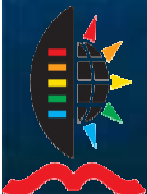


Water and Biofuel Research in SA

Centre for Water Resources Research
University of KwaZulu-Natal, Pietermaritzburg

Richard Kunz & Graham Jewitt
SANCID 2012 Symposium

22nd November 2012



Overview of Presentation

- National Biofuels Strategy for South Africa
 - Feedstock production limited by water availability, not land
- Mandatory blending rates
 - Biofuel production target volume
- Two WRC-funded projects on water use of biofuel feedstocks
 - Mapping areas climatically suited to feedstock growth
 - Assessment of feedstock water use and yield
 - Mapping and modelling framework overview
- Other bioenergy research initiatives
 - DST's Bioenergy Atlas

Biofuels Industry in South Africa

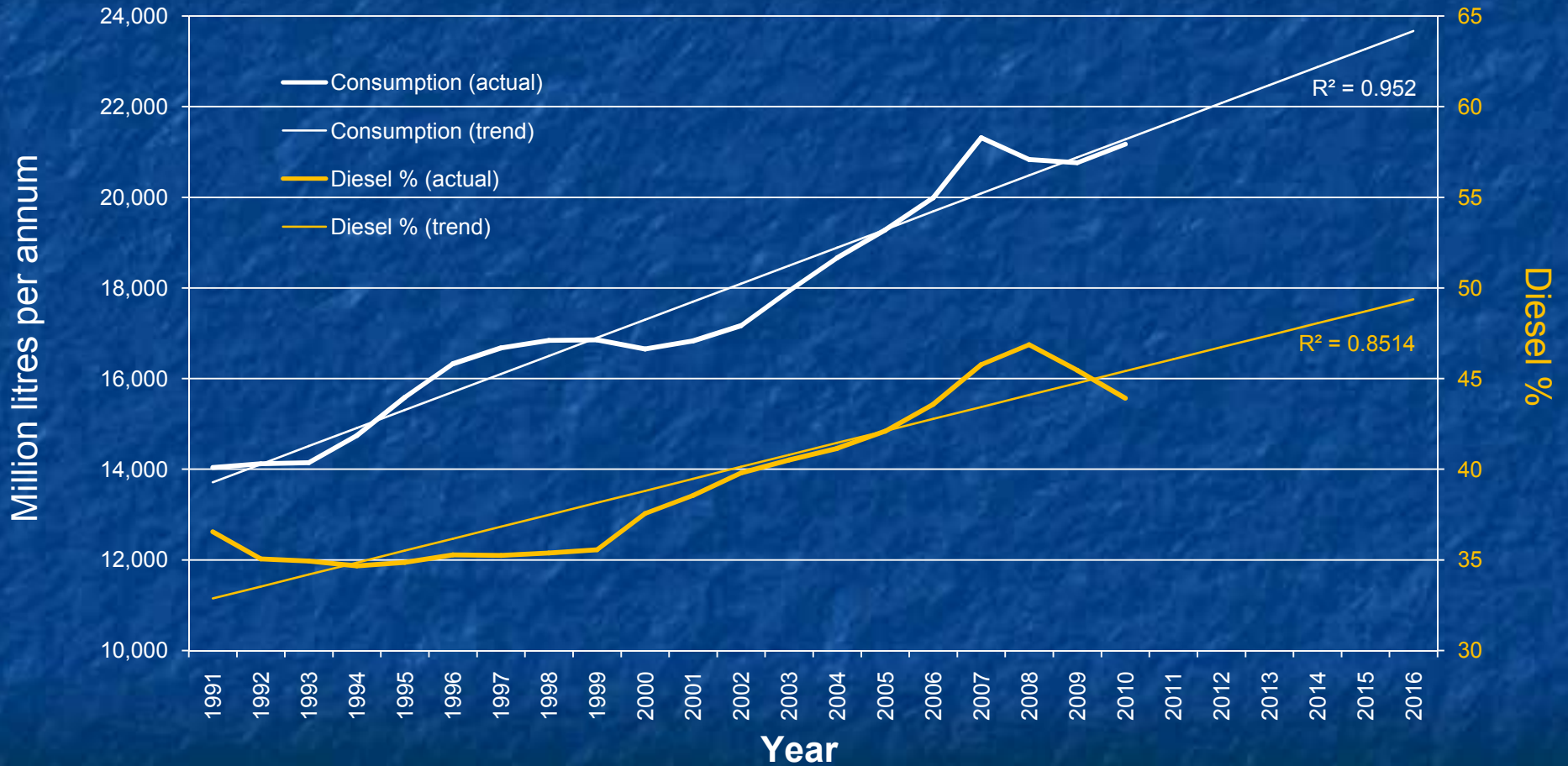
- Biofuel : Production of transport fuel from biomass containing
 - Sugar (crops → bioethanol)
 - Starch (crops → bioethanol)
 - Oil (crops/trees → biodiesel)
- The revised National Biofuels Industrial Strategy of 2007
 - 400 million litres of biofuel produced within five years (conservative)
 - Land area requirements for feedstock production
 - 300,000 ha of under-utilised arable land located in the former homelands
 - Impact of biofuel production on water quality and quantity
 - WRC should conduct research into the impacts of biofuel production on both water quality and quantity (prior to the roll out of the strategy)

Mandatory Blending Rates

- Minimum mandatory blending rates:
 - Biodiesel 5 % v/v: $0.05 \times 9.3 \text{ billion L (2010)} = 465 \text{ million L an}^{-1}$
 - Bioethanol 2-10 % v/v: $0.02 \times 11.8 \text{ billion L (2010)} = 240 \text{ million L an}^{-1}$
 $0.10 \times 11.8 \text{ billion L (2010)} = 1200 \text{ million L an}^{-1}$
 - Should research focus on bioethanol feedstocks?
- Proposed processing plants:
 - Cradock ethanol: 90 million L an⁻¹ from 230,000 t grain sorghum
or 1,200,000 t sugarbeet
 - Bothaville ethanol: 150 million L an⁻¹ from 400,000 t grain sorghum
or 375,000 t maize
 - Coega IDZ biodiesel: 288 million L an⁻¹ from 1,300,000 t soybean

Petroleum Demand in SA

Source: SAPIA (2012)



Does SA have sufficient land and water to produce > 700 million litres of biofuel?

Water Research Commission

- Two biofuel projects funded by the WRC:
 - **Project K4/1772**
 - “Scoping study on water use of crops/trees for biofuels in South Africa”
 - Reported published in November 2009
 - **WRC Report No. 1772/1/09 (ISBN 978-1-77005-884-2)**
 - High uncertainties exist for emerging crops, in particular:
 - **Sweet Sorghum**
 - **Sugarbeet**
 - Feedstocks that may use more water than natural vegetation:
 - **Sugarcane**
 - **Sweet Sorghum**
 - **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 pages 198-199 of WRC Knowledge Review 2011/12
 - http://www.wrc.org.za/Pages/KH_KnowledgeReviews.aspx?dt=8&ms=59;

Project Background

- Funding Water Research Commission (K5/1874)
Department of Agriculture, Forestry and Fisheries
- Contractor Centre for Water Resources Research (CWRR, UKZN)
- 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
- Principal Researcher Mr Richard Kunz
- Budget R 7.4 million



The Project Team

- UKZN
 - Prof Graham Jewitt (Project Leader)
 - Richard Kunz (Principal Researcher)
 - **Prof Colin Everson** (Crop water use)
 - **Dr Michael Mengistu** (Crop water use)
- UP
 - Prof Elsa du Toit (Moringa)
 - Prof Martin Steyn (Crops)
- CSIR
 - Dr Mark Gush (Jatropha)
 - Vivek Naiken (Field Technician)



Capacity Building

- UKZN
 - Andrew Pickles (Sweet Sorghum)
 - Thobani Khomo (GIS mapping)
 - Ofentse Mokonoto (Water use modelling)
 - Richard Kunz (Crop yield modelling)
- UP
 - Michael Ghebru (Moringa)
 - Hanson Hlope (Sweet Sorghum)



The Reference Group

- WRC Managers
 - Dr Andrew Sanewe
 - Dr Gerhard Backeberg
- Reference Group
 - Mr AT van Coller (DAFF)
 - Ms N Fourie (DWA)
 - Mr X Hadabe (DWA)
 - Prof A Brent (Stellenbosch University)
 - Mr P van Heerden (PICWAT)
 - Mr D Versfeld (Dirk Versfeld cc)
 - **Dr A Singels** (SASRI)
 - Mr A Meyer (SASOL – New Energy Group)
 - Dr T Mali (SANERI)
 - Mr S Xosa (DST)
 - Mr K Zihlangu (DoE)

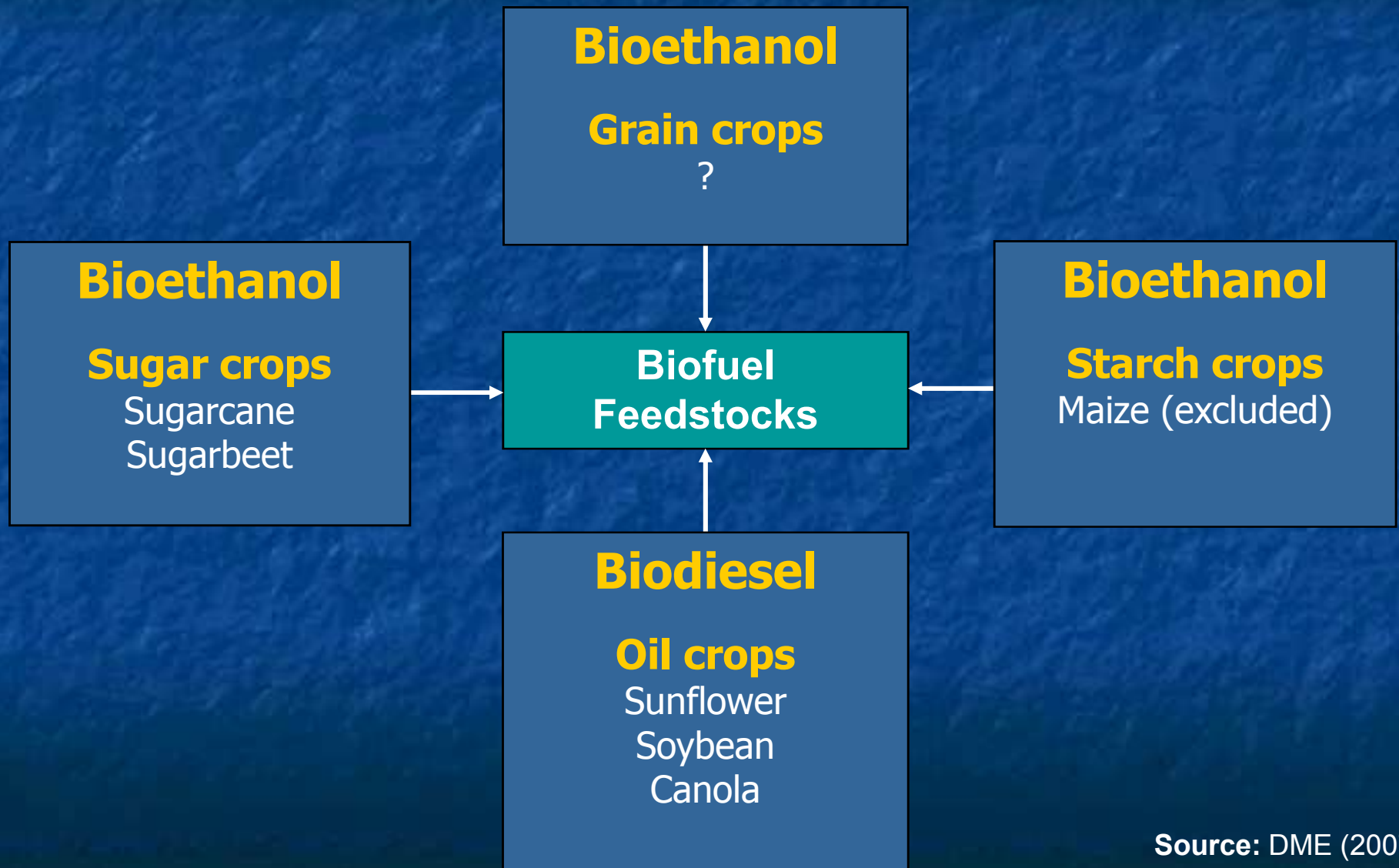
Project's General Objective

- To determine the water use of:
 - Potential biofuel feedstocks
 - Crops (annual)
 - Trees (perennial)
- for biofuel production
 - Bioethanol
 - Biodiesel
- in selected bio-climatic regions of South Africa
 - High potential (i.e. optimal)
 - Low potential (i.e. sub-optimal)

