What Are We Doing To Our Climate? And What Is The Climate Likely to Do To Us?

A Focus on Grasslands

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What are we doing to our Climate?

We are Emitting Vast Amounts of Greenhouse Gases into the Atmosphere re. Energy

We are Emitting Vast Amounts of Greenhouse Gases into the Atmosphere

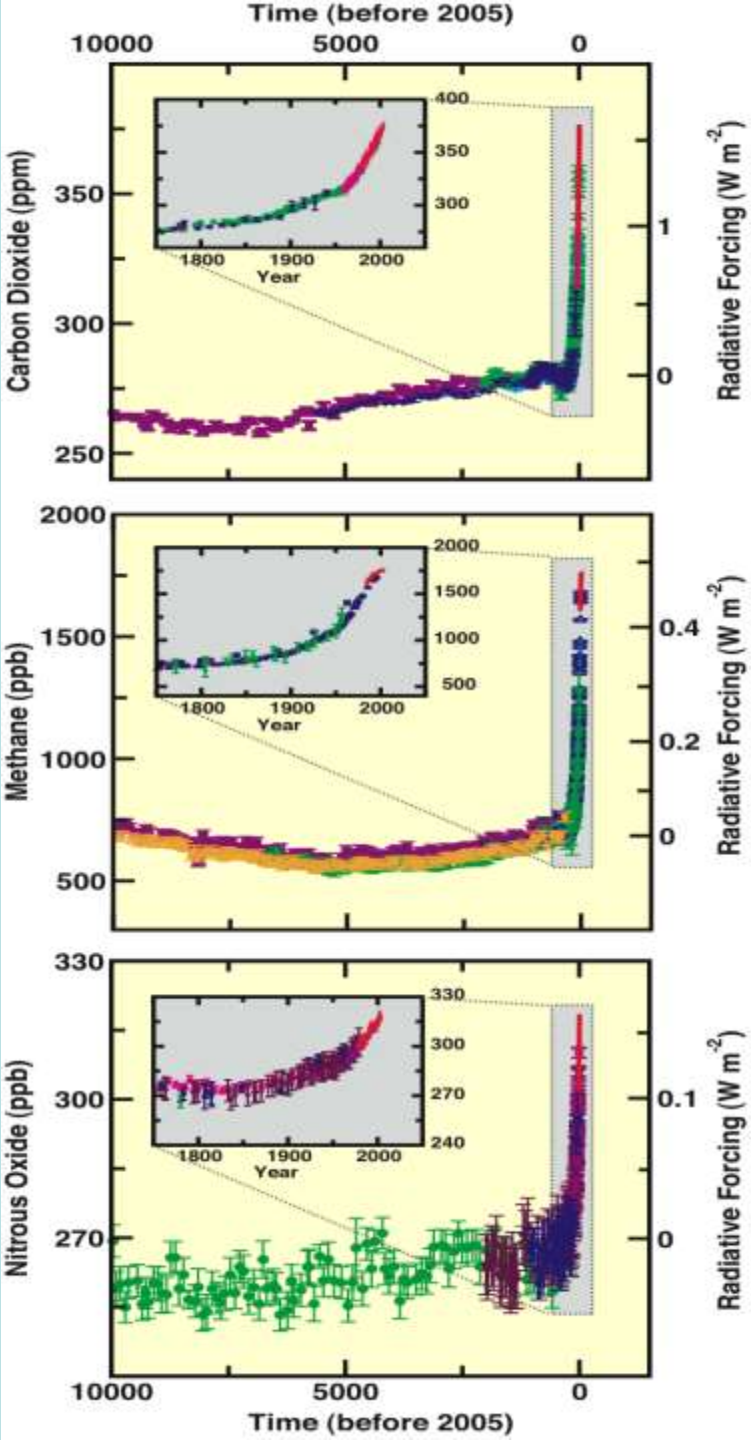
Re. Transportation

The Result…1

CO_2

CH_4

N_2O



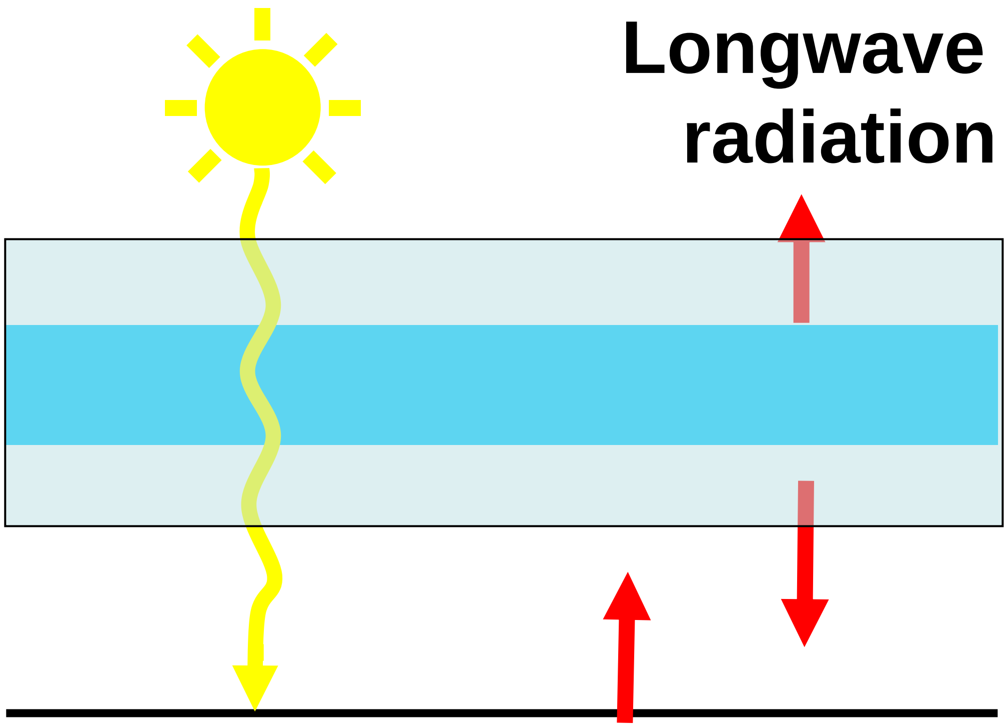
Considerable changes have occurred since the industrial revolution

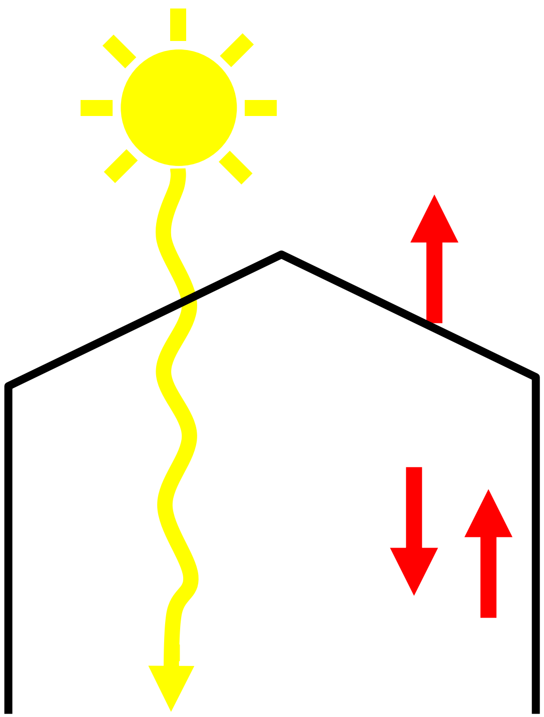
CO_2 radiative forcing has increased by ~ 20% in past 10 years

IPCC Figure SPM-1

Result 2: The Enhanced Greenhouse Effect

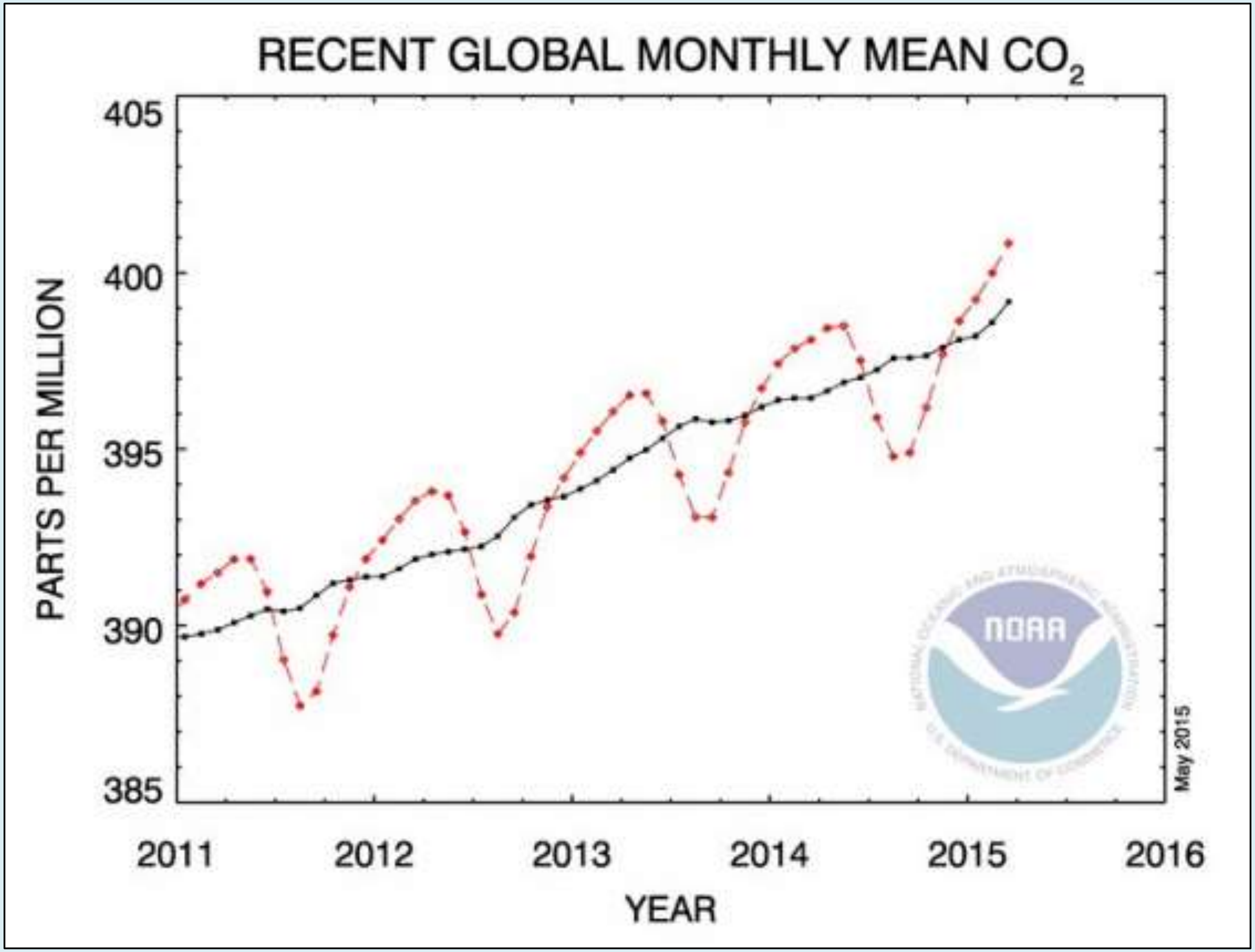
Solar radiation





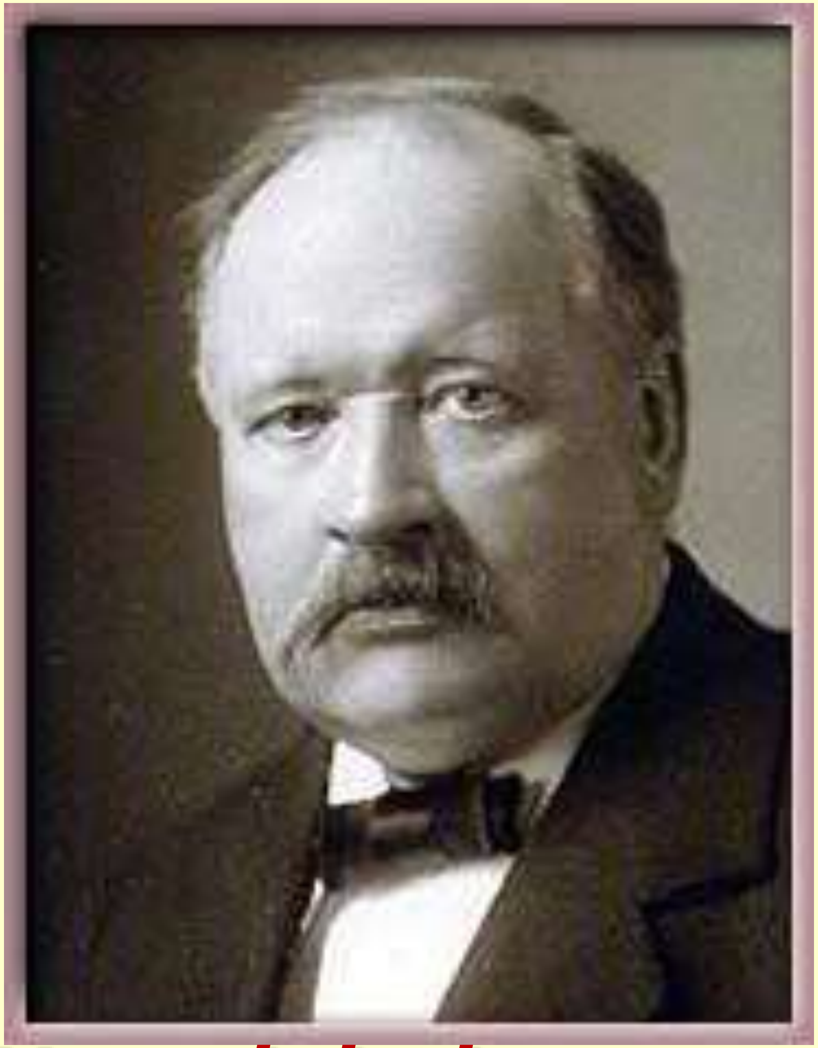

CAPE POINT
GLOBAL ATMOSPHERE WATCH
STATION
South African
Weather Service

Carbon Dioxide Concentrations in the Atmosphere are Increasing



NOAA, 7 May 2015

The Effects Have Been Known for a Long Time



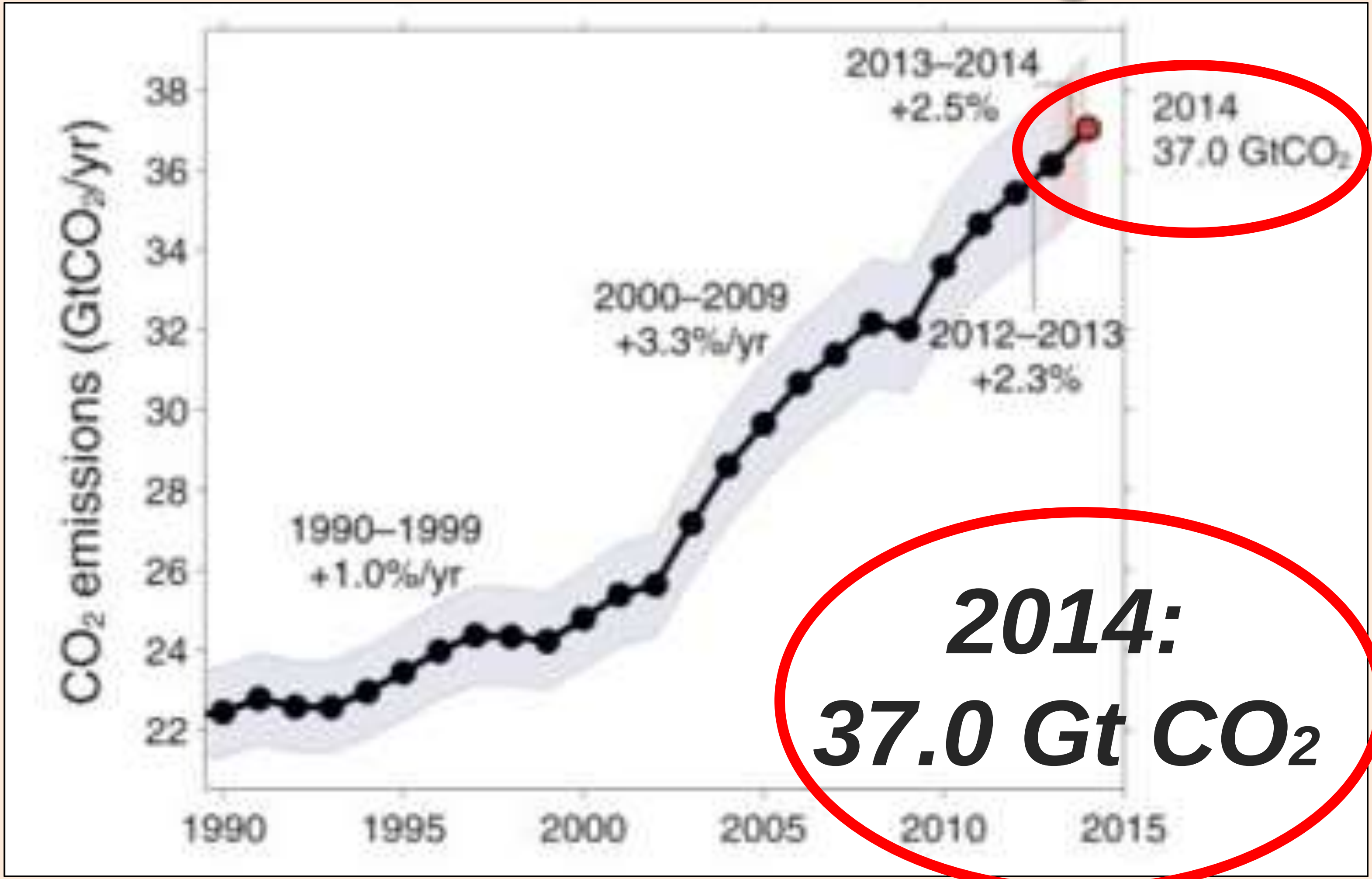
Svante ARRHENIUS

1859 born 15 February
1884 PhD in Physics 4th Class
1896 First scientist to calculate how changes in CO_2 through burning fossil fuels could alter surface temperatures through the Greenhouse Effect
1903 Nobel Prize for Chemistry

How right he was, and yet so wrong!

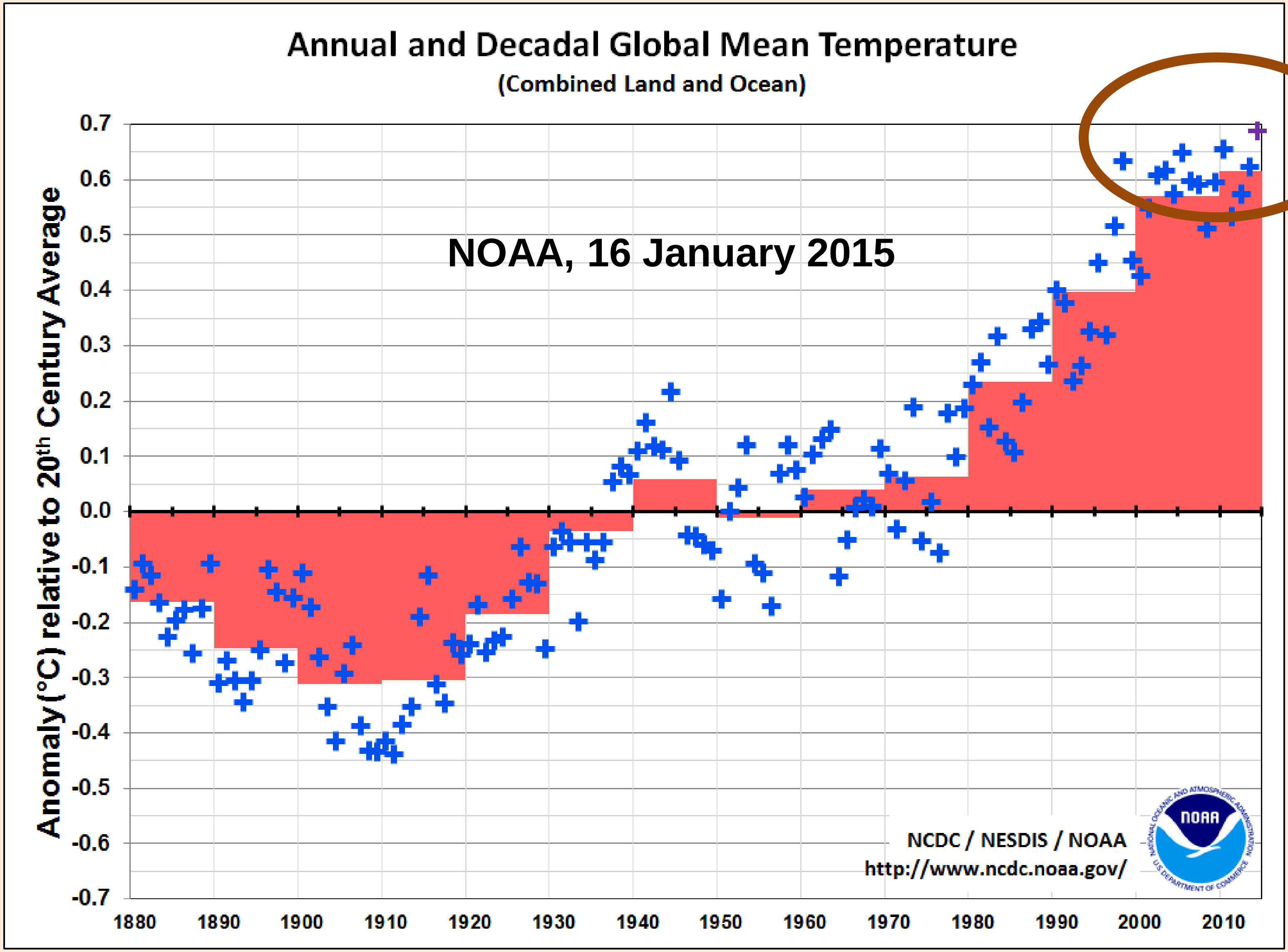
How much are we Emitting into the Atmosphere?

