Water and Biofuel Research in SA

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

Richard Kunz

Bioenergy Cluster Committee Workshop

20th February 2013

Mandatory Blending Rates

- Minimum mandatory blending rates:
  - Biodiesel 5 % v/v: 0.05 × 9.3 billion L (2010) = 465 million L an^{-1}
  - Bioethanol 2-10 % v/v: 0.02 × 11.8 billion L (2010) = 240 million L an^{-1}
    0.10 × 11.8 billion L (2010) = 1200 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

Source: DoE (2012)

Is Land Availability an Issue?

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

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: [1]DME (2006) [2]SASA (2009) [3]BFAP (2008) [4]BFAP (2009)

Is Land Availability an Issue?

- Sufficient land exists to produce biofuel feedstocks in SA
  - 3.0 million ha of under-utilised land in the former homelands (DME, 2007)
  - 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)

Is Water Availability an Issue?

- 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
- Specific questions that DWA need addressing:
  - Water use of processing plants?
  - Water use impacts of communal land farming?
    - Within 80 km radius of proposed processing plant
  - Which feedstocks should be declared a SFRA?

Is Water Availability an Issue?

- 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)

    Source: CEPLAGA (2009)

  - 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: Maclachlan (2012)

Water use of Biofuel Production

- National Biofuels Industrial Strategy (DME, 2007)
  - 2006 Feasibility Study urged government to assess impact of biofuel production on water quantity and water quality
- 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

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;

WATER RESEARCH COMMISSION

Project Background

- Funding — Water Research Commission (K5/1874)
- 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

WATER RESEARCH COMMISSION

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)
  - Prof Mark Laing (ACCI)
  - Mr Ian Doidge (ACCI)
- UP
  - Prof Elsa du Toit (Moringa)
  - Prof Martin Steyn (Crops)
- CSIR
  - Dr Mark Gush (Jatropha)
  - Vivek Naiken (Field Technician)

The Reference Group

- WRC Manager
  - 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 (SANEDI)
  - Mr S Xosa (DST)
  - Mr K Zihlangu (DoE)

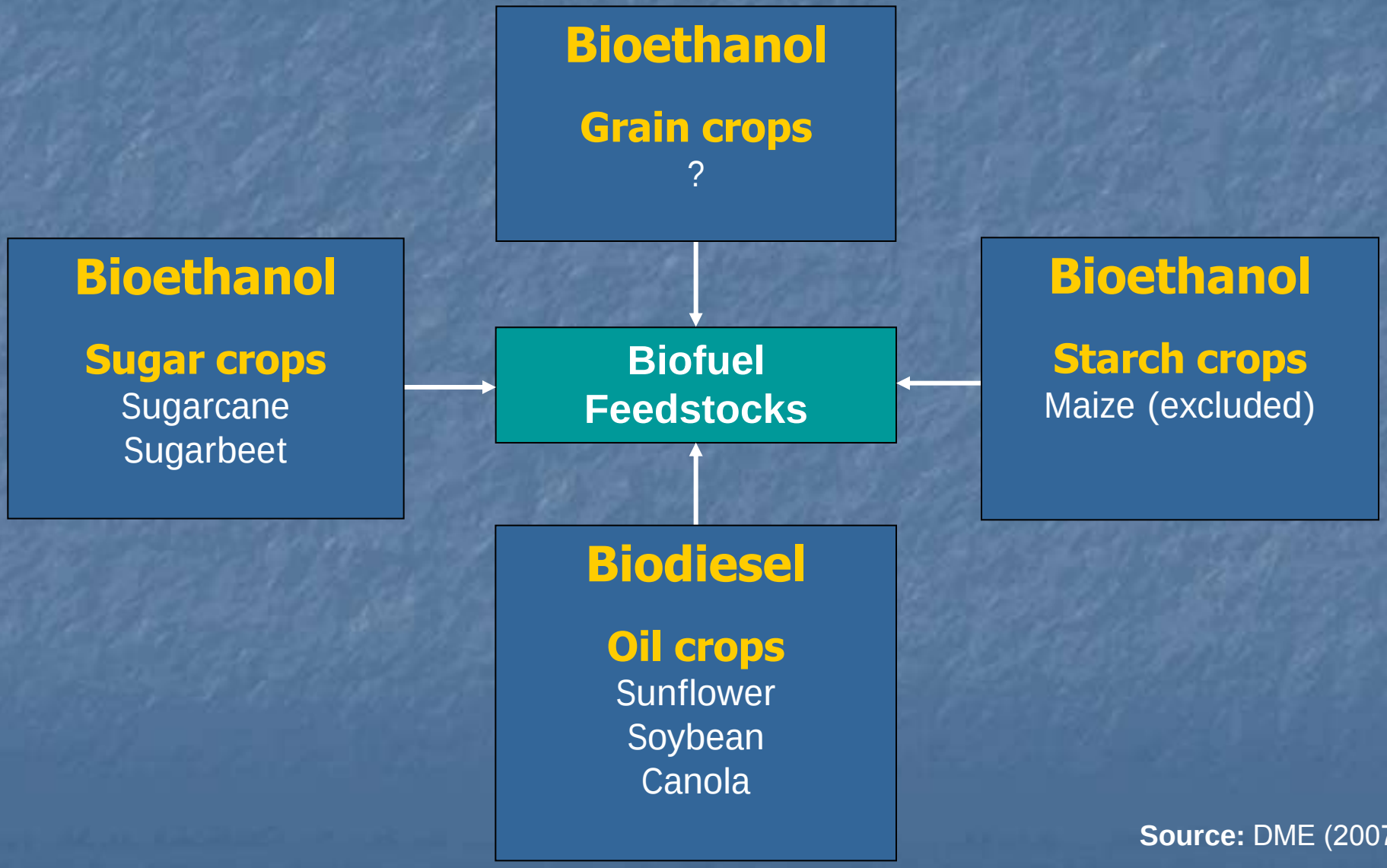
Project's General Objective

- 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
- Map areas optimally suited to biofuel feedstock production
  - GIS-based study to apply optimum growth criteria to spatial data sets
- Determine the available knowledge on water use of feedstocks
  - Literature review and workshop
- Measure the water use and yield of potential feedstocks
  - Field trials conducted at Ukulinga (UKZN) and Hatfield (UP)
- Estimate the water use and yield of specific feedstocks
  - Simulation modelling using hydrological & crop yield models

