Progress made on using earth observation based estimation of grass nutrients and biomass as indicators of rangeland (forage) quality and quantity in the savanna environments

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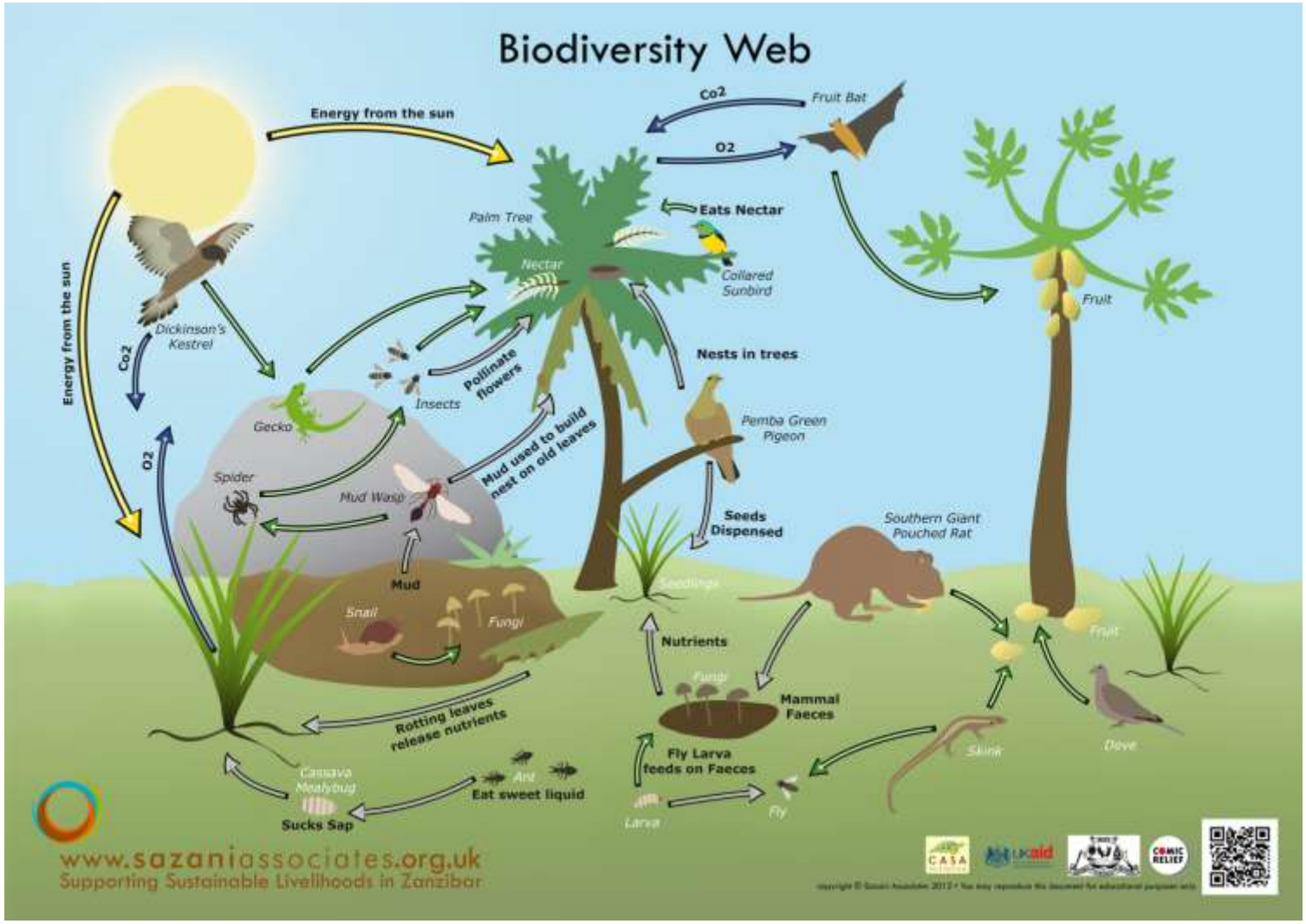
Introduction



Biodiversity is a critical ecosystem service – enabling **Ecotourism** and provide **food resources**

Grazing areas for

Livestock productions and Wildlife

Global Change – LULC and Climate change

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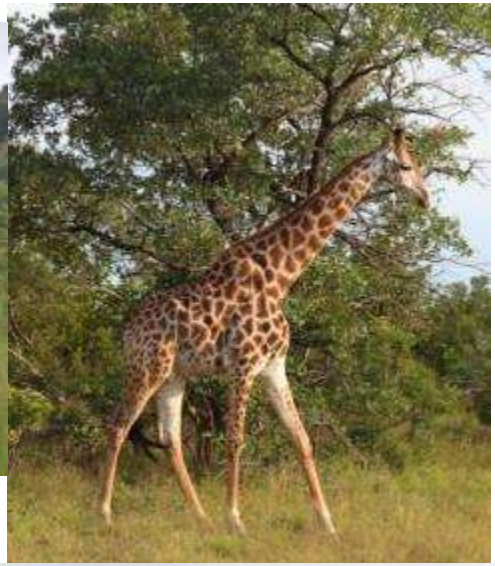
Introduction

Remnants of intact wild animals are in protected areas~ 10% of SA's land mass
Rural community relies on communal grazing lands for their livelihood



Conserve

Feeding Patterns of Grazers and the Browsers

Livestock production – Poverty alleviation

Introduction – indicators of rangeland quality and quantity

- Grass **nitrogen concentration** (N%) as an indicator grass quality, and also correlate to protein—major nutrient for herbivores
- **Grass biomass** as indicator of quantity of grazing resources
- …affects the movement and feeding patterns of domestic and wild herbivores
- …spatial zoning for **grazing camps**, **stocking rates**, **carrying capacity** of herbivores in rangelands

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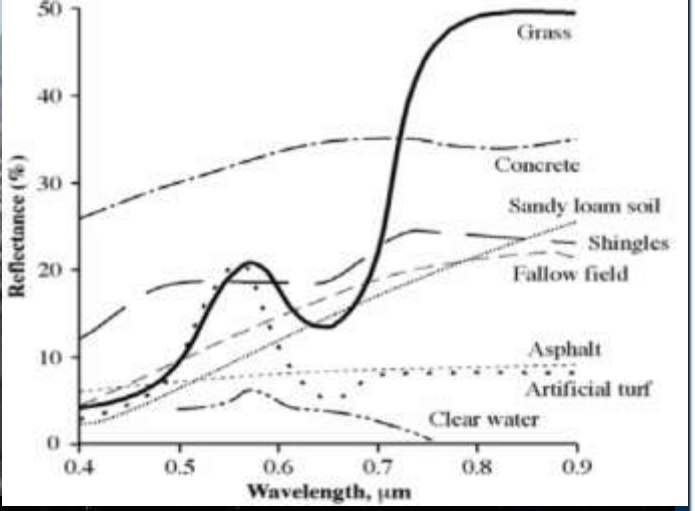
Introduction - Scaling leaf N estimations

- Distribution of grass nutrients and biomass occur at various scales such as
  - Local (e.g. Site level)
  - Regional (e.g entire KNP and surrounding areas)
  - Global

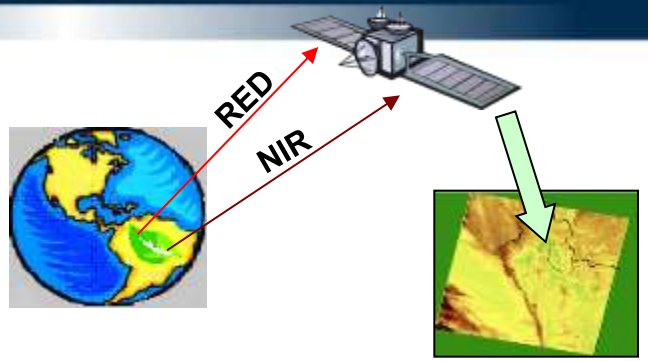
Point-based testing of ecological theories

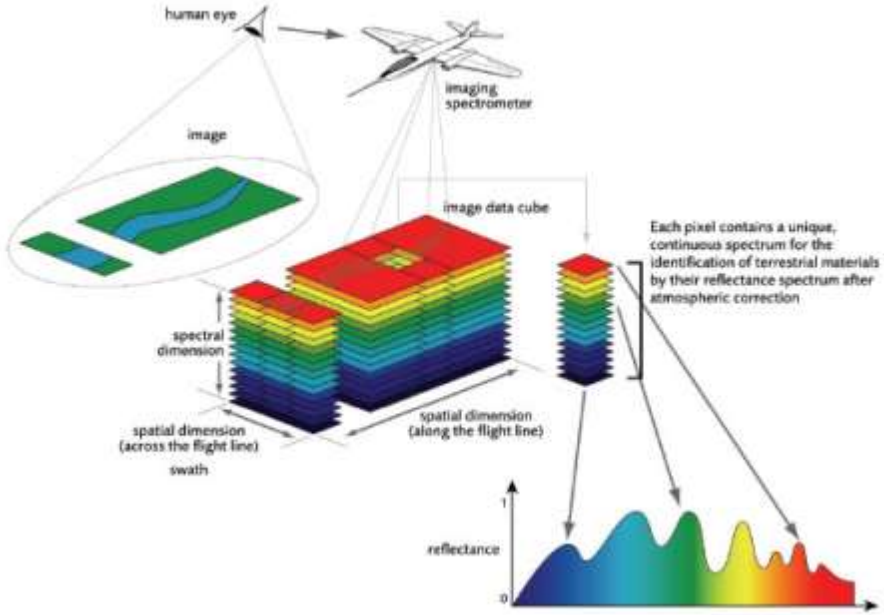
- Traditional field techniques to measure grass nutrient and biomass concentrations are **laborious and time consuming**.



