

# Annex A: Maps

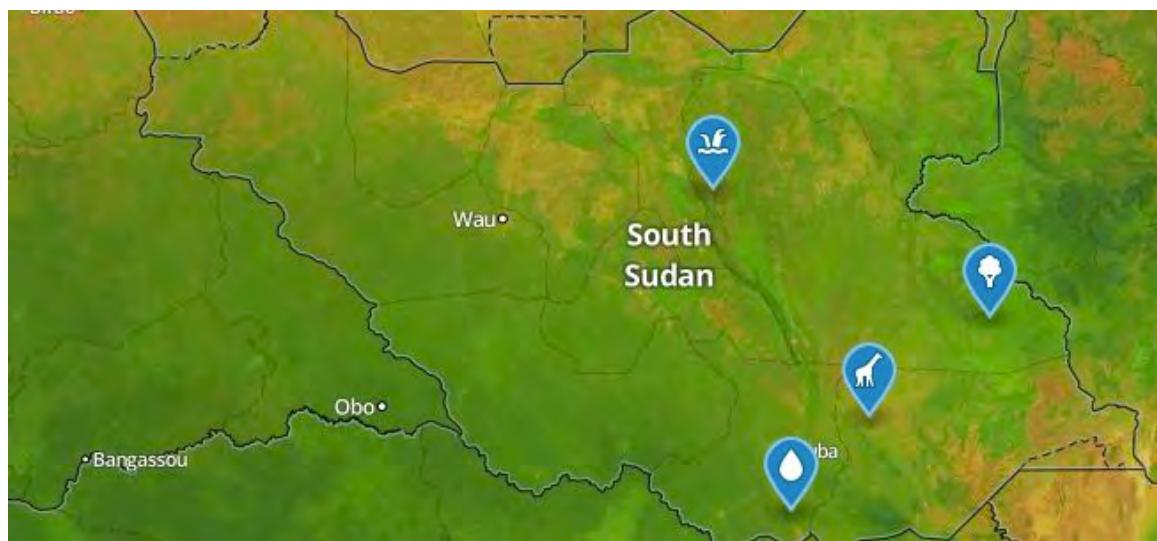


A collection of maps displaying the intersection between natural resources and human activities in South Sudan – prepared for USAID by the Cadmus Group and Geosprocket LLC.

## **Background: An assessment of existing, environmentally-focused spatial data infrastructure for South Sudan.**

### **Overview**

The relatively-young Republic of South Sudan has abundant resources. While mineral resources in the form of oil and gas have been the focus of international interest, geopolitical conflict and some internal division, the country's natural resources are of similar - arguably greater - importance. Since gaining autonomy in 2005 and independence in 2011, the government of South Sudan has enacted varying measures to protect these resources, which include dramatic wildlife migration routes in Bandingilo National Park and essential ecosystem services from the massive Sudd wetland complex:



Though South Sudan is better positioned economically than many of its neighbors, it still grapples with extreme poverty. It is under such conditions that great pressure can be brought to bear on natural resources, and it is imperative that they be governed with the right balance of empowerment and sustainability. Enabling this balance is a clear and regular assessment of the country's biodiversity and forest resources. Following up on a [2007 report on environmental threats and opportunities in South \(then 'Southern'\) Sudan](#), USAID is undertaking a post-independence analysis of the same resources, policies and features.

A major component of this study is an audit of existing geospatial resources that describe some portion of South Sudan's ecological spectrum. Too often - particularly in the realm of international development - mapping efforts are duplicated and results missed; it is our hope to build on established work for the present initiative, as well as to be able to pass on the resources we find. Subsequent phases of this study include remote sensing analyses of forest type and desertification patterns, as well as a geospatial investigation of the human footprint on the country's natural resources. But below is an accounting of the datasets available now that relate to the ecological landscape of South Sudan.

## Note on Edits & Contributions

This catalog is not static, and it is only possible to keep it updated with support from community stakeholders. As such, all constructive [pull requests](#) will be honored, with the hope that valuable contributions will keep this resource current.

## Dataset Categories

This catalog places an emphasis on national-scale datasets. Though many useful studies and maps are focused on regions and localities in South Sudan (here is [an excellent example](#) from Gorsevski et al.), for the purposes of this study we are interested in patterns and processes that can be assessed at national scale and moderate resolution.

Datasets are categorized by broad theme below. Some are hosted in this repository and others (due to file size restrictions) are linked to external resources. Wherever possible, global- and continental-scale datasets have been clipped to the [South Sudan area of interest](#), which includes disputed areas and a 20km buffer beyond the national border.

### Land Use & Land Cover

Name	Source	Type	Format	Notes
UMD - Global Forest Cover Change 2000-2012	University of Maryland/Google	LULC	GeoTIFF	Available in Tiled Format
Africover - Land Cover Datasets	FAO/GLCN - Africover	LULC	GeoTIFF	Outdated - imagery vintage is 1994-1999
National LULC 2010	FAO/GLCN - Africover	LULC	PDF	Unfortunately not available here in portable format - imagery vintage is 2010
MODIS Land	Boston	LULC	HDF/GeoTIFF	Coarse resolution w/

Cover	University/NASA			high category detail
OSM - Land Use	Openstreetmap	LULC	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>

Additional Academic Studies of land use/land cover in South Sudan are [available here](#), though not with downloadable datasets.

## Built Infrastructure

Name	Source	Type	Format	Notes
OSM - Roads	Openstreetmap	Built Infrastructure	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
OSM - Airfields	Openstreetmap	Built Infrastructure	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
OSM - Walls/Barriers	Openstreetmap	Built Infrastructure	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
OSM - Railway	Openstreetmap	Built Infrastructure	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
UNDP - Airfields	UNITAR	Built Infrastructure	GeoJSON	Authoritative
UNDP - Roads	UNITAR	Built Infrastructure	GeoJSON	Not as extensive as OSM
GAM - Travel Time	Nelson et al. (2008)	Built Infrastructure	GeoJSON	Dated - Based on Yr 2000

## Political Boundaries & Places

Name	Source	Type	Format	Notes
Africover - Major Towns	FAO - Africover	Places	GeoJSON	Data from pre-independence
Africover - Minor Towns	FAO - Africover	Places	GeoJSON	Data from pre-independence
Natural Earth - Disputed Areas	Natural Earth	Political Boundaries	GeoJSON	Moderate resolution
Natural Earth - Populated Places	Natural Earth	Places	GeoJSON	

Natural Earth - National Boundary	Natural Earth	Political Boundaries	GeoJSON	Does not conform exactly with other datasets
OSM - National Boundary	Openstreetmap	Political Boundaries	GeoJSON	Matches GAUL, encompasses disputed areas
OSM - National AOI	Openstreetmap	Political Boundaries	GeoJSON	Used as the clip boundary for all other datasets
OSM - States	Openstreetmap	Political Boundaries	GeoJSON	County designation in Upper Nile State Unclear
OSM - Populated Places	Openstreetmap	Places	GeoJSON	Not as extensive as UNITAR or Africover
UNDP - Counties	UNITAR	Political Boundaries	GeoJSON	Covers all but a small disputed section of Kafia Kingi
UNDP - States	UNITAR	Political Boundaries	GeoJSON	Authoritative
UNITAR - Polling Stations	UNITAR	Places	GeoJSON	Used for independence referendum
UNITAR - Populated Places	UNITAR	Places	GeoJSON	Authoritative

## Hydrology

Name	Source	Type	Format	Notes
Africover-Rivers	FAO - Africover	Hydrology	GeoJSON	Outdated - Imagery ca. 1995-1999
Africover-Surface Water	FAO - Africover	Hydrology	GeoJSON	Outdated - Imagery ca. 1995-1999
OSM - Waterway Polygon	OpenStreetmap	Hydrology	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
OSM - Waterway Point	OpenStreetmap	Hydrology	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>

OSM - Waterway Line	OpenStreetmap	Hydrology	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
OSM - Wetland Polygons	OpenStreetmap	Hydrology	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>

### Protected/Habitat Areas

Name	Source	Type	Format	Notes
IUCN - Elephant Range	International Union for the Conservation of Nature	Habitat	GeoJSON	2007 Vintage - Currently being updated
OSM - Conservation Areas	Openstreetmap	Protected Areas	GeoJSON	Extracted February 2014 - Access more recent versions <a href="#">here</a>
WDPA - Protected Areas	World Database of Protected Areas	Protected Areas	GeoJSON	Poor data availability in South Sudan

### Mineral Resources

Name	Source	Type	Format	Notes
ECOS - Oil Concessions	European Coalition on Oil in Sudan	Mineral	GeoJSON	2007 Vintage - Provided on <a href="#">ECOS Homepage</a> with notes about planned subdivision of concession block B
ECOS - Oil Fields of Abyei	European Coalition on Oil in Sudan	Mineral	PDF	2006 Vintage - Oil production in a disputed area.

### Data Providers

- [FAO/GLCN \(Africover\)](#) - Global Land Cover Network
- [ECOS](#) - European Coalition on Oil in Sudan
- [IUCN](#) - International Union for the Conservation of Nature
- [Natural Earth Data](#)
- [OpenStreetmap](#)
- [UNITAR](#) - United Nations Institute for Training and Research
- [WDPA](#) - World Database of Protected Areas
- [Google](#) - Compiled via directed Map Maker initiative

## Tools for Working With Geospatial Data

- [OGRE](#) - Online conversion to/from GeoJSON and Shapefile formats
- [Quantum GIS](#) - Full-features Open-Source desktop GIS platform
- [geojson.io](#) - Online GIS editing application; GeoJSON-native
- [GDAL/OGR](#) - The Geographic Data Abstraction Library; meant for programmatic dataset manipulation

## Analysis Methods

### Wetlands

Derived from MOD12Q1 - MODIS Land Cover Product - for the year 2012, provided by the National Aeronautics and Space Administration. This dataset has a nominal resolution of 500m, and consists of [IGBP Land Cover Classes](#) 0 (Water) and 11 (Wetlands). The geometry file available here has been converted to vector TopoJSON format and simplified by 40% using a modified visvalingam algorithm to preserve topology.

### Rangeland Change

This analysis was conducted with two sets of sequential-year MODIS reflectance (Nadir BRDF-Adjusted Reflectance - NBAR) data; 2001-2003 and 2011-2013. Mean Normalized Difference Vegetation Index (NDVI - a commonly-used measure of vegetation health) was calculated per pixel for each 3-year set, then the newer dataset was subtracted from the older. Changes in NDVI of greater than 0.1 were extracted and intersected with IGBP Rangeland classes (Grassland, Open Shrubland and Savanna) derived from MOD12Q1 data. The resulting "Rangeland Change" dataset was then converted to vector format for inclusion in this study.

A more nuanced portrait of rangeland change over the past decade could conceivably be obtained by calculating changes within each of the parent IGBP rangeland classes (e.g. Grasslands), but such an analysis is beyond the scope of this study.

### Travel Time

Derived from a study by [Nelson et al \(2008\)](#), this dataset was converted from raster by a simple contour extraction at an interval of 360 minutes. This produced isobars representing 6-hour intervals of travel required to reach the nearest city of 50,000 or more by land. Data latency is a potential source of error in this dataset; it

represents conditions in the year 2000, and transit network datasets have greatly improved in availability over that time period.

## Forest Cover Change

Produced by [Hansen et al.](#), the Global Forest Cover Change dataset represents forest cover and forest cover change at a spatial resolution of 30m, though it has been degraded to 500m for use in the current study. The original forest cover change analysis was performed on thousands of images from the USGS Landsat program, acquired between 2000 and 2012. The final determination of forest cover change was made with a weighted supervised classification algorithm.

The subset of this data available here was clipped to the South Sudan ROI polygon, then converted to vector format and simplified using a modified visvalingam algorithm to preserve topology.

