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

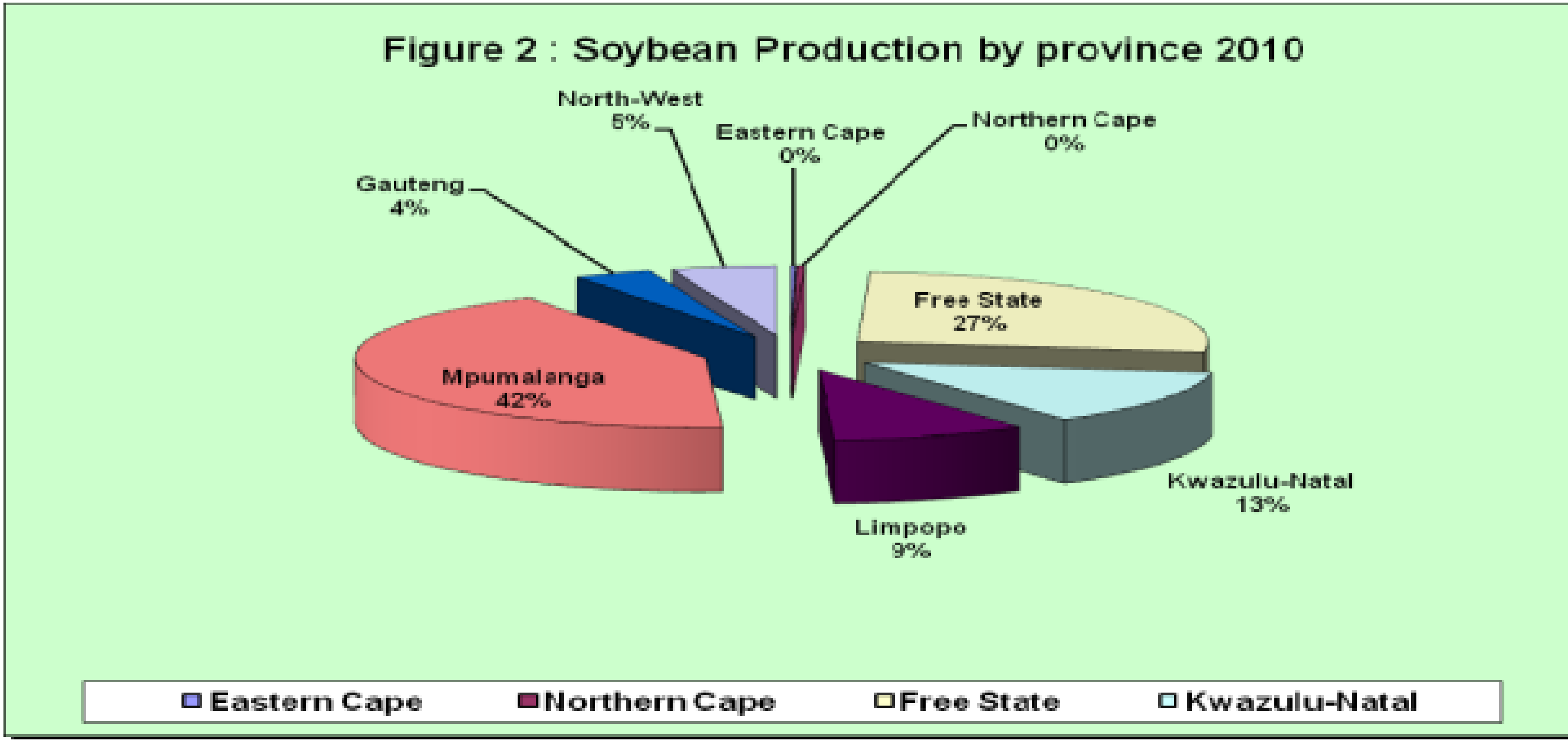
Soybean as a Biofuel Feedstock

- Soybean production in SA ranges from 450,000 to 500,000 t an^{-1}
- 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 the cost of high quality protein animal feed

  in SA
  - Coega IDZ biodiesel: 288 million L an^{-1} from 1,300,000 t soybean

Soybean Production by Province



Source: Statistics and Economic Analysis

Soybean Production by District

Major production areas in South Africa

Source: DAFF, 2010

Province	District	Towns
Mpumalanga	Gert Sibande	Morgenzon, Volkrust, Piet Retief, Perdekop
	Nkangala	Ermelo
	Mankaligwa	Secunda
Free State	Thabo Mofutsanyane	Bethlehem, Warden
	Fezile Dabi	Villiers, Vrede
Kwa-Zulu Natal	Umgungundlovu	Greytown
	Amajuba	Normandien
	Zululand	Pongola, Vryheid
	UMzinyathi	Dundee
	eThekwini	Winterton, Bergville
Limpopo	Waterberg	Koedoeskop, Naboomspruit
	Sekhukhune	Groblersdal, Marble Hall
North West	Ngaka Modiri Malema	Mafikeng, Delareyville, Lichtenberg, Zeerust
	Dr. Kenneth Kaunda	Potchefstroom
		Ventersdorp, Klerksdorp
	Bojanala	Rustenburg, Moretele, Koster, Brits
Gauteng	Metsweding	Bapsfontein, Bronkorspruit
	Sedibeng	Heidelberg/Nigel

