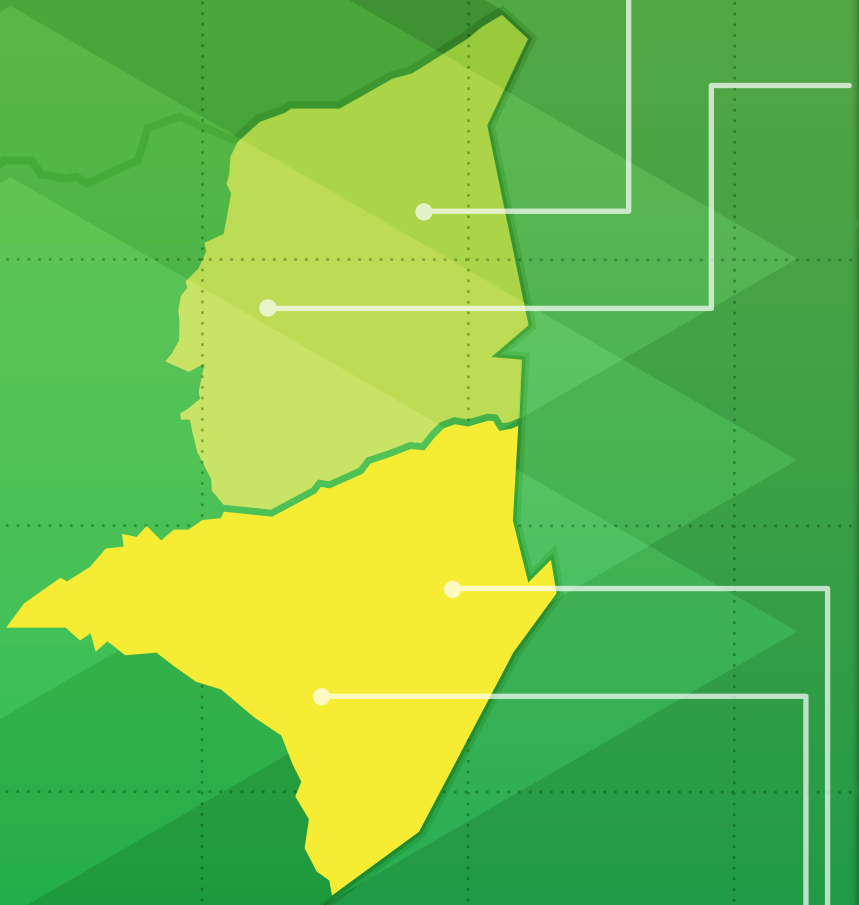
Food and Agriculture Organization of the United Nations



A rapid geospatial analysis of Nampula and Cabo Delgado Provinces in Mozambique

A rapid geospatial analysis of Nampula and Cabo Delgado provinces in Mozambique

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Acronyms and abbreviations

EVI	Enhanced vegetation index
FAO	Food and Agriculture Organization of the United Nations
GEE	Google earth engine
GRVI	Green red vegetation index
LCML	land cover meta language
LULC	Land use and land cover
MNDWI	Modified normalized difference water index
MSI	Moisture stress index
NDRBI	Normalized difference red-blue index
NIR	Near infrared
NFI	National forest inventory
reNDVI	Red-edge normalized difference vegetation index
RF	Random forest
SAVI	Soil adjusted vegetation index
SNIC	Simple non-iterative clustering
SRTM	Shuttle radar topography mission

Executive summary

The Republic of Mozambique is one of the most vulnerable countries in the world to weather variability and natural and climate hazards. In terms of economic development, Cabo Delgado and Nampula provinces, located in the northernmost part of the country, are the most unstable and far behind than other provinces in Mozambique. Despite the economic instability, escalating conflicts and insurgencies, along with climatic shocks, are significantly affecting the agricultural sector and livelihoods. The situation is worsening and disproportionately affected by the COVID-19 pandemic. In this context, the Food and Agriculture Organization of the United Nations (FAO) conducted a geospatial assessment of Cabo Delgado and Nampula provinces of Mozambique for the period 2016–2021, with a particular focus on key indicators related to access to energy (biomass), food (change of agricultural land) and water (agricultural drought).

By combining remote sensing and geospatial information (for example population, land cover and administrative boundary) and other information sources, this assessment identified geographic areas and exposed household that are most affected by changes. To conduct this assessment, the methodology included development of new land cover maps for 2016 and 2021. The land cover change, based on Sentinel 2 optical data and using Google Earth Engine (GEE), allowed agriculture, forest and biomass change assessment. Forest biomass estimates were derived from the National Forest Inventory (NFI) and integrated with land cover for change assessment. Drought assessment was derived using standardized vegetation index (SVI) and standardized precipitation index (SPI).

The key finding of this assessment were that: (1) Nampula province is most affected by droughts; (2) the most negative changes from 2016 to 2021 at admin level 3 in a) agricultural area were in found Mossuril, Nacala-A-Velha, Namapa, Alua and Memba postos of Nampula province b) forest area were in N'Gapa, Meluco, Chapa of Cabo Delgado and Corrane and Meti postos of Nampula province and (3) the most exposed population to drought, agriculture land and forest lost was found in Nampula province.

Recommendations are made for further improvement of similar geospatial assessment in the future in Mozambique, summarised as follow: (1) use of ISO standard LCML in describing land cover in detail; (2) preparation and regular updating of national data at required administrative level; (3) updating demographic and geographic boundaries for the IDP sites; (4) collection and use of field data for validation and calibration; (5) use of high-resolution satellite imagery and innovative geospatial technologies; (6) use of various vegetation indices, biophysical and socioeconomic indicators; (7) combine different sources of information from different stakeholders and platforms such as agroecological zoning by crop types, FAOSTAT and other national agriculture and crop statistics; and (8) consultation, collaboration and coordination with other local, regional and national stakeholders involved in land monitoring and conflict risk management.

1 Background

Cabo Delgado province is located in the northernmost part of Mozambique, bordering the neighbouring country of United Republic of Tanzania. More than 2 320 000 people live in 82 625 km^2 area. The province's climate is characterized as a tropical savanna climate. In terms of economic development, the province lagged the rest of Mozambique. The conflicts and insurgencies along with climate shocks have even made it worse. Some of the populated area including Pemba are categorized as crisis phase in terms of food security (IPC phase October 2020 – January 2021). Discovery of natural gas and rubies brought the hope in development for the Cabo Delgado population. But the appearance of insurgency characterized by attacks in the villages has been a key factor of displacement and misery. Maize, sorghon and cowpeas are the main crops during the growing season.

Nampula province is located in the north-eastern part of Mozambique with an area of 79 010 km^2. Also known as "The capital of North", Nampula is the centre of business in northern Mozambique. With a population of 743 125 it is the third largest city in Mozambique after Maputo and Matola. The province has been facing extreme crises and needs humanitarian assistance.

In this context, improvement of the agricultural system along with judicious planning is an important prerequisite to improve the food security and minimize conflicts. The state-of-the-art remote sensing data and geospatial tools has a key role to play in this regard. This document presents the results of the remote sensing and geospatial analysis carried out in the Cabo Delgado and Nampula provinces, including the internally displaced person(s) (IDP) site areas that provides spatially explicit information related to drought, forest and agricultural land change during 2016 to 2021.

2 Objectives

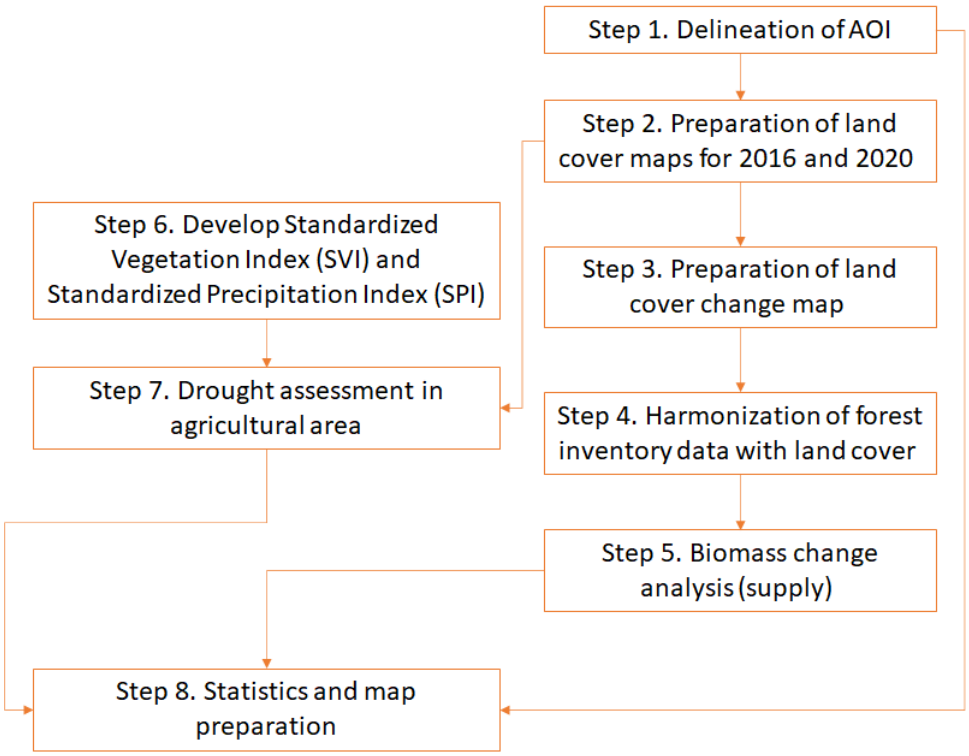
The objectives of the assessment were to:

- To undertake a geospatial analysis to assess changes in agriculture, forest and biomass and to provide a spatially explicit information on the changes.
- To conduct a geospatial analysis to assess drought.
- To identify priority geographic areas that are most affected due to land cover changes and drought.

3 Data and methodology

The methodological approach for the assessment takes into consideration of several constraints specially lack of field data and incomplete data. The approach is presented in Figure 01 and elaborated in following subsections.

Figure 01. Methodological approach



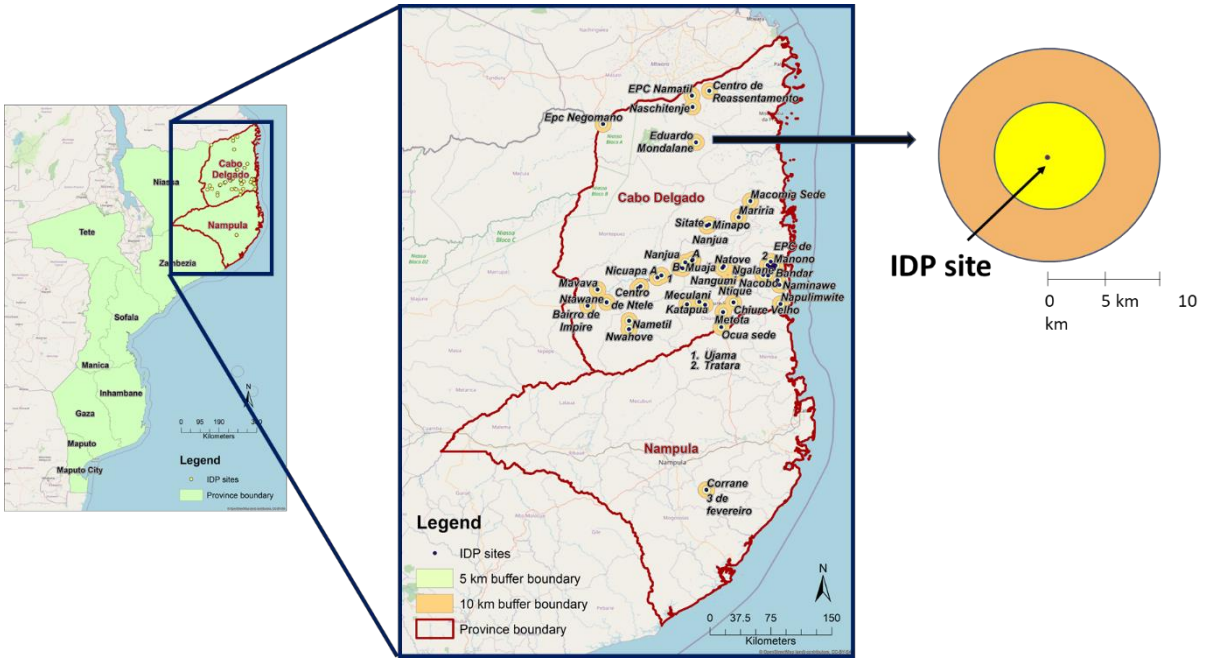
3.1 Geographic scope

This analysis focus on Cabo Delgado and Nampula provinces. Administrative boundaries from Humanitarian Data Exchange platform (HDX)[1] was used to delineate Cabo Delgado and Nampula provinces at admin level 3 (Posto). In total, 122 Posto (level 3, 57 in Cabo Delgado and 65 in Nampula), 40 districts (level 2, 17 in Cabo Delgado and 23 in Nampula) and two provinces (level 1, Cabo Delgado and Nampula) have been analysed.

Additional results for land cover and biomass change are provided in and around each IDP sites (19 in total) in Cabo Delgado and Nampula provinces. For this, buffers of 5 km and 5 to 10 km have been created around the IDP site locations. Figure 02 presents the delineation of the geographic areas for this assessment.

[1] https://data.humdata.org/

Figure 02. Delineation of geographic areas for the assessment



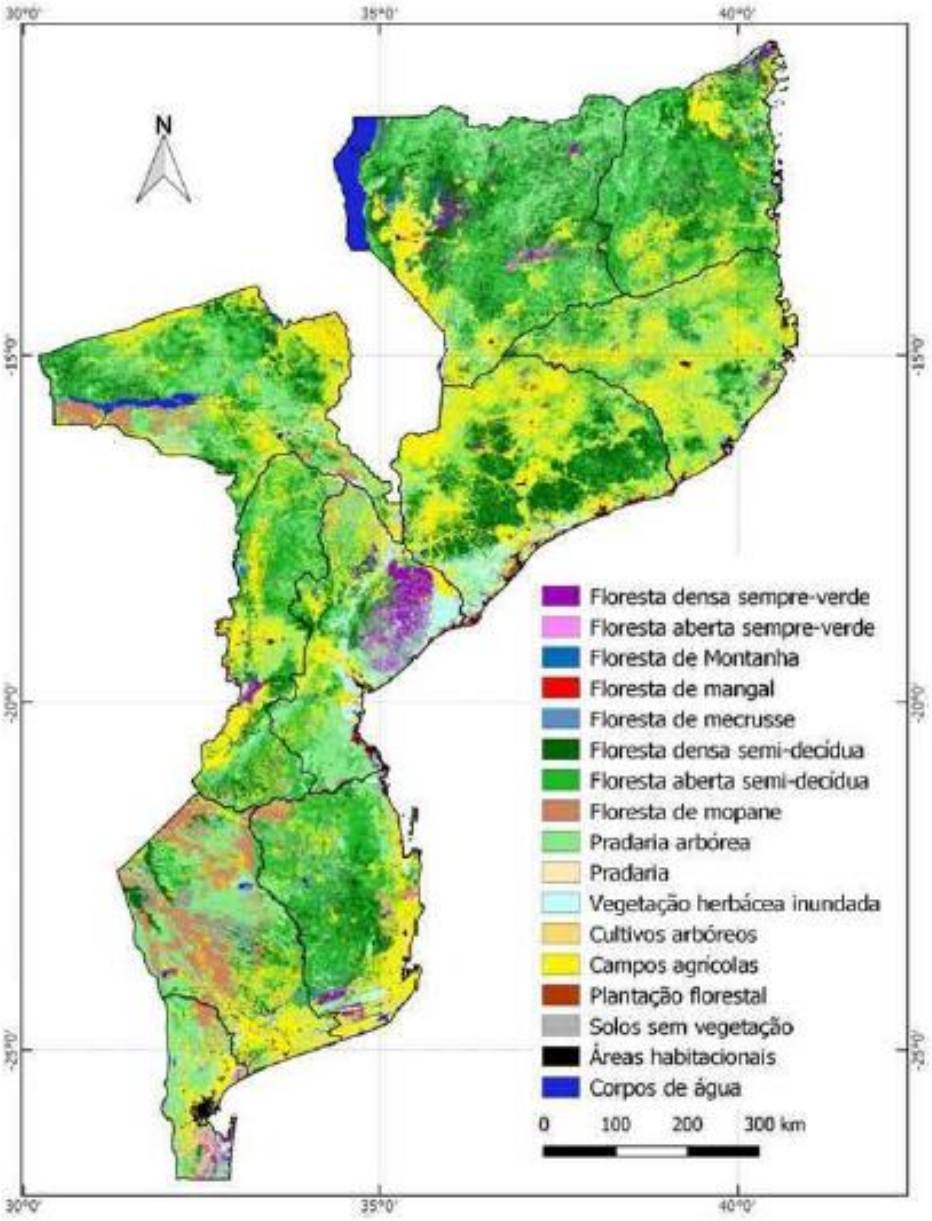
Sources: Administrative boundary: *HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
IDP sites: FAO Mozambique

3.2 Preparation of land cover and land cover change maps

3.2.1 Legend and training data

Seventeen land cover classes based on the national land cover map of 2016 (FNDS, 2020) were considered for land cover mapping and subsequent assessment. The land covers are bare ground, flooded herbaceous area, forest deciduous closed, forest deciduous open, Forest evergreen closed, forest evergreen open, forest plantation, mangrove, mecrusse, mountain forest, non-tree cultivation, prairie, prairie tree, rock without vegetation, tree cultivation, urban area and waterbody. No detailed descriptions of these land cover classes were available during the assessment. Training samples for the land cover mapping have been collected from this national map (Figure 03) by allocating two hundred randomly selected sample points for each of the land covers. Outliers in the training data for each of the land cover classes were identified using several spectral bands and indices and excluded from further analysis.

Figure 03. Mozambique land cover map of 2016



Source: FNDS 2020. *Mapa de cobertura florestal de Moçambique 2016 [Mozambique Forest Cover Map 2016]*. Maputo, Mozambique, Fundo Nacional de Desenvolvimento Sustentavel. www.fnds.gov.mz/mrv

3.2.2 Satellite and ancillary data

Sentinel 2 (S2) optical data were used. Of the 13 spectral bands of S2 in the visible, near-infrared and short-wave infrared parts of the spectrum, 6 spectral bands of blue [496.6nm (S2A) / 492.1nm (S2B)], green [560nm (S2A) / 559nm (S2B)], red [664.5nm (S2A) / 665nm (S2B)], red edge 2 [740.2nm (S2A) / 739.1nm (S2B)], near infrared [835.1nm (S2A) / 833nm (S2B)] and short-wave infrared 1 [1613.7nm (S2A) / 1610.4nm (S2B)] were used.

Analysis Ready Data (ARD) data from Sentinel 2, available through the Google earth Engine (GEE), were retrieved. All images from January to December for the years of 2016 and 2021 were used. Clouds were masked and were transformed to temporal composites (i.e. January–April, May–August and September–December) to achieve spatially homogenous and temporally equidistant images, allowing a uniform processing framework for the whole county (Griffiths *et al.*, 2020). Apart from satellite images, ancillary data used for mapping land cover were elevation (SRTM 30m), slope (derived from SRTM 30m), aspect (derived from SRTM 30m).

3.2.3 Image segmentation

An object based image analysis (OBIA) approach was adopted to create image objects. In particular, the simple non-iterative clustering (SNIC) super-pixel segmentation, available in GEE, was used. The SNIC algorithm starts from seeds created on a regular grid and then, groups pixels into super-pixel clusters based on their distance from cluster centroids, considering the normalized five-dimensional space of CIELAB color and spatial coordinates. Subsequently, all image pixels are added to priority queues based on their connectivity to existing super-pixel clusters. Each time a pixel with the smallest distance to the cluster's centroid is added, an updated centroid value and priority queue is generated for each growing cluster (Achanta and Süsstrunk, 2017).

Parameters needed to be set in the SNIC segmentation are the seed distance, segment compactness, connectivity and the neighbourhood size. Based on trial and error and visual inspection, SNIC parameters were selected after various experiments, based on visual inspection to produce the most homogeneous and meaningful objects within the experiment test sites and in accordance with the concept that "a good segmentation is one that shows little over-segmentation and no under-segmentation" (G.J. and G., 2008). The SNIC parameters were set to a) seed distance of 100 pixels, b) segment compactness = 1, c) 8-pixel connectivity and d) neighbourhood size of 256 pixels.

3.2.4 Classification

A wide range of spectral and spatial features were considered in the classification process and used to calculate descriptive statistics for each image object (**Table 01**). For land cover classification, random forest (RF), a popular supervised machine learning algorithm, was used. RF model is nonparametric and fits multiple decision tree classifiers on various subsamples of the dataset using averaging/majority to improve the predictive accuracy and control over fitting (Breiman, 2001). It uses only a part of the samples for training and keeps the remaining (so called out-of-the bag samples) for an internal error estimate, called out-of-bag (OOB) error. RF has been proven to be robust to reference data errors up to 15 percent, works well with small sample sizes and highly dimensional feature spaces. In addition, it has a small execution time compared to other classification methods (Inglada *et al.*, 2017). For the above reasons, RF has been widely used in LULC classification studies and has shown the best performance in object based classification (Ma *et al.*, 2017).

Table 01. Features considered in the classification process

Feature name	Statistics per object	Index formula	Data source
Original bands			
B2, B3, B4, B6, B8, B11	Mean		S2 L1C
Spectral indices			
NDVI	Mean	(NIR – Red) / (NIR + Red)	S2 L1C
reNDVI	Mean	(NIR – RE2) / (NIR + RE2)	S2 L1C
MNDWI	Mean	(Green - SWIR1) / (Green + SWIR1)	S2 L1C
GRVI	Mean	(Green - Red) / (Green + Red)	S2 L1C
NDRBI	Mean	(Red - Blue) / (Red + Blue)	S2 L1C
MSI	Mean	SWIR1/NIR	S2 L1C
EVI	Mean	2.5 * ((NIR - Red) / (NIR + 6 * Red - 7.5 * Blue + 1))	S2 L1C
$SAVI_{0.5}$	Mean	((NIR - Red) / (NIR + Red + 0.5)) * (1 + 0.5)	S2 L1C
Object shape properties			
Perimeter		P	
Area		A	
From factor		4PiA/P	
Square pixel metric		1 – (4sqrt(A)/P)	
Fractal dimension			
Shape index		P/4sqrt(A)	
Ancillary data			
Elevation, slope, aspect	Mean		SRTM

3.2.5 Land cover change map

Land cover change map was prepared by overlaying the land cover maps of 2016 and 2021 and subsequently used for biomass change analysis.

3.3 Harmonization of forest inventory data with land cover and biomass change analysis

In the national forest inventory (NFI), biomass data were not available for all land cover classes (MITADER, 2018). Accordingly, average biomass was used for forest class and zero for other land cover classes for which biomass data were not available in the NFI (**Table 02**).

Table 02. Biomass per land cover class

SL	2016 LC map class	Agriculture/forest	Biomass data available	TB (Mg/ha)
1	Tree cultivation	Other	No	0
2	Non-tree cultivation	Agriculture	No	0
3	Forest plantation	Forest	No	93.77
4	Prairie	Other	No	0
5	Prairie tree	Other	No	0
6	Flooded herbaceous area	Other	No	0
7	Water body	Other	No	0
8	Urban area	Other	No	0
9	Bare ground	Other	No	0
10	Rock without vegetation	Other	No	0
11	Mangrove	Forest	No	93.77
12	Mecrusse	Forest	Yes	99.23
13	Mountain forest	Forest	Yes	129.09
14	Forest evergreen closed	Forest	Yes	129.09
15	Forest deciduous closed	Forest	Yes	87.05
16	Mopane	Forest	Yes	58.4
17	Forest evergreen open	Forest	Yes	129.09
18	Forest deciduous open	Forest	Yes	87.05

Source: MITADER 2018. *Inventário Florestal Nacional [National Forest Inventory]*. Maputo, Mozambique, Fundo Nacional de Desenvolvimento Sustentavel. https://fnds.gov.mz/mrv/index.php/documentos/relatorios/26-inventario-florestal-nacional/file

3.4 Drought assessment

Draught assessment was based on calculation of Standardized Vegetation Index (SVI) and Standardized Precipitation Index (SPI). The SVI describes the probability of variation from the normal Enhanced Vegetation Index (EVI) over multiple years of data, on a 16-day time step. The EVI images are level 3 products based on data captured by MODIS. The SVI is calculated by taking the EVI of the pixel i during week j for year k minus the mean for pixel i during week j over n years, divided by standard deviation of pixel i during week j over n years (Peters *et al.*, 2002).

The SPI describes the probability of variation from the normal precipitation over multiple years of data, on a specific time step. The SPI is calculated by taking the precipitation of the pixel i during timeframe j of year k minus the mean of pixel i during timeframe j over n years, divided by standard deviation of pixel i during timeframe j over n years. As the vegetation might need some time to respond to rainfall, a shift of five days for the calculated 16-day SPI was applied - SPI calculations started five days before the MODIS start dates and end the calculations five days earlier than the MODIS end dates as well.

SVI value less than – 1.96 represent areas with vegetation decrease at 95 percent confidence level. However, such decrease of vegetation may be natural or man-made. Accordingly, SVI with value less than – 1.96 (5 percent significant level) with SPI less than 0 (decreased precipitation) were combined to identify drought and non-agricultural lands from the 2021 land cover map were masked out to identify drought in agricultural land.

3.5 Statistics and map preparation

Lack of ground data and low accuracy of the baseline data[2] was a major concern for the assessment. Such uncertainty usually propagates in subsequent analyses. Accordingly, the results were scaled that provides a comparative result across the units of analysis (e.g. Posto) instead of absolute values of changes. Demographic data for the IDP sites were not complete and hence, should be used accordingly.

Necessary statistics for different AOIs (admin levels and IDP site locations) were prepared to produce different maps and tables as reported in the results section. Detail information on land cover change, drought, etc. for individual Posto and IDP site are provided in appendix. In addition, .kml files have been prepared to facilitate any user with Google Earth to visualise some of the results, as listed below.

Change in agricultural area at Posto level from 2016 to 2021 is available here.
Change in forest area at Posto level from 2016 to 2021 is available here.
Change in biomass at Posto level from 2016 to 2021 is available here.
Percentage of agricultural area affected by drought in 2021 at Posto level is available here.

[2] Overall accuracy of the 2016 national land cover map was 65.2% ± 1.7% at 95% confidence interval.

4 Results

4.1 Changes in agriculture, forest and biomass at admin level

4.1.1 Change in agriculture area

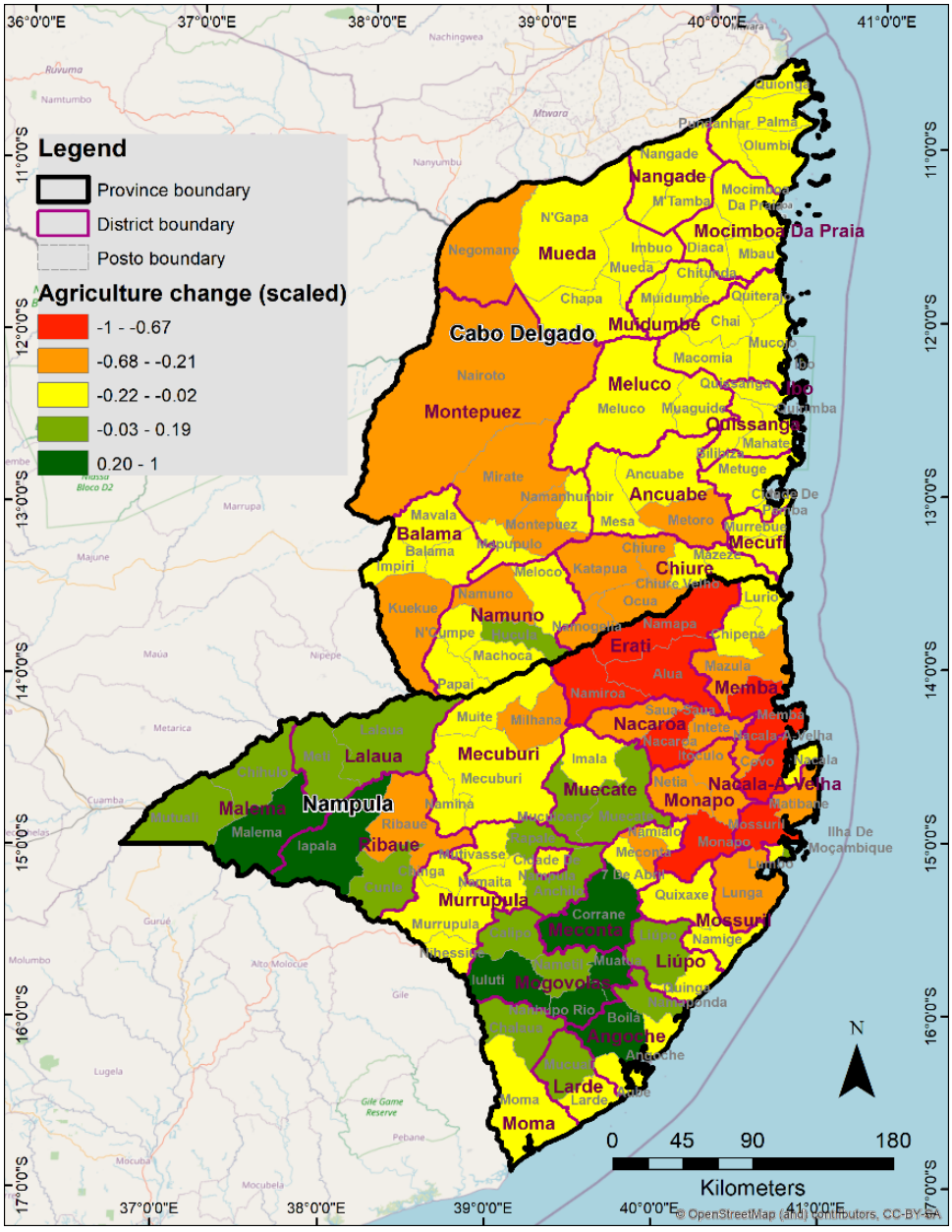
Figure 4 shows the change in the agriculture area from 2016 to 2021 at the admin level 3 (Posto). The changes in agricultural land were scaled between –1 to 1, where positive change indicates that agricultural land increased while negative means decreased in agricultural land from 2016 to 2021. The highest negative change in agriculture area (reduction) was found in Mossuril (Nampula province). In addition, reduction in agricultural land mostly found in Nampula province (Mossuril, Nacala-A-Velha, Erati, Memba, Monapo and Nacaroa districts). In contrast, the results further indicate that most of the positive change in agriculture area (increased) was also detected Nampula province. Top ten most affected Posto due to loss in agricultural land are listed in Table 3.

Table 03. Top ten most affected Posto due to loss of agricultural land

PROVINCE	DISTRICT	POSTO	CODE	POPULATION	AREA (SQ KM)	RANK
NAMPULA	Mossuril	Mossuril	MZ071603	47 282	848	1
NAMPULA	Nacala-A-Velha	Nacala-A-Velha	MZ072002	77 709	845	2
NAMPULA	Erati	Namapa	MZ070302	150 885	2 259	3
NAMPULA	Erati	Alua	MZ070301	114 715	1 913	4
NAMPULA	Memba	Memba	MZ071104	100 259	1 385	5
NAMPULA	Monapo	Monapo	MZ071502	179 258	1 233	6
NAMPULA	Nacaroa	Nacaroa	MZ072102	74 677	934	7
NAMPULA	Erati	Namiroa	MZ070303	70 852	1 528	8
NAMPULA	Monapo	Itoculo	MZ071501	69 068	1 243	9
CABO DELGADO	Montepuez	Nairoto	MZ011104	15 873	12 080	10

Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

Figure 04. Change in agricultural area from 2016 to 2021 at admin level 3 (Posto)



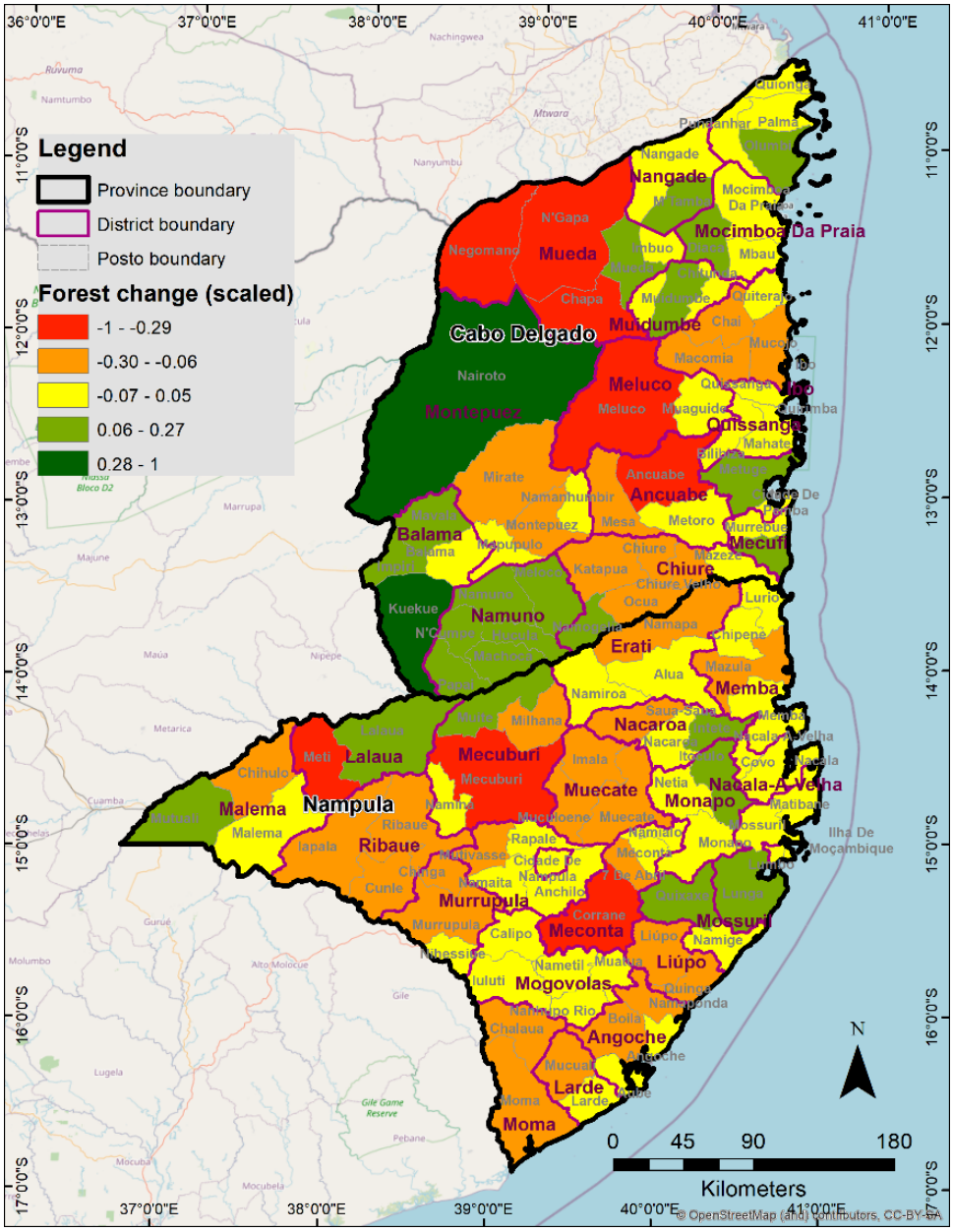
Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

4.1.2 Change in forest area

Figure 5 shows the changes in the forest area from 2016 to 2021 at admin 3 level (Posto). The changes in forest area were scaled between –1 and 1, where positive means that forest area is increased while negative means decrease in forest area from 2016 to 2021. The highest loss in forest area was found in N'Gapa, Meluco and Chapa posto in Cabo Delgado and Corrane and Metiin posto in Nampula province Some positive

changes in forest area were also detected in Cabo Delgado and Nampula. Table 4 lists the top ten most affected Posto due to forest loss between 2016 and 2021.

Figure 05. Change in forest area from 2016 to 2021 at admin level 3 (Posto)



Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Table 04. Top ten most affected Posto due to loss of forest area

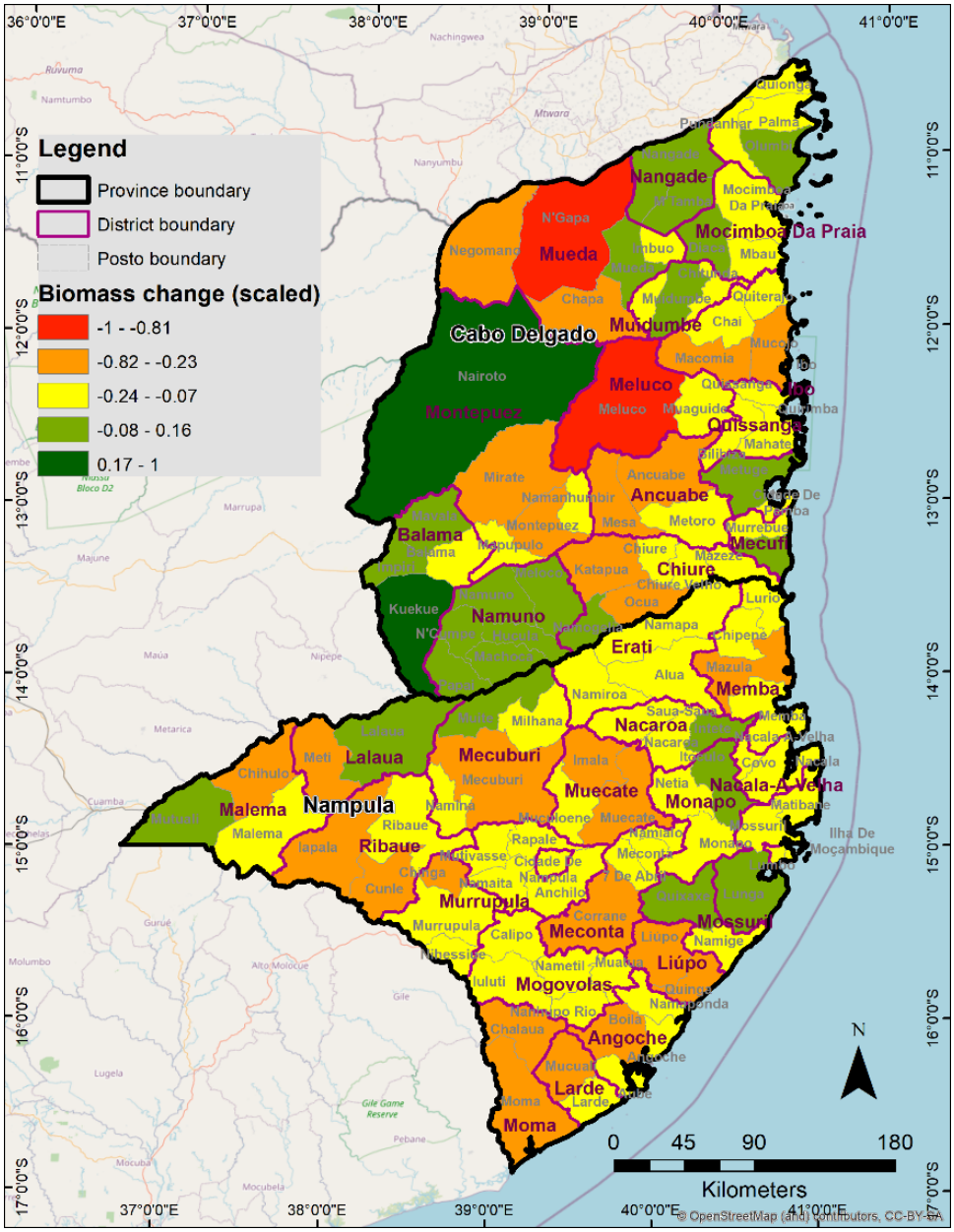
PROVINCE	DISTRICT	POSTO	CODE	POPULATION	AREA (SQ KM)	RANK
CABO DELGADO	Mueda	N'Gapa	MZ011204	36 945	4 493	1
CABO DELGADO	Meluco	Meluco	MZ010801	15 344	4 525	2
CABO DELGADO	Mueda	Chapa	MZ011201	36 789	2 033	3
NAMPULA	Meconta	Corrane	MZ070902	72 163	2 317	4
NAMPULA	Lalaua	Meti	MZ070502	22 607	1 660	5
CABO DELGADO	Mueda	Negomano	MZ011205	3 352	3 023	6
NAMPULA	Mecuburi	Mecuburi	MZ071001	108 127	3 641	7
CABO DELGADO	Ancuabe	Ancuabe	MZ010101	48 102	2 090	8
NAMPULA	Malema	Chihulo	MZ070801	24 871	1 687	9
NAMPULA	Muecate	Muecate	MZ071703	74 980	1 908	10

Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

4.1.3 Change in biomass

Figure 6 shows the change in the biomass from 2016 to 2021 at the admin level (Posto). The changes in biomass were scaled from –1 to 1 where positive means that biomass is increased while negative means decrease in biomass from 2016 to 2021. The highest loss in biomass was found in N'Gapa and Meluco in Cabo Delgado province. Positive change in biomass was mostly detected the Cabo Delgado areas. Top ten most affected Posto due to biomass loss are the same for forest loss as listed in Table 4. This is because biomass loss is based on only forest loss due unavailability of biomass data for the land covers other than forest.

Figure 06. Change in biomass from 2016 to 2021 at admin level 3 (Posto)



Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Figure 7 shows the top ten most affected Postos due to forest and agriculture land loss and drought. The result shows that all the most affected Posto by drought are located in Nampula province. Most affected Postos by agricultural land loss were also concentrated in the Nampula province. In contrast, Cabo Delgado province has most of the Postos highly affected due to forest land loss.

Figure 07. Top ten most affected Posto due to forest loss, agricultural land loss and drought

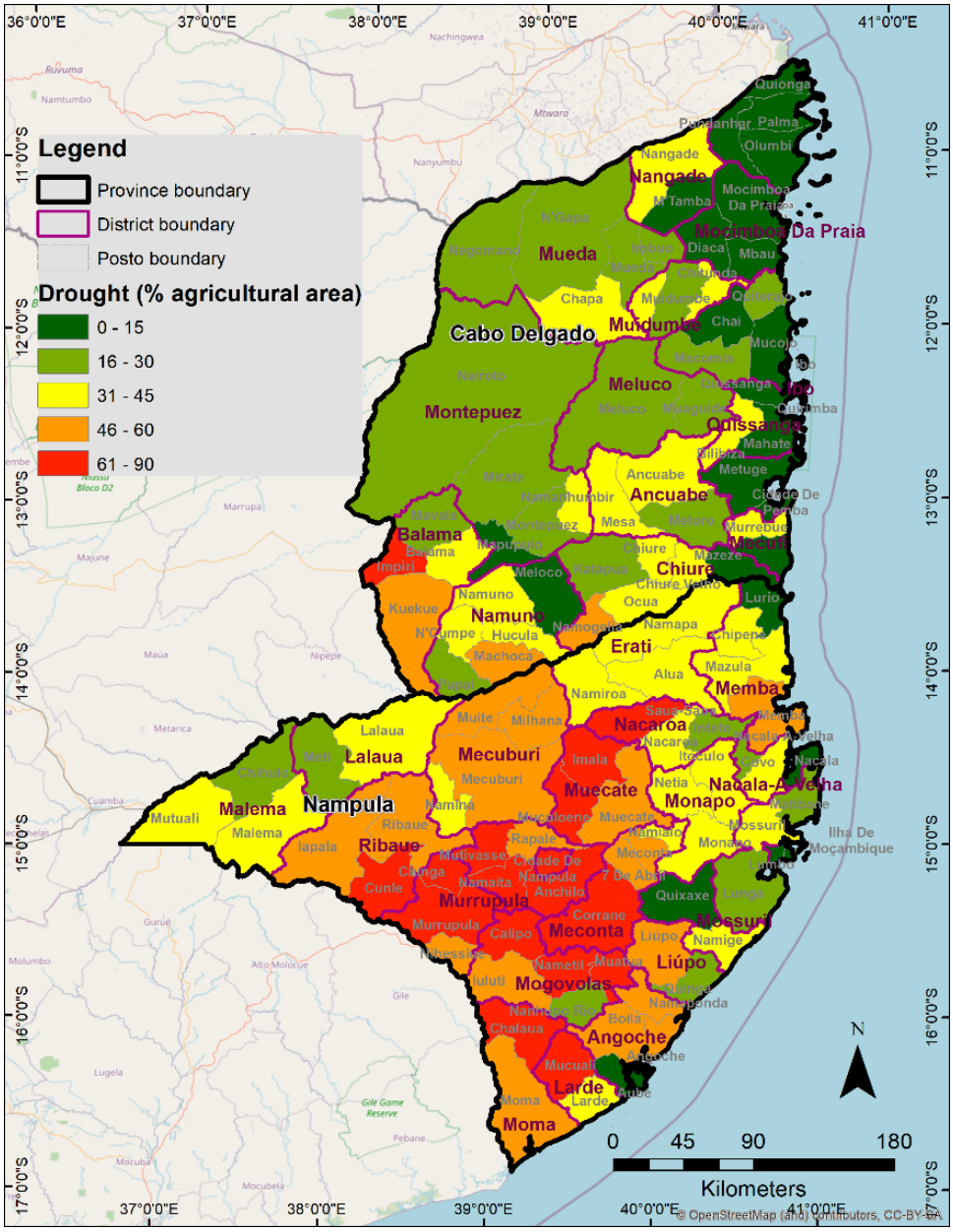
Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

4.2 Drought at admin level

Figure 9 shows drought affected agriculture area in 2021 at the admin level 3 (Posto). The affected agricultural area by drought was shown in percentage of the agricultural land affected by drought in the Posto. The highest the percentage, the more agriculture area is affected. The results indicate that most Nampula province was highly affected by

drought. Few affected agriculture area by drought were found in Cabo Delgado province. Top ten affected Posto due to drought are listed in Table 5.

Figure 08. Drought affected agricultural area in 2021 at admin level 3 (Posto)



Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Table 05. Top ten most affected Posto due to drought in agricultural land

PROVINCE	DISTRICT	POSTO	CODE	POPULATION	AREA (SQ KM)	RANK
NAMPULA	Meconta	Corrane	MZ070902	72 163	2 317	1
NAMPULA	Mogovolas	Iuluti	MZ071302	84 815	1 390	2
NAMPULA	Mecuburi	Mecuburi	MZ071001	108 127	3 641	3
NAMPULA	Ribaue	Iapala	MZ072302	135 324	2 623	4
NAMPULA	Muecate	Muecate	MZ071703	74 980	1 908	5
NAMPULA	Moma	Chalaua	MZ071401	97 859	1 400	6
NAMPULA	Mogovolas	Nametil	MZ071304	172 972	911	7
NAMPULA	Mogovolas	Muatua	MZ071303	49 681	605	8
NAMPULA	Murrupula	Murrupula	MZ071802	149 689	1 958	9
NAMPULA	Rapale	Anchilo	MZ072201	145 876	1 317	10

Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

4.3 Population exposed to loss in agricultural land, forest and drought

Apart from identifying the most affected Posto due to drought, agriculture and forest loss, population exposed to these drivers were also estimated at Posto level. Table 6, Table 7 and Table 8 present the most affected Posto due to the population exposed to agricultural land loss, forest loss and drought, respectively. Figure 9 presents the top ten most affected Posto considering the highest number of population exposed to forest and agriculture land loss and drought.

Table 06. Top ten most affected Posto due to population exposed to agricultural land loss

PROVINCE	DISTRICT	POSTO	CODE	POPULA-TION	AREA (SQ KM)	RANK
NAMPULA	Nacala	Nacala	MZ071901	294 727	319	1
NAMPULA	Cidade De Nampula	Cidade De Nampula	MZ070201	847 218	330	2
CABO DELGADO	Cidade De Pemba	Cidade De Pemba	MZ010401	260 693	100	3
NAMPULA	Monapo	Monapo	MZ071502	179 258	1 233	4
NAMPULA	LiÃºpo	Quinga	MZ070702	135 307	758	5

PROVINCE	DISTRICT	POSTO	CODE	POPULA-TION	AREA (SQ KM)	RANK
NAMPULA	Angoche	Aube	MZ070102	150 061	552	6
NAMPULA	Erati	Namapa	MZ070302	150 885	2 259	7
NAMPULA	Monapo	Netia	MZ071503	211 250	1 040	8
NAMPULA	Erati	Alua	MZ070301	114 715	1 913	9
NAMPULA	Nacala-A-Velha	Nacala-A-Velha	MZ072002	77 709	845	10

Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

Table 07. Top ten most affected Posto due to population exposed to forest loss

PROVINCE	DISTRICT	POSTO	CODE	POPULATION	AREA (SQ KM)	RANK
CABO DEL-GADO	Cidade De Pemba	Cidade De Pemba	MZ010401	260 693	100	1
NAMPULA	Mogovolas	Nametil	MZ071304	172 972	911	2
NAMPULA	Monapo	Netia	MZ071503	211 250	1 040	3
NAMPULA	Moma	Moma	MZ071402	233 737	2 510	4
NAMPULA	Memba	Mazula	MZ071103	182 390	1 570	5
NAMPULA	Rapale	Anchilo	MZ072201	145 876	1 317	6
NAMPULA	Angoche	Boila	MZ070103	104 360	1 253	7
NAMPULA	LiÃºpo	Quinga	MZ070702	135 307	758	8
NAMPULA	Mogovolas	Iuluti	MZ071302	84 815	1 390	9
NAMPULA	Moma	Chalaua	MZ071401	97 859	1 400	10

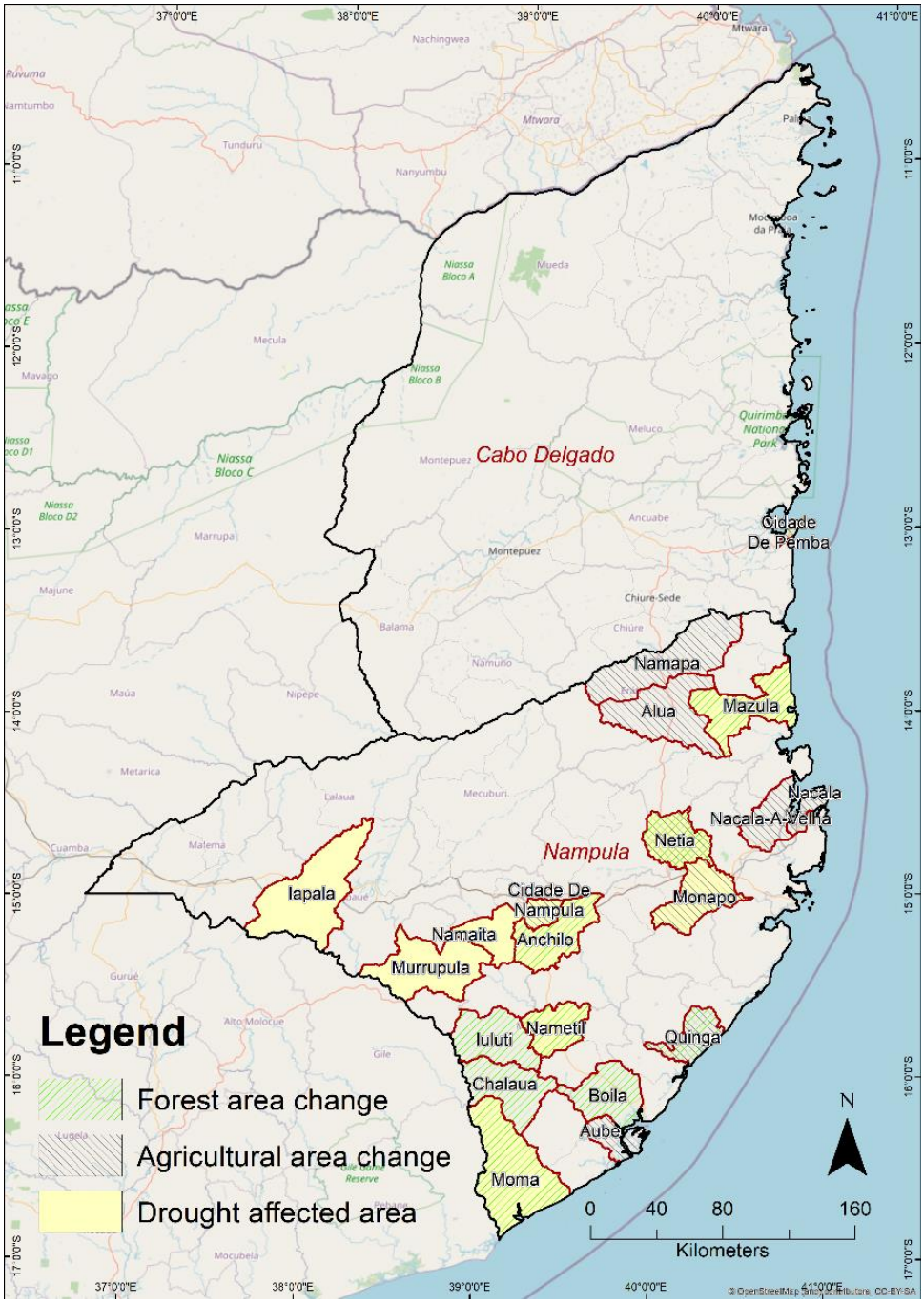
Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

Table 08. Top ten most affected Posto due to population exposed to drought in agricultural land

PROVINCE	DISTRICT	POSTO	CODE	POPULATION	AREA (SQ KM)	RANK
NAMPULA	Cidade De Nampula	Cidade De Nampula	MZ070201	847 218	330	1
NAMPULA	Moma	Moma	MZ071402	233 737	2 510	2
NAMPULA	Mogovolas	Nametil	MZ071304	172 972	911	3
NAMPULA	Murrupula	Murrupula	MZ071802	149 689	1 958	4
NAMPULA	Rapale	Anchilo	MZ072201	145 876	1 317	5
NAMPULA	Monapo	Netia	MZ071503	211 250	1 040	6
NAMPULA	Rapale	Namaita	MZ072203	118 352	822	7
NAMPULA	Ribaue	Iapala	MZ072302	135 324	2 623	8
NAMPULA	Monapo	Monapo	MZ071502	179 258	1 233	9
NAMPULA	Memba	Mazula	MZ071103	182 390	1 570	10

Sources: Administrative boundary: HDX 2021. *Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021. Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints*. WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

Figure 09. Top ten most affected Posto considering exposed population to forest loss, agricultural land loss and drought



Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

4.4 Change in biomass in and around internally displaced person(s) settlements

Table 9 and Table 10 present the most affected areas in and around the IDP sites due to biomass loss between 2016 to 2021. Within the 5 km from IDP sites location 12, that includes the IDP sites of Nanjua A, Nanjua B, Nasimoja, Muaja and Centro de Nanhupo B is the most affected. Location 10 (the IDP sites of Nangumi, Cujupane, Natove and Ntique) is the most affected for the 5 to 10 km areas from IDP sites.

Table 09. Top five most affected areas within 5 km from internally displaced person(s) settlements due to biomass loss

LOCATION ID	RANK	IDP SITE NAMES
12	1	Nanjua A, Nanjua B, Nasimoja, Muaja, Centro de Nanhupo B
6	2	Meculani, Katapua, Marrupa
5	3	Ocua sede, Chiure Velho, Metota
10	3	Nangumi, Cujupane, Natove, Ntique
1	5	3 de Corrane, Fevereiro

Table 10. Top five most affected areas within 5 to 10 km from internally displaced person(s) settlements due to biomass loss

LOCATION ID	RANK	IDP SITE NAMES
10	1	Nangumi, Cujupane, Natove, Ntique
5	2	Ocua sede, Chiure Velho, Metota
6	3	Meculani, Katapua, Marrupa
12	4	Nanjua A, Nanjua B, Nasimoja, Muaja, Centro de Nanhupo B
13	5	Sitate, Minapo

5 Recommendations

Following recommendations are made on the use of geospatial tools along with national and field data for further improvement of similar geospatial assessment in the future in Mozambique.

- National data (geospatial and tabular) should be prepared and regularly updated for possible lowest administrative boundaries, by sectors, land cover (with documented legend as far as possible using LCML ISO 19144-2) and other relevant information.
- Improve land cover information, crop mask and crop type mapping using geospatial technologies.
- Demographic and socioeconomic information collected through household survey should be incorporated.
- Tools and applications for collecting field data using combined approach through field survey and crowdsourcing, involving national stakeholders, should be developed.
- Technical capacities in using geospatial for preparing baseline information and assess risks and impacts should be enhanced through required technical assistance.
- The potential of geospatial technologies and information in strengthening collaboration and partnership among the various stakeholder groups and organisations should be leveraged.
- Satellite images, vegetation indices, agroecological zoning information by crop types, FAOSTAT, national agricultural statistics, crop calendars, market prices should be integrated to obtain national disaggregated crop statistics, consistent with the national ones.
- Use higher spatial resolution satellite imagery for specific prioritised geographic areas to go in further detail is recommended.
- Collaboration with regional and national entities involved in land monitoring and conflict risk management is to be enhanced.
- Targeted indicators to be used for geospatial analyses and for interventions are to be clearly defined.
- Strategic planning for longer-term should be undertaken at the early stage of emergency interventions to ensure the long-term sustainability of livelihoods and natural resources.

