LAND COVER ATLAS OF
THE REPUBLIC OF SOUTH SUDAN

LAND COVER ATLAS OF THE REPUBLIC OF SOUTH SUDAN

Second edition

Cover photograph:
©FAO/Mayak Akuot

Abstract

South Sudan is a landlocked country of 658 842 km^2 that stands out as a highly biodiverse country, characterized by extensive fertile land, diverse animal species, and abundant natural resources. However, despite the wealth of these natural resources, the country's economy remains one of the weakest globally, primarily due to persistent conflicts and wars. Following a lengthy civil war, South Sudan achieved independence in 2011, becoming the world's youngest nation. Regrettably, the brief period of peace was disrupted in December 2013 when another conflict erupted, plunging the country into renewed instability. This conflict has exacerbated environmental and humanitarian challenges in addition to the already fragile situation.

The majority of South Sudan's population relies on climate-sensitive sectors such as agriculture, fishery, and forestry for their livelihoods, aligning with the Sustainable Development Goals (SDGs). However, the instability caused by the conflict has severely impacted farmers, hindering agricultural activities and resulting in widespread food shortages, exacerbating poverty and hunger. Moreover, the environmental consequences of the instability, including deforestation, drought, and desertification, pose additional challenges to sustainable development and the achievement of SDGs related to climate action.

To gain a comprehensive understanding of the intricate and dynamic processes resulting from conflicts and war on natural resources and socioeconomic dynamics, assessing land cover change becomes invaluable. These maps provide critical insights into the transformation of land cover within the country. In 2011, the first Land Cover Atlas of the Republic of South Sudan was created, offering essential information regarding land cover distribution across administrative units and sub-basins. A decade later, an updated version of this atlas has been developed, providing an improved understanding of the changing land dynamics.

This updated Land Cover Atlas integrates the work on land cover undertaken by several projects, supporting food security and sustainable land resources management in South Sudan overall, shedding light on the importance of comprehending the coverage of specific land cover classes. One noteworthy finding is the extensive area of grasslands, which covers 37.8 percent of the country's land and stands as the dominant land cover class. This prevalence of grassland indicates the potential for agricultural activities, as it offers fertile ground for cultivating crops and supporting livestock grazing. Additionally, the substantial coverage of open natural vegetation, occupying 26.8 percent of the land, signifies the presence of diverse ecosystems and habitats. This land cover class plays a vital role in supporting biodiversity, including various plant and animal species.

In contrast, the classes identified with the least coverage were perennial water bodies (0.3 percent) and bare land (0.7 percent), highlighting the scarcity and fragility of these resources. Identifying regions with limited coverage of land cover classes brings attention to areas prone to soil erosion, reduced agricultural productivity, and increased vulnerability to climate change impacts. This understanding guides policymakers in implementing targeted interventions to combat land degradation, promote reforestation and afforestation efforts, and restore degraded landscapes.

In conclusion, understanding the distribution of different land cover classes, as revealed by the updated Land Cover Atlas, holds paramount importance and is an innovative approach in helping to understand land cover dynamics. It enables decision-makers to harness this knowledge for strategic planning and informed decision-making in sectors such as agriculture, conservation, water resource management, and land degradation prevention. By recognizing the distribution and dynamics of land cover, stakeholders can work towards sustainable development goals, ecological resilience, and improved livelihoods in South Sudan.

The development and utilization of the Land Cover Atlas highlight the significance of innovation, collaboration, and partnerships in decision-making processes and land cover management. By fostering collaborative efforts between organizations like the Food and Agriculture Organization of the United Nations (FAO), the Government of South Sudan, and supportive donors, a comprehensive understanding of land dynamics can be achieved. This collaborative approach enables stakeholders to work together towards effective resource management, resilience-building, and sustainable development, benefiting the people and environment of South Sudan.

Contents

Tables

Maps

Figures

Foreword

The Food and Agriculture Organization of the United Nations (FAO) released the "Land Cover Atlas of the Republic of South Sudan" in 2011, which was developed by the "Sudan Institutional Capacity Programme: Food Security Information for Action" (SIFSIA) with funding from the European Union, in cooperation with the South Sudanese Government. Now a decade later, FAO has developed an updated Land Cover Atlas of the Republic of South Sudan, resulting from a programmatic approach for sustainable natural resources and livelihood management to tackle the rampant food insecurity in the country. The development of the land cover information activity was supported by several projects as follows (i) Strengthening the livelihoods resilience of pastoral and agro-pastoral communities in South Sudan's cross border areas with Sudan, Ethiopia, Kenya, and Uganda (OSRO/SSD/703/EC) – European Union; (ii) Strengthening the resilience of households to food insecurity in South Sudan (OSRO/SSD/105/EC) – European Union; (iii) Sustainable Agriculture for Economic Resilience (SAFER, OSRO/SSD/709/USA) – USAID; (iv) Humanitarian Response and Resilience in South Sudan (HARRIS, OSRO/SSD/604/UK) – UKAID; and (v) Strengthening the preparedness of vulnerable communities to climate shocks and natural hazards in South Sudan (OSRO/SSD/006/SWI) – Swiss Agency for Development and Cooperation.

Since gaining independence, land resources have changed considerably due to many factors, namely, civil unrest with people displacements leading to increased pressure on available resources, a huge influx of returnees and the efforts of urbanization and development in addition to food demands. This has resulted in deforestation and land degradation. The displacements of pastoral communities added a new dimension of inter and intra-tribal conflicts over natural resources as the displaced communities searched for alternative pasturelands and water sources for their livestock. Due to a lack of up-to-date information on the state of the natural resources in the country, it was difficult to substantially map out the resources available and quantify the magnitude of damage caused by climate related hazards.

In response to these challenges, FAO, in collaboration with the government and with support from different donors initiated the update of the South Sudan land cover database, making use of FAO Geospatial Unit's technical know-how, more updated geospatial methodologies and high resolution satellite images. The process for updating the database was initiated in 2017, considering this tool is of capital importance in supporting various programmes, plans and strategies, this updated atlas meets the need for up-to-date land cover information. The recent advancements in Earth Observation missions made it possible to conduct multi-temporal and multi-spectral analyses of land cover with greater accuracy and efficiency. The information available in the atlas is organized at national, state, and county levels, taking into consideration the disputed area of Abyei. Each section provides information on the distribution of land cover in cartographic form as a map and tabular data. These products offer valuable insights to users regarding the availability and distribution of land resources, with the primary objective of creating an accurate initial inventory of natural resources.

Meshack Malo
FAO Representative in South Sudan

Acknowledgements

Acronyms

AOI   area of interest

EO   Earth Observation

ESA   European Space Agency

ESRI   Environmental System Research Institute

FAO   Food and Agriculture Organization

GIS   Geographic Information System

ISO   International Standards Organization

LC   land cover

LCCS   Land Cover Classification System

LCML   Land Cover Meta Language

NDVI   Normalized Difference Vegetation Index

NDWI   Normalized Difference Water Index

NIR   near infrared

OBIA   Object-based Image Analysis

OSM   Open Street Map

SDG   Sustainability Development Goal

UML   Unified Modelling Language

UNGGIM   United Nations Global Geospatial Information Management

USAID   United States Agency for International Development

Executive summary

Understanding natural resources' utilization, distribution, temporal variations, and human activities is crucial for sustainable land management, especially in areas facing long-standing crises and significant environmental challenges. The competition for natural resources such as water, grassland, and wood among various stakeholders with diverse visions and interests is not only responsible for land degradation but also often a key driver of tensions and violent conflicts. Therefore, obtaining this fundamental information is imperative for promoting sustainable land use and mitigating the negative impacts of resource competition.

In this regard, land cover mapping is essential to support the growing concern regarding food and nutrition security to improve the resilience of livelihoods to threats and crises in the context of climate change.

This atlas contains the land cover dataset for South Sudan, which was prepared as a part of portfolio of projects aimed at enhancing governance and preventing conflicts in cross-border areas of South Sudan. The ultimate goal is to reduce displacement and irregular migration by promoting household food security, nutrition, and income. Creating an accurate initial inventory of natural resources is critical in sustaining this achievement over time. Therefore, the new land cover dataset will allow mapping of natural resources, human settlements and human activities in South Sudan. It will represent the updated dataset developed for South Sudan, integrating high-resolution multi-temporal imagery, object-based image analysis, machine-learning algorithms, and LCML to support the Natural Resource Management strategy, land use planning, and other innovative approaches.

The use of land cover mapping and land cover change monitoring can further assist in and contribute to the following:

- Identification and suitability of livestock migratory routes.
- Estimation of charcoal production and impact on natural wood biomass.
- Participatory and community mapping for development of conflict mitigation strategies.
- Assessment of Socio-Economic Systems.
- Assessment of landscape complexity and hotspot mapping (e.g. cropland/grassland interspersion).
- Supporting crop monitoring.

©FAO/Mayak Akuot

Introduction

Land cover assessment and monitoring of its dynamics are essential for the sustainable management of natural resources, environmental protection, food security, humanitarian programmes and many other purposes. Consistent land cover is critical for assessing the distribution and extension of agriculture types, buildings, natural resources, water, forest and other vegetation types. Land cover is recognized as a fundamental dataset for addressing several UN Sustainability Development Goals (SDGs) as well as national and sub-national plans and strategies.

South Sudan is a landlocked country in East Africa, bordered by Ethiopia, Sudan, the Central African Republic, the Democratic Republic of the Congo, Uganda and Kenya. With a population estimated around 11 million in 2022, the food security situation in South Sudan is more precarious than it has ever been since the country gained independence in 2011. Two out of three people are in a situation of food security and 80 percent of the population work in the agricultural sector. Ongoing conflicts and crises, combined with impacts from climate change, and land degradation have impacted their livelihoods. Despite significant humanitarian aid, natural resources can be better used to improve and support sustainable livelihoods, in particular in changing environments. However, since 2011, land cover as an essential information about natural resources for planning and management was not updated nationally.

The availability of accurate and up-to-date land cover data is crucial for South Sudan due to several reasons i.e., for effective land management, crop planning, and resource allocation; for urban expansion planning, infrastructure development, and the prevention of encroachment on environmentally sensitive areas. Furthermore, it also benefits sustainable management of natural resources, conservation and protection from encroachment or degradation and for disaster and climate risk management in South Sudan. By providing a foundational layer of information, land cover data aids in informed decision-making, sustainable development, and the overall well-being of the country and its people.

Geographic Information System (GIS) and Remote Sensing (RS) are valuable geospatial tools utilized for precise and accurate land cover mapping. These technologies have significantly improved the ability to map land cover by integrating multi-temporal and multi-sensor optical and radar images. Over the years, these tools have undergone rapid advancements, benefiting from the latest Earth Observation missions, cloud computing, and the use of land cover meta-language (LCML). LCML, developed jointly by FAO and ISO, serves as an international standard that promotes interoperability and coherence among national land cover datasets. These advancements enable faster coverage of large areas, providing reliable data for monitoring changes in land cover over time. Moreover, the integration of artificial intelligence (AI) and machine learning techniques has further enhanced the effectiveness of land cover mapping, facilitated better land management practices and has supported sustainable development.

Despite the advancements in geospatial technologies and tools, challenges and limitations remain, inhibiting the creation of consistent and relevant land cover maps for use in developing regions. A major obstacle is the complication that arises from combining various technologies in the day-to-day operations within teams with limited technical capacities. Consequently, enhancing these capacities is crucial for the development of national datasets that are created, verified, and distributed within the country.

The land cover mapping approach developed for South Sudan is a dynamic process derived from the FAO's decadal experience building detailed national land cover databases, including those for Jordan, Lesotho, South Sudan, Libya, Senegal, Fouta Djallon, Uruguay, Pakistan, and Afghanistan. It is consistent with the dataset developed in 2011 to ensure sustainability of the system (FAO, 2011)[1]. The FAO approach to land cover mapping combines innovative technologies, multi-temporal high-resolution imagery, standards, and tools developed specifically to assess land characteristics. This approach evolves and develops continuously in a constant balance of theoretical and technical aspects derived from the innovation of remote sensing and GIS technologies.

The main objectives of the development of the national land cover are as follows:

- To produce an updated and detailed geo-referenced Land Cover Database indicating in detail the land cover classes and their distribution at the national scale.

- To provide baseline information for research, project planning and design, monitoring, policy and programme reviews.

- To provide data to support statistical analysis for food security, hazard impact assessments and natural resource monitoring.

- To ultimately act as a useful instrument in the development of sustainable solutions for the conflict over limited natural resources.

---

1 FAO. 2011. Land Cover Atlas of the Republic of South Sudan (fao.org), Food and Agriculture Organization of the United Nations, Rome.

©FAO/Mayak Akuot

2

METHODOLOGY

Land cover mapping of South Sudan

2.1 General

Developing a land cover dataset is a complex task that requires the interaction ferent factors. The phases implemented for the land cover mapping production chain (Figure 1) are listed below:

1. Preliminary study of the area of interest.
2. Selection and acquisition of ancillary data.
3. Imagery selection, acquisition and download.
4. Segmentation and preparation of the vector layers (shapefile format).
5. Object attributes enrichment (i.e. NDVI, LC data, elevation data).
6. Preparation of the preliminary legend and photo-keys.
7. Specific analysis (i.e. water and wetlands, agriculture areas, percentage of vegetation cover).
8. Pre-classification of the shapefiles.
9. Harmonization and finalization of the land cover dataset.

The system is very flexible and it can be adapted to the different needs of the country depending on the availability of resources, personnel, time, existing data and previous experience.

Figure 1. Land cover mapping production chain
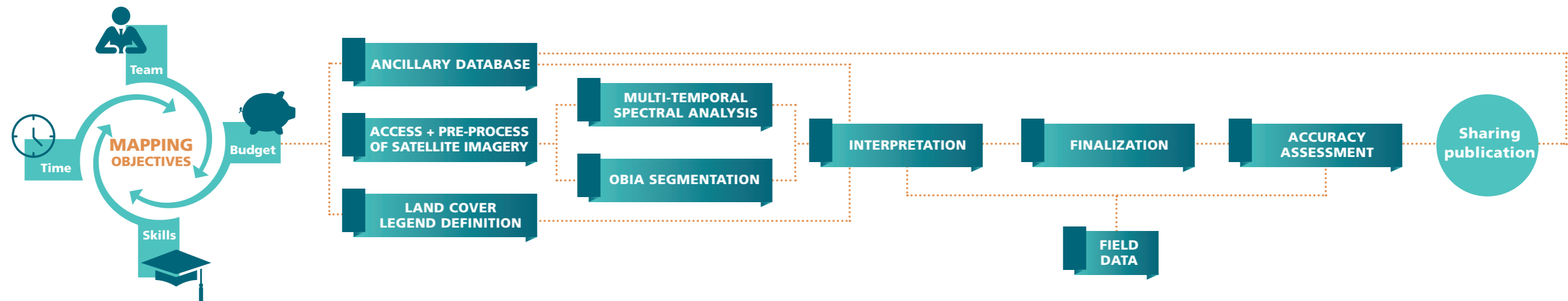
Source: Authors' own elaboration

2.2 Ancillary datasets

A preliminary needed step of any land cover mapping activities is to build a geospatial standardized catalogue of available ancillary information on land, climate, soil, topography, hydrography and administrative political subdivisions. Statistical tabular socio-economic data may also be a useful source of information. All this information affects the occurrence and composition of natural features such as vegetation and water resources as well as the presence of people and the inputs that those people provide to the land, in terms of agricultural activities, forest exploitation, built-up artificial elements just to cite a few.

The ancillary data supports the land cover interpretation, when the spectral information of acquired satellite imagery are converted into land cover classes. More generally, ancillary datasets support photo-interpreters and validation of intermediate products particularly when disambiguation of particular land cover classes are required, and therefore can be used to further discriminate land cover classes that can not be easily identified by remote sensed imagery. For instance, thematic layers on irrigated land support to distinguish between rainfed and irrigated agriculture. Detailed crop calendars of the study area allow to narrow down the presence of only determined crops during particular seasons of the growing period allowing to identify the main cropping patterns.

Of particular interest, the analysis of existing national, regional or global land cover datasets and their land cover classification systems, allow not only to understand the main land features expected but also to assess which are the main limitations when discriminating between particular attributes (e.g. trees and shrubs).

Finally, ancillary datasets are used for reporting and layouts of final products. Thematic layers such as administrative divisions, main roads or urban areas and shaded relief allow a better contextualization and representation of land cover data. They also needed for reporting on statistics of land cover classes by subnational divisions or by other natural divisions (e.g. watersheds or agro-ecological zones). The use of official national boundary and the correct depiction of possible disputed areas with neighborhood countries is also particular relevant if public dissemination of results is required.

South Sudan is divided into ten states that are further subdivided into 78 counties. Digital files (ESRI shapefiles) of state and counties were provided by the National Bureau of Statistics and used for map layouts and reporting statistics on land cover.

Table 1. List of main themes collected

Theme	Dataset
Crop Calendar	FAO Crop Calendar[1]
Administrative boundaries and area of study	United Nations Geospatial[2] NBS/OCHA[3]
Protected areas	World Database on Protected Areas (WDPA)[4]
Hydrology	JRC Global Surface Water[5] HydroLAKES[6]
Land cover	ESA CCI Land Cover map[7] Land Cover Atlas of South Sudan[8]
Elevation	ASTER Global Digital Elevation Map[9]
Streets	Global Roads Open Access Data Set (gROADS), Version 1[10]
Populated Places	GeoNames[11]

Sources. **1**: *FAO. GIEWS - Global Information and Early Warning System https://www.fao.org/giews/countrybrief/country.jsp?code=SSDGIEWS;* **2**: *United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations;* **3**: *NBS/OCHA;* **4**: *UNEP-WCMC and IUCN (2018) Protected Planet: The World Database on Protected Areas (WDPA), [02/2018], Cambridge, UK;* **5**: *Pekel, J., Cottam, A., Gorelick, N. and Belward, A., Global Surface Water - Data Access, Nature, 2016, doi:10.1038/nature20584, JRC109054;* **6**: *Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. (2016). Estimating the -volume and age of water stored in global lakes using a geostatistical approach. Nature Communications,* **7**: *13603. https://doi.org/10.1038/ncomms13603; 7: ESA. Land Cover CCI Product User Guide Version 2. Tech. Rep. (2017). Available at: maps.elie.ucl.ac.be/CCI/ viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf;* **8**: *FAO 2011. Land Cover Atlas of the Republic of South Sudan. Rome, Italy;* **9**: *Ministry of Economy, Trade, and Industry (METI) of Japan and United States National Aeronautics and Space Administration (NASA). ASTER GDEM v2;* **10**: *Center for International Earth Science Information Network - CIESIN - Columbia University, and Information Technology Outreach Services - ITOS - University of Georgia. 2013. Global Roads Open Access Data Set, Version 1 (gROADSv1). Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4VD6WCT;* **11**: *GeoNames. GeoNames. http://geonames.org/*

2.3 The land cover legend of South Sudan

A fundamental part in the production of a land cover dataset is the definition of the legend. FAO has contributed significantly to the development of the Land Cover Meta Language (LCML) which became a joint FAO/ISO standard (ISO 19144-2:2012) and is based on the original FAO Land Cover Classification System (LCCS) first developed in 2000 (Di Gregorio and Jansen, 2000).

The LCML model represents a powerful tool to characterize geographic features in a more modern approach with respect to the conventional methods. According to the LCML model, land cover can be represented using a shared dictionary composed by simple predefined and standardized atomic elements (i.e. tree, shrub, herb, building etc.) rather than categories (Di Gregorio, 2016), that can be then recombined in different ways to represent different real-world features. The combination of LCML basic objects is then further characterised by additional attributes that are defined as traits and characteristics. The LCML basic elements or objects, their relationships, inheritance, properties and characteristics associated with them, are formalized in a Unified Modelling Language (UML) class diagram, as part of the standard.

This common reference framework allows comparison and correlation of land cover classes regardless of mapping scale, land cover type, data collection method or geographical location.

The definition of the land cover classes can be basically defined by two different approaches: the classes are discussed according to the specific need of the project/s that require the land cover mapping, or alternatively the identification of classes is done on the maximum number of classes that can be extracted based on the limited availability of resources, time and image qualities. This latter approach was followed as it guarantees a higher number of classes and the final land cover dataset can fit multiple purposes.

The land cover legend developed for the South Sudan land cover of 2011 (FAO, 2011), was the reference for the generation of the new legend. However, during the interpretation phases additional classes were added or merged depending on the capability to further discriminate between similar classes, and following workshops with national stakeholders and experts held in the country in 2018 and 2019. For example, after discussion with national experts, it was suggested to introduce the discrimination between small and medium/large field sizes in order to specify the boundary between commercial/semi-commercial agricultural activity and subsistence farming. The class "Herbaceous crop irrigated" was also included especially to better describe the situation in the Renk State where intensive agriculture is widely present.

Therefore, several adjustments and iterations were involved, before arriving at the final 2022 land cover legend, which includes 26 classes (Table 2). For a more detailed description, see Section 3 - Photokeys

Table 2. Land cover legend of South Sudan

Land cover type	Land cover name	HEX#	Land cover code	Land cover description
HERBACEOUS CROP RAINFED	Herbaceous crop rainfed (small fields)	F5F57A	HCRs	Rainfed cultivation (mainly herbaceous crops with small field size), occasionally with scattered natural trees
	Herbaceous crop rainfed (medium/large fields)	E6E600	HCRml	Rainfed cultivation (mainly herbaceous crops with field size, from large to medium), occasionally with scattered natural trees
HERBACEOUS CROP IRRIGATED	Herbaceous crop irrigated	F5A27A	HCIR	Irrigated cultivation (herbaceous, shrub and tree crops)
TREE CROP PLANTATION	Tree crop plantation	F1932D	TPL	Tree crop (plantations and orchards)
MIXED UNIT	Mixed unit (rural settlements - natural vegetation - herbaceous crop rainfed)	E65518	CU	Areas principally occupied by rural settlements areas interspersed in a significant fraction of natural vegetation. Small cultivated crops and/or orchards are present
	Mixed unit (herbaceous crop rainfed - natural vegetation - rural settlements)	A83800	CU1	Areas principally occupied by small crop fields interspersed in a significant fraction of natural vegetation. Settlements are also present
	Mixed unit (herbaceous crop rainfed - natural vegetation)	72190E	CUsh	Areas principally occupied by agriculture interspersed in a significant fraction of natural vegetation
BUILT-UP	Rural settlement	441514	RA	Low density urban built-up areas interspersed with small cultivated herbaceous crops and/or orchards
	Built-up area	686868	BU	High and medium density urban built-up area occasionally with trees. Different types of costruction are included
BARE AREAS	Bare soil	FFEBBE	BS	Bare area/undifferentiated area not used for cultivation and usually devoid of grass and shrub cover
	River bank	D7D79E	RB	River bank (soil/sand deposits) + perennial/periodic flowing fresh water
	Bare rock	A87000	BR	Rock outcrops
CLOSED NATURAL VEGETATION	Closed woody vegetation	46663C	TC	Undifferentiated natural closed trees
	Closed woody vegetation on mountain areas	2F4B29	TCm	Undifferentiated natural closed trees above 2 500 m asl
OPEN NATURAL VEGETATION	Open woody vegetation	759D46	TO	Natural woodland open vegetation, occasionally with sparse or closed herbaceous coverage shrubs from closed to sparse/scattered with natural vegetation (shrub and herbaceous)
	Open woody vegetation on mountain areas	4E9458	TOm	Natural woodland open vegetation, occasionally with sparse or closed herbaceous coverage shrubs from closed to sparse/scattered with natural vegetation (shrub and herbaceous), above 2 500 m asl
GRASSLAND	Herbaceous closed to open (with sparse woody vegetation)	BADD69	HCO	Relatively dense herbaceous natural vegetation occasionally with sparse shrubs
	Grassland	AAFF00	HCS	Herbaceous natural vegetation with coverage from dense to sparse
VEGETATION on WETLAND AREAS	Closed woody vegetation on wetland	882E72	CCW	Trees and shrubs dominated closed vegetation in an usually flooded or liable to flooding area
	Open woody vegetation on wetland	FF73DF	OCW	Tree and shrubs dominated open vegetation in an usually flooded or liable to flooding area
	Grassland on wetland	FFBEE8	HCW	Herbaceous dominated vegetation in an usually flooded (4–12 months) or liable to flooding area
	Seasonal wetland	D69DBC	HCWs	Herbaceous dominated vegetation in a periodically inundated (← 2–4 months) area
PERENNIAL WATER BODIES	Water body perennial/artificial pond	004DA8	WBP	Natural perennial fresh waterbody and artificial waterbody
	River perennial	004DA8	RP	Water course
SEASONAL WATER BODIES	Water body seasonal	00C5FF	WBnP	Natural fresh waterbody with oscillations in water level with perennial closed/open natural herbaceous vegetation
	River seasonal	00C5FF	RnP	Water course non-perennial

Source: Authors' own elaboration

2.4 Satellite imagery

The land cover of South Sudan was developed based on the interpretation the Sentinel-2 (S2) satellite data. Sentinel-2 mission is an Earth observation mission developed by the European Space Agency (ESA) as part of the Copernicus Programme. Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging made of twin satellites; Sentinel-2A and Sentinel-2B, each carrying onboard multispectral imaging instruments (MSI) with the capabilities of recording 13 wide-swaths bands. The primary objective of the Sentinel-2 mission is to provide high-resolution satellite data for land cover/use, monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas, climate change and disaster monitoring (Phiri et al. 2020).