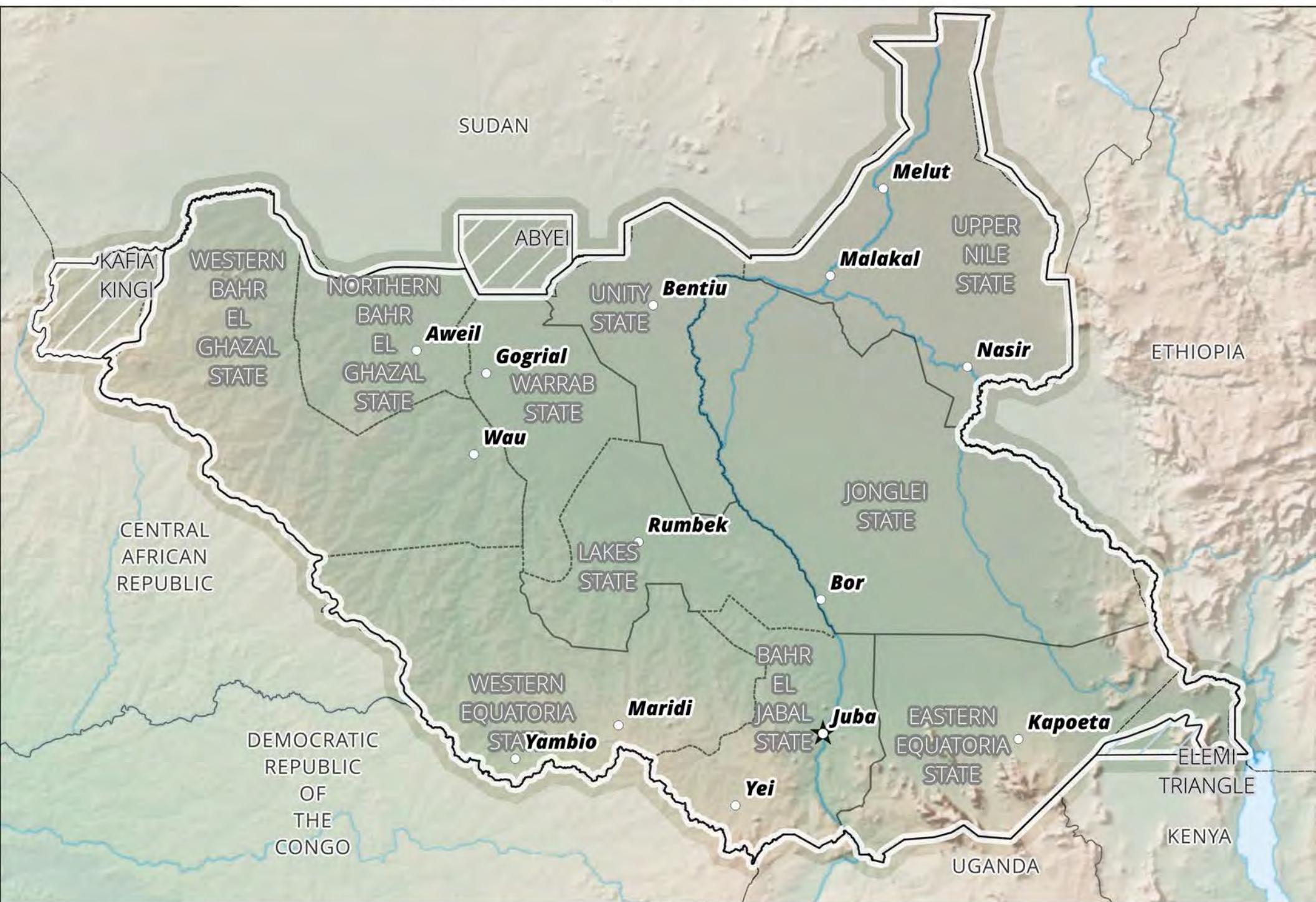
For the current study, an attempt was made to adapt part of the Hansen methodology to identify patterns of desertification over the same time period in the Sahelian region of South Sudan. Specifically, this included the same imagery inputs in a Random Forests ensemble classification scheme trained with ancillary datasets such as Africover and high-resolution imagery. However, results were not promising with well under 60% accuracy assessed, and the approach was abandoned.

**Note: the static version of the forest cover change map includes barely-perceptible instances of forest cover loss over the past decade; these are mostly concentrated in the vicinity of Bor and Yei. This is partially an artifact of the spatial scale of the imagery, but may also be an indicator of reasonably-stable forest cover.**

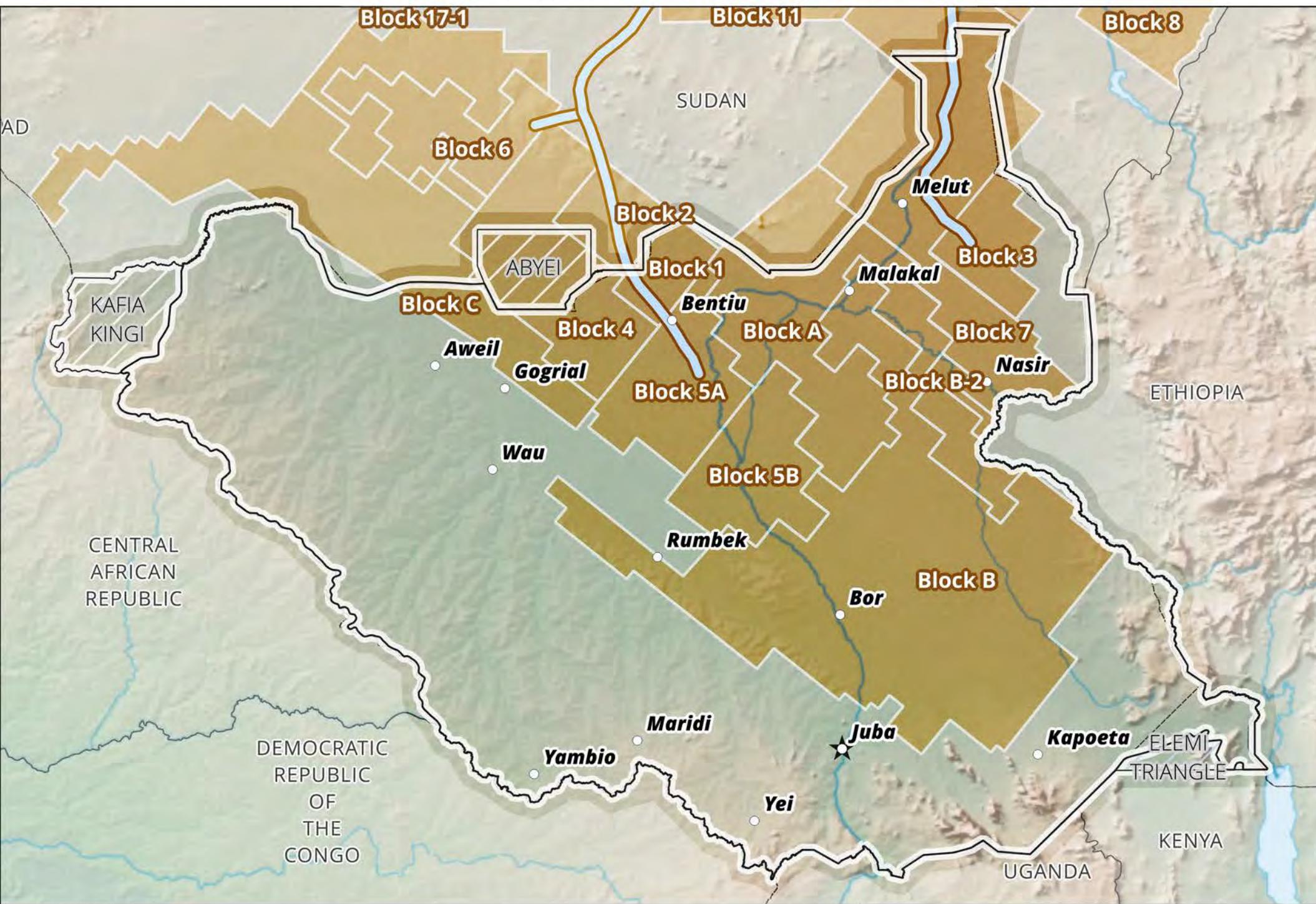
# 1 - Regional View



## 2 - States and Major Cities of South Sudan



### 3 - Oil Concession Blocks & Infrastructure

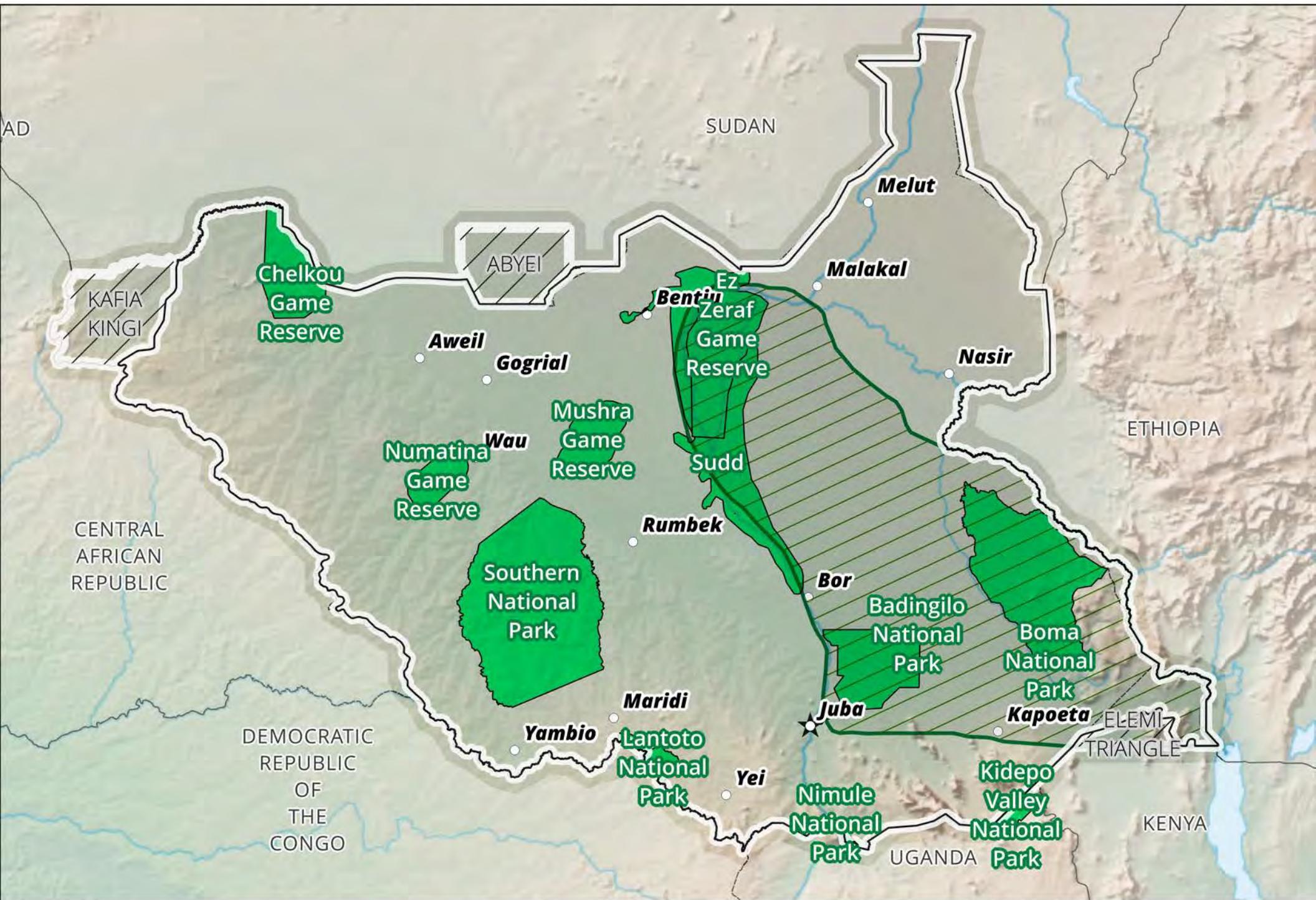


Oil Pipeline

Oil/Gas Concession Block

Data Sources: Natural Earth | OpenStreetmap Contributors | USGS | European Coalition on Oil in Sudan (2007 Data)

