Bioenergy in water scarce countries: Experiences from South Africa

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Task 43 Workshop – Bioenergy & Water

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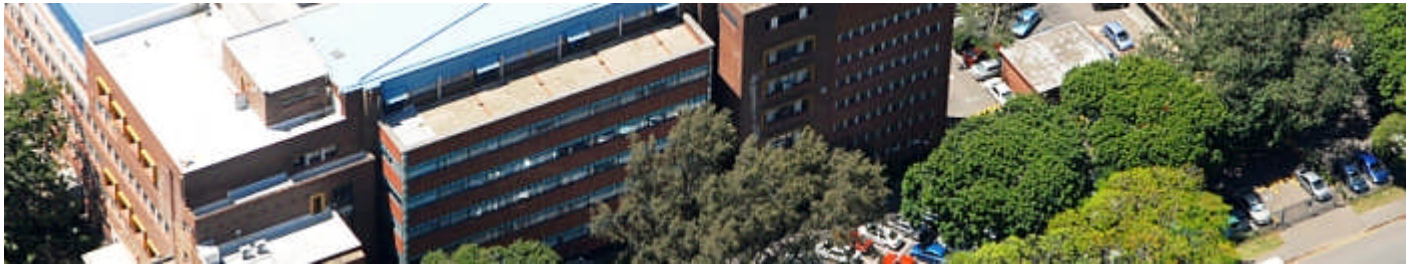
University of KwaZulu-Natal http://www.ukzn.ac.za/

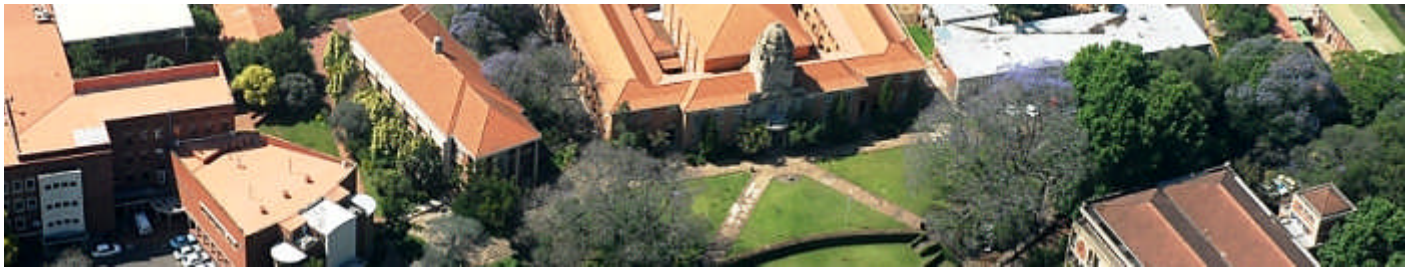
Five campuses

In two major cities:



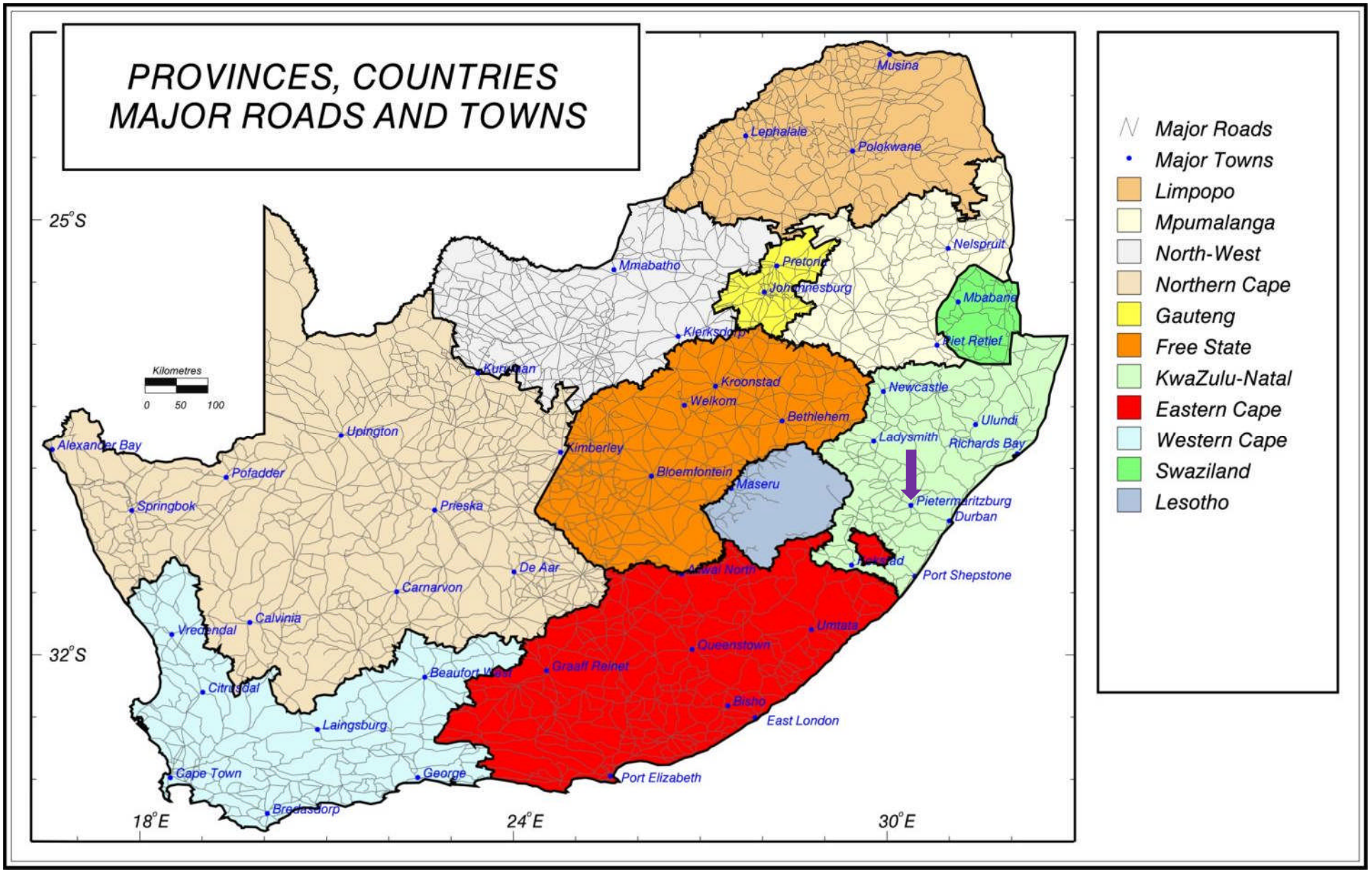
Durban

Pietermaritzburg



> 40,000 students

> 4,000 staff



Area 1,219,090 km^2; 9 Provinces; 11 official Languages

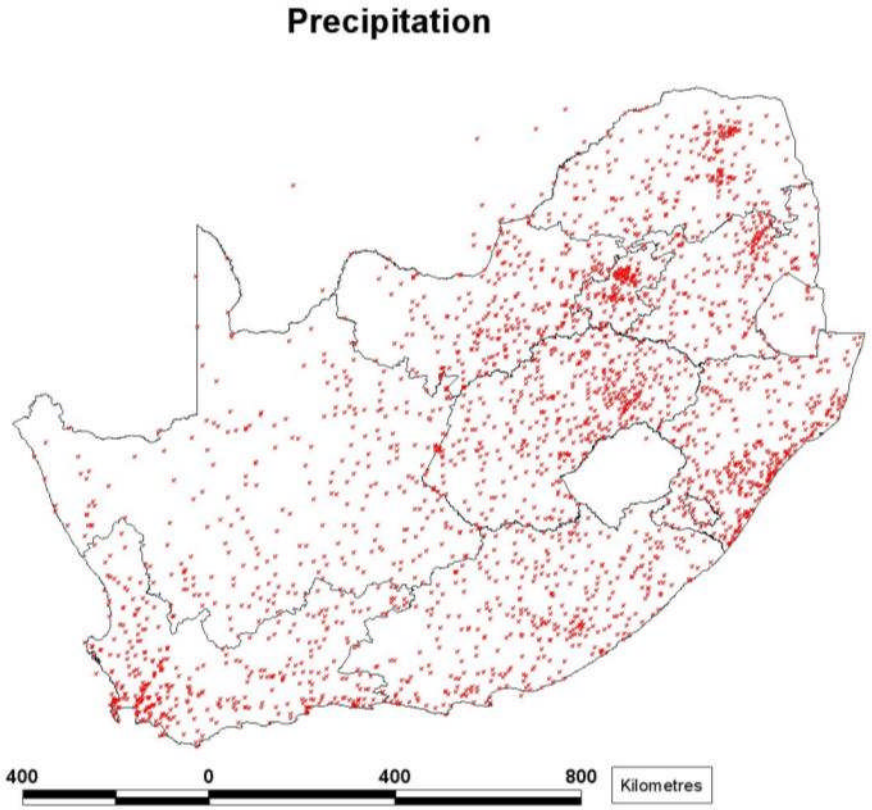
≈50 million people (79% African; 10% White; 11% Coloured/Indian)

