ABSTRACT: 427

SPATIAL ASSESSMENT OF OPTIMUM GROWING AREAS FOR POTENTIAL BIOFUEL FEEDSTOCKS IN SOUTH AFRICA

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Energy production using fossil-based fuels (coal, oil and natural gas) has environmental and health effects that have the potential to increasingly endanger human welfare. Renewable energy will not be exhausted, unlike fossil fuels that are not being renewed at a rate at which they are currently being consumed. Renewable energy can improve access to clean energy, can limit the use of fossil fuels and thus reduce pollution. Biofuels are fuels produced from biomass and this study is based on liquid biofuel feedstock (i.e. biodiesel).

This study examines optimum growth criteria of the key biofuel feedstocks. Optimum growth criteria of feedstocks i.e. soybean is discussed. Its characteristics and present distribution are also discussed. The document also presents a project proposal that seeks to improve on existing maps which show the potential for feedstock production in South Africa. In previous studies, only rainfall and temperature were considered as the main mapping criteria. This study aims to add other mapping criteria such a relative humidity, frost and soil texture. Soybean was selected as an example feedstock, to show how the additional mapping criteria will improve the initial assessment of the feedstock's biofuel potential.

Spatial assessment of optimum growing areas for potential biofuel feedstock (Soybean) in South Africa

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OVERVIEW

- INTRODUCTION
- LITERATURE REVIEW
- AIMS AND OBJECTIVES
- METHODOLOGY
- RESULTS AND DISCUSSION
- CONCLUSION

INTRODUCTION

- Biofuel is a renewable fuel that can be manufactured from conventional agricultural crops
- Feedstock is a raw material supplied to a machine or processing plant from which other products can be made

The SA gov biofuel motivation

- Declining crude oil reserves
- Impact of fossil fuel use on GHG emissions
- Less dependency on crude oil imports
- Potential positive impact of biofuel production in rural areas

Biofuels in SA

The National Biofuel Strategy of 2007

- Production needs to be scaled up to meet the proposed minimum target of**:**
  - 2% (400 million litres per annum) within 5 years
  - This short-term target not realised

Land area requirements for feedstock production

- 300,000 ha under-utilised arable land in rural areas

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)