The Global Carbon Budget

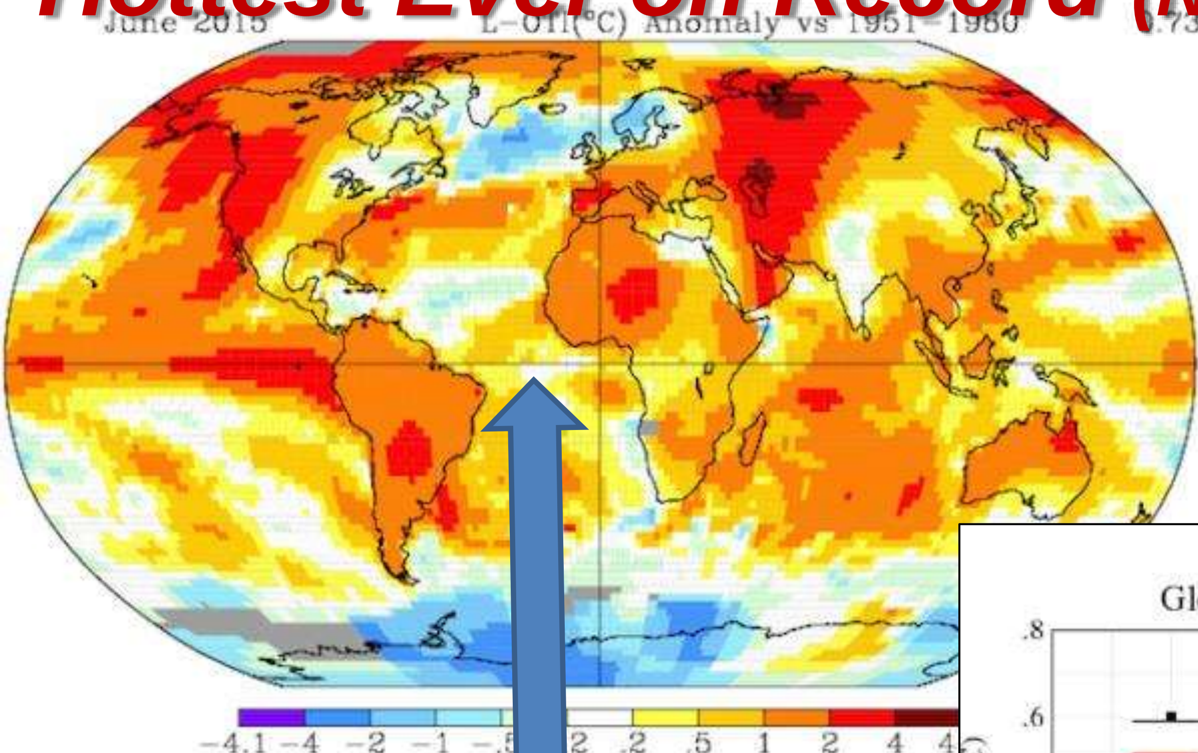


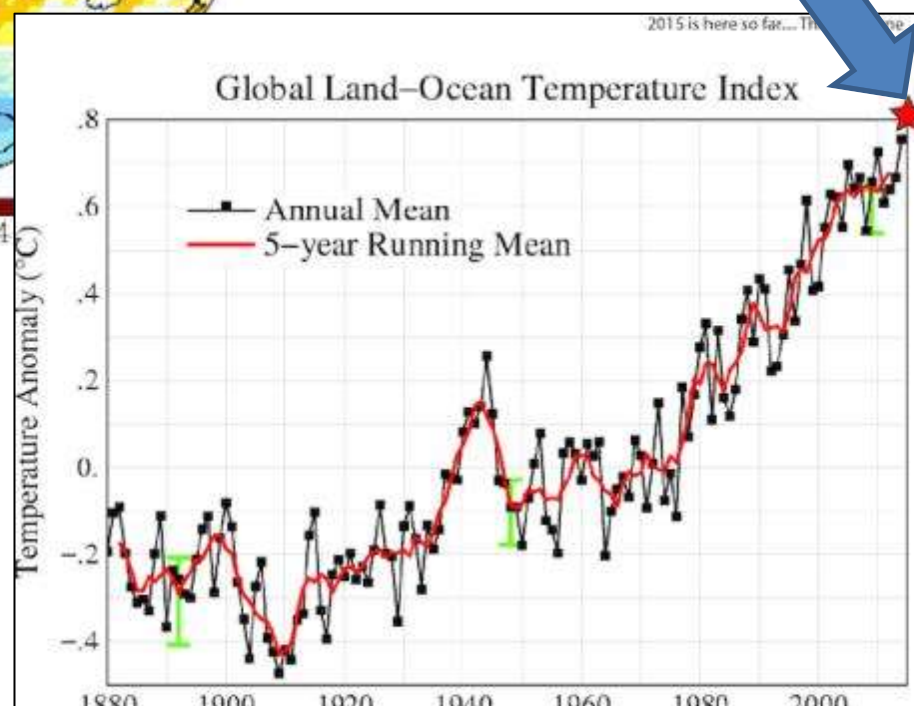
2014:
37.0 Gt CO_2

Result 3: Globally, 2014 was the Hottest Year Ever



… and it Continues: January – June 2015 Hottest Ever on Record (NOAA, 18 July 2015)



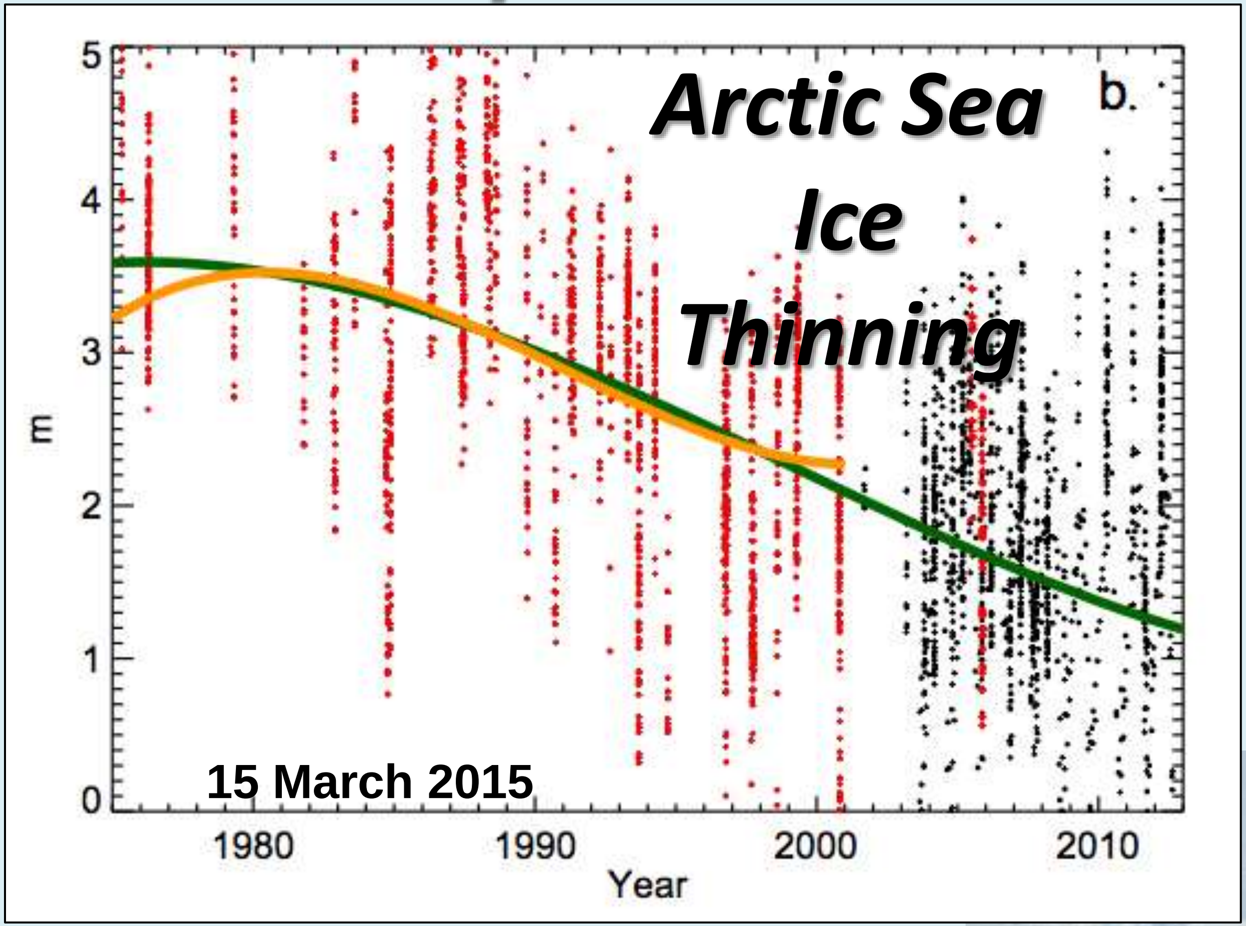


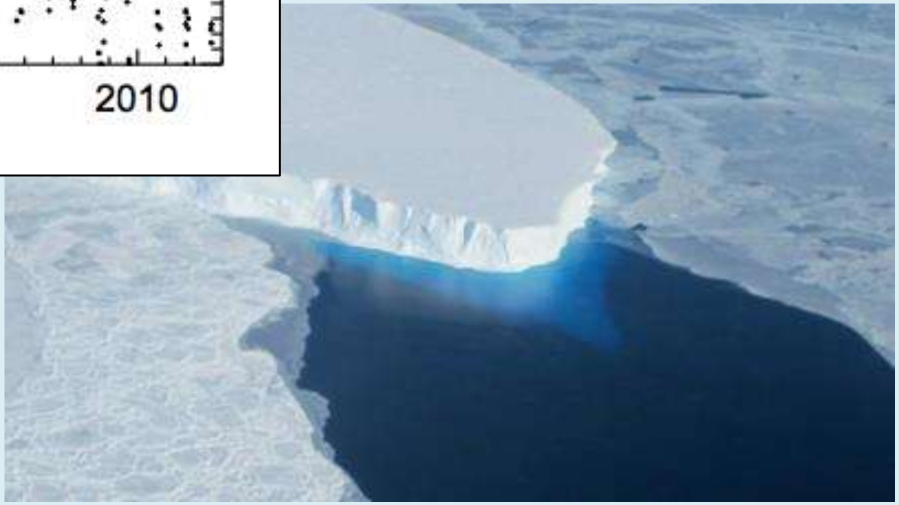
18 July 2015

June 2015 Hottest Ever Globally! …and likely to continue (NOAA)

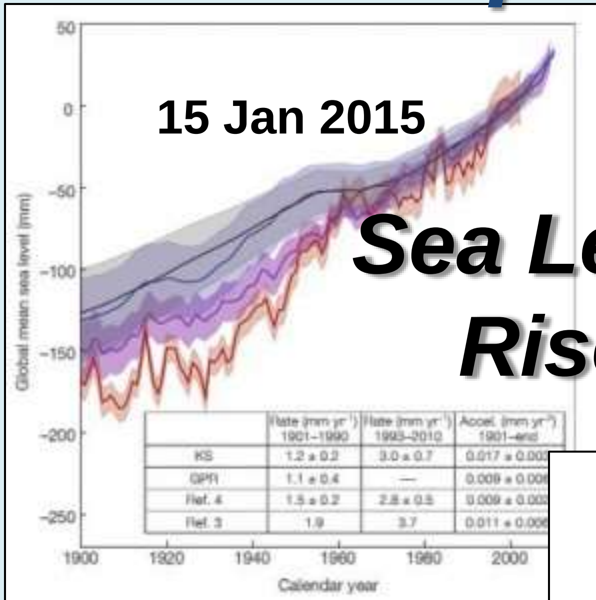
So, What Are Some Consequences … General

Consequences? And with that, …

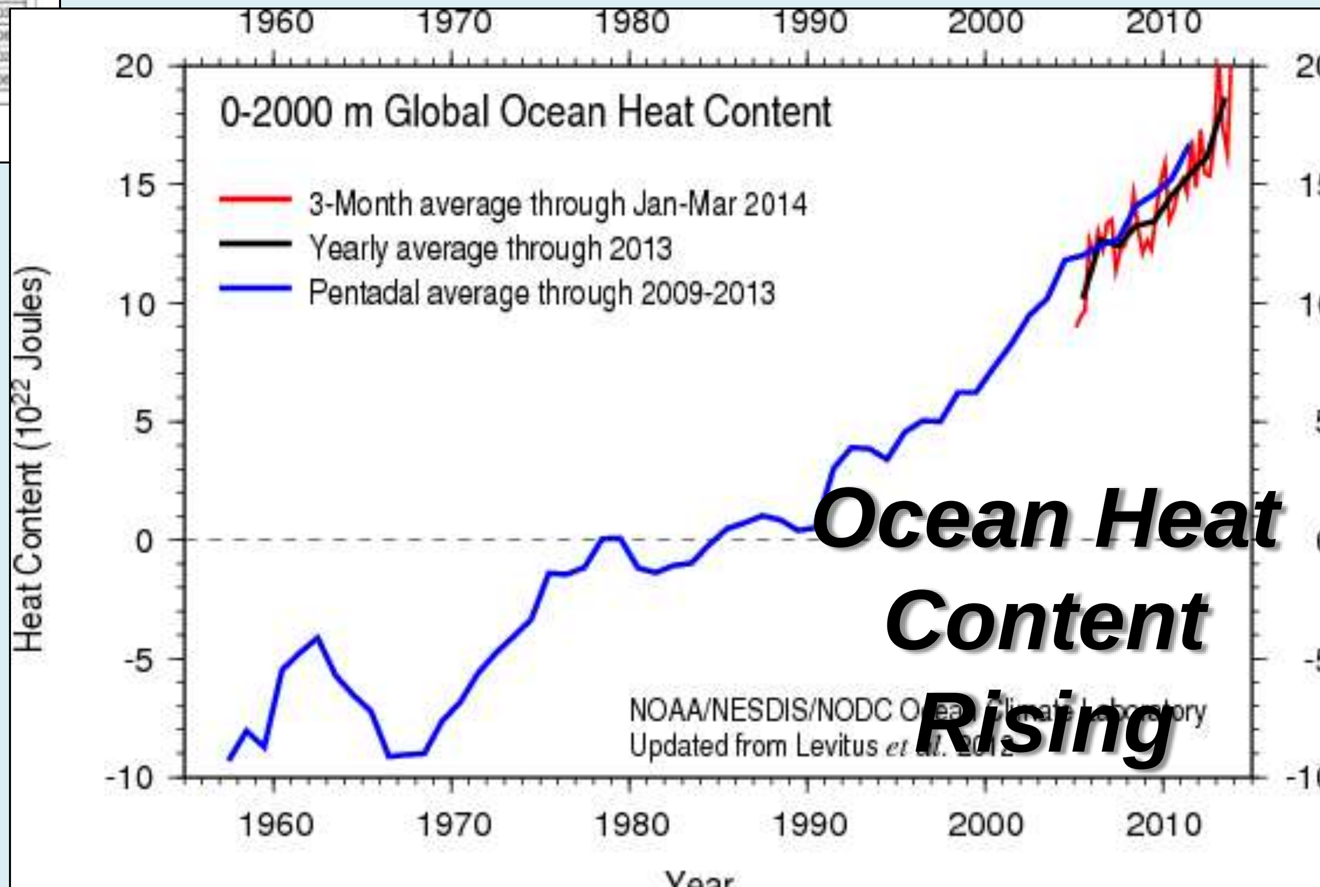




Consequences? And with that, …

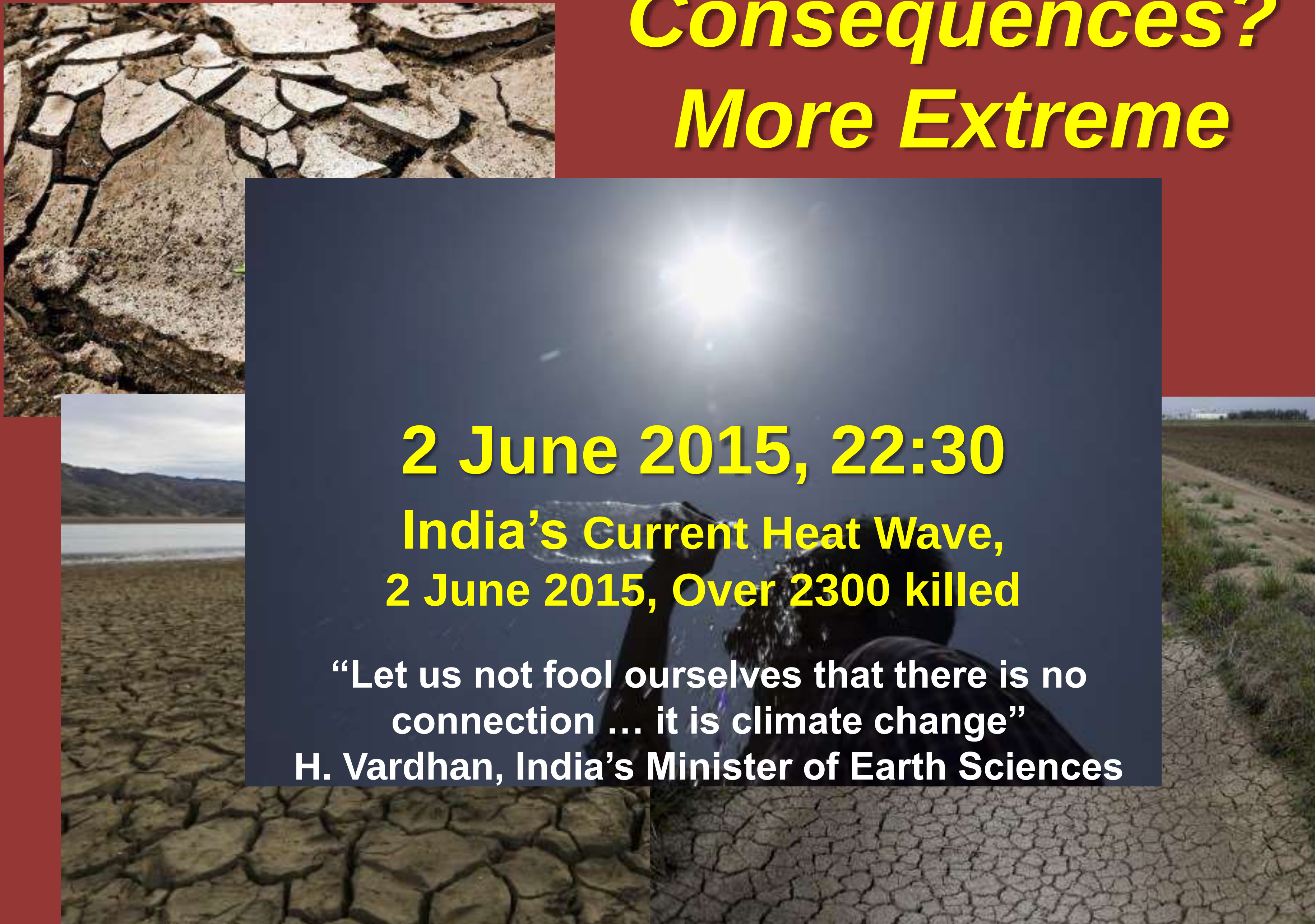


Sea Level Rise



Ocean Heat Content Rising

Consequences? More Extreme



2 June 2015, 22:30

India's Current Heat Wave,
2 June 2015, Over 2300 killed

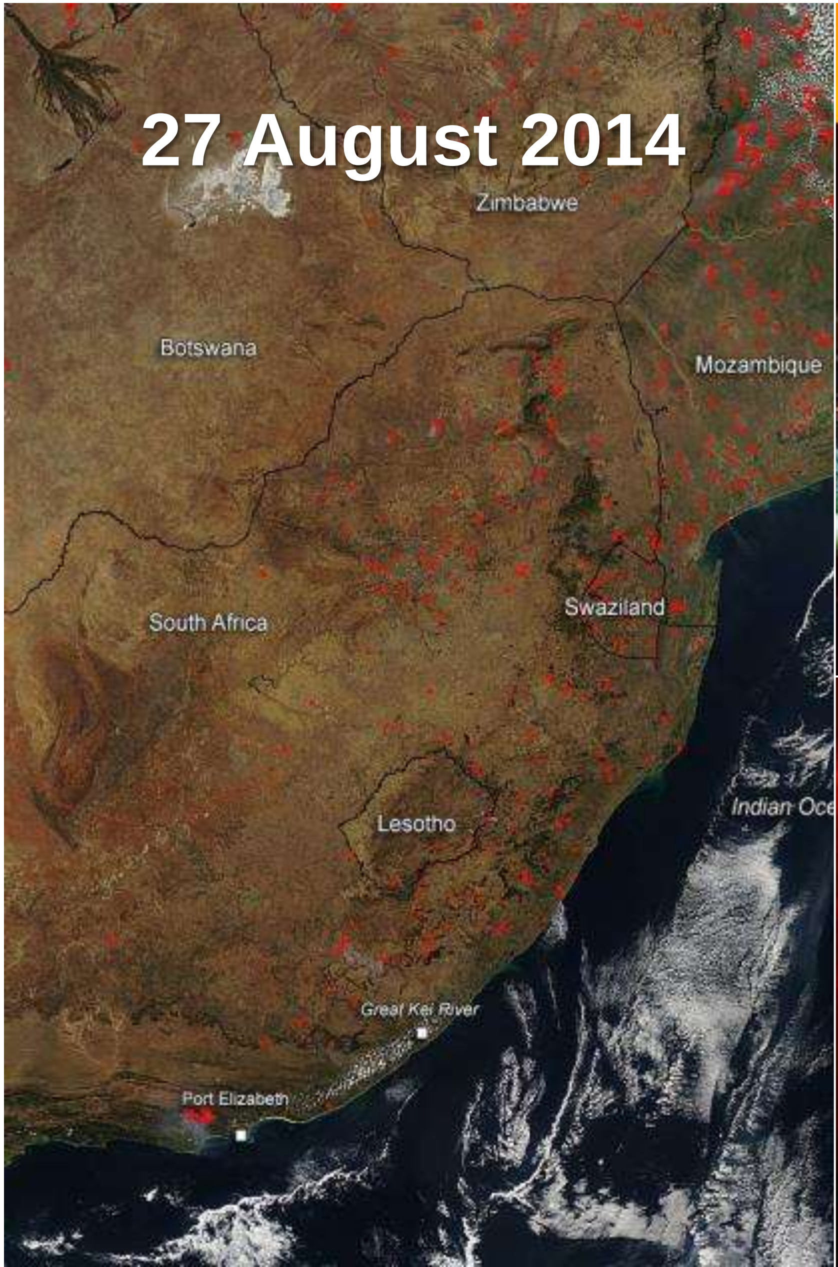
"Let us not fool ourselves that there is no connection … it is climate change"
H. Vardhan, India's Minister of Earth Sciences

Consequences?
Old Trees Most Likely to Die

More Severe Storms…
Signs of Climate Change…???

Durban, 11 December 2009

Consequences? More Frequent Fires



And, what is our climate likely to do to us?

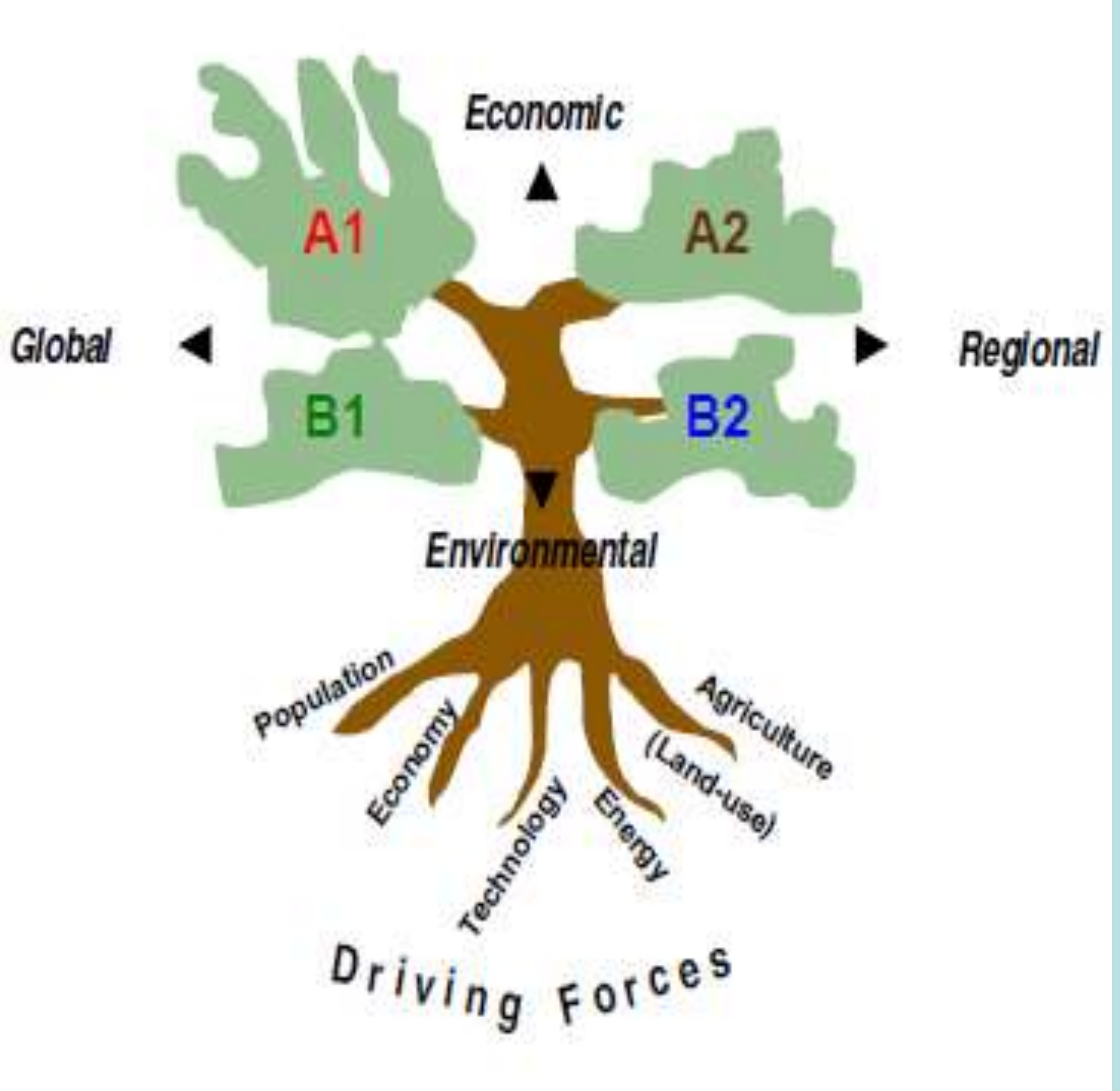
To answer that, we first need to do scenario projections into the future…

So, just a little bit of science!