Remote Sensing

•..obtained by sensing and recording reflected or emitted energy and processing, analyzing, and applying this information.





•…interactions between earth surface materials and electromagnetic energy.

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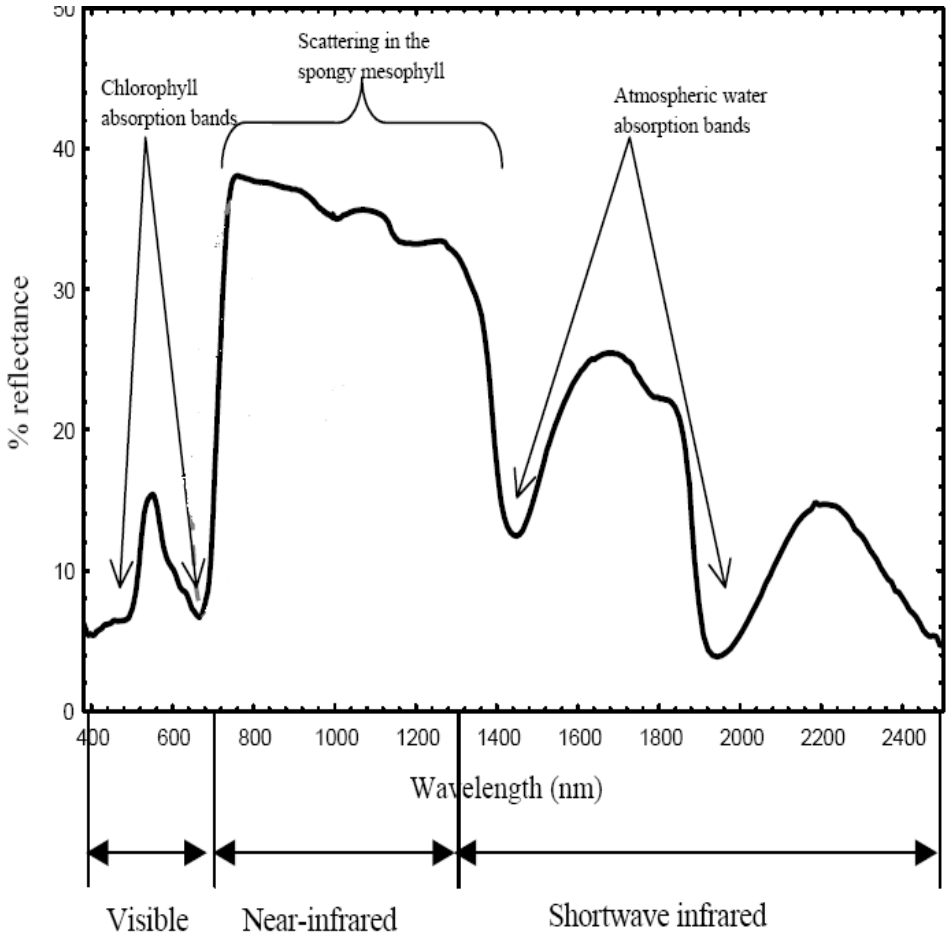
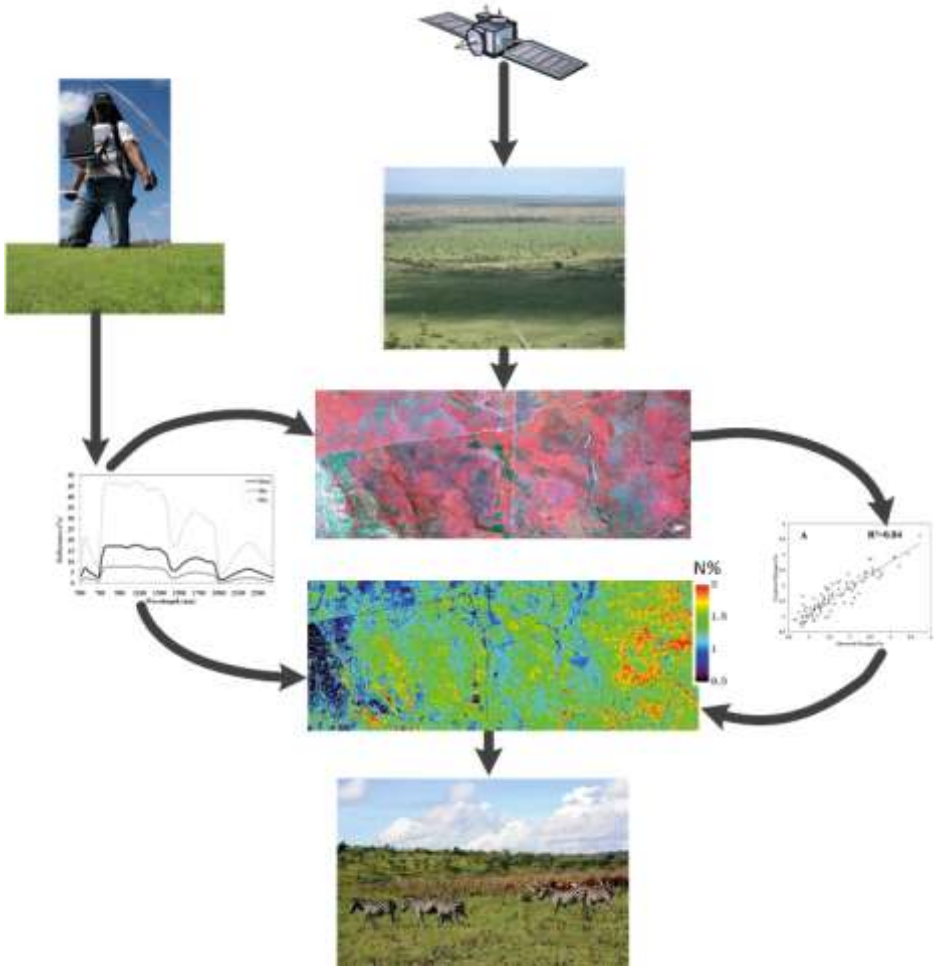
Introduction (cont.)

- Remote sensing techniques provide opportunity to map leaf N and biomass at various scales.
  - successes (**Hyperspectral/ Spectroscopy**)-**N** & **Chlorophyll**
  - Challenges (Regional estimation)
  - Spectral and Spatial Resolution
  - **New RapidEye, WorldView 2**
  - **Sentinel-2 (TBL 2016)**
  - **Biomass has been plausible to estimate using remote Sensing – various scales**



Introduction (cont.): General workflow for estimating leaf N and biomass



Spatial-based testing of ecological theories

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Research Objective

The objective of the study is to review the studies focusing on the earth observation based estimation of leaf N and biomass as indicators of rangeland quality and quantity at various scales.

