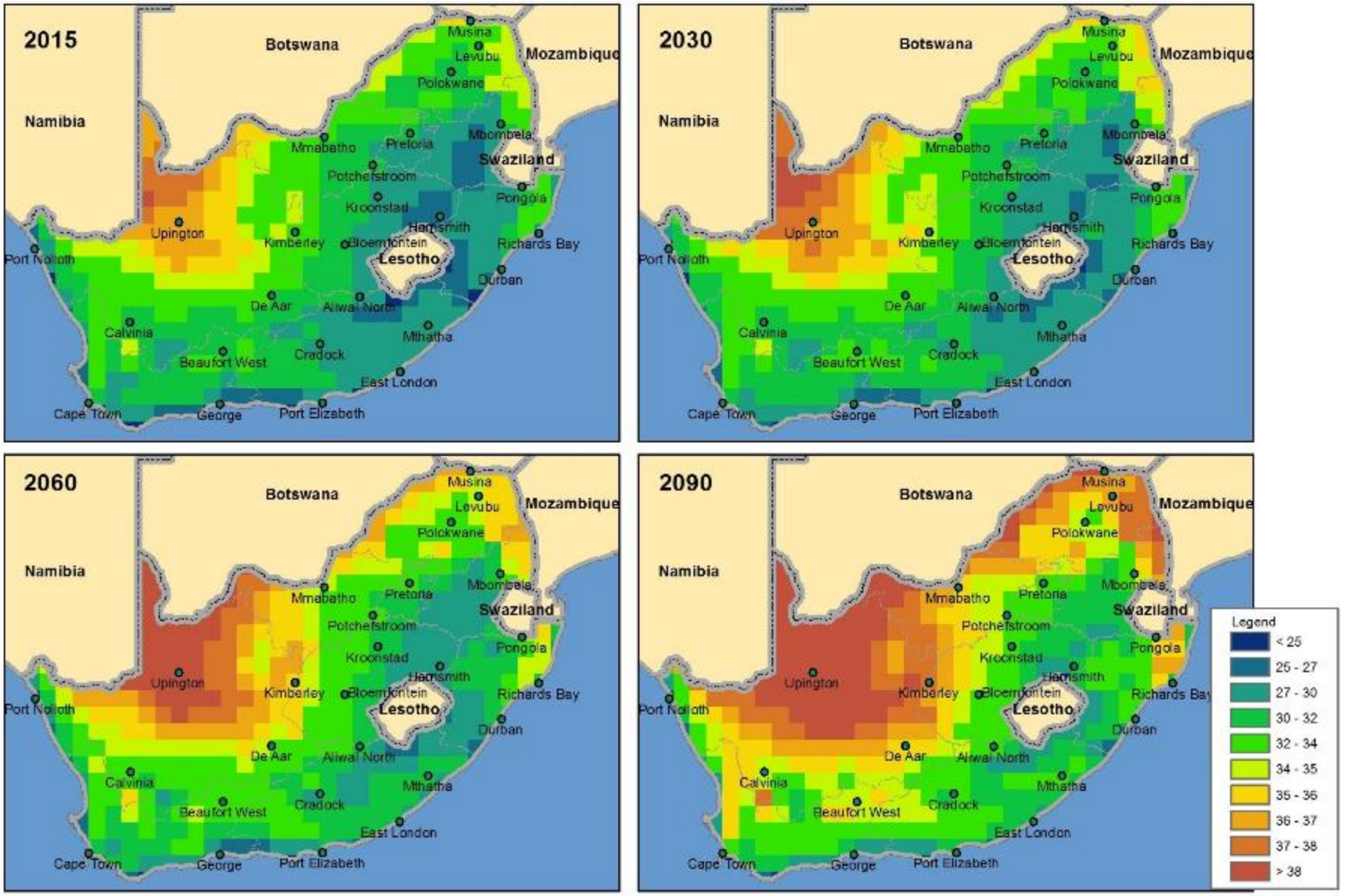
agriculture, forestry & fisheries

Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Average maximum temperature (ºC)

