Quantifying Beef Cattle Grazing Behaviour Using Sentinel-2 Data in the Strandveld Region of South Africa

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~70% of available land in SA
= unsuitable for cultivation
→ extensive ruminant grazing

Climate change & population growth
→ maximize productive use
→ livestock farming

Comprehensive understanding of livestock grazing behaviour

Various factors influence animal behavior

BACKGROUND

Better knowledge of animal grazing behavior
→ animal observation
= correct management

Observe animal in its most natural state → minimal human interference

GPS & satellite technology
→ Remote sensing (RS)

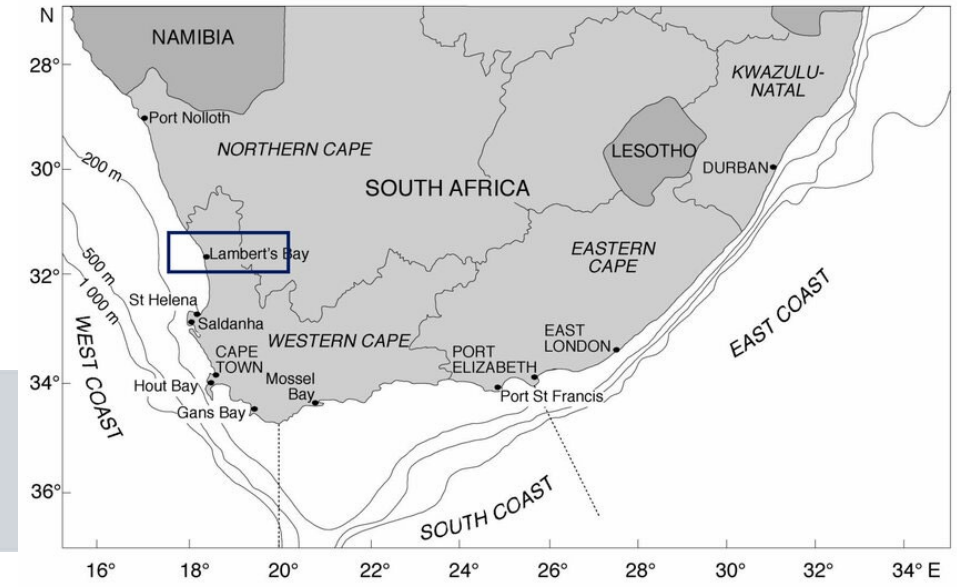
Bailey et al., 2019; Hunt et al., 2003; Jansen et al., 2021; Kilgour et al., 2012; Scholtz *et al.*, 2013; Wong & Candolin, 2015

AIMS

- Determine & compare seasonal differences in extensive grazing behaviour of 2 beef cattle breeds.

- Evaluate 8 different vegetation indices for predicting beef cattle grazing behaviour.

METHODOLOGY: EXPERIMENTAL SITE



Nortier experimental farm (32.020665 S, 18.195552 E)	• north of Lambert's Bay • Western Cape, South Africa
Mediterranean climate	• April – September: 76% of the total long-term yearly rainfall of 221mm • Summers: warm and dry & Winters: colder and marked by erratic rainfall
Vegetation	• Strandveld (type 34) • landscape mainly Strandveld dunes
Limited crop production	• extensive sheep/ cattle production • reliant on natural pastures

Acocks, 1988; Cloete & De Villiers, 1987; Cloete et al., 2007; Engelbrecht et al., 2009; Schloms, 2007

METHODOLOGY: ANIMAL MANAGEMENT

Six Bonsmara (Bos taurus indicus) &

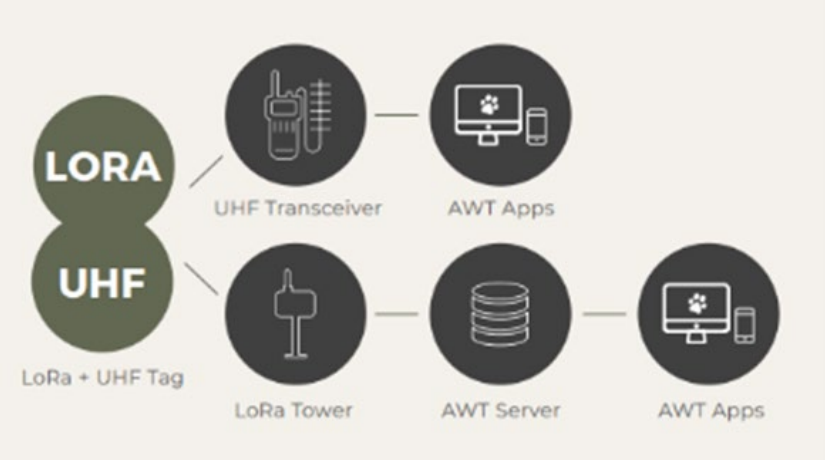
Six Nguni (Bos taurus africanus) cows in one herd