A country which experiences intense rainfall events…

…as well as dry conditions

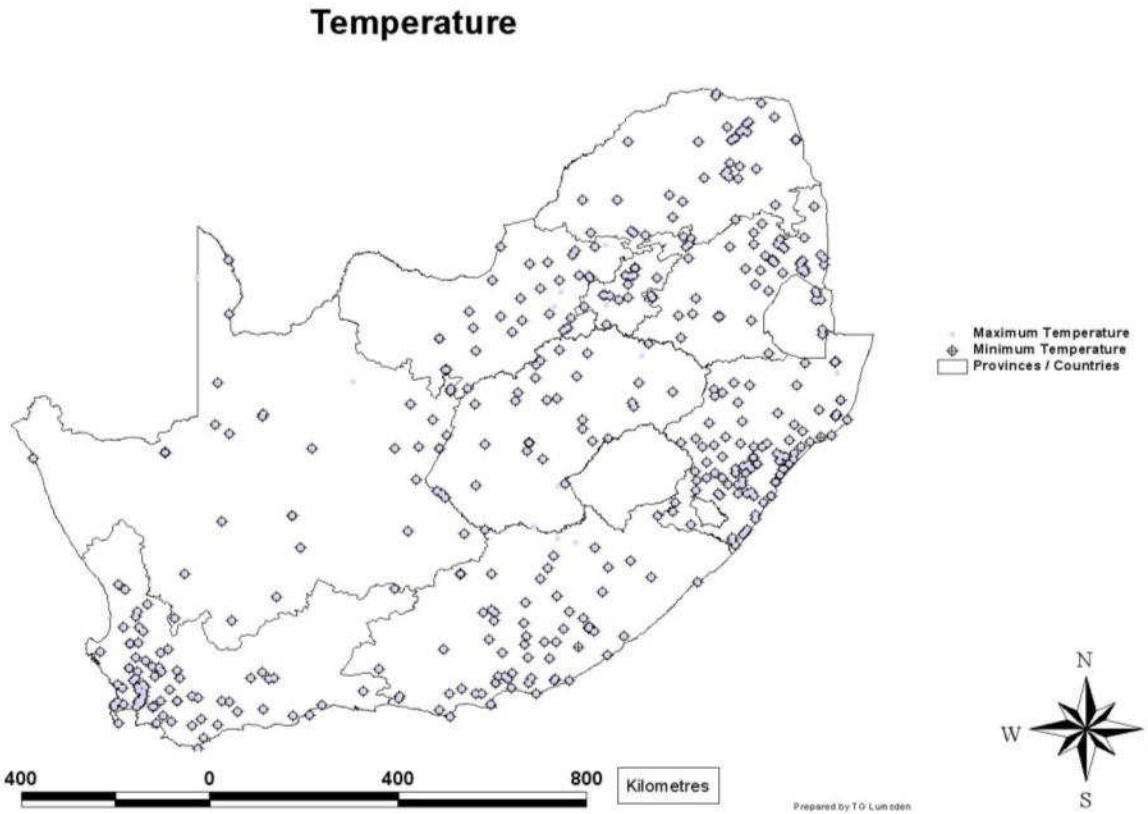
A country with irrigated commercial farming…

…and dryland subsistence cultivation



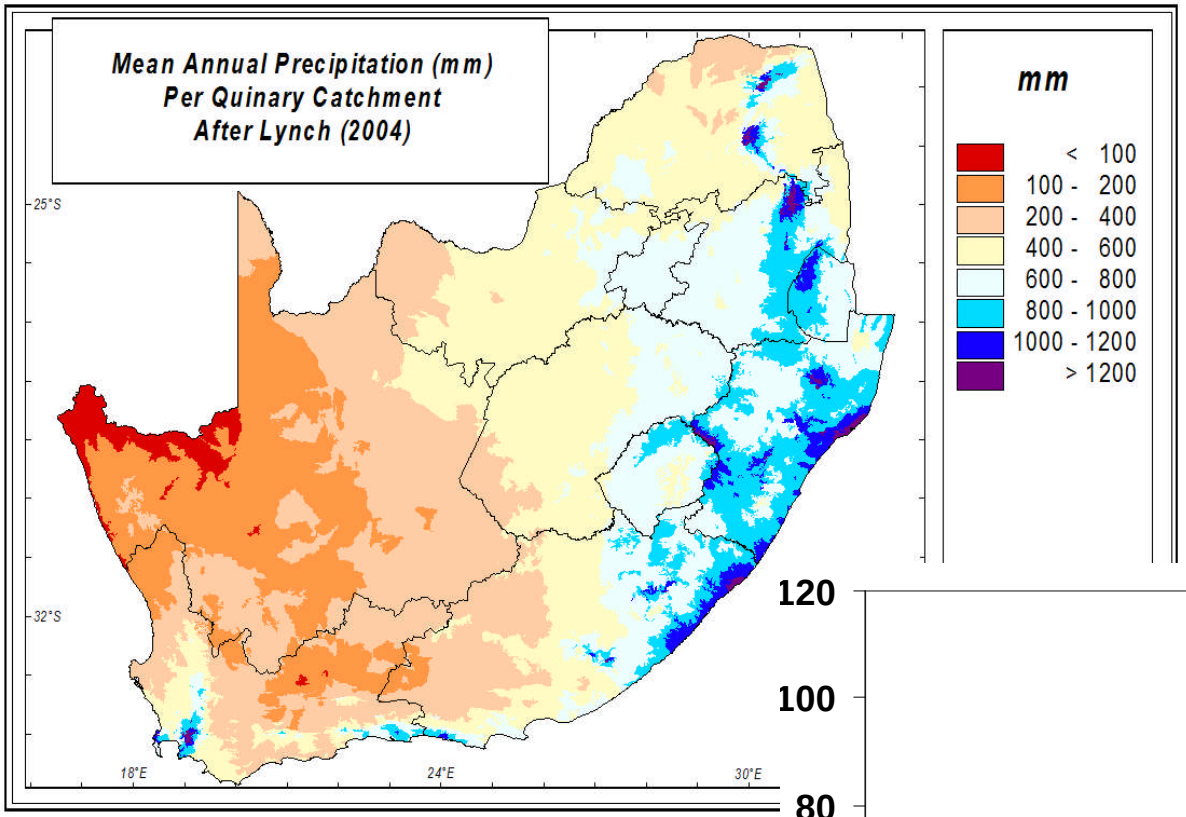
A country with over

10,000 rainfall stations…



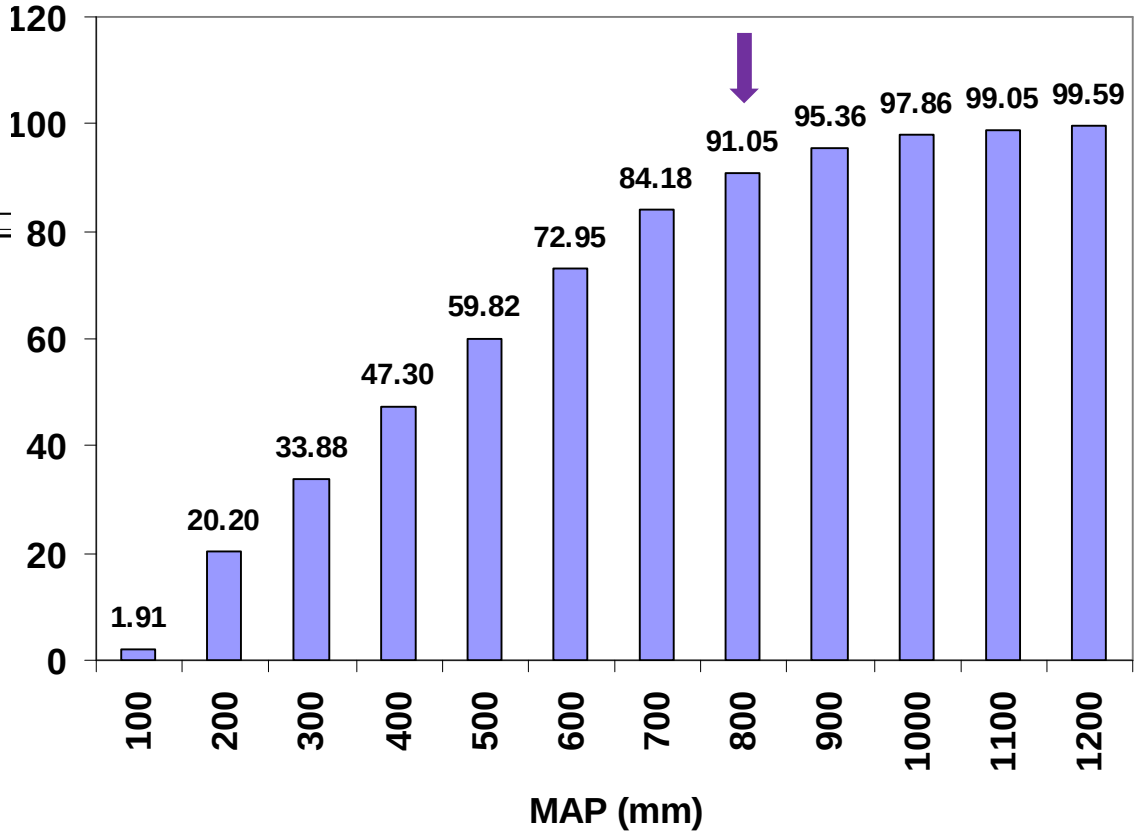
…but less than 1000

temperature stations



A country with an annual rainfall < 500 mm (half the world average)...

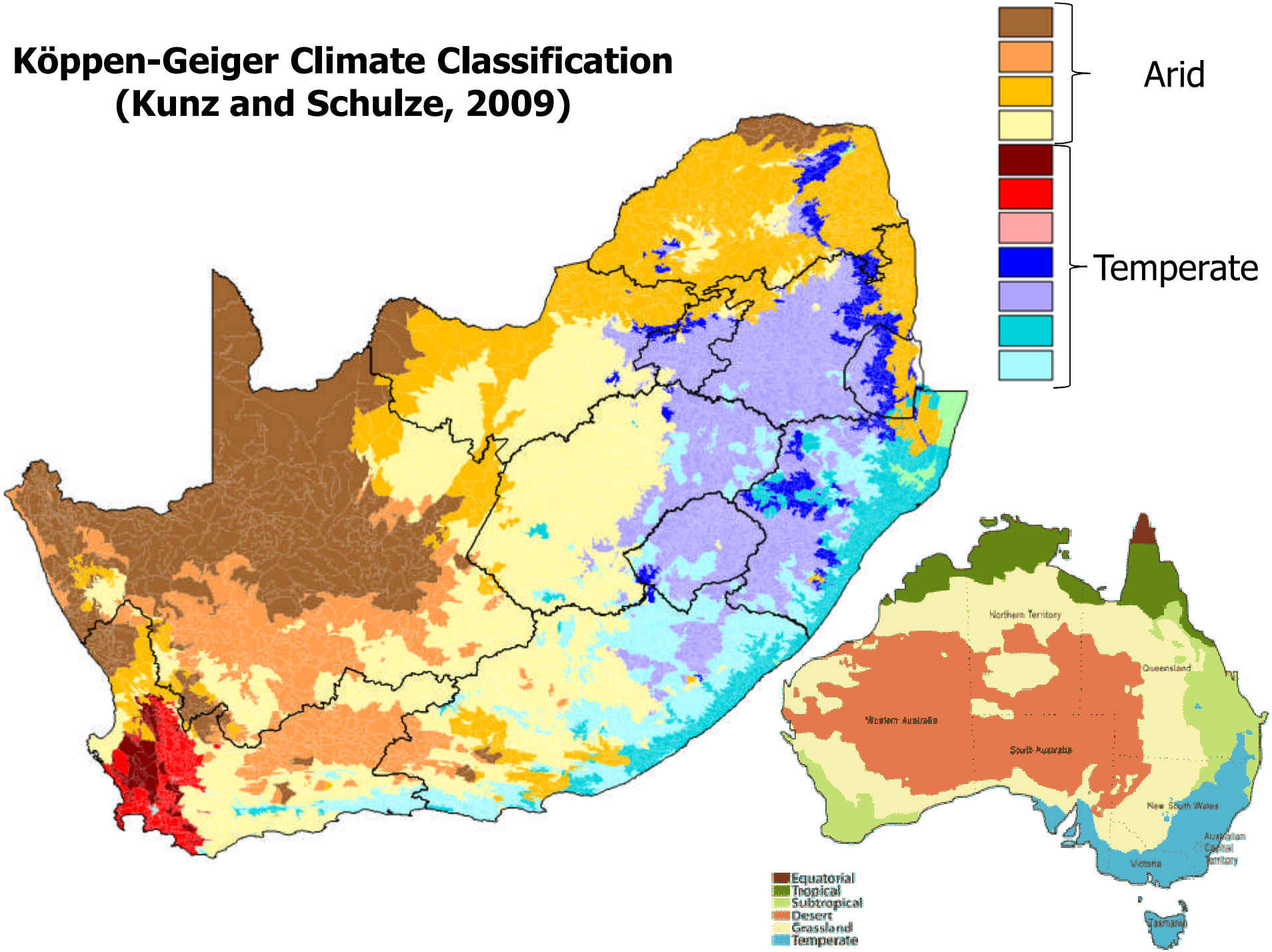
< 10% of the country receives more than 800 mm



