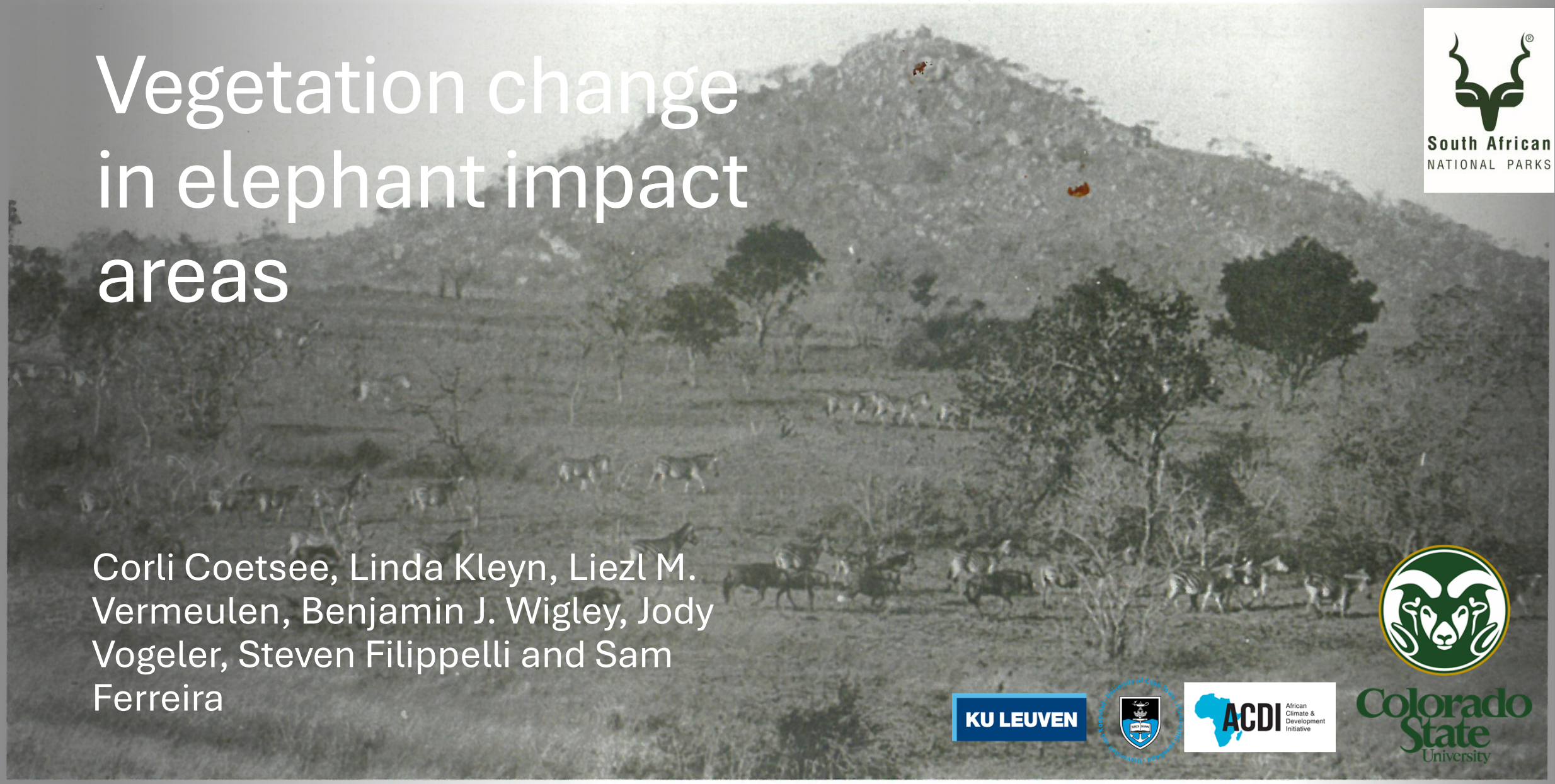
Vegetation change in elephant impact areas

Corli Coetsee, Linda Kleyn, Liezl M. Vermeulen, Benjamin J. Wigley, Jody Vogeler, Steven Filippelli and Sam Ferreira

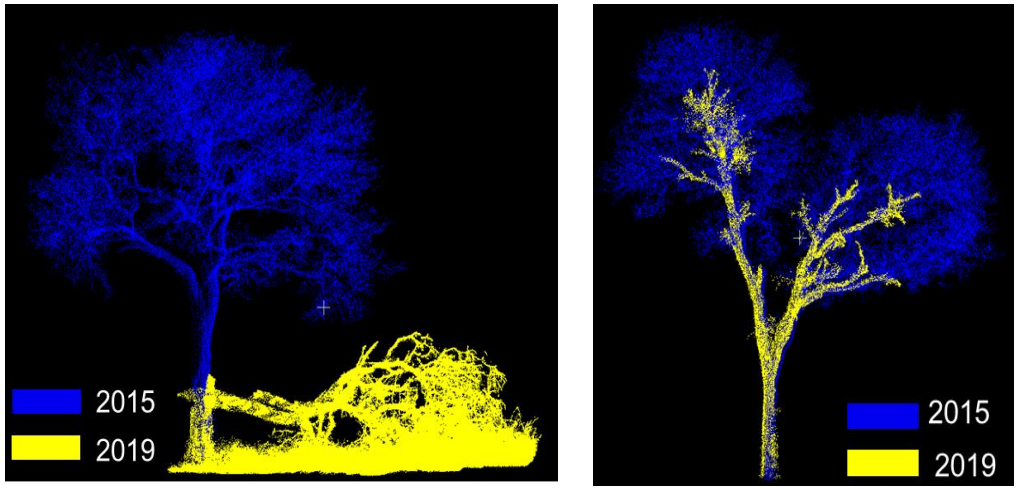


Paul Selby, from *The Kruger National Park 1933*

The open parkland landscape with sparse woody vegetation and numerous wildebeest and zebra at Pretoriuskop in the 1920s.

Introduction

- Changes in vegetation may happen because of many different drivers; droughts, floods, wind, fire, elephants, etc.



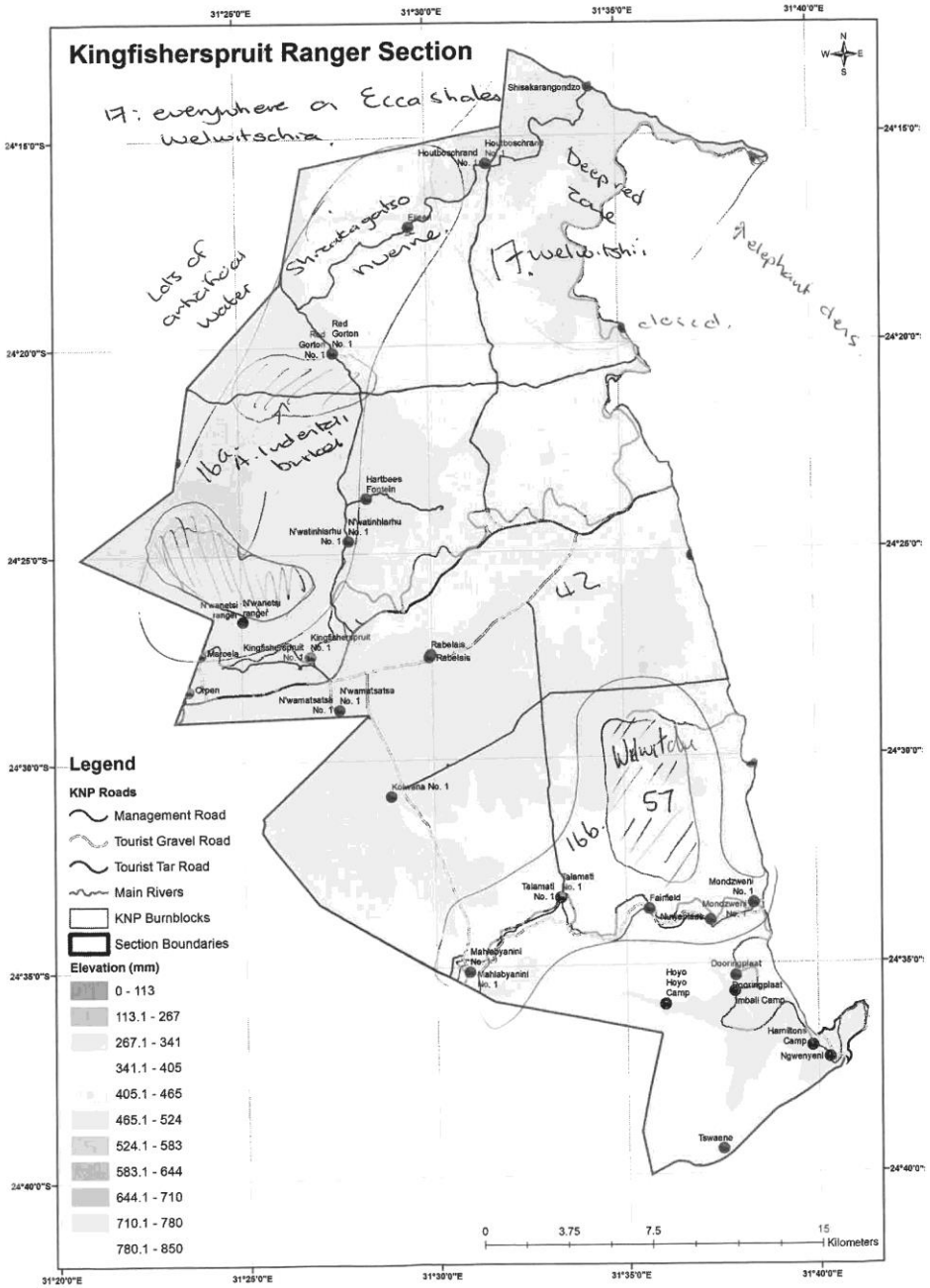
(a) (b)

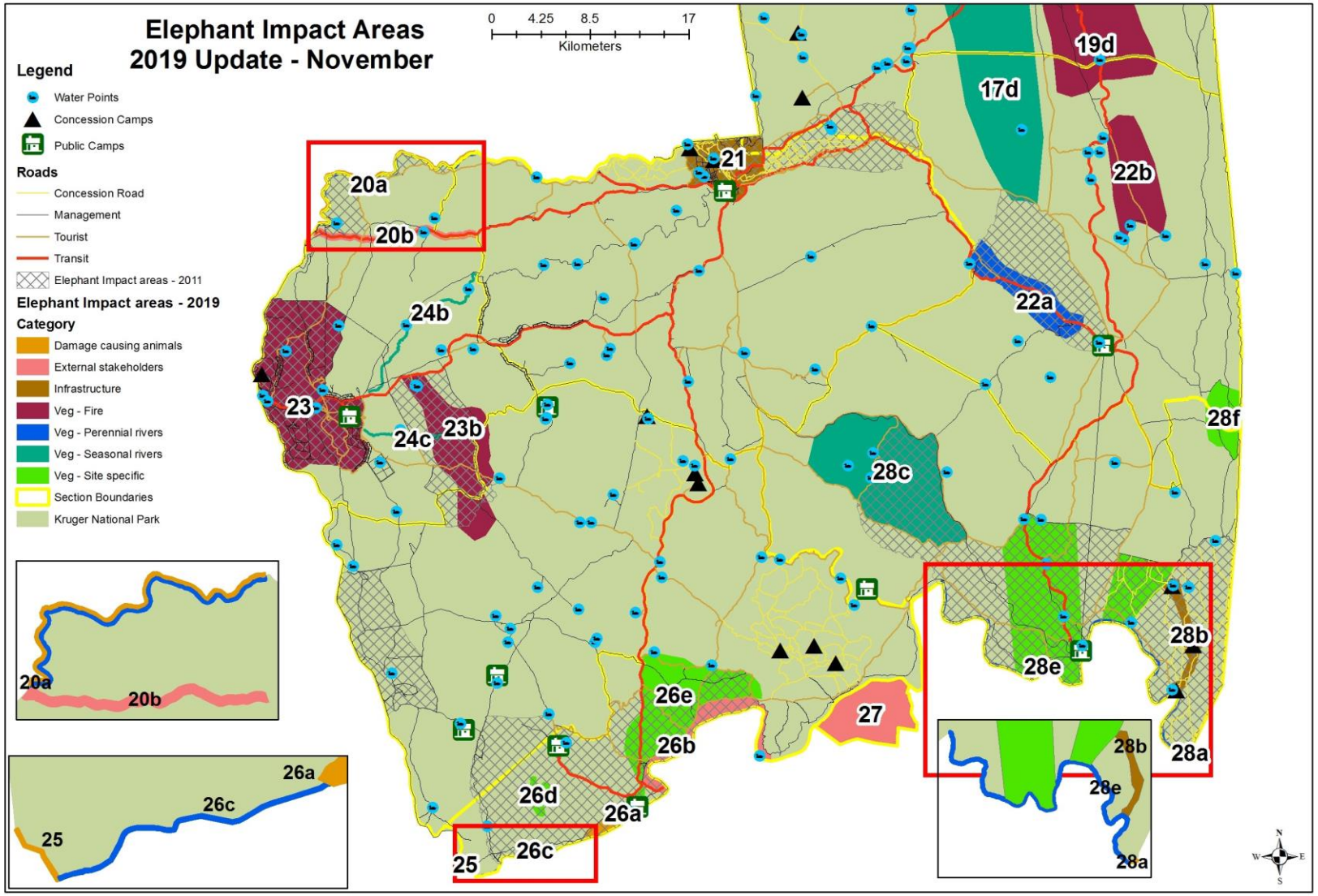
Muumbe, T.P.; Baade, J.; Raumonen, P.; Coetsee, C.; Singh, J.; Schmullius, C. Quantifying Tree Structural Change in an African Savanna by Utilizing Multi-Temporal TLS Data. *Remote Sens.* **2025**,

Figure 16. (**a**) An example of a tree that succumbed to the effects of elephant damage. The image shows the trees standing in 2015 (blue), and on the ground in 2019 (yellow) (**b**) An example of a tree that succumbed to the effects of drought—the image shows the tree with a crown in 2015 (blue) and having lost most of its crown in 2019 (yellow).

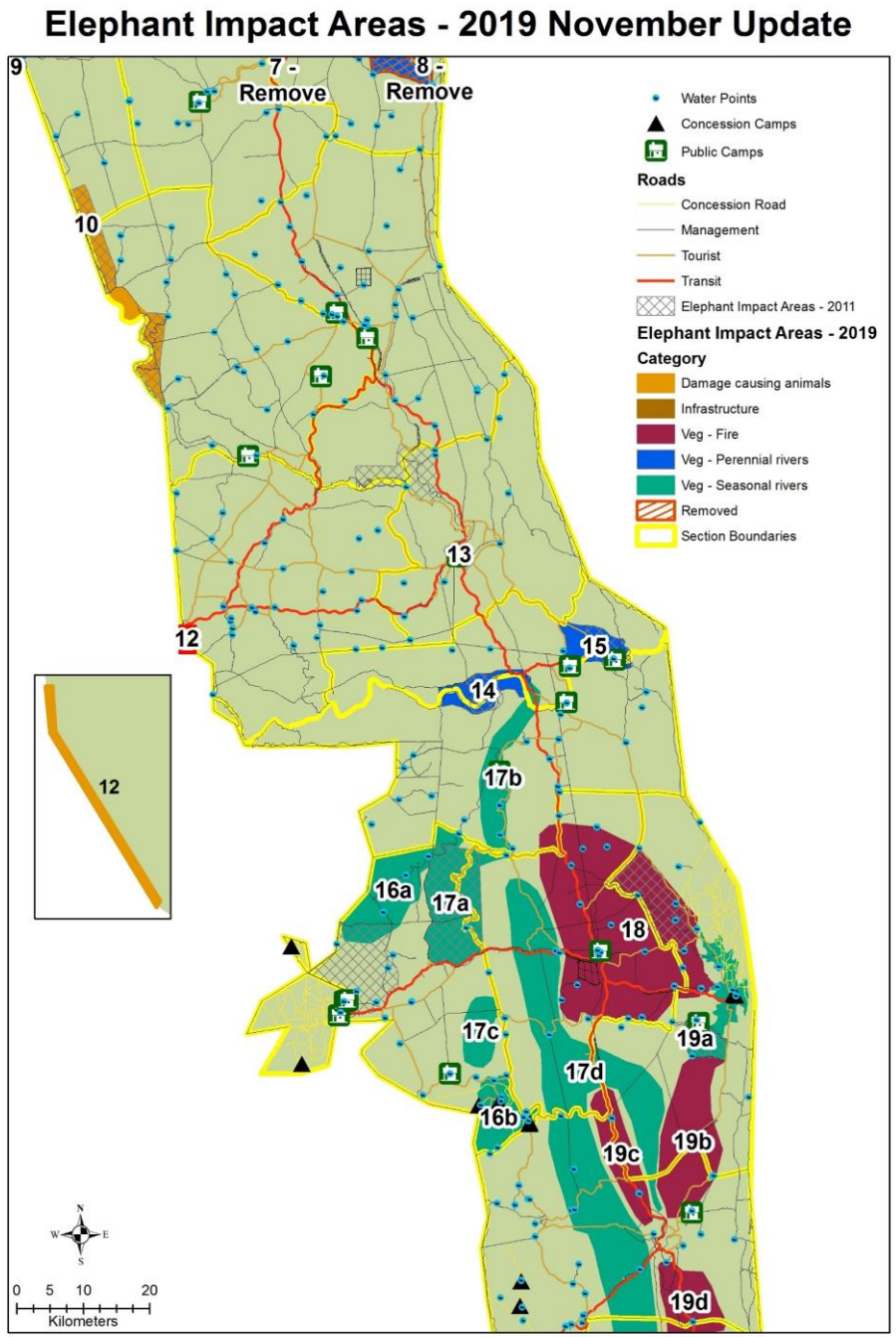
Introduction (cont.)

- During 2019, we interviewed all rangers and other personnel to find out where areas with high elephant impact were
- We asked for possible mechanisms
- What long-term changes are taking place in these areas?