The Sentinel-2 images attained for the generation of LCDB comprises 108 Sentinel-2 tiles covering the initially defined AOI (including a 10 km country buffer), as illustrated in Figure 2. Over these tiles, the availability of multi-temporal acquisitions for the period December 2016 – November 2017 was investigated.

Figure 2. Sentinel-2 tiles
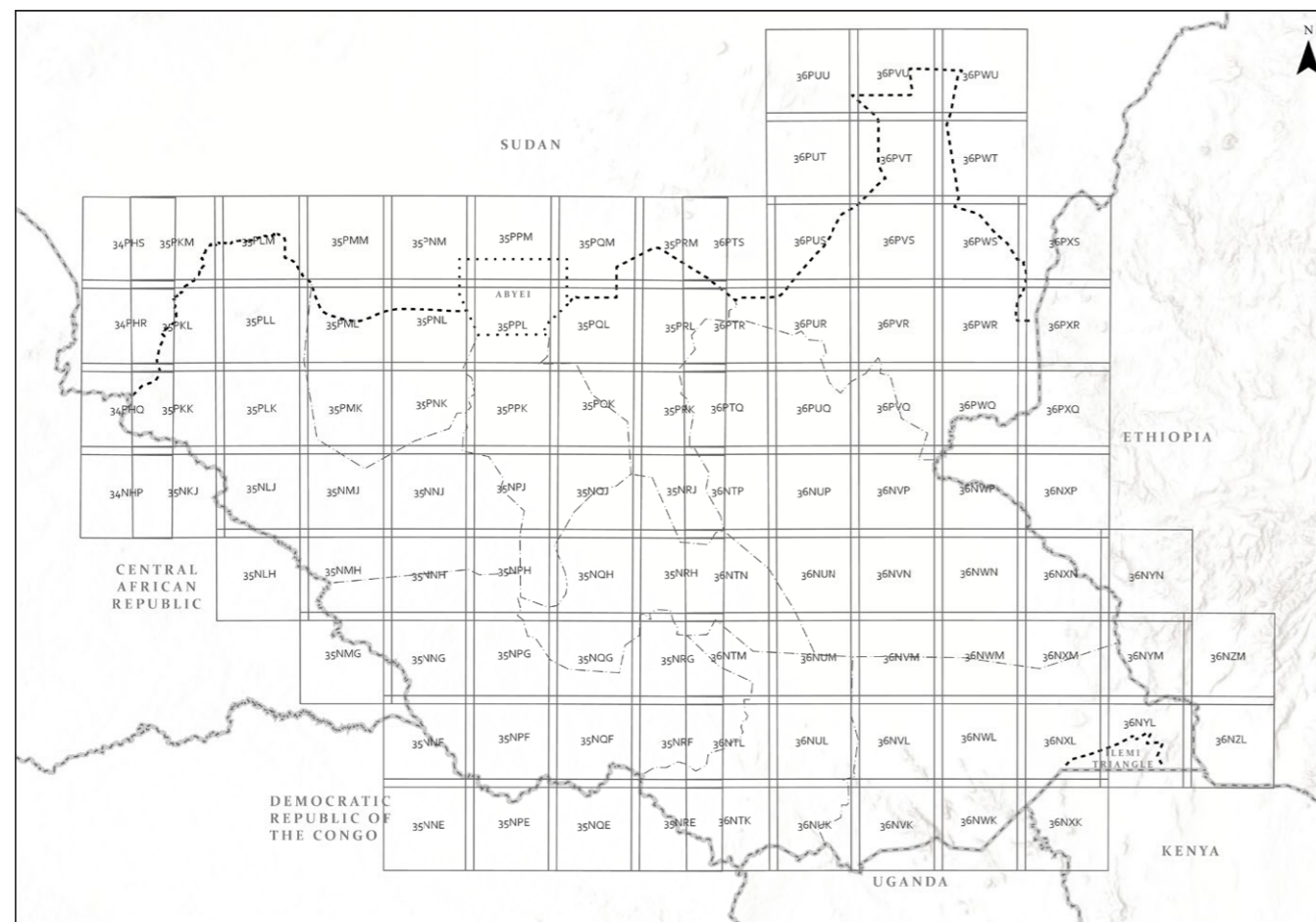
Notes: Country and states boundaries on this map do not imply acceptance or recognition by the Government of South Sudan. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

Sources: Authors' own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

[1]8 Band2 - Blue (490 mm), Band3 - Green (560 mm), Band4 - Red (665 mm) and Band8 - NIR (842 mm). 9 Band5 - Vegetation Red Edge (705 nm), Band6 - Vegetation Red Edge (740 nm), Band7 - Vegetation Red Edge (783 nm), Band8A - Vegetation Red Edge (865 nm), Band11 - SWIR (1 610 nm), Band12 - SWIR (2 190 nm). 10 Band1 - Coastal aerosol (443 nm), Band9 - Water vapour (945 nm), Band10 - SWIR Cirrus (1 375 nm).

In total, 3 264 individual tiles were downloaded from the ESA Data Hub. Each downloaded tile consists of thirteen compressed JPEG-2000 images, each image representing one single band. The thirteen bands have three different resolutions (10 m, 20 m and 60 m) (Figure 3) and characteristics[1].

Figure 3. Sentinel-2 bands
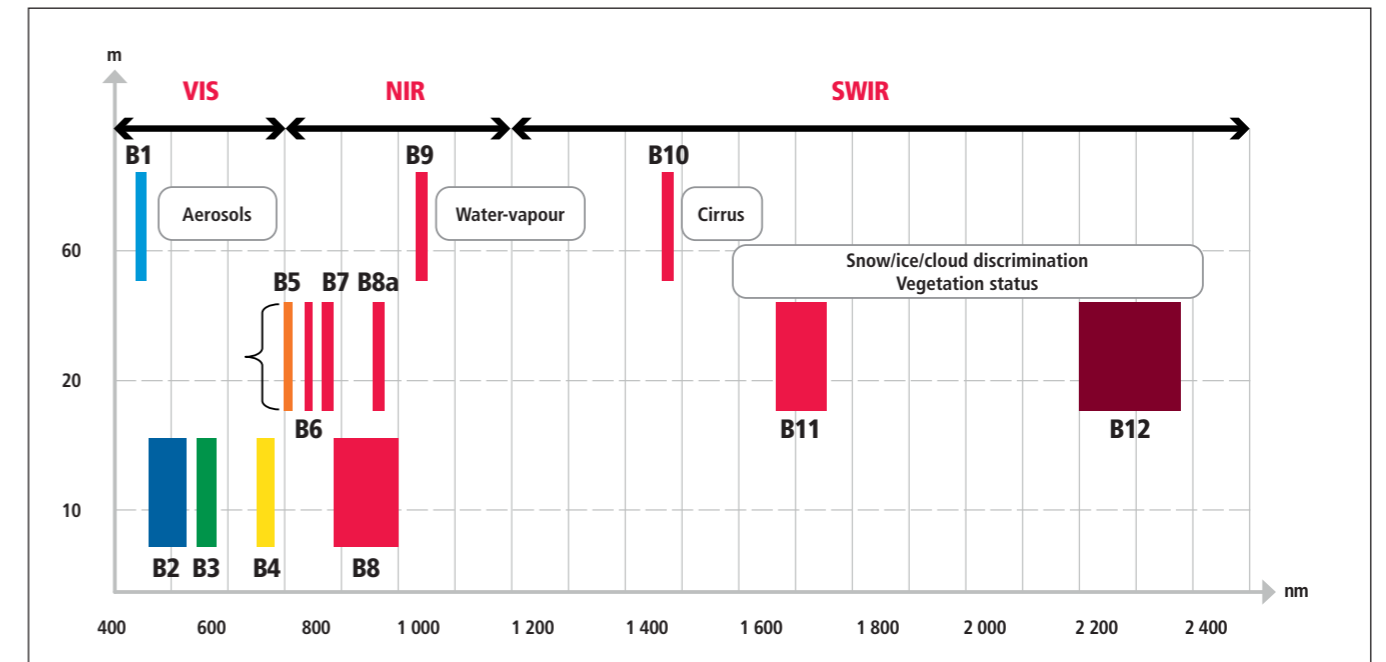
Sources: European Space Agency. Bulletin 161 - 1st quarter 2015. http://esamultimedia.esa.int/docs/EarthObservation/Sentinel-2_ESA_Bulletin161.pdf

In order to optimize storage and to display images according to defined band combinations, all the individual bands are stacked together through a process call band composite. Only bands at the same spatial resolution can be composite together. This limited the choice to the bands B2, B3, B4, and B8. Since band B2 is not used in the segmentation, it was not included in the final band composite. Once the bands are composite, tiles can be displayed in different combinations to enhance particular features (Figure 4).

Figure 4. True colour composite (left) and false colour composite (right)

Sources: European Space Agency. Copernicus Sentinel data 2017

Monthly mosaics were generated using ERDAS IMAGINE software, Mosaic Pro module. Some mosaic techniques can help minimize the abrupt changes along the boundaries of the overlapping rasters. Two monthly mosaics for the whole study area, one covering the period May – August 2017 and the second for the month of November 2017 (Figure 5), were used in the classification process.

Figure 5. Mosaic generated for the month of November 2017 in false colour composite
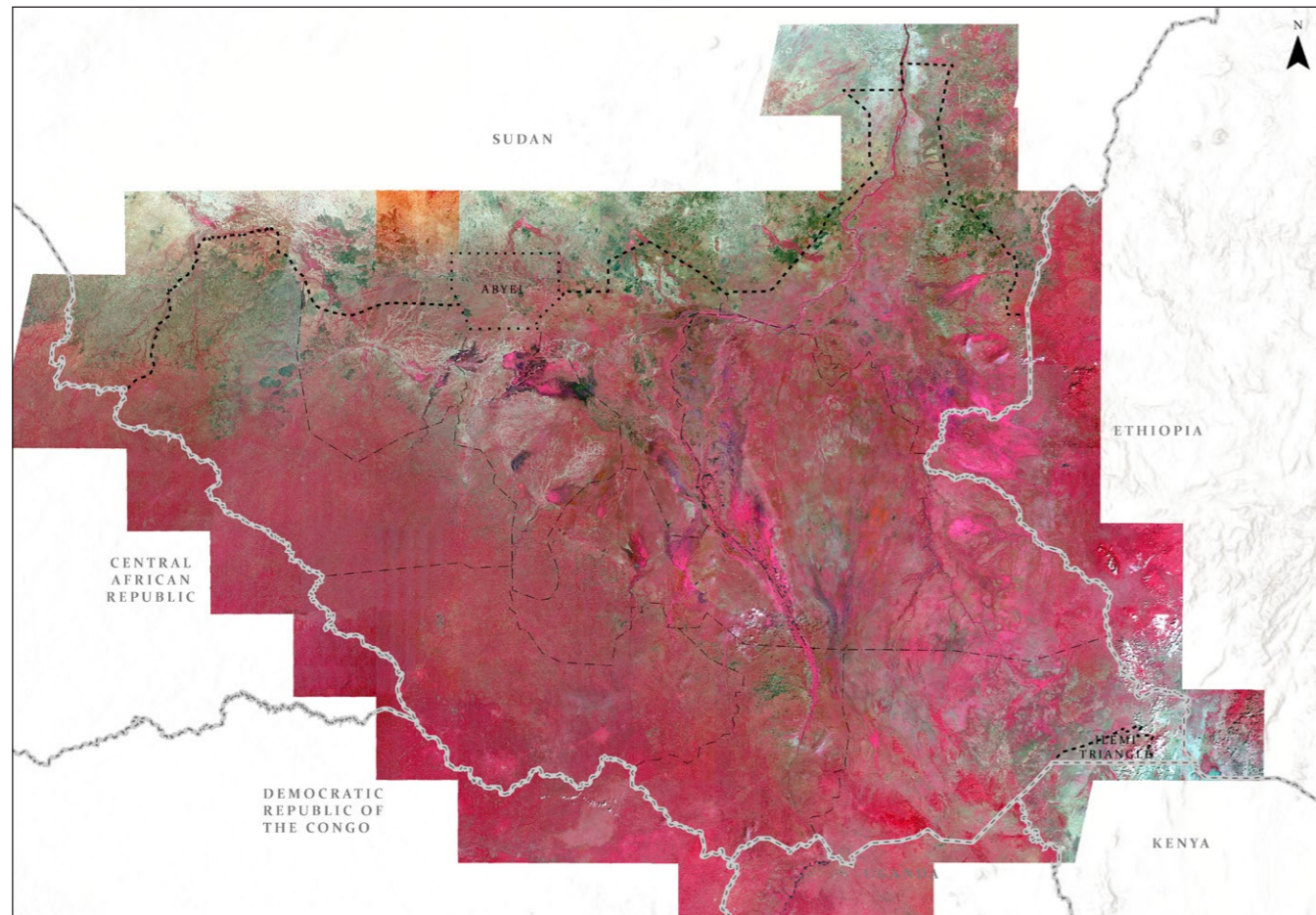
Notes: Country and states boundaries on this map do not imply acceptance or recognition by the Government of South Sudan. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

Sources: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA; European Space Agency. Copernicus Sentinel data 2017

2.5 Satellite image segmentation

For land cover mapping projects, remote sensing satellite data needs to be converted into information that can be exploited by users. Based on literature, the best method to assure a high level of thematic detail is the Object-Based-Image-Analysis (OBIA).

OBIA attempts to translate the human visual perception into rules to identify image objects in semi-automatic ways, increasing the repeatability and production, while reducing time and costs. The basis of OBIA is the grouping of pixels into segments then classified into meaningful objects based on their spatial and spectral homogeneity. This is a bottom-up region merging technique that begins considering each pixel as a separate segment, which is consequently aggregated into larger segments. The aggregation is based on homogeneity conditions set by the user, and it stops when the heterogeneity between two segments exceeds defined thresholds. The final segmented layer should have the correct balance between number of polygons and the level of detail represented, following the principle "as large as possible as small as necessary".

The segmentation was performed using the software Trimble eCognition. The software requires the definition of a ruleset to translate spectral statistics of visually interpreted land cover samples into information, which is then used to perform a supervised land cover classification based on Random Forest algorithm. Random forest is a classification algorithm that builds multiple decision trees and merges them together to get a more accurate classification compared to other techniques, such as maximum likelihood and conventional decision trees. At the end of this complex process the image objects are classified based on the classifier model and training sample statistics.

2.6 Image interpretation and harmonization

During the interpretation process polygons are labelled with a predefined land cover code. The process can be executed automatically, semi-automatically or visually/manually. A combination of processes was adopted for the classification of the South Sudan land cover dataset.

First, a set of reclassification rules were implemented. This procedure considered a series of attributes calculated for each individual polygons and predefined thresholds for each of them. Calculated additional attributes that were used to support the interpretation process included: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), most represented land cover class from Land Cover Atlas (FAO 2011) in each polygon.

In particular, Normalized Difference Vegetation Index (NDVI), is a remote sensing global index for vegetation mapping through satellite imagery and it is calculated by a normalization equation between red and near-infrared bands that is affected by chlorophyll content in vegetation. Higher chlorophyll leads to higher reflectance in near-infrared (NIR) and absorption in red bands.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NDVI helps to differentiate vegetation from other types of land cover (i.e. artificial) and determine its overall state. It also allows to define and visualize vegetated areas on the map as well as detect abnormal changes in the growth process. NDVI calculation range from -1 to 1. Negative values correspond to areas with water surfaces, manmade structures, rocks, clouds, snow; bare soil usually falls within 0.1–0.2 range; and plants will always have positive values between 0.2 and 1. Healthy, dense vegetation canopy should be above 0.5, and sparse vegetation will most likely fall within 0.2 to 0.5.

NDWI is a commonly used index to detect and delineate water-like feature and high soil moisture areas (McFeeteres, 1996). The formula for calculating NDWI is:

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$$

Where near-infrared (NIR) and green represent the spectral reflectance values acquired in the near-infrared and green portion of the electromagnetic spectrum, respectively. Theoretically, NDWI values range from -1 to +1. The visible green wavelengths maximize the typical reflectance of the water surface. The near-infrared wavelengths maximize the high reflectance of terrestrial vegetation and soil features, while minimizing the low reflectance of water features. The result of the NDWI equation is positive values for water features and negative ones (or zero) for soil and terrestrial vegetation.

Then, a final visual interpretation step is done by the photo-interpreter to refine the automatically assigned land cover code. This phase is supported by the use of very high-resolution images (i.e. Google Maps, Bing) and the large numbers of ancillary data collected. The aim of this final review is to increase the accuracy of the land cover dataset, by interpreting the land cover also at a more detailed scale (i.e. state and county levels).

The final land cover dataset must show the overall characteristics of:

- reliability;
- logical consistency, and
- completeness.

The reliability affects the usability and life expectancy of the product. Indeed, data suitable for one application may not be fit for use for another. Anyhow, the overall quality of the output must reflect a general logical consistency and completeness of the data represented accordingly with the scale, data source and compilation method. The finalization of the land cover dataset refers to a series of steps necessary for the generation of a consistent dataset at country level. These steps include:

- final review;
- tile/county matching;
- topology check;
- dataset harmonization (i.e adjustments for bordering polygons, overlaps, gaps etc.), and
- generation of the outputs.

Harmonization is the process of adjusting differences and inconsistencies among the different interpretation layers within the country to consolidate the fifteen tiles in one consistent final dataset. The harmonization is essential to generate a consistent land cover model of the country minimizing the differences and subjectivity of the different interpreters.

2.7 Accuracy assessment

When dealing with mapping, two basic parameters have to be considered: accuracy and precision. The accuracy refers to the closeness of a measured value to a standard or known value, while the precision refers to the closeness of two or more measurements to each other.

In general, the level of accuracy and precision required for particular applications varies greatly, and highly precise data can be very difficult and costly to produce and/or collect. The attribute accuracy is another parameter which influences the quality of the land cover dataset, depending on the quality of the interpretation provided and the degree of correspondence between the data and the real world. This is the parameter that most influences the final quality of the land cover dataset. The ability to achieve this correspondence also depends on the development of a realistic legend and class structure, and photo-keys that help to ensure that the features are correctly interpreted.

To systematically describe the accuracy, a matrix of omission and commission (confusion matrix) within the classification interpretation (for manual or automated classification systems) is usually build. This kind of matrix is typically generated against the EO data based land cover classification and ground survey validation samples. Validation may also be undertaken against classifications made from higher-resolution imagery or aerial surveys (e.g. Google Earth, Bing), rather than all through field-based methods.

The accuracy assessment was undertaken through random stratified samples validated using data from Google Earth. For each land cover map at county level the number of samples was calculated proportionally to the extension of each land cover class. The accuracy assessment has been calculated for various counties (Torit, Twic, Kapoeta South, Abyei and Renk) that present different extensions and complexity. The results of the confusion matrix for the county of Renk are shown in Table 3.

The accuracy parameters calculated are:

- Overall accuracy: proportion of correctly classified land cover. Sum of the correct classifications (diagonal elements) divided by the number of samples (for the county of Renk, a total of 1 058 samples was extracted).
- User's accuracy: per class probability that a sample unit in the map belongs to the same class on the ground. The diagonal elements are divided by the classification total.
- Producer´s accuracy: per class probability that a unit on the ground is classified in the same class on the map. The diagonal elements are divided by the reference total.

The overall accuracy is obviously dependent on the number of interpreted classes. By increasing the thematic detail, inevitably the overall accuracy tends to decrease for spectrally similar classes. Merging similar classes increases the overall classification accuracy. The analysis is however very sensitive and obviously the final value of the accuracy can be further improved depending on the resources and time available.

Table 3. Confusion matrix for the county of Renk

Confusion matrix	BS	BU	CCW	CU	CU1	HCIR	HCO	HCRml	HCRs	HCS	HCW	HCWs	OCW	RA	RB	RnP	RP	TC	TO	WBnP	WBP	TOTAL	USER'S ACCURACY (%)
BS	48						7			4										1		60	80%
BU	1	1								1												3	33%
CCW			4																			4	100%
CU				2																		2	100%
CU1	1				1		2															4	25%
HCIR						18																18	100%
HCO	19						244				1		3						5			272	90%
HCRml						3	1	237	7	3									2			253	94%
HCRs									6	1												7	86%
HCS	7						83	1	2	95	1		1					7	17			214	44%
HCW	3		1				2	4	1		27		3									41	66%
HCWs								2				8	1						1			12	67%
OCW			1										7									8	88%
RA														2								2	100%
RB	5									1	3				2							11	18%
RnP											2					0						2	0%
RP																	3					3	100%
TC							1											22	4			27	81%
TO	4									4			3					6	94			111	85%
WBnP													1							1		2	50%
WBP																					2	2	100%
TOTAL	88	1	6	2	1	21	338	246	15	109	30	13	19	2	2	0	3	35	124	1	2	1 058	
PRODUCER'S ACCURACY (%)	55%	100%	67%	100%	100%	86%	72%	96%	40%	87%	90%	62%	37%	100%	100%	0%	100%	63%	76%	100%	100%		OVERALL ACCURACY 824 (77.8%)

Source: Authors' own elaboration

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 – FALSE COLOR (November 2017)	GOOGLE EARTH

HCRs

HERBACEOUS CROP RAINFED (SMALL FIELDS)
Small contiguous and isolated rainfed crop fields occasionally with scattered natural trees. Field size ≥ 1–2 ha. Predominant crop types: maize, sesame and sorghum. This class is predominantly located in Upper Nile and Western Bahr El Ghazal states.

Herbaceous Crop Rainfed
Map Code: HCRs

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory

Cultivated and Managed Vegetation

Rainfed

Field Size
Size: min=1.0 max=2.0

HCRml

HERBACEOUS CROP RAINFED (MEDIUM/LARGE FIELDS)
Medium to large contiguous rainfed crop fields occasionally with scattered natural trees. Field size ≥ 2–100 ha. Predominant crop types: maize, sesame and sorghum. This class is predominantly located in Upper Nile and Western Bahr El Ghazal states.

Herbaceous Crop Rainfed
Map Code: HCRml

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop : 0

Herbaceous Growth Forms
Presence type: Mandatory

Cultivated and Managed Vegetation

Rainfed

Field Size
Size: min=2.0 max=100.0
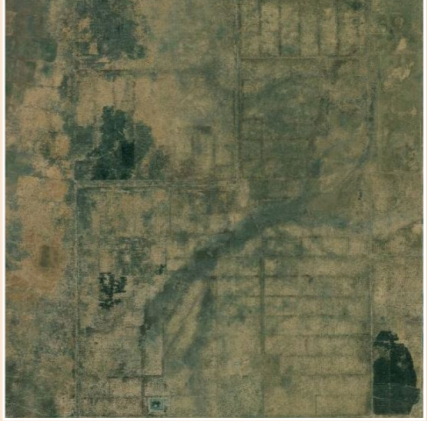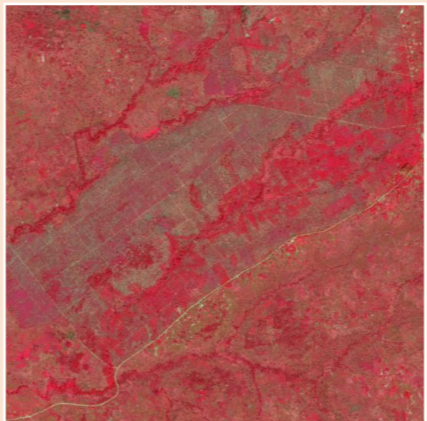
LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH

HCI

HERBACEOUS CROP IRRIGATED
Land cultivated and permanently irrigated. This class includes also post flooding areas with cultivations found regularly distributed along the rivers. Crop fields can have different sizes and different growth forms (herbaceous and shrubs).

▶ **Herbaceous Irrigated Crop**
Map Code: HCIR

| Horizontal Pattern 1 | — | Stratum 1 Presence type: Mandatory Ontop: 0 | — | Herbaceous Growth Forms Presence type: Mandatory | — | Cultivated and Managed Vegetation | — | Irrigation |

TPL

TREE CROP PLANTATION
Cultivated and managed vegetation with the uppermost canopy layer dominated by trees. Planted tree with high coverage (60–100%). Regular orchards plantations.