## 4 - Boma-Jonglei Landscape & Protected Areas of South Sudan

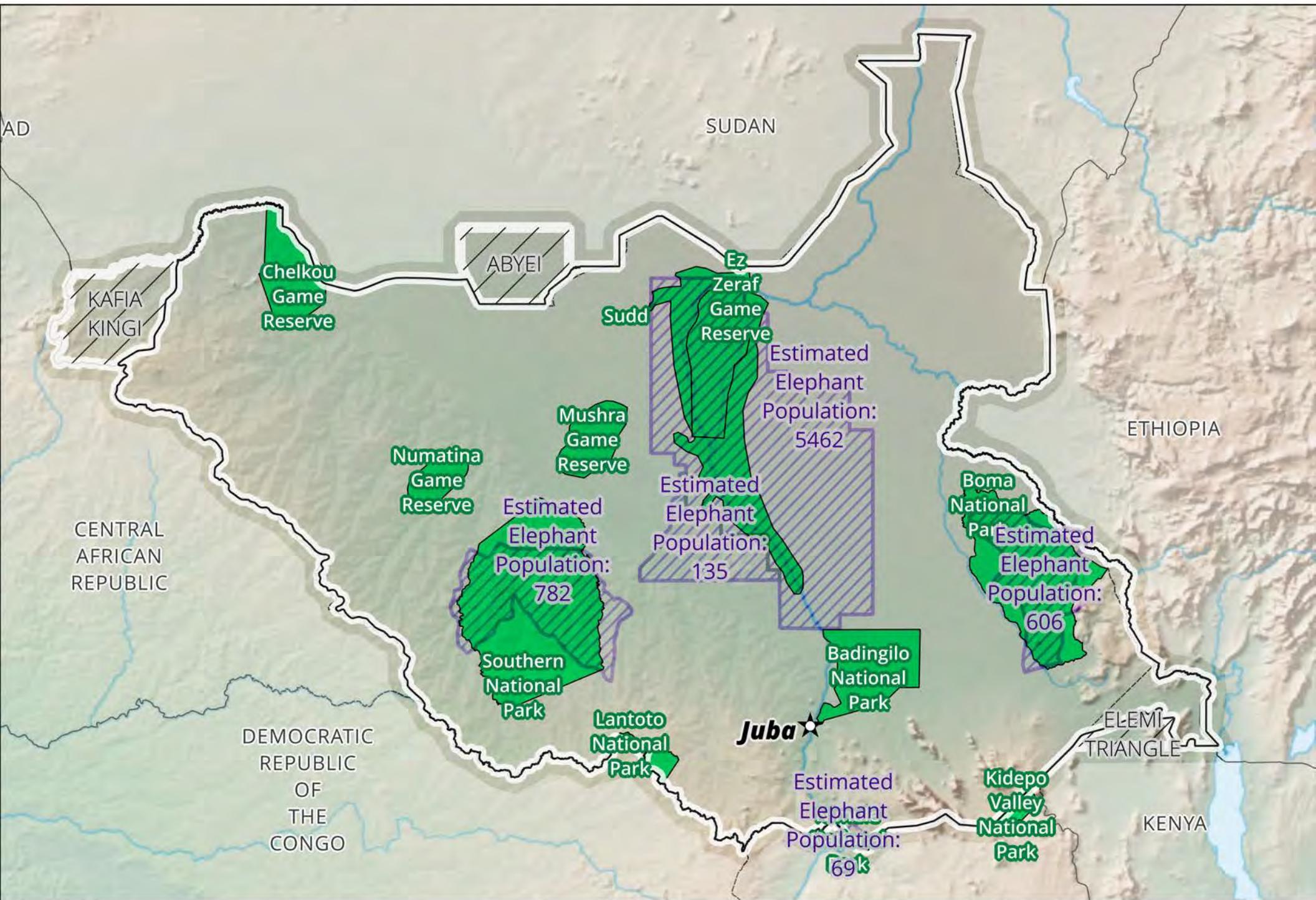


Protected/Conserved Areas

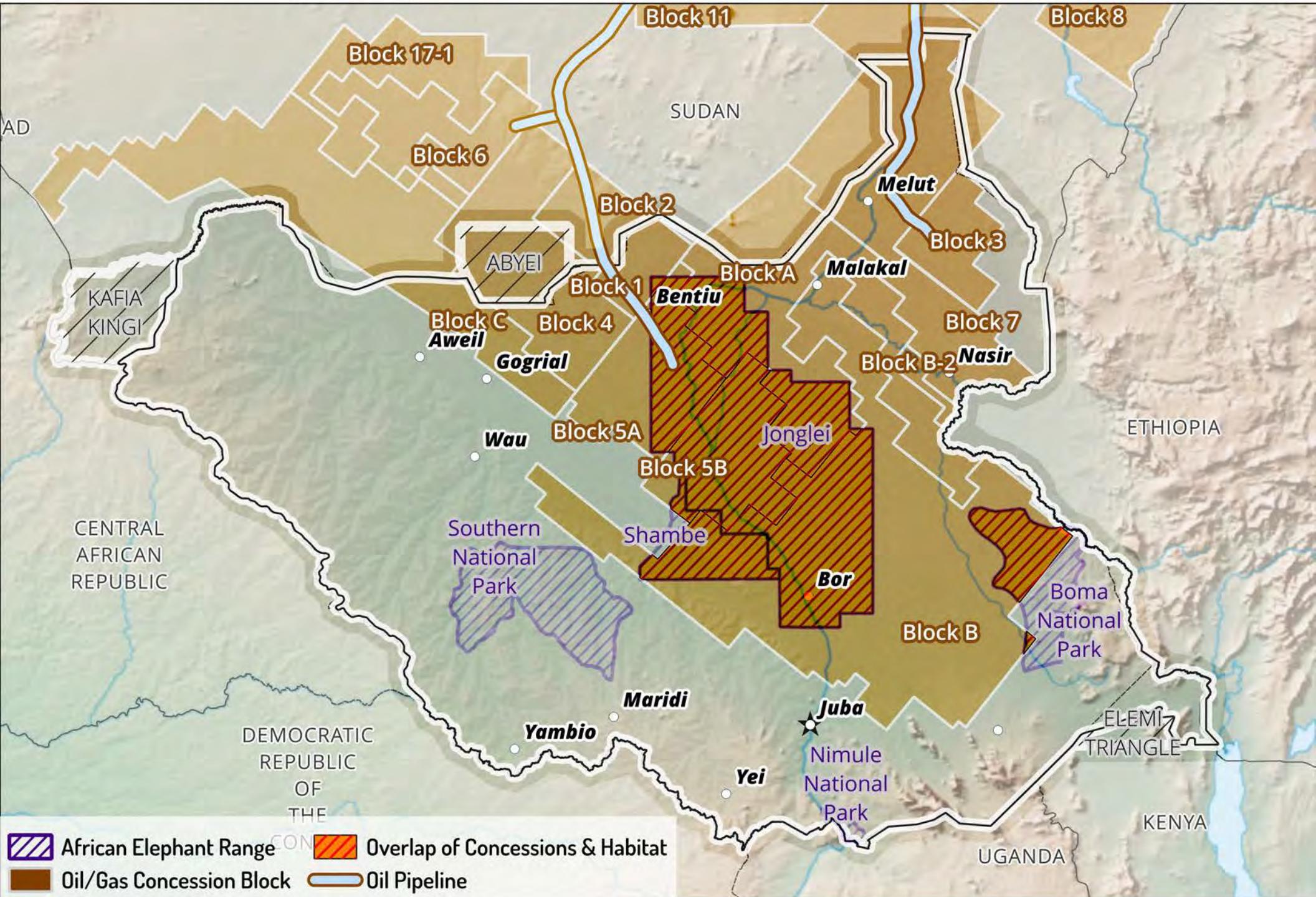
Boma-Jonglei Landscape

Data Sources: Natural Earth | OpenStreetmap Contributors | USGS | World Conservation Society | USAID

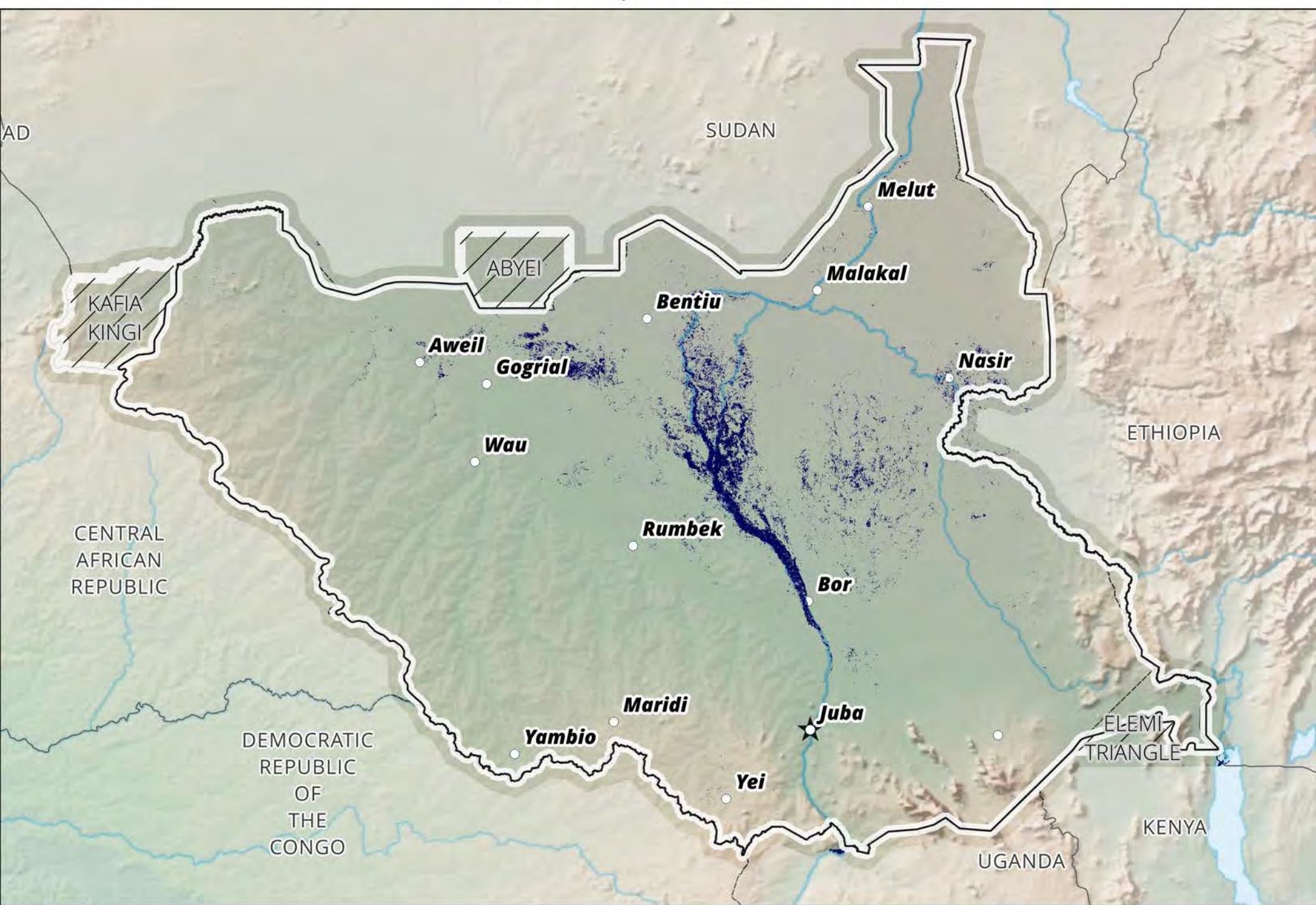
## 5 - Elephant Habitat & Protected Areas of South Sudan