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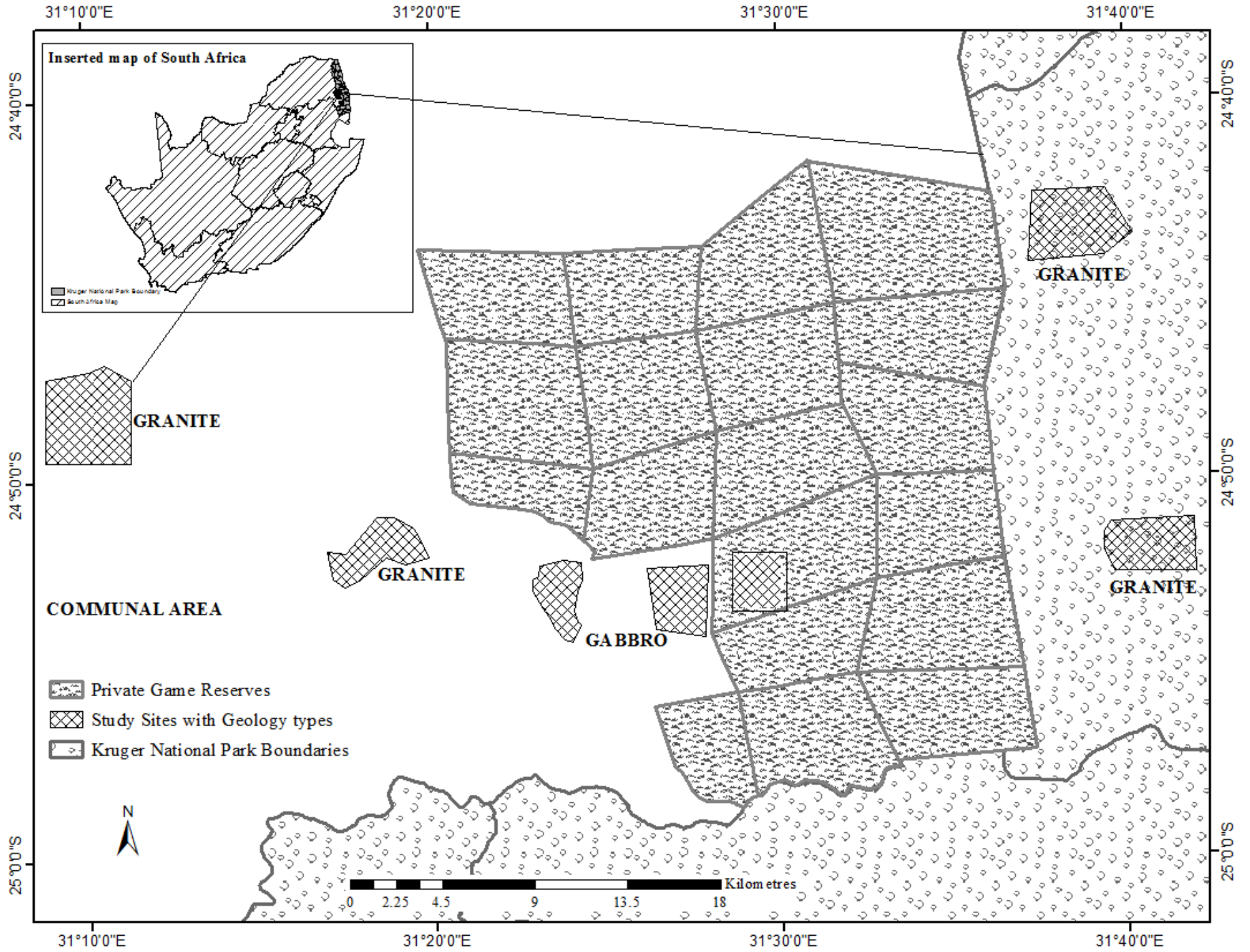
31°10'0"E
31°20'0"E
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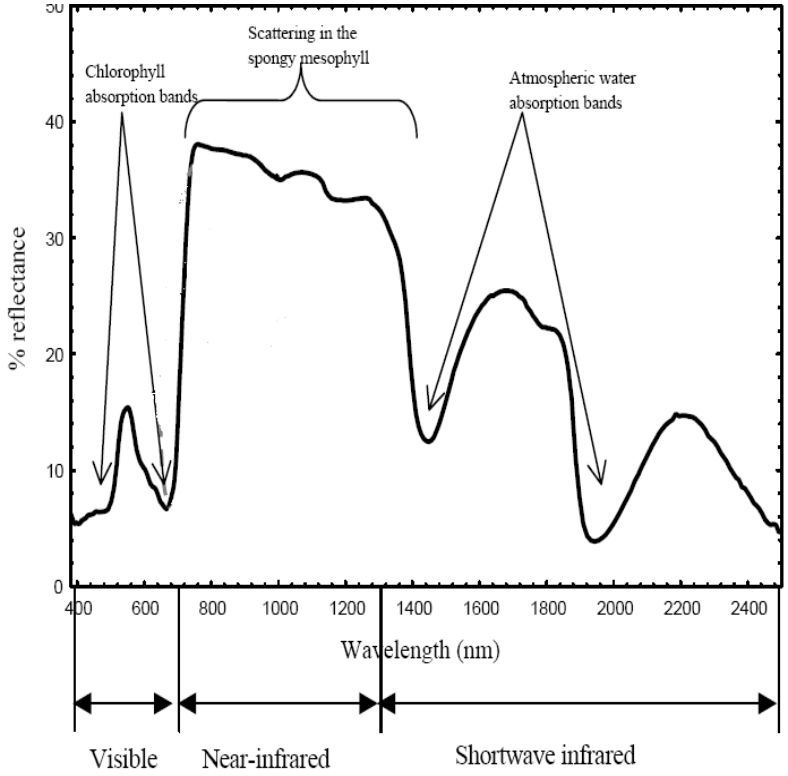
24°40'0"S
24°50'0"S
25°0'0"S
Inserted map of South Africa
Kruger National Park Boundary
South Africa Map
GRANITE
GRANITE
GRANITE
GRANITE
GABBRO
COMMUNAL AREA
Private Game Reserves
Study Sites with Geology types
Kruger National Park Boundaries
N
Kilometres
0 2.25 4.5 9 13.5 18

Data Acquisition and Analysis

- Review of literature on EO based estimation of leaf N and biomass
- About 16 papers were considered in this study – savanna
  - in situ (ASD) – Airborne - Satellite.
- Recorded descriptive stats - precision and accuracy indicators such as R^2, RMSE, RRMSE
- Recorded spectral transformation – statistics – parametric – nonparametric
- Data tabulated and graphs were used to visualize the results
- Very basic analysis was done

Results – statistics used for EO based leaf N and biomass retrieval

- **The estimation of leaf N and biomass has been empirically-based,**
  - **Simple regression – use of vegetation indices**
    - **Narrow and broadband based**
  - **Multivariate (Parametric) : PLSR, SMLR**
    - **Known absorption features**
    - **Full spectrum**
    - **Vegetation indices**
    - **Integrated modelling approach (VI+ Ecol.)**
  - **Machine learning algorithms : ANN, RF.**
    - **Vegetation indices (narrow and broadband)**
    - **Absorption features**



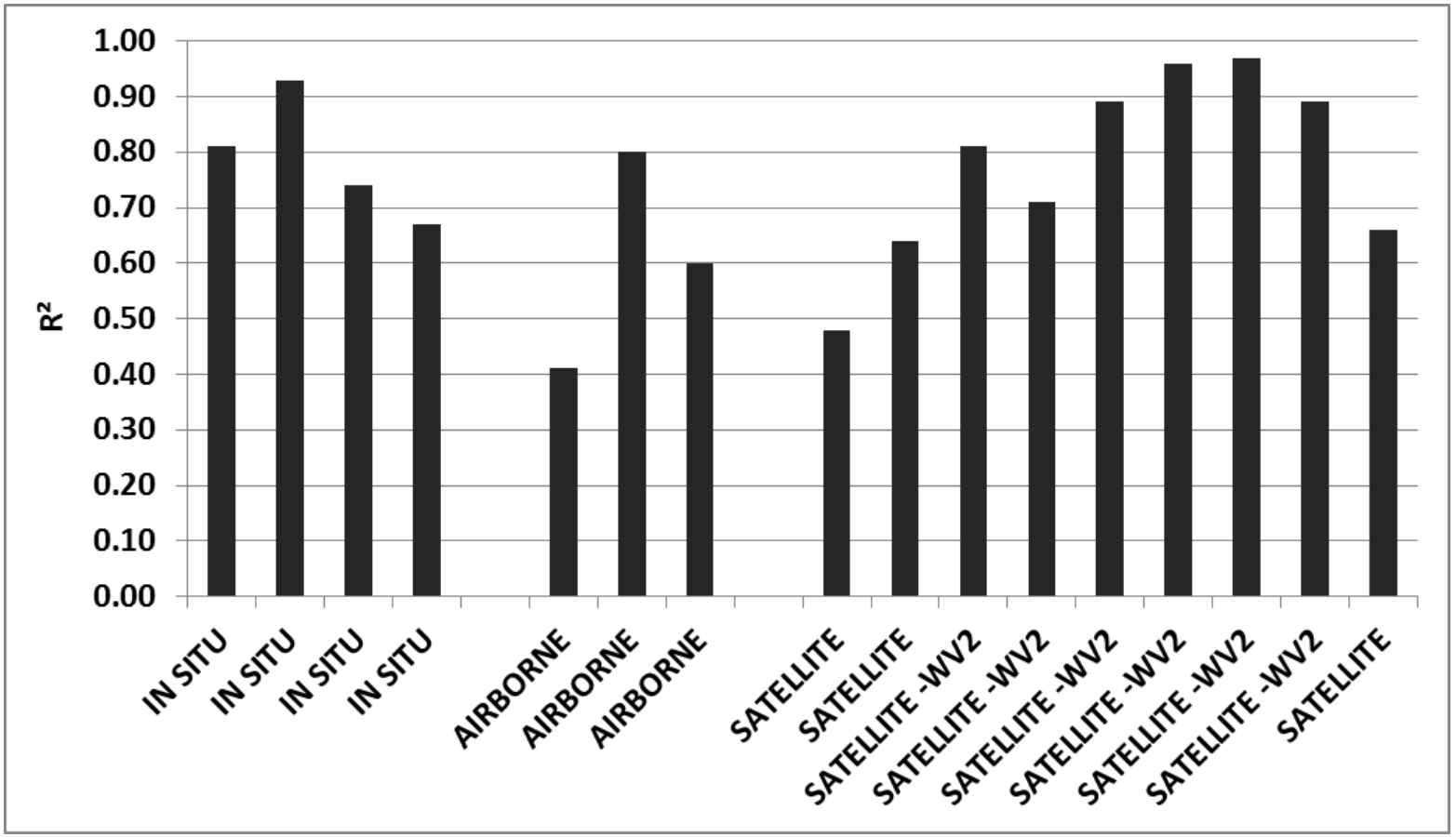
Results (leaf N(%) statistics from various papers)