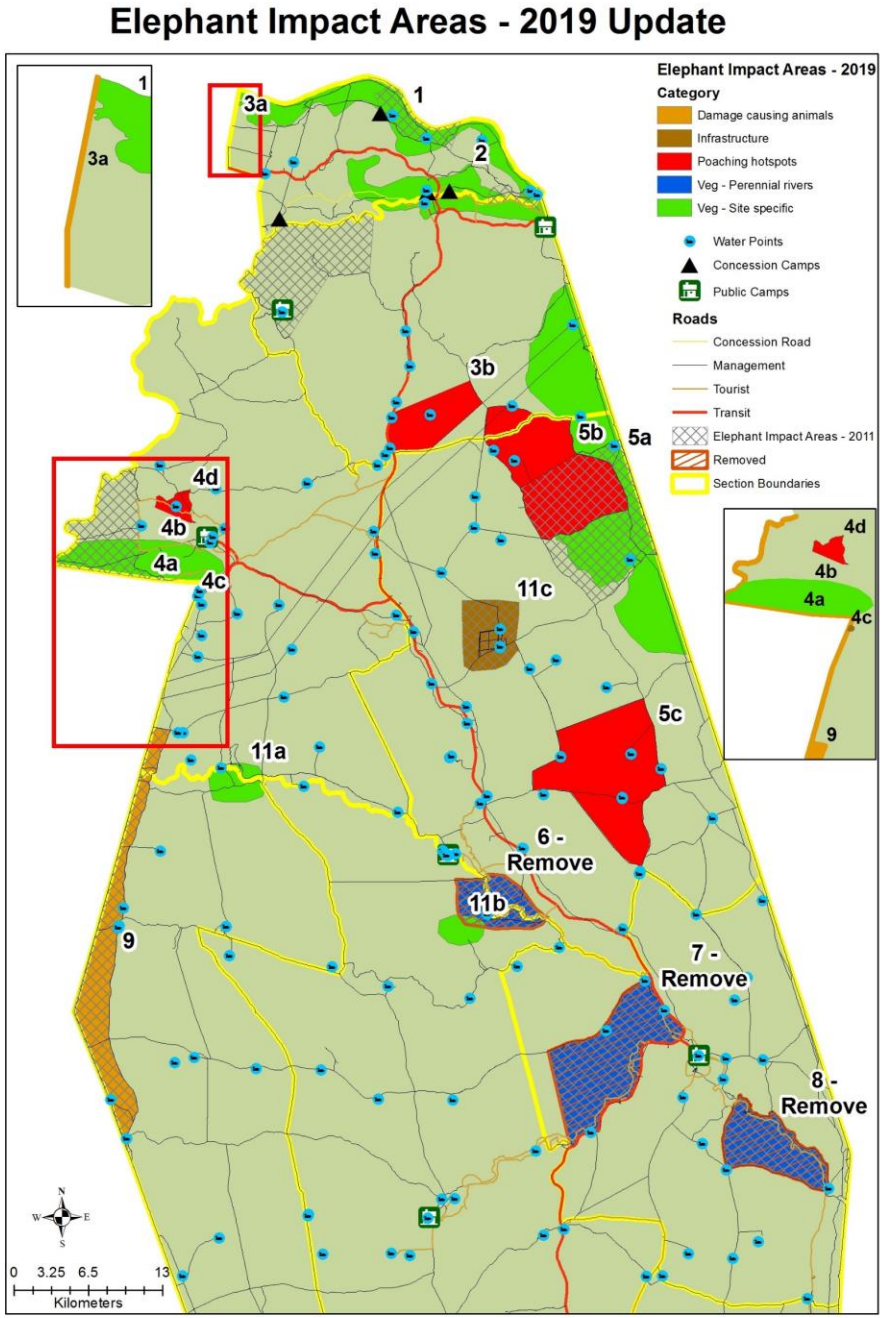


Category 1 includes areas along the major perennial rivers. Here vegetation dynamics are strongly dependent on flooding regimes with natural cycles of low riparian vegetation after major floods and slow succession to thicker vegetation in the floodplain and riverbed.



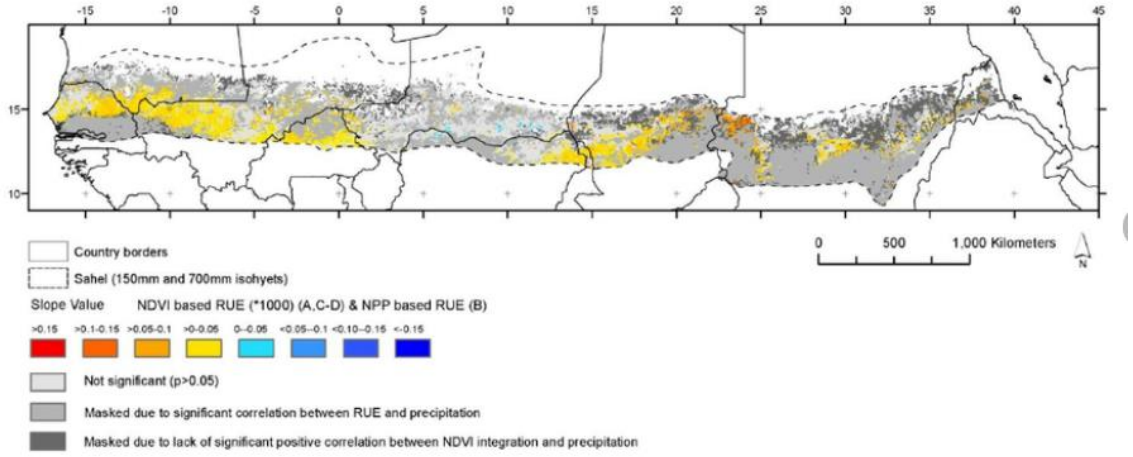
Category 2 includes areas where elephants typically have the most impact on vegetation; these are areas on fertile soils with plenty of water available year-round and where elephants impact greatly on palatable species.

Elephants may also have high impacts in **Category 3** but the effects of elephants are exacerbated by intense and frequent fires. Tree species such as kiaat (*Pterocarpus angolensis*) are very susceptible to fire damage after bark is removed or otherwise browsed on by elephants.



Category 4 represents areas where elephants don't necessarily have a huge impact currently but the vegetation type or habitat is rare in the park.

Methods



- Rain use efficiency:
  - A rain use efficiency (RUE) time series, a widely used remote sensing proxy for ecosystem functioning was generated
  - RUE is typically derived by calculating the ratio between net primary productivity (NPP) (using NDVI as a proxy) and total precipitation of a given period
  - Remote sensing time series analysis and breakpoint detection were used to identify patterns and changes in ecosystem functioning for the KNP for the years 1982 to 2015

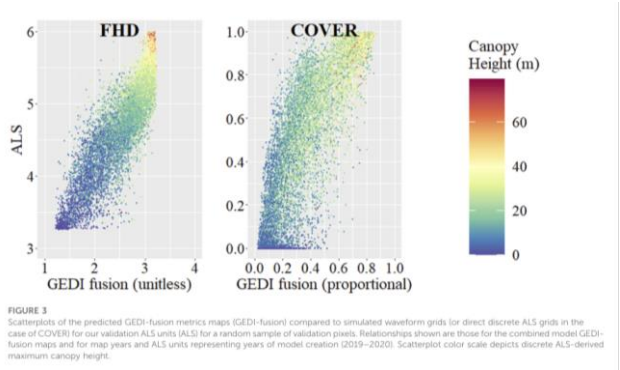
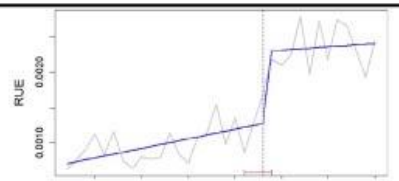
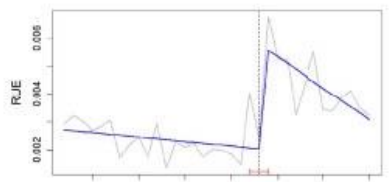
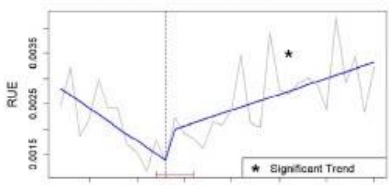
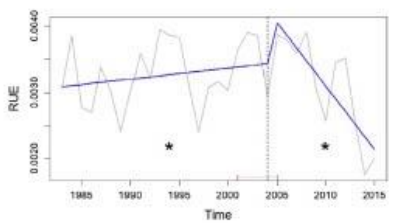


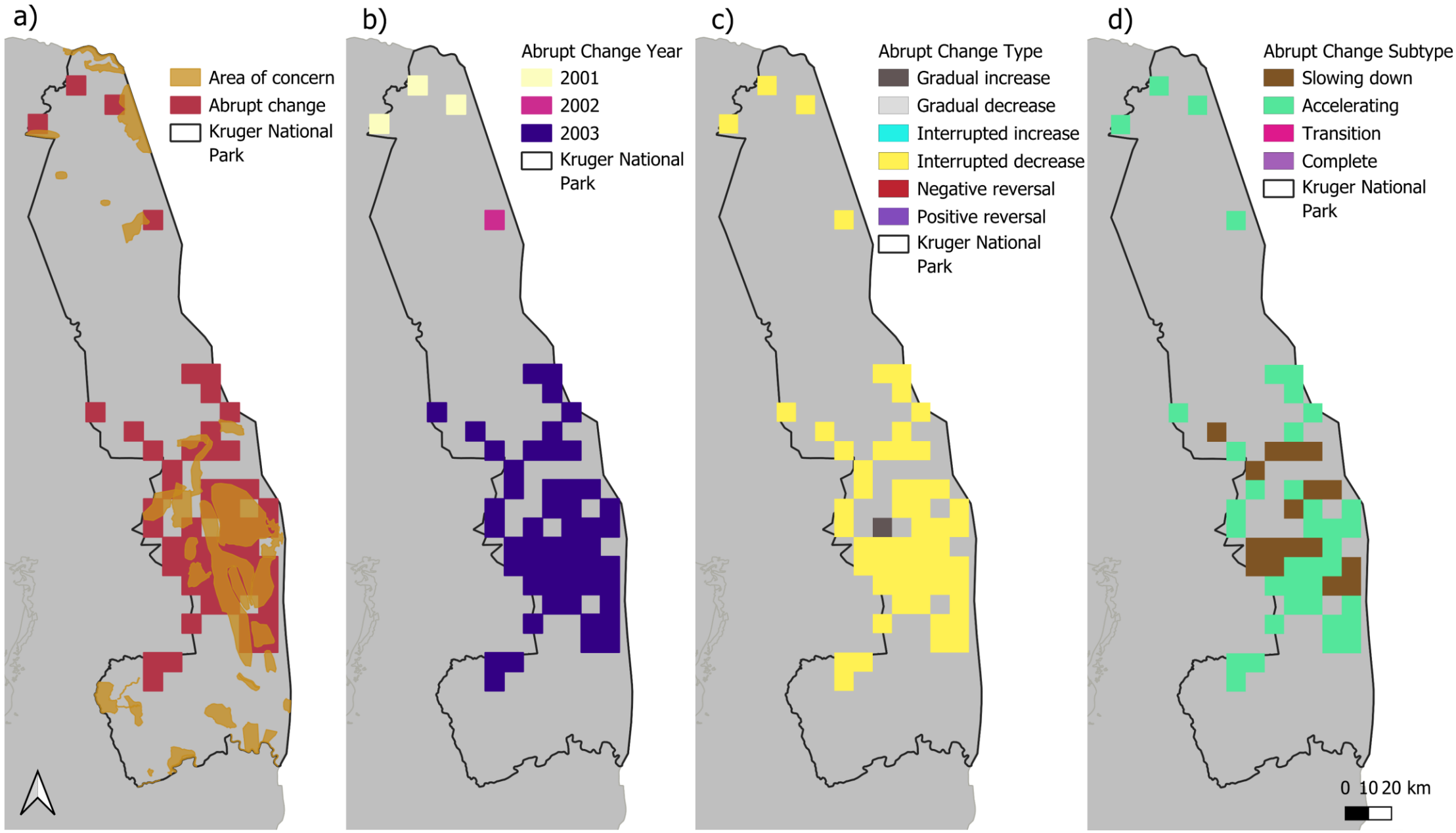
FIGURE 3
Scatterplots of the predicted GEDI-fusion metrics maps (GEDI-fusion) compared to simulated waveform grids (or direct discrete ALS grids in the case of COVER) for our validation ALS units (ALS) for a random sample of validation pixels. Relationships shown are those for the combined model GEDI-fusion maps and for map years and ALS units representing years of model creation (2019–2020). Scatterplot color scale depicts discrete ALS-derived maximum canopy height.

- Woody change – GEDI fusion product
  - The Global Ecosystem Dynamics Investigation (GEDI), provides publicly available samples of vegetation structure across near global extents - Spaceborn LiDAR sensor mounted on the International Space Station
  - We combined GEDI footprint samples with continuous remote sensing data sources to predict woody cover at 30 m resolutions and annual time steps
  - Continuous remote sensing predictors included spectral Landsat indices and backscatter metrics from Synthetic Aperture Radar (SAR). SAR information was derived from PALSAR 1 and 2, operated by the Japanese Aerospace Exploration Agency. The temporal extents of those missions constrained our annual structure predictions to 2007-2010 (PALSAR 1) and 2015-2022 (PALSAR 2)
  - GEDI-fusion maps have been used to support wildlife habitat modelling (Vogeler, J. C., Fekety, P. A., Elliott, L., Swayze, N. C., Filippelli, S. K., Barry, B., ... & Vierling, K. T. (2023). Evaluating GEDI data fusions for continuous characterizations of forest wildlife habitat. Frontiers in Remote Sensing, 4, 1196554.)

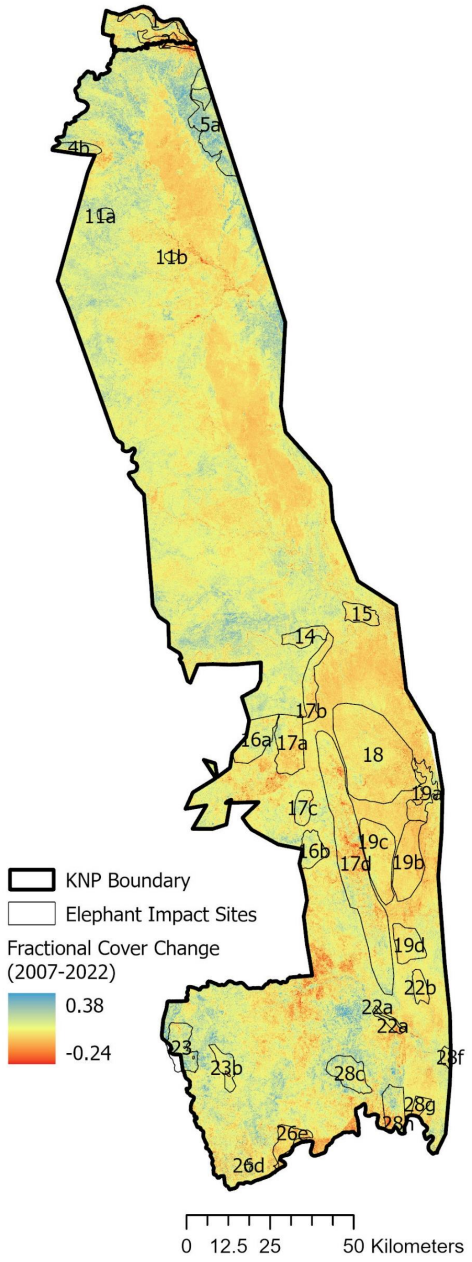
Results: Rain use efficiency

Table 1 Abrupt change type and subtype characterisation as defined by Bernardino et al. (2020). Adapted from Vermeulen et al. (2024).

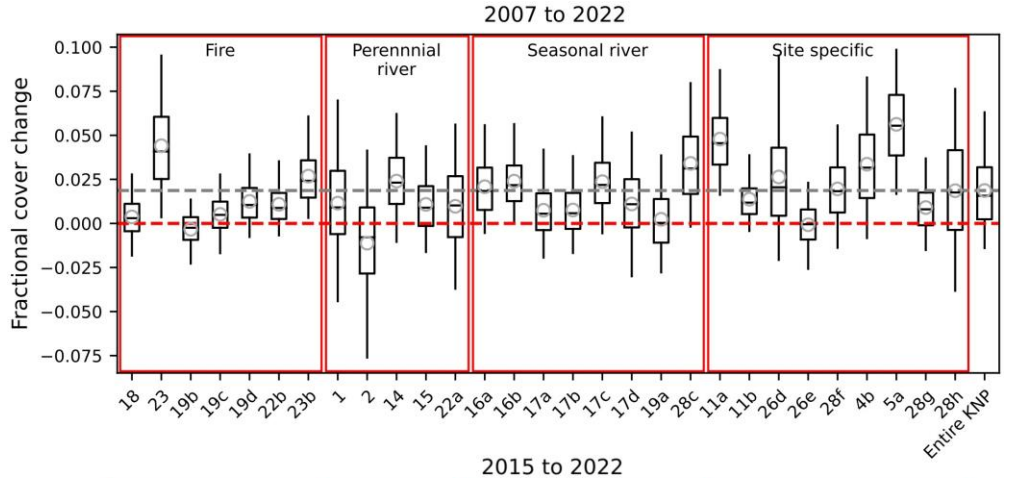
Change type	Description		Change subtype	Description
Interrupted increase	An abrupt shift is observed, yet the trend maintains a positive direction both preceding and following the breakpoint.		Slowing down	Ecosystem functioning undergoes an overall shift, with the magnitude of change **decreasing** after the breakpoint.
Interrupted decrease	An abrupt shift is observed, yet the trend maintains a negative direction both preceding and following the breakpoint.		Accelerating	Ecosystem functioning undergoes an overall shift, with the magnitude of change **increasing** after the breakpoint.
Positive reversal	An abrupt shift is observed as the trend shifts from a decrease to an increase		Transition	A reversal trend that is in a **transitional phase.**
Negative reversal	An abrupt shift is observed as the trend shifts from an increase to a decrease		Complete	The reversal that has **completed already**


a)
Area of concern
Abrupt change
Kruger National Park
b)
Abrupt Change Year
2001
2002
2003
Kruger National Park
c)
Abrupt Change Type
Gradual increase
Gradual decrease
Interrupted increase
Interrupted decrease
Negative reversal
Positive reversal
Kruger National Park
d)
Abrupt Change Subtype
Slowing down
Accelerating
Transition
Complete
Kruger National Park
0 10 20 km