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Appendix 01. Change in agriculture, forest and biomass from 2016 to 2021 and draught in 2021 by Posto, District and Province

Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
Nampula	Meconta	7 De Abril	MZ070901	46 567	553	60	35	21	245	151	-859 917
Nampula	Erati	Alua	MZ070301	114 715	1 913	371	107	34	293	247	-405 919
Nampula	Rapale	Anchilo	MZ072201	145 876	1 317	101	182	129	19	9	-100 272
Cabo Delgado	Ancuabe	Ancuabe	MZ010101	48 102	2 090	117	104	35	1484	1077	-3 904 611
Nampula	Angoche	Angoche	MZ070101	66 932	474	17	30	17	61	34	-232 557
Nampula	Angoche	Aube	MZ070102	150 061	552	23	4	0	183	163	-150 487
Cabo Delgado	Balama	Balama	MZ010201	97 921	971	298	267	81	54	64	141 259
Cabo Delgado	Quissanga	Bilibiza	MZ011801	15 946	787	7	5	2	522	574	552 921
Nampula	Angoche	Boila	MZ070103	104 360	1 253	78	272	125	331	99	-2 119 044
Nampula	Mogovolas	Calipo	MZ071301	91 973	1 085	83	169	117	31	22	-87 947
Cabo Delgado	Macomia	Chai	MZ010601	15 604	1 054	11	9	1	649	538	-1 315 365
Nampula	Moma	Chalaua	MZ071401	97 859	1 400	155	250	158	294	108	-1 699 520
Cabo Delgado	Mueda	Chapa	MZ011201	36 789	2 033	23	36	12	1413	858	-5 061 704
Nampula	Malema	Chihulo	MZ070801	24 871	1 687	17	50	14	708	350	-3 096 834
Nampula	Murrupula	Chinga	MZ071801	33 715	572	3	20	17	389	168	-1 898 613
Nampula	Memba	Chipene	MZ071101	56 891	784	12	5	2	311	296	-353 818
Cabo Delgado	Muidumbe	Chitunda	MZ011301	32 789	526	10	4	2	291	345	401 201
Cabo Delgado	Chiure	Chiure	MZ010301	101 619	621	210	82	27	184	76	-956 214
Cabo Delgado	Chiure	Chiure Velho	MZ010302	35 583	623	56	47	15	275	117	-1 435 795
Nampula	Cidade De Nam-	Cidade De Nampula	MZ070201	847 218	330	8	5	4	1	1	5 770

Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
	pula										
Cabo Delgado	Cidade De Pemba	Cidade De Pemba	MZ010401	260 693	100	3	0	0	7	3	-35 632
Nampula	Meconta	Corrane	MZ070902	72 163	2 317	90	483	359	924	422	-4 488 415
Nampula	Nacala-A-Velha	Covo	MZ072001	29 904	288	89	31	9	18	59	362 518
Nampula	Ribaue	Cunle	MZ072301	45 120	1 424	96	135	94	435	258	-1 515 060
Cabo Delgado	Mocimboa Da Praia	Diaca	MZ011001	19 804	1 020	8	2	0	611	745	800 803
Cabo Delgado	Namuno	Hucula	MZ011401	20 004	762	71	92	39	21	306	2 482 164
Nampula	Ribaue	Iapala	MZ072302	135 324	2 623	205	336	195	637	438	-1 717 798
Cabo Delgado	Ibo	Ibo	MZ010501	11 748	58	0	0	0	29	27	-15 890
Nampula	Ilha De MoÃ§ambique	Ilha De MoÃ§ambique	MZ070401	55 006	50	0	0	0	7	8	5 870
Nampula	Muecate	Imala	MZ071701	46 672	1 220	146	134	90	414	160	-2 264 119
Cabo Delgado	Mueda	Imbuo	MZ011202	15 390	530	6	4	1	266	302	512 221
Cabo Delgado	Balama	Impiri	MZ010202	23 068	772	23	21	13	31	411	3 616 996
Nampula	Nacaroa	Intete	MZ072101	51 812	685	220	98	29	68	175	924 453
Nampula	Monapo	Itoculo	MZ071501	69 068	1 243	233	71	26	140	242	917 125
Nampula	Mogovolas	Iuluti	MZ071302	84 815	1 390	223	443	230	108	28	-704 431
Cabo Delgado	Chiure	Katapua	MZ010303	32 693	1 675	133	48	7	1 249	1073	-2 203 323
Cabo Delgado	Balama	Kuekue	MZ010203	28 079	2 470	163	45	22	283	1675	14 377 962
Nampula	Lalaua	Lalaua	MZ070501	83 816	2 871	176	247	103	446	538	943 494
Nampula	Larde	Larde	MZ070601	67 011	735	29	6	2	119	83	-259 721
Nampula	LiÃºpo	LiÃºpo	MZ070701	51 659	1 363	18	59	30	854	626	-2 789 967
Nampula	Ilha De MoÃ§ambique	Lumbo	MZ070402	14 795	131	21	2	0	10	13	42 424

Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
Nampula	Mossuril	Lunga	MZ071601	49 899	1 825	145	2	1	466	670	269 5147
Nampula	Memba	Lurio	MZ071102	15 764	711	11	5	1	482	404	-715 924
Cabo Delgado	Nangade	M'Tamba	MZ011501	27 515	1 027	5	3	0	759	853	881 635
Cabo Delgado	Namuno	Machoca	MZ011402	35 266	931	107	70	37	31	233	1 850 329
Cabo Delgado	Macomia	Macomia	MZ010602	50 994	1 378	9	17	3	1025	900	-2 056 920
Cabo Delgado	Quissanga	Mahate	MZ011802	20 916	875	5	7	0	486	400	-1 267 275
Nampula	Malema	Malema	MZ070802	136 325	2 359	100	230	75	573	511	-495 130
Cabo Delgado	Montepuez	Mapupulo	MZ011101	35 551	743	156	115	14	119	145	253 500
Nampula	Mossuril	Matibane	MZ071602	52 930	707	123	16	4	63	68	116 253
Cabo Delgado	Balama	Mavala	MZ010204	20 416	1 284	73	76	17	358	563	1 890 824
Cabo Delgado	Chiure	Mazeze	MZ010304	17 475	693	9	2	0	362	414	448 104
Nampula	Memba	Mazula	MZ071103	182 390	1 570	195	134	53	467	239	-2 029 372
Cabo Delgado	Mocimboa Da Praia	Mbau	MZ011002	11 317	785	3	1	0	459	448	-311 948
Nampula	Meconta	Meconta	MZ070903	18 287	460	115	55	28	102	69	-287 417
Nampula	Mecuburi	Mecuburi	MZ071001	108 127	3 641	381	369	198	812	404	-3 738 432
Cabo Delgado	Mecufi	Mecufi	MZ010701	40 905	620	30	3	0	217	322	1 057 518
Cabo Delgado	Namuno	Meloco	MZ011403	31 816	1 406	171	122	17	386	721	2 658 865
Cabo Delgado	Meluco	Meluco	MZ010801	15 344	4 525	59	70	19	3 731	2952	-8 855 867
Nampula	Memba	Memba	MZ071104	100 259	1 385	401	137	63	102	55	-419 901
Cabo Delgado	Ancuabe	Mesa	MZ010102	36 354	1 414	30	3	1	1 230	1031	-2 833 165
Nampula	Lalaua	Meti	MZ070502	22 607	1 660	28	52	11	998	530	-4 288 200
Cabo Delgado	Ancuabe	Metoro	MZ010103	58 002	1 418	124	48	14	766	694	-901 676
Cabo Delgado	Metuge	Metuge	MZ010901	42 981	1 460	54	8	1	675	960	3 081 220

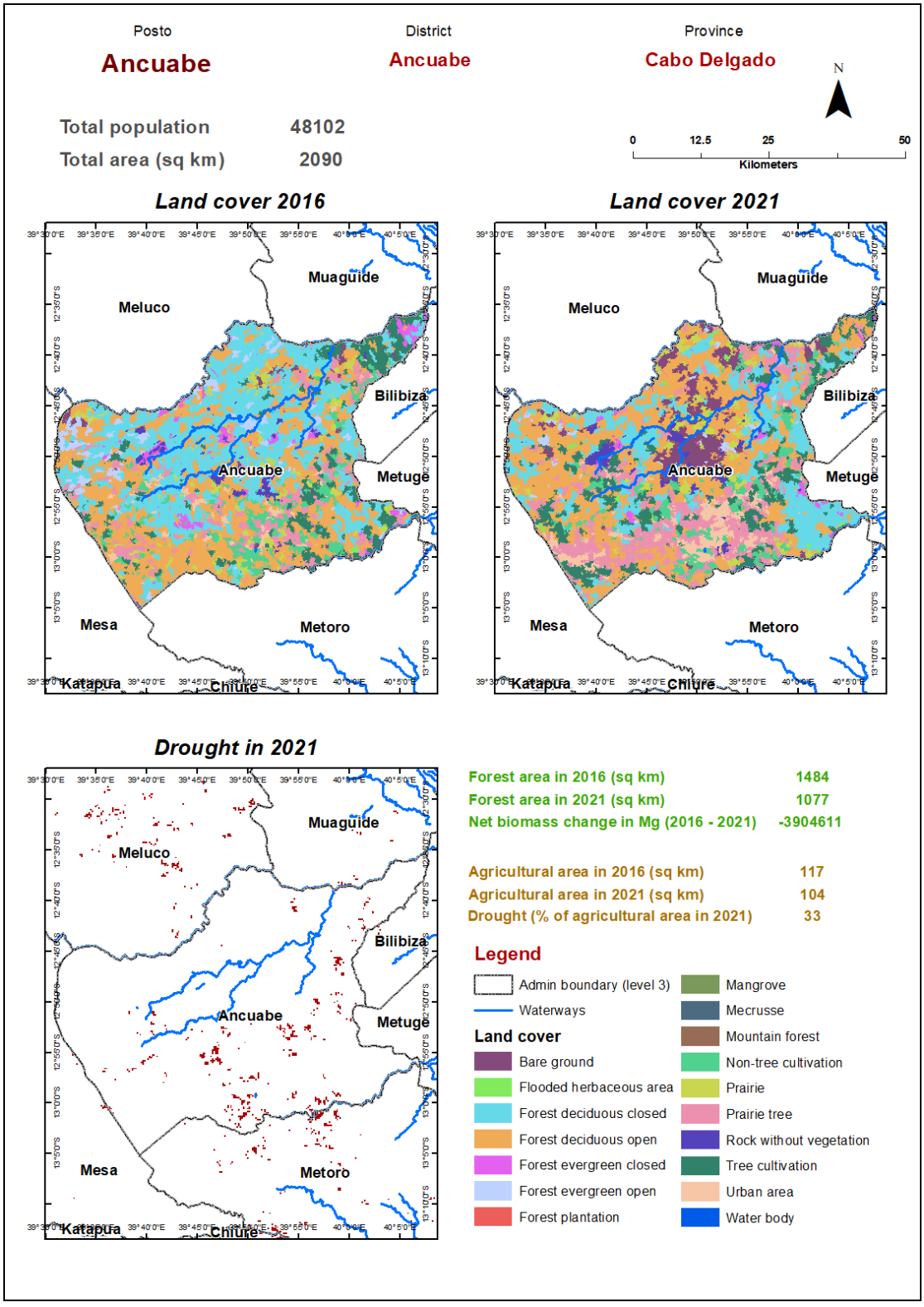
Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
Cabo Delgado	Metuge	Mieze	MZ010902	64 820	128	6	0	0	42	18	-203 220
Nampula	Mecuburi	Milhana	MZ071002	19 929	1 275	163	110	51	423	328	-902 132
Cabo Delgado	Montepuez	Mirate	MZ011102	44 104	3 118	239	186	43	1 758	1645	-2 805 976
Cabo Delgado	Muidumbe	Miteda	MZ011302	29 757	474	9	4	2	267	318	543 570
Cabo Delgado	Mocimboa Da Praia	Mocimboa Da Praia	MZ011003	85 987	1 668	2	1	0	1 028	1050	-612 930
Nampula	Moma	Moma	MZ071402	233 737	2 510	47	64	34	389	231	-1 487 280
Nampula	Monapo	Monapo	MZ071502	179 258	1 233	276	36	15	234	224	30 785
Cabo Delgado	Montepuez	Montepuez	MZ011103	142 963	1 211	156	89	18	502	371	-1 582 012
Nampula	Mossuril	Mossuril	MZ071603	47 282	848	355	14	5	26	52	306 152
Cabo Delgado	Meluco	Muaguide	MZ010802	10 513	1 204	5	11	2	848	854	-89 684
Nampula	Mogovolas	Muatua	MZ071303	49 681	605	45	206	137	65	5	-553 404
Cabo Delgado	Macomia	Mucojo	MZ010603	17 807	1 117	7	1	0	544	395	-2 205 326
Nampula	Larde	Mucuali	MZ070602	42 875	1 109	20	45	31	574	364	-1 692 450
Nampula	Muecate	Muculoene	MZ071702	26 211	978	30	58	35	484	342	-1 148 091
Nampula	Muecate	Muecate	MZ071703	74 980	1 908	267	325	182	447	142	-2 737 846
Cabo Delgado	Mueda	Mueda	MZ011203	58 331	1 148	27	17	5	393	579	2 350 533
Cabo Delgado	Muidumbe	Muidumbe	MZ011303	31 261	1 096	15	3	1	776	878	1 096 657
Nampula	Mecuburi	Muite	MZ071003	48 841	1 498	173	128	69	135	243	977 216
Cabo Delgado	Mecufi	Murrebue	MZ010702	18 000	615	49	19	7	221	230	106 812
Nampula	Murrupula	Murrupula	MZ071802	149 689	1 958	176	182	130	355	261	-678 831
Nampula	Rapale	Mutivasse	MZ072202	31 127	810	59	73	51	241	109	-1 178 163
Nampula	Malema	Mutuali	MZ070803	70 820	2 007	88	120	39	296	424	1 358 456
Cabo Delgado	Namuno	N'Cumpe	MZ011404	40 692	721	82	48	19	6	98	849 645

Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
Cabo Delgado	Mueda	N'Gapa	MZ011204	36 945	4 493	78	38	8	2 280	896	-11 253 966
Nampula	Nacala	Nacala	MZ071901	294 727	319	22	0	0	14	16	30 384
Nampula	Nacala-A-Velha	Nacala-A-Velha	MZ072002	77 709	845	366	26	9	16	20	78 215
Nampula	Nacaroa	Nacaroa	MZ072102	74 677	934	353	124	49	145	94	-464 639
Cabo Delgado	Montepuez	Nairoto	MZ011104	15 873	12 080	286	128	36	5 127	6011	7 832 234
Nampula	Rapale	Namaita	MZ072203	118 352	822	48	39	30	98	73	-209 083
Cabo Delgado	Montepuez	Namanhumbir	MZ011105	36 430	654	12	3	1	567	488	-1 160 938
Nampula	Erati	Namapa	MZ070302	150 885	2 259	385	81	28	448	336	-1 377 171
Nampula	Angoche	Namaponda	MZ070104	40 398	740	29	125	74	159	43	-1 187 210
Nampula	Mogovolas	Nametil	MZ071304	172 972	911	203	232	156	64	7	-527 062
Nampula	Meconta	Namialo	MZ070904	77 355	348	81	50	20	13	4	-83 961
Nampula	Mogincual	Namige	MZ071201	25 796	848	12	2	1	245	254	114 920
Nampula	Mecuburi	Namina	MZ071004	50 003	776	75	62	25	98	22	-659 033
Nampula	Erati	Namiroa	MZ070303	70 852	1 528	266	44	19	210	235	219 989
Cabo Delgado	Chiure	Namogelia	MZ010305	34 535	712	157	76	41	99	211	876 026
Cabo Delgado	Namuno	Namuno	MZ011405	110 718	1 239	247	191	60	83	297	1 893 680
Cabo Delgado	Nangade	Nangade	MZ011502	62 681	1 940	23	22	8	899	976	1 360 328
Nampula	Mogovolas	Nanhupo Rio	MZ071305	55 072	719	163	337	86	57	6	-476 486
Cabo Delgado	Mueda	Negomano	MZ011205	3 352	3 023	105	32	7	732	297	-4 056 738
Nampula	Monapo	Netia	MZ071503	211 250	1 040	144	73	33	41	22	-196 097
Nampula	Murrupula	Nihessiue	MZ071803	36 909	564	58	43	24	18	20	13 893
Cabo Delgado	Chiure	Ocua	MZ010306	54 689	1 048	153	46	16	397	250	-1 529 264
Cabo Delgado	Palma	Olumbi	MZ011601	12 433	1 232	2	0	0	789	880	958 203

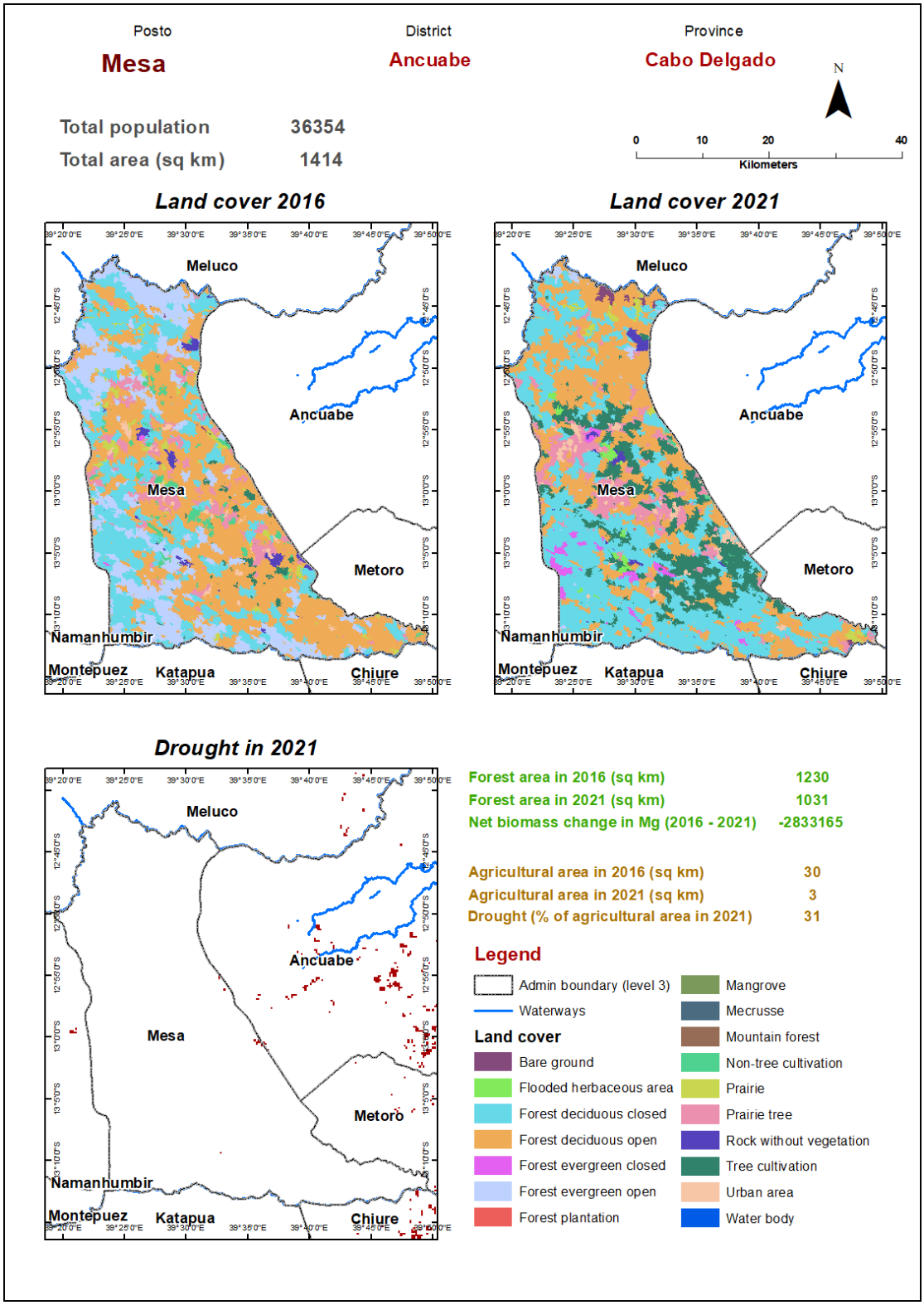
Province	District	Posto	Admin code	Total population	Total area (sq km)	Agricultural area in 2016 (sq km)	Agricultural area in 2021 (sq km)	Draught affected agricultural area (sq km)	Forest area in 2016 (sq km)	Forest area in 2021 (sq km)	Biomass change (Mg)
Cabo Delgado	Palma	Palma	MZ011602	32 915	899	9	0	0	602	665	599 834
Cabo Delgado	Namuno	Papai	MZ011406	16 384	923	69	23	6	32	219	1 669 504
Cabo Delgado	Palma	Pundanhar	MZ011603	5 245	785	4	1	0	516	525	66 490
Nampula	LiÃºpo	Quinga	MZ070702	135 307	758	14	1	0	332	153	-2 137 478
Cabo Delgado	Palma	Quionga	MZ011604	7 568	607	1	0	0	360	382	22 108
Cabo Delgado	Ibo	Quirimba	MZ010502	2 294	16	0	0	0	5	3	-27 662
Cabo Delgado	Quissanga	Quissanga	MZ011803	4 882	455	6	3	0	252	245	-32 989
Cabo Delgado	Macomia	Quiterajo	MZ010604	10 626	642	2	2	0	464	437	-421 525
Nampula	Mogincual	Quixaxe	MZ071202	28 818	1 435	36	0	0	925	1054	967 535
Nampula	Rapale	Rapale	MZ072204	86 529	713	50	97	52	12	4	-76 612
Nampula	Ribaue	Ribaue	MZ072303	127 787	2 201	207	138	71	266	174	-855 269
Nampula	Nacaroa	Saua-Saua	MZ072103	24 505	1 095	233	140	84	304	172	-1 199 131

Sources: *Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries*. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021.
Population: Bondarenko M., Kerr D., Sorichetta A., and Tatem, A.J. 2020. *Census/projection-disaggregated gridded population datasets, adjusted to match the corresponding UNPD 2020 estimates, for 51 countries across sub-Saharan Africa using building footprints.* WorldPop, University of Southampton, UK. doi:10.5258/SOTON/WP00683

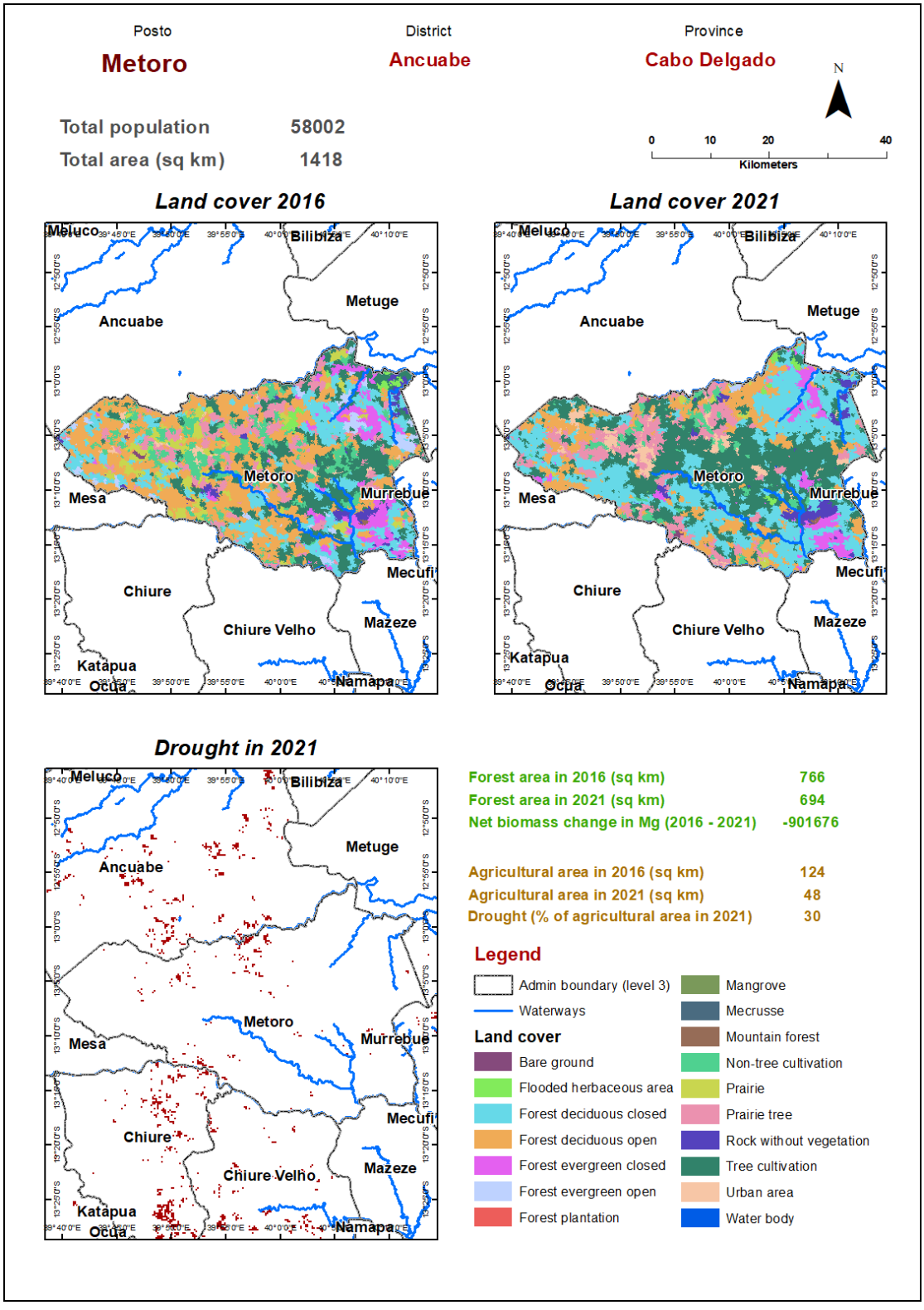
Appendix 02. Change in agriculture, forest and biomass between 2016 to 2021 and agricultural draught in 2021 by Posto



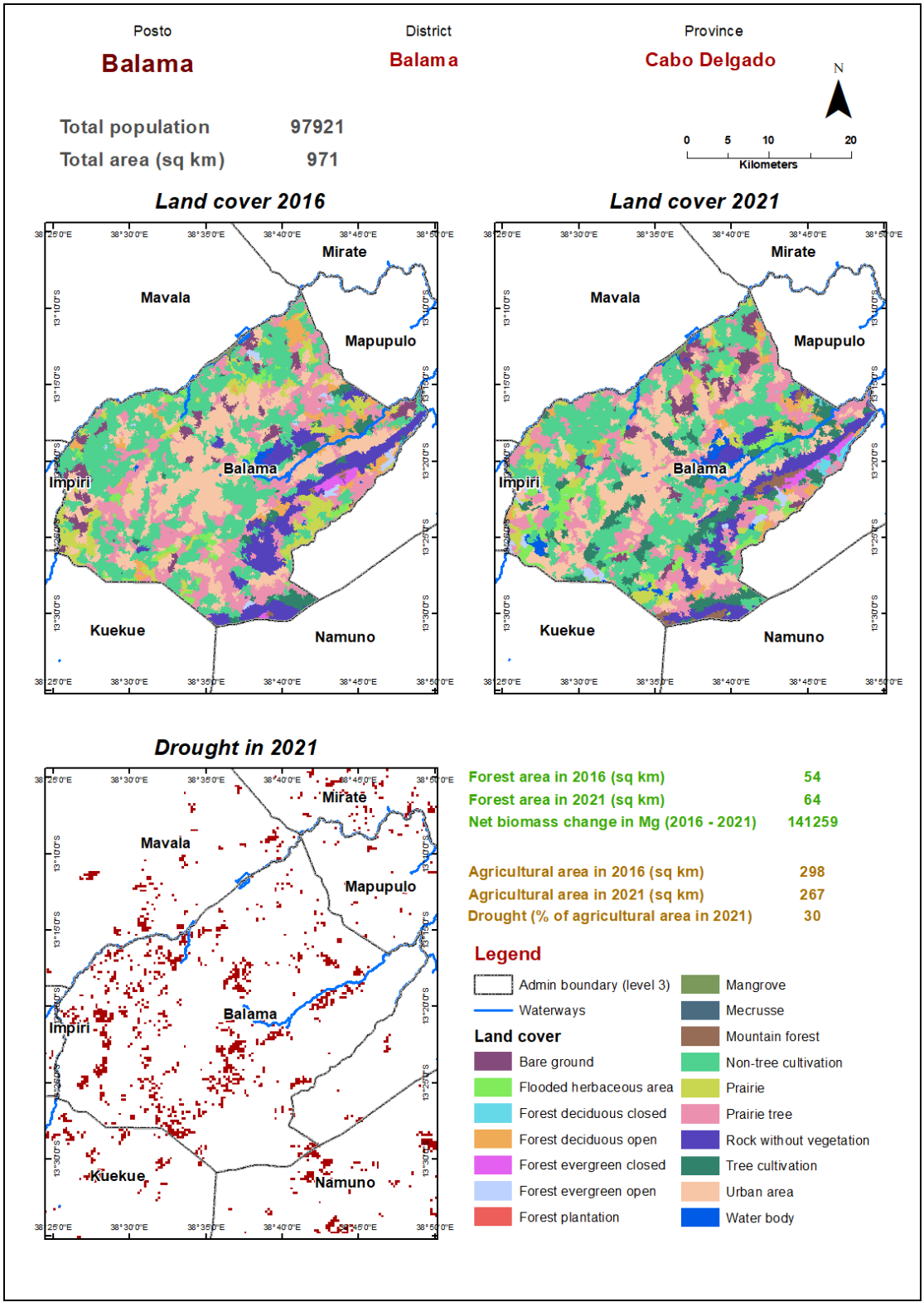
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



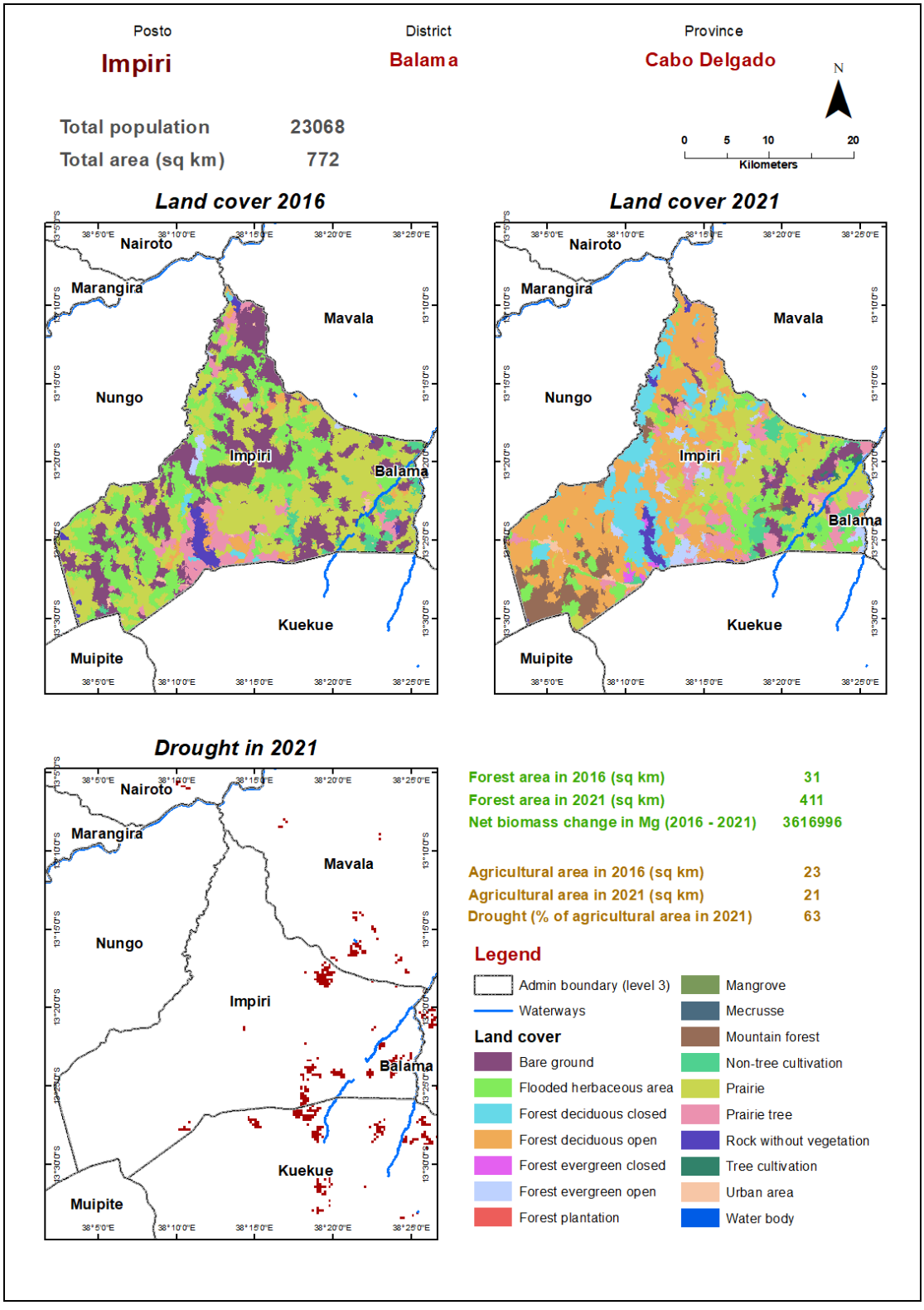
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Kuekue

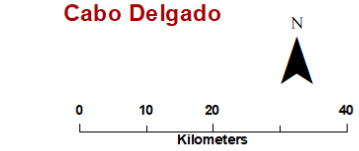
District

Balama

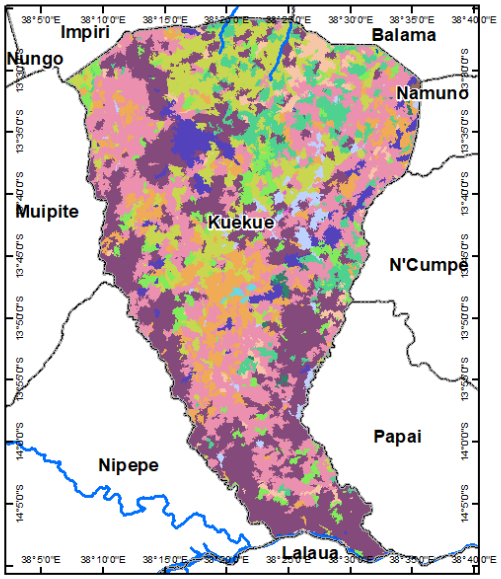
Province

Cabo Delgado

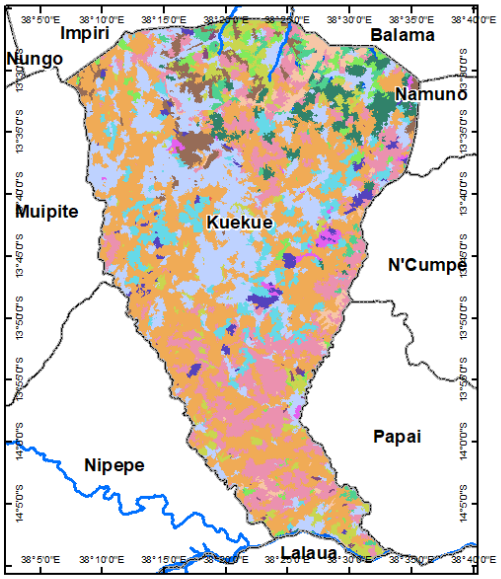
Total population	28079
Total area (sq km)	2470



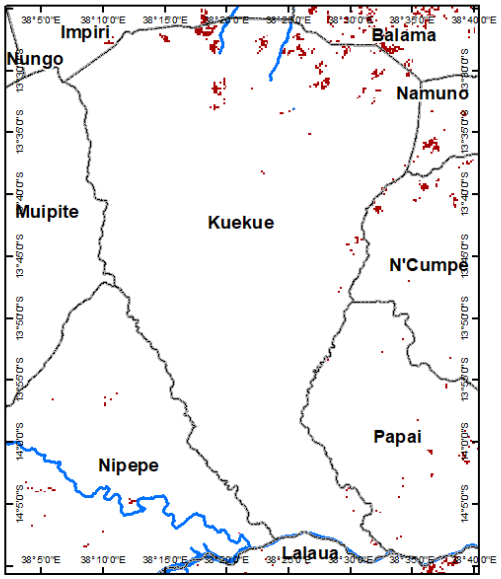
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	283
Forest area in 2021 (sq km)	1675
Net biomass change in Mg (2016 - 2021)	14377962
Agricultural area in 2016 (sq km)	163
Agricultural area in 2021 (sq km)	45
Drought (% of agricultural area in 2021)	50

Legend

- Admin boundary (level 3)
- Waterways

Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Mavala

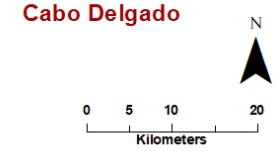
District

Balama

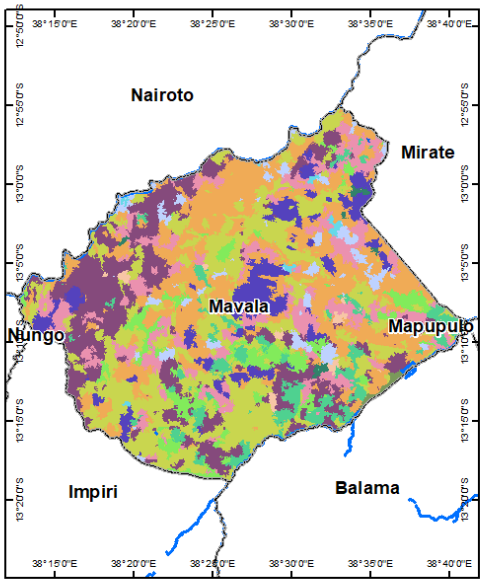
Province

Cabo Delgado

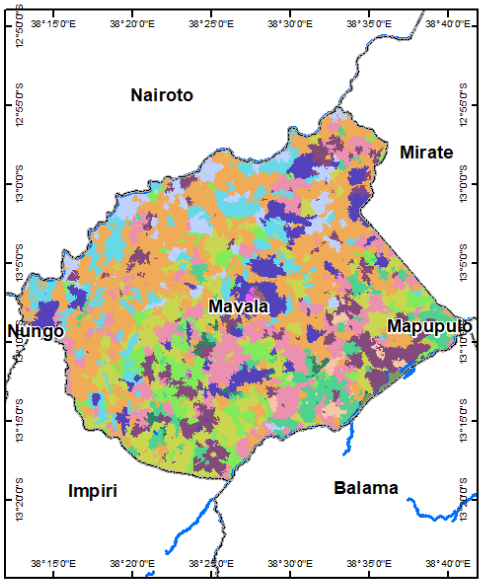
Total population	20416
Total area (sq km)	1284



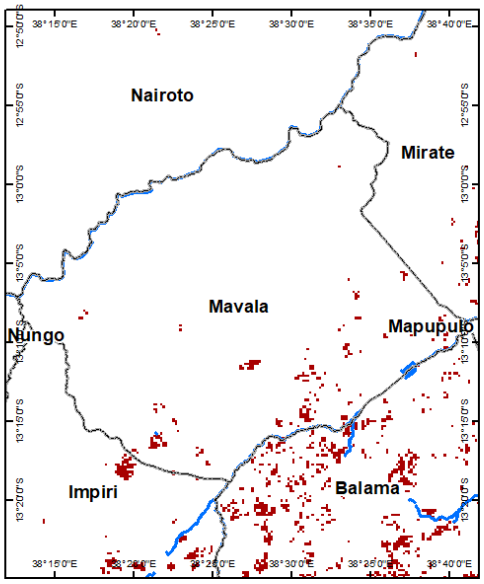
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	358
Forest area in 2021 (sq km)	563
Net biomass change in Mg (2016 - 2021)	1890824
Agricultural area in 2016 (sq km)	73
Agricultural area in 2021 (sq km)	76
Drought (% of agricultural area in 2021)	22

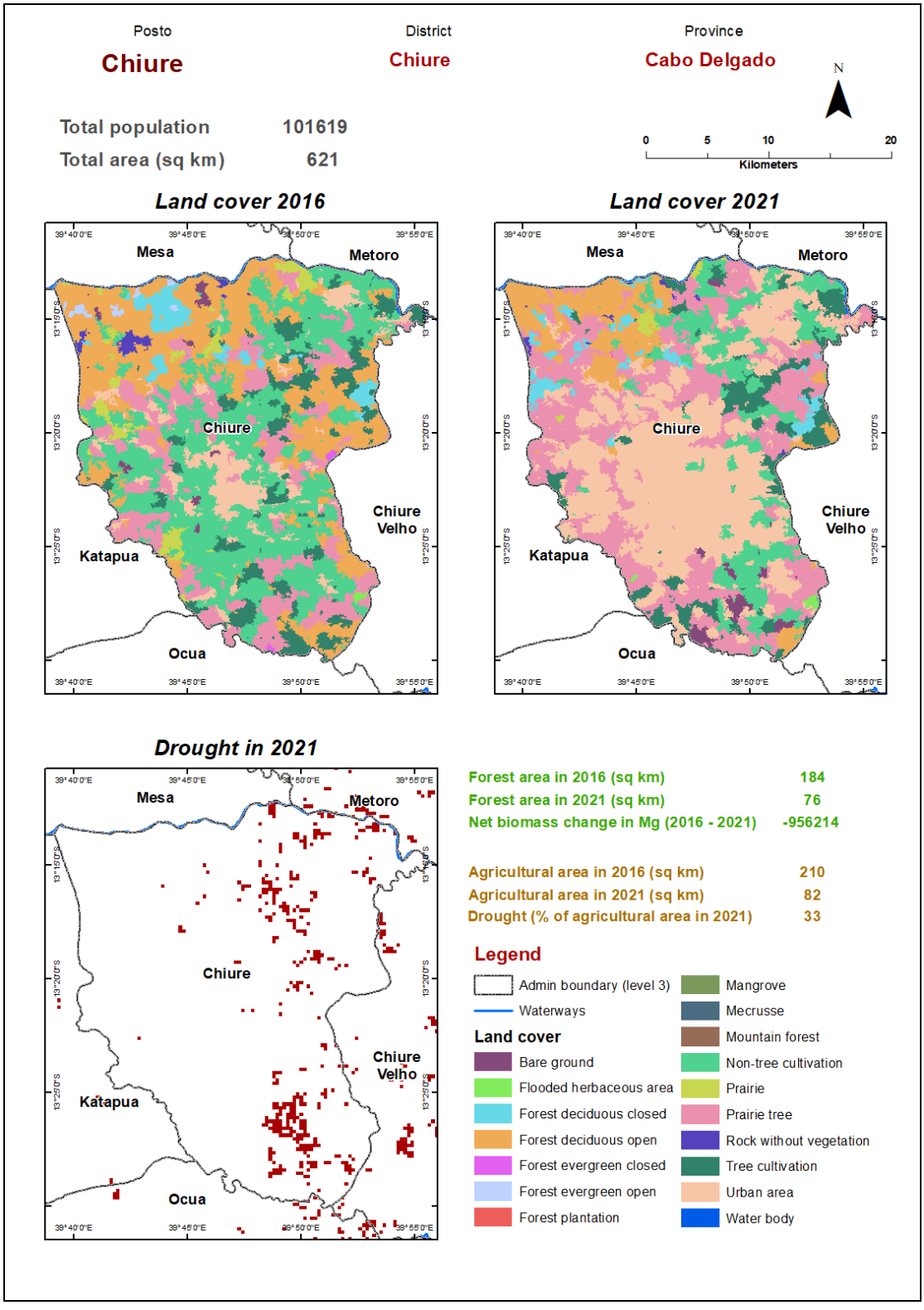
Legend

- Admin boundary (level 3)
- Waterways

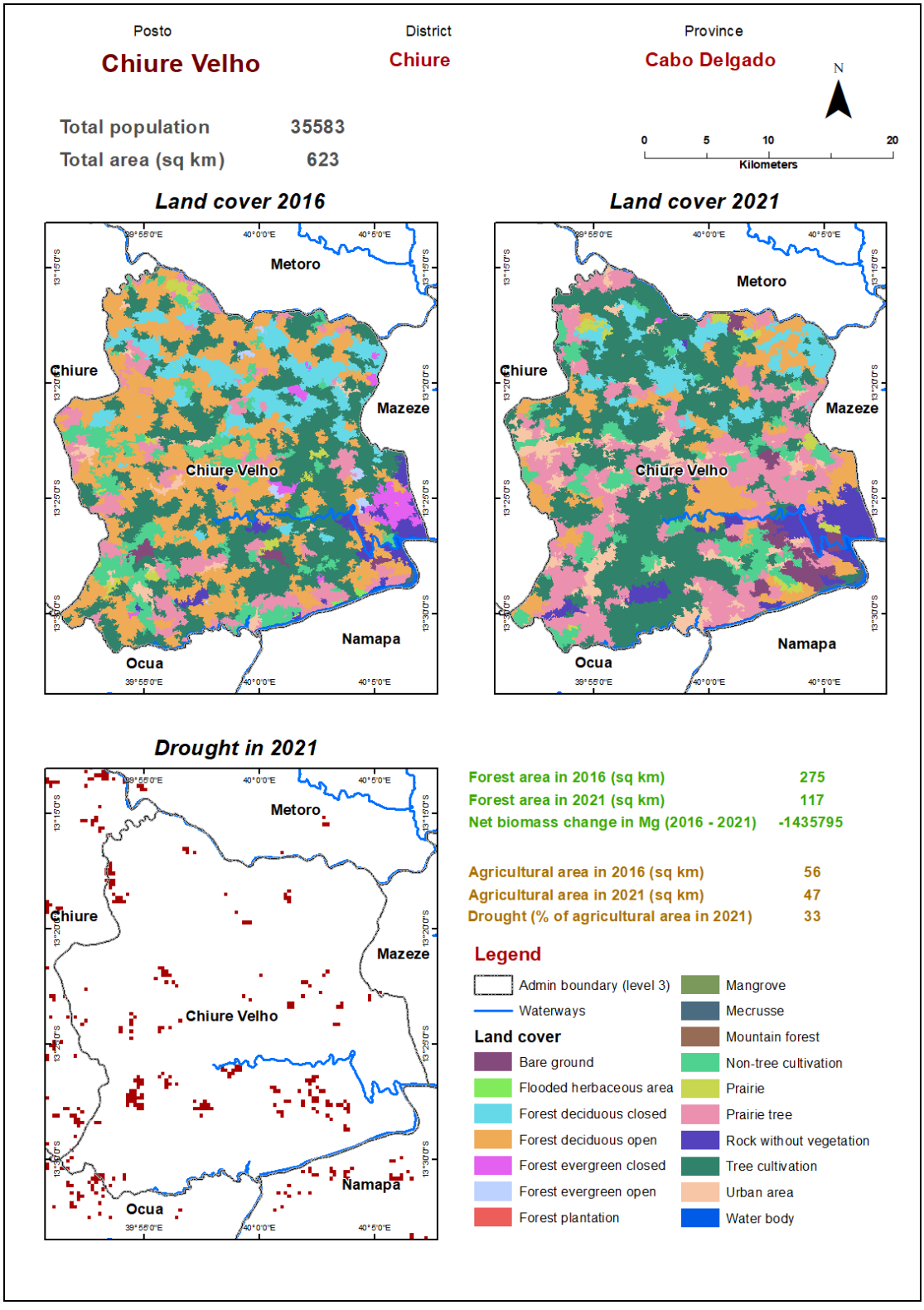
Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

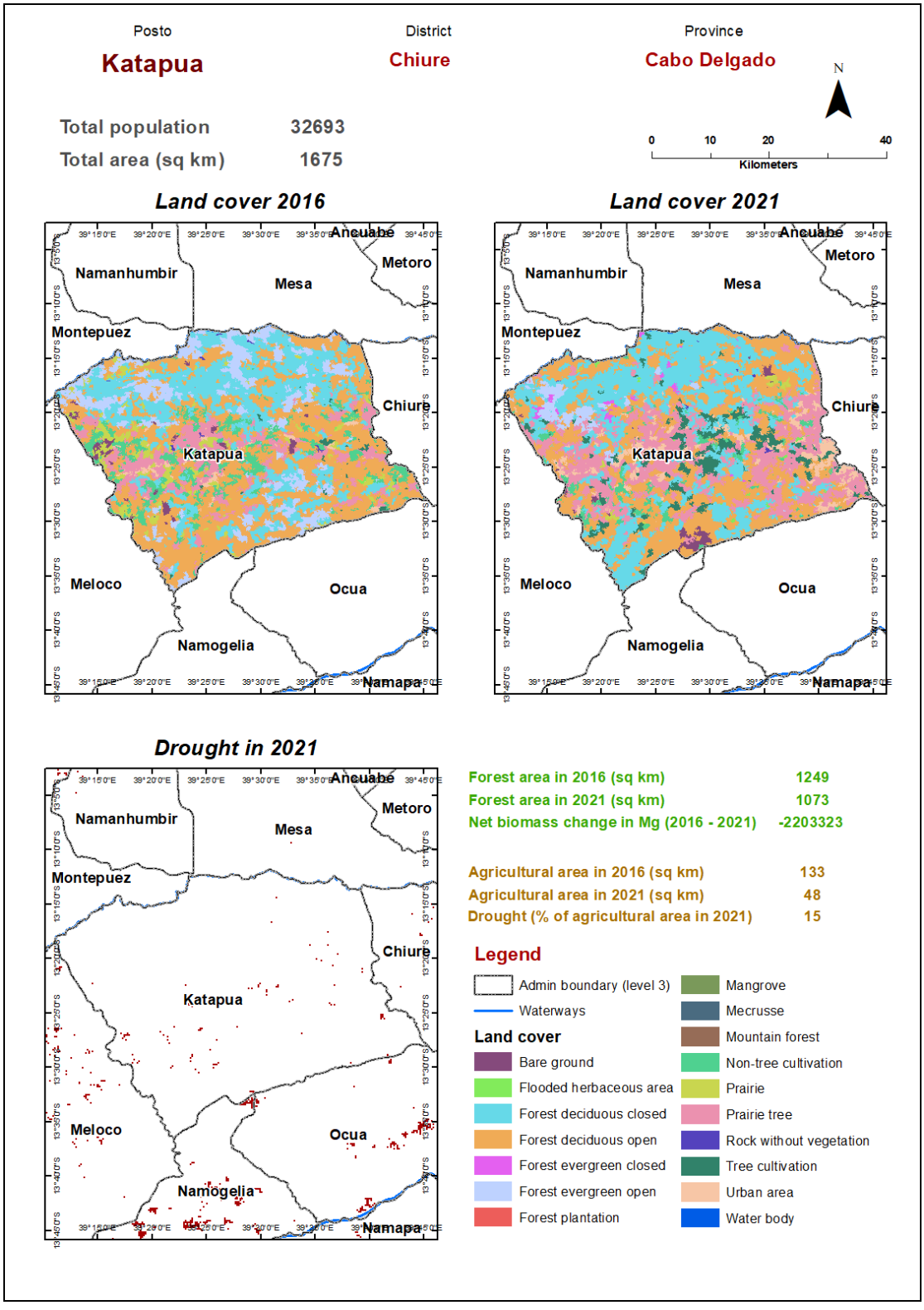
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Mazeze

District

Chiure

Province

Cabo Delgado

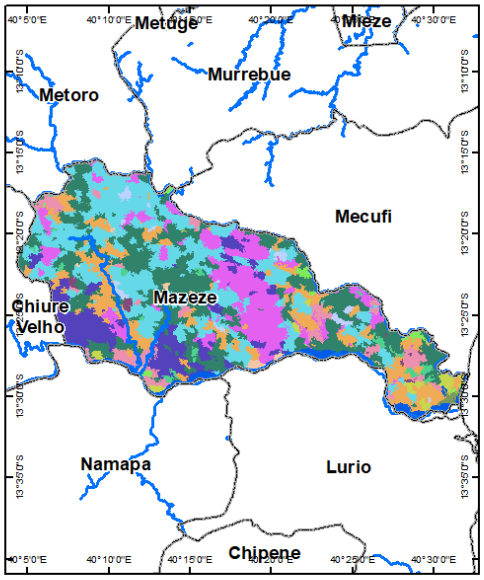
Total population	17475
Total area (sq km)	693

N

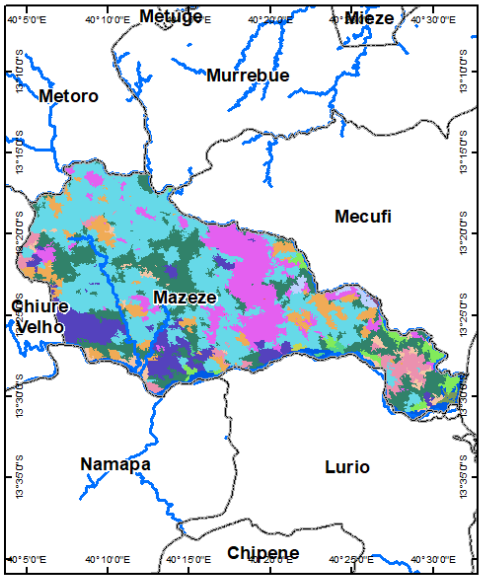
0 5 10 20

Kilometers

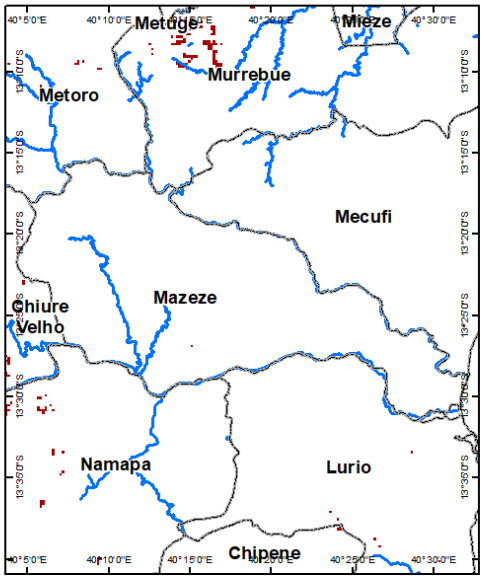
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	362
Forest area in 2021 (sq km)	414
Net biomass change in Mg (2016 - 2021)	448104
Agricultural area in 2016 (sq km)	9
Agricultural area in 2021 (sq km)	2
Drought (% of agricultural area in 2021)	7

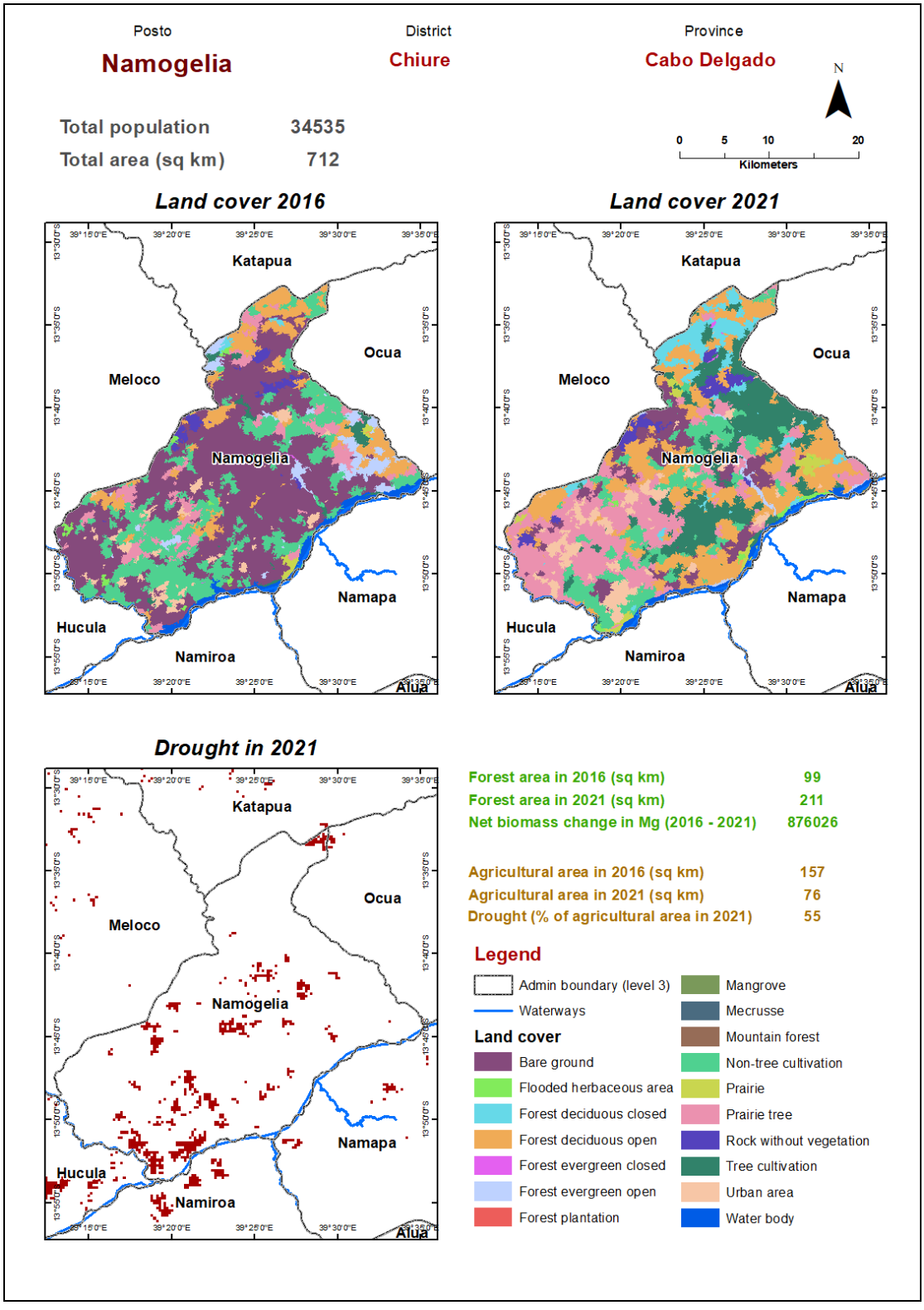
Legend

- Admin boundary (level 3)
- Waterways

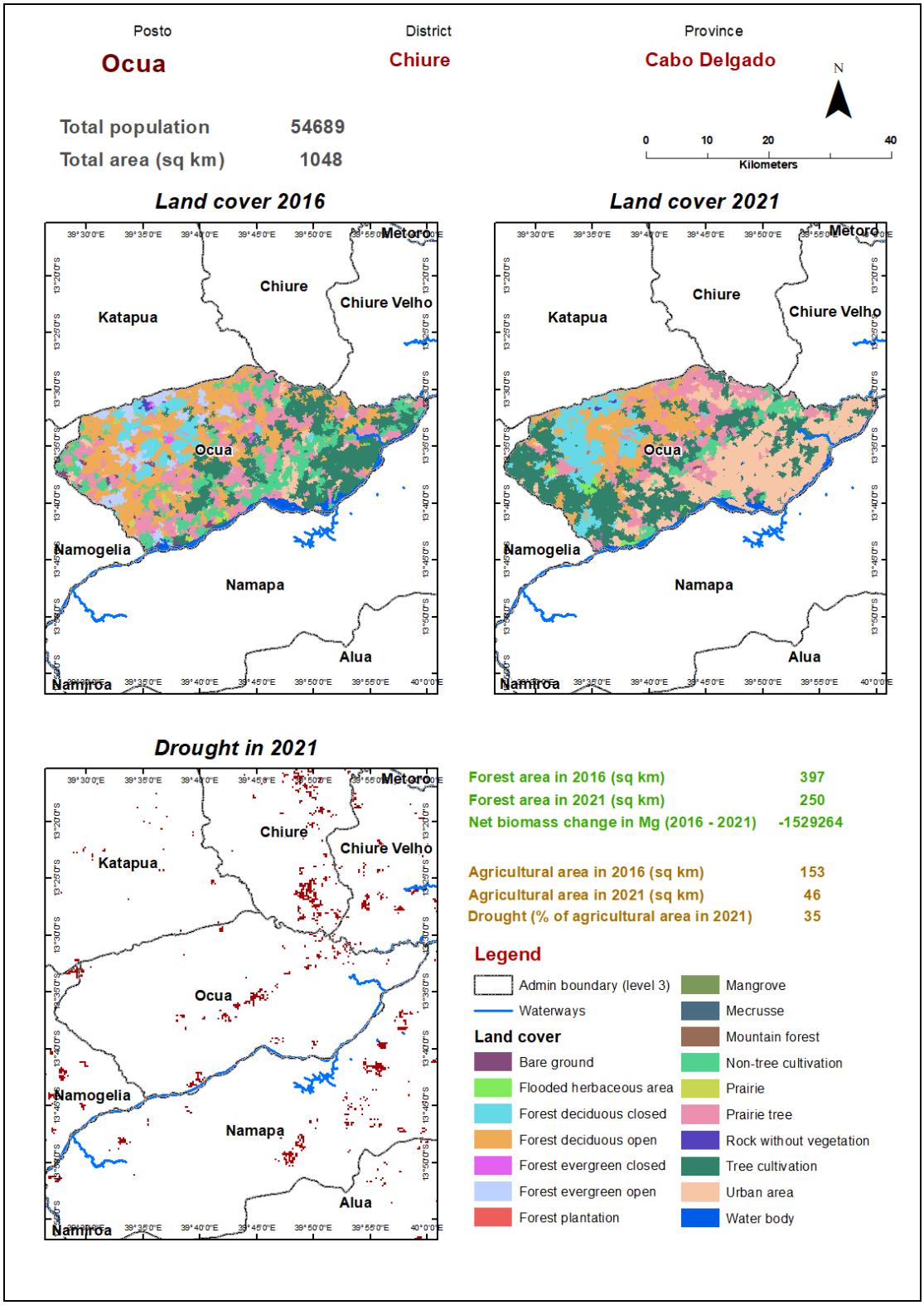
Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

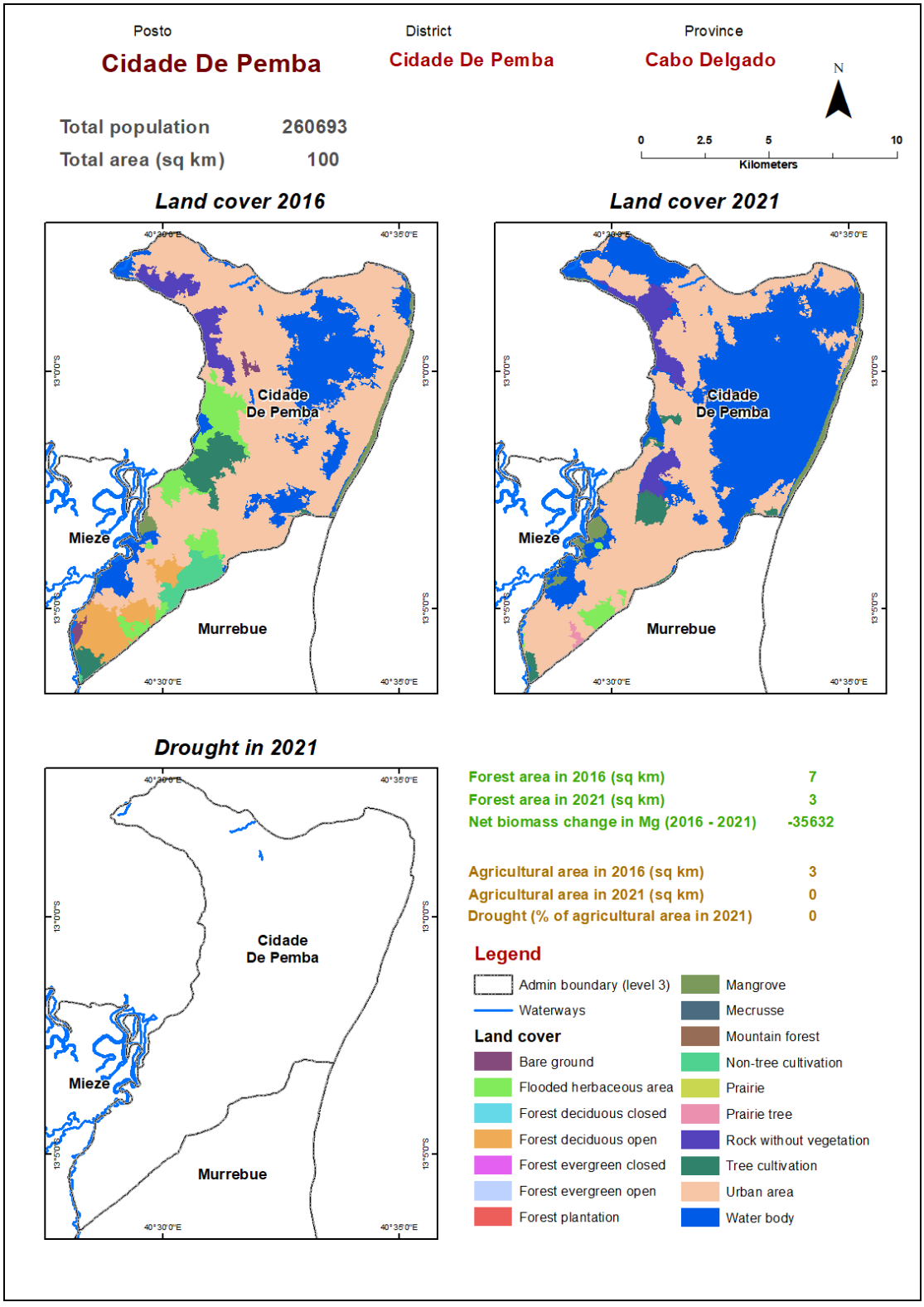
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



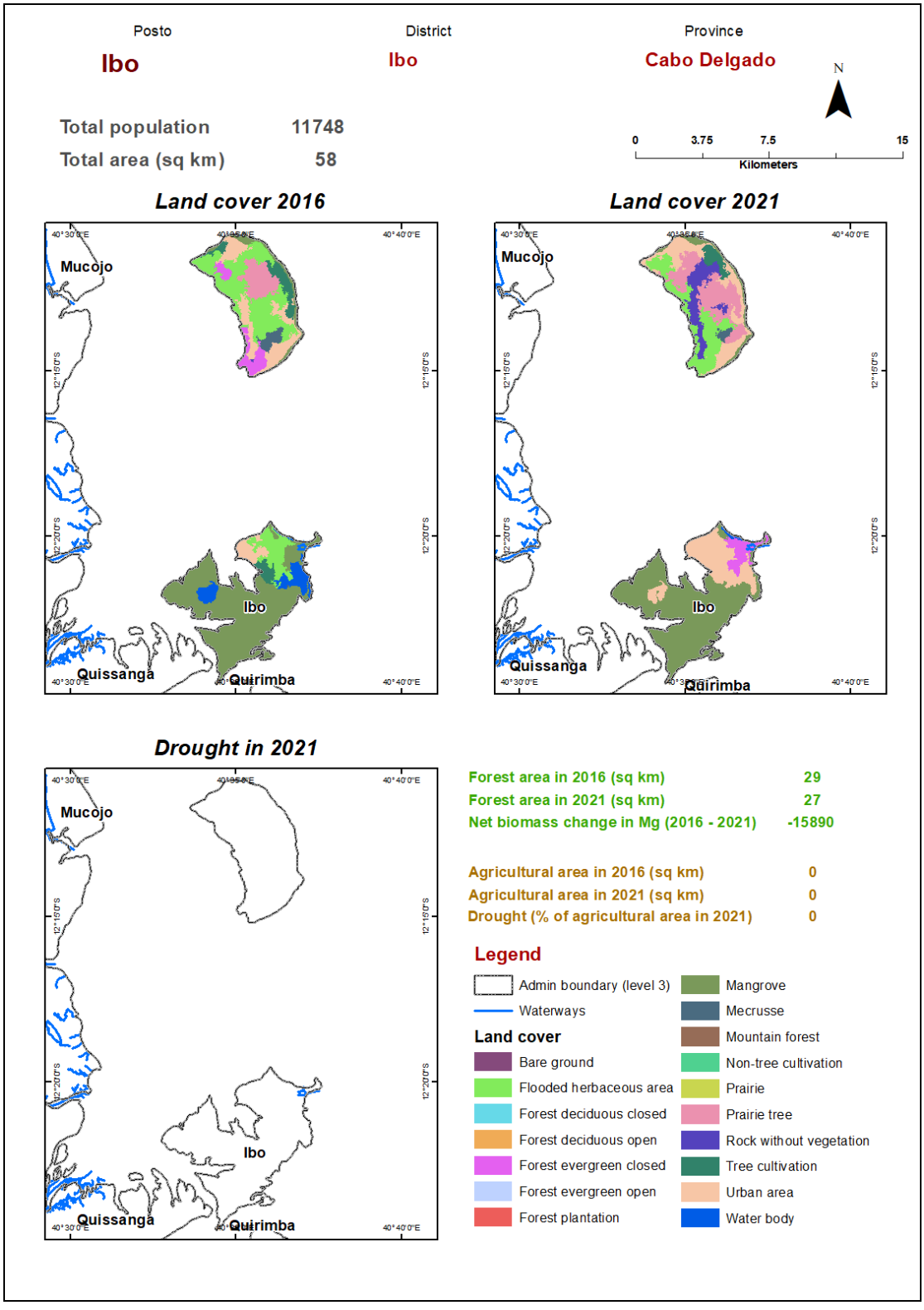
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



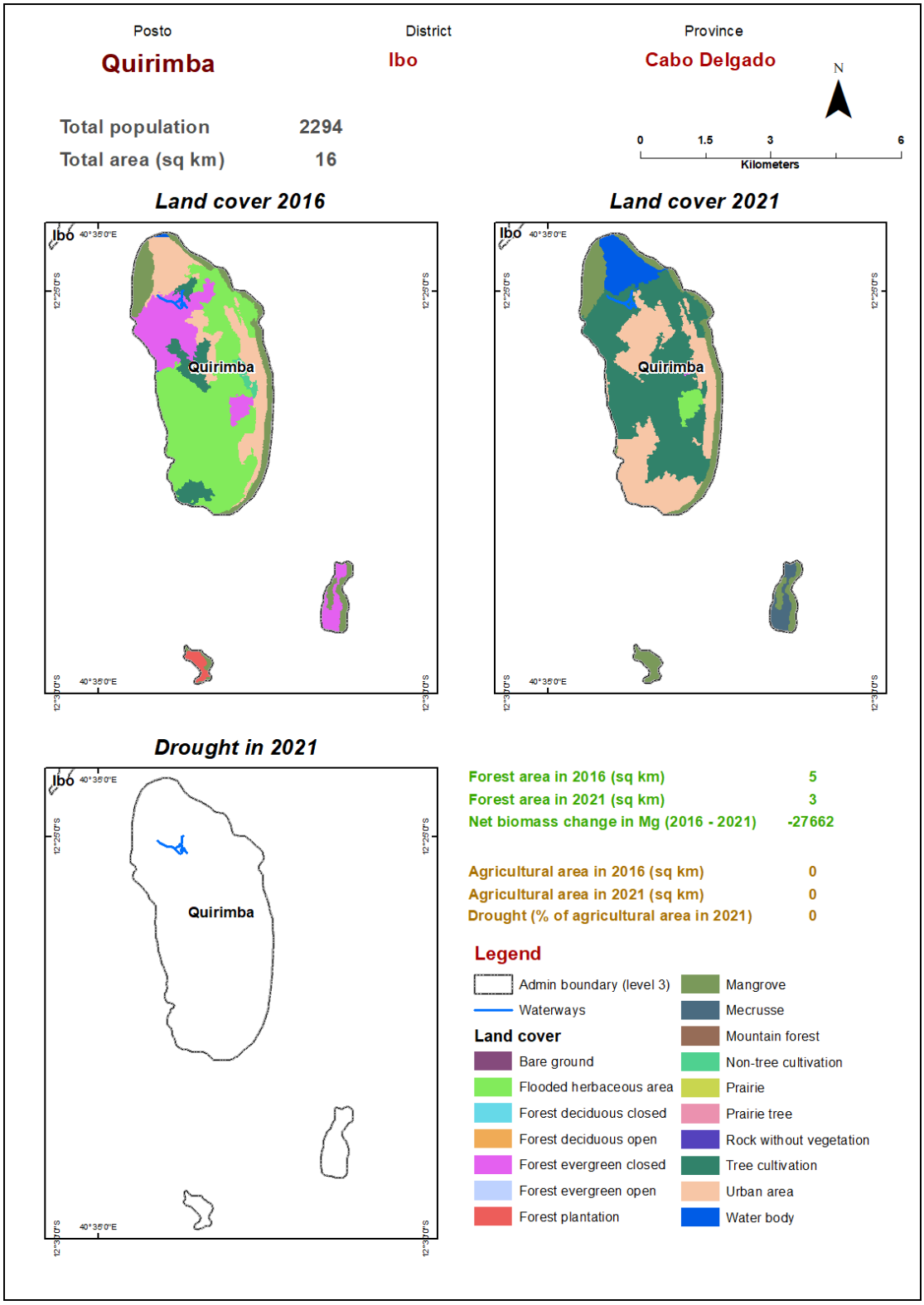
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Chai

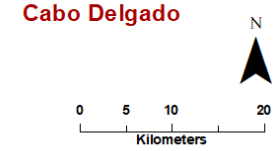
District

Macomia

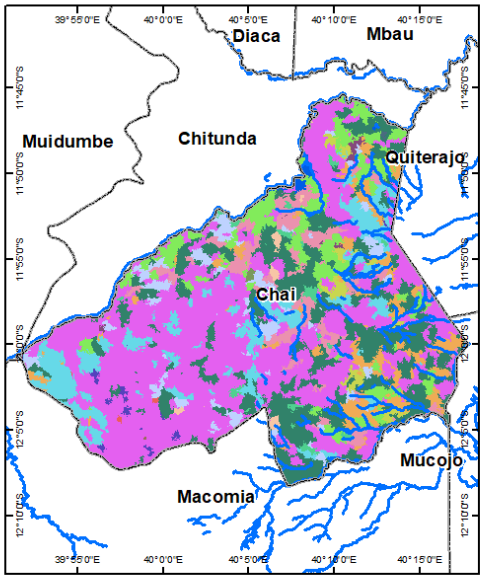
Province

Cabo Delgado

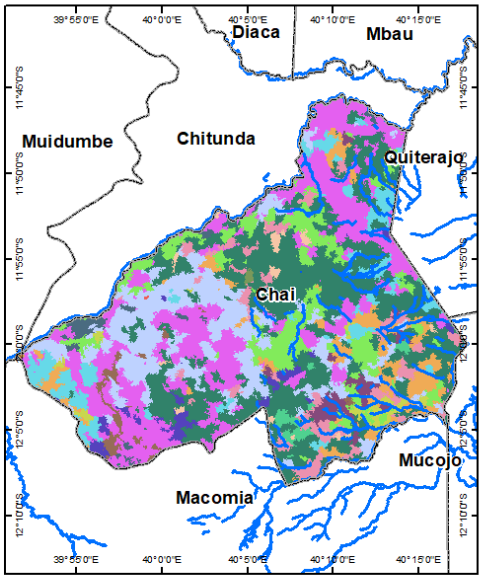
Total population	15604
Total area (sq km)	1054



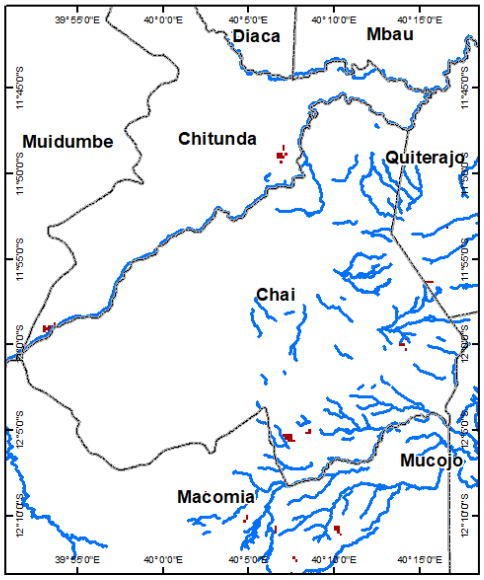
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	649
Forest area in 2021 (sq km)	538
Net biomass change in Mg (2016 - 2021)	-1315365
Agricultural area in 2016 (sq km)	11
Agricultural area in 2021 (sq km)	9
Drought (% of agricultural area in 2021)	14