South Africa has mountains and high rainfall in places…

…yet, is largely semi-desert

Köppen-Geiger Climate Classification (Kunz and Schulze, 2009)



Presentation Key Points

Highlight aspects of biofuel feedstock production that are unique to SA:

- Proposed biofuels policy & mandatory blending rates (background)
- Exclusion of maize for food security concerns (food vs. fuel debate)
- Banning of Jatropha due to possible alien invasive threat
- No irrigation of feedstocks and how this will be enforced
- The SFRA concept pertaining to land use change

Biofuels in South Africa

The revised National Biofuels Industrial Strategy of 2007

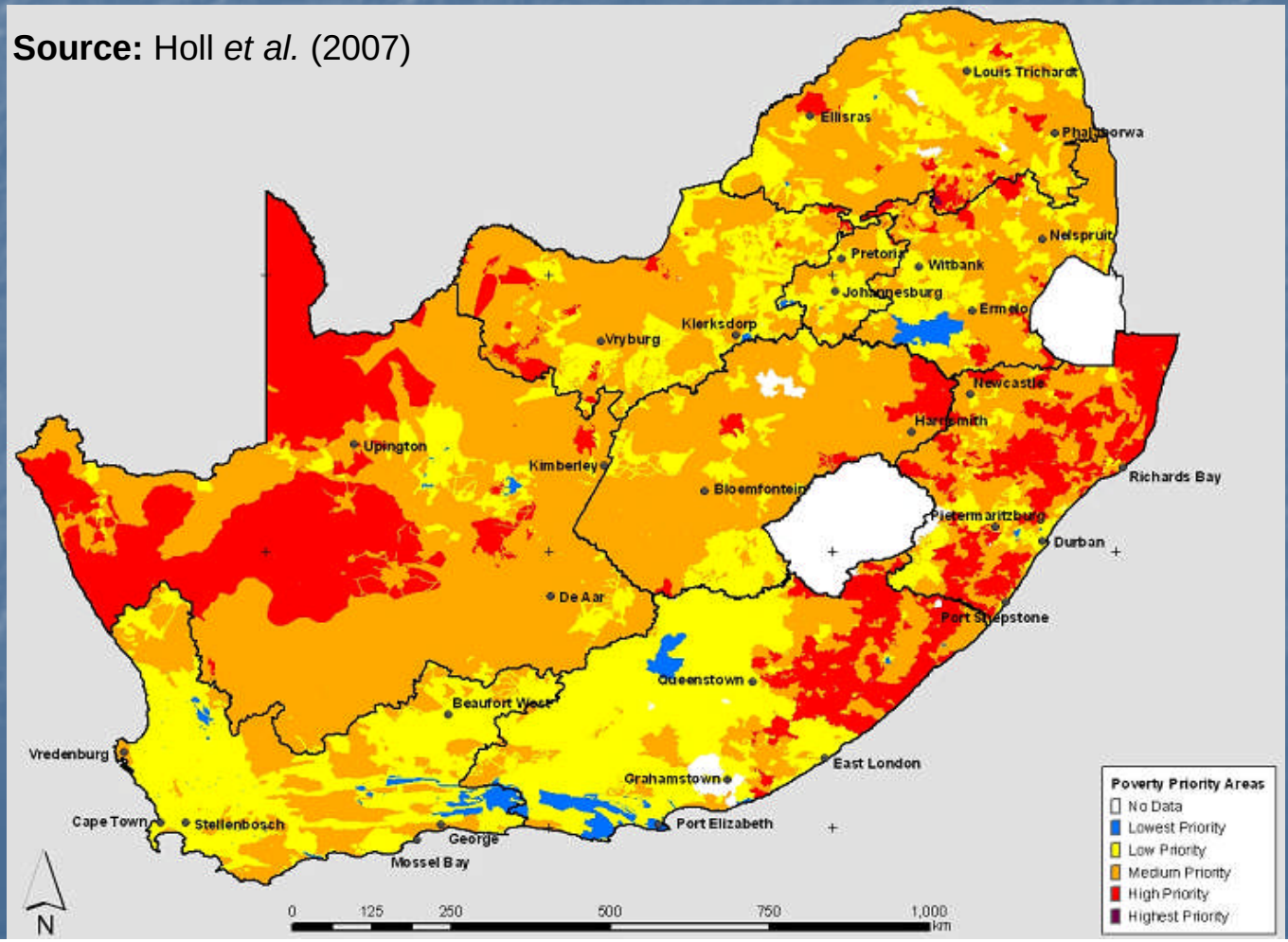
- 400 million litres of biofuel produced within five years (conservative)
  - This short-term target will not be realised
- Key drivers of the biofuels industry
  - Alleviate poverty in rural areas
  - Stimulate rural economic development
  - Promoting agricultural development in rural areas
- Land area requirements for feedstock production
  - 300,000 ha of under-utilised arable land located in the rural areas
  - *Sufficient arable land exists for feedstock growth*

Source: DME (2007)