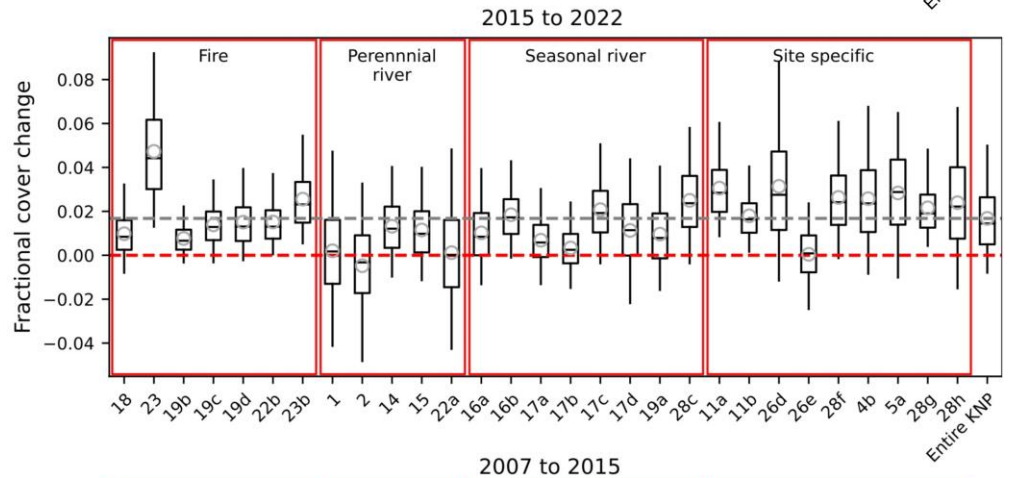
Results: Woody cover change



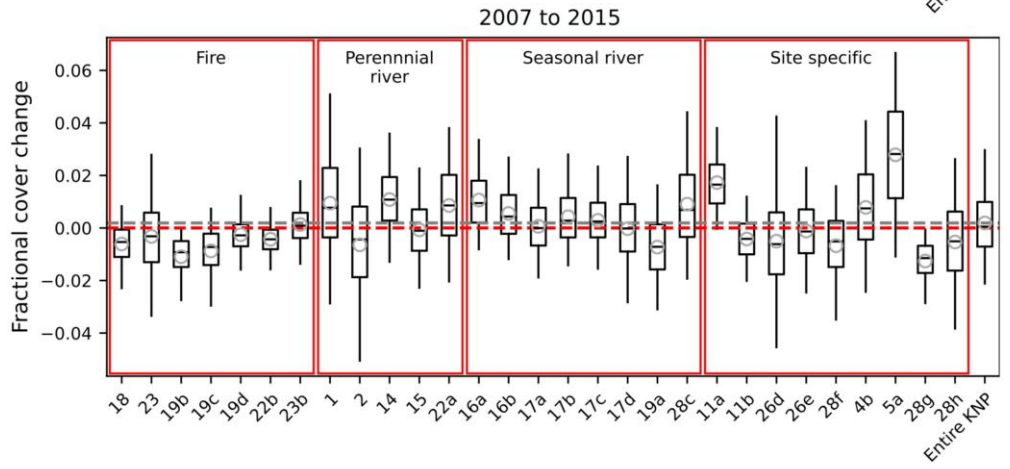
Results: Woody cover change



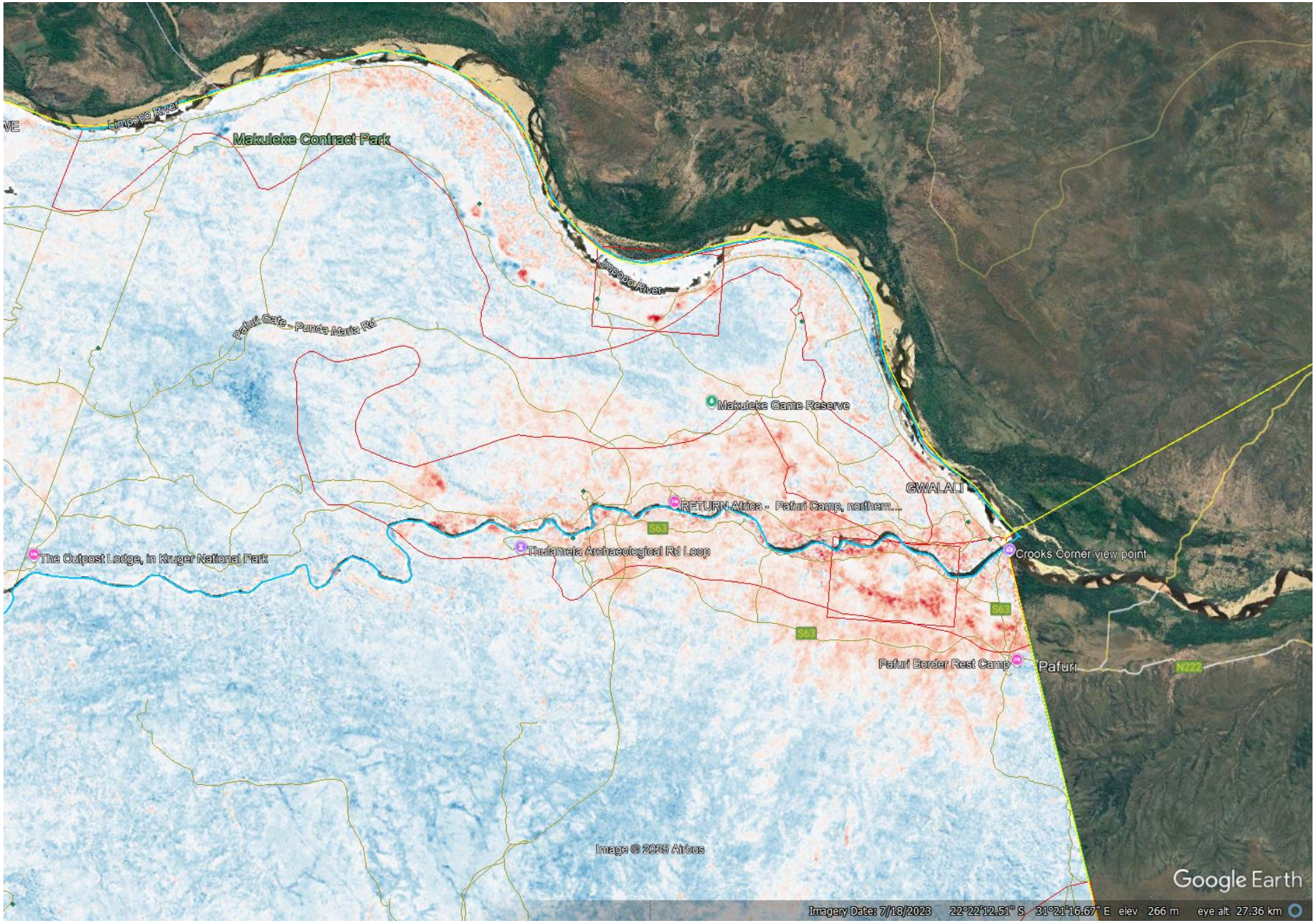
2007-2022



2015-2022

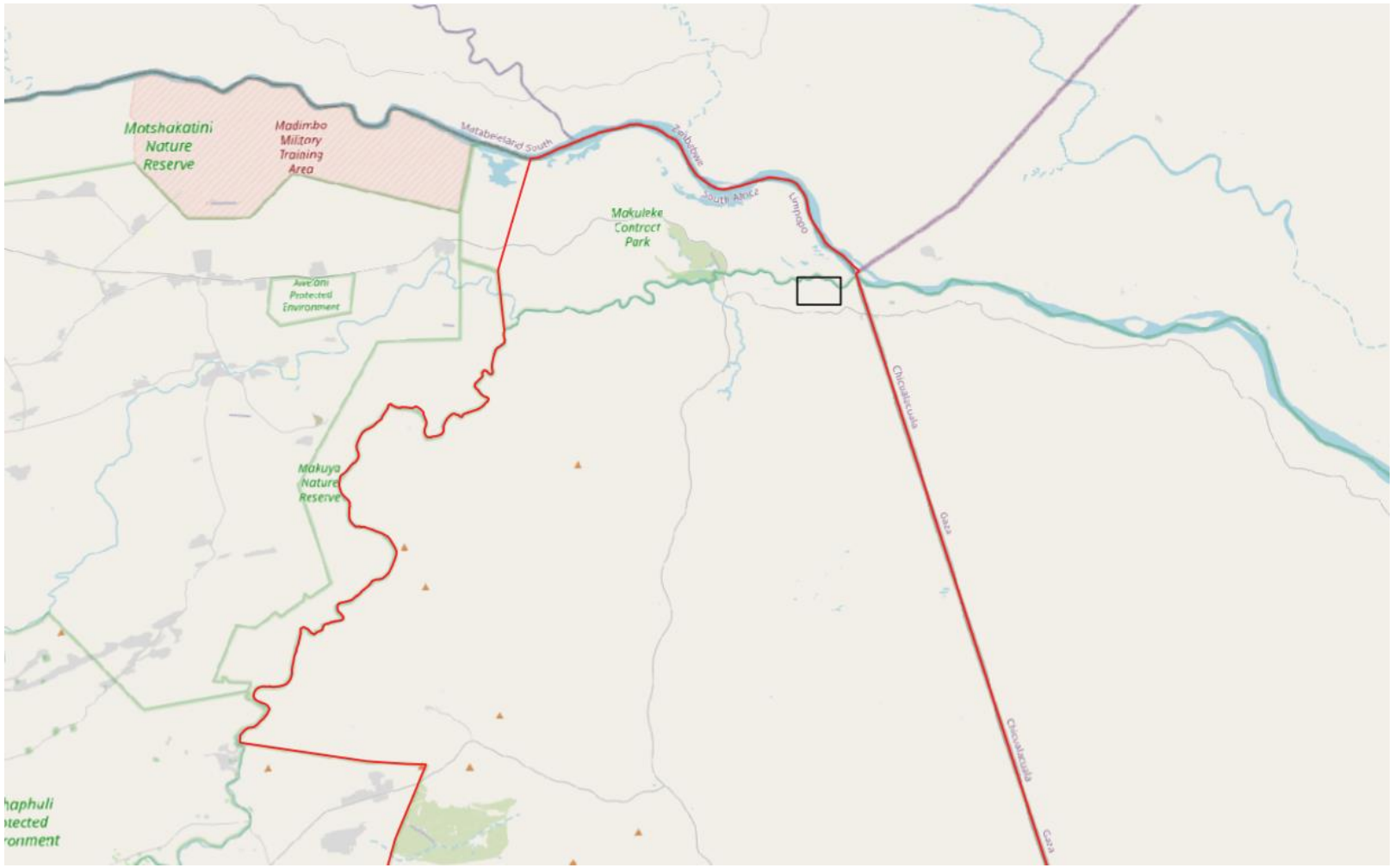


2007-2015


Limpopo River
Makuleke Contract Park
Limpopo River
Pafuri Gate - Punda Maria Rd
Makuleke Game Reserve
GWALALI
RETURN Africa - Pafuri Camp, northern...
S63
Thulamela Archaeological Rd Loop
The Outpost Lodge, in Kruger National Park
Crooks Corner view point
S63
S63
Pafuri Border Rest Camp
Pafuri
N222
Image © 2025 Airbus
Google Earth
Imagery Date: 7/18/2023 22°22'12.51" S 31°21'16.67" E elev 266 m eye alt 27.36 km

Luvuvhu River

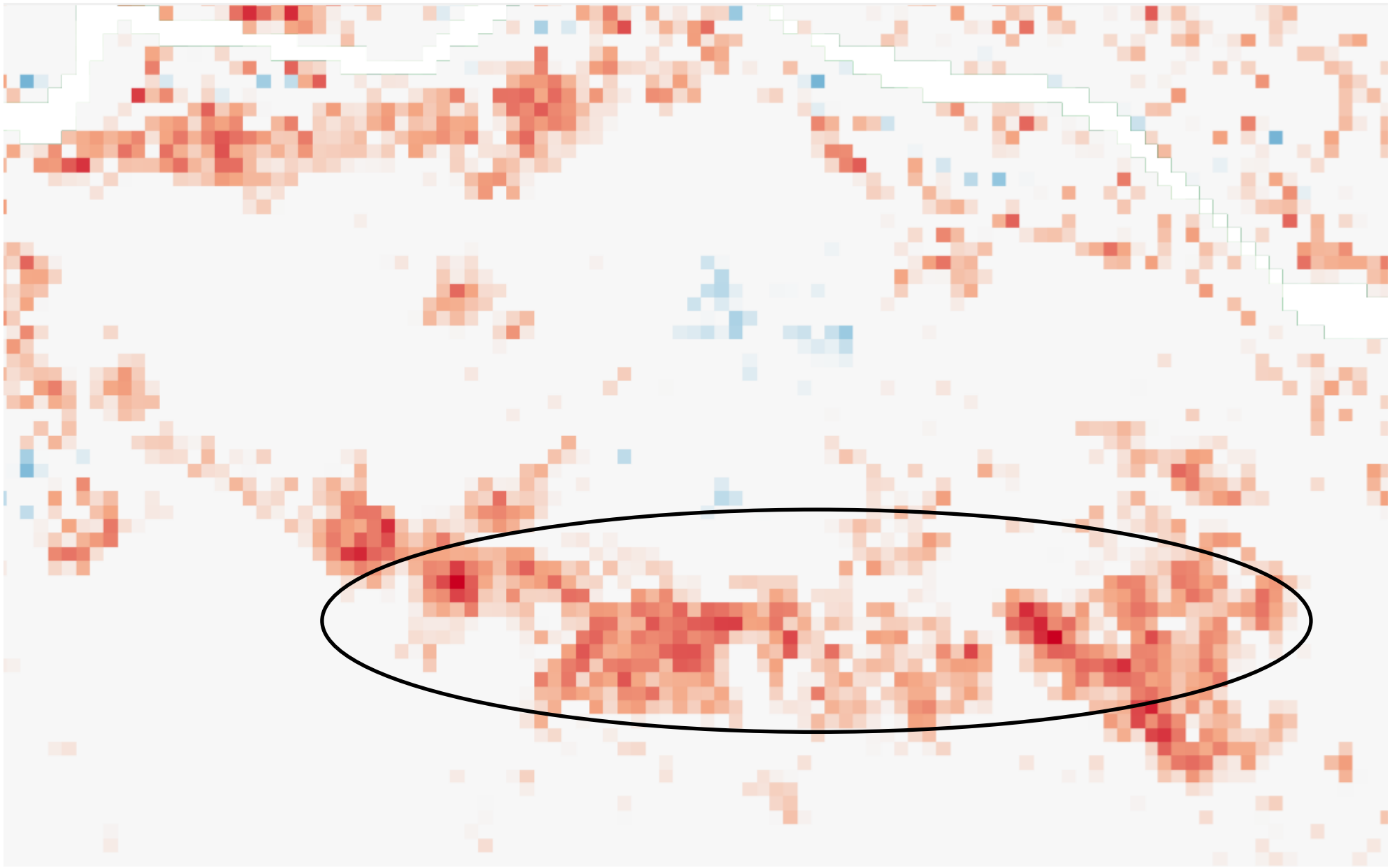
KNP North


Matshakatini
Nature
Reserve
Madimbo
Military
Training
Area
Mutabielard South
Zelbidone
South Africa
Limpopo
Makuleke
Contract
Park
Makuya
Nature
Reserve
Chicualacuala
Gaza