Proposed Feedstocks in Strategy



Source: DME (2007)

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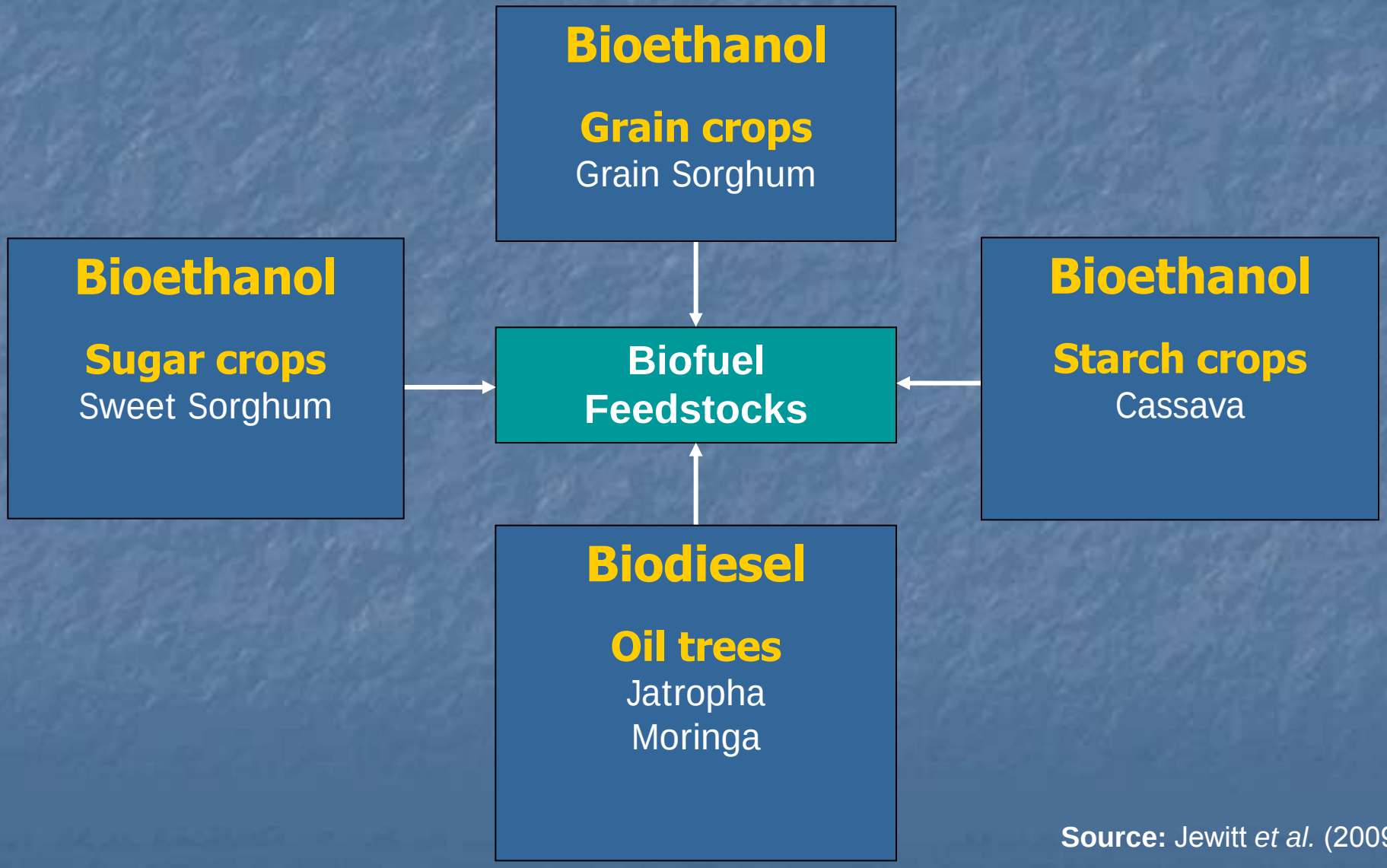
2010

Other Potential Feedstocks



Source: Jewitt *et al.* (2009)