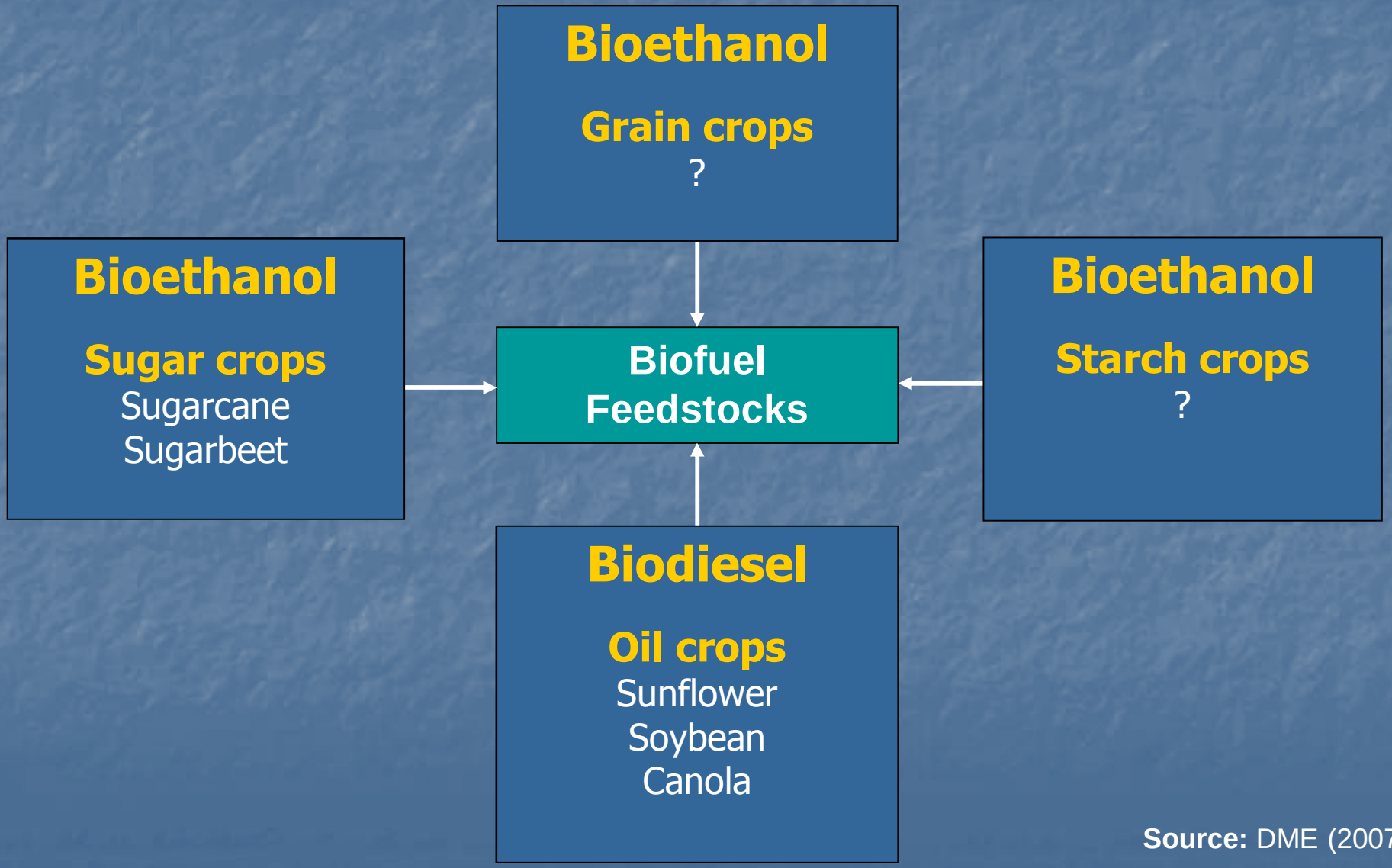
Poverty Alleviation

Poverty priority index map

- Regions in red exhibiting the highest poverty priority index

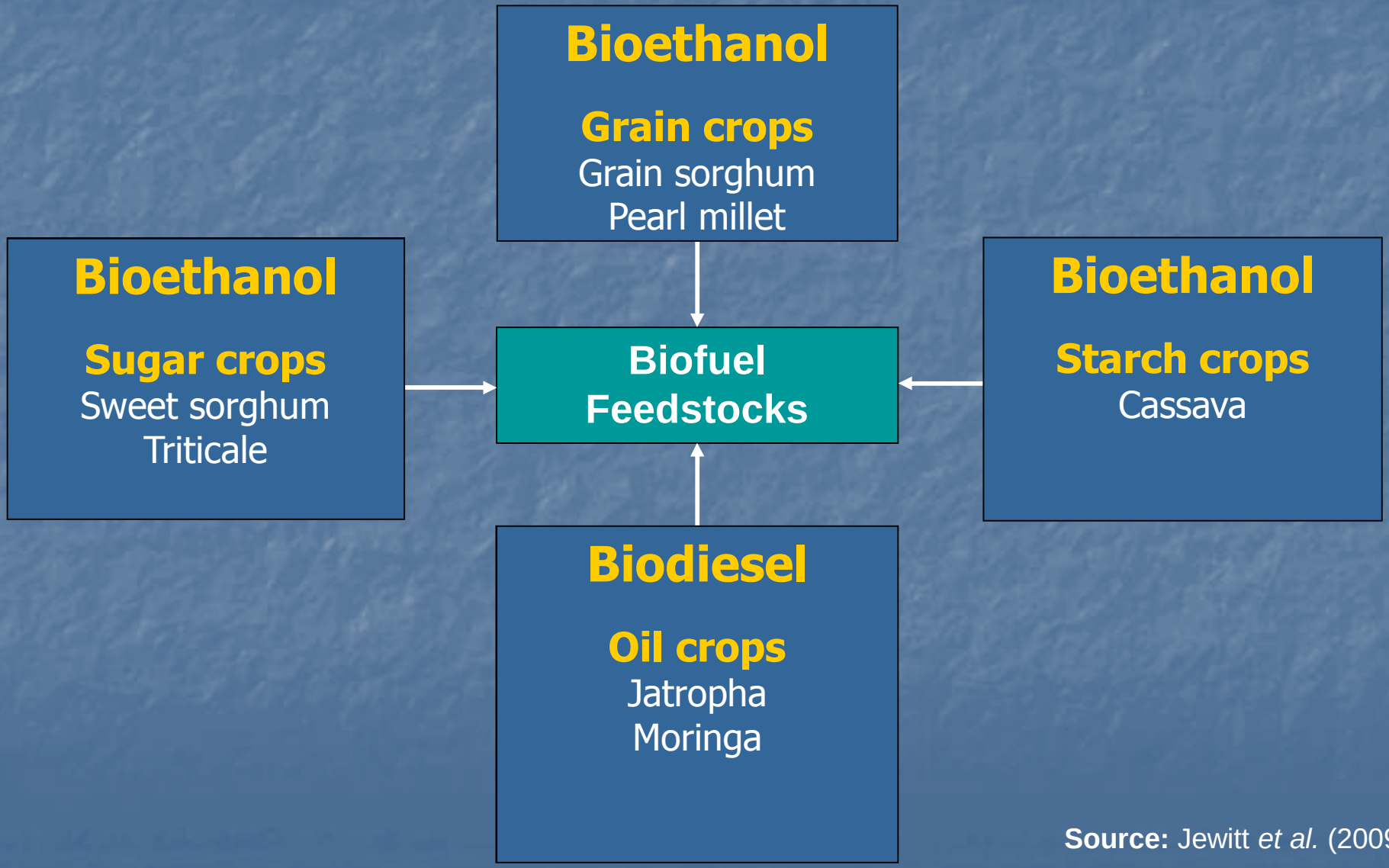


Proposed Feedstocks in Strategy



Source: DME (2007)

Other Potential Feedstocks Identified



Source: Jewitt *et al.* (2009)

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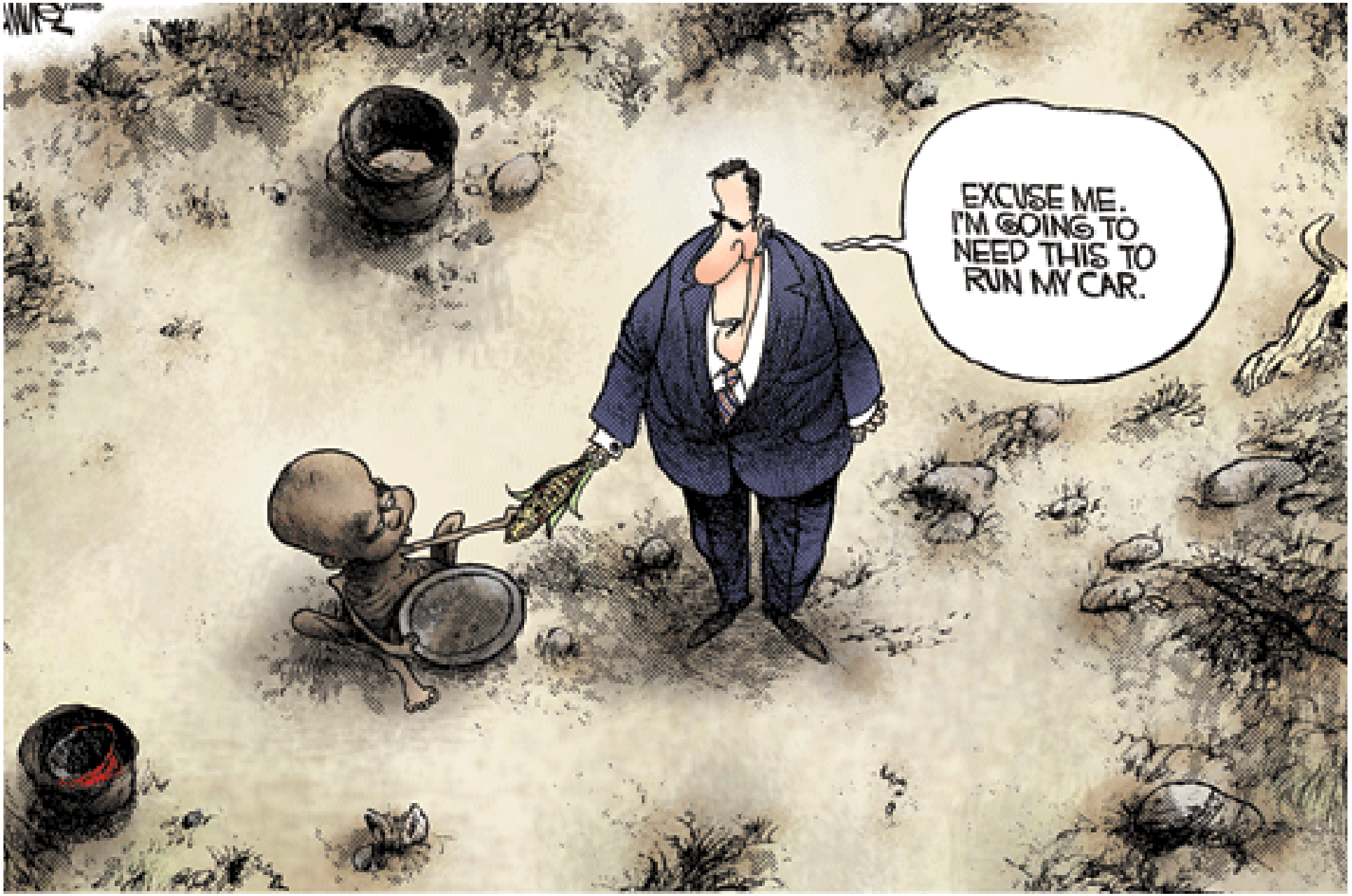
Exclusion of Maize as a Potential Feedstock



Export of White Maize

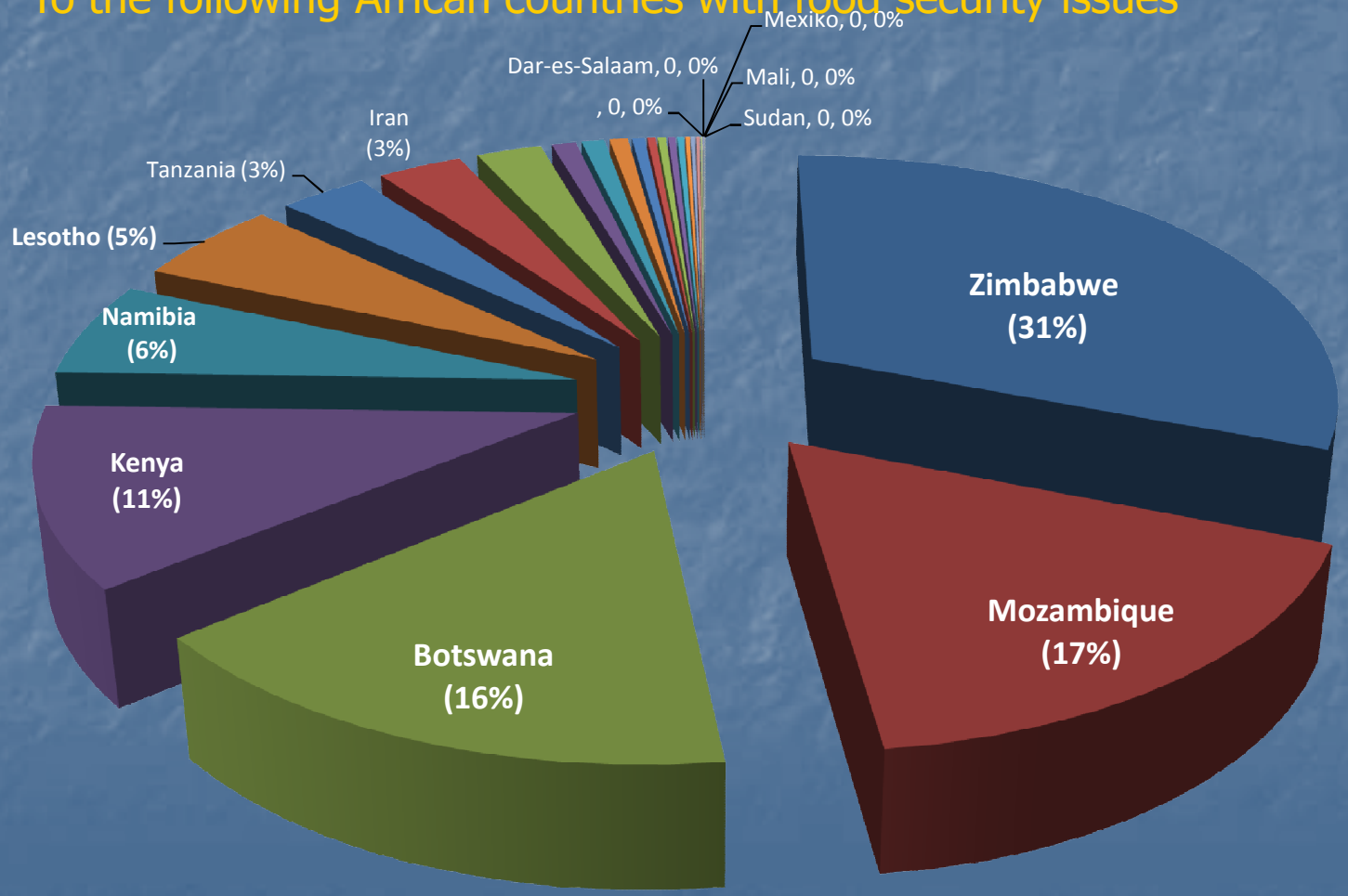
Trend wise, approximately 1 million ton annual export to African countries