- natural vegetation - no supplementary feed
- December 2022 - November 2023 (12 months)
- similar age (born between August and November 2020)
- granted adaptation period

Ethical clearance:

- Stellenbosch University's Research Ethics Committee: Animal Care and Use (reference number: ACU-2023-24740)

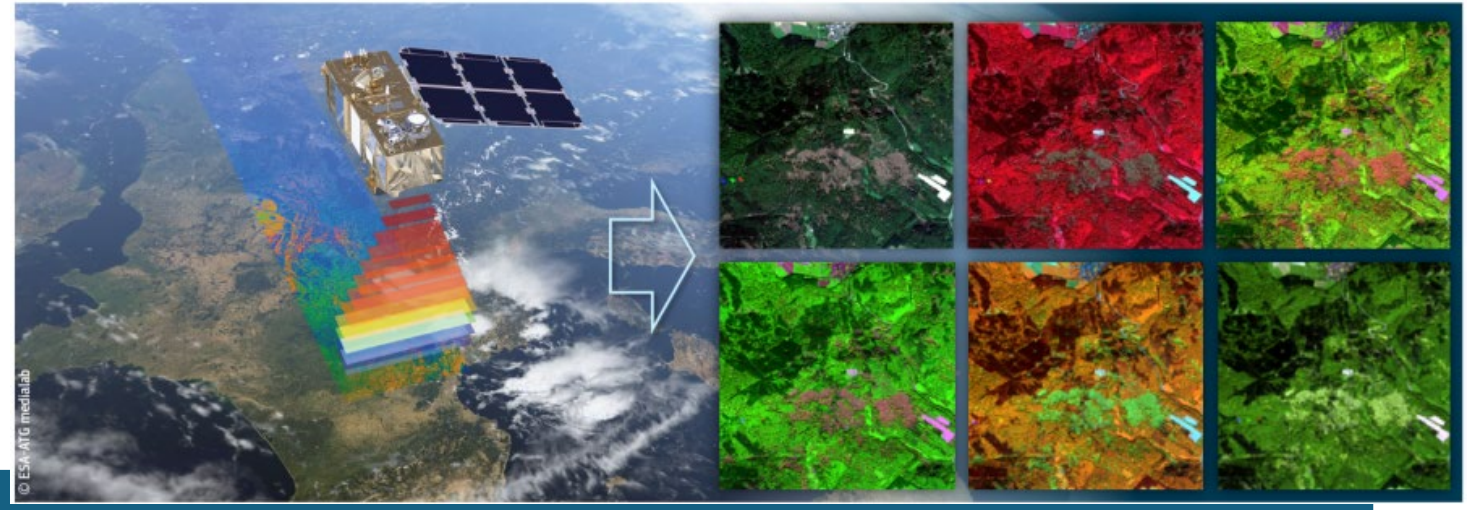
METHODOLOGY: DATA COLLECTION



Animal movement data

- **December 2022 – August 2023 (summer, autumn, winter): 290ha**
  - 5 camps & 2 central waterpoints: all gates opened
  - allowing access to the same area year-round: better comparison between seasons
- **September – November 2023 (spring): 177ha**
  - 2 camps closed off, 1 central waterpoint
- **Each cow fitted with LoRa (GPS/UHF) collar**
  - secure near real-time GPS animal tracking
  - bidirectional communications between collars & tracker application: enabled by solar-powered tower unit
  - Inmarsat satellite constellation as communications backhaul
  - individual animal's GPS location at half-hourly intervals: ~ 200 000 GPS coordinates

METHODOLOGY: DATA COLLECTION



Satellite imagery

- Google Earth Engine: Sentinel-2 satellite images
- multispectral high-resolution sensor operating on 13 different bands
- collect data on the reflectance of land surfaces at a wide range of wavelengths
- new image for any given location generated every 5 days
- all cloud-free Sentinell-2 images extracted
- top-of-atmosphere radiance values converted to surface reflectance values: Sen2Cor.
- 8 spectral indices generated