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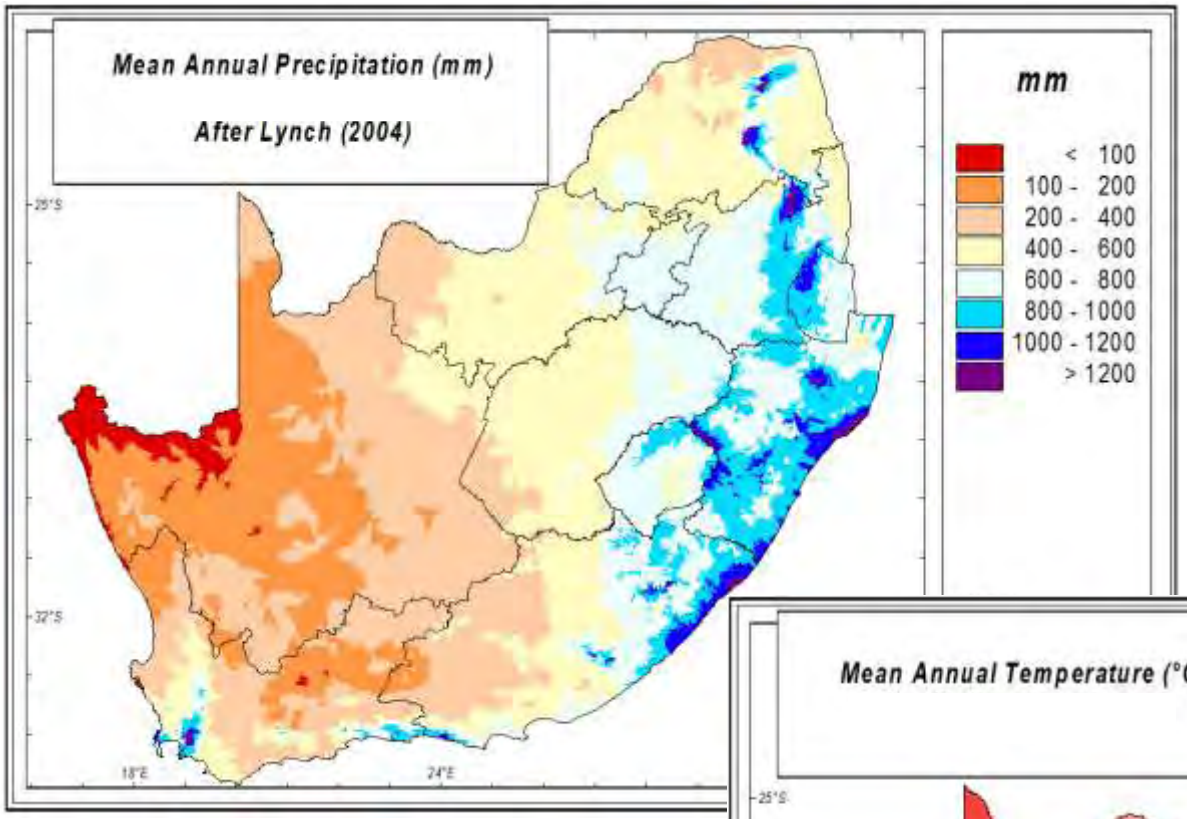
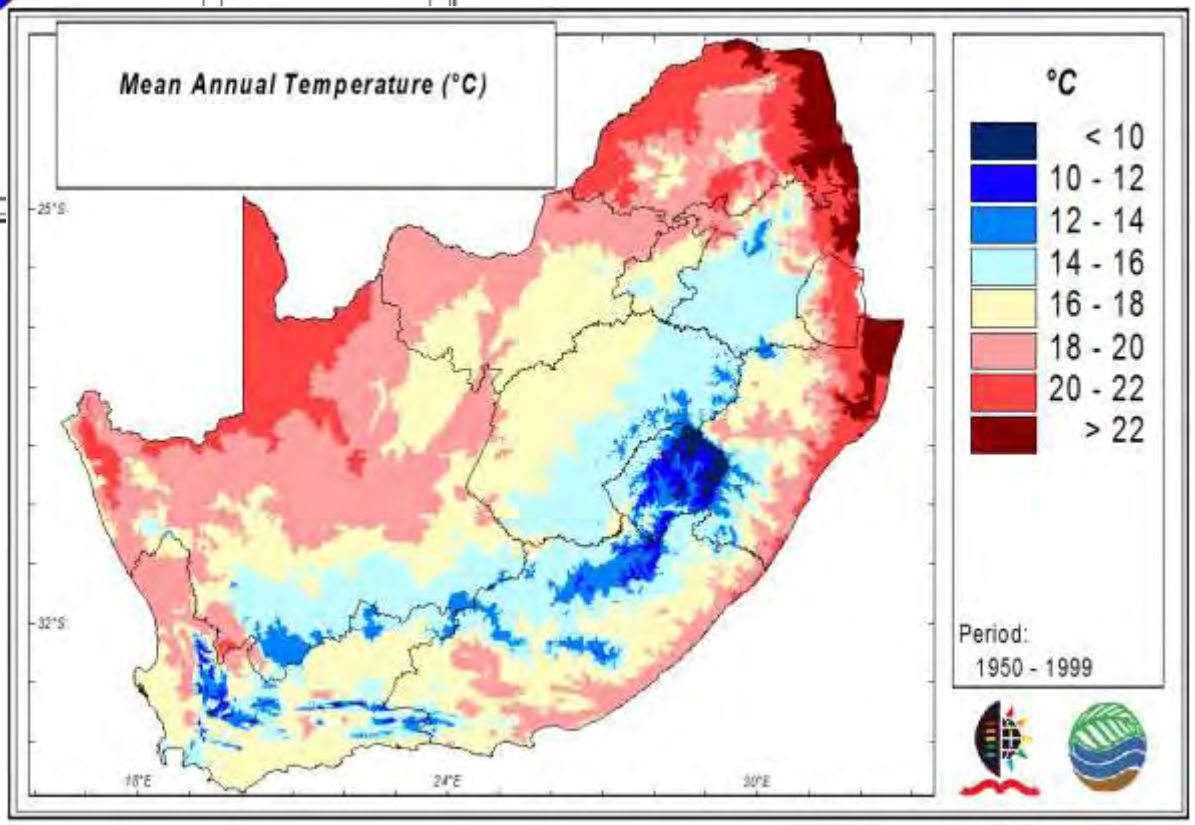
Climatic Thresholds for Growth