Source: Lemmer (2009)

Export of White Maize

Export of approximately 1 million tons of white maize:

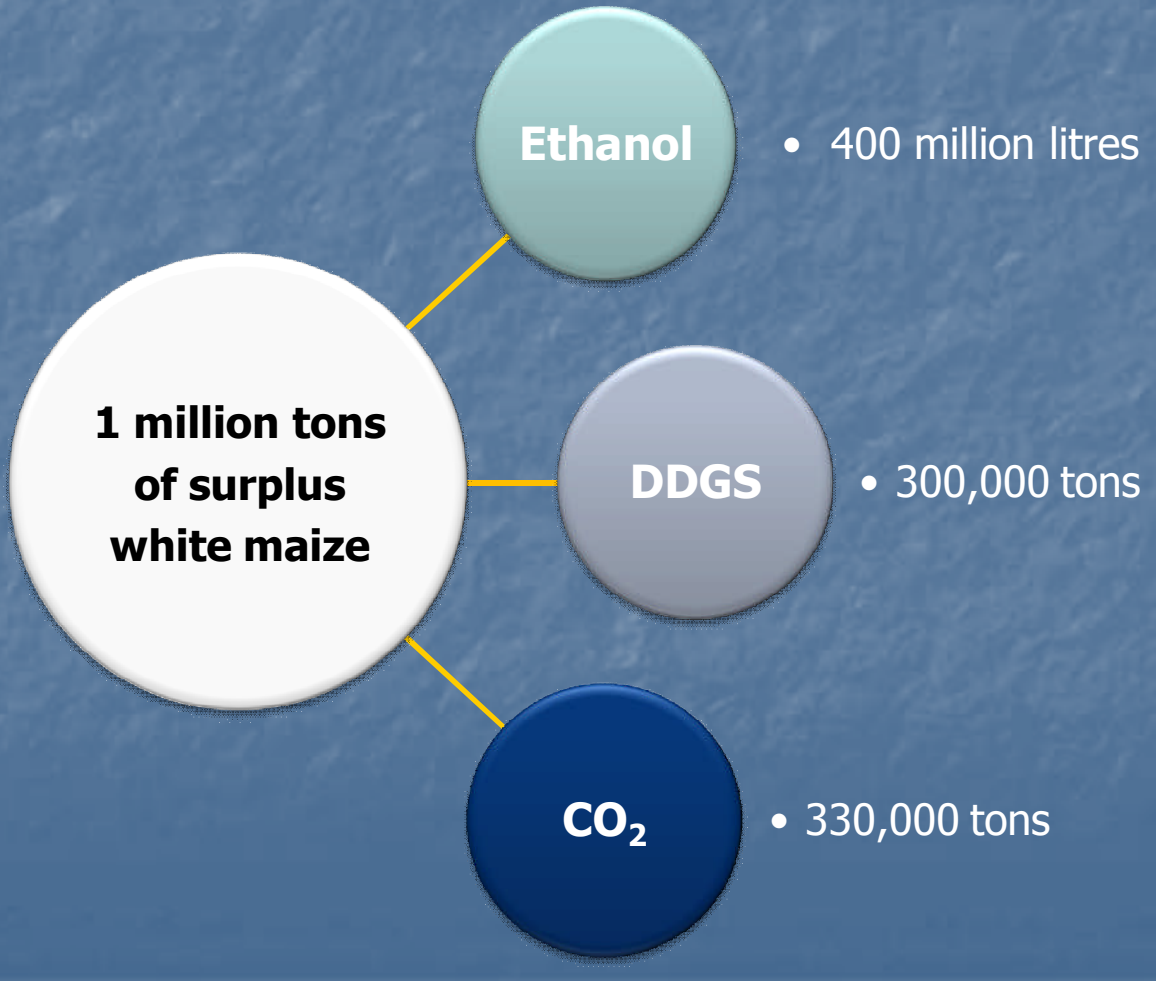
- To the following African countries with food security issues



Source: Lemmer (2009)

Ethanol Production from Maize

- Assuming an ethanol-from-maize processing plant existed in SA, and
- South Africa did not export maize to its food insecure neighbours

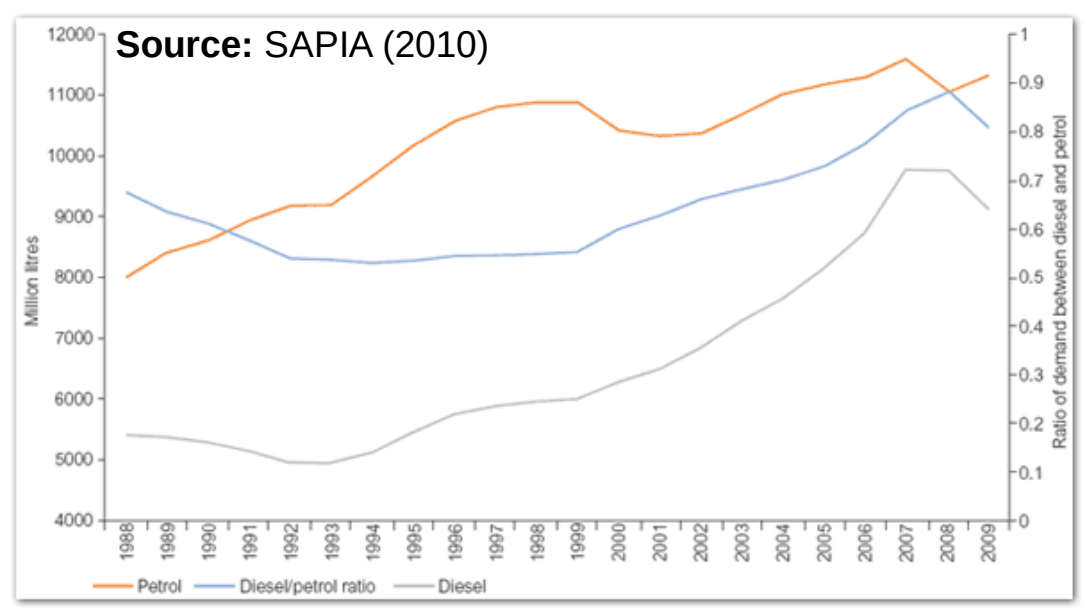


Source: DME (2006)

Proposed Mandatory Blending Rates

- Released on 16th October 2011 by DoE for public comment
  - Minimum 2% ethanol blend
  - Minimum 5% biodiesel blend

- Required biofuel production capacity
  - 220 million litres of ethanol
  - 450 million litres of biodiesel



Water is Limiting, not Land!

- Studies of biofuel production potential:
  - Tend to focus on land availability, not water availability
  - Biofuel expansion will affect water availability and vice versa
  - In South Africa, water will limit feedstock production, not land

- Recommendation of the National Biofuels Task Team:
  - The government should determine the impacts of
    - commercial and
    - small-scale production
  - of biofuel feedstock on both
    - water quality and
    - water quantity
  - prior to the roll out of the strategy

Source: DME (2006)

Water Research Commission

- Brief background:
  - Establishes water research needs and priorities
  - Provides funding for water research according to priority
  - Promotes effective transfer of information and technology
  - Enhances knowledge & capacity building within the water sector
  - Established in 1971 by the Water Research Act (Act No. 34)

- Biofuel projects funded by the commission:
  - Project K4/1772
    - "Scoping study on water use of crops/trees for biofuels in South Africa"
    - Reported published in November 2009
  - Project K5/1874
    - "Water use of cropping systems adapted to bio-climatic regions in South Africa and suitable for biofuel production"
    - For more detail, refer to page 155 of their Knowledge Review 2010/11
    - http://www.wrc.org.za/Pages/KH_KnowledgeReviews.aspx?dt=8&ms=59;

Project Background

- **Funding** — Initiated by the Water Research Commission (K5/1874)
  Co-funding from Dept. of Agriculture, Forestry & Fisheries
- **Contractor** — School of Bioresources Engineering and Environmental Hydrology (BEEH), University of KwaZulu-Natal (UKZN), South Africa
- **Title** — Water use of cropping systems adapted to bio-climatic regions in South Africa and suitable for biofuel production
- **Length** — April 2009 – Mar 2015 (6 year)
- **Project Leader** — Prof. Graham Jewitt
- **Budget** — R 7.4 million

Proposed Biofuel Processing Plants

- Funded by the:
  - Industrial Development Corporation (IDC)
  - Central Energy Fund (CEF)
- Proposed plants:

Capacity (million litres)	Preferred Feedstock	Alternative Feedstock	Irrigated feedstock?
90	Grain sorghum	Sugarbeet	Yes
100	Sugarcane		Yes
100	Cassava	Sugarcane	

- Dryland or irrigated feedstock?
  - Two EIA's indicated the feedstock will be irrigated

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Mainly Dryland Feedstock Production

- Department of Water Affairs' position on irrigated feedstock:
  - South Africa is a water scarce country
    - Only 9% of rainfall is generated into runoff (i.e. MAR/MAP = 0.09)
  - "...ill afford the use of current or potential irrigation water for fuel production rather than growing crops for food"
  - Irrigation only allowed in exceptional circumstances
    - Detailed motivation must be provided (e.g. rural development)
  - This stance may severely limit investment in the biofuels industry
- How the government plans to enforce this "no-irrigation" policy:
  - Department of Energy
    - License to produce biofuels is granted if feedstock is only rainfed
  - Department of Water Affairs
    - Will charge water at industrial rates, not subsidised agricultural rates

Should water scarce countries produce biofuel from irrigated feedstock?