Addabbo et al., 2016; Harmse et al., 2022; Marzialetti et al., 2019; Main-Knorn et al., 2017; https://learn.opengeoedu.de/en/fernerkundung/vorlesung/copernicus/Sentinel-2-Teil-1

METHODOLOGY: DATA COLLECTION

Table 1 *Spectral indices and the formula used to generate each index*

Index	Formula	Reference
Bare soil index	$BSI = \frac{(Red + SWIR) - (NIR + Blue)}{(Red + SWIR) + (NIR + Blue)}$	(Rikimaru & Miyatake, 1997)
Chlorophyll red edge index	$CIr = \frac{Red\ edge\ 3}{Red\ edge\ 1} - 1$	(Al-Shammari *et al.*, 2024)
Green chlorophyll index	$GCI = \frac{(NIR)}{(Green)} - 1$	(Gitelson *et al.*, 2005)
Modified normalised difference vegetation index	$MNDVI = \frac{c\ .NIR - Red}{c\ .NIR + Red}$	(Vaiopoulos *et al.*, 2004)
Moisture stress index	$MSI = \frac{(MidIR)}{(NIR)}$	(Harmse *et al.*, 2022)
Normalised difference moisture index	$NDMI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$	(Xiao *et al.*, 2019)
Normalised difference vegetation index	$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$	(Rouse *et al.*, 1974)
Soil adjusted vegetation index	$SAVI = \frac{1.5\ \times (NIR - Red)}{(NIR + Red + 0.5)}$	(Huete, 1988)

METHODOLOGY: DATA ANALYSIS

Hot spot analysis

- incidents → GPS point data on cattle location
- aggregation polygons (zones) → 40 x 40m areas organised in a regular array (fishnet)
- grazing ruminants flock around water points & rest along camp boundaries
  → buffer 30m from water points & 10m from fences
- GPS data subjected to statistically significant spatial clustering analysis
  → Getis-Ord Gi* statistic
  - Optimised Hot Spot Analysis (OHA) tool of ArcGIS 10.7
    - A feature's local sum & that of its neighbours are compared proportionately to the sum of all features.
    - Gi* statistic specifies statistical significance: z-scores & p-values
    - z-score > 2 (95% CI) = hot spots; z-score < -2 (95% CI) = cold spot

ESRI, 2017; Getis & Ord, 1992; Harmse et al., 2022; MLA, 2024; Ord & Getis, 1995

METHODOLOGY: DATA ANALYSIS

Spectral index analysis

- Visual representations of 8 Sentinel 2-derived indices at 10m x 10m resolution: created in ArcGIS 10.7
- Relationship between Gi* z-scores & corresponding Sentinel-2 derived spectral indices investigated
  - non-parametric Generalised Additive Models (GAMs)
  - fit smooth function
  - model the relationship in RStudio version 4.2.0