Scenarios into the Future…up to 2013

SRES Scenario Storylines Considered by the IPCC

(after Nakićenović *et al.*, 2000; graphic from IPCC-TGICA, 2007)



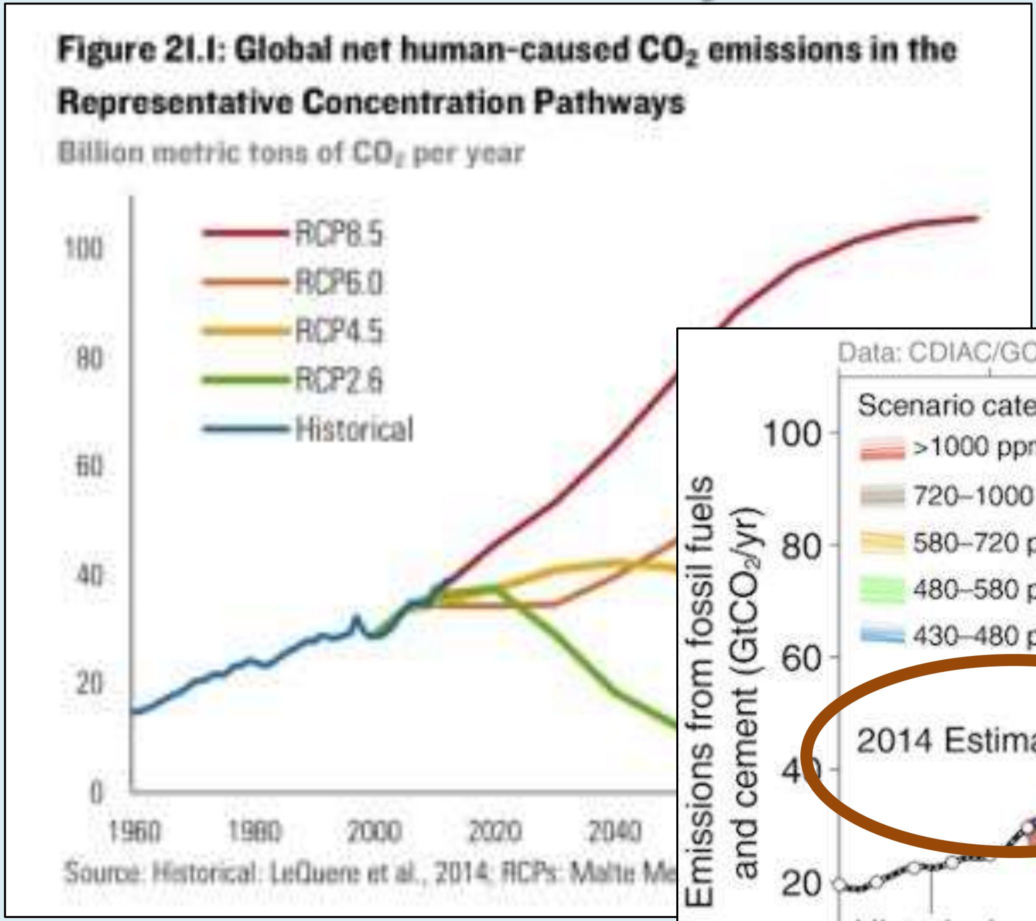
A1: A world of rapid economic growth and rapid introductions of new and more efficient technologies

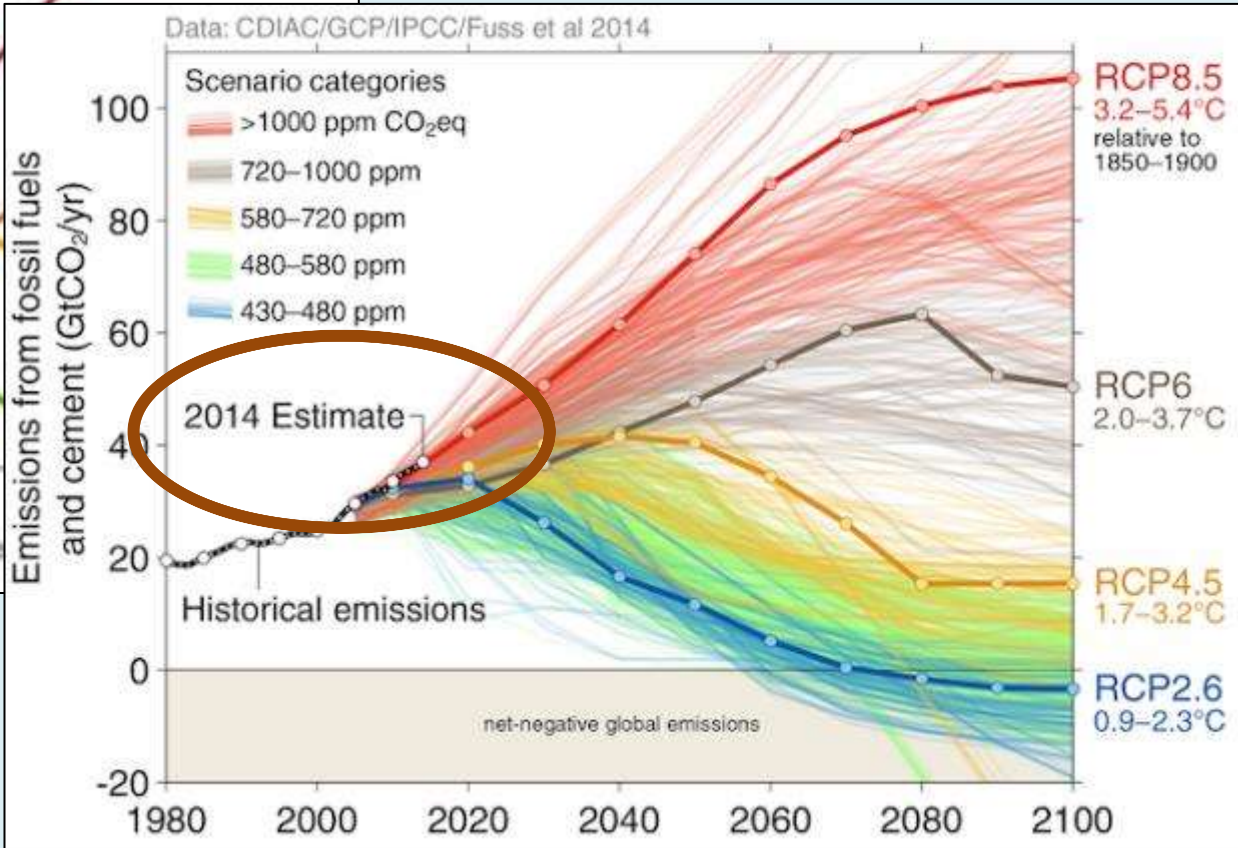
A2: A very heterogeneous world with an emphasis on family values and local traditions

B1: A world of dematerialization and introduction of clean technologies

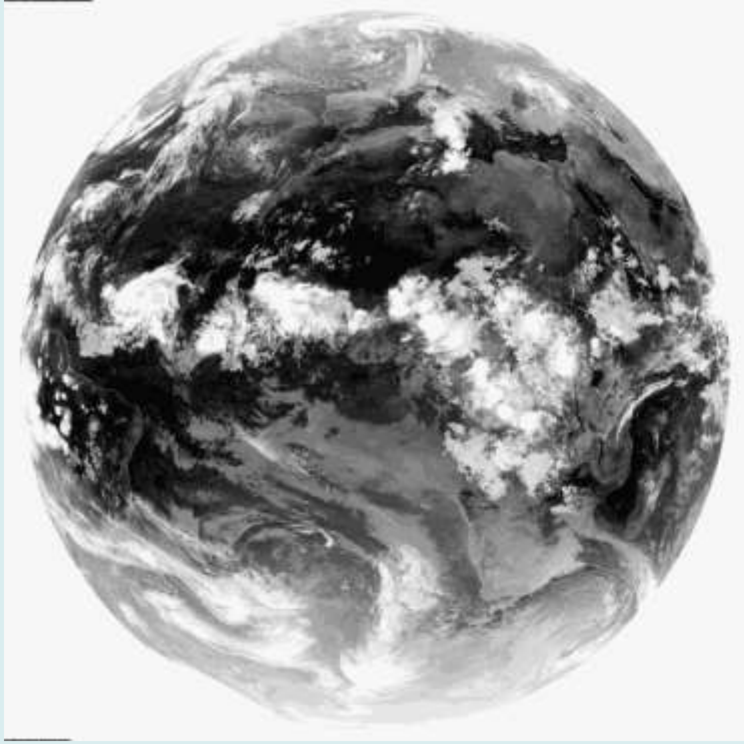
B2 A world of emphasis on local solutions to economic and environmental sustainability

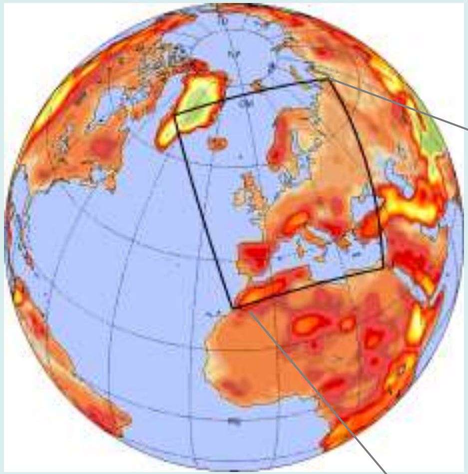
Scenarios into the Future Since 2013, RCPs, Generated by Global Climate Models, GCMs



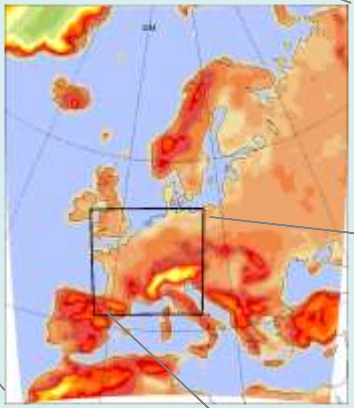


To Apply GCMs, they Require Downscaling to Local Scales

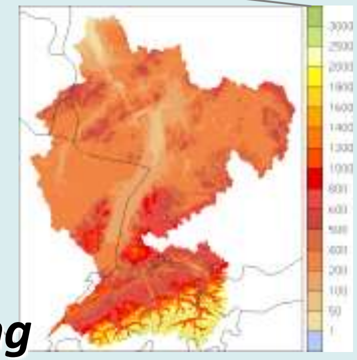




Global Climate Models (GCMs) (e.g. HadCM3, ECHAM5, ~200 km)



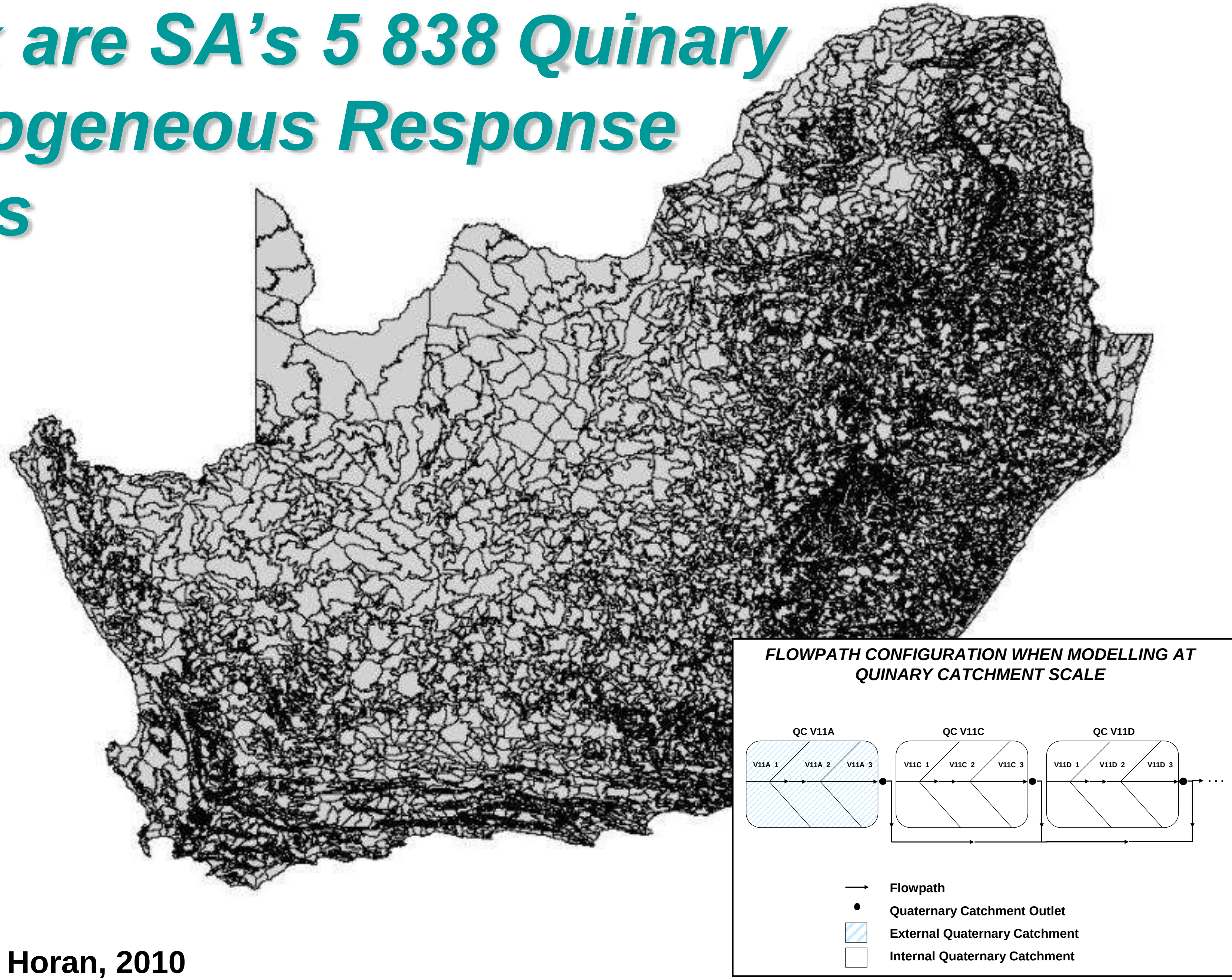
Regional Climate Models (RCMs) or statistical downscaling (~25 km)



Impact Models (~5 km)

Hewitson, 2010

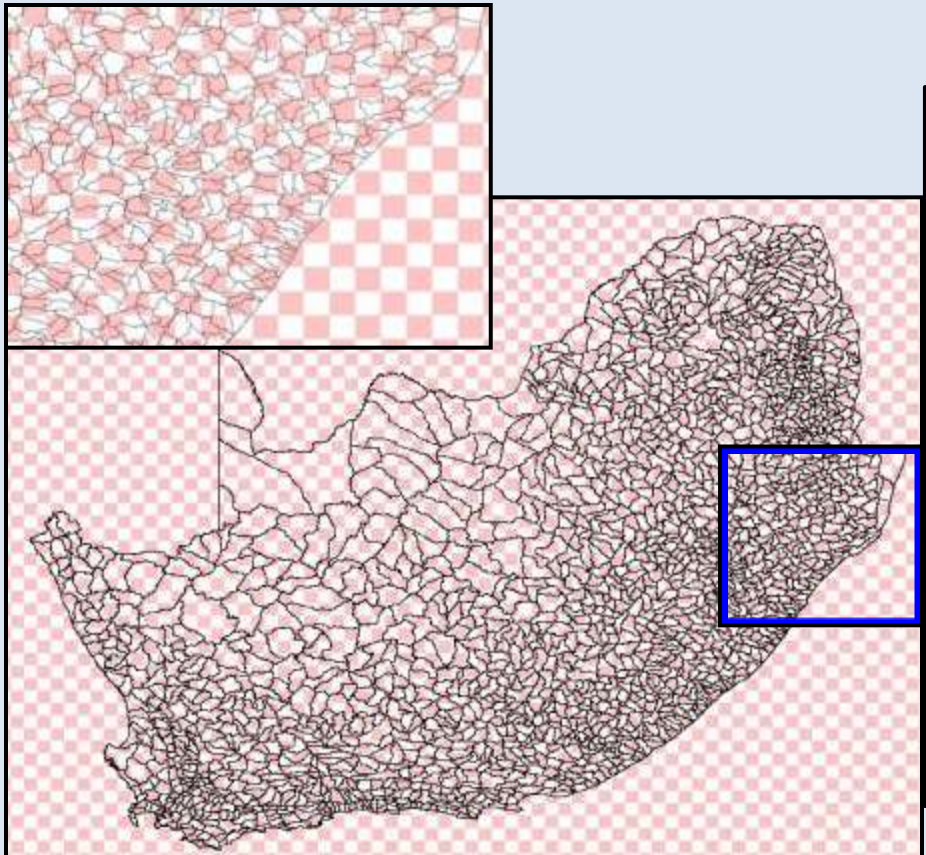
The Local Scale at which we Work are SA's 5 838 Quinary Homogeneous Response Zones

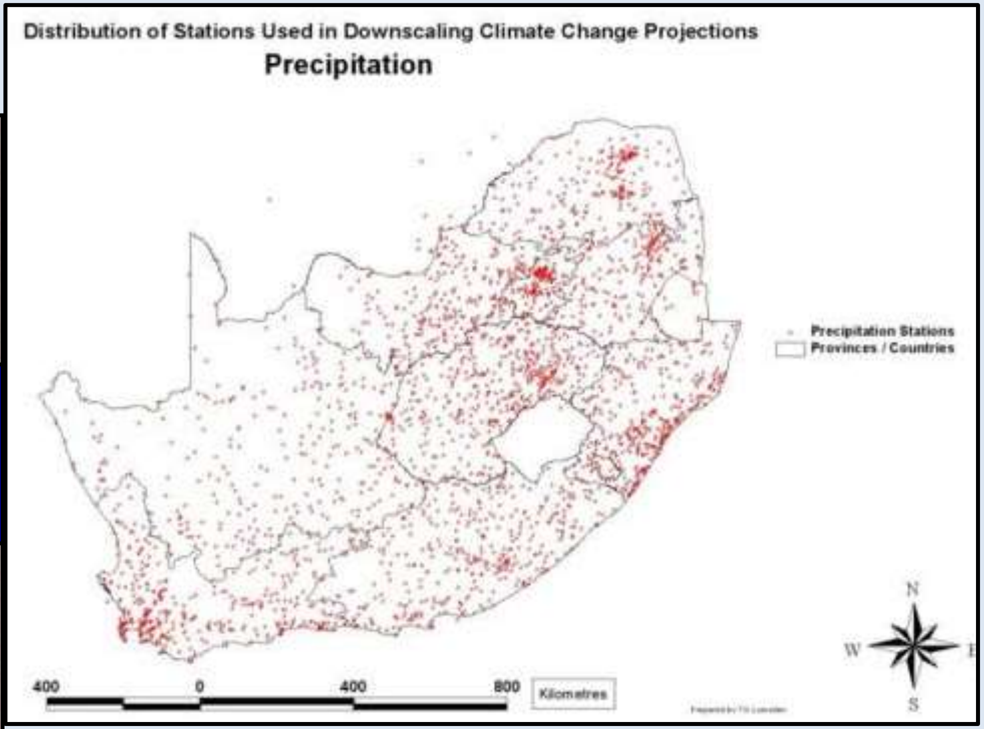


Schulze & Horan, 2010

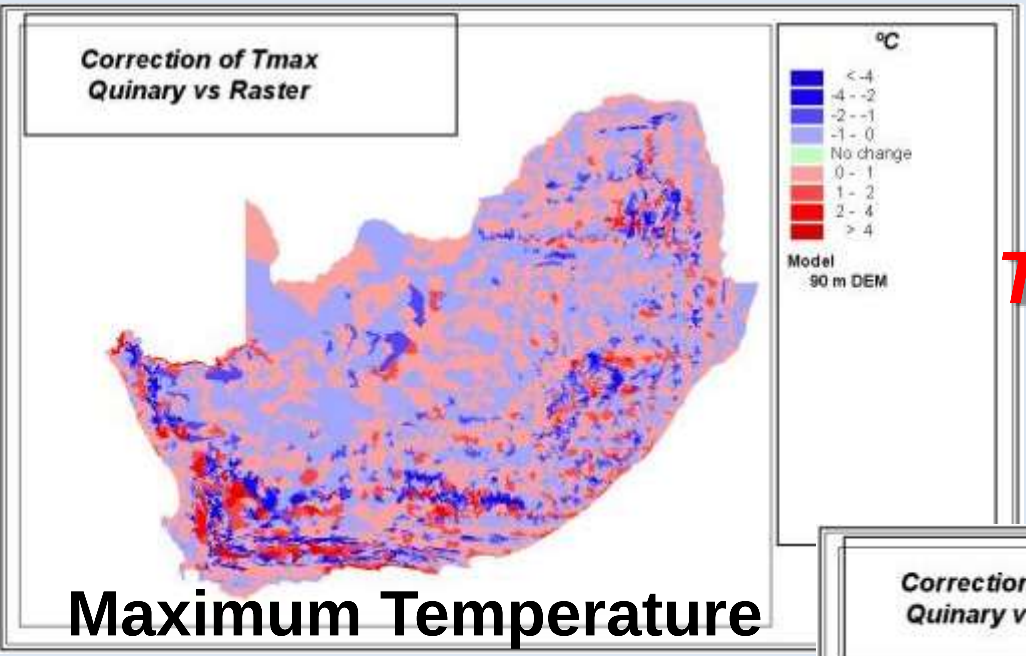
The Downscaling Dilemma: Raster vs Station