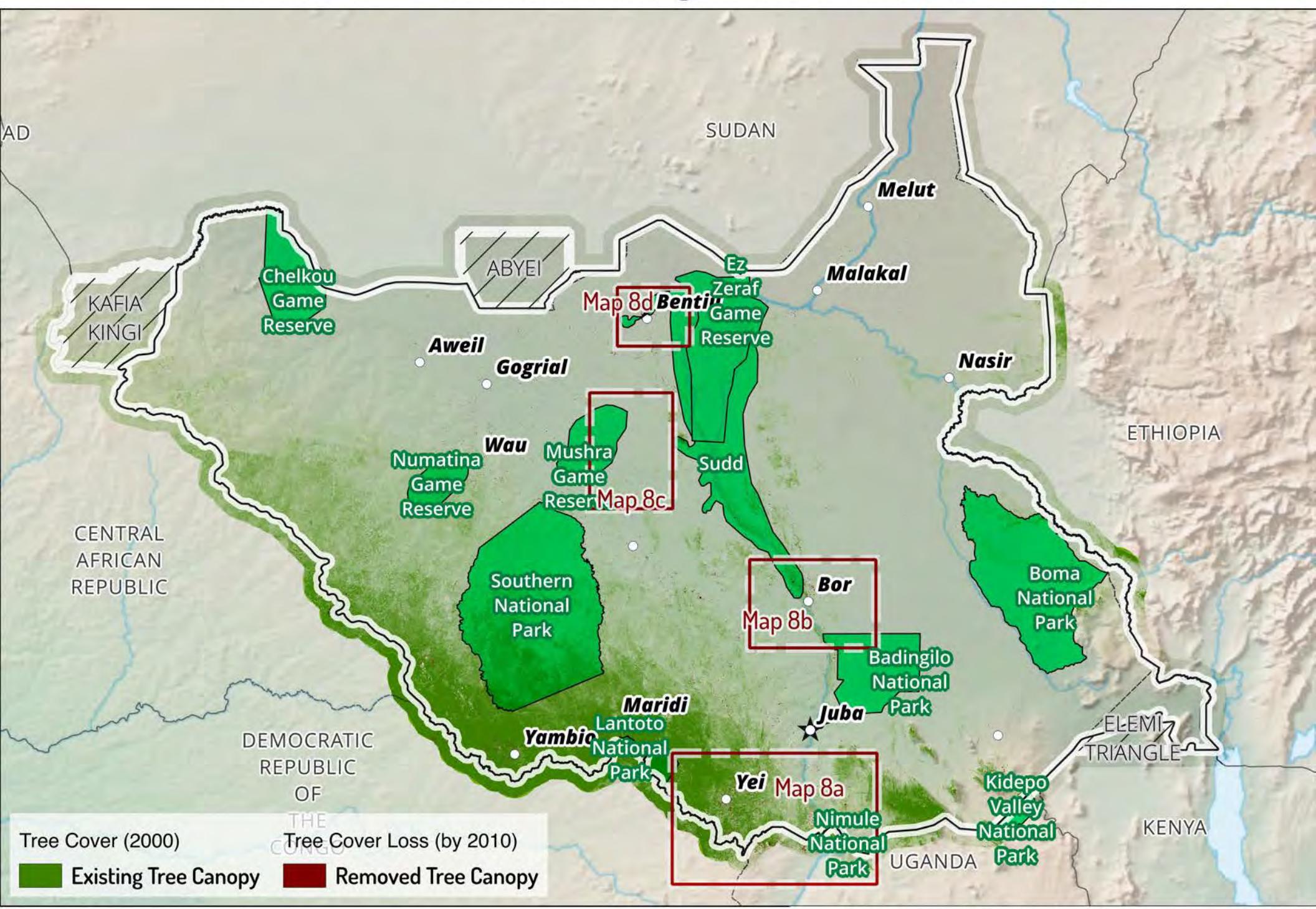
## 6 - Overlap of Elephant Habitat & oil/Gas Concessions in South Sudan



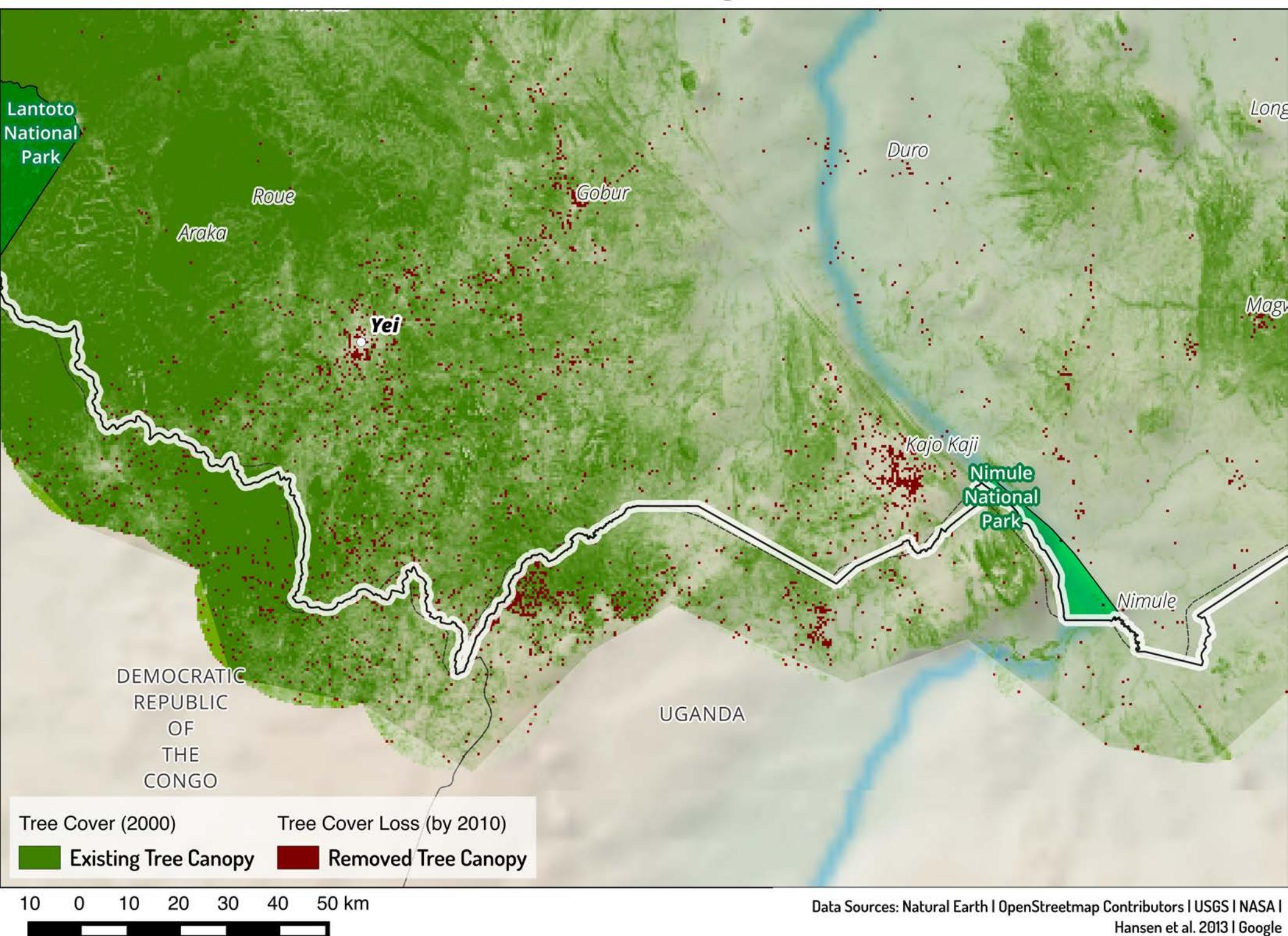
## 7 - Wetland Complexes in South Sudan



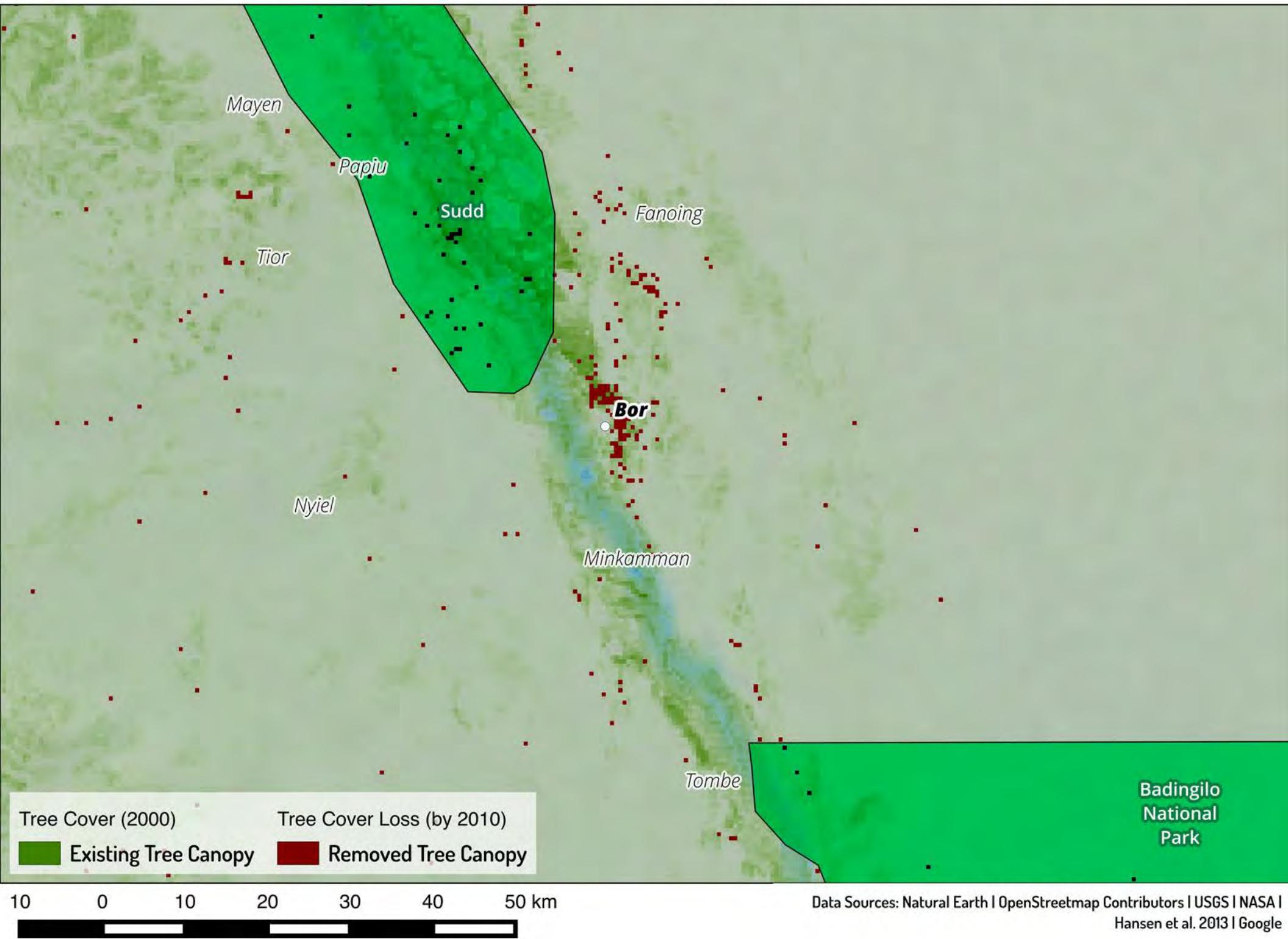
## 8 - Forest Cover and Forest Change in South Sudan, 2000-2012