Aims and Objectives

- Identify suitable feedstocks for biofuel production in SA
 - Literature review & workshop identified potential feedstocks
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 - Simulation modelling using hydrological & crop yield models

Proposed Feedstocks in Strategy



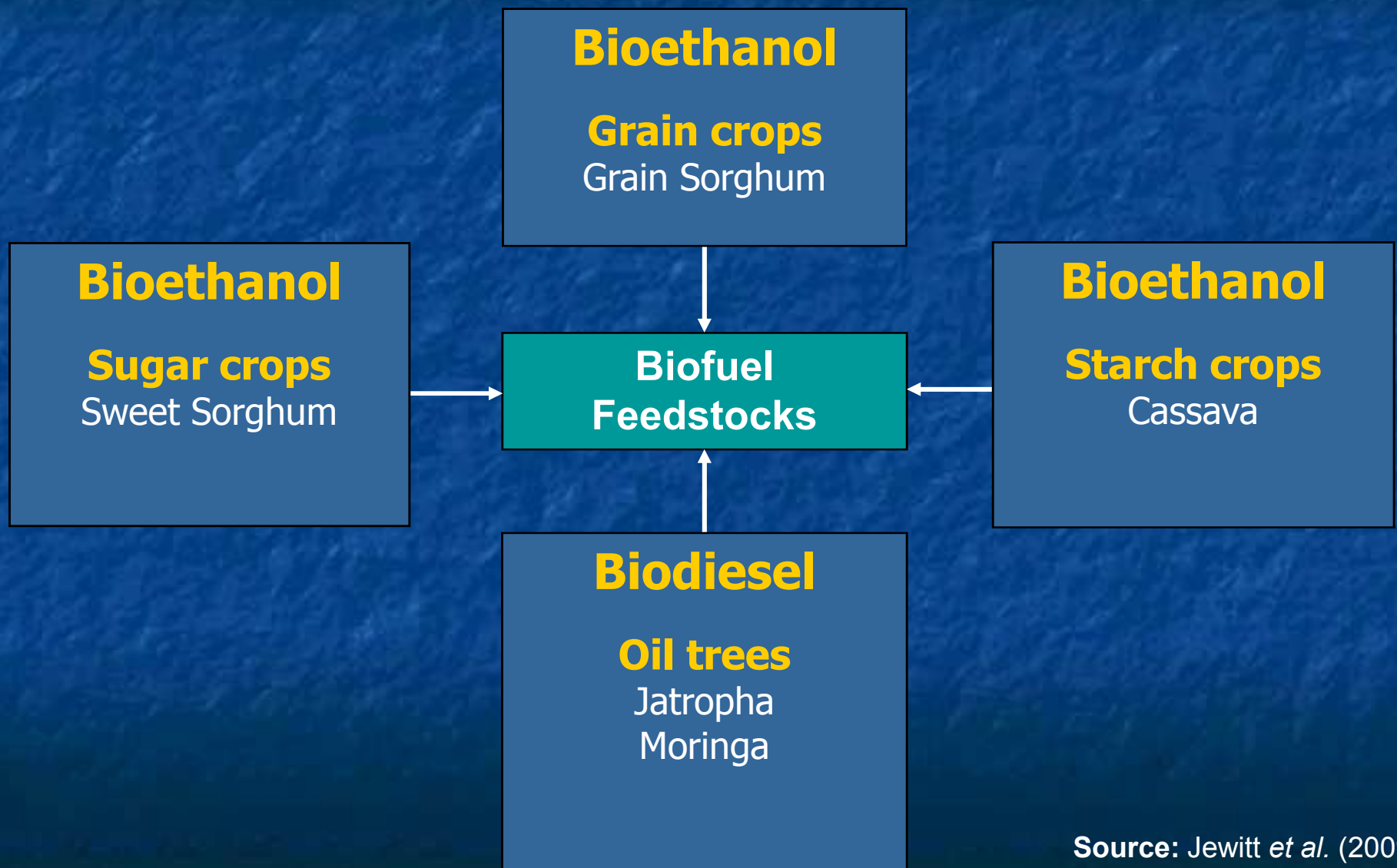
Source: DME (2007)



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Other Potential Feedstocks



Source: Jewitt *et al.* (2009)

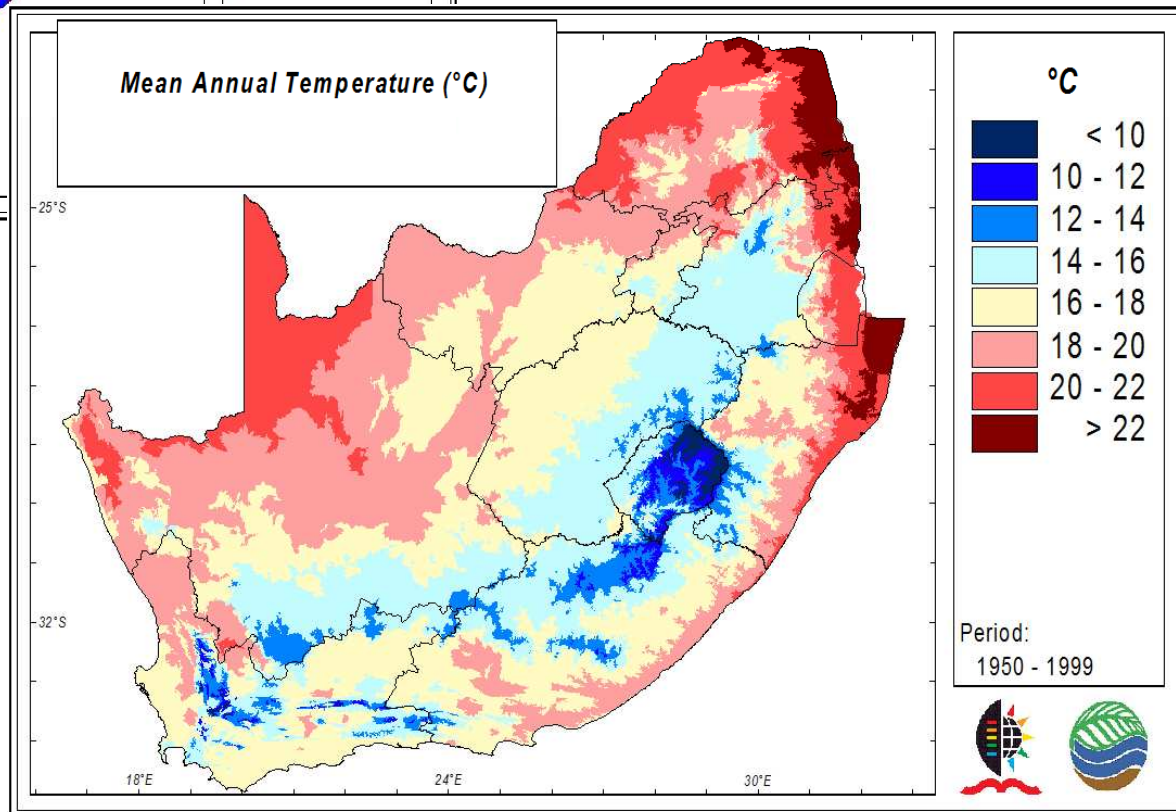
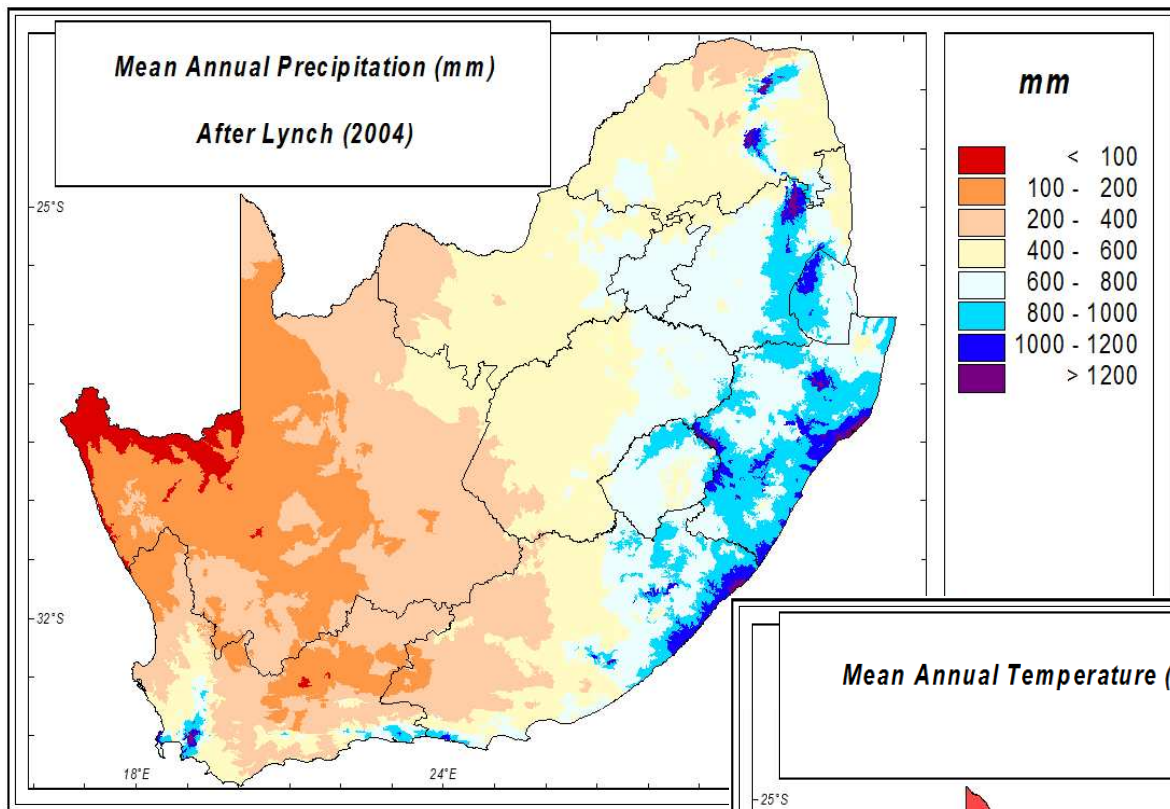
Aims and Objectives

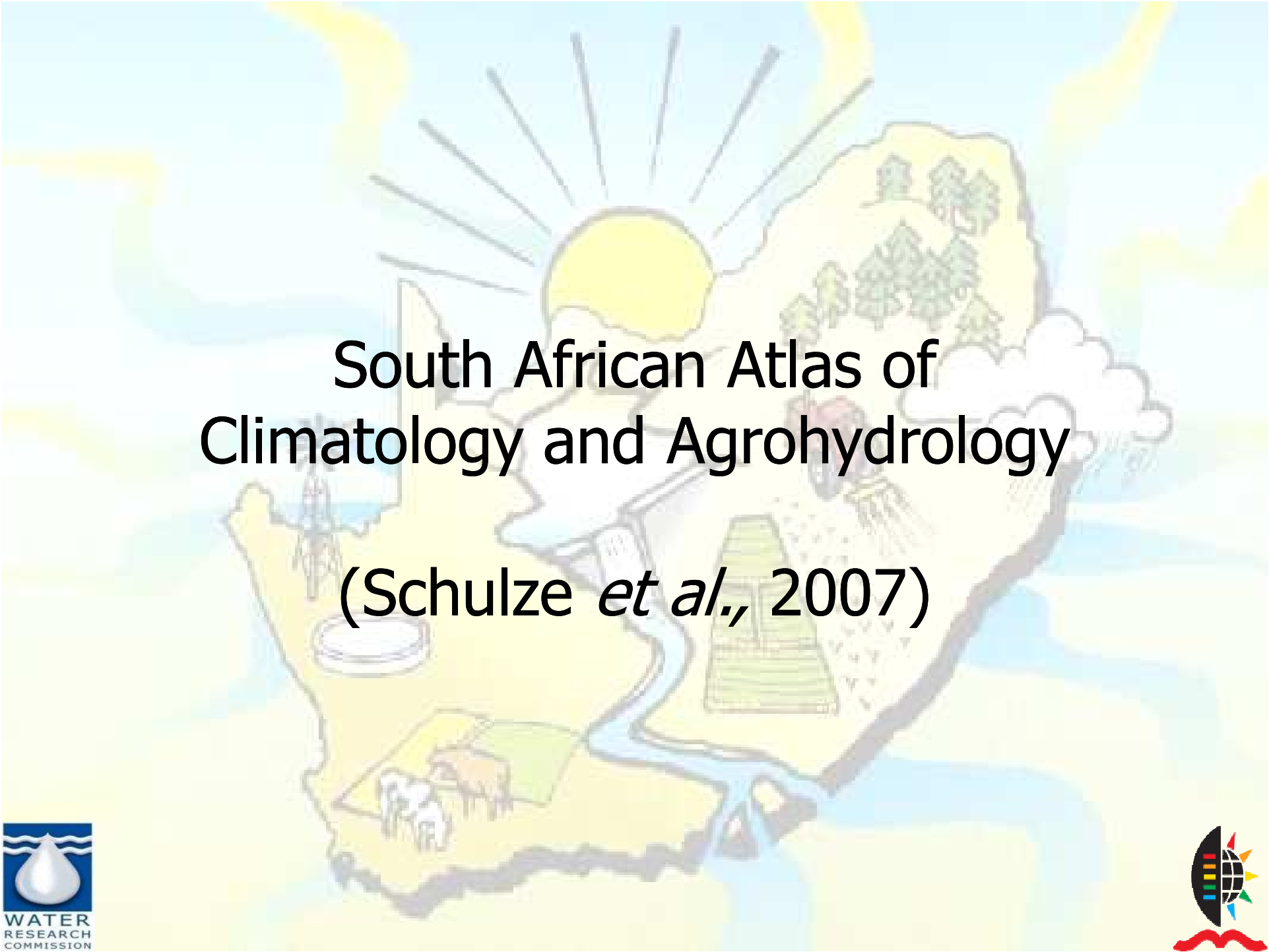
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Climatic Thresholds for Growth