Legend

- Admin boundary (level 3)
- Waterways

Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Macomia

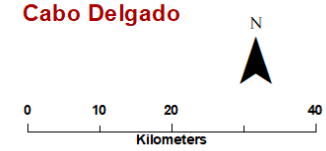
District

Macomia

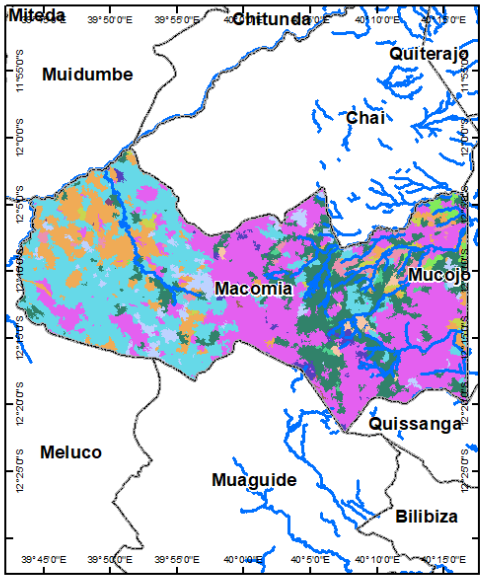
Province

Cabo Delgado

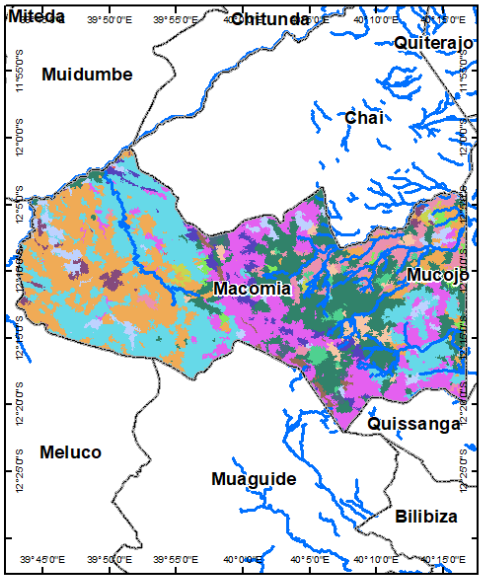
Total population	50994
Total area (sq km)	1378



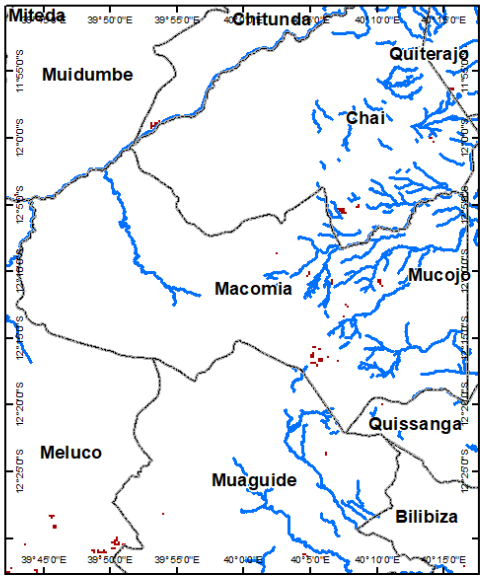
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	1025
Forest area in 2021 (sq km)	900
Net biomass change in Mg (2016 - 2021)	-2056920
Agricultural area in 2016 (sq km)	9
Agricultural area in 2021 (sq km)	17
Drought (% of agricultural area in 2021)	16

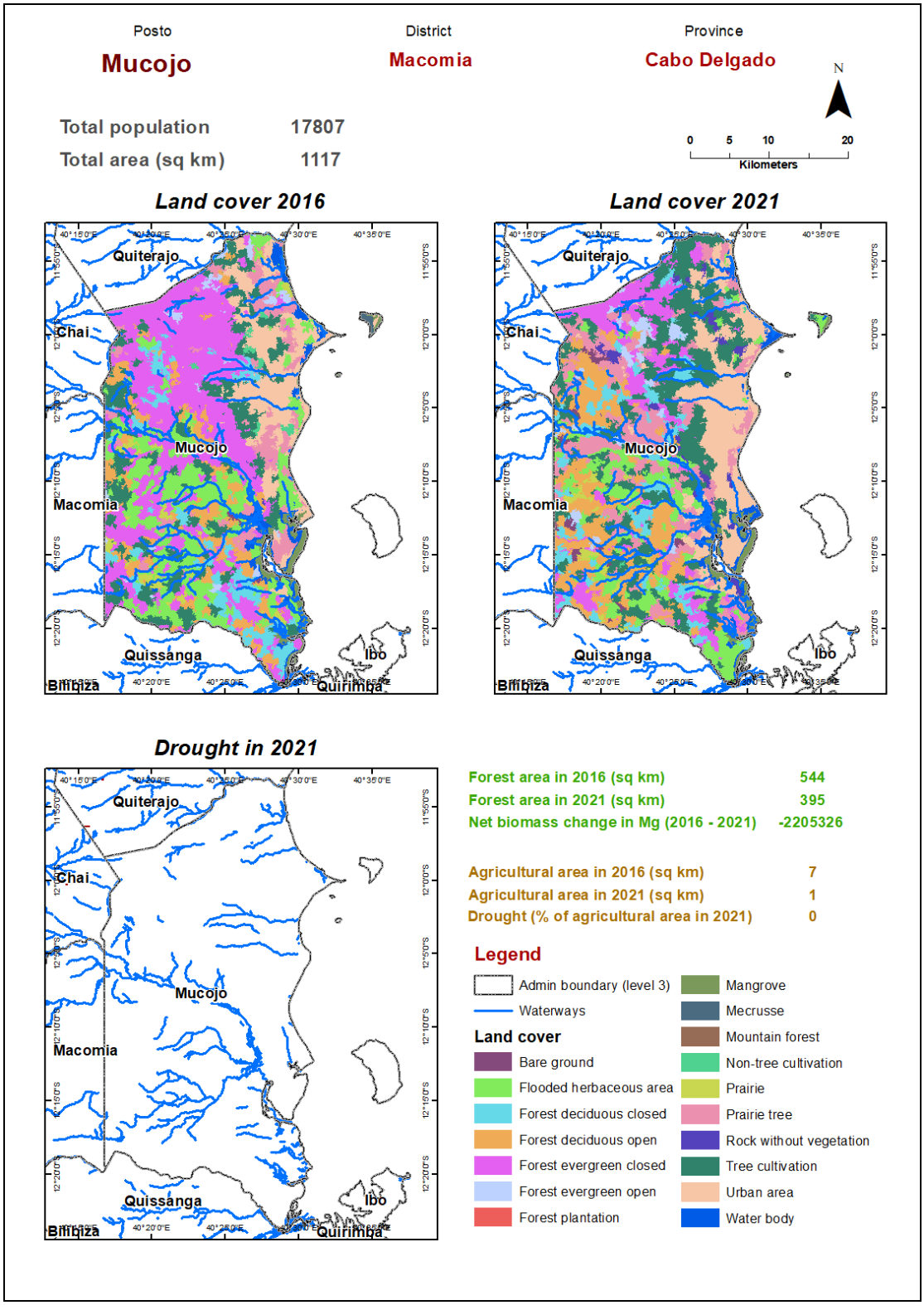
Legend

- Admin boundary (level 3)
- Waterways

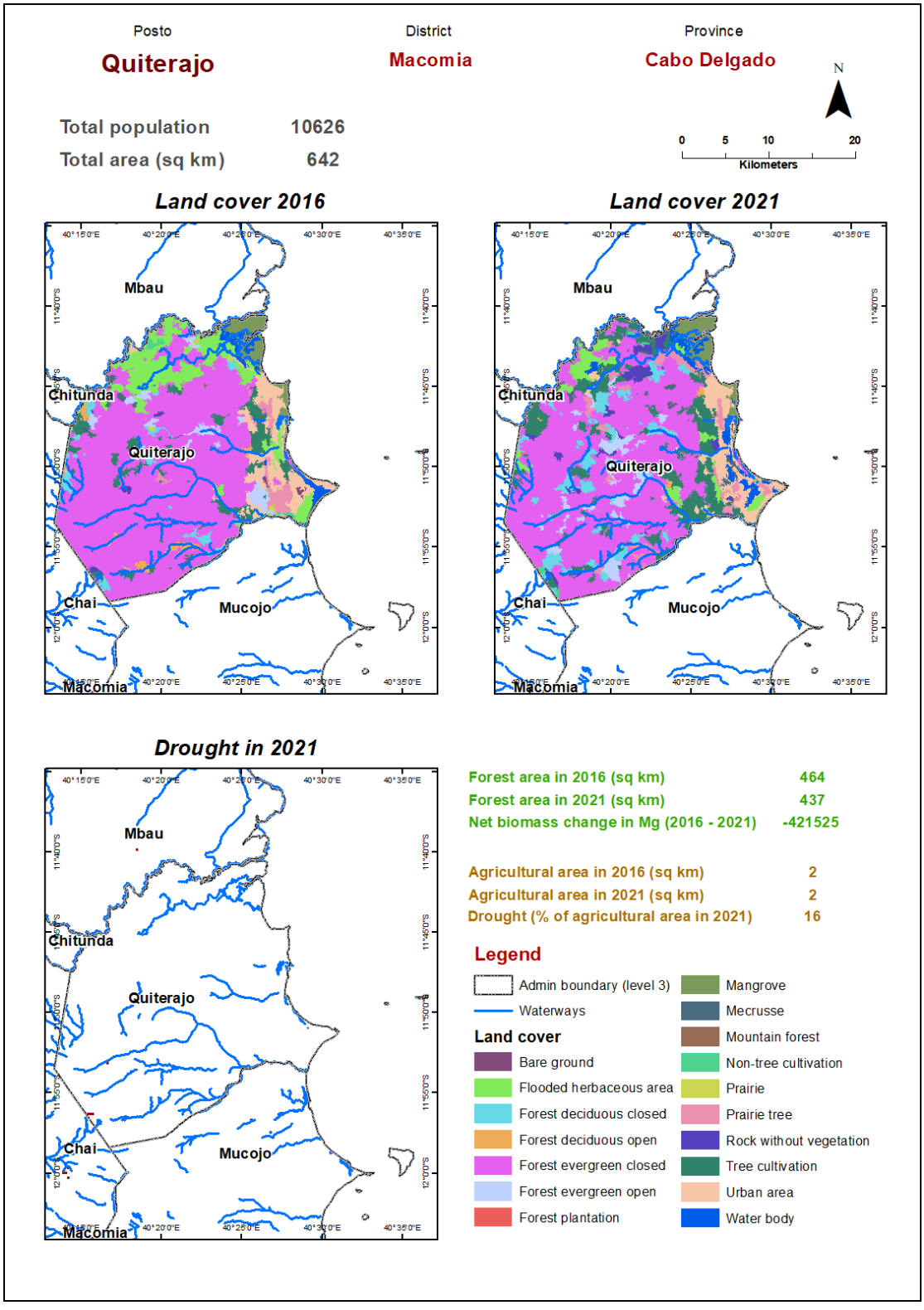
Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

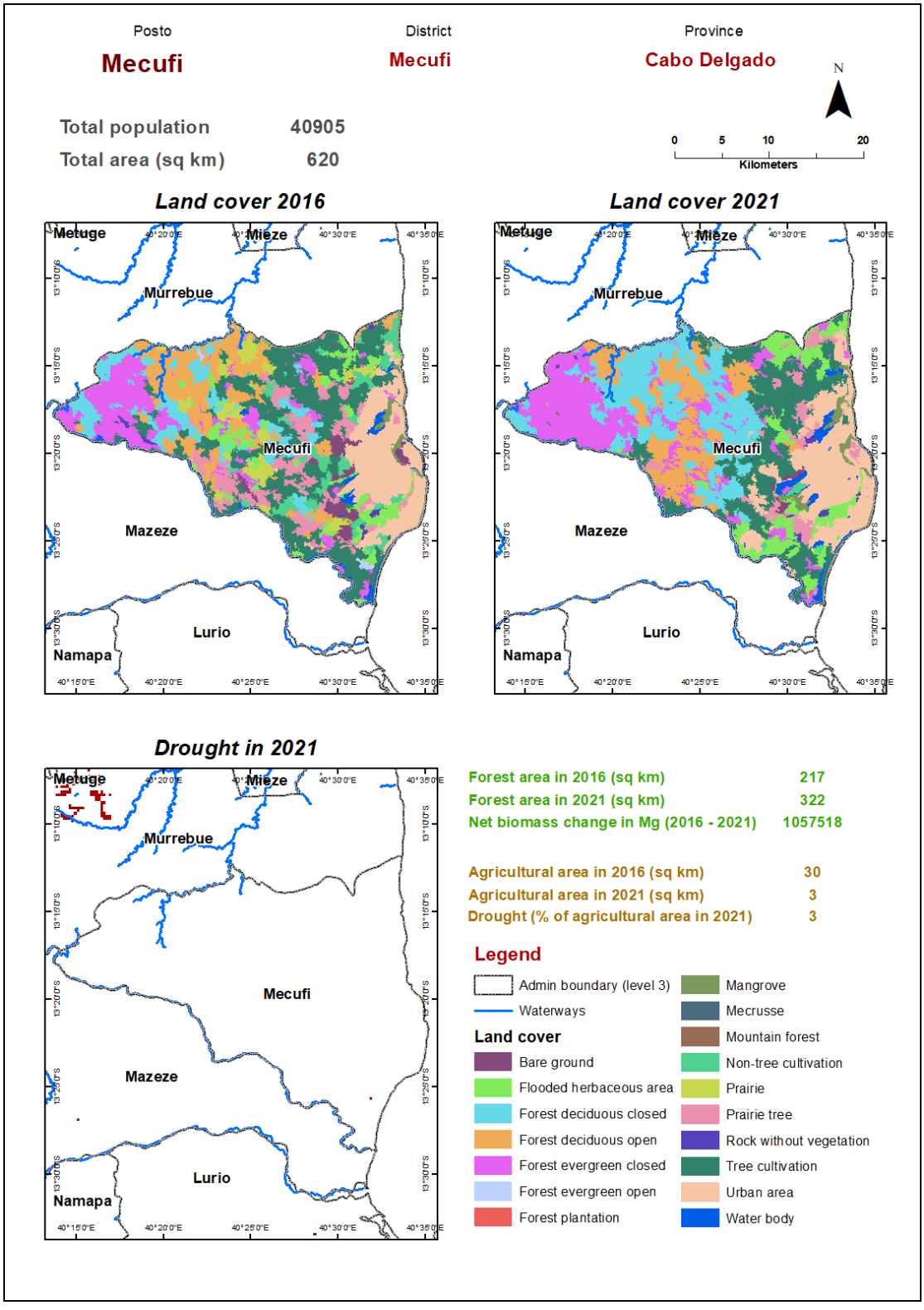
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



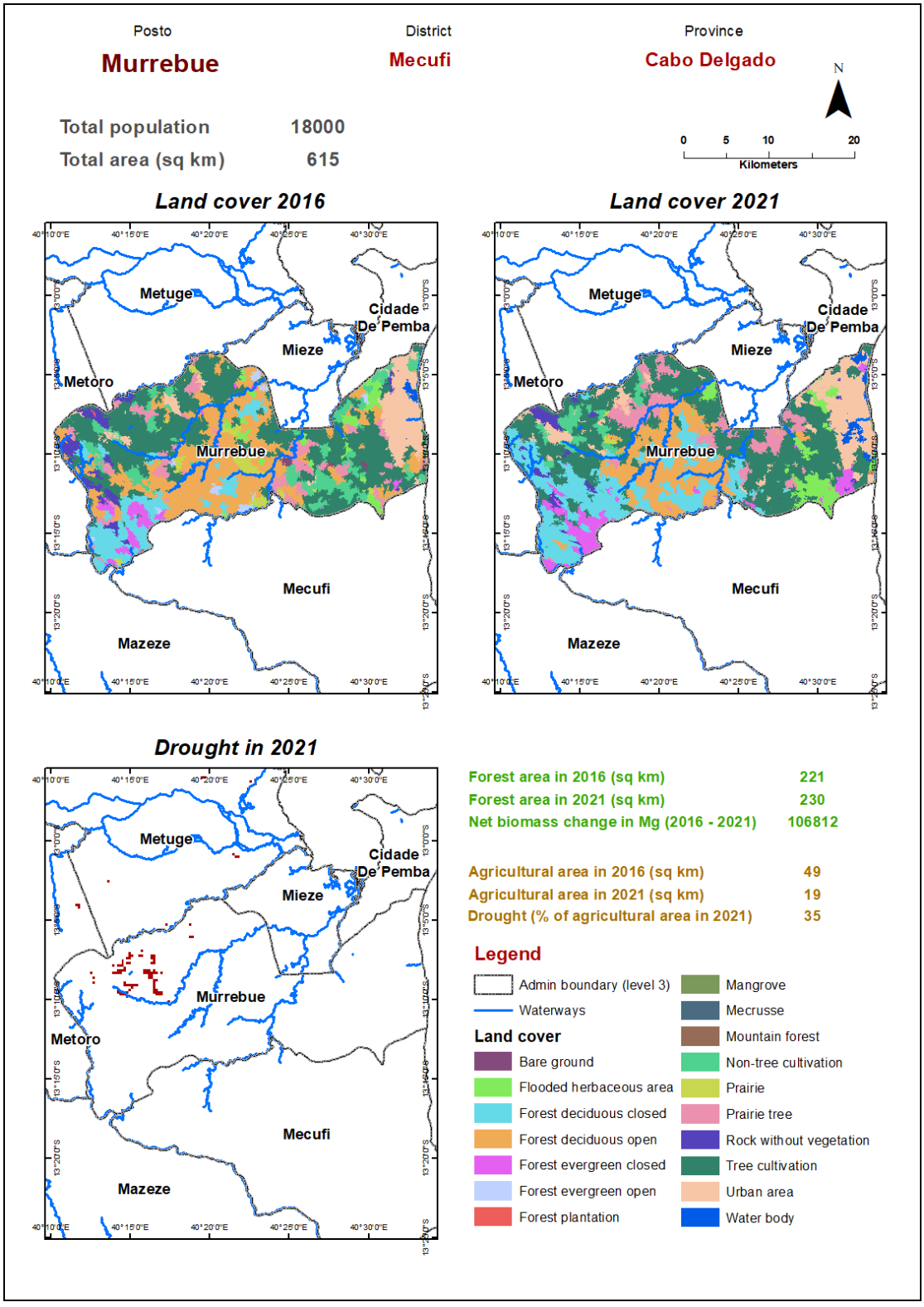
Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



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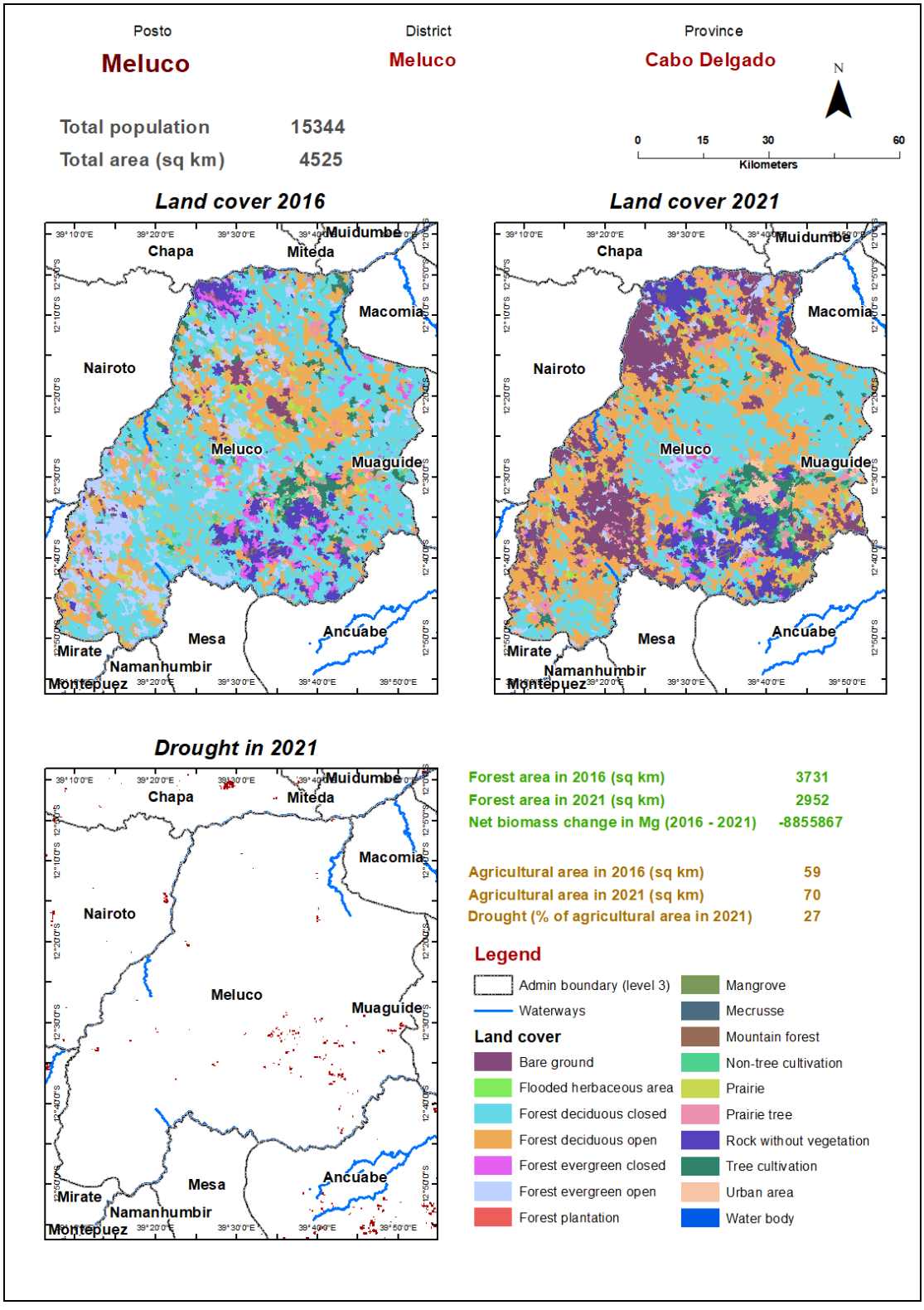

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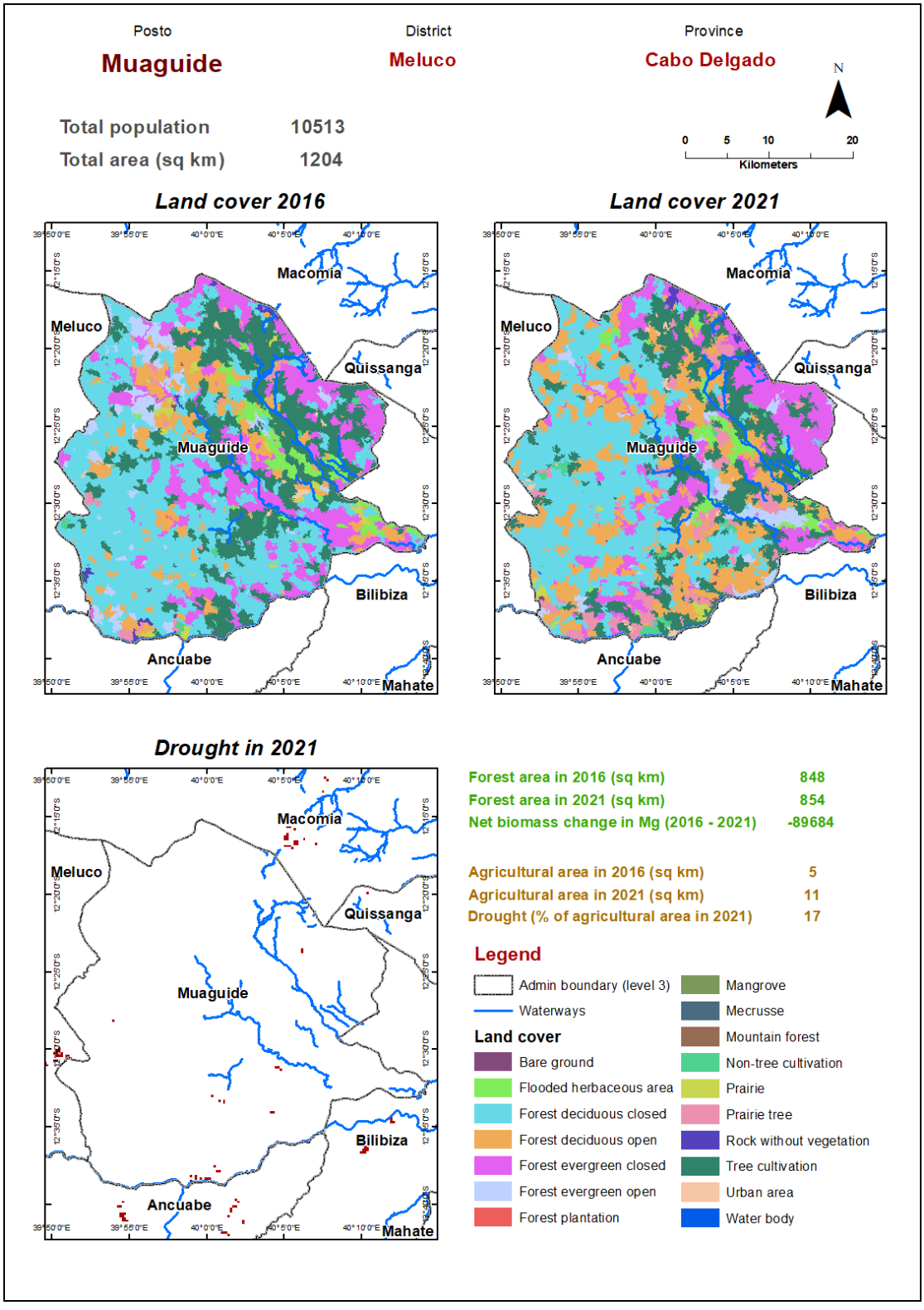

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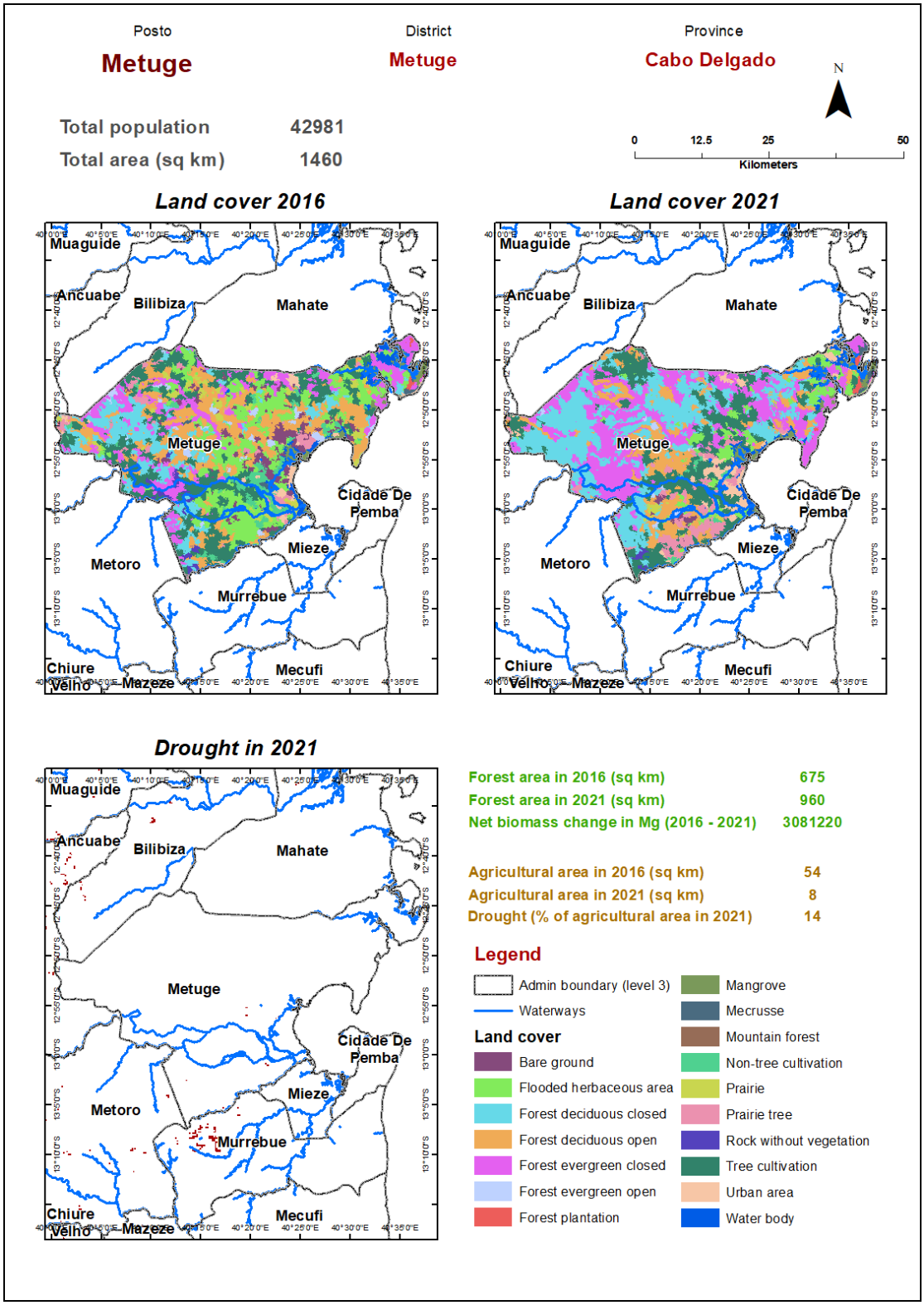

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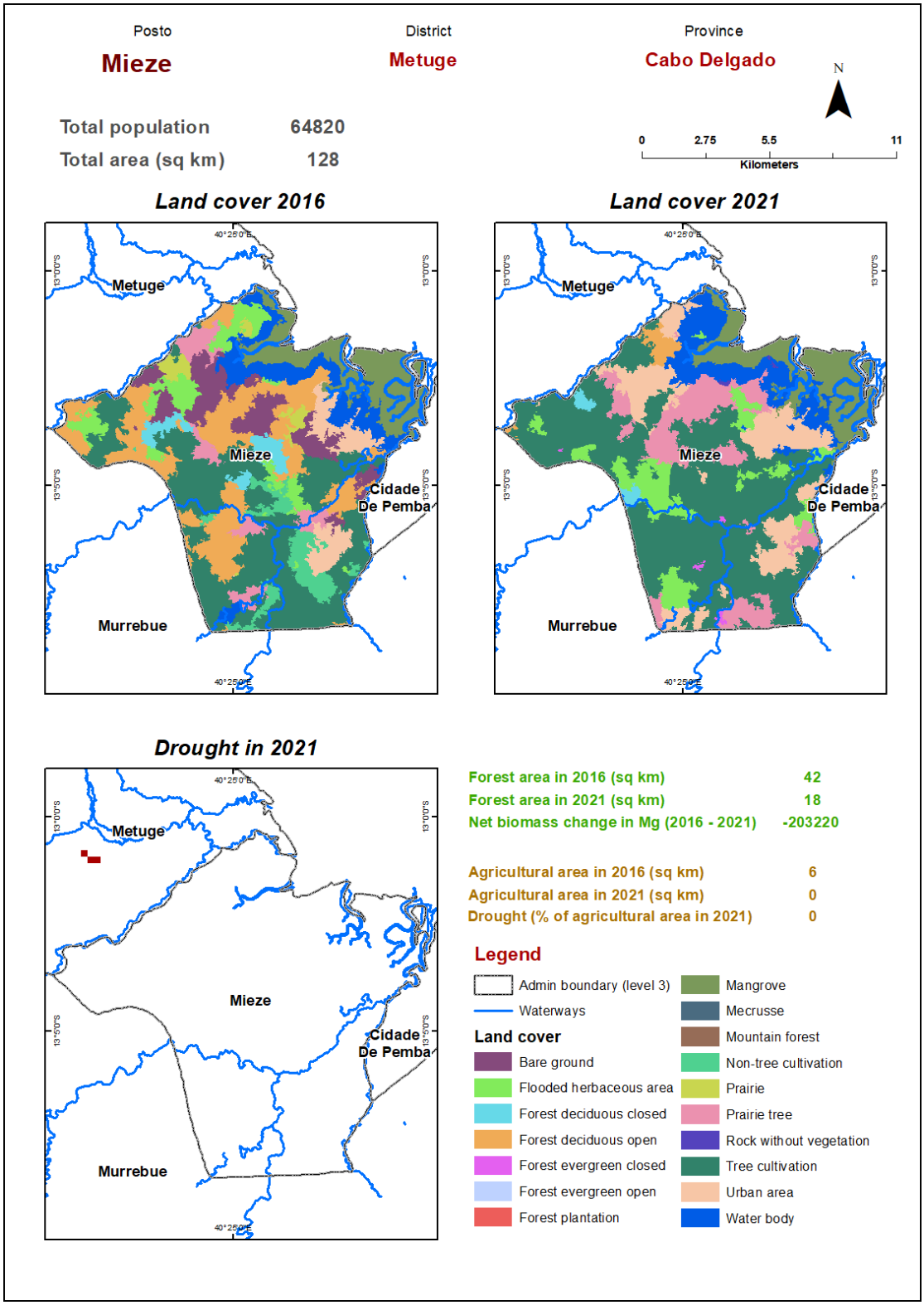

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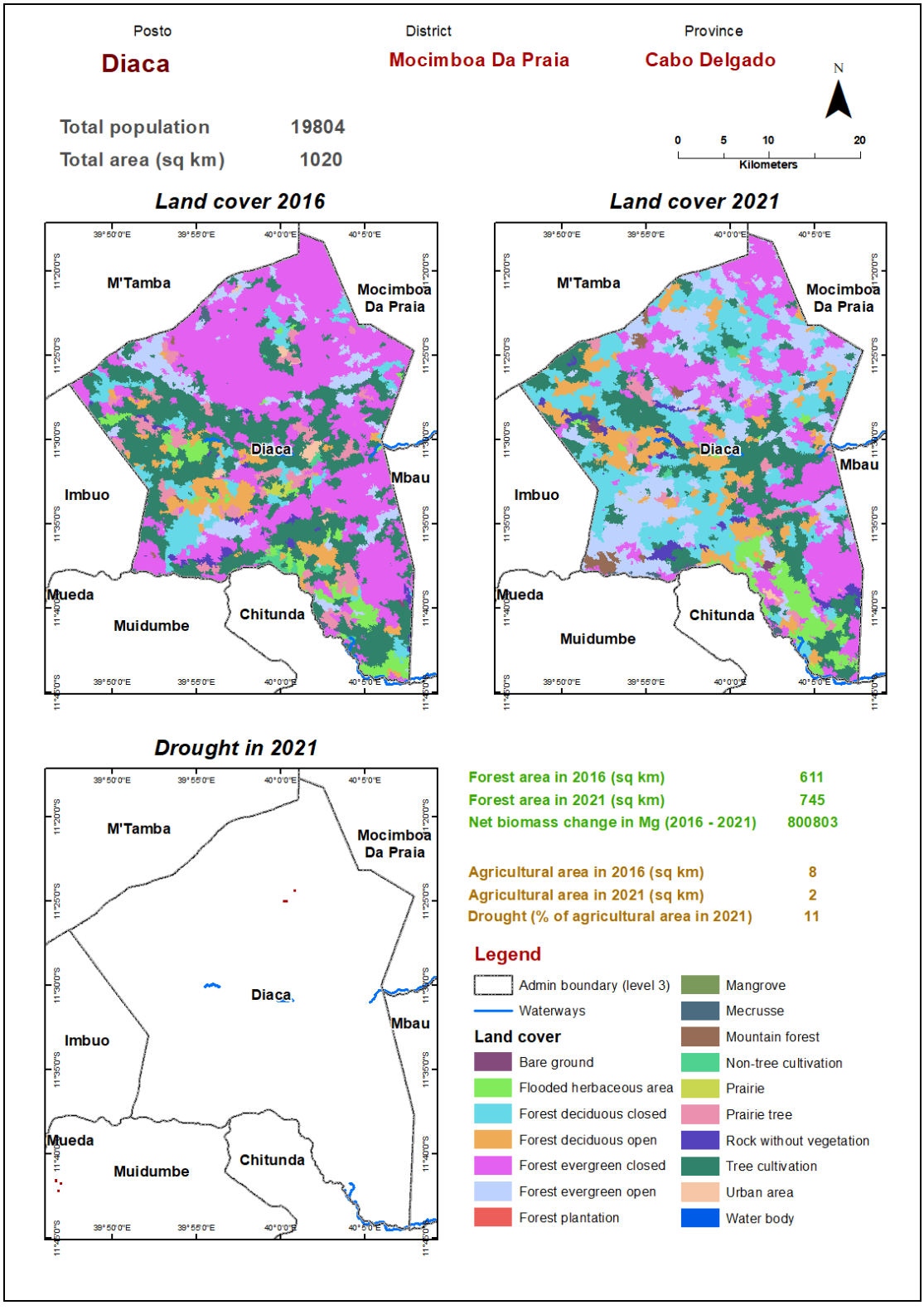

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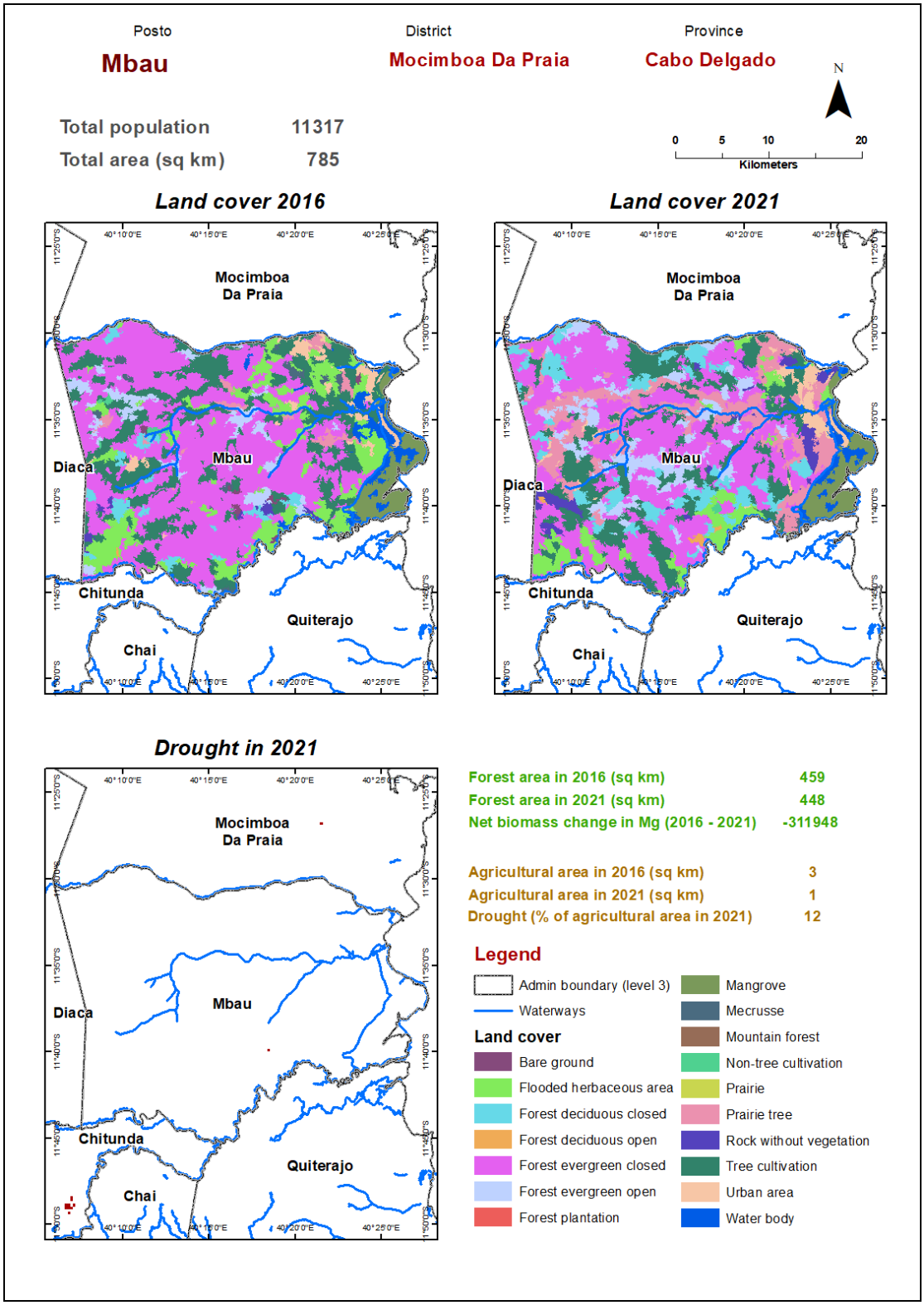

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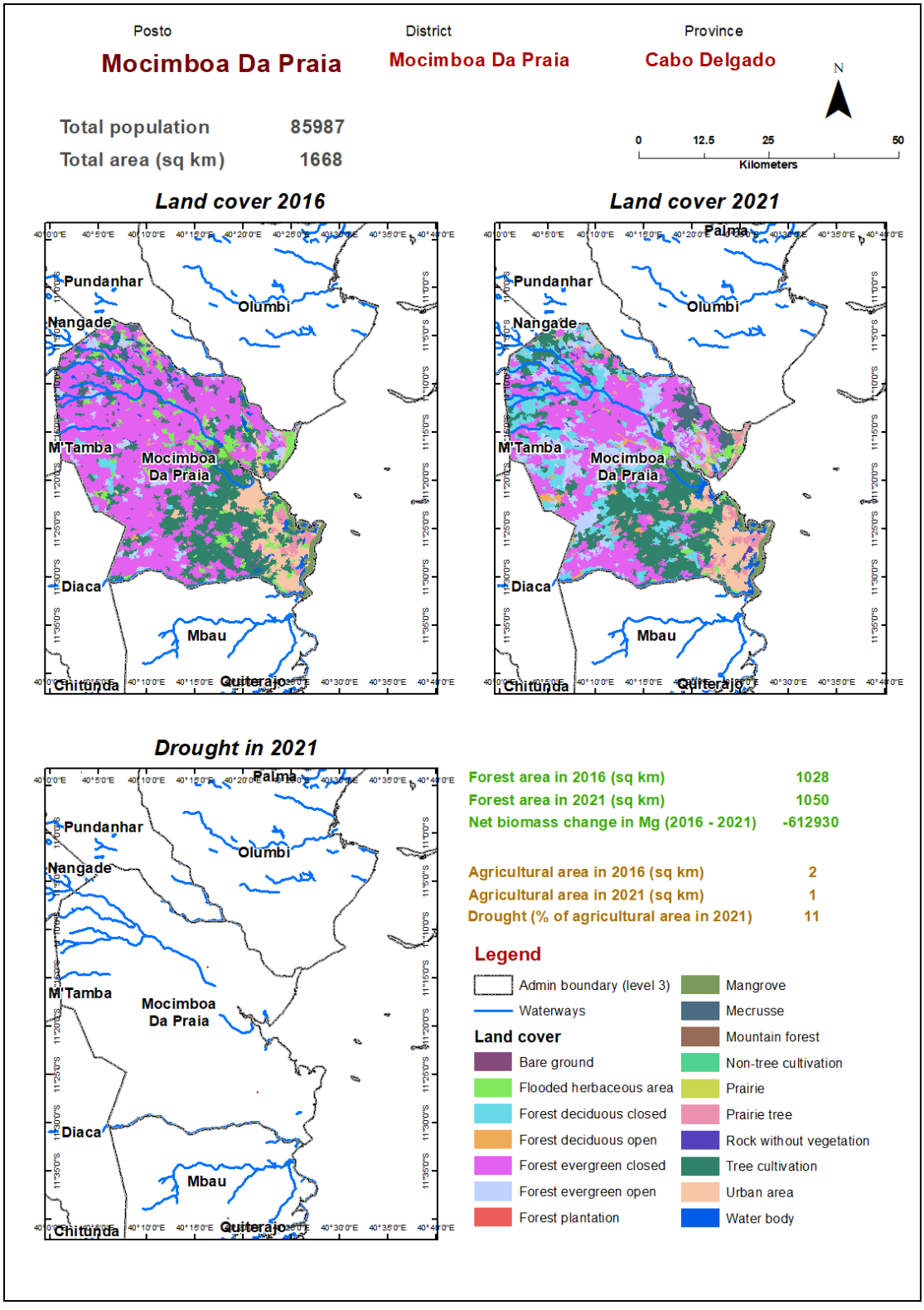

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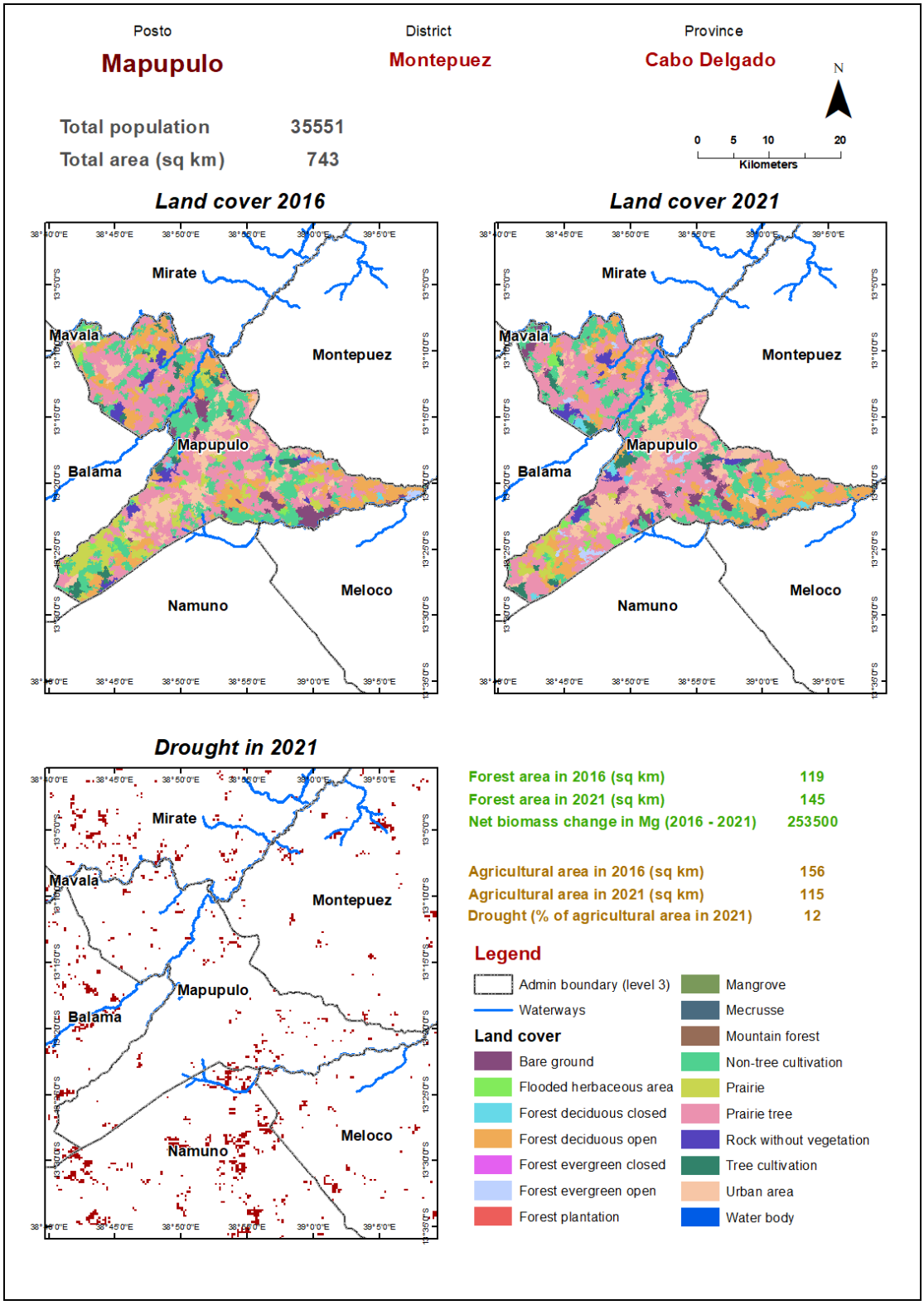

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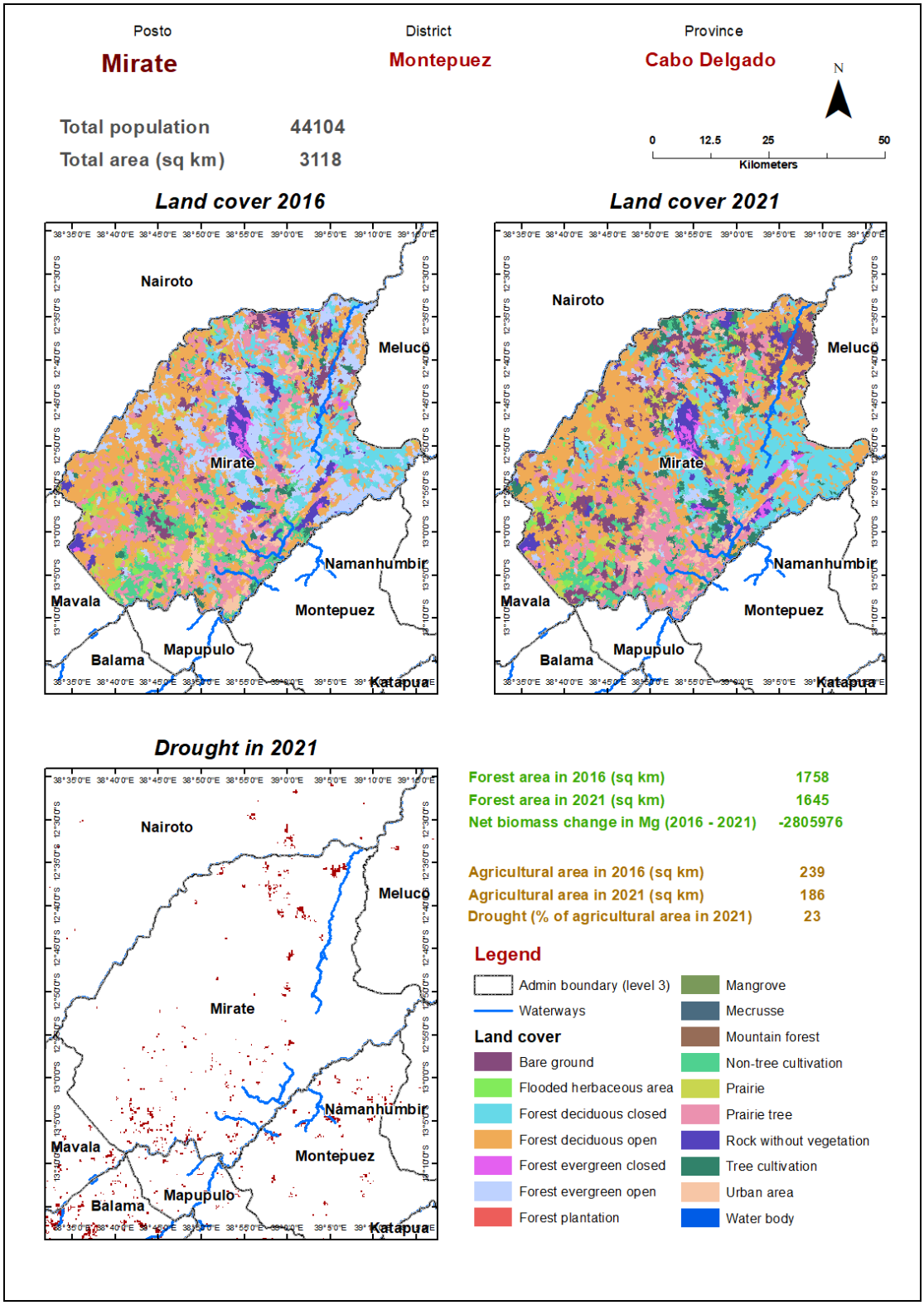

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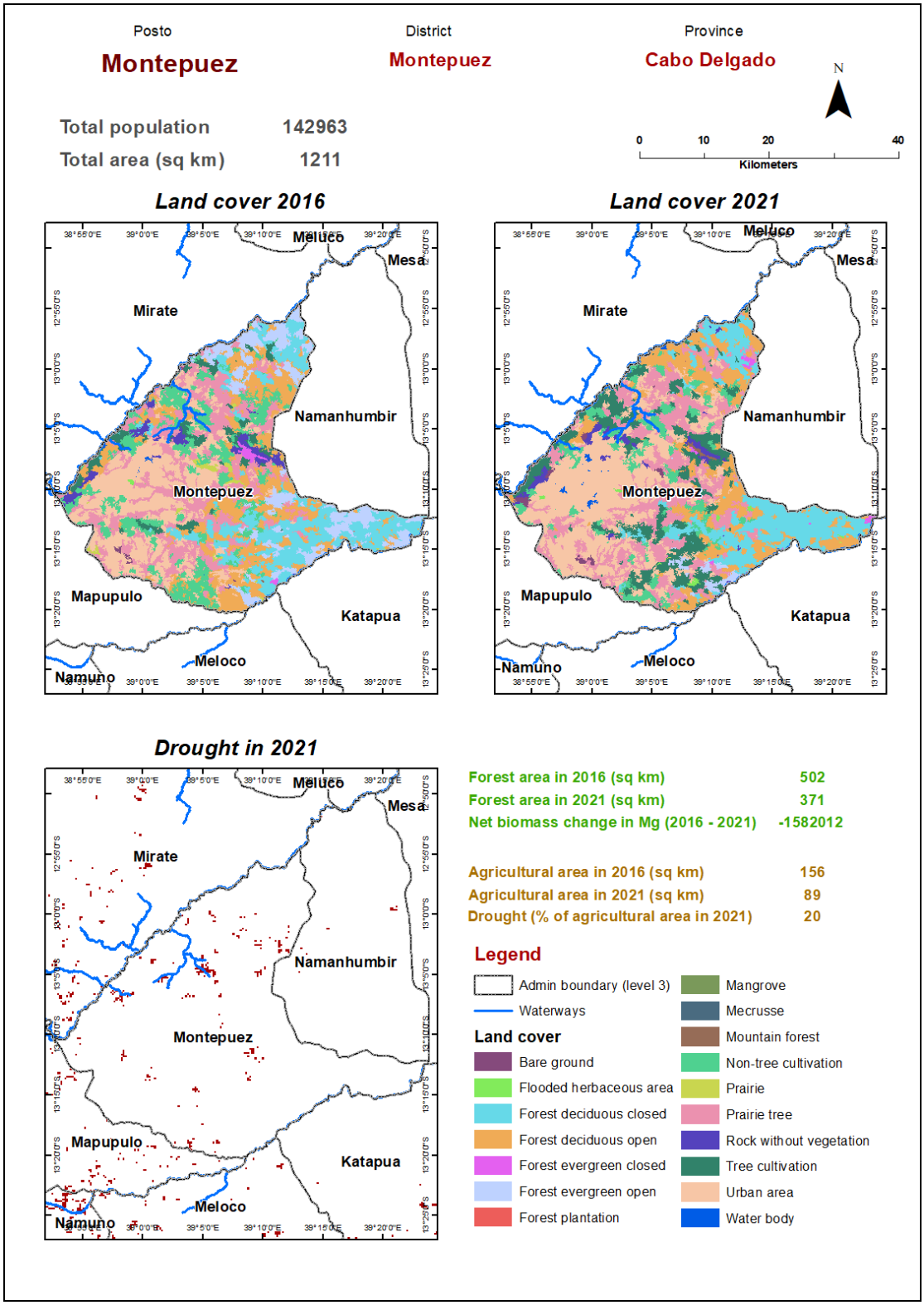

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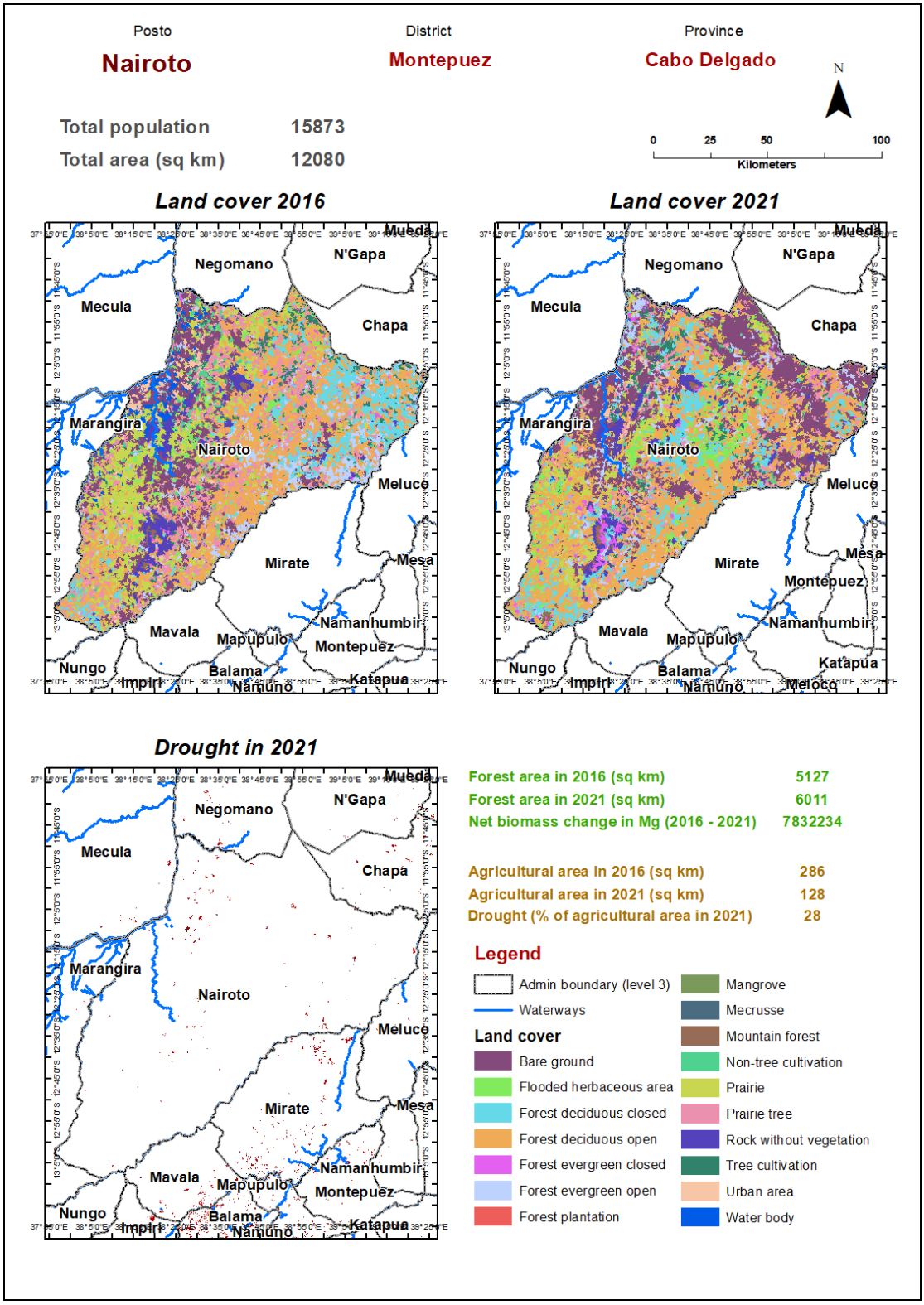

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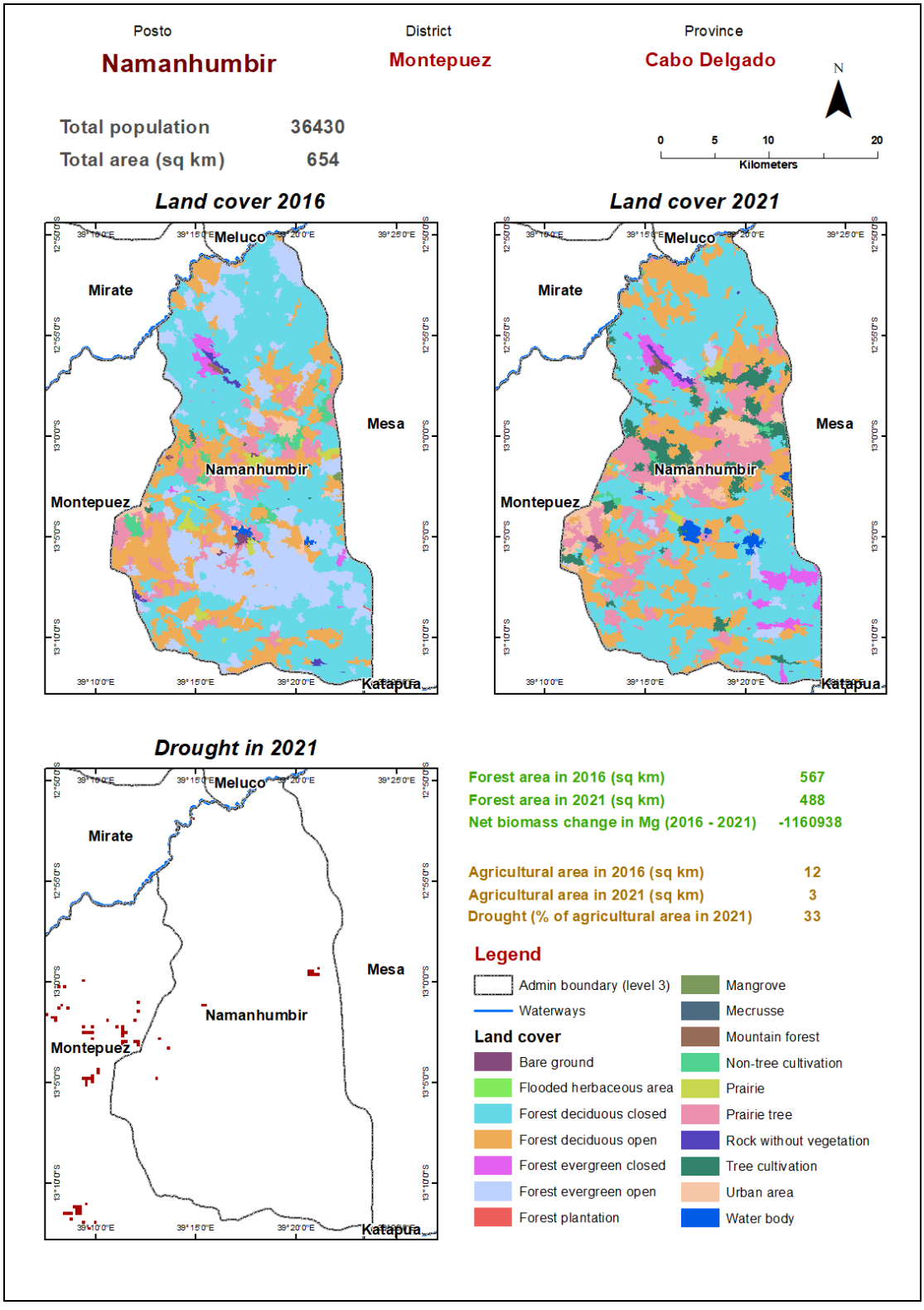

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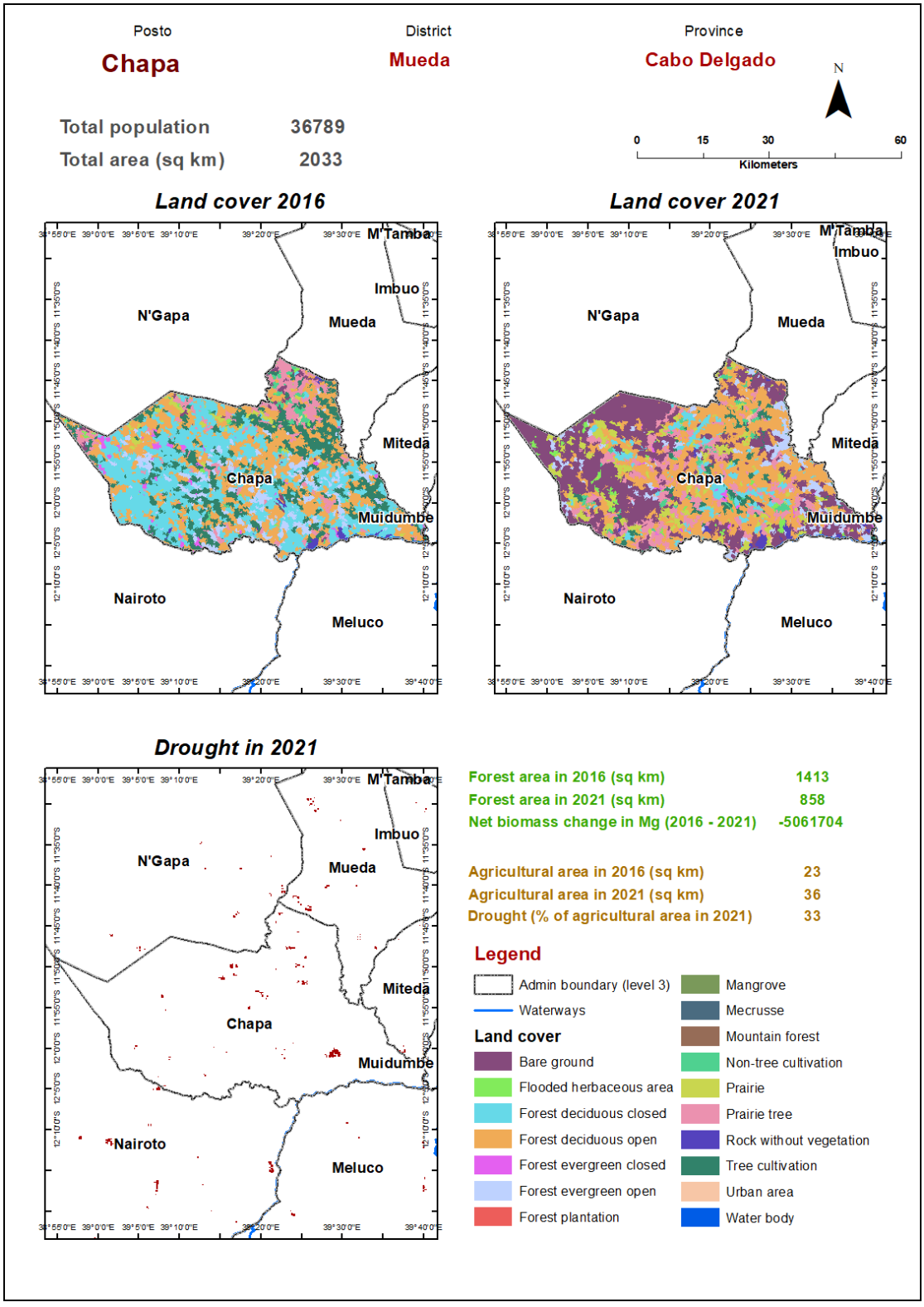