		Leaf N (%)			R^2		RMSE		RRMSE			
	ASD - *IN SITU*	Min	Max	Mean	min	max	min	max	min	max	Technique	Reference
IN SITU		0.34	1.06	0.70	0.58	0.81	0.08	0.11	11	16	PLSR/Non_linear/INT	Ramoelo et al. 2013
IN SITU		0.38	2.00	0.78	0.74	0.93	0.02	0.22	3	28	CR Indices/SMLR	Mutanga et al. 2004
IN SITU	Wet Season	0.60	2.20	0.37	0.42	0.74		0.19		51	Bands/INT/SMLR	Knox et al. 2012
IN SITU	Dry Season	0.40	1.50	0.20		0.67		0.12		60	Bands/INT/SMLR	Knox et al. 2012
	AIRBORNE											
AIRBORNE		0.31	0.91	0.53	0.34	0.41	0.16	0.20	30	38	ANN	Knox et al. 2011
AIRBORNE						0.80		0.27			ANN	Skidmore et al. 2010
AIRBORNE		0.83	3.42	1.55	0.38	0.60	0.13	0.16	8	10	ANN/RE	Mutanga et al. 2004
	SATELLITE											
SATELLITE	**RapidEye (leaf)**	0.53	1.44	0.84	0.45	0.48	0.12	0.14	14	17	Indices/ SMLR/PLSR	Ramoelo et al. 2012
SATELLITE	**RapidEye (canopy)**	35.00	119.00	63.45	0.56	0.64	11.00	12.30	17	19	Indices/ SMLR/PLSR	Ramoelo et al. 2012
SATELLITE	**WV-2 (Grass) - Apr**	0.49	0.78	0.61		0.81		0.05		8	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2 (Grass) - Jul**	0.40	0.72	0.49		0.71		0.04		8	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2 (Grass) - Mar**	0.51	1.21	0.70		0.89		0.08		11	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2 (Grass+Trees) - Apr**	0.49	2.63	0.89		0.96		0.12		14	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2 (Grass+Trees) - Jul**	0.40	2.02	0.83		0.97		0.10		11	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2 (Grass+Trees) - Mar**	0.51	1.21	1.11		0.89		0.26		23	RF/ Bands/ Indices	Ramoelo et al. in Press
SATELLITE	**WV-2**	0.34	1.08	0.67	0.16	0.66	0.21	0.10		13	Indices/PLSR	Zengeya et al. 2013

Results (leaf biomass statistics from various papers)

	Biomass (kg/ha or g/m2)			R^2		RMSE		RRMSE		
	Min	Max	Mean	Min	Max	Min	Max		Technique	Reference
SATELLITE - WV2 - Dry	68	592	260		0.91		45	17	RF/Indices	Ramoelo et al. In press
SATELLITE - WV2 - Wet	77	619	372		0.9		59	16	RF/Indices	Ramoelo et al. In press
SATELLITE - WV2 - Wet	72	1152	408		0.84		105	26	RF/Indices	Ramoelo et al. In press
SATELLITE - RE (Wet)	284	1536	800		0.27				SRegr/Indices	Ramoelo et al. 2013
SATELLITE - RE/LS8 -Dry	52	344	127	0.81	0.86	11	13	10	RF/Bands	Ramoelo et al. 2014
SATELLITE - LS/ SPOT/ AVHRR	2.7	7.34	4.5	0.54	0.79				SRegr/Indices/Bands	Samimi and Kraus 2004
SATELLITE - NOAA - AVHRR					0.42	332	440		NDVI	Wessels et al. 2006
SATELLITE - MODIS	42	9622	3796		0.6		830	22	Co-kriging/PCA	Mutanga and Rugege 2006
SATELLITE - SPOT Vegetation	208	7312	3760		0.69				Indices/ TS	Verbesselt et al. 2006

Results: Progress on remote sensing based Leaf N(%) estimation



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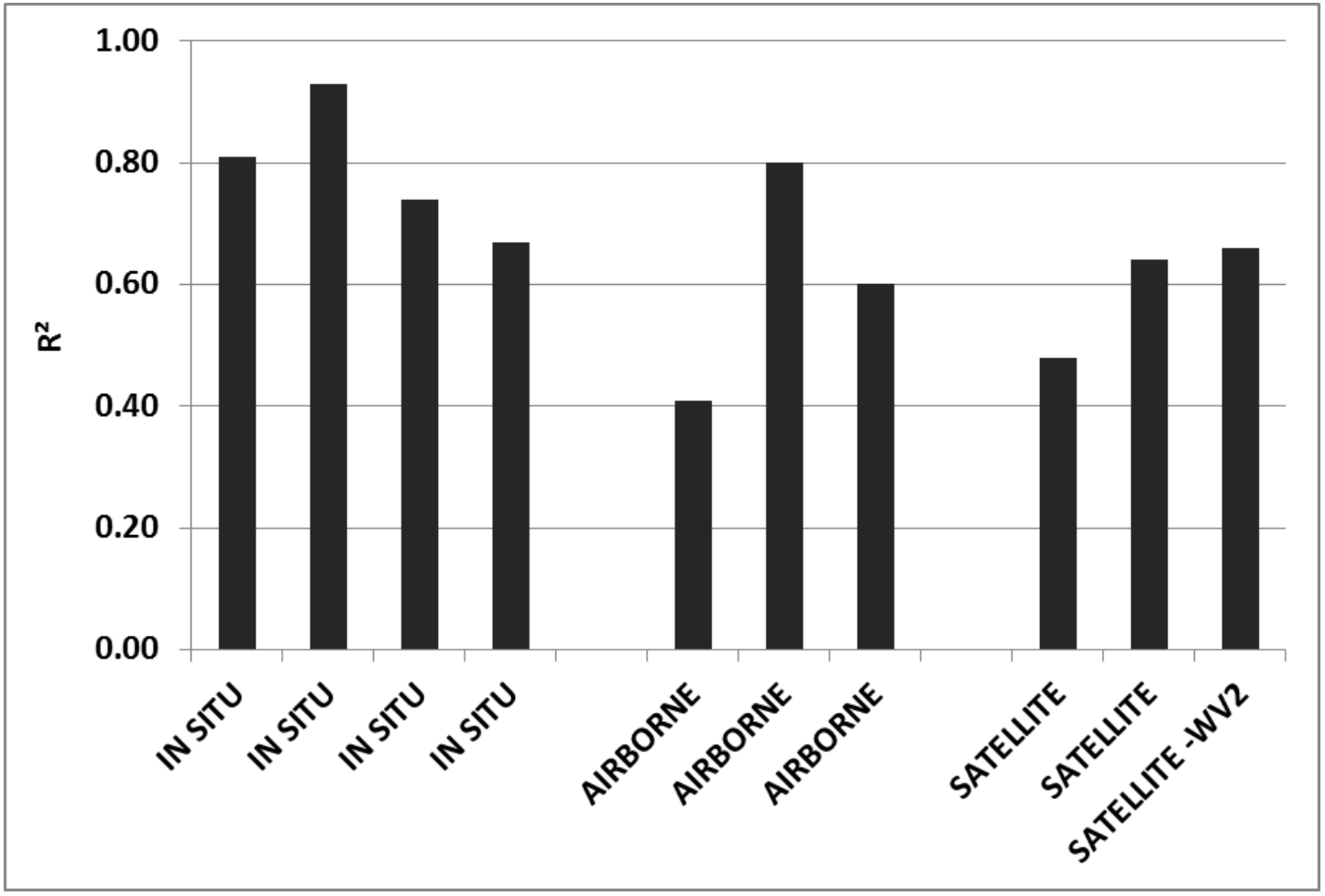