Crops	MAP (mm)	SRT (mm)	MAT (°C)	T _{ave} (°C)	T _{min} (°C)	T _{max} (°C)	Plant date	Growth days
Canola	500 - 1000				> 5	< 25	1 st Jun	140
Cassava	> 1000		20 - 29					
Jatropha	500 - 1500		11 - 28		Frost free areas			
Sorghum		450 - 650		20 - 25 (T _{jan} > 21)			1 st Nov	115
Soybean		550 - 700		20 - 30			1 st Nov	150
Sugarbeet	550 - 750		15 - 25		> -1		1 st Aug	200
Sugarcane	850 - 1500		> 18		T _{jun} > 5 T _{jul} > 5			
Sunflower		400 - 600		18 - 25 (T _{jan} > 19)			1 st Dec	125

Source: Jewitt *et al.* (2009)

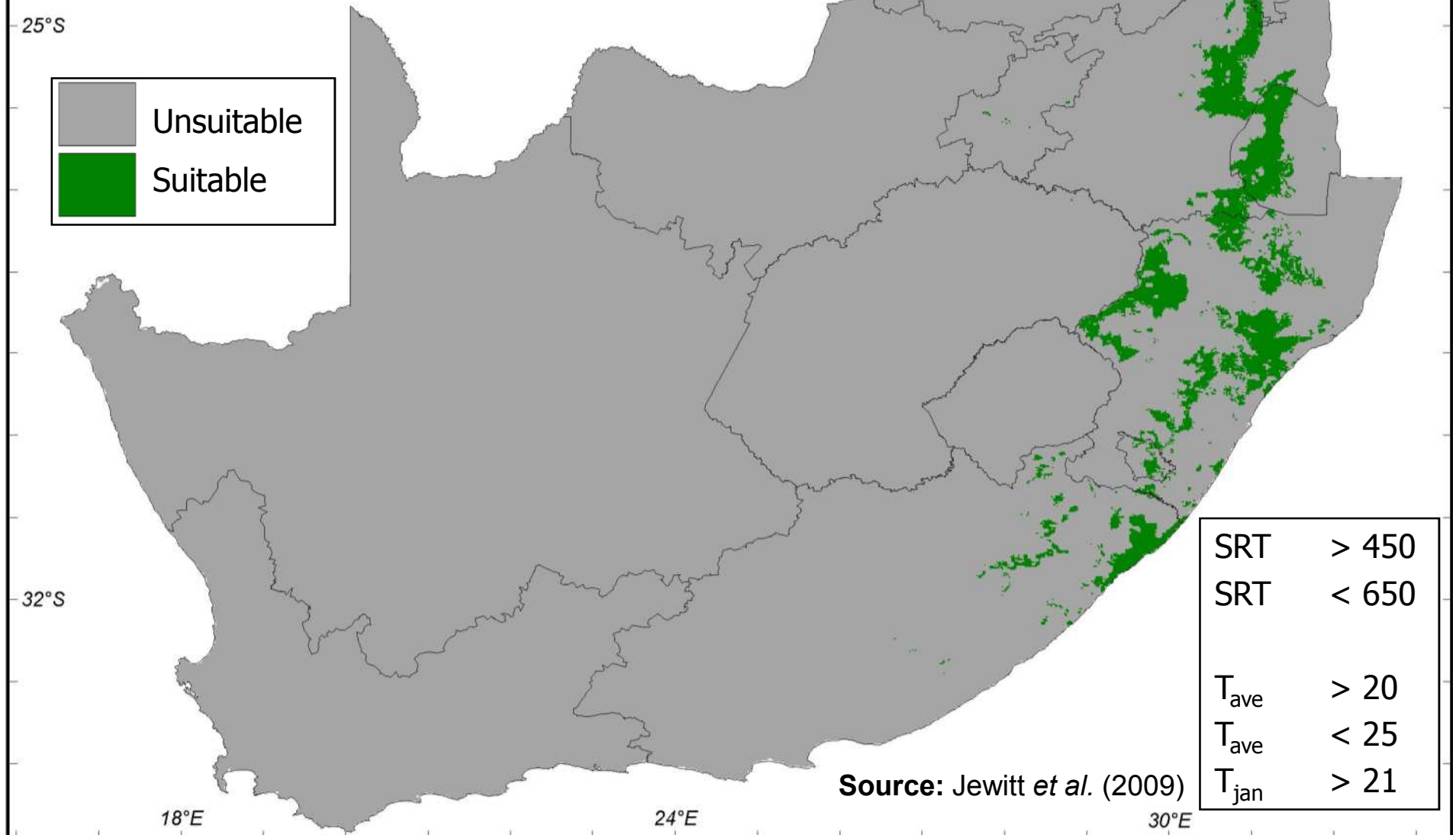


A stylized map of South Africa is the central focus, rendered in light yellow and blue tones. Overlaid on the map are various icons representing climate and agriculture: a large sun with rays at the top, a cluster of green trees on the right, a blue river winding through the center, a white cloud on the right, a windmill on the left, a pyramid in the lower center, and a farm with cows and a barn in the bottom left. The background is a light blue sky with yellow clouds.

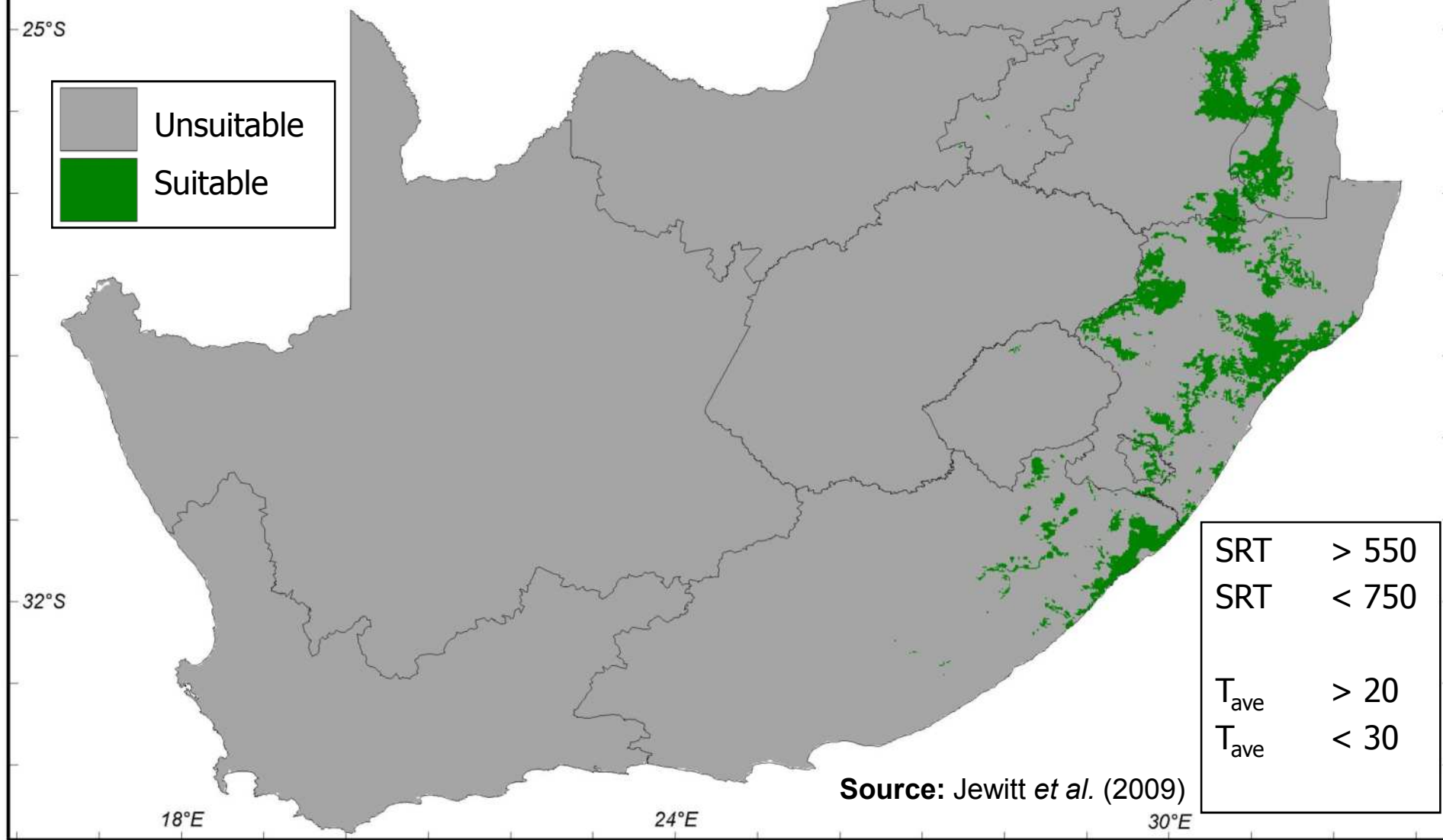
South African Atlas of Climatology and Agrohydrology

(Schulze *et al.*, 2007)

CLIMATIC OPTIMUM GROWTH AREAS FOR SWEET SORGHUM (*Sorghum vulgare Pers.*)