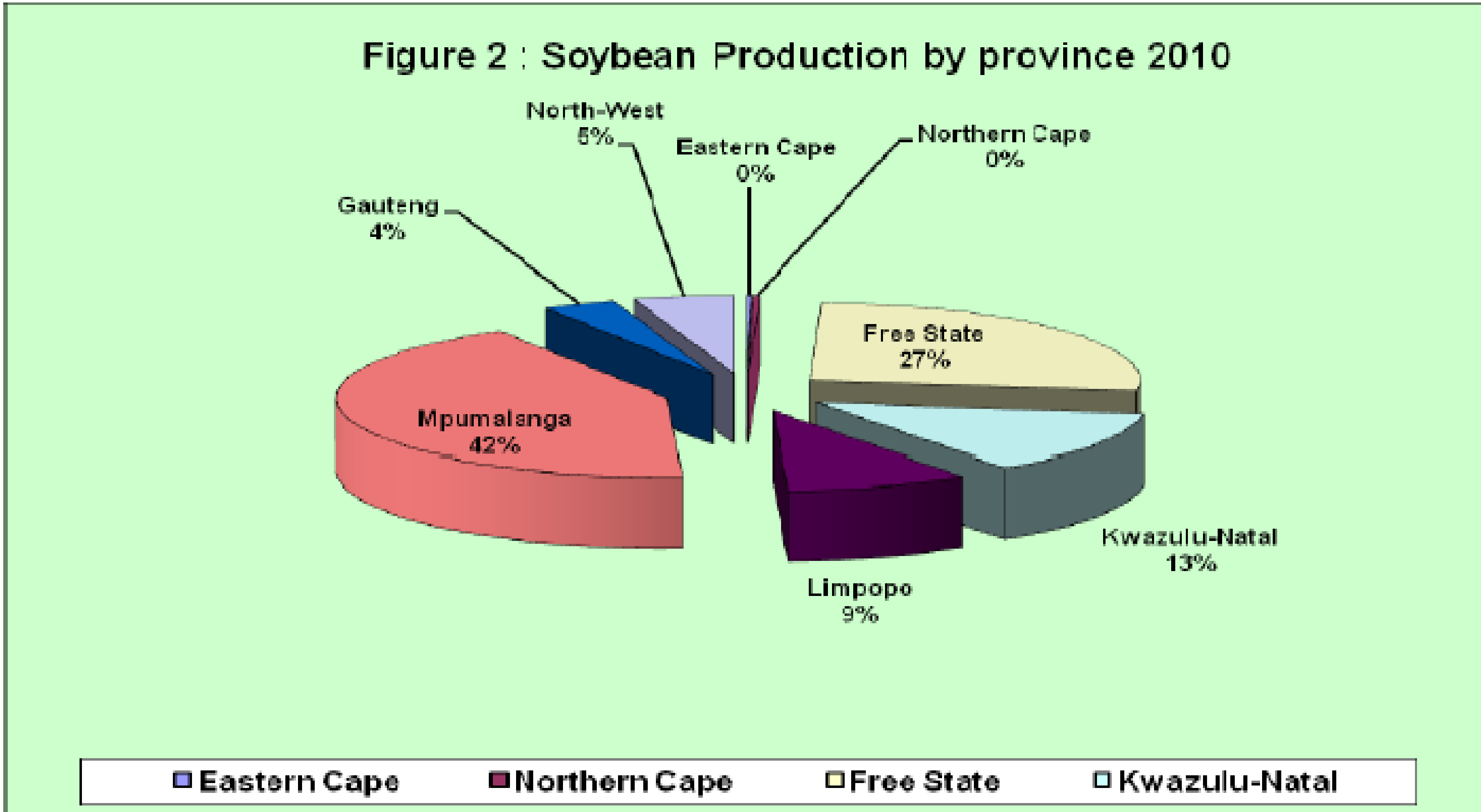
Soybean as a Biofuel Feedstock

- Soybean production in S.A ranges from 450,000 to 500,000 tons per annum
- Average yield of 2.5 to 3 t/ha under dry-land conditions
- Second largest source of vegetable oil in SA after sunflower
- By-product of biodiesel processing is animal feed

  which is currently imported
- Reduce of cost of high quality protein animal feed

  in SA

Soybean Production by Province



Source: Statistics and Economic Analysis

Expansion of Soybean Production: Concerns…

1. Land Use and Food Security

- Competition between food *vs*. fuel
- Possible increase in food prices

2. Environmental impacts

- If not well planned, bioenergy development has the potential to:
  - Destroy biodiversity
  - Deplete/pollute water resources

Aim and Objectives

Aim

- To map areas suitable for soybean cultivation

Objectives

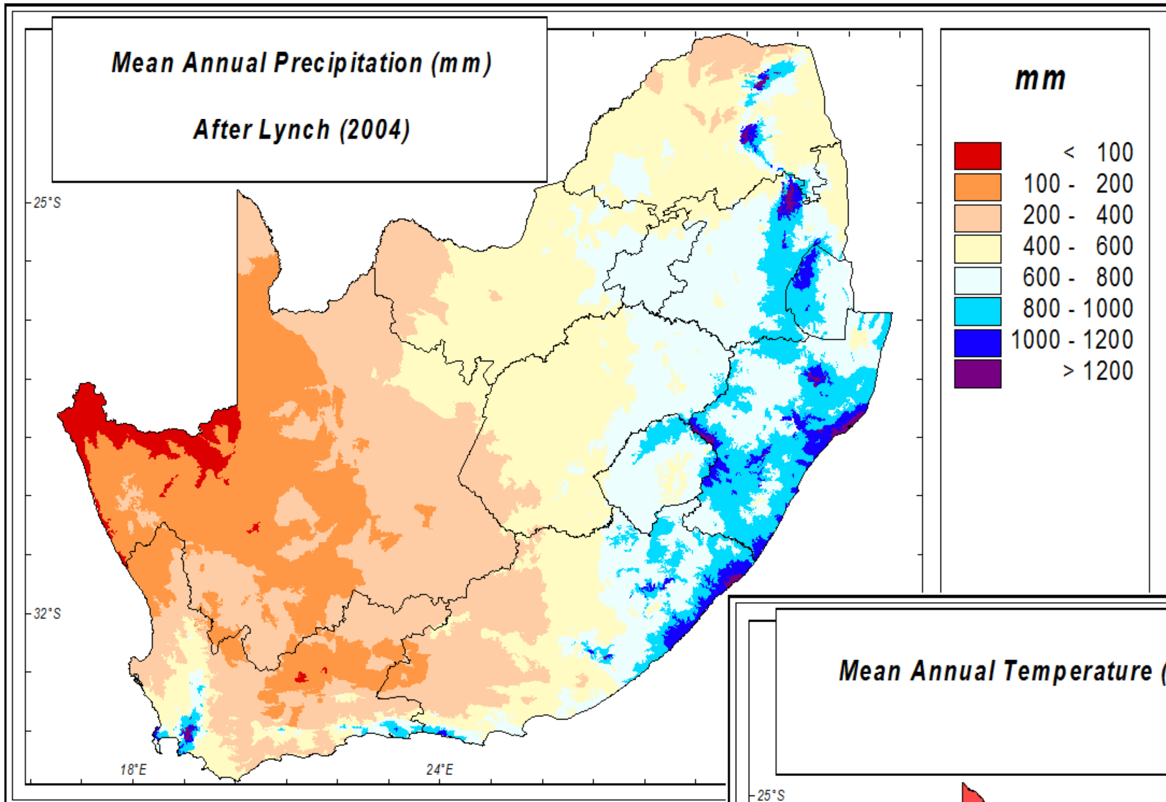
- To incorporate
  - Climatic
  - Edaphic
  - Biotic factors