▶ **Tree Crop**
Map Code: TPL

| Horizontal Pattern 1 | — | Stratum 1 Presence type: Mandatory Ontop : 0 | — | Herbaceous Growth Forms Presence type: Mandatory | — | Cultivated and Managed Vegetation | — | Orchard and other Plantation / Rainfed |

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
CU	**MIXED UNIT (RURAL SETTLEMENTS - NATURAL VEGETATION - HERBACEOUS CROP RAINFED)** Areas characterized by rural settlements interspersed in a significant fraction of natural vegetation. Small rainfed crop fields are present with different percentage depending on specific zones.		

Complex Unit
Map Code: CU

- **Rural Settlement**
  - **Stratum 1** Presence type: Mandatory Ontop: 0
    - **Building** Presence type: Mandatory Cover: min=0.0 max=50.0 Construction Material: Light Material
      - **Construction Use** Type: Small buildings associated to rural areas

- **Natural Vegetation**
  - **Stratum 1** Presence type: Mandatory Ontop: 0
    - **Growth Forms** Presence type: Mandatory Cover: min=40.0 max=80.0
      - **Natural or Seminatural Vegetation**

- **Crop Fields**
  - **Stratum 1** Presence type: Optional Ontop: 0
    - **Herbaceous Growth Forms** Presence type: Mandatory Cover: min=0.0 max=20.0
      - **Cultivated and Managed Vegetation**
        - **Rainfed**
        - **Field Size** Size: min=0.0 max=10.0

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
CU1	**MIXED UNIT (HERBACEOUS CROP RAINFED - NATURAL VEGETATION - RURAL SETTLEMENTS)** Areas principally occupied by agriculture (small crop fields) interspersed in a significant fraction of natural vegetation. Rural settlements can be also present.		
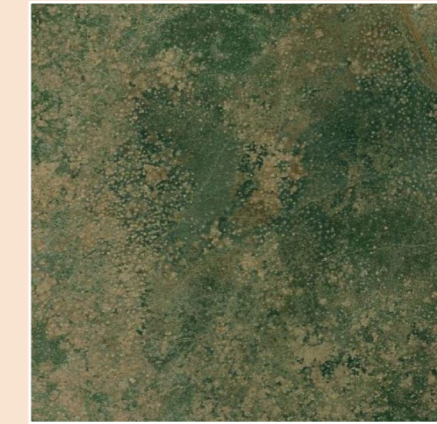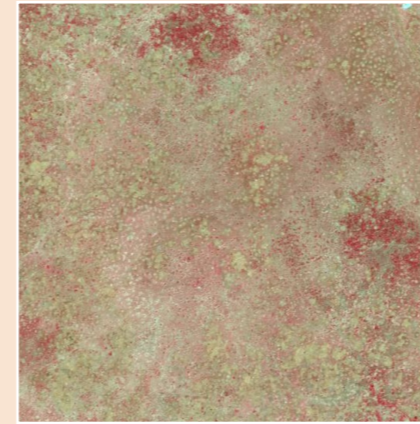
Complex Unit 1
Map Code: CU1

Crop Fields

Stratum 1
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory
Cover: min=10.0 max=50.0

Cultivated and Managed Vegetation

Rainfed

Field Size
Size: min=2.0 max=10.0

Natural Vegetation

Stratum 1
Presence type: Mandatory
Ontop: 0

Growth Forms
Presence type: Mandatory

Natural or Seminatural Vegetation

Settlements

Stratum 1
Presence type: Optional
Ontop: 0

Building
Presence type: Mandatory
Construction Material: Light Material

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
CUsh	**MIXED UNIT (HERBACEOUS CROP RAINFED – NATURAL VEGETATION)** Areas occupied by agriculture interspersed in a significant fraction of natural vegetation in almost equal percentage. The boundaries of the single elements are vague and indistinct. Shifting cultivation is the practice indicated for this unit. Rural settlements can be also present but they are not significant elements in the composition of the class.		
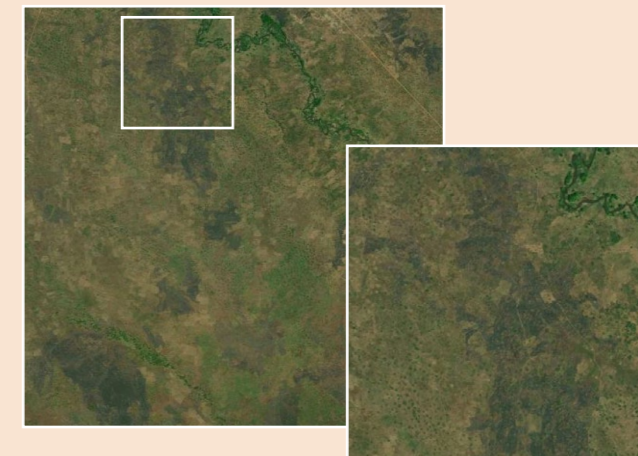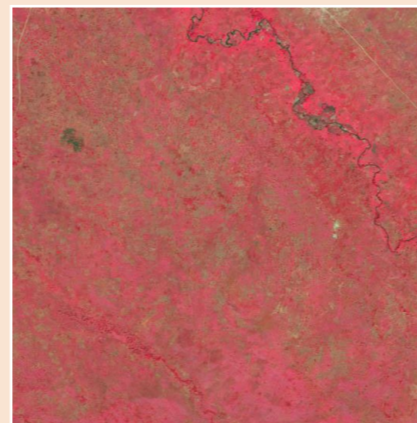
Complex Unit Shifting Cultivation
Map Code: CUsh
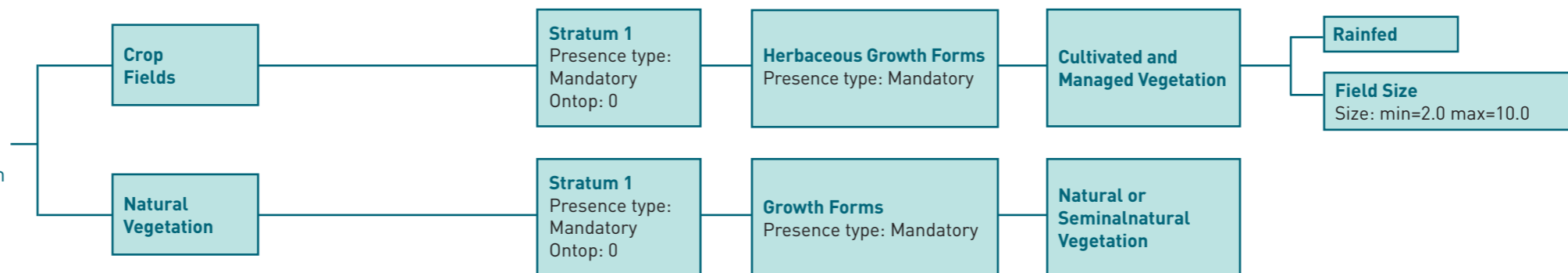
- Crop Fields
  - Stratum 1
    Presence type: Mandatory
    Ontop: 0
    - Herbaceous Growth Forms
      Presence type: Mandatory
      - Cultivated and Managed Vegetation
        - Rainfed
        - Field Size
          Size: min=2.0 max=10.0
- Natural Vegetation
  - Stratum 1
    Presence type: Mandatory
    Ontop: 0
    - Growth Forms
      Presence type: Mandatory
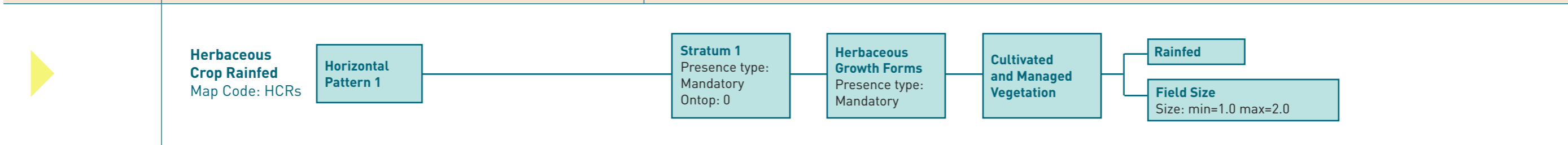   - Natural or Seminalnatural Vegetation

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH

RA

RURAL SETTLEMENT
Low-density urban built-up areas with small cultivated herbaceous crops and/or orchards and other plantations.
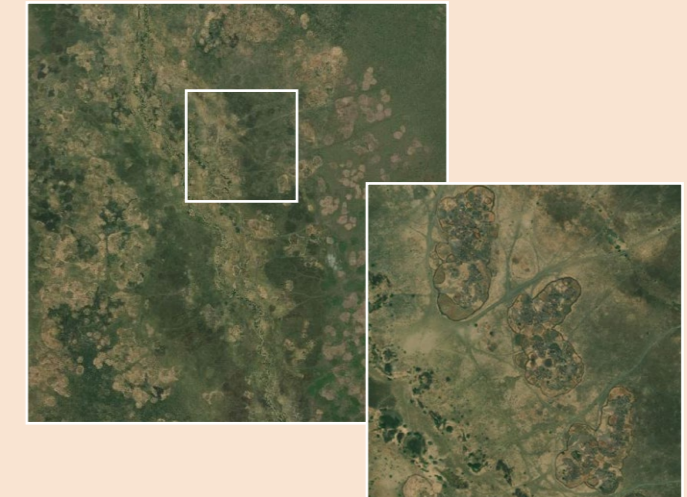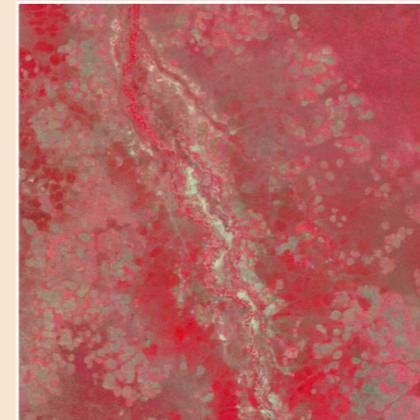
Rural Settlement
Map Code: RA
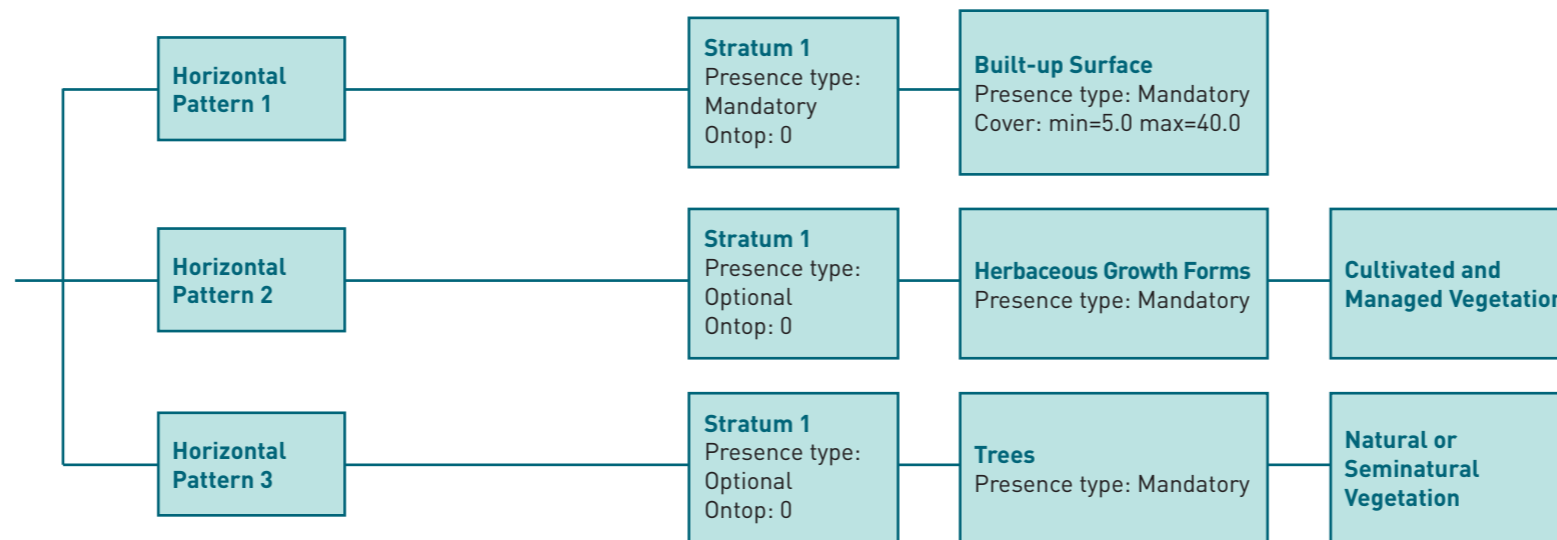
Horizontal Pattern 1 → **Stratum 1**
Presence type: Mandatory
Ontop: 0 → **Built-up Surface**
Presence type: Mandatory
Cover: min=5.0 max=40.0

Horizontal Pattern 2 → **Stratum 1**
Presence type: Optional
Ontop: 0 → **Herbaceous Growth Forms**
Presence type: Mandatory → **Cultivated and Managed Vegetation**

Horizontal Pattern 3 → **Stratum 1**
Presence type: Optional
Ontop: 0 → **Trees**
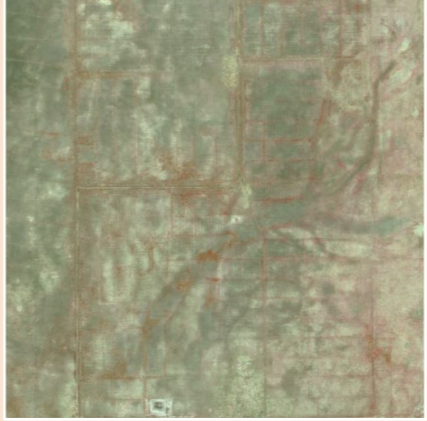Presence type: Mandatory → **Natural or Seminatural Vegetation**

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
BU	**BUILT-UP AREA** The land is covered by buildings, roads and artificial surfaced areas. Coverage from high to medium density. Different types of build-up are included in this class (i.e. urban, airports, oilfields).		
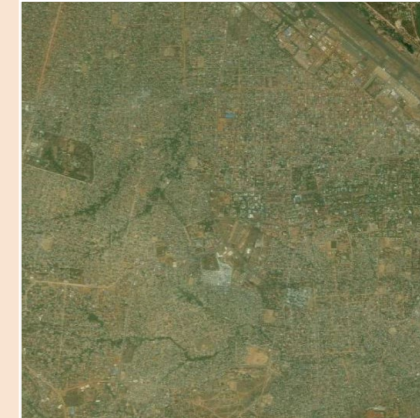
Built-Up Area
Map Code: BU

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Building
Presence type: Mandatory

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
BS	**BARE SOIL** Bare and undifferentiated areas not used for cultivation and usually devoid of grass and shrub cover. Salty surfaces are also included in this class.		

Bare Soil
Map Code: BS

Horizontal Pattern 1

Stratum 1
Presence type: Optional
Ontop: 0

Bare Soil
Presence type: Mandatory

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
RB	**RIVER BANK** River bank (soil/sand deposits) with perennial/periodic flowing fresh water. Riverbank is the land above or the ground alongside the edge of a river. Water presence is optional.		
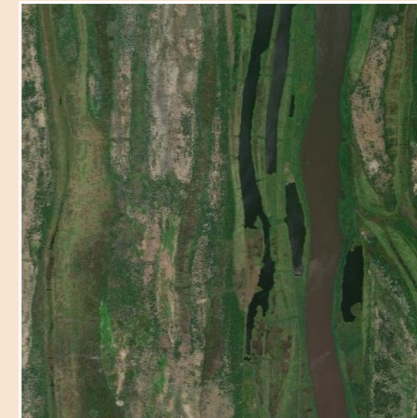
River Bank
Map Code: RB

Horizontal Pattern 1

Stratum 2
Presence type: Mandatory
Ontop: 0

Growth Forms
Presence type: Mandatory
Cover: min=0.0 max=20.0

Stratum 1
Presence type: Optional
Ontop: 0

Soil Sand Deposit Surface
Presence type: Mandatory

Stratum 3
Presence type: Optional
Ontop: 0
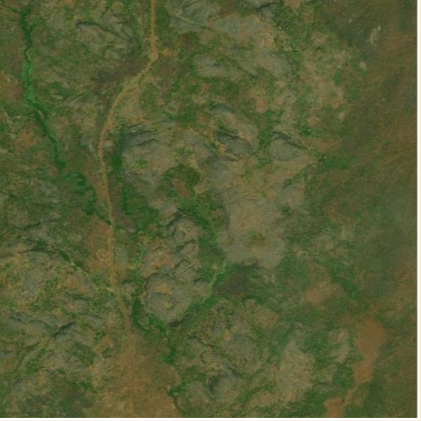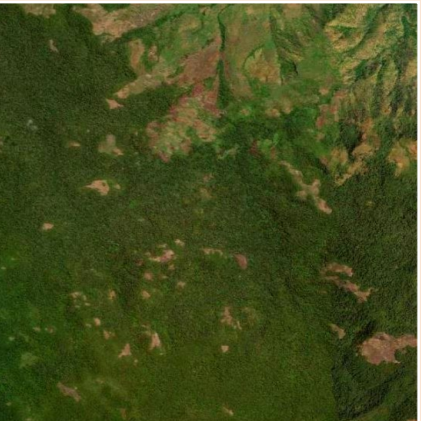
Water Body
Presence type: Mandatory
Dynamics: Flowing
Position: Above Surface
Periodic Variation / Periodic Variation:
- Description: Describe a periodic variation element
- Persistence Units: Months

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
BR	**BARE ROCK** Rock outcrops usually devoid of grass and shrub cover. Inselberg are typically in this area. It is an isolated rock hill, knob, ridge, or small mountain that rises abruptly from a gently sloping or virtually level surrounding plain.		

▶ **Bare Rock**
Map Code: BR

| Horizontal Pattern 1 | Stratum 1
Presence type: Mandatory
Ontop: 0 | Bare Rocks
Presence type: Mandatory |

| TC and TCm | **CLOSED WOODY VEGETATION AND CLOSED WOODY VEGETATION ON MOUNTAIN AREAS**
Natural closed trees and shrubs, with cover between 40–100%. TCm class is found above 2 500m asl. | | |

▶▶ **Woodland (Closed)**
Map Code: TC

| Horizontal Pattern 1 | Stratum 1
Presence type: Mandatory
Ontop : 0 | Woody Growth Forms
Presence type: Mandatory
Cover: min=40.0 max=100.0 |

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
TO and TOm	**OPEN WOODY VEGETATION AND OPEN WOODY VEGETATION ON MOUNTAIN AREAS** Natural open woodland with cover between 10–40%. Occasionally with sparse or closed herbaceous vegetation cover. TOm is found above 2 500m asl.		
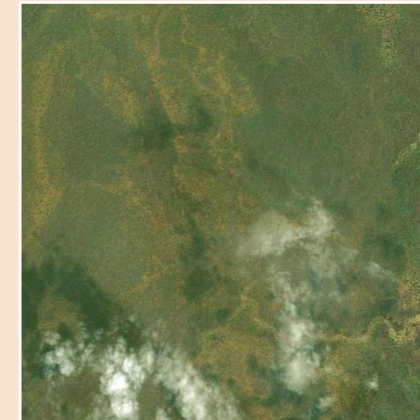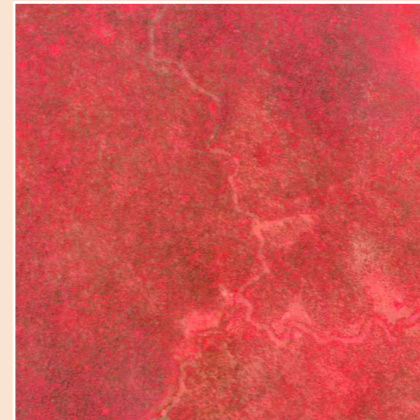
Woodland (Open)
Map Code: TO
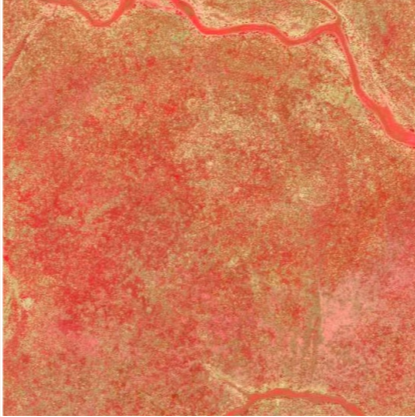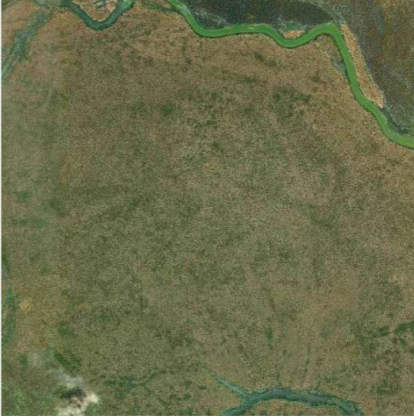
Horizontal Pattern 1 ── Stratum 1
Presence type: Mandatory
Ontop: 0 ── Woody Growth Forms
Presence type: Mandatory
Cover: min=10.0 max=40.0

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH

| HCO | **HERBACEOUS CLOSED TO OPEN (WITH SPARSE WOODY VEGETATION)** Relatively dense herbaceous natural vegetation (with cover between 10–100%), occasionally with sparse shrubs and trees (< 10 %). | | |

Herbaceous closed to open (with sparse woody vegetation)
Map Code: HCO

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory
Cover: min=10.0 max=100.0

Natural or Seminatural Vegetation

Stratum 2
Presence type: Optional
Ontop: 0

Trees
Presence type: Mandatory
Cover: min=1.0 max=10.0

Natural or Seminatural Vegetation

Stratum 3
Presence type: Optional
Ontop: 0

Shrubs
Presence type: Mandatory
Cover: min=1.0 max=10.0

Natural or Seminatural Vegetation

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
HCS	**GRASSLAND** Relatively dense to sparse natural herbaceous vegetation cover.		
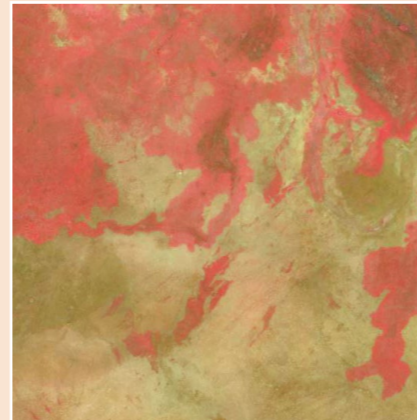
Grassland
Map Code: HCS

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory
Cover: min=1.0 max=99.0
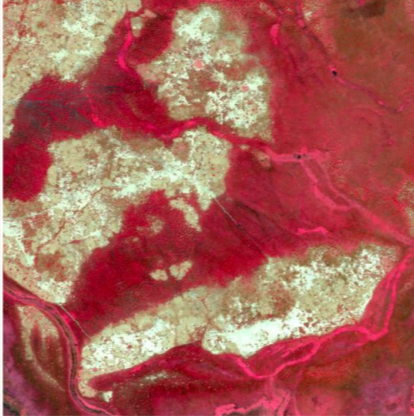
Natural or Seminatural Vegetation

CCW

CLOSED WOODY VEGETATION ON WETLAND
This class includes forested/shrubland areas, dominated by trees.
It is a low-lying land usually flooded or liable to flooding by fresh, stagnant or circulating water.

