UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

WATER RESEARCH COMMISSION

Centre for Water Resources Research

Water use and nutritional value of indigenous root and tuber food crops

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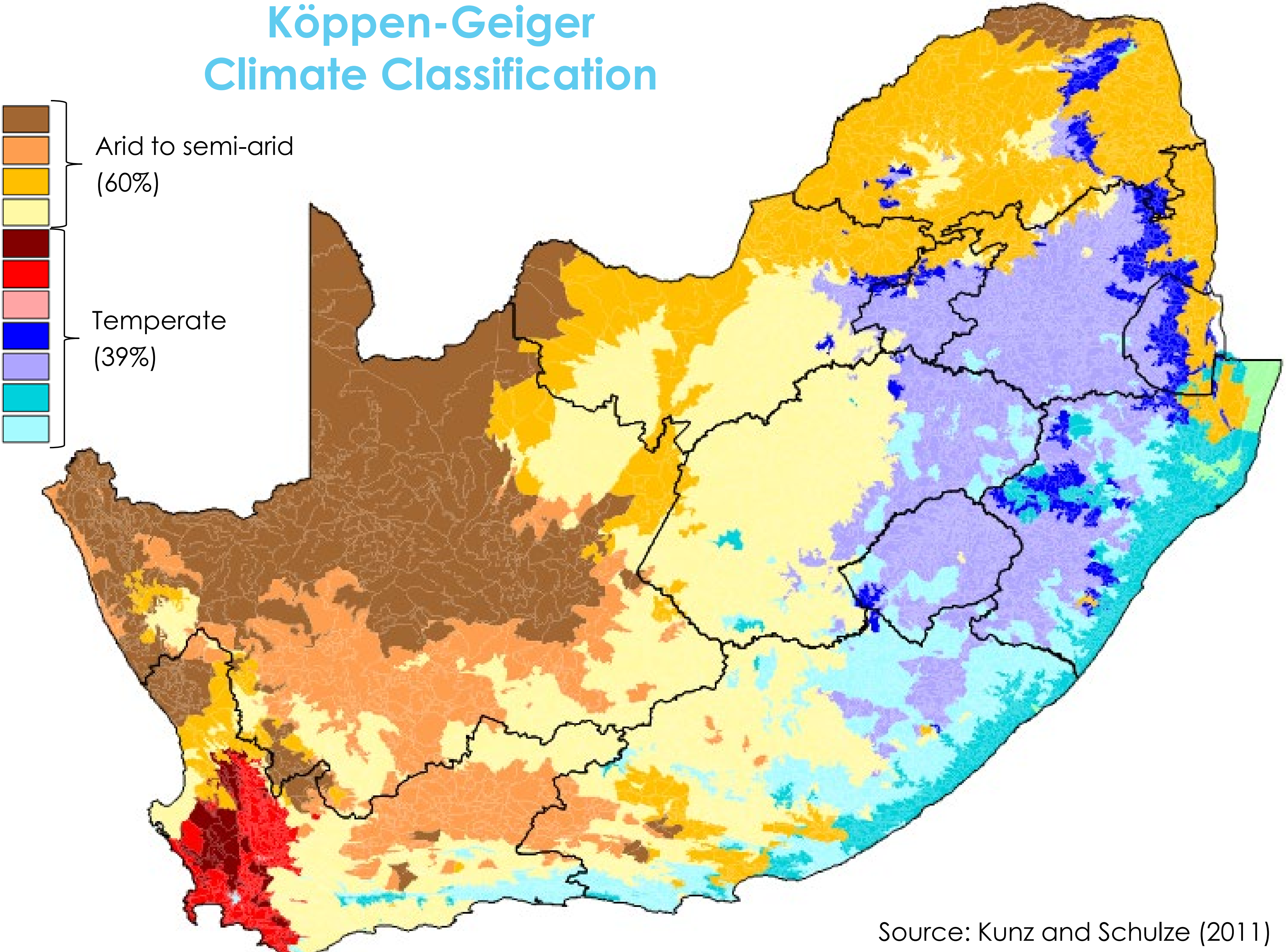
WRC Dialogue on World Food Day
"Our actions are our future - better production, better nutrition, a better environment and a better life"