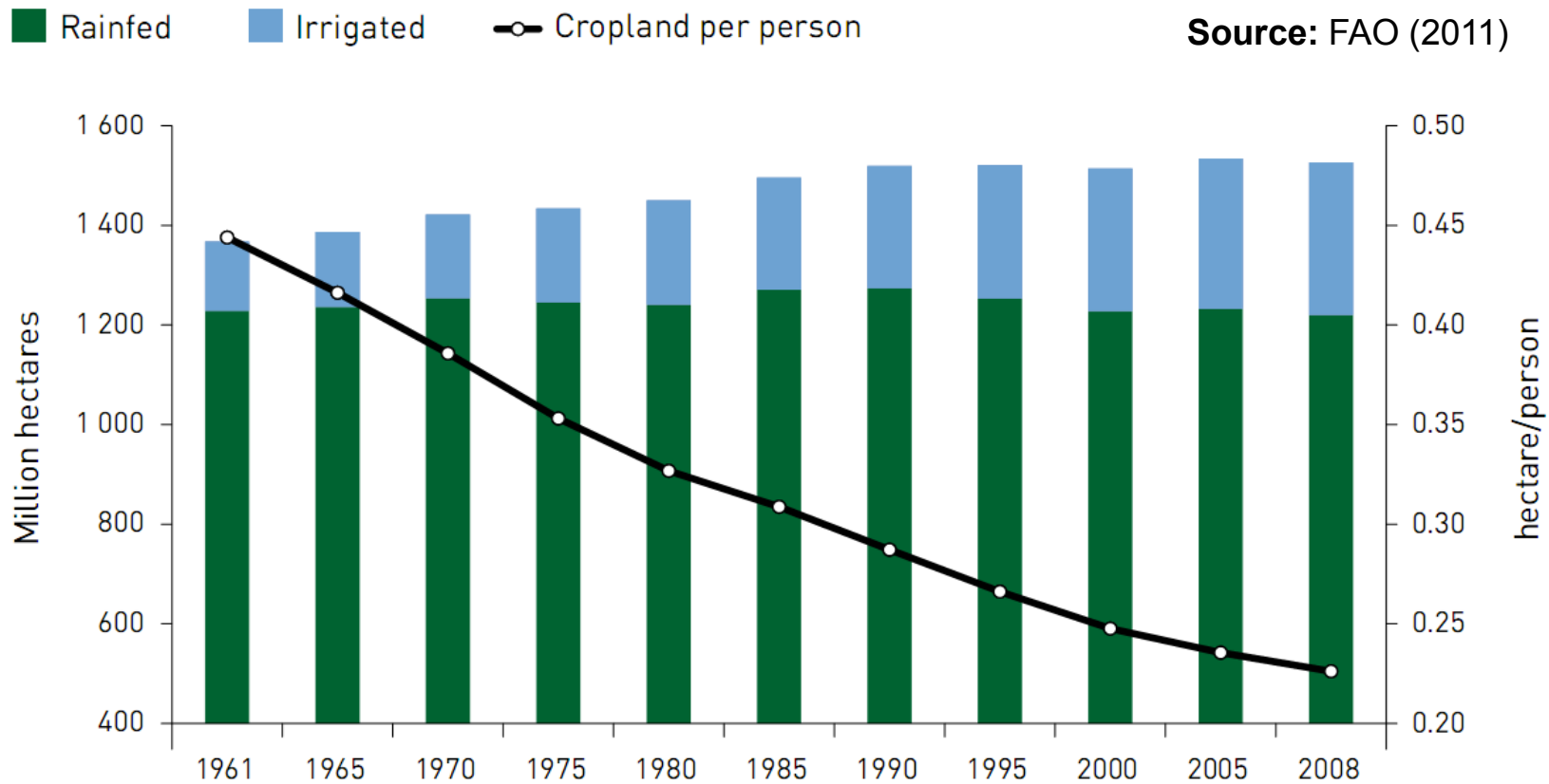
CLIMATIC OPTIMUM GROWTH AREAS FOR SOYBEAN (*Glycine max*)



Source: Jewitt *et al.* (2009)

Land Area for Food Production

- Arable land needed for food production
 - 13 million ha required to feed 51.8 million people (@ 0.25 ha/person)
 - Expansion of agricultural land to feed the growing population

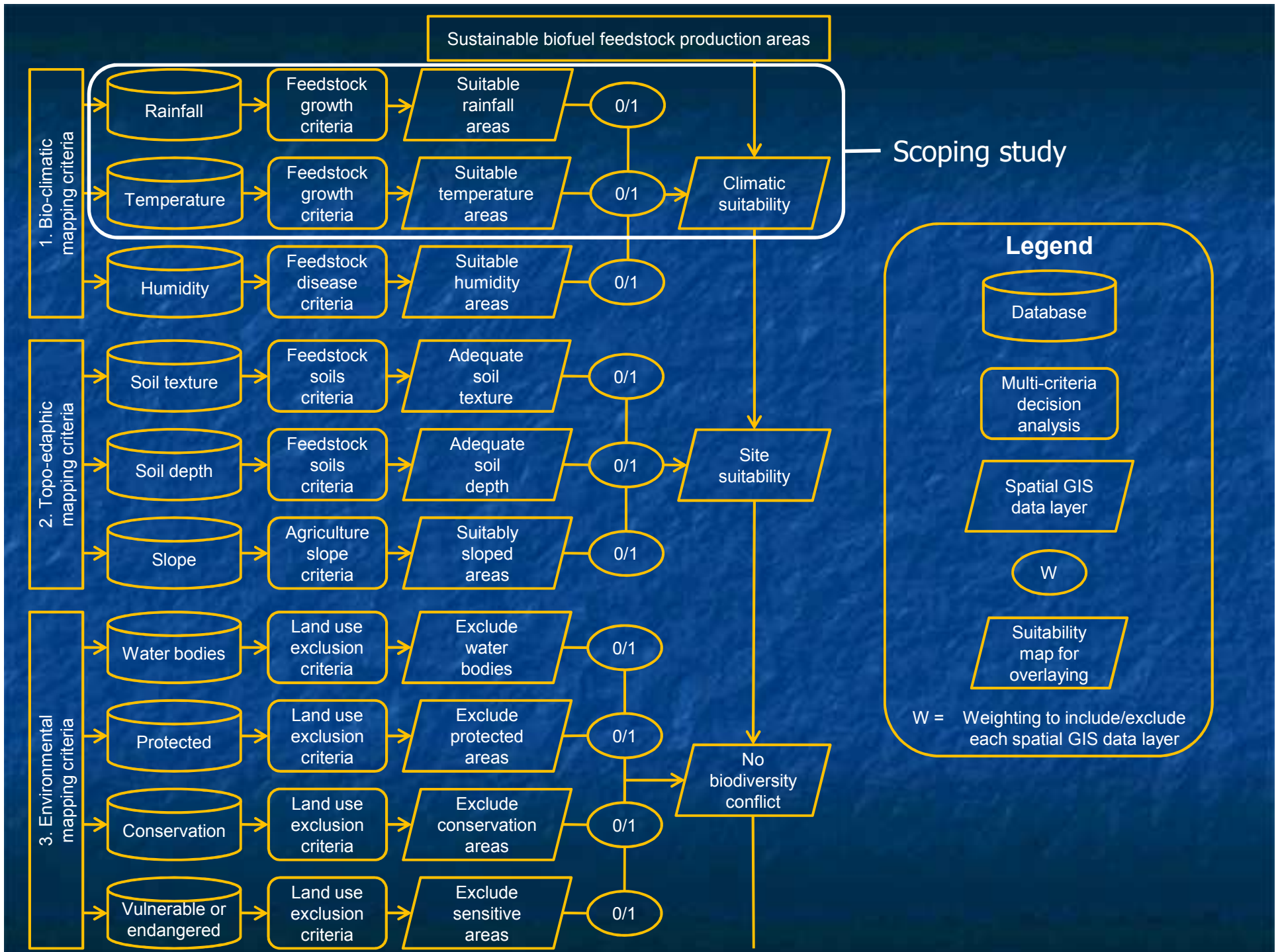


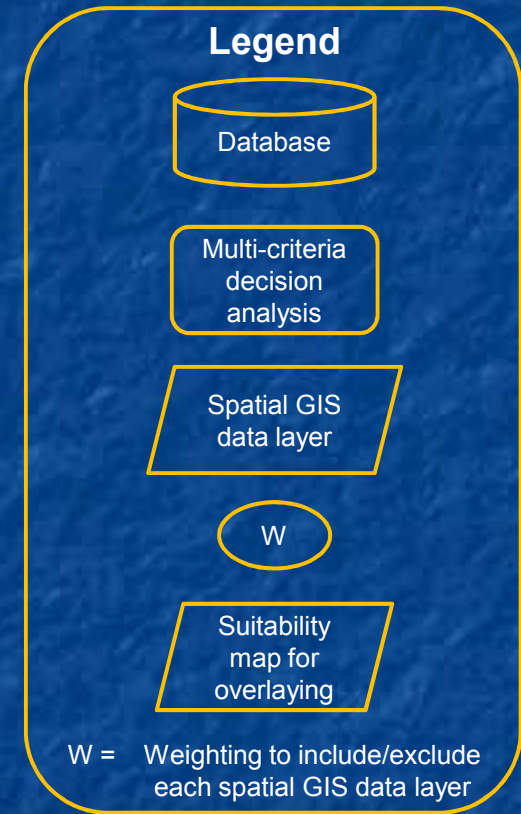
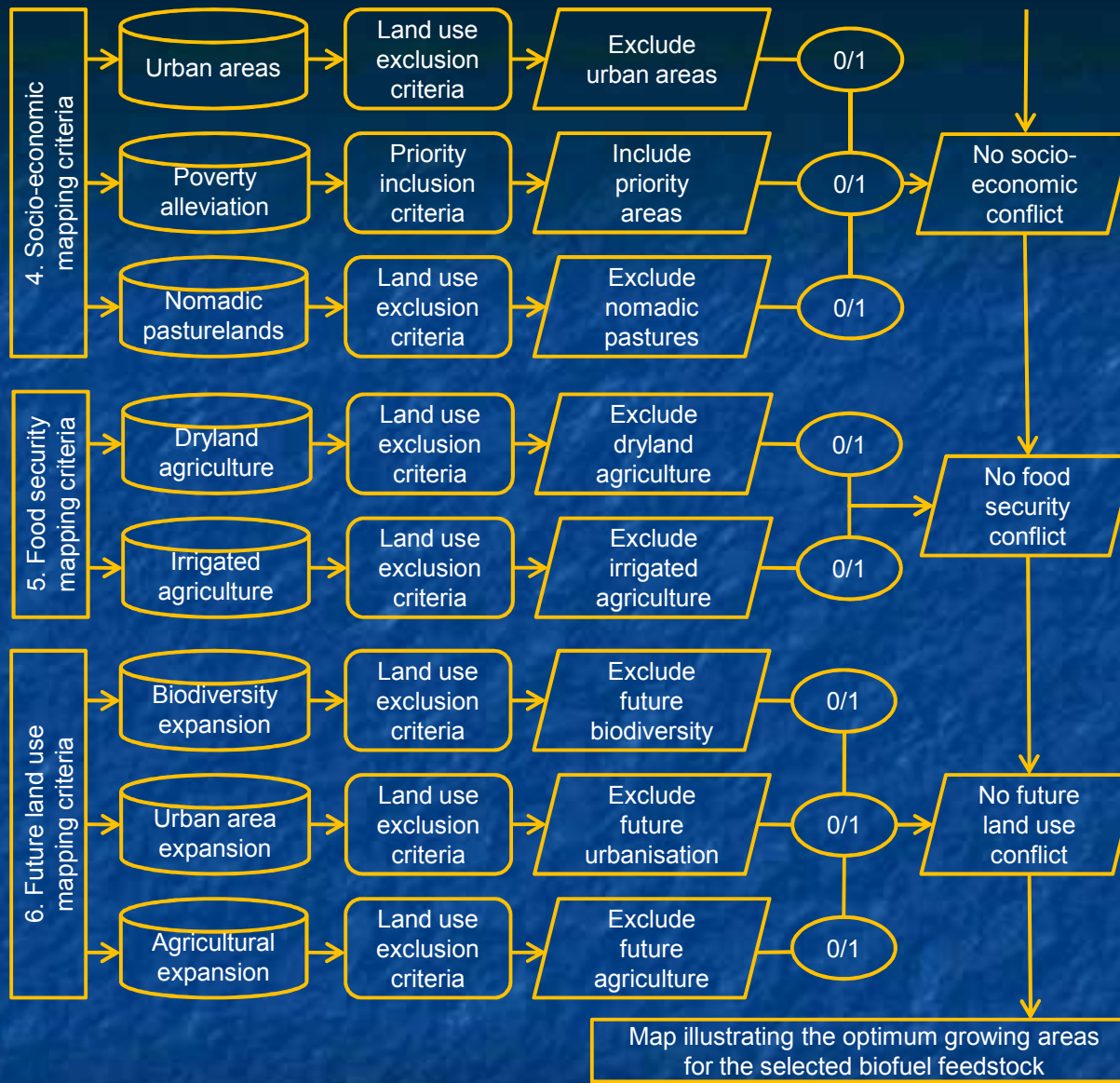
Land Area for Biofuel Production

- Sufficient land exists to produce biofuel feedstocks in SA
- 3.0 million ha of under-utilised land in the former homelands (DME, 2007)
- At least 30 % of Cradock grain sorghum sourced from developing farmers
- Expand agriculture in KZN by 1 million ha by 2030 (PGDP, 2012)
 - 22 % of arable Ngonyama Trust land (former KwaZulu) is idle (Lyne, 1989)

Province	Arable land in South Africa (ha)		
	Potential	Developing	Commercial
Free State	4,221,423	34,900	4,186,523
North West	3,360,459	951,975	2,408,484
Western Cape	2,454,788	0	2,454,788
Eastern Cape	1,172,901	529,400	643,501
Limpopo	1,700,442	530,700	1,169,742
Mpumalanga	1,734,896	137,898	1,596,998
KwaZulu-Natal	1,199,675	360,700	838,975
Gauteng	438,623	0	438,623
Northern Cape	454,465	0	454,465
Total	16,737,672	2,545,573	14,192,099

Source:
DAFF (2012)





Mapping of Suitable Production Areas

Land Area for Biofuel Production

- Land area required to produce 1 million litres of biofuel
 - More land area required to produce biodiesel than ethanol
 - 220,000 ha required to produce 630,000 tons of grain sorghum