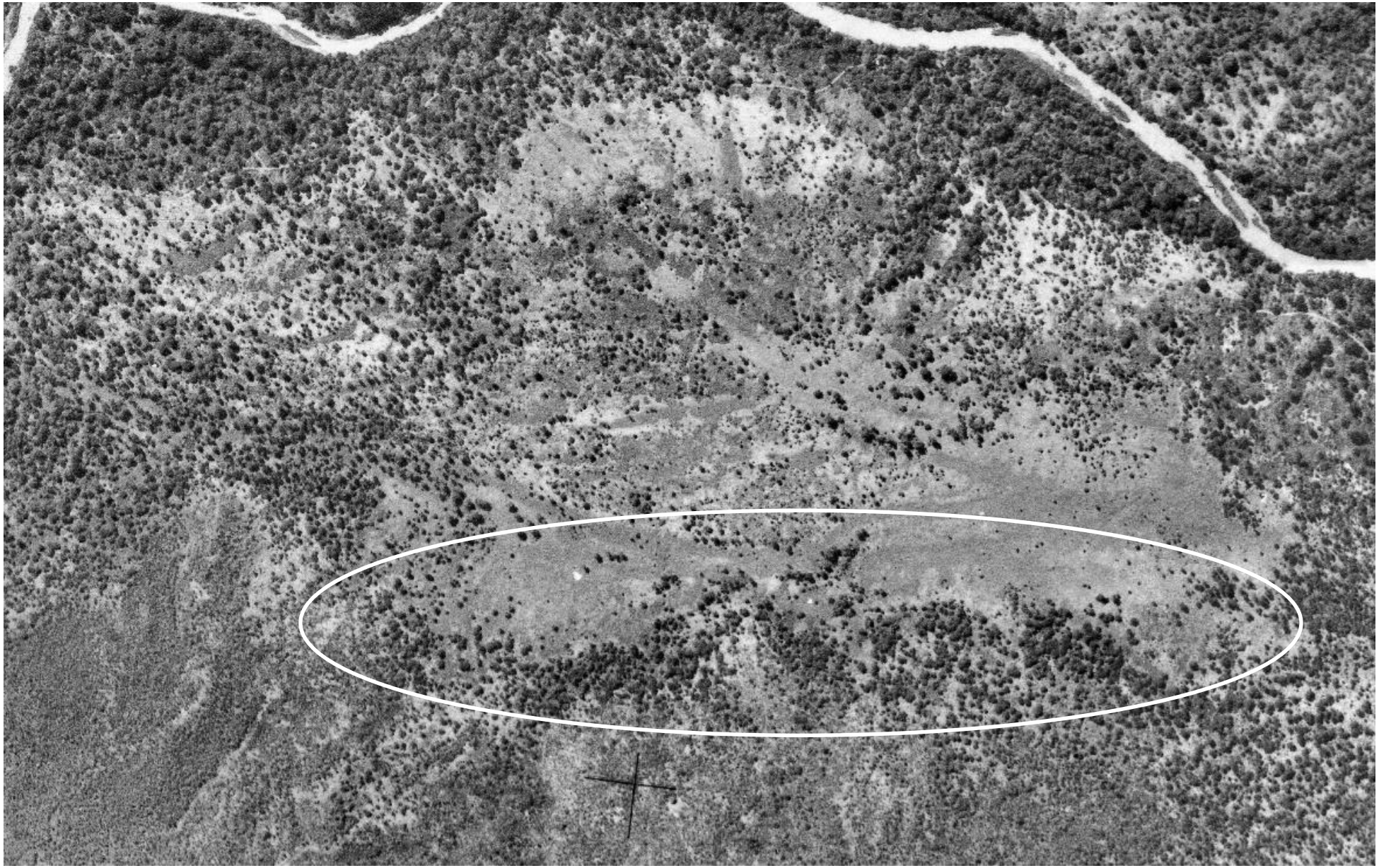
2007-2022

GEDI-fusion Woody Cover Change

Scale 1:11 500



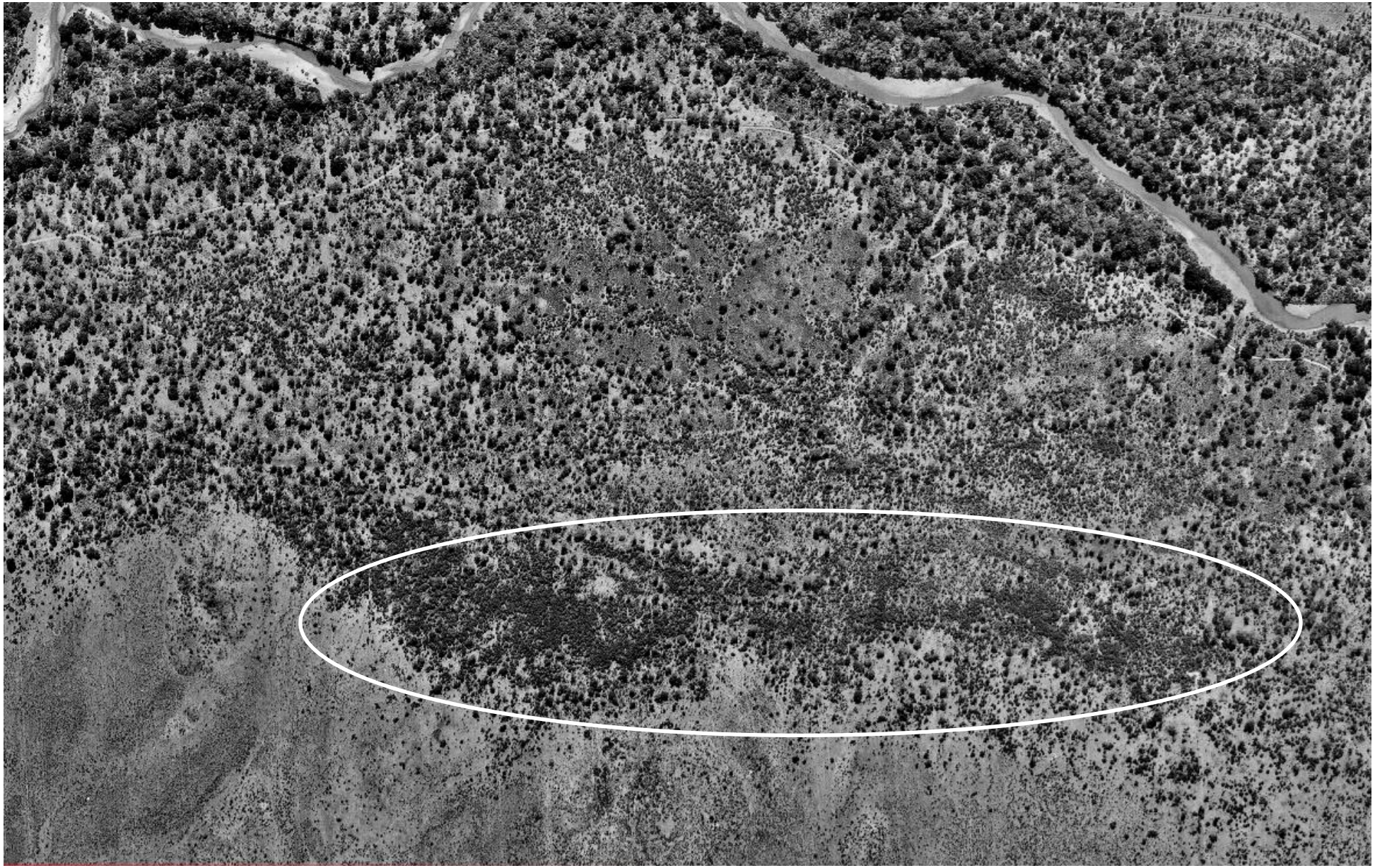
1942



Source CD:NGI

Scale 1:11 500

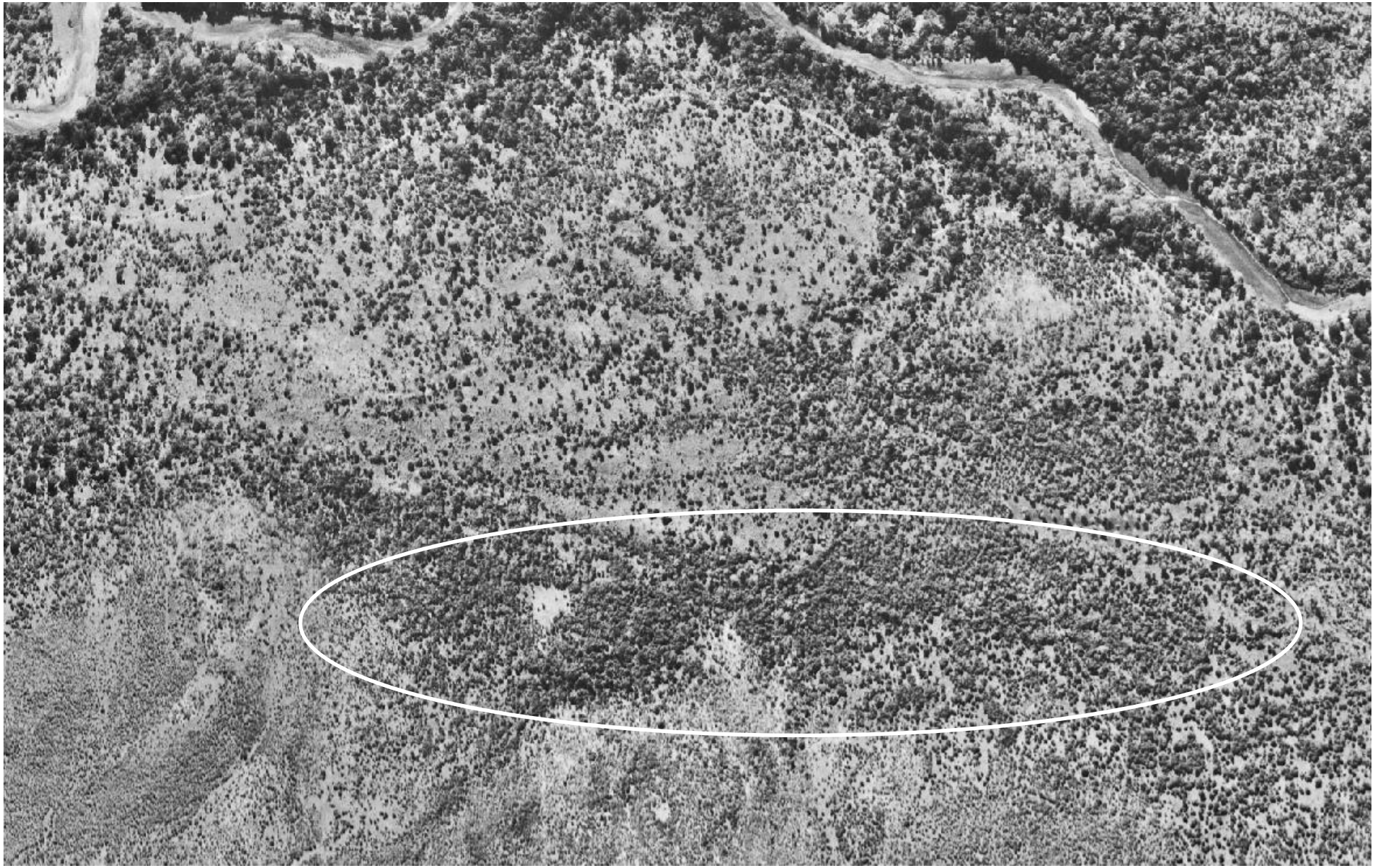
1965



Source CD:NGI

Scale 1:11 500

1985



Source CD:NGI

Scale 1:11 500

2005

Source GEarth

Scale 1:11 500

2007

Source GEarth

Scale 1:11 500

2010

Source GEarth

Scale 1:11 500

2012

Source GEarth

Scale 1:11 500

2018

Flood 2013

Source GEarth

Scale 1:11 500

2020

Source GEarth

Scale 1:11 500

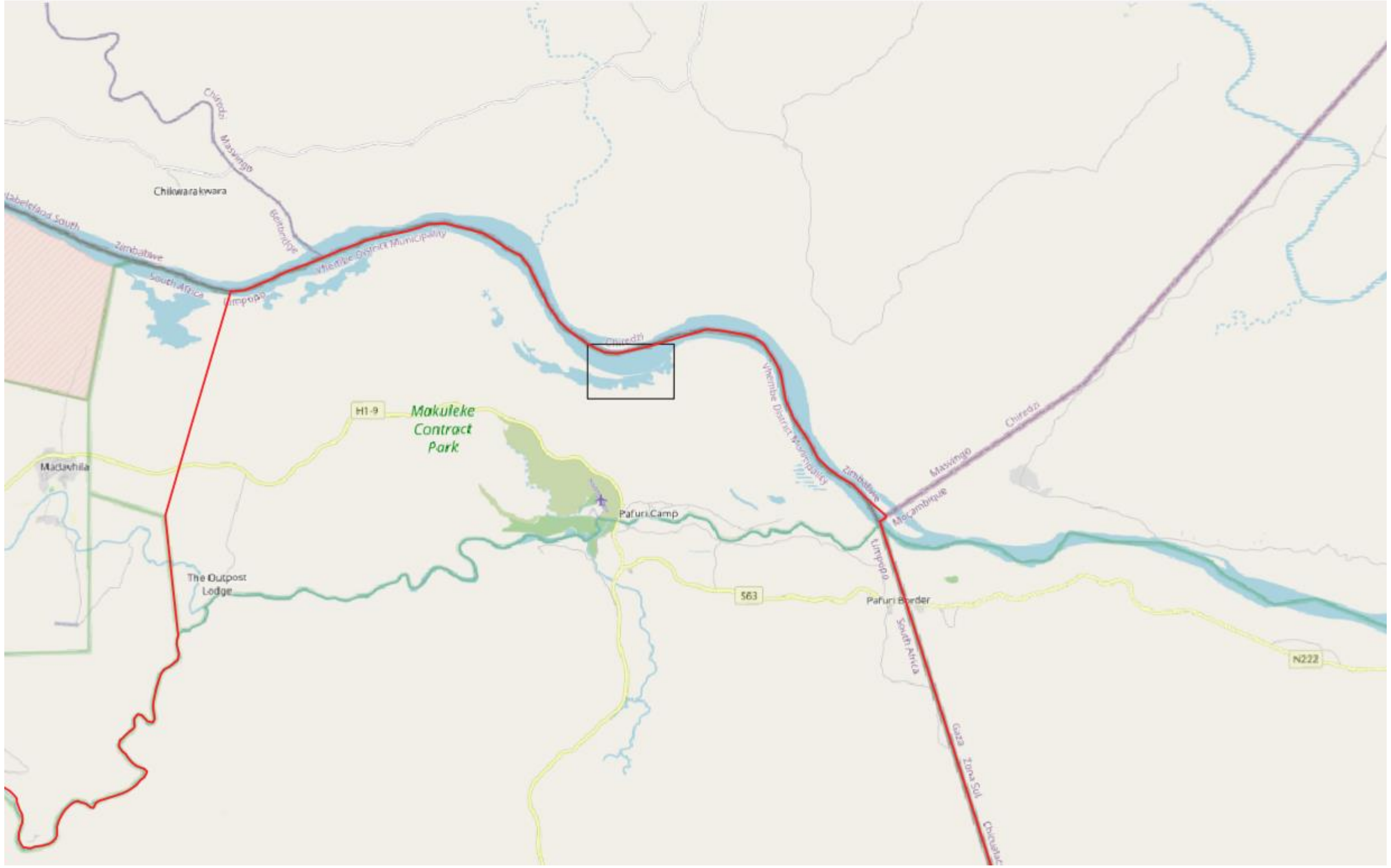
2023

Source GEarth

Scale 1:11 500

Limpopo River East

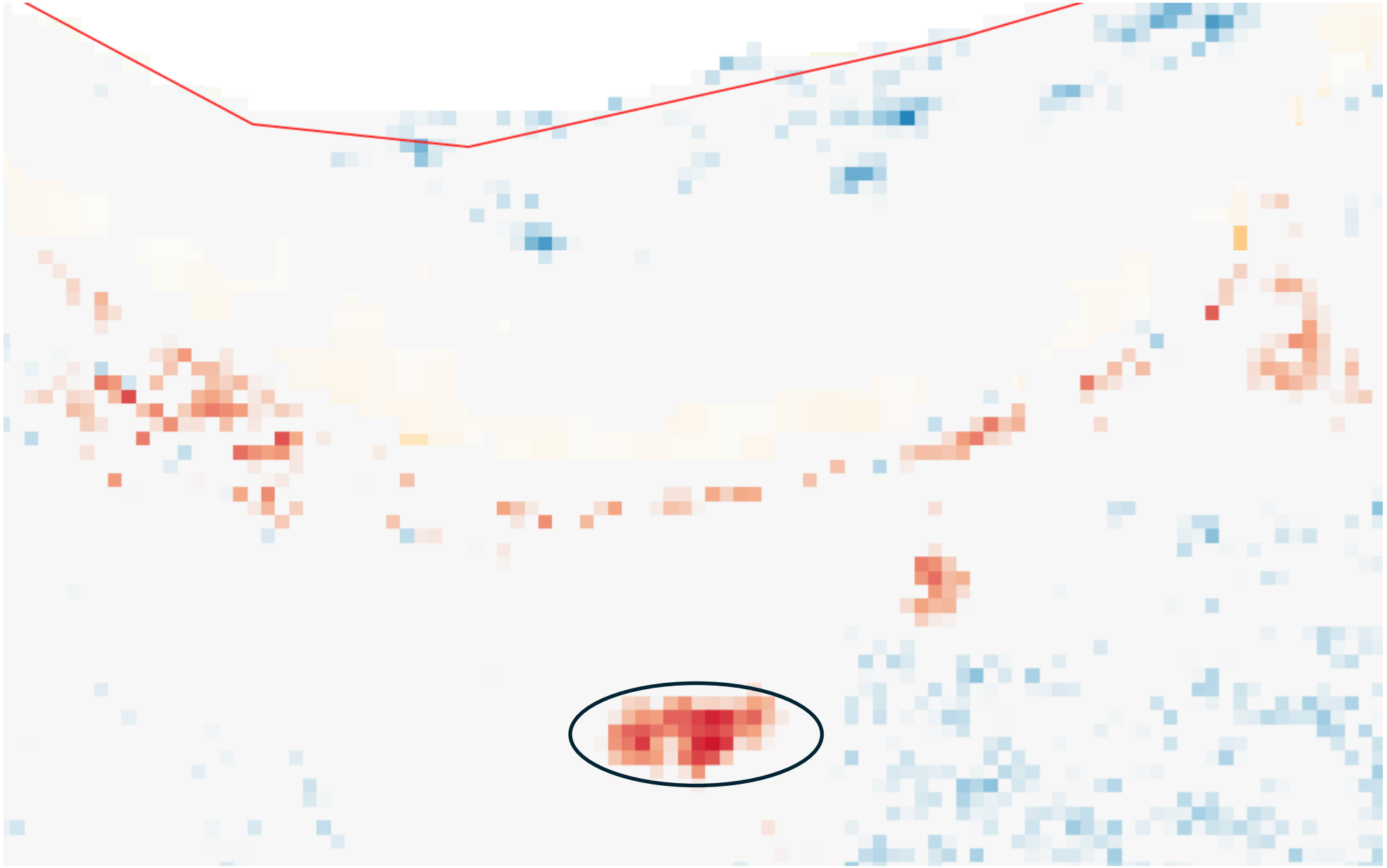
KNP North


Chikwarakwara
Zimbabwe
South Africa
Limpopo
Vhembe District Municipality
Chiredzi
Masvingo
H1-9
Makuleke
Contract
Park
Madavhila
Pafuri Camp
The Outpost
Lodge
S63
Pafuri Border
Moçambique
Gaza
Zona Sul
N222