Expansion of Soybean Production: Concerns…

1. Land Use and Food Security

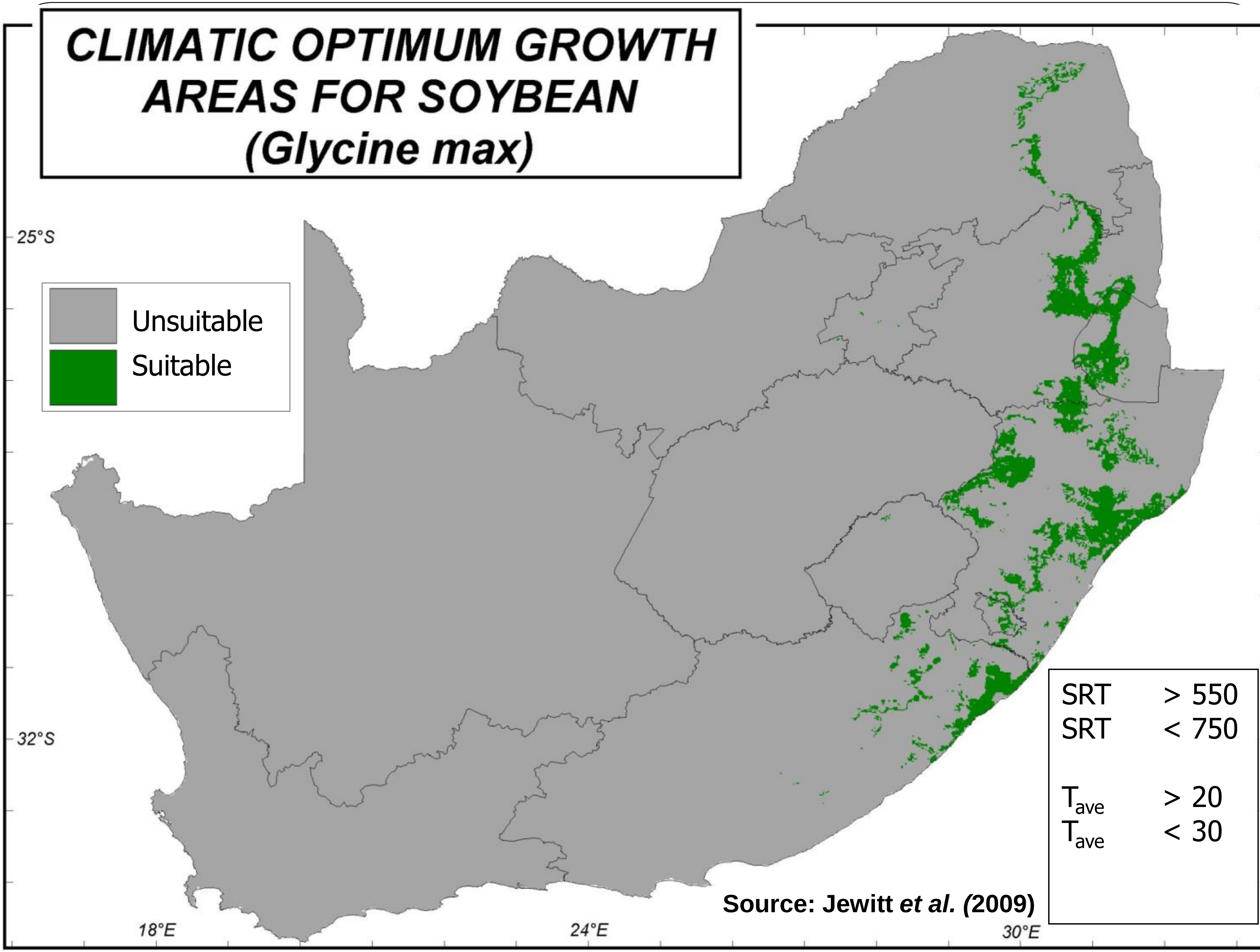
- Competition between food *vs*. fuel
- Possible increase in food prices