Crop	Extraction yield (litres per ton)	Crop mass (tons)	Crop yield (tons per ha)	Harvest area (hectares)
Sugarcane	81.4 ¹	12,285	64.79 ²	191
Maize	402.3 ¹	2,486	4.92 ⁴	506
Sorghum	370.0 ³	2,703	2.94 ⁴	919
Sunflower	398.0 ¹	2,513	1.55 ⁴	1,625
Soybean	171.4 ¹	5,834	1.60 ⁴	3,646

Data sources:

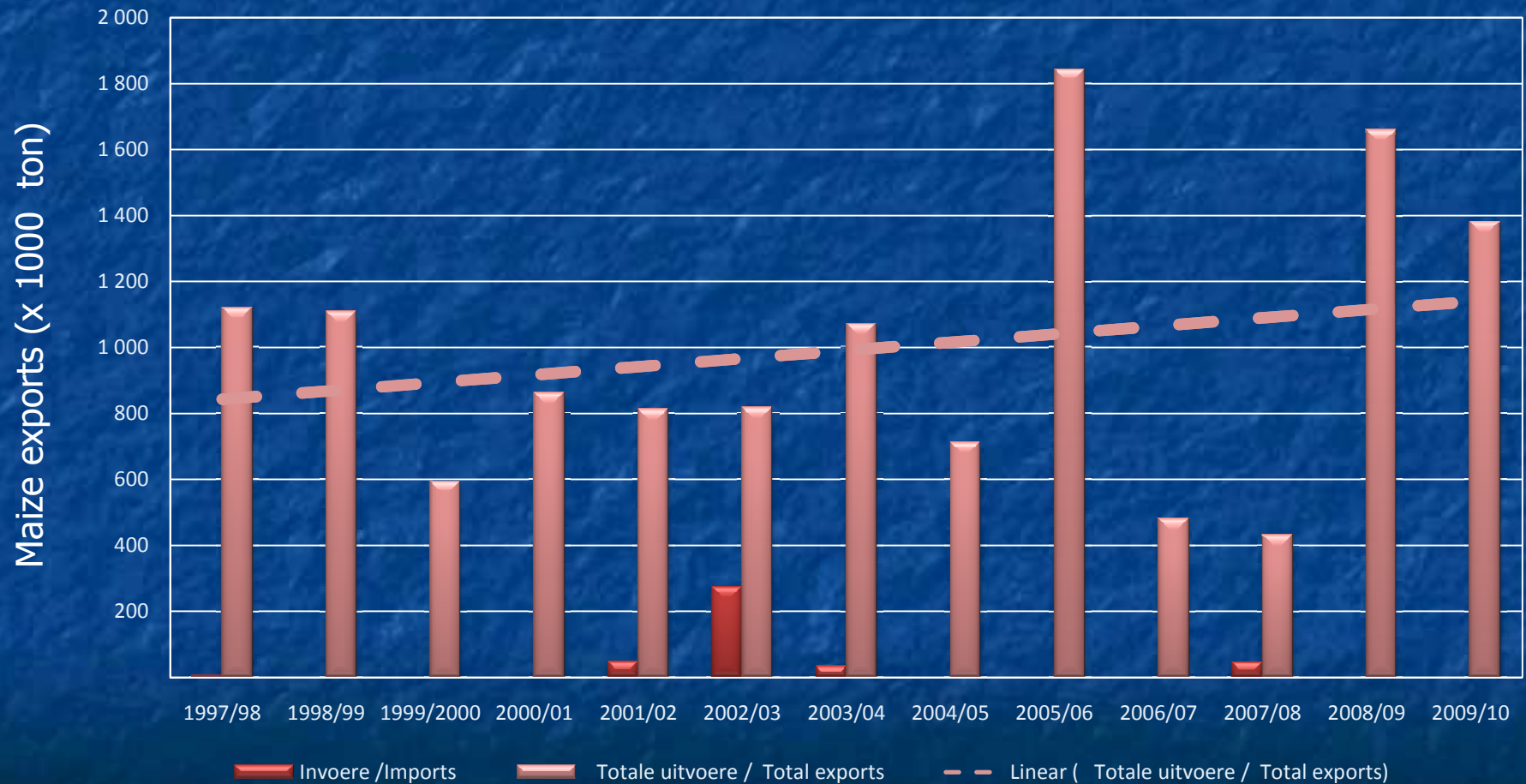
¹DME (2006)

²SASA (2009)

³BFAP (2008)

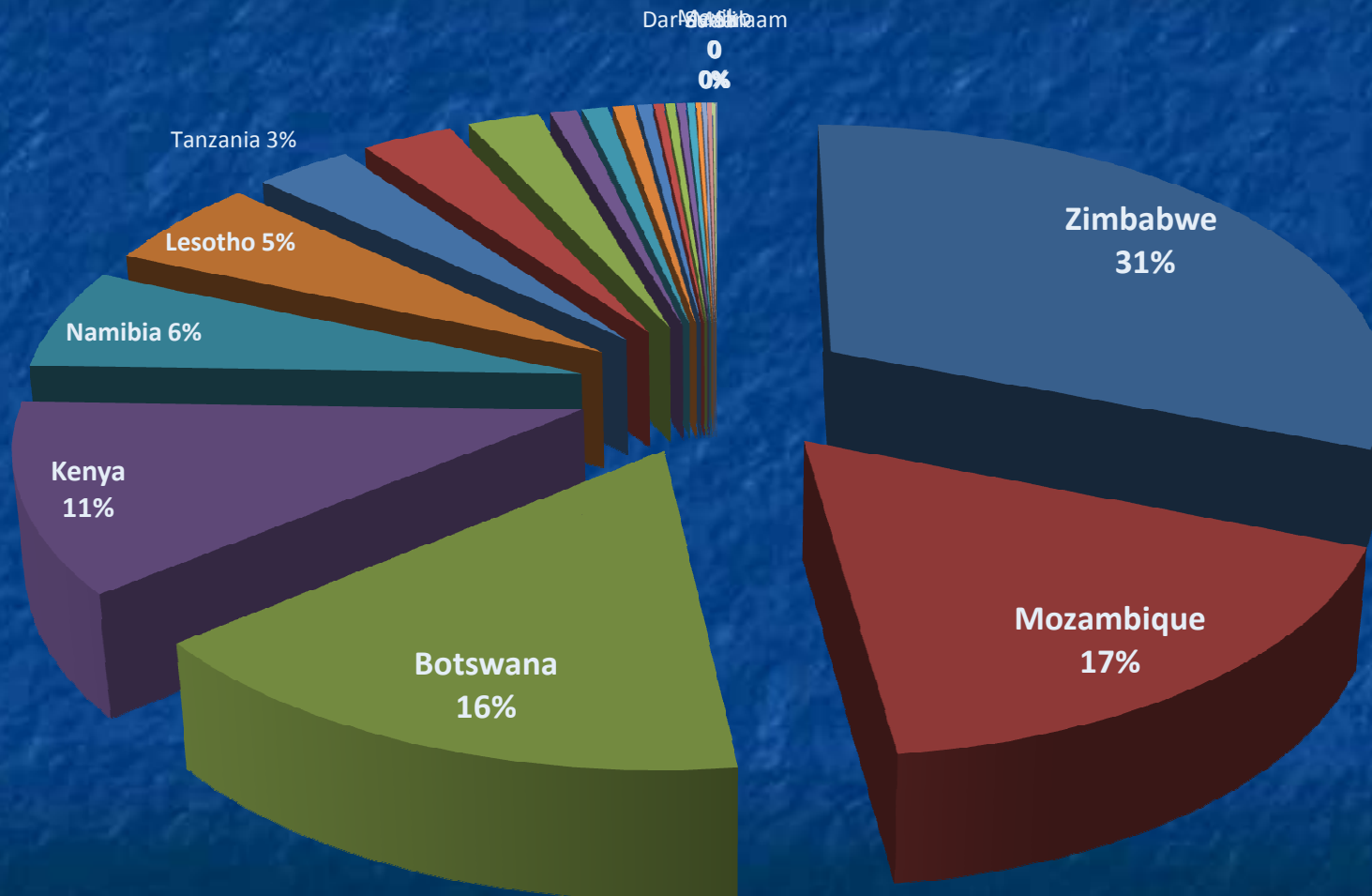
⁴BFAP (2009)

1.1 million tons of white maize exported annually to Africa



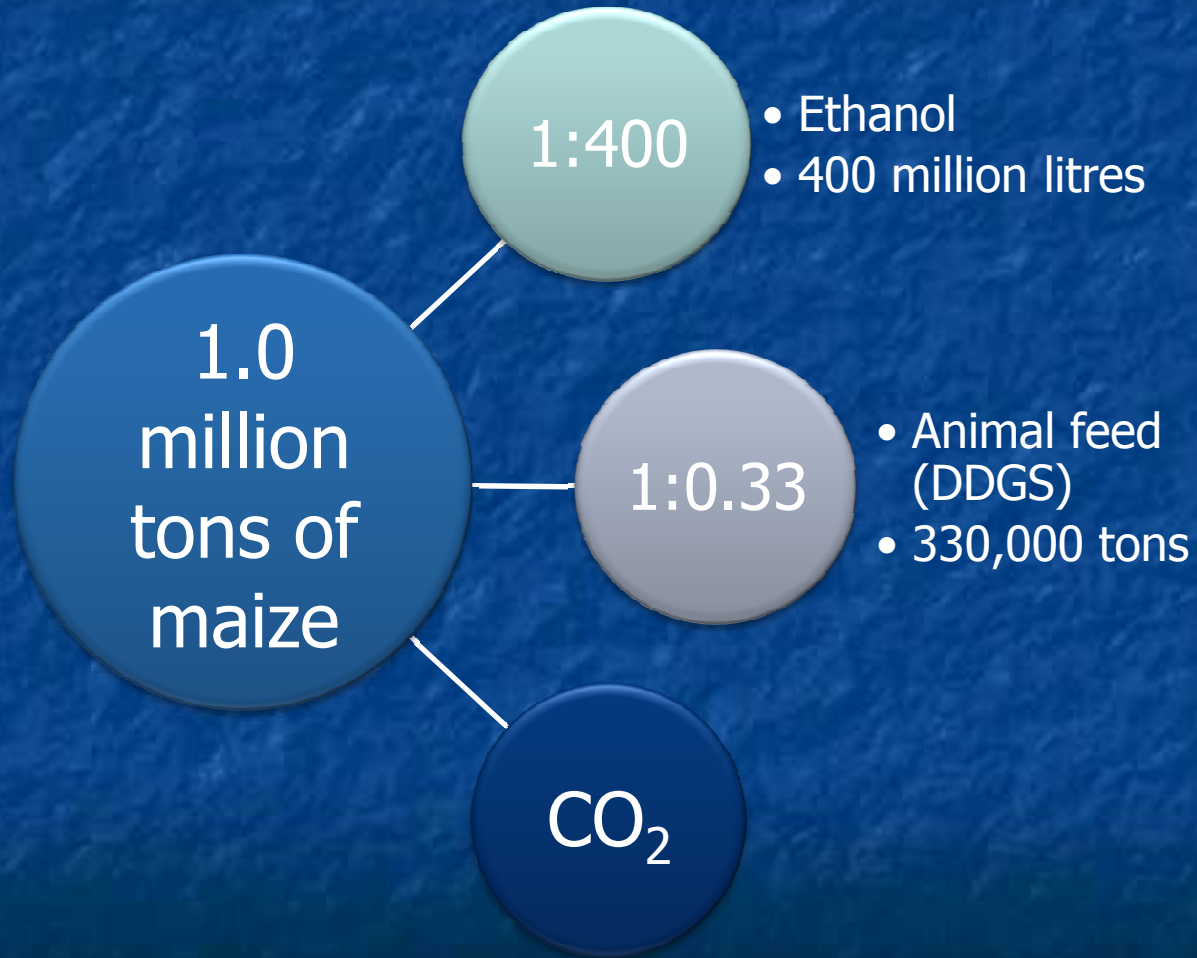
Source: Lemmer (2009)

White maize is exported to African countries



Source: Lemmer (2009)