If yes, this would benefit:

Commercial farmers with irrigation permits

NOT

Small-grower farmers

in the rural areas

The Solution?

- South Africa cannot afford to expand the land area under irrigation
  - ≈ 1.5 million hectares which utilises 62% of total water resources
- Without irrigation, the list of potential feedstocks is different
  - Winter plantings of sugarbeet are high risk
  - Drought resistant feedstocks (e.g. sweet sorghum) pose less risk
- Solution? Improve irrigation efficiency by converting from:
  - Flood (55-65% efficient) to
  - Micro/drip (85-95% efficient)
- Use the water savings to expand the footprint of irrigated agriculture
  - Give preference to food production, not biofuel production

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The Water Footprint

- Water Footprint (WF) to produce 1 litre of biofuel
  - Majority of water is used in the agricultural production phase
  - When yields are low, WFs are high and visa versa

Feedstock	WF (Litres)
Sugarbeet	1,388
Potato	2,399
Sugarcane	2,516
Cassava	2,926
Wheat	4,946
Sorghum	9,812
Soybean	13,676
Canola	14,201
Jatropha	19,924

Sugarbeet is 14 times more water efficient than Jatropha

Water use of biodiesel is larger than that of ethanol

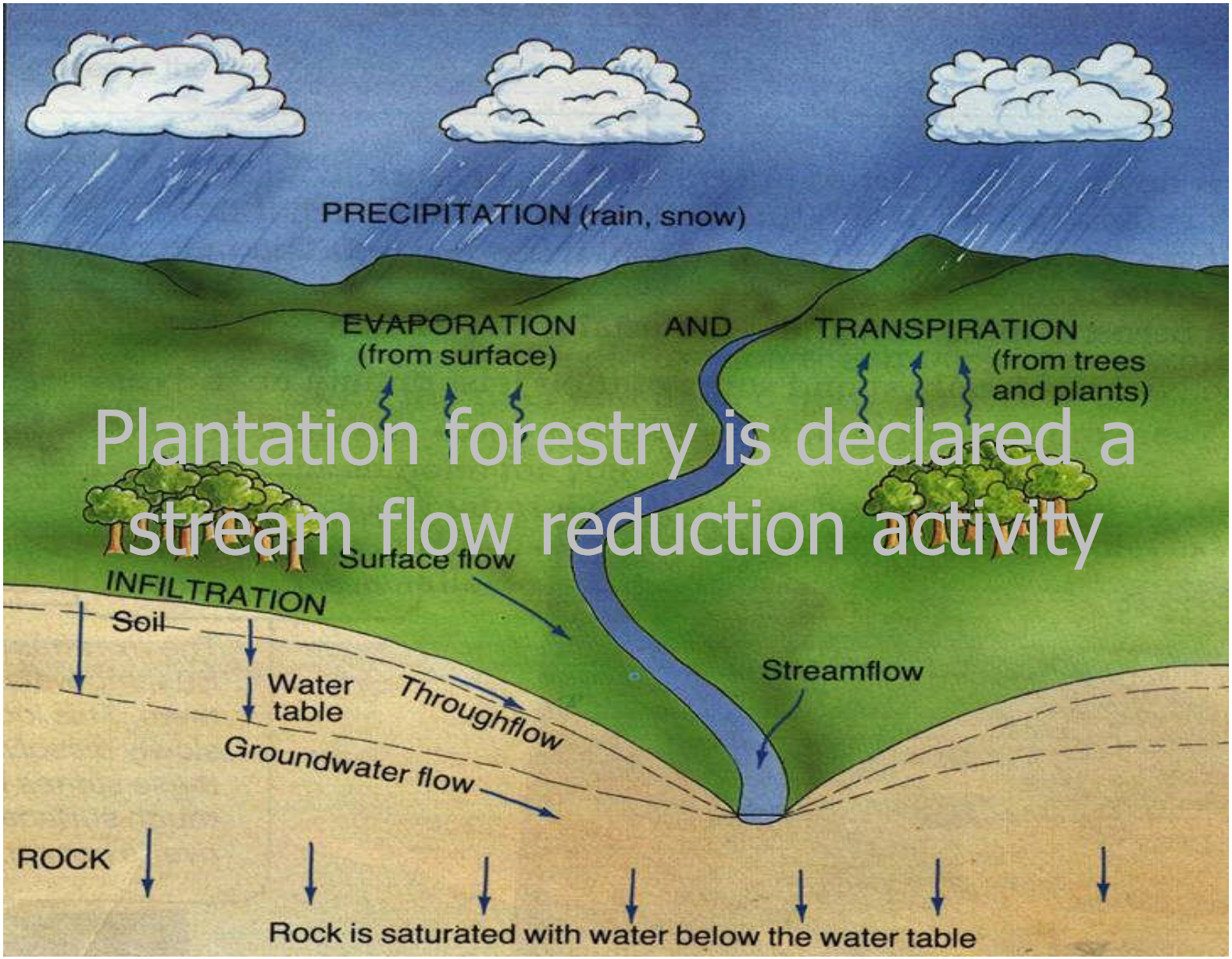
Source: Gerbens-Leenes *et al.* (2009)

The Water Footprint

- Criticism of the WF concept:
  - Reduces complexity to a single value based on average conditions
    - Discards too much detail to retain conceptual clarity and scientific rigor
  - No assessment of impact on local or regional water resources
    - Especially during low flow months
    - The mean annual statistic is meaningless!
  - No cognisance of water resource availability
    - Limited resources in dry areas vs.
    - Abundant and renewable resources in wet areas

Source: www.waterfootprint.org

Forest plantations “consume” water, therefore less water moves downward & downslope into groundwater & streams. Hence, soil moisture deficits rise & the river may run dry during low flow periods.



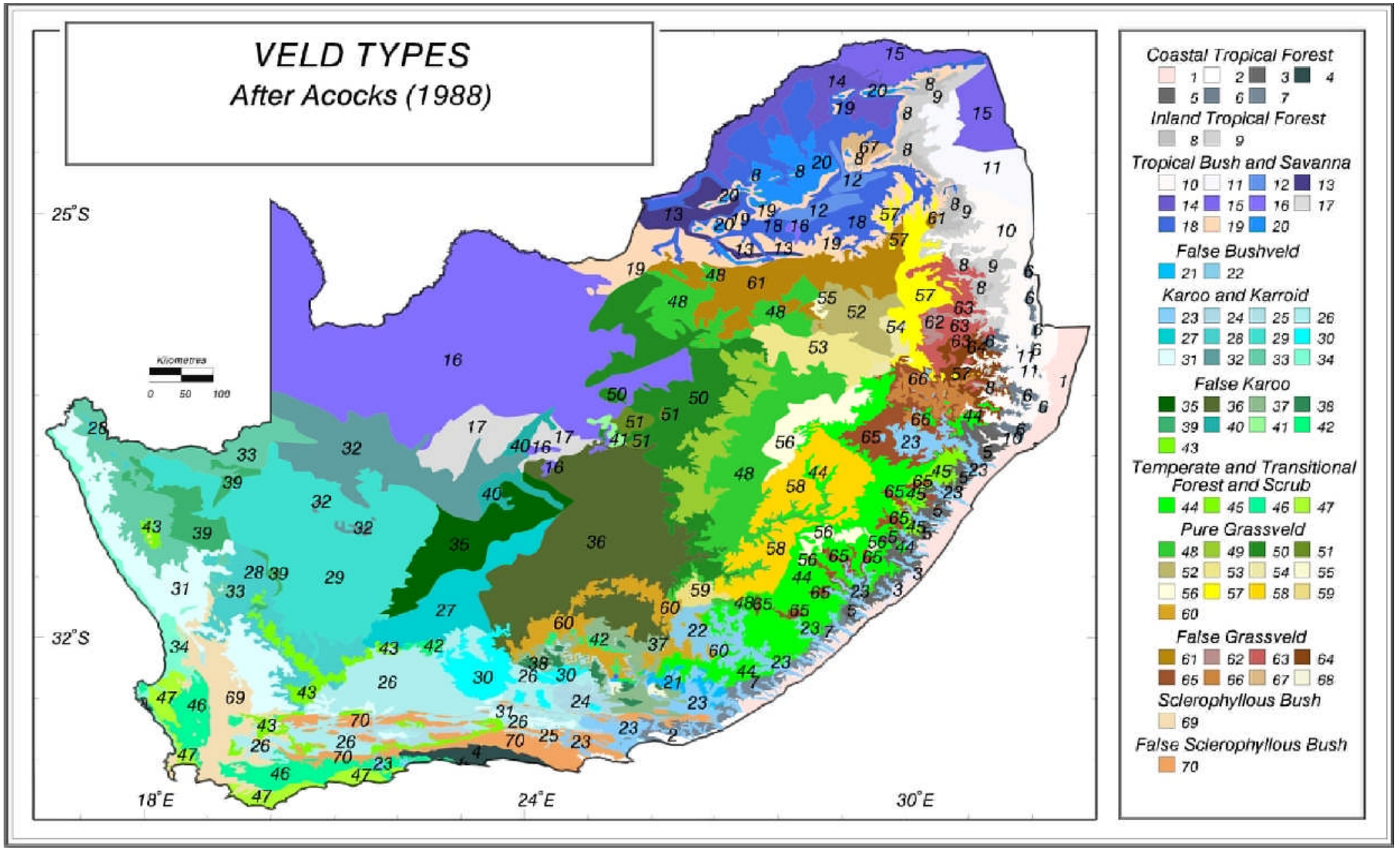
Plantation forestry is declared a stream flow reduction activity