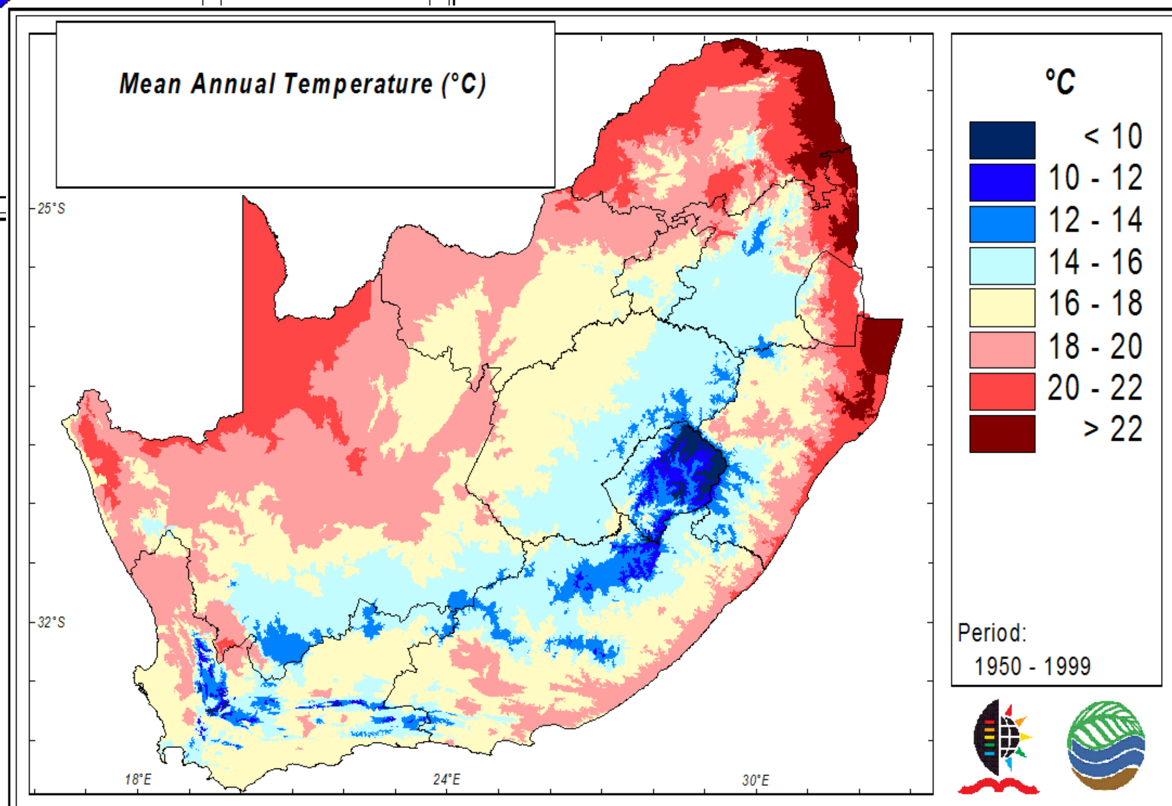
Factors affecting soybean growth

- **Rainfall**
- **Temperature**
- **Relative humidity**
  - Potential for diseases (e.g. soybean rust)
- **Soils and topography**

South African Atlas of
Climatology and Agrohydrology

(Schulze *et al.*, 2007; 2008)