Maize-to-ethanol Production

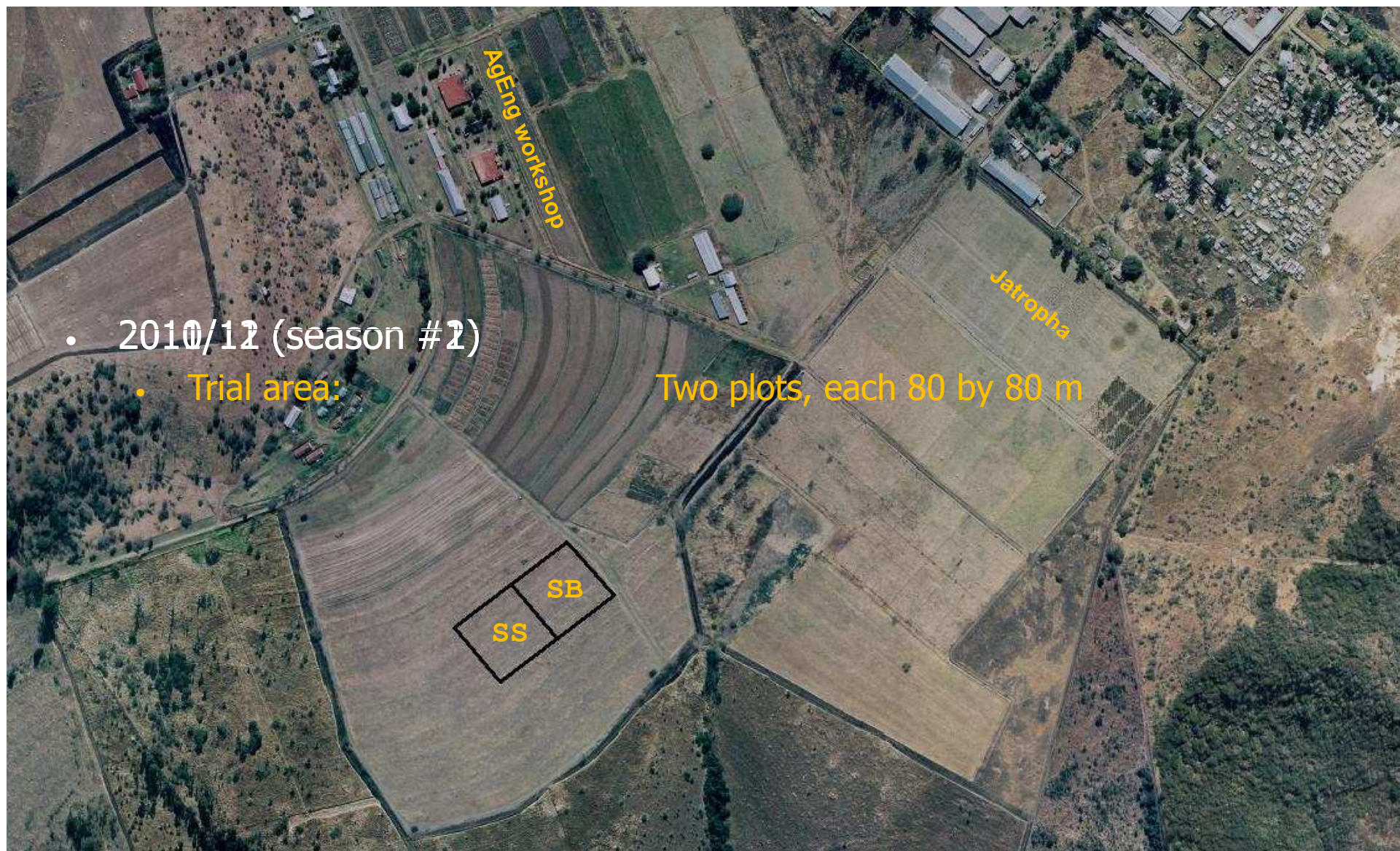


Source: Lemmer (2009)

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Location of Ukulinga Trials



- 2010/11 (season #1)

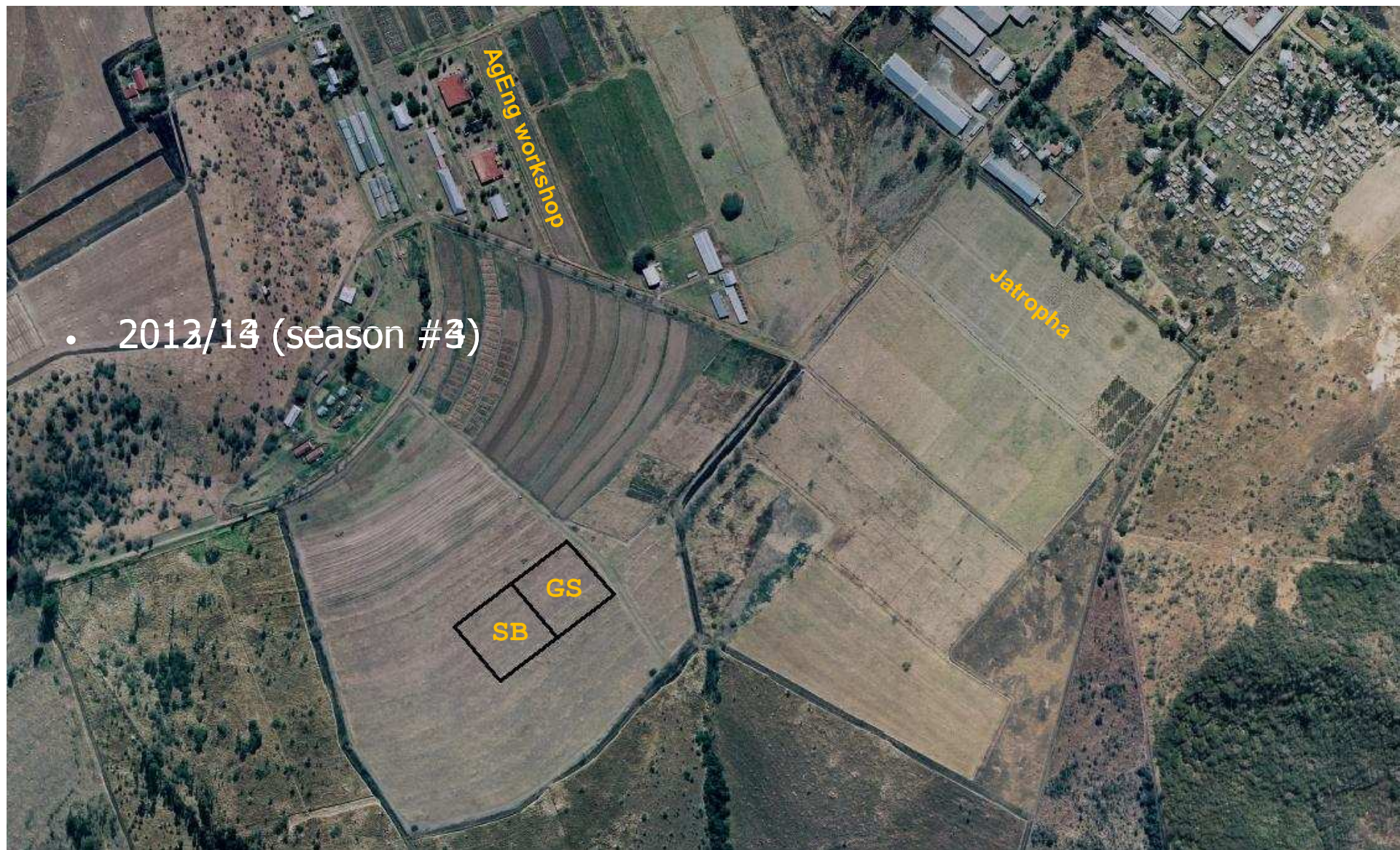
- Trial area:

Two plots, each 80 by 80 m

Location of Ukulinga Trials



Location of Ukulinga Trials

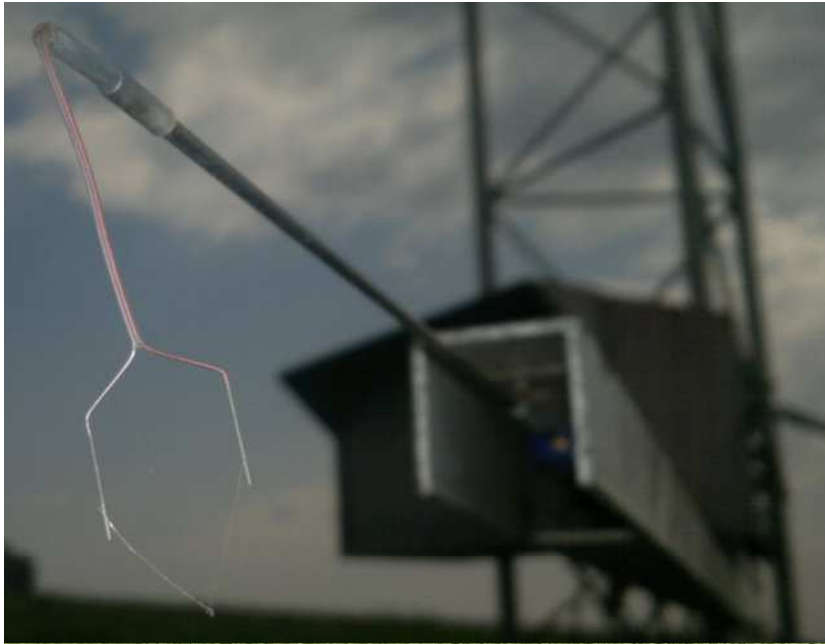


Measuring Feedstock Water Use



Measuring Feedstock Water Use

← Surface Renewal (fine-wire thermocouple)



Sweet Sorghum (Ukulinga)



01/02/2011

Sweet Sorghum (Ukulinga)





Jatropha (Ukulinga)





Aims and Objectives

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Feedstock Water Use

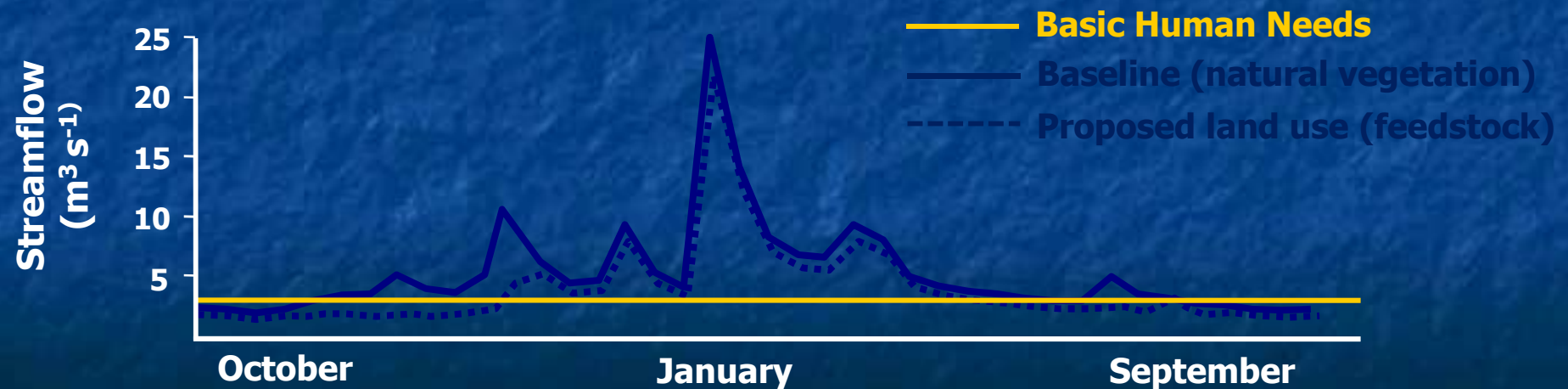
- DWA's stance on feedstock irrigation:
 - DWA promotes use of unproductive land under dryland conditions
 - DWA does not support irrigation of biofuel feedstocks
 - Irrigation water charged at industrial rate, not subsidised agricultural rate
 - Animal feed (DDGS + beet pulp) is the main product
 - Ethanol is a by-product
- Specific questions that DWA need addressing:
 - Water use impacts of communal land farming?
 - Within 80 km radius of proposed processing plant
 - Which feedstocks should be declared a SFRA?
 - Water use of processing plants?