2. Environmental impacts

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

Case Study

- 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)

Aim and Objectives

Aim

- To map areas suitable for soybean (Scoping study)
- To improve the approach used in previous mapping studies

Objectives

(a) To undertake detailed literature review for biofuel feedstocks

(b) To account for climatic factors affecting feedstock production

(c) To account for edaphic factors affecting feedstock production

(d) To account for biotic factors affecting feedstock production

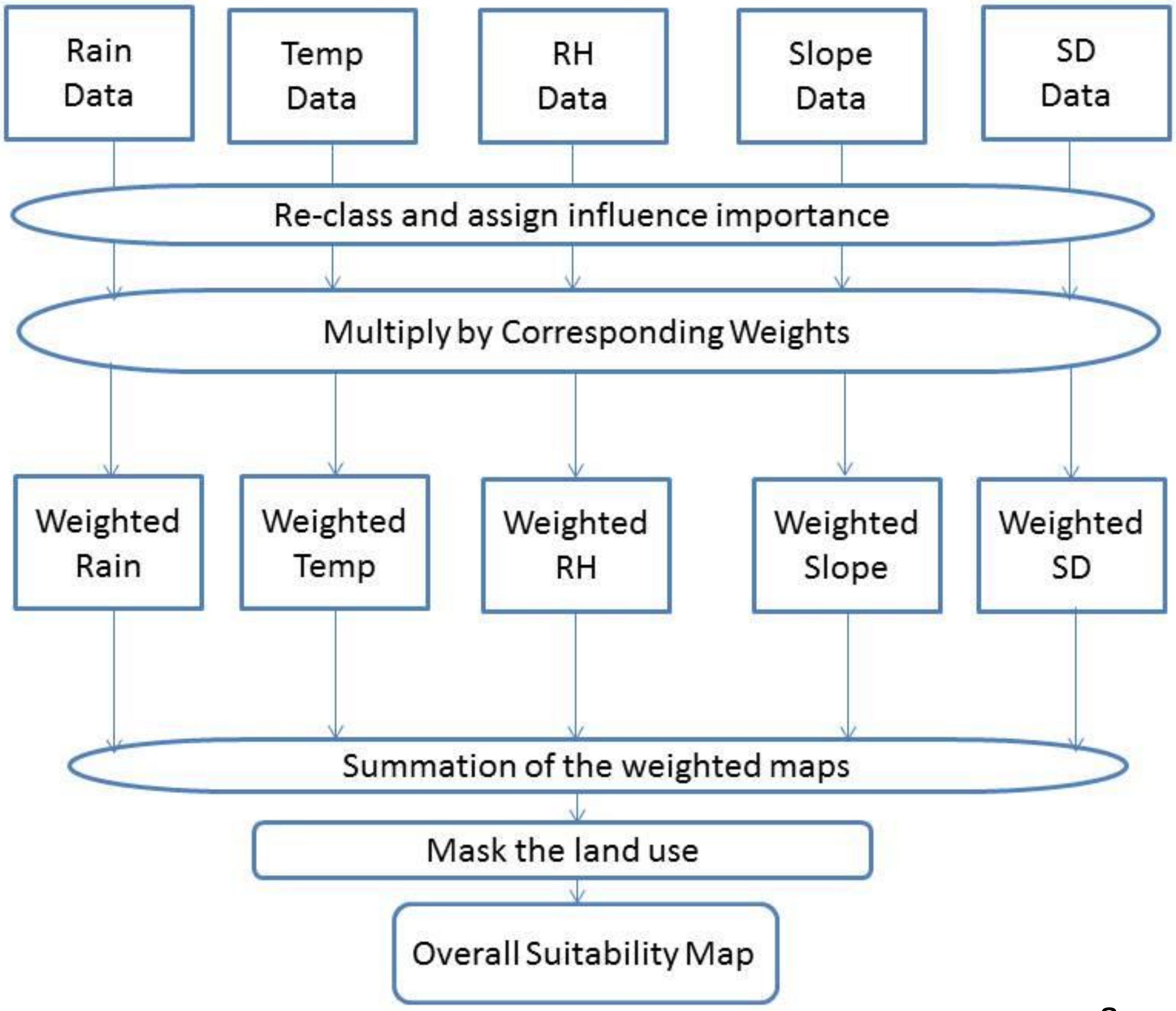
Methodology 1: Literature Review

- **Update the factors limiting feedstock growth:**
  - Rainfall
    - Seasonal rainfall
  - Temperature
    - Monthly average and monthly maximum
  - Relative humidity
    - Potential for disease occurrence (e.g. soybean rust)
  - Soils and topography
    - Soil depth and slope