Median of six climate projections for 2015, 2030, 2060 and 2090

ARC • LNR



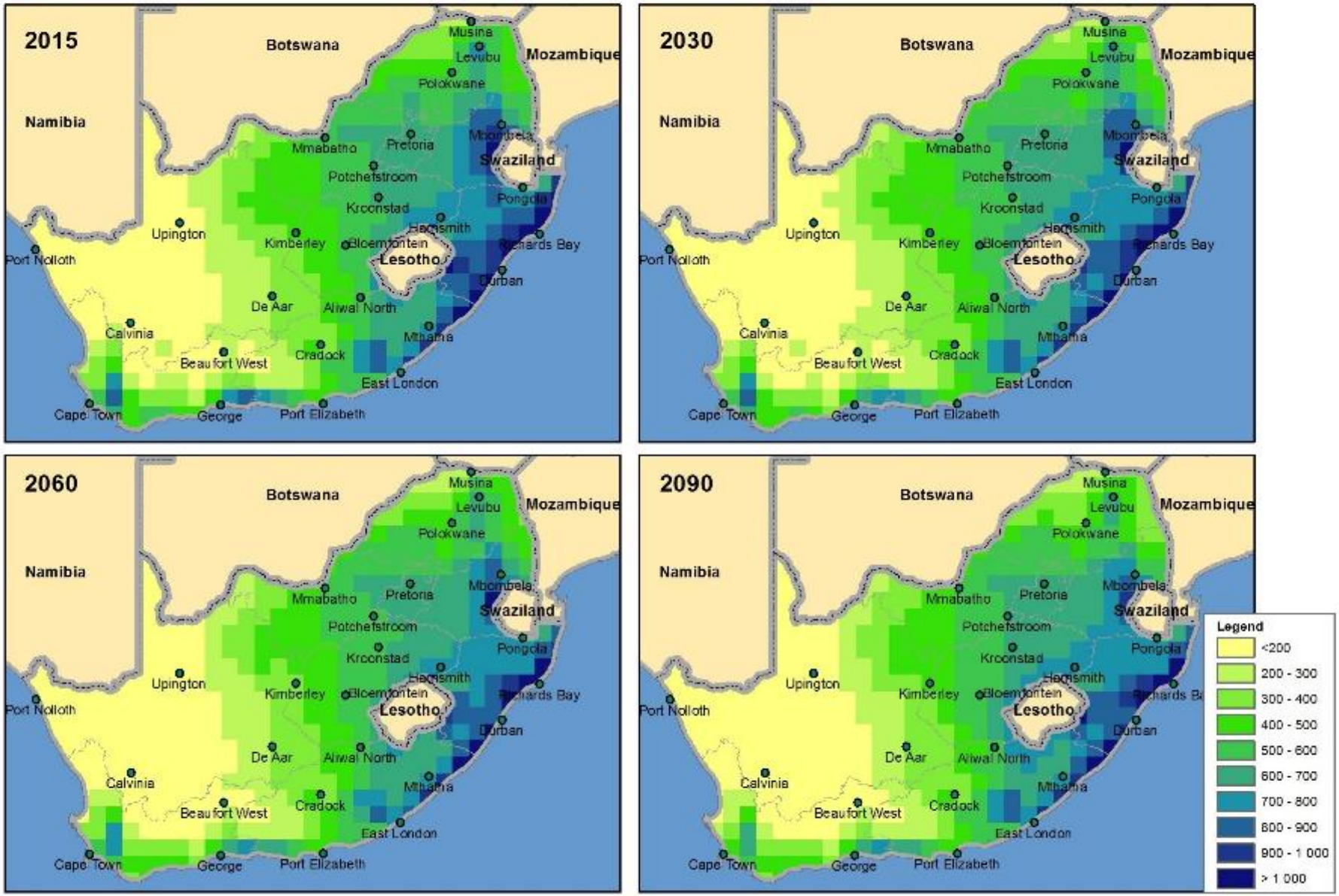
agriculture, forestry & fisheries

Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Average annual rainfall (mm)

Median of six climate projections for 2015, 2030, 2060 and 2090

ARC • LNR



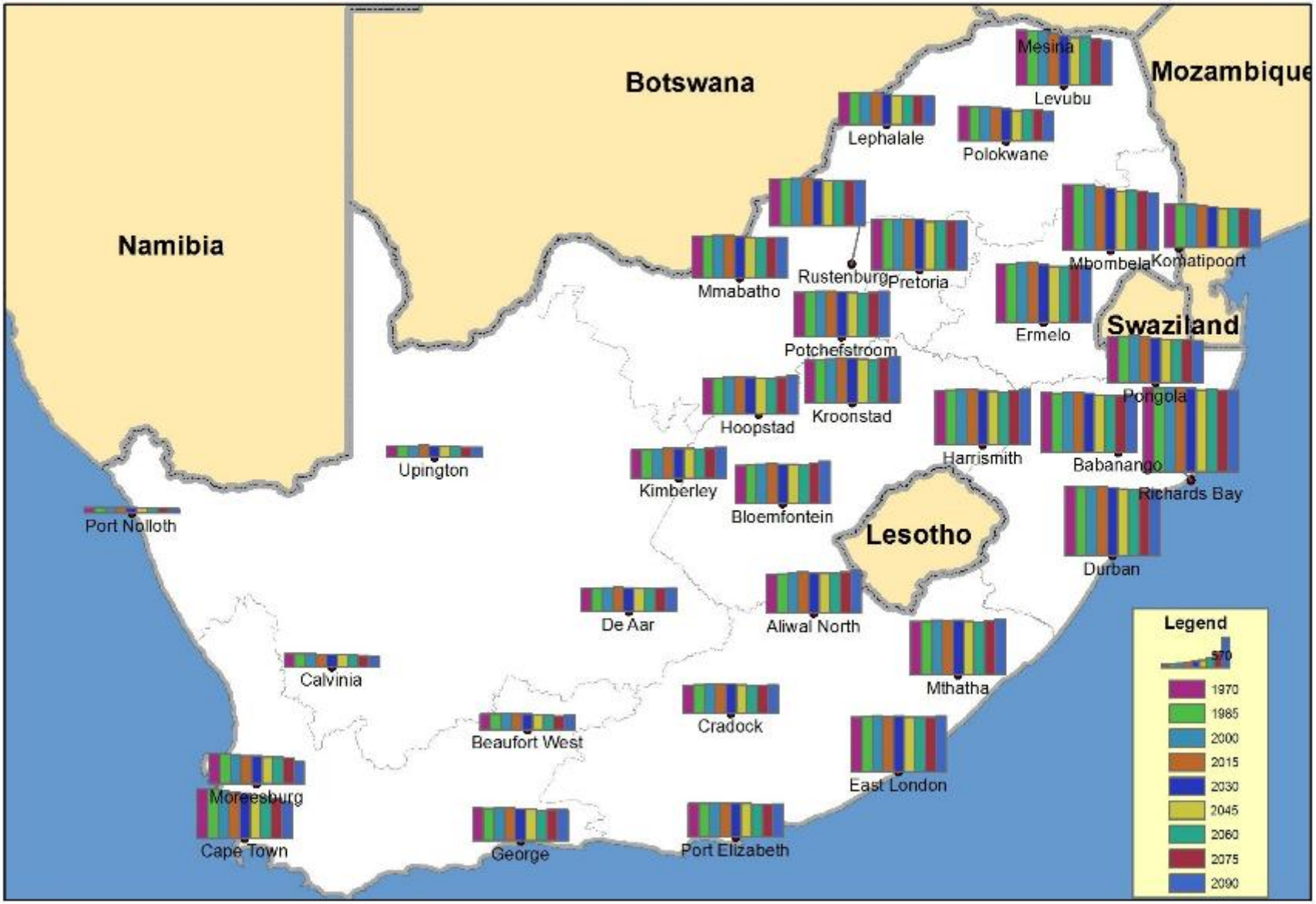
agriculture, forestry & fisheries

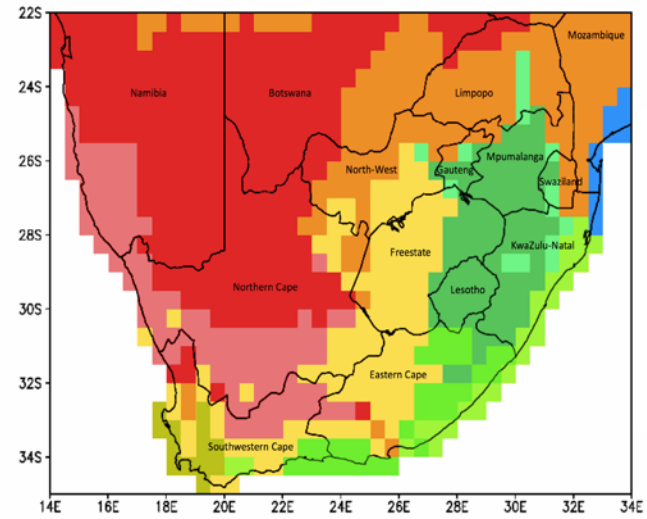
Department of Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Average annual rainfall (mm)