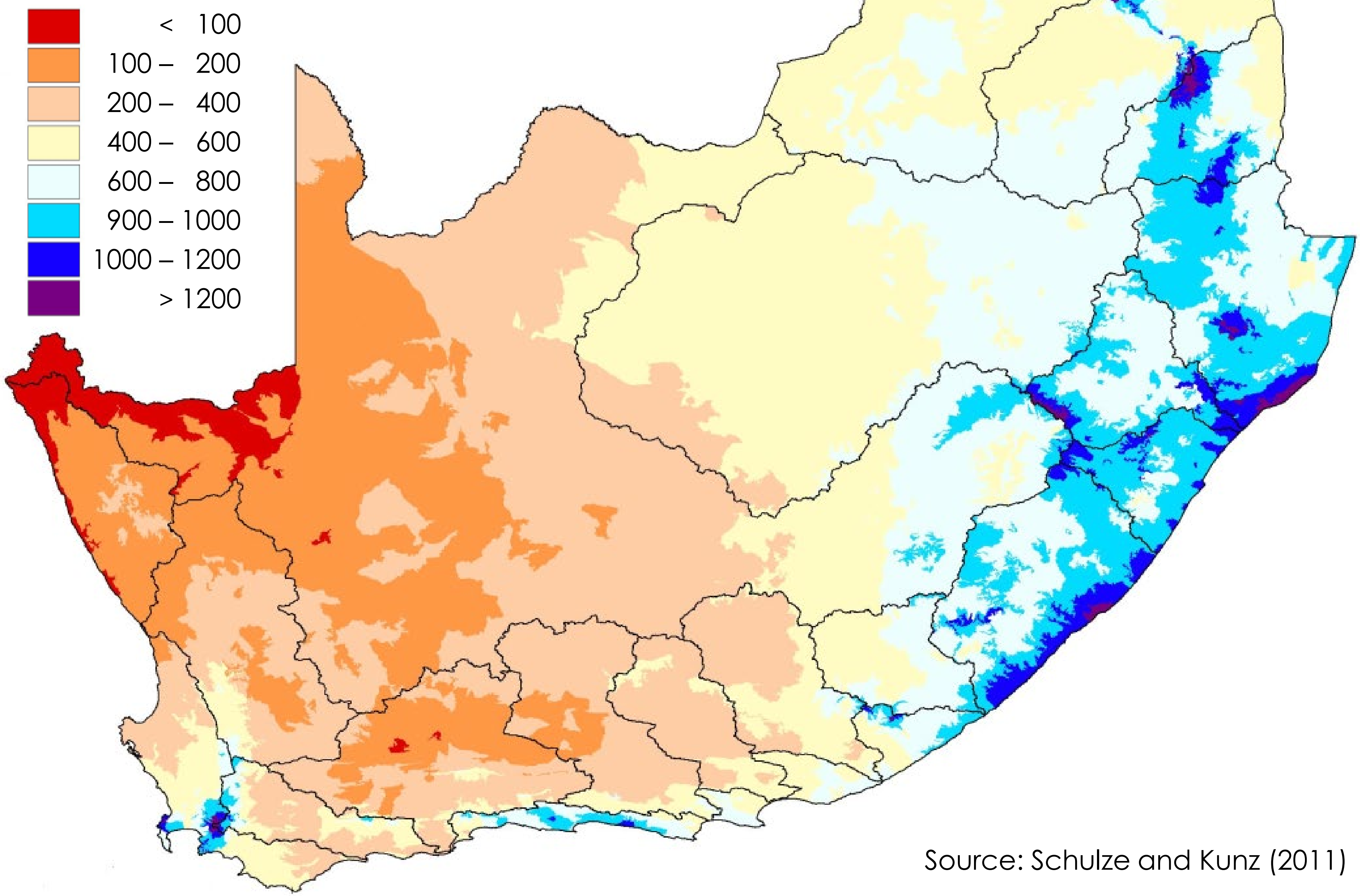
15 October 2021

Köppen-Geiger Climate Classification



Source: Kunz and Schulze (2011)

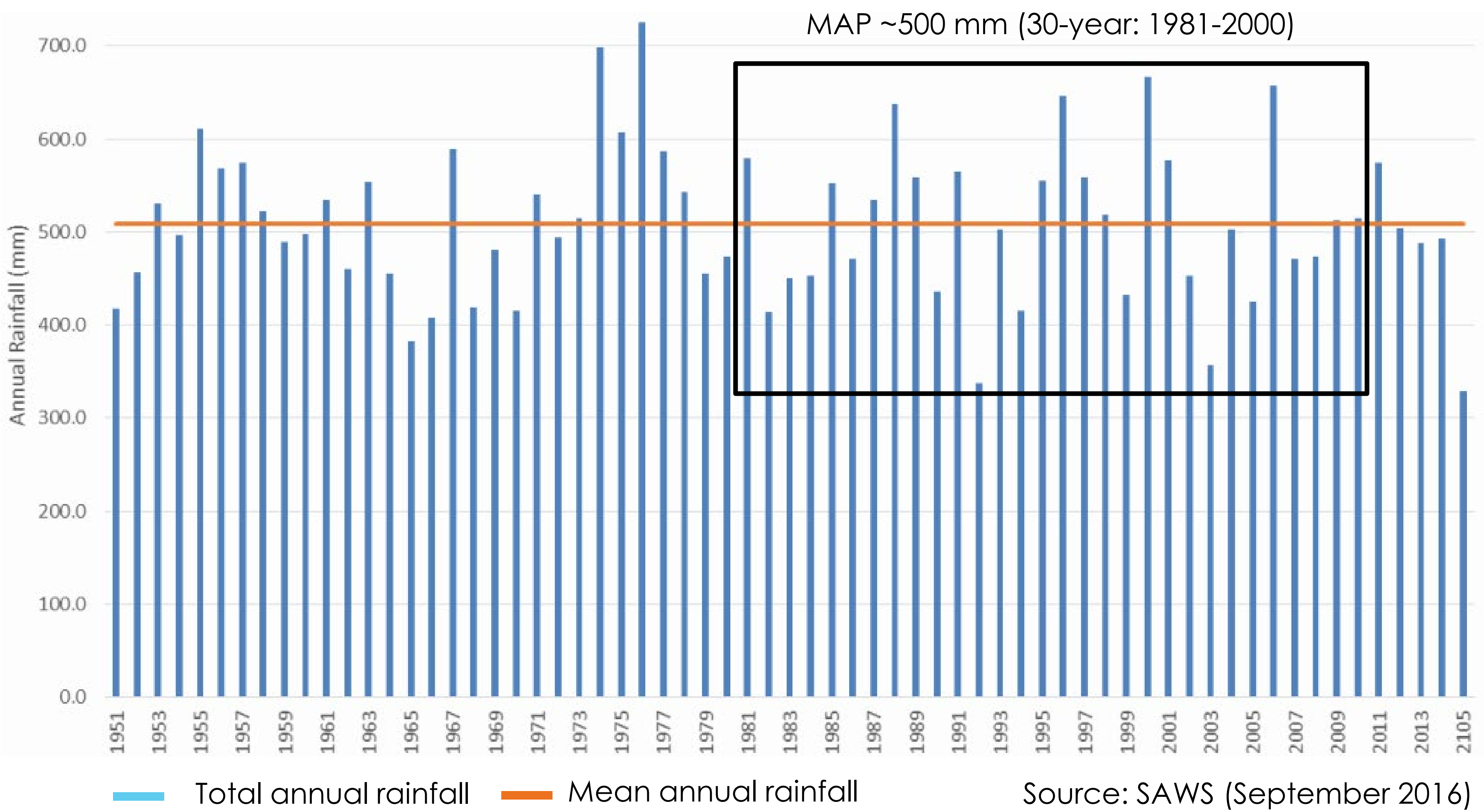
Mean Annual Precipitation (MAP in mm)



Source: Schulze and Kunz (2011)