Optimum Growth Criteria

Source	Annual rainfall (mm)	Seasonal rainfall (mm)	T_{ave} (^{0}C)	Frost Tolerance	RH_{ave} (%)	Slope (%)	Soil Depth (mm)	pH	Soil Texture	Rank
Jewitt et al. (2009) recommended		550-700	20-30							3
Smith (1994)	> 700	450-700	18-35 Sub Jan > 19				600-1300		No very Sandy/ poorly drained	3
Smith (1998)	> 700	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
Schoeman and Walt (2006)	> 600		25							
Schulze & Maharaj (2006)	> 600		Jan > 18							5
INR (2004), Kassam (2012)						0-12				2
Ebrahim (2007), Singels (2013)						0-20				1
Nunkumar et al. (2009)					< 75					4
Schulze & Maharaj (2008)	> 600		Jan > 18							5
Schulze & Kunz (2010)	> 600		Jan > 18							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				300-400	6-6.5	loamy	7

Methodology 2: Mapping



Source: After Koikai, 2008

Methodology 3: Rainfall

- Growth season: November to March
- Accumulated seasonal rainfall total
- Classified seasonal rainfall into optimum and sub-optimum classes (Reclassify)

Suit classes	No	Abs	Sub	Opt	Sub	Abs	No
	0	1	2	3	2	1	0
Nov-Mar	0-450	450-550	550-700	700-900	900-1000	1000-1100	>1100

Methodology 3: Rainfall

- Rainfall distribution according to crop coefficients
  - Apportioned per month based on K_{cm}

FAO, 2013	Local	
0.3 - 0.4	0.72	Initial stage (20 to 25 days)
0.7 - 0.8	0.72	Development stage (25 to 35 days)
1.0 - 1.2	1.00	Mid-season stage (45 to 65 days)
0.7 - 0.8	1.03	Late-season stage (20 to 30 days)
0.4 - 0.5	0.84	At harvest

- Monthly rainfall distribution classes (700 - 900 mm):
  - Month 1 — 70 - 90
  - Month 2 — 135 - 170
  - Month 3 — 165 - 210
  - Month 4 — 195 - 250
  - Month 5 — 135 - 180

Methodology 4: Temp & Humidity

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

Suit classes	No	Abs	Sub	Opt	Sub	Abs	No
	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 Suitability=3
  - 60- 75 Medium disease risk Suitability=2
  - 75- 80 High disease risk Suitability=1
  - >80 Very high disease risk Suitability=0

Methodology 5: Depth & Slope

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

- Slope (%) (Reclassify)
  - < 4 Optimum Suitability=3
  - 4-8 Sub-optimum Suitability=2
  - 8-10 Absolute Suitability=1
  - >10 Unsuitable Suitability=0

Methodology 6: Weightings

- Assigned influence of importance
  - Monthly rainfall 4 (Odindo, 2013)
  - Monthly temperature 2
  - Monthly relative humidity 1
  - Soil depth 1
  - Slope 2

  Total **10**

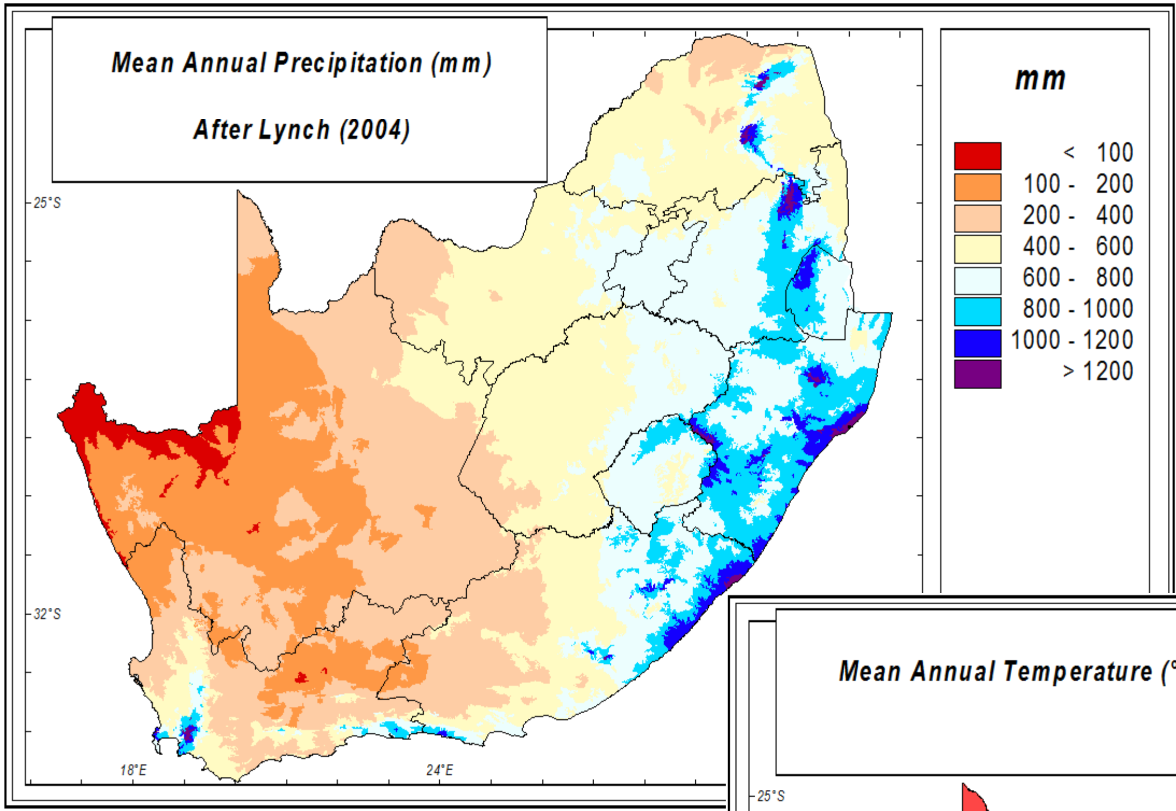
- Weighting varied per month
  - e.g. Monthly relative humidity weightings
    - Month 1 0.1
    - Month 2 0.1
    - Month 3 0.2
    - Month 4 0.3
    - Month 5 0.3