Woodland (Closed) on Wetland
Map Code: CCW

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Wood Growth Forms
Presence type: Mandatory
Cover: min=40.0 max=100.0

Stratum 2
Presence type: Mandatory
Ontop: 0

Water Body
Presence type: Mandatory
Position: Above Surface
Periodic Variation / Periodic Variation:
- Description: Describe a periodic variation element
- Persistence Units: Months

Water Salinity
Type: Fresh

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH

| OCW | **OPEN WOODY VEGETATION ON WETLAND**
This class includes areas mainly covered by trees and shrubs often with herbaceous vegetation. Dominated by shrub and herbaceous life form.
It is a low-lying land usually flooded or liable to flooding by fresh, stagnant or circulating water. | | |
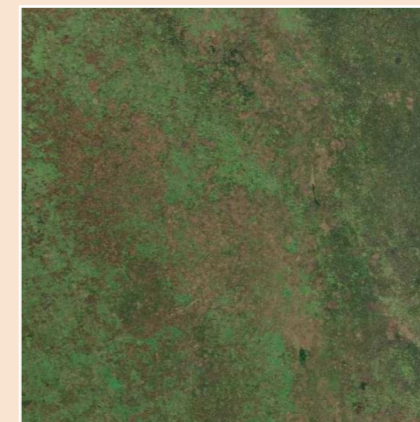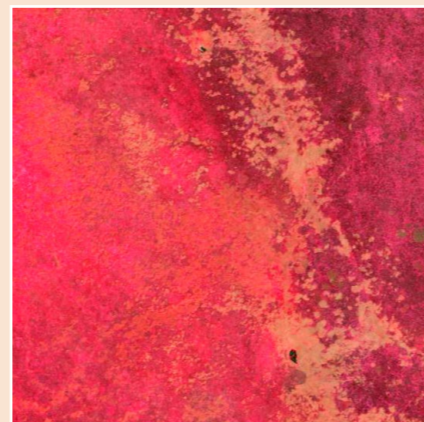
Woodland (Open) on Wetland
Map Code: OCW

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Woody Growth Forms
Presence type: Mandatory
Cover: min=5.0 max=40.0

Stratum 2
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory

Natural or Seminatural Vegetation

Stratum 3
Presence type: Mandatory
Ontop: 0

Water Body
Presence type: Mandatory
Periodic Variation / Periodic Variation:
- Description: Describe a periodic variation element
- Persistence Units: Months

Water Salinity
Type: Fresh

HCW and HCWs

GRASSLAND ON WETLAND
This class includes non-forested area covered by herbaceous vegetation. Dominated by herbaceous life form.
It is a low-lying land usually flooded or liable to flooding by fresh, stagnant or circulating water. The class HCWs (Seasonal Wetland) is characterized periodical inundations (< 2–4 months).
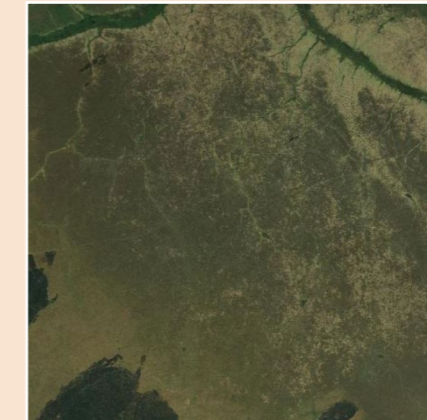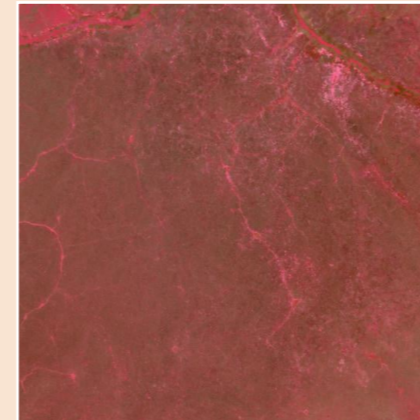
Grassland on Wetland
Map Code: HCW

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Herbaceous Growth Forms
Presence type: Mandatory
Cover: min=1.0 max=100.0

Natural or Seminatural Vegetation

Stratum 2
Presence type: Mandatory
Ontop: 0

Water Body
Presence type: Mandatory
Periodic Variation / Periodic Variation:
- Description: Describe a periodic variation element
- Persistence Units: Months

Water Salinity
Type: Fresh

LAND COVER CODE	CLASS NAME DESCRIPTION	SENTINEL 2 - FALSE COLOR (November 2017)	GOOGLE EARTH
WBP and WBnP	**WATER BODY PERENNIAL AND NON-PERENNIAL** Natural perennial and non-perennial fresh water bodies (standing) with oscillations in water level with closed/open natural herbaceous vegetation. Artificial water bodies are also included in this class. Marshes can often be found at the edges of lakes and streams, where they form a transition between the aquatic and terrestrial ecosystems.		
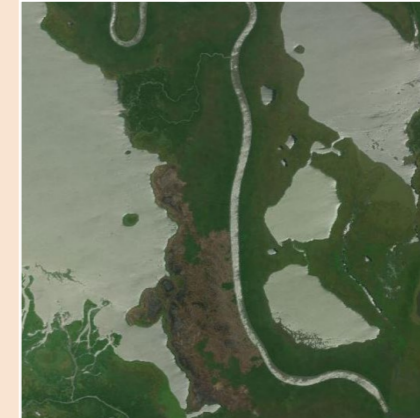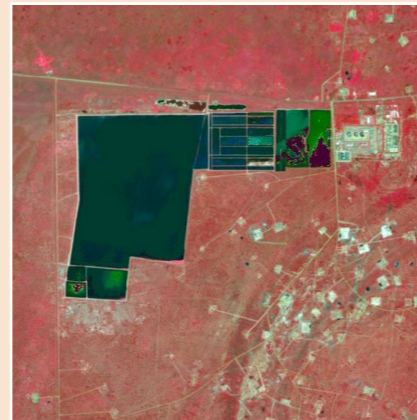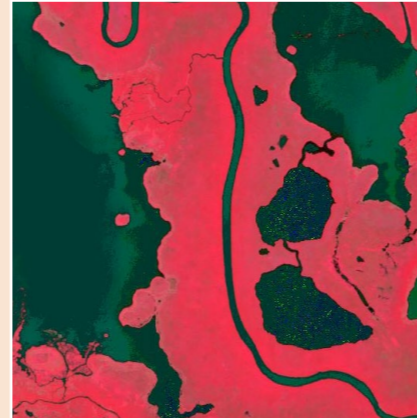
Water Bodies Perennial
Map Code: WBP

- Horizontal Pattern 1
  - Stratum 1
    Presence type: Mandatory
    Ontop: 0
    - Water Body
      Presence type: Mandatory
      - Artificiality
        Type: Natural
      - Water Salinity
        Type: Fresh

Water Bodies Non-Perennial
Map Code: WBnP

- Unconsolidated Surface Characteristics
- Horizontal Pattern 1
  - Stratum 1
    Presence type: Mandatory
    Ontop: 0
    - Water Body and Associated Surface
      Presence type: Mandatory
      Periodic Variation / Periodic Variation:
      - Description: Describe a periodic variation element
      - Period Type: Atmospheric
      - Persistence Units: Months
      - Artificiality
        Type: Natural
      - Water Salinity
        Type: Fresh

RP and RnP	**RIVER PERENNIAL AND NON-PERENNIAL** Water course. Natural waterbody flowing (fresh water) RnP class includes water courses with water periodic variation 0–12 months.		
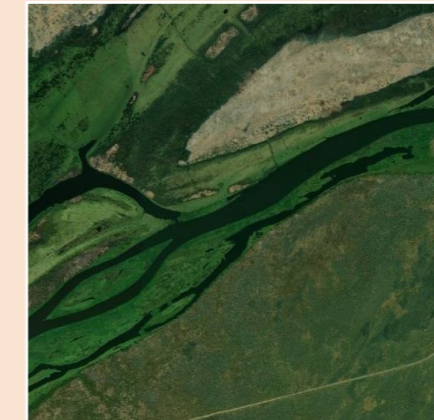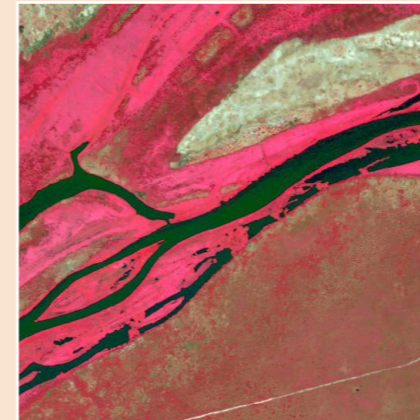
River Perennial
Map Code: RP

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Water Body
Presence type: Mandatory
Dynamics: Flowing
Position: Above Surface

Artificiality
Type: Natural

Water Salinity
Type: Fresh

River Non-Perennial
Map Code: RnP

Unconsolidated Surface Characteristics

Horizontal Pattern 1

Stratum 1
Presence type: Mandatory
Ontop: 0

Water Body
Presence type: Mandatory

Artificiality
Type: Natural

Water Salinity
Type: Fresh

MAPS

4

South Sudan

South Sudan is a landlocked country bordered by Sudan in the north, Ethiopia and Kenya in the east, Uganda and the Democratic Republic of Congo in the south, and the Central African Republic in the west. South Sudan is constituted by 10 states, each state is further divided into counties.

The main feature of the country is the White Nile river extending over clay plains and slopes gradually rising southward to mountains up to 3 000 meters above sea level in the Imatong Hills. The Sudd wetland is the inland delta of the White Nile and one of the largest swamps worldwide. The forest resources of South Sudan cover approximately 37 percent of the total area of the country. Natural forests are diverse including rainfall savannah, woodlands and special areas of mountainous vegetation, making it one of the richest areas of concentrations of biodiversity in Africa. Herbaceous vegetation covers around 38 percent of the total area of the country.

Agriculture is estimated at about 6 846 km^2 and is mainly found in Upper Nile, Central and Eastern Equatoria states. However, cultivable area is also a consistent part of the Mixed Unit classes, where areas under crops is interspersed with natural vegetation and rural settlements.

Cereals, primarily sorghum and maize, millet and rice are the dominant staple crops in South Sudan.
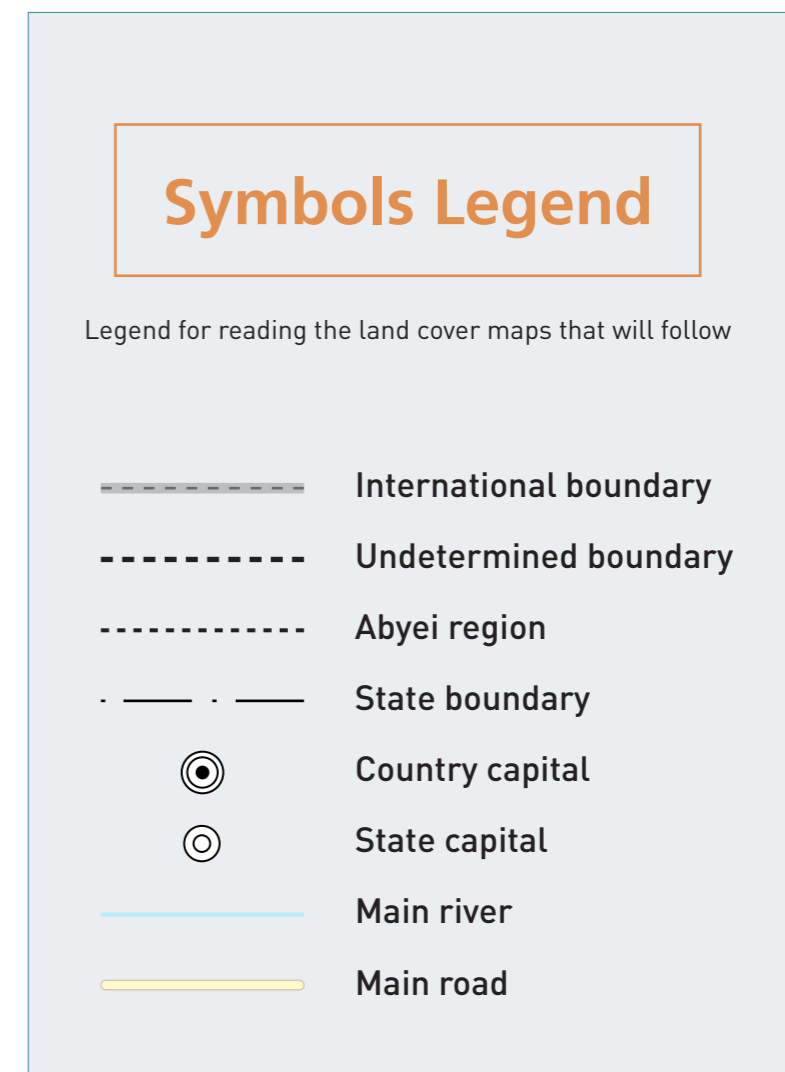
Symbols Legend

Legend for reading the land cover maps that will follow

―――――	**International boundary**
‑ ‑ ‑ ‑ ‑	**Undetermined boundary**
· · · · · ·	**Abyei region**
· ― · ―	**State boundary**
◉	**Country capital**
◎	**State capital**
――――――	**Main river**
――――――	**Main road**

Notes: Country and states boundaries on this map do not imply acceptance or recognition by the Government of South Sudan. Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

Sources: United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

Land Cover Class		Central Equatoria	Eastern Equatoria	Jonglei	Lakes	Northern Bahr el Ghazal	Unity	Upper Nile	Warrap	Western Bahr el Ghazal	Western Equatoria	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED													
Herbaceous crop rainfed (small fields)		636.2	574.5	25.7	111.8	101.3	415.7	3 956.2	175.7	321.6	118.2	6 436.9	1.0
Herbaceous crop rainfed (medium/large fields)													
HERBACEOUS CROP IRRIGATED													
Herbaceous crop irrigated		0.0	0.0	0.0	0.0	0.0	0.0	342.6	0.0	0.0	0.0	342.6	0.1
TREE CROP PLANTATION													
Tree crop plantation		18.7	0.0	0.0	24.2	0.0	0.0	0.50	2.5	1.5	18.6	66.1	0.0
MIXED UNIT													
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		2 627.3	1 169.4	1 807.3	2 915.6	6 386.7	1 393.2	944.0	6 485.4	1 961.0	2 548.3	28 238.0	4.4
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)													
Mixed unit (herbaceous crop rainfed - natural vegetation)													
BUILT-UP													
Rural settlement		133.5	88.6	125.2	43.7	85.1	182.6	220.7	349.5	49.2	52.4	1 330.4	0.2
Built-up area													
BARE AREAS													
Bare soil		104.5	259.4	298.3	343.8	106.0	240.3	1 915.6	235.1	420.6	760.7	4 684.2	0.7
River bank													
Bare rock													
CLOSED NATURAL VEGETATION													
Closed woody vegetation		4 795.0	6 545.1	6 342.2	1 347.9	1 764.7	897.1	1 935.9	1 943.7	22 747.3	12 779.2	61 098.1	9.6
Closed woody vegetation on mountain areas													
OPEN NATURAL VEGETATION													
Open woody vegetation		17 981.3	29 092.4	28 555.2	7 990.2	8 583.0	4 957.7	11 170.8	5 615.3	33 097.6	23 234.5	1 170 278.0	26.8
Open woody vegetation on mountain areas													
GRASSLAND													
Herbaceous closed to open (with sparse woody vegetation)		12 617.4	28 580.1	48 487.3	19 640.5	9 874.8	16 472.1	41 788.1	10 631.4	19 334.2	32 608.6	240 034.5	37.8
Grassland													
VEGETATION on WETLAND AREAS													
Closed woody vegetation on wetland		4 021.9	6 862.5	35 383.3	10 455.1	4 189.8	12 160.8	14 419.3	10 286.5	14 481.5	7 392.0	119 652.8	18.8
Open woody vegetation on wetland													
Grassland on wetland													
Seasonal wetland													
PERENNIAL WATER BODIES													
Water body perennial / artificial pond		120.3	14.5	669.5	270.5	55.8	326.2	397.4	203.8	74.5	45.4	2 177.9	0.3
River perennial													
SEASONAL WATER BODIES													
Water body seasonal		14.5	84.3	161.1	163.4	25.9	107.3	90.5	85.0	39.0	1.2	772.0	0.1
River seasonal													
TOTAL LAND		43 070.6	73 270.9	121 854.7	43 306.6	31 173.1	37 152.9	77 181.7	36 013.9	92 527.9	79 559.1	635 111.4	100
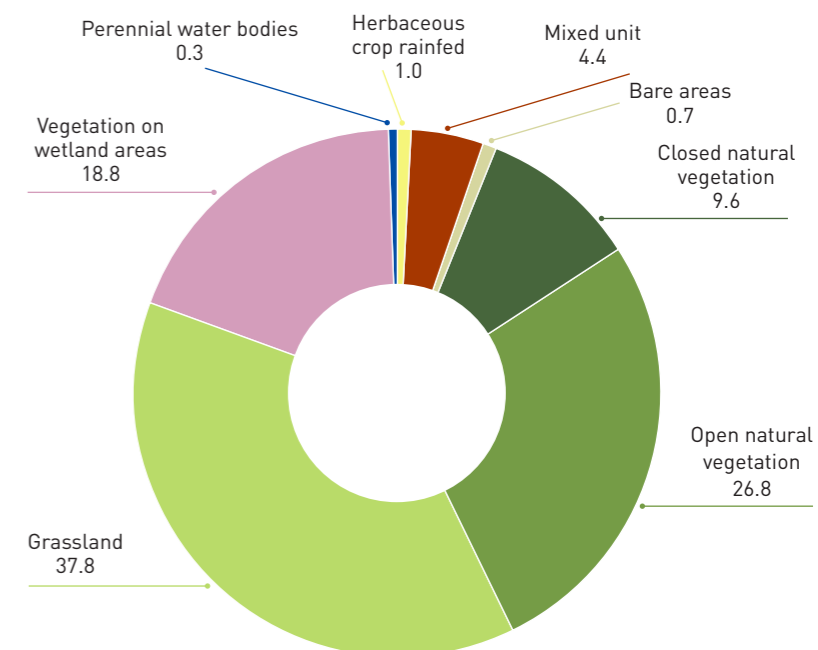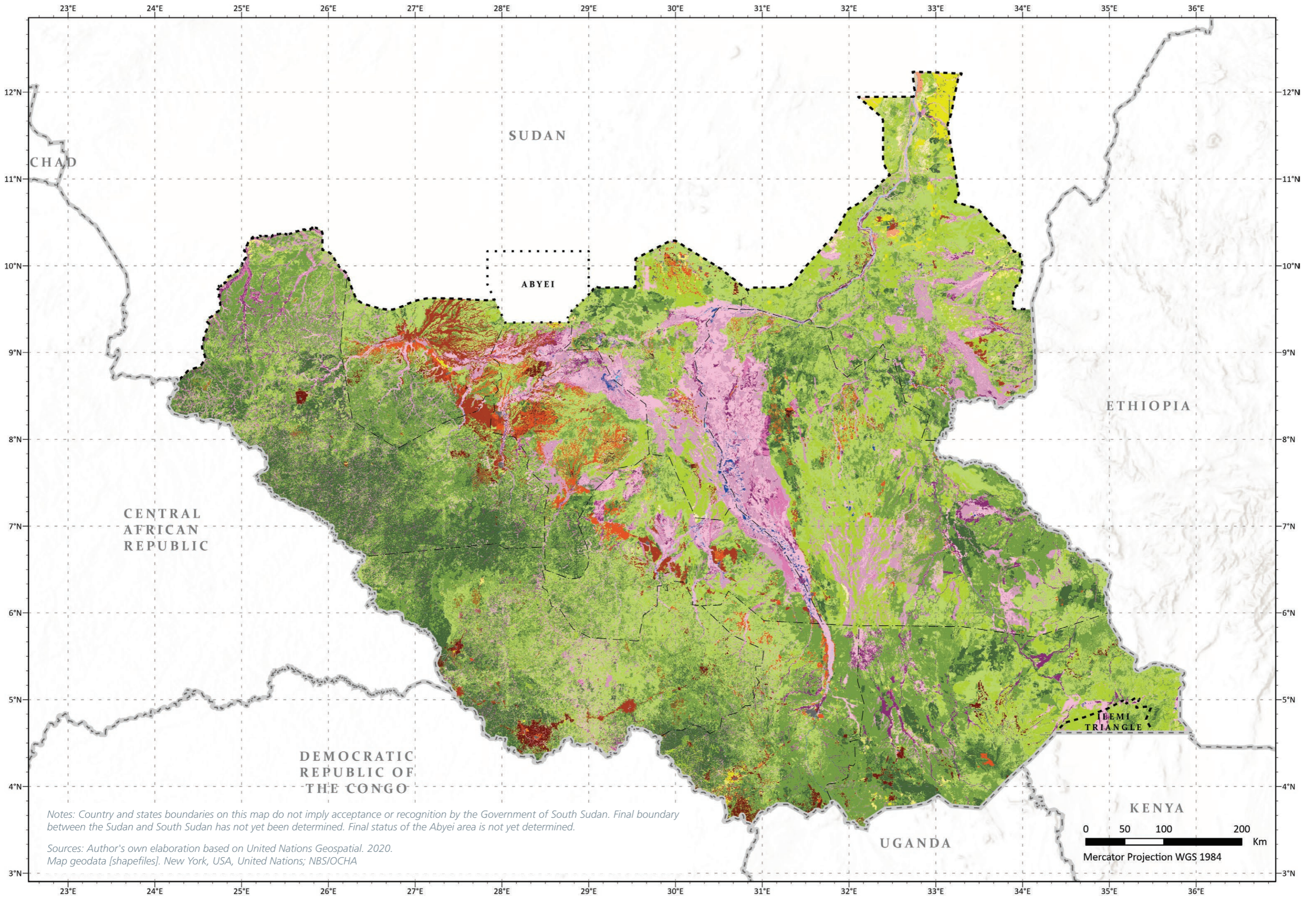
© FAO/Stefanie Glinski

Perennial water bodies 0.3
Herbaceous crop rainfed 1.0
Mixed unit 4.4
Bare areas 0.7
Closed natural vegetation 9.6
Vegetation on wetland areas 18.8
Open natural vegetation 26.8
Grassland 37.8

CHAD

SUDAN

CENTRAL
AFRICAN
REPUBLIC

ABYEI

ETHIOPIA

DEMOCRATIC
REPUBLIC OF
THE CONGO

LEMI
TRIANGLE

KENYA

UGANDA

0   50   100   200
                                    Km

Mercator Projection WGS 1984

Central Equatoria

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

Land Cover Class		Juba	Kajo-keji	Lainya	Morobo	Terekeka	Yei	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED									
Herbaceous crop rainfed (small fields)		46.0	0.8	74.9	108.0	6.2	400.4	636.2	1.5
Herbaceous crop rainfed (medium/large fields)									
HERBACEOUS CROP IRRIGATED									
Herbaceous crop irrigated		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION									
Tree crop plantation		0.0	0.0	15.5	0.0	0.0	3.2	18.7	0.0
MIXED UNIT									
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		358.9	325.4	235.7	534.2	728.6	444.6	2 627.3	6.1
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)									
Mixed unit (herbaceous crop rainfed - natural vegetation)									
BUILT-UP									
Rural settlement		113.2	0.9	1.3	0.2	2.9	15.1	133.5	0.3
Built-up area									
BARE AREAS									
Bare soil		54.1	6.7	11.2	6.9	10.4	15.1	104.5	0.2
River bank									
Bare rock									
CLOSED NATURAL VEGETATION									
Closed woody vegetation		777.9	477.6	376.0	125.8	79.6	2 958.2	4 795.0	11.1
Closed woody vegetation on mountain areas									
OPEN NATURAL VEGETATION									
Open woody vegetation		10 233.4	1 554.1	1 403.3	404.8	3 071.7	1 314.0	17 981.3	41.7
Open woody vegetation on mountain areas									
GRASSLAND									
Herbaceous closed to open (with sparse woody vegetation)		4 952.9	105.9	1 222.5	151.7	5 187.5	996.9	12 617.4	29.3
Grassland									
VEGETATION on WETLAND AREAS									
Closed woody vegetation on wetland		1 759.2	25.8	159.3	5.4	1 530.7	541.5	4 021.9	9.3
Open woody vegetation on wetland									
Grassland on wetland									
Seasonal wetland									
PERENNIAL WATER BODIES									
Water body perennial / artificial pond		63.9	4.0	1.7	0.1	48.1	2.5	120.3	0.3
River perennial									
SEASONAL WATER BODIES									
Water body seasonal		5.6	0.1	0.2	0.0	8.0	0.6	14.5	0.0
River seasonal									
TOTAL LAND		18 365.2	2 501.1	3 501.6	1 336.9	10 673.8	6 692.0	43 070.6	100.0

Central Equatoria state is located in the southern part of the country, bordering with Uganda and Democratic Republic of Congo.

Most of the land is covered by natural vegetation, mainly open vegetation with shrubs and grassland (42 and 30 percent of the total area respectively). Herbaceous crops cultivations cover 1.5 percent of the total land.