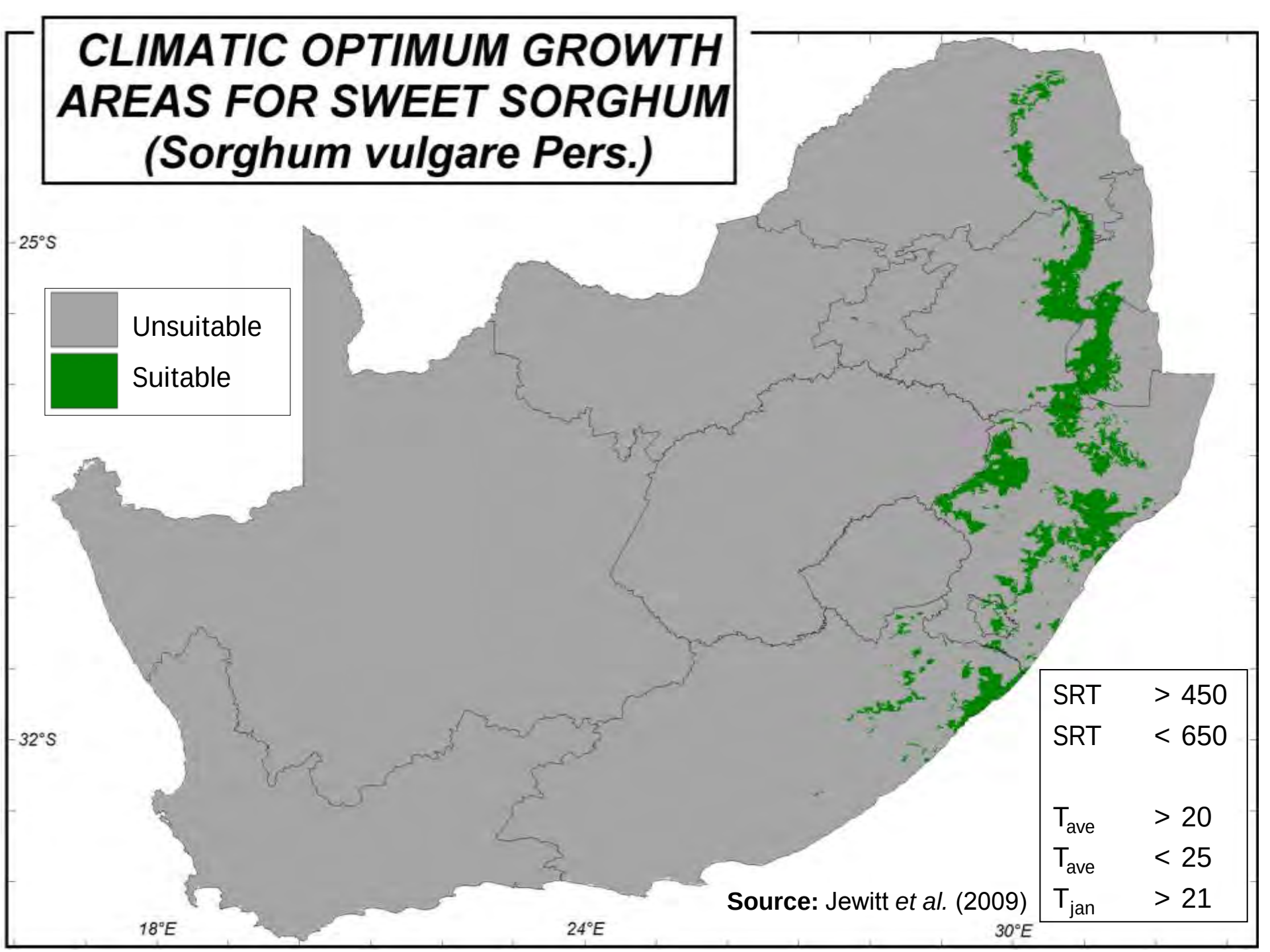
Crops	MAP (mm)	SRT (mm)	MAT (°C)	T_{ave} (°C)	T_{min} (°C)	T_{max} (°C)	Plant date	Growth days
Canola	500 - 1000				> 5	< 25	1st Jun	140
Cassava	> 1000		20 – 29					
Jatropha	500 - 1500		11 – 28		Frost free areas			
Sorghum		450 - 650		20 - 25 (T_{jan} > 21)			1st Nov	115
Soybean		550 - 700		20 - 30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

Source: Jewitt *et al.* (2009)

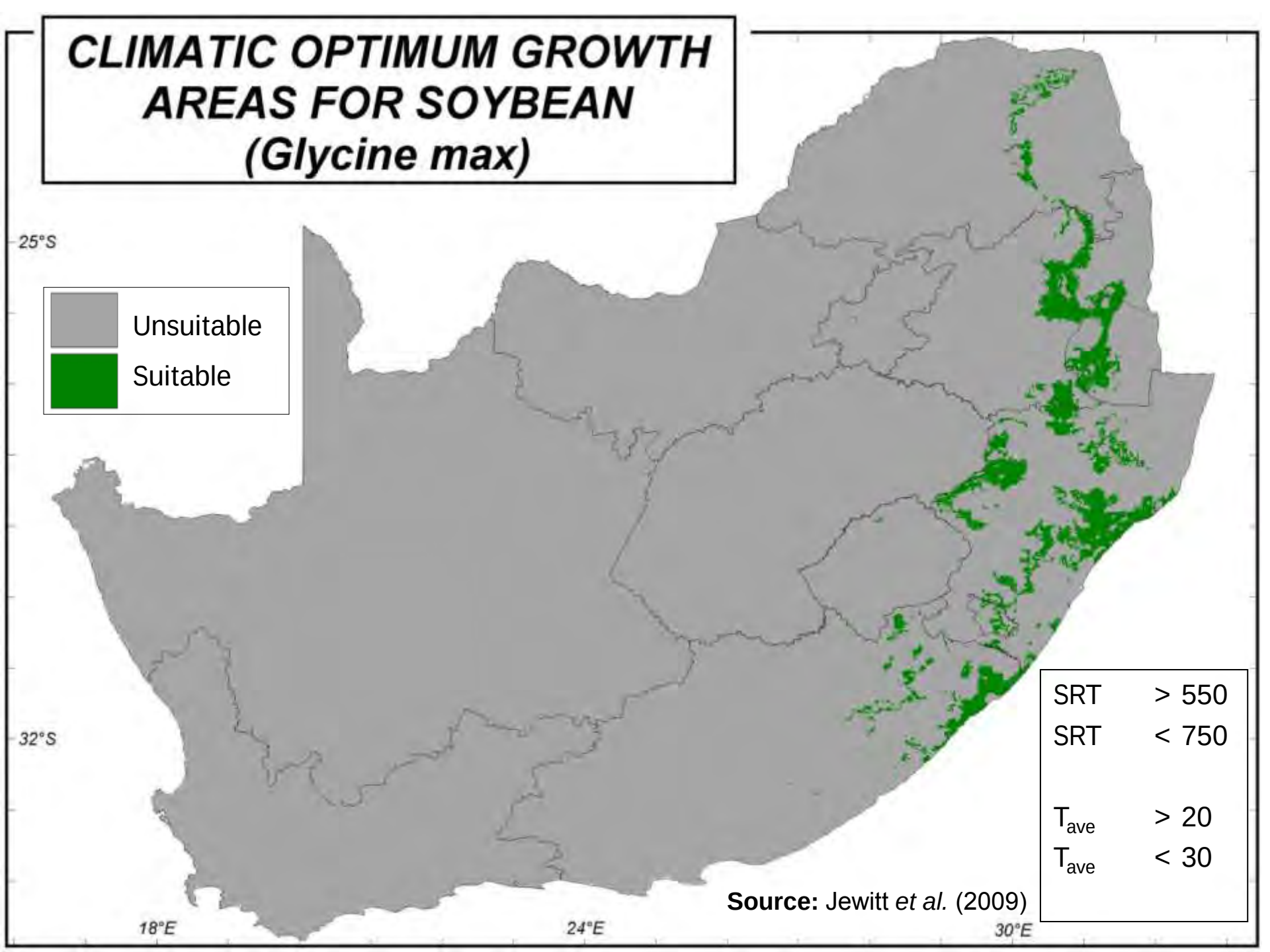

Mean Annual Precipitation (mm)
After Lynch (2004)
mm
< 100
100 - 200
200 - 400
400 - 600
600 - 800
800 - 1000
1000 - 1200
> 1200
25°S
32°S
18°E
24°E