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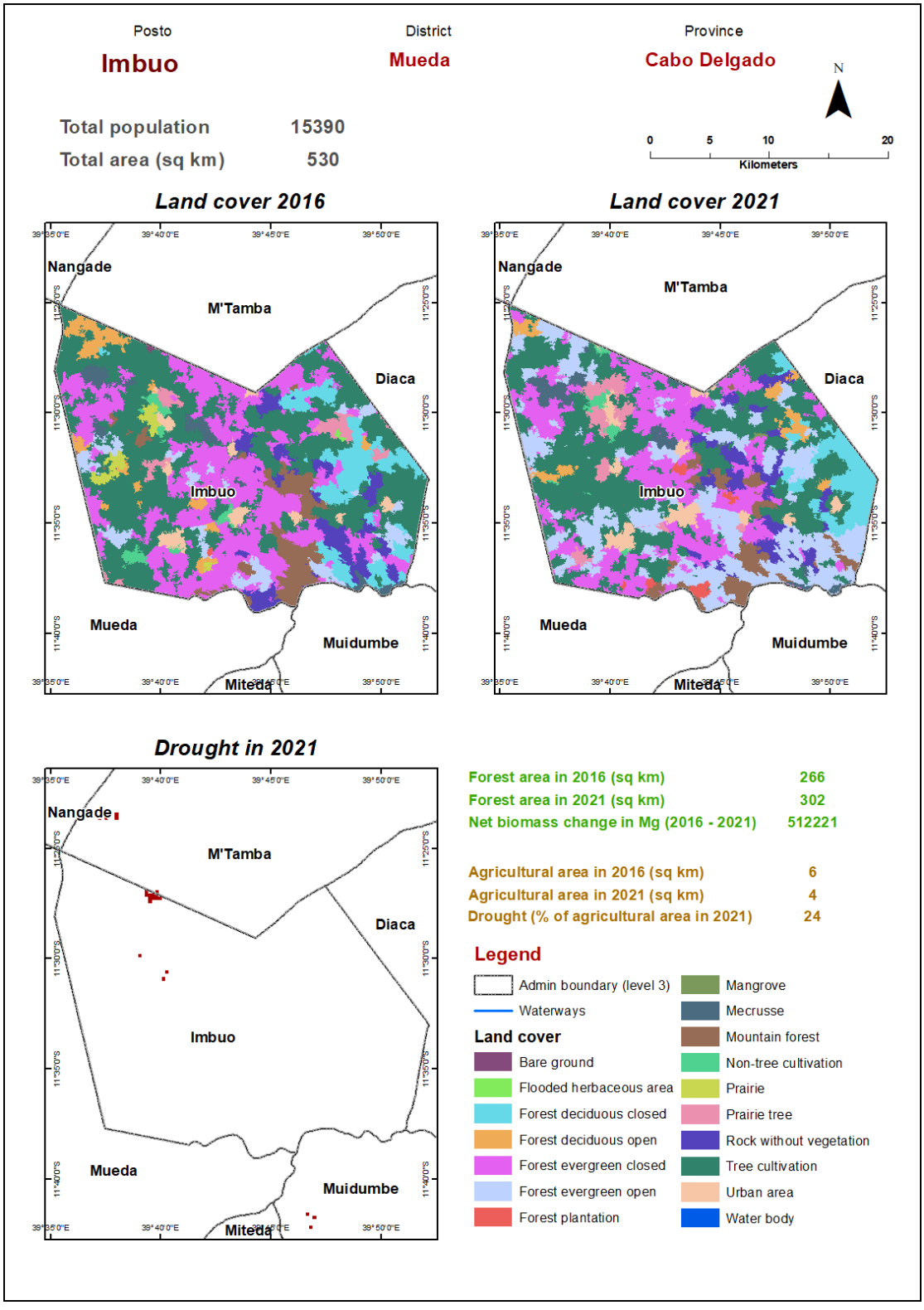

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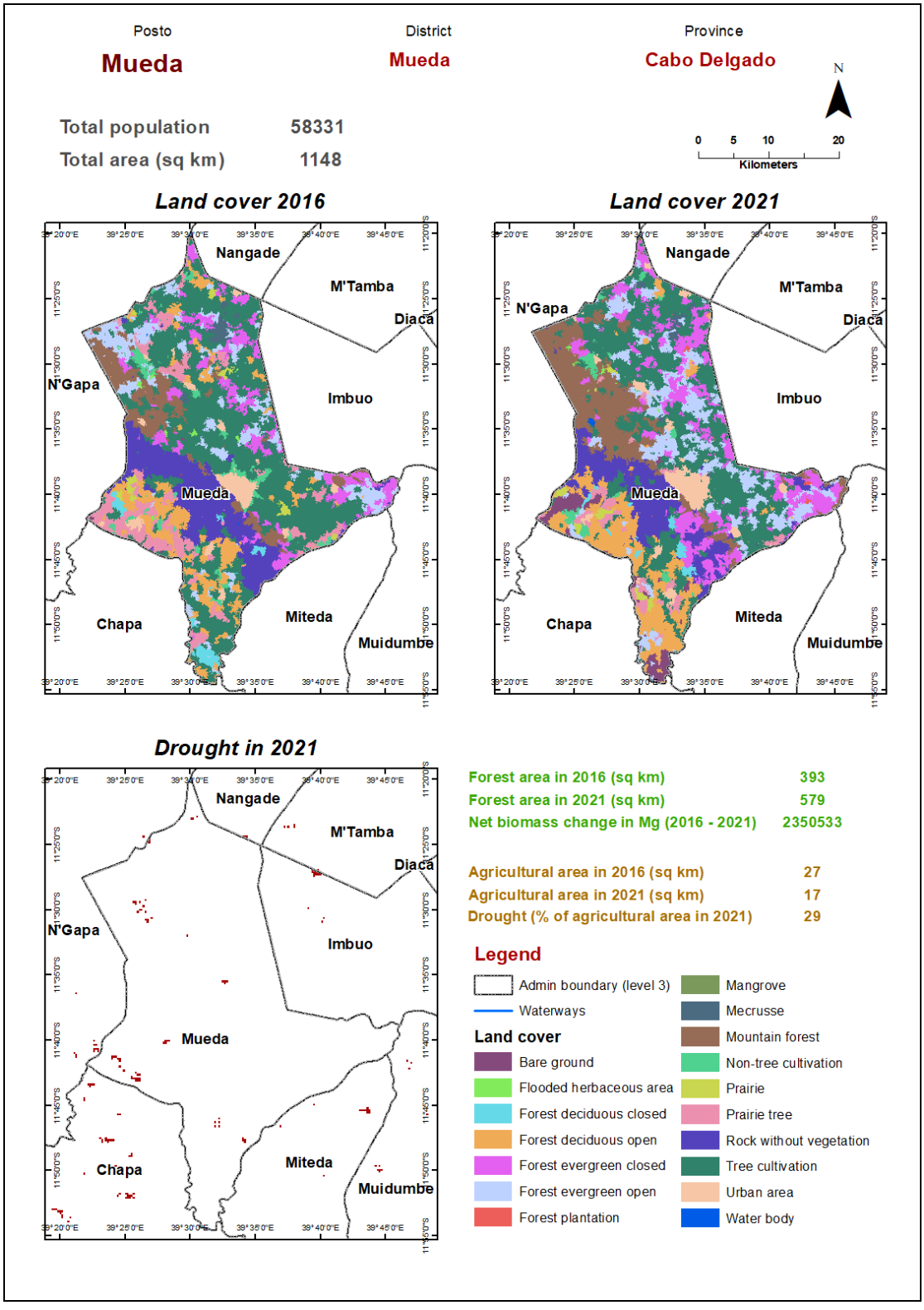

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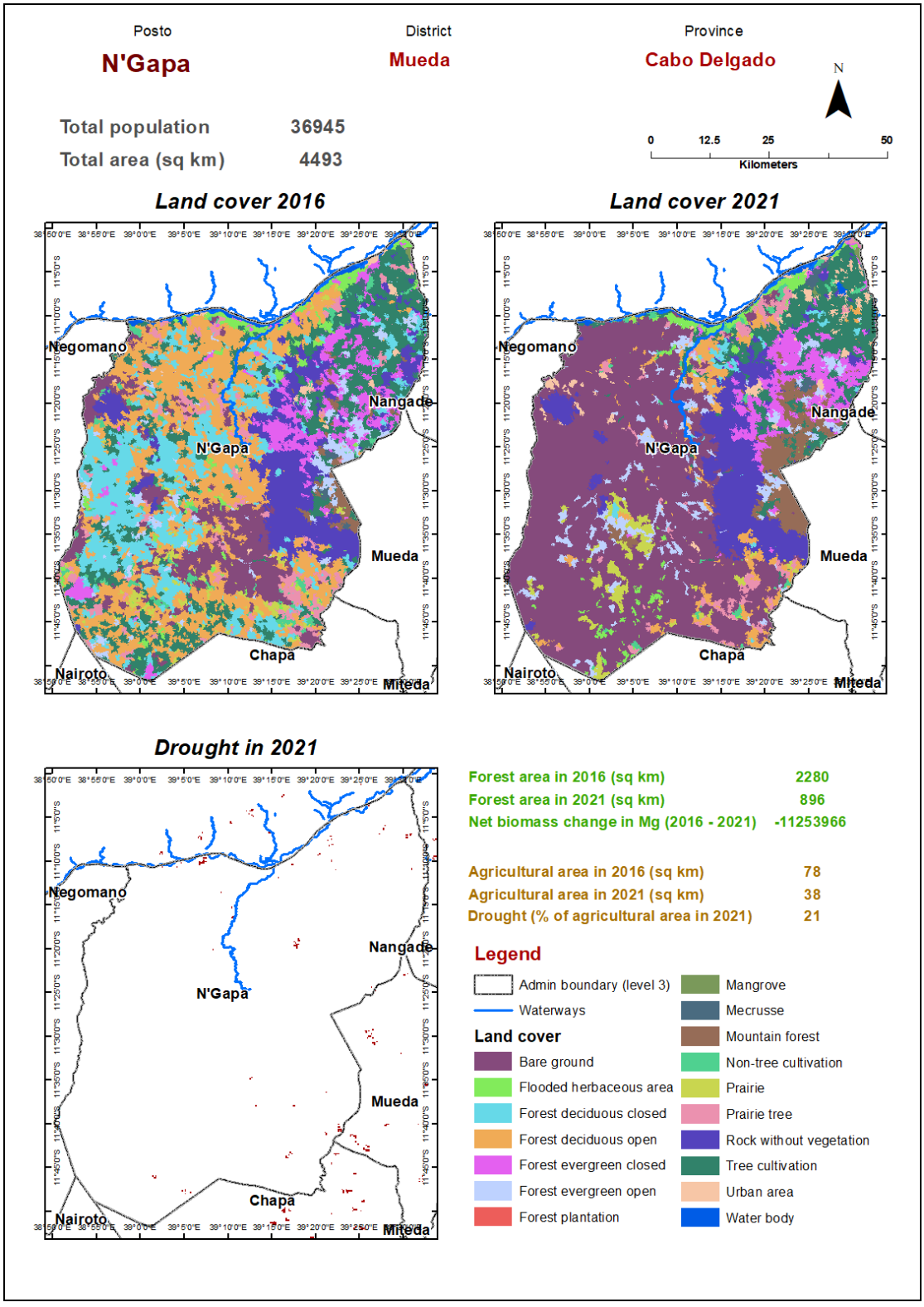

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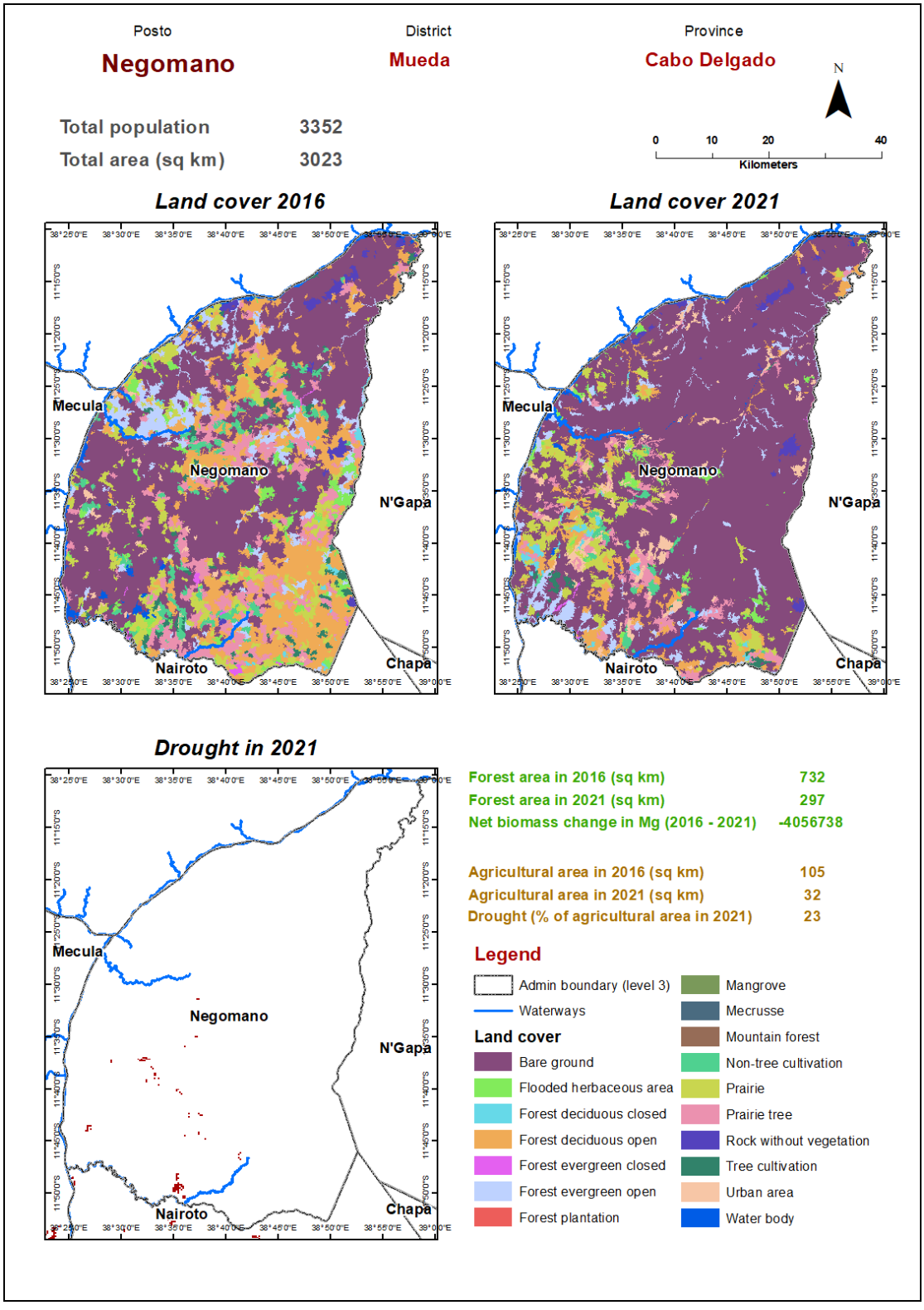

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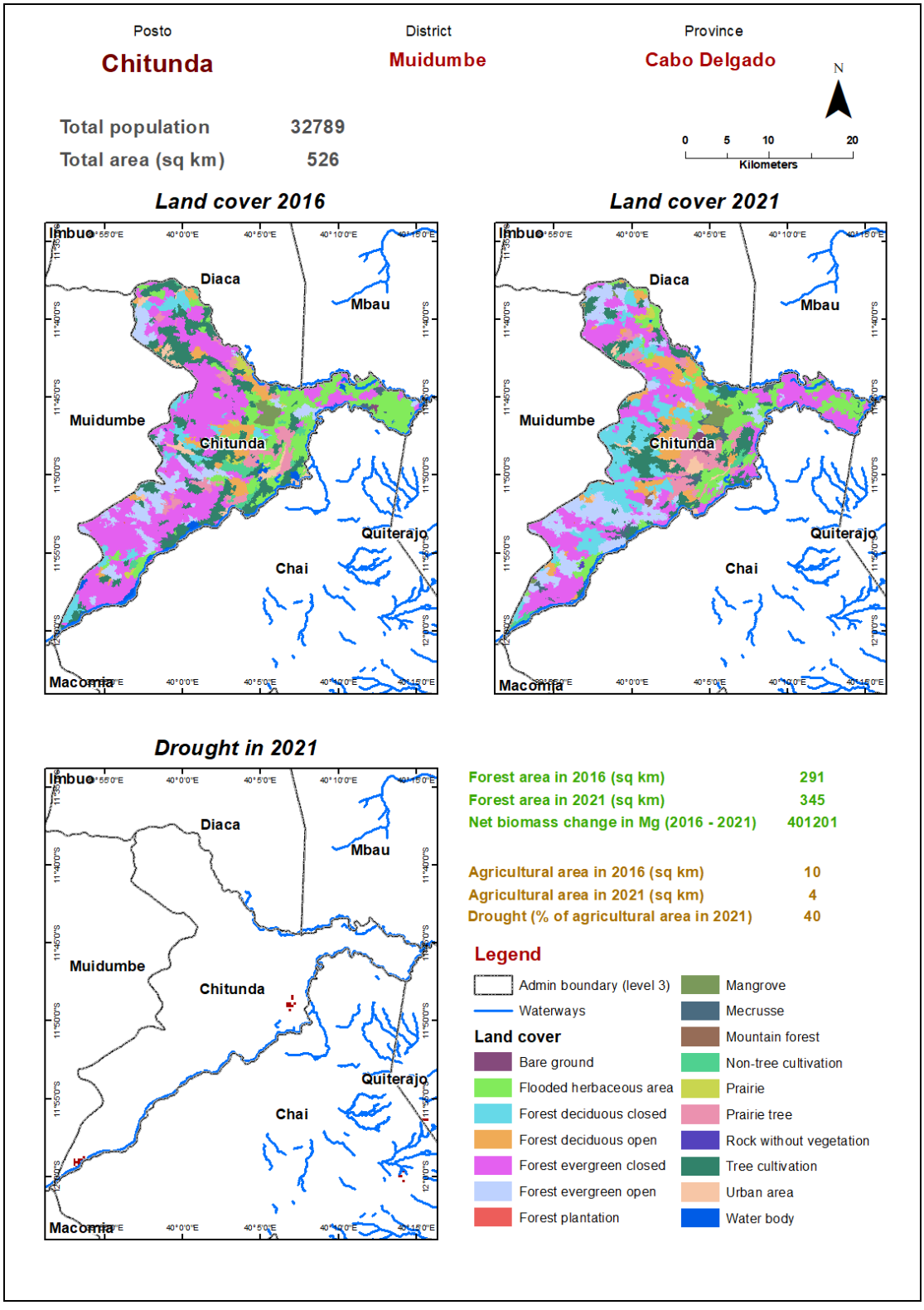

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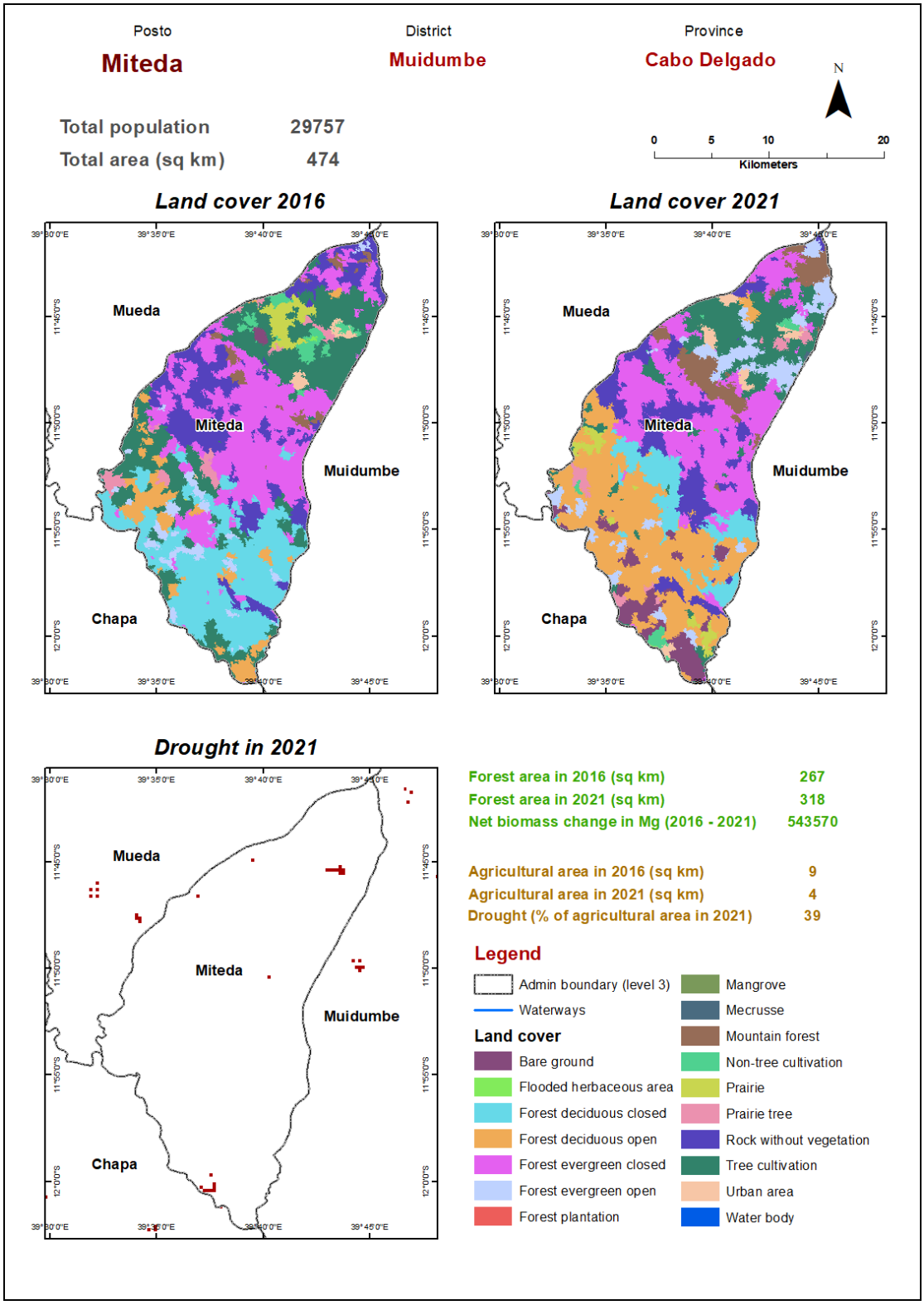

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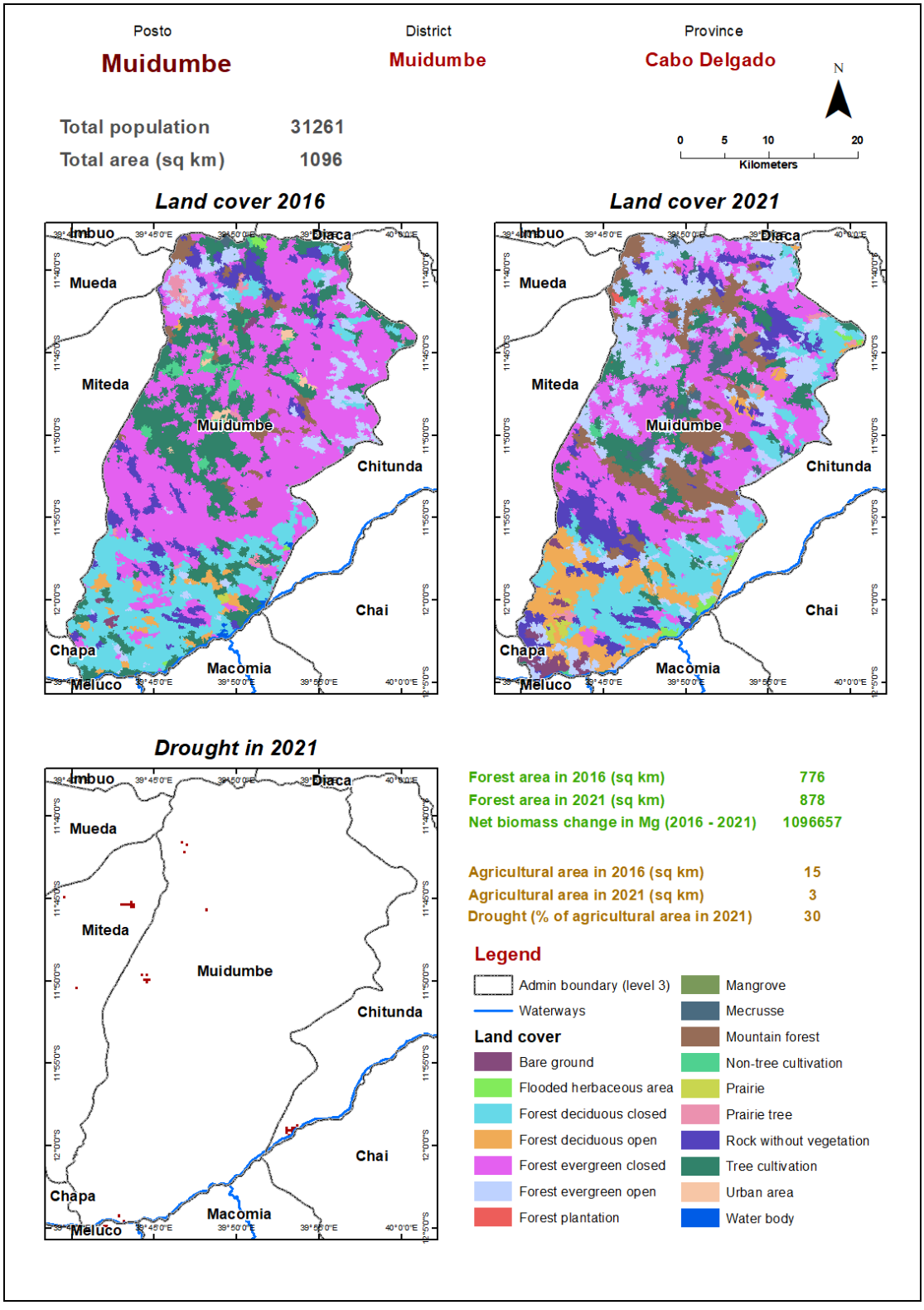

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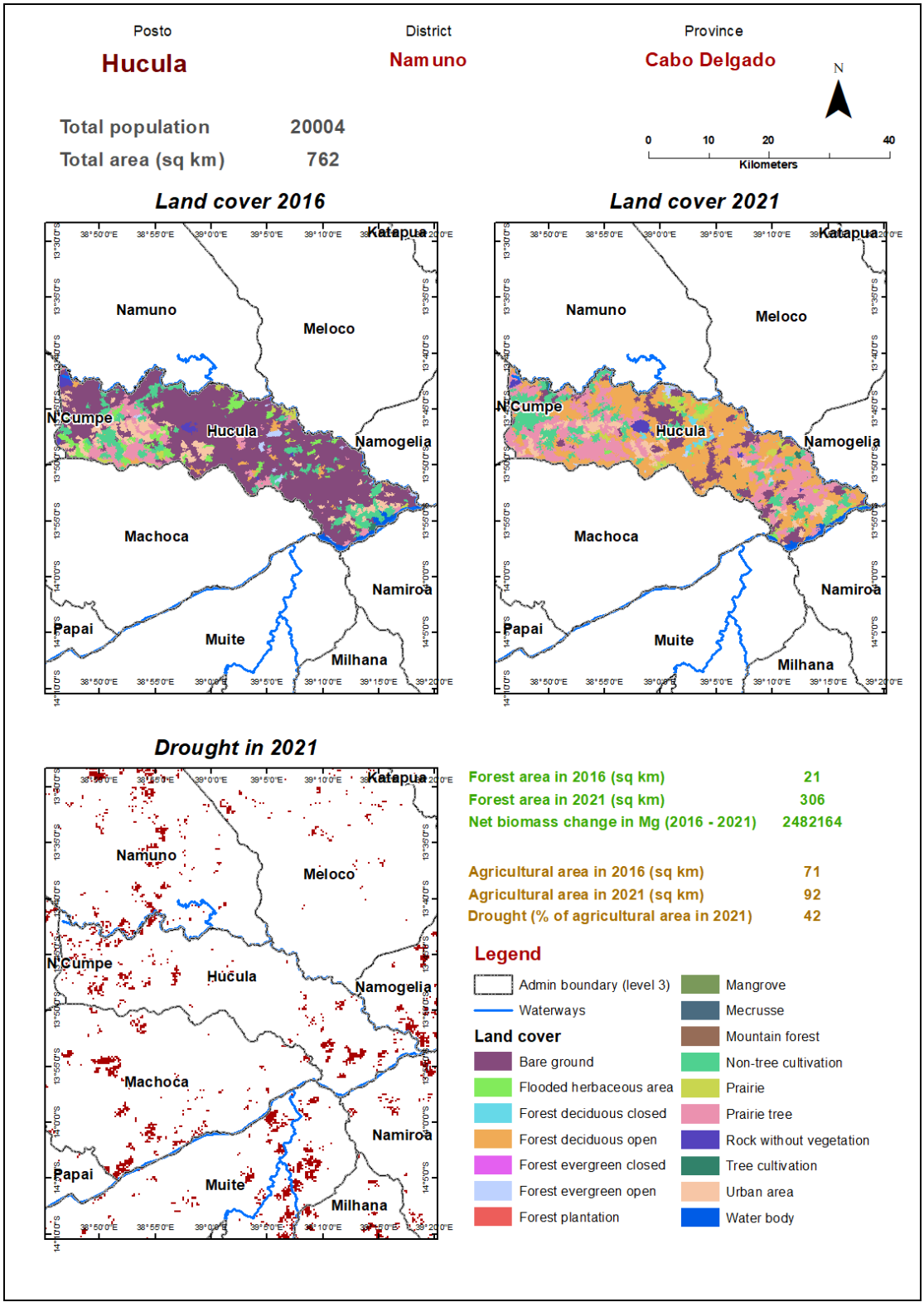

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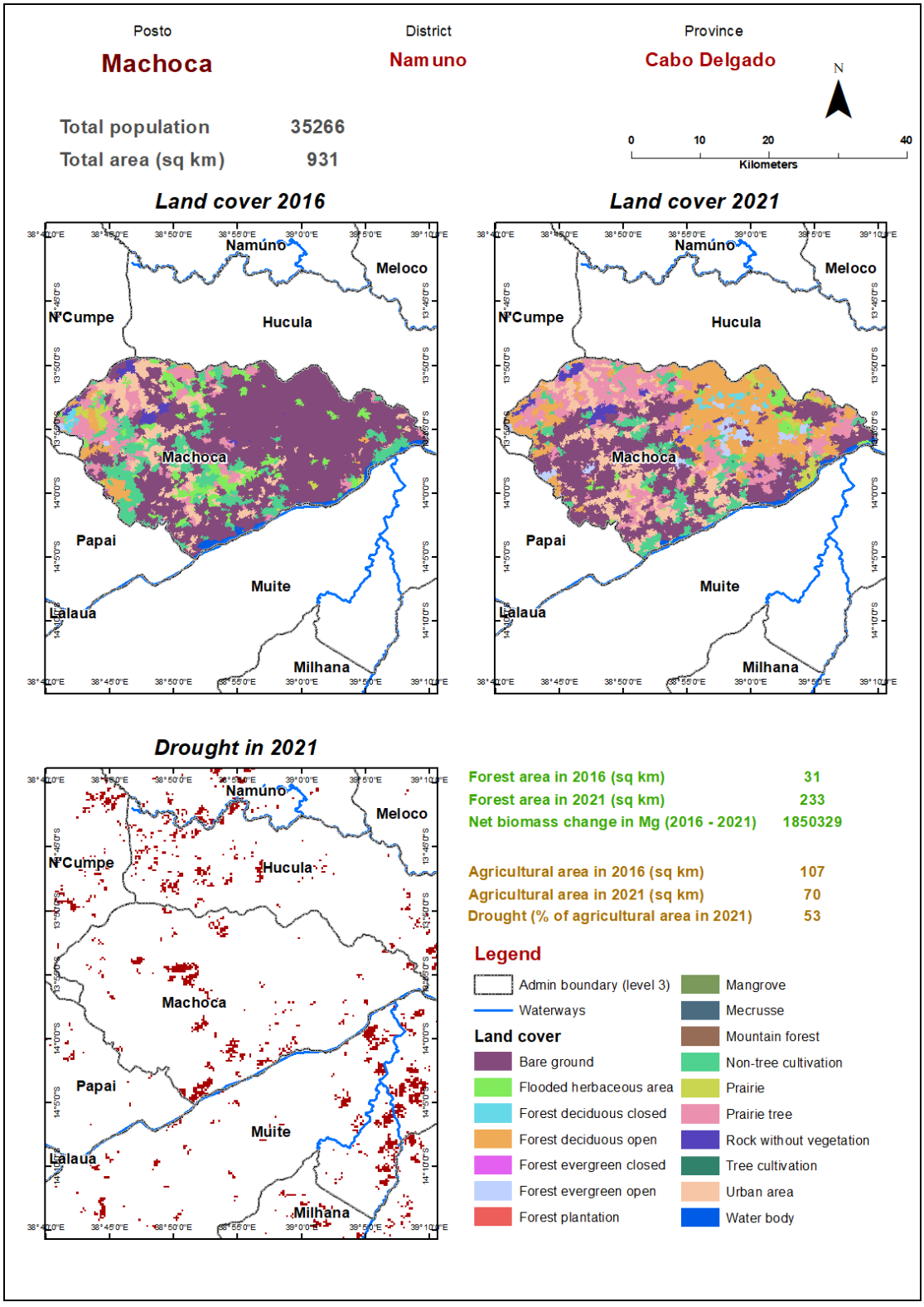

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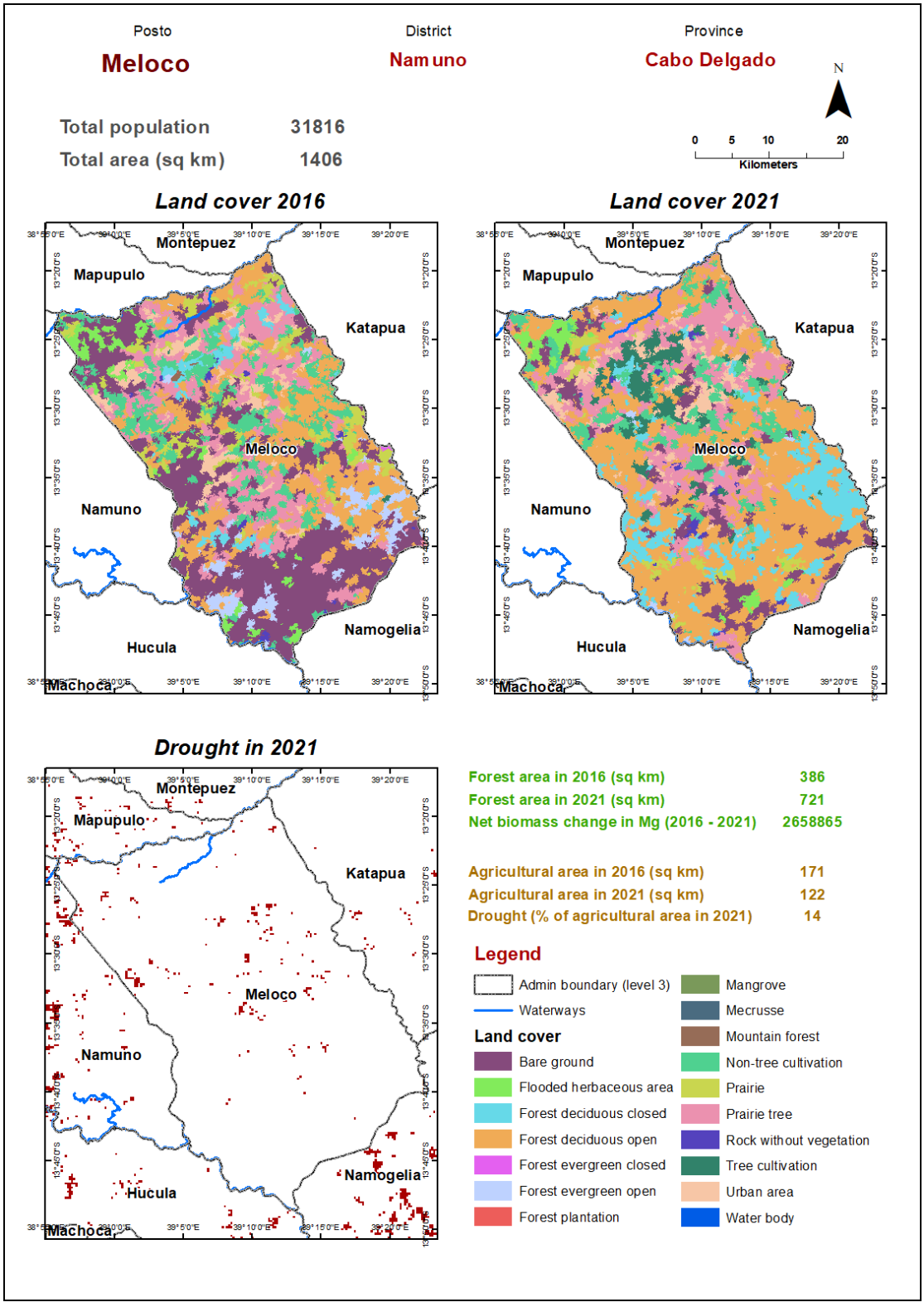

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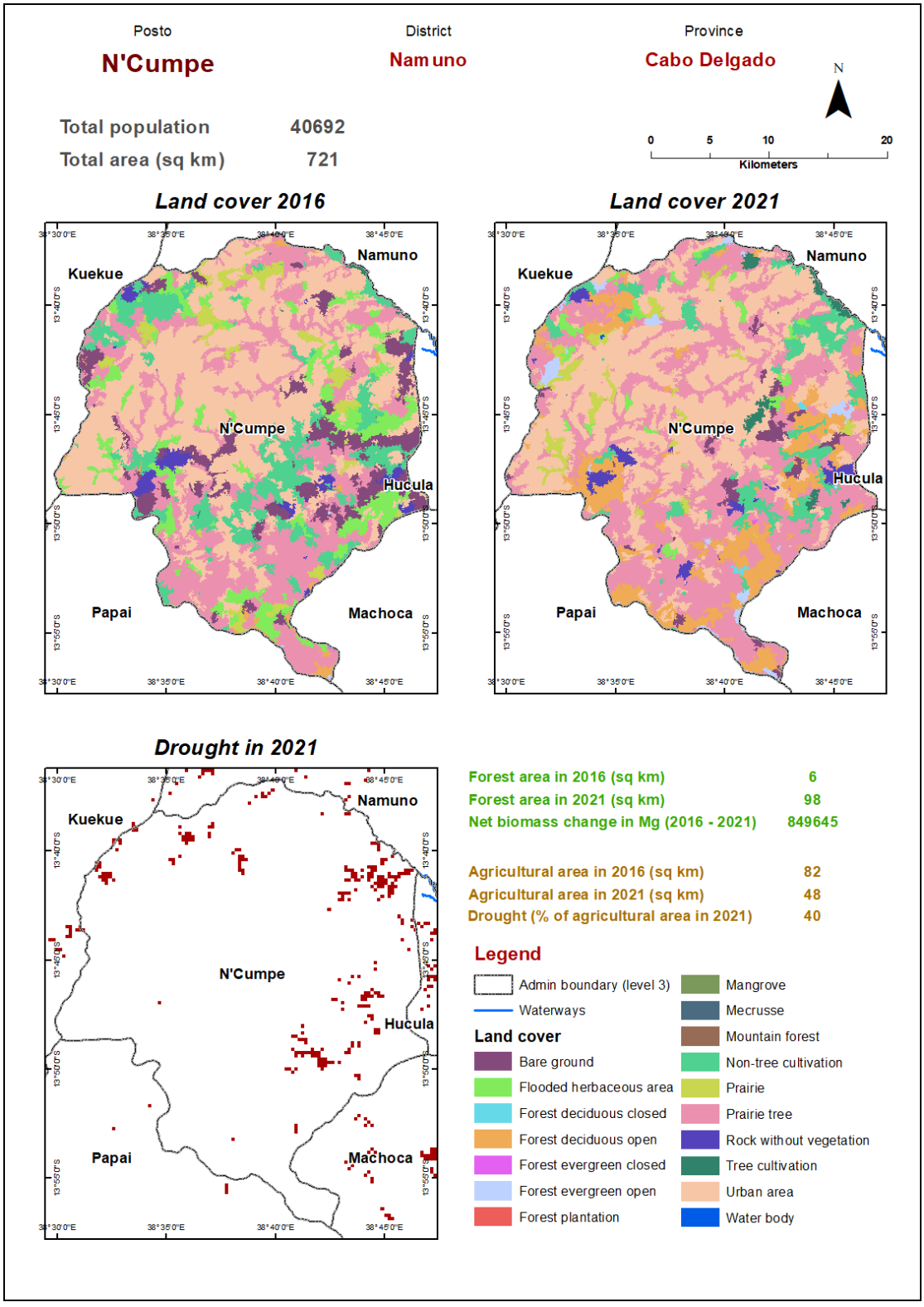

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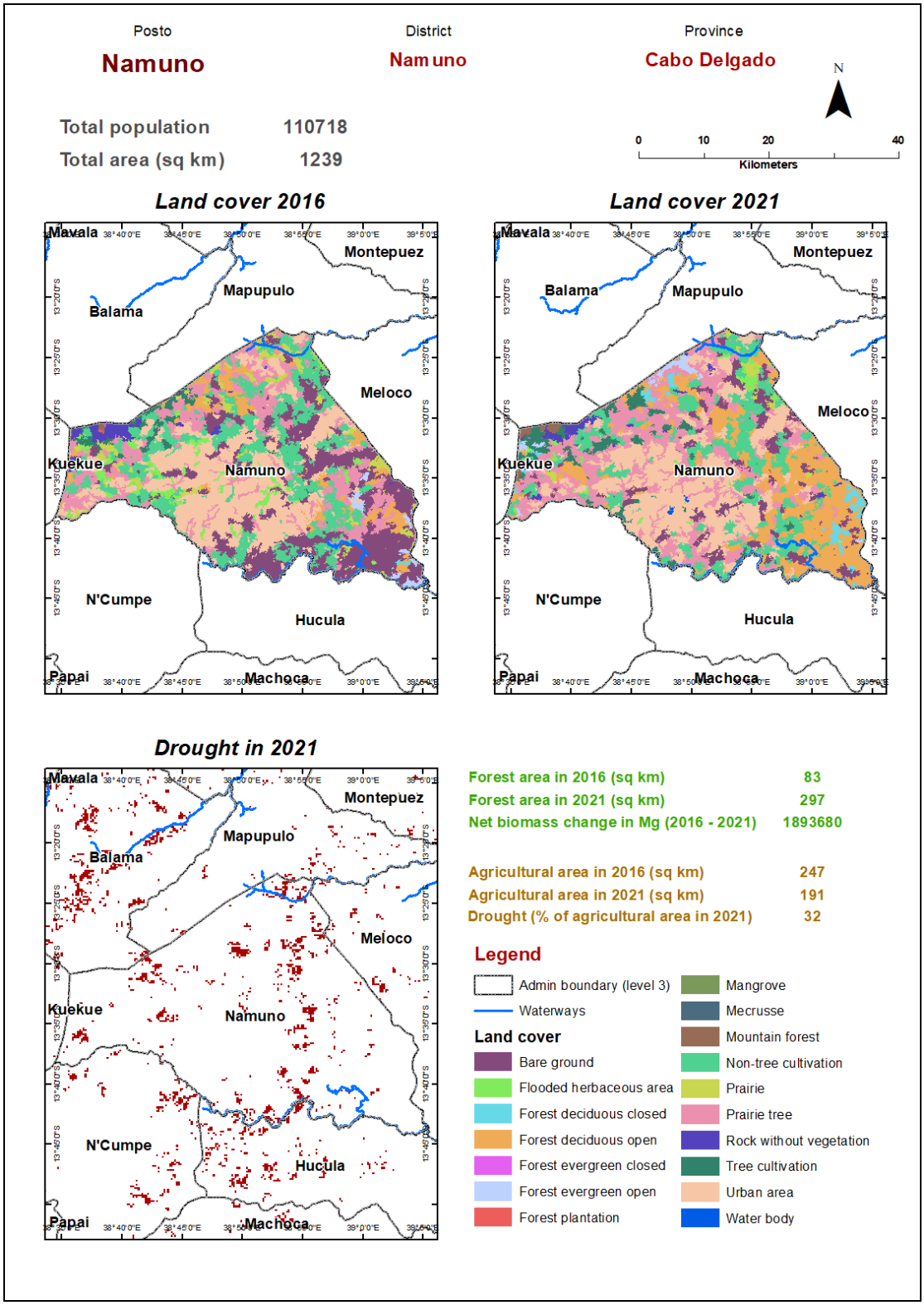

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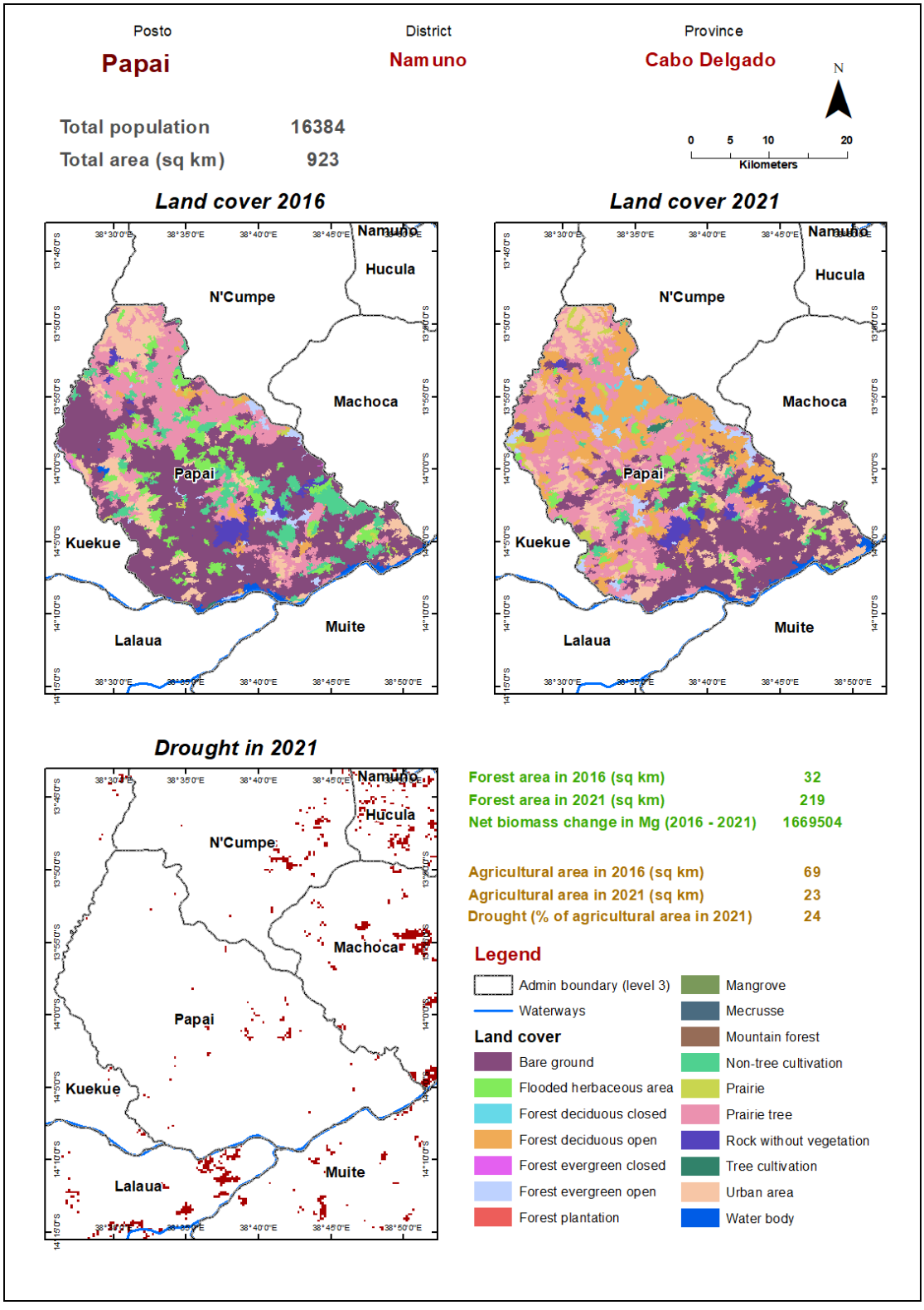

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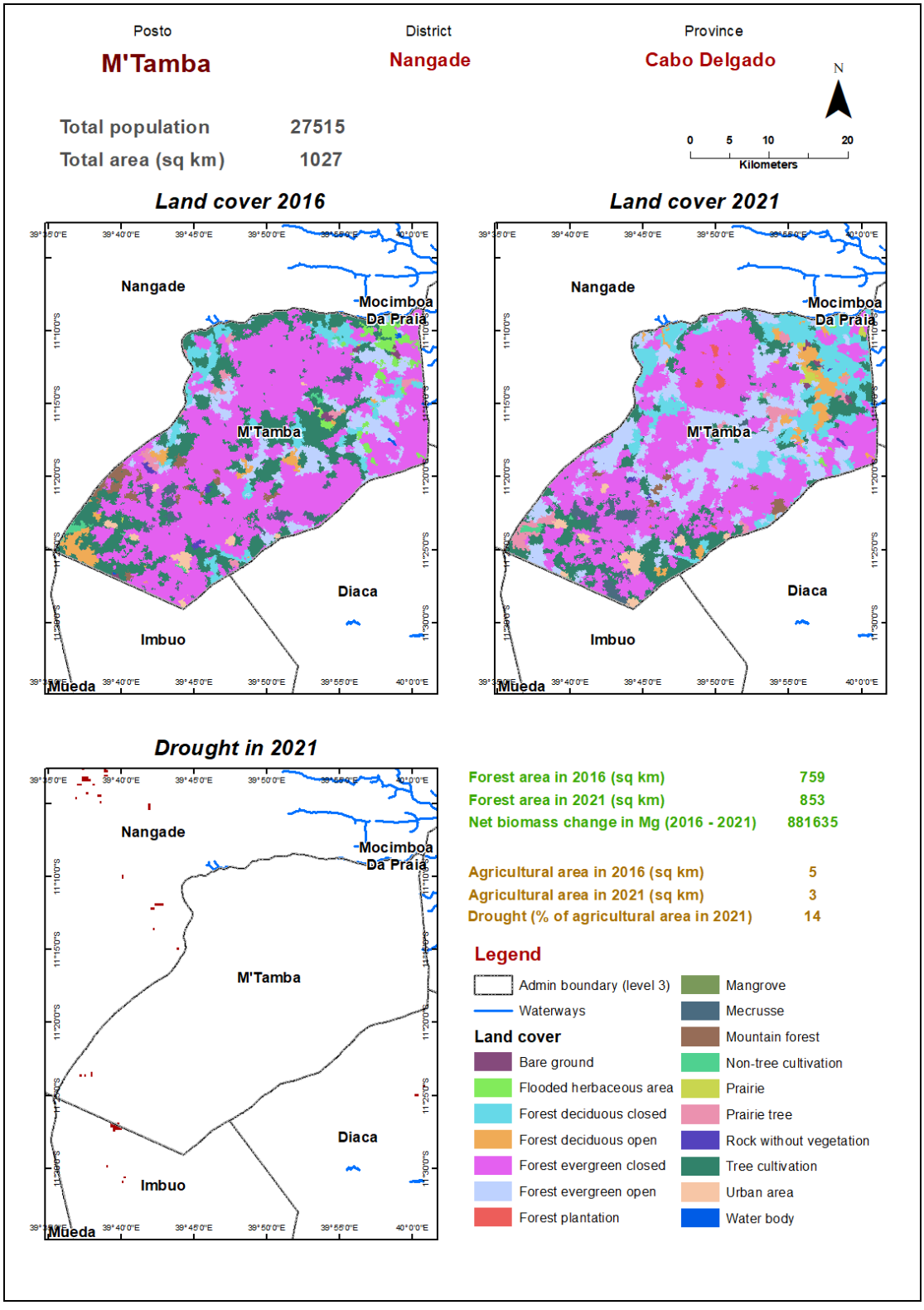

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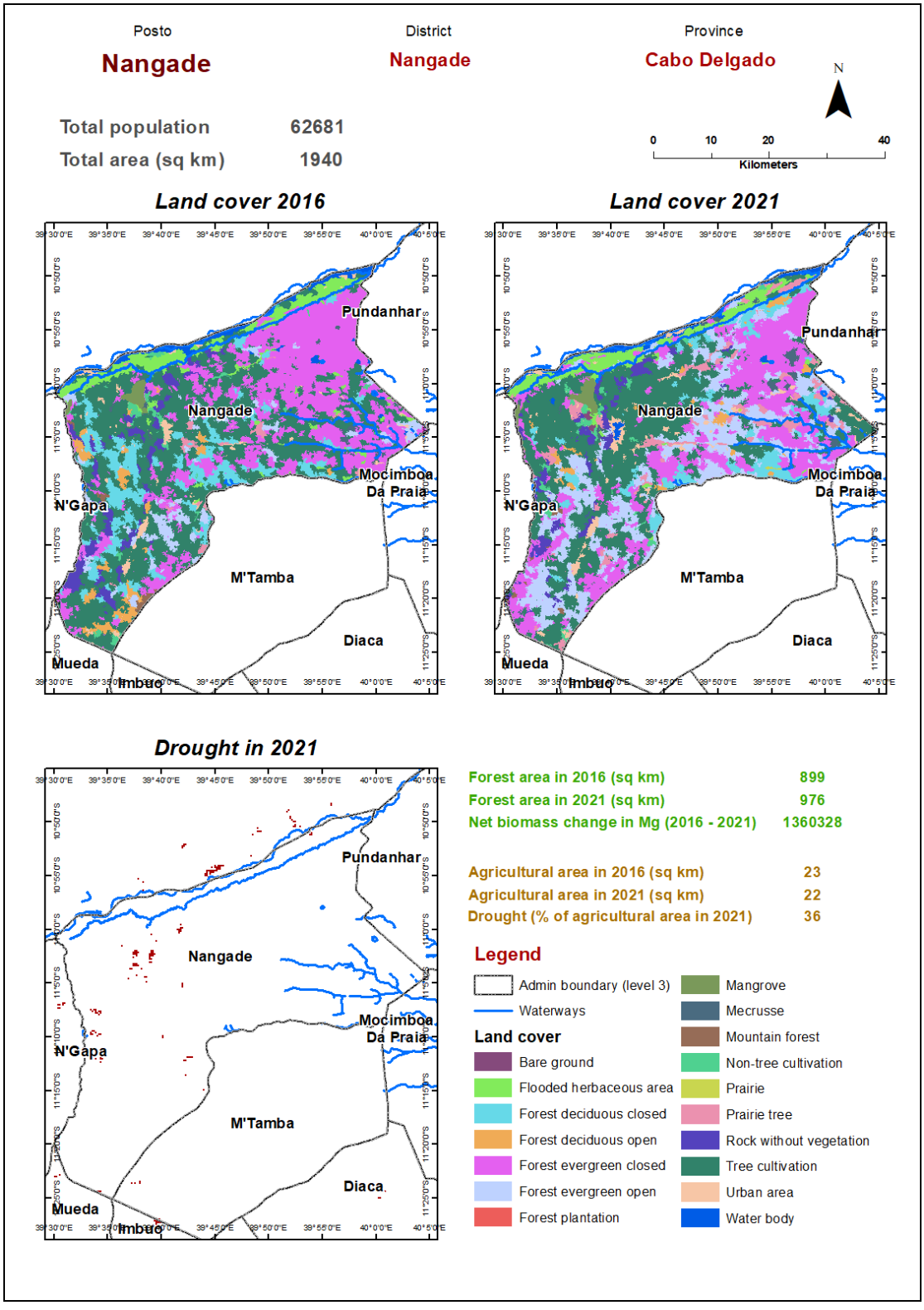

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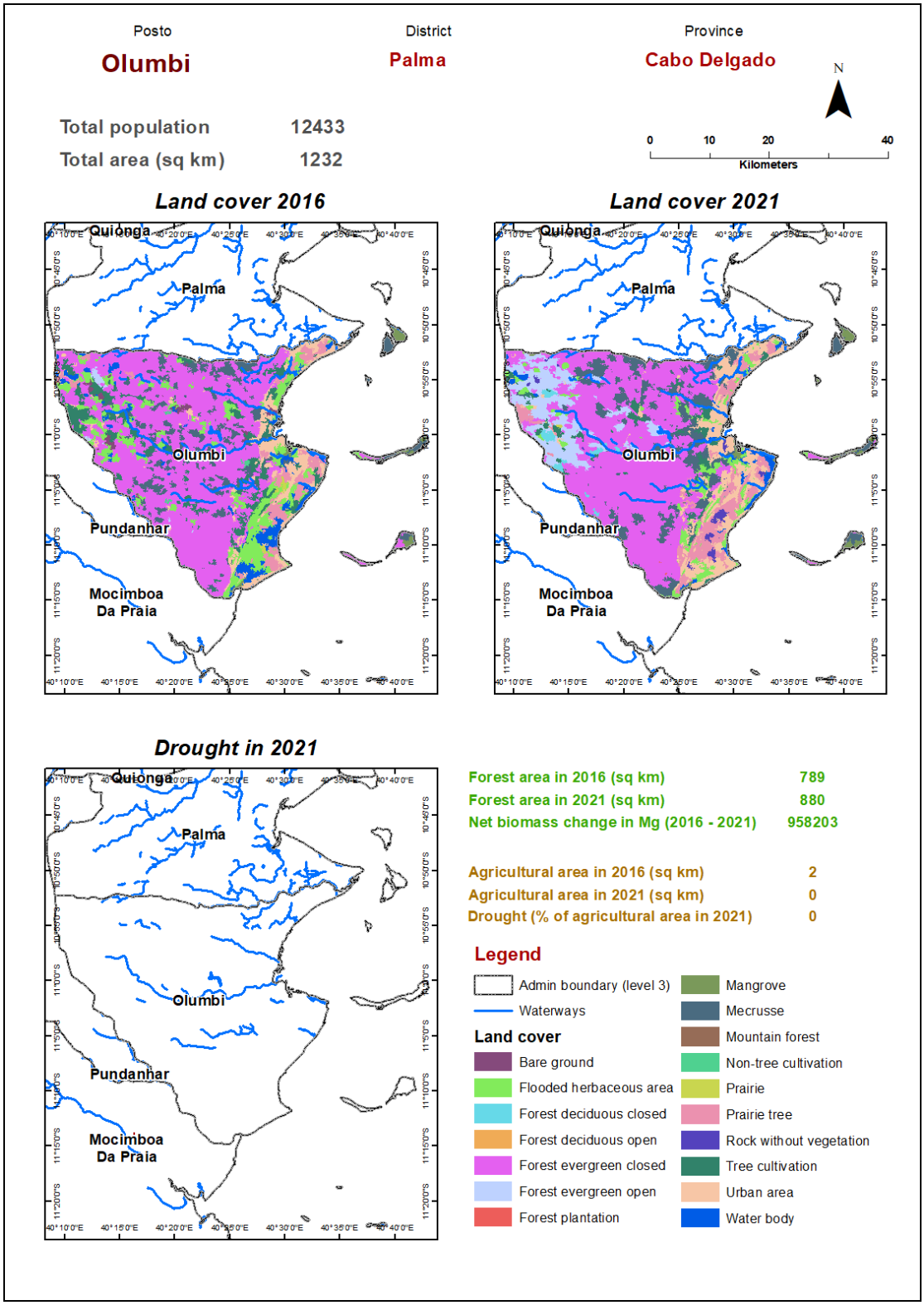

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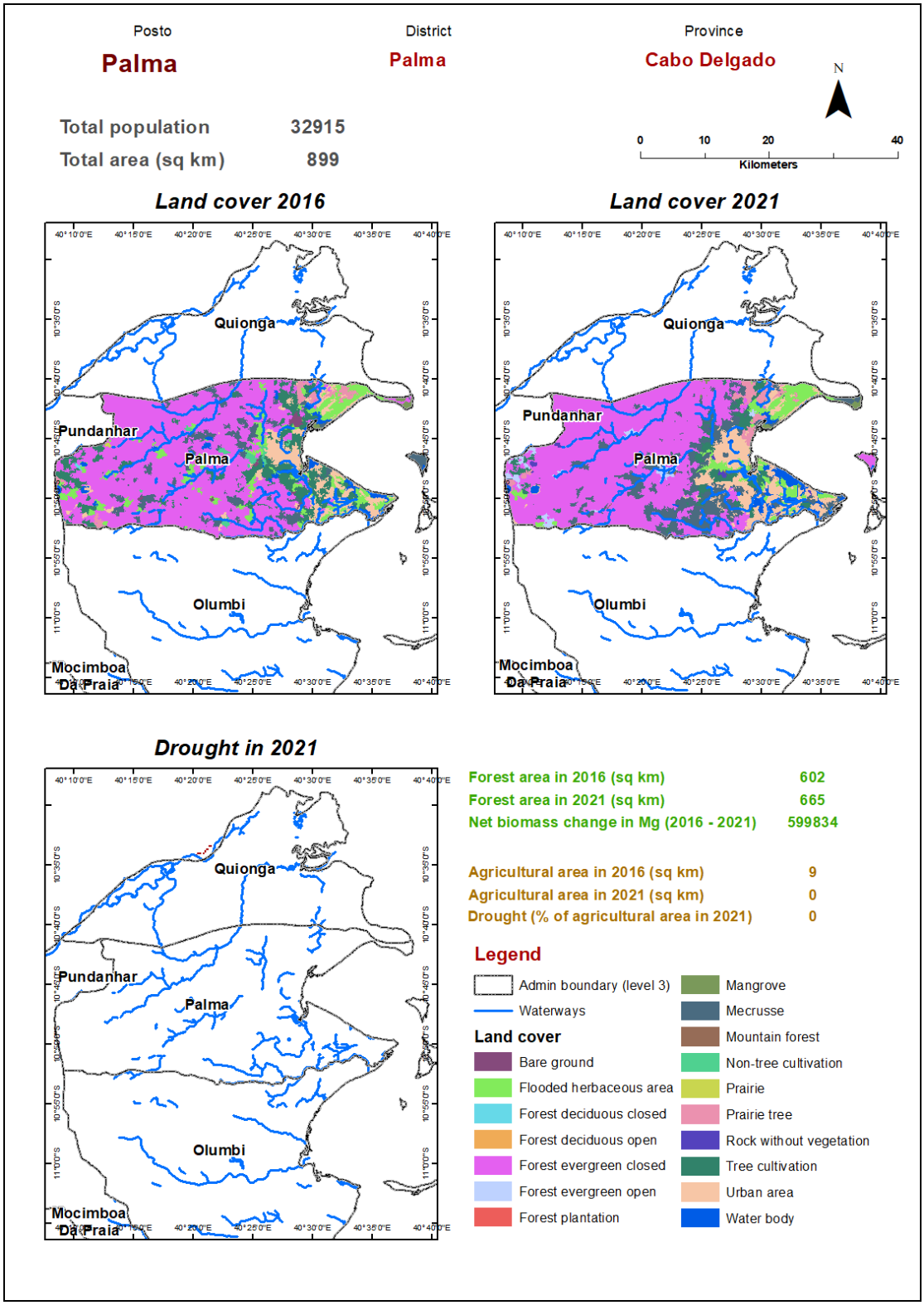

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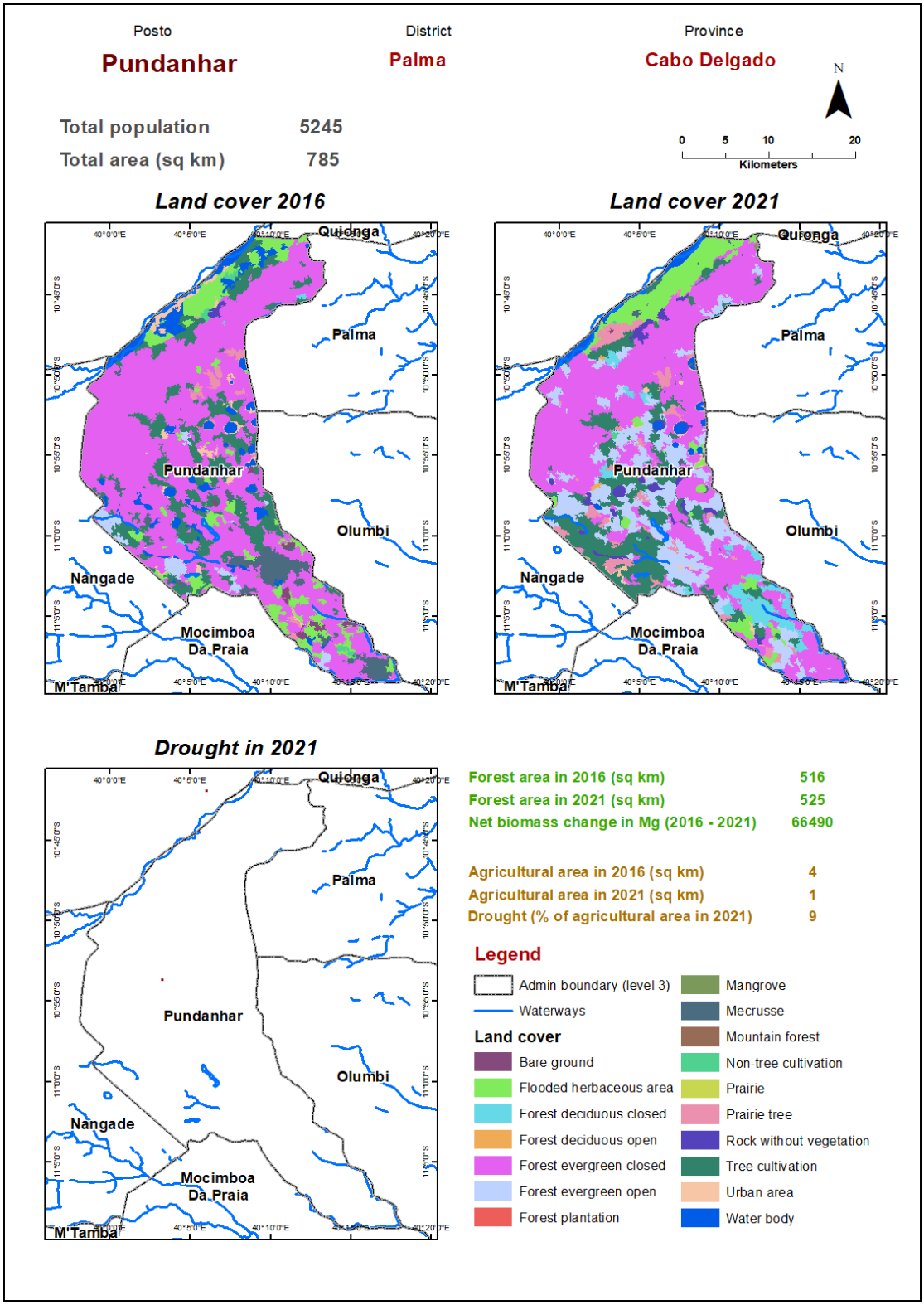