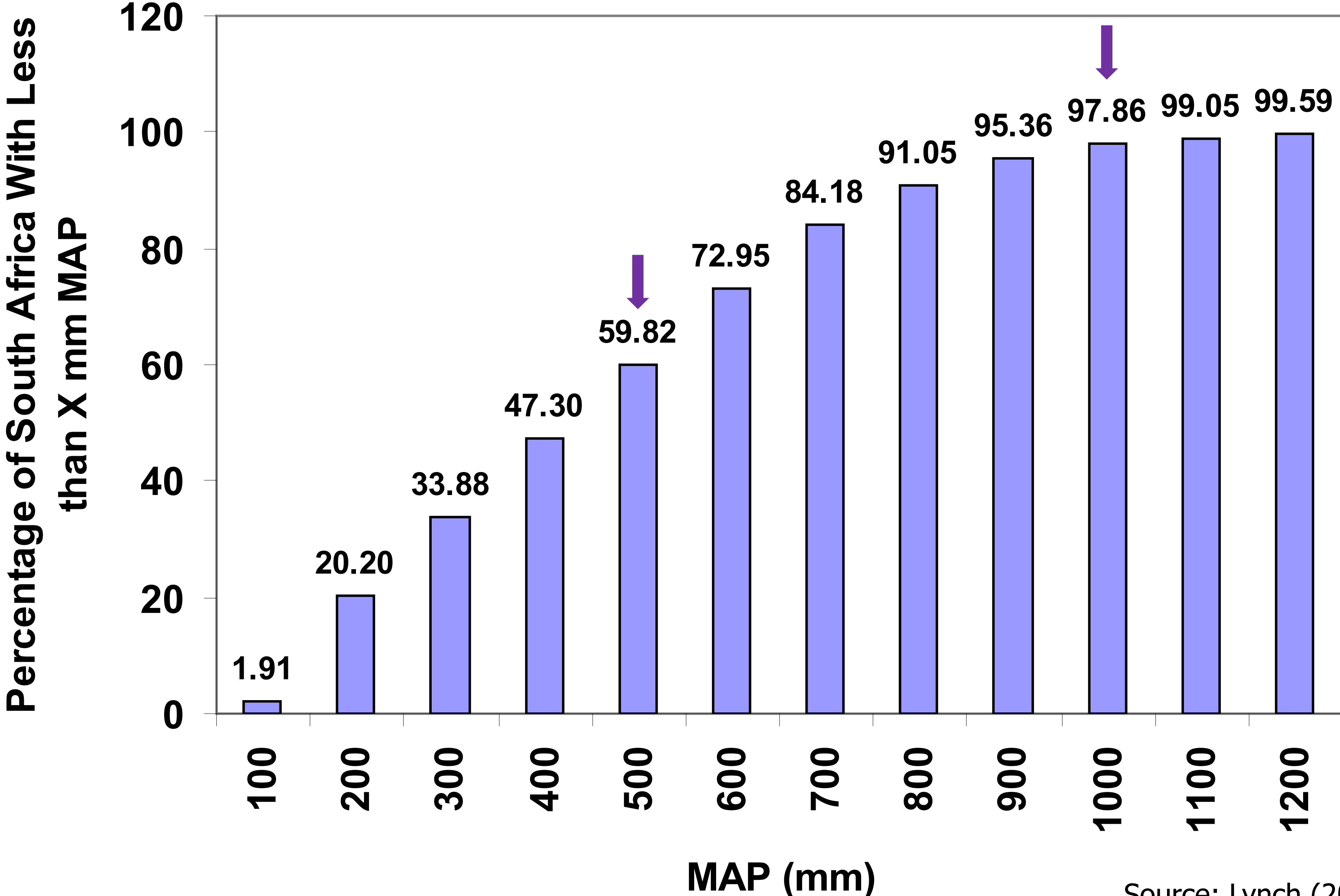
South Africa is a water scarce country

- MAP ~500 mm (half world's average)
- World's 30th driest country
- Low and highly variable rainfall
- Yet, 90% of crop production is rainfed



Source: SAWS (September 2016)

~60% of SA receives ≤ 500 mm of annual precipitation
~2% of SA receives > 1000 mm of annual precipitation



Source: Lynch (2004)

Water-stressed Catchments

- **Water allocation in strategic catchments**
  - Expansion of irrigated crop production is highly unlikely

Catchment	Supply (Available)	Demand (Required)	Balance
Mkomasi	31	99	-68
Upper Thukela	394	425	-31
Bushmans, Buffalo	137	149	-12
Mooi	128	137	-9
Lower Thukela	79	93	-14
Mvoti, Mlazi, Lovu	86	118	-32
uMngeni	**414**	**504**	**-90**
South Coast	25	41	-16
Mzimkulu	16	50	-34

Source: DWS (2018)

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Small Scale Farmers

- **Affected by numerous constraints**
  - Low and erratic rainfall
    - Dominant factor affecting crop production
    - Cannot easily be improved with irrigation
  - Marginal, less fertile soils
  - Limited access to information (e.g. production guidelines)
    - Unable to make informed decisions
  - Low and unreliable yields
    - Food and nutrition insecurity
  - Limited access to markets
    - Low infrastructural development

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Small Scale Farmers

- **How can scientists help farmers?**
  - Need to fully understand their vulnerability
  - Help revive and strengthen indigenous knowledge systems
  - Produce knowledge that benefits both society and the economy

- **Enable farmers to grow crops that:**
  - are resilient to climate risks
    - drought and heat stress tolerant
  - produce reasonable yields with less water
    - exhibit high crop (and nutritional) water productivity
  - improve agro-biodiversity and dietary diversity
  - promote the development of new value chains
    - e.g. biofuel production from crops

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Underutilised indigenous food crops may be part of the solution

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Benefits of Indigenous Crops

- **Why produce underutilised indigenous crops?**
  - Nutrient dense
    - Improve household nutrition security
  - More resilient to climate risks
    - “Drought insurance” crops (drought and heat stress tolerant)
  - Require few external inputs for production
  - Produce reasonable yields where other crops cannot
  - Reduce dominance of cereal-based cropping systems
  - Revive agricultural production and alleviate poverty
    - Potential to be commercialised (and industrialised)

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Benefits of Indigenous Crops

- **Why produce underutilised indigenous crops?**
  - The following SDGs can be addressed:

Benefits of Indigenous Crops

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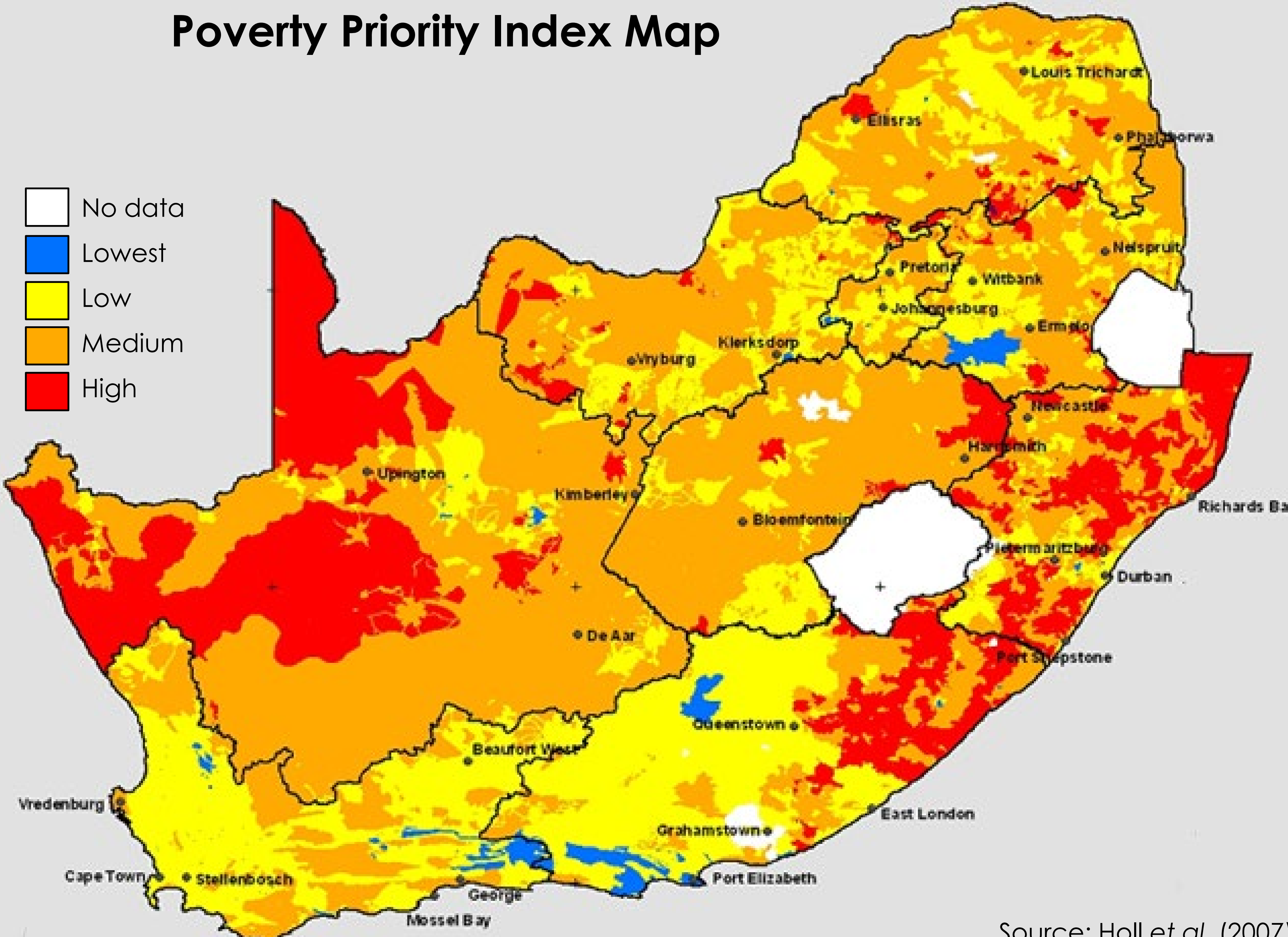
SDG	Description	
1	End poverty in all forms everywhere	
2	End hunger Achieve food security	Improve nutrition Promote sustainable agriculture
3	Ensure healthy living	Promote well-being
8	Promote sustainable economic growth and employment	
15	Halt and reverse: • land degradation • biodiversity loss	Combat desertification

Poverty Priority Index Map



Source: Holl *et al.* (2007)

Challenges

- **Indigenous crops exhibit vast potential, yet remain underutilised**
  - Why? Mainly due to lack of research focus
    - Historically, more attention given to cereal crops
    - Imbalance is being addressed by WRC

- **Main factors hindering indigenous crop production**
  - Lack of production guidelines
    - limits adoption of these crops and upscaling of crop production
  - Lack of detailed physiological information
    - restricts use of crop models
  - Absence of well-developed and supported value chains
    - no formal seed systems (value chains remain rudimentary)

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Research investment is key to address and overcome these challenges

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Background

- **WRC-funded research on underutilised crops**
  - More than 2 decades of research to date
  - Goal: promote underutilised and indigenous food crops
  - Three main research themes
    - (a) Drought and heat tolerance
    - (b) Water use and nutritional value
    - (c) Nutritional water productivity
- **Draft research agenda (Modi and Mabhaudhi, 2016)**
  - To guide future research funding related to underutilised crops
  - Identified 13 priority crops based on:
    - drought, heat tolerance and nutritional value
  - Highlighted significant gaps in knowledge on crop production

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Background

WRC PROJECT NO. (AUTHORS)	PROJECT DESCRIPTION
1771 (Modi & Mabhaudhi, 2013)	Water-use and drought tolerance of selected crops, e.g. amaranth, groundnut, taro, millet
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2274 (Modi & Mabhaudhi, 2017)	Determining water use of grain and legume crops, e.g. sorghum, maize, cowpea, groundnut
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2717 (Mabhaudhi et al., 2022)	Model water use (present & future) and develop production guidelines for certain crops, e.g. taro, amaranth, groundnut, sorghum
2019/20-00088 (Kunz et al., 2024)	**Water use of root and tuber food crops, e.g. cassava, sweet potato, taro, tannia, yam**

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Root and Tuber Crop Project

- **4-year WRC-funded research project**
  - R2 million (Apr 2020 to Mar 2024)
- **Principal investigators**
  - Prof Tafadzwa Mabhaudhi
  - Mr Richard Kunz
- **Project's main goals:**
  - Contribute to the existing knowledge base of RTCs
  - Promote the sustainable production of RTCs
    - by small scale farmers (poverty alleviation)
  - Upscale production of RTCs from small to large scale

Root and Tuber Crop Project

- **Specific objectives**
  - Conduct detailed review of:
    - crop water use and yield
    - nutritional and health benefits
  - Identify major gaps in knowledge
  - Then address these gaps through field work
    - Measure crop water use, yield and nutrient content
  - To improve existing knowledge of crop and nutritional WP
  - Model the water use and yield of RTCs
  - Develop land suitability maps and production guidelines

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Literature Review

- **Classification of RTCs (Lebot, 2019)**
  - Belong to different botanical families
    - produce underground food
    - vegetatively propagated
  - None are indigenous to SA
    - but have become indigenised
  - Tannia and yam
    - remain mostly underutilised

Common name	Botanical name	Family name	LP	MP	KZN	FS	EC	WC
Cassava	*Manihot Esculenta*	Euphorbiaceae	√	√	√			
Potato	*Solanum Tuberosum*	Solanaceae	√		√	√		√
Sweet potato	*Ipomoea batatas*	Convolvulaceae	√	√	√			√
Taro	*Colocasia Esculenta*	Araceae		√	√		√	√
Tannia	*Xanthosoma* spp.	Araceae						
Yam	*Dioscorea* spp.	Dioscoreaceae						