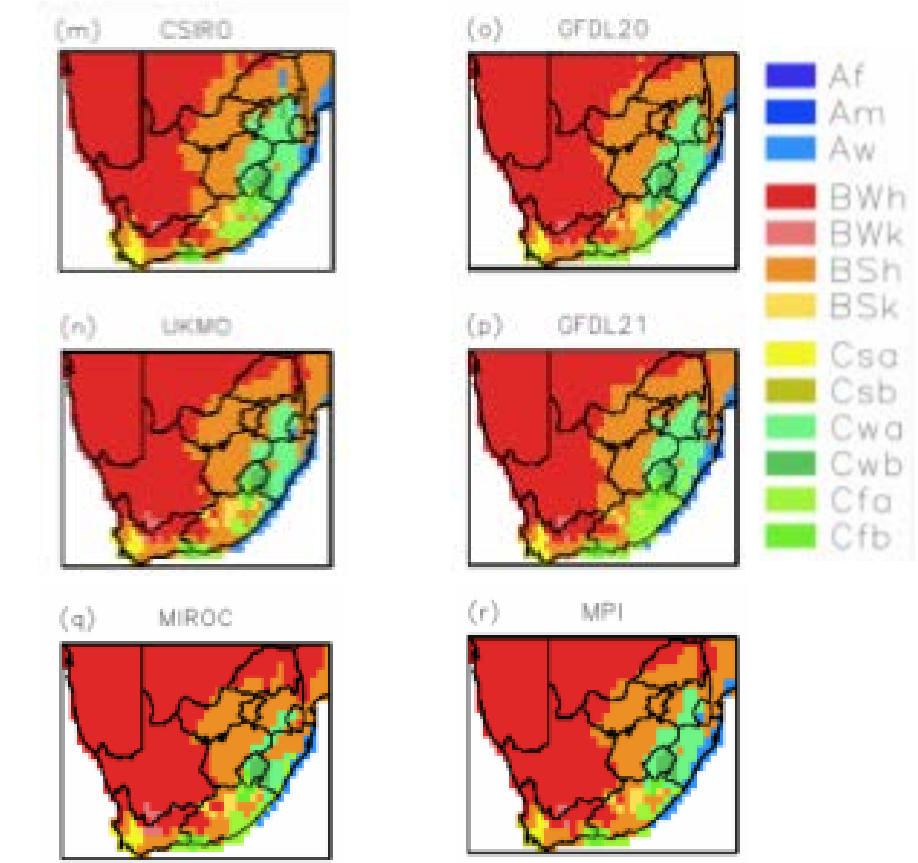
Median of six climate projections

ARC • LNR





Shifting climate zones: Projected Koppen-Geiger climate zones for a 3ºC increase in the average global temperature
A basic trend towards warmer and drier conditions



1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100 - MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100 - MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a or b) & $1 \leq T_{mon10} < 4$

The percentage of area covered by the respective Köppen-Geiger climate zones over southern Africa (Africa south of 22º S) under the baseline climate as well as projected ensemble average and range of coverage for the 1, 2 and 3ºC temperature worlds.

A			Tropical
	f		- Rainforest
	m		- Monsoon
	w		- Savannah
B			Arid
	W		- Desert
	S		- Steppe
		h	- Hot
		k	- Cold
C			Temperate
	s		- Dry Summer
	w		- Dry Winter
	f		- Without dry season
		a	- Hot Summer
		b	- Warm Summer
		c	- Cold Summer

Köppen-Geiger Code	*Current baseline climate*	*1 ° C global warming*	*2 ° C global warming*	*3 ° C global warming*
Af	*0.0000*	*0.0207; 0.0; 0.1245*	*0.0000; 0.0; 0.0*	*0.0207; 0.0; 0.1245*
Am	*0.0000*	*0.0415; 0.0; 0.1245*	*0.0623; 0.0; 0.3736*	*0.0415; 0.0; 0.2491*
Aw	*1.7435*	*2.0963; 1.6189; 2.4907*	*2.8228; 2.1171; 3.2379*	*3.9021; 2.1171; 5.8531*
BWh	*33.1258*	*41.3242; 35.9900; 45.4545*	*49.1905; 43.5865; 54.4209*	*52.7190; 47.3225; 59.6513*
BWk	*11.7061*	*6.9946; 6.6002; 7.3474*	*3.3832; 2.9888; 3.9851*	*0.8094; 0.3736; 1.6189*
BSh	*19.4271*	*22.9349; 19.9253; 25.5293*	*26.0066; 22.0423; 28.1445*	*27.9576; 24.9066; 29.8879*
BSk	*13.3250*	*7.6795; 7.3474; 7.9701*	*3.9851; 3.3624; 4.6077*	*1.1623; 0.6227; 1.4944*
Csa	*0.2491*	*0.3528; 0.1245; 0.6227*	*1.0585; 0.6227; 1.3699*	*1.1831; 0.6227; 1.4944*
Csb	*1.6189*	*1.3076; 1.2453; 1.4944*	*0.7057; 0.3736; 0.9963*	*0.2698; 0.1245; 0.6227*
Cwa	*1.8680*	*4.6493; 3.3624; 5.8531*	*5.6247; 2.9888; 8.0946*	*6.3304; 2.9888; 8.3437*
Cwb	*9.5890*	*6.3097; 4.9813; 8.3437*	*2.7605; 1.8680; 3.9851*	*1.2868; 0.9963; 1.6189*
Cfa	*3.2379*	*3.5700; 2.6152; 4.3587*	*3.1133; 1.7435; 4.1096*	*3.4247; 1.9925; 5.4795*
Cfb	*4.1096*	*2.7190; 1.9925; 3.3624*	*1.2868; 0.8717; 1.8680*	*0.8925; 0.1245; 1.2453*

M. C. Peel[1], B. L. Finlayson[2], and T. A. McMahon[1]

[1]Department of Civil and Environmental Engineering, The University of Melbourne, Victoria, Australia
[2]School of Anthropology, Geography and Environmental Studies, The University of Melbourne, Victoria, Australia

Hydrol. Earth Syst. Sci., 11, 1633–1644, 2007
www.hydrol-earth-syst-sci.net/11/1633/2007/

Köppen-Geiger climate zones

1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100 - MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100 - MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a or b) & $1 \leq T_{mon10} < 4$