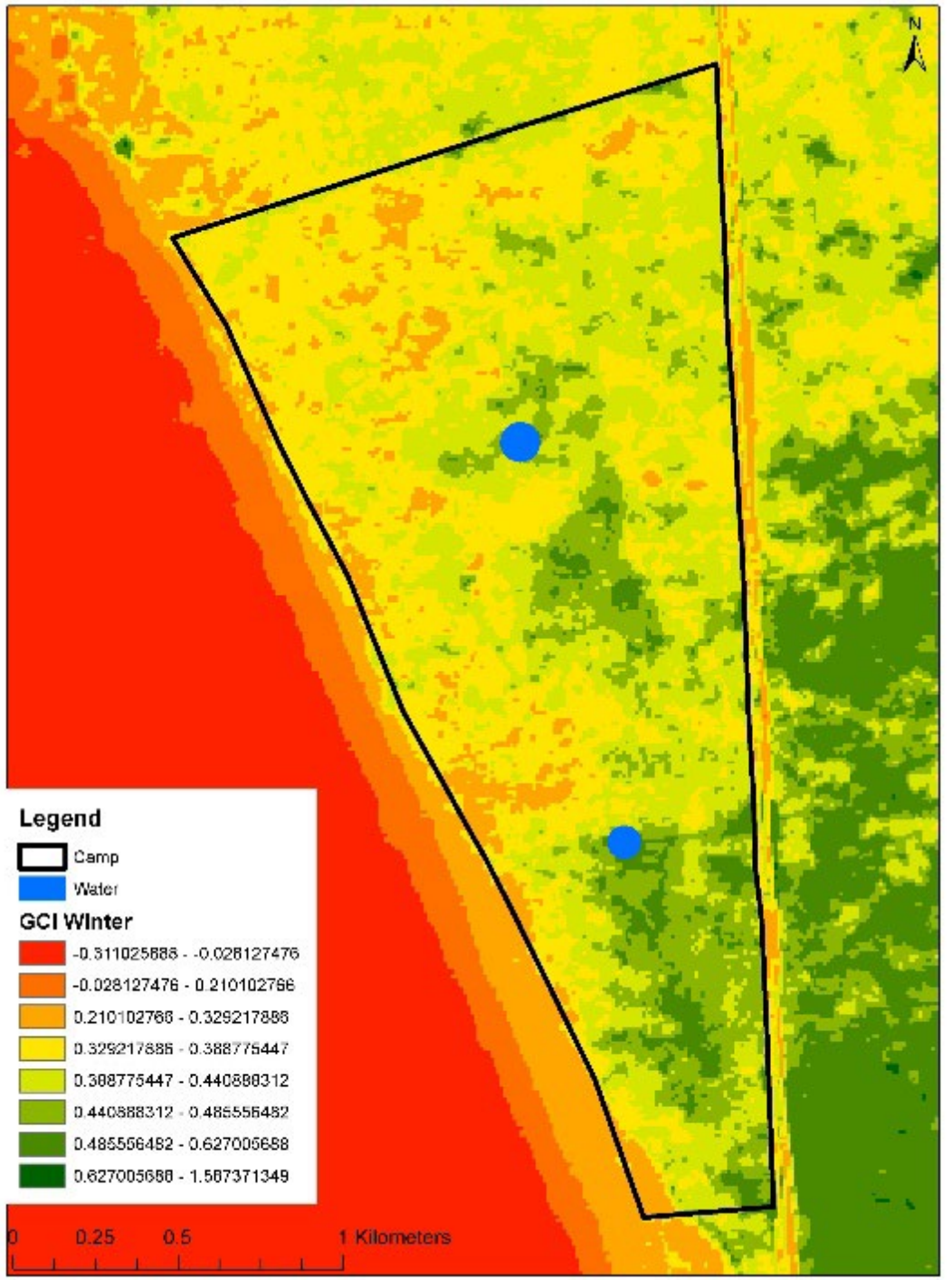
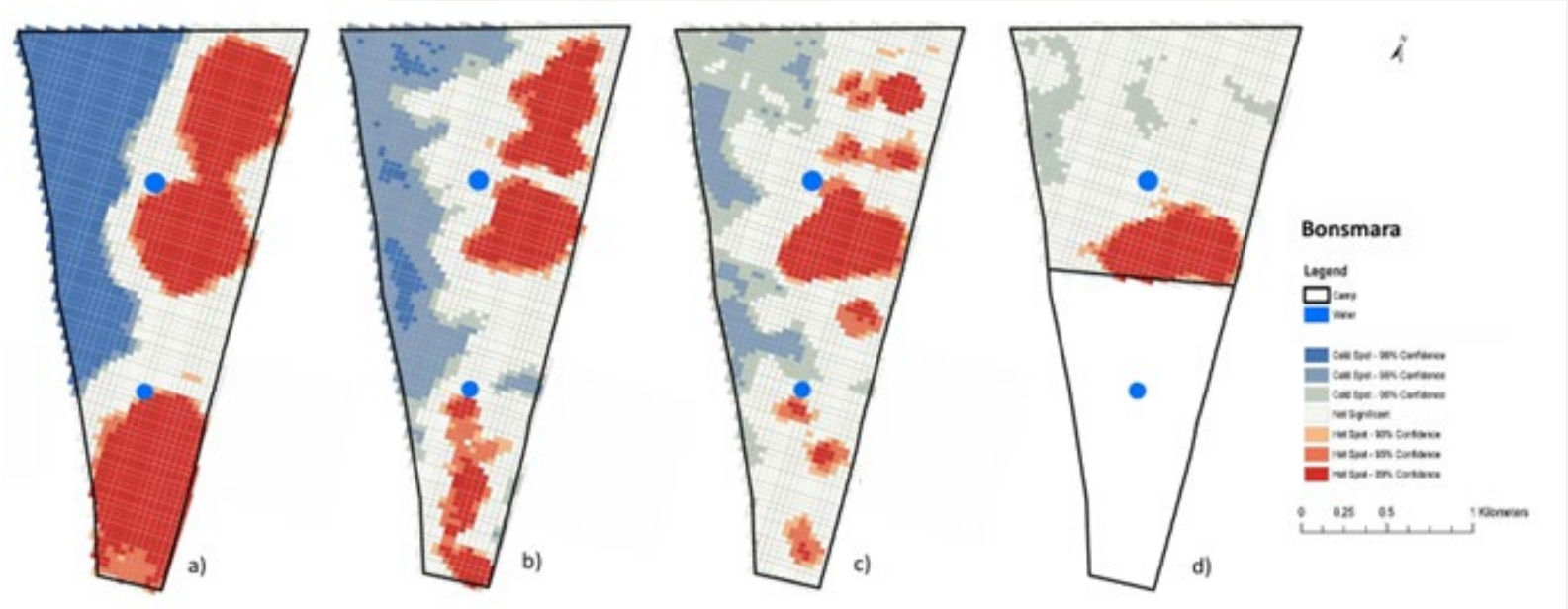