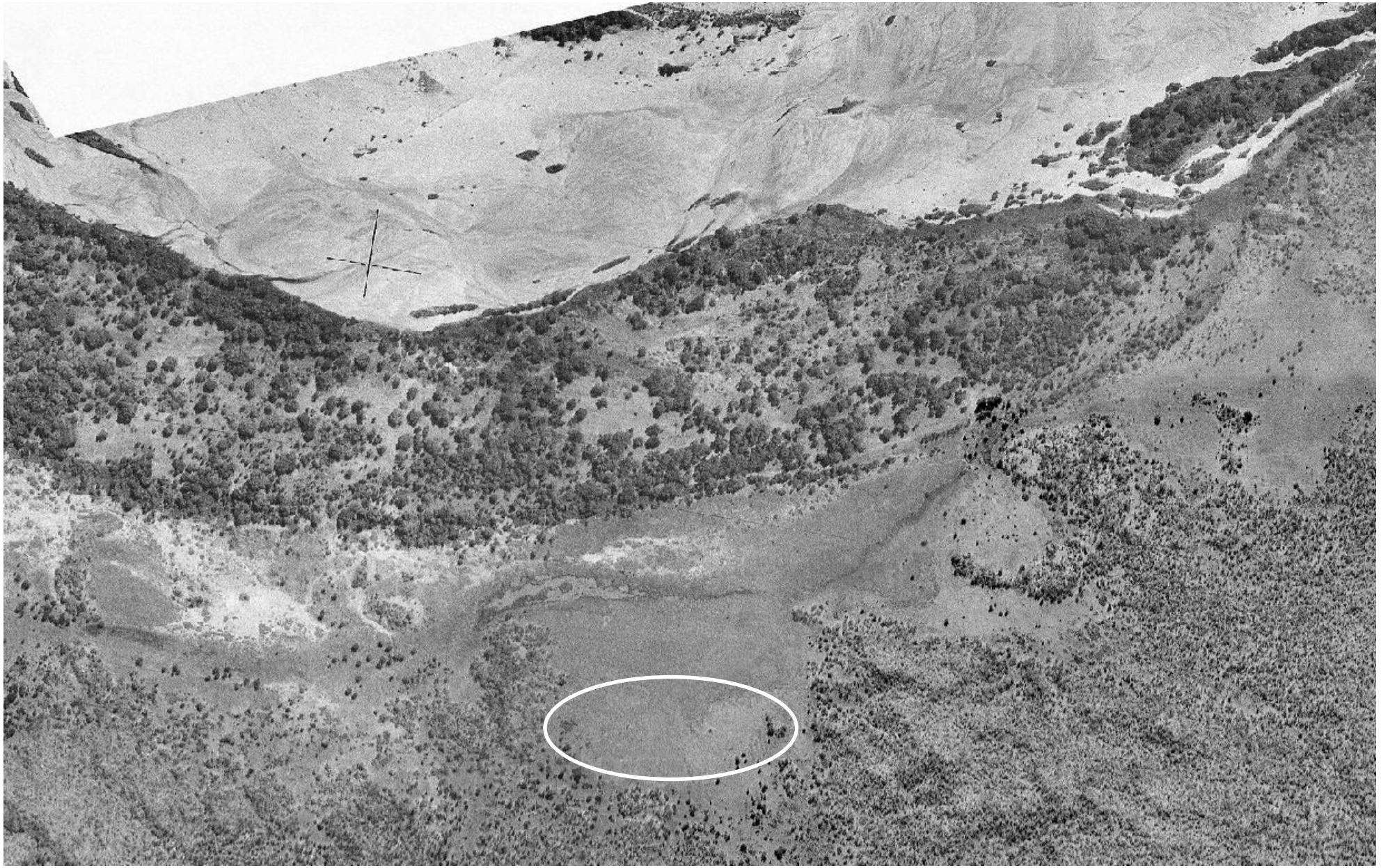
2007-2022

GEDI-fusion Woody Cover Change

Scale 1:11 500



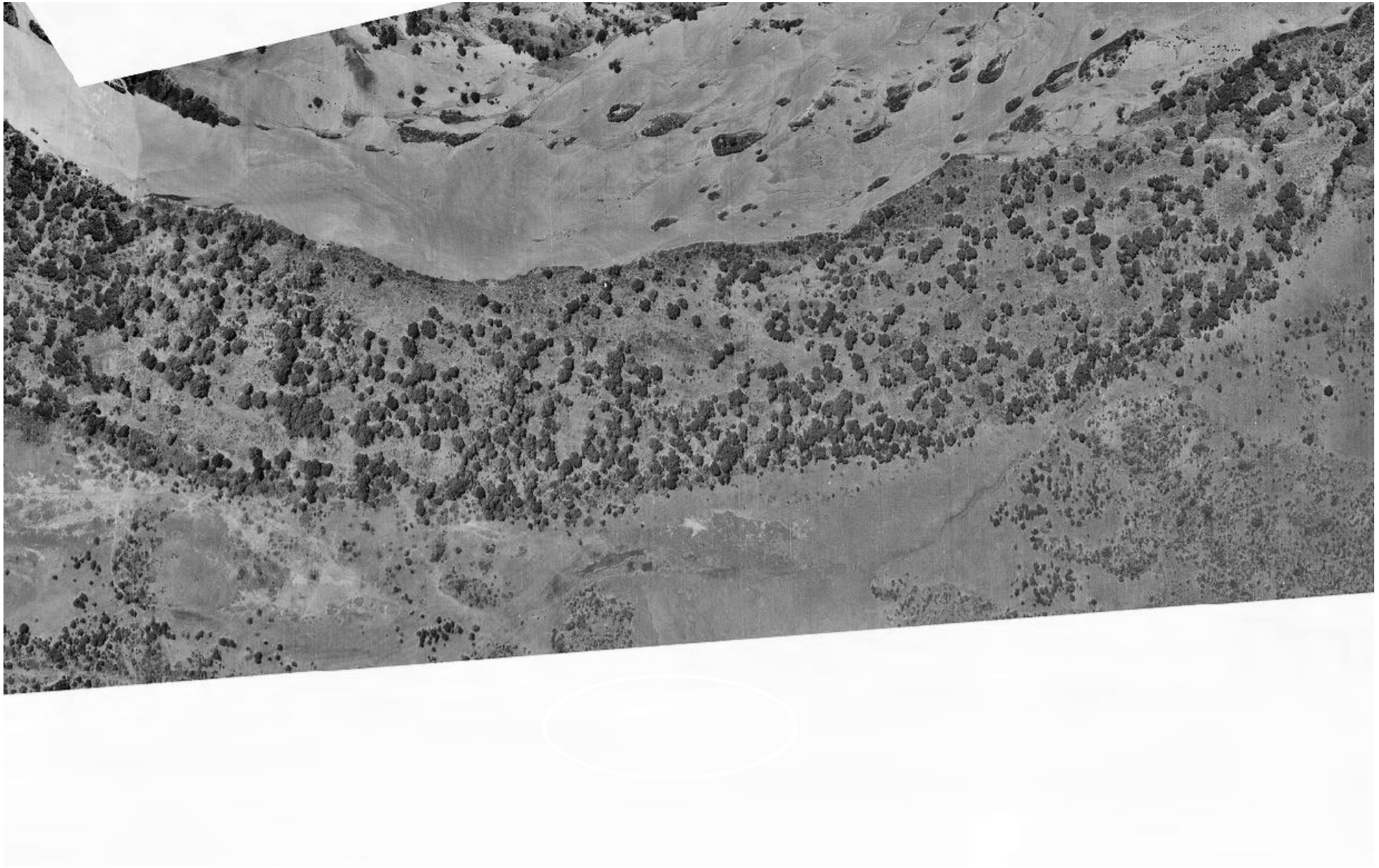
1942



Source CD:NGI

Scale 1:11 500

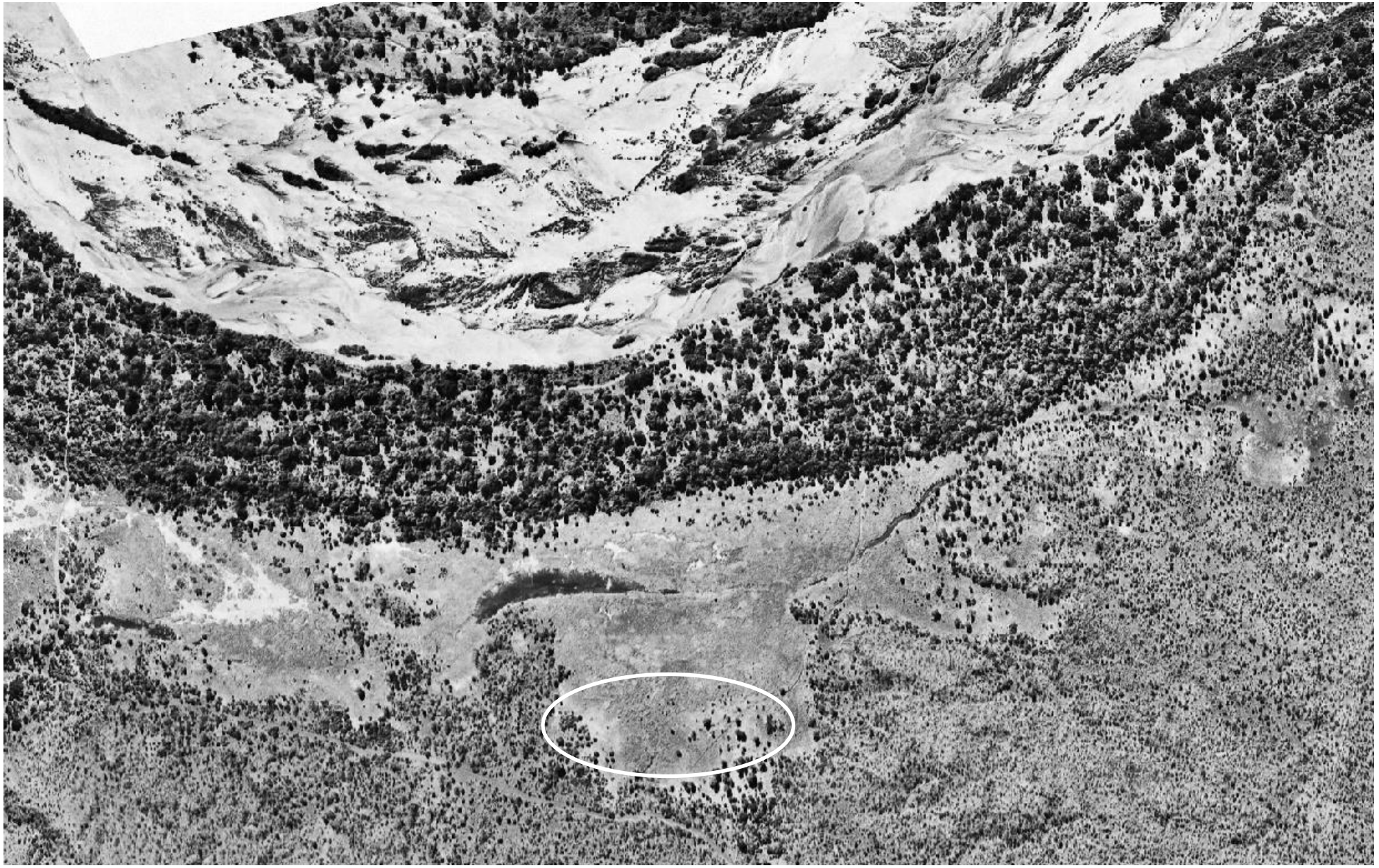
1965



Source CD:NGI

Scale 1:11 500

1985



Source CD:NGI

Scale 1:11 500

2005/8

Massive floods 2000

Source GEarth

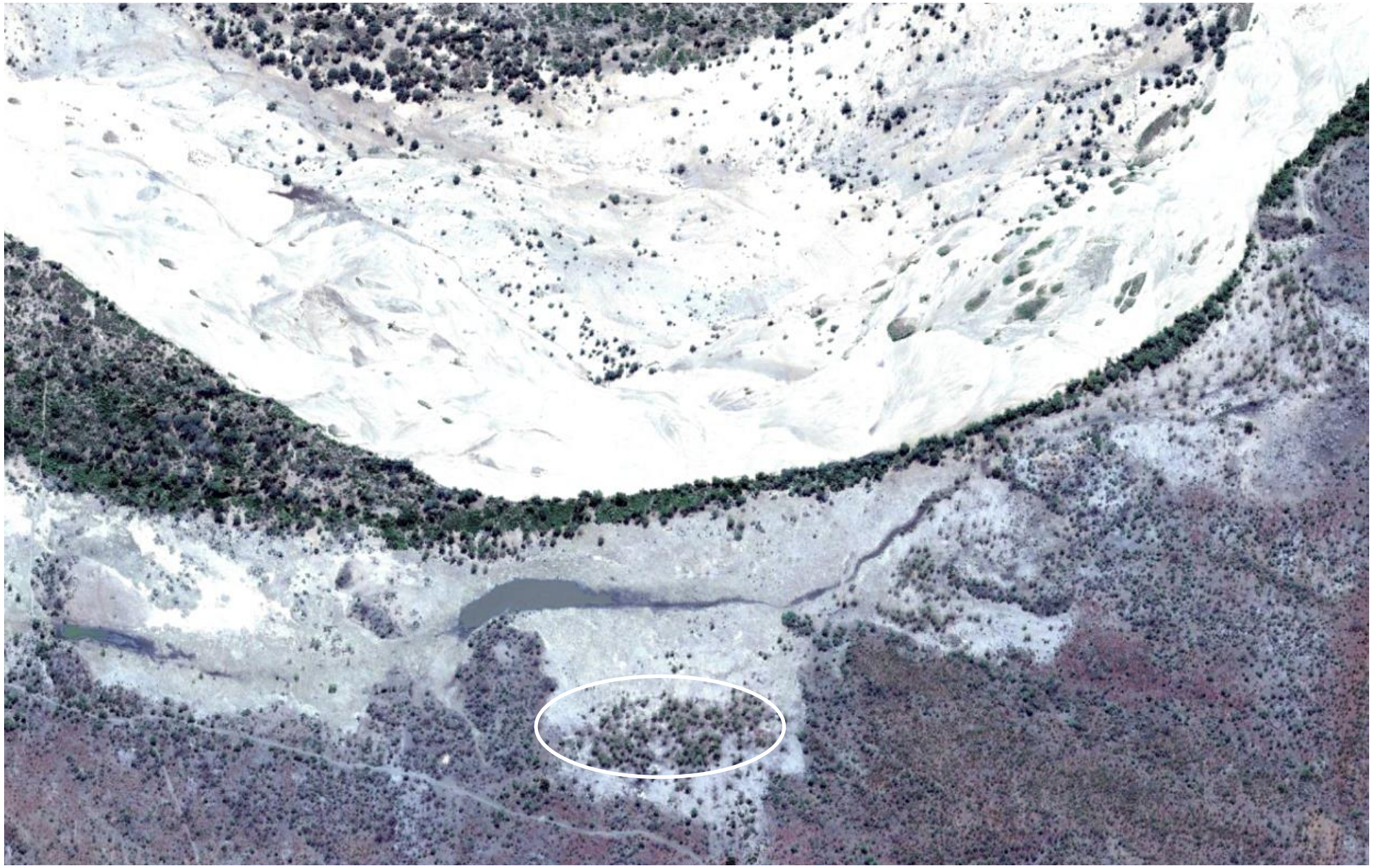
Scale 1:11 500

2007/6

Source GEarth

Scale 1:11 500

2012/10



Source GEarth

Scale 1:11 500

2015

Source CD:NGI

Scale 1:11 500

2018

Source CD:NGI

Scale 1:11 500

2019/5

Source GEarth

Scale 1:11 500

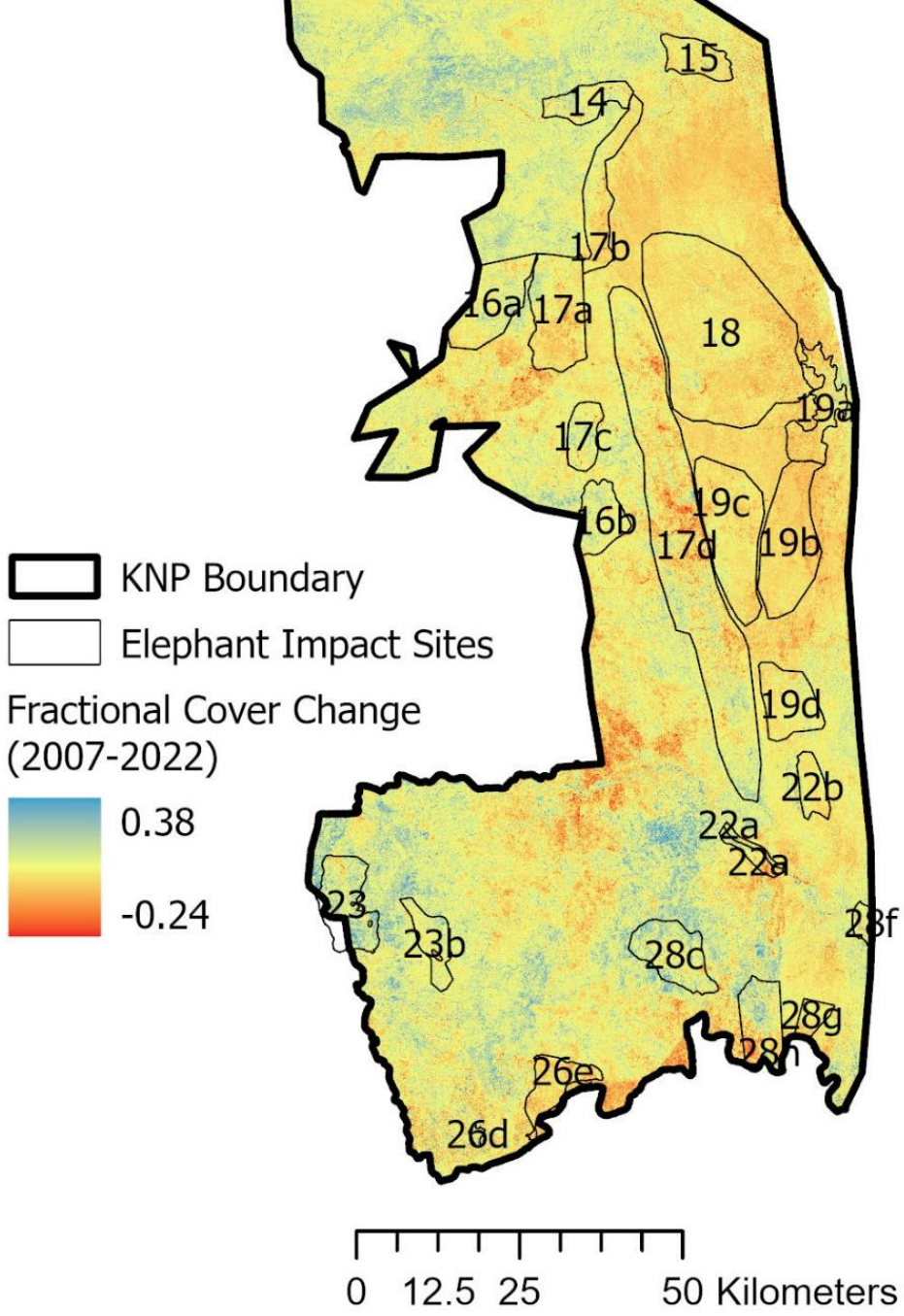
2023/7

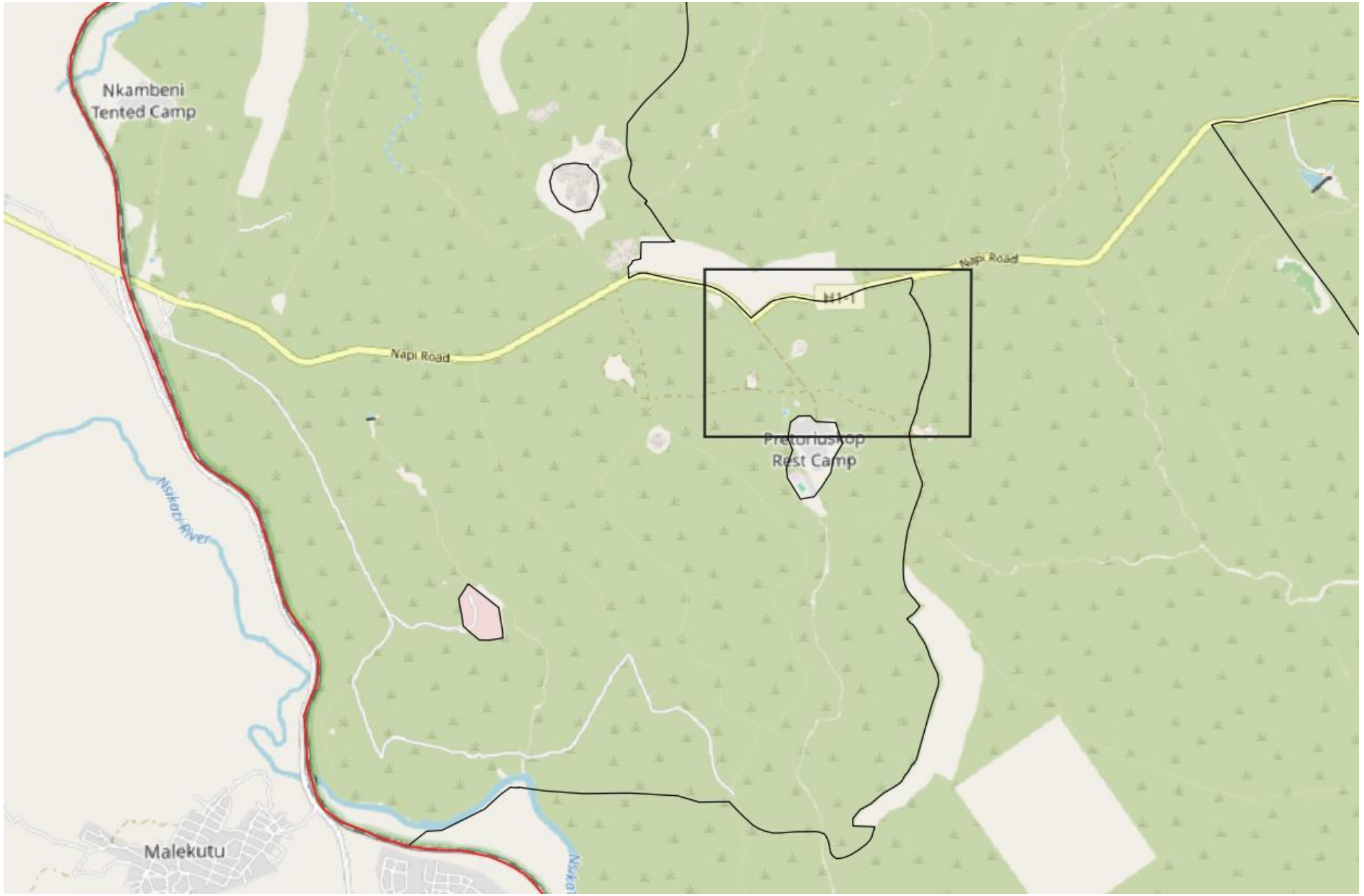
Source GEarth

Scale 1:11 500

Pretoriuskop

KNP South

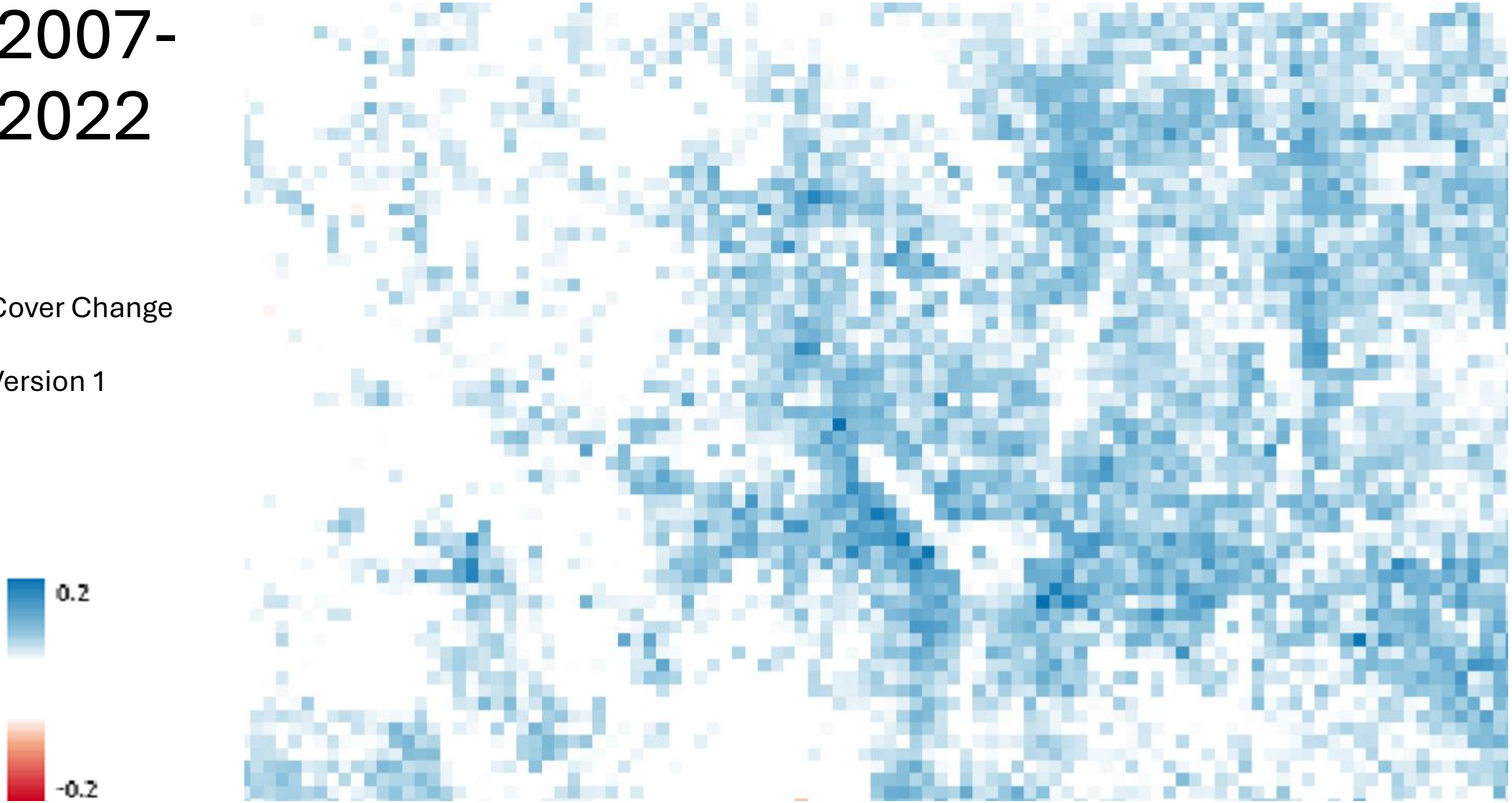



Nkambeni
Tented Camp
Napi Road
Napi Road
M1-1
Pretoriuskop
Rest Camp
Nsikazi River
Malekutu

2007-2022

Cover Change

Version 1