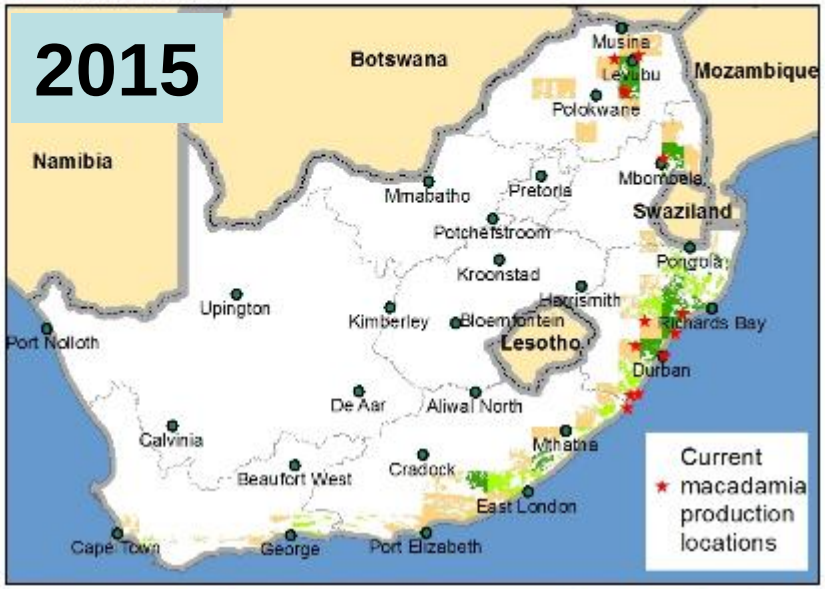
*MAP = mean annual precipitation, MAT = mean annual temperature, T_{hot} = temperature of the hottest month, T_{cold} = temperature of the coldest month, T_{mon10} = number of months where the temperature is above 10, P_{dry} = precipitation of the driest month, P_{sdry} = precipitation of the driest month in summer, P_{wdry} = precipitation of the driest month in winter, P_{swet} = precipitation of the wettest month in summer, P_{wwet} = precipitation of the wettest month in winter, $P_{threshold}$ = varies according to the following rules (if 70% of MAP occurs in winter then $P_{threshold}$ = 2 x MAT, if 70% of MAP occurs in summer then $P_{threshold}$ = 2 x MAT + 28, otherwise $P_{threshold}$ = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.

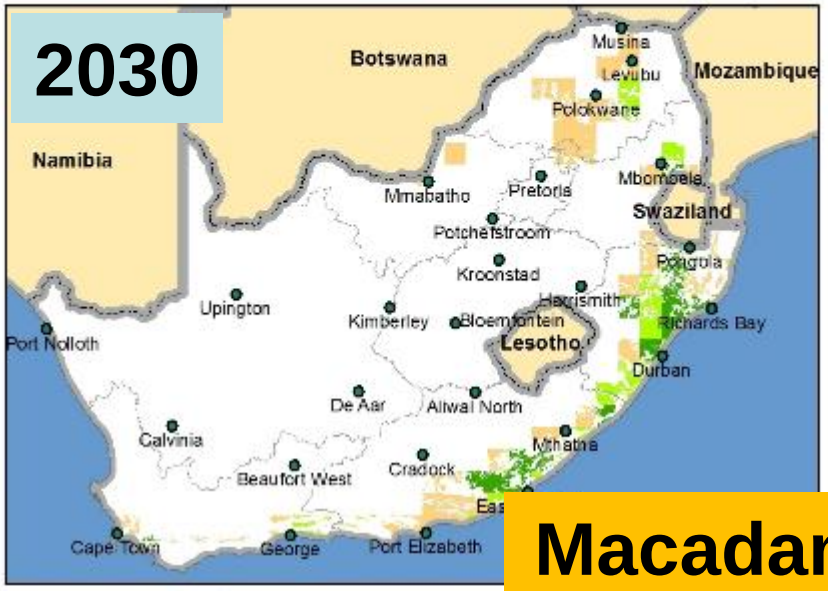
agriculture, forestry & fisheries
Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

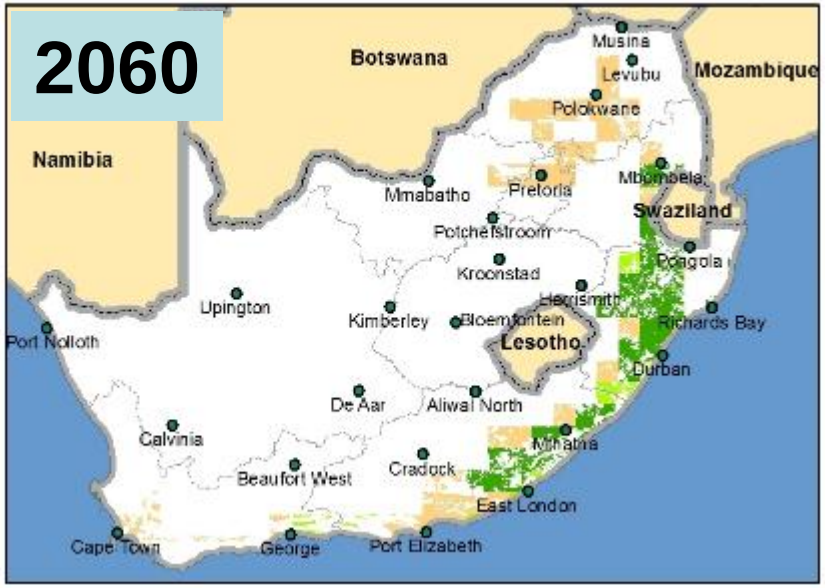
Suitability for macadamia production (supplementary irrigation)

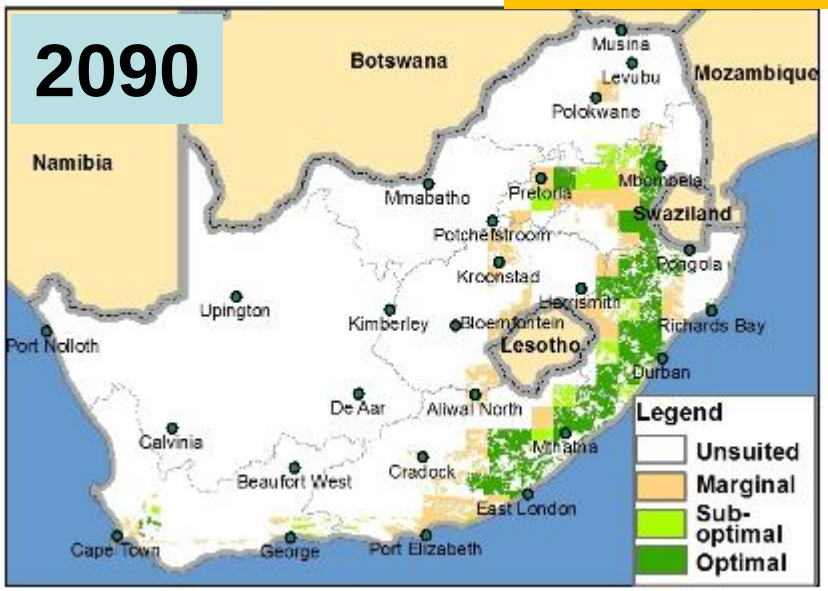
Criteria: rainfall, minimum temperature, maximum temperature
Median of six climate projections for 2015, 2030, 2060 and 2090