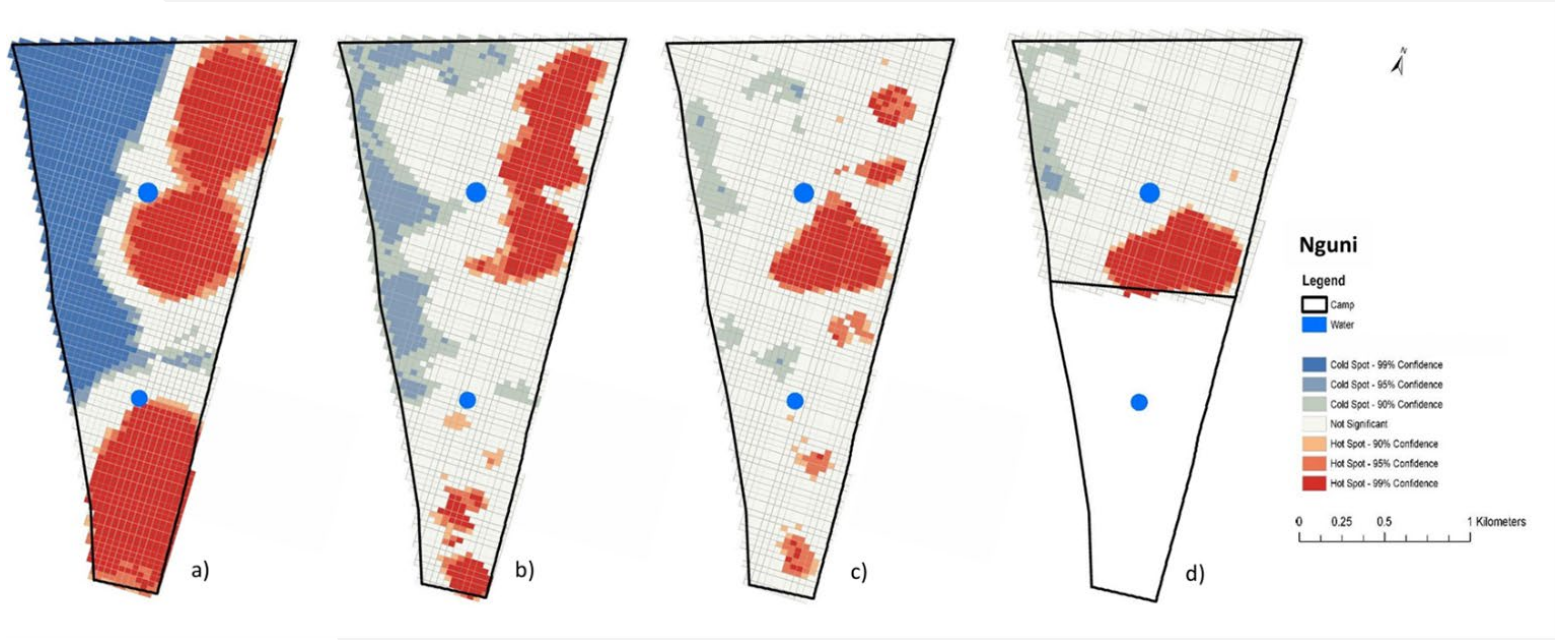