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

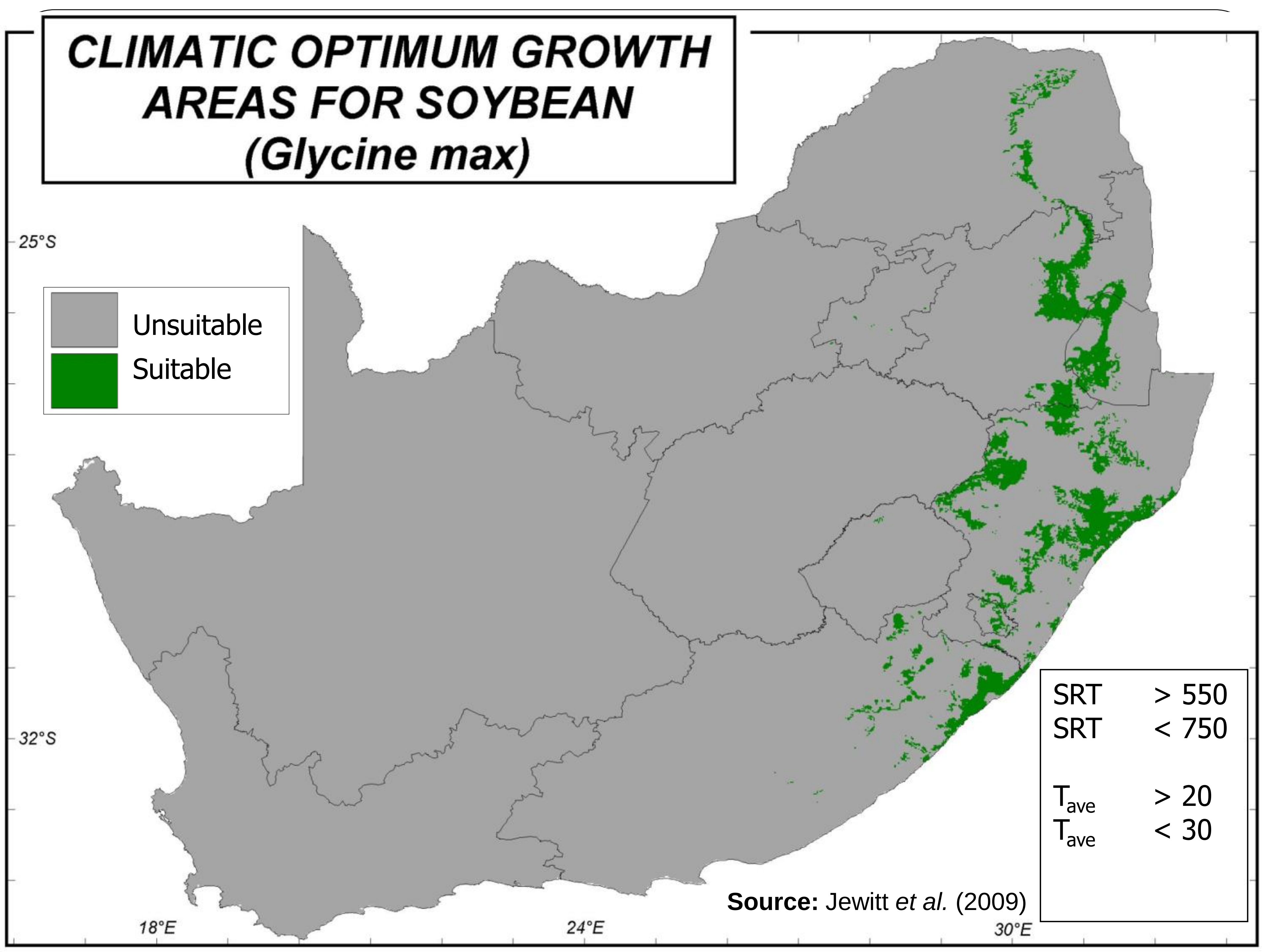
Case Study #1

- Scoping study (Jewitt *et al*., 2009)
  - Aim of study
    - Map potential growing areas and
    - Estimate water use of biofuel feedstocks

  - Only considered climatic mapping factors

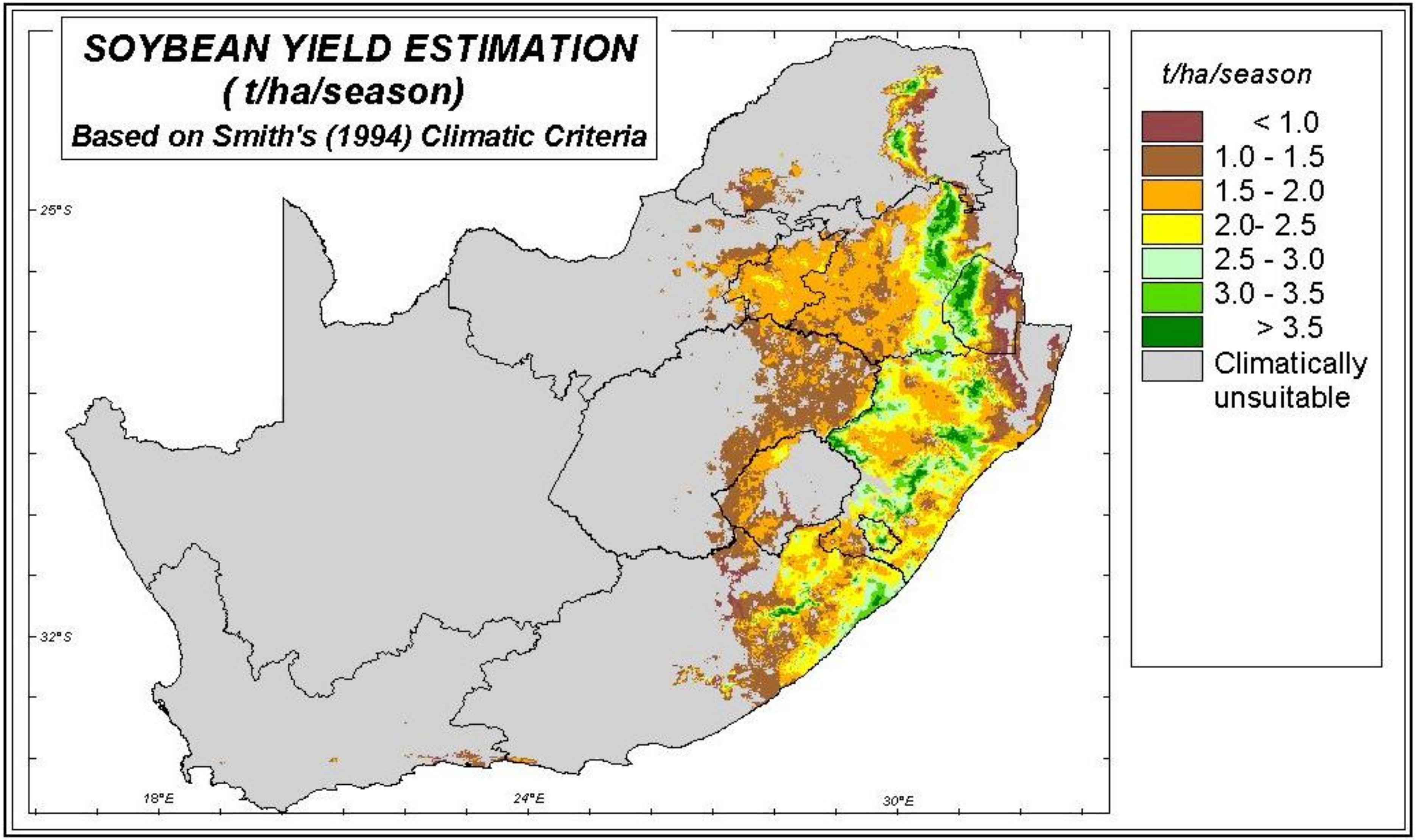
  - Soil parameters & disease risk were not considered

  - Further work is therefore necessary to refine the potential growing areas


CLIMATIC OPTIMUM GROWTH AREAS FOR SOYBEAN (Glycine max)
Unsuitable
Suitable
25°S
32°S
18°E
24°E
30°E
SRT > 550
SRT < 750
T_{ave} > 20
T_{ave} < 30
Source: Jewitt et al. (2009)

Case Study #2

- Soybean yield estimation (Schulze & Maharaj, 2007)
  - Soybean yield (t/ha/season) estimated using:
    - Accumulated rainfall (mm) from October to March
    - Accumulated heat units (base 10°C) from October to March
  - Yields estimates were not adjusted to account for:
    - Soil characteristics
    - Level of farm management
  - Different mapping criteria used to scoping study