ARC • LNR





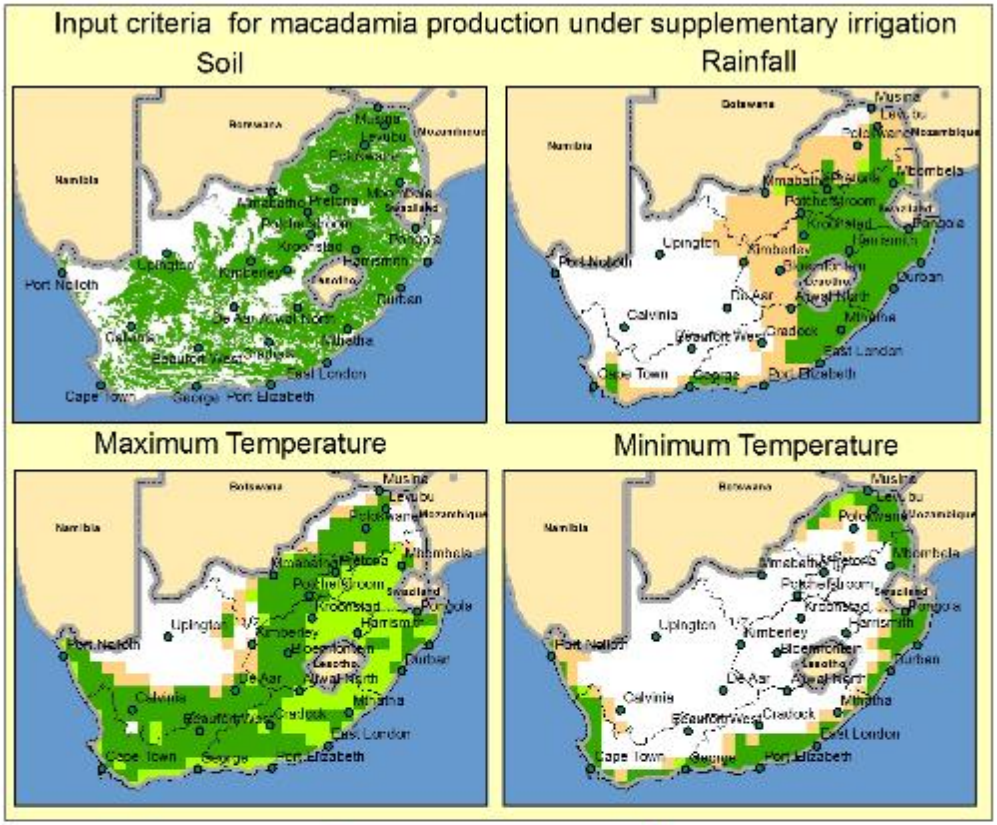




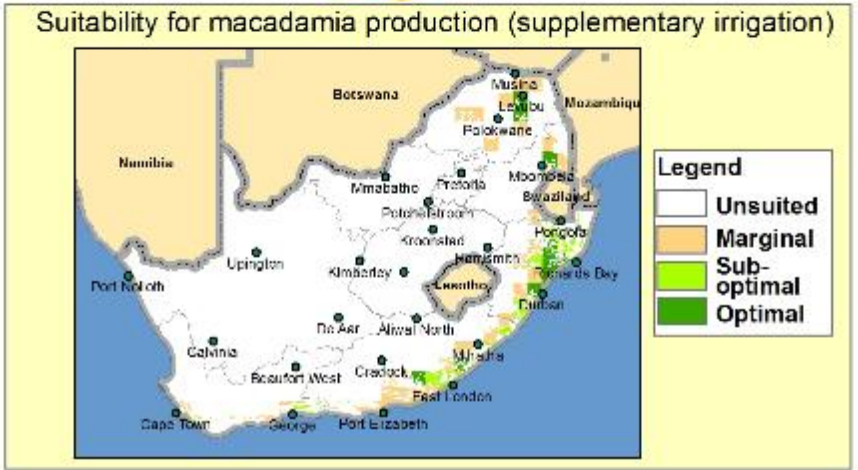
Macadamia

Environmental suitability criteria for macadamia Production under supplementary irrigation