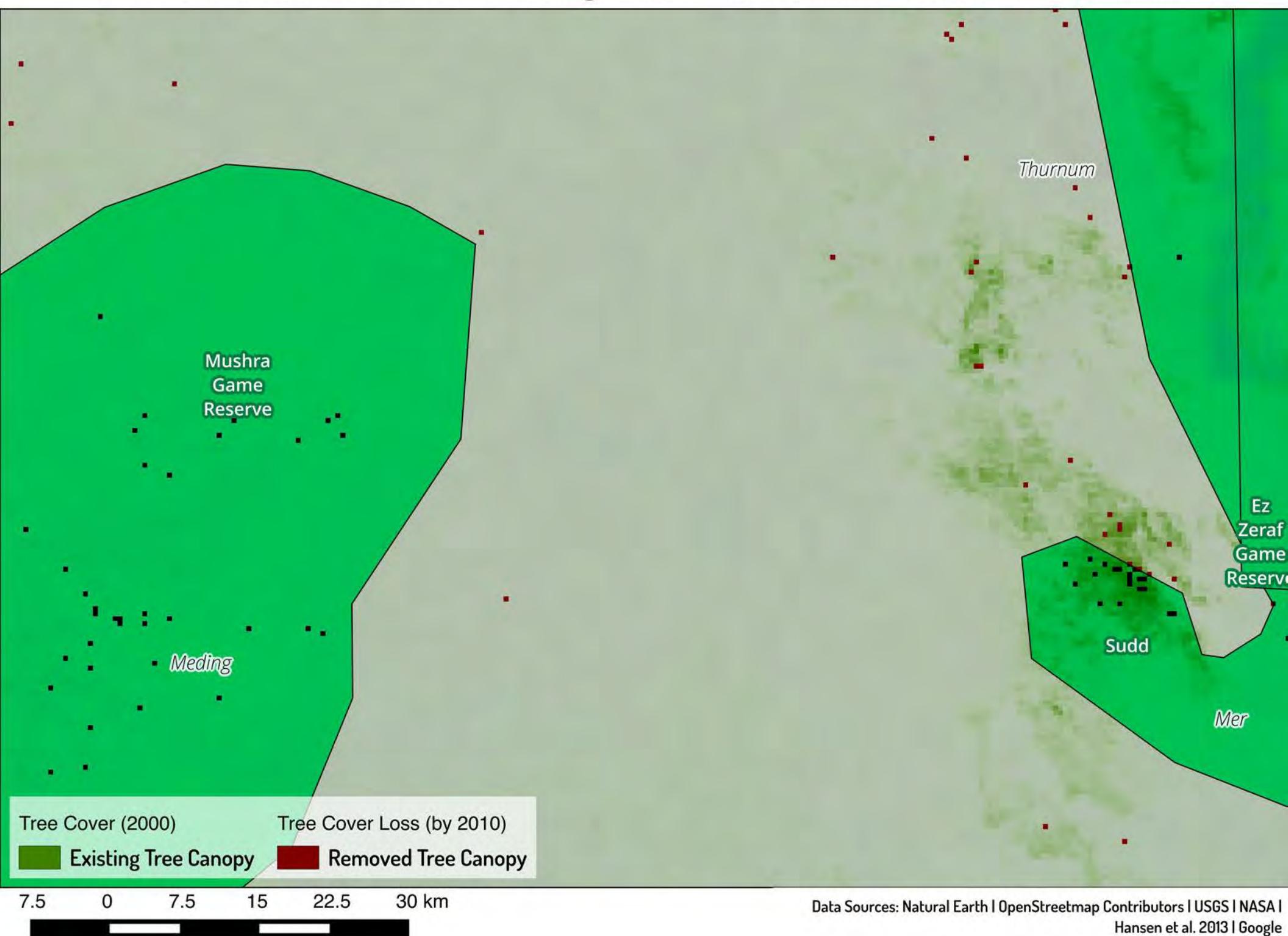
## 8a - Forest Cover and Forest Change Near Yei, 2000-2012



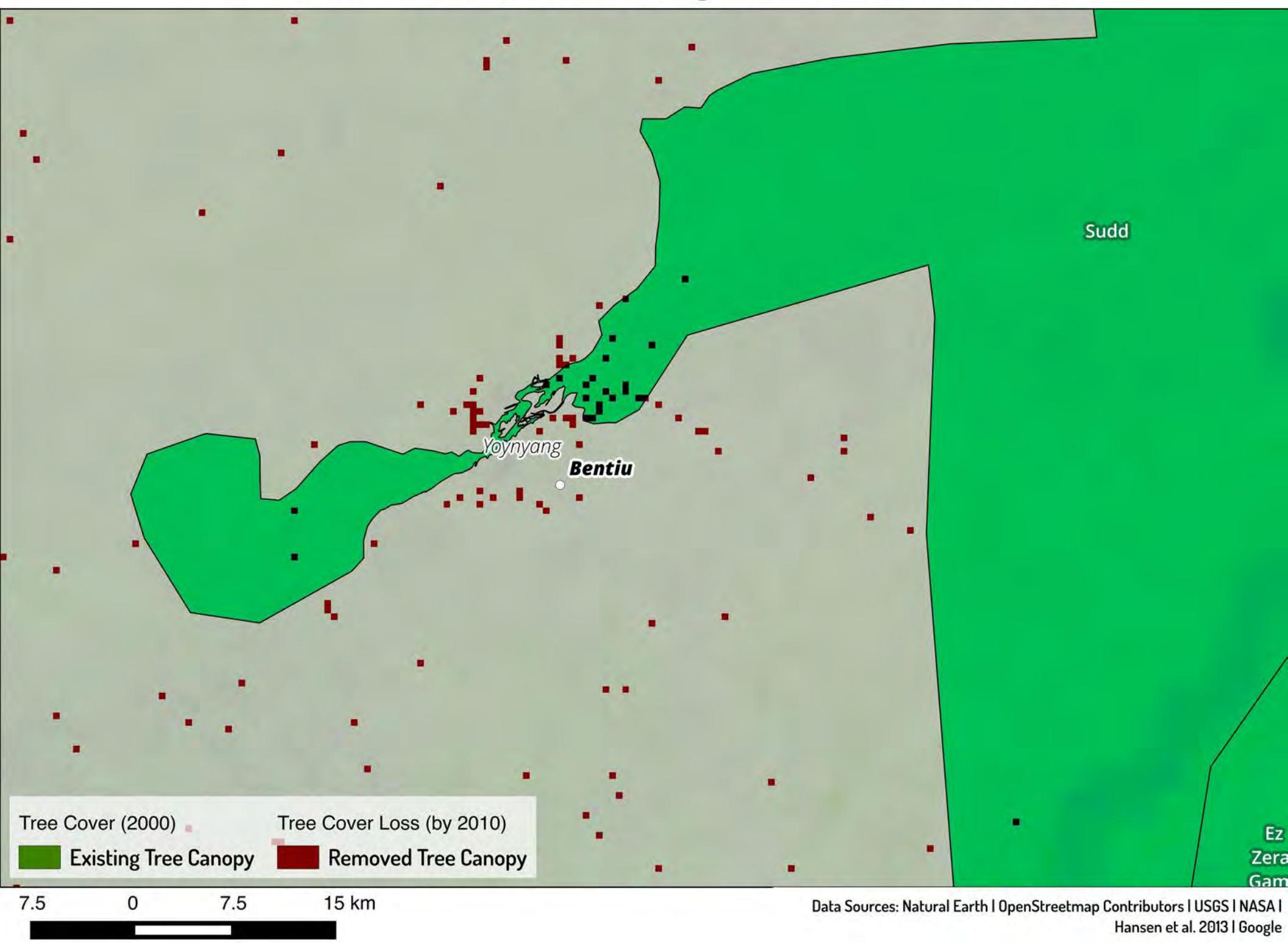
## 8b - Forest Cover and Forest Change Near Bor, 2000-2012



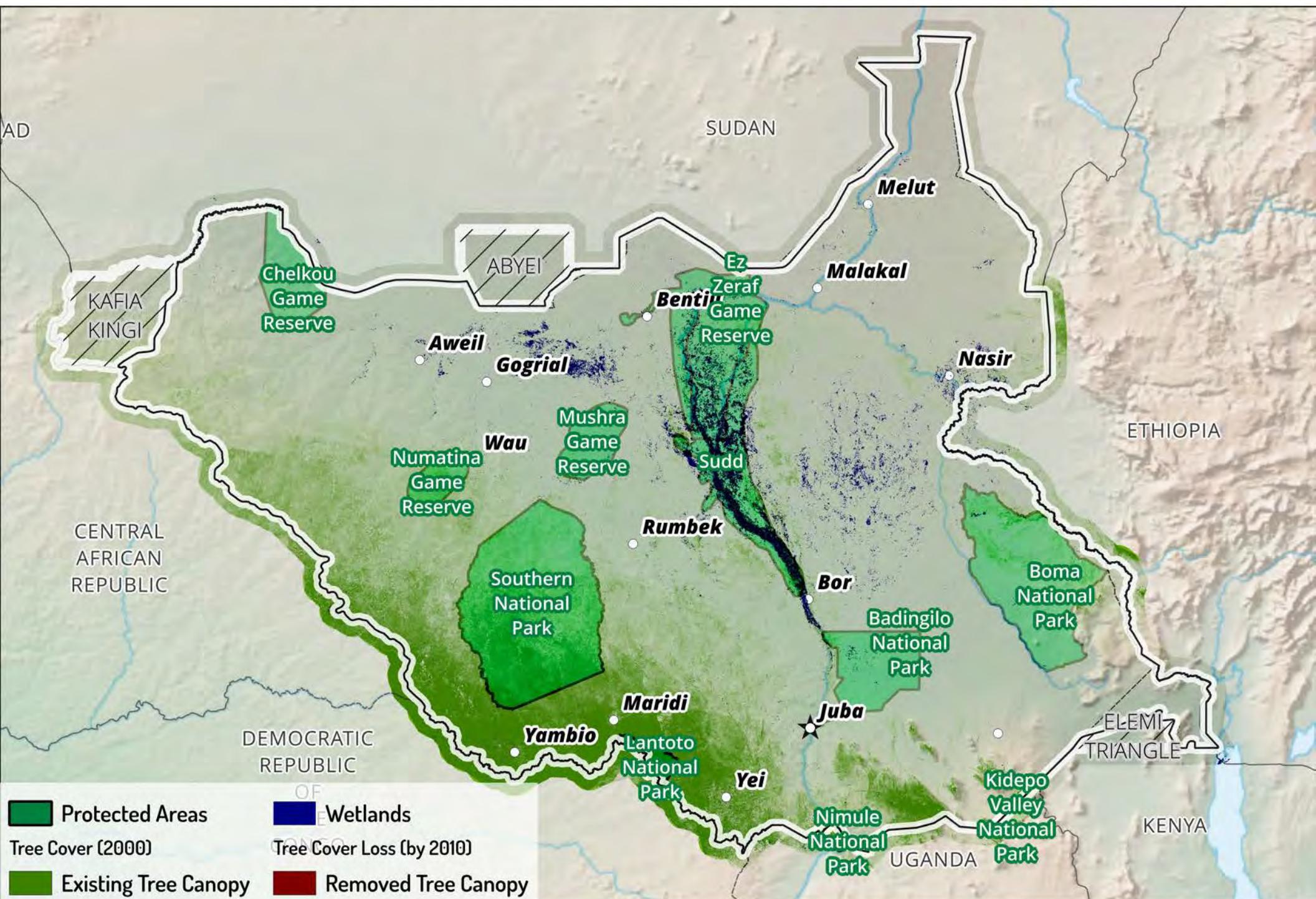
## 8c - Forest Cover and Forest Change Near Mushra Game Reserve, 2000-2012



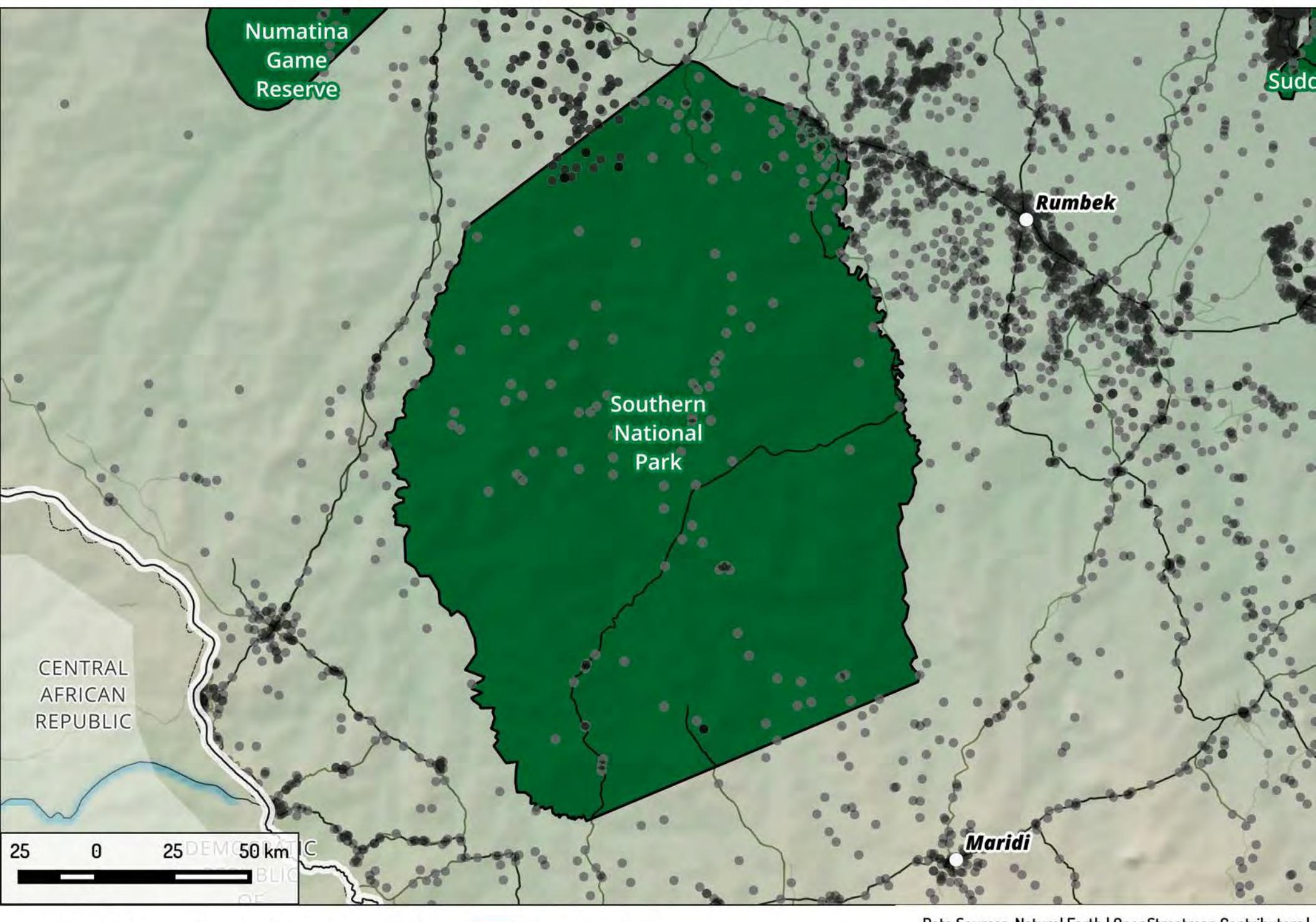
## 8d - Forest Cover and Forest Change Near Bentiu, 2000-2012