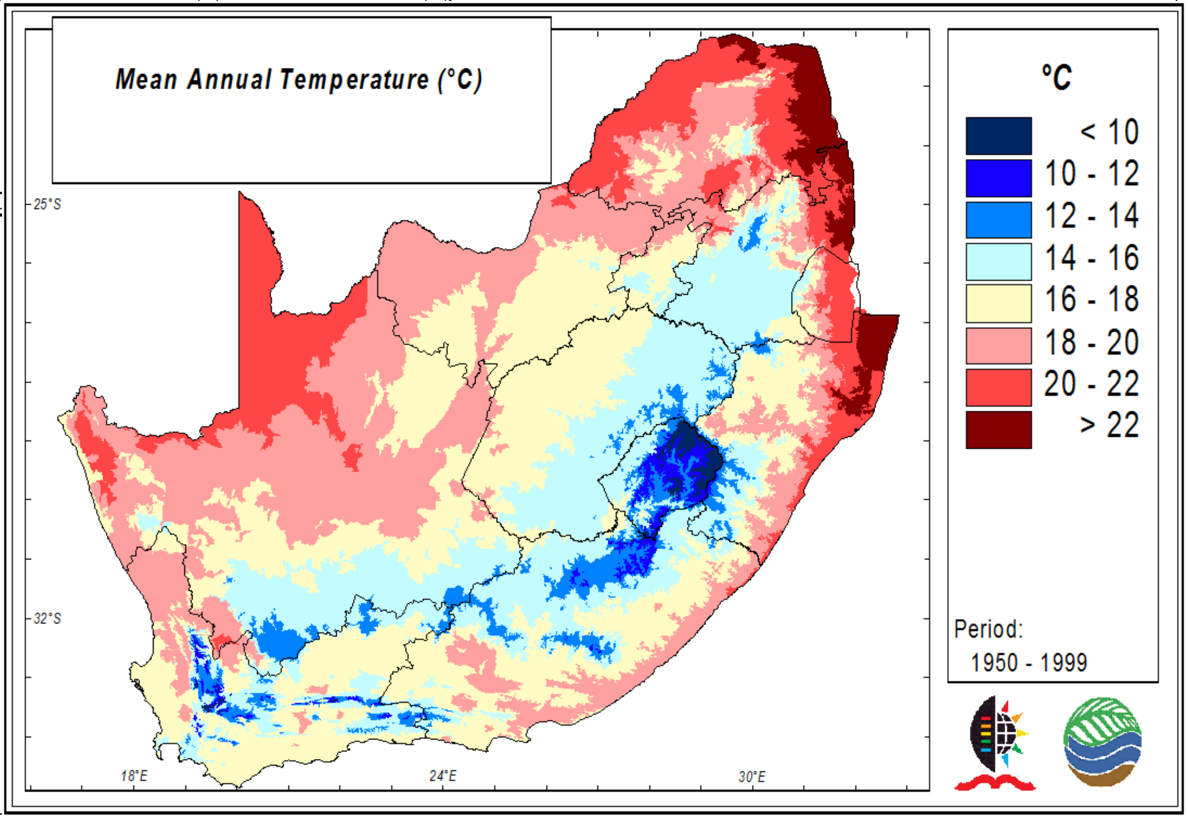
Criteria and Ranking

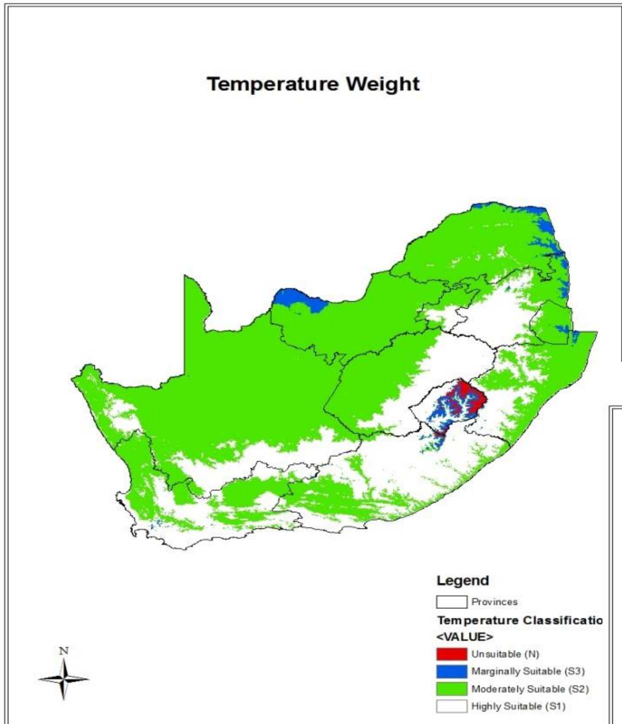
Suitability Values	Unsuitable	Low Suitability	Medium Suitability	High Suitability	Medium Suitability	Low Suitability	Unsuitable	Assigned Influence Importance	Decimal Weight
Reclass Values	0	1	2	3	2	1	0		
MR01 (mm)	0-45	45-55	55-70	70-90	90-100	100-110	>110	0.4	0.04
MR02 (mm)	0-85	85-105	105-135	135-170	170-200	200-220	>220	0.9	0.09
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	0.9	0.09
MR05 (mm)	0-90	90-110	110-135	135-180	180-210	210-230	>230	0.5	0.05
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 (%)	100-10	10-8	8-4	4-0				2	0.2
Total								**10**	**1**

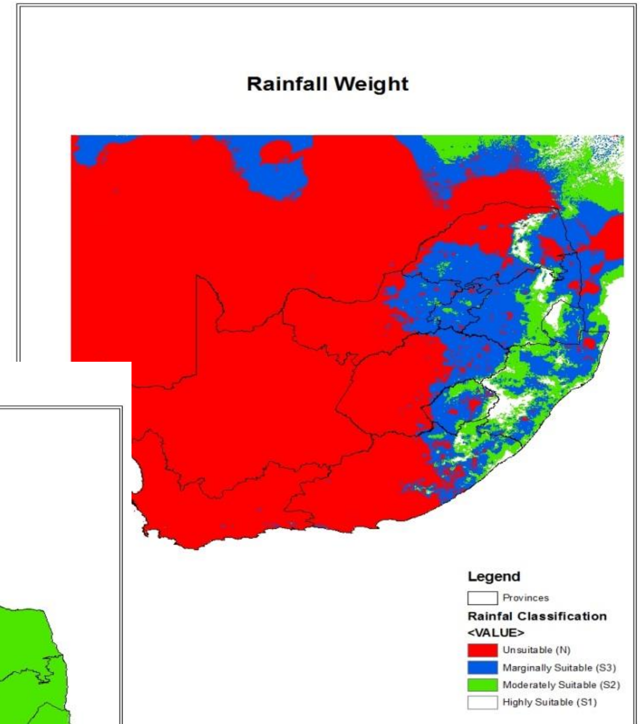
South African Atlas of Climatology and Agrohydrology