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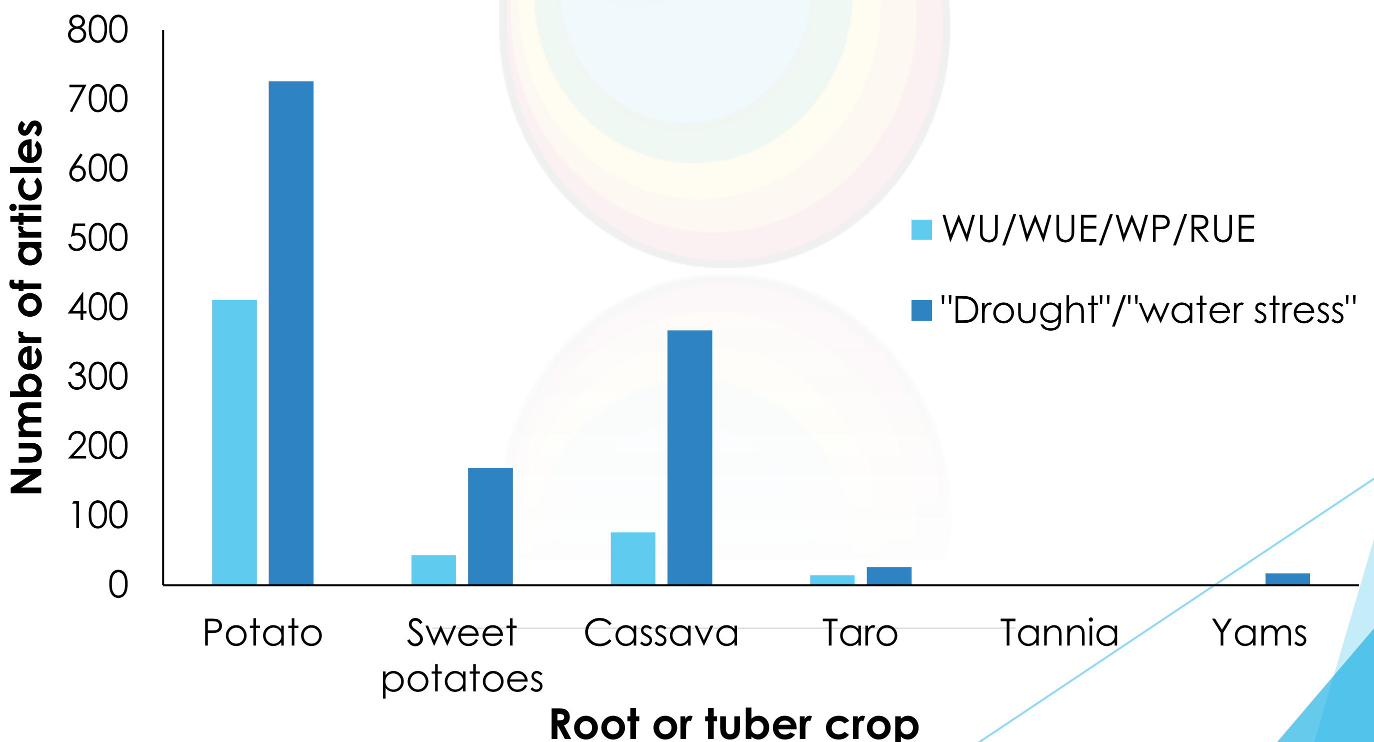
Literature Review

- **Availability of information (2000-2020)**
  - Disproportionate attention given to individual RTCs
    - most research on potato (not discussed)
    - least research on tannia and yams (not discussed)
  - Focus on cassava, sweet potato and taro



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Literature Review
Cassava

- **Crop water use**
  - Large range (500–1750 mm) in optimum water requirement
  - High drought tolerance
    - Deep rooting system
    - Should translate to high CWP/WUE
    - Similar CWP as sorghum
- **Edible vs industrial cassava**
  - Highlights the role of biotechnology and plant breeding research
  - Edible cassava
    - Low starch, high protein, low cyanide, high Zn, Fe and vitamin A
  - Industrial cassava
    - High starch, low protein, high cyanide (discourage animal ingestion)
    - 27-37% of starch (fresh weight), compared to 15-28% for other RTCs
    - Bioethanol yield of 6000 L ha^{-1} (vs 4900 L ha^{-1} for sugarcane)

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Literature Review
Sweet Potato

- **Crop water use**
  - Large range (700-1500 mm) in optimum water requirement
  - Short cycle crop (3-5 months)
  - Moderate drought tolerance
    - Not during first six weeks of establishment
    - Decreases leaf area when water stressed

- **Common cultivars**
  - Staple type (e.g. A40)
    - White flesh and white/purple skin
    - Higher starch and dry-matter content
  - Dessert type (e.g. A45, 199062.1)
    - Orange flesh and orange skin
    - Higher beta-carotene content

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Literature Review
Taro

- **Crop water use**
  - High water requirement (1750-2500 mm) relative to other RTCs
    - Due to genotype differences (upland vs lowland)
    - Requires further investigation to confirm high water use

- **Genotypes**
  - Upland taro (e.g. Umbumbulu landrace)
    - Eddoe type more drought tolerant than dasheen type
    - Better adapted to water-limited production (good stomatal control)

  - Lowland taro (e.g. KwaNgwanase landrace)
    - Usually planted in low-lying areas (e.g. coastal areas of northern KZN)
    - Prefers waterlogged (i.e. swamp) areas

  - Upland taro more water use efficient than lowland taro

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Literature Review

- **Main findings on crop water use and water productivity**
  - Disproportionate attention given to individual RTCs
    - Most for potato and cassava; least for tannia and yams
  - When compared to cereal crops:
    - research on crop water use and water productivity is scarce
    - amount of water required for successful production is unclear
  - Lack of credible information (evidence is anecdotal)
    - Will limit promotion and production of RTCs (especially in new areas)
  - Drought avoidance mechanisms usually have high yield penalty
    - e.g. water stressed yam delays tuber initiation, thus reducing final yield

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  - Taro and sweet potato highlighted as priority crops

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Literature Review

- **Purpose of literature review**
  - Highlight existing knowledge gaps
  - Identify RTCs that are:
    - drought tolerant (e.g. cassava)
    - water use efficient (e.g. sweet potato)
    - nutrient dense (e.g. taro and yam)
  - Help focus project's research efforts

	Cassava	Sweet potato	Taro
Drought tolerance	**High**	Moderate	Low
Growing period (days)	300-600	90-150	180-240
Expected yields (t ha^{-1})	11-21	4-10	4-24
Crop water use (mm)	500-1750	700-1500	*1750-2500*
Water productivity (kg m^{-3})	0.19-0.24	**0.65-0.95**	0.53-0.71
Energy (kcal)	130-160	86-170	**276-352**

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Root and Tuber Crops (RTCs)

- **Nutrient composition: RTCs provide**
  - energy (kcal) from
    - carbohydrates (mostly)
    - protein
  - $^{1}/_{3}$ the energy of wheat/rice
    - due to high moisture content
  - more energy per unit land than cereals
    - due to high root/tuber yields
  - good source of dietary fibre

- **Superior nutritional content of taro**
  - High energy and protein content
  - High protein digestibility
  - Farmers in Umbumbulu (KZN)
    - Sell produce to Woolworths & Pick 'n Pay

Highest values	Cass-ava	Sweet potato	Taro
Energy (kcal)	160	170	**352**
Carbs (%)	83	**90**	86
Protein (%)	2.0	4.8	**7.8**
Crude fat (%)	0.3	0.4	0.8
Crude fibre (%)	1.8	**3.7**	3.0
Moisture (%)	67	69	68
Starch (g)	**37**	28	25

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Root and Tuber Crops (RTCs)