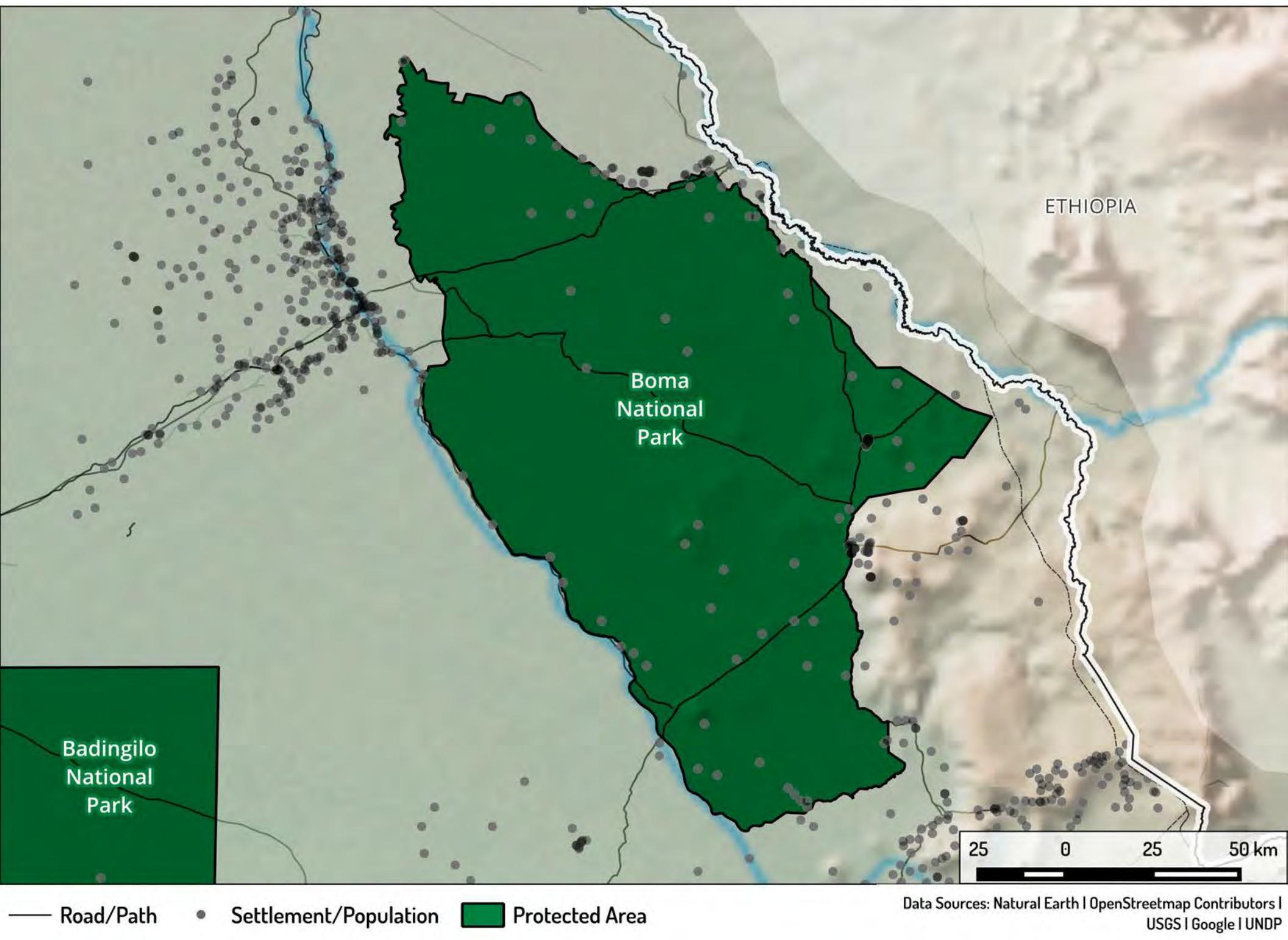
## 9 - Forest Cover, Wetlands and Protected Areas in South Sudan



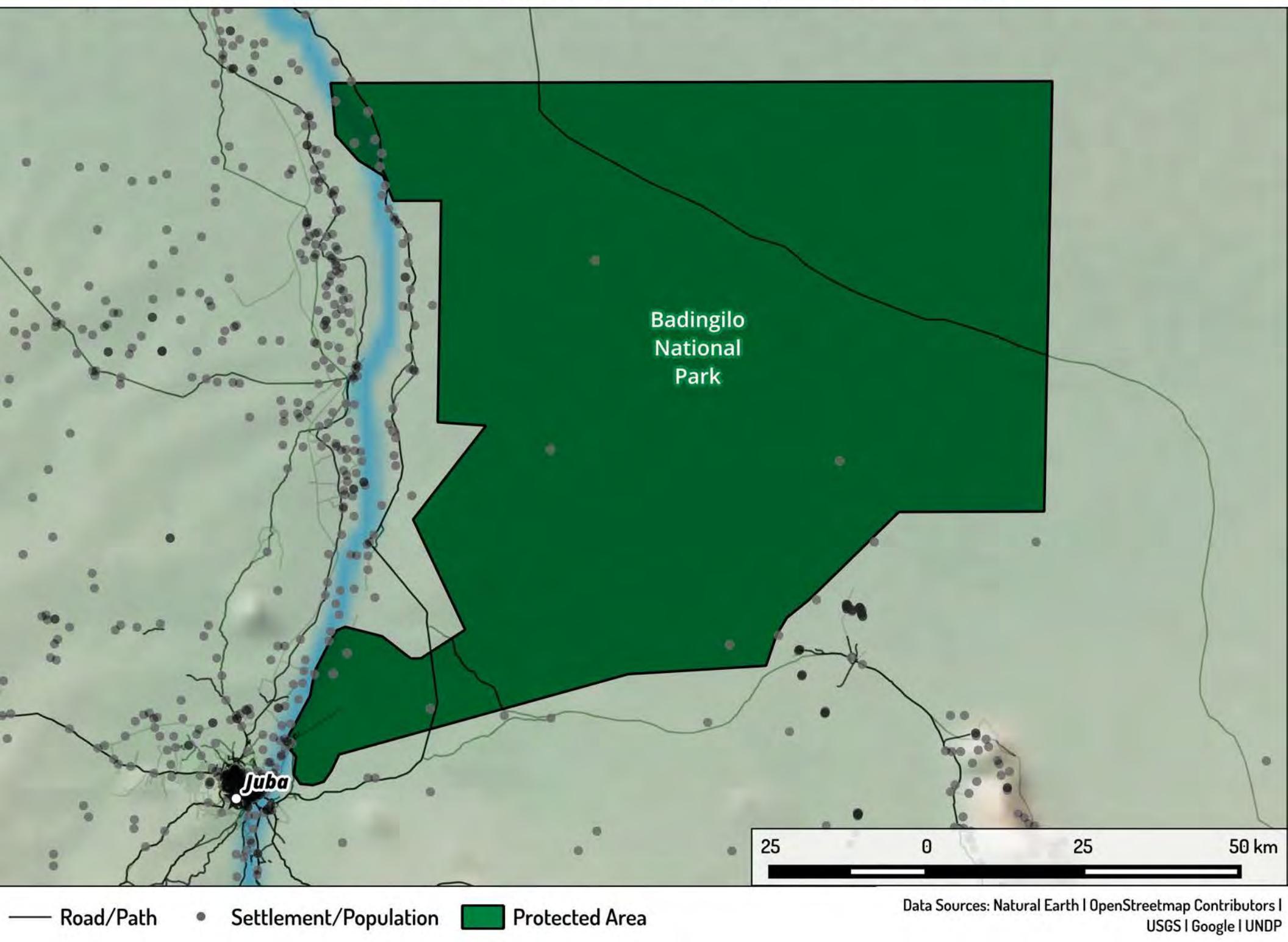
## 10 - Human Infrastructure in Southern National Park



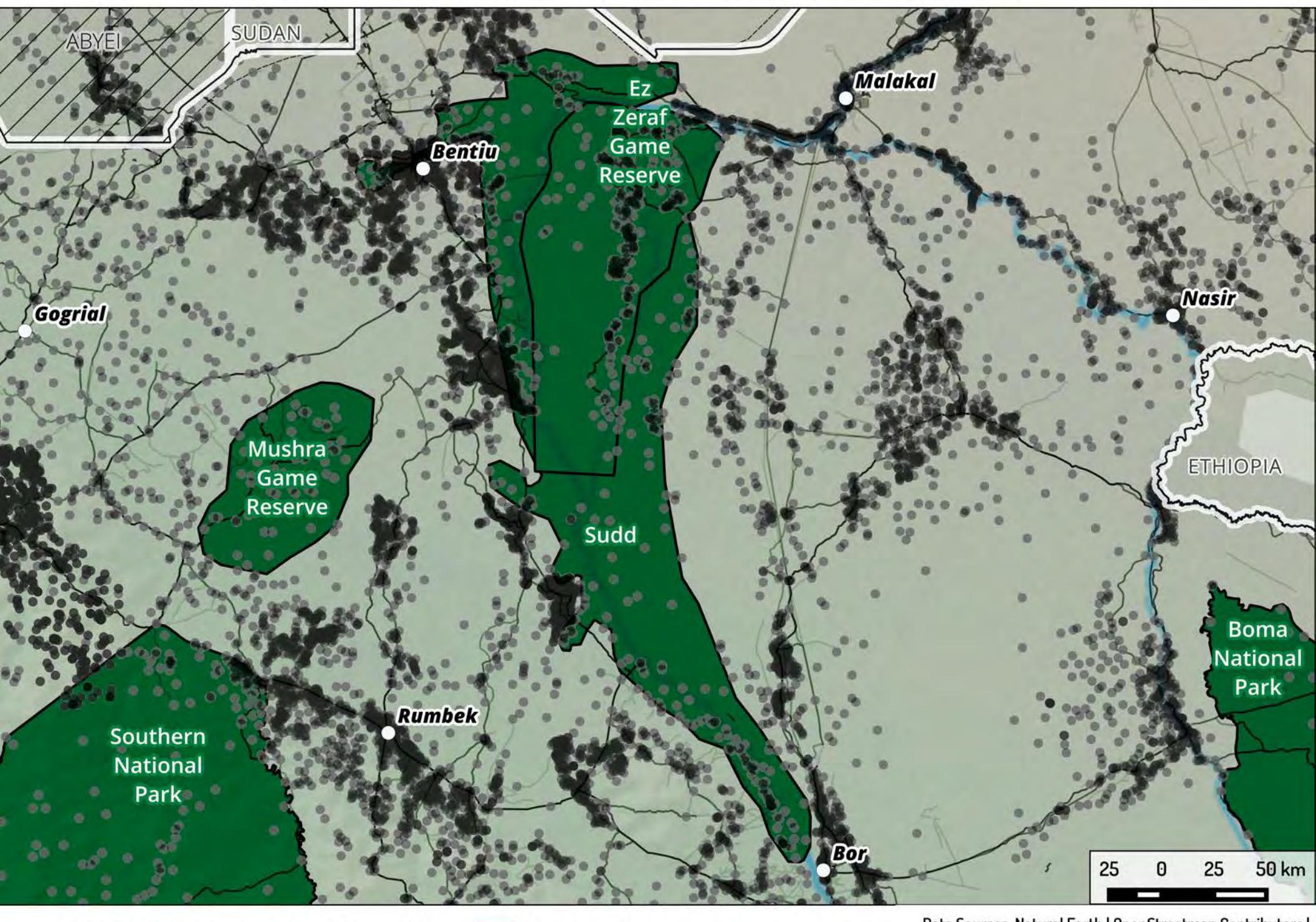
## 11 - Human Infrastructure in Boma National Park