- ***For GCMs downscaled to ~ 50 km (1/2 degree), 499 raster points cover SA***
  **** But, there are 5 838 Quinaries covering SA***
  **** i.e. on average 11.6 Quinaries per raster point***
  **** But, Quinaries have different altitudes, temperatures, rainfalls***
  **** How do you reconcile, adjust, correct, especially in mountainous, runoff producing regions?***
- ***WE NEED TO 'BIAS CORRECT'***



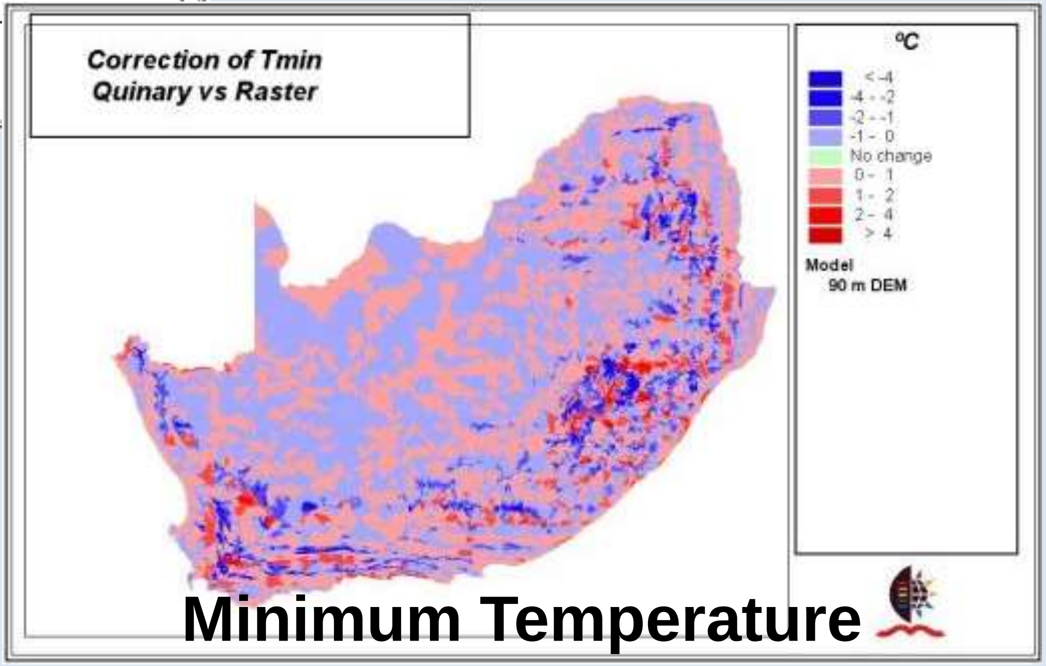


Bias Correcting for Topography



Maximum Temperature

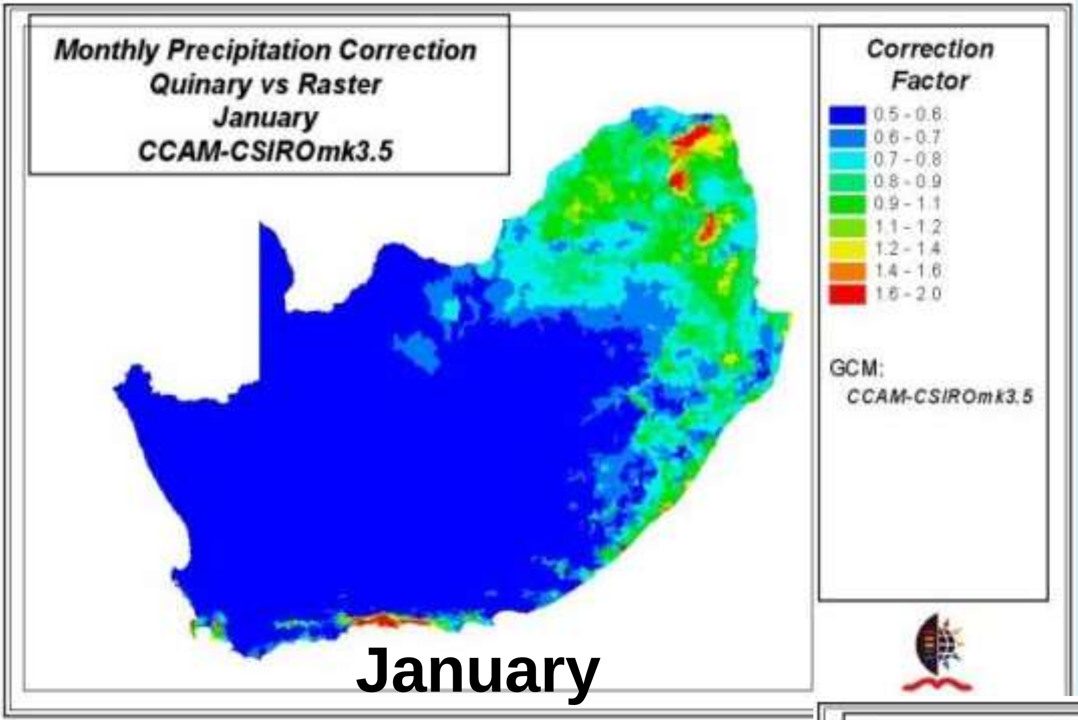
Maximum & Minimum Temperature Corrections: Raster to Quinary

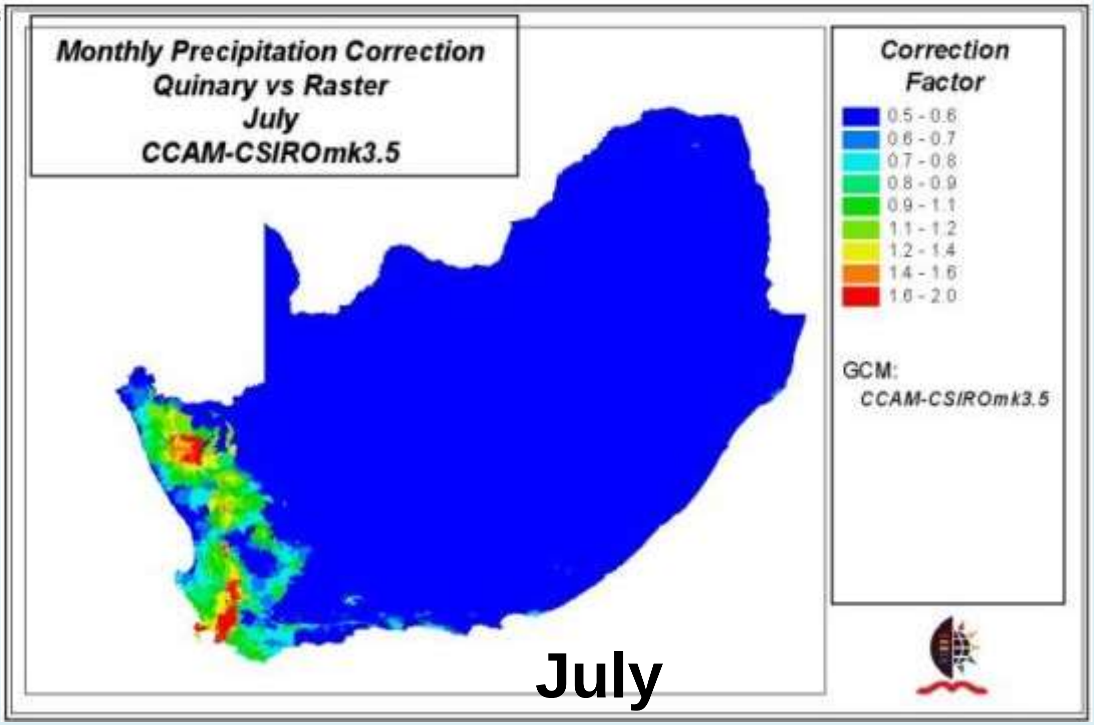


Minimum Temperature

Schulze, Kunz, Lumsden & Davis, LTAS 2014

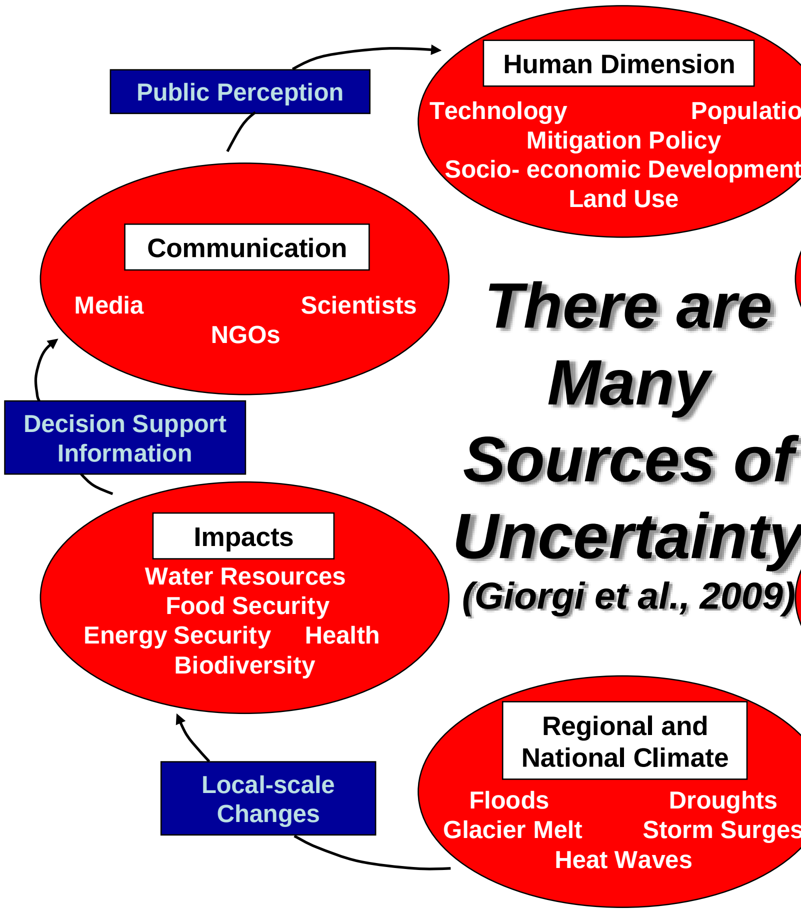
Bias Correcting for Rainfall





Schulze, Kunz, Lumsden & Davis, LTAS 2014

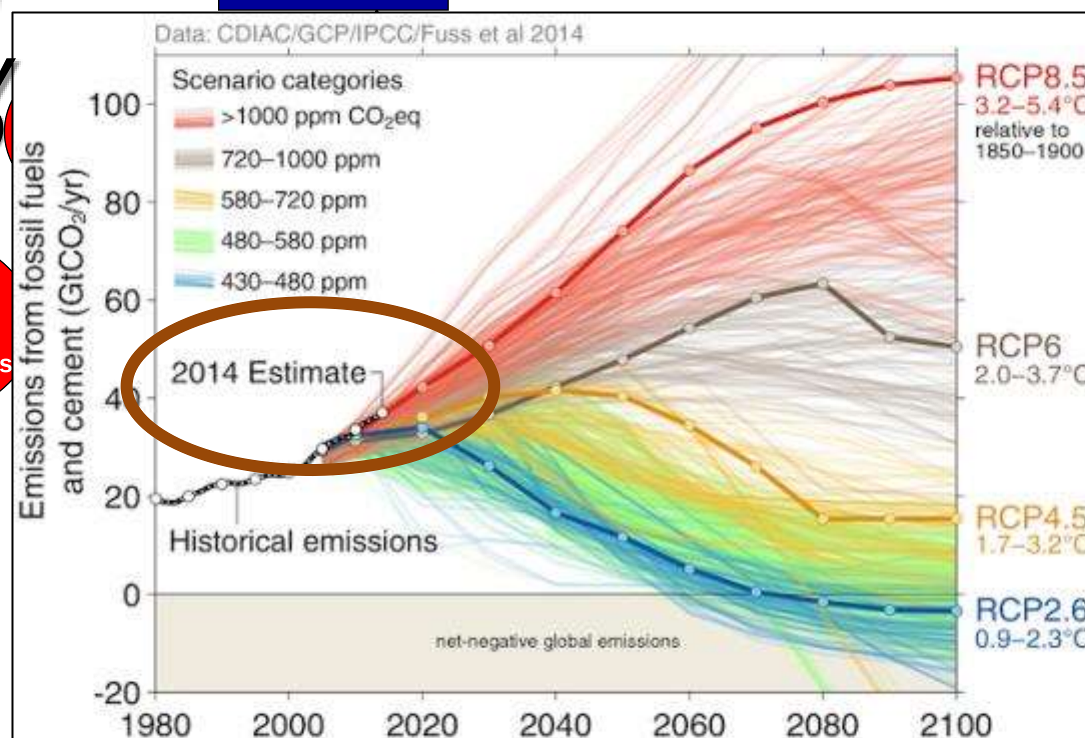
What Confidence do we have in Climate Projections into the Future?



There are Many Sources of Uncertainty

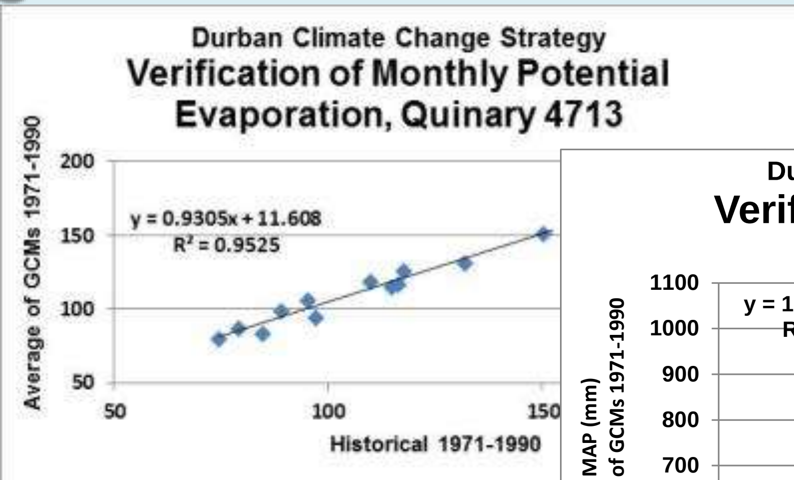
(Giorgi et al., 2009)

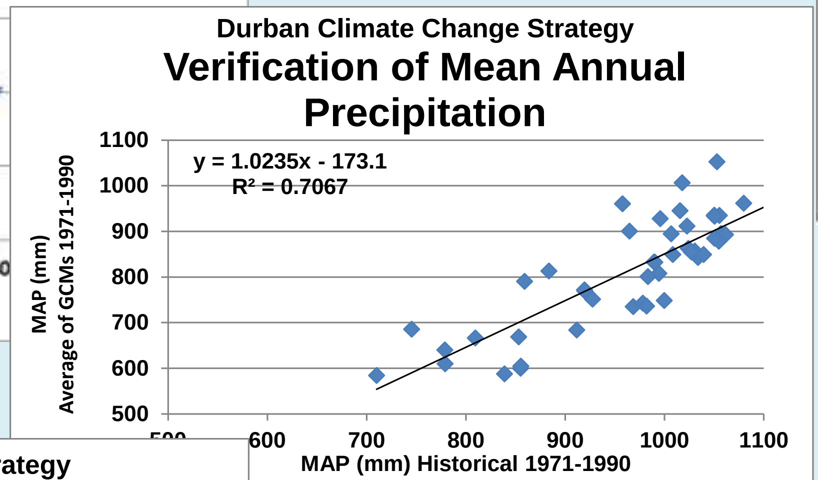
Result: GCMs give Varying Results

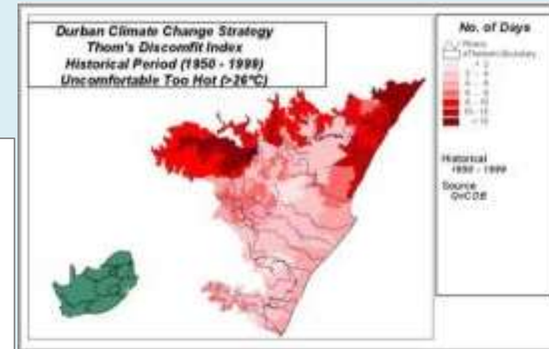


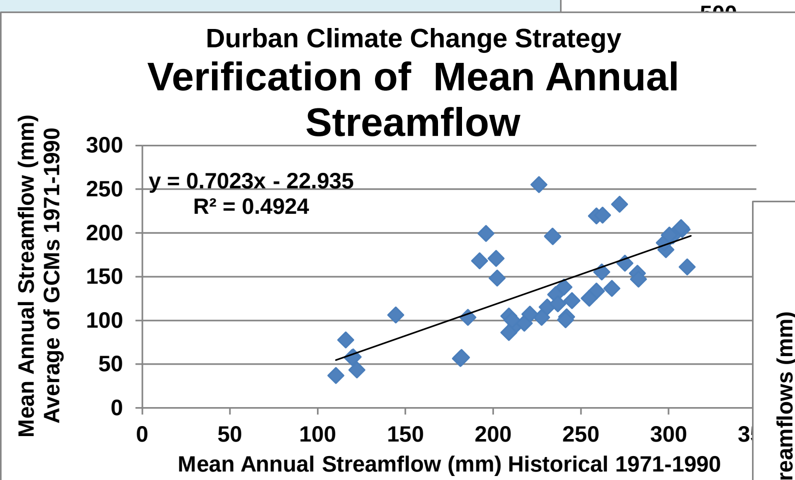
Hence the Need to Use Multiple Models

So, how Confident are we that Downscaled GCMs will give Credible Results on Projected Future Conditions?

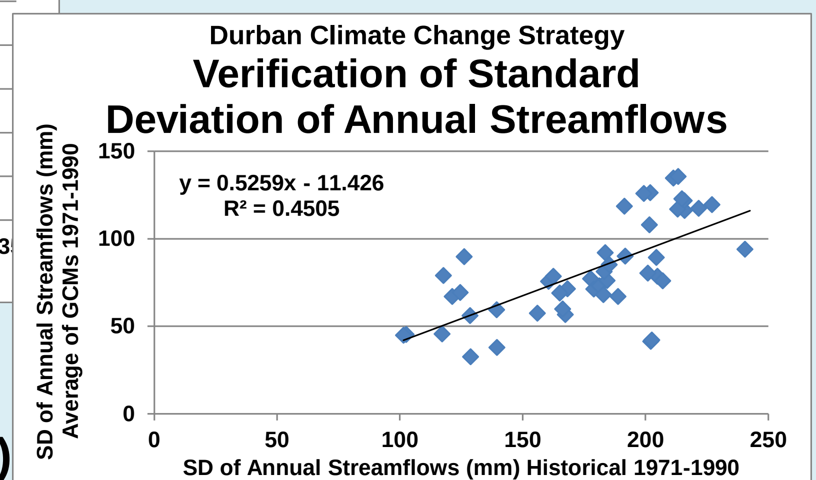






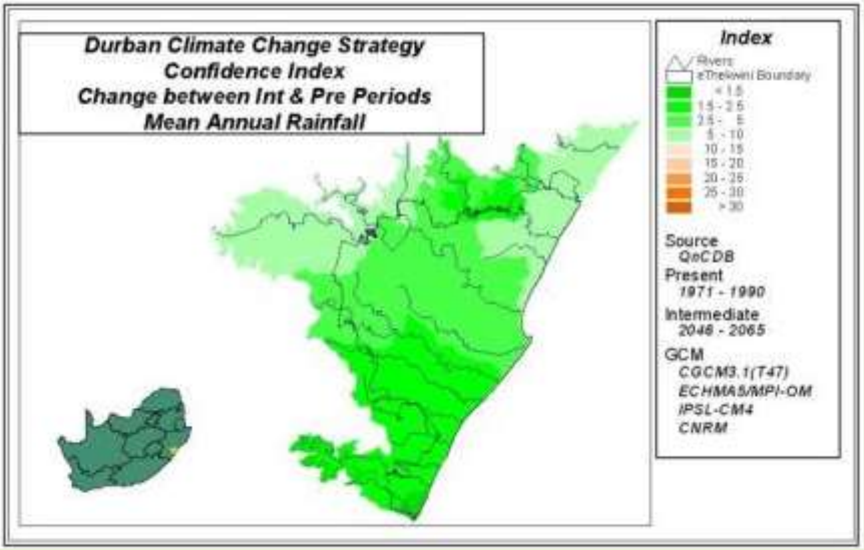


A Hierarchy of Confidences



Schulze & Davis, DCCS (2014)

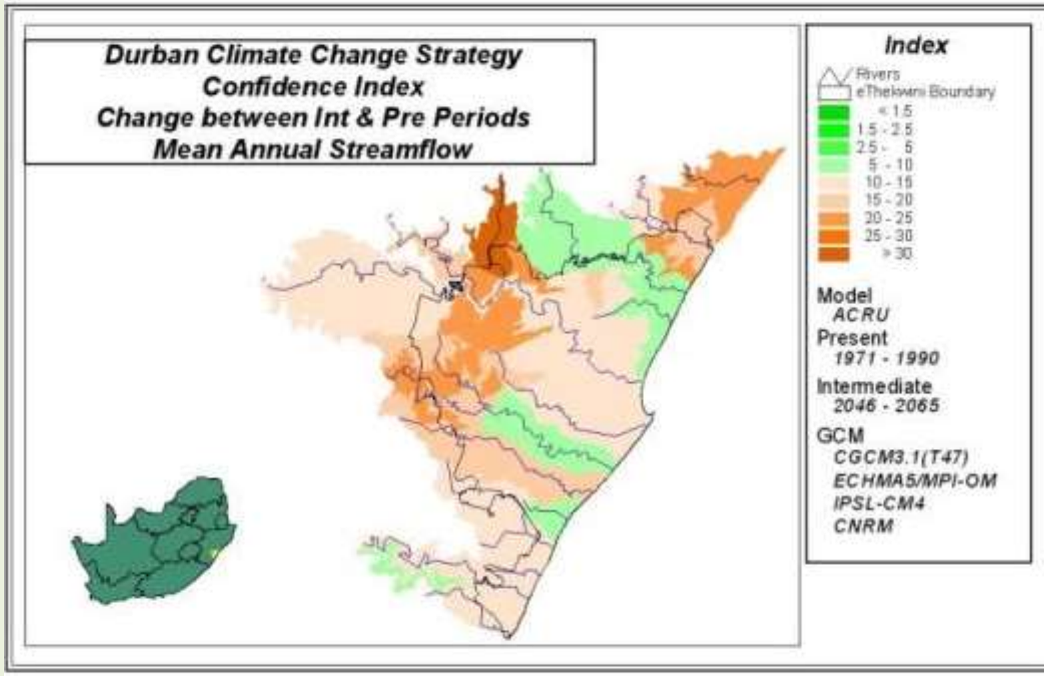
We are More Confident in Some Outputs than in Others, and More Confident in Some Areas than in Others



Mean Annual Rainfall

CI = CV (%) of Ratio Changes of All GCMs Used

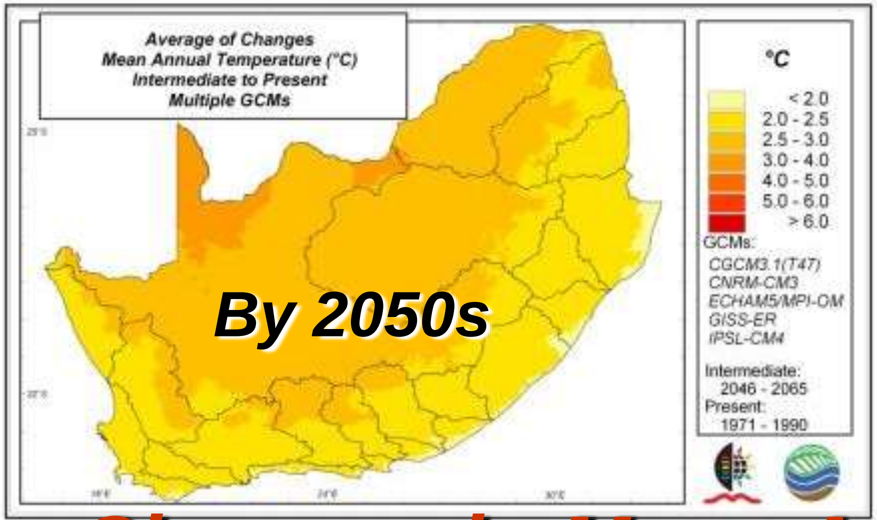
Mean Annual Accumulated Streamflow

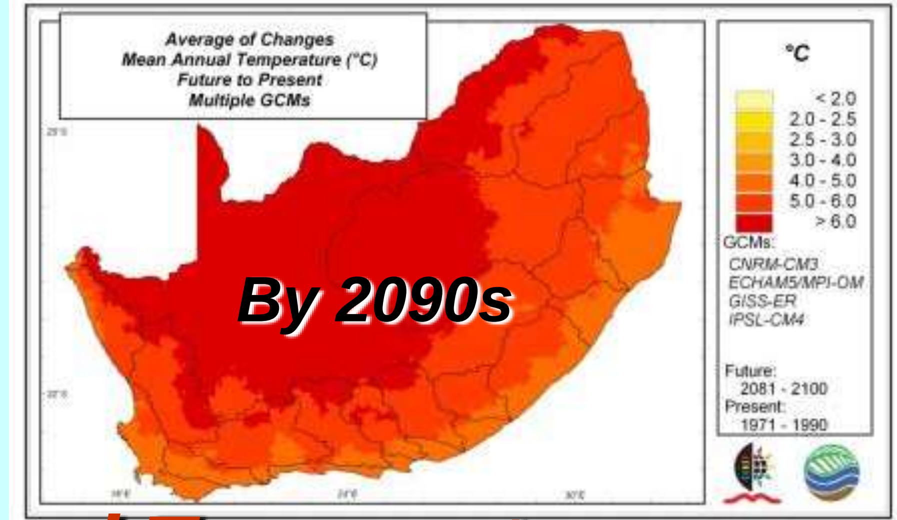


Interpretation?
Implications?