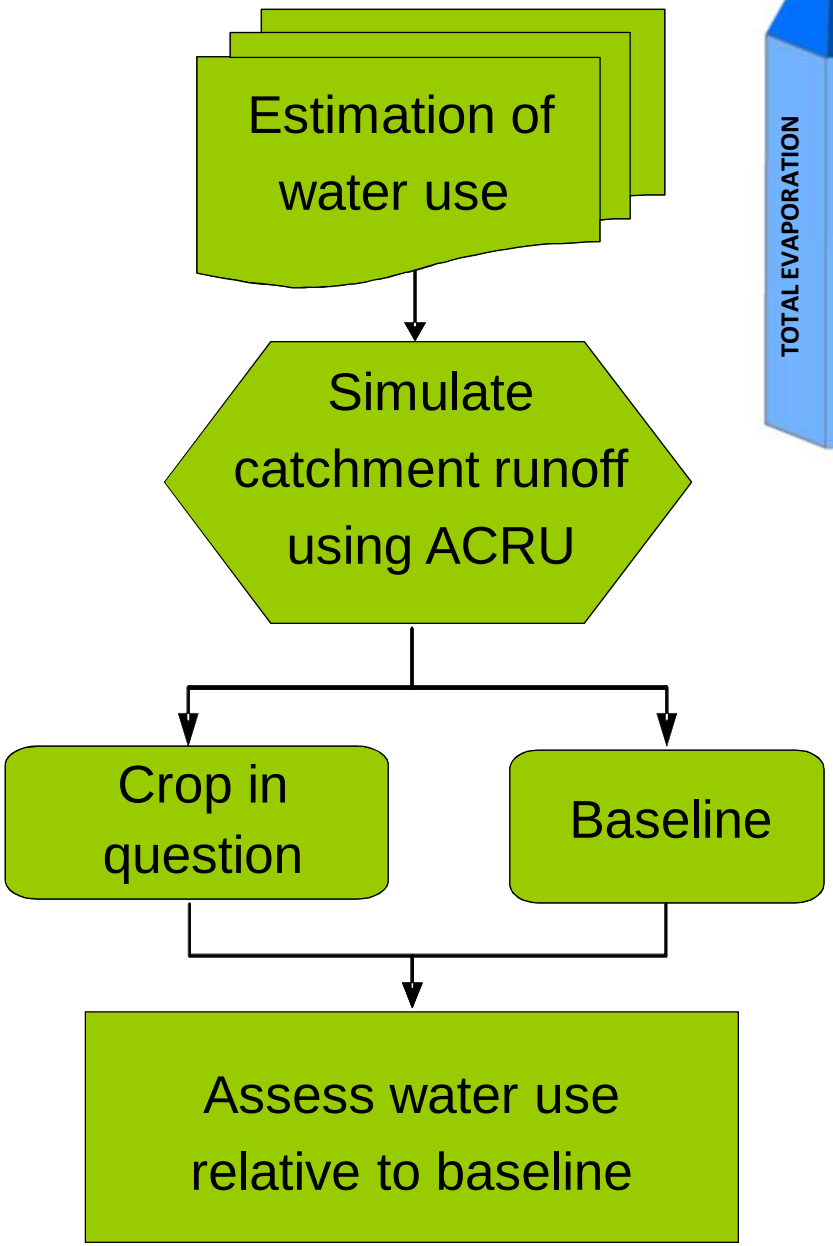
Estimation of Water Use

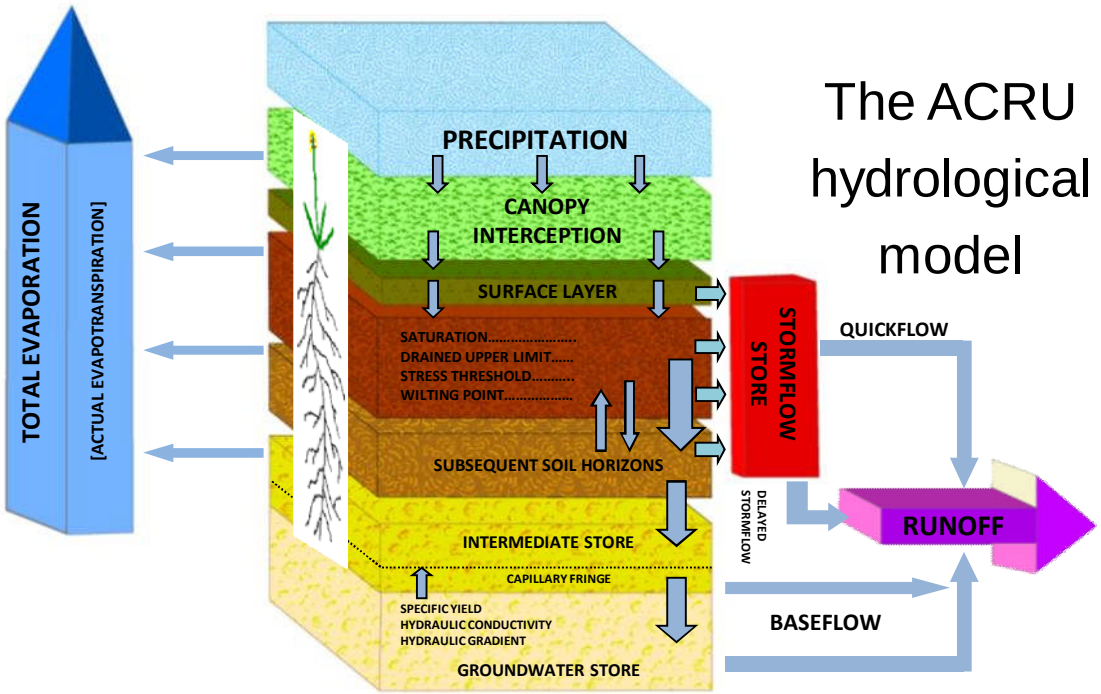
- 1st step: Estimate the feedstock's accumulated total evaporation
  - Over the growth cycle
  - Green water component of the water footprint
- 2nd step: In the context of the SFRA legislation, estimate the:
  - reduction in runoff caused by increased feedstock evapotranspiration,
  - relative to the "natural" baseline
- What is the "natural" baseline?
  - Actual land use being replaced
  - Natural vegetation map (Acocks, 1988)
    - Pristine or pre-settlement conditions
  - "Veld" means natural grazing land

Source: Jewitt *et al.* (2009)

Acocks Veld Types Map of South Africa







The ACRU hydrological model

Parameterise ACRU for:

- Baseline conditions (natural vegetation)
- Each biofuel crop

Simulate catchment annual runoff for:

- Baseline conditions (MAR_{base})
- Each biofuel crop (MAR_{crop})

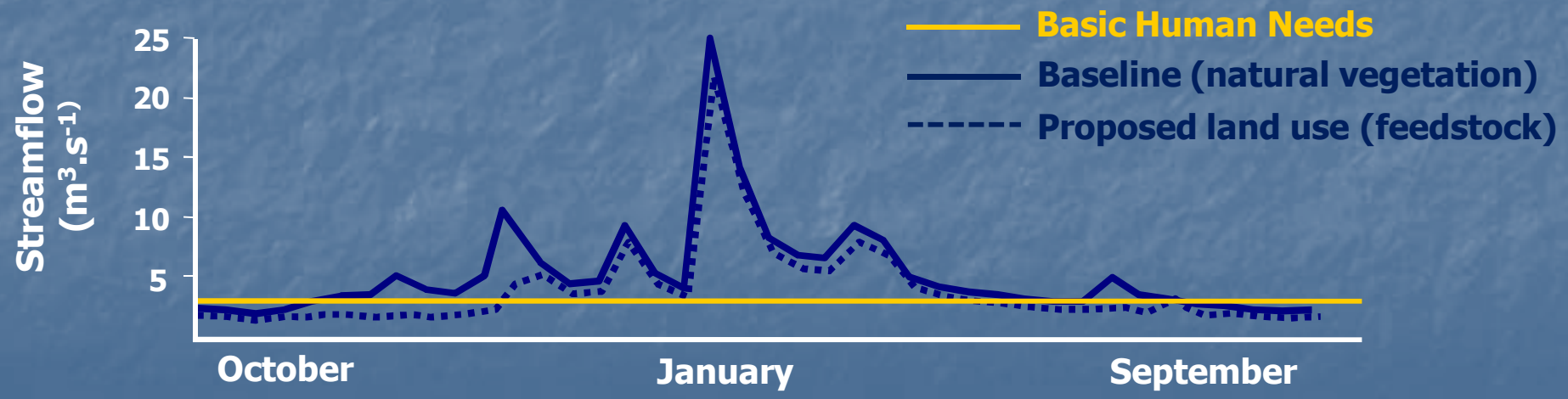
Estimated water use = $MAR_{base} - MAR_{crop}$

- Monthly and annual basis

Impact of Land Use on Blue Water

- Does the reduction in stream flow compromise water required for:
  - Basic human needs, or
  - Environmental flows?