Vegetation on wetland areas 9.3
Herbaceous crop rainfed 1.5
Mixed unit 6.1
Built-up 0.3
Closed natural vegetation 11.1
Open natural vegetation 41.7
Grassland 29.3

Eastern Equatoria

Land Cover Class	Budi	Ikotos	Kapoeta East	Kapoeta North	Kapoeta South	Lafon	Magwi	Torit	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED										
Herbaceous crop rainfed (small fields)	12.6	111.3	33.5	0.0	7.5	80.3	193.3	136.1	574.5	0.8
Herbaceous crop rainfed (medium/large fields)										
HERBACEOUS CROP IRRIGATED										
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION										
Tree crop plantation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIXED UNIT										
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	141.8	56.0	282.8	167.8	4.9	16.9	291.7	207.5	1 169.4	1.6
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)										
Mixed unit (herbaceous crop rainfed - natural vegetation)										
BUILT-UP										
Rural settlement	0.1	3.6	17.7	23.8	17.5	1.3	13.5	11.1	88.6	0.1
Built-up area										
BARE AREAS										
Bare soil	6.6	9.2	197.0	9.7	16.0	5.4	9.4	6.1	259.4	0.4
River bank										
Bare rock										
CLOSED NATURAL VEGETATION										
Closed woody vegetation	989.2	581.5	1 095.4	886.0	97.2	1 019.9	570.8	1 305.0	6 545.1	8.9
Closed woody vegetation on mountain areas										
OPEN NATURAL VEGETATION										
Open woody vegetation	2 527.7	2 130.1	7 153.7	1 368.0	222.2	9 273.9	3 690.2	2 726.6	29 092.4	39.7
Open woody vegetation on mountain areas										
GRASSLAND										
Herbaceous closed to open (with sparse woody vegetation)	1 729.2	505.8	18 307.6	3 237.2	818.2	3 161.3	226.2	594.6	28 580.1	39.0
Grassland										
VEGETATION on WETLAND AREAS										
Closed woody vegetation on wetland	311.6	109.3	2 707.3	31.0	9.7	2 671.0	176.3	846.4	6 862.5	9.4
Open woody vegetation on wetland										
Grassland on wetland										
Seasonal wetland										
PERENNIAL WATER BODIES										
Water body perennial / artificial pond	0.0	0.0	0.0	0.0	0.0	0.1	14.0	0.3	14.5	0.0
River perennial										
SEASONAL WATER BODIES										
Water body seasonal	13.8	0.8	46.2	5.4	6.3	1.0	10.2	0.5	84.3	0.1
River seasonal										
TOTAL LAND	**5 732.6**	**3 507.6**	**29 841.1**	**5 729.0**	**1 199.4**	**16 231.1**	**5 195.8**	**5 834.2**	**73 270.9**	**100**

Eastern Equatoria state is located in the southeastern region of the country, bordering with Uganda, Kenya and Ethiopia on the east.

Open vegetation is the most represented land cover class. Most of the land is covered by natural vegetation, mainly open vegetation with shrubs and grassland.

Imatong Mountains are mainly located in Eastern Equatoria and with plains and the lower parts of the mountains covered by deciduous woodland, wooded grassland and bamboo thickets to the north and west.

Herbaceous crop rainfed 0.8
Mixed unit 1.6
Bare areas 0.4
Closed natural vegetation 8.9
Open natural vegetation 39.7
Grassland 39.0
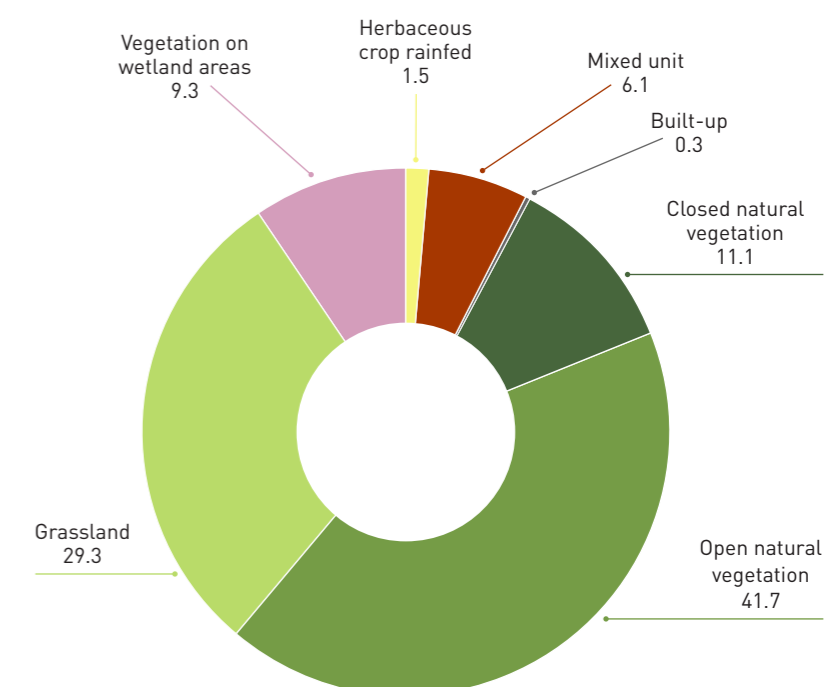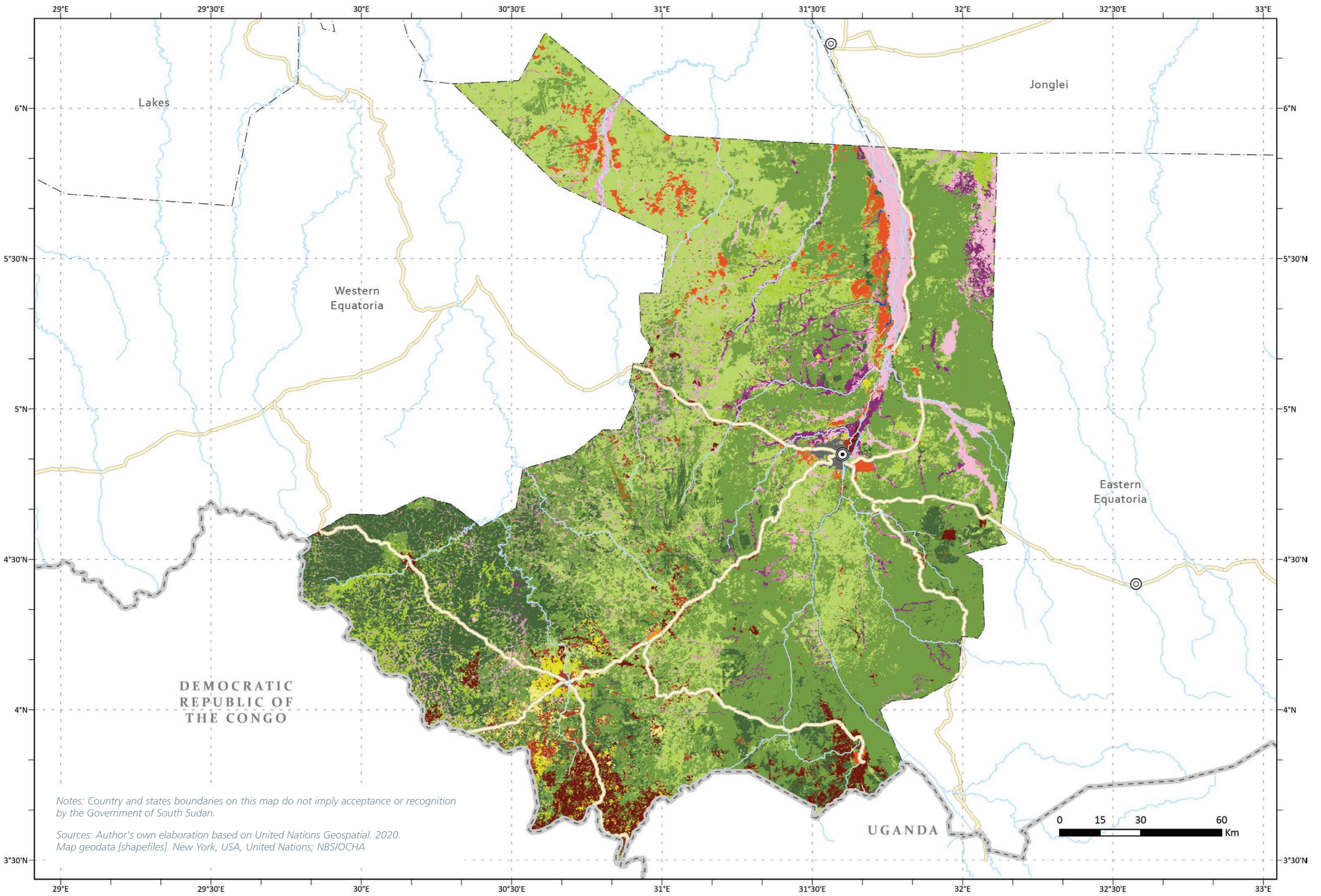Vegetation on wetland areas 18.8
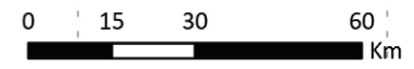
Western Equatoria

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

Land Cover Class	Ezo	Ibba	Maridi	Mundri East	Mundri West	Mvolo	Nagero	Nzara	Tambura	Yambio	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED												
Herbaceous crop rainfed (small fields)	0.4	3.9	1.2	39.9	3.6	0.5	31.1	14.5	12.4	10.8	118.2	0.1
Herbaceous crop rainfed (medium/large fields)												
HERBACEOUS CROP IRRIGATED												
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION												
Tree crop plantation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	5.1	18.6	0.0
MIXED UNIT												
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	217.8	161.2	298.8	94.0	144.0	90.6	12.6	402.2	282.7	844.4	2 548.3	3.2
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)												
Mixed unit (herbaceous crop rainfed - natural vegetation)												
BUILT-UP												
Rural settlement	7.1	1.7	2.9	4.7	4.6	0.4		5.4	6.6	19.2	52.4	0.1
Built-up area												
BARE AREAS												
Bare soil	99.2	11.2	209.1	11.5	65.0	5.3	169.2	26.1	138.8	25.2	760.7	1.0
River bank												
Bare rock												
CLOSED NATURAL VEGETATION												
Closed woody vegetation	1 508.8	225.2	812.8	273.9	827.5	24.2	2 946.6	1 710.5	3 645.5	804.0	12 779.2	16.1
Closed woody vegetation on mountain areas												
OPEN NATURAL VEGETATION												
Open woody vegetation	2 617.7	1 259.3	2 406.6	1 386.8	2 485.4	807.5	3 534.3	1 587.9	4 720.8	2 428.4	23 234.5	29.2
Open woody vegetation on mountain areas												
GRASSLAND												
Herbaceous closed to open (with sparse woody vegetation)	2 343.4	5 709.4	3 617.2	2 856.1	2 288.4	4 385.7	2 269.2	2 446.2	2 963.8	3 729.1	32 608.6	41.0
Grassland												
VEGETATION on WETLAND AREAS												
Closed woody vegetation on wetland	1 353.5	2 293.0	355.9	414.0	57.2	397.1	297.7	343.2	844.2	1,036.2	7 392.0	9.3
Open woody vegetation on wetland												
Grassland on wetland												
Seasonal wetland												
PERENNIAL WATER BODIES												
Water body perennial / artificial pond	8.2	0.9	0.6	3.2	6.5	9.9	6.7	4.3	4.0	1.1	45.4	0.1
River perennial												
SEASONAL WATER BODIES												
Water body seasonal	0.0	0.0	0.0	0.1	0.0	0.6	0.3	0.0	0.1	0.0	1.2	0.0
River seasonal												
TOTAL LAND	8 156.1	9 665.7	7 705.1	5 084.2	5 882.2	5 721.8	9 267.8	6 553.8	12 618.8	8 903.6	79 559.1	100.0

Western Equatoria state is located in the southwestern region of the country, bordering with Central African Republic and Democratic Republic of Congo.

Open vegetation is the most represented land cover class. Most of the land is covered by natural vegetation, mainly open vegetation with shrubs and grassland (29 and 41 percent of the total area respectively).

The total area covered by crops is not extensive, as it only accounts for 140 km². Mixed units, which also include rainfed herbaceous crop areas, cover only 3.2 percent of the entire land area.

Vegetation on wetland areas 9.3 · Mixed unit 3.2 · Bare areas 1.0 · Closed natural vegetation 16.1 · Open natural vegetation 29.2 · Grassland 41.0
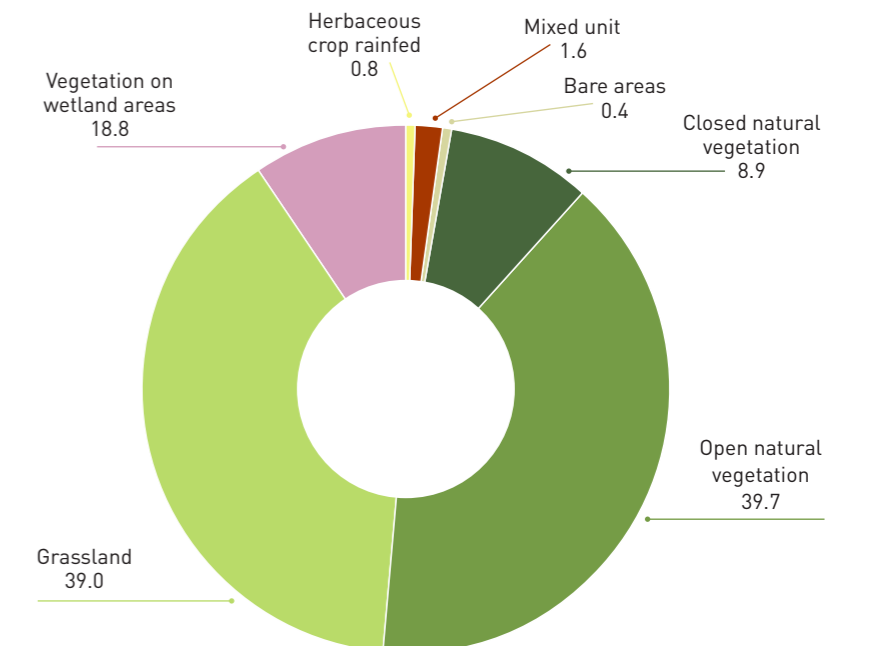
Lakes

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA
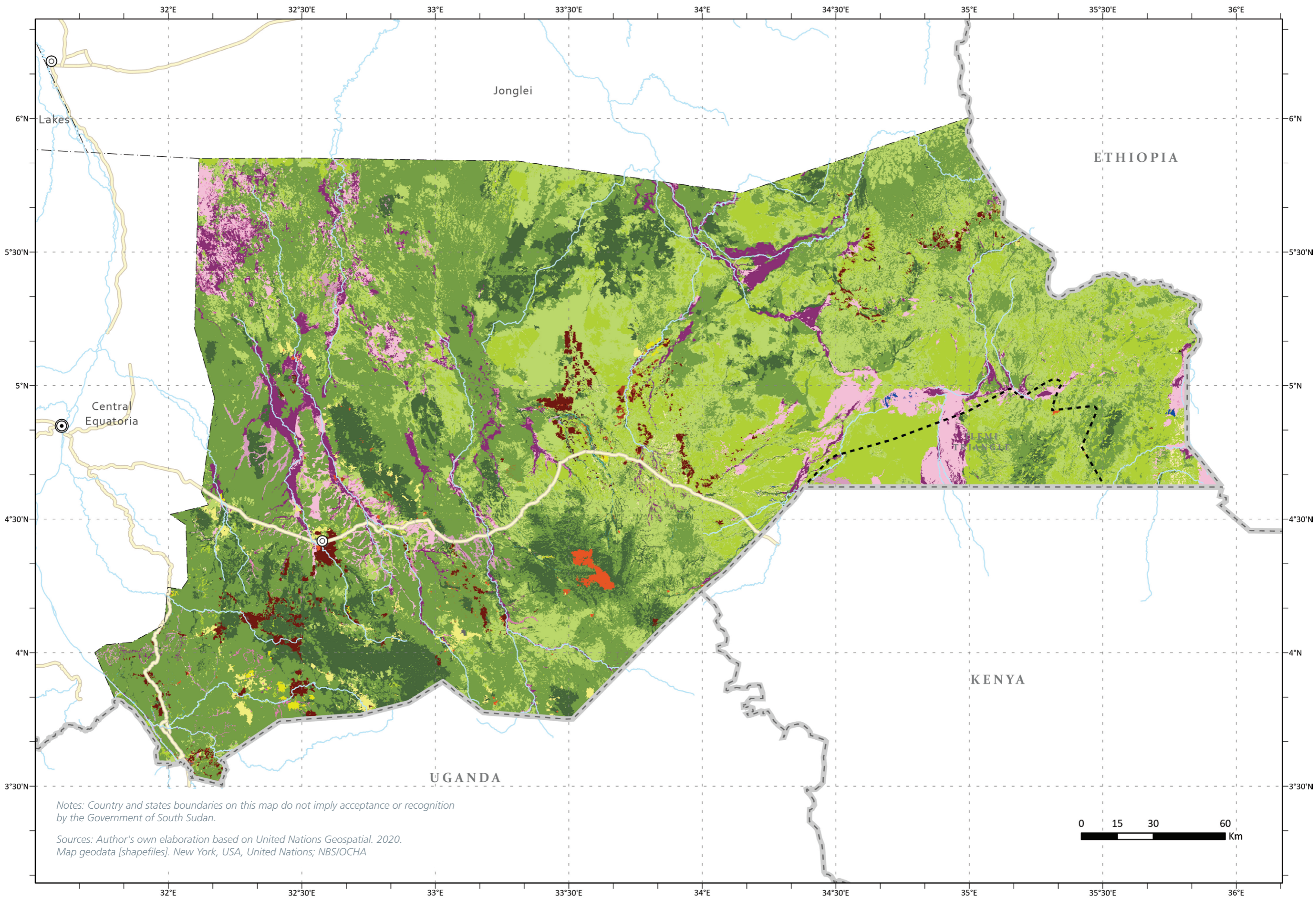
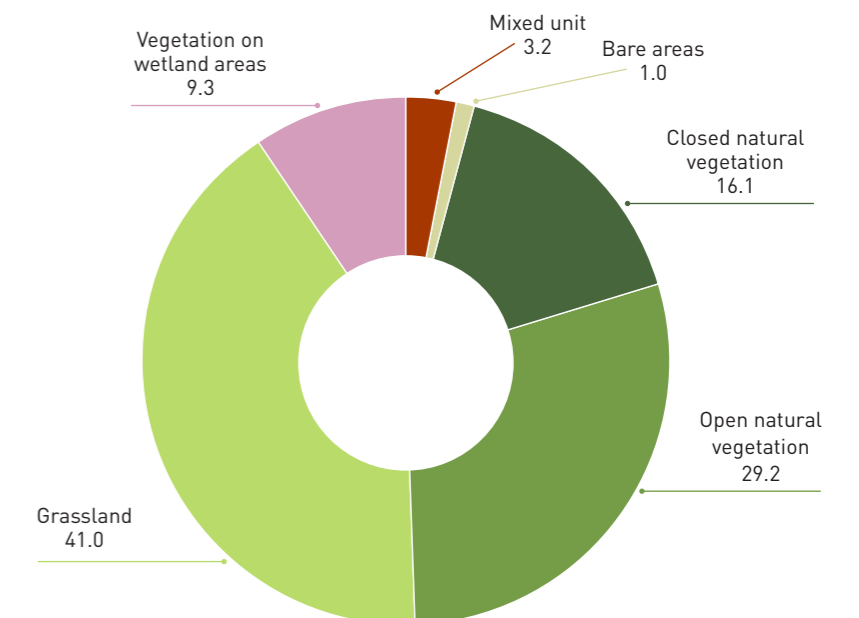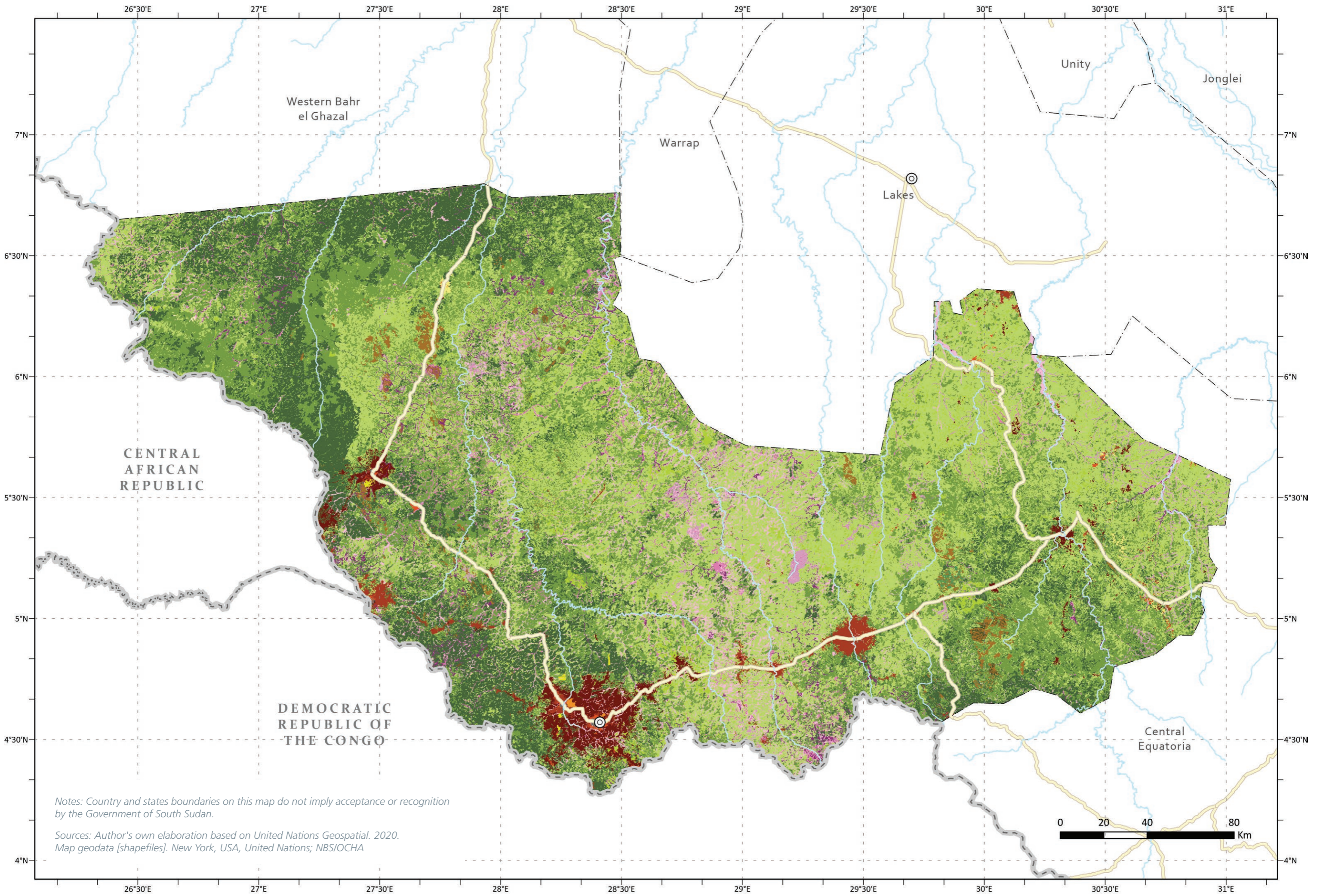| Land Cover Class	Awerial	Cueibet	Rumbek Centre	Rumbek North	Wulu	Yirol East	Yirol West	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED									
Herbaceous crop rainfed (small fields)	0.7	0.0	0.0	109.5	1.5	0.0	0.0	111.8	0.3
Herbaceous crop rainfed (medium/large fields)									
HERBACEOUS CROP IRRIGATED									
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION									
Tree crop plantation	0.0	0.0	0.0	23.8	0.0	0.2	0.2	24.2	0.1
MIXED UNIT									
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	220.9	845.2	823.6	73.6	154.5	397.2	400.6	2 915.6	6.7
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)									
Mixed unit (herbaceous crop rainfed - natural vegetation)									
BUILT-UP									
Rural settlement	0.4	2.4	21.7	1.6	0.2	3.4	14.0	43.7	0.1
Built-up area									
BARE AREAS									
Bare soil	1.8	13.9	162.0	2.3	149.8	3.2	10.9	343.8	0.8
River bank									
Bare rock									
CLOSED NATURAL VEGETATION									
Closed woody vegetation	29.6	398.0	87.2	102.2	575.1	43.3	112.6	1 347.9	3.1
Closed woody vegetation on mountain areas									
OPEN NATURAL VEGETATION									
Open woody vegetation	1 519.5	987.1	538.7	736.6	2 769.5	756.5	682.2	7 990.2	18.5
Open woody vegetation on mountain areas									
GRASSLAND									
Herbaceous closed to open (with sparse woody vegetation)	1 484.3	1 607.6	2 885.0	2 126.1	7 332.3	1 528.8	2 676.4	19 640.5	45.4
Grassland									
VEGETATION on WETLAND AREAS									
Closed woody vegetation on wetland	1 190.2	1 019.9	2 796.5	921.0	883.6	2 731.3	912.6	10 455.1	24.1
Open woody vegetation on wetland									
Grassland on wetland									
Seasonal wetland									
PERENNIAL WATER BODIES									
Water body perennial / artificial pond	90.0	4.3	17.9	6.8	13.8	113.4	24.3	270.5	0.6
River perennial									
SEASONAL WATER BODIES									
Water body seasonal	8.8	1.0	103.2	10.8	6.4	2.6	30.5	163.4	0.4
River seasonal									
TOTAL LAND	4 546.2	4 879.4	7 436.0	4 114.3	11 886.7	5 579.8	4 864.2	43 306.6	100.0

Lakes state is characterized by a vast expanse of fertile land and abundant water resources with wetland areas covering 24 percent of the total land area.