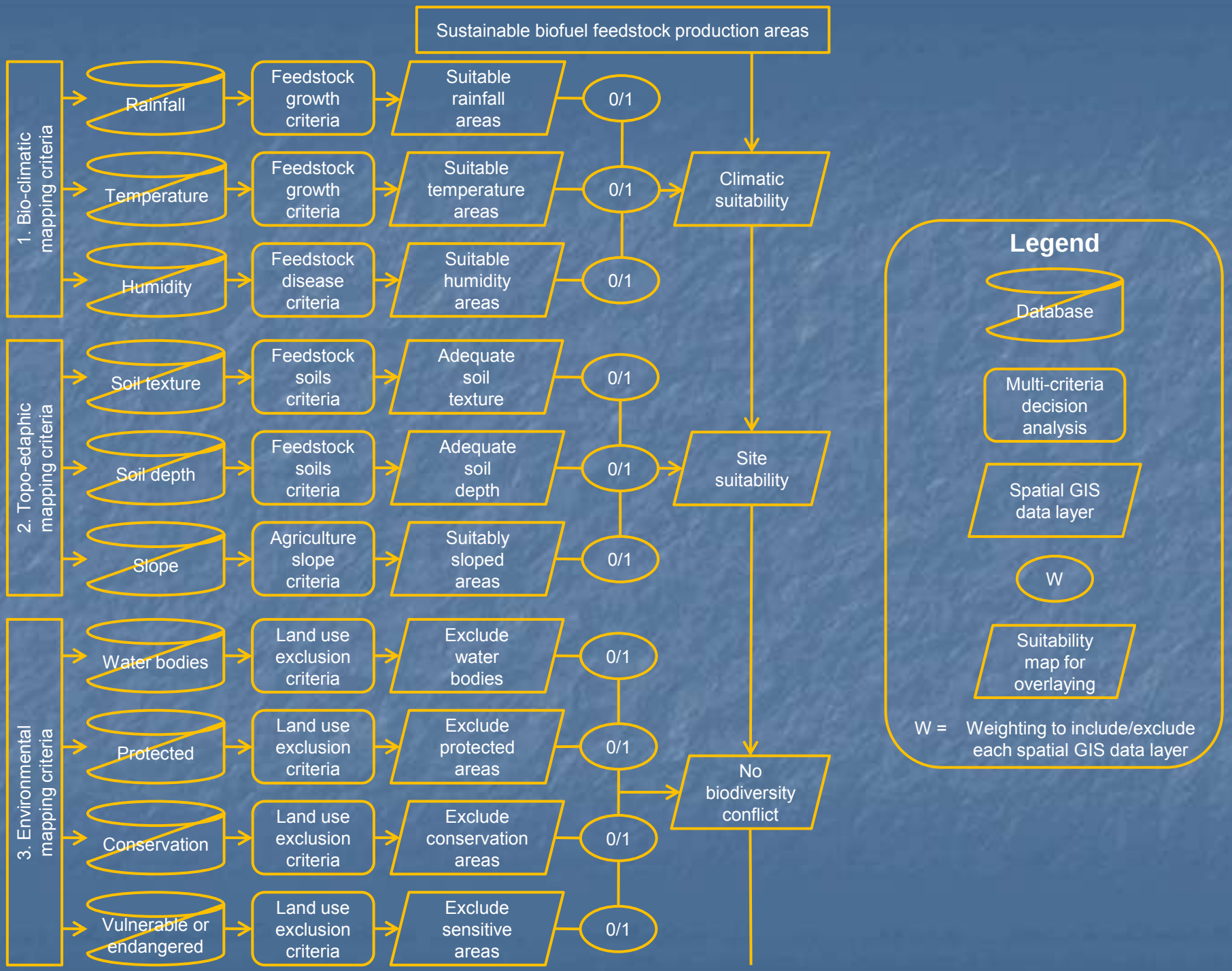

Mean Annual Temperature (°C)
°C
< 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
> 22
Period:
1950 - 1999
25°S
32°S
18°E
24°E
30°E