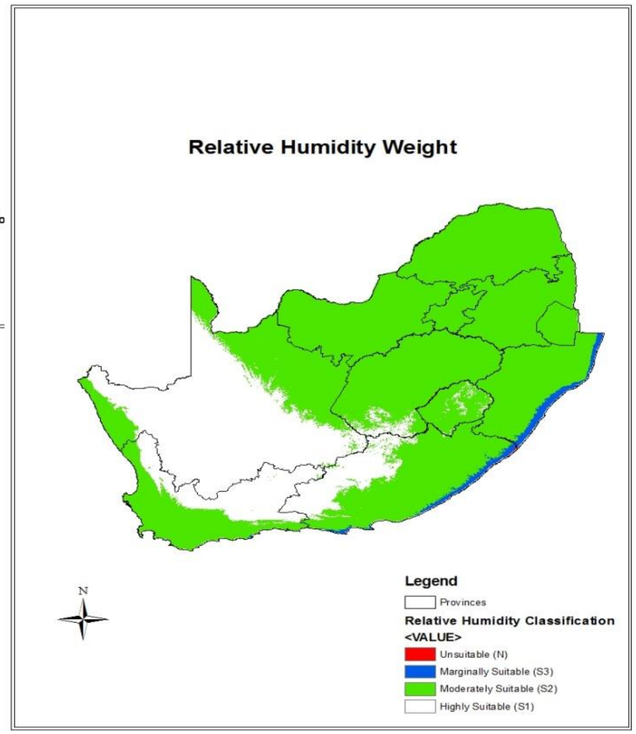
(Schulze *et al.*, 2007; 2008)