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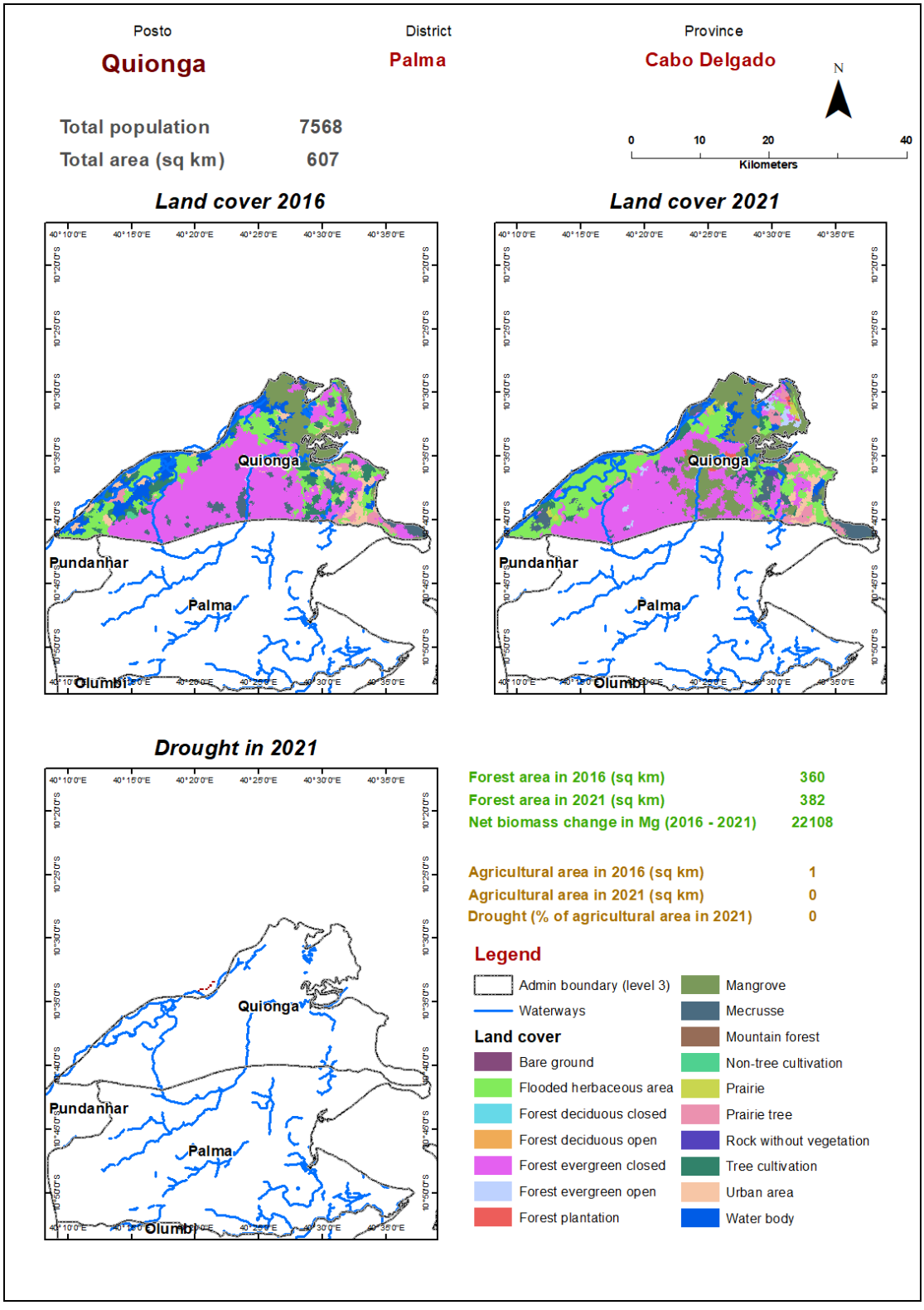

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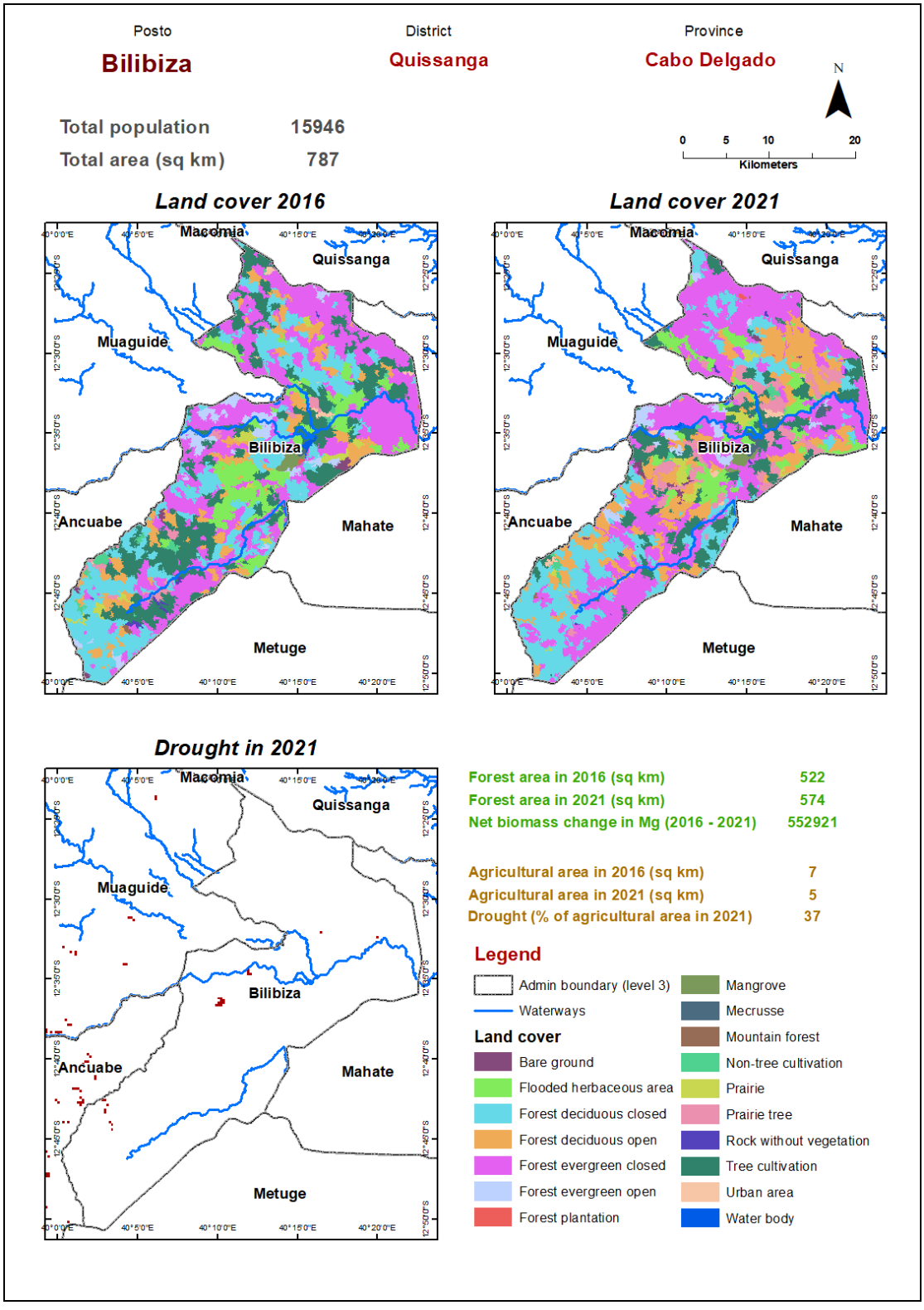

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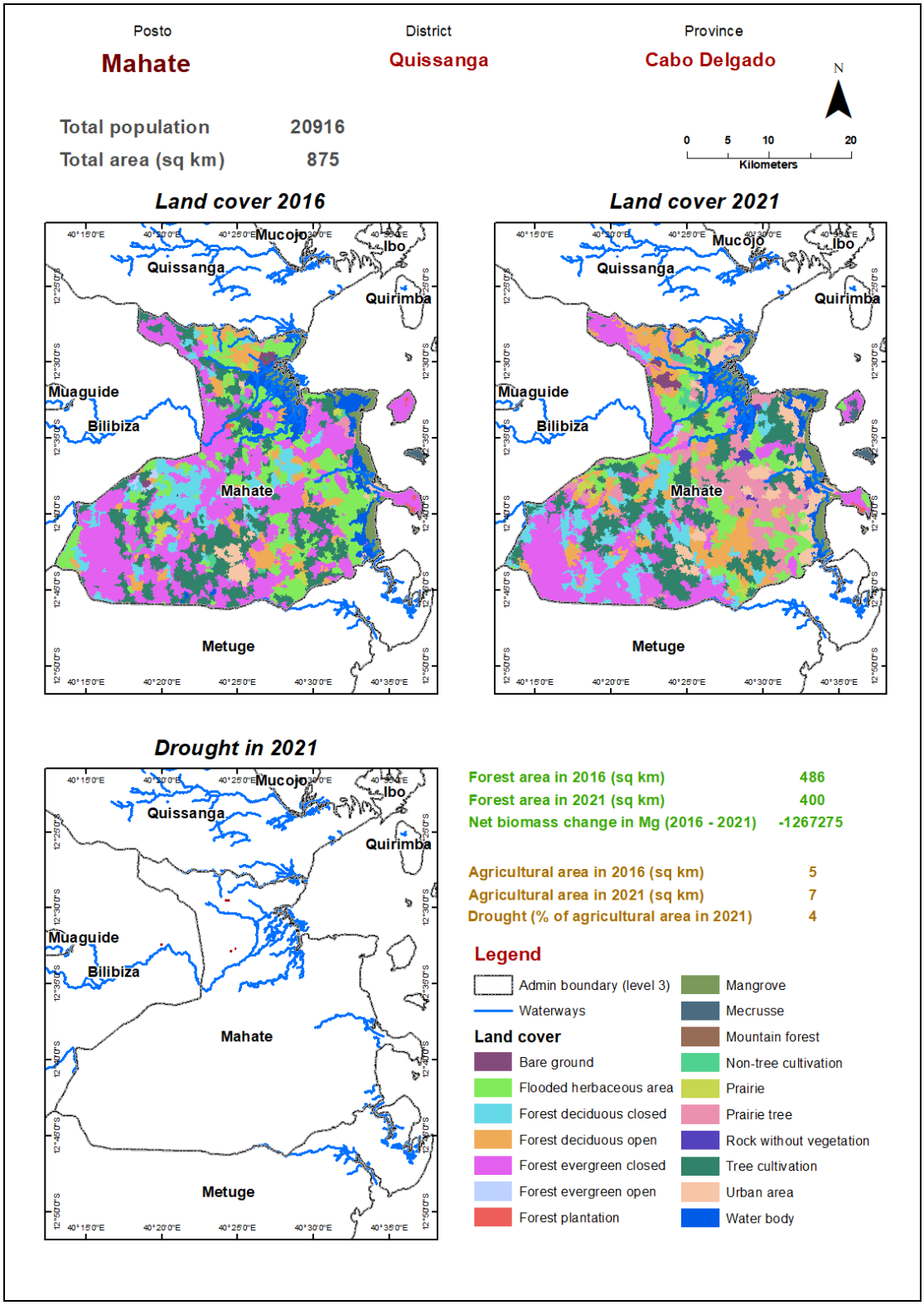

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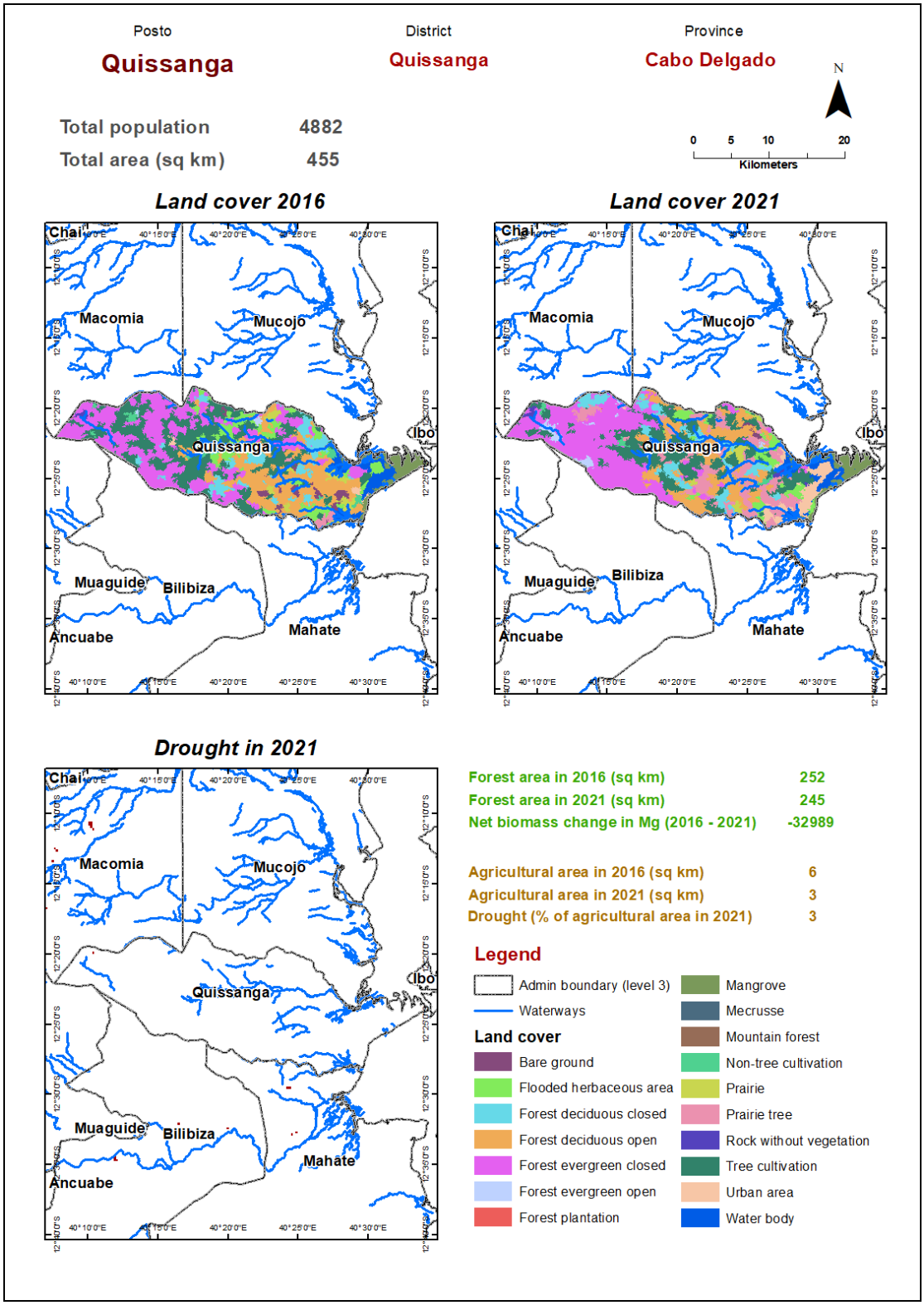

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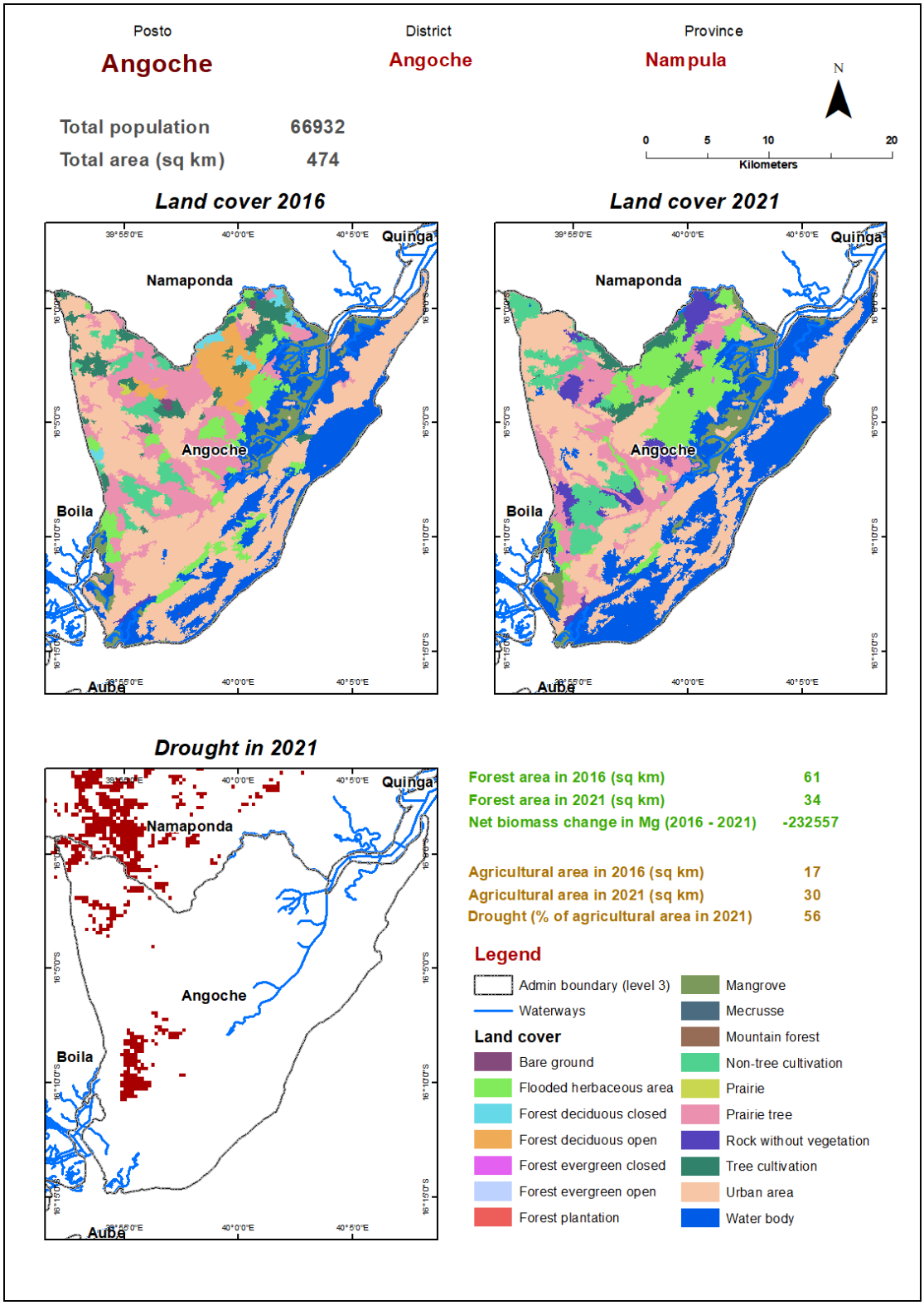

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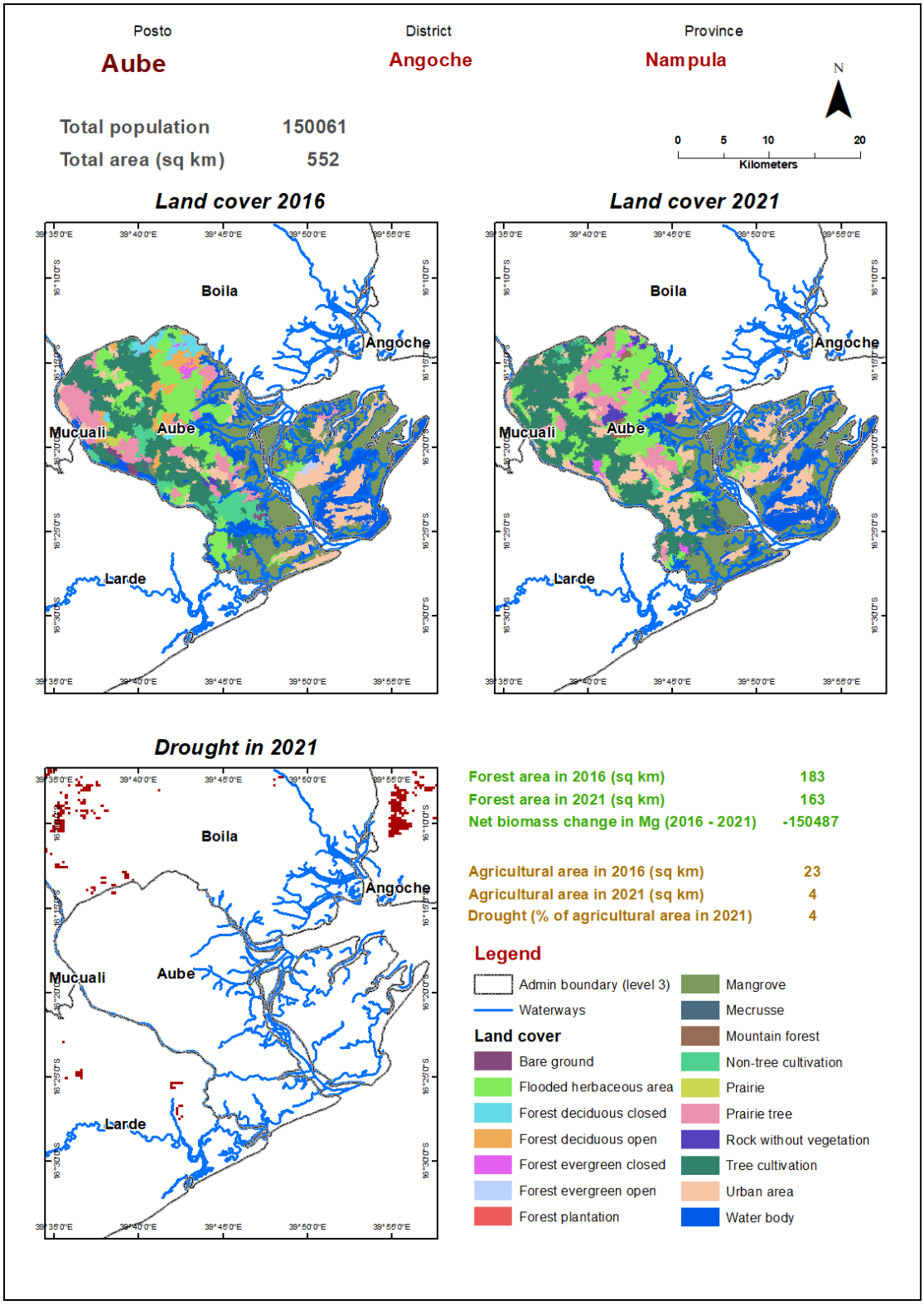

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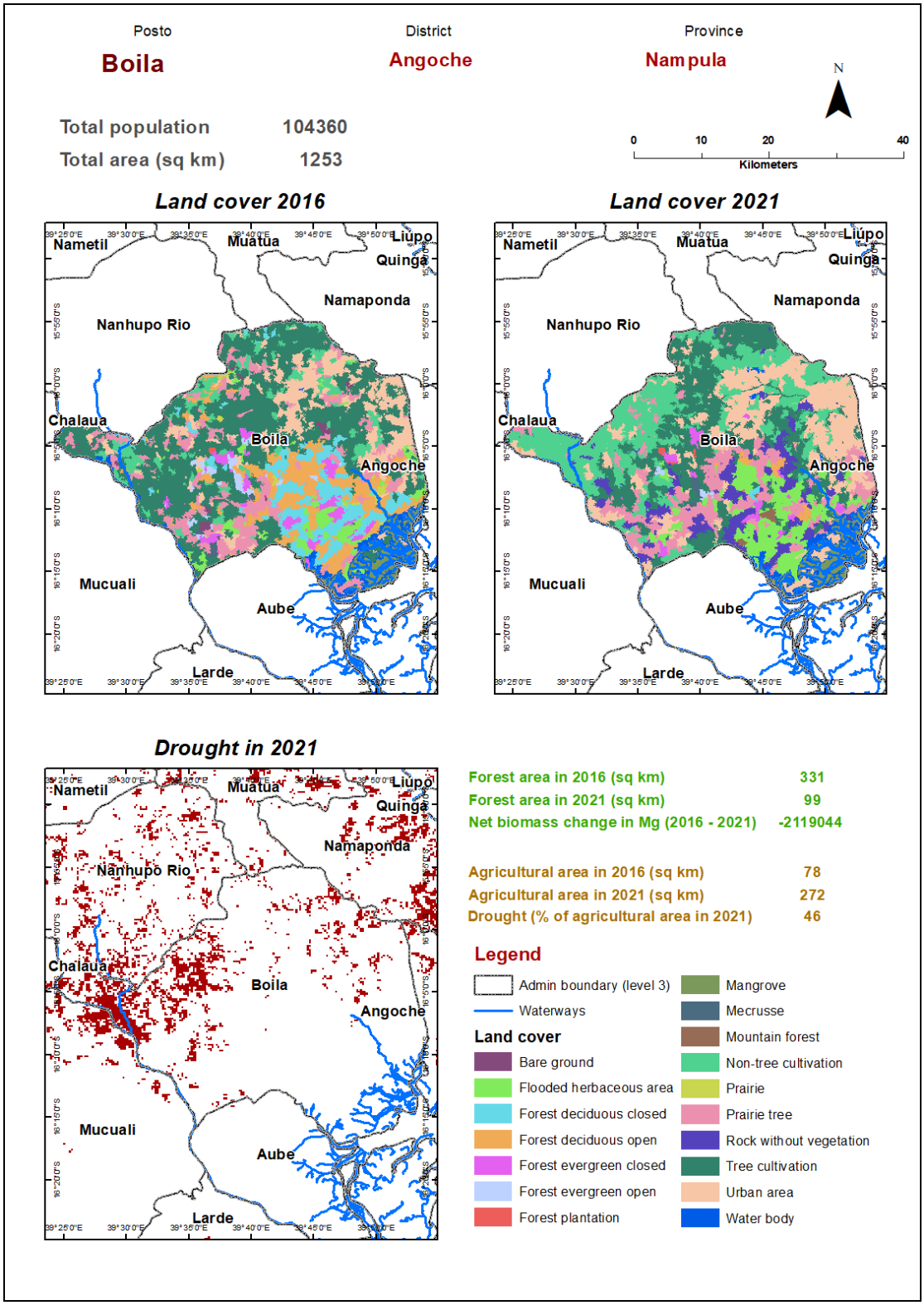

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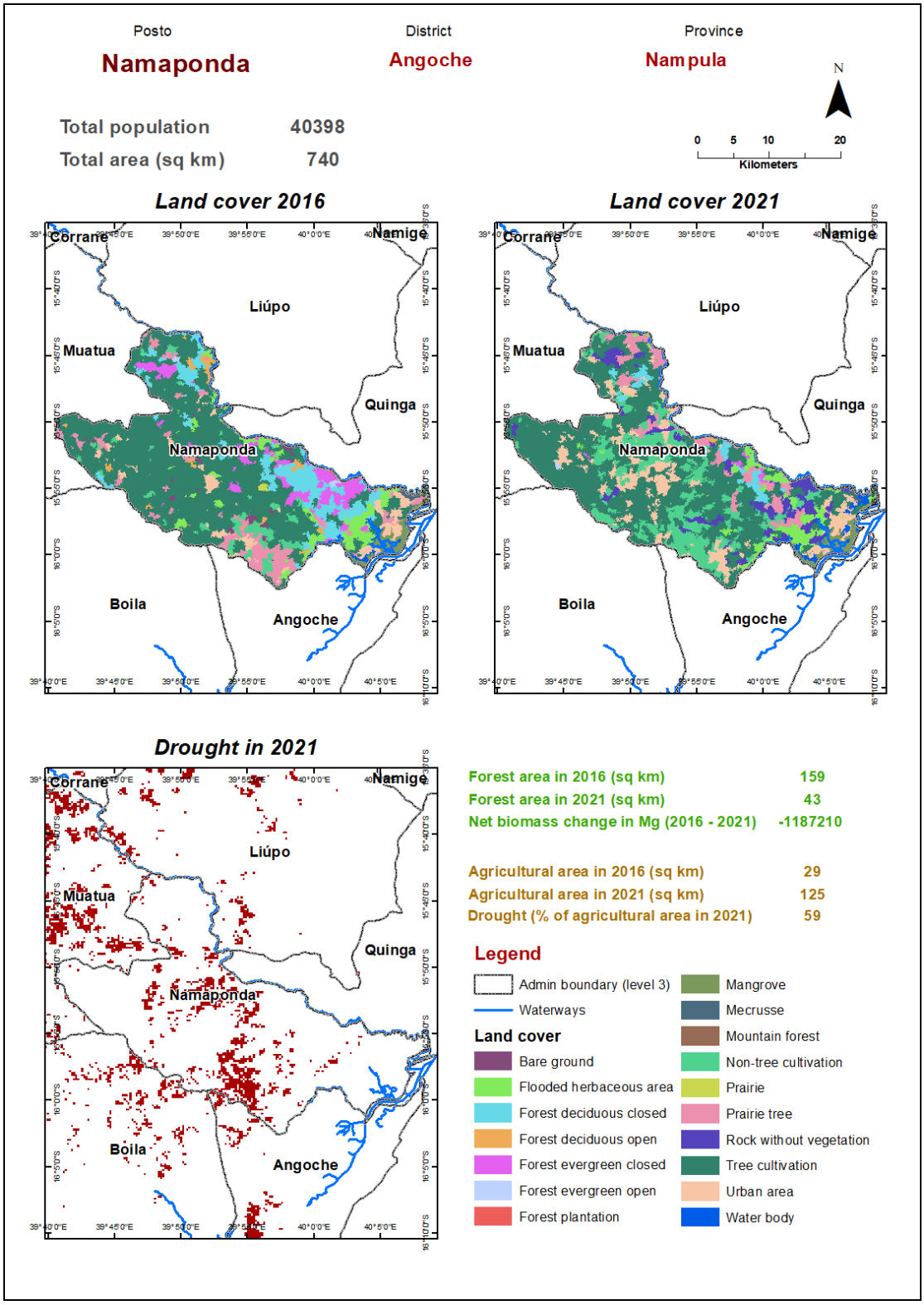

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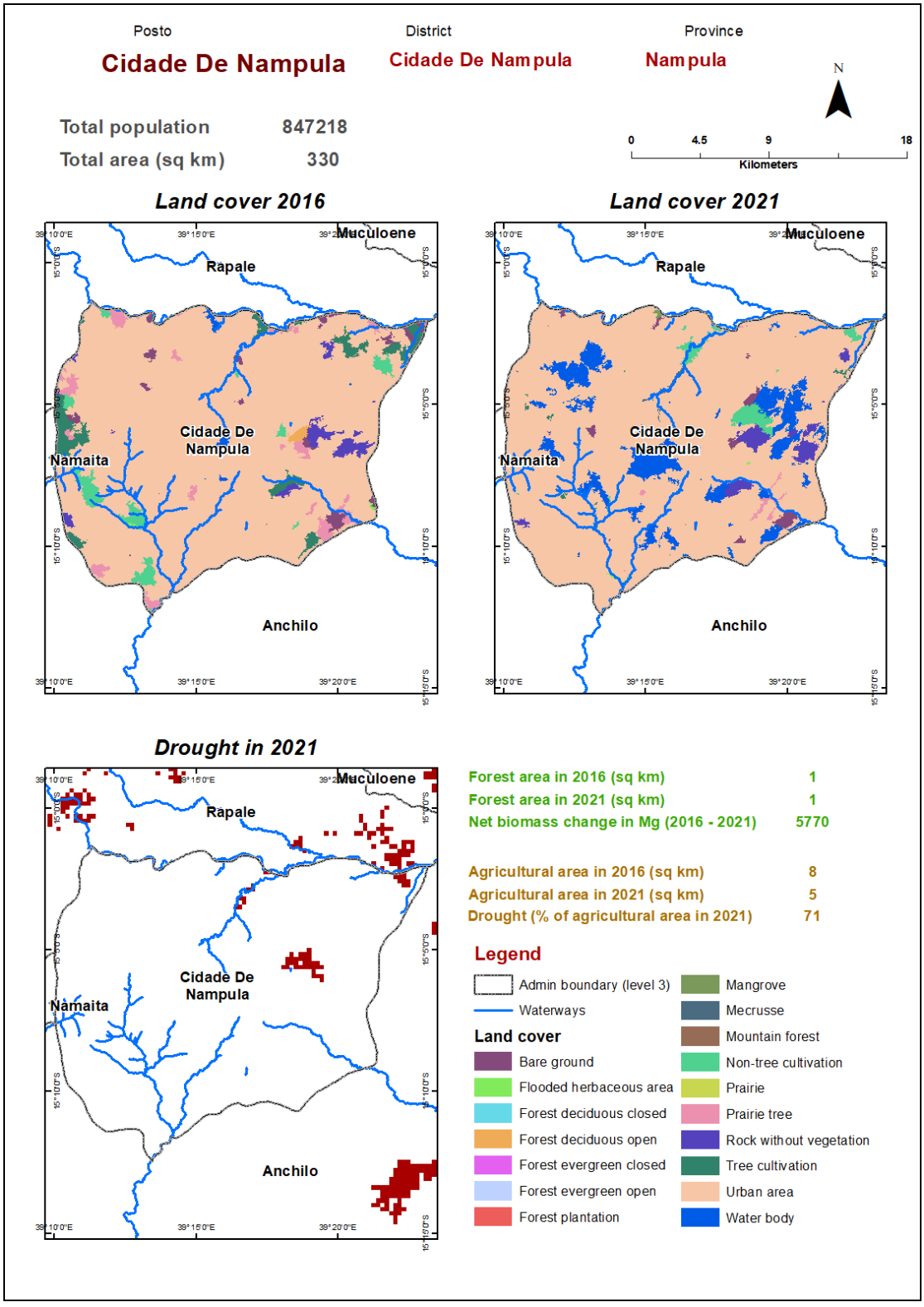

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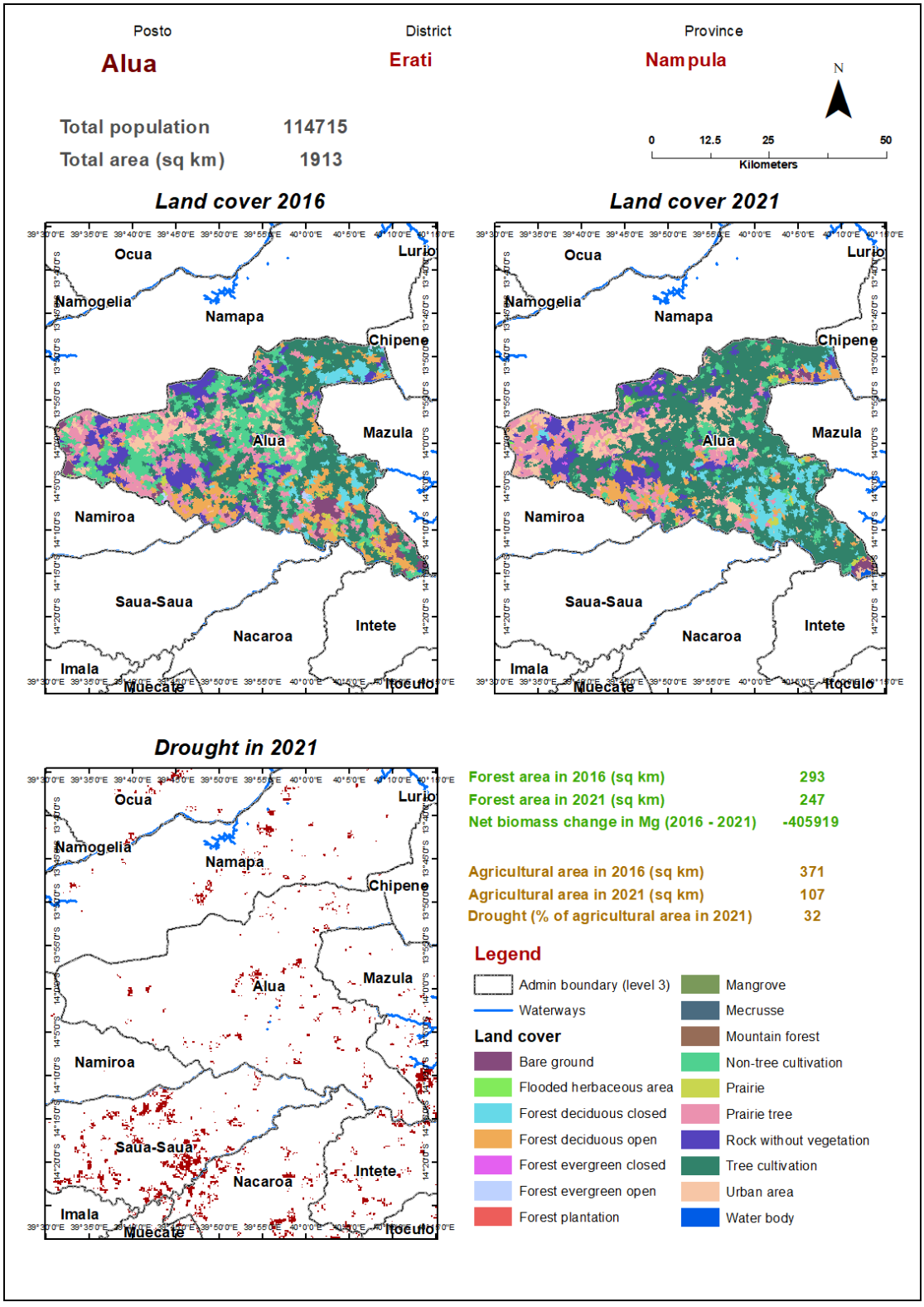

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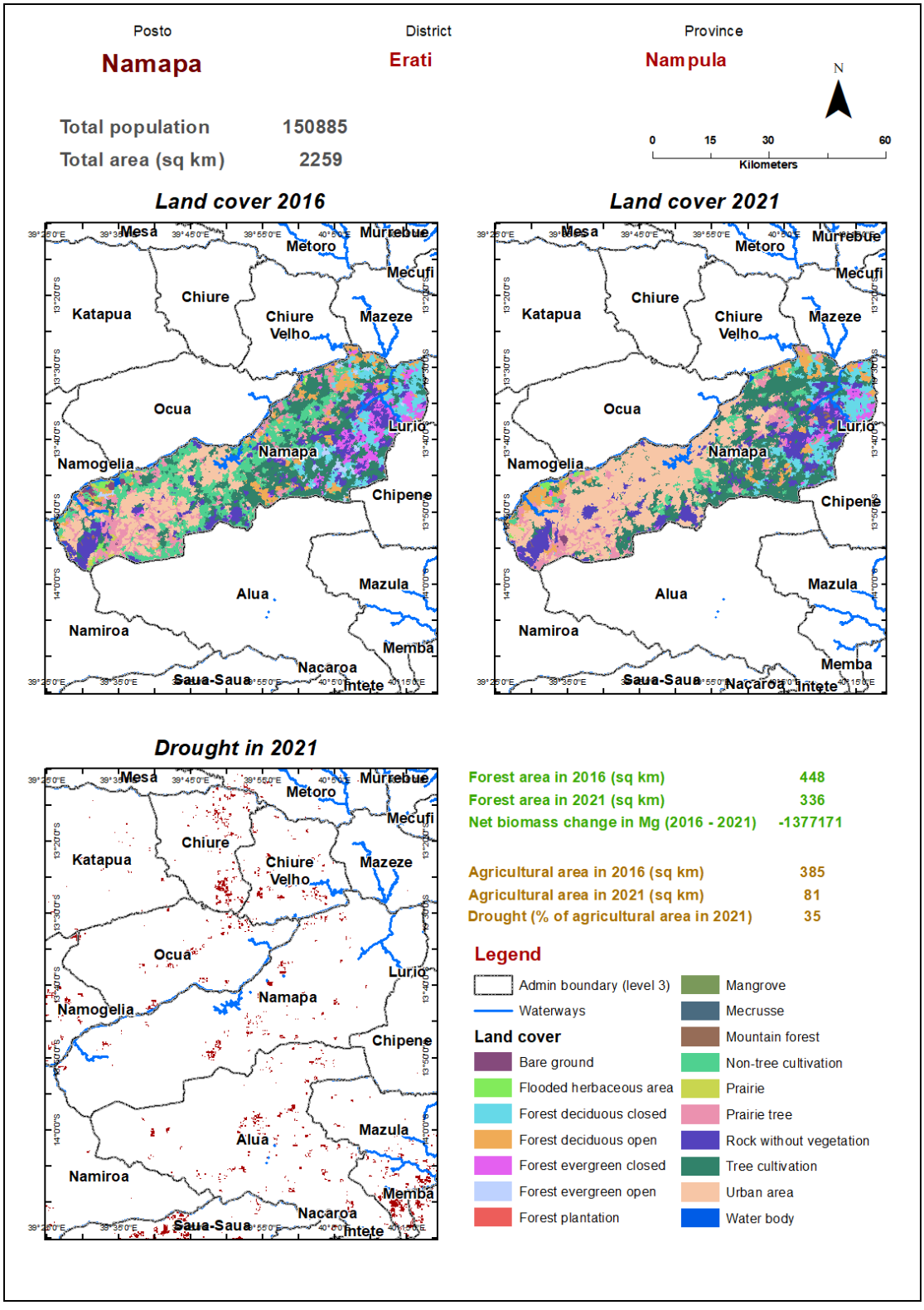

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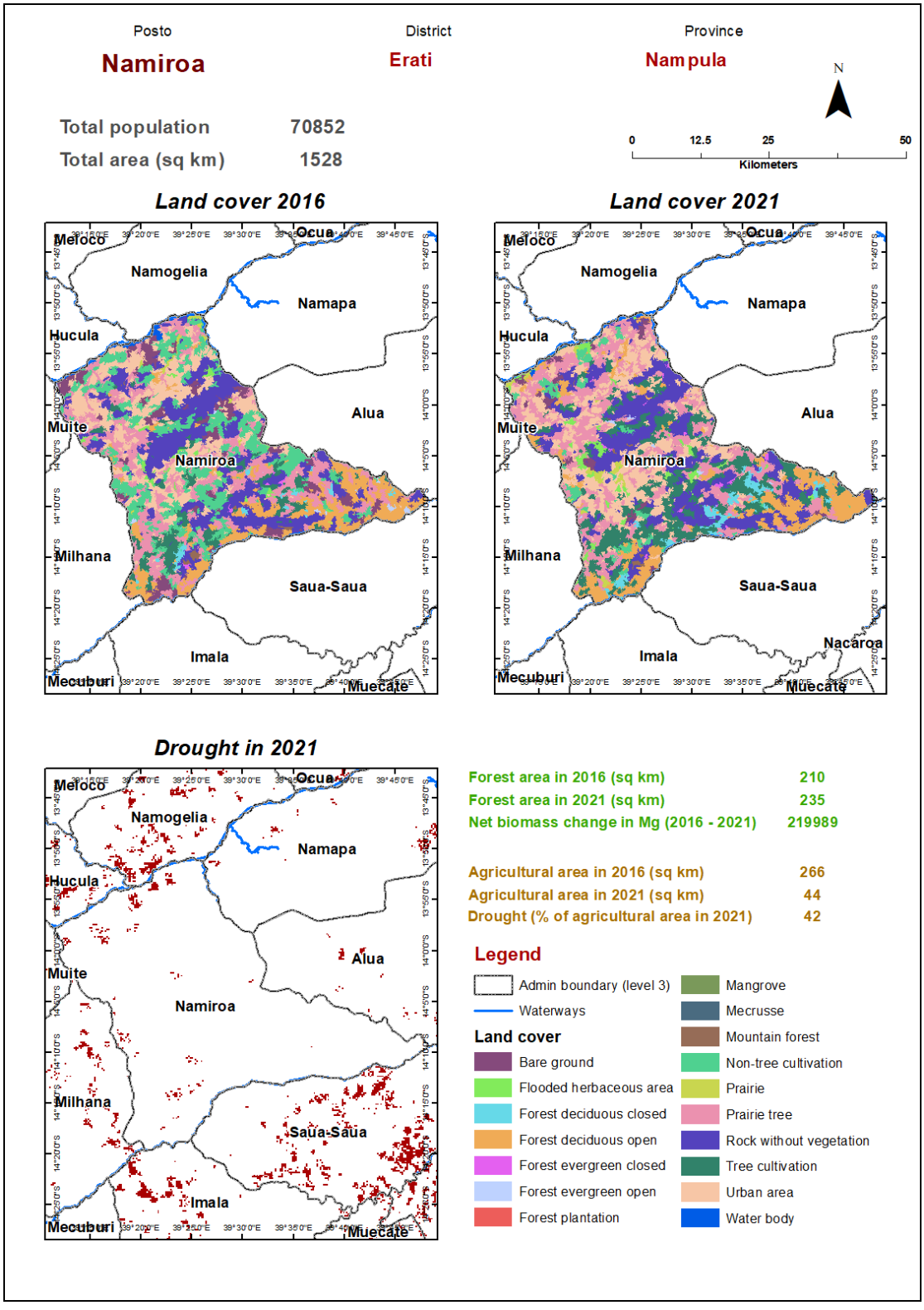

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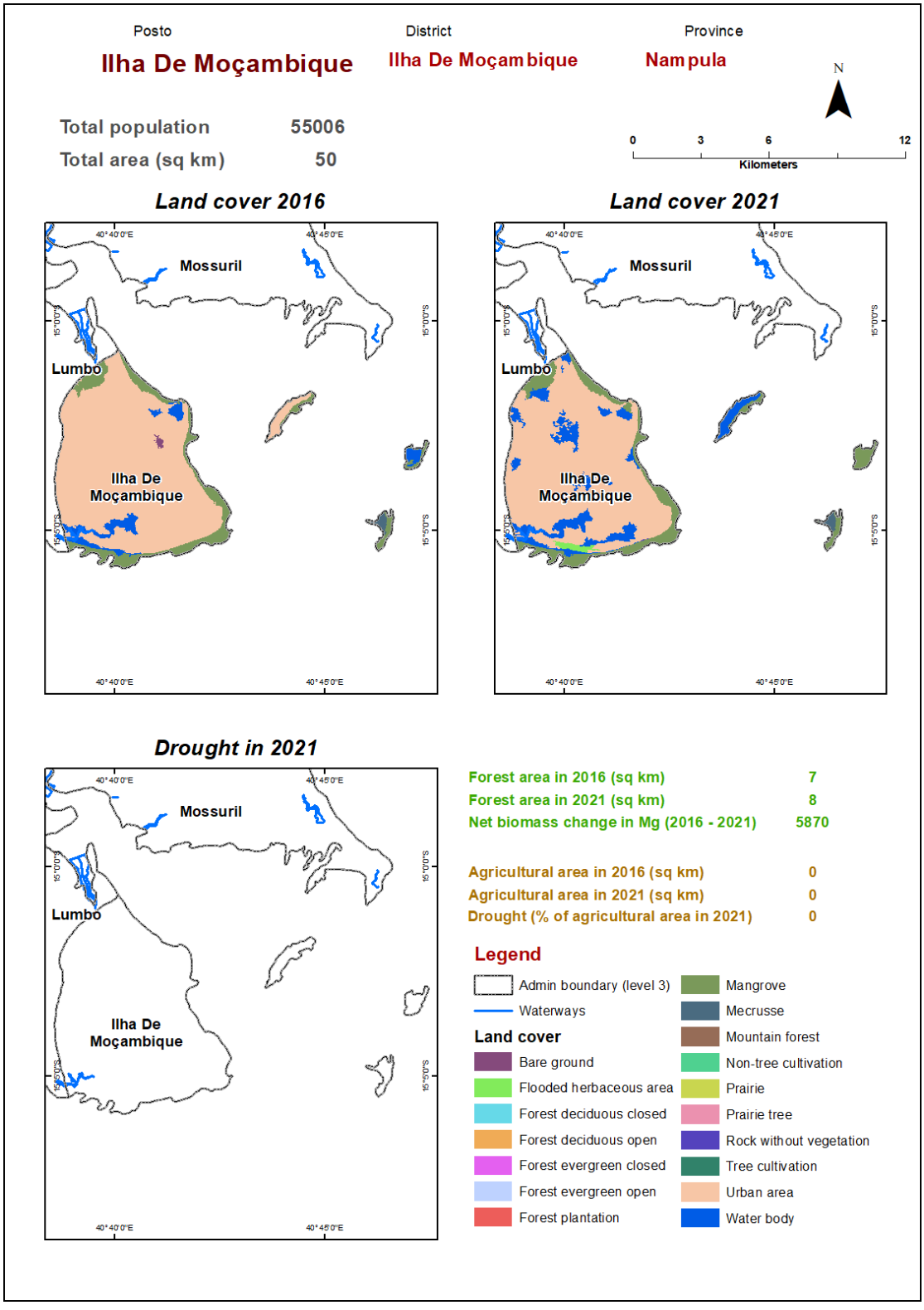
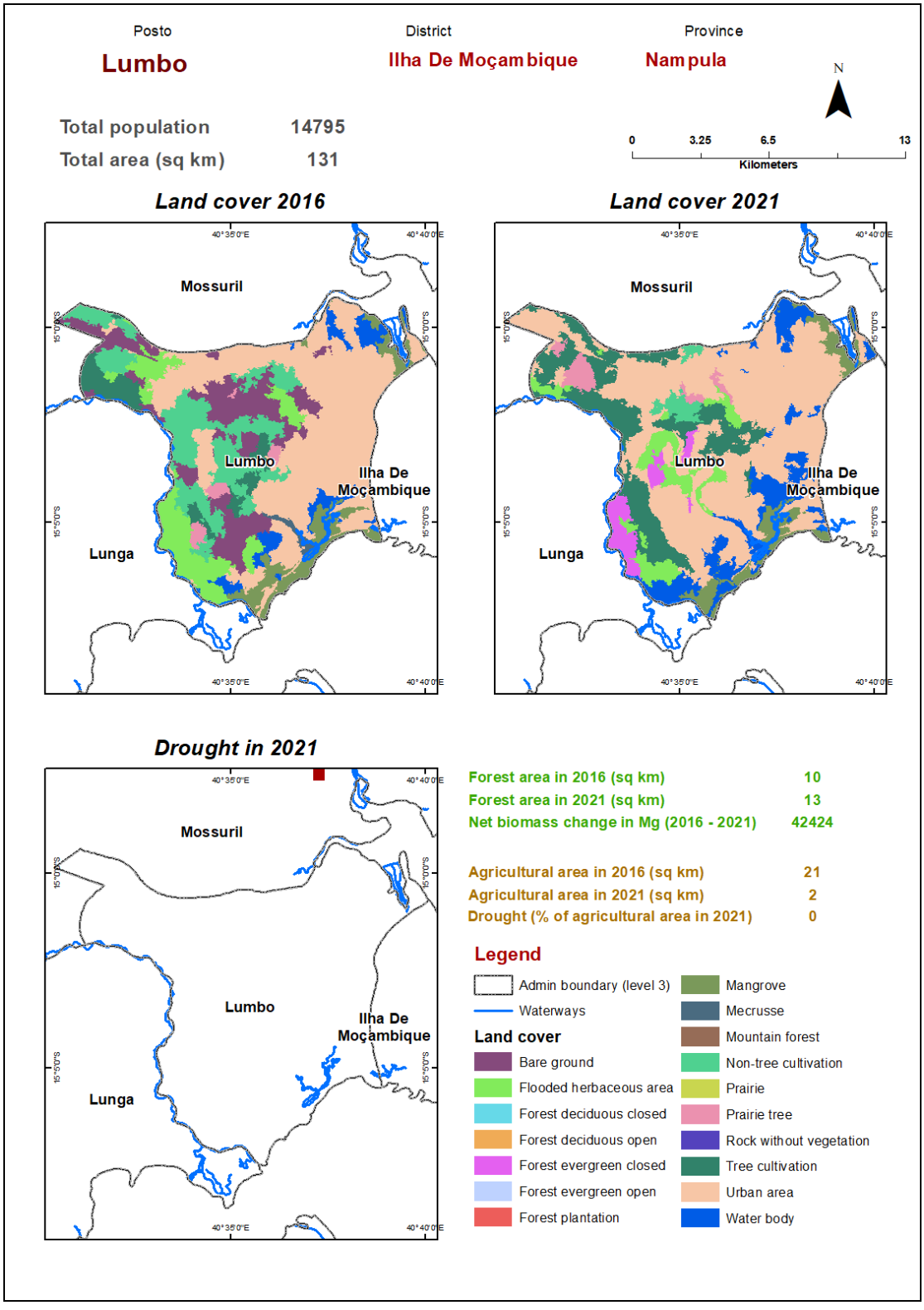


Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021

Posto

Lalaua

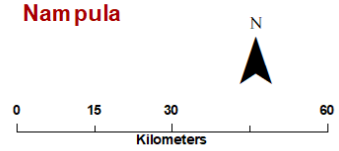
District

Lalaua

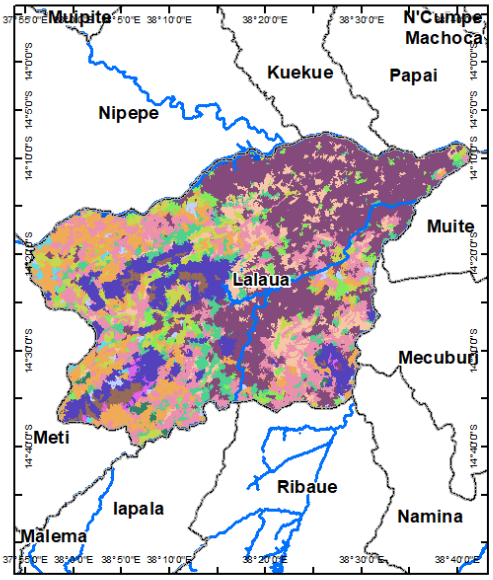
Province

Nampula

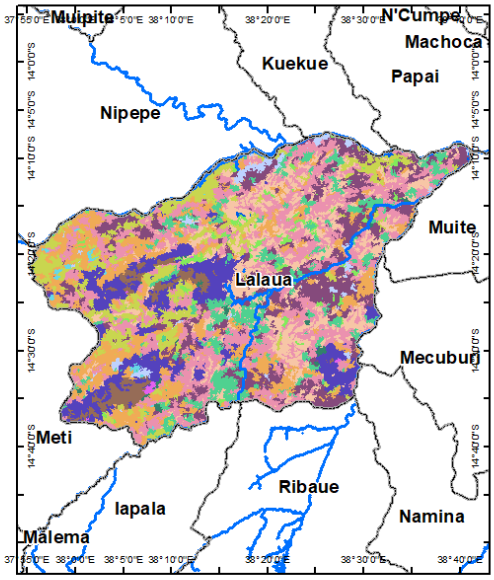
Total population	83816
Total area (sq km)	2871



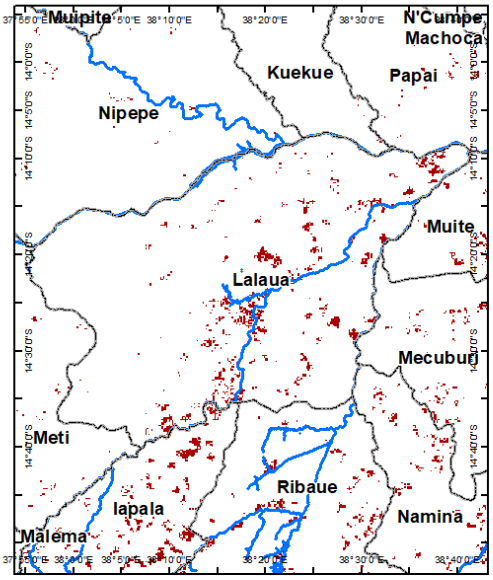
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	446
Forest area in 2021 (sq km)	538
Net biomass change in Mg (2016 - 2021)	943494
Agricultural area in 2016 (sq km)	176
Agricultural area in 2021 (sq km)	247
Drought (% of agricultural area in 2021)	42

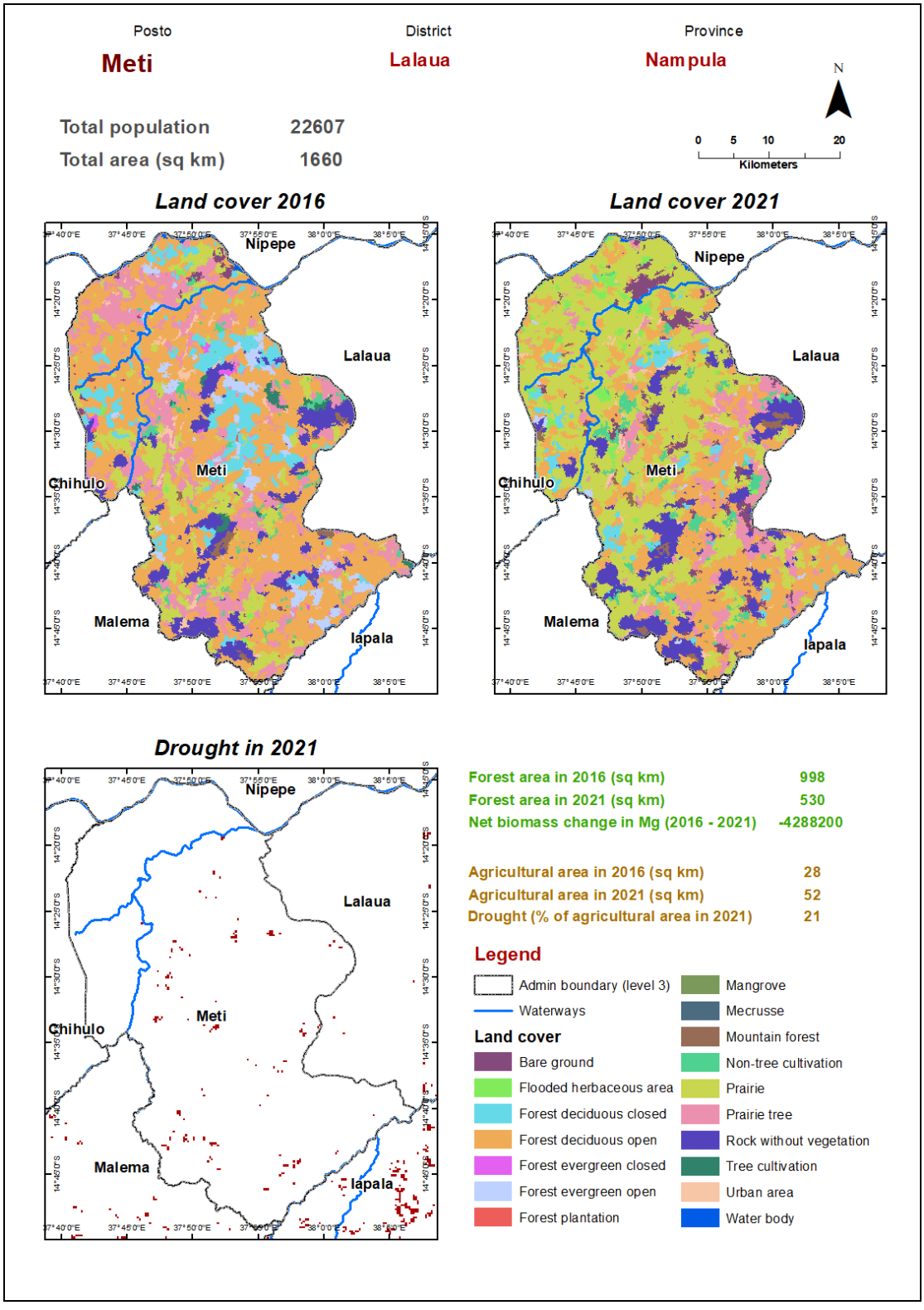
Legend

- Admin boundary (level 3)
- Waterways

Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
- Tree cultivation
- Urban area
- Water body

Sources: Administrative boundary: HDX 2021. Mozambique - Subnational Administrative Boundaries. The Humanitarian Data Exchange. https://data.humdata.org/dataset/cod-ab-moz. Accessed on 20 October 2021



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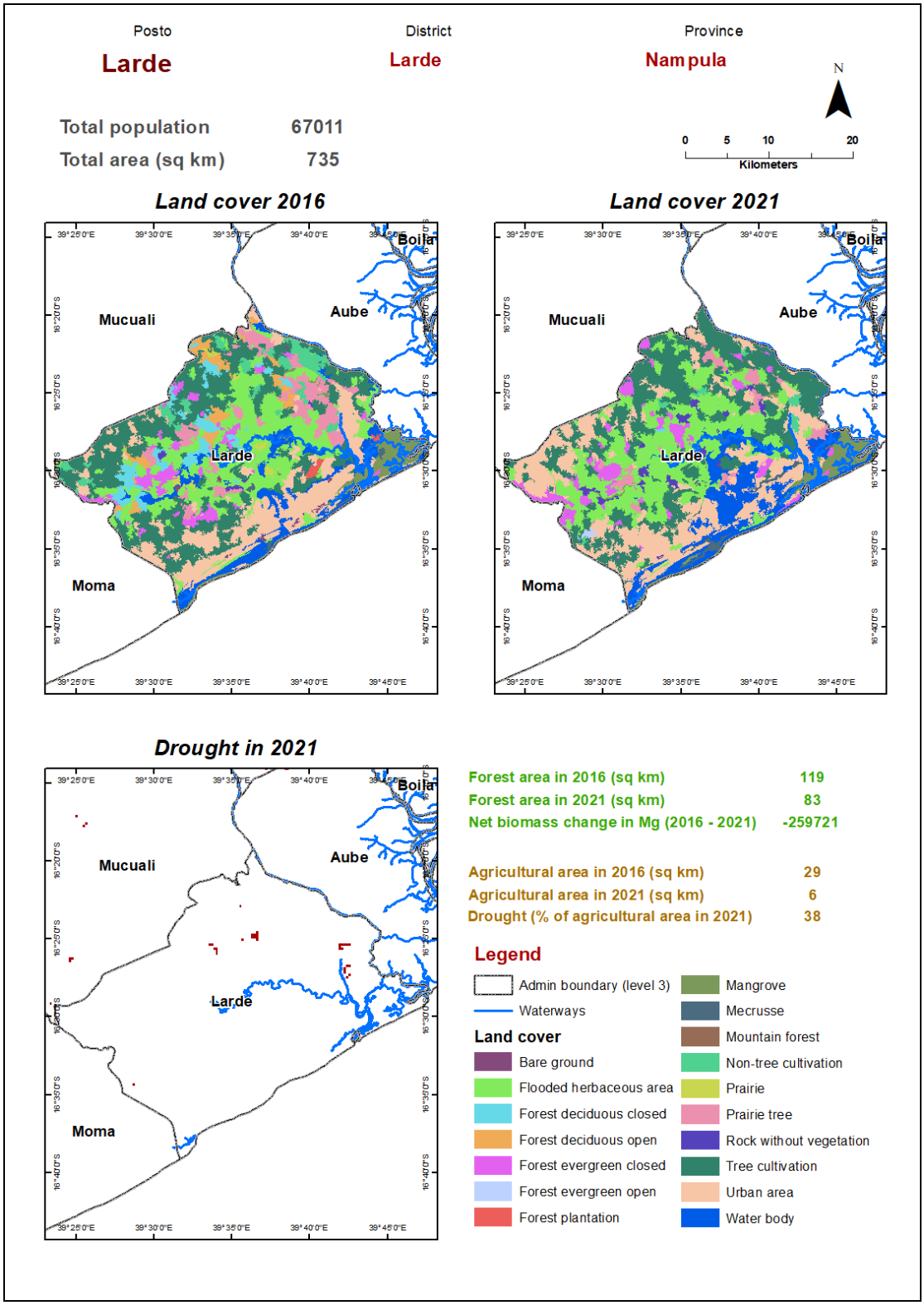

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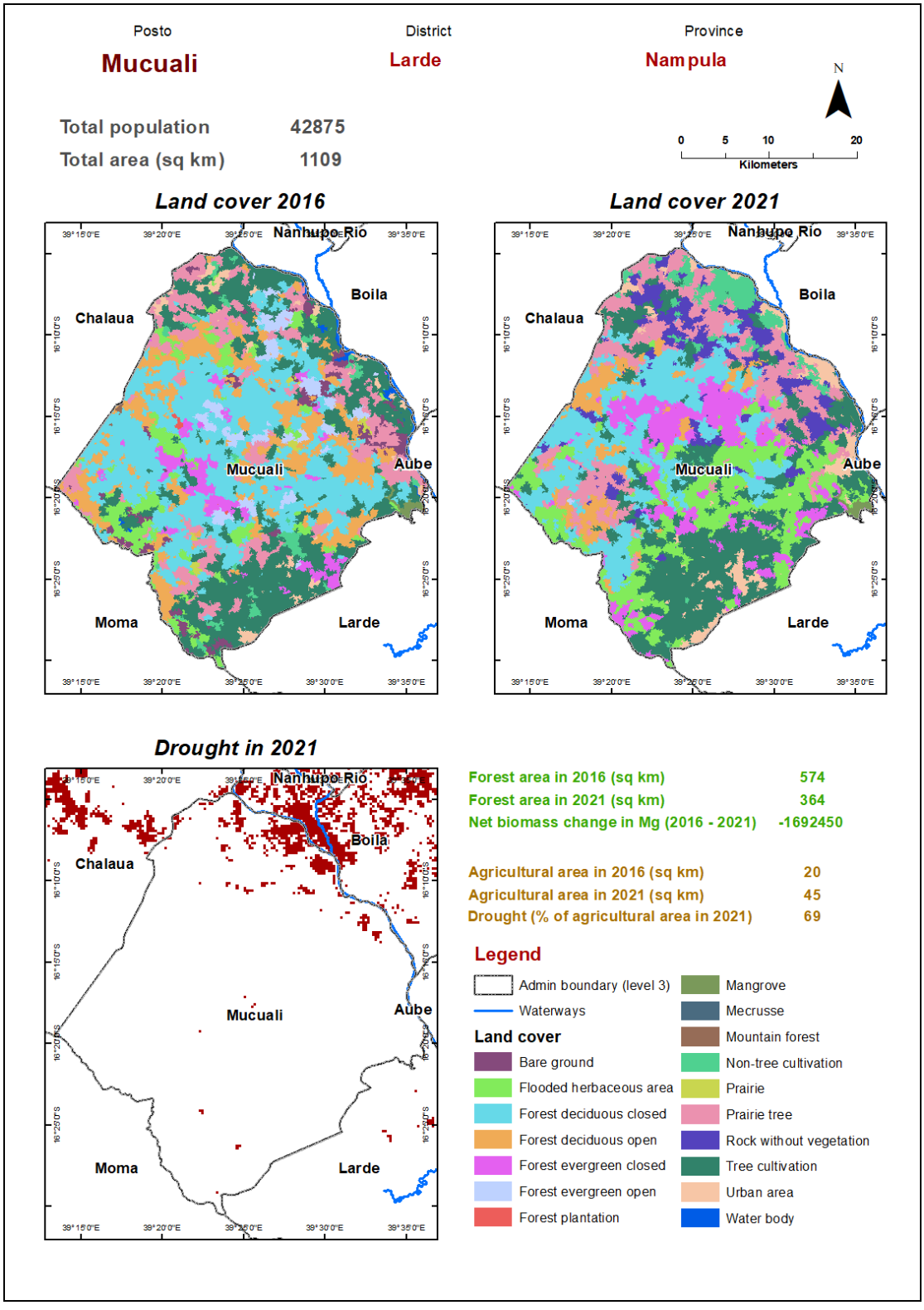