- **Mineral composition**
  - Taro is high in Ca, Mg, P & Na
  - Sweet potato is high in K
    - reduce blood pressure
- **Vitamin composition**
  - Sweet potato is very high in vitamin A
    - due to beta-carotene content
- **Vitamin A deficiency in children**
  - Problem is SSA
  - Cause of night blindness
  - Addressed by eating sweet potato
    - orange fleshed varieties

Highest values	Cass-ava	Sweet potato	Taro
Zinc (mg)		8.4	2.6
Manganese (mg)		4.9	1.9
Calcium (mg)	33	48	**132**
Magnesium (mg)	21	111	**415**
Phosphorus (mg)	27	159	**340**
Sodium (mg)	14	55	**1521**
Potassium (mg)	271	**1242**	340
Vitamin A (IU)	13	**14187**	
Vitamin C (mg)	**20.6**	2.4	14.3
Thiamine (mg)	0.09	0.08	0.18
Riboflavin (mg)	0.05	0.06	0.04
Niacin (mg)	0.85	0.56	1.30

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Root and Tuber Crop Project

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Way Forward

- **Field-based research**
  - Focus on upland taro (eddoe type) and sweet potato (orange flesh)
    - high nutritional value
    - potential to create new value chains in marginal areas
  - Measure over the growing season
    - crop water use via eddy covariance and surface renewal
      - confirm crop water requirement (especially taro)
    - crop growth (LAI, chlorophyl content, stomatal conductance)
  - Measure at harvest
    - yield of roots/tubers and leaves
      - calculate crop water productivity
    - nutrient content of roots/tubers and leaves
      - calculate nutritional water productivity

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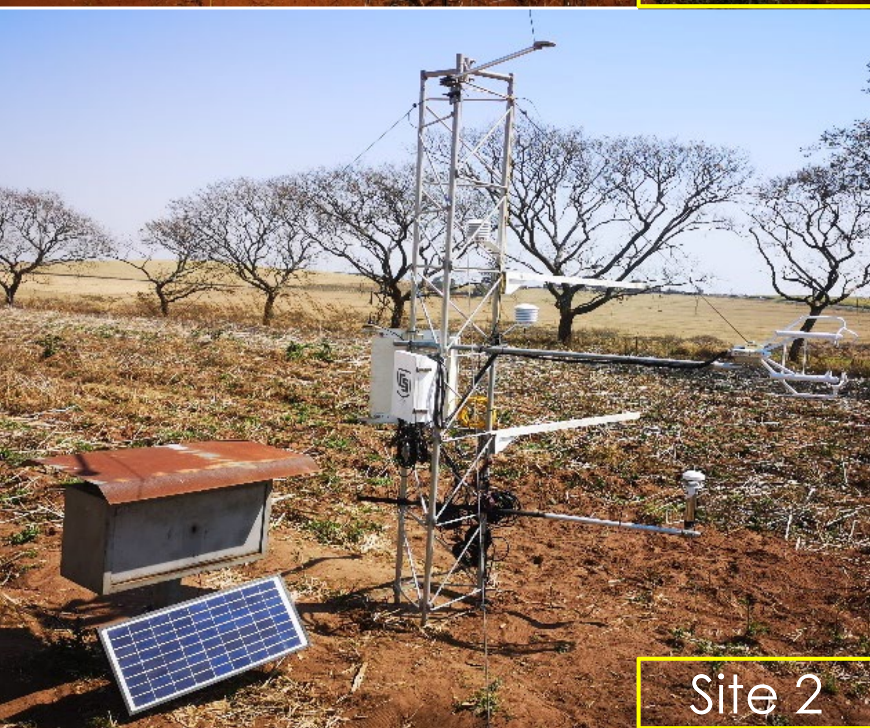