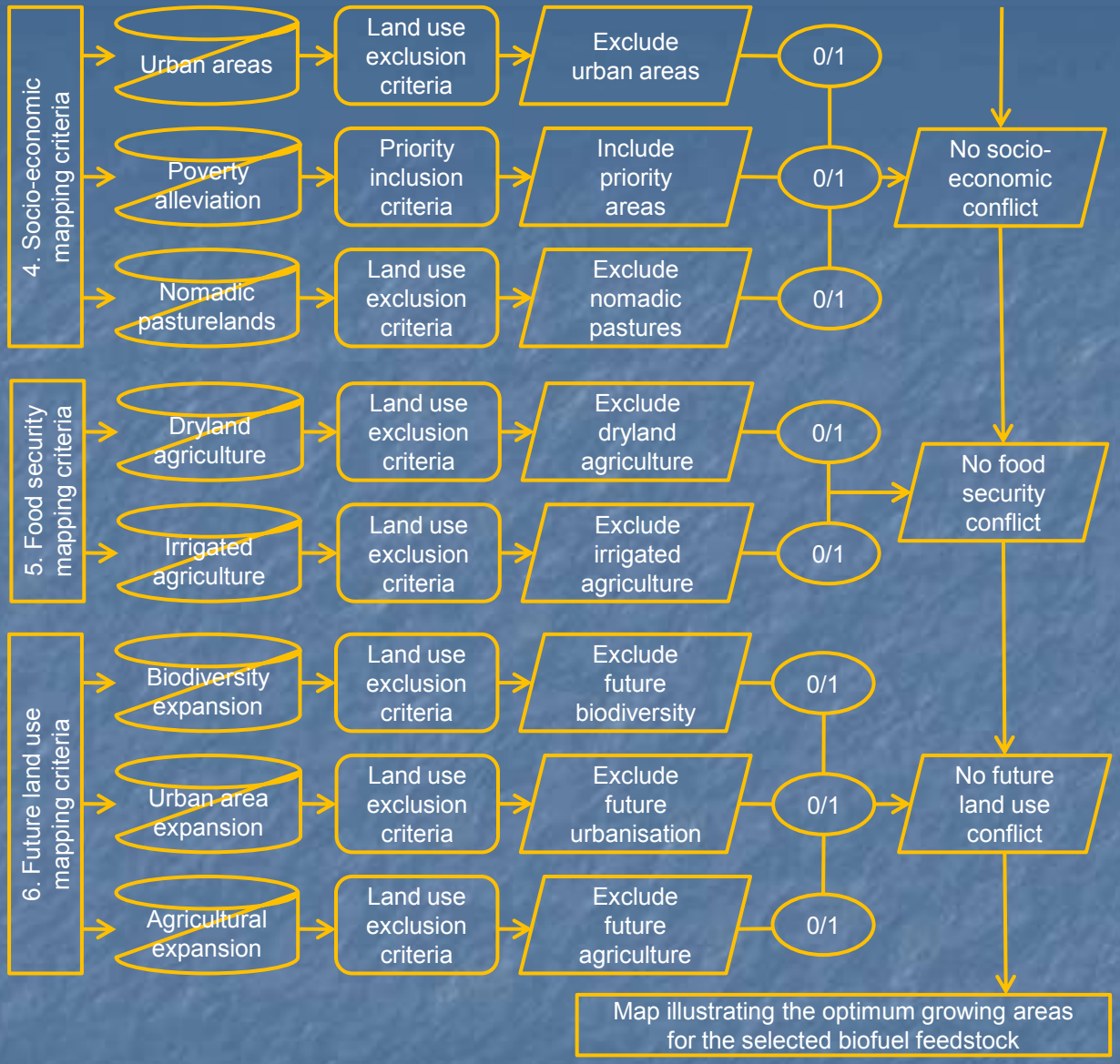
CLIMATIC OPTIMUM GROWTH AREAS FOR SWEET SORGHUM (*Sorghum vulgare* Pers.)

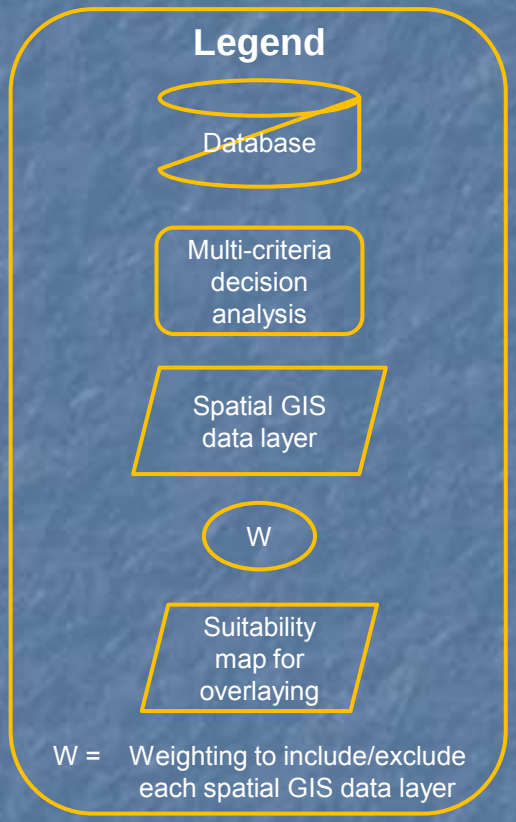


CLIMATIC OPTIMUM GROWTH AREAS FOR SOYBEAN (*Glycine max*)




Sustainable biofuel feedstock production areas
1. Bio-climatic mapping criteria
Rainfall
Feedstock growth criteria
Suitable rainfall areas
0/1
Temperature
Feedstock growth criteria
Suitable temperature areas
0/1
Humidity
Feedstock disease criteria
Suitable humidity areas
0/1
Climatic suitability
2. Topo-edaphic mapping criteria
Soil texture
Feedstock soils criteria
Adequate soil texture
0/1
Soil depth
Feedstock soils criteria
Adequate soil depth
0/1
Slope
Agriculture slope criteria
Suitably sloped areas
0/1
Site suitability
3. Environmental mapping criteria
Water bodies
Land use exclusion criteria
Exclude water bodies
0/1
Protected
Land use exclusion criteria
Exclude protected areas
0/1
Conservation
Land use exclusion criteria
Exclude conservation areas
0/1
Vulnerable or endangered
Land use exclusion criteria
Exclude sensitive areas
0/1
No biodiversity conflict
Legend
Database
Multi-criteria decision analysis
Spatial GIS data layer
W
Suitability map for overlaying
W = Weighting to include/exclude each spatial GIS data layer





Mapping of Suitable Production Areas

Aims and Objectives

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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

- 2011/12 (season #3)

Measuring Feedstock Water Use

Measuring Feedstock Water Use

Surface Renewal (fine-wire thermocouple)

Sweet Sorghum (Ukulinga)

01/02/2011

Sweet Sorghum (Ukulinga)

Sweet Sorghum (Hatfield)