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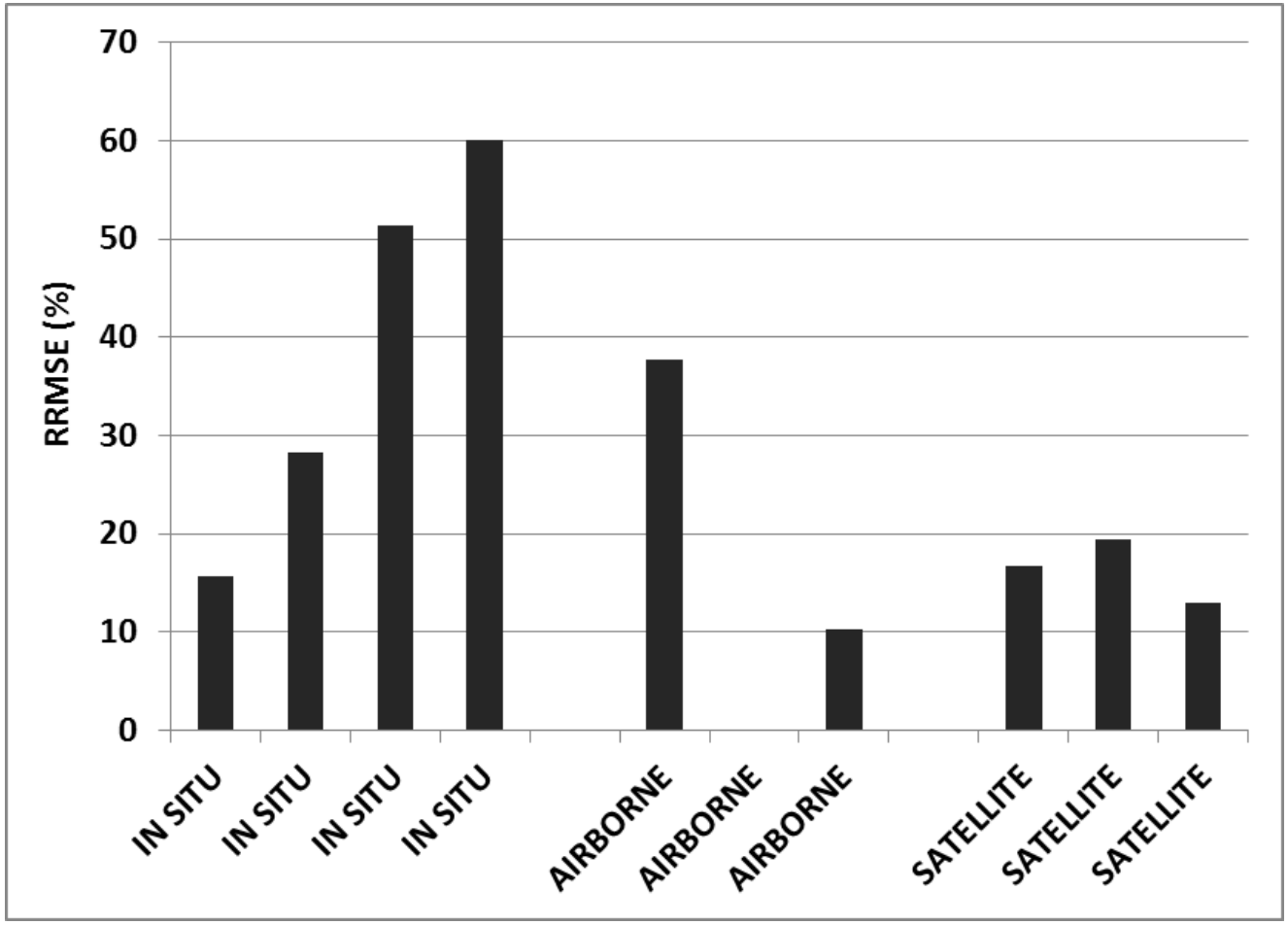

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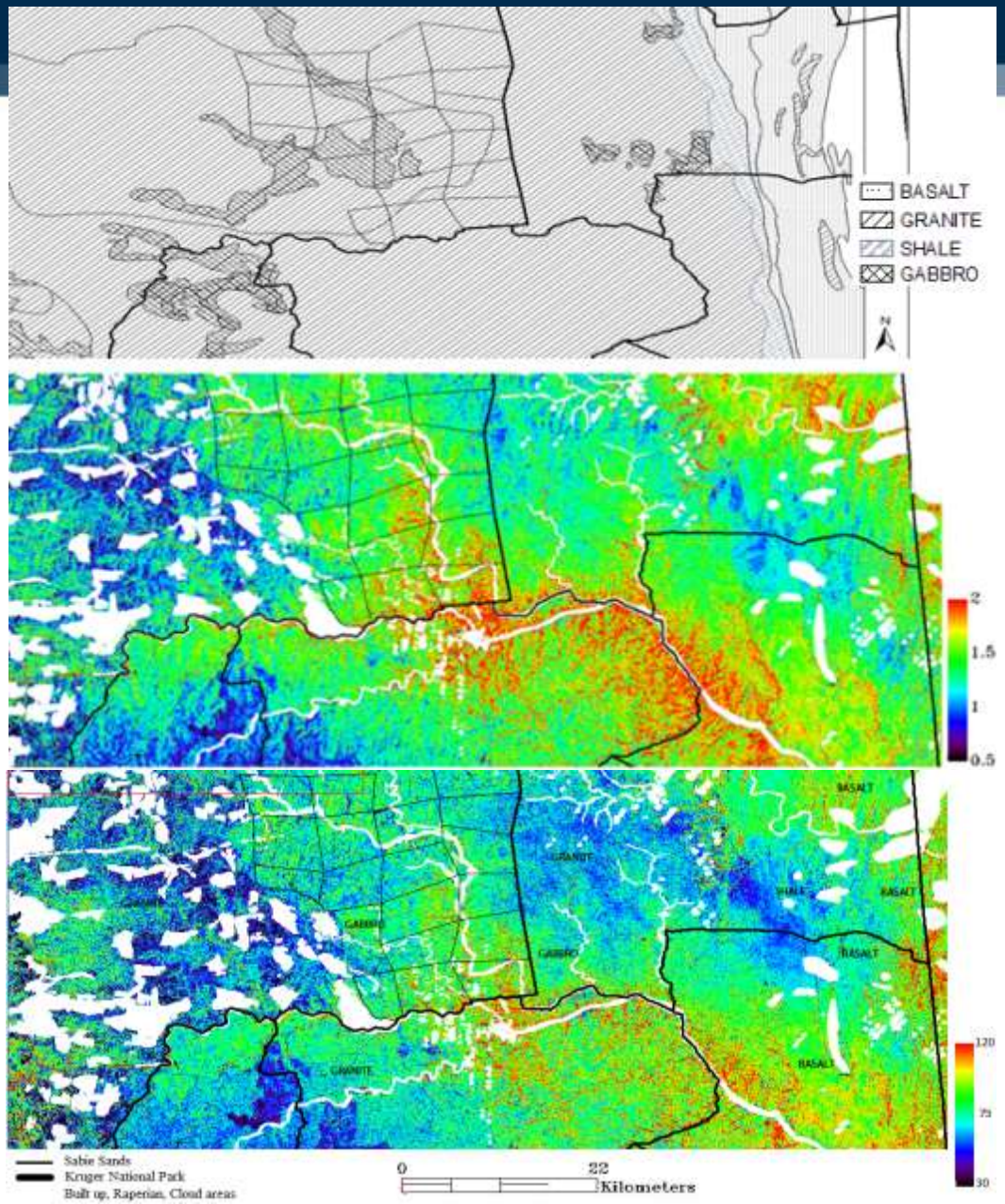
Results: Examples of mapping leaf N (%)