Fountainhill Estate
(near Wartburg, KZN)
29.450°S; 30.533°E; 851 m

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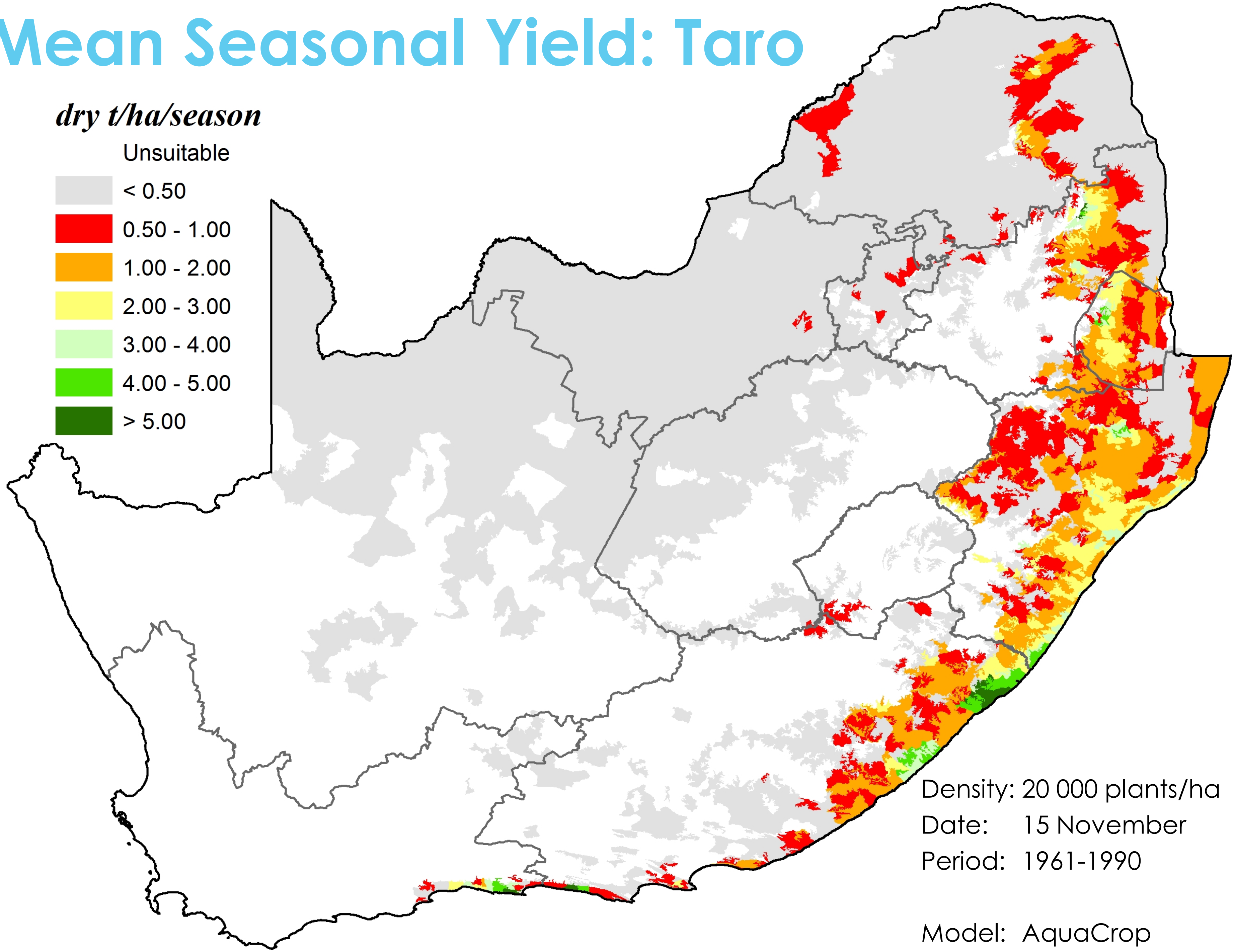
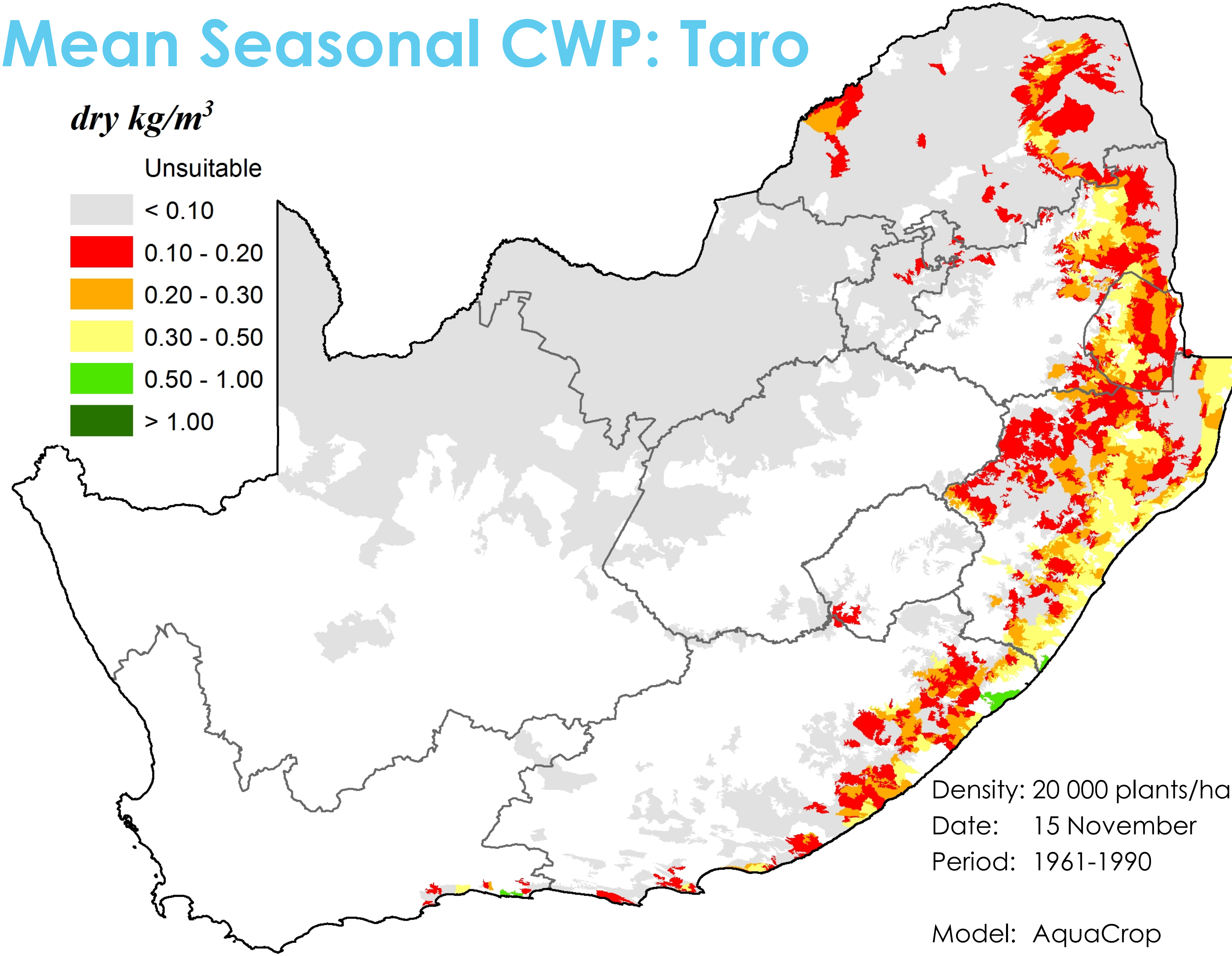
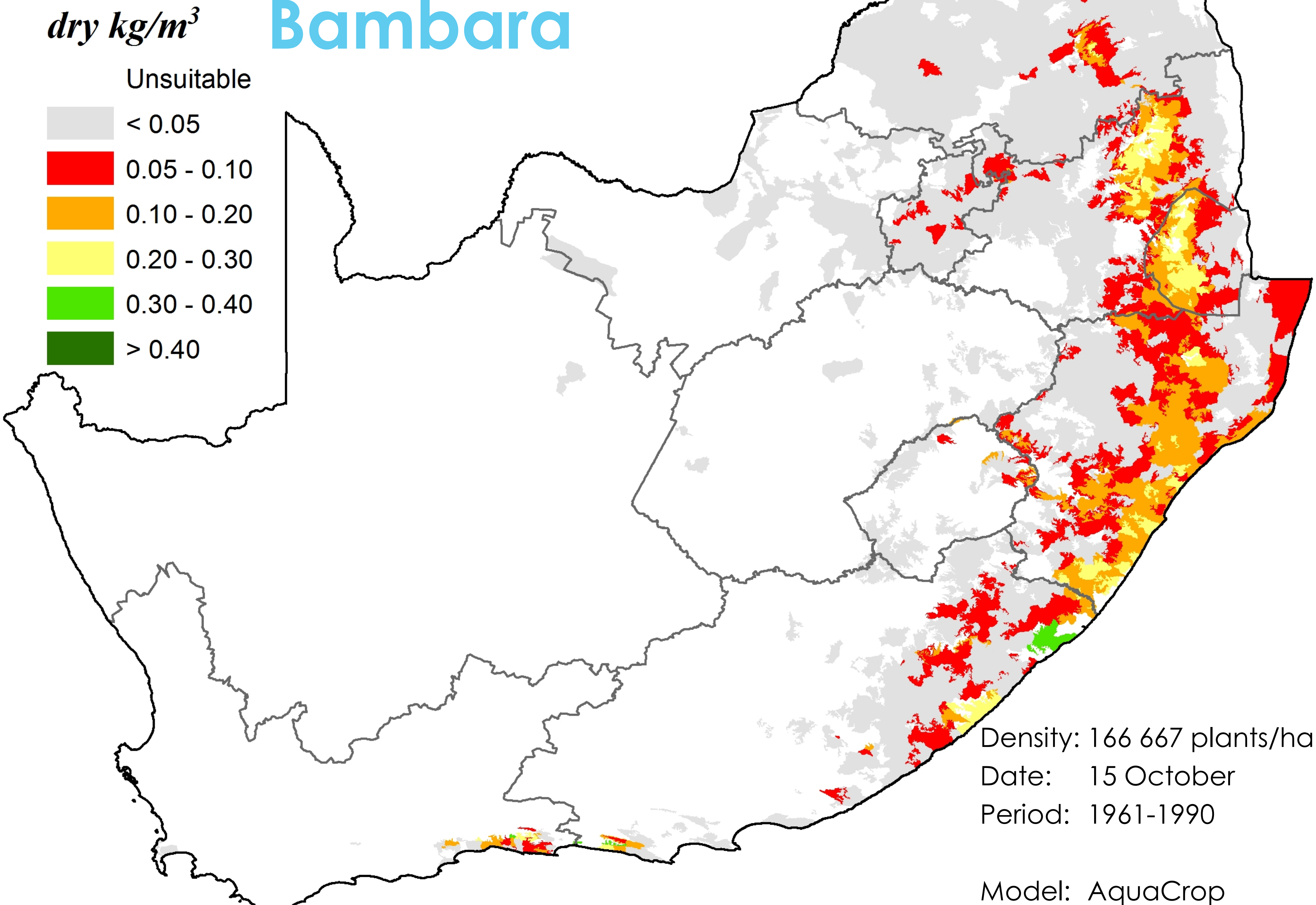
Mean Seasonal Yield: Taro