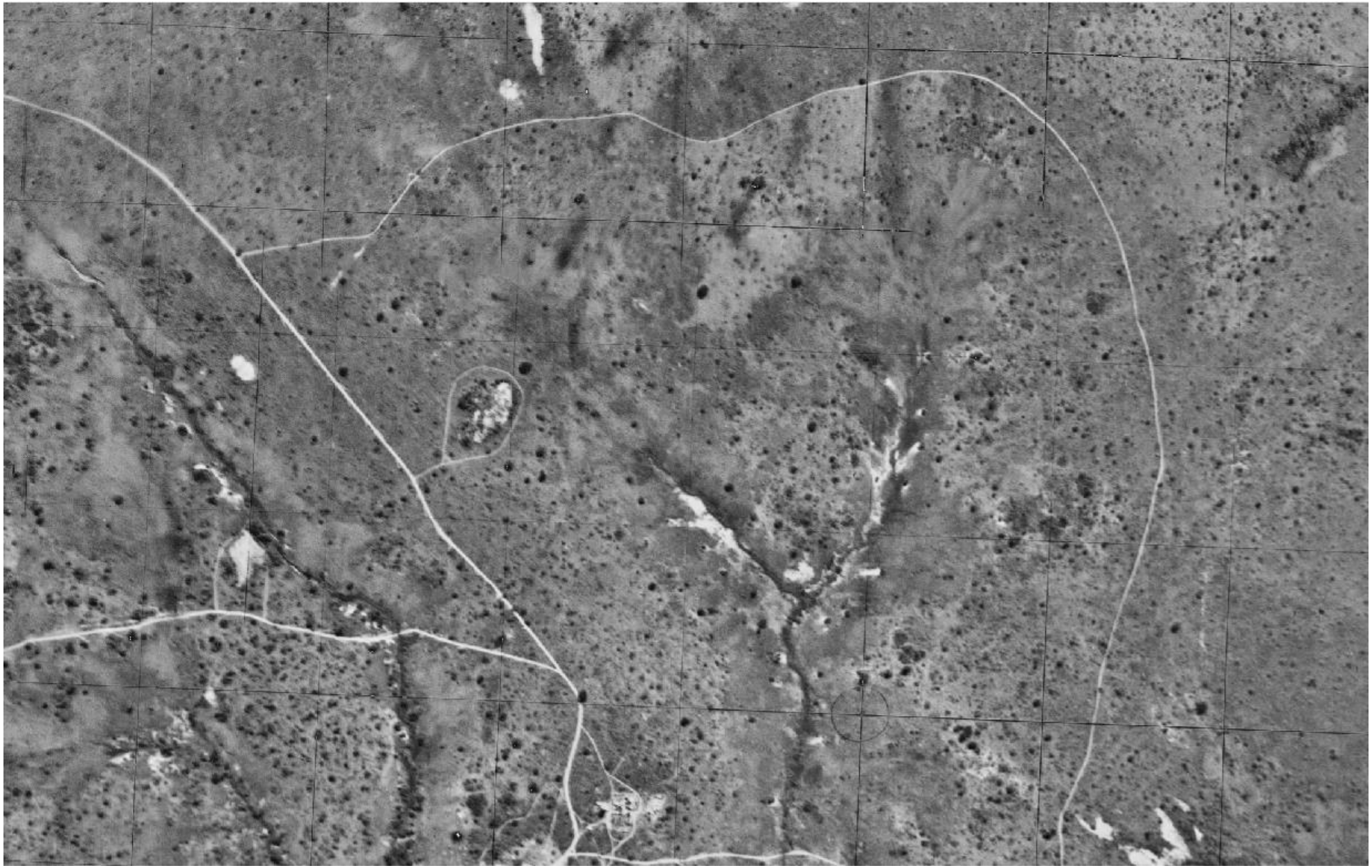


1940

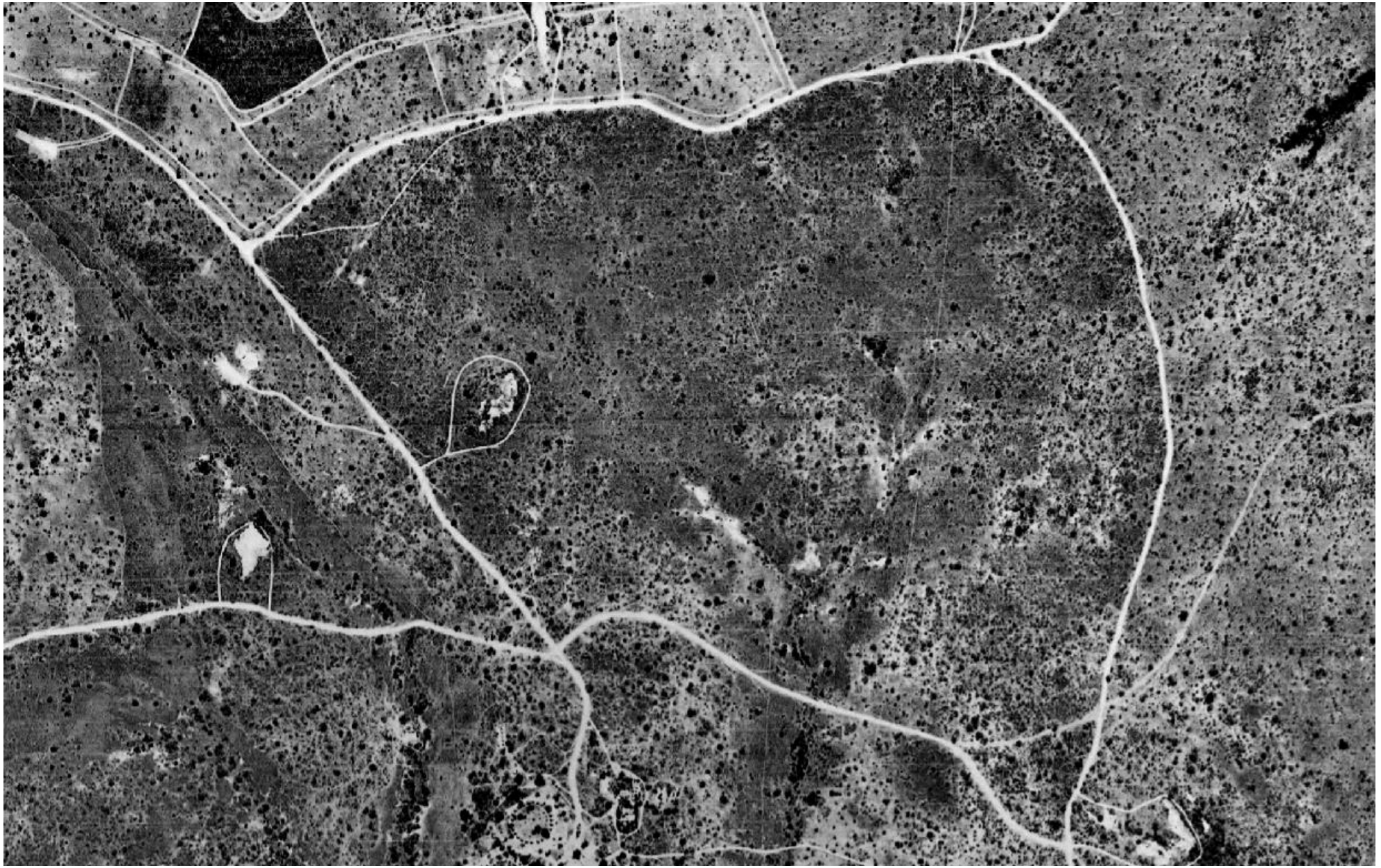
From an annual burning policy since the 1920s and before (which incidentally made it one of the best game viewing areas in the 1930s), all fires were suppressed between 1947-1954

Source CD:NGI

Scale 1:11 500



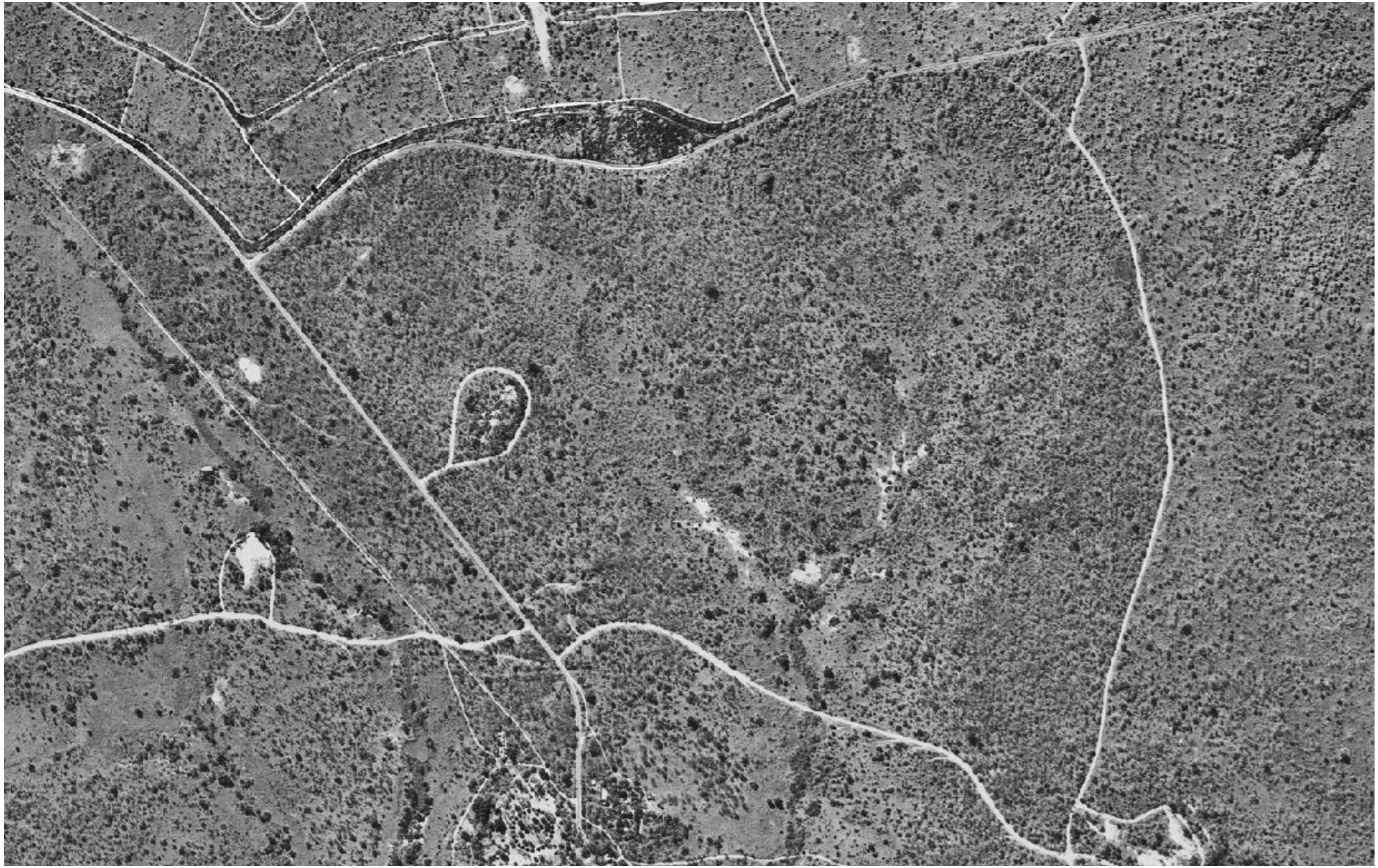
1965



Source CD:NGI

Scale 1:11 500

1985



Source CD:NGI

Scale 1:11 500

2004

Scale 1:11 500

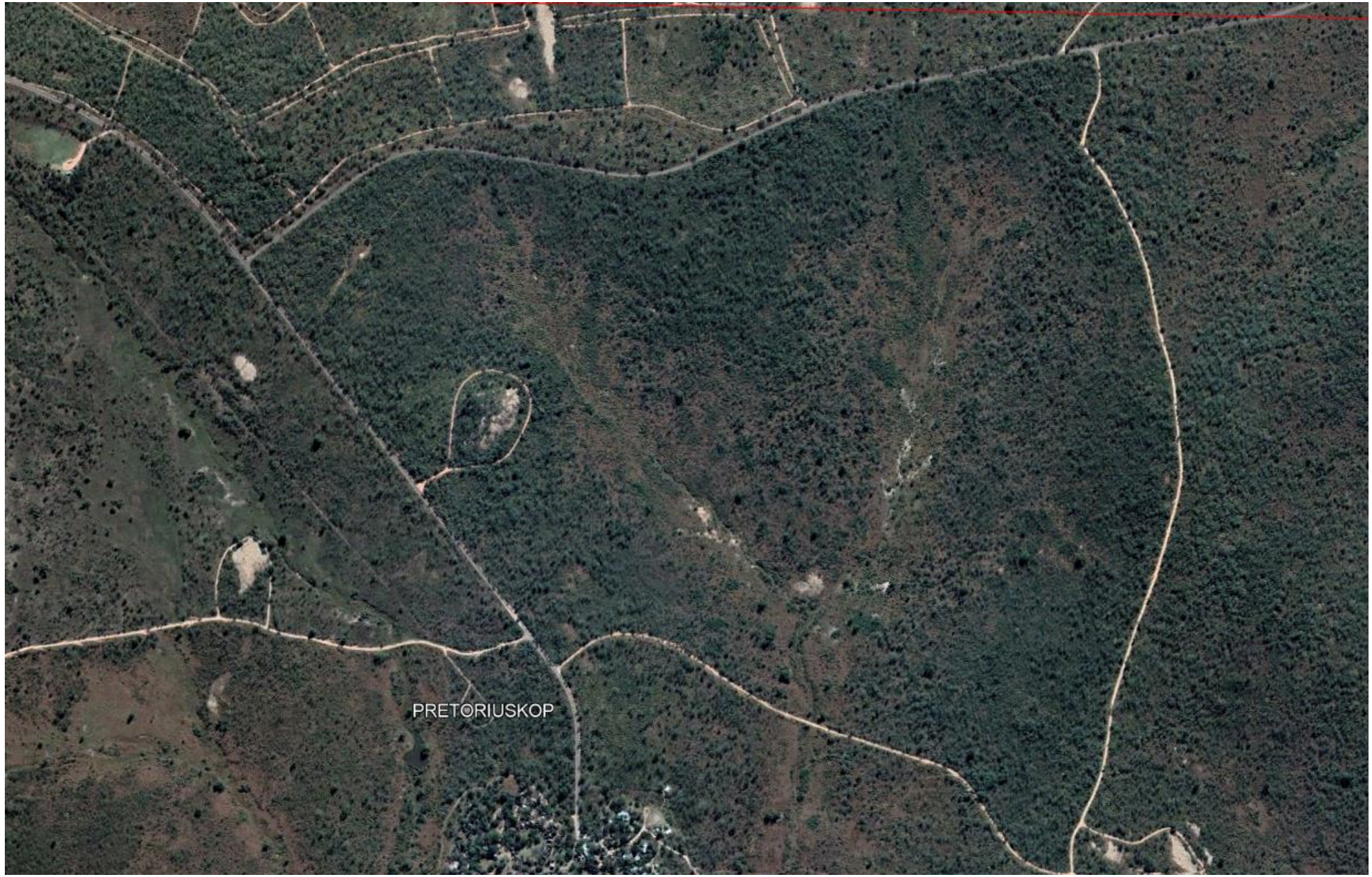
2012

Scale 1:11 500

2020

Scale 1:11 500

2022



Scale 1:11 500

2024

Manungu Koppie

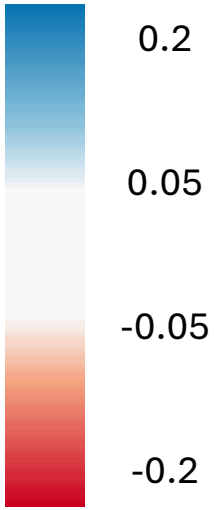
KNP South west of Pretoriuskop


Hazyview
Hazyview Airport
Nyongane
Numbi park
Tshabalala
Nkambeni
R538
Numbipark
Salubindza
Komzer
Nkambeni Tented Camp
H1-1
Bojwana
Phola
Chochelba
Manzini
Legogoto
Jerusalem
Ngcobaneni
Malekutu
Lundi
Makoko
Nsikazi
Malekutu
eMdlankhomo
Pretoriuskop Rest Camp