Schulze & Davis, DCCS (2014)

And, what is our climate likely to do to us in South Africa?

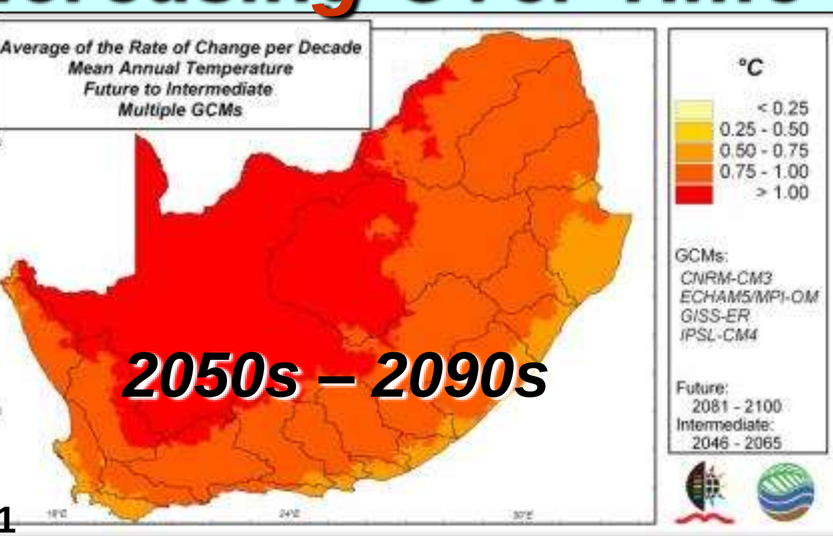




Changes in Mean Annual Temperature are Projected to be Significant

What are the consequences?

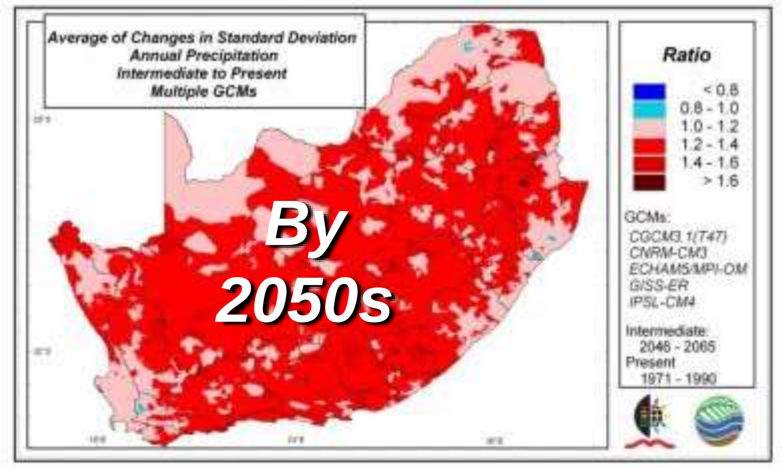
Rate of Change/Decade Increasing Over Time

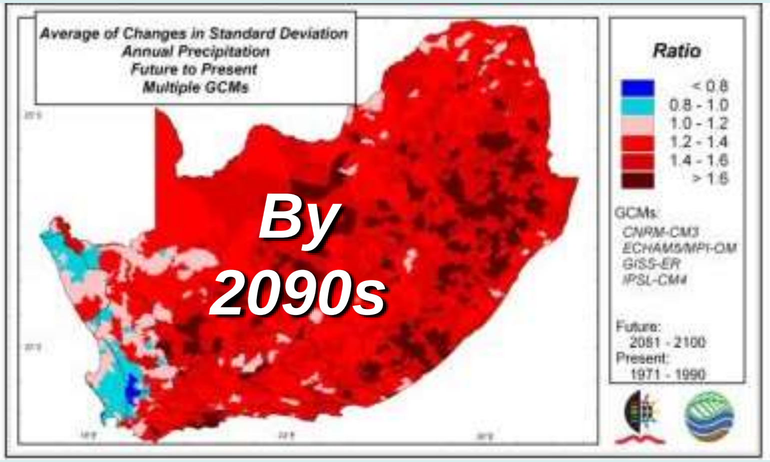


Schulze, 2011

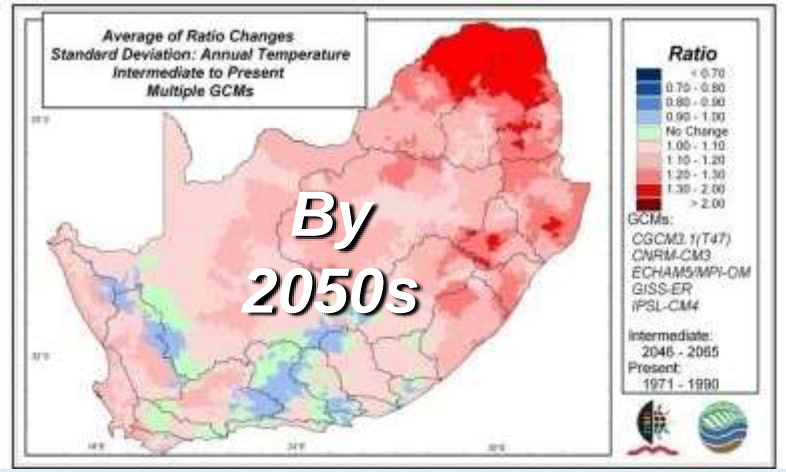
Future Year-to-Year Variability will Change…the Case of Projected Rainfall and Temperature over SA (Schulze, 2011)

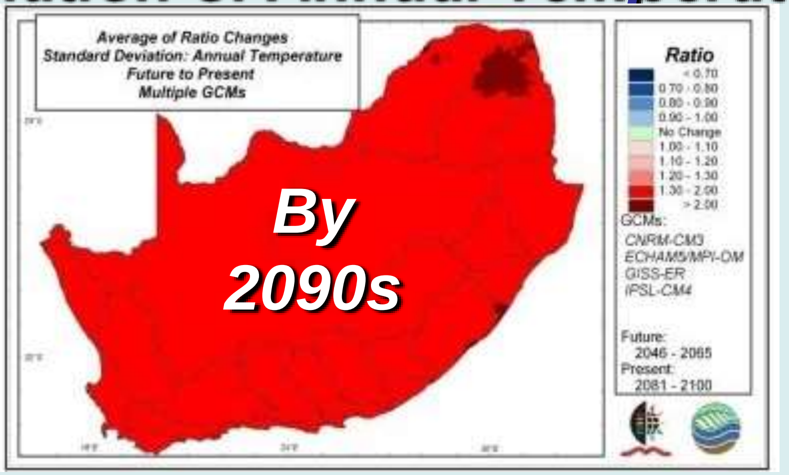
Changes in the Standard Deviation of Annual Rainfall





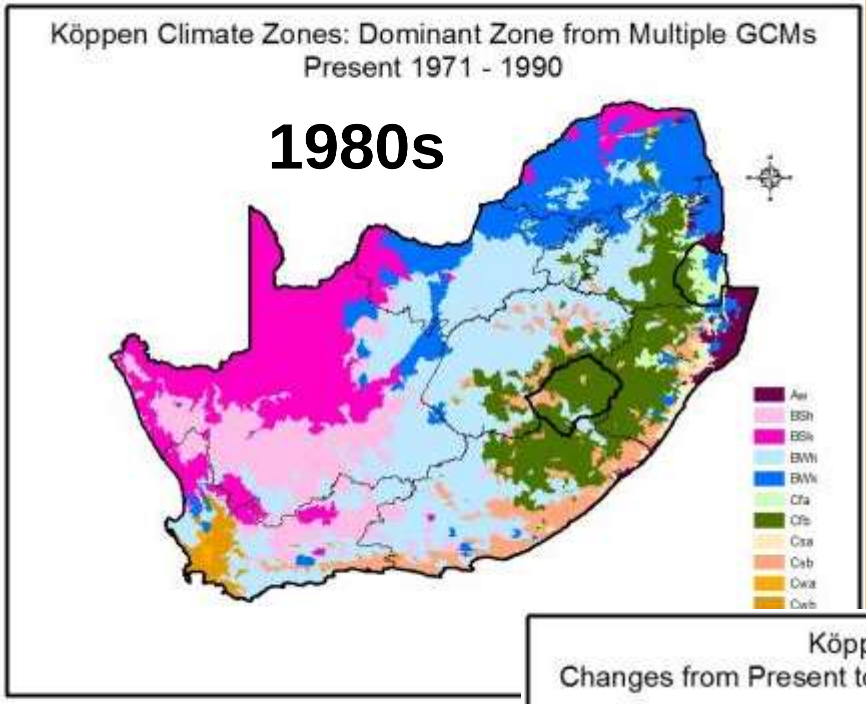
Changes in the Standard Deviation of Annual Temperature

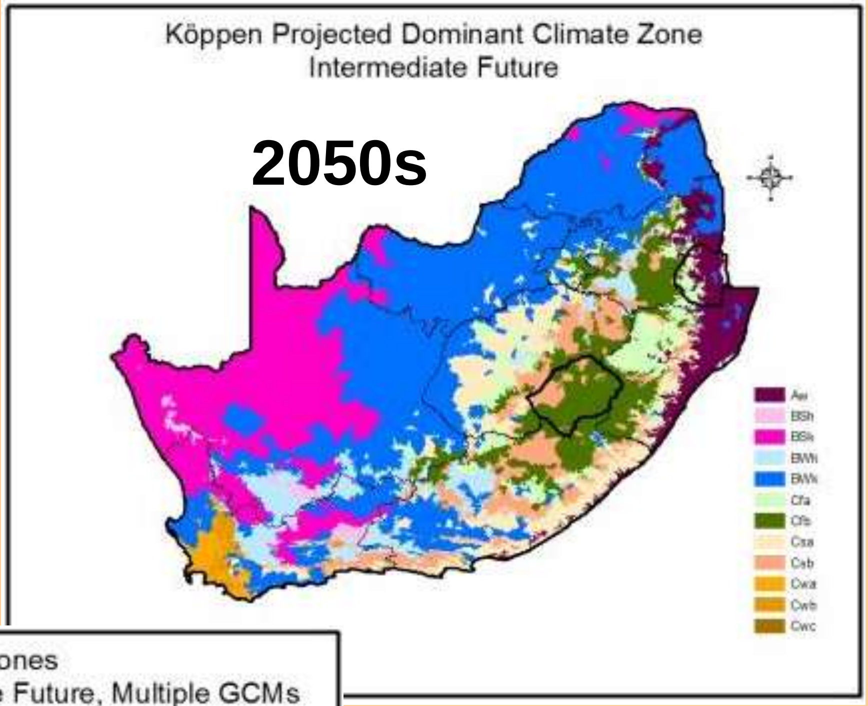


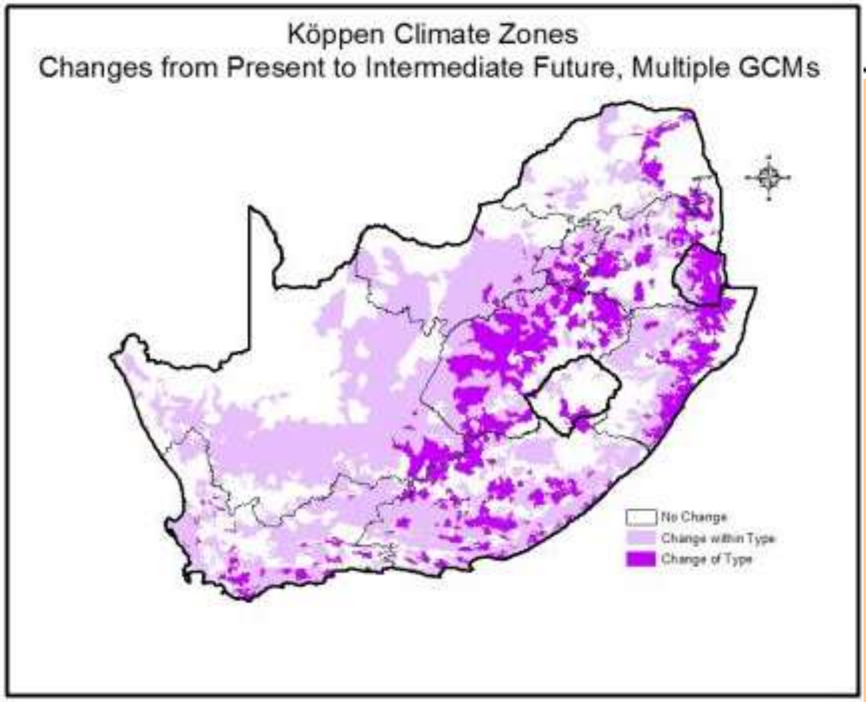


and what are the agric/health/DRM consequences?

How are SA's Climate Zones Projected to Change?







Areas Vulnerable to Change

Let's Consider A High Value Export Crop

Example: Table Grapes

(Schulze 2014)

Case Study

Objective

Nature

Soil & Climate

Management

Long Term Practices
(Establishment, row orientation, vine spacing, trellising/training/pruning practices

Short Term Practices
(Irrigation techniques, fertilization, canopy management)

Harvest Criteria

Photosynthetic Activity

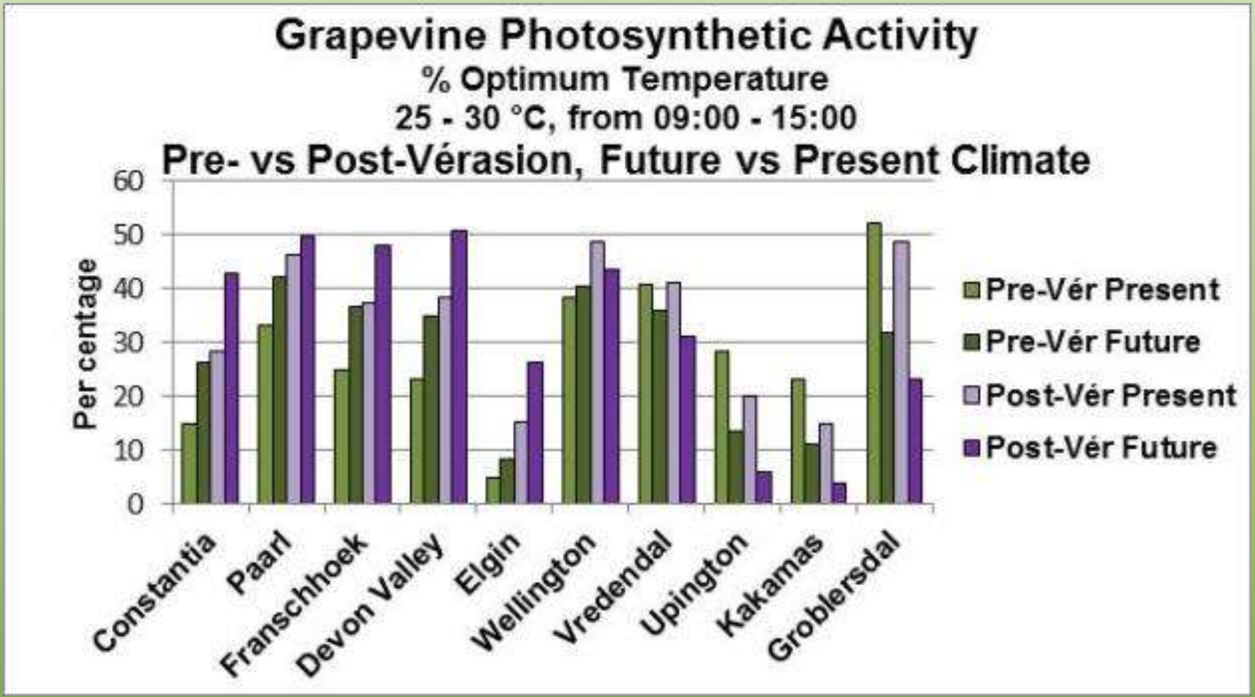
Colour and Flavour

Sugar & Potassium Accumulation

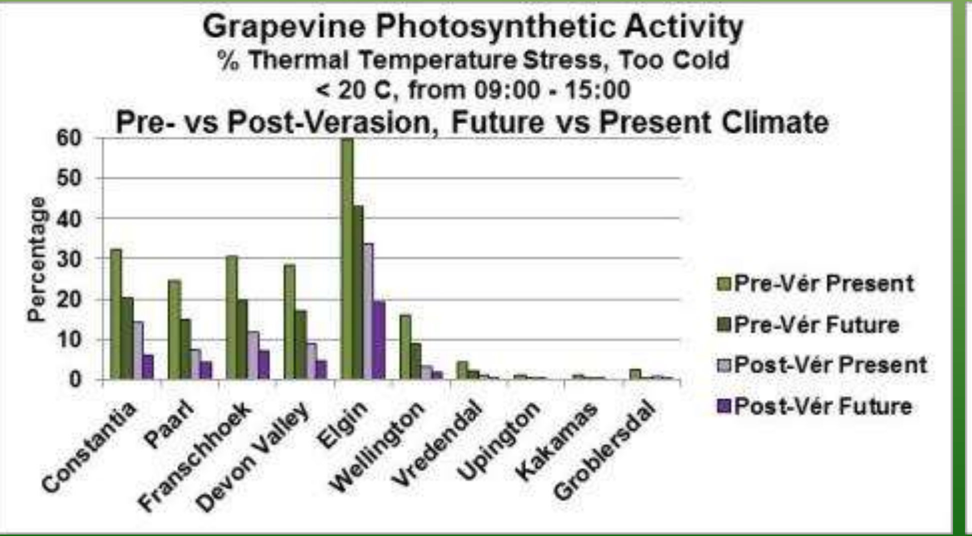
Organic Acid Formation

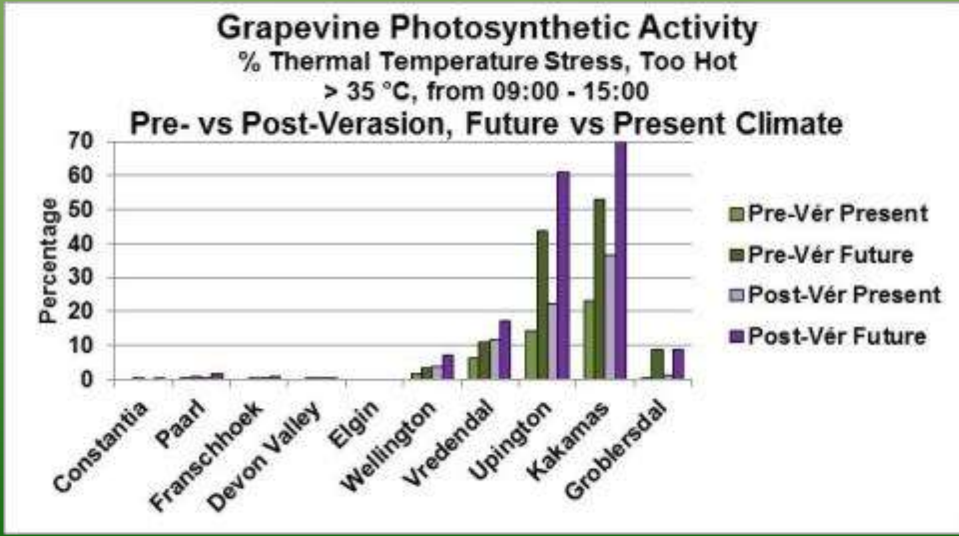
Pre- vs Post Véraison
Optimal vs Too Cold/Too Hot

Comparative Analysis, Photosynthetic Analysis Future vs Present Climatic Conditions



Schulze, 2014





Adaptation strategies
Olifants West

Wine grape cultivars

Red wine grape cultivars that will **be more tolerant** towards climate change include **Cabernet Sauvignon, Pinotage and Ruby**. Red wine grape cultivars that will be **most vulnerable** towards climate change are **Shiraz and Merlot**.