Agriculture is the major source of income for the local population, and the majority of the people are engaged in farming. The mixed rural areas are characterized by small farming communities that cultivate crops such as maize, sorghum and ground nuts. Mixed land cover classes represent 6.7 percent of the total land area.

Despite its rich agricultural potential, Lakes state faces several challenges in the sector, including droughts, floods, and conflicts over land and water resources.

Perennial water bodies 0.6
Seasonal water bodies 0.4
Mixed unit 6.7
Bare areas 0.8
Closed natural vegetation 16.1
Open natural vegetation 18.5
Grassland 45.4
Vegetation on wetland areas 24.1

Jonglei

Land Cover Class		Akobo	Ayod	Bor South	Canal/Pigi	Duk	Fangak	Nyirol	Pibor	Pochalla	Twic East	Uror	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED														
Herbaceous crop rainfed (small fields)		4.6	11.2	5.1	0.0	0.0	0.4	0.0	2.2	2.1	0.0	0.0	25.7	0.0
Herbaceous crop rainfed (medium/large fields)														
HERBACEOUS CROP IRRIGATED														
Herbaceous crop irrigated		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION														
Tree crop plantation		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIXED UNIT														
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		119.3	417.9	123.5	32.9	94.3	216.1	202.8	120.9	5.1	129.6	344.7	1 807.0	1.5
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)														
Mixed unit (herbaceous crop rainfed - natural vegetation)														
BUILT-UP														
Rural settlement		10.8	73.5	20.6	0.0	2.5	7.8	2.0	2.0	0.0	4.3	1.6	125.2	0.1
Built-up area														
BARE AREAS														
Bare soil		0.4	8.7	185.2	4.3	3.9	10.7	4.6	69.2	0.2	7.0	4.1	298.3	0.2
River bank														
Bare rock														
CLOSED NATURAL VEGETATION														
Closed woody vegetation		162.8	1 375.1	251.8	567.8	245.0	154.1	636.2	2 293.7	507.8	42.9	105.0	6 342.2	5.2
Closed woody vegetation on mountain areas														
OPEN NATURAL VEGETATION														
Open woody vegetation		2 057.8	1 511.7	1 006.6	1 710.2	681.1	579.2	1 588.8	11 796.9	4 426.5	326.1	2 870.3	28 555.2	23.4
Open woody vegetation on mountain areas														
GRASSLAND														
Herbaceous closed to open (with sparse woody vegetation)		5 611.6	2 221.3	6 900.2	1 983.1	2 392.7	1 883.4	3 907.1	11 852.8	1 698.1	2 329.9	7 706.9	48 487.3	39.8
Grassland														
VEGETATION on WETLAND AREAS														
Closed woody vegetation on wetland		996.1	7 669.3	5 330.0	126.0	3 313.2	4 824.9	710.9	6 791.1	1 595.9	2 980.3	1 045.5	35 383.3	29.0
Open woody vegetation on wetland														
Grassland on wetland														
Seasonal wetland														
PERENNIAL WATER BODIES														
Water body perennial / artificial pond		16.5	155.4	117.1	21.7	107.7	78.4	7.0	38.9	9.7	105.1	11.8	669.5	0.5
River perennial														
SEASONAL WATER BODIES														
Water body seasonal		2.8	1.7	1.1	0.1	16.9	6.1	9.3	18.6	15.8	14.4	74.3	161.1	0.1
River seasonal														
TOTAL LAND		8 982.7	13 445.9	13 941.4	4 446.2	6 857.2	7 761.2	7 068.7	32 986.4	8 261.2	5 939.7	12 164.1	121 854.7	100

Jonglei state, located in the eastern region of South Sudan, is a vast area with a land size of over 120 000 km².

The region is known for its abundant natural resources. Wetlands cover 30 percent of the state land area. With an estimated population of 1.8 million (IPC May 2017 Report), the state is home to a diverse range of ethnic groups, many of whom rely on agriculture for their livelihoods. The main source of income is agro-pastoralism with livestock production the predominant source of income.

Climate change and water scarcity pose additional threats, with droughts and floods becoming more frequent and severe in recent years.

Perennial water bodies 0.5
Mixed unit 1.5
Closed natural vegetation 5.2
Vegetation on wetland areas 29.0
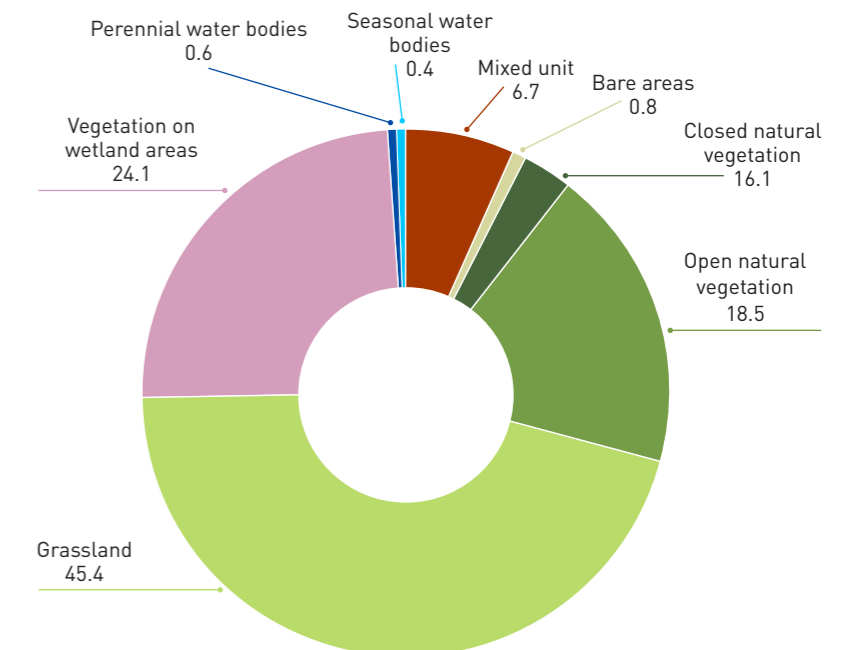Open natural vegetation 23.4
Grassland 39.8

Unity

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.
Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA
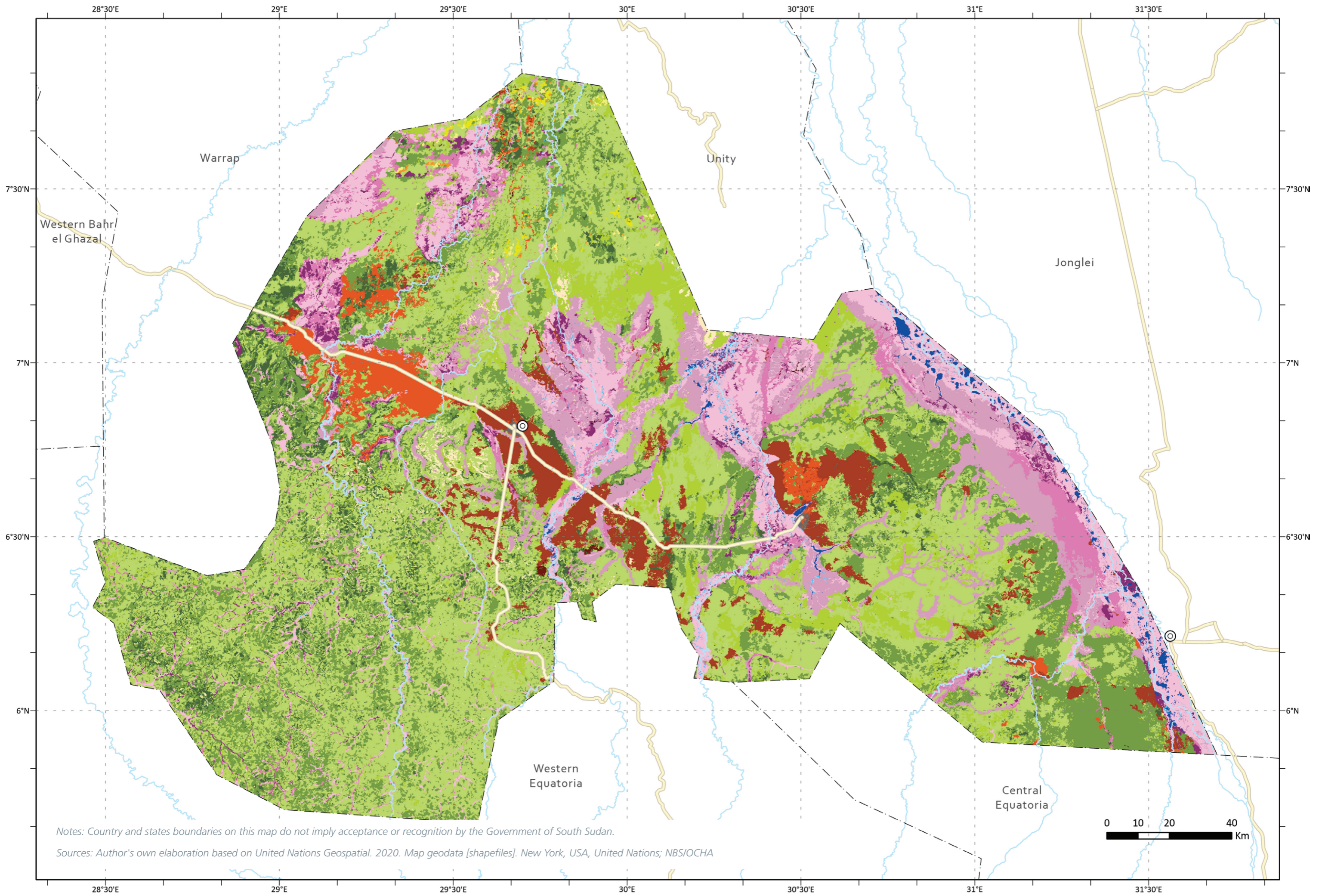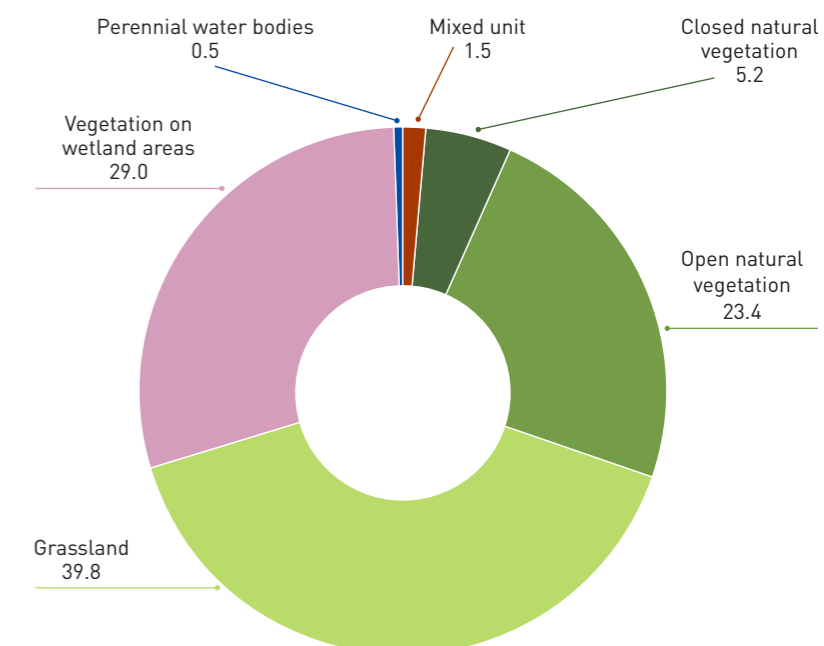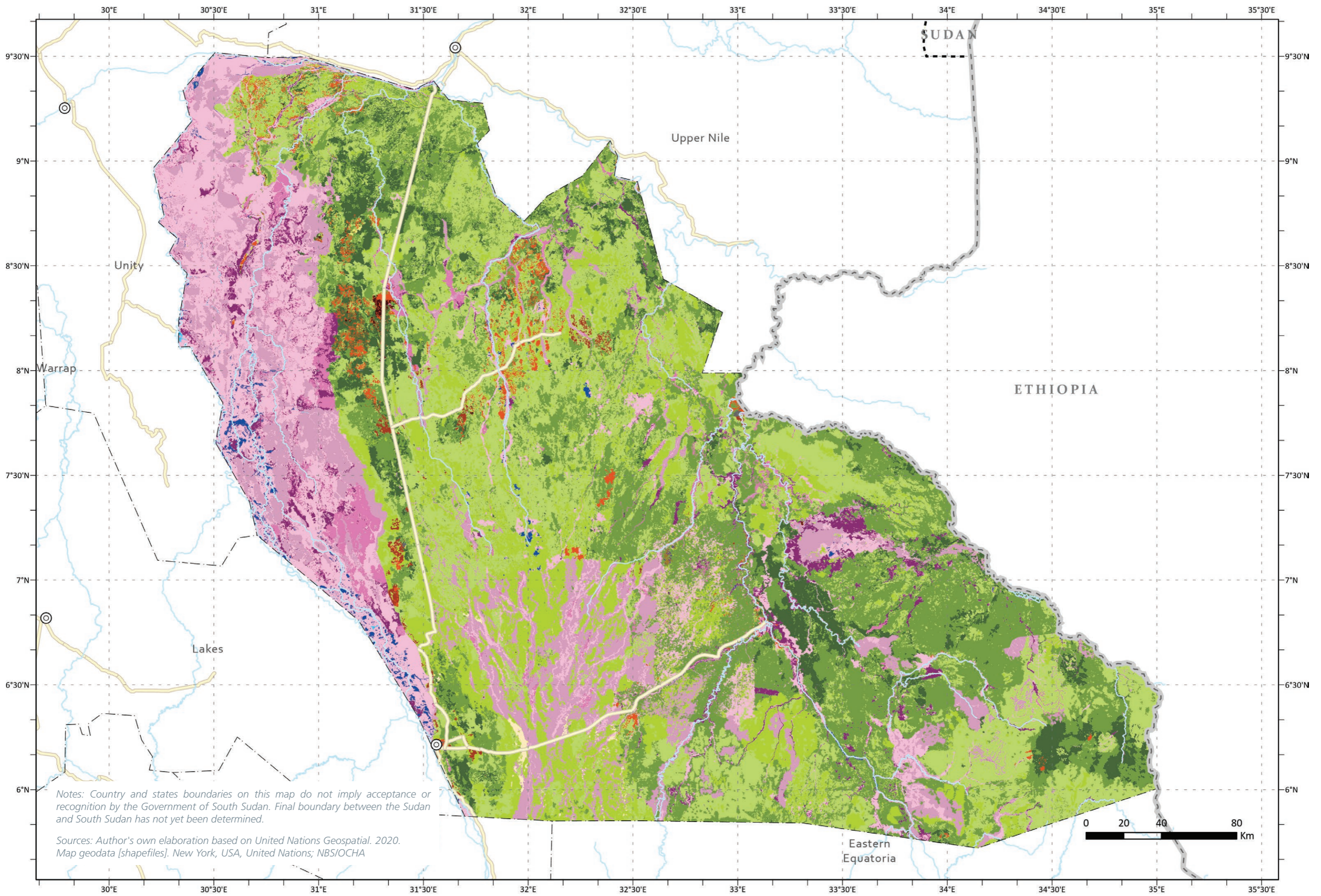
Land Cover Class	Abiemnhom	Guit	Koch	Leer	Mayendit	Mayom	Panyijiar	Pariang	Rubkona	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED											
Herbaceous crop rainfed (small fields)	26.5	8.5	1.4	52.7	49.0	1.2	33.0	241.4	2.0	415.7	1.1
Herbaceous crop rainfed (medium/large fields)											
HERBACEOUS CROP IRRIGATED											
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION											
Tree crop plantation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIXED UNIT											
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	0.0	62.7	104.8	94.2	93.9	82.0	146.4	728.1	81.1	1 393.2	3.7
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)											
Mixed unit (herbaceous crop rainfed - natural vegetation)											
BUILT-UP											
Rural settlement	1.7	8.6	3.9	1.7	0.8	42.2	1.8	71.8	50.1	182.6	0.5
Built-up area											
BARE AREAS											
Bare soil	3.3	21.5	13.1	4.6	3.9	54.2	110.1	8.3	21.1	240.3	0.6
River bank											
Bare rock											
CLOSED NATURAL VEGETATION											
Closed woody vegetation	370.2	0.4	15.9	0.0	0.3	288.2	14.9	136.5	70.7	897.1	2.4
Closed woody vegetation on mountain areas											
OPEN NATURAL VEGETATION											
Open woody vegetation	772.8	432.9	702.5	0.5	200.1	798.0	100.2	728.9	1 221.6	4 957.7	13.3
Open woody vegetation on mountain areas											
GRASSLAND											
Herbaceous closed to open (with sparse woody vegetation)	1 156.5	1 249.5	1 449.6	326.2	808.5	1 252.8	2 710.4	5 788.6	1 730.1	16 472.1	44.3
Grassland											
VEGETATION on WETLAND AREAS											
Closed woody vegetation on wetland	75.0	1 654.8	2 100.4	1 124.6	1 873.3	1 675.6	2 057.4	1 207.0	392.5	12 160.8	32.7
Open woody vegetation on wetland											
Grassland on wetland											
Seasonal wetland											
PERENNIAL WATER BODIES											
Water body perennial / artificial pond	0.0	11.6	26.5	26.7	10.3	38.8	159.7	50.3	2.3	326.2	0.9
River perennial											
SEASONAL WATER BODIES											
Water body seasonal	0.2	0.1	0.3	2.1	27.4	41.5	10.4	23.8	1.6	107.3	0.3
River seasonal											
TOTAL LAND	2 406.3	3 450.5	4 418.5	1 633.5	3 067.4	4 274.5	5 344.3	8 984.7	3 573.3	37 152.9	100

Unity state is located in the northern region of South Sudan, bordering Sudan to the north. The majority of the population in Unity State rely on agriculture for their livelihoods, with the primary crops being sorghum, maize, and millet.

A large amount of the total land is covered by open vegetation (58 percent) and wetlands (33 percent). With Warrap and Jonglei states it is part of the Eastern Flood Plains region.

Perennial water bodies 0.9
Herbaceous crop rainfed 1.1
Mixed unit 3.7
Built-up 0.5
Bare areas 0.6
Closed natural vegetation 2.4
Vegetation on wetland areas 32.7
Open natural vegetation 13.3
Grassland 44.3

Notes: Country and states boundaries on this map do not imply acceptance or recognition
by the Government of South Sudan. Final boundary between the Sudan and South Sudan
has not yet been determined. Final status of the Abyei area is not yet determined.

Sources: Author's own elaboration based on United Nations Geospatial. 2020.
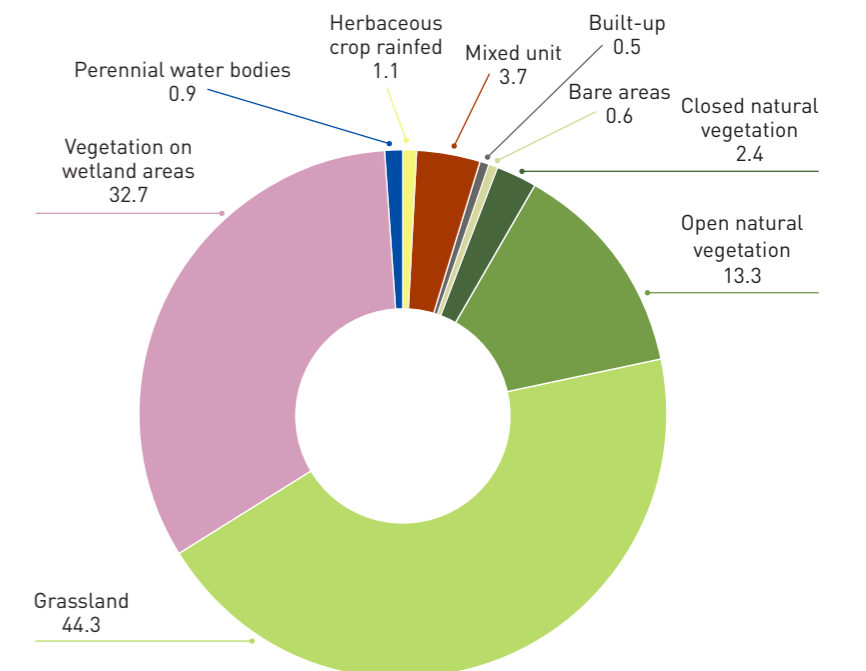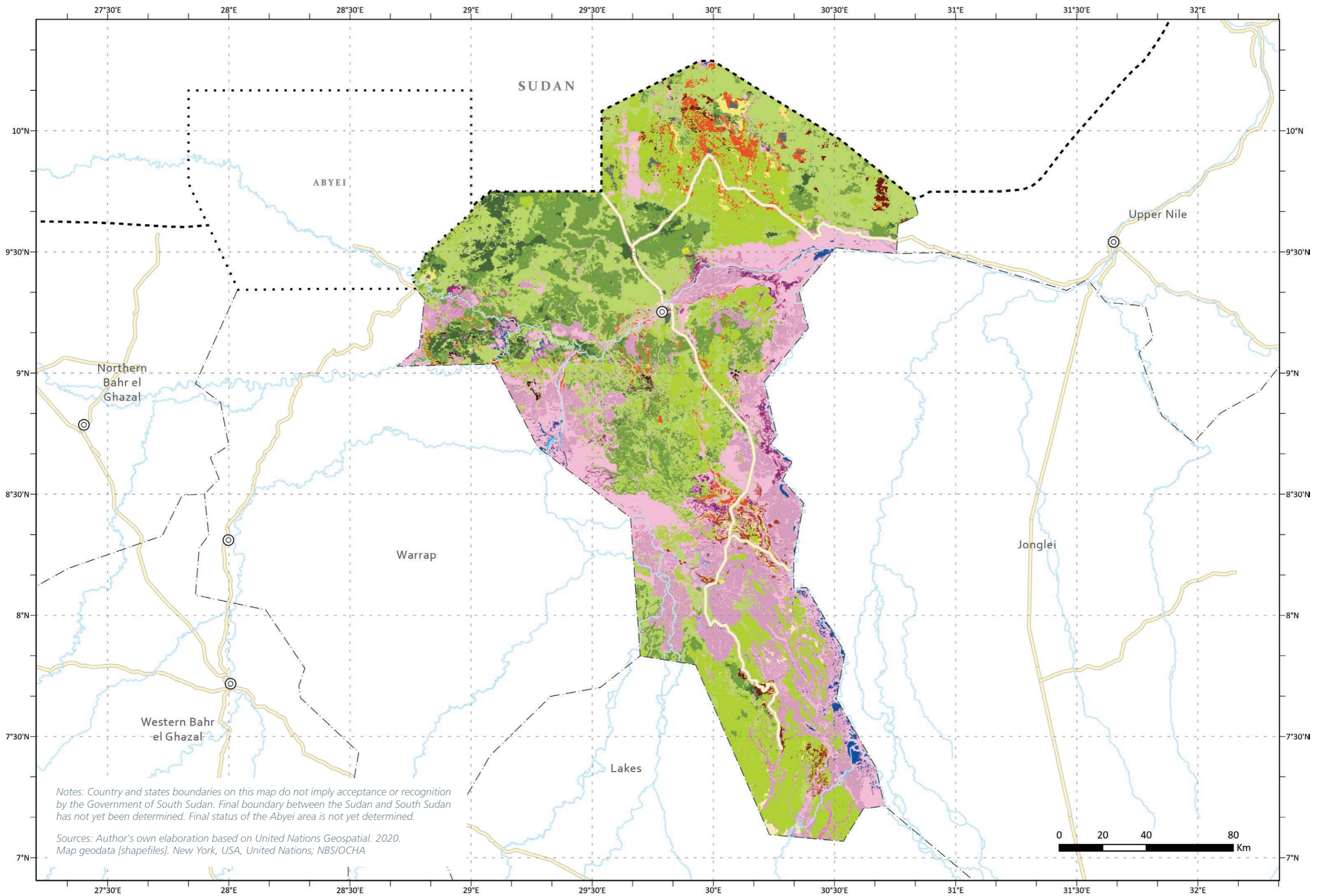Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