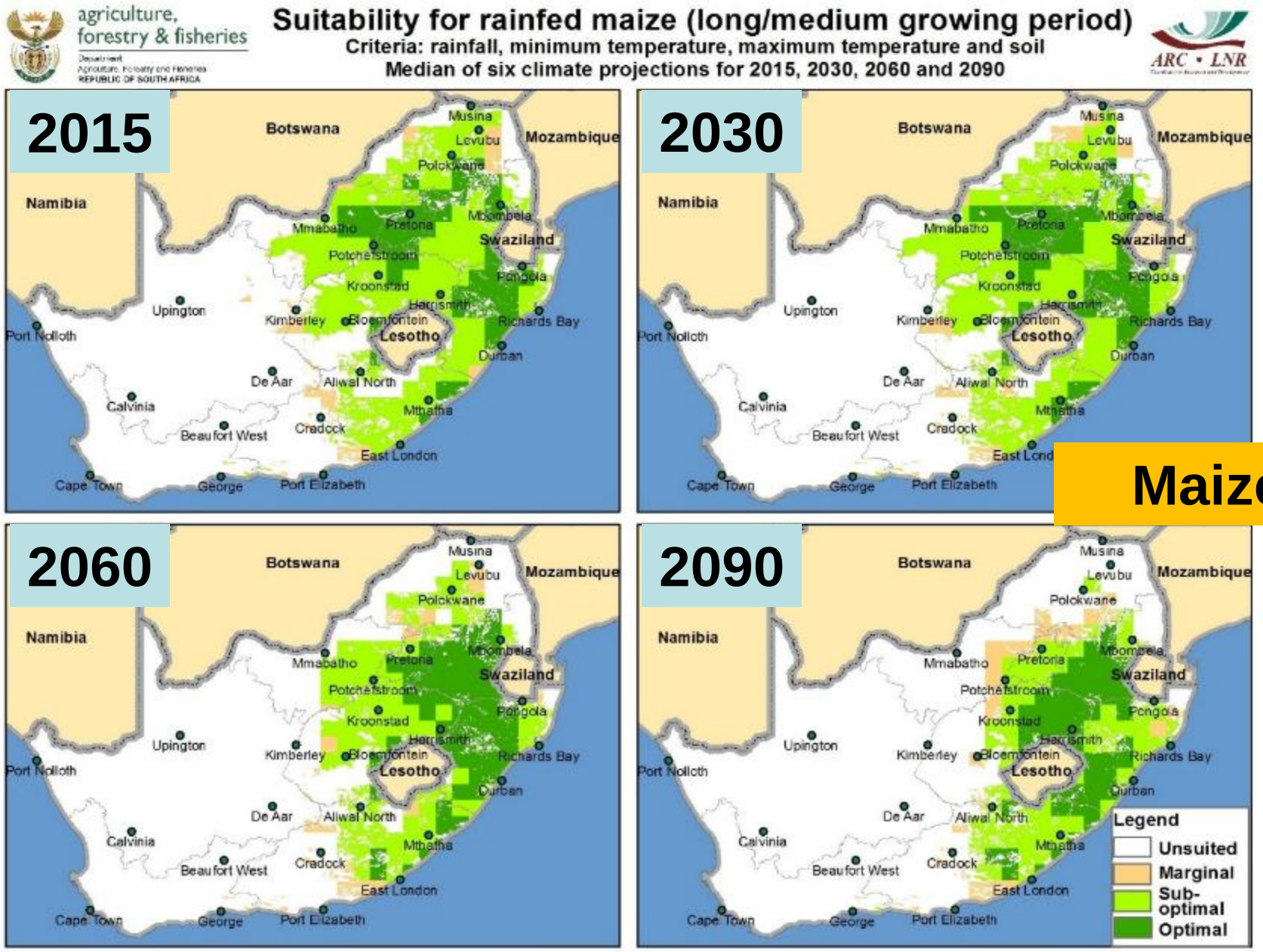
Land attribute \ Suitability class	Optimal	Unsuited
Annual rainfall (mm)	>=600	<400
T_{min} (°C) July	>7	<6
T_{max} (°C) Nov-Feb	<=29	>34
Soil depth (mm)		<500
Topsoil clay (%)		<6 and >40%



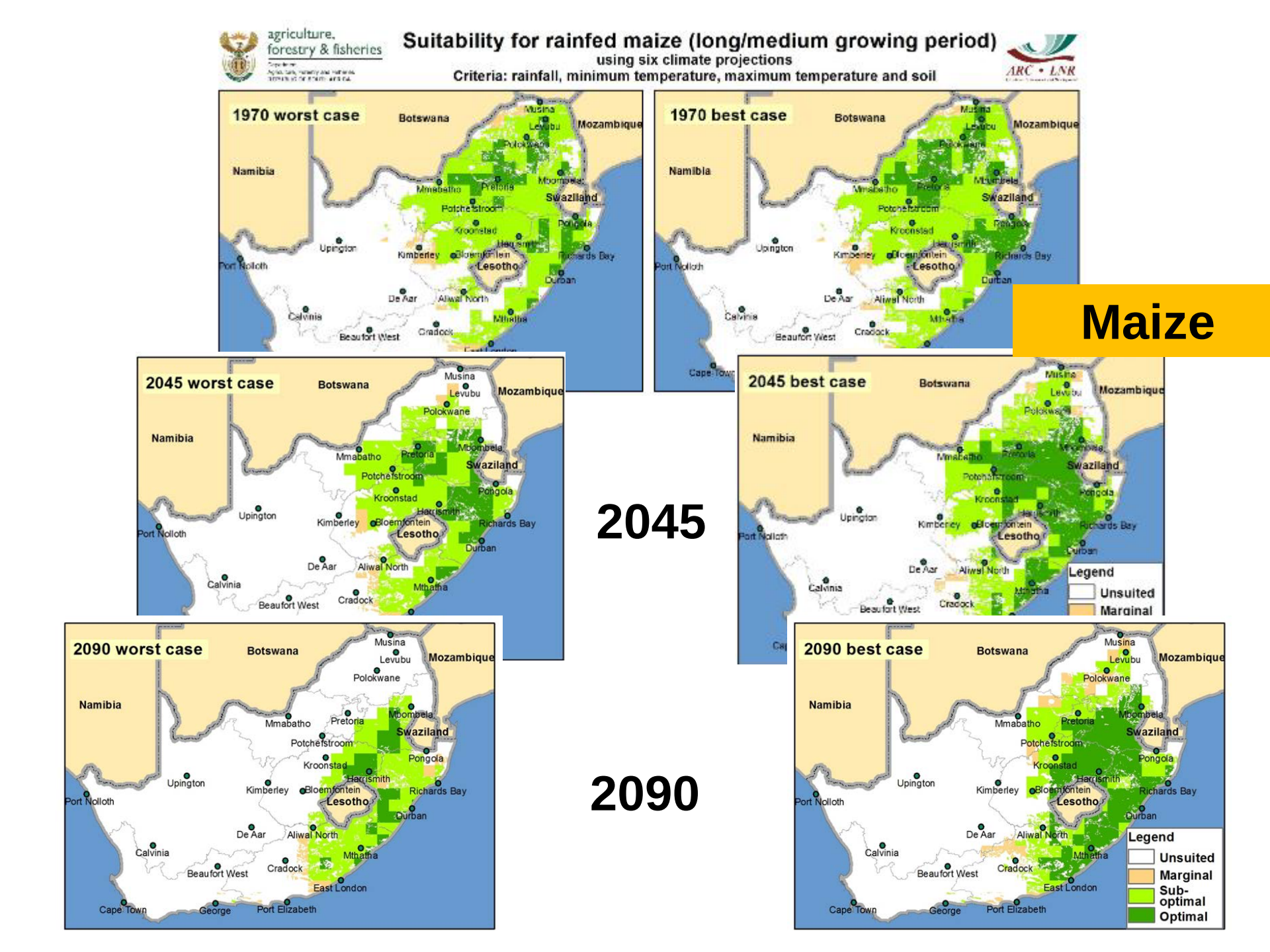
Lowest suitability class of criteria



Implications for production?