Oosthuizen and Louw, 2014



Adaptation strategies
Olifants West

<u>White wine</u> grape cultivars that will be **more tolerant** towards climate change include **Chenin Blanc and Colombard**. White wine grape cultivars that will be **most vulnerable** towards climate change include **Sauvignon Blanc and Chardonnay.**

Oosthuizen and Louw, 2014

Let's Now Focus on Climate Change Grasslands

Examples: 1. Kikuyu Yields
2. Fodder Banking
3. Grassland Yields
4. Sub-Biome Types
5. Short vs. Tall Grasslands
6. Forage Quality
7. Fire Danger

1. How is CC Projected to Impact on KIKUYU Yields

Smith's (2006) Rule-Based Model of Kikuyu Yield (*Pennisetum clandestinum*)

as expressed in equation form (Schulze, 2011)

$$Y_{kik} = P_{eom} \,.\, P_{su} \,.\, D_{kik} / 100$$

where Y_{ki} = kikuyu yield (t/ha/season)

P_{eom} = effective rainfall fraction for October to March

$= 0.60 + 0.00125(P_{su} - 480)$ for $400 < P_{su} < 720$

$= 0.90 - 0.00063(P_{su} - 720)$ for $720 < P_{su} < 960$

$= 0.75 - 0.00125(P_{su} - 960)$ for $960 < P_{su} < 1040$

$= 0.65 - 0.00063(P_{su} - 1040)$ for $1040 < P_{su} < 1300$

with P_{su} = accumulated rainfall (mm) for October to March

and D_{kik} = dry matter yield index for kikuyu

$= 1.8 + 0.0010(H_{su} - 1000)$ for $1000 < H_{su} < 1700$

$= 2.5 + 0.0010(H_{su} - 1700)$ for $1700 < H_{su} < 2200$

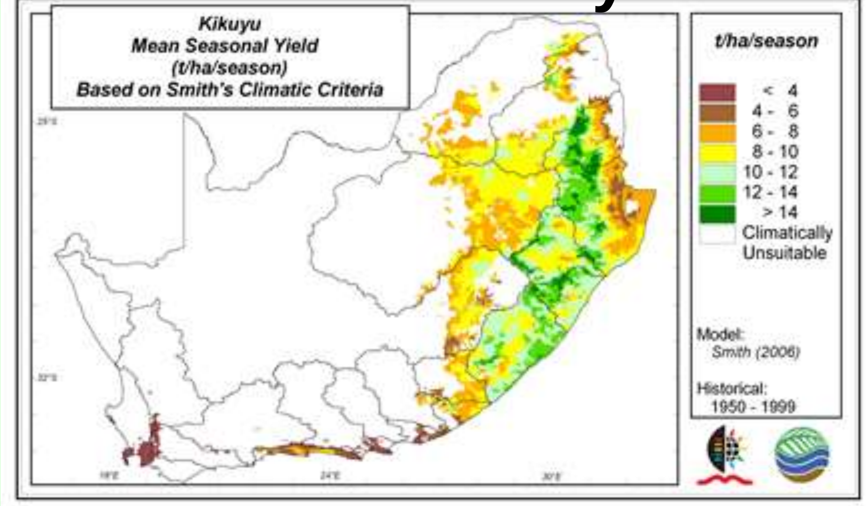
$= 2.0 + 0.0008(H_{su} - 2200)$ for $2200 < H_{su} < 2800$

where H_{su} = accumulated heat units (base 10°C) in degree days for October to March

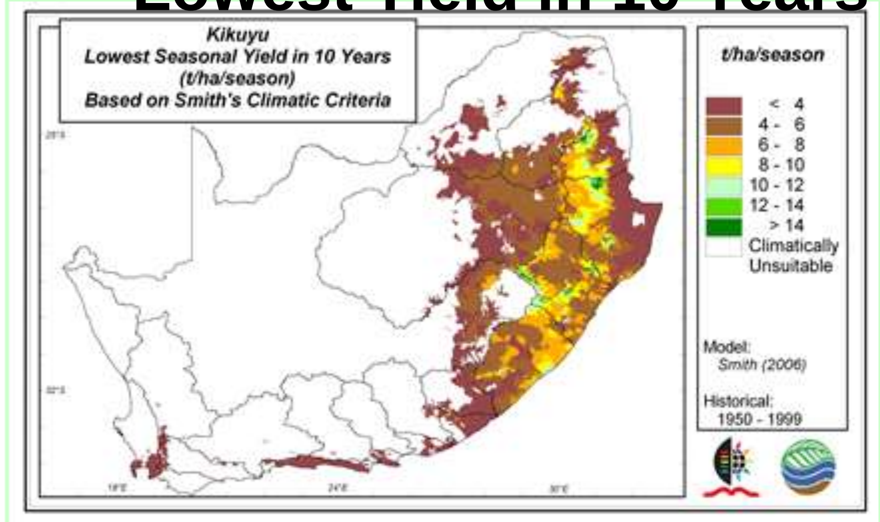
Kikuyu Yields Under Historical Climatic Conditions

(Schulze, 2011)

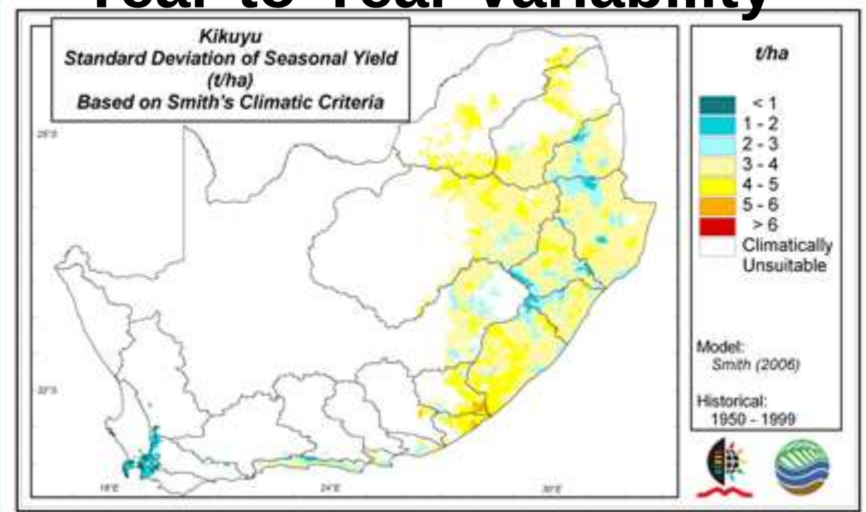
Mean Rainfed Kikuyu Yield



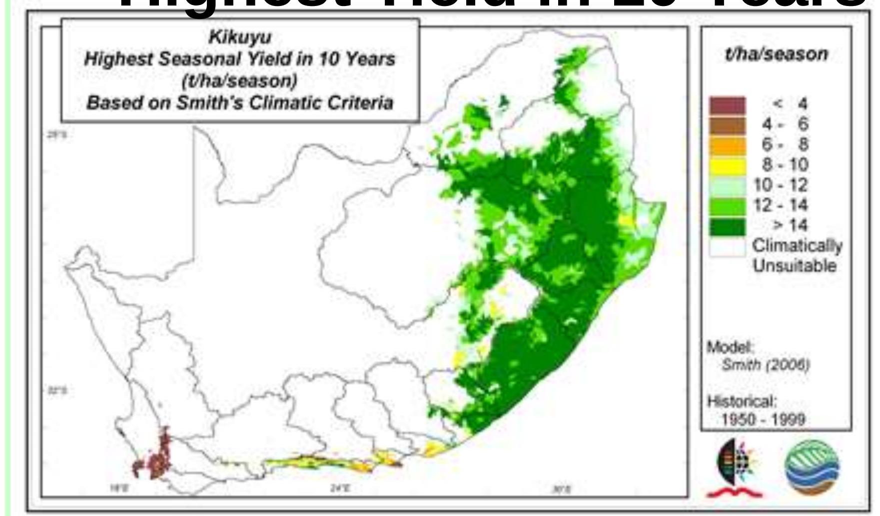
Lowest Yield in 10 Years



Year-to-Year Variability



Highest Yield in 10 Years

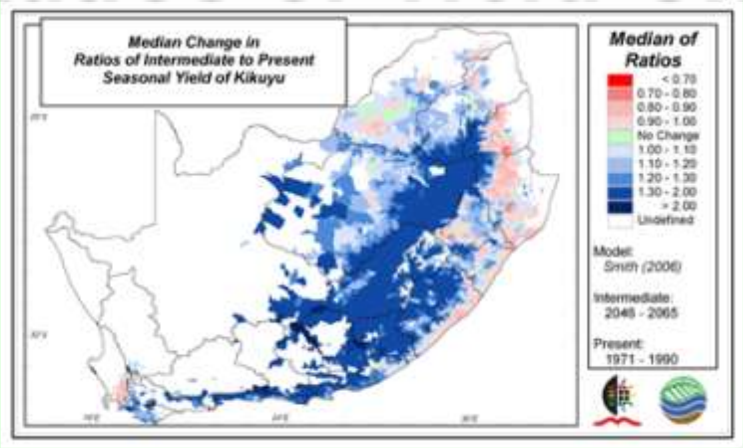


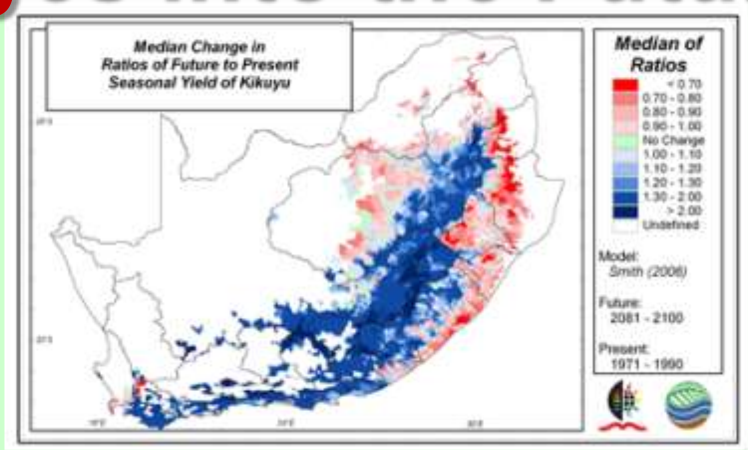
Kikuyu Yields into the Future

(Schulze, 2011)

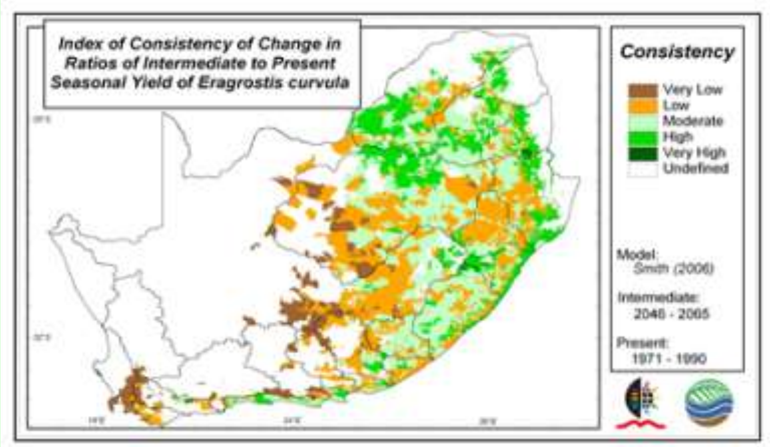
Results from Multiple Climate Models

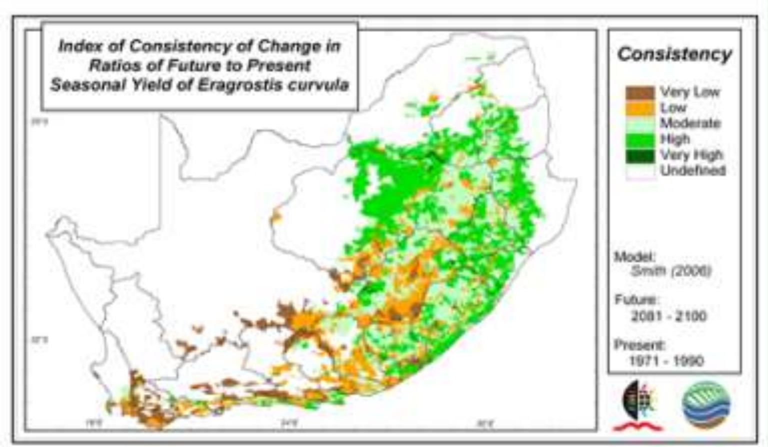
Ratios of Yield Changes into the Future





… and, how confident are we of the results?





2. Fodder Banking in Future Climates

A fodder bank (or fodder reserve) is

- a **store** of conserved fodder
- in the form **of natural herbage** (e.g. *Eragrostis curvula)*, which is
- deliberately **accumulated**, above the normal seasonal requirements,
- in a year of **above average grassland yields**,
- to **make good the shortage** when feed availability unpredictably falls below expectation because of a
  - drought year, or worse still
  - consecutive years of drought (Jones, 1983; Mohamed-Saleem *et al*., 1987).

Q: What is an "above average" year? a "drought" year?

A: When herbage yields are 1 standard deviation above or below average yields!

Q: What is the minimum amount to be banked?

A: ≡ 1 standard deviation of average yield

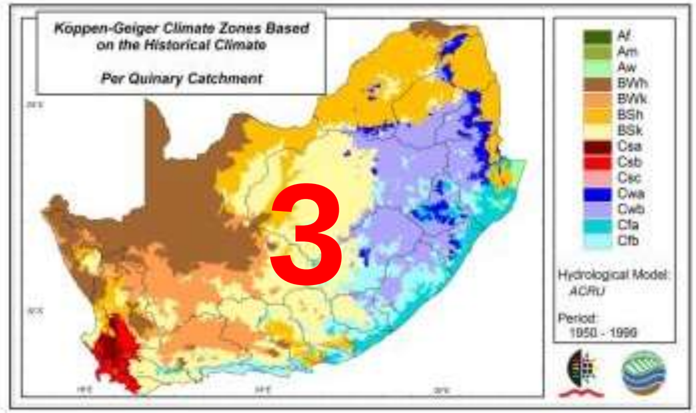
Q: What is the ideal fodder bank size?

A: ≡ 2 standard deviations of average yields

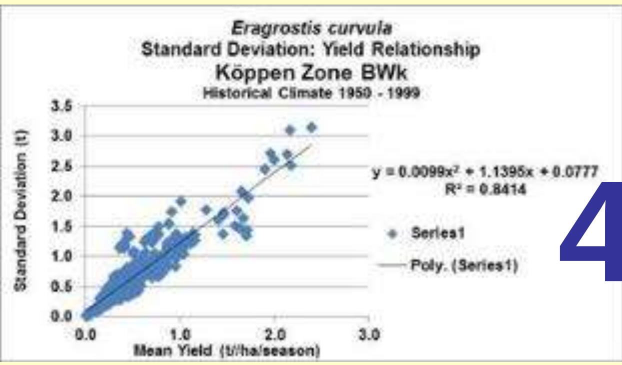
$Y_{ec} = P_{eom} \, . \, P_{su} \, . \, D_{ec} / 100$

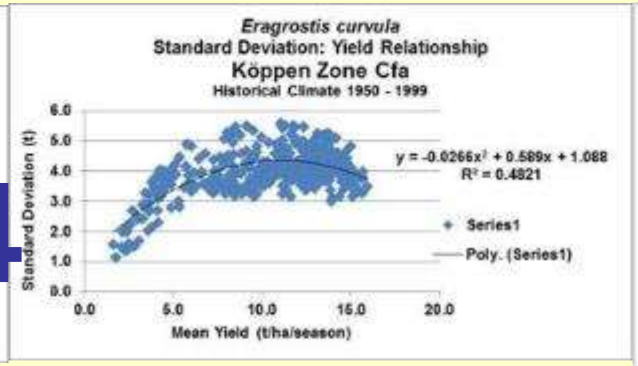
where	Y_{ec}	=	*Eragrostis curvula* yield (t/ha/season)
	P_{eom}	=	effective rainfall fraction for October to March
		=	$0.60 + 0.00125 \; (P_{su} - 480)$ for $400 < P_{su} < 720$
		=	$0.90 - 0.00063 \; (P_{su} - 720)$ for $720 < P_{su} < 960$
		=	$0.75 - 0.00125 \; (P_{su} - 960)$ for $960 < P_{su} < 1040$
		=	0.65 - 0.0[illegible] (P_{su} - 1040) for $1040 < P_{su} < 1300$
with	P_{su}	=	accumulated ra[illegible]all (mm) for October to March
and	D_{ec}	=	dry matter [illegible] index for *Eragrostis curvula*
		=	1.6 + 0.0[illegible] - 1000) for $1000 < H_{su} < 1400$
		=	$2.0 + 0.0020 \; (H_{su} - 1400)$ for $1400 < H_{su} < 1800$
		=	$2.8 - 0.0010 \; (H_{su} - 1800)$ for $1800 < H_{su} < 2200$
		=	$2.4 - 0.0020 \; (H_{su} - 2200)$ for $2200 < H_{su} < 2800$
where	H_{su}	=	accumulated heat units (base 10 °C) for October to March with lower limit of 1000 and an upper limit of 2800 °days.

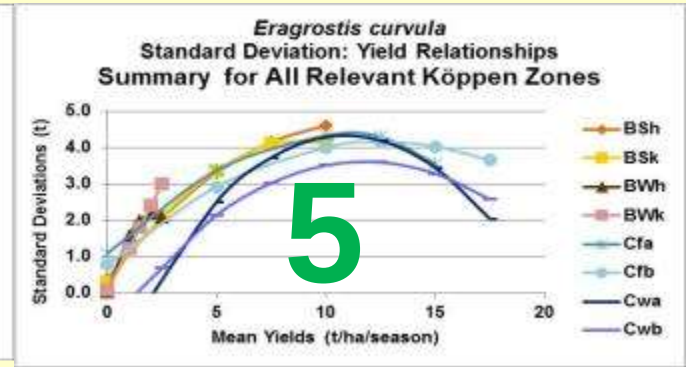
2



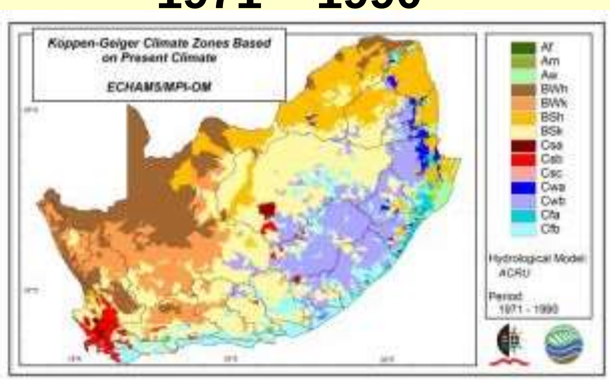
Steps in Developing a Fodder Banking Model for South Africa



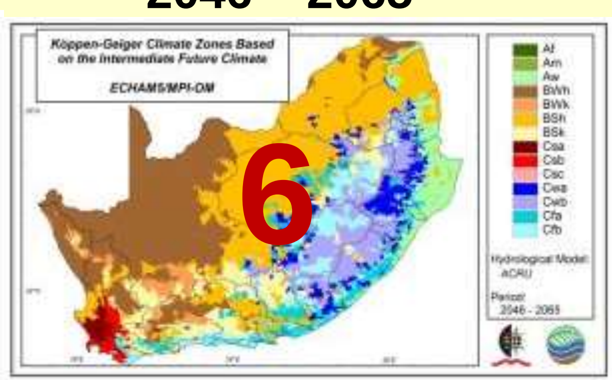




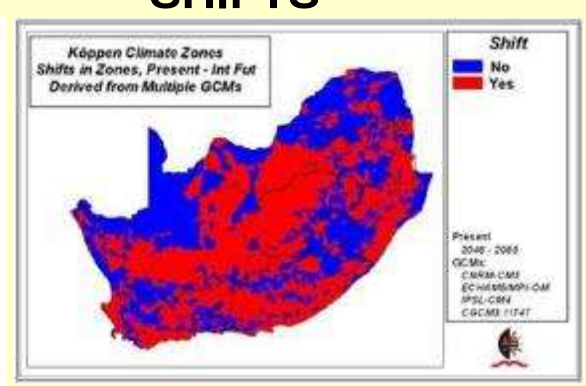
1971 – 1990



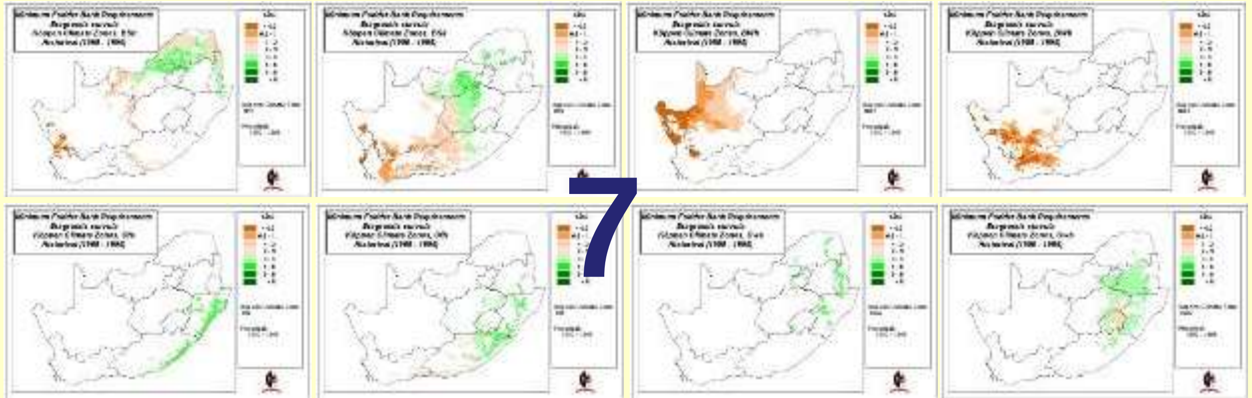
2046 – 2065



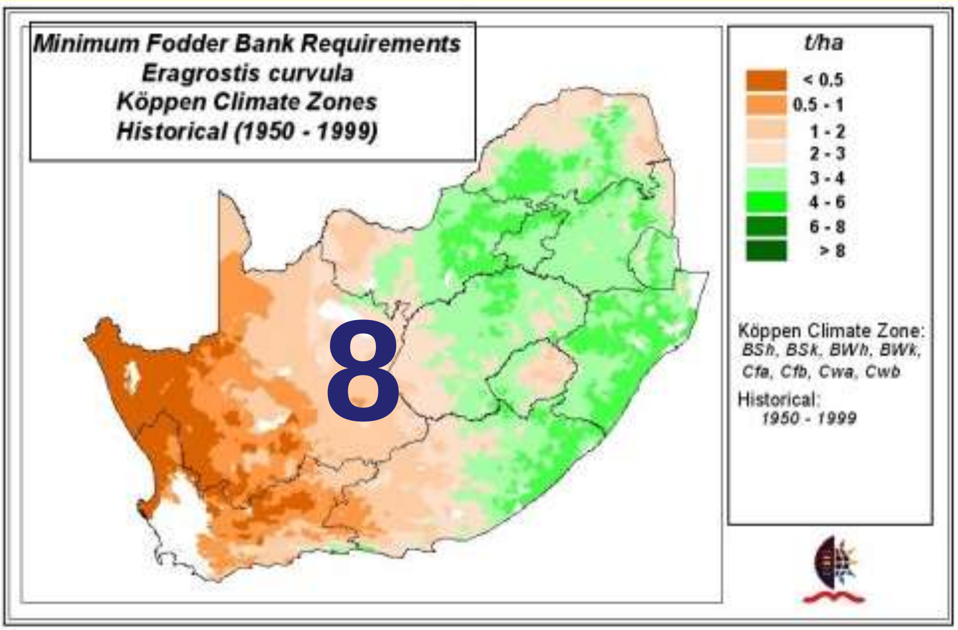
SHIFTS

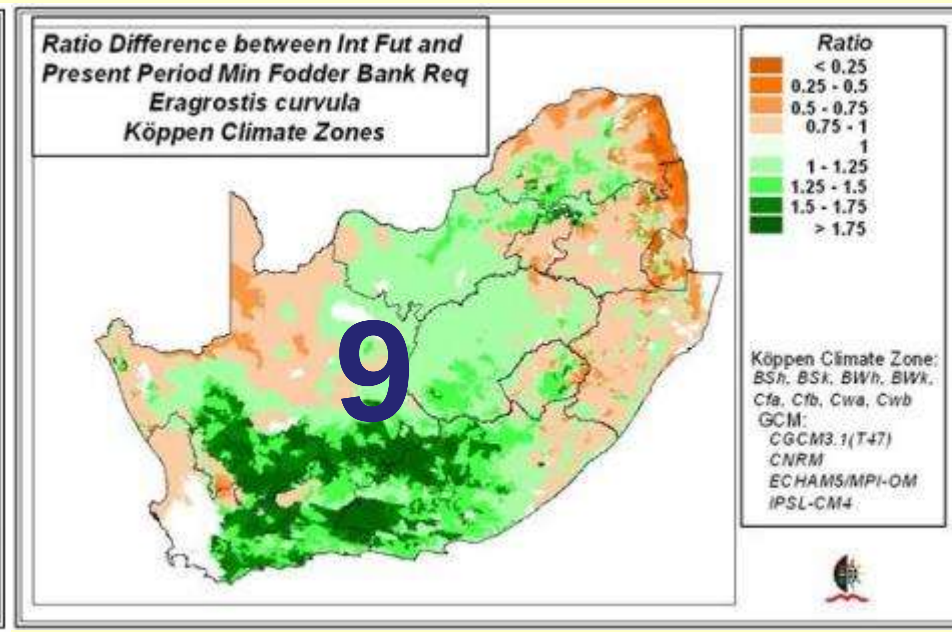


Schulze & Davis, LTAS (2013)