Ramoelo et al. 2012, Journal of Applied Earth Observation and Geoinformatics

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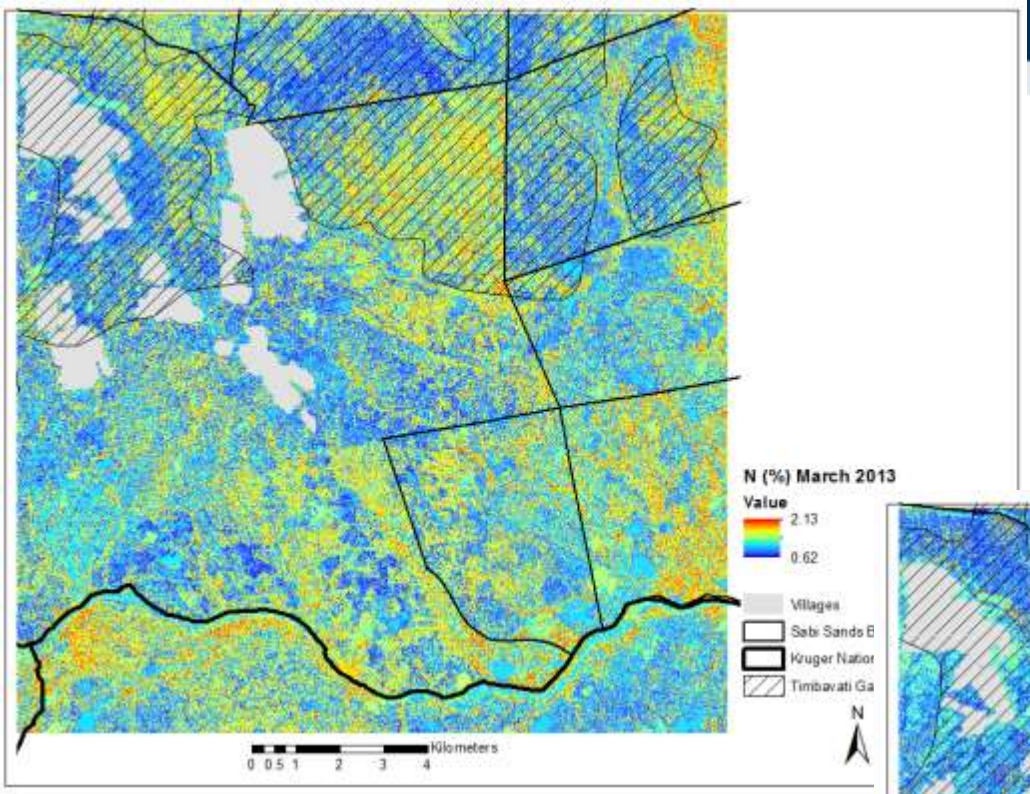
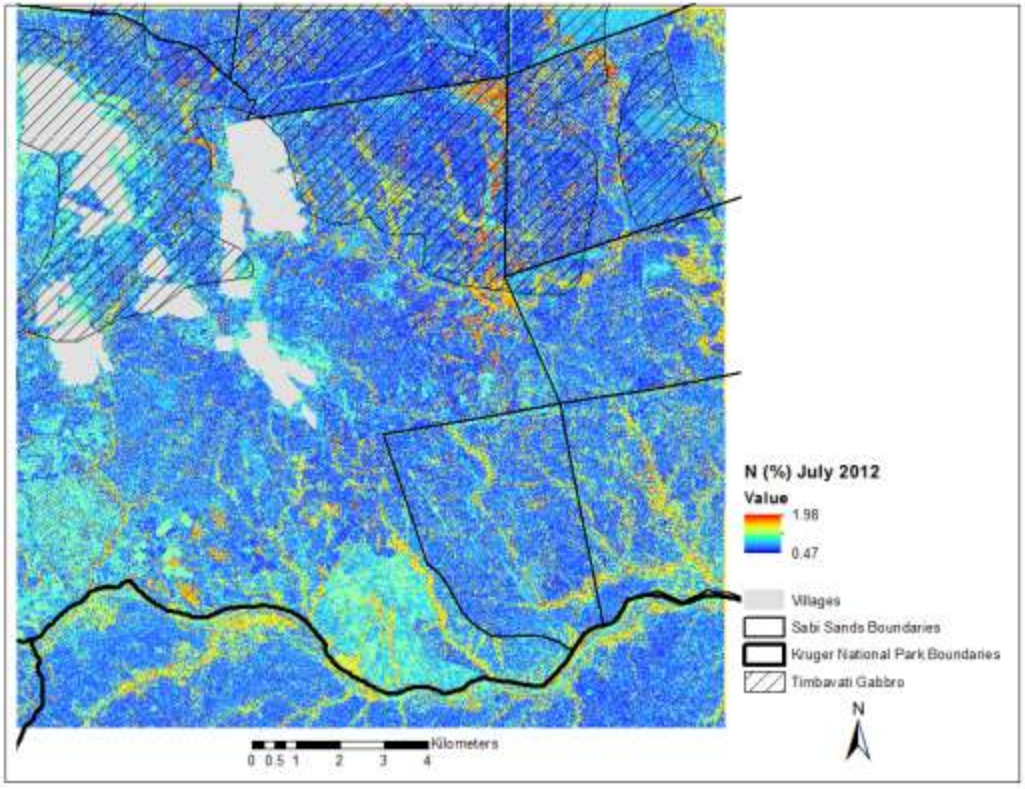
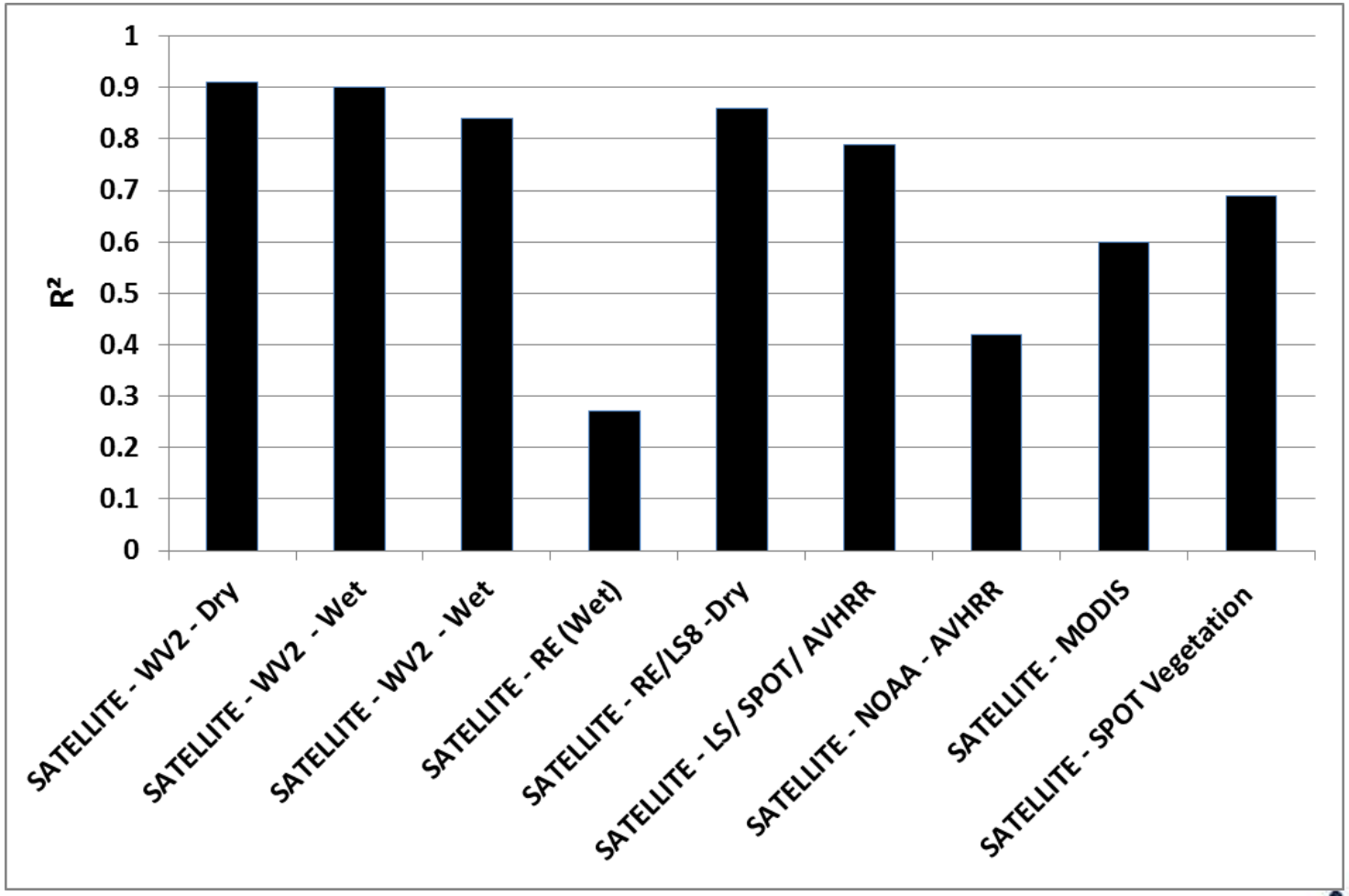
Results: Examples of mapping leaf N (%)