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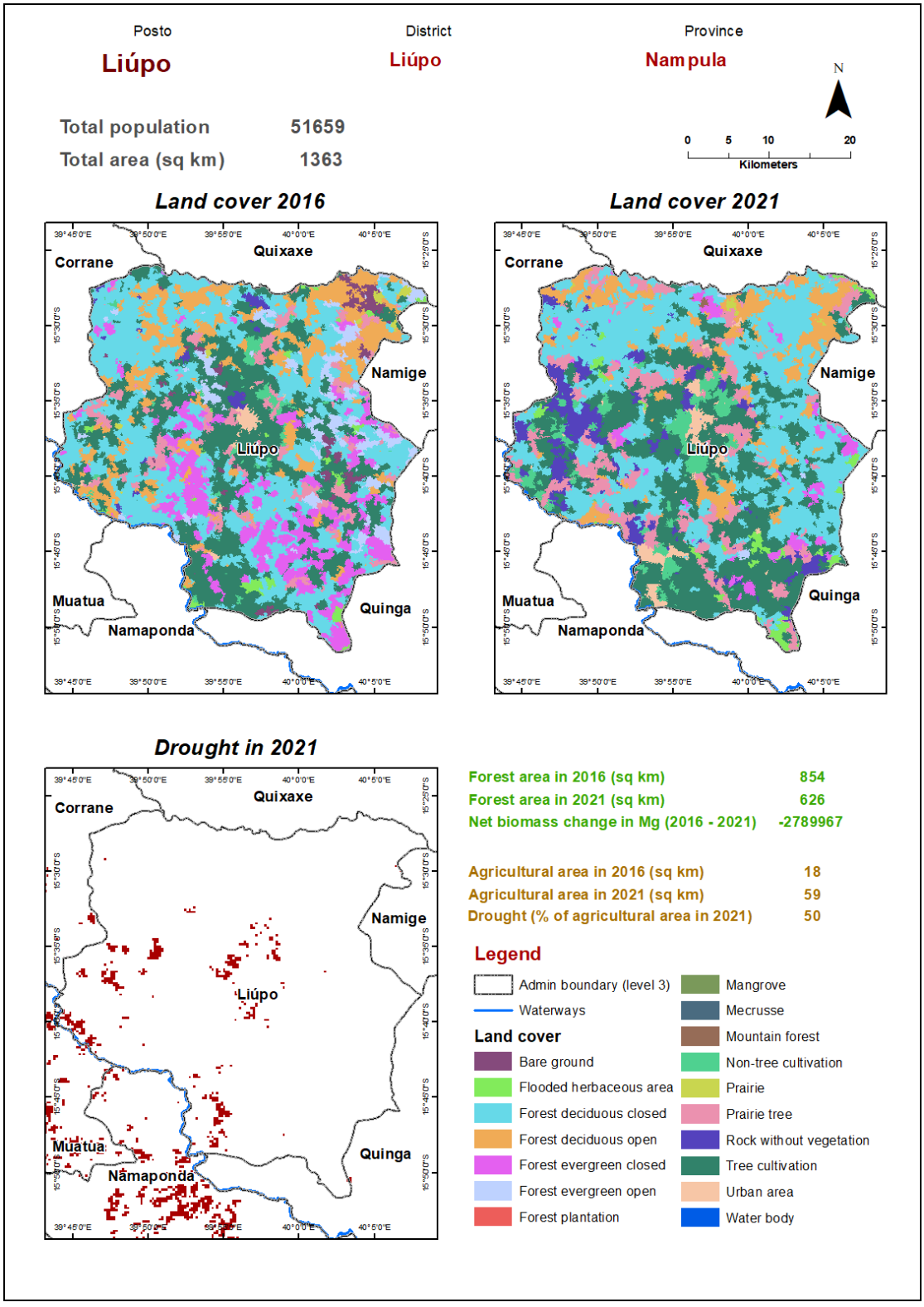

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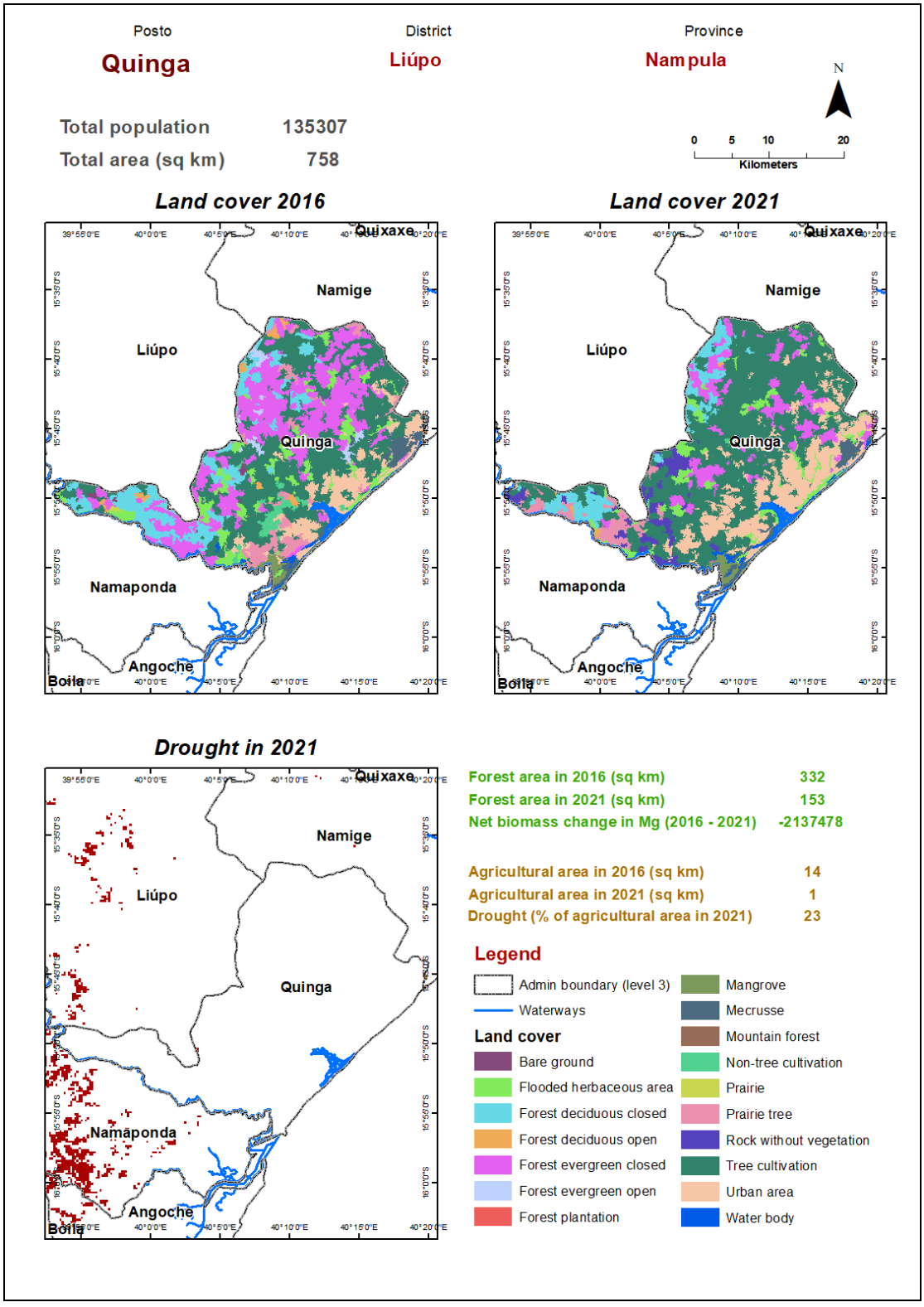

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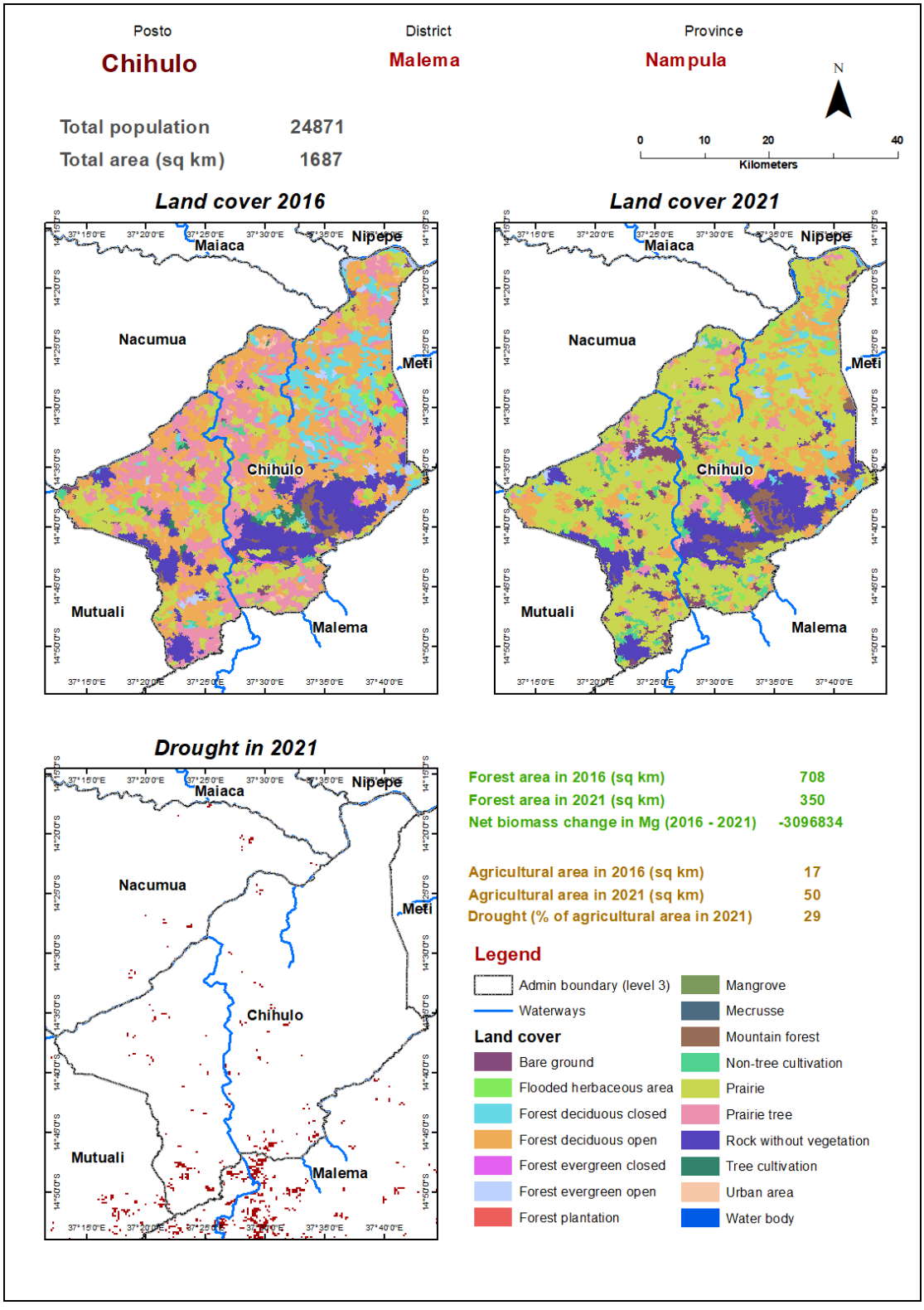

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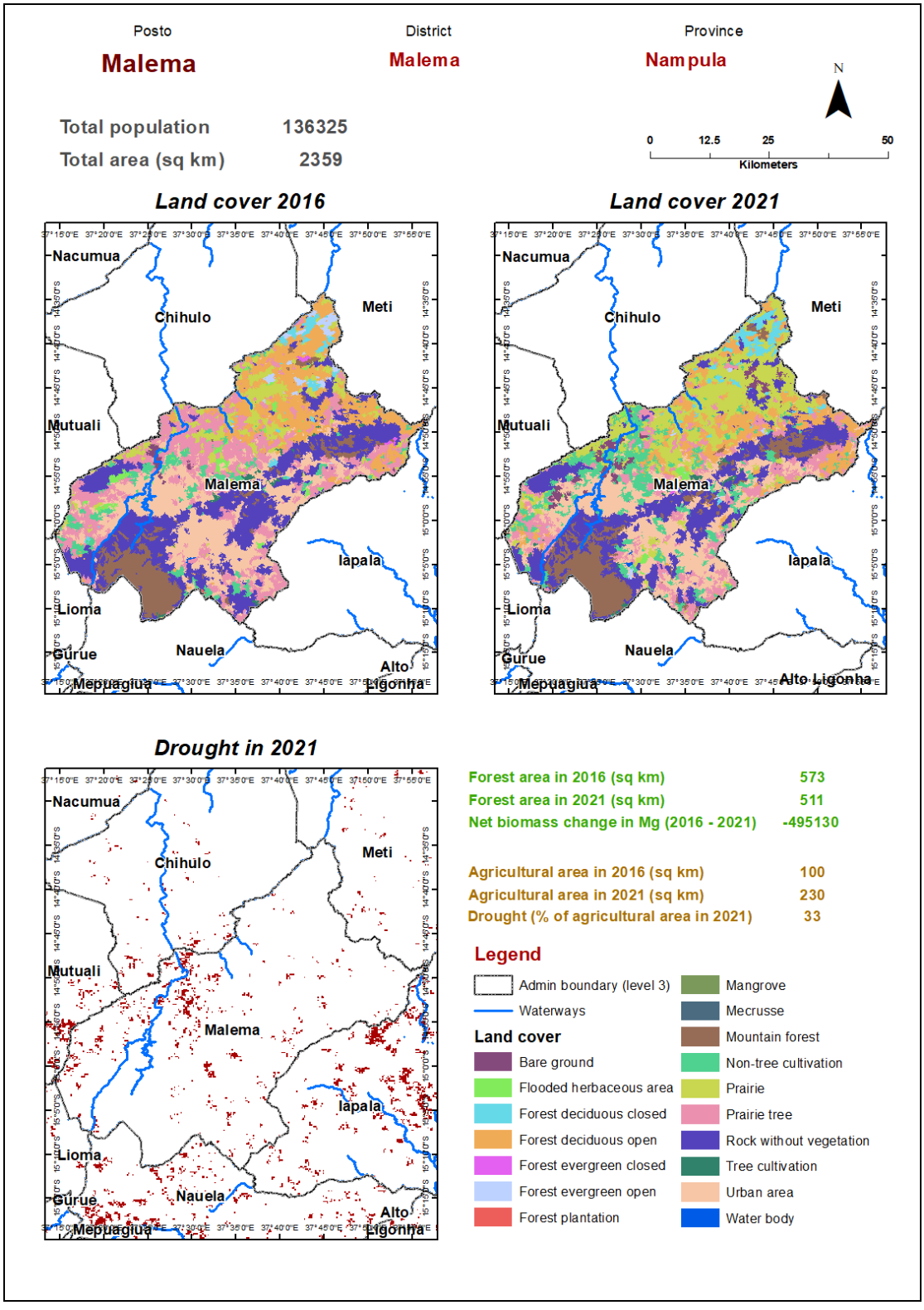

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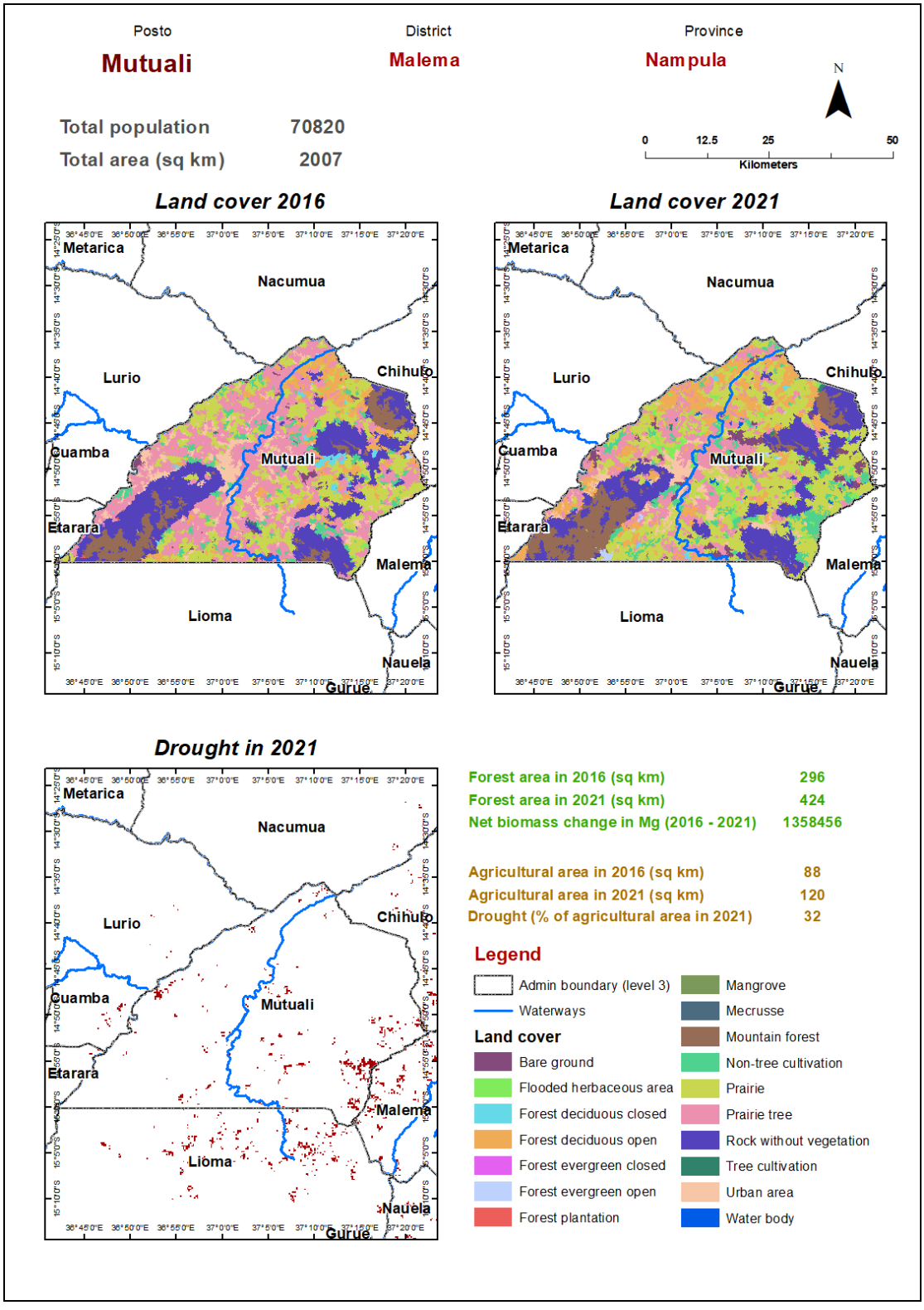

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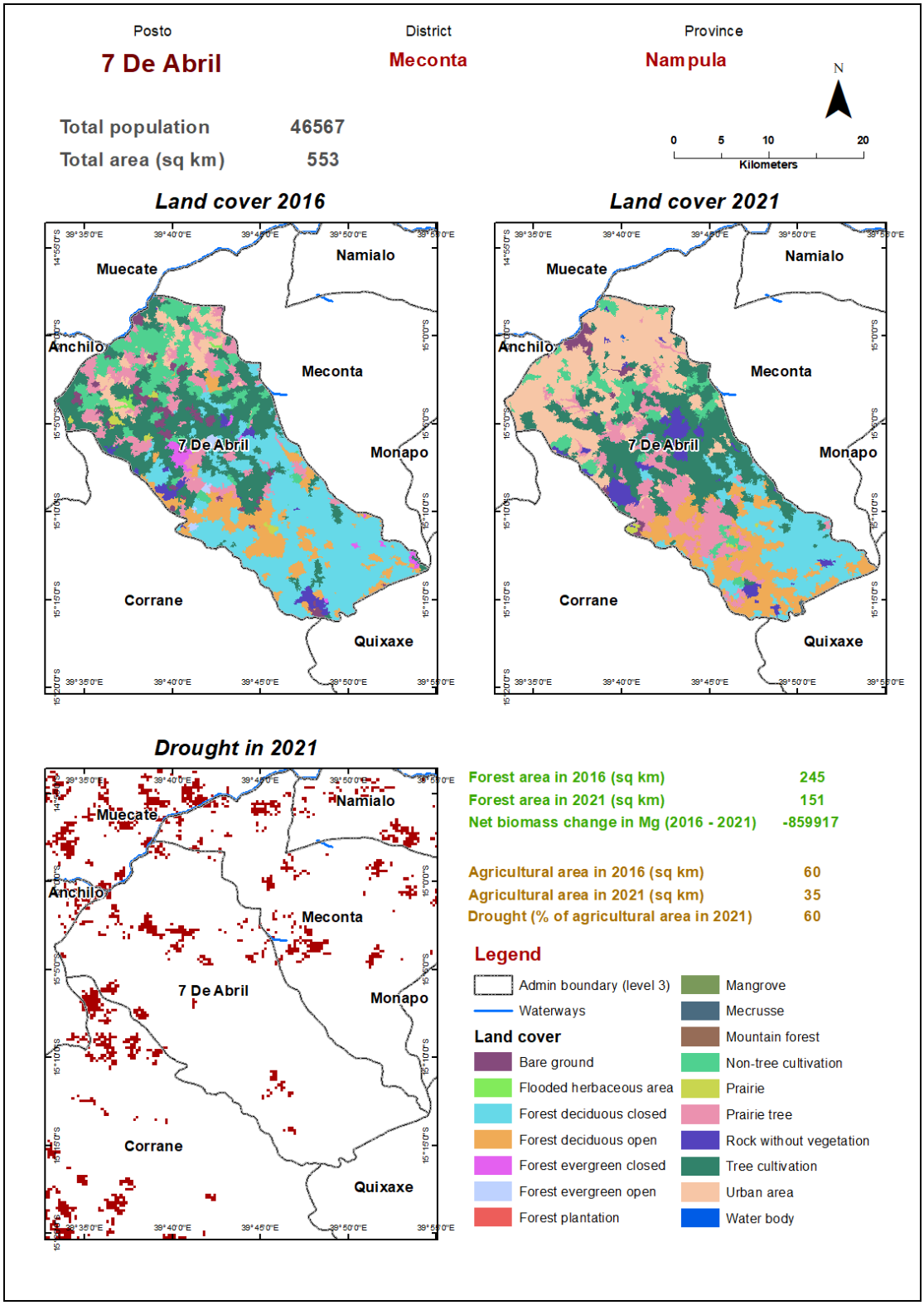

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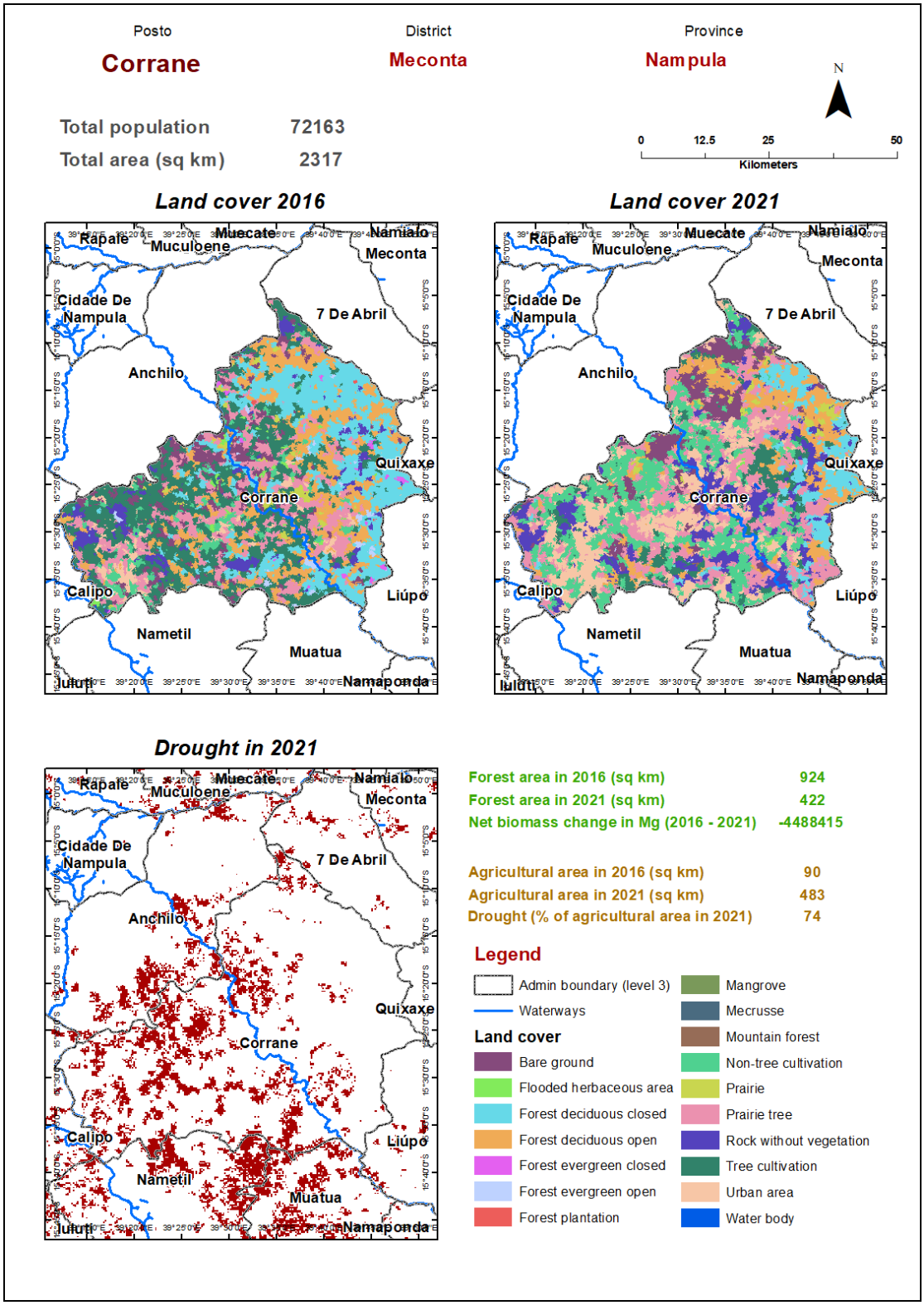

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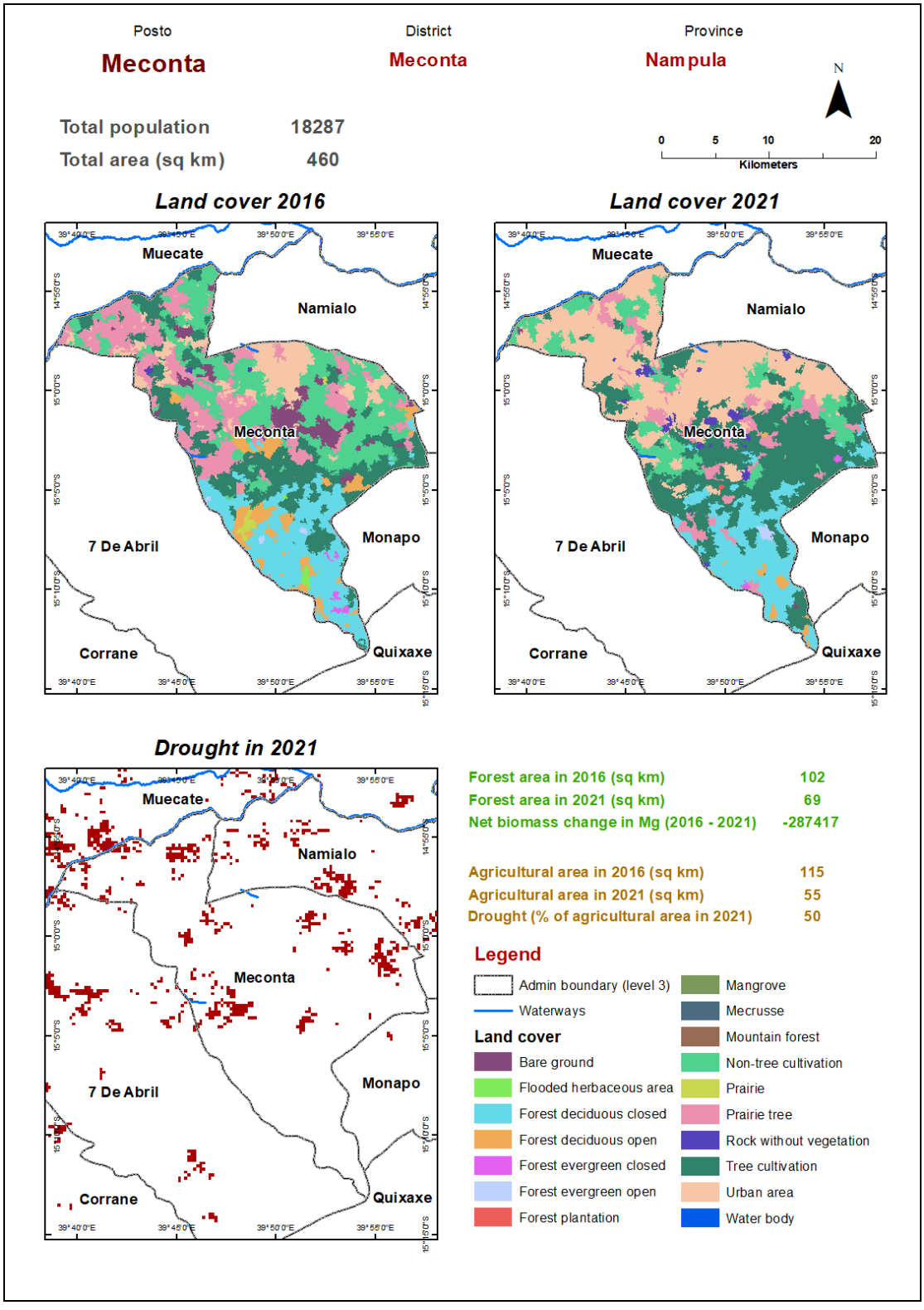

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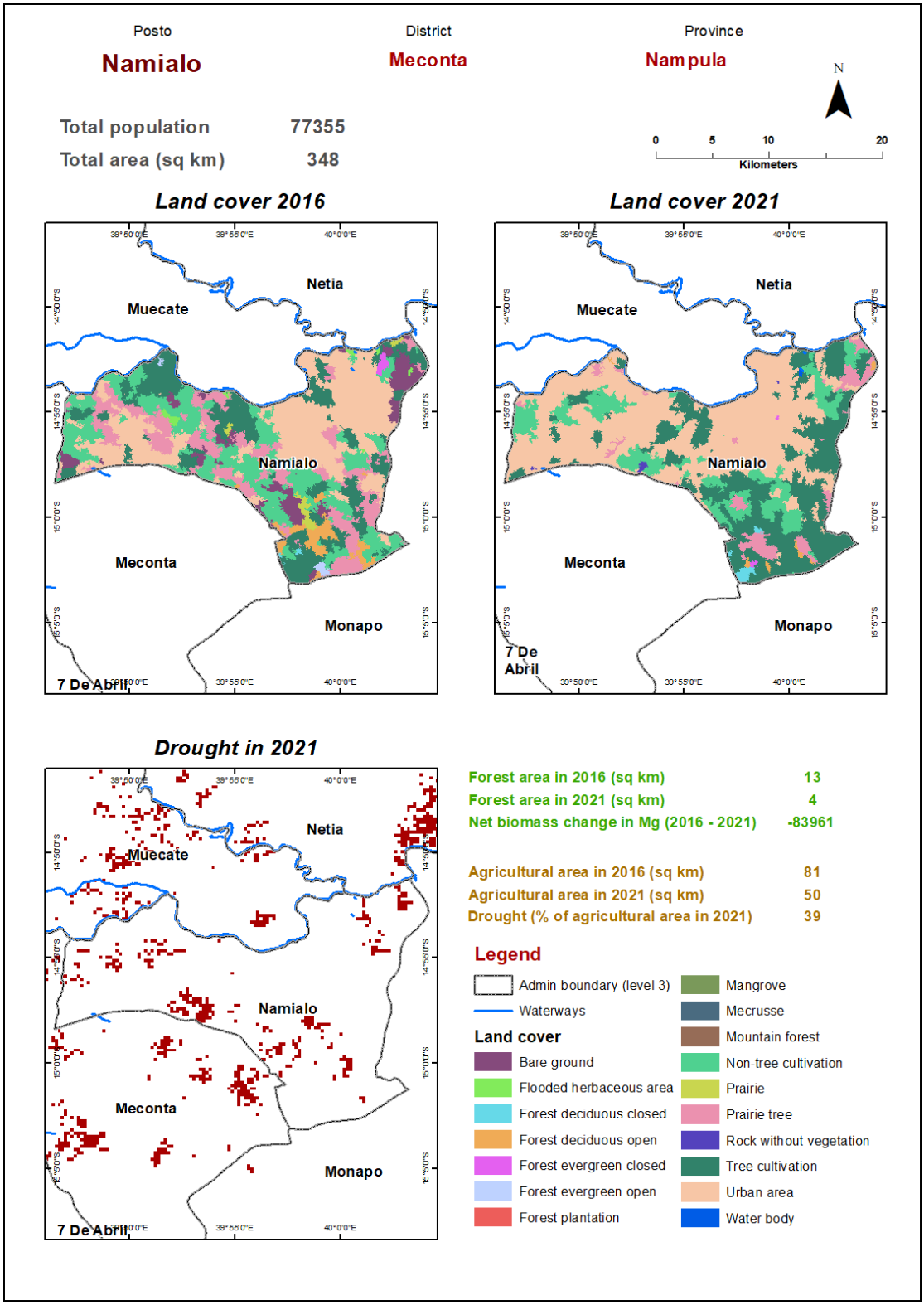

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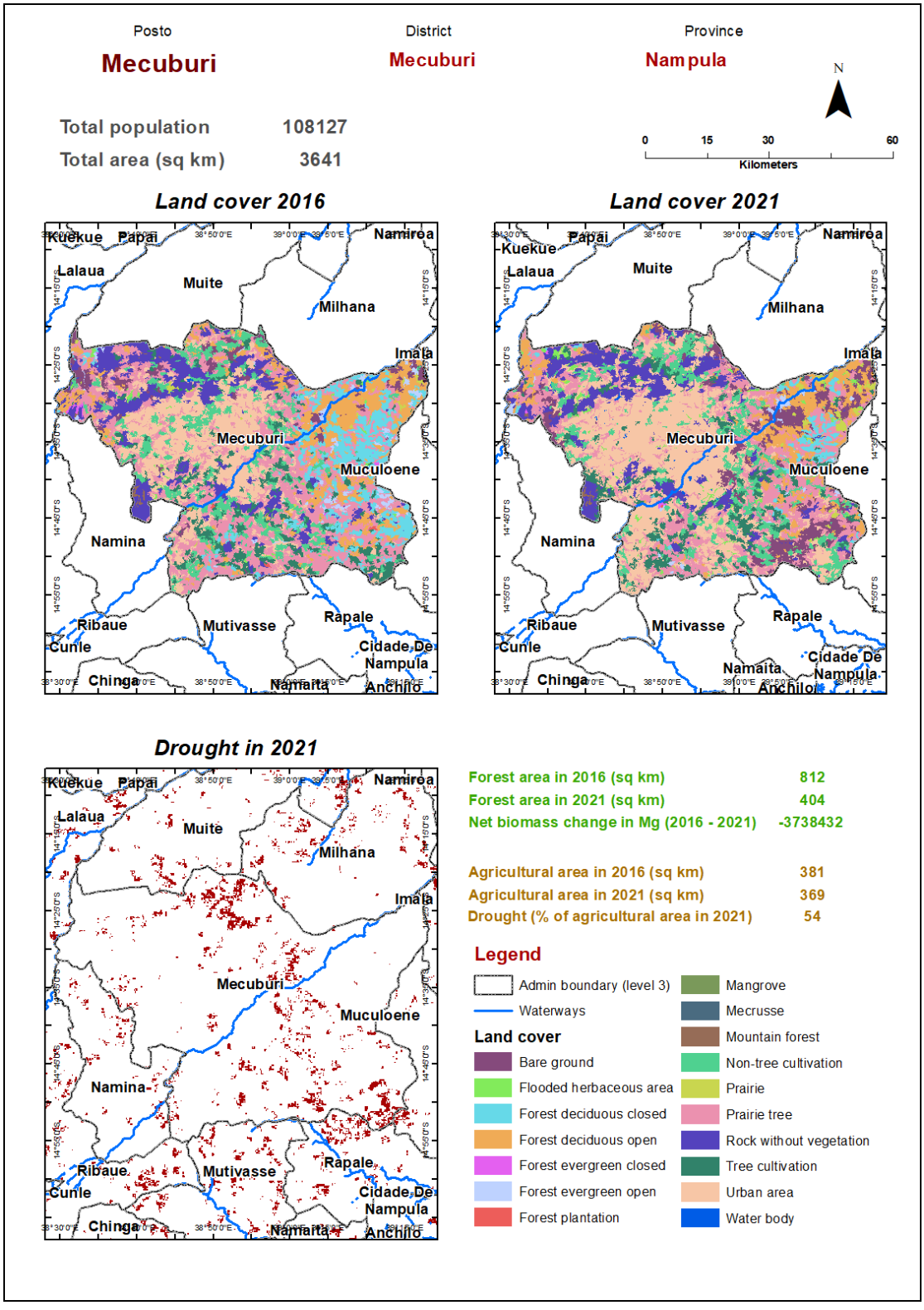

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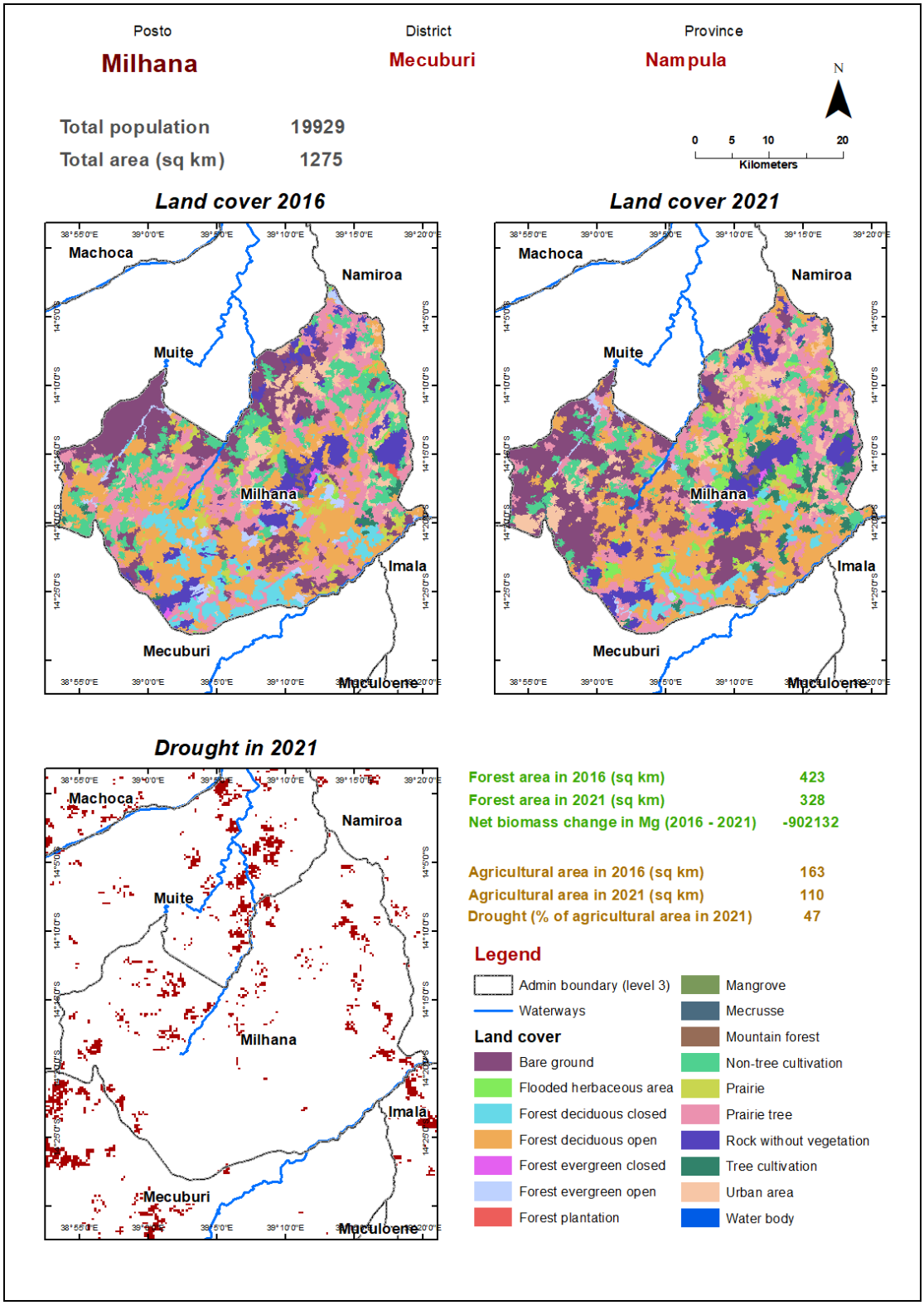

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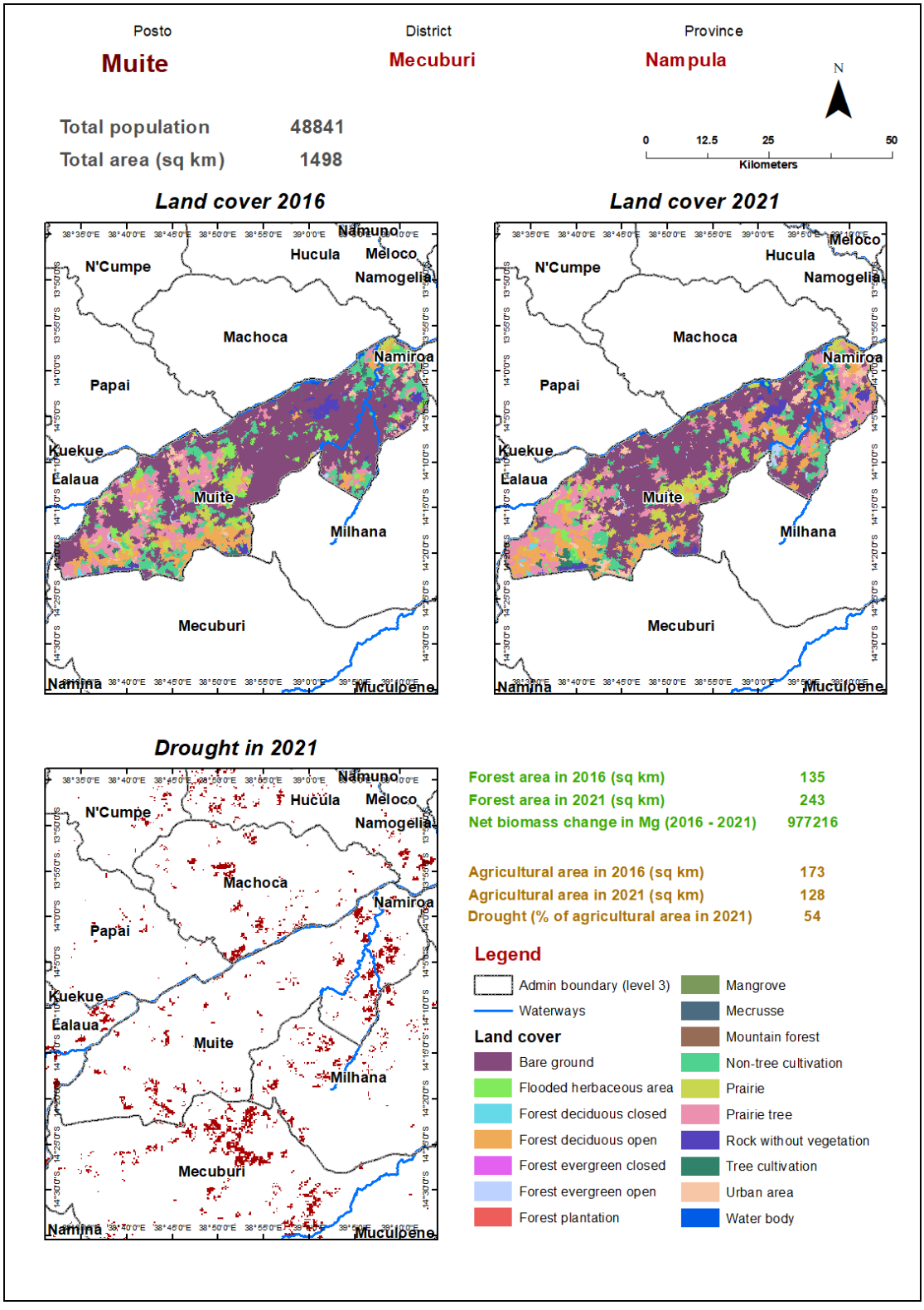

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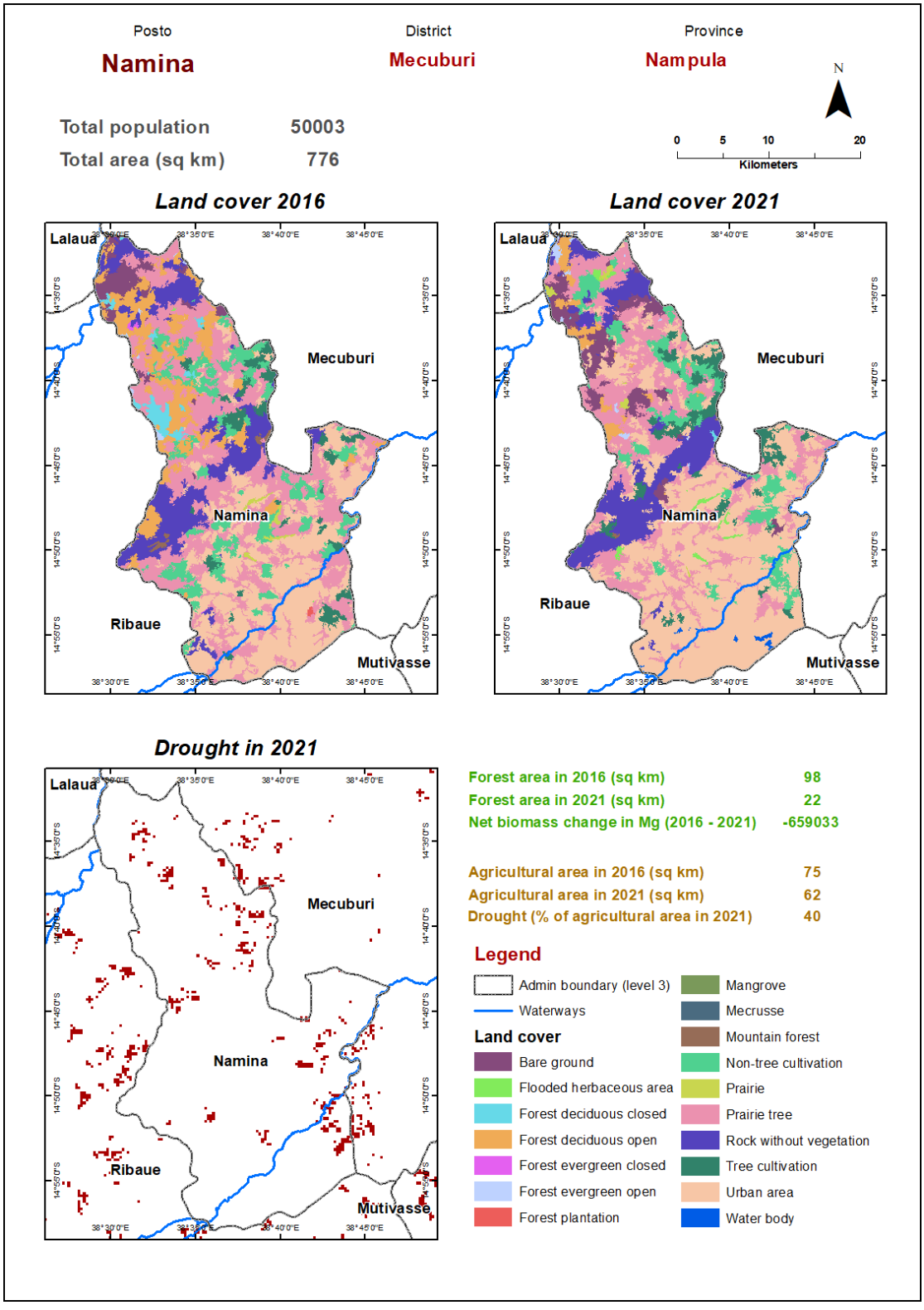

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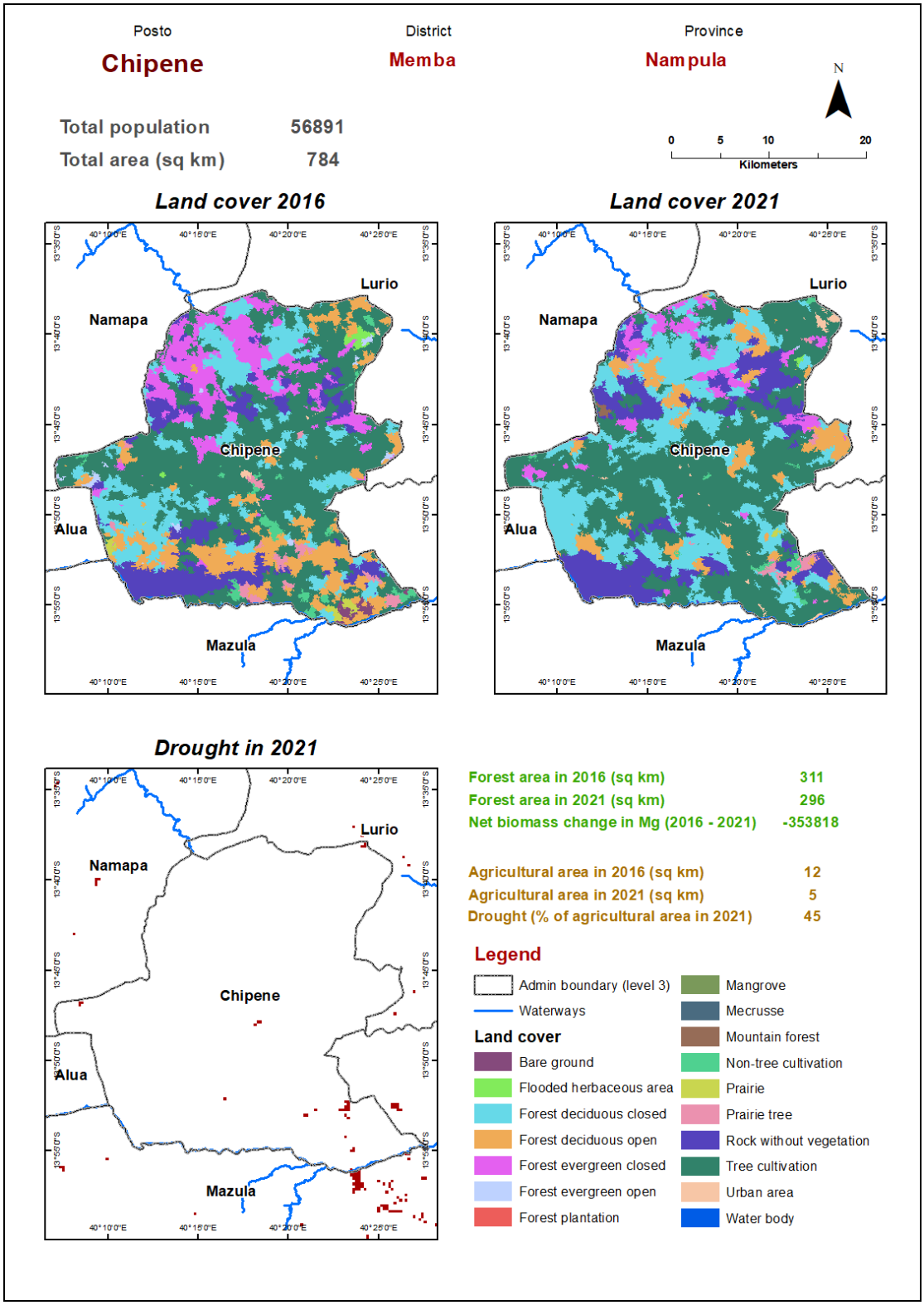

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Posto

Lurio

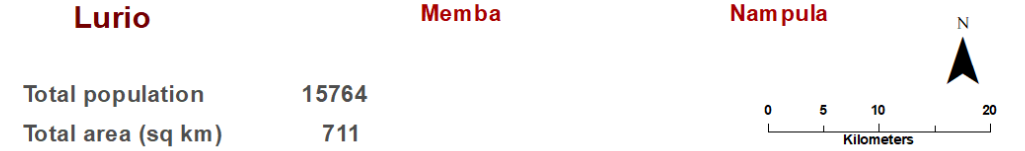
District

Memba

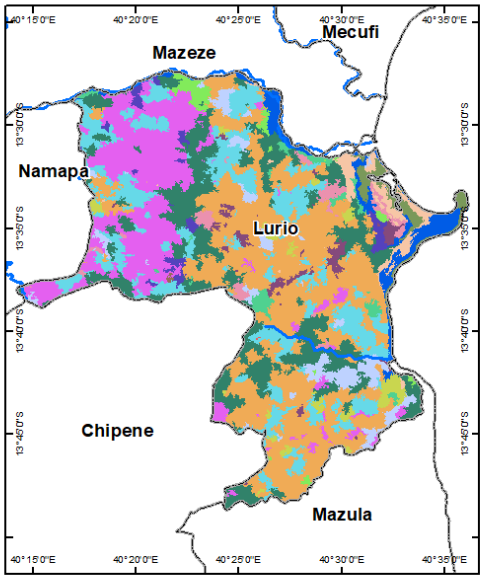
Province

Nampula

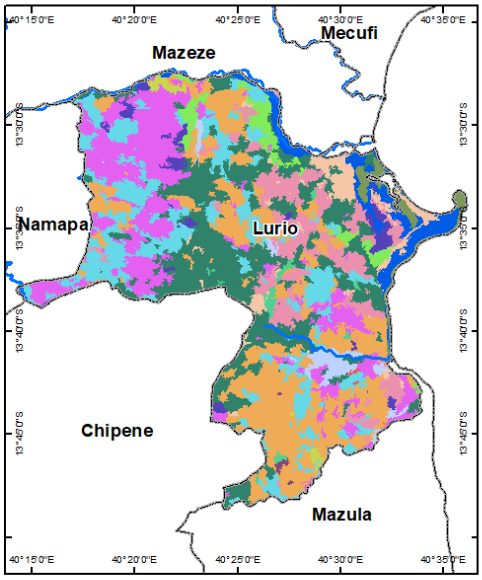
Total population	15764
Total area (sq km)	711



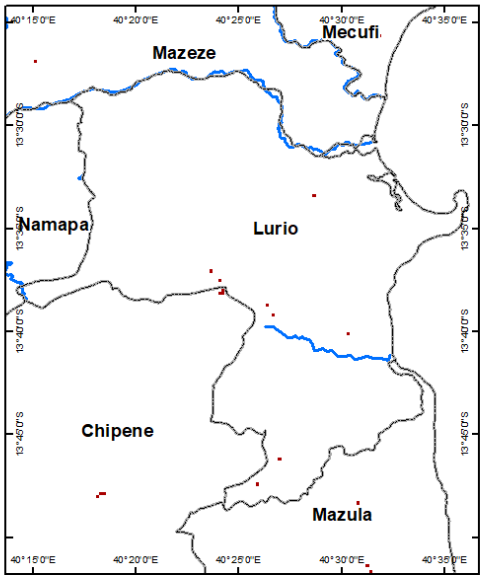
Land cover 2016



Land cover 2021



Drought in 2021



Forest area in 2016 (sq km)	482
Forest area in 2021 (sq km)	404
Net biomass change in Mg (2016 - 2021)	-715924
Agricultural area in 2016 (sq km)	11
Agricultural area in 2021 (sq km)	5
Drought (% of agricultural area in 2021)	12

Legend

- Admin boundary (level 3)
- Waterways

Land cover

- Bare ground
- Flooded herbaceous area
- Forest deciduous closed
- Forest deciduous open
- Forest evergreen closed
- Forest evergreen open
- Forest plantation
- Mangrove
- Mecrusse
- Mountain forest
- Non-tree cultivation
- Prairie
- Prairie tree
- Rock without vegetation
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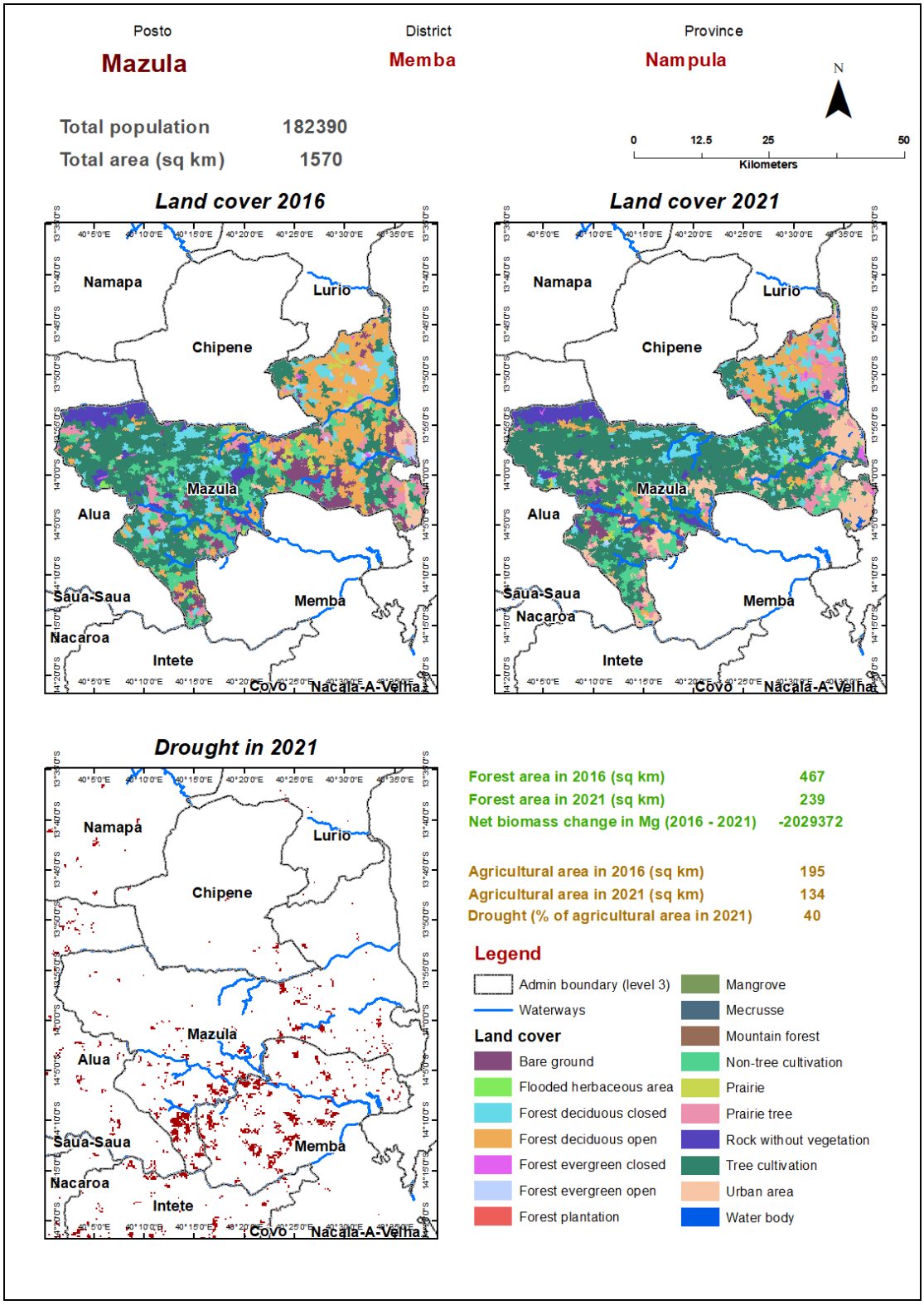

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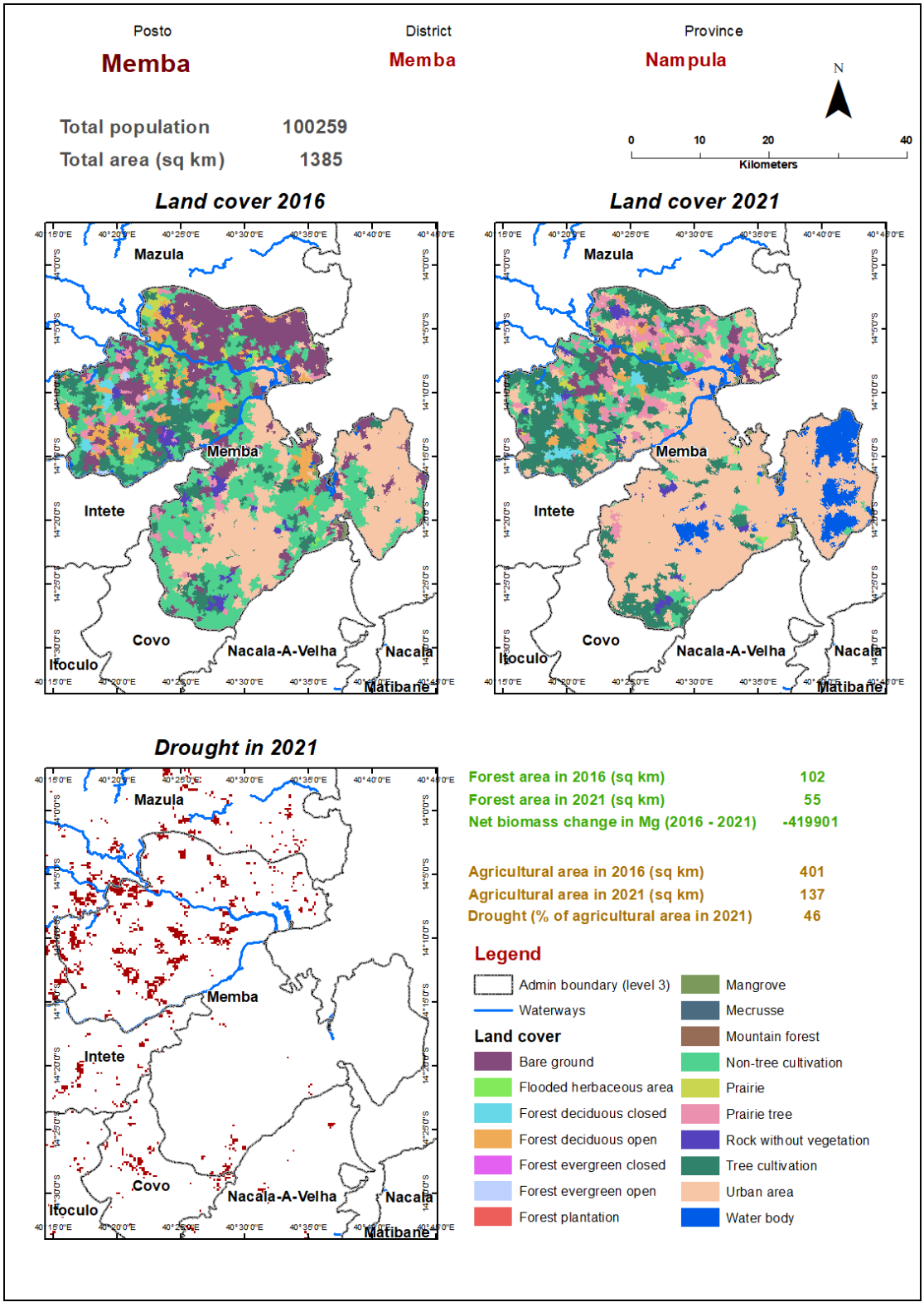