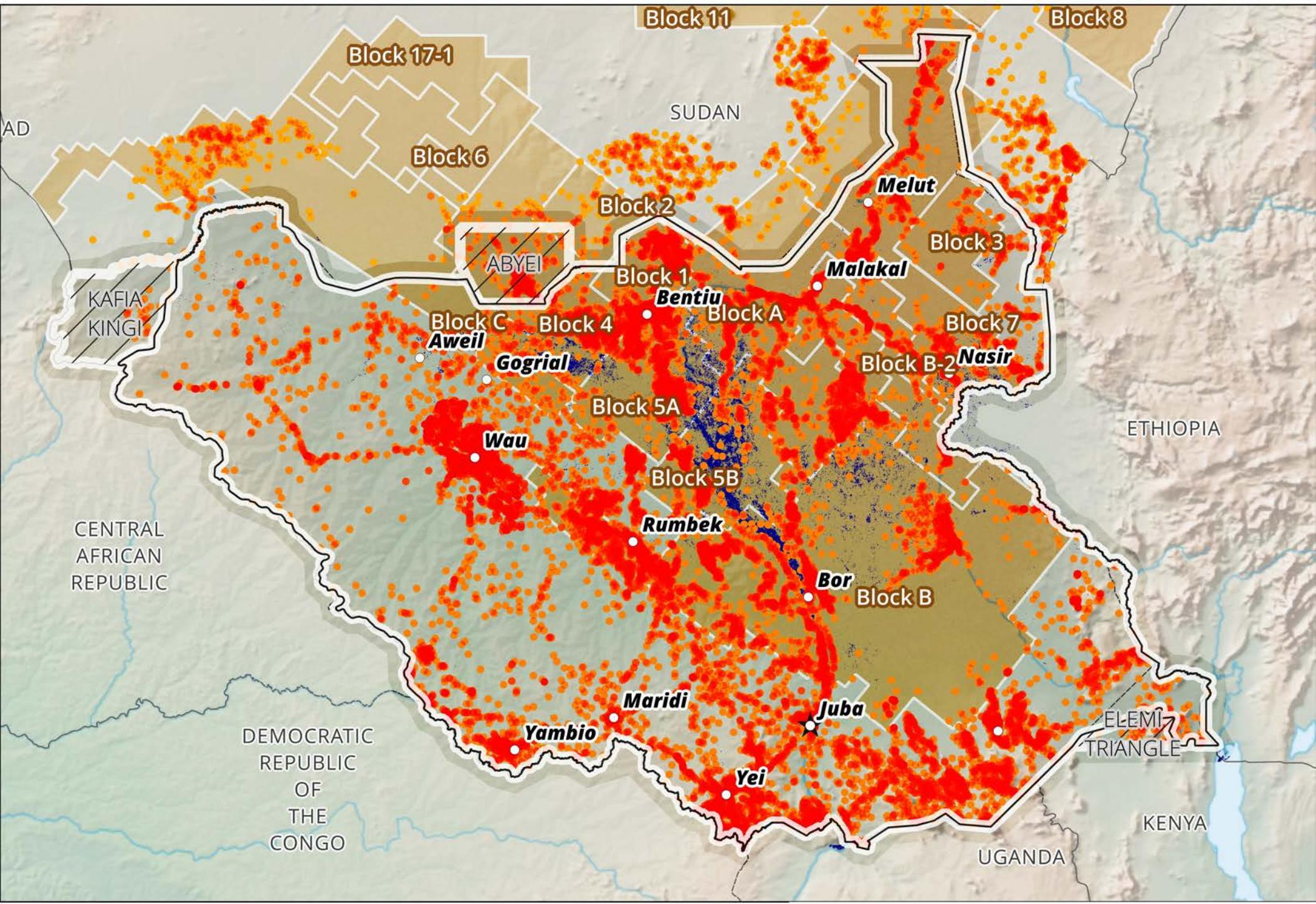
## 12 - Human Infrastructure in Badingilo National Park



# 13 - Human Infrastructure in the Sudd Wetland Area



## 14 - Overlap of Wetlands with Oil/Gas Concessions and the Human Footprint



Oil/Gas Concession Block

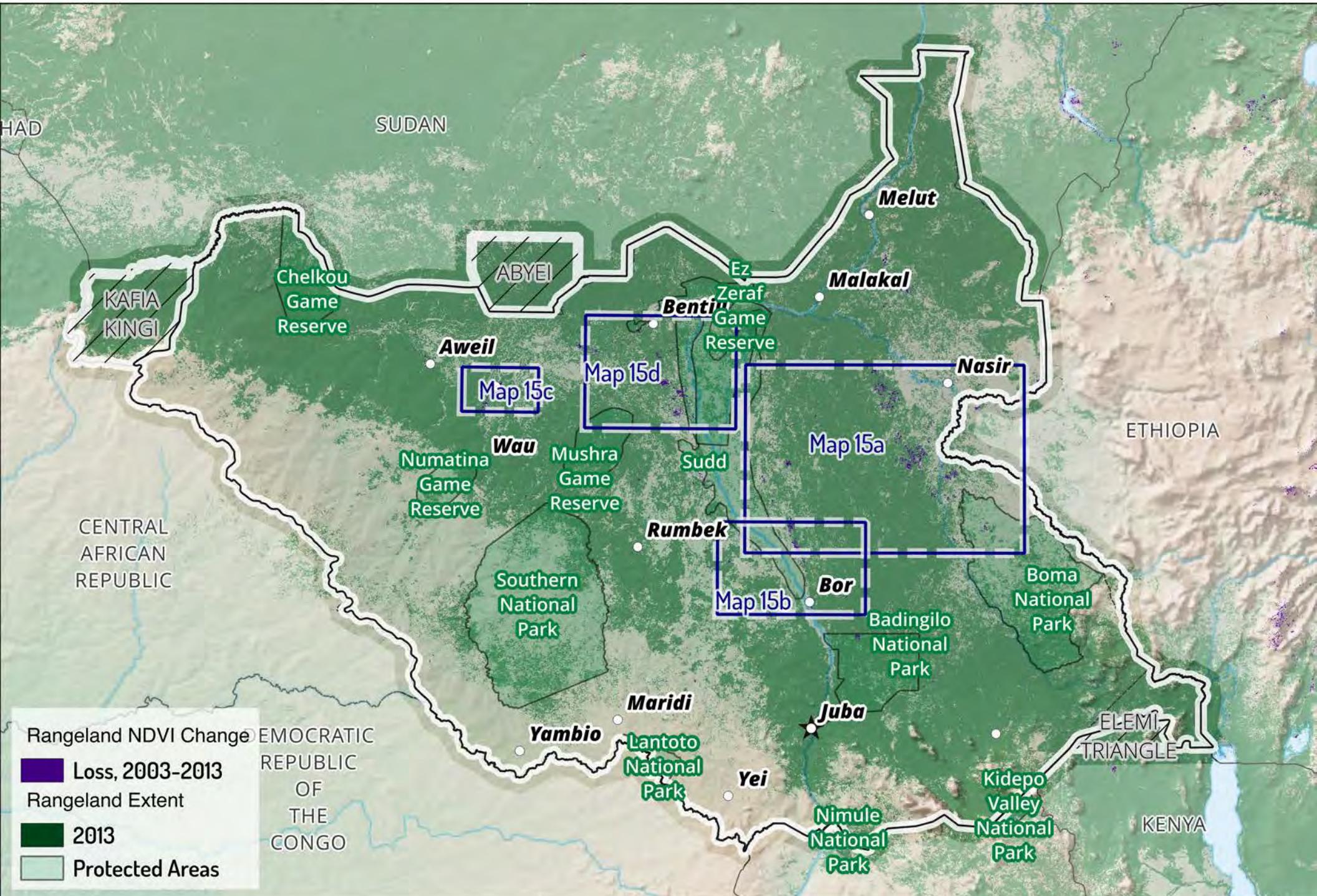
Wetland

• Settlement/Population

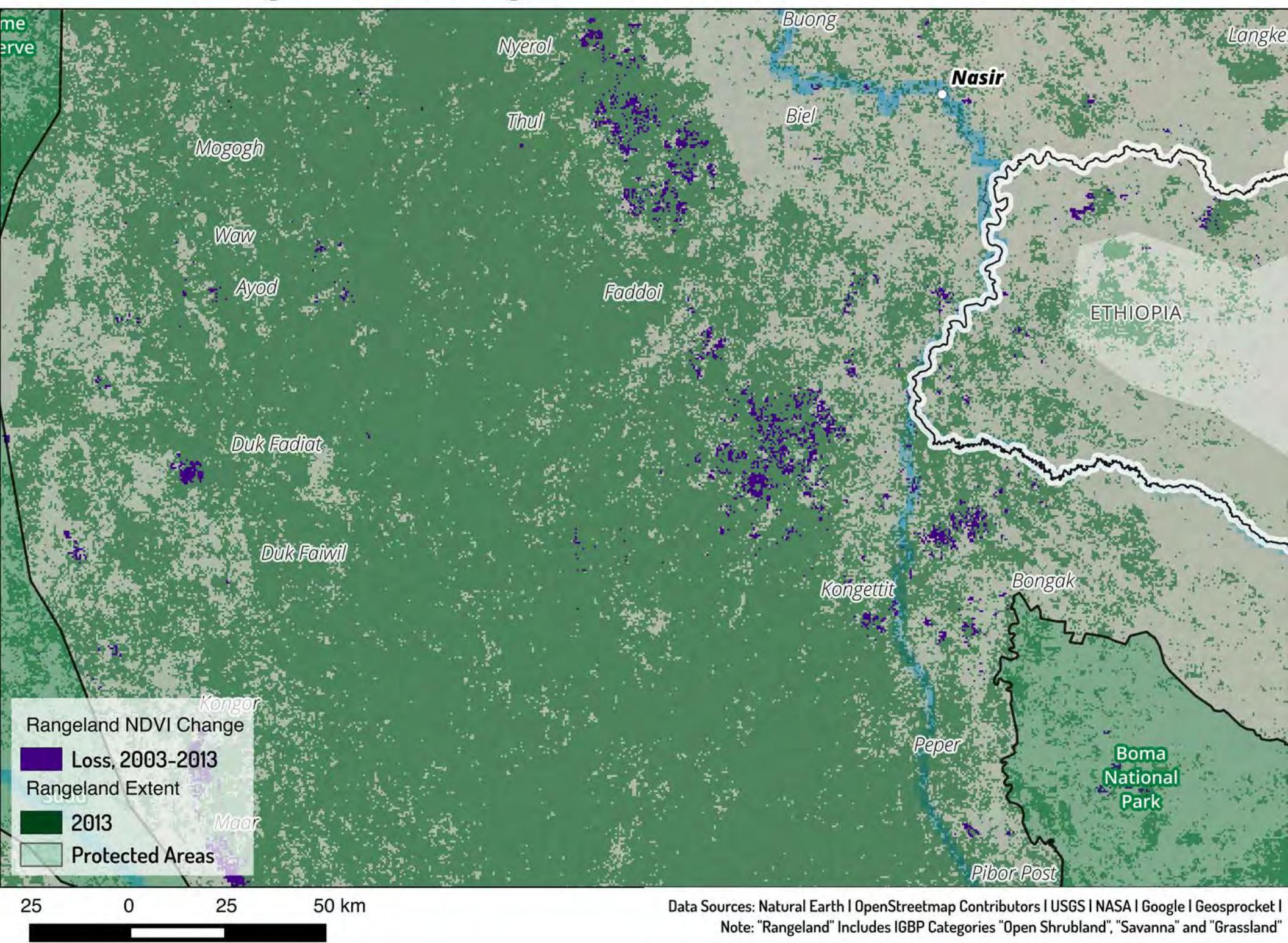
Data Sources: Natural Earth | OpenStreetmap Contributors | USGS | UNDP |