Schulze and Maharaj, 2010

Optimum Growth Criteria

Source	Annual rainfall (mm)	Seasonal rainfall (mm)	T_{ave} (^{o}C)	Frost Tolerance	RH_{ave} (%)	HU(GDD) Base 10 ^{o}C	Soil Depth (mm)	pH	Soil Texture	Rank
Jewitt et al. (2009) recommended		550-700	20-30							3
Jewitt et al. (2009) literature review										
Smith (1994)	> 700	450-700	18-35 Sub Jan > 19 > Abs			1100-2400	600-1300		No very Sandy/ poorly drained	3
Smith (1998)	> 700	> 450 550-700		Medium			600-1200			3
Smith (2006)		550-700					600-1200			2
FAO (2006)	600-1500 Opt 450-1800 Abs		20-33 Opt 10-38 Abs					5.5-6.5 Opt 4.5-8.5 Abs	Medium, organic	6
Schulze & Maharaj (2006)	> 600		Jan > 18			> 1500 100-2600 (Oct-Mar)				5
Nunkumar et al. (2009)					< 75					4
Schulze & Maharaj (2008)	> 600		Jan > 18			100-2600 (Oct-Mar)				5
Schulze & Kunz (2010)	> 600		Jan > 18			100-2600 (Oct-Mar)				5
DAFF (2010)		500-900	13-30 25 Opt							1
DAFF (2010)-At planting			15-18					6.0-6.5 Opt > 5.2 Sub		1
Bassam, 2010	500-750		24-25 Opt 20-25 Sub				30-40	6-6.5	loamy	7
Final	**600-1800**	**450-900**	**18-33**	**Medium**	**< 75**	**1500-2600**	**> 500**	**5.5-6.5**	**loamy**	

Approach

- Suitability modelling
- Analytical Hierarchy Process (AHP) (Saaty, 1980)
- where each criterion is compared with the other
- according to importance, on a scale from 1 to 9
- where 1 = *equal preference* between two factors; 9 = a particular factor is *extremely favored* over the other
- weight estimate is calculated

Methodology

- Growth season: November to March
- Accumulated seasonal rainfall total (450-900 mm)
  - Apportioned per month based on crop coefficients
    - 0.3 - 0.4 Initial stage (20 to 25 days)
    - 0.7 - 0.8 Development stage (25 to 35 days)
    - 1.0 - 1.2 Mid-season stage (45 to 65 days)
    - 0.7 - 0.8 Late-season stage (20 to 30 days)
    - 0.4 - 0.5 At harvest (FAO, 2002)
  - Monthly rainfall distribution classes (mm):
    - Month 1 70 - 90
    - Month 2 135 - 170
    - Month 3 165 - 210
    - Month 4 195 - 250
    - Month 5 135 - 180

Methodology

- Monthly means of daily average temperature (°C)
  - At germination
  - Rest of the growing season

	No	Abs	Sub	Opt	Sub	Abs	No
Month	0	1	2	3	2	1	0
Nov	0-10	10-13	13-15	15-18	18-25	25-33	33-100
Dec-Mar	0-10	10-18	18-23	23-27	27-30	30-33	33-100

- Daily average relative humidity (%)
  - 0-60 Low disease risk
  - 60-75 Medium disease risk
  - 75-80 High disease risk
  - 80-100 Very high disease risk

Methodology

- Soil depth (mm)
  - <200 Unsuitable Ranking=0
  - 200-300 Absolute Ranking=1
  - 300-500 Sub-optimum Ranking=2
  - >500 Optimum Ranking=3

- Slope (%)
  - < 8 Optimum Ranking=3
  - 8-16 Sub-optimum Ranking=2
  - 16-30 Absolute Ranking=1
  - >30 Unsuitable Ranking=0