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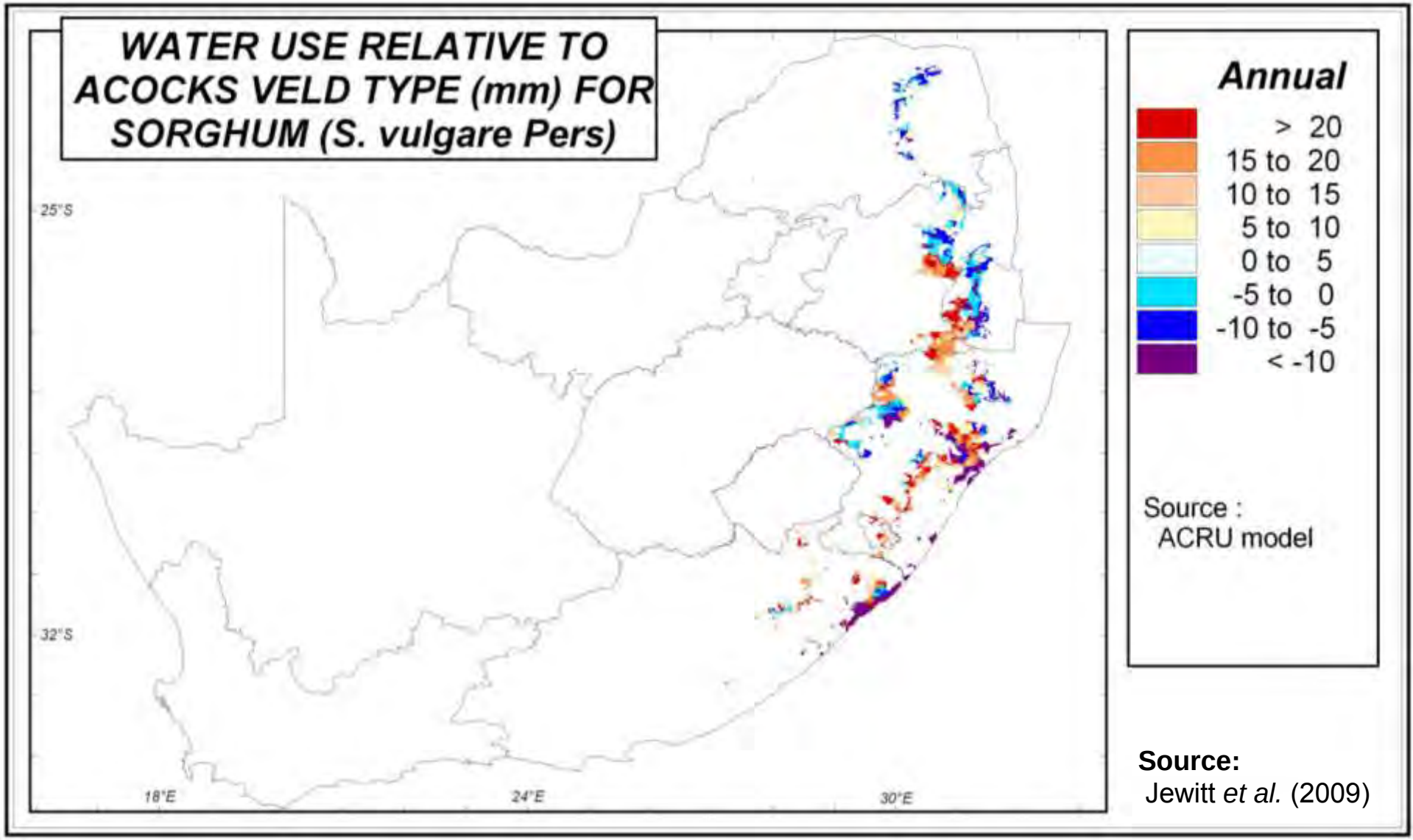
Water Use = $MAR_{base} - MAR_{crop}$ in mm. Hence, $MAR_{crop} < MAR_{base}$

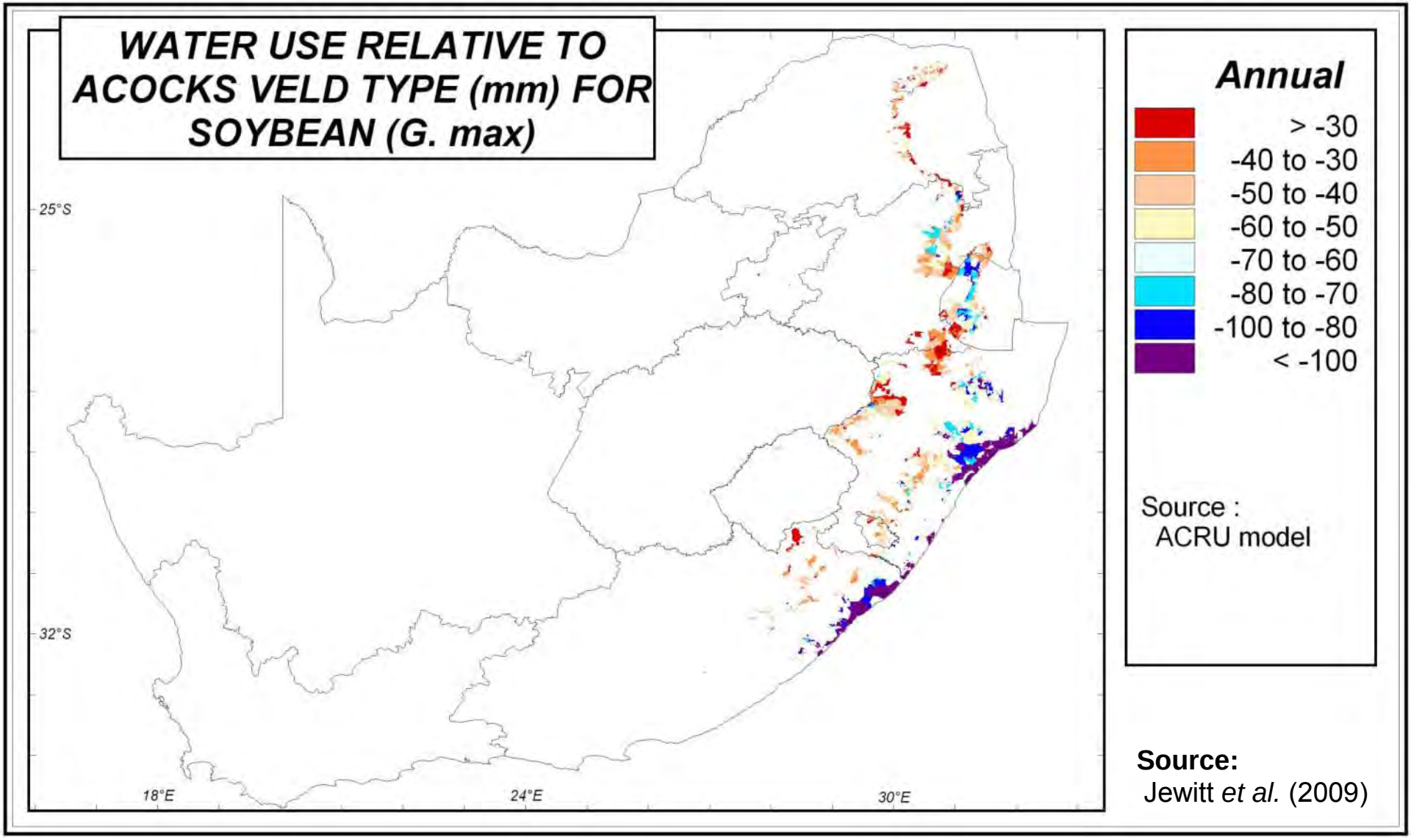
Sorghum uses more water than natural vegetation