Steps in Developing a Fodder Banking Model for South Africa, Now and into the Future





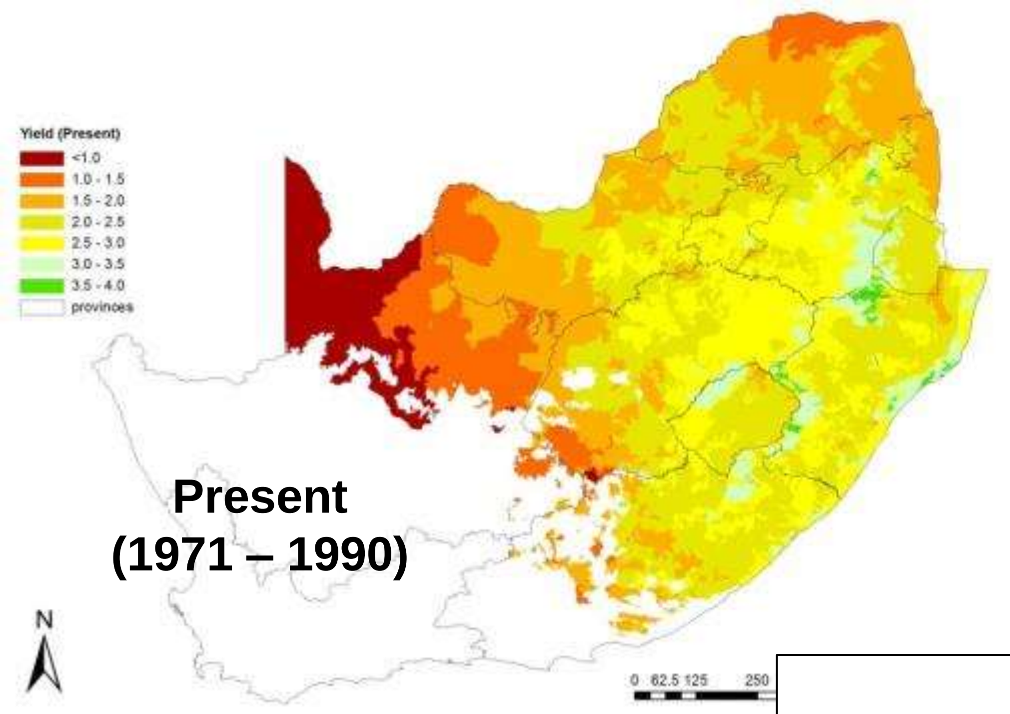
So much for the Science …

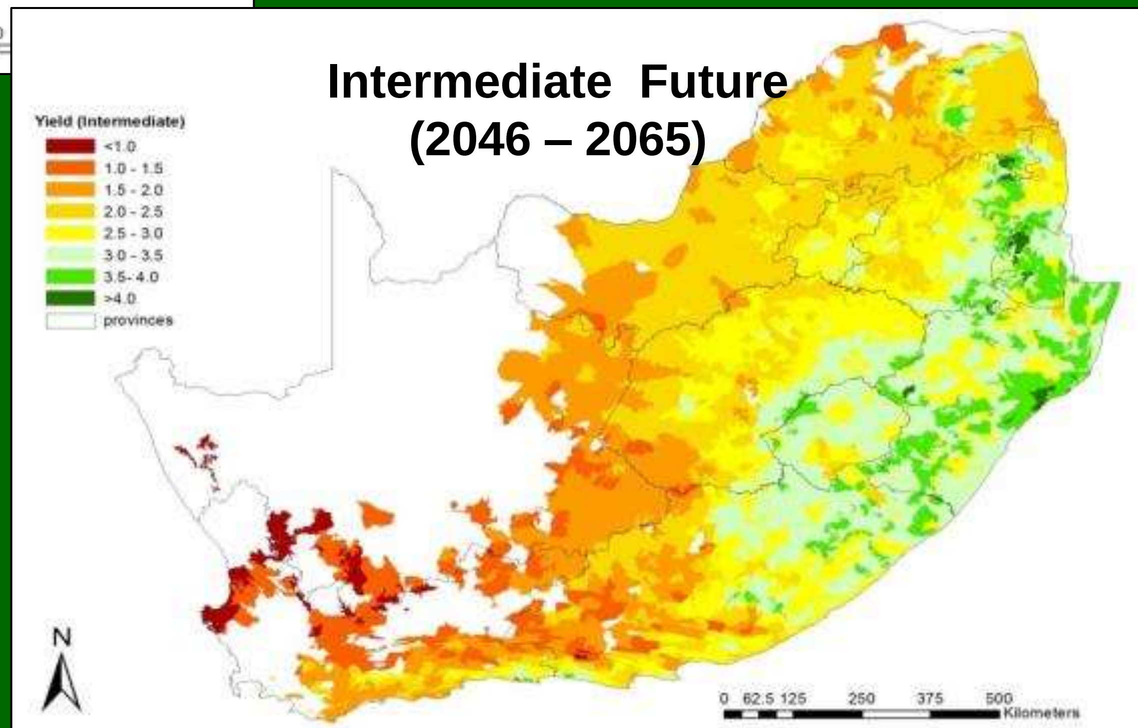
But, What Does it Imply?

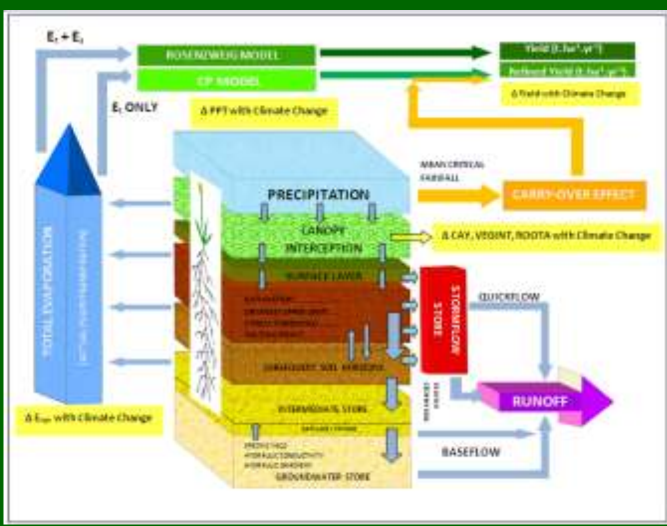
Schulze & Davis, LTAS (2013)

3. Grassland Yields ($t.ha^{-1}.yr^{-1}$) under Different Climate Scenarios

Derived from the Median Ranked of 5 A2 GCMs





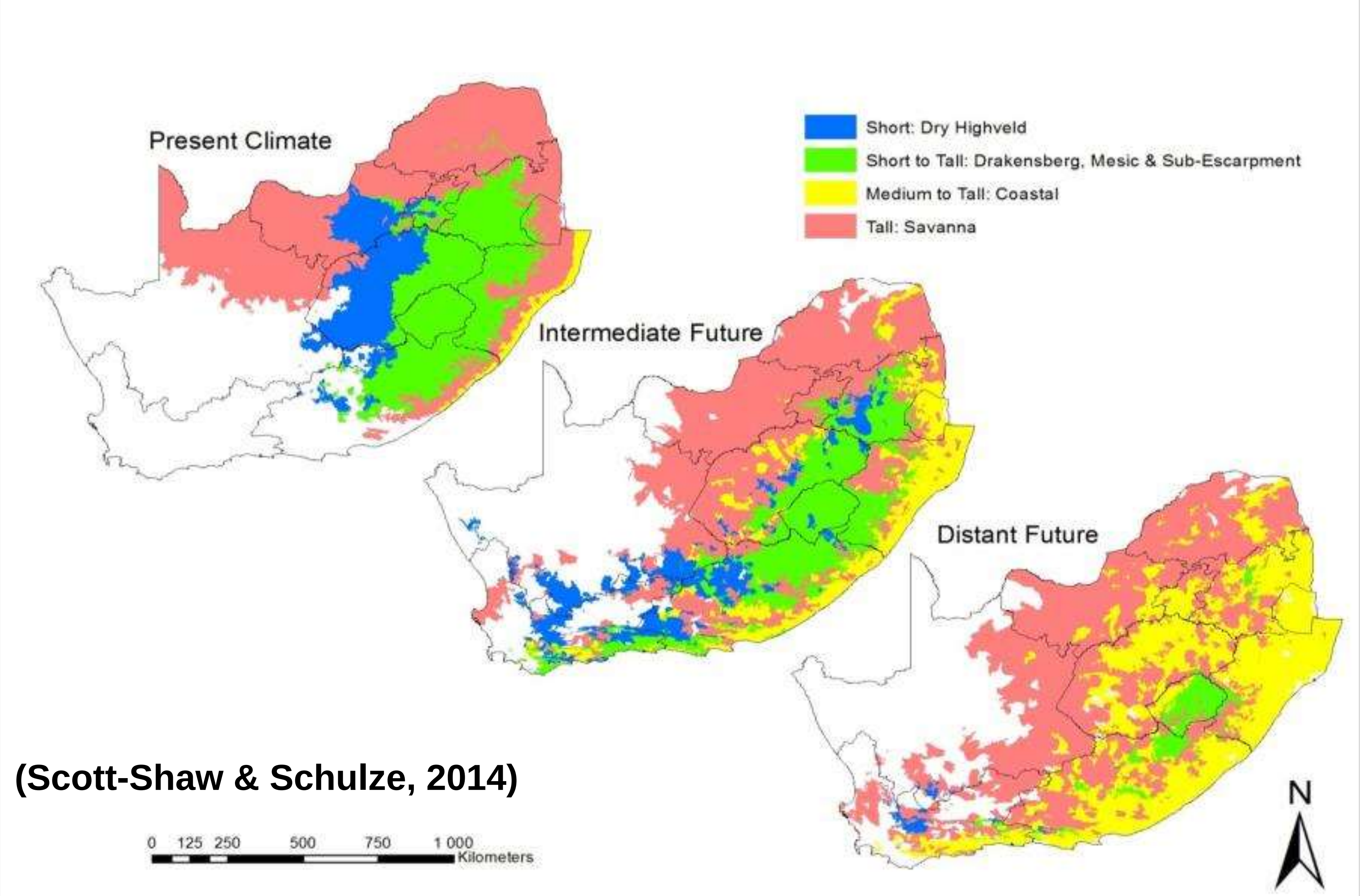


Implications?

(Scott-Shaw & Schulze, 2014)

4. How Will Areas Suitable for Sub-Biome Grassland Types Change into the Future?

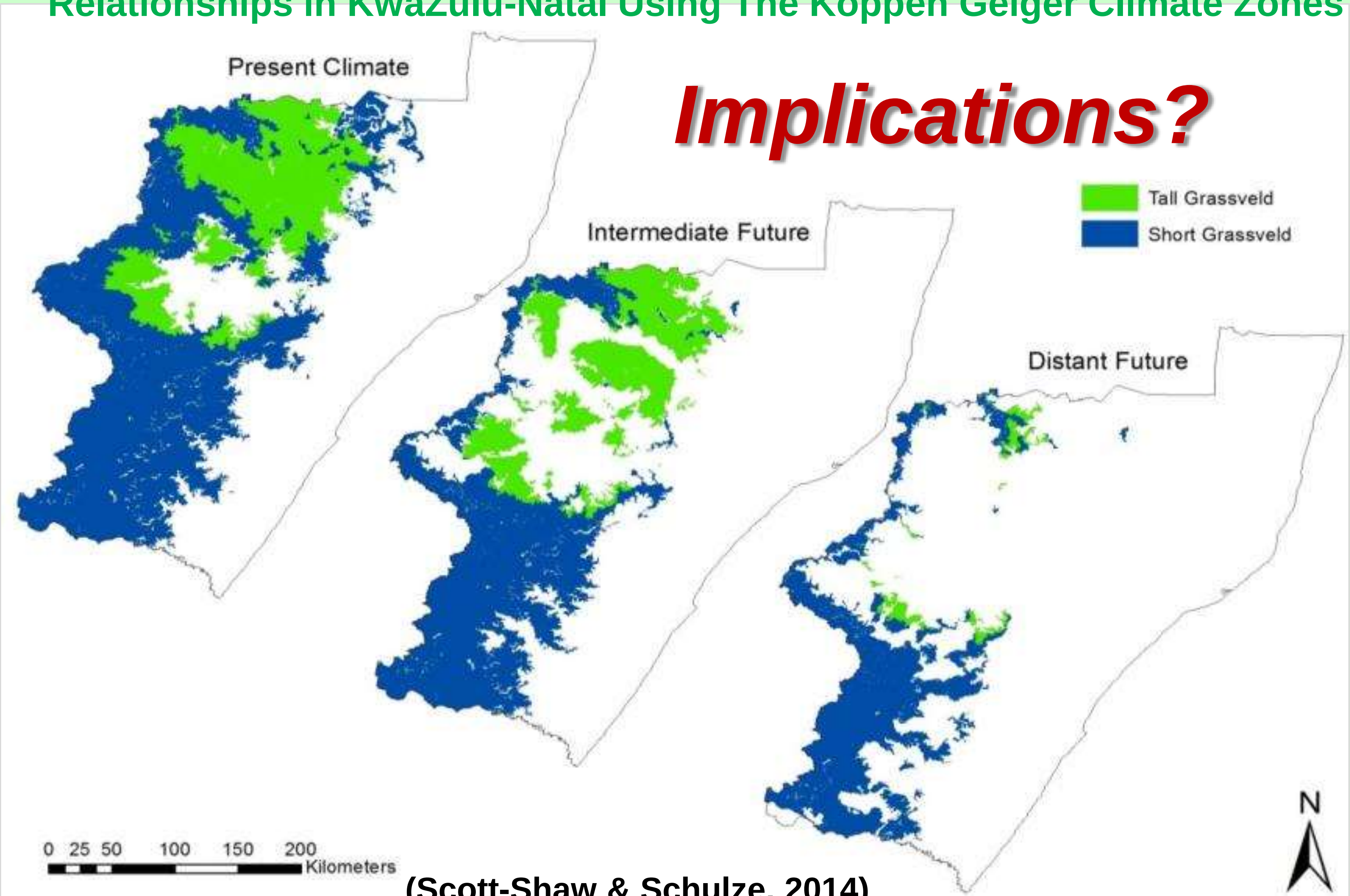
Relating Muscina & Rutherford (2006) Sub-Biome Types to Köppen Geiger Climate Zones



(Scott-Shaw & Schulze, 2014)

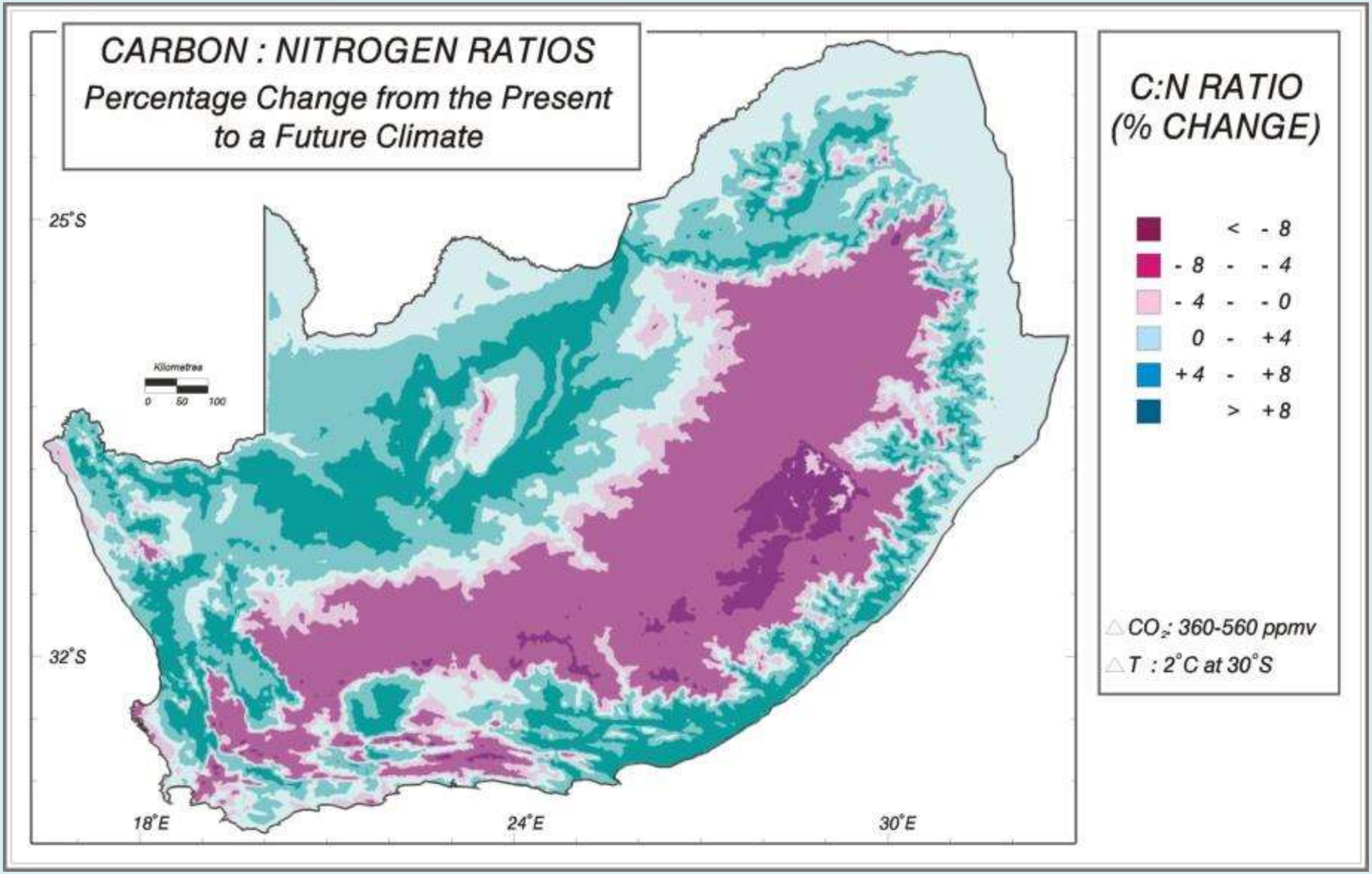
5. How Will Short vs. Tall Grassland Types Change Into The Future?

Relationships in KwaZulu-Natal Using The Köppen Geiger Climate Zones

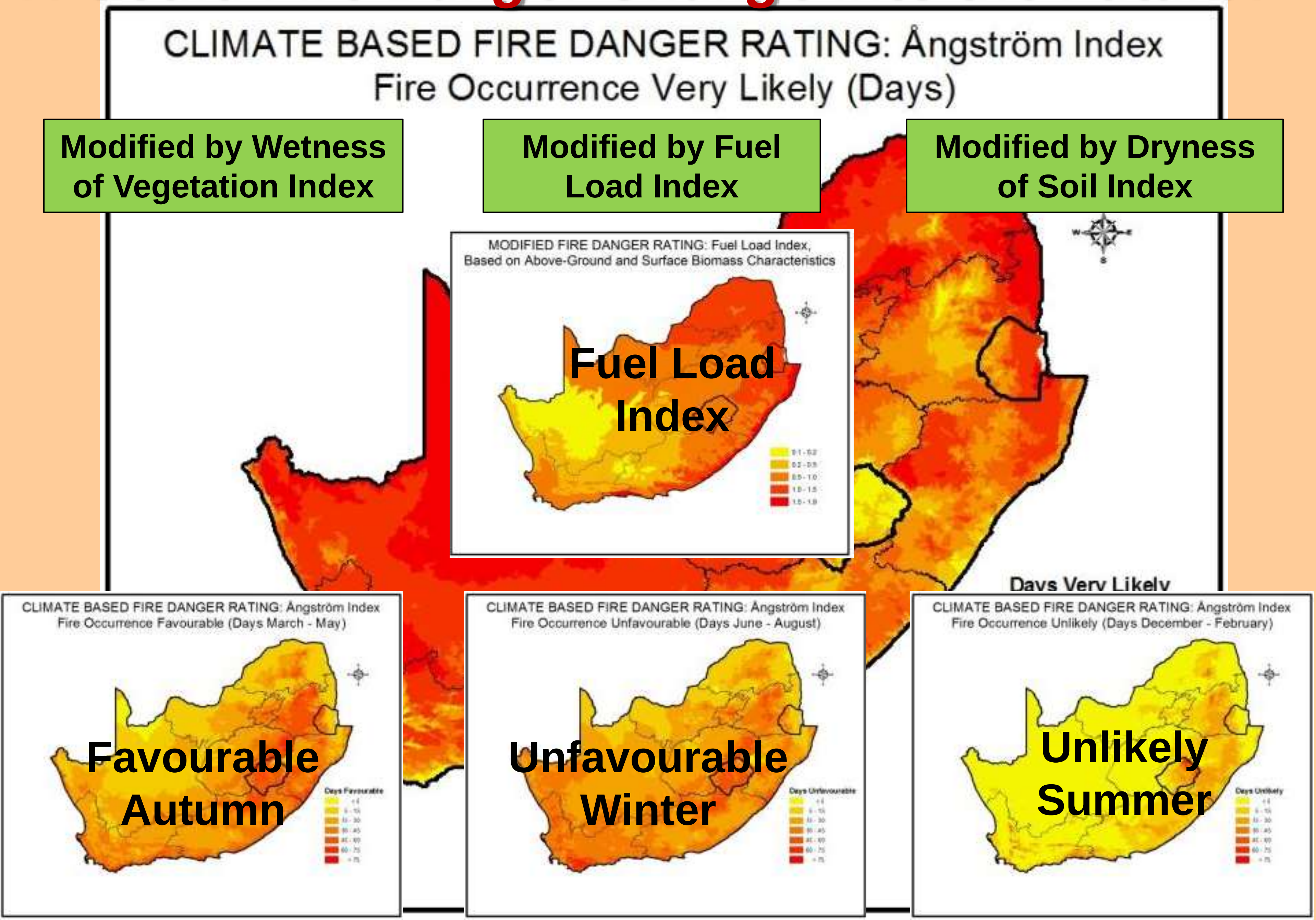


(Scott-Shaw & Schulze, 2014)