Maize


agriculture, forestry & fisheries
Suitability for rainfed maize (long/medium growing period)
using six climate projections
Criteria: rainfall, minimum temperature, maximum temperature and soil
ARC • LNR
1970 worst case
1970 best case
Maize
2045 worst case
2045 best case
2045
2090 worst case
2090 best case
2090
Botswana
Namibia
Mozambique
Swaziland
Lesotho
Musina
Levubu
Polokwane
Mmabatho
Pretoria
Mbombela
Potchefstroom
Pongola
Kroonstad
Harrismith
Upington
Kimberley
Bloemfontein
Richards Bay
Port Nolloth
Durban
De Aar
Aliwal North
Mthatha
Calvinia
Beaufort West
Cradock
East London
Cape Town
George
Port Elizabeth
Legend
Unsuited
Marginal
Sub-optimal
Optimal

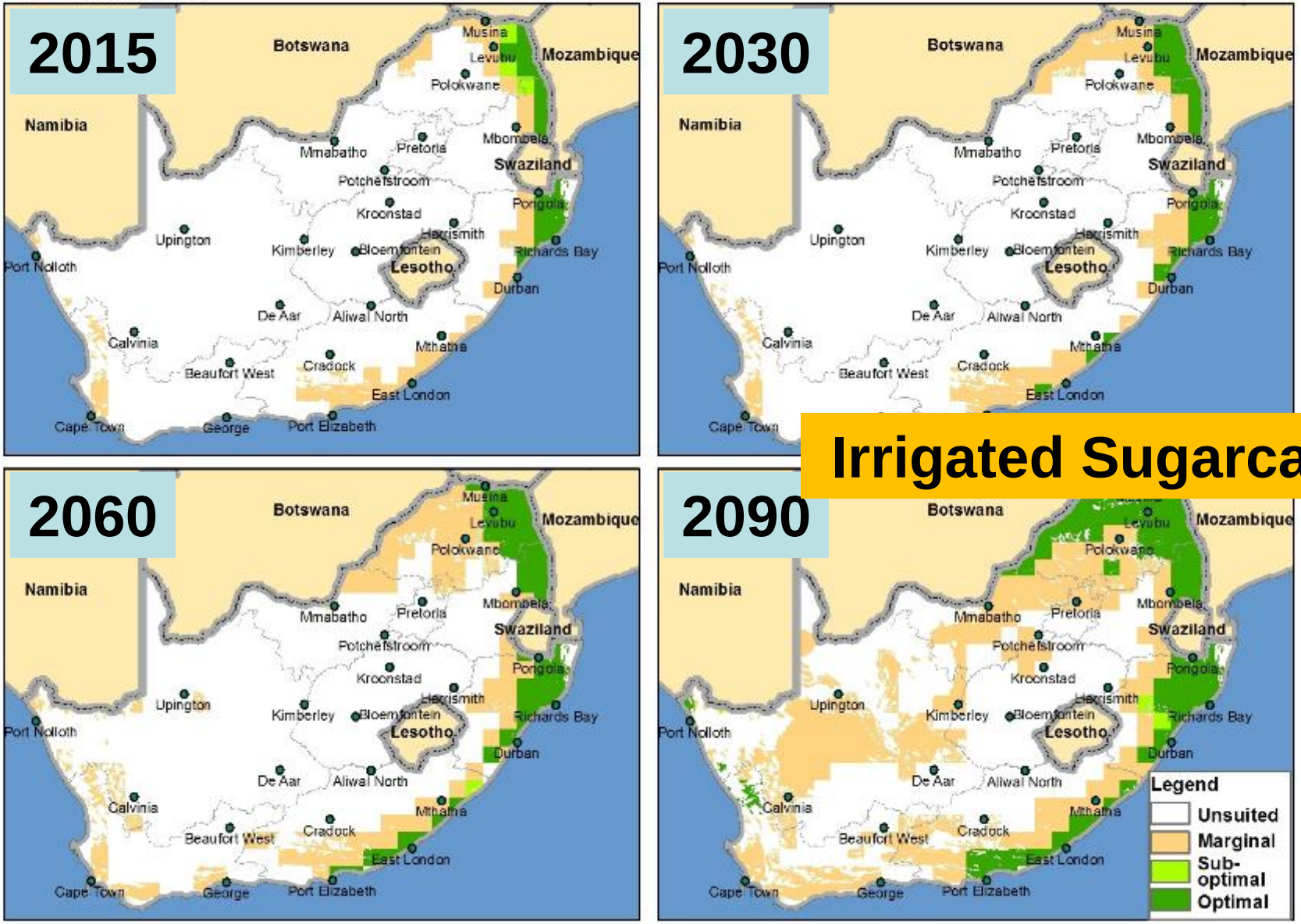
agriculture, forestry & fisheries

Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Suitability for irrigated sugarcane

Criteria: minimum temperature, annualized irrigated yield and soil
Median of six climate projections for 2015, 2030, 2060 and 2090