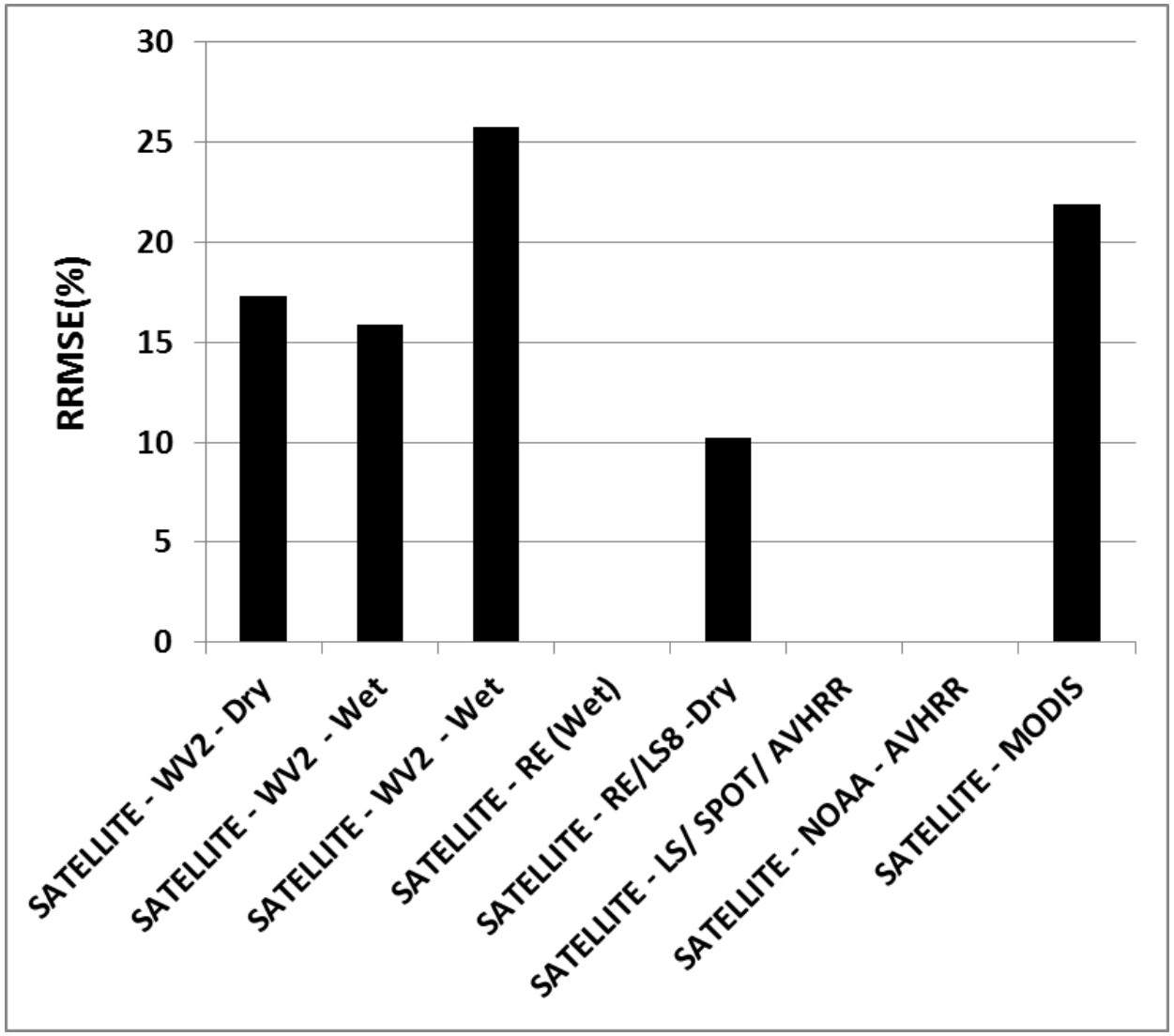




Results: Progress on remote sensing based biomass estimation



Results: Progress on remote sensing based biomass estimation



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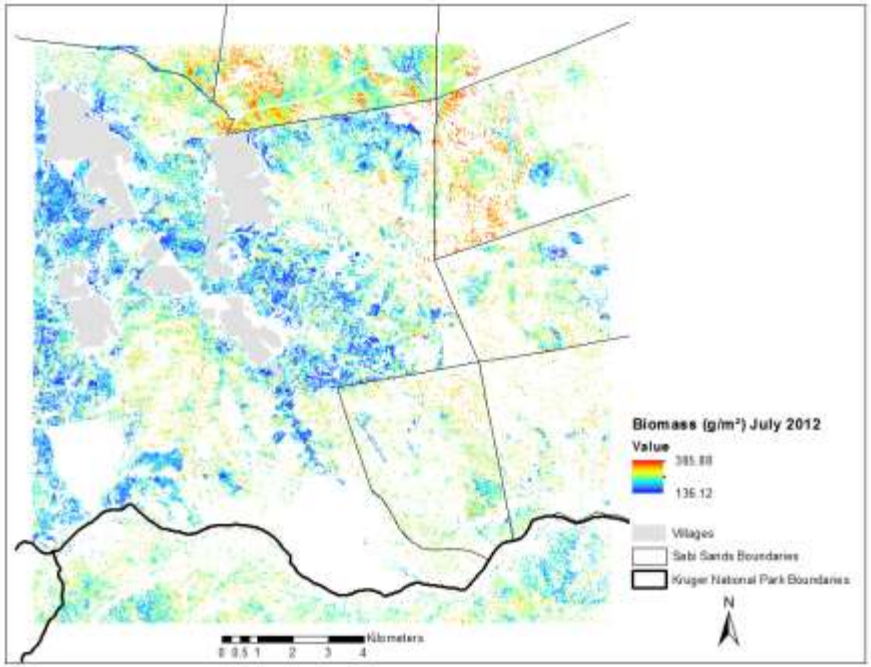
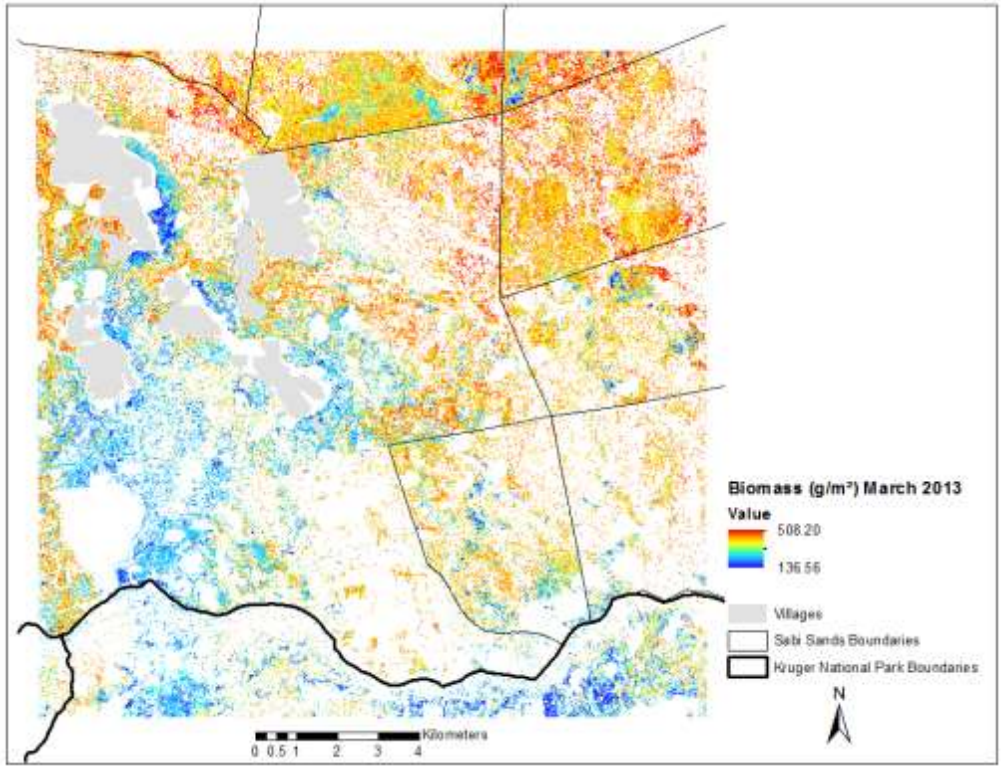
Results: Examples of biomass maps – WorldView-2





Summary and Conclusions

- Several opportunities
  - Emergence of RapidEye, WV-2 and Sentinel-2 data (To be free for Africa) provide an opportunity to assess grass quality and quantity for planning and management rangeland systems.