- If so, declare the land use a Stream Flow Reduction Activity (SFRA):
  - DWA controls where and how much can be planted



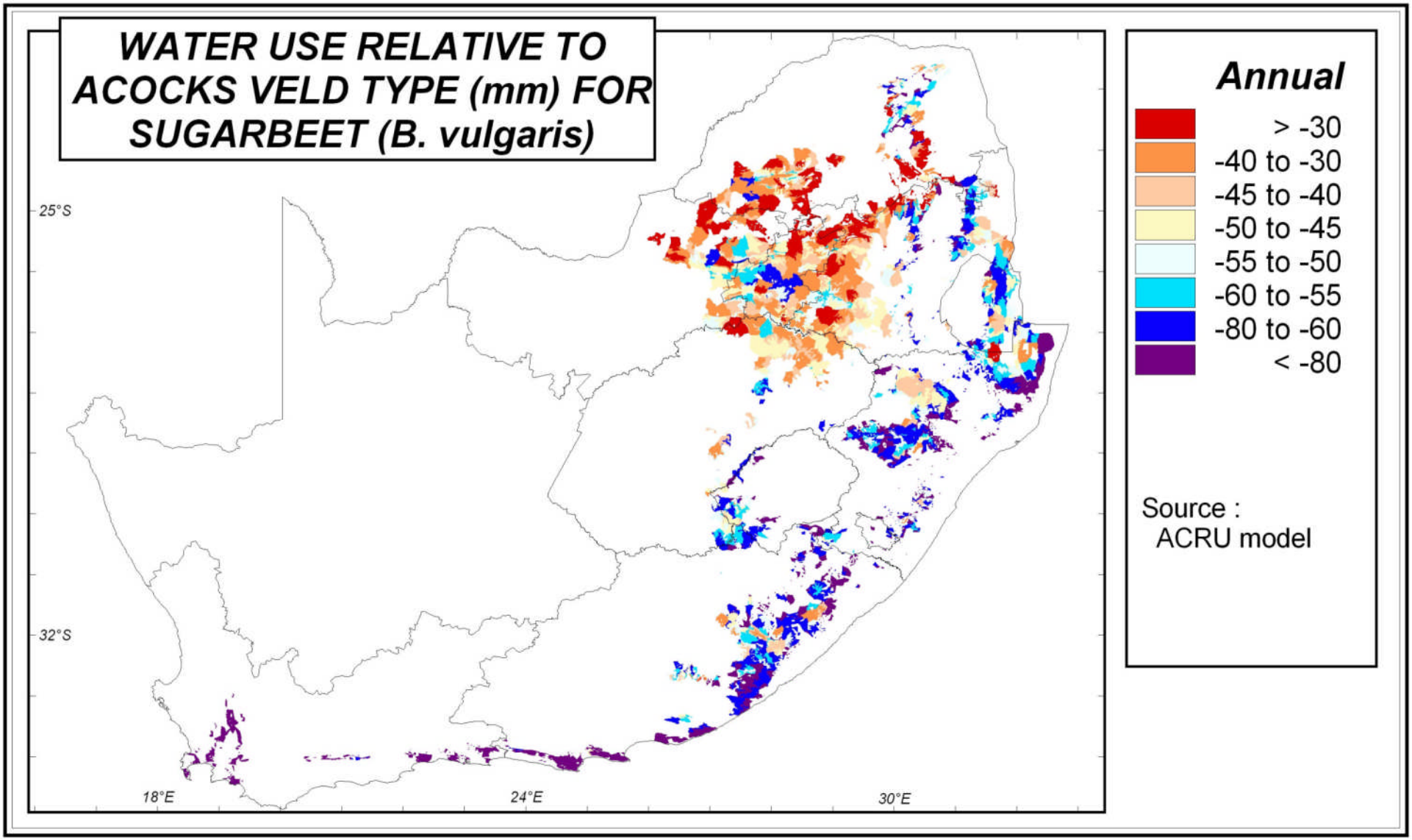
Measuring Feedstock Water Use

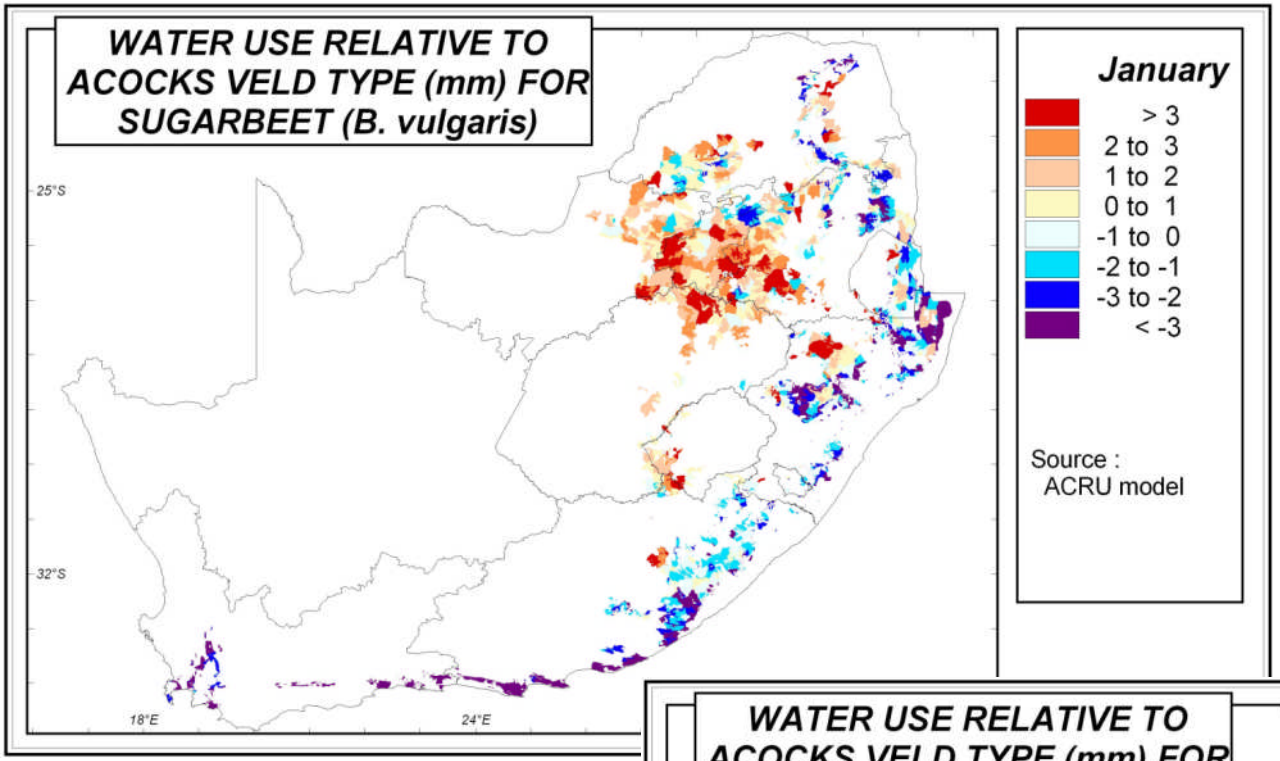
Measuring Feedstock Water Use

← Surface Renewal (fine-wire thermocouple)

Water Use = $MAR_{base} - MAR_{crop}$ in mm. Hence, $MAR_{crop} > MAR_{base}$

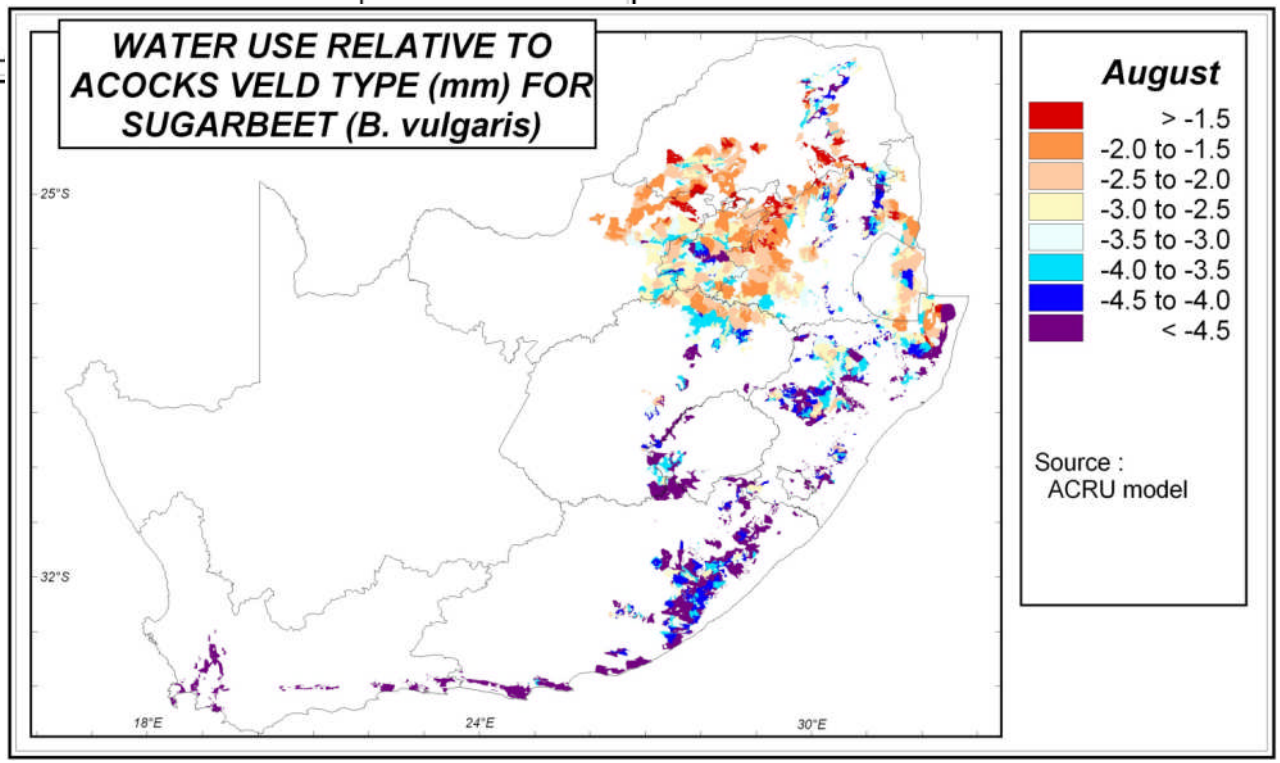
Sugarbeet uses less water than natural vegetation





Seasonal Differences

Crop uses more water than baseline in summer, especially inland areas.



Seasonal Differences

Crop uses less water than baseline in winter, especially coastal areas.

Discussion

- Crops that may use less water than natural vegetation
  - Sugarbeet
  - Sunflower
  - Canola
  - Soybean
- Crops that may use more water than natural vegetation
  - Sugarcane
  - Sweet sorghum
- Will biofuel production change the national water "picture"?
  - Impact at the local scale is uncertain
  - Impact on low flows is of more concern

Source: Jewitt *et al.* (2009)

The Way Forward

- Improve irrigation efficiency
  - Convert flood irrigation systems to micro/drip
  - Use the water savings to expand the area under irrigation
- Improve water productivity
  - Defined as crop yield per volume of water evapotranspired ($kg.m^{-3}$)
  - If crop yields are low, water productivity is low (and visa versa)
  - What is the role of biotechnology in improving crop yields?
    - 1.8 million ha of Bt maize grown in South Africa
  - Avoid marginal sites for crop production
    - Deviates from the Biofuel Strategy's goal to alleviate rural poverty

Useful References

- The impact of biofuel feedstock production on water resources: a developing country perspective
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