ARC • LNR



Irrigated Sugarcane

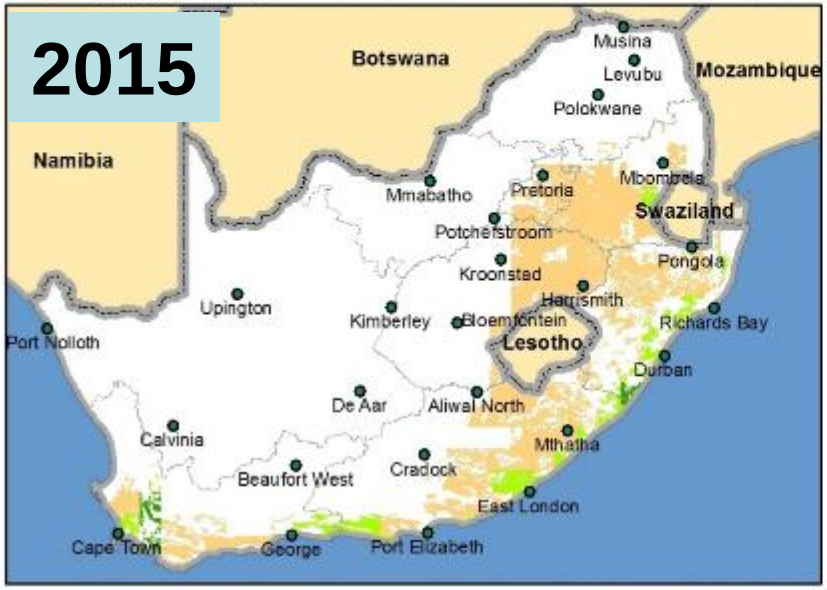
agriculture, forestry & fisheries

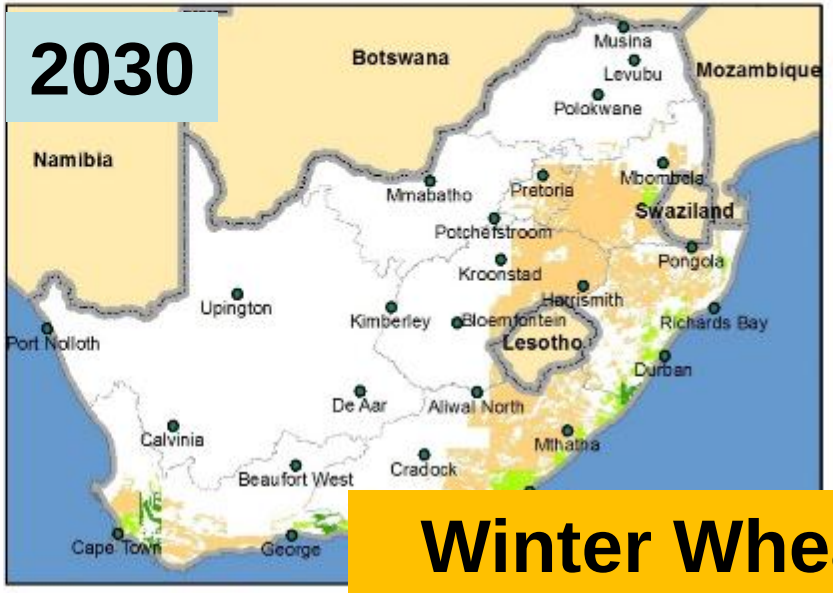
Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Suitability for rainfed wheat (Winter rainfall, May to Nov)

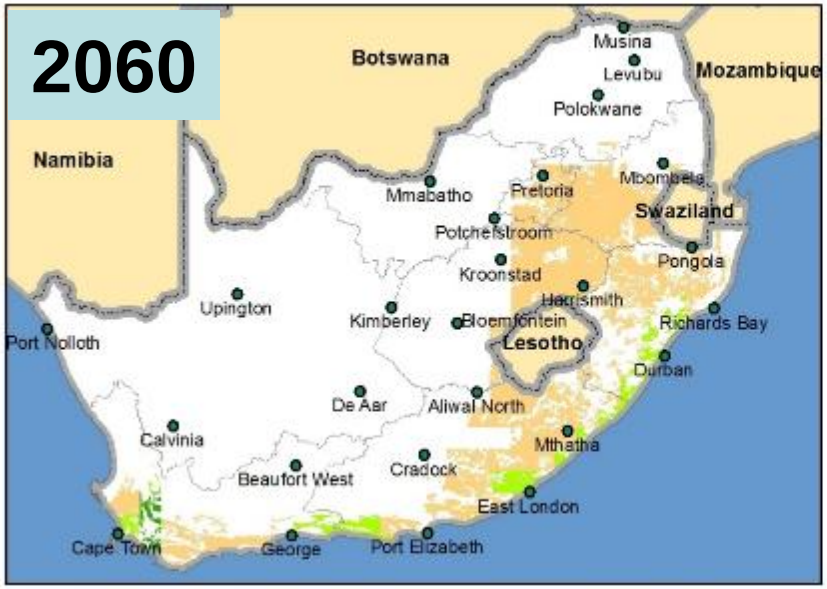
Criteria: rainfall, minimum temperature, maximum temperature and soil
Median of six climate projections for 2015, 2030, 2060 and 2090

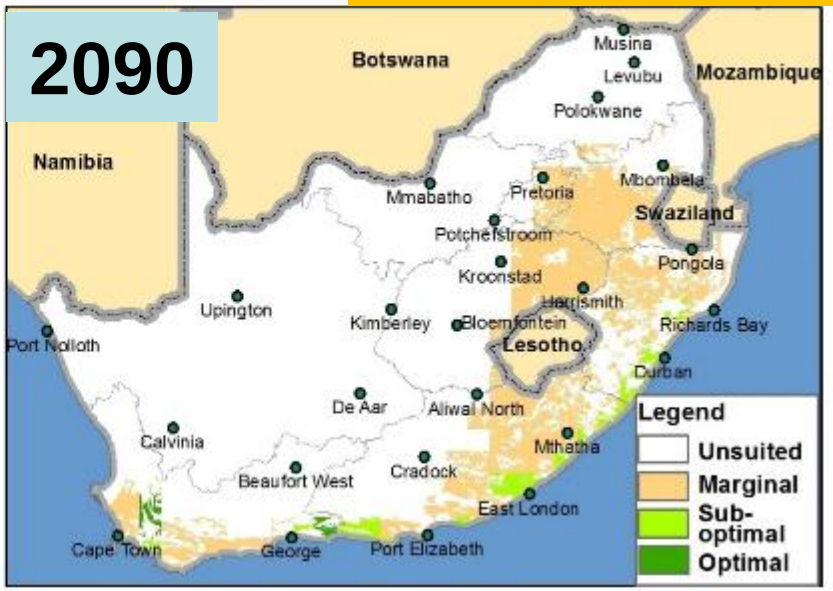
ARC • LNR





Winter Wheat





The crop suitability maps are based on environmental criteria only and do not consider the following:

- *New cultivars:* Development of new cultivars could make it possible to plant in higher temperatures, which would change the production areas correspondingly.
- *Plant diseases:* Climate change will affect the fecundity, dispersal and distribution of plant diseases and pests. Higher temperatures will increase overwintering of pathogens and pests, modify host susceptibility to infection, accelerate pathogen and vector life cycles and increase the sporulation and infectiousness of fungi.
- *Effect of increased CO_2:* Increased CO_2 levels are likely to have a positive effect on potential water use efficiency and crop productivity. Crops such as potato, cotton, wheat, and soybeans benefit substantially from additional atmospheric CO_2, while crops such as maize, sorghum and sugarcane are more limited.

Summary

- **Observed and projected trends in climate variables have implications for agriculture in South Africa**
- **Temperature and rainfall changes may result in a shift in climate zones predominantly towards warmer and therefore more arid**
- **Different crops are not affected the same way by climate change as climate zones shift**
- **The production area of some crops could increase (sugarcane, groundnut and cotton)**
- **The production area of most crops could decrease (examples include maize, soybean, sorghum, sunflower, potato and Smuts finger grass),**
- **The production area for wheat mostly remain unchanged,**
- **The role of climate monitoring through good quality weather station networks cannot be overstated – towards monitoring climate change, differentiate between change and variability and to evaluate climate change projections**

ARC • LNR
Excellence in Research and Development