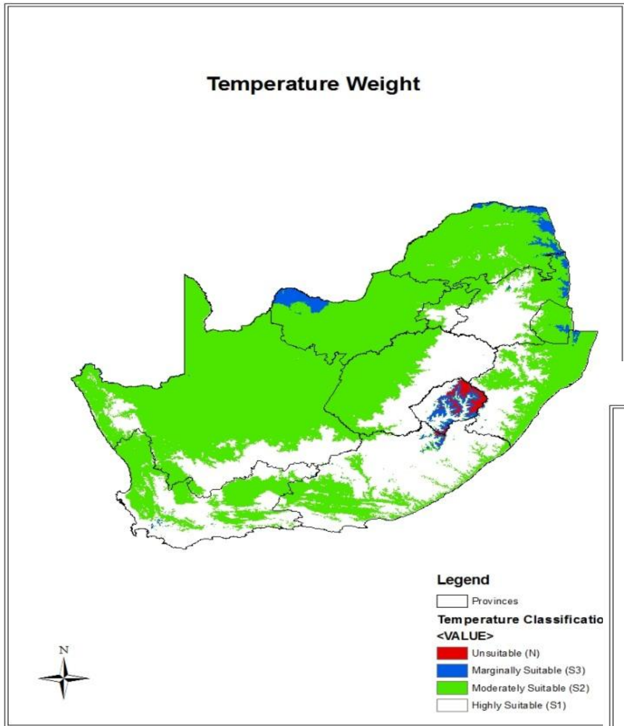
Methodology

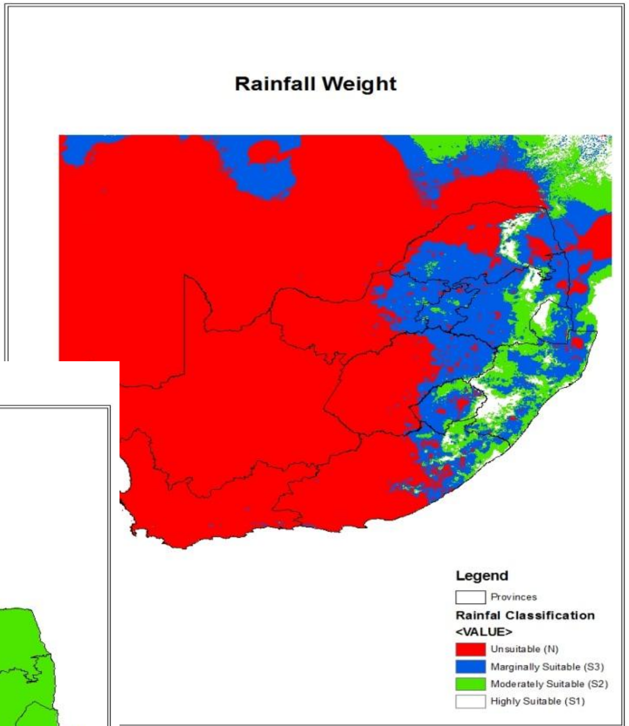
- Assigned influence of importance
  - Monthly rainfall 4
  - Monthly temperature 2
  - Monthly relative humidity 1
  - Soil depth 1
  - Slope 2

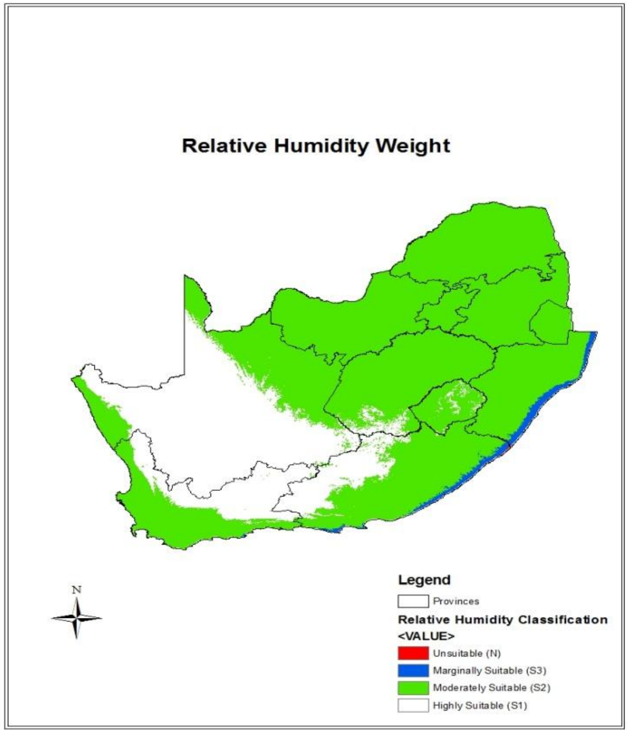
  Total **10**
- Decimal weighting varied per month
  - Monthly relative humidity
    - Month 1 0.1
    - Month 2 0.1
    - Month 3 0.2
    - Month 4 0.3
    - Month 5 0.3

Criteria and Ranking

Suitability Values	Unsuitable	Low Suitability	Medium Suitability	High Suitability	Medium Suitability	Low Suitability	Unsuitable	Assigned Influence Importance	Decimal Weight
Reclass Values	0	1	2	3	2	1	0		
MR01 (mm)	0-45	45-55	70	90	100	110	>110	0.4	0.04
MR02 (mm)	0-85	85-105	105-135	135-170	170-200	200-220	>220	0.75	0.075
MR03 (mm)	0-105	105-130	130-165	165-210	210-250	250-270	>270	1.3	0.13
MR04 (mm)	0-125	125-150	150-195	195-250	250-290	290-320	>320	0.75	0.075
MR05 (mm)	0-90	90-110	110-135	135-180	180-210	210-230	>230	0.8	0.08
Month1 Temp (^{o}C)	0-10	10-13	13-15	15-18	18-25	25-33	>33	0.5	0.05
Month2 Temp (^{o}C)	0-10	10-18	18-23	23-27	27-30	30-33	>33	0.2	0.02
Month3 Temp (^{o}C)	0-10	10-18	18-23	23-27	27-30	30-33	>33	0.3	0.03
Month4 Temp (^{o}C)	0-10	10-18	18-23	23-27	27-30	30-33	>33	0.5	0.05
Month5 Temp (^{o}C)	0-10	10-18	18-23	23-27	27-30	30-33	>33	0.5	0.05
Month1 RH (%)	100-80	80-75	75-60	60-0				0.1	0.01
Month2 RH (%)	100-80	80-75	75-60	60-0				0.1	0.01
Month3 RH (%)	100-80	80-75	75-60	60-0				0.2	0.02
Month4 RH (%)	100-80	80-75	75-60	60-0				0.3	0.03
Month5 RH (%)	100-80	80-75	75-60	60-0				0.3	0.03
Soil Depth (mm)	0-200	200-300	300-500	500-1200				1	0.1
Slope (%)	100-30	30-16	16-8	8-0				2	0.2
Total								**10**	**1**