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





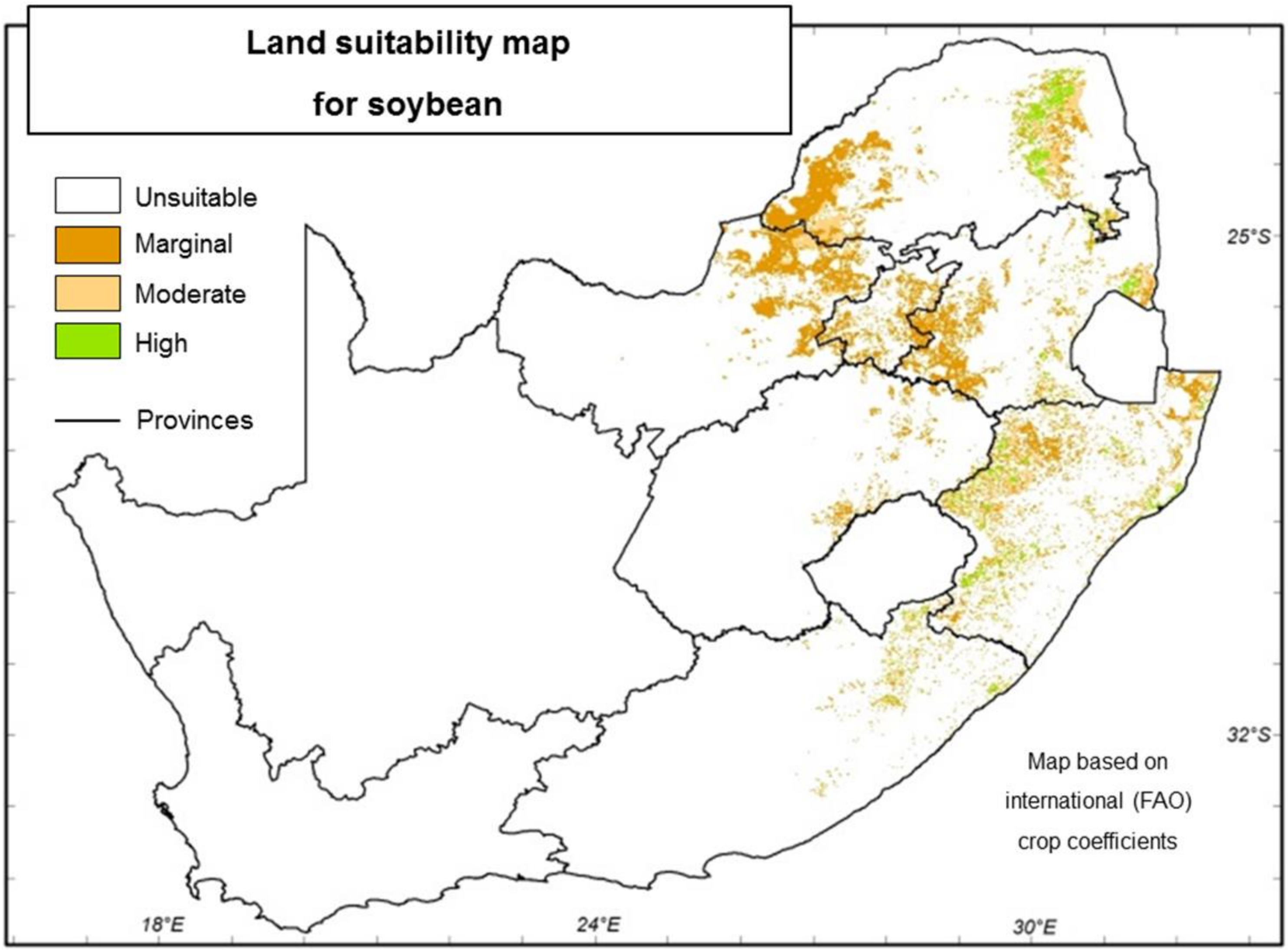


Raster calculator

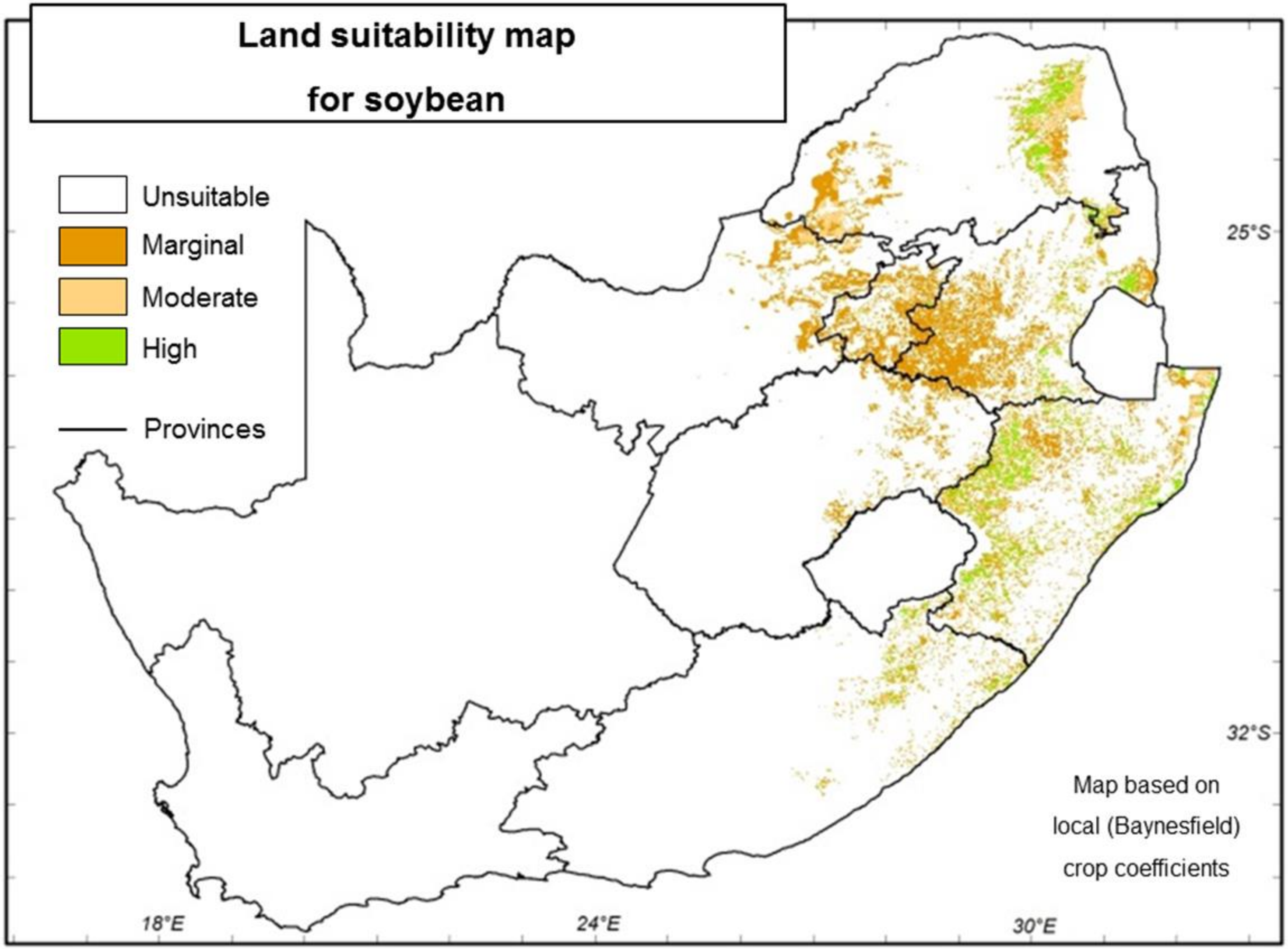
Rain Weight =((Reclass_rfl_1 * 0.04) + (Reclass_rfl_2 * 0.09) + (Reclass_rfl_3 * 0.13)+ Reclass_rfl_4 * 0.09) + (Reclass_rfl_5 * 0.08))

S = Rfl weight + Tmp weight + RH weight + Slpe weight + Soild weight (**minute* minute**)

Potential Soybean Production Areas (Based on FAO crop coefficients)



Potential Soybean Production Areas (Based on Local crop coefficients)



Discussion

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

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