- Challenges
  - **There are several issues, but progress is eminent**

- Leaf N and biomass can be used as input to determine
  - **Carrying capacity** for browsers and grazers
  - **Spatial zoning** for grazing camps
  - **Contact risk models-** Livestock and Wildlife

- Hence, facilitating planning and management of rangelands for farmers, rangers, park managers, game farmers etc.

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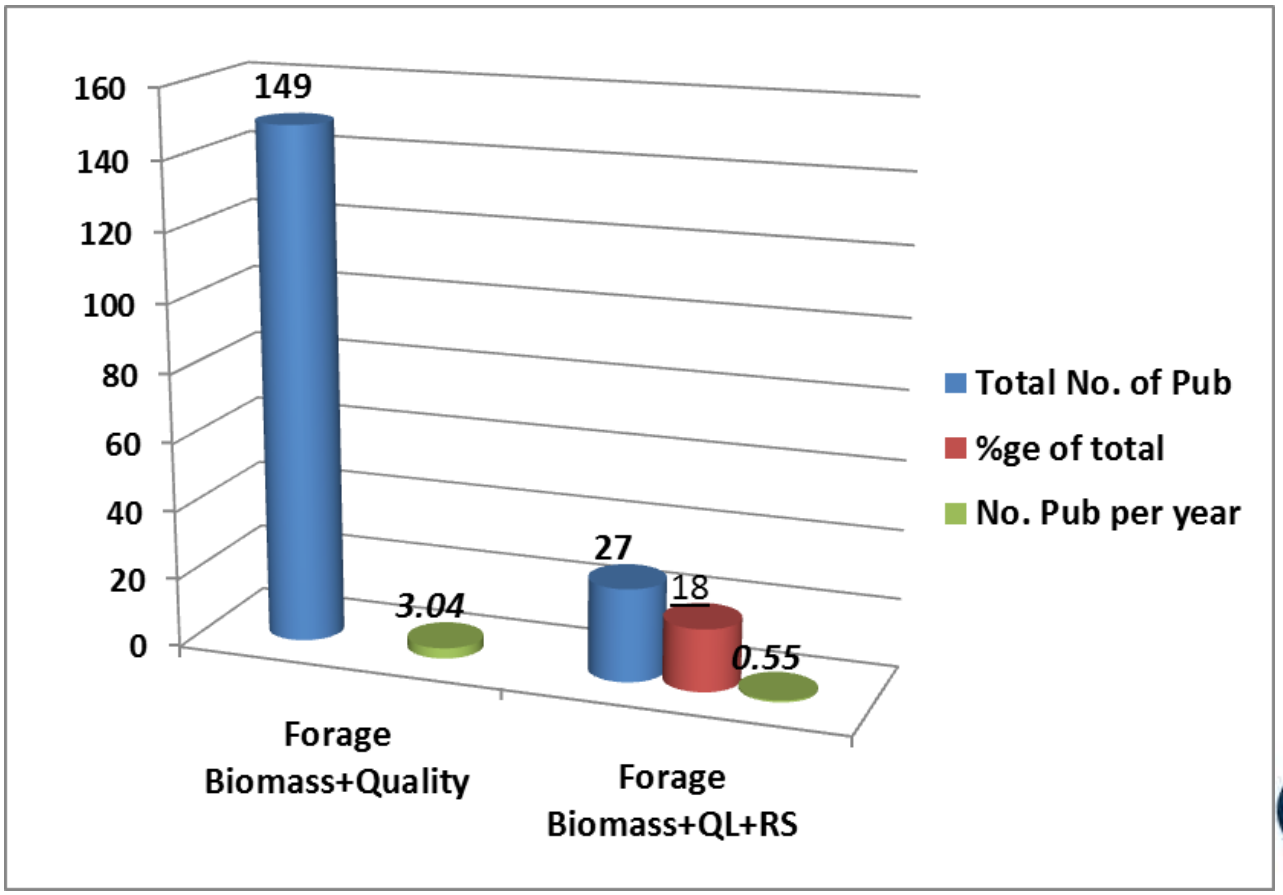
Quick Overview: Forage biomass and quality Research in AJRFS

- **African Journal of Range & Forage Science** established in 1966
- About **149** papers were published – Forage biomass and quality
- About **27** papers used remote sensing (RS) for forage biomass and quality assessment



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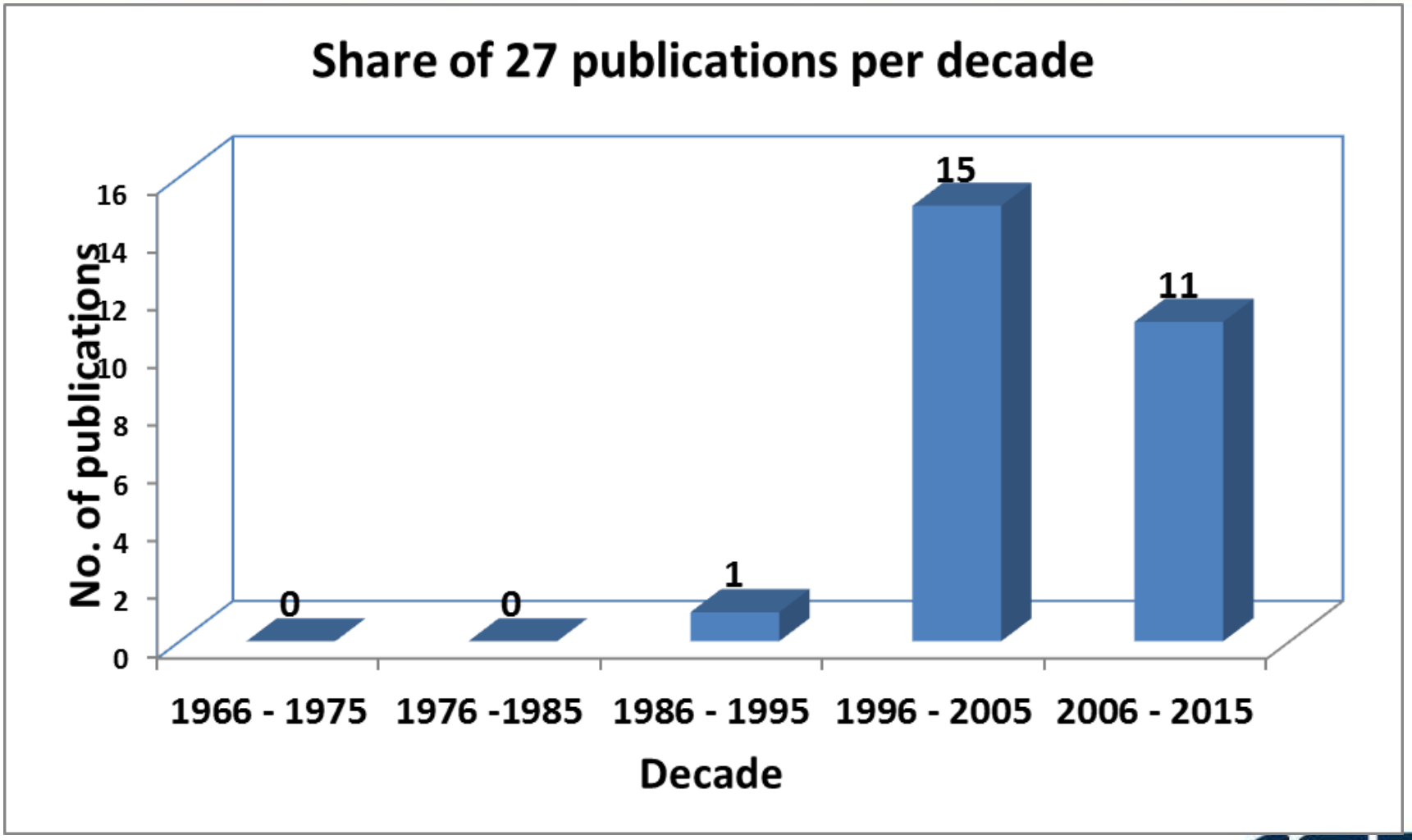
Forage biomass and quality and RS Research in AJRFS (Cont.)



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Forage biomass and quality and RS Research in AJRFS (Cont.)

- ***Focus areas***
- **Third Decade**
  - Vegetation change – production
- **Fourth Decade**
  - Biomass/production
  - Change detection or Monitoring vegetation
  - Desertification
- **Fifth decade**
  - **Quality (Review)**
  - Biomass
  - Bush encroachment
  - Fire impact
  - Species discrimination and composition
  - Degradation
  - Evapotranspiration / Water use efficiency

There is a scope of remote sensing in rangeland assessment and monitoring

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Acknowledgement

- CSIR's PG and YREF,
- NRF Thuthuka funding – Post PhD Track

Thank YOU