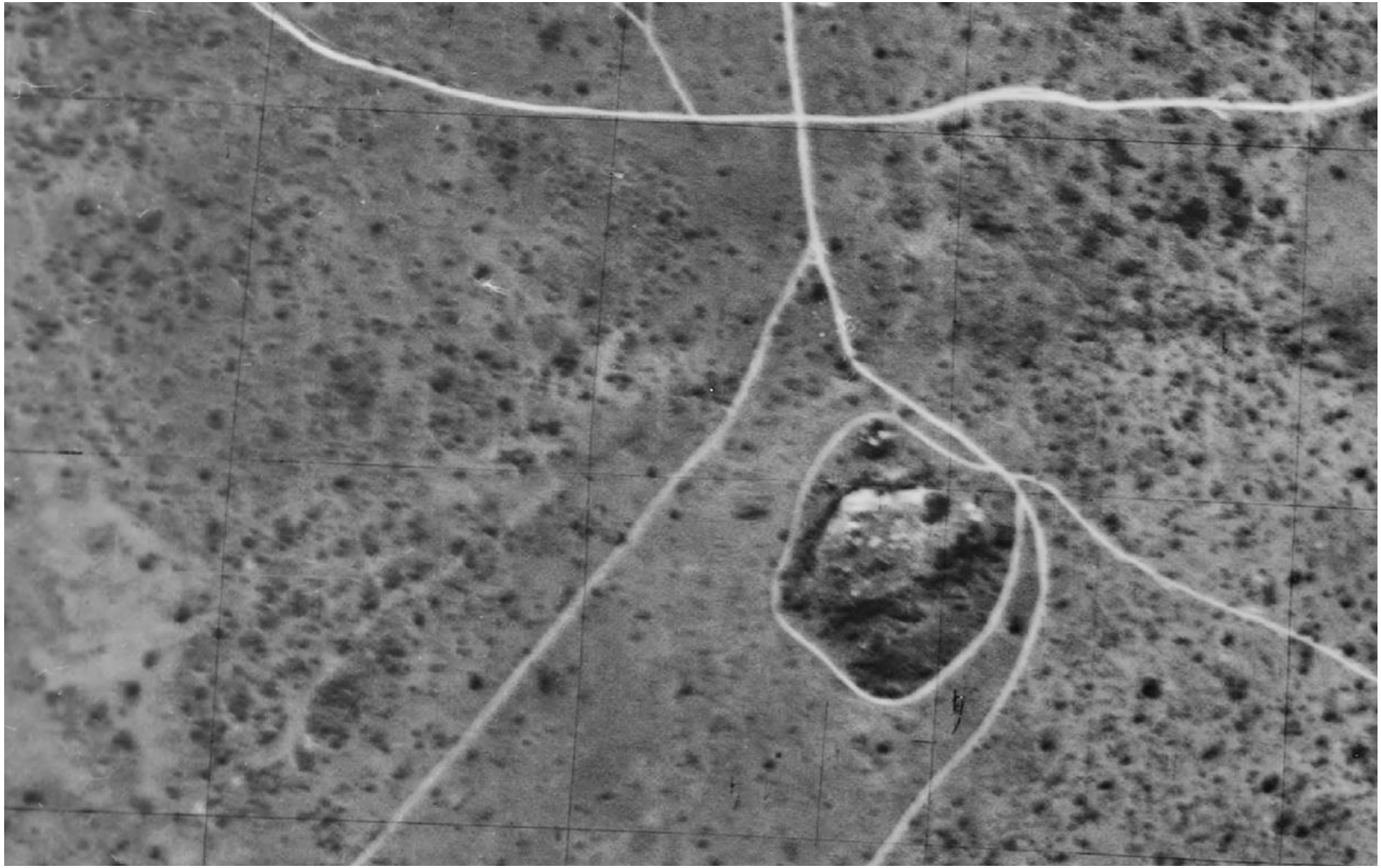
2007-2022

GEDI-fusion Woody Cover Change

Scale 1: 5 750



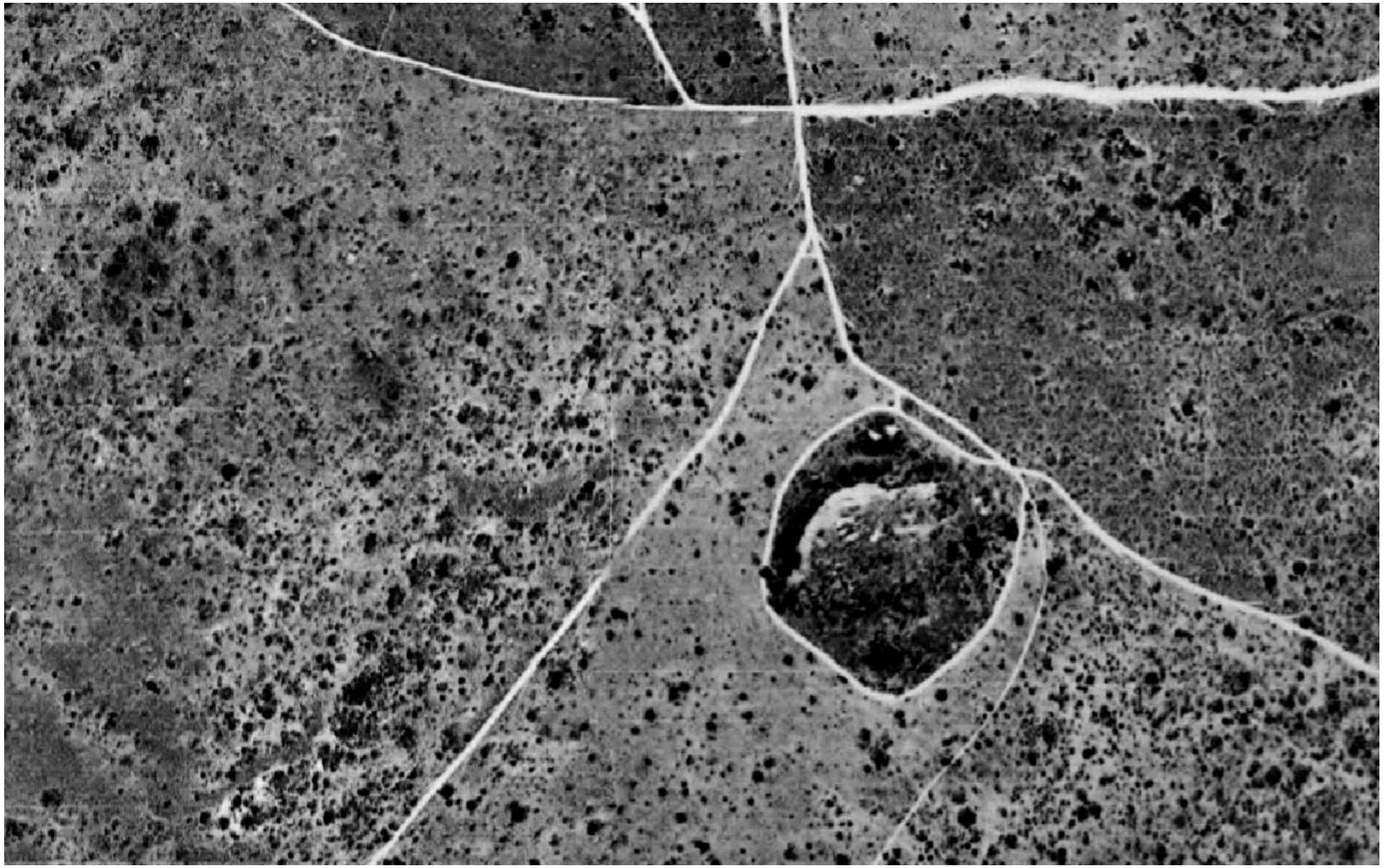
1940



Source CD:NGI

Scale 1: 5 750

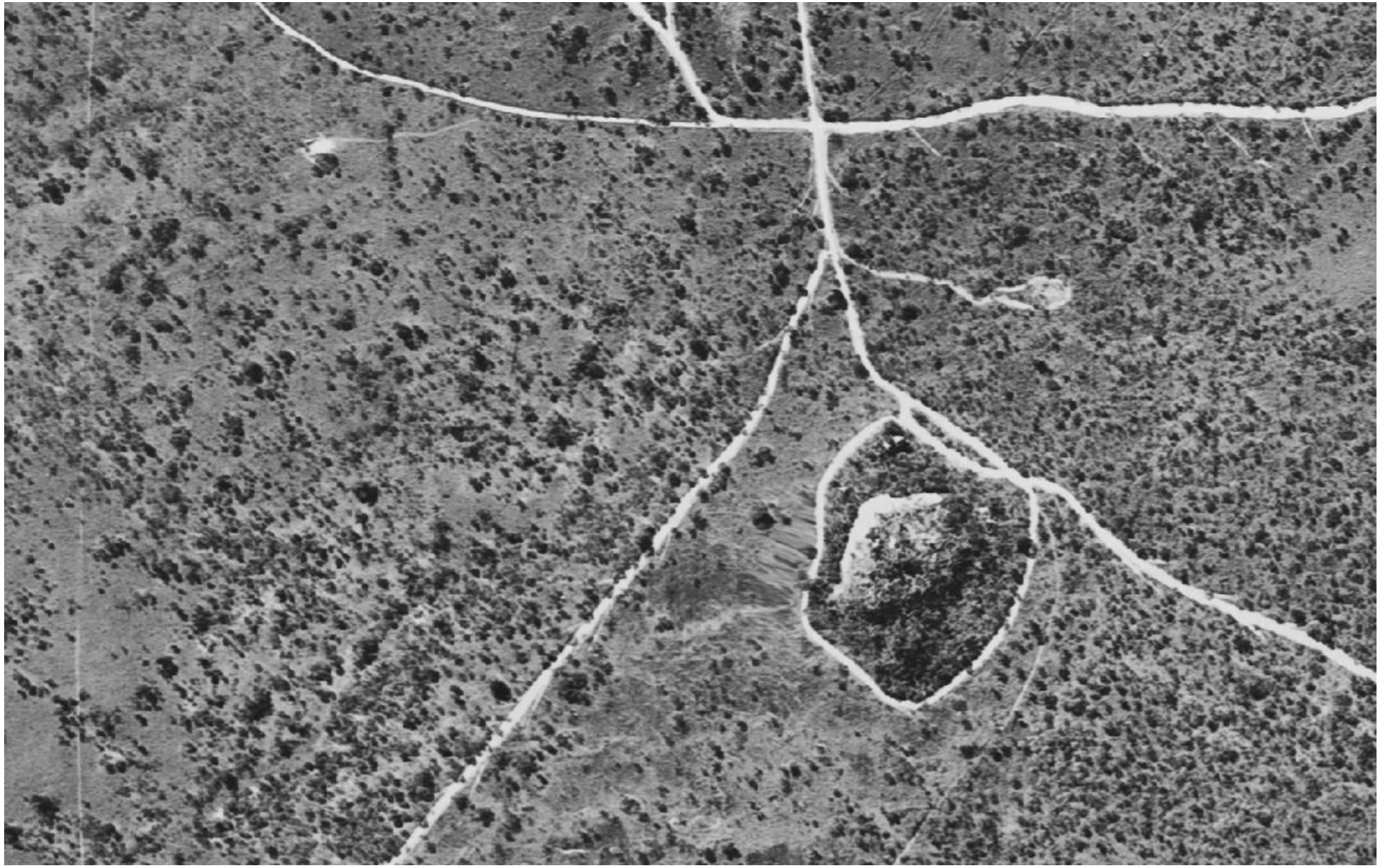
1965



Source CD:NGI

Scale 1: 5 750

1985



Source CD:NGI

Scale 1: 5 750

2004

Source GEarth

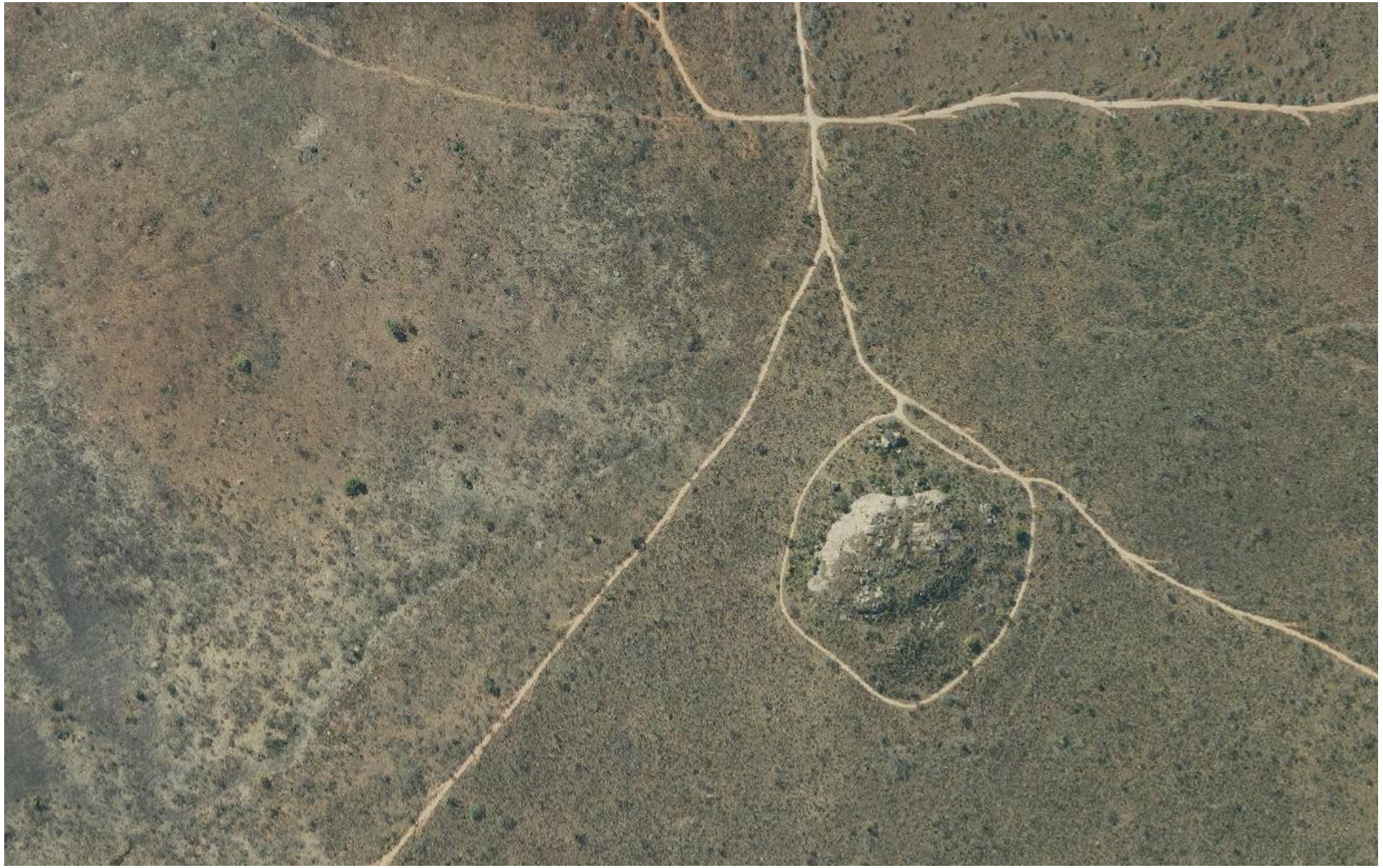
Scale 1: 5 750

2013

Source GEarth

Scale 1: 5 750

2018



Source CD:NGI

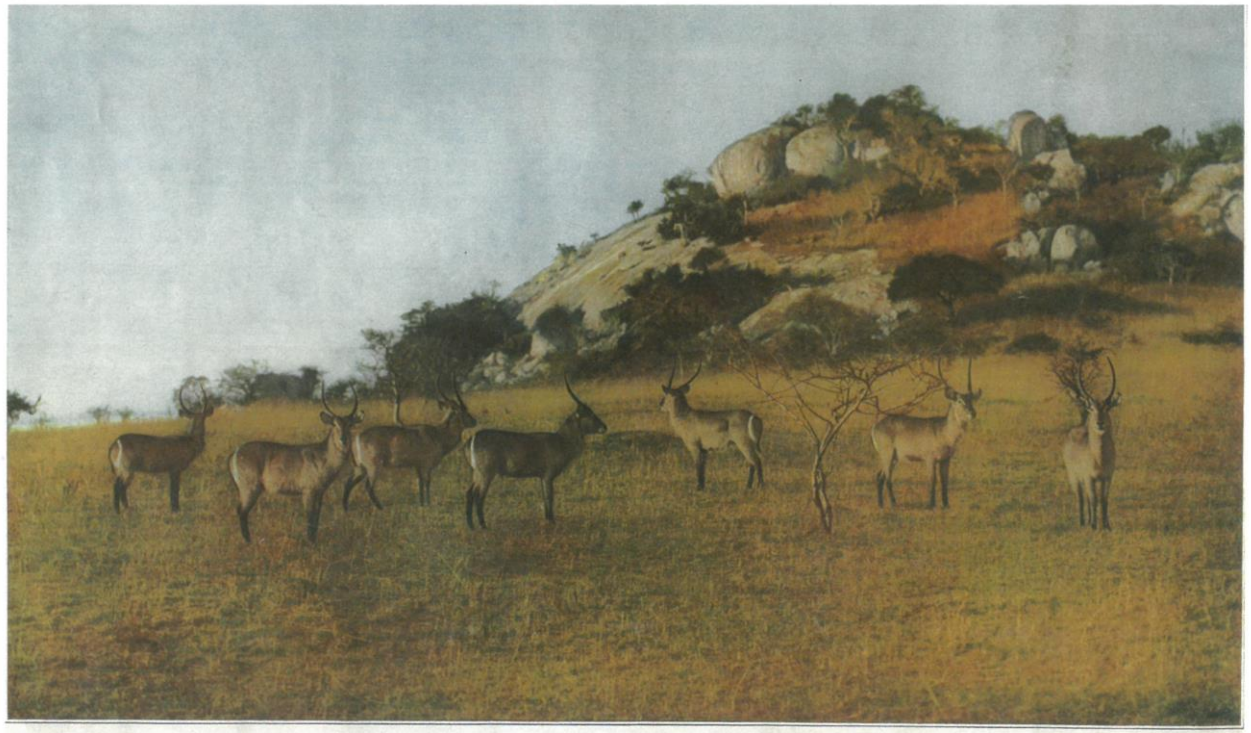
Scale 1: 5 750

2022

Source GEarth

Scale 1: 5 750

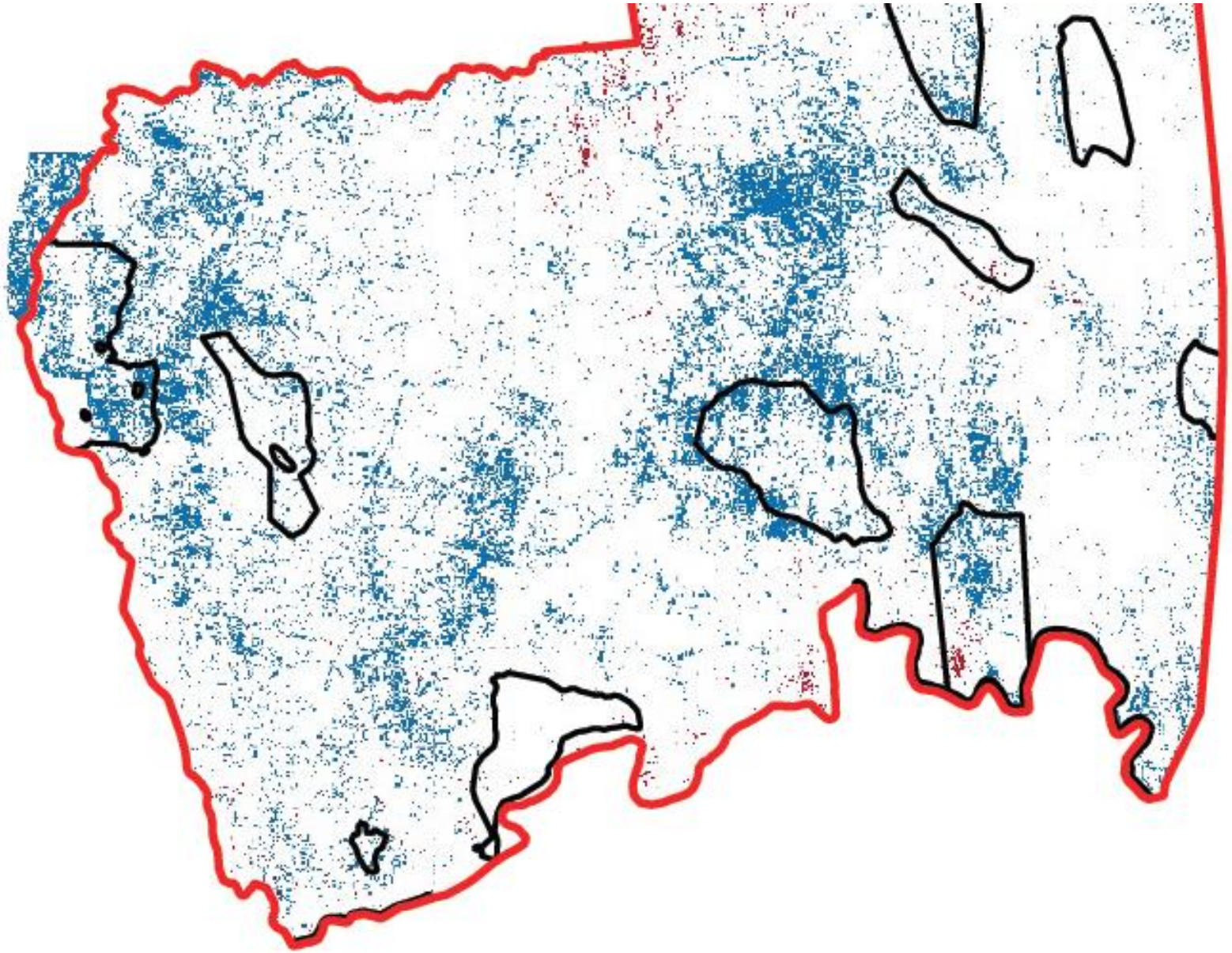
2024



PART OF A VAST SANCTUARY FOR WILD LIFE EXTENDING FOR THOUSANDS OF SQUARE MILES IN THE EASTERN TRANSVAAL: A TYPICAL SCENE IN THE KRUGER NATIONAL PARK.

The Kruger National Park in the Eastern Transvaal, South Africa, covering some thousands of square miles, is the greatest sanctuary for wild life in the world, and a subject of such varied and tremendous interest that we need offer no apology for illustrating it again. This picture is typical of certain parts of the game country, characterised by large granite boulders and hardy euphorbias. The handsome animals with their quaint marking are ringed waterbuck—next to wildebeeste the most numerous antelope in the sanctuary. Owing largely to the preponderance of females, the waterbuck is prolific, and this is fortunate, as it falls an easy victim to many natural enemies, particularly the lion. The Kruger National Park, one of South Africa's greatest natural assets, lies in that mysterious and fascinating portion of the country known as the Low Veld, where the rigours of winter are unknown. It stretches for hundreds of miles under the great northern ramparts of the Drakensberg range, which marks the vast terrace of the High Veld. The abrupt demarcation of the Low Veld along this great barrier is a geological wonder, and, scenically, an arresting and memorable sight. The story of this great reserve has been admirably told by Lieut.