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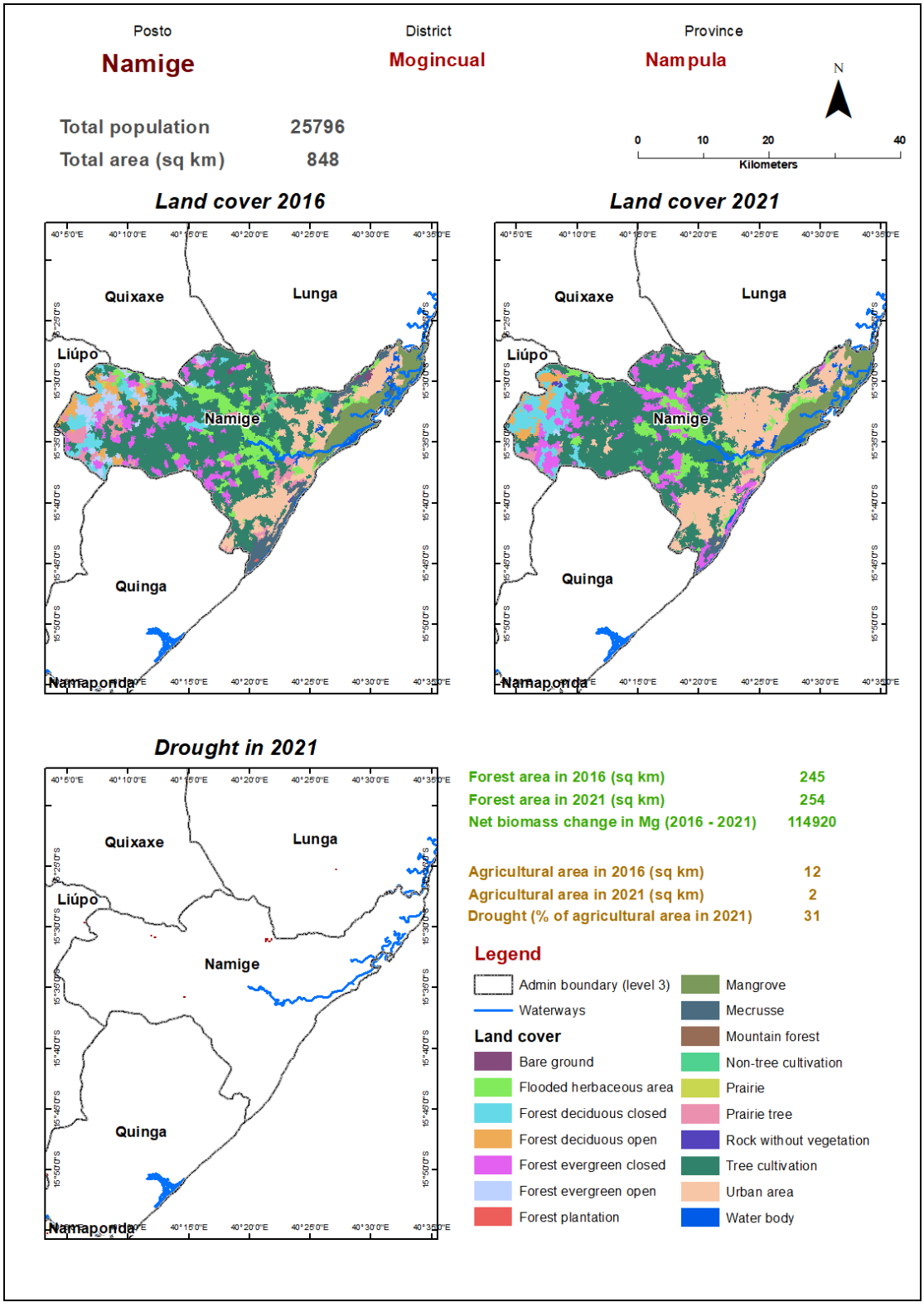

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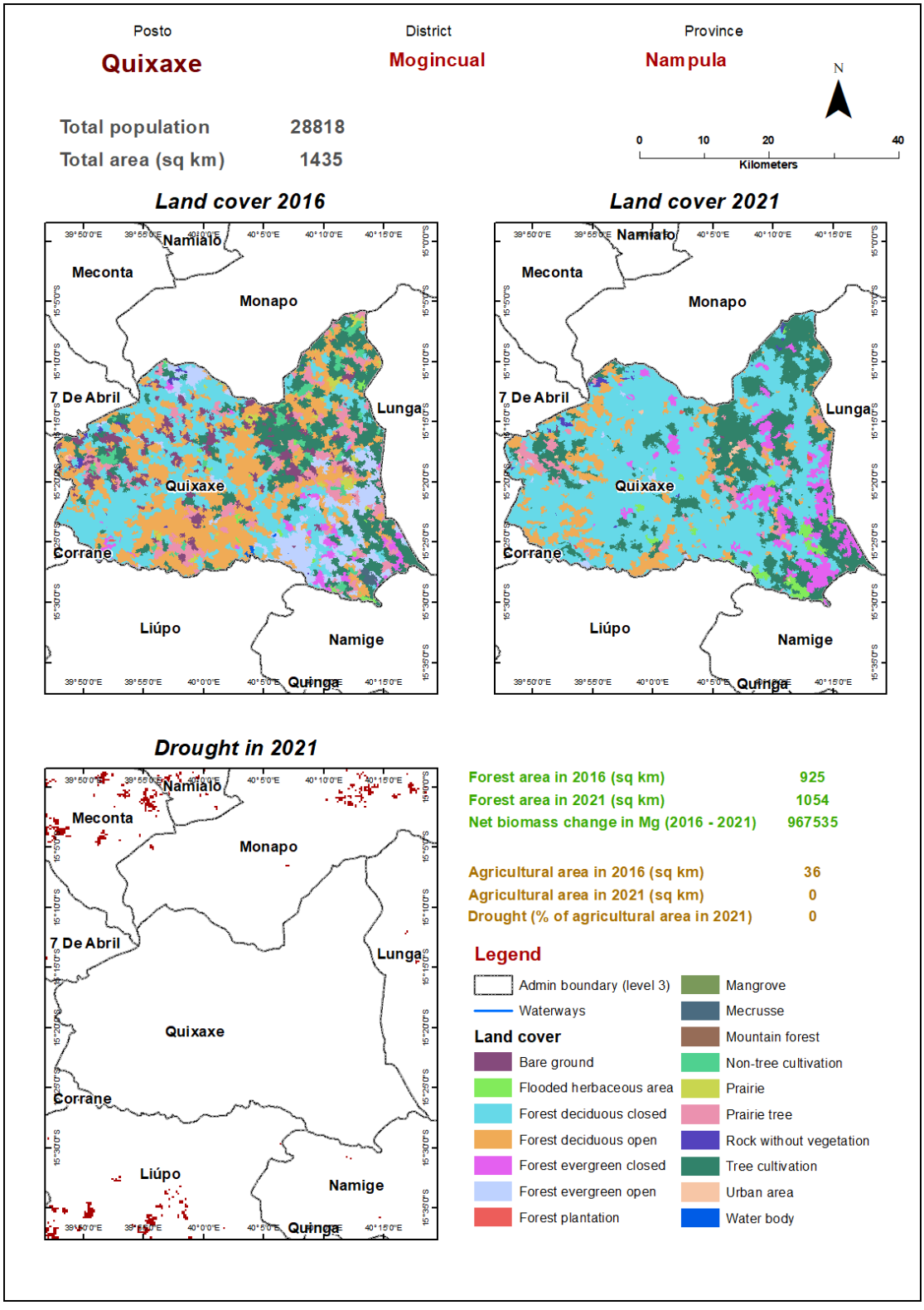

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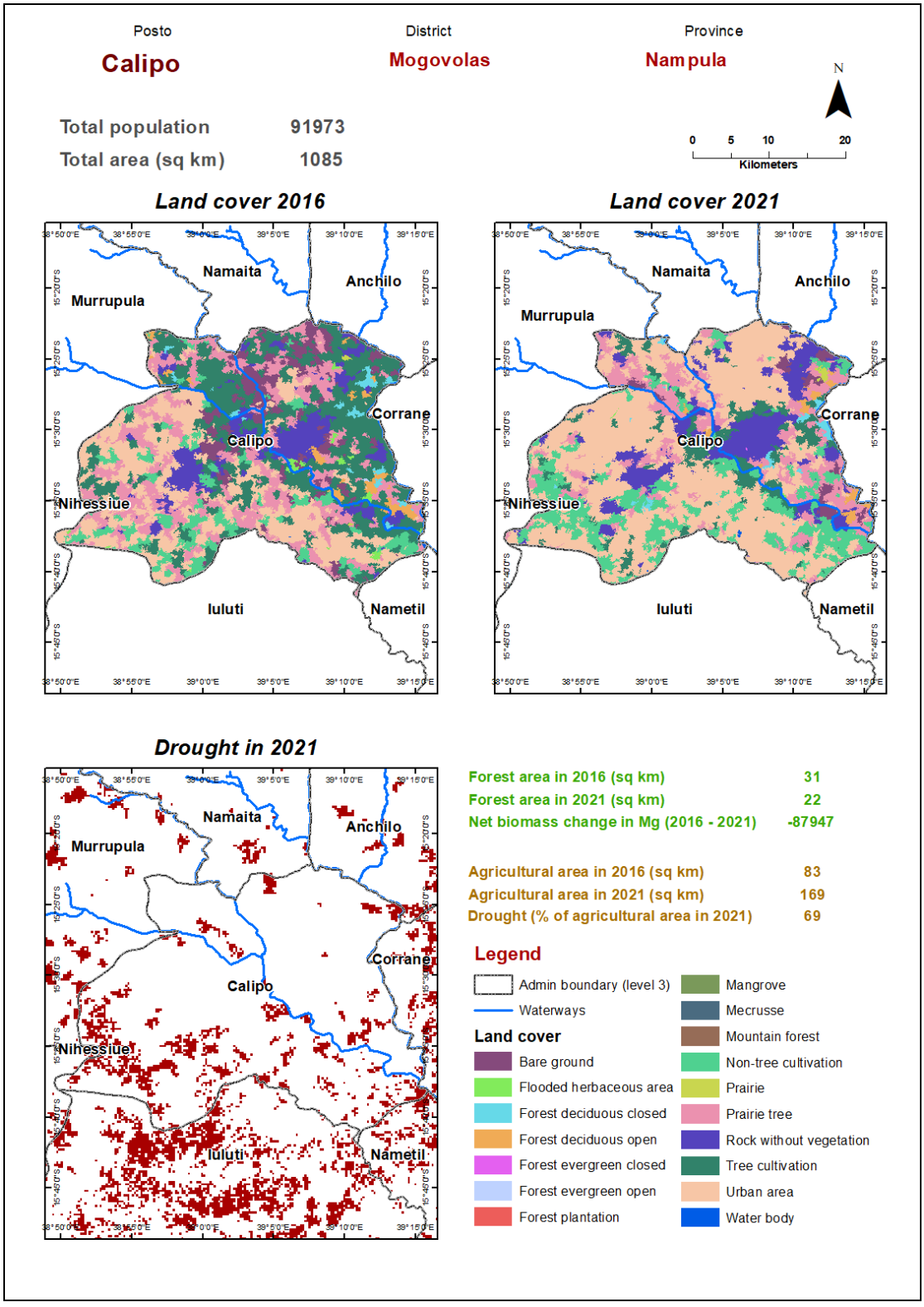

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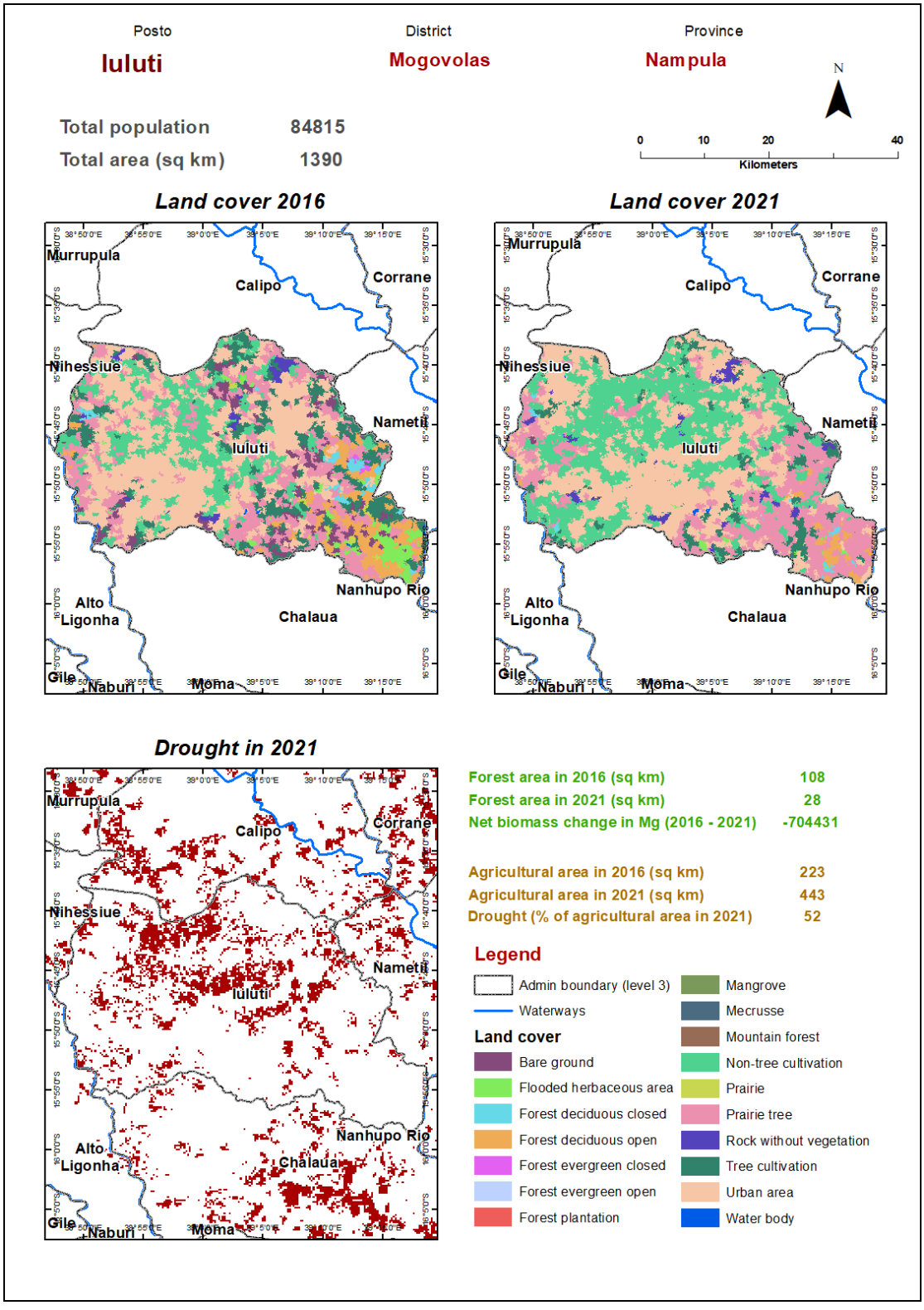

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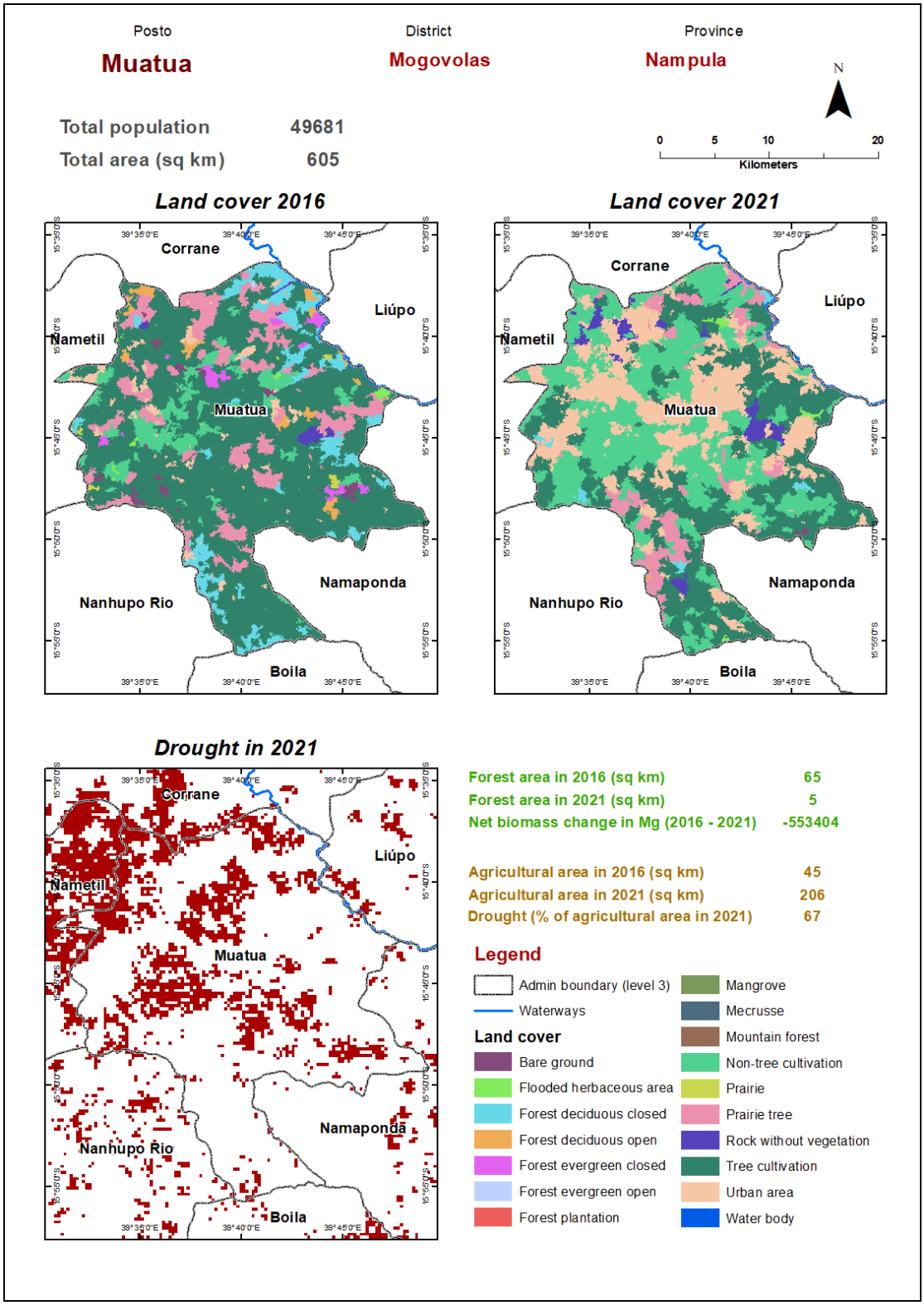

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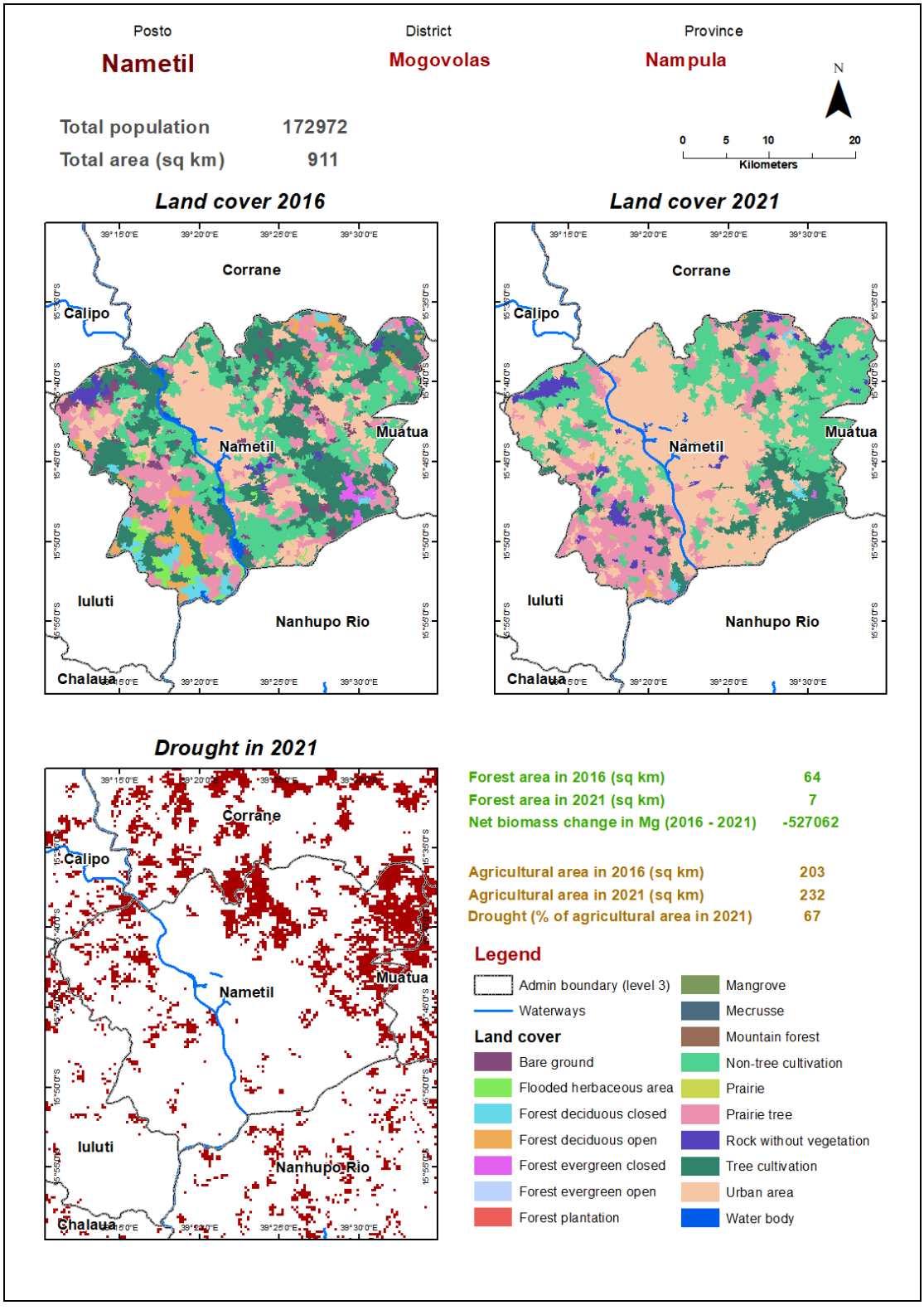

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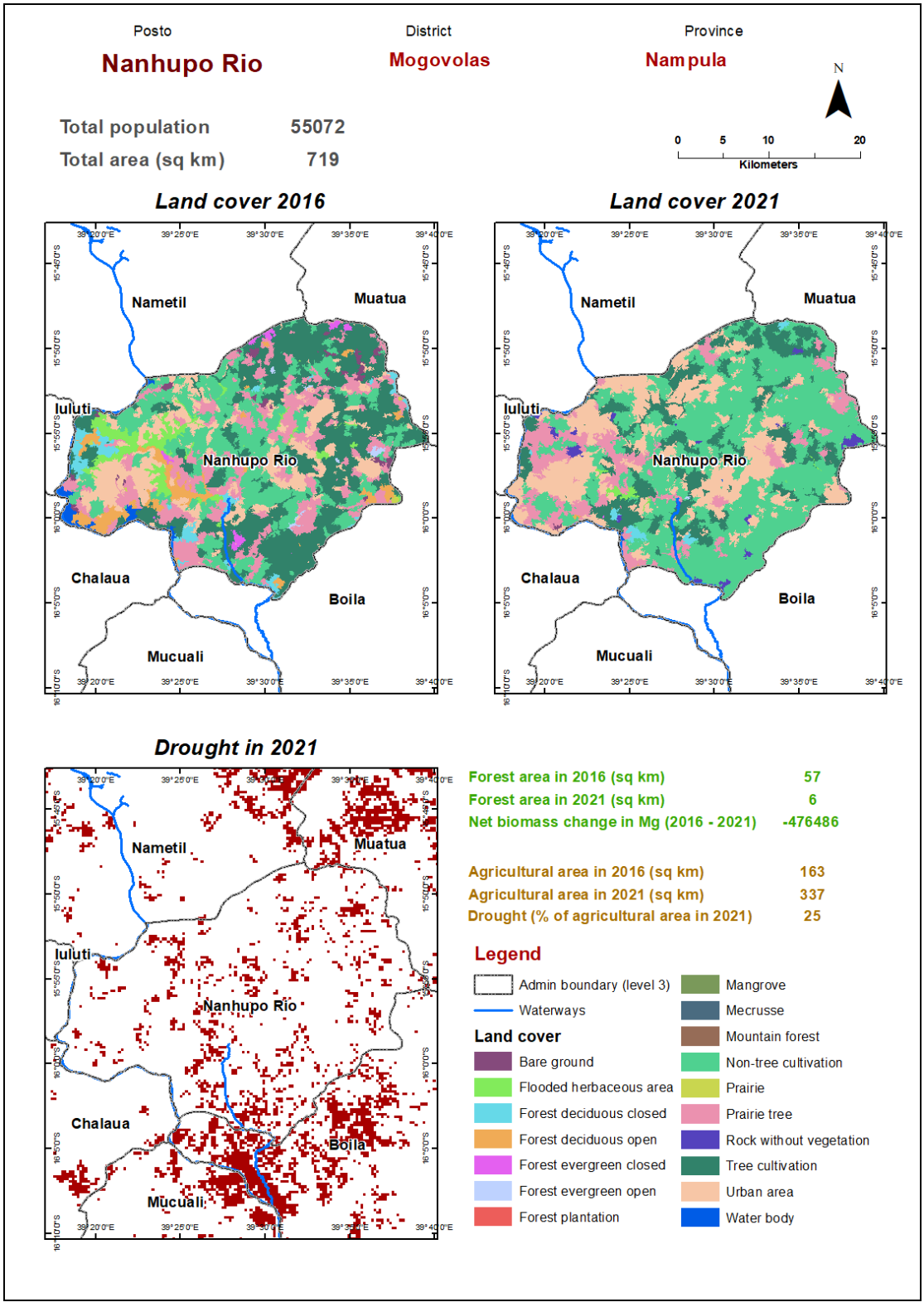

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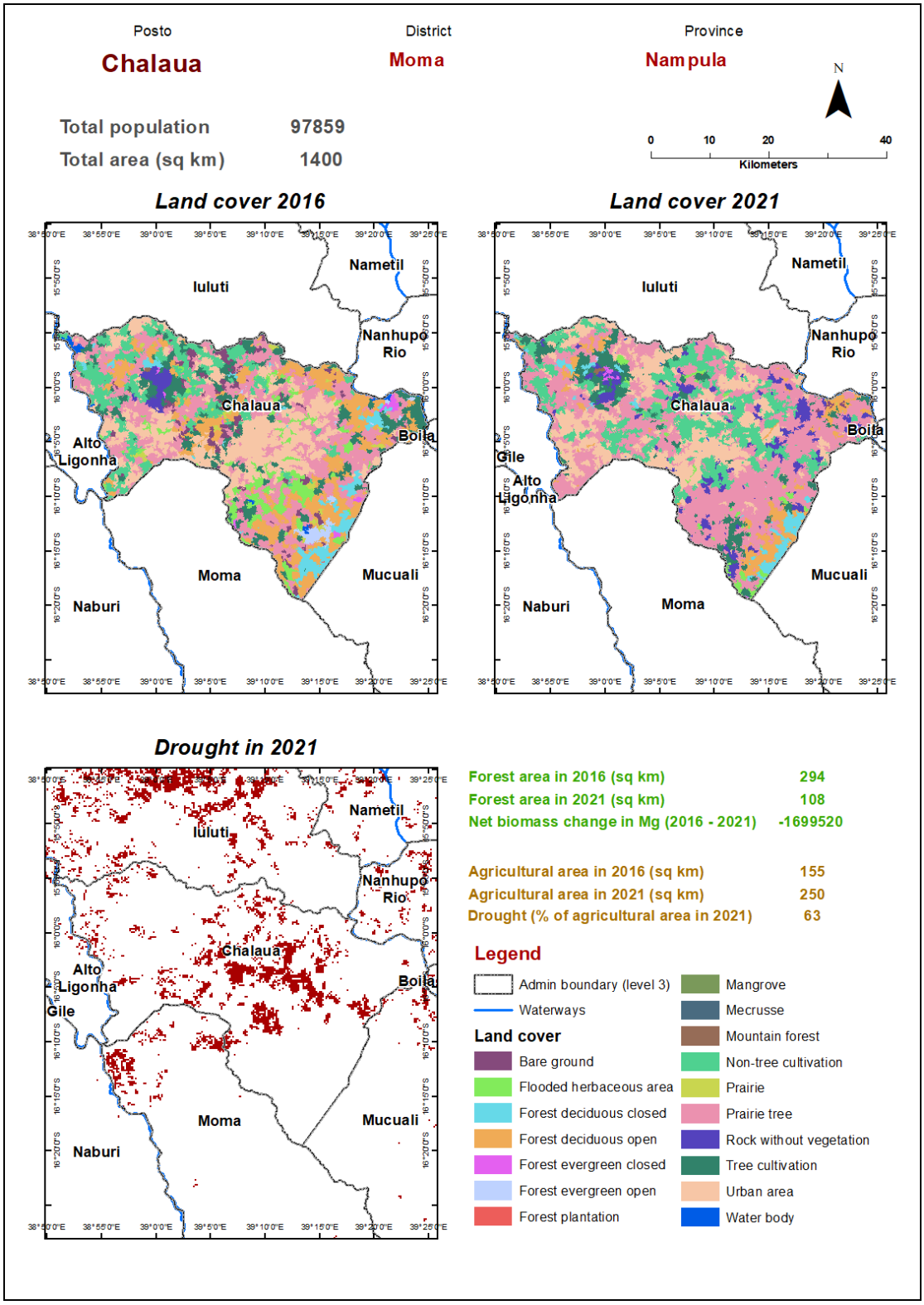

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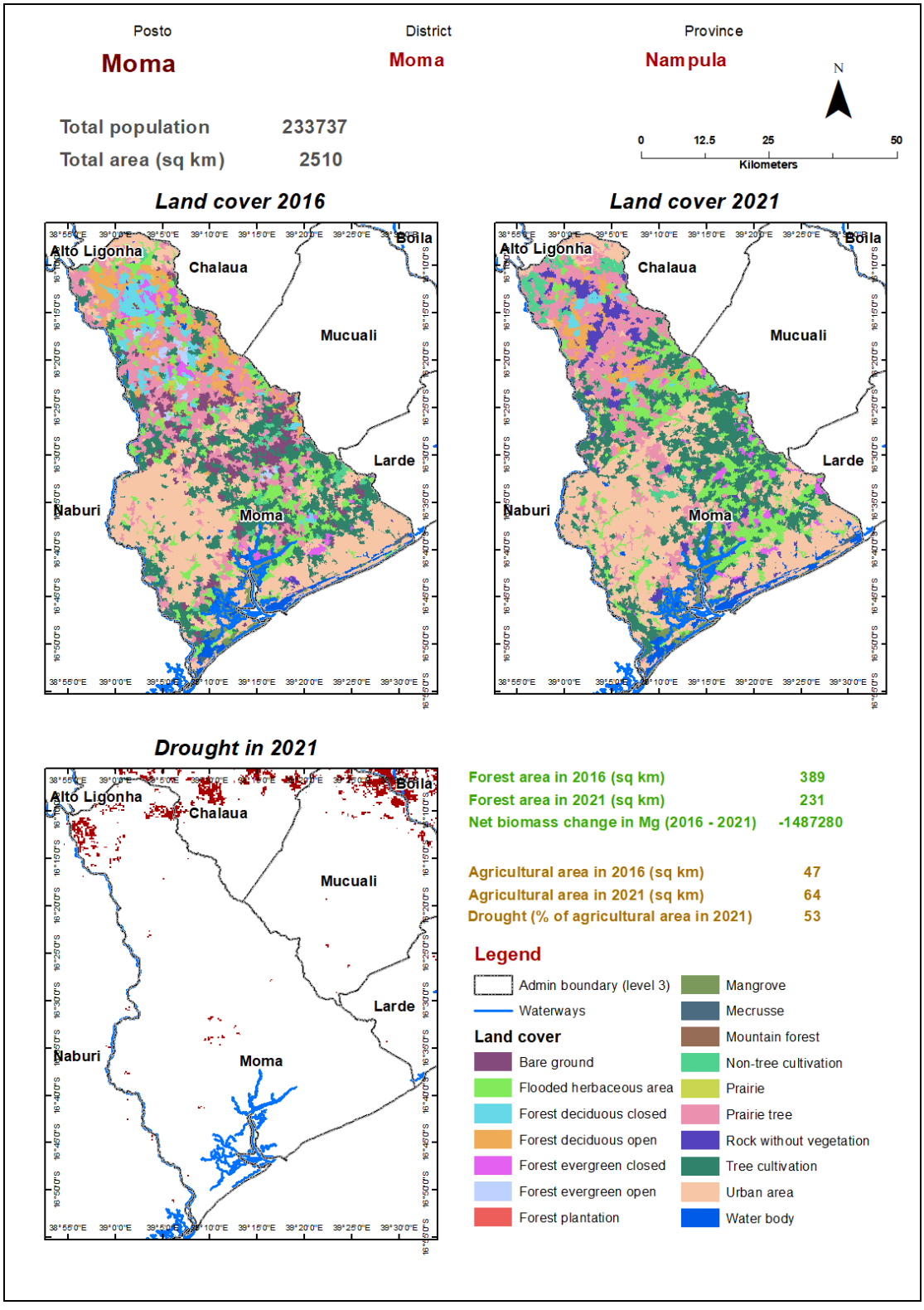

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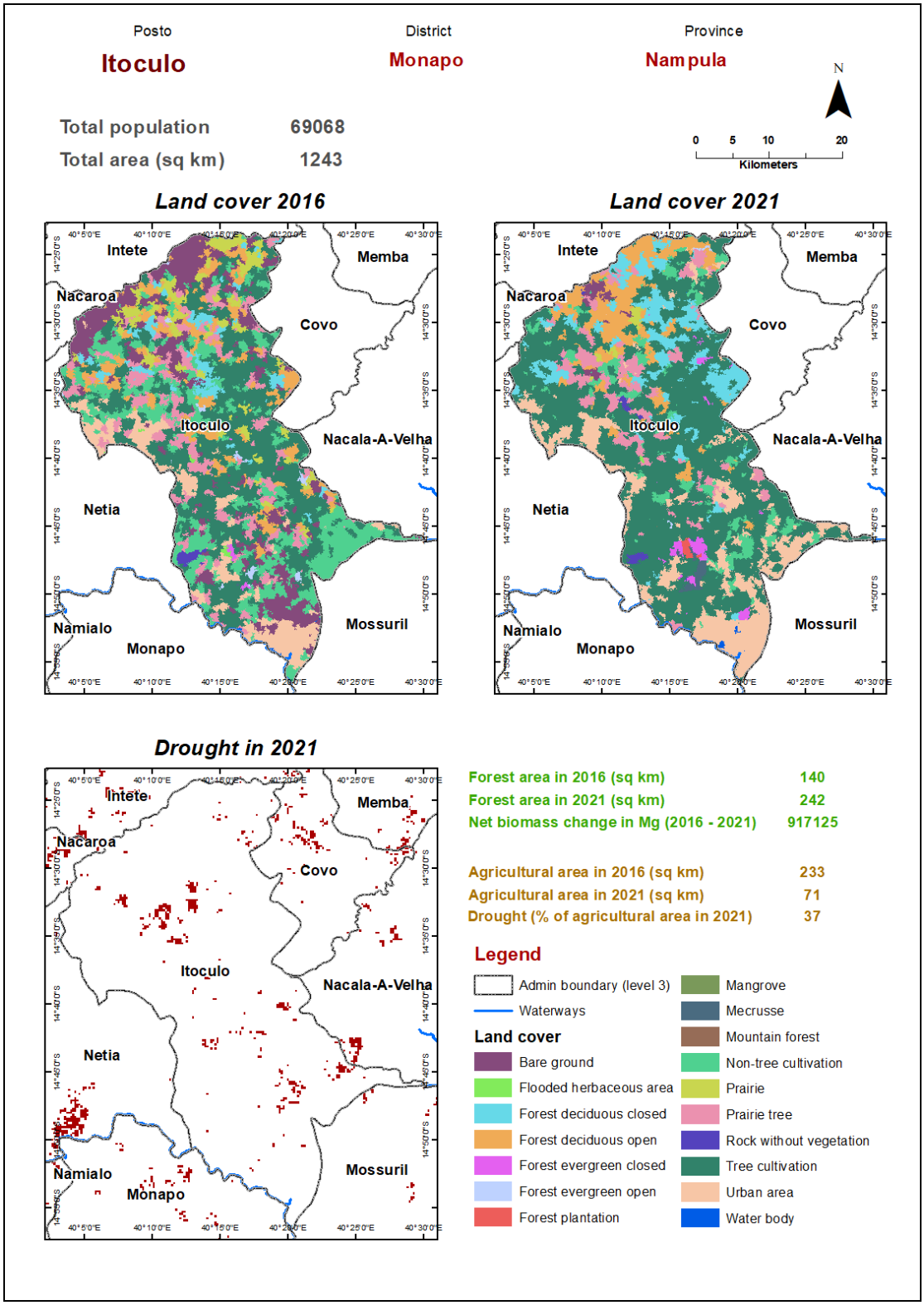

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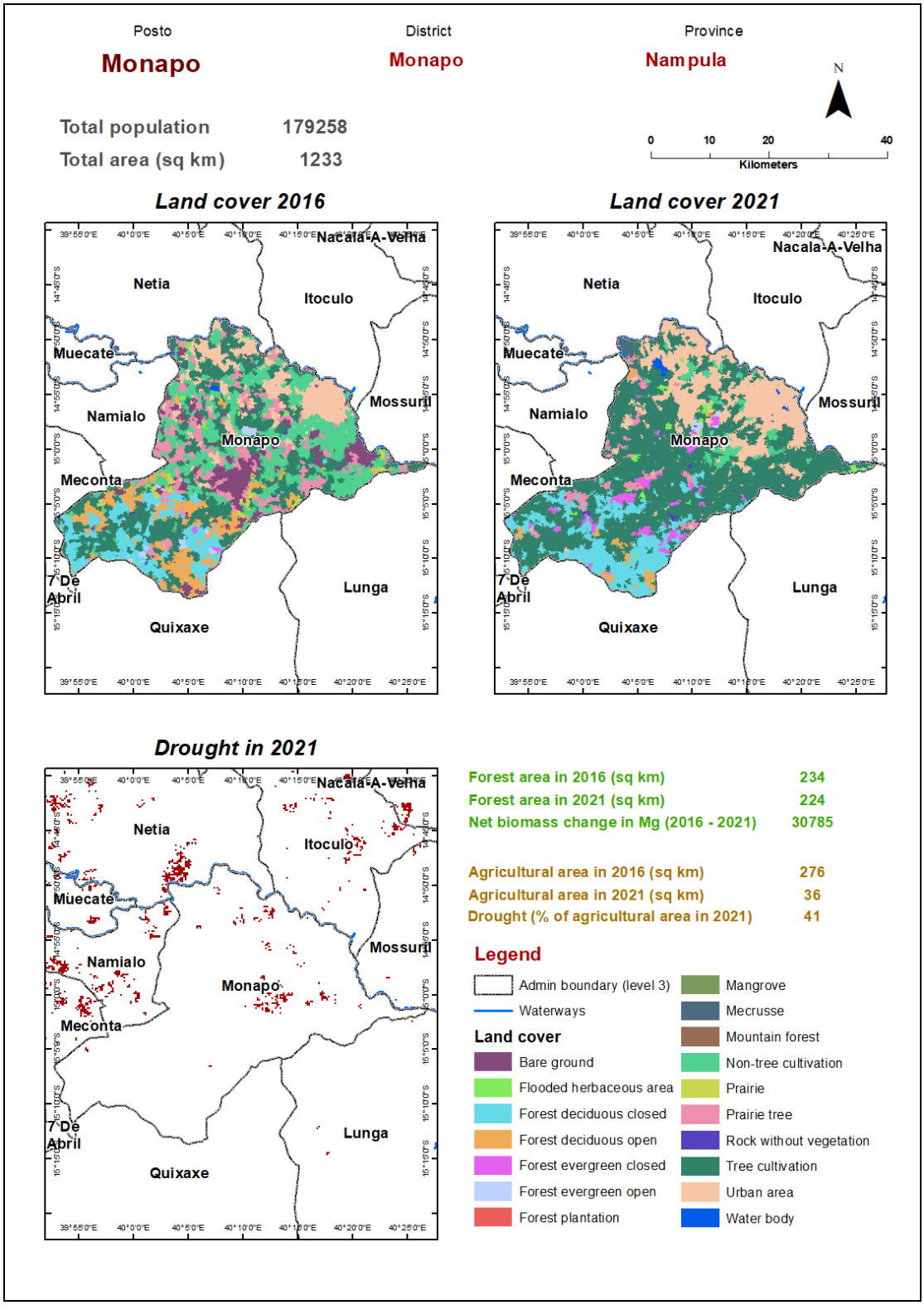

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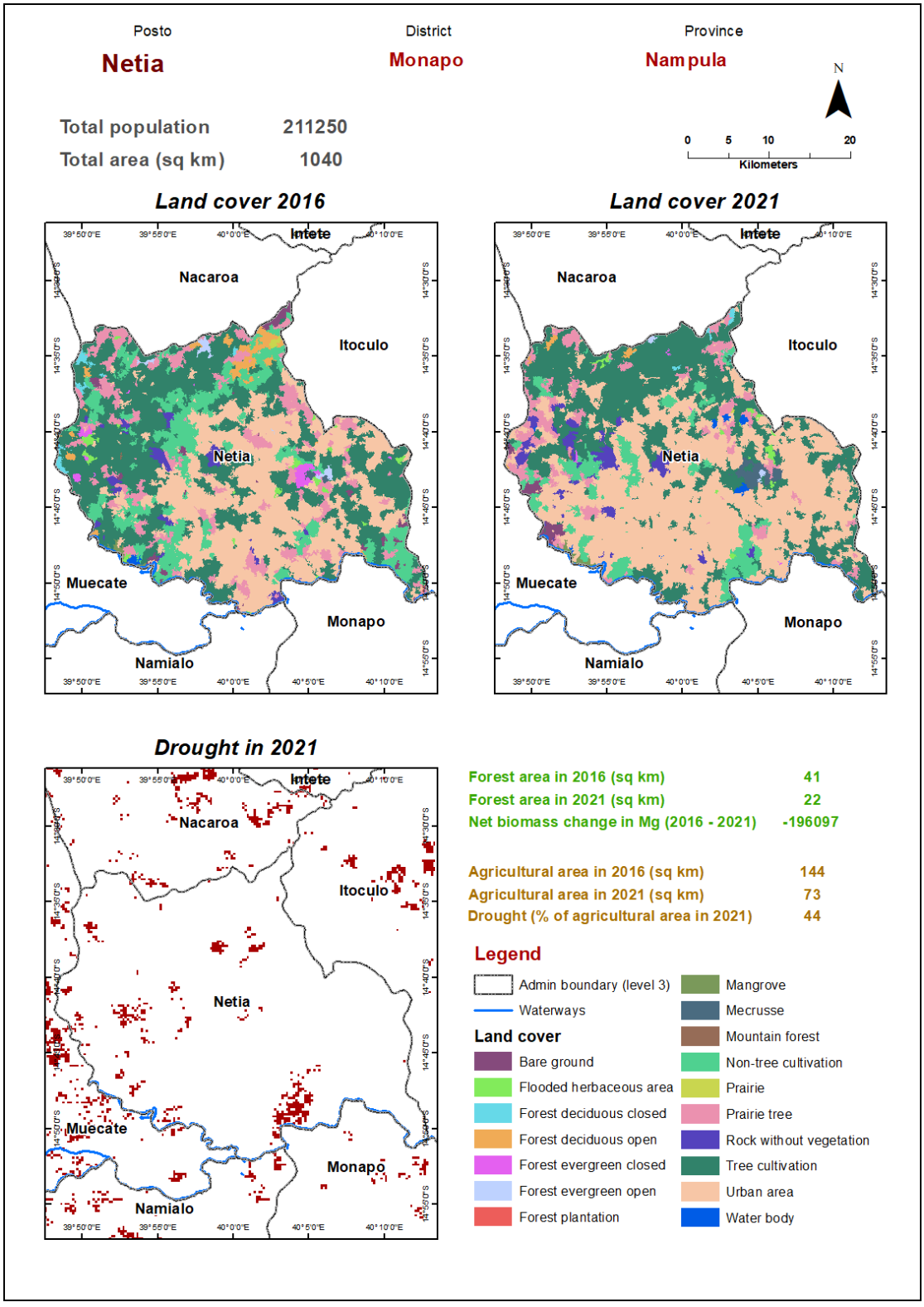

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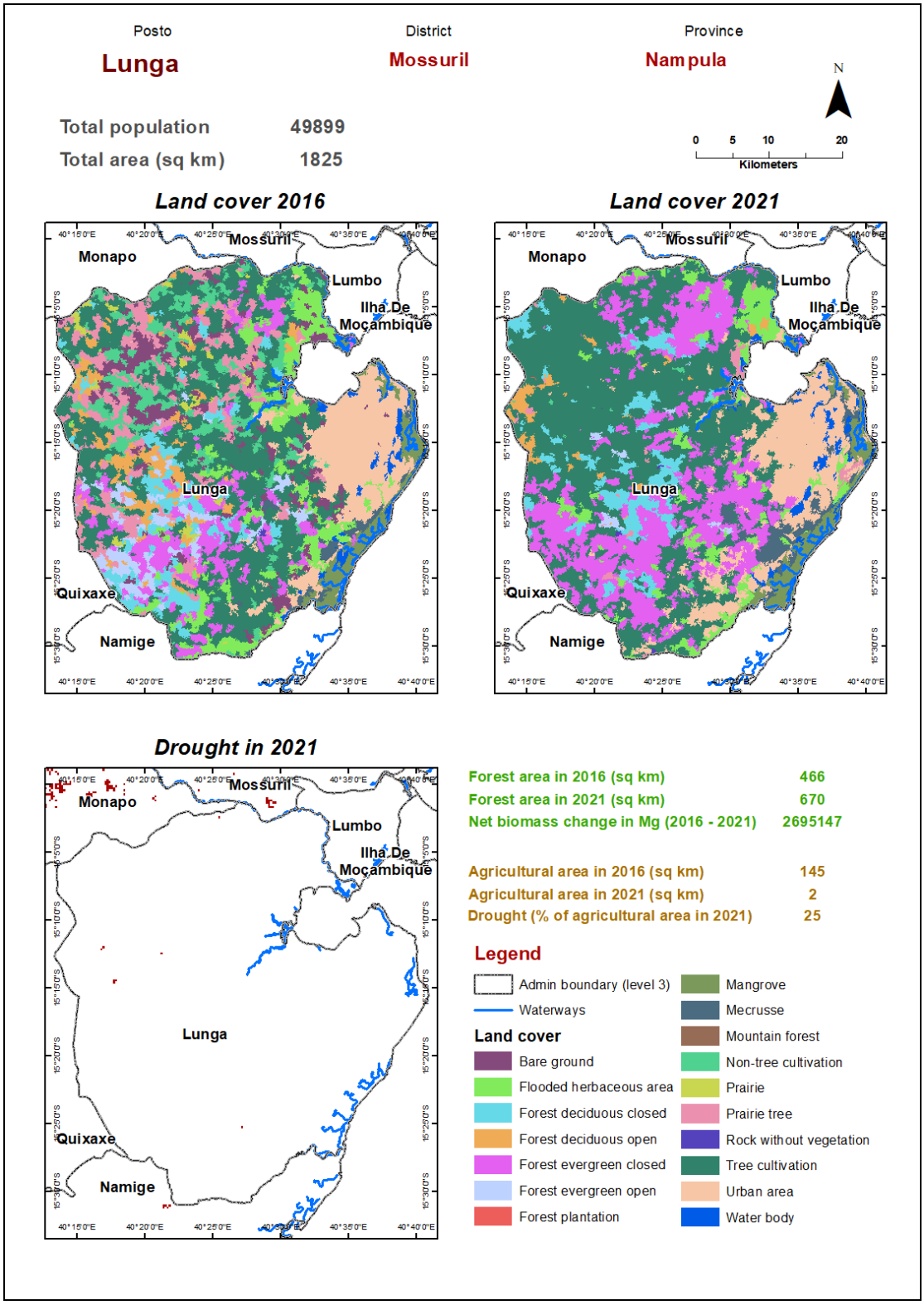

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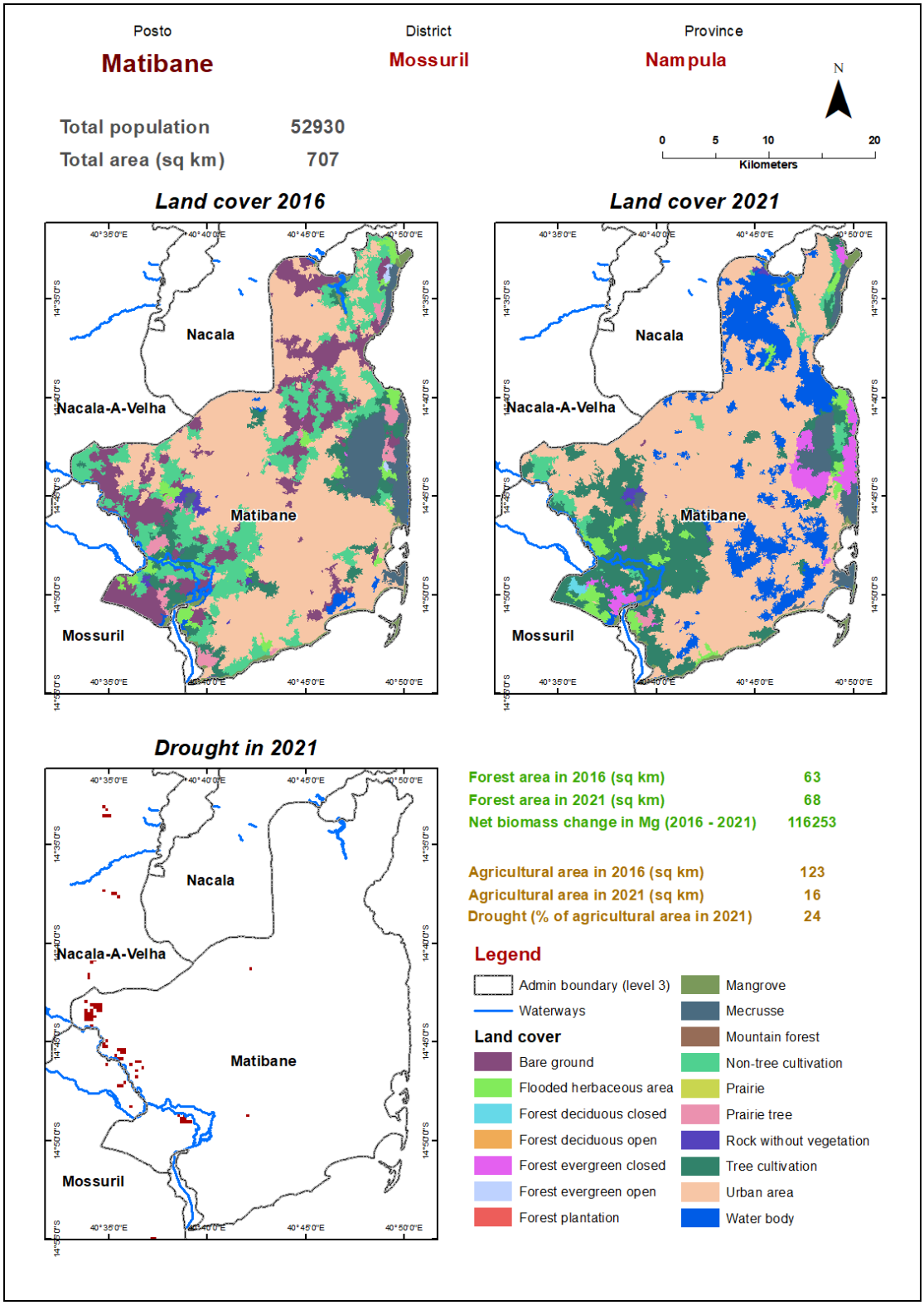

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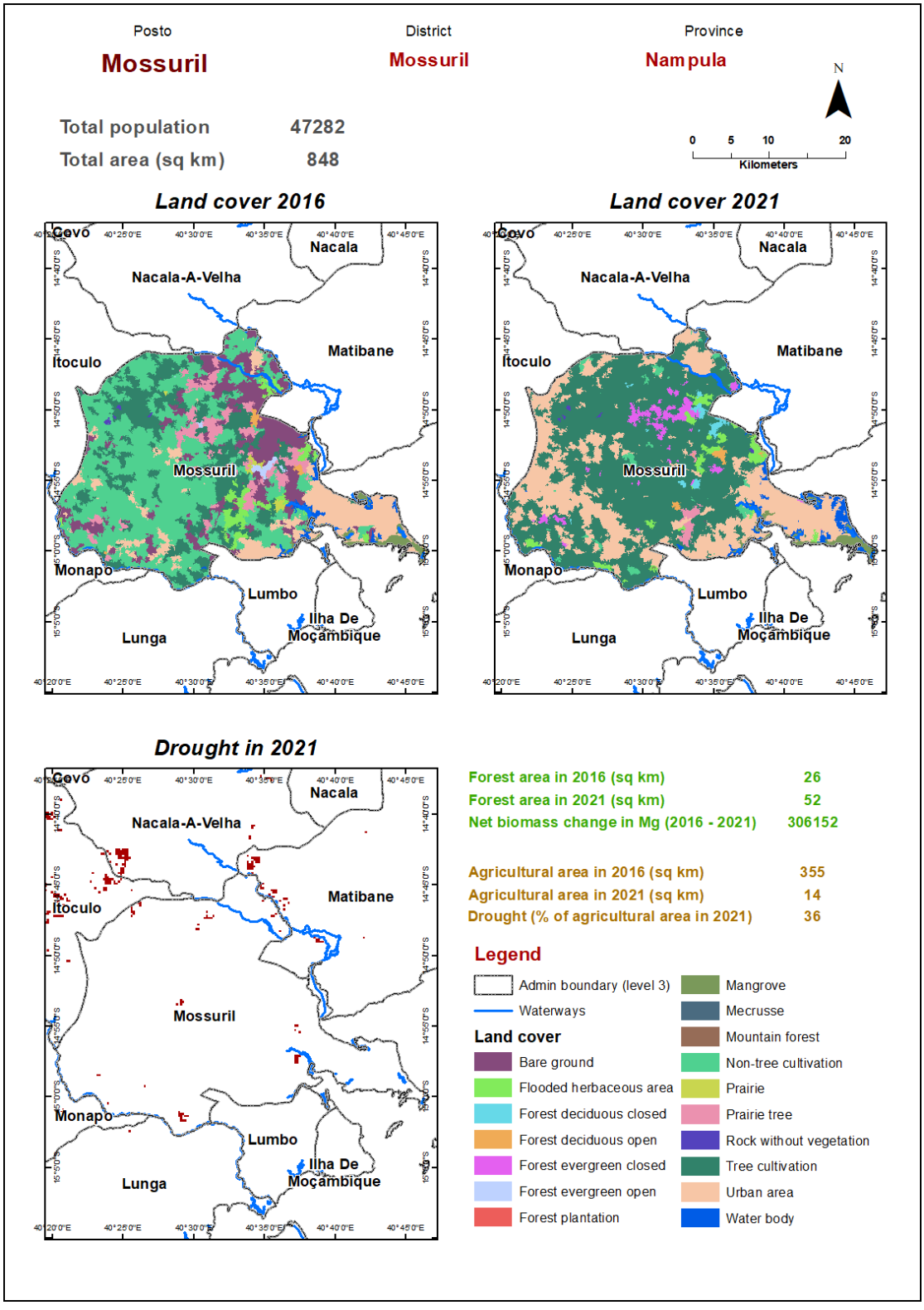

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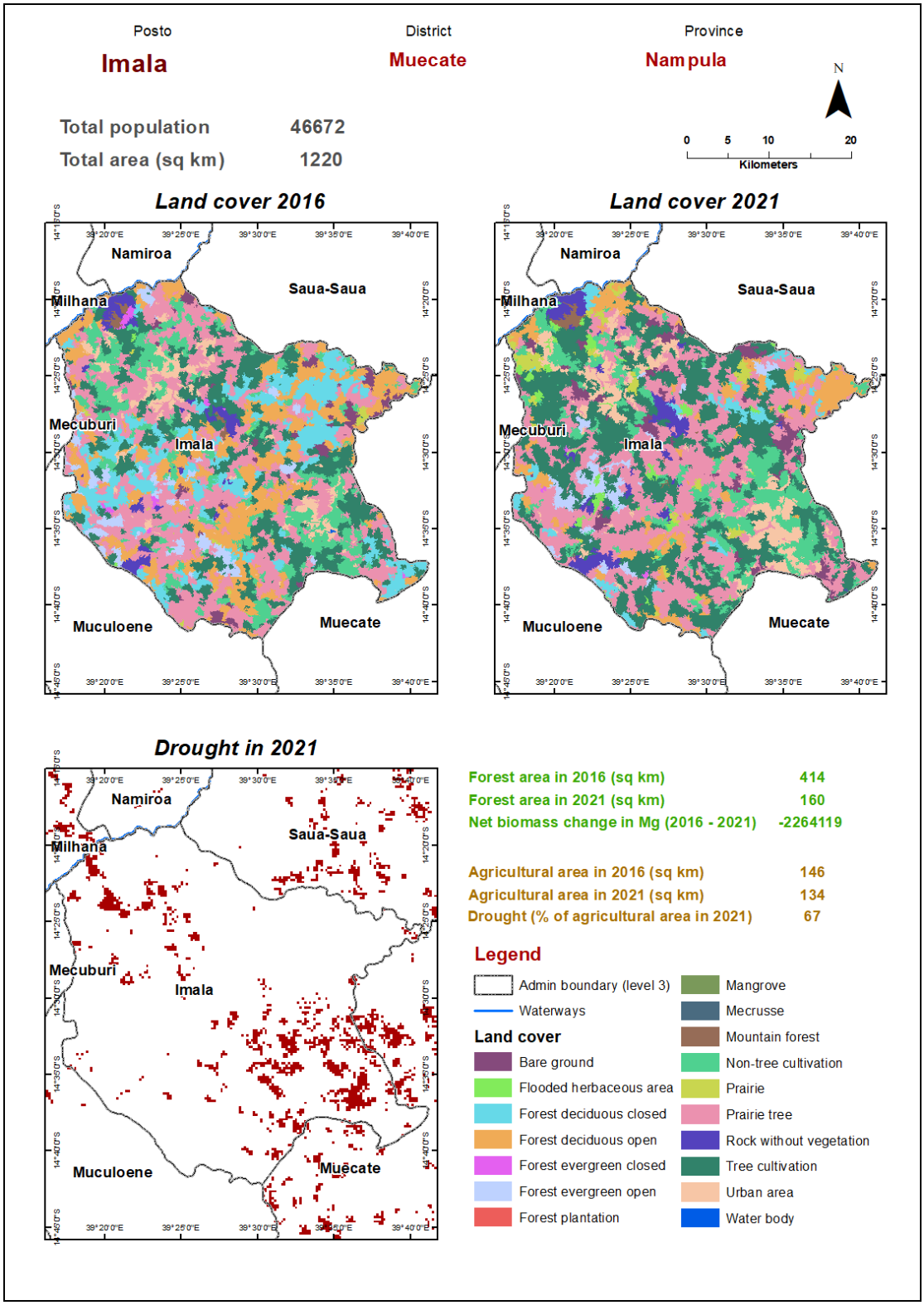

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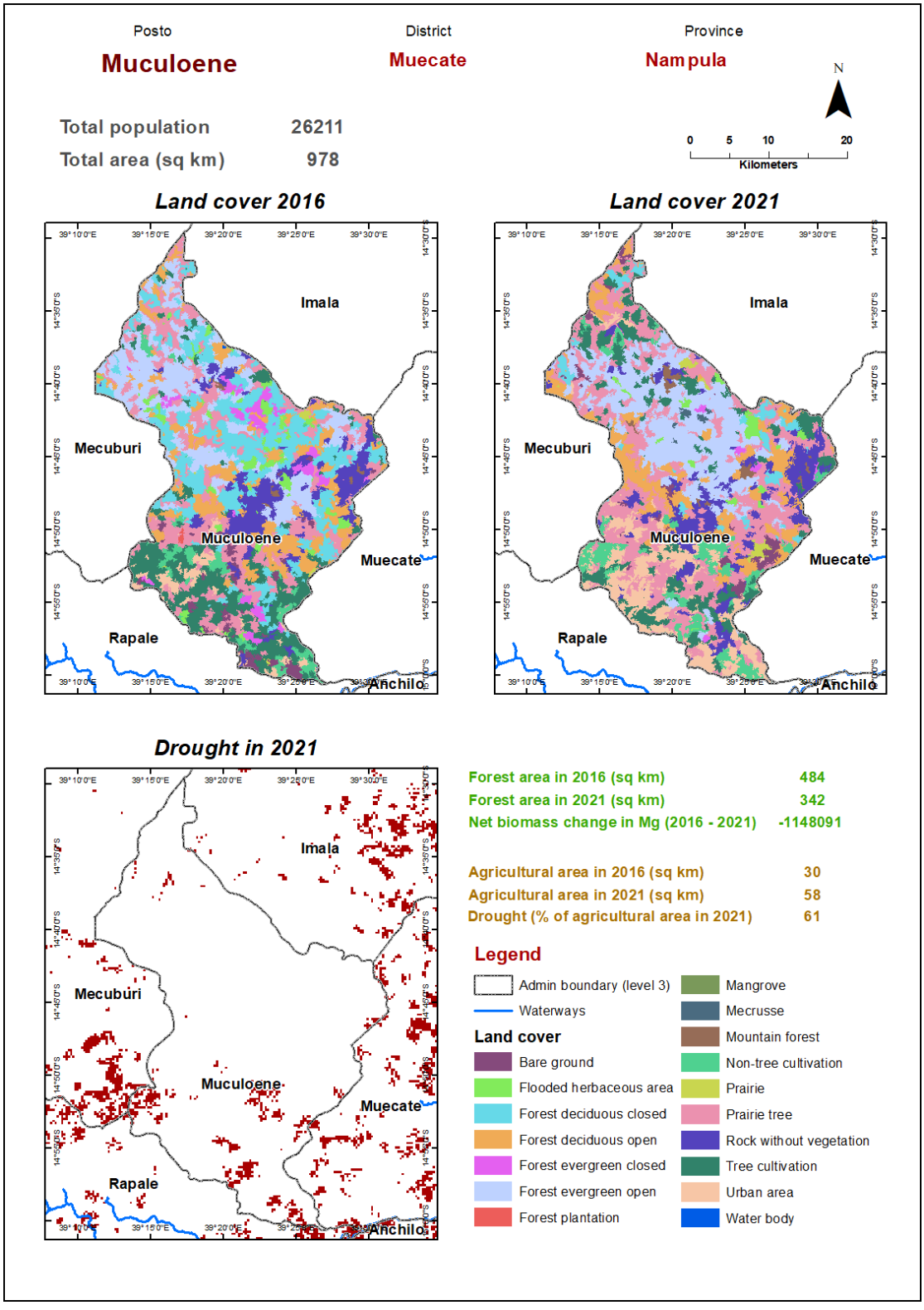

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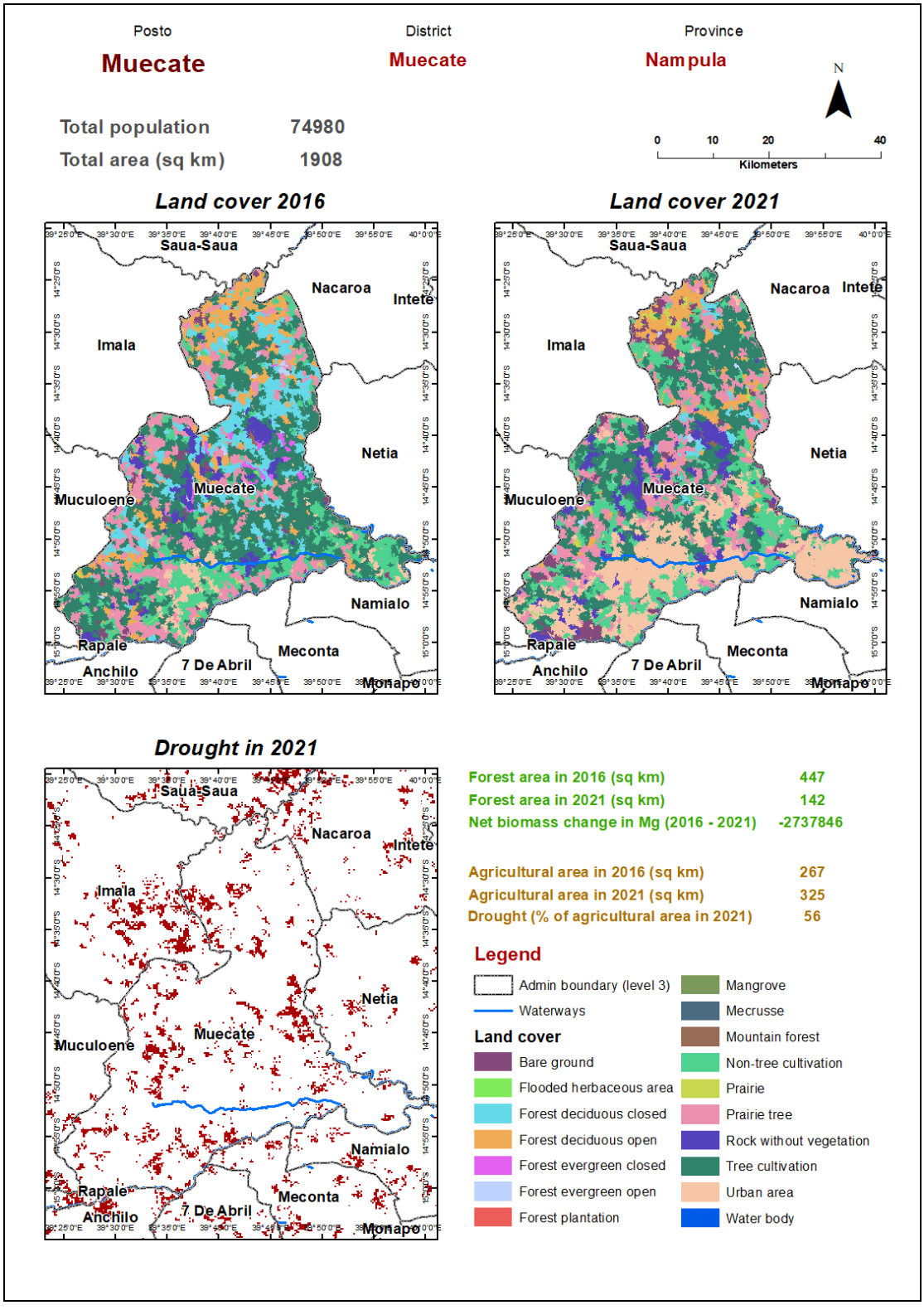