Source:
Jewitt *et al.* (2009)

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

Soybean uses less water than natural vegetation



Source:
Jewitt *et al.* (2009)

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

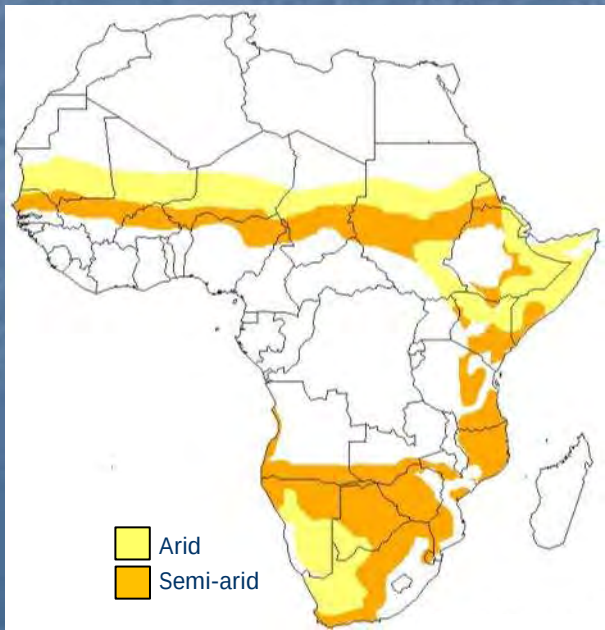
Mapping Component	Modelling Component	Constraints Component
Identify areas optimally suited to biofuel production using climatic, edaphic, topographic and biotic factors limiting feedstock growth	Estimate the water use and yield of biofuel feedstocks using appropriate simulation models to determine the upper limit of biofuel production potential	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

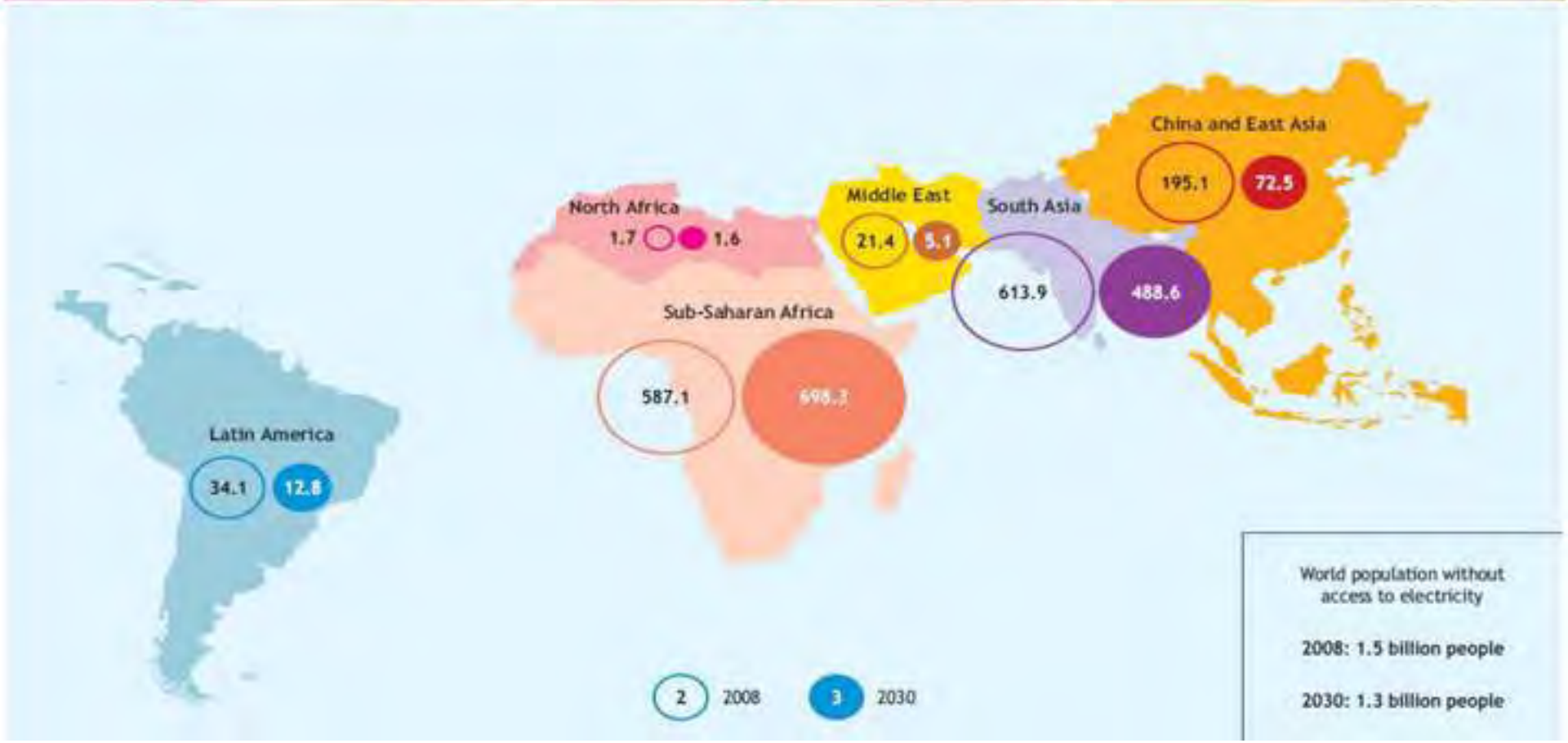
Other Studies

- 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



World Energy Outlook 2009

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