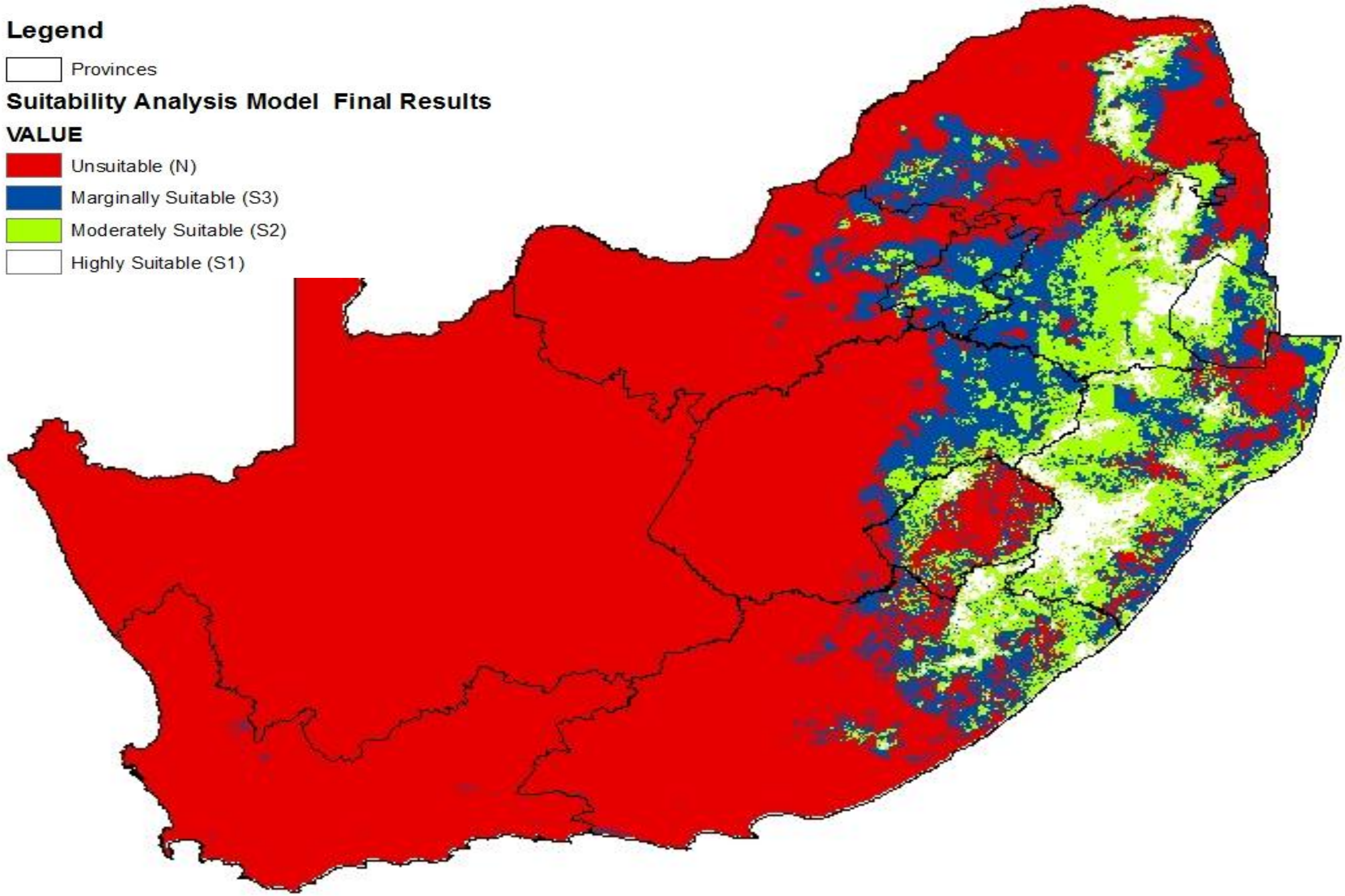


Raster calculator

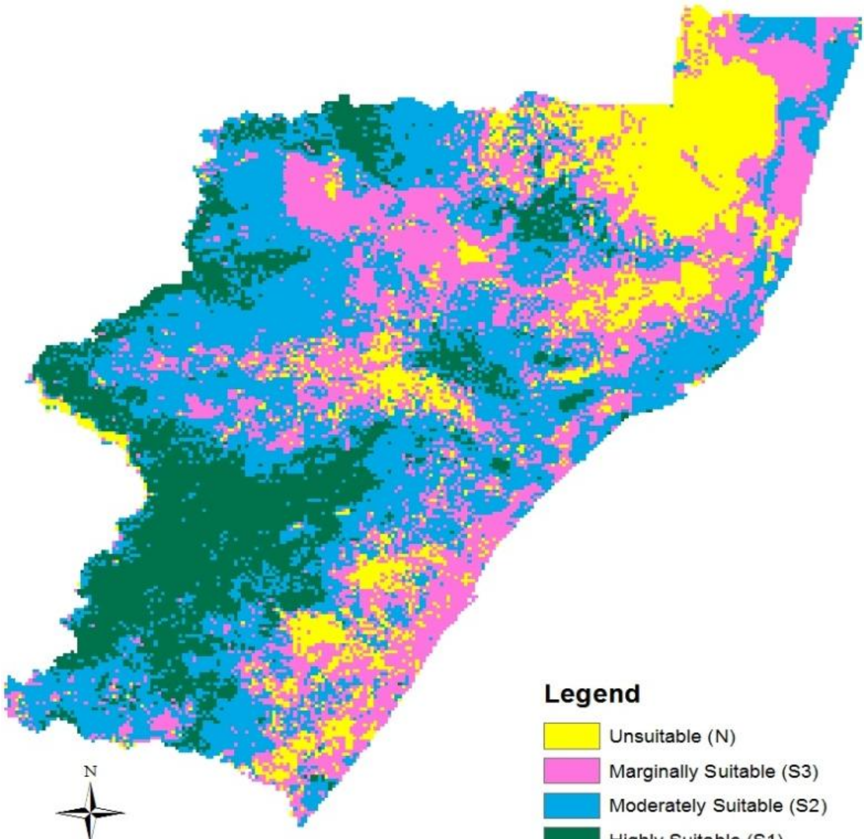
Rain Weight =((Reclass_rfl_1 * 0.04) + (Reclass_rfl_2 * 0.075) + (Reclass_rfl_3 * 0.13)+ Reclass_rfl_4 * 0.075) + (Reclass_rfl_5 * 0.08))