-Col. J. Stevenson-Hamilton, Warden of the Reserve, in "The Low Veld—its Wild Life and its People" (Cassell). He describes the give-and-take of Nature in the regulation of wild life; the destruction formerly wrought by native tribes and by ruthless hunters; the wonders, many unexplored, of bird life, flora, and vegetation; and the habits of various species—in short, a picture of the wilds before they came under civilised control. To-day this great sanctuary, under the rigorous protection of the South African Government, is restoring to Nature what she was in danger of losing through the ravages of man, and as an area of travel it has few rivals. South Africa is gradually coming into its own as a new and comparatively unexplored field of change for the overseas traveller, and our readers may be glad to know that information about this Dominion can be readily obtained from the Director, Publicity and Travel Bureau, South Africa House, 73, Strand, London, W.C.2.

Paul Selby


KNP Boundary
Elephant Impact Sites 2019
GEDI Fusion Woody Cover Change 2007 to 2022
Greater than 5% change
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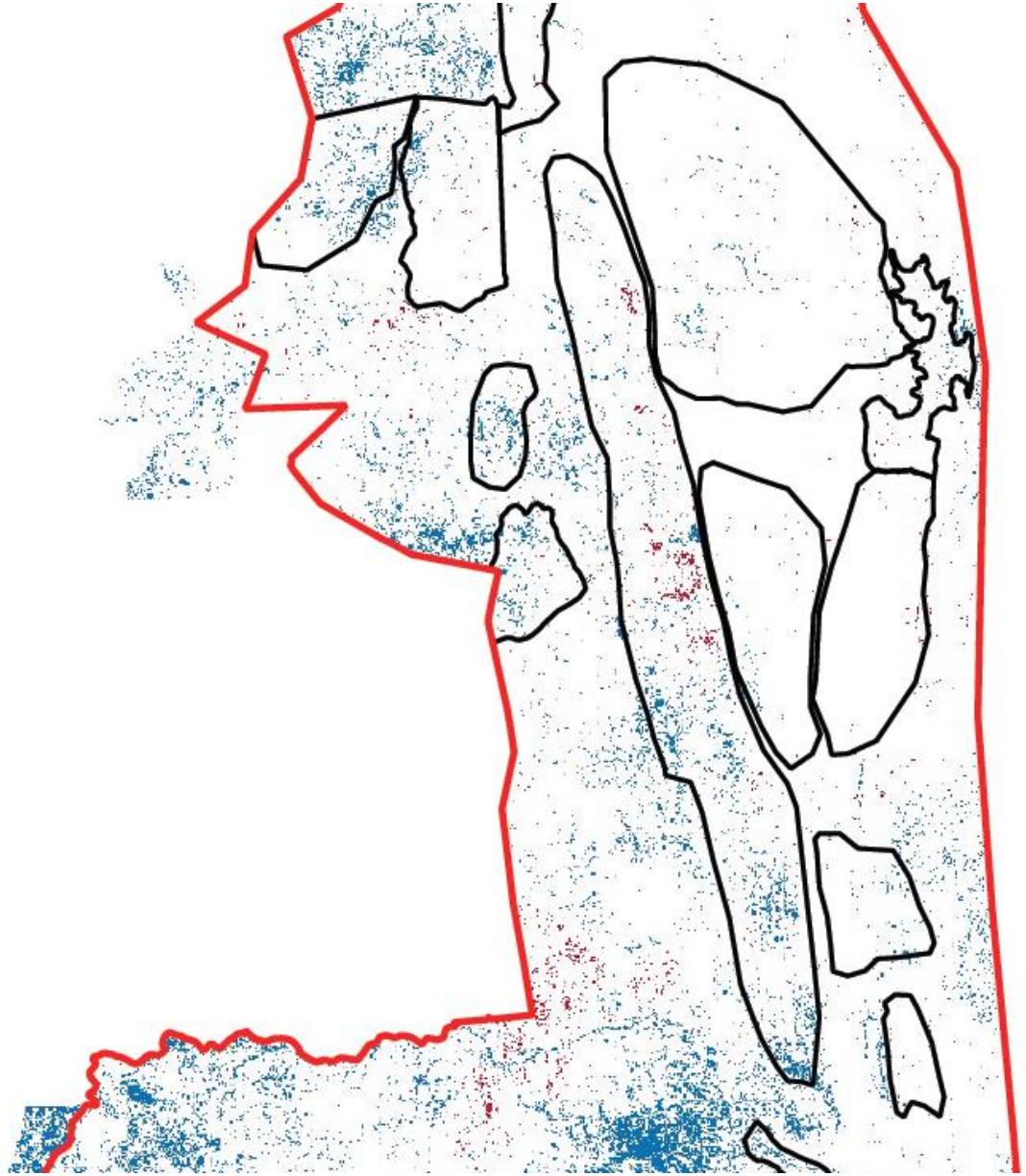

KNP Boundary

Elephant Impact Sites 2019

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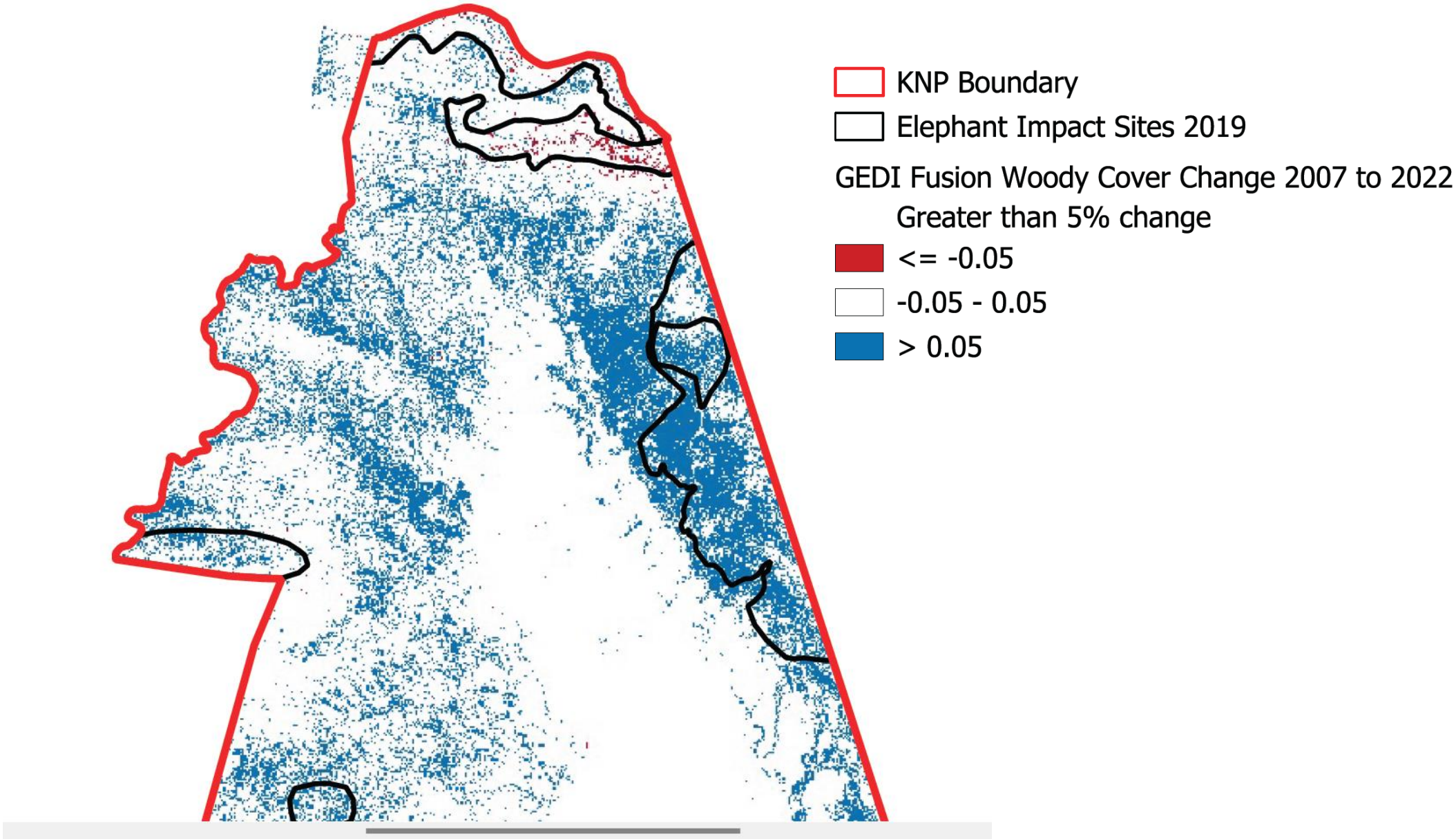
KNP Boundary
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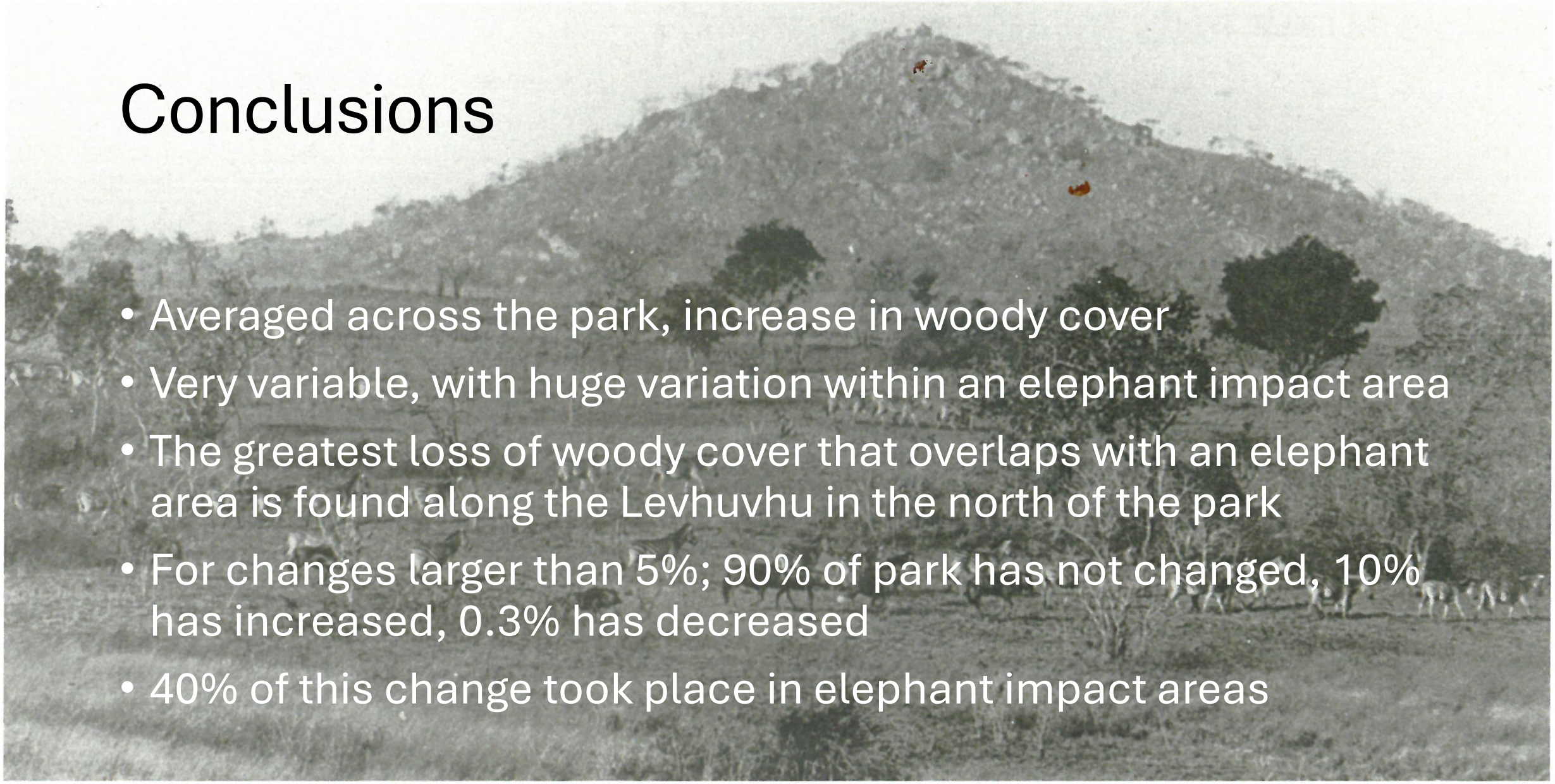
> 0.05

Conclusions

- Averaged across the park, increase in woody cover
- Very variable, with huge variation within an elephant impact area
- The greatest loss of woody cover that overlaps with an elephant area is found along the Levhuvhu in the north of the park
- For changes larger than 5%; 90% of park has not changed, 10% has increased, 0.3% has decreased
- 40% of this change took place in elephant impact areas



Paul Selby, from *The Kruger National Park 1933*

The open parkland landscape with sparse woody vegetation and numerous wildebeest and zebra at Pretoriuskop in the 1920s.