SUDAN

ABYEI

Upper Nile

Northern
Bahr el
Ghazal

Warrap

Jonglei

Western Bahr
el Ghazal

Lakes

0   20   40   80
                    Km
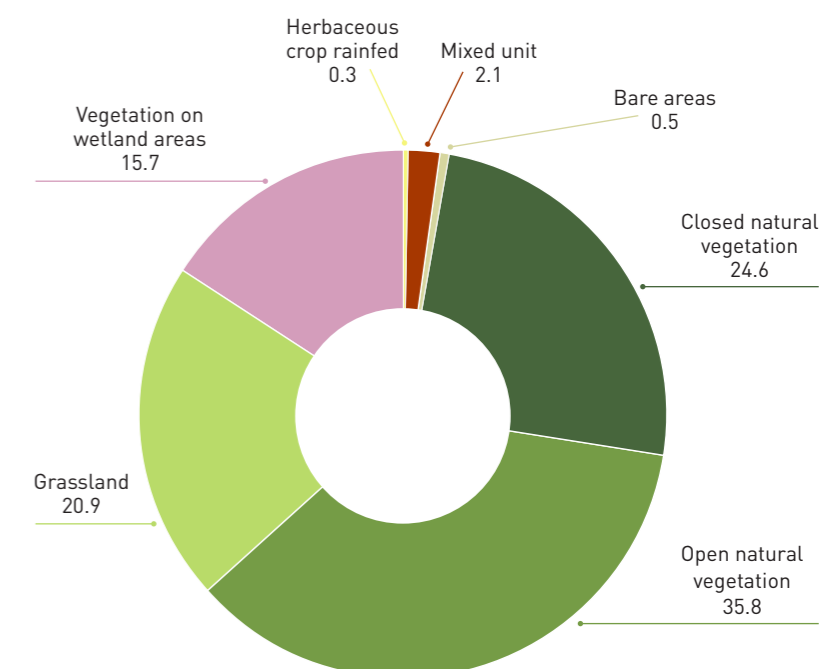
Western Bahr el Ghazal

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA
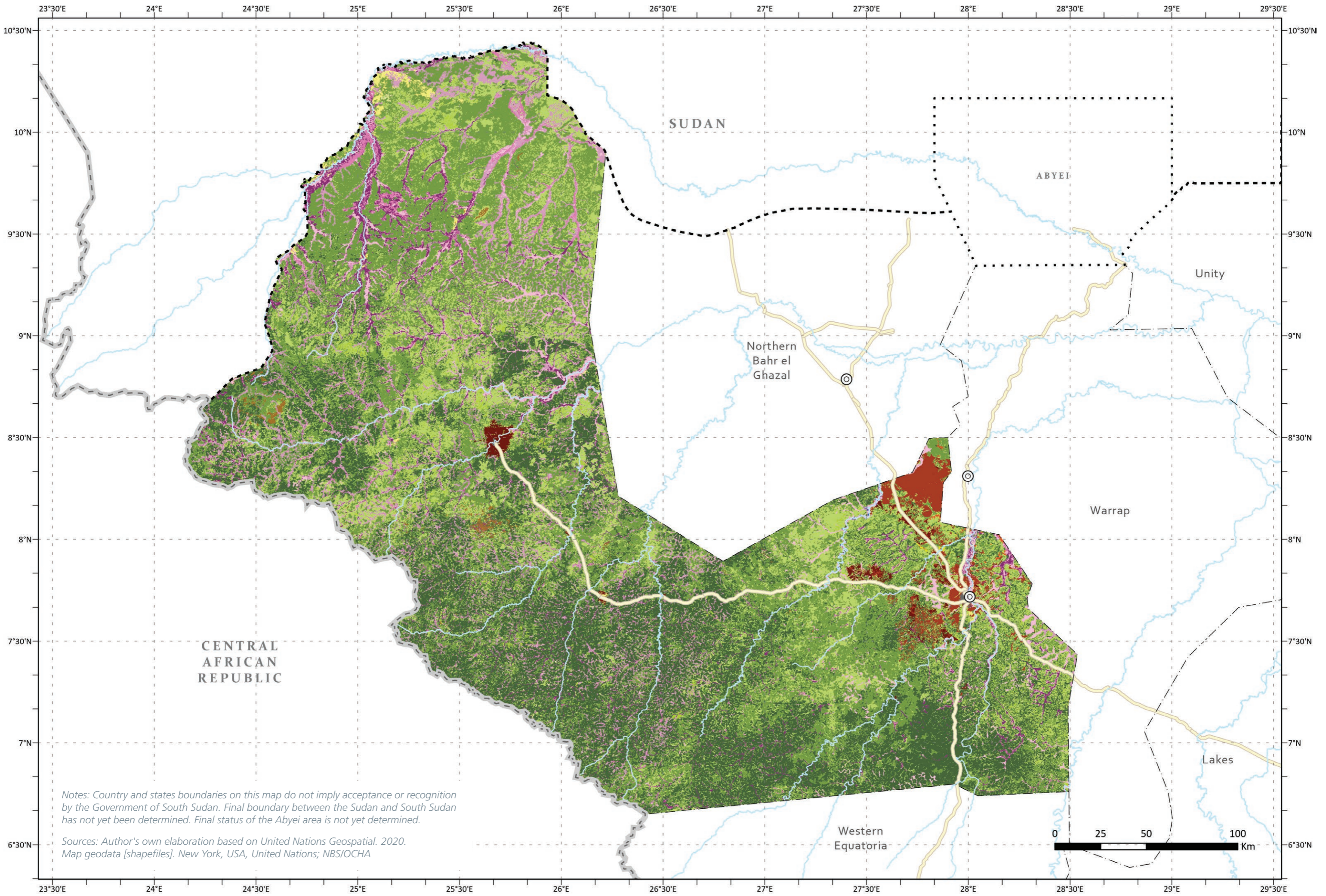
Land Cover Class		Jur River	Raga	Wau	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED						
Herbaceous crop rainfed (small fields)		23.0	284.3	14.3	321.6	0.3
Herbaceous crop rainfed (medium/large fields)						
HERBACEOUS CROP IRRIGATED						
Herbaceous crop irrigated		0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION						
Tree crop plantation		0.1	1.2	0.2	1.5	0.0
MIXED UNIT						
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		1 236.3	224.5	500.3	1 961.0	2.1
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)						
Mixed unit (herbaceous crop rainfed - natural vegetation)						
BUILT-UP						
Rural settlement		2.8	15.5	30.8	49.2	0.1
Built-up area						
BARE AREAS						
Bare soil		55.4	348.5	16.6	420.6	0.5
River bank						
Bare rock						
CLOSED NATURAL VEGETATION						
Closed woody vegetation		1 968.7	14 057.4	6 721.2	22 747.3	24.6
Closed woody vegetation on mountain areas						
OPEN NATURAL VEGETATION						
Open woody vegetation		2 575.2	23 324.0	7 198.4	33 097.6	35.8
Open woody vegetation on mountain areas						
GRASSLAND						
Herbaceous closed to open (with sparse woody vegetation)		3 049.7	12 657.3	3 627.2	19 334.2	20.9
Grassland						
VEGETATION on WETLAND AREAS						
Closed woody vegetation on wetland		1 160.2	12 069.9	1 251.4	14 481.5	15.7
Open woody vegetation on wetland						
Grassland on wetland						
Seasonal wetland						
PERENNIAL WATER BODIES						
Water body perennial / artificial pond		22.7	29.1	22.7	74.5	0.1
River perennial						
SEASONAL WATER BODIES						
Water body seasonal		22.5	13.2	3.3	39.0	0.0
River seasonal						
TOTAL LAND		10 116.6	63 024.9	19 386.4	92 527.9	100

The state of Western Bahr el Ghazal is located in the western region of Sudan. The land is primarily used for farming, but natural vegetation are the dominant land cover classes.

The estimated population of Western Bahr el Ghazal in 2017 was 0.5 million (IPC May 2017 Report), with a significant portion of the population living in rural settlement areas.

Despite the abundance of natural resources in the region, it faces numerous challenges including limited access to markets, poor infrastructure, and ongoing conflicts.

Herbaceous crop rainfed 0.3
Mixed unit 2.1
Bare areas 0.5
Vegetation on wetland areas 15.7
Closed natural vegetation 24.6
Grassland 20.9
Open natural vegetation 35.8

SUDAN

ABYEI

Unity

Northern
Bahr el
Ghazal

Warrap

CENTRAL
AFRICAN
REPUBLIC

Lakes

Western
Equatoria

0   25   50   100
Km

Warrap

Land Cover Class		Gogrial East	Gogrial West	Tonj East	Tonj North	Tonj South	Twic	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED									
Herbaceous crop rainfed (small fields)		27.7	0.4	0.5	0.9	30.3	116.0	175.7	0.5
Herbaceous crop rainfed (medium/large fields)									
HERBACEOUS CROP IRRIGATED									
Herbaceous crop irrigated		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION									
Tree crop plantation		1.9	0.0	0.0	0.0	0.0	0.6	2.5	0.0
MIXED UNIT									
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		1 304.0	1 477.2	816.4	1 426.8	656.4	804.7	6 485.4	18.0
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)									
Mixed unit (herbaceous crop rainfed - natural vegetation)									
BUILT-UP									
Rural settlement		173.3	40.0	78.3	5.4	45.3	7.2	349.5	1.0
Built-up area									
BARE AREAS									
Bare soil		37.4	66.7	14.4	36.3	22.5	57.7	235.1	0.7
River bank									
Bare rock									
CLOSED NATURAL VEGETATION									
Closed woody vegetation		169.4	24.7	25.2	110.1	1 596.9	17.5	1 943.7	5.4
Closed woody vegetation on mountain areas									
OPEN NATURAL VEGETATION									
Open woody vegetation		189.7	315.7	690.0	1 858.2	2 302.4	259.3	5 615.3	15.6
Open woody vegetation on mountain areas									
GRASSLAND									
Herbaceous closed to open (with sparse woody vegetation)		453.3	1 212.3	2 405.9	4 172.7	1 612.0	775.2	10 631.4	29.5
Grassland									
VEGETATION on WETLAND AREAS									
Closed woody vegetation on wetland		2 036.0	1 234.5	405.4	3 524.9	1 179.4	1 906.4	10 286.5	28.6
Open woody vegetation on wetland									
Grassland on wetland									
Seasonal wetland									
PERENNIAL WATER BODIES									
Water body perennial / artificial pond		17.4	32.3	0.1	124.5	11.5	18.0	203.8	0.6
River perennial									
SEASONAL WATER BODIES									
Water body seasonal		37.8	25.1	0.3	16.7	0.9	4.2	85.0	0.2
River seasonal									
TOTAL LAND		4 447.8	4 428.9	4 436.4	11 276.5	7 457.4	3 966.9	36 013.9	100.0

Warrap state is located in the northern central area of the country. Agriculture plays a significant role in the region's economy and livelihoods. The area's fertile soil allows for the cultivation of various crops, including sorghum, maize, and cassava.

Farming in Warrap is predominantly small-scale and often relies on traditional techniques, with farmers having limited access to modern technologies and machinery. Mixed classes, consisting of natural vegetation along with rural settlements and herbaceous crops, represent 18 percent of the state land area.

Poor infrastructure and a lack of storage facilities can also pose a challenge, often leading to post-harvest losses. Despite these challenges, the Warrap region has the potential to increase its agricultural productivity and improve the livelihoods of its farmers.

Perennial water bodies 0.6
Herbaceous crop rainfed 0.5
Mixed unit 18.0
Vegetation on wetland areas 28.6
Built-up 1.0
Bare areas 0.7
Closed natural vegetation 5.4
Open natural vegetation 15.6
Grassland 29.5

Notes: Country and states boundaries on this map do not imply acceptance or recognition
by the Government of South Sudan. Final status of the Abyei area is not yet determined.

Sources: Author's own elaboration based on United Nations Geospatial. 2020.
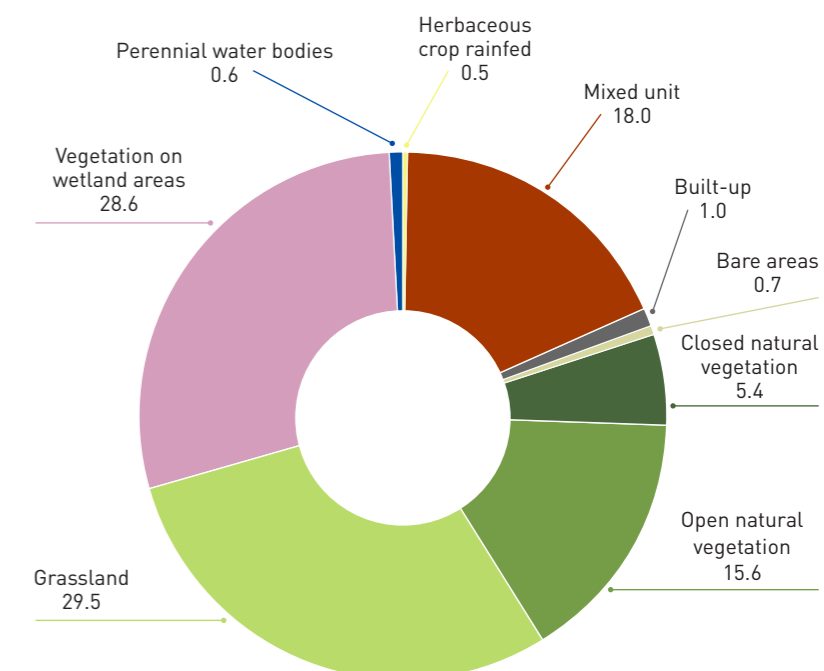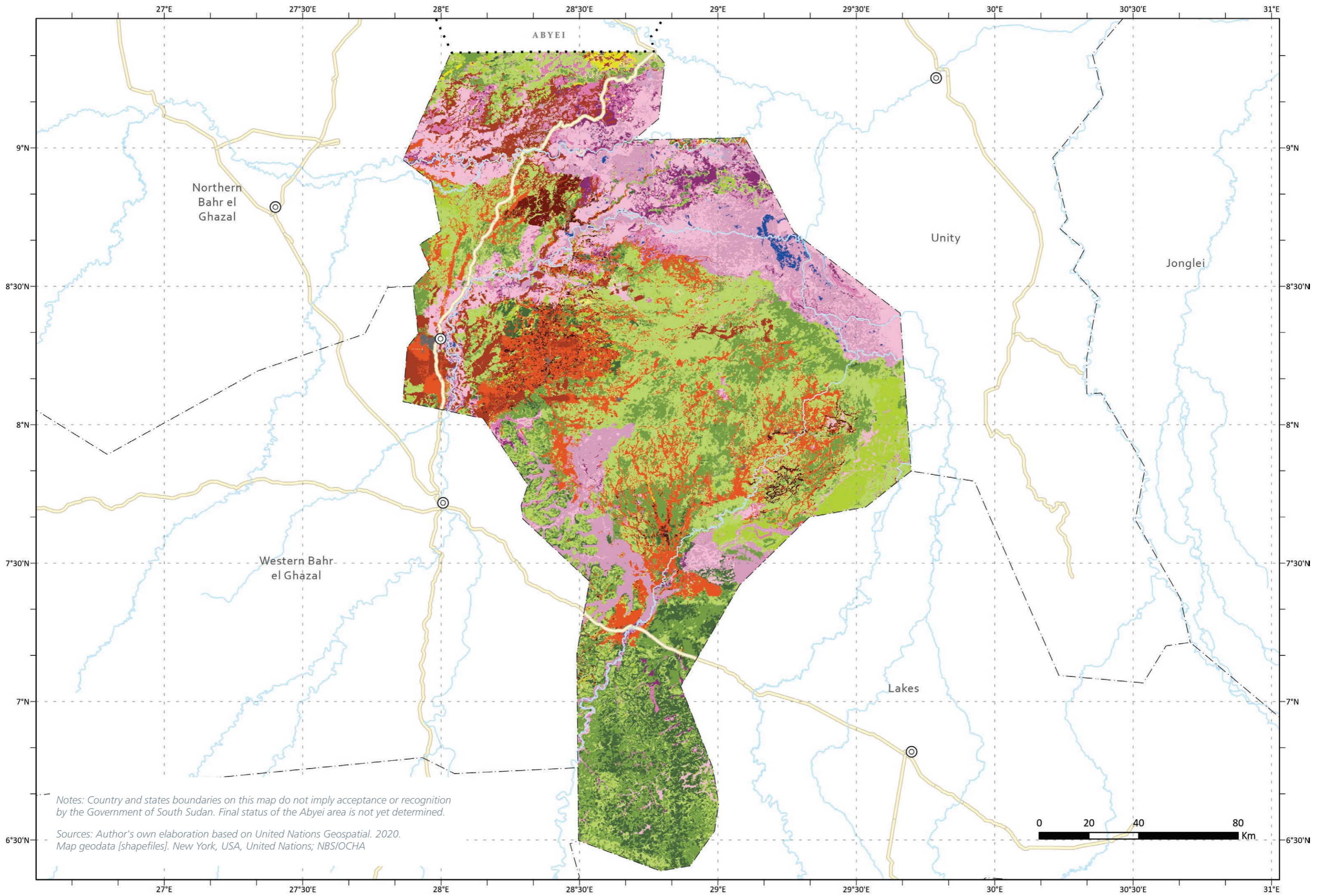Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA
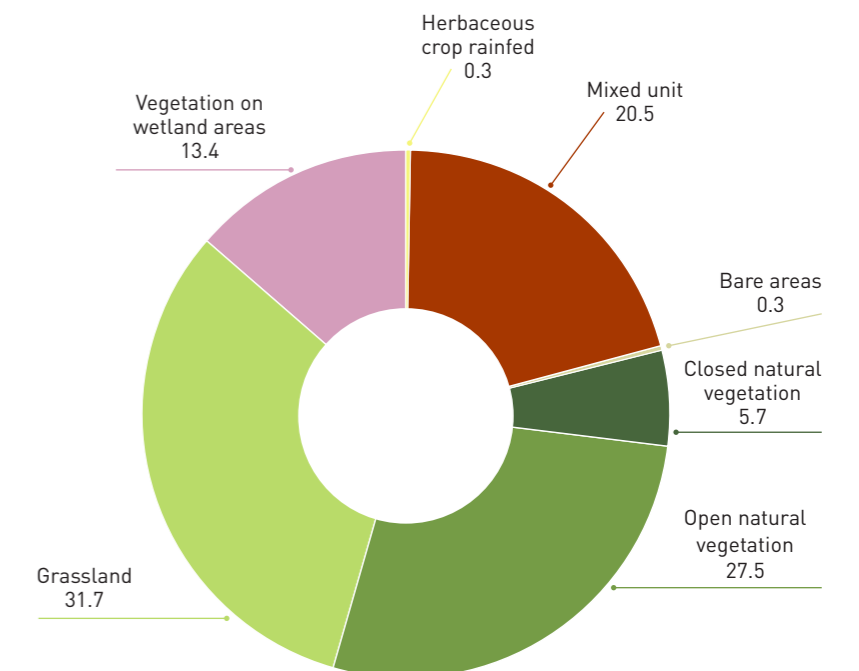
Northern Bahr el Ghazal

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

Land Cover Class	Aweil Centre	Aweil East	Aweil North	Aweil South	Aweil West	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED							
Herbaceous crop rainfed (small fields)	7.1	14.9	0.2	5.1	73.9	101.3	0.3
Herbaceous crop rainfed (medium/large fields)							
HERBACEOUS CROP IRRIGATED							
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TREE CROP PLANTATION							
Tree crop plantation	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MIXED UNIT							
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	724.7	2 356.4	1 146.1	597.4	1 562.2	6 386.7	20.5
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)							
Mixed unit (herbaceous crop rainfed - natural vegetation)							
BUILT-UP							
Rural settlement	0.7	3.7	3.1	54.0	23.6	85.1	0.3
Built-up area							
BARE AREAS							
Bare soil	32.3	7.0	47.2	10.1	9.4	106.0	0.3
River bank							
Bare rock							
CLOSED NATURAL VEGETATION							
Closed woody vegetation	1 416.4	27.0	282.3	11.7	27.3	1 764.7	5.7
Closed woody vegetation on mountain areas							
OPEN NATURAL VEGETATION							
Open woody vegetation	5 329.3	708.3	804.2	453.2	1 288.0	8 583.0	27.5
Open woody vegetation on mountain areas							
GRASSLAND							
Herbaceous closed to open (with sparse woody vegetation)	2 167.4	2 544.0	3 482.4	542.9	1 138.1	9 874.8	31.7
Grassland							
VEGETATION on WETLAND AREAS							
Closed woody vegetation on wetland	1 570.7	754.6	637.7	308.6	918.2	4 189.8	13.4
Open woody vegetation on wetland							
Grassland on wetland							
Seasonal wetland							
PERENNIAL WATER BODIES							
Water body perennial / artificial pond	11.6	8.8	8.2	7.1	20.2	55.8	0.2
River perennial							
SEASONAL WATER BODIES							
Water body seasonal	12.5	8.7	0.9	1.5	2.3	25.9	0.1
River seasonal							
TOTAL LAND	11 272.6	6 433.3	6 412.2	1 991.8	5 063.2	31 173.1	100.0

Northern Bahr el Ghazal is in the northern part of South Sudan, bordering Sudan.

The agricultural practices in Northern Bahr el Ghazal are largely subsistence-oriented, with small-scale farmers using traditional farming methods. This is also highlighted by the mixed unit land cover classes that represent 20 percent of the total land area.

The main crops grown are sorghum, ground nuts and rice in the semi-mechanized Aweil rice scheme. Northern Bahr el Ghazal still faces significant challenges, such as the effects of climate change, insecurity, and sporadic outbreaks of livestock diseases.