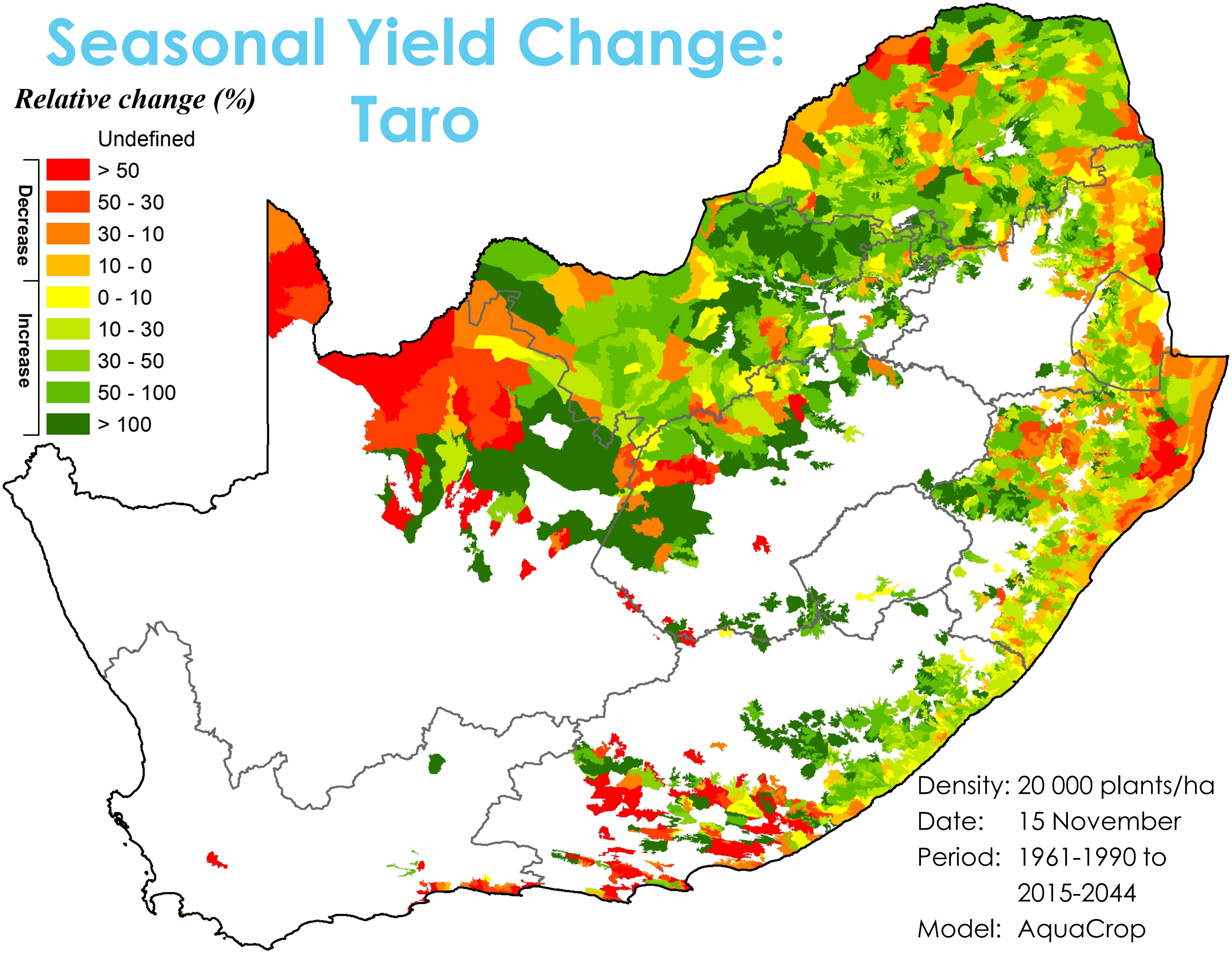
Mean Seasonal CWP: Taro



Mean Seasonal CWP: Bambara



Seasonal Yield Change: Taro



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The Important Role of RTCs

- **Better production**
  - Drought and heat tolerant (e.g. cassava)
    - resilient to climate variability and change
  - More crop choices for farmers
    - improve agro-biodiversity in SA
  - Tolerate low agricultural inputs and marginal soils
    - produce reasonable yields where other crops cannot

- **Better nutrition**
  - Nutrient dense (e.g. taro and yam)
  - Alleviate malnutrition and hunger
  - Improve dietary diversity in SA

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The Important Role of RTCs

- **Better environment**
  - High crop water productivity (e.g. sweet potato)
    - more "crop" per "drop"
  - High nutritional water productivity
    - potato (5626) > maize (3856) > wheat (2279) > rice (1989 kcal m^{-3})
  - Strive towards most beneficial use of scarce water resources
- **Better life**
  - Revive, expand and improve agricultural production
  - Increase profitability of smallholder farming systems
  - Alleviate rural poverty and reduce inequality
    - especially in KZN and E. Cape
  - Improve food and nutrition security
    - household and national level

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Thank You

If you have any unanswered questions, email:

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