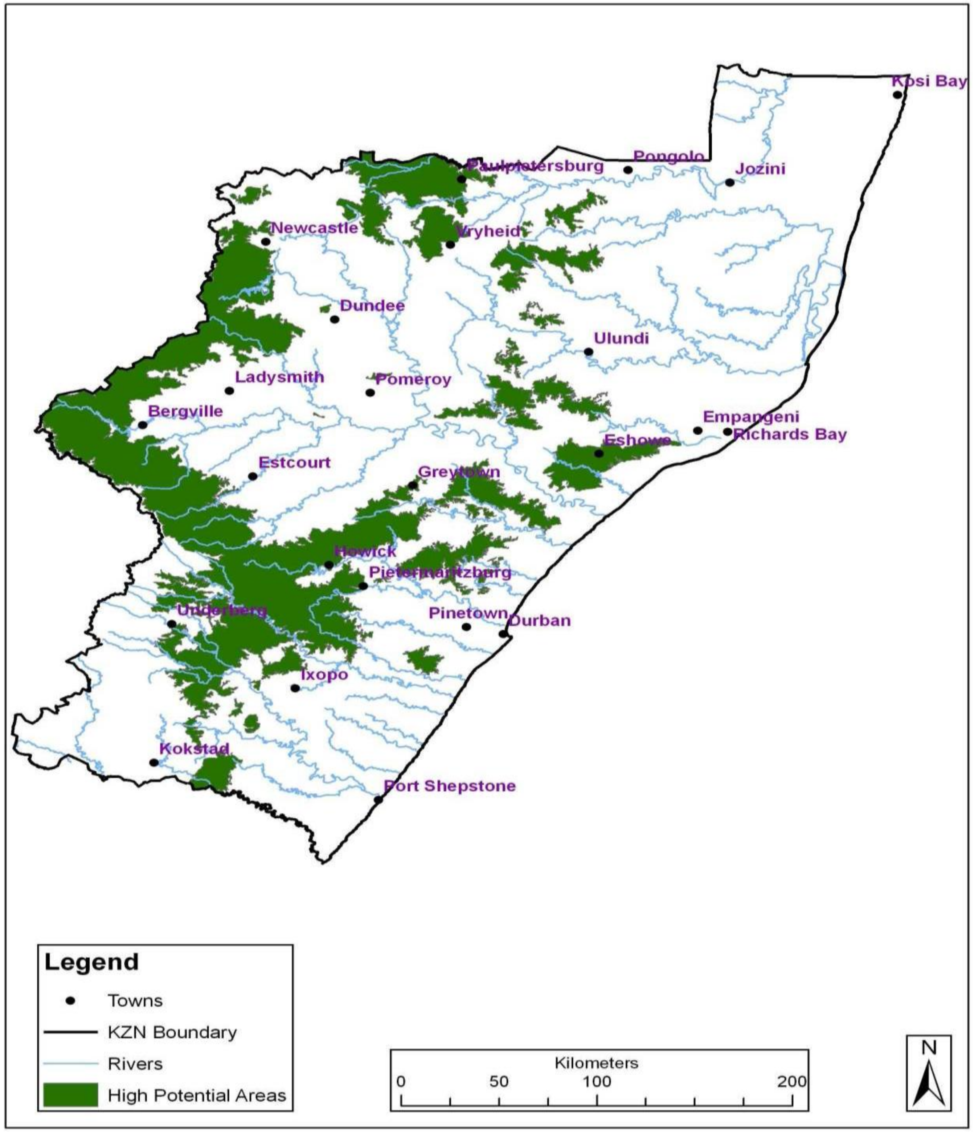
S = Rfl weight + Tmp weight + RH weight + Slpe weight + Soild weight

Potential Soybean Production Areas



Comparison to Previous Studies





Discussion

- Greatest potential identified in
  - KwaZulu-Natal
  - Limpopo
  - Mpumalanga
  - Free State (FS)

- Least Potential
  - Gauteng
  - Eastern Cape (Why build the processing plant near Coega?)

The Way Forward

- Work in progress
- Removal of “No-go” areas
  - Urban areas
  - Water bodies
  - Mining areas
  - Conservation areas

The Way Forward

- Assign yield estimates to each suitability class
  - Highly suitable
  - Moderately suitable
  - Marginal suitable

- Modelling yield estimates using
  – AQUACROP (FAO)
  – SWB (UP)

Acknowledgements

- Water Research Commission for funding
- "Water use of cropping systems adapted to bio-climatic regions in South Africa and suitable for biofuel production (K5/1874)"
- 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;

THANK YOU