6. How Is Forage Quality Projected To Change Into The Future (Schulze et al., 1995)



7. Could Fire Danger Change into the Future?

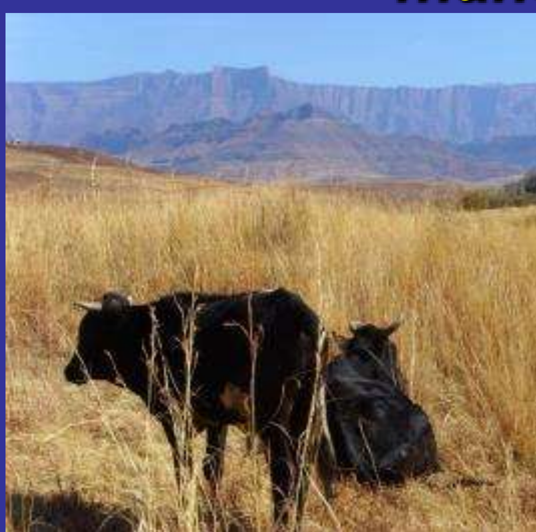


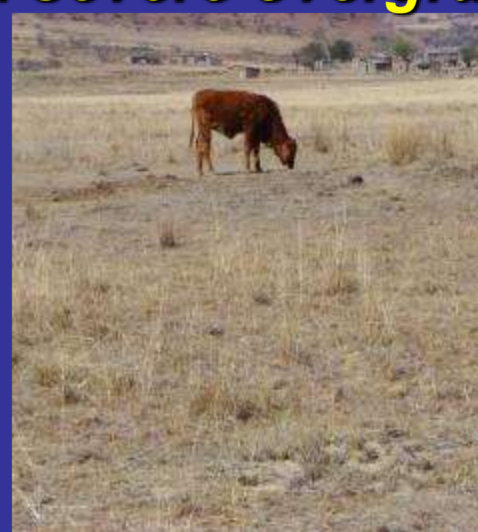
NOTE !! CC Will be Superimposed Over Often Already Damaged Natural Capital

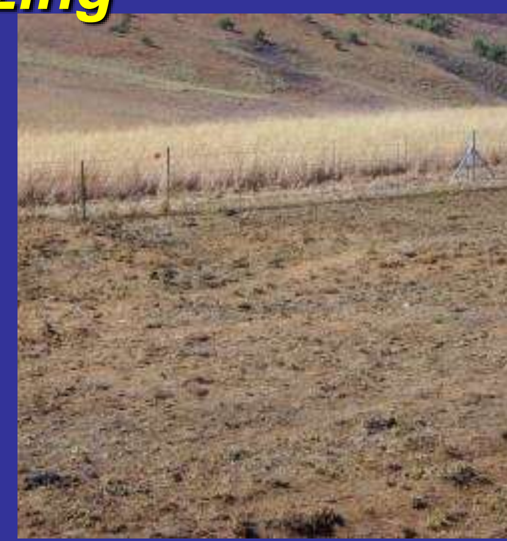
by Common Farming Practices

Extensive annual grassland burning

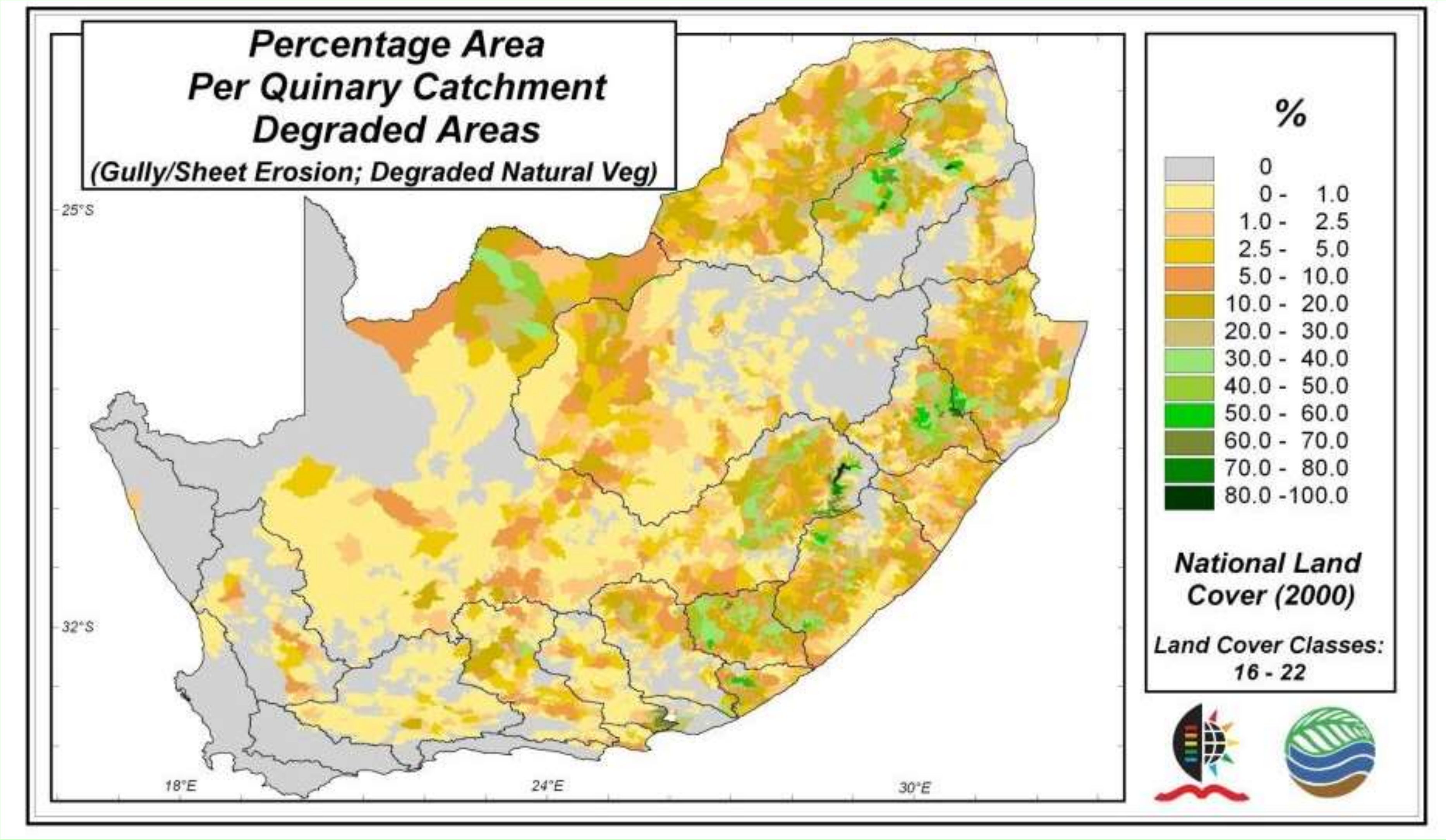
…and severe overgrazing





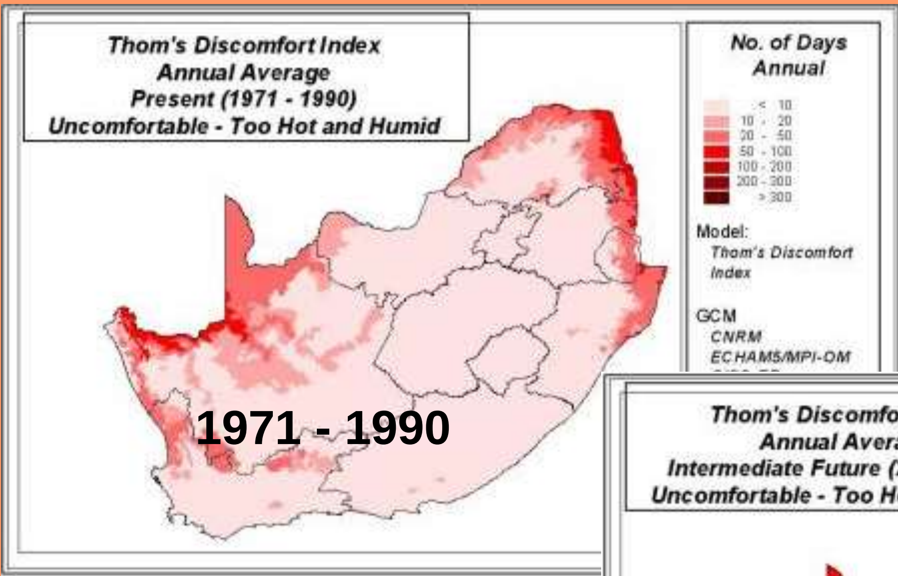


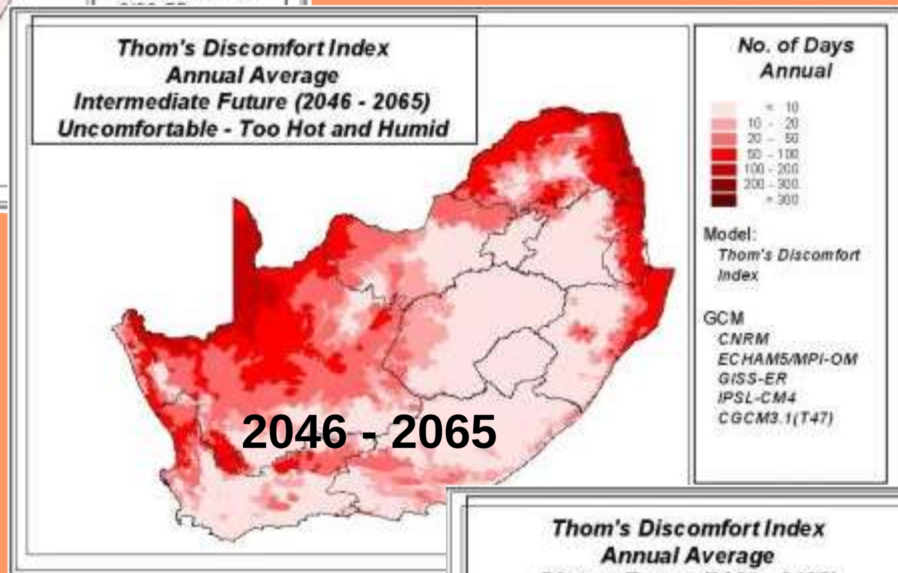
FACT!! Large Tracts of SA are Now Already Physically Degraded, & Livestock Practices (and Politics) Have Played Their Role

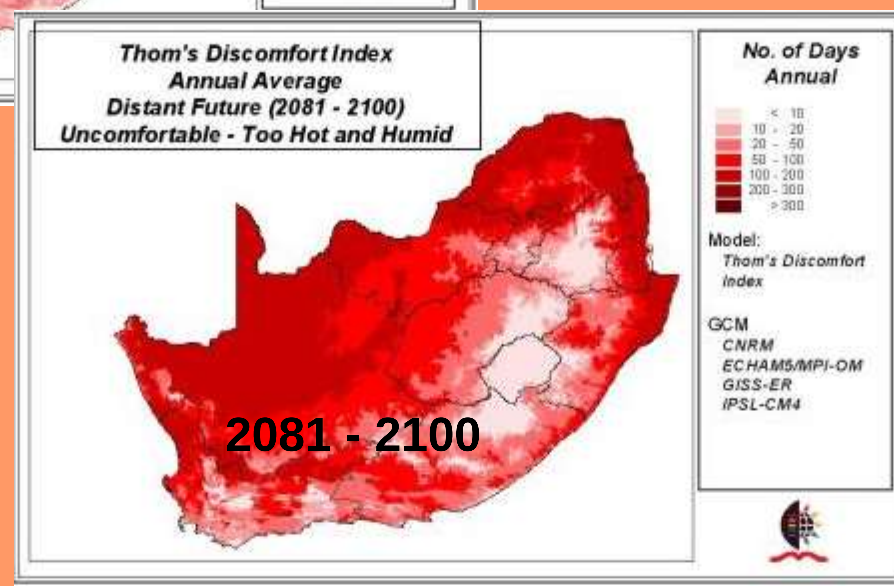


We Have To Consider Other Secondary Impacts, e.g. Human Comfort

Case Study



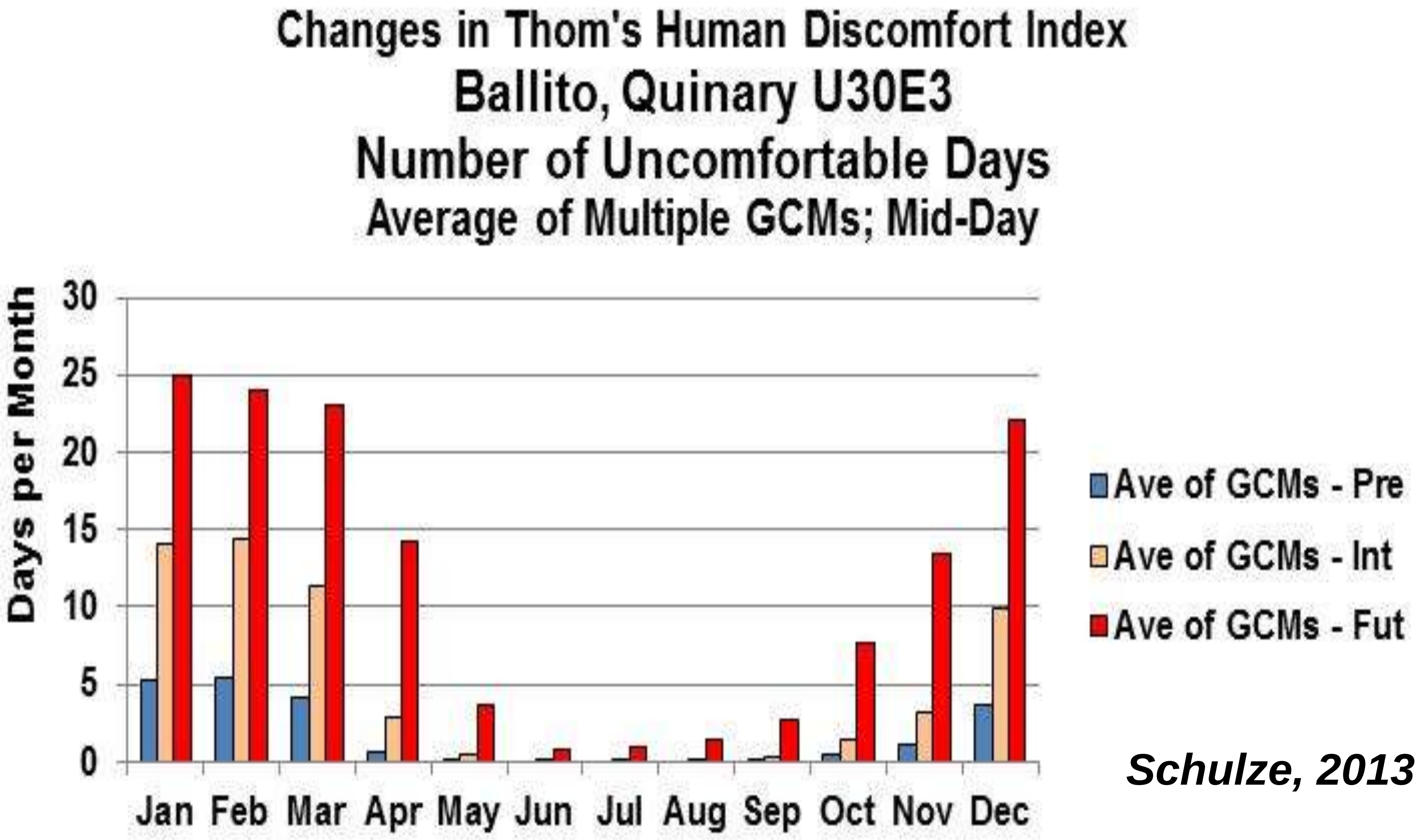




Thom’s Human Discomfort Index Uncomfortable Days / Year

Schulze & Davis, LTAS (2013)

And, looking more closely…



Schulze, 2013

Repercussions: Labour, Tourism, School Holidays, Energy

Where to Now?

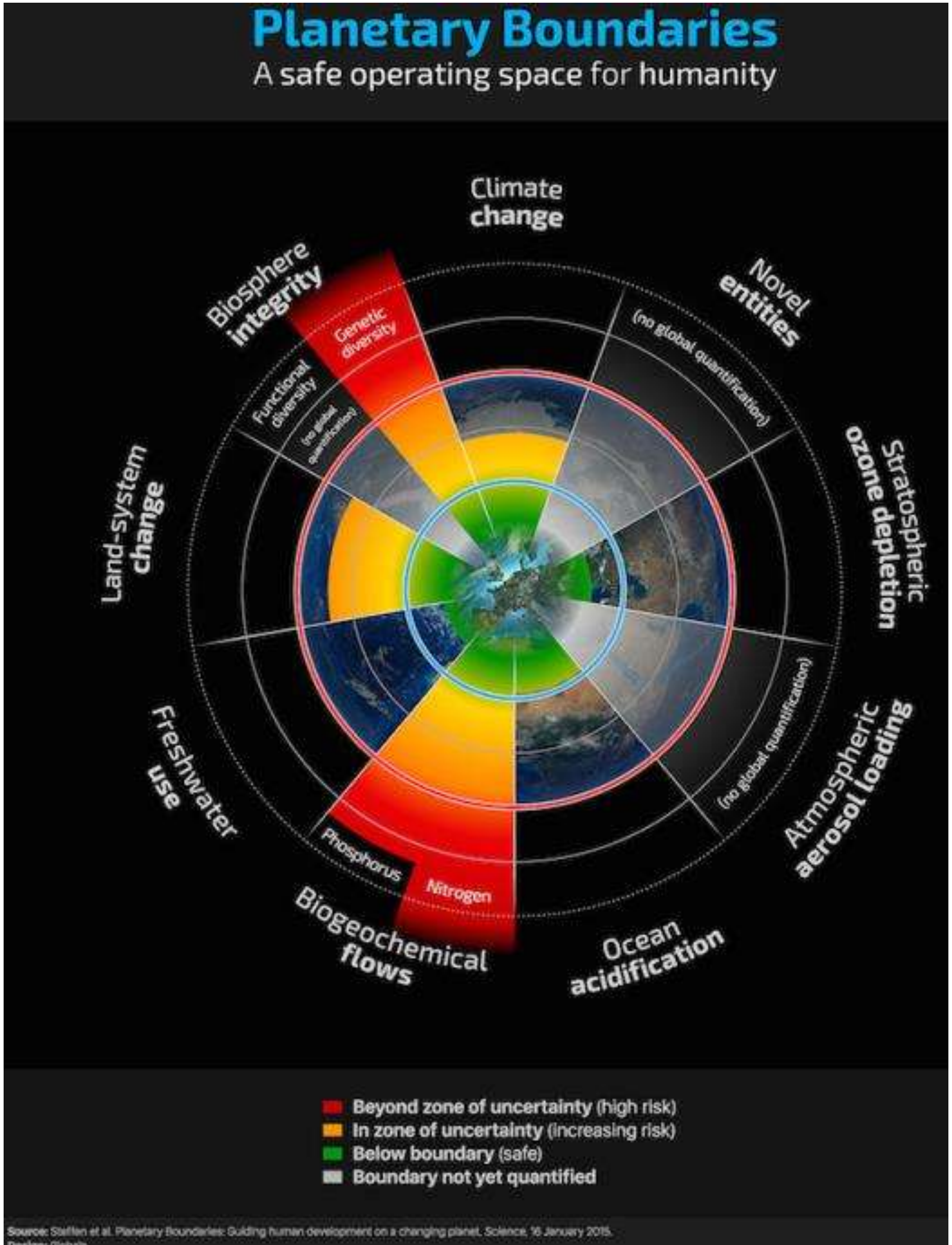
What we should NOT do!

We Cannot Stick our Head in the Sand and Pretend There is No Crisis

Neither can we assume that divine intervention help us this time around!

Where to Now?

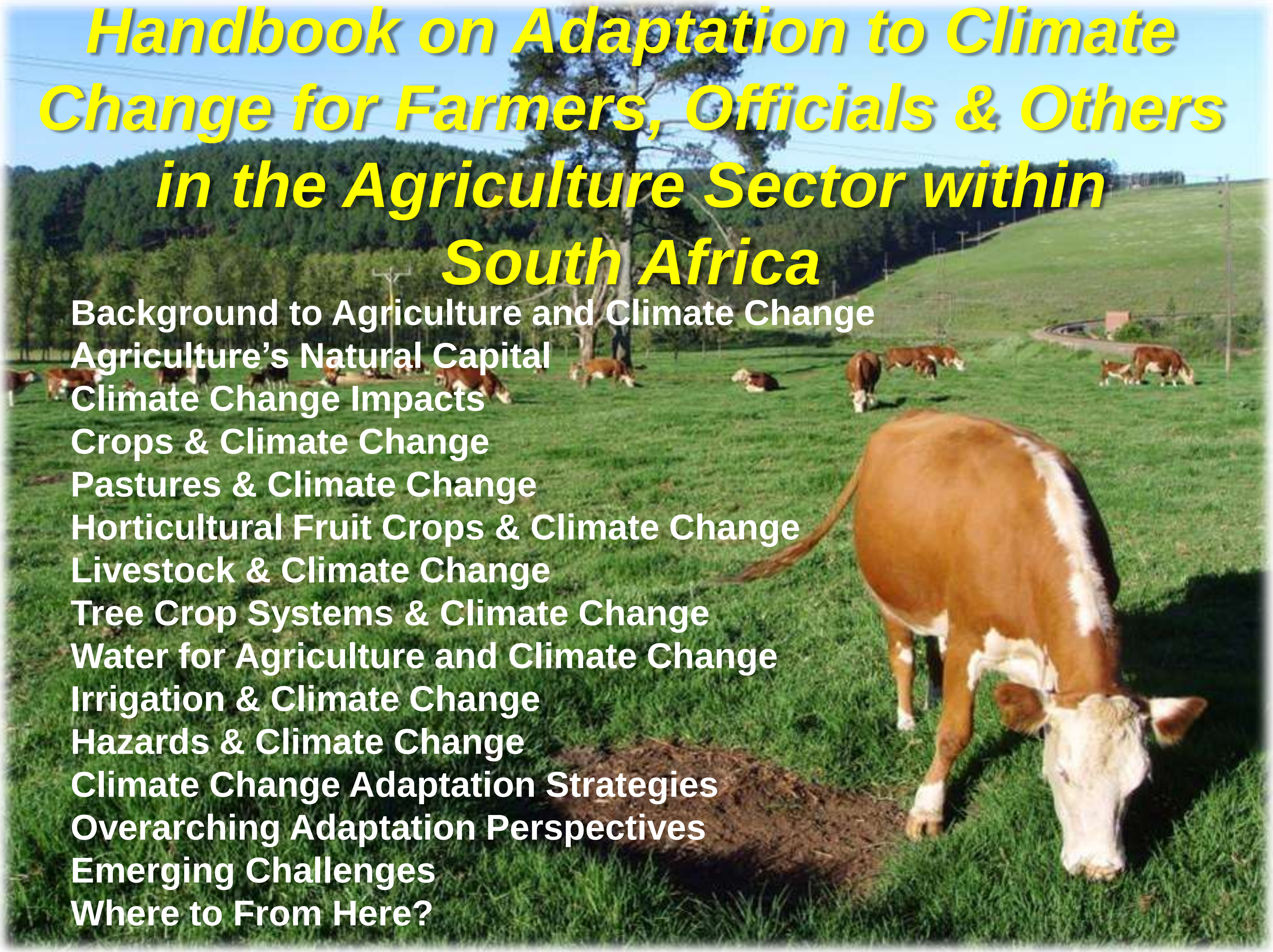
A Point to Ponder!



Is Humanity Still in a "Safe Operating Space"?

Steffen et al. (2015) in Science

- *Four of nine planetary boundaries (incl. CC) are already beyond the "safe" space*
- *We are now on a 4°C trajectory of warming*
- *Can the planet support +10 B people post 2050?*
- *Or will we have overshot the Earth's bio-capacity? with large losses to biodiversity, wetlands, croplands, terrestrial C stores?*


Handbook on Adaptation to Climate Change for Farmers, Officials & Others in the Agriculture Sector within South Africa
Background to Agriculture and Climate Change
Agriculture’s Natural Capital
Climate Change Impacts
Crops & Climate Change
Pastures & Climate Change
Horticultural Fruit Crops & Climate Change
Livestock & Climate Change
Tree Crop Systems & Climate Change
Water for Agriculture and Climate Change
Irrigation & Climate Change
Hazards & Climate Change
Climate Change Adaptation Strategies
Overarching Adaptation Perspectives
Emerging Challenges
Where to From Here?