European Coalition on Oil in Sudan (2007)

# 15 - Rangeland Loss & Degredation in South Sudan, 2003-2013



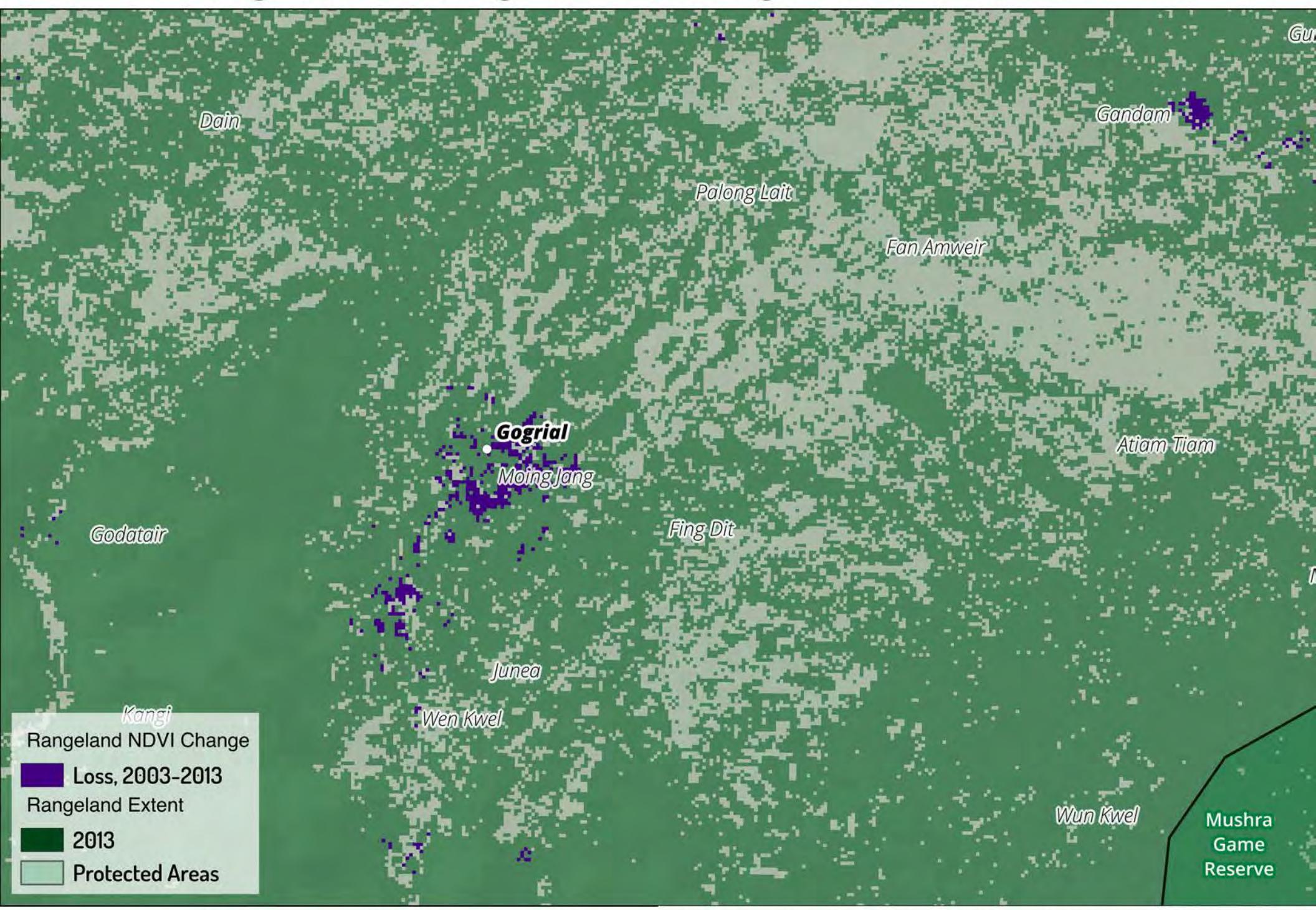
# 15a - Rangeland Loss & Degredation in Eastern South Sudan, 2003-2013



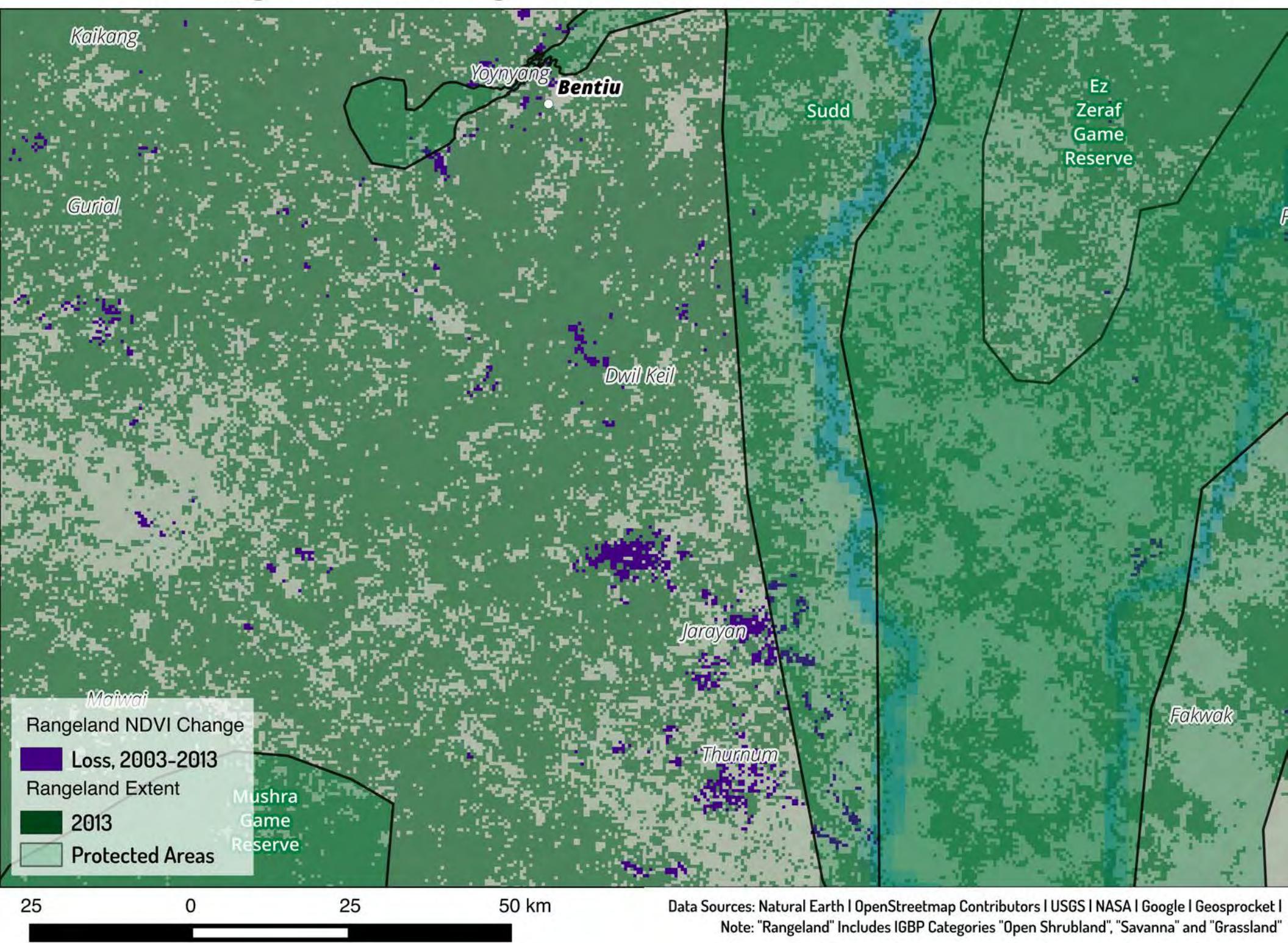
# 15b - Rangeland Loss & Degradation Near Bor, South Sudan, 2003-2013



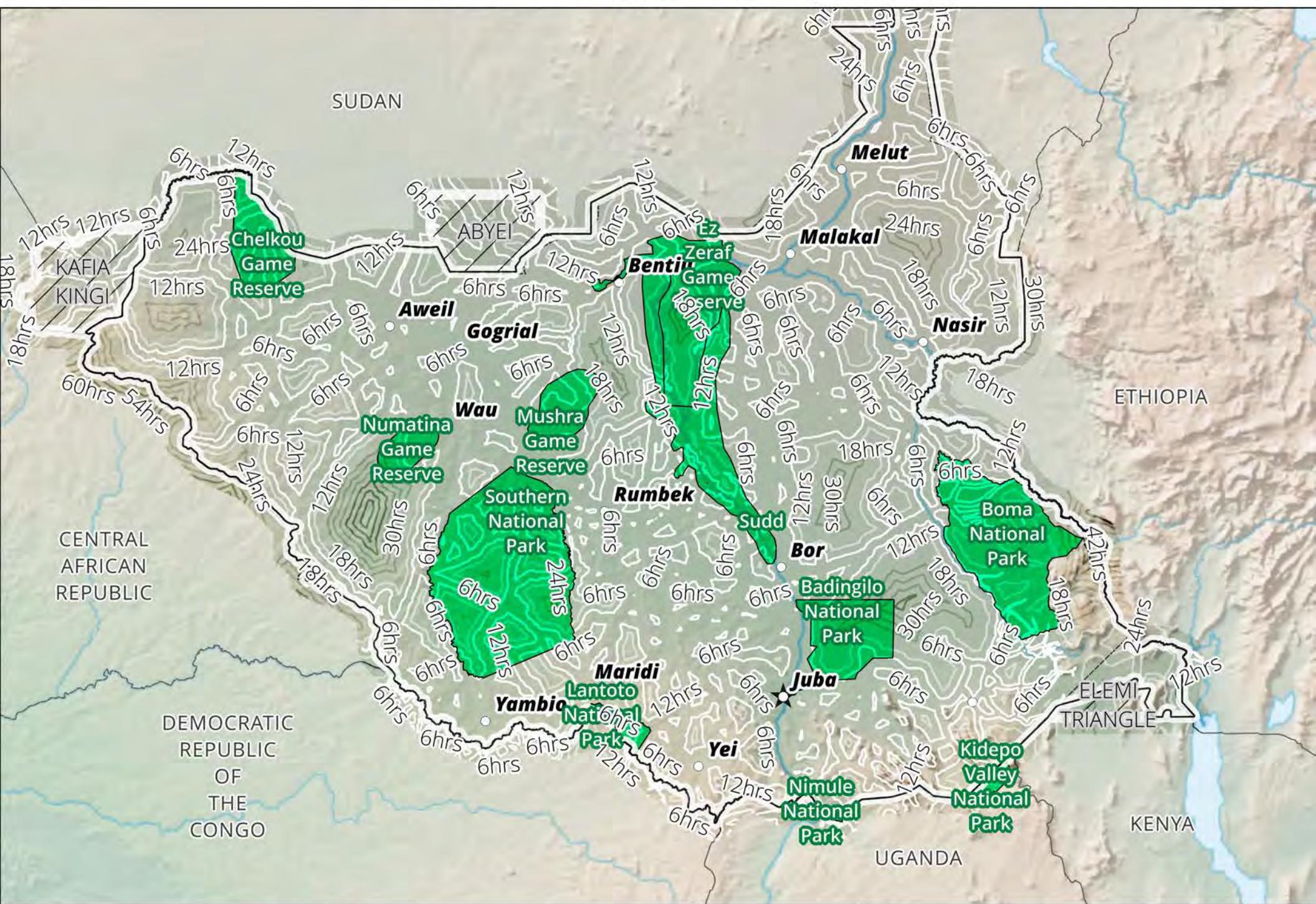
# 15c - Rangeland Loss & Degredation Near Gogrial, South Sudan, 2003-2013



# 15d - Rangeland Loss & Degredation Near Bentiu, South Sudan, 2003-2013



# 16 - Travel Time by Land to Major Cities



Data Sources: Natural Earth | OpenStreetmap Contributors | USGS |

Nelson et al. 2008