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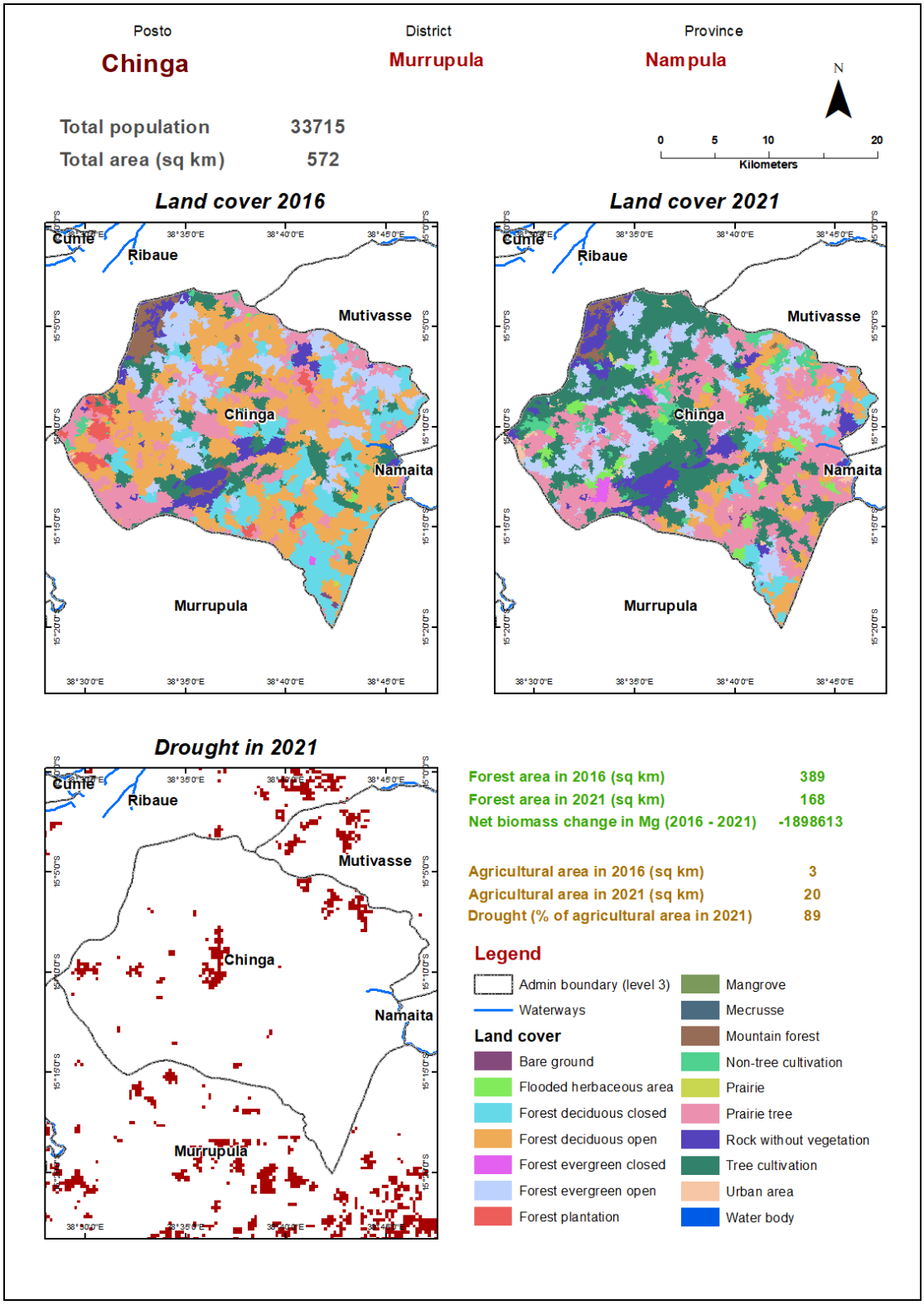

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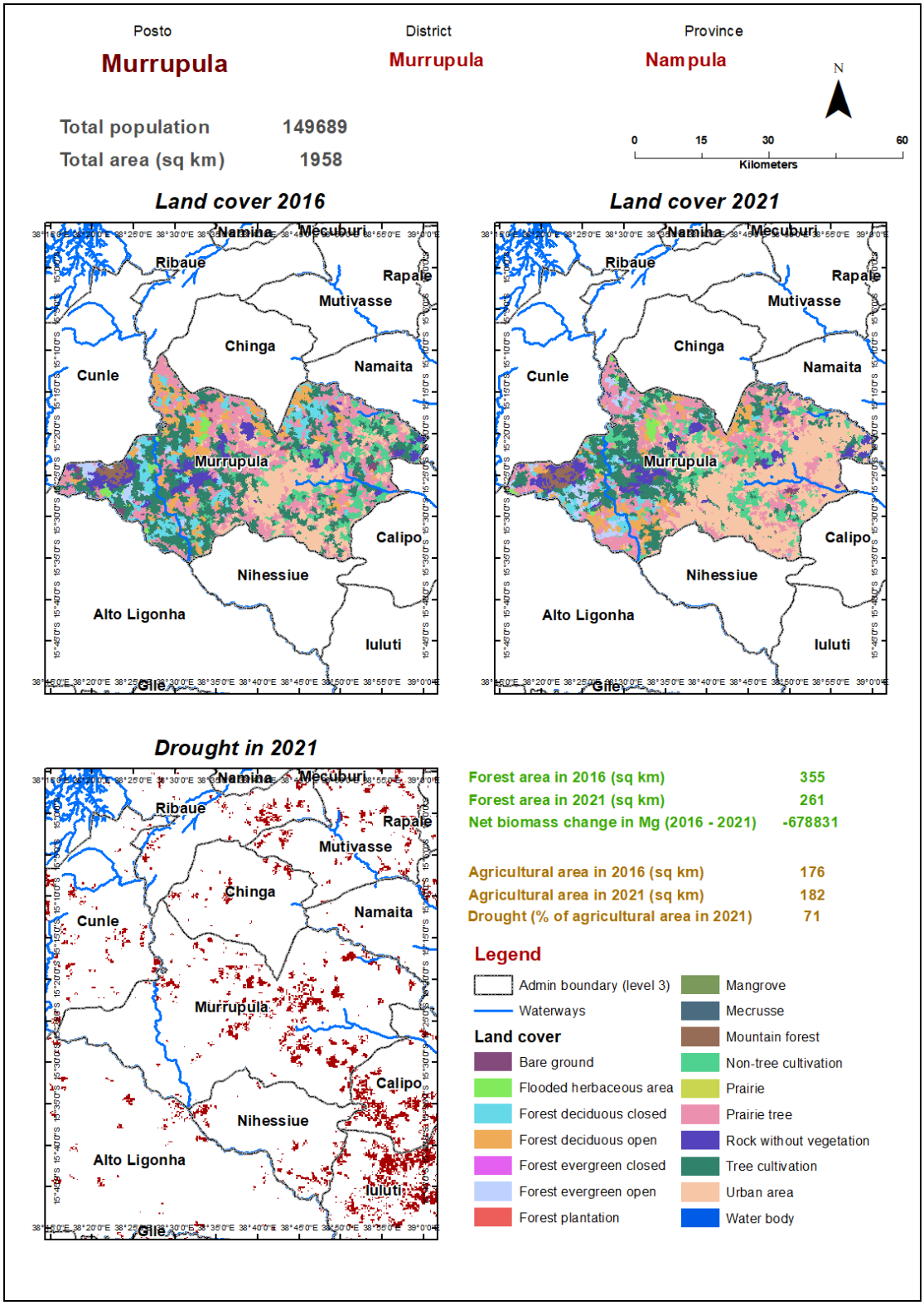

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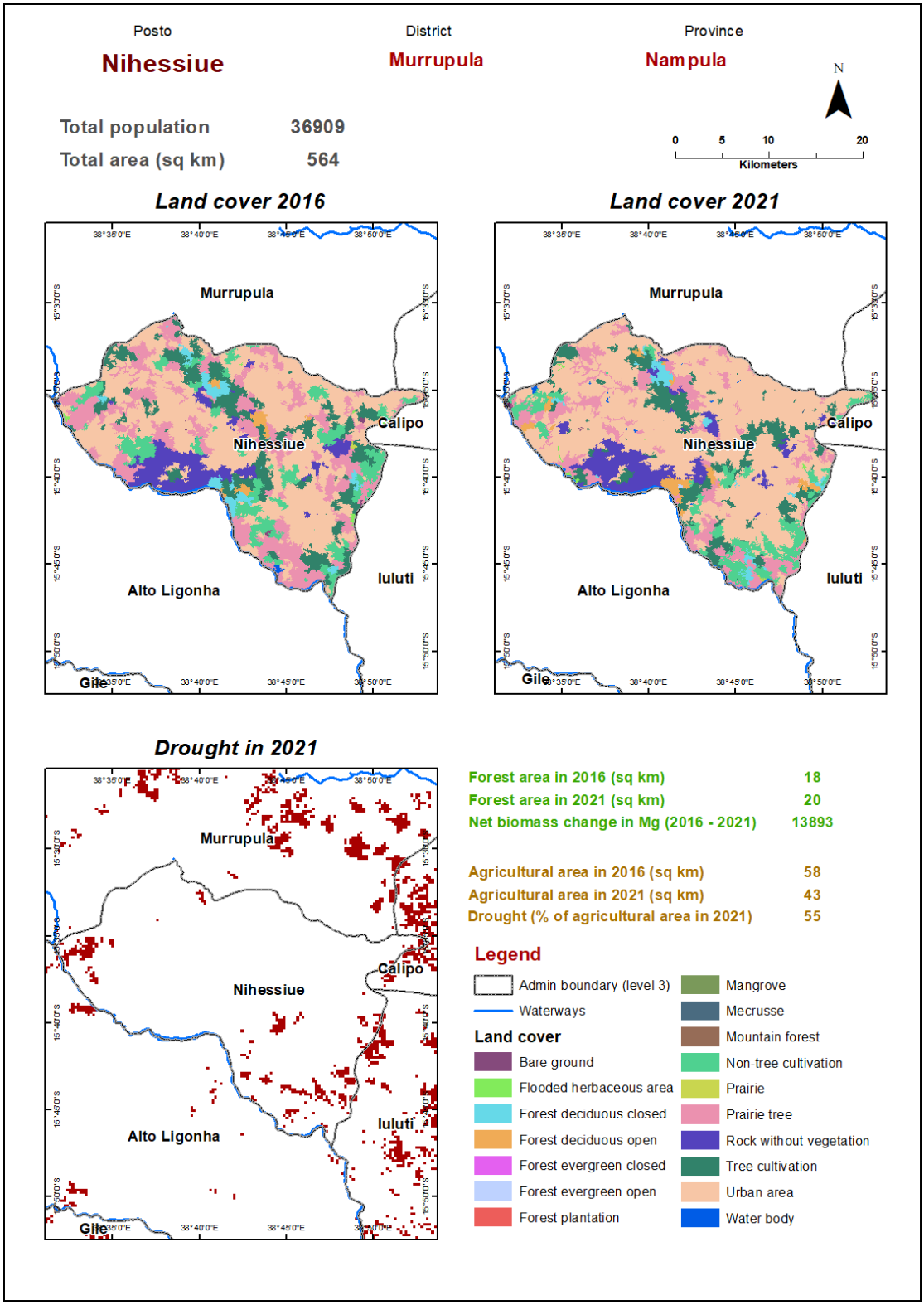

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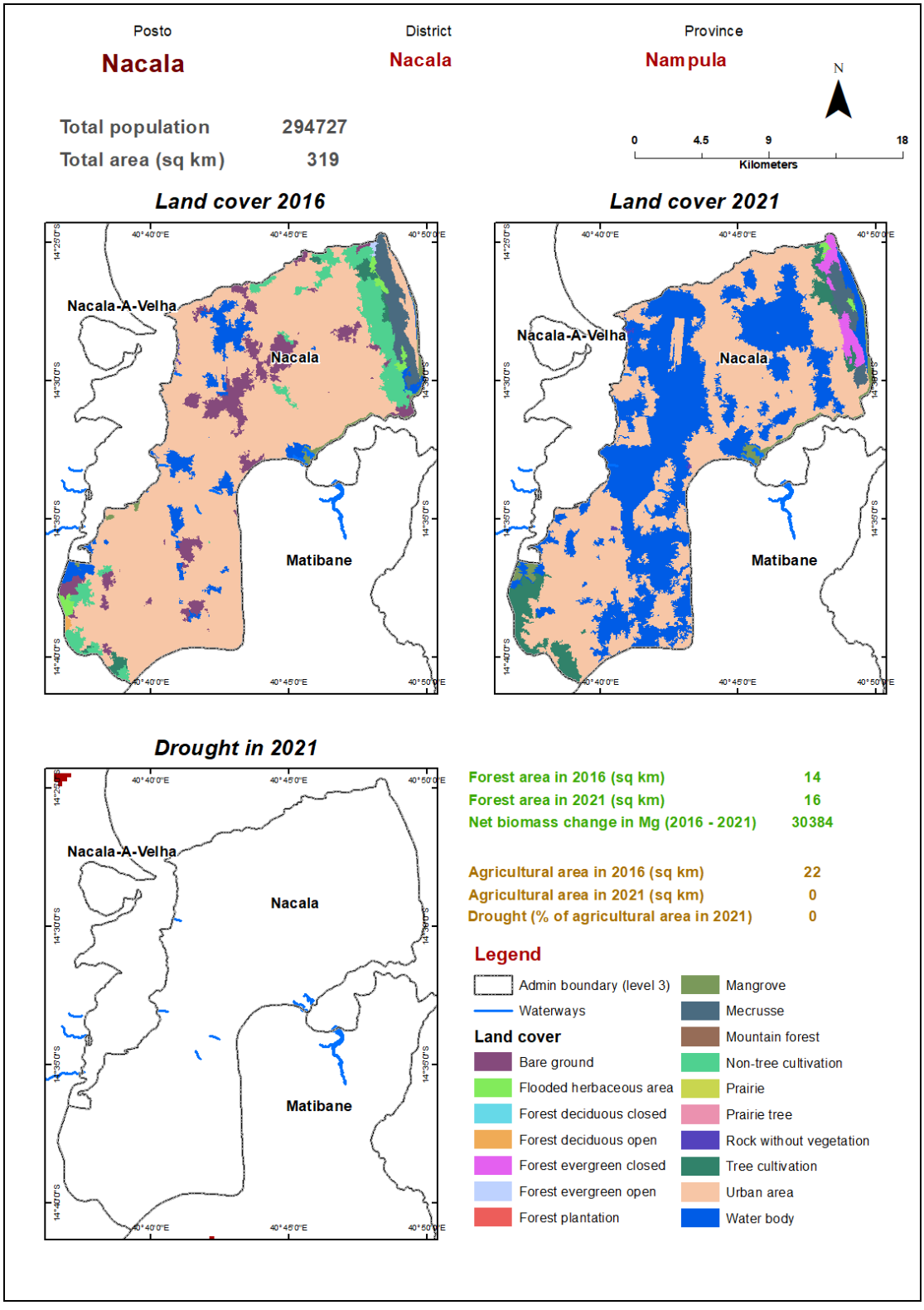

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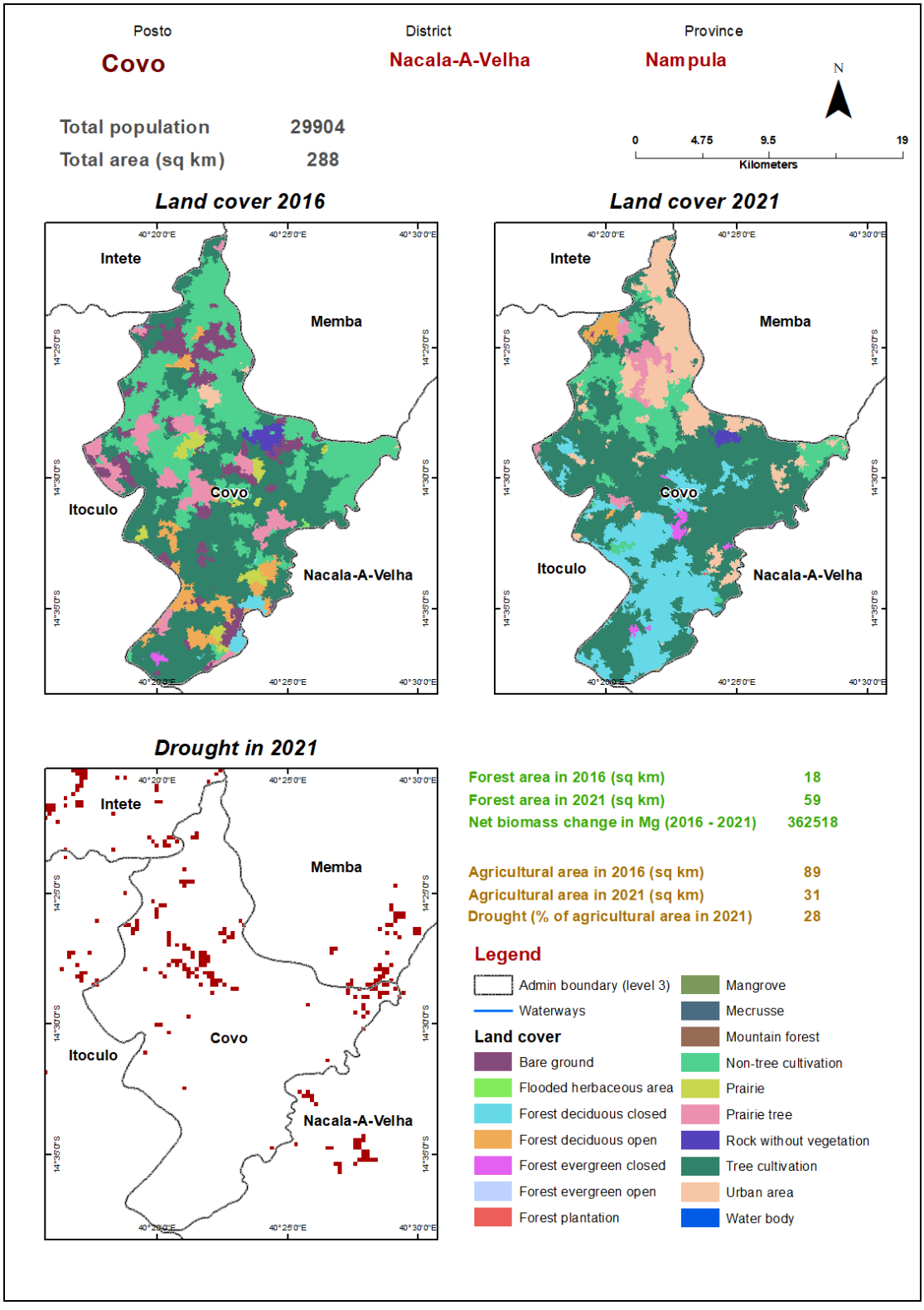

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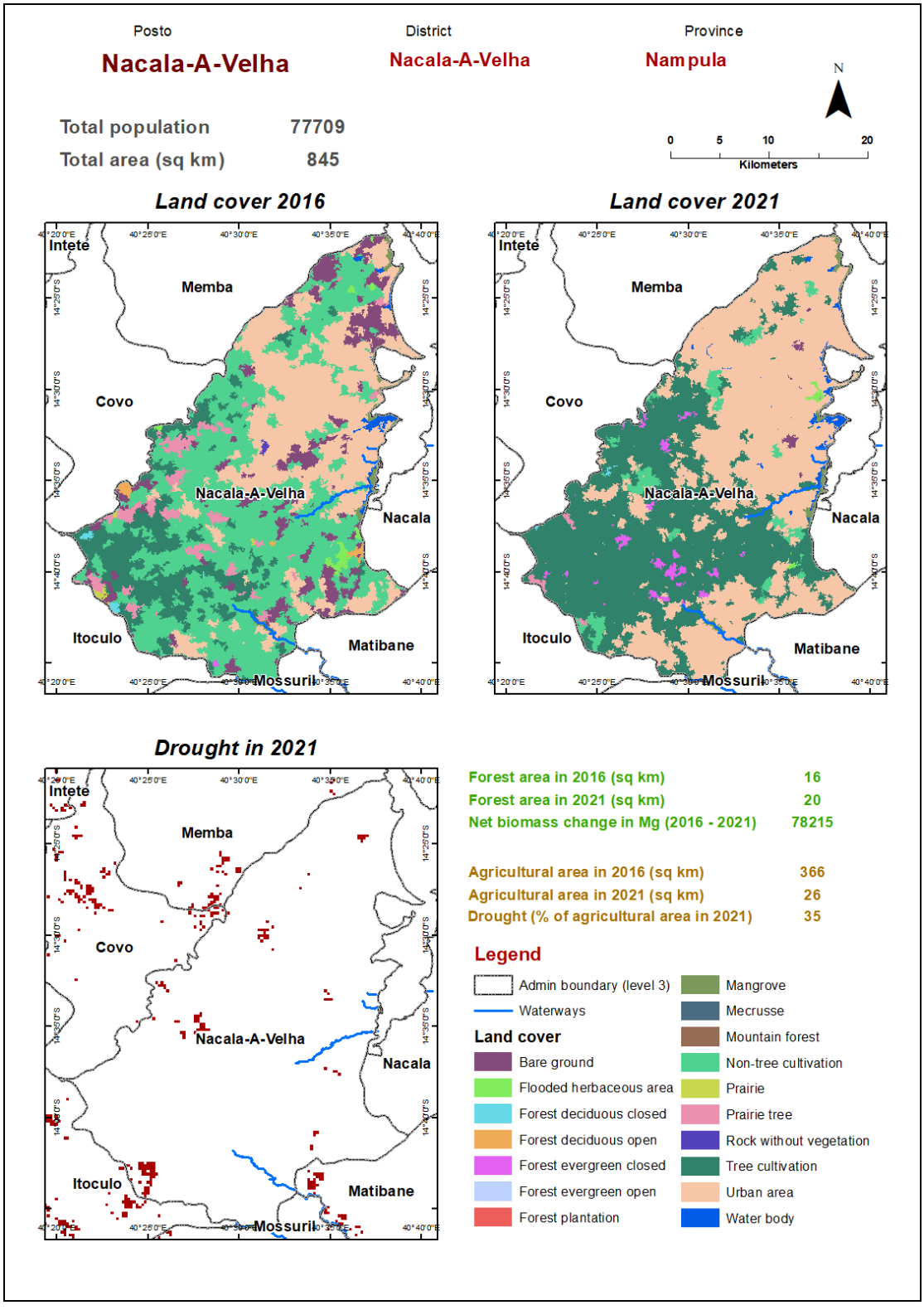

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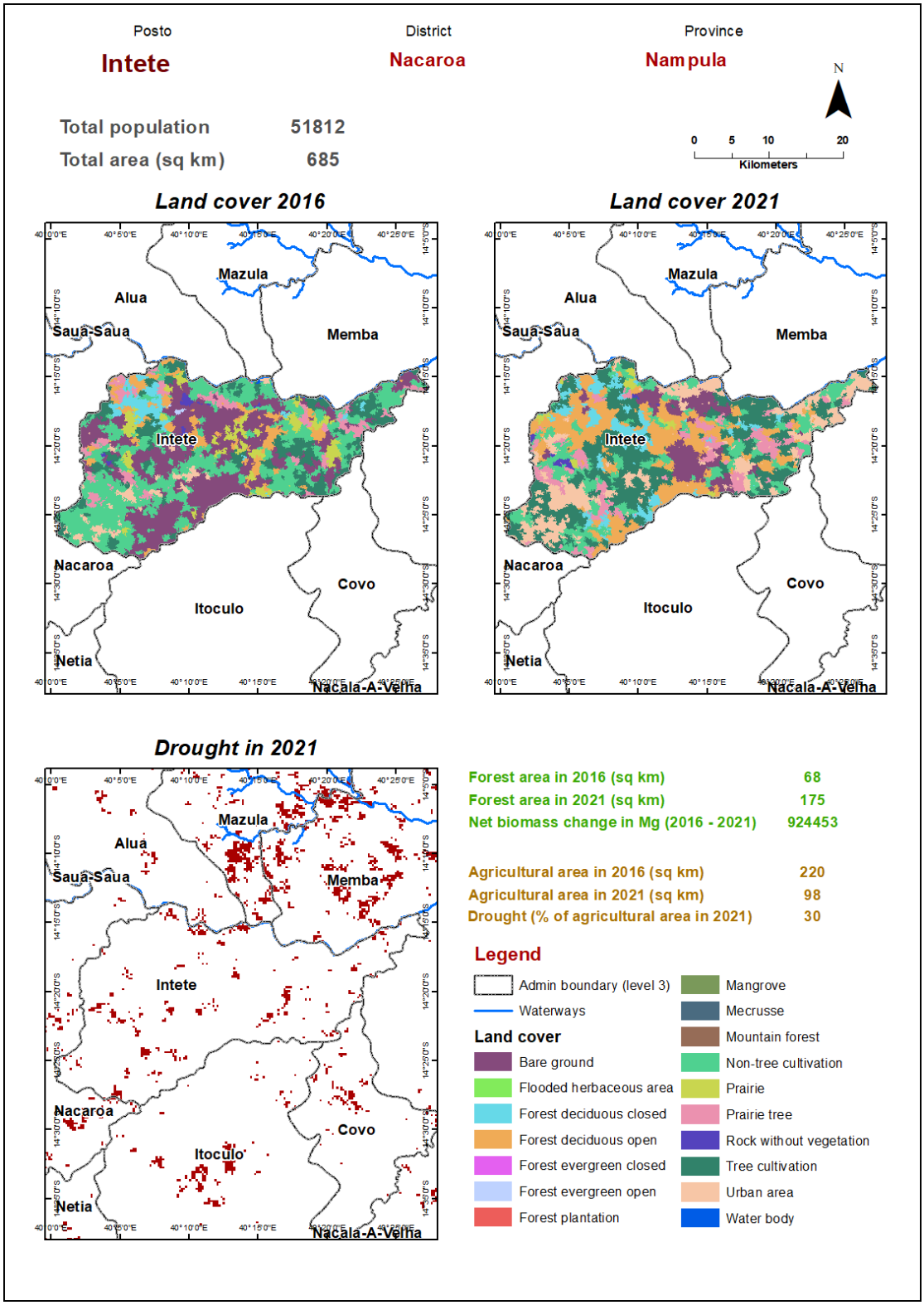

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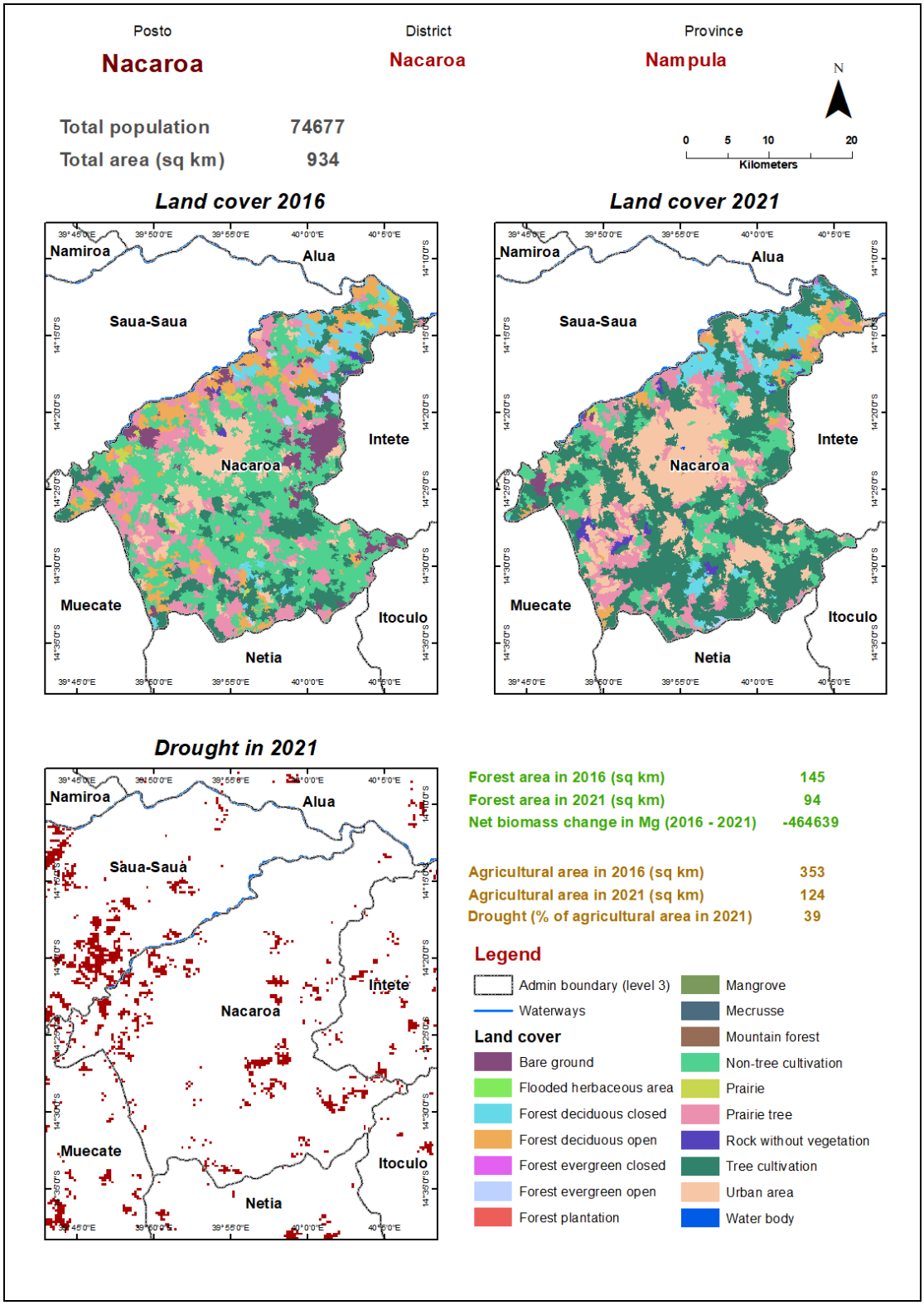

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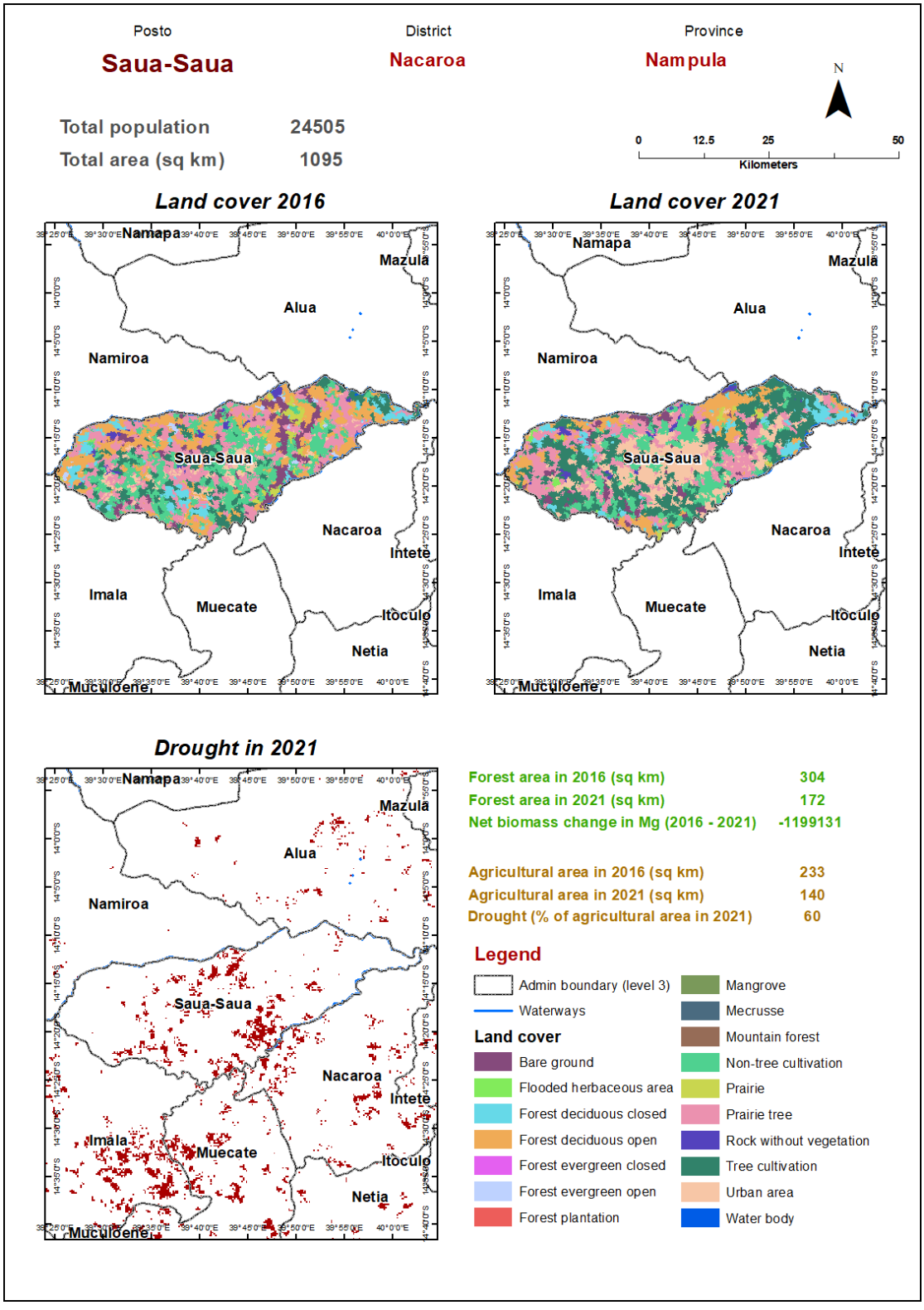

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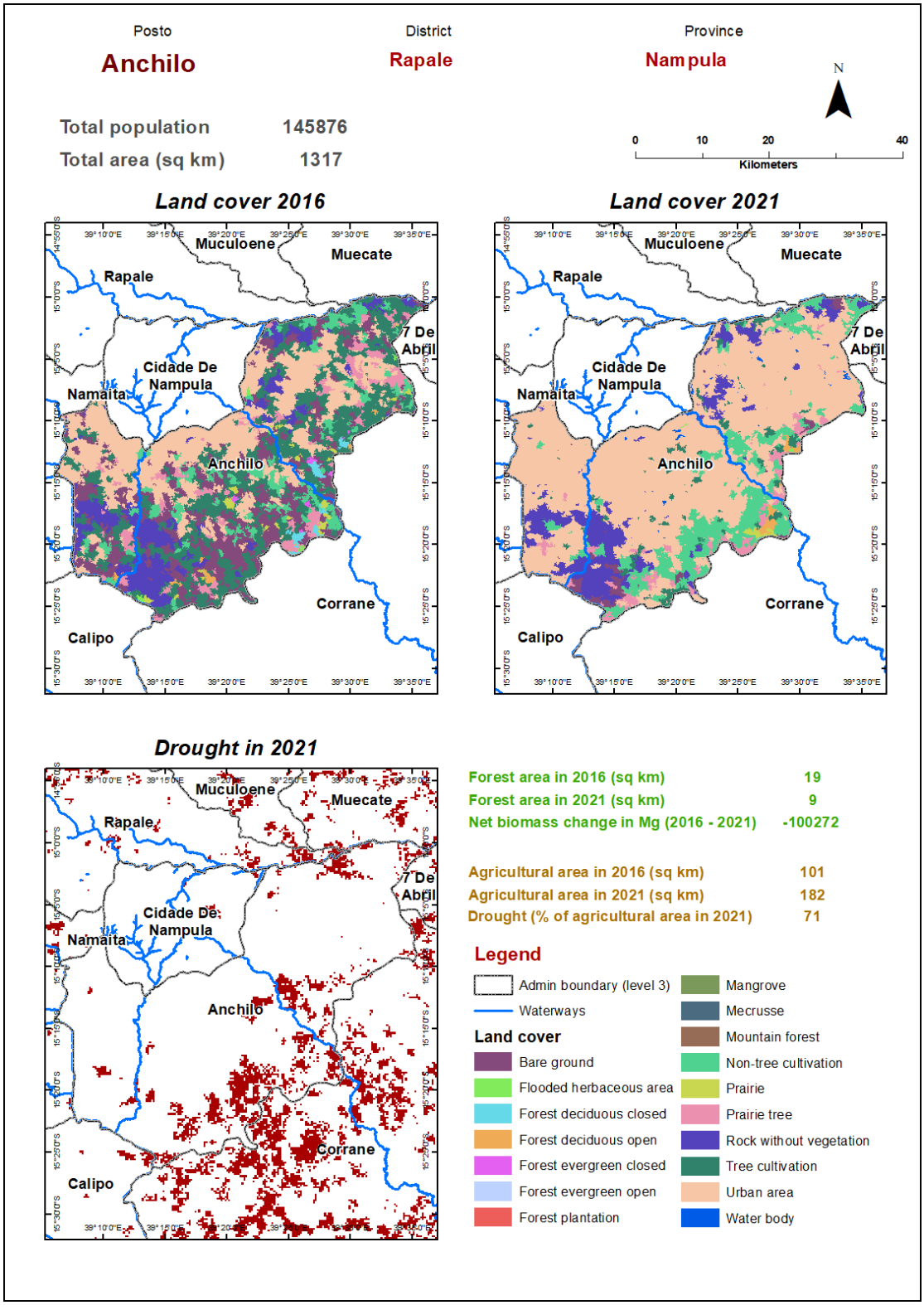

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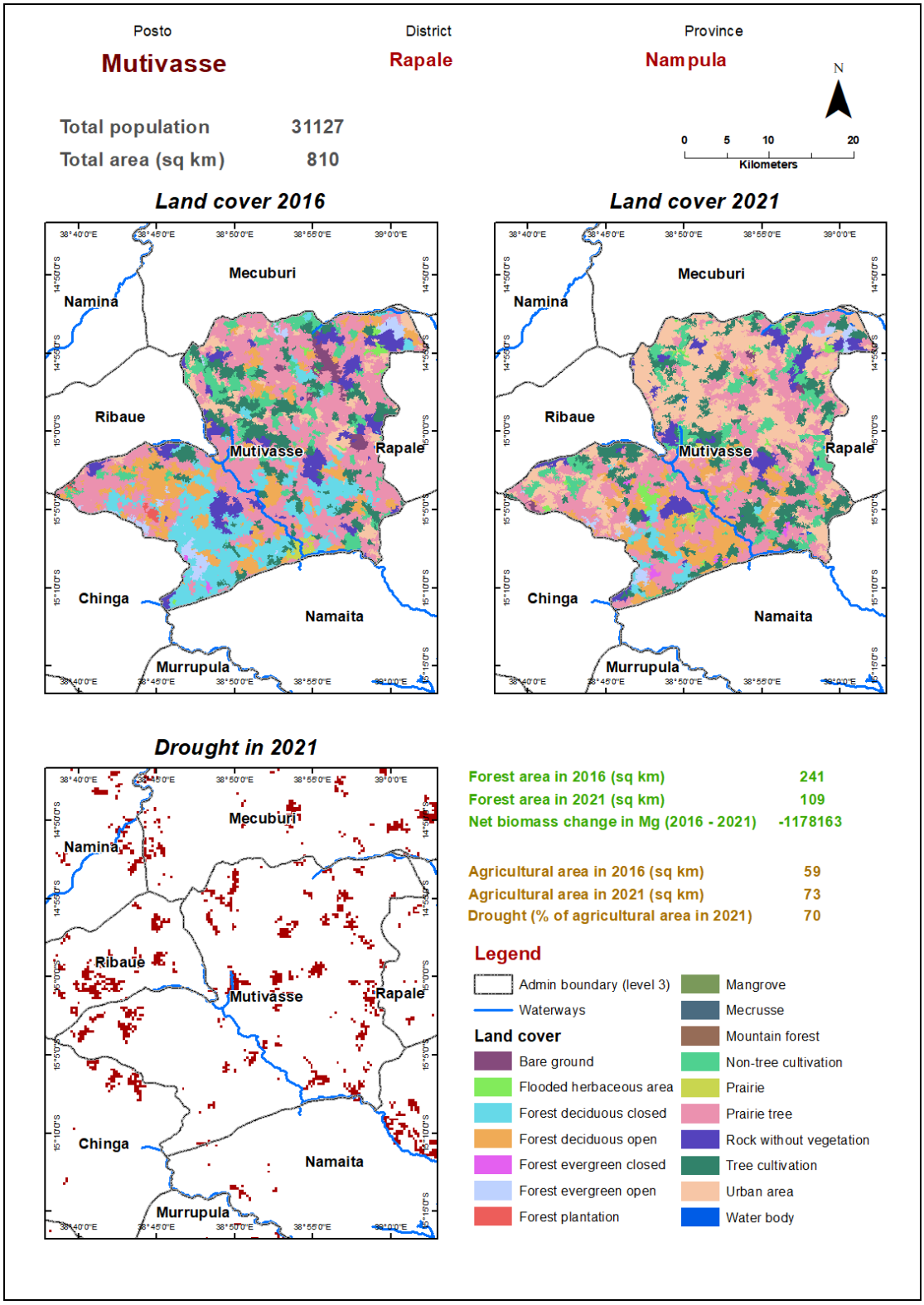

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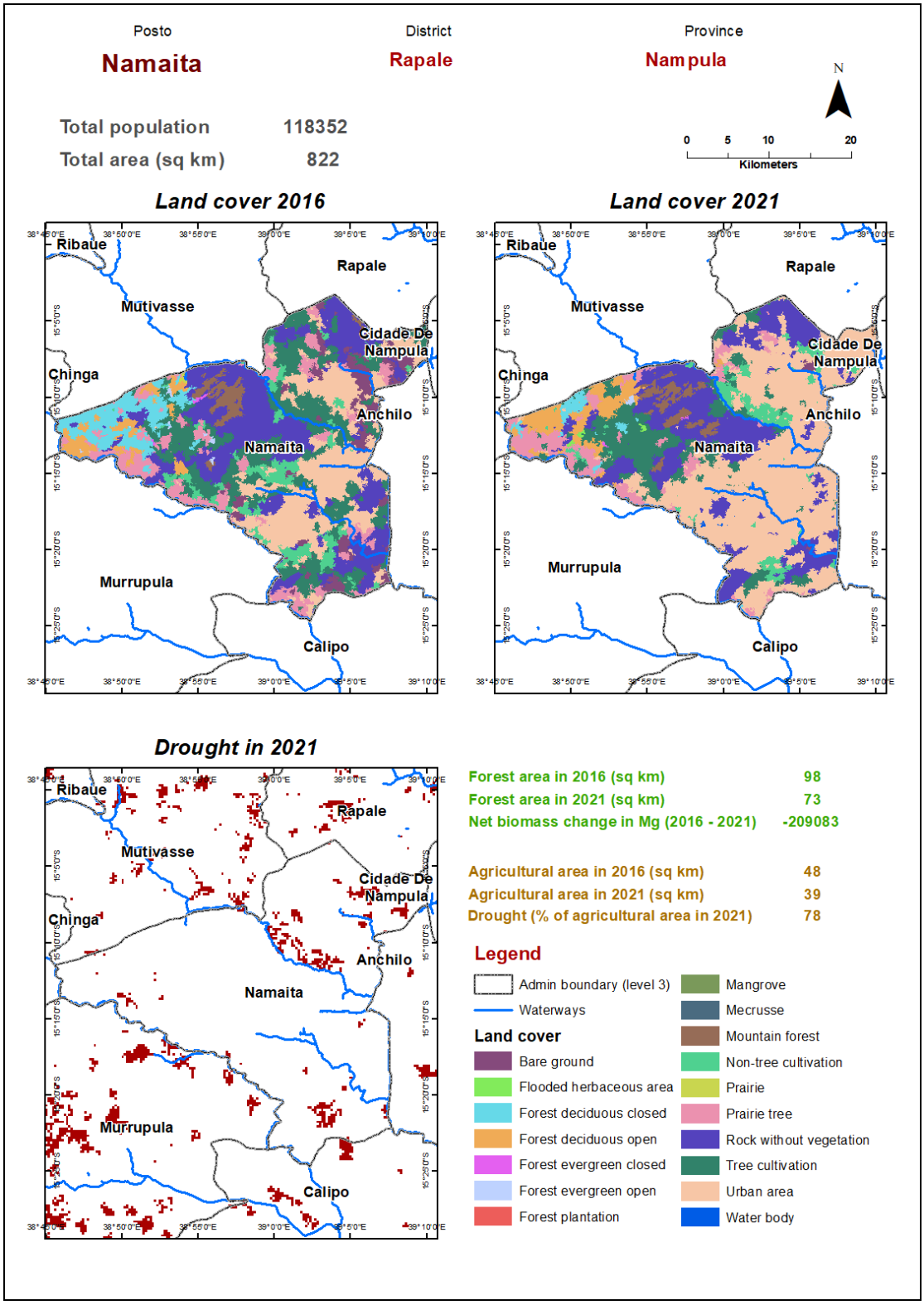

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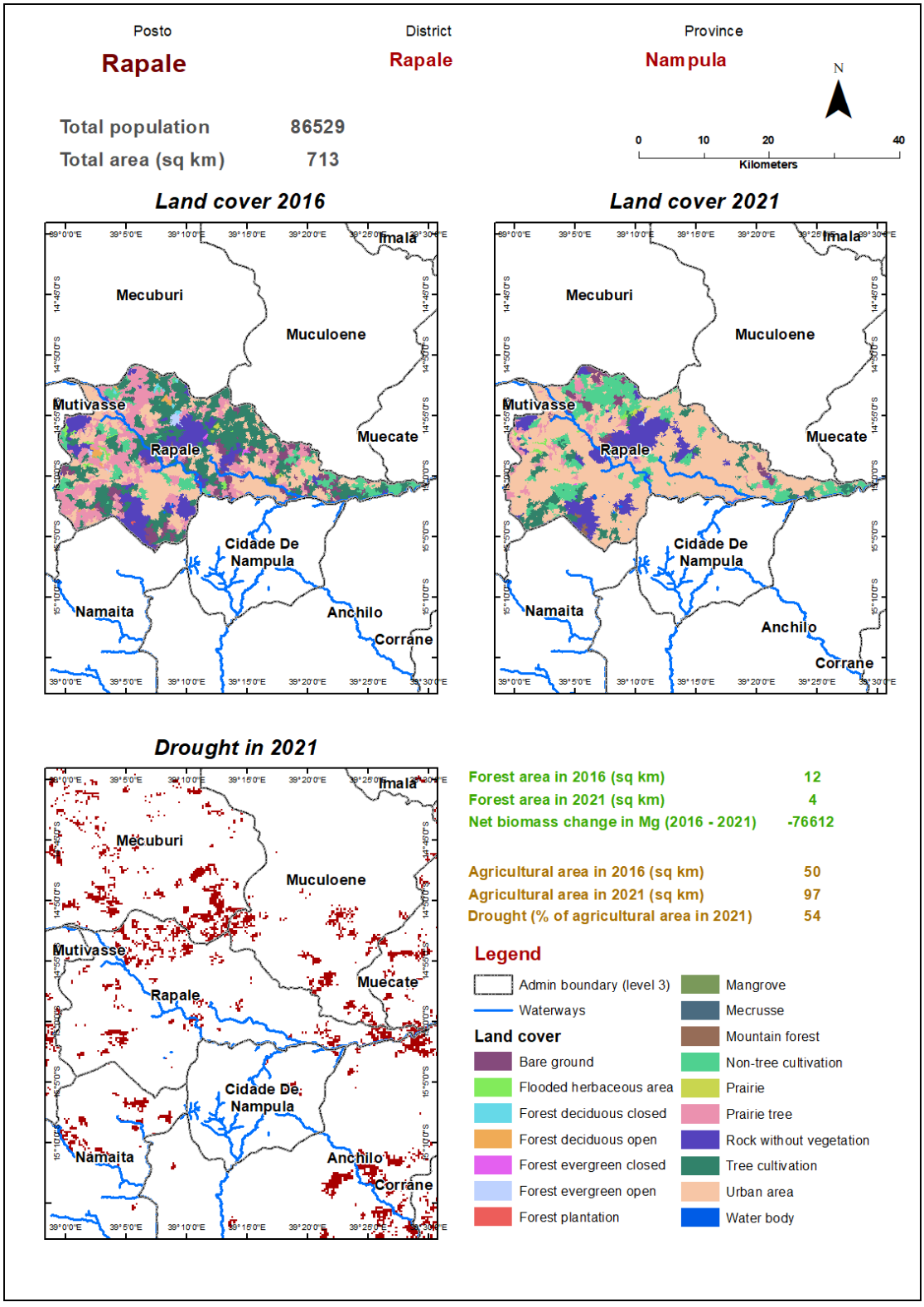

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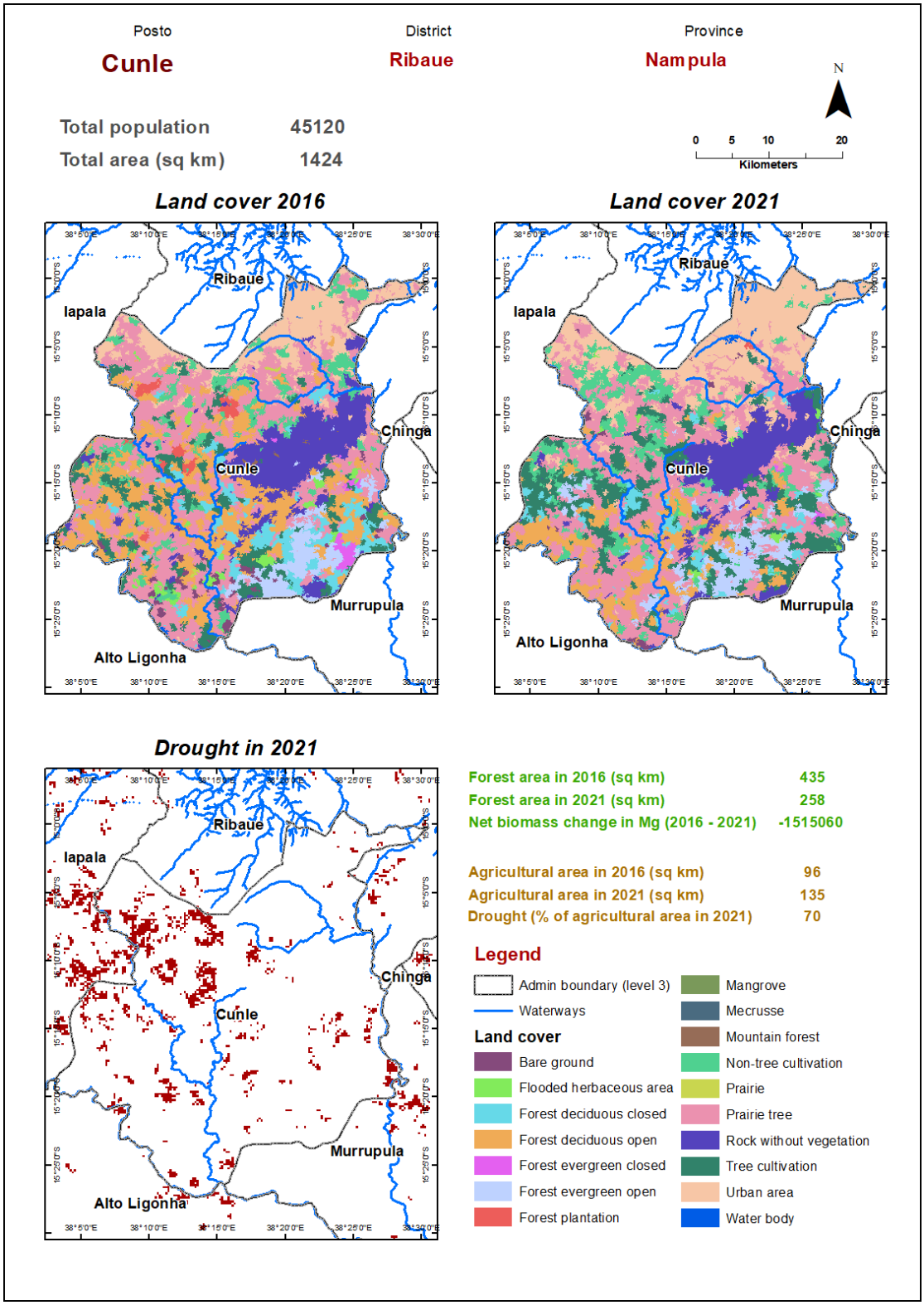

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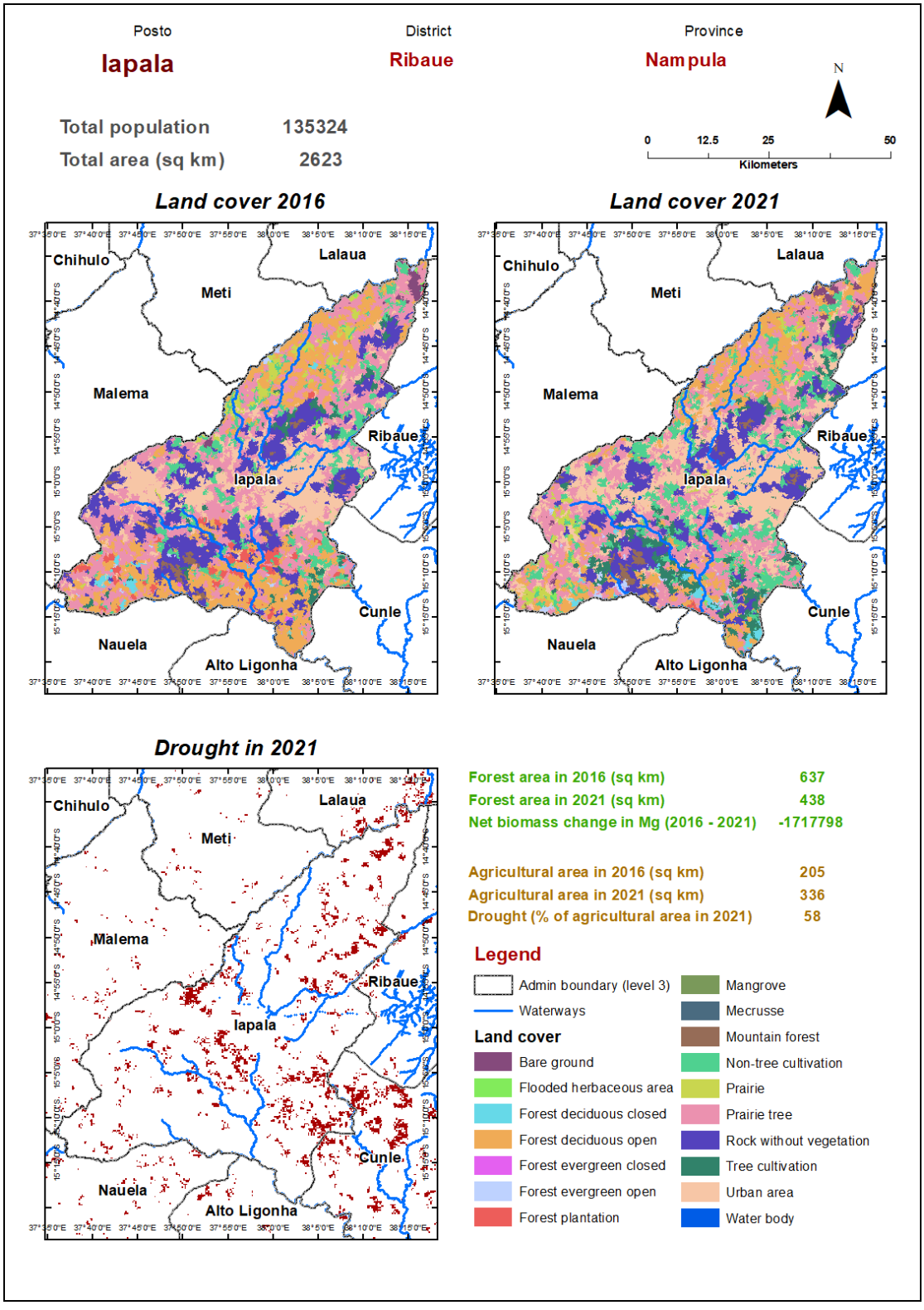

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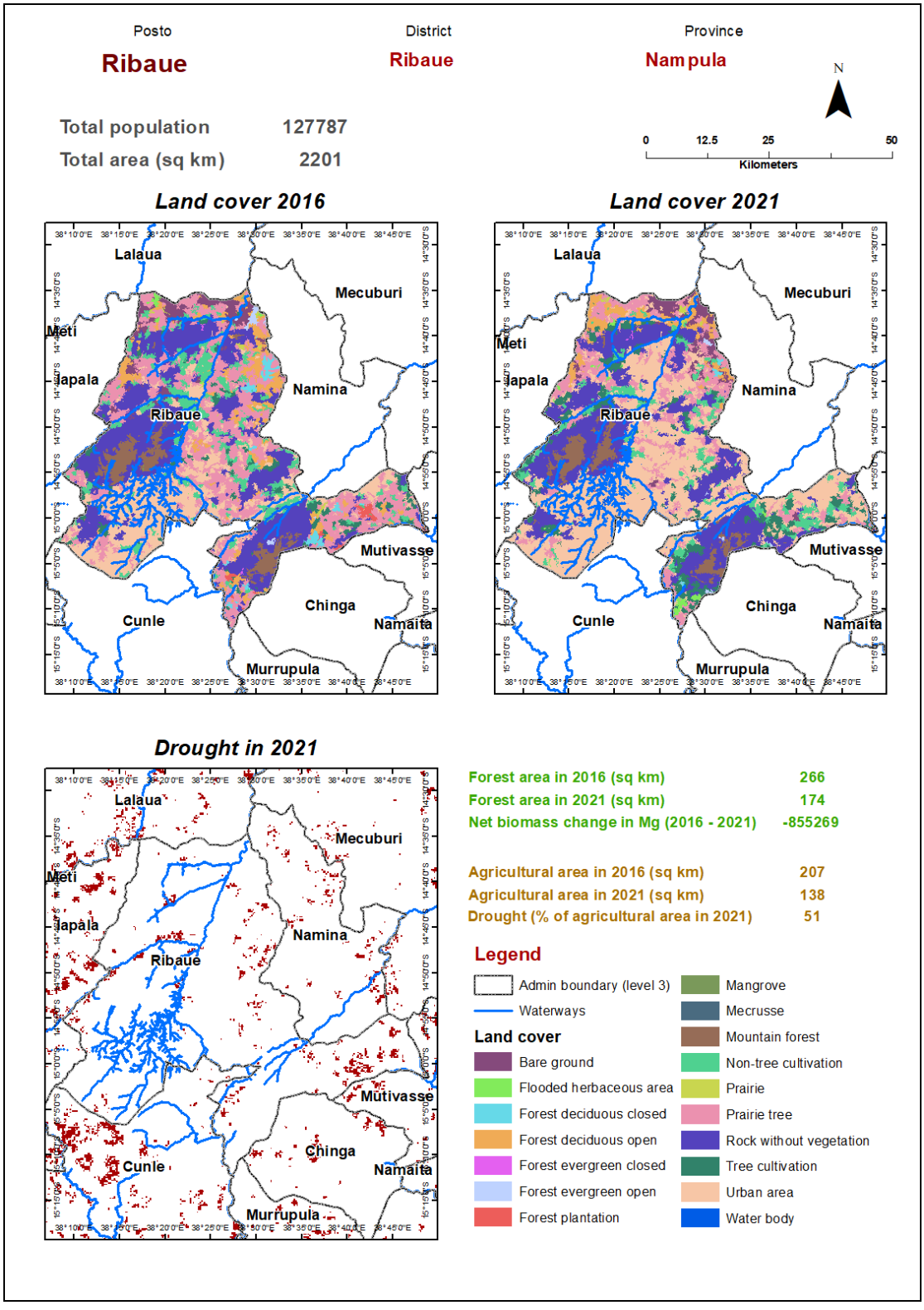

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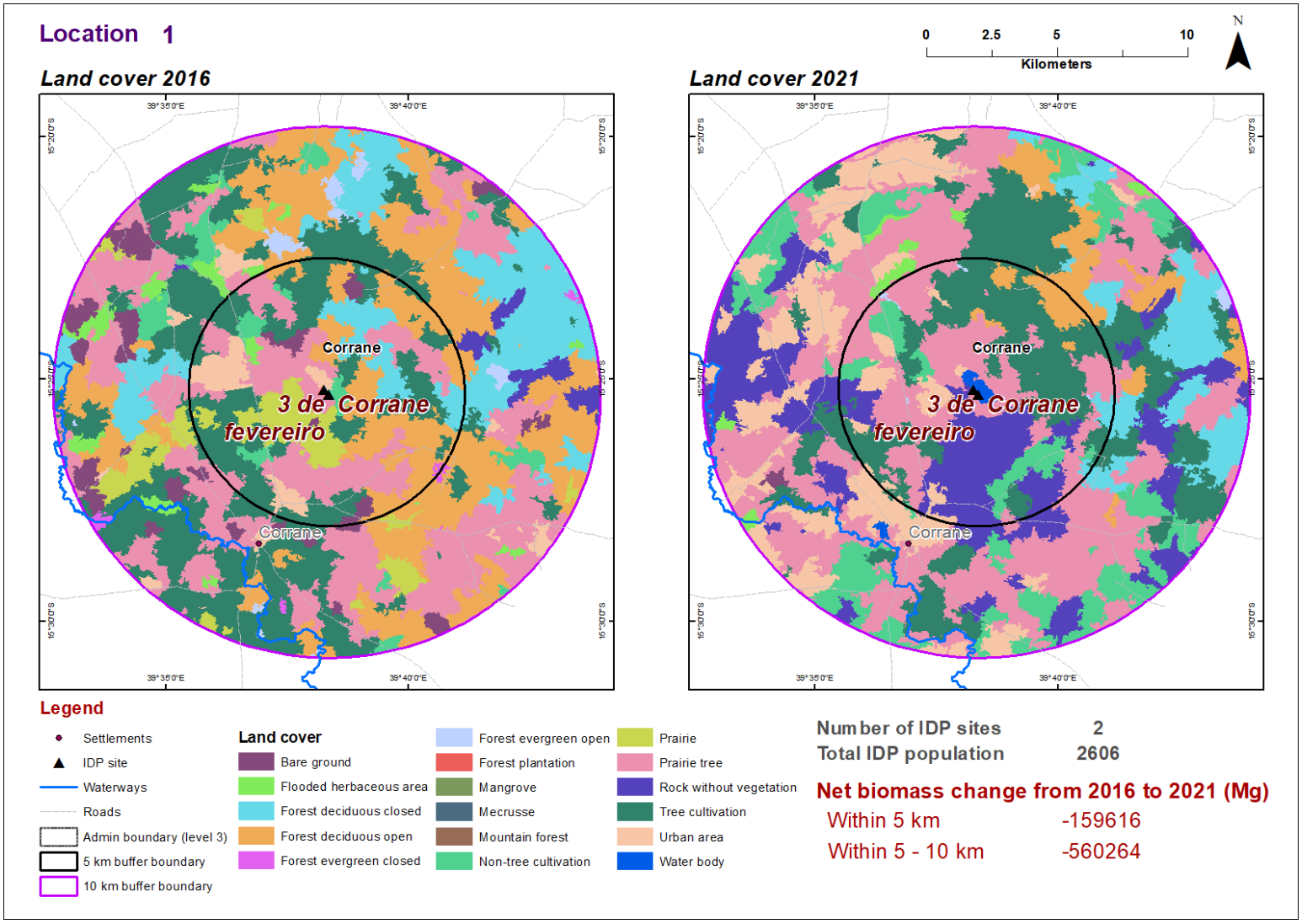
Appendix 03. Change in biomass between 2016 to 2021 by internally displaced person(s) settlements



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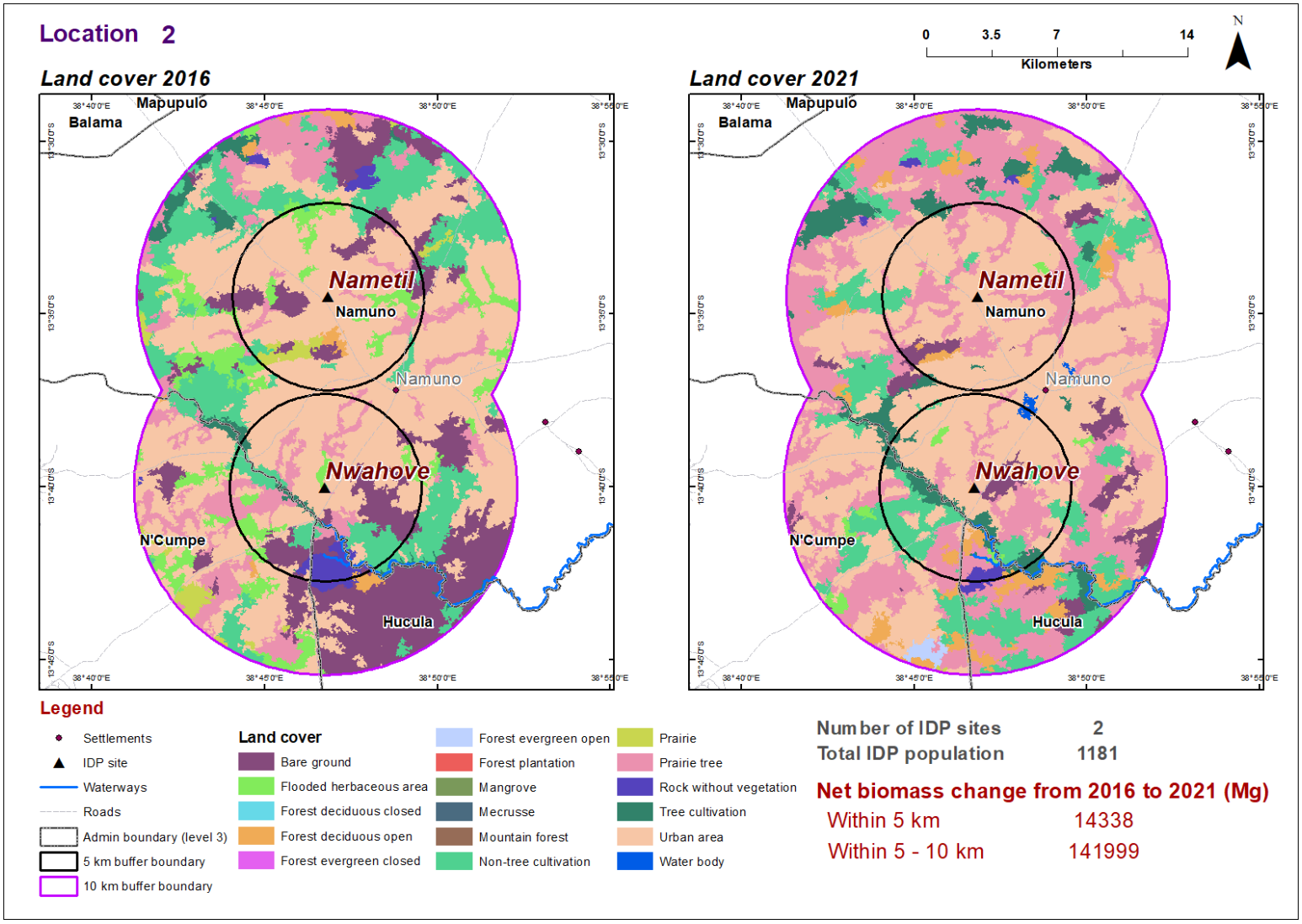

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