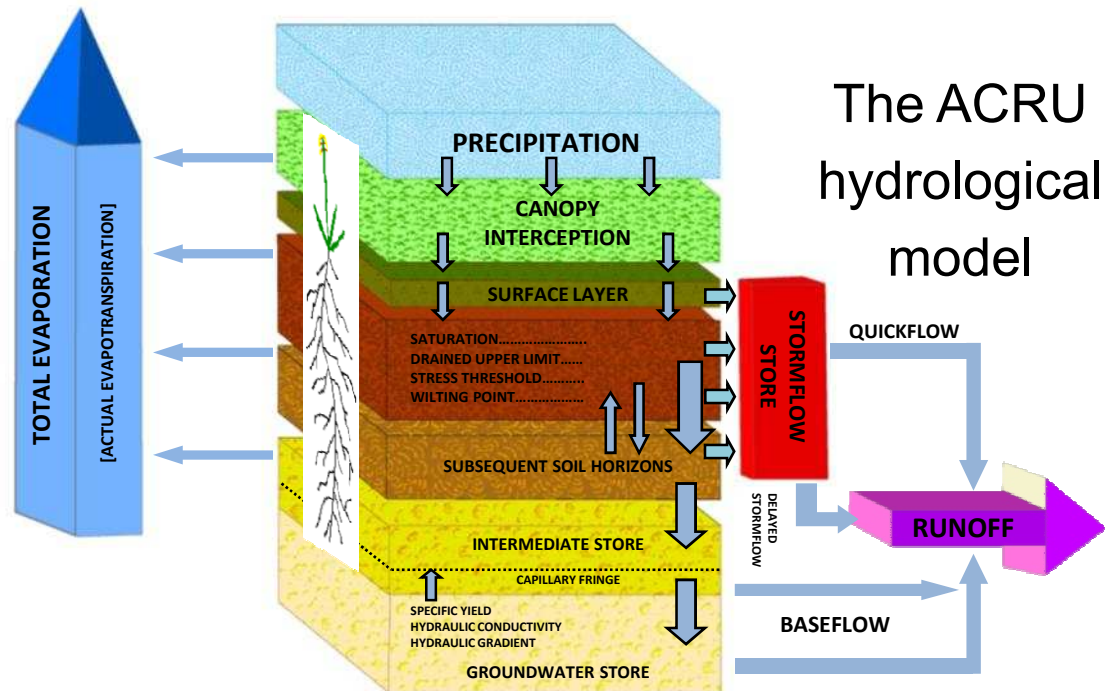
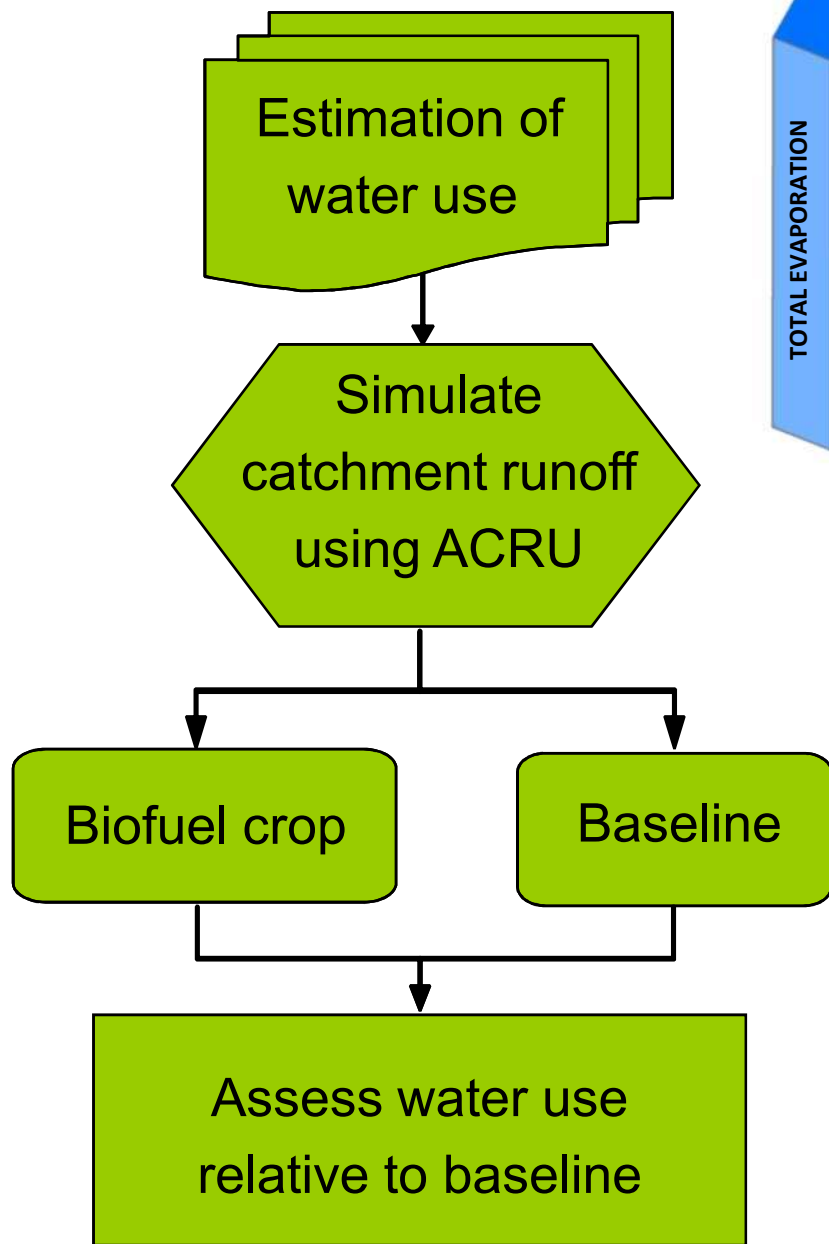
Feedstock Water Use

- Water used to grow the feedstock > water used to produce the biofuel
 - Water use during growth stage is the biggest unknown
 - MozPEL sugarcane-to-ethanol project at Dombe, Mozambique
 - Offices and houses: 0.65 ML d⁻¹
 - Processing plant: 3.24 ML d⁻¹
 - Irrigation requirement: 449 ML d⁻¹ (20,000 ha @ 820 mm per annum)
 - IDC grain sorghum-to-ethanol project at Cradock, Eastern Cape
 - Processing plant: 4.44 ML d⁻¹
 - DRDLR “forfeited” 120 ha of land (@ 1,350 mm of irrigation)
 - Irrigation requirement: ? ML d⁻¹
 - 8,000 ha of farmland purchased to date (require additional 1,000 ha)
 - 70 % of the sugarbeet lands will be flood irrigated
 - Canals are 240 km in length (25 % conveyance losses)
 - Evaporative demand ranges from 1,100 to 1,350 mm
- Source:** CEPLAGA (2009)
- Source:** Maclachlan (2012)

Impact of Land Use on Streamflow

- 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





Parameterise ACRU for:

- Baseline conditions (natural vegetation)
- Each biofuel crop

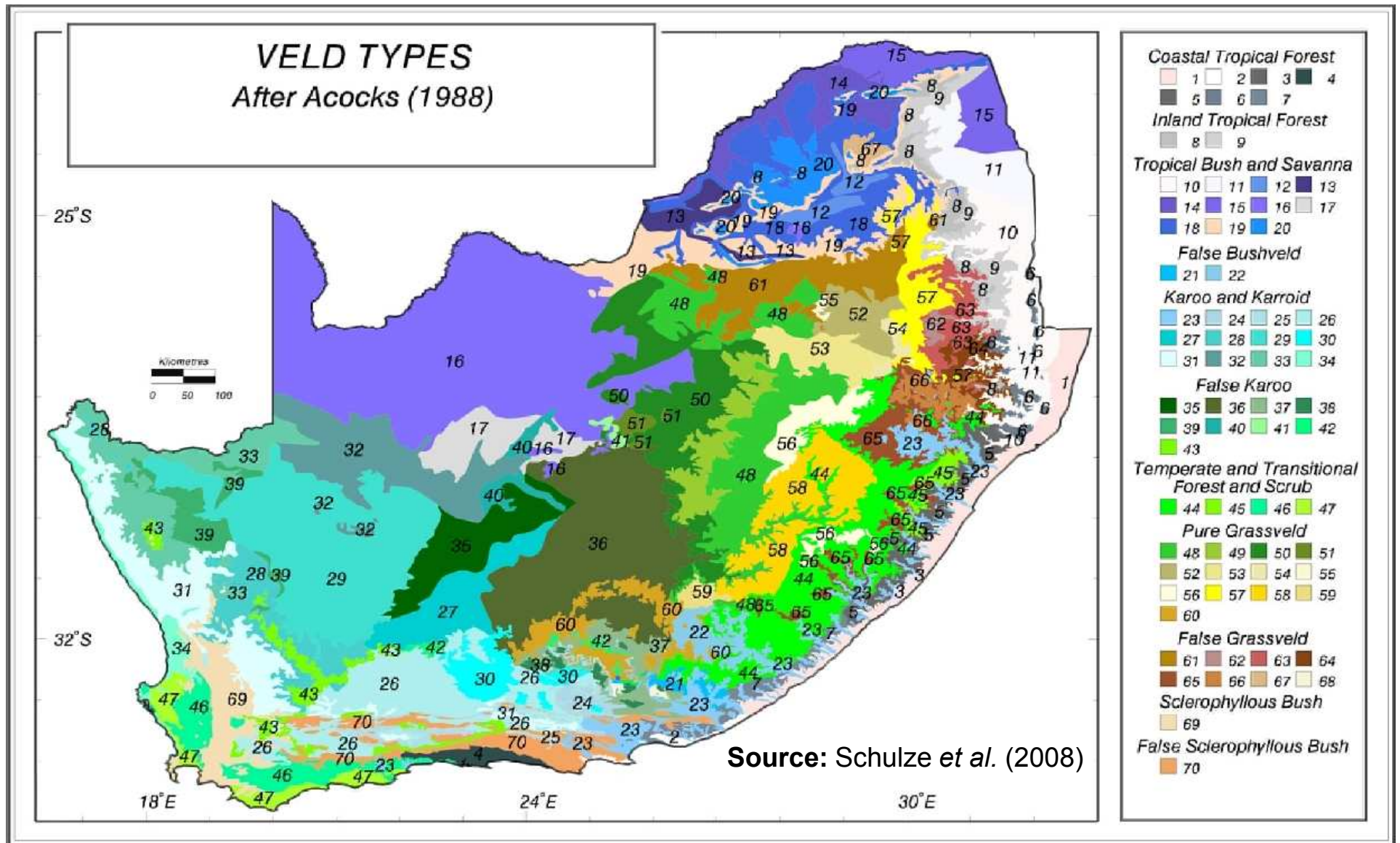
Simulate catchment annual runoff for:

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

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

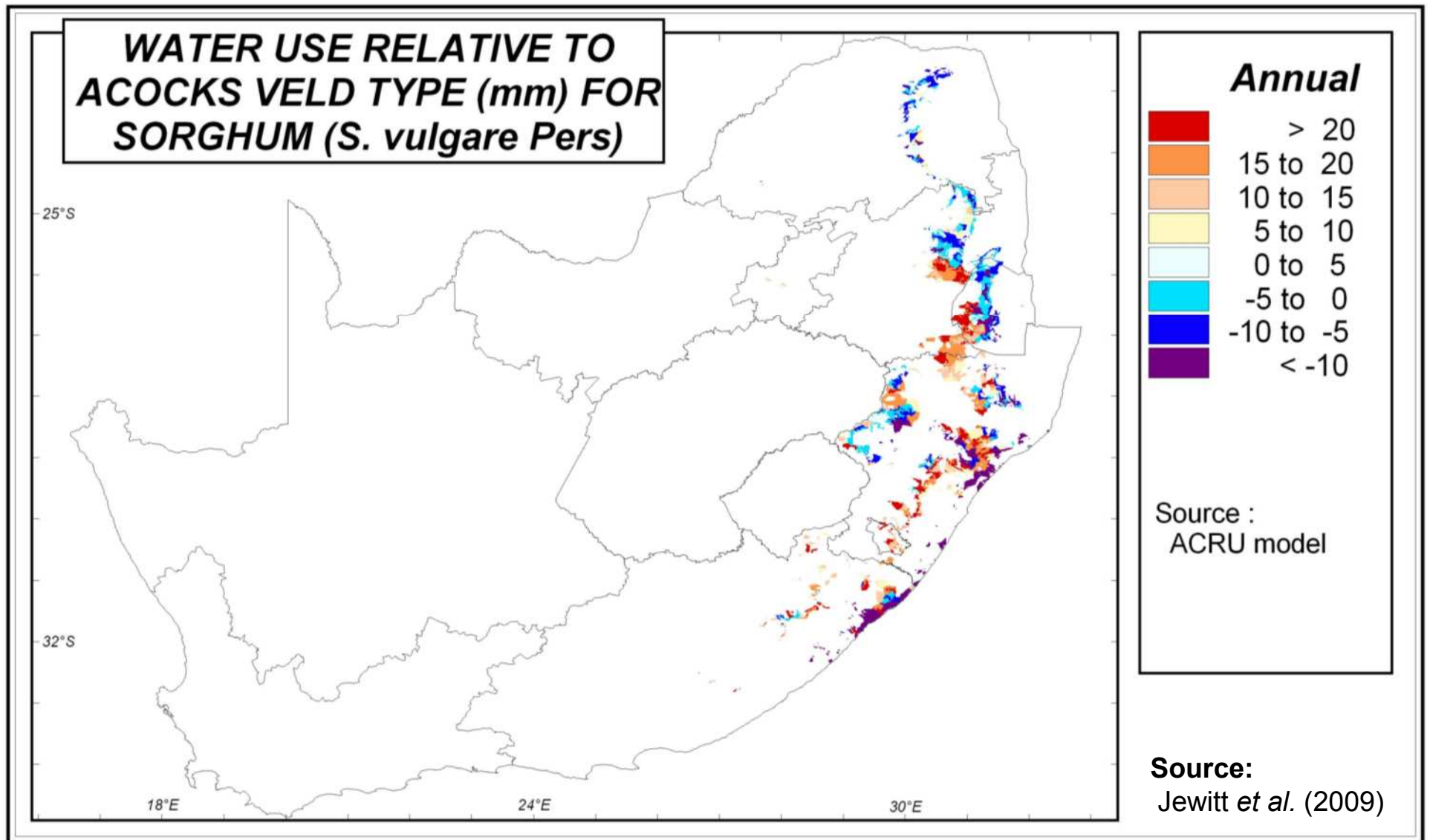
- Monthly and annual basis

Acocks Veld Type Map of SA



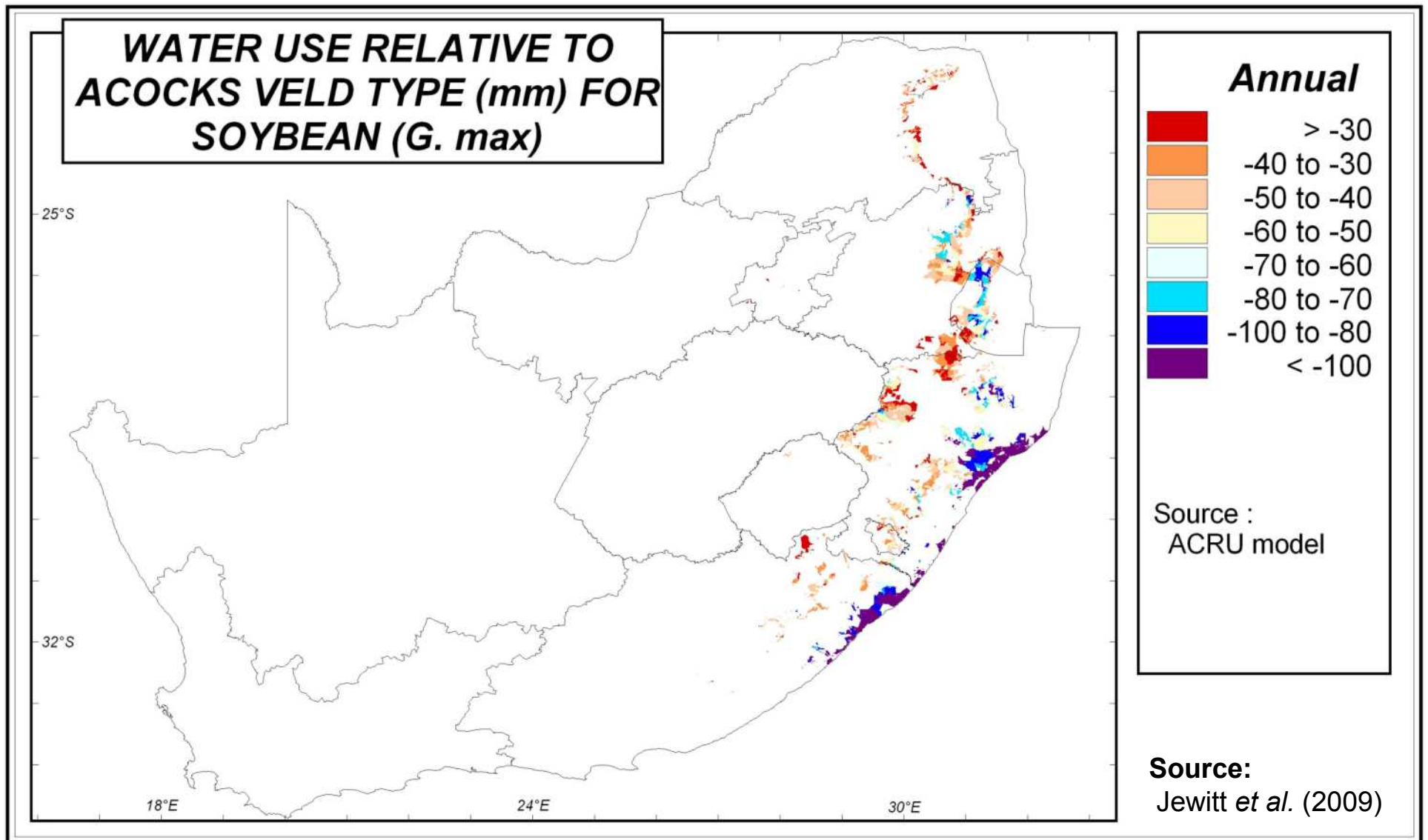
Water Use = $MAR_{base} - MAR_{crop}$ in mm. Hence, $MAR_{crop} < MAR_{base}$

Sorghum uses more water than natural vegetation



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

Soybean uses less water than natural vegetation



Feedstocks to Consider

- Recommendations from the biofuels technical meeting (July 2012)
 - Crops where sufficient knowledge exists (i.e. suitable for modelling):
 - Sugarcane, Maize, Cassava
 - Sunflower, Canola
 - Napier Grass
 - Crops selected initially for field trial research:
 - Sugarbeet, Sweet Sorghum
 - Jatropha, Moringa
 - Crops selected for current and future trials:
 - Sweet Sorghum (ratoon)
 - Grain Sorghum
 - Soybean
 - Sugarbeet (stressed)

Approach

The development of an implementable GIS-based mapping and modelling framework to quantify the sustainable production potential of selected biofuel feedstocks under various environmental and social constraints

Mapping Component

Identify areas optimally suited to biofuel production using climatic, edaphic, topographic and biotic factors limiting feedstock growth

Modelling Component

Estimate the water use and yield of biofuel feedstocks using appropriate simulation models to determine the upper limit of biofuel production potential

Constraints Component

Selection of various environmental and social constraints to “filter” out areas not suitable for the sustainable production of selected biofuel feedstocks

Important Design Criteria

Flexible framework to accommodate the inclusion of other components (e.g. economics)

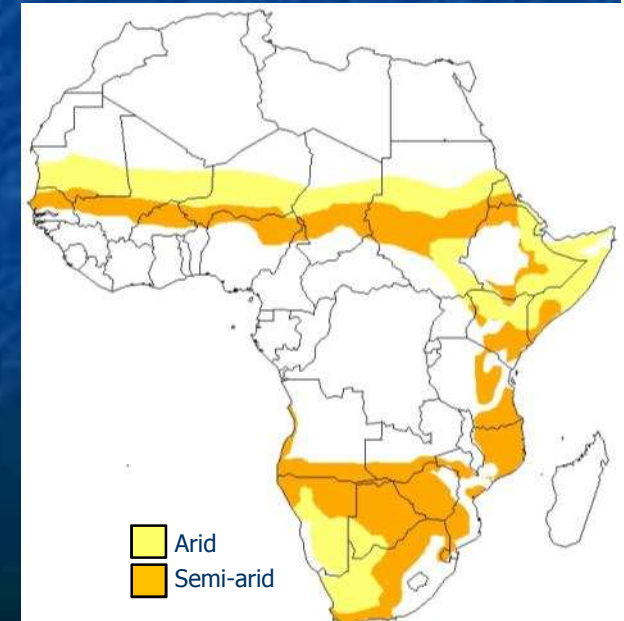
Scale-independent and thus applicable at both national and provincial level

Adaptable to changing legislation and policies that principally affect feedstock production

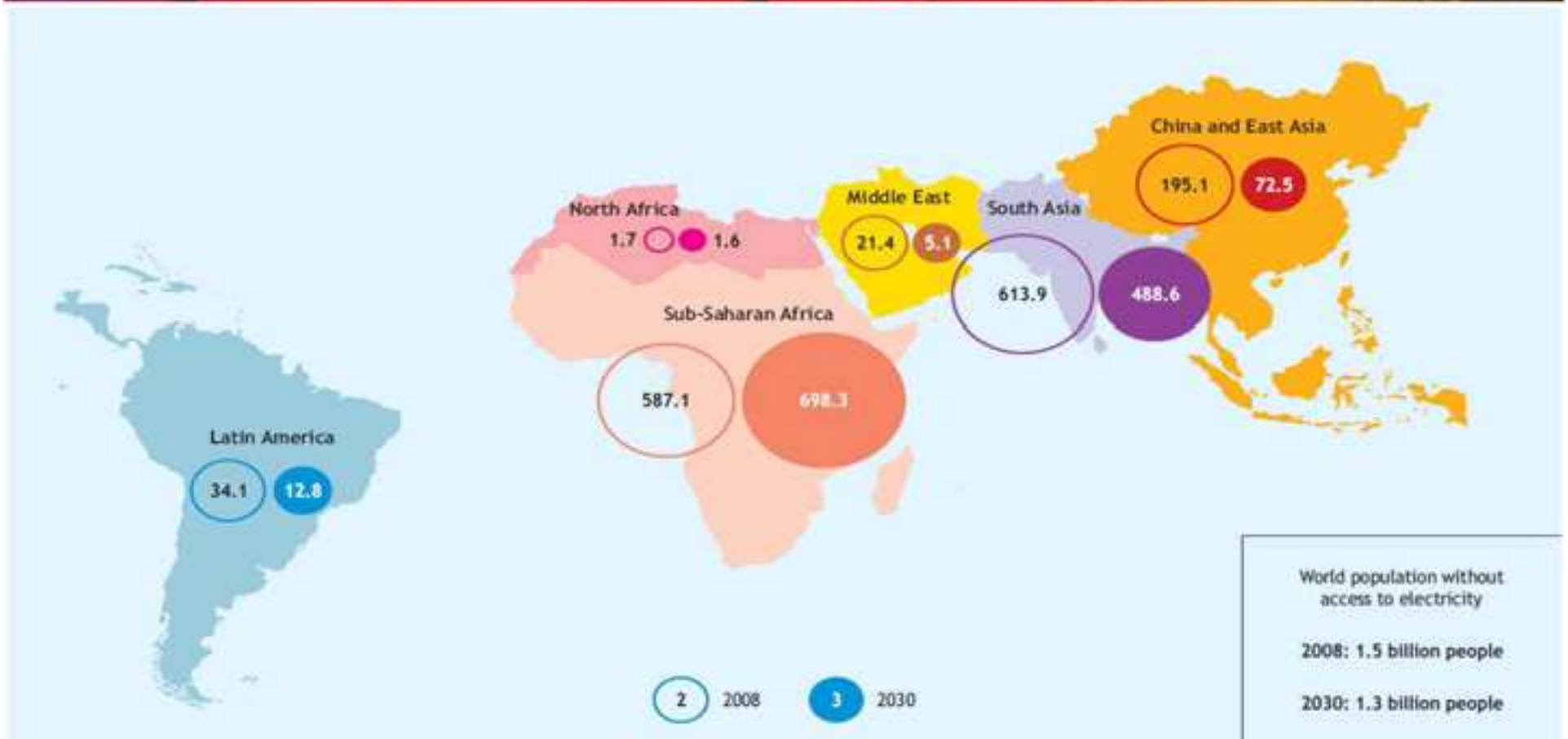
Multi-criteria decision making approach to manage the selection of “filtering” constraints

Other Studies

- Other bioenergy studies:
 - **Gauteng Integrated Energy Strategy (GIES)**
 - University of Johannesburg (Prof H Annegarn)
 - EnerKey Research Project (Dr L Eltrop, Stuttgart University)
 - **COMPETE project:**
 - Main project objectives:
 - Stimulate bioenergy production in arid and semi-arid regions in Africa
 - Improve the quality of life of the rural population
 - Support the preservation of intact ecosystems
 - For more information:
 - Website: <http://www.compete-bioafrica.net/>
 - **DST Bioenergy Atlas:**
 - To be completed by September 2013
 - Overlaps with biofuels project mapping work



Number of people without access to electricity in the Reference Scenario (millions)



Sources: <http://www.worldenergyoutlook.org/>
http://www.iea.org/country/graphs/weo_2009/fig2-10.jpg