Herbaceous crop rainfed 0.3
Mixed unit 20.5
Bare areas 0.3
Closed natural vegetation 5.7
Open natural vegetation 27.5
Grassland 31.7
Vegetation on wetland areas 13.4

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined. Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA
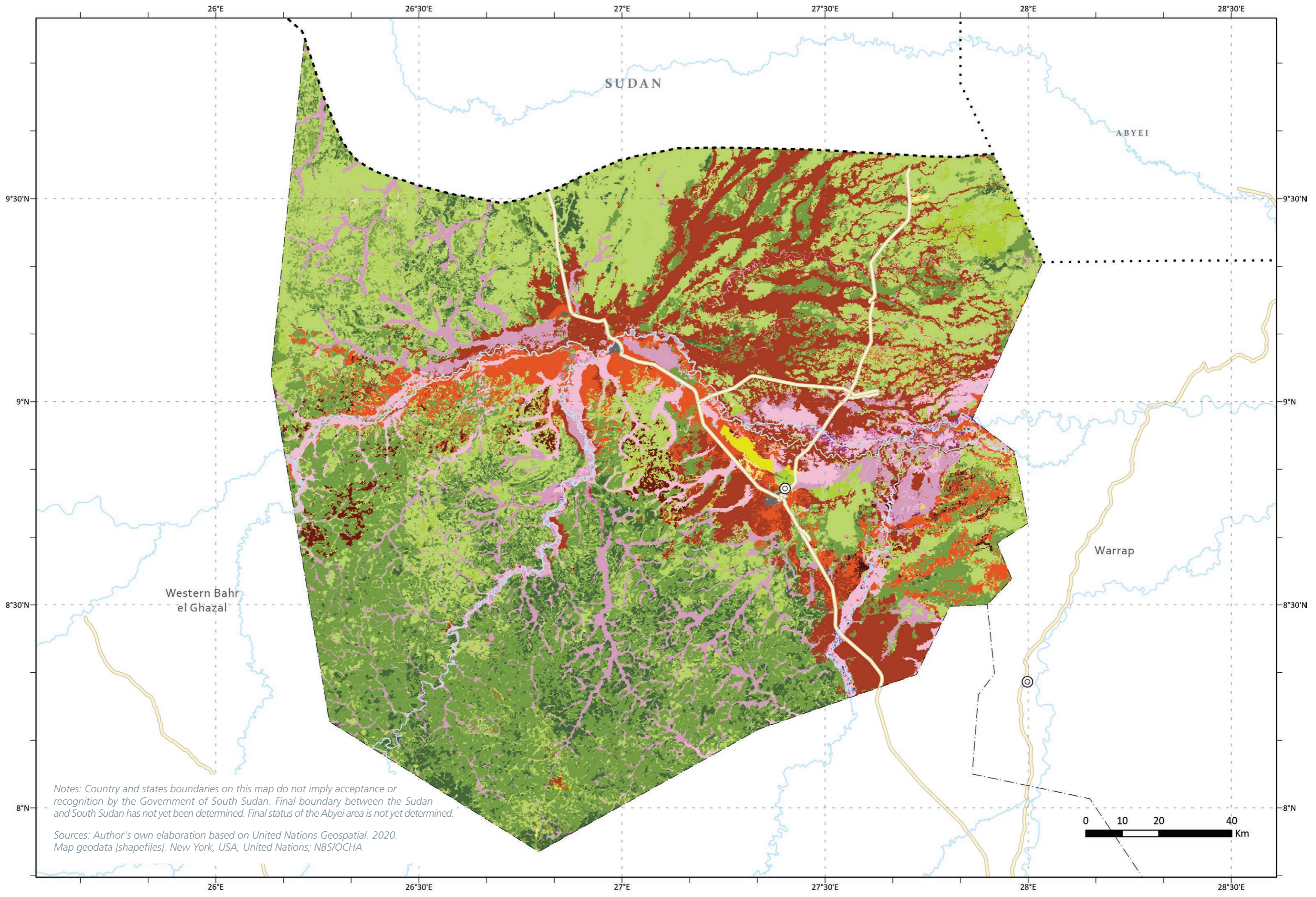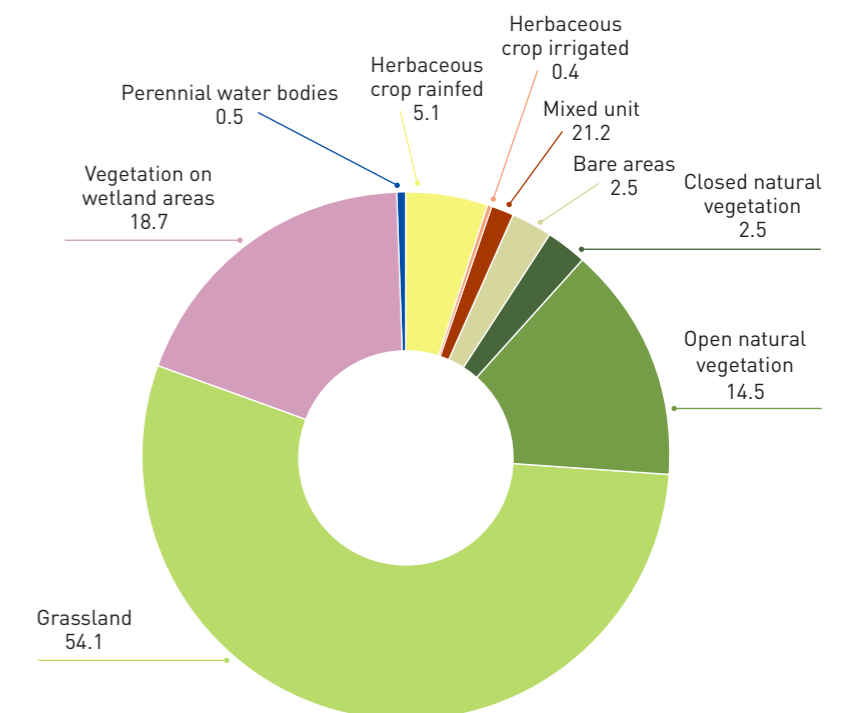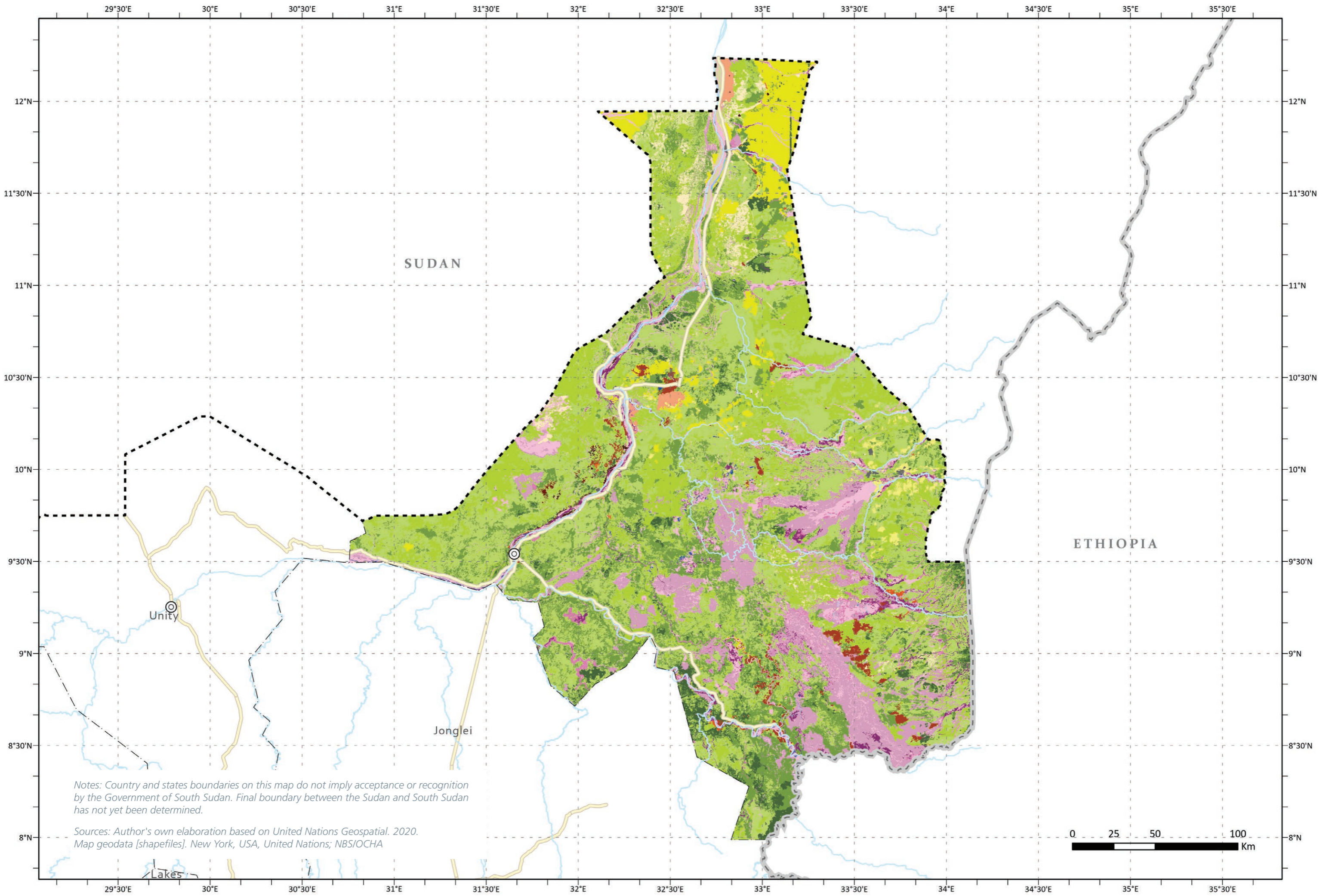
Land Cover Class	Baliet	Fashoda	Longochuk	Luakpiny/ Nasir	Maban	Maiwut	Malakal	Manyo	Melut	Panyikang	Renk	Ulang	TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED														
Herbaceous crop rainfed (small fields)	1.5	2.0	7.0	38.8	526.7	4.4	2.1	294.6	576.2	19.7	2 477.0	6.2	3 956.2	5.1
Herbaceous crop rainfed (medium/large fields)														
HERBACEOUS CROP IRRIGATED														
Herbaceous crop irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	172.4	0.0	169.9	0.0	342.6	0.4
TREE CROP PLANTATION														
Tree crop plantation	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
MIXED UNIT														
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)	17.0	83.2	283.2	181.4	57.2	71.6	14.3	33.6	119.5	4.5	26.0	52.6	944.0	1.2
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)														
Mixed unit (herbaceous crop rainfed - natural vegetation)														
BUILT-UP														
Rural settlement	1.5	67.0	0.7	0.3	40.9		32.1	9.4	26.9	0.1	40.4	1.5	220.7	0.3
Built-up area														
BARE AREAS														
Bare soil	29.4	56.0	243.8	3.0	42.3	5.5	2.0	764.7	66.6	3.9	692.7	5.6	1 915.6	2.5
River bank														
Bare rock														
CLOSED NATURAL VEGETATION														
Closed woody vegetation	291.7	49.0	132.6	83.1	26.7	161.7	10.9	6.8	156.5	36.5	249.5	730.8	1 935.9	2.5
Closed woody vegetation on mountain areas														
OPEN NATURAL VEGETATION														
Open woody vegetation	2 674.8	280.6	536.7	1 376.4	791.3	401.2	126.6	674.1	852.8	955.0	1 047.8	1 453.4	11 170.8	14.5
Open woody vegetation on mountain areas														
GRASSLAND														
Herbaceous closed to open (with sparse woody vegetation)	5 944.6	2 436.2	3 511.9	1 583.3	7 881.4	1 568.7	451.0	4 037.8	4 463.3	3 510.0	4 590.3	1 809.8	41 788.1	54.1
Grassland														
VEGETATION on WETLAND AREAS														
Closed woody vegetation on wetland	2 628.9	590.3	2 181.7	1 910.9	2 428.3	1 539.2	98.2	766.1	445.2	442.5	672.4	715.6	14 419.3	18.7
Open woody vegetation on wetland														
Grassland on wetland														
Seasonal wetland														
PERENNIAL WATER BODIES														
Water body perennial / artificial pond	32.5	27.0	5.9	31.6	6.9	5.0	17.1	87.0	52.7	34.6	52.9	44.2	397.4	0.5
River perennial														
SEASONAL WATER BODIES														
Water body seasonal	51.5	2.1	16.1	3.3	7.3	0.1	0.2	0.2	4.3	1.5	3.4	0.6	90.5	0.1
River seasonal														
TOTAL LAND	11 673.6	3 593.3	6 919.5	5 212.0	11 809.6	3 757.4	754.5	6 674.6	6 936.5	5 008.1	10 022.3	4 820.3	77 181.7	100.0

The Upper Nile state is in the northeastern region of the country. It represents an important agricultural region that is known for its fertile soil and abundant water resources.

Upper Nile has the largest cropland area of the country, accounting for 63 percent of the national cropland area. The major crops grown are maize in the south and sorghum, sesame and pearl millet in central to northern parts. Almost all irrigated crops are in Upper Nile (343 km²). Mechanized farming, is practised mainly in the counties of Renk and Melut.

Perennial water bodies 0.5
Herbaceous crop rainfed 5.1
Herbaceous crop irrigated 0.4
Mixed unit 21.2
Bare areas 2.5
Closed natural vegetation 2.5
Vegetation on wetland areas 18.7
Open natural vegetation 14.5
Grassland 54.1

SUDAN

ETHIOPIA

Unity

Jonglei

Lakes

0   25   50   100
Km

Abyei

Land Cover Class		TOTAL km²	TOTAL%
HERBACEOUS CROP RAINFED			
Herbaceous crop rainfed (small fields)		62.5	0.6
Herbaceous crop rainfed (medium/large fields)			
HERBACEOUS CROP IRRIGATED			
Herbaceous crop irrigated		0.0	0.0
TREE CROP PLANTATION			
Tree crop plantation		0.0	0.0
MIXED UNIT			
Mixed unit (settlements - natural vegetation - herbaceous crop rainfed)		447.4	4.2
Mixed unit (herbaceous crop rainfed - natural vegetation - settlements)			
Mixed unit (herbaceous crop rainfed - natural vegetation)			
BUILT-UP			
Rural settlement		12.3	0.1
Built-up area			
BARE AREAS			
Bare soil		488.2	4.6
River bank			
Bare rock			
CLOSED NATURAL VEGETATION			
Closed woody vegetation		225.8	2.1
Closed woody vegetation on mountain areas			
OPEN NATURAL VEGETATION			
Open woody vegetation		866.5	8.2
Open woody vegetation on mountain areas			
GRASSLAND			
Herbaceous closed to open (with sparse woody vegetation)		7 687.7	72.9
Grassland			
VEGETATION on WETLAND AREAS			
Closed woody vegetation on wetland		729.9	6.9
Open woody vegetation on wetland			
Grassland on wetland			
Seasonal wetland			
PERENNIAL WATER BODIES			
Water body perennial / artificial pond		25.1	0.2
River perennial			
SEASONAL WATER BODIES			
Water body seasonal		1.4	0.0
River seasonal			
TOTAL LAND		10 546.8	100

Notes: Final boundary between the Sudan and South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.
Sources: Author's own elaboration based on United Nations Geospatial. 2020. Map geodata [shapefiles]. New York, USA, United Nations; NBS/OCHA

Vegetation on wetland areas 6.9
Herbaceous crop rainfed 0.6
Mixed unit 4.2
Bare areas 4.6
Closed natural vegetation 2.1
Open natural vegetation 8.2
Grassland 72.9

SUDAN

Northern
Bahr el
Ghazal

Warrap

Unity

0   5   10   20
                                    Km

REFERENCES
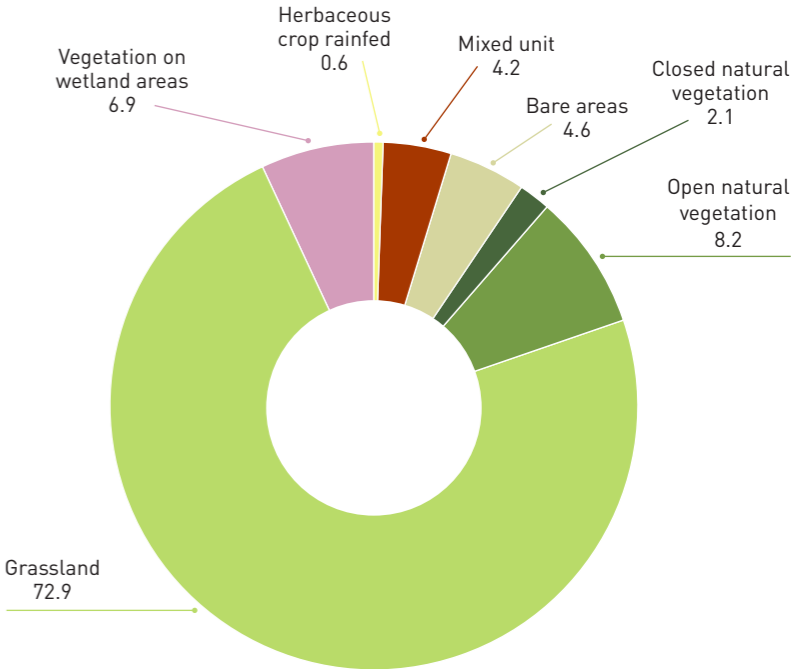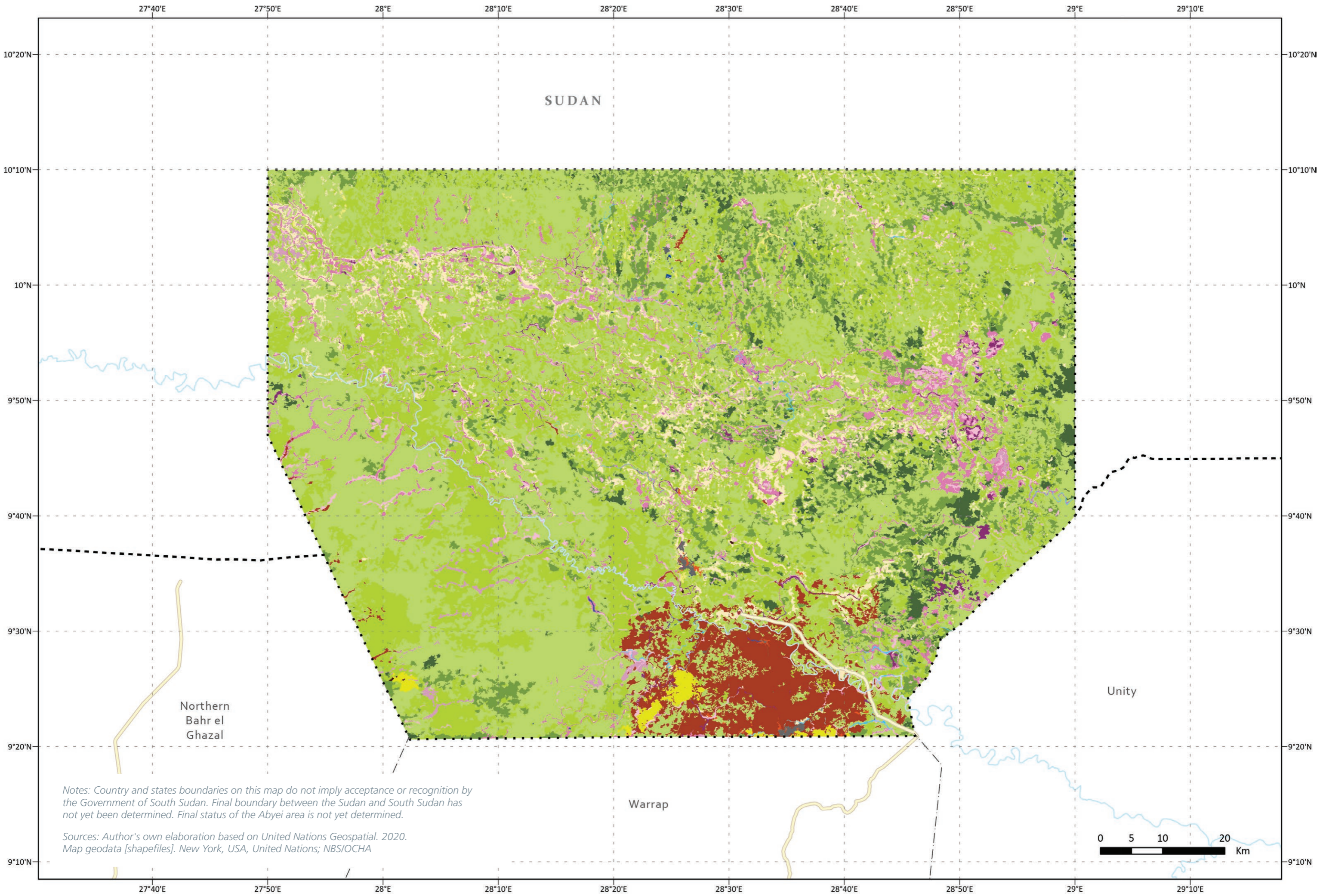
Center for International Earth Science Information Network – CIESIN, Columbia University, Information Technology Outreach Services – ITOS and University of Georgia. 2013. *Global Roads Open Access Data Set, Version 1 (gROADSv1).* Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927 H4V D6WCT.

Di Gregorio, A. 2016. *Land Cover Classification System, Software version 3.* Available on http://www.fao.org/3/a-i5232e.pdf

Di Gregorio, A., Jansen, L.J.M. 2000. *Land Cover Classification System (LCCS): Classification Concepts and User Manual.* FAO, Rome (Incl. CD-ROM with application software)

European Space Agency. 2017. *Land Cover CCI Product User Guide Version 2. Technical Report.* Available at: maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

European Space Agency. *Bulletin 161 - 1st quarter 2015.* http://esamultimedia.esa.int/docs/EarthObservation/Sentinel-2_ESA_Bulletin161.pdf

European Space Agency. *Copernicus Sentinel data 2017*

FAO. 2011. *Land Cover Atlas of the Republic of South Sudan.* Rome, Italy

FAO. *GIEWS - Global Information and Early Warning System* https://www.fao.org/giews/countrybrief/country.jsp?code=SSDGIEWS

FAO. 2023. *Special report – 2022 FAO Crop and Food Supply Assessment Mission (CFSAM) to the Republic of the Sudan. CFSAMs Special Reports, 20 March 2023.* Rome. https://doi.org/10.4060/cc5009en

GeoNames. *GeoNames.* http://geonames.org/

IPC. 2017. *Integrated Food Security Phase Classification. The Republic Of South Sudan. Current Period Classified: May 2017.* https://www.ipcinfo.org/ipc-country-analysis/details-map/fr/c/1026196/?iso3=SSD

Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. 2016. *Estimating the -volume and age of water stored in global lakes using a geostatistical approach.* Nature Communications, 7: 13603. https://doi.org/10.1038/ncomms13603

Ministry of Economy, Trade, and Industry (METI) of Japan and United States National Aeronautics and Space Administration (NASA). *ASTER GDEM v2*
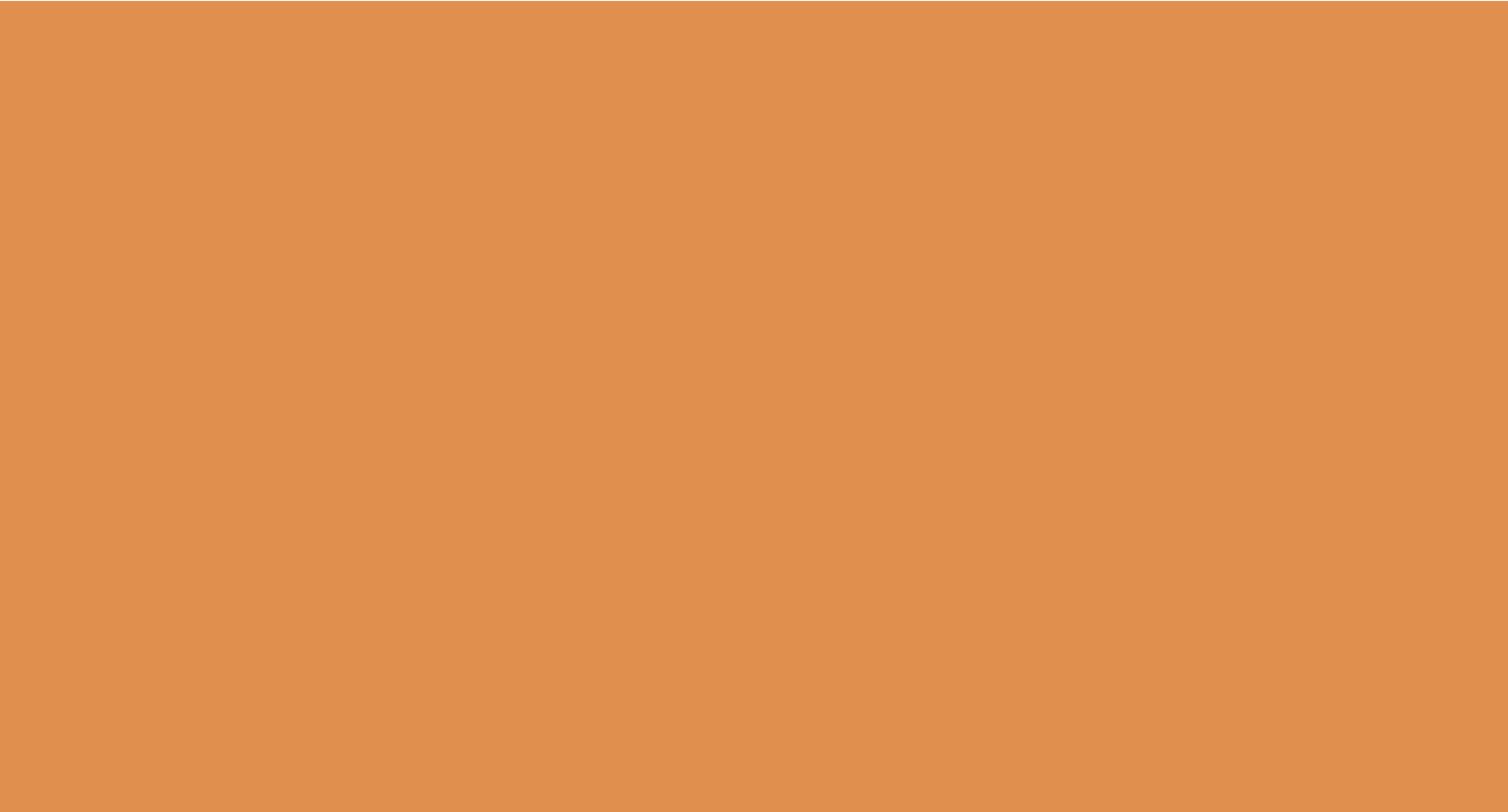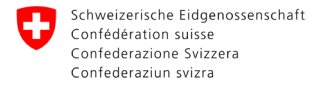
Pekel, J., Cottam, A., Gorelick, N. and Belward, A. 2016. *Global Surface Water - Data Access.* Nature. doi:10.1038/nature20584, JRC109054

Phiri, D., Simwanda, M., Salekin, S., Nyirenda, V.R., Murayama, Y. and Ranagalage, M. 2020. *Sentinel-2 Data for Land Cover/Use Mapping: A Review. Remote Sensing.* 12(14):2291. https://doi.org/10.3390 rs12142291

UNEP-WCMC and IUCN. 2018. *Protected Planet: The World Database on Protected Areas (WDPA).* Cambridge, UK

United Nations Geospatial. 2020. *Map geodata [shapefiles].* New York, USA, United Nations