Figure 1 *Hot and cold spot locations of Bonsmara cattle during a) summer, b) autumn, c) winter, and d) spring*



RESULTS: HOT SPOT ANALYSIS

Figure 2 *Hot and cold spot locations of Nguni cattle during a) summer, b) autumn, c) winter, and d) spring*



RESULTS: HOT SPOT ANALYSIS

Table 2 *Area (ha and %) of camp classified as hot spot, cold spot or not significant*

		Bonsmara				Nguni			
		Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Total camp size	ha	289.8	289.8	289.8	177.0	289.8	289.8	289.8	177.0
Hot spot	ha	122.6	74.3	61.5	30.1	122.7	62.0	51.5	28.2
	%	42.3	25.6	21.2	17.0	42.3	21.4	17.8	15.9
Cold spot	ha	99.1	97.1	81.7	36.4	103.9	71.5	44.4	30.8
	%	34.2	33.5	28.2	20.6	35.9	24.7	15.3	17.4
Not significant	ha	68.2	118.4	146.6	110.5	63.2	156.3	194.0	118.0
	%	23.5	40.9	50.6	62.4	21.8	53.9	66.9	66.7

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Not significant	ha	68.2	118.4	146.6	110.5	63.2	156.3	194.0	118.0
	%	23.5	40.9	50.6	62.4	21.8	53.9	66.9 *	66.7

DISCUSSION: OHA

- Bonsmara & Nguni
  - More selective during dry seasons
  - Gradual grazing distribution during wet seasons
- Autumn, winter, spring:
  - Nguni < hot & cold areas than Bonsmara
  - Nguni > non-significant areas than Bonsmara

  →Nguni grazed less selectively and more gradually
- Heritage breeds revisited previously grazed areas less often
  → fewer grazing hotspots
- Note: avoidance of western/coastal side

Nyamuryekung'e et al., 2022

RESULTS: VEGETATION INDICES

Table 3 *Adjusted R^2-values of Generalised Additive Models (GAMs) fitted to the Gi* z-score from the OHA and the vegetation and soil moisture index scores for Bonsmara and Nguni cattle during the four seasons*

		Spectral index							
		BSI	**CIR**	**GCI**	**MNDVI**	**MSI**	**NDMI**	**NDVI**	**SAVI**
Bonsmara	**Summer**	0.286	0.248	0.248	0.212	0.214	0.212	0.032	0.033
	Autumn	0.291	0.208	0.208	0.253	0.254	0.253	0.029	0.030
	Winter	0.107	0.196	0.196	0.101	0.100	0.101	0.056	0.056
	Spring	0.021	0.086	0.086	0.013	0.013	0.013	0.048	0.059
Nguni	**Summer**	0.315	0.253	0.253	0.237	0.239	0.237	0.026	0.035
	Autumn	0.257	0.174	0.174	0.248	0.249	0.248	0.032	0.033
	Winter	0.089	0.186	0.186	0.090	0.091	0.090	0.051	0.051
	Spring	0.014	0.101	0.101	0.010	0.011	0.010	0.055	0.054

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	Spring	0.014	0.101	0.101	0.010	0.011	0.010	0.055	0.054

DISCUSSION: VEGETATION INDICES

- Most variation explained
  - Summer & Autumn: BSI (25,7% – 31,5%)
  - Winter & Spring: CIR & GCI (8,6% - 19,6%)

- BSI: Bare soil index
- CIR: Chlorophyll red edge index; GCI: Green chlorophyll index

- NDVI & SAVI: smallest R^2 values for both breeds, ¾ seasons
  - Unexpected: usually good predictors in arid regions

CONCLUSION & RECOMMENDATIONS

- Confirmed livestock expand their daily feeding areas in response to low forage availability/seasonal variation
  - Vegetation vulnerable to overgrazing during dry seasons
- Breed selection
  - Heritage breeds, e.g., Nguni = more even grazing distribution
- Relationship between grazing behaviour & vegetation condition → predict movement & preferred grazing areas → management
- Integration of GPS location data & RS imagery allows spatiotemporal comparisons of grazing preferences & vegetation conditions
  - Not one-size-fits-all

Bradley & O'sullivan 2011; Browning *et al.,* 2018; Falú *et al.,* 2014; Handcock *et al.,* 2009

CONCLUSION & RECOMMENDATIONS

- Consider
  - Different vegetation indices
  - Soil chemistry & vegetation composition
  - Heterogeneous vegetation
  - Coastal influence

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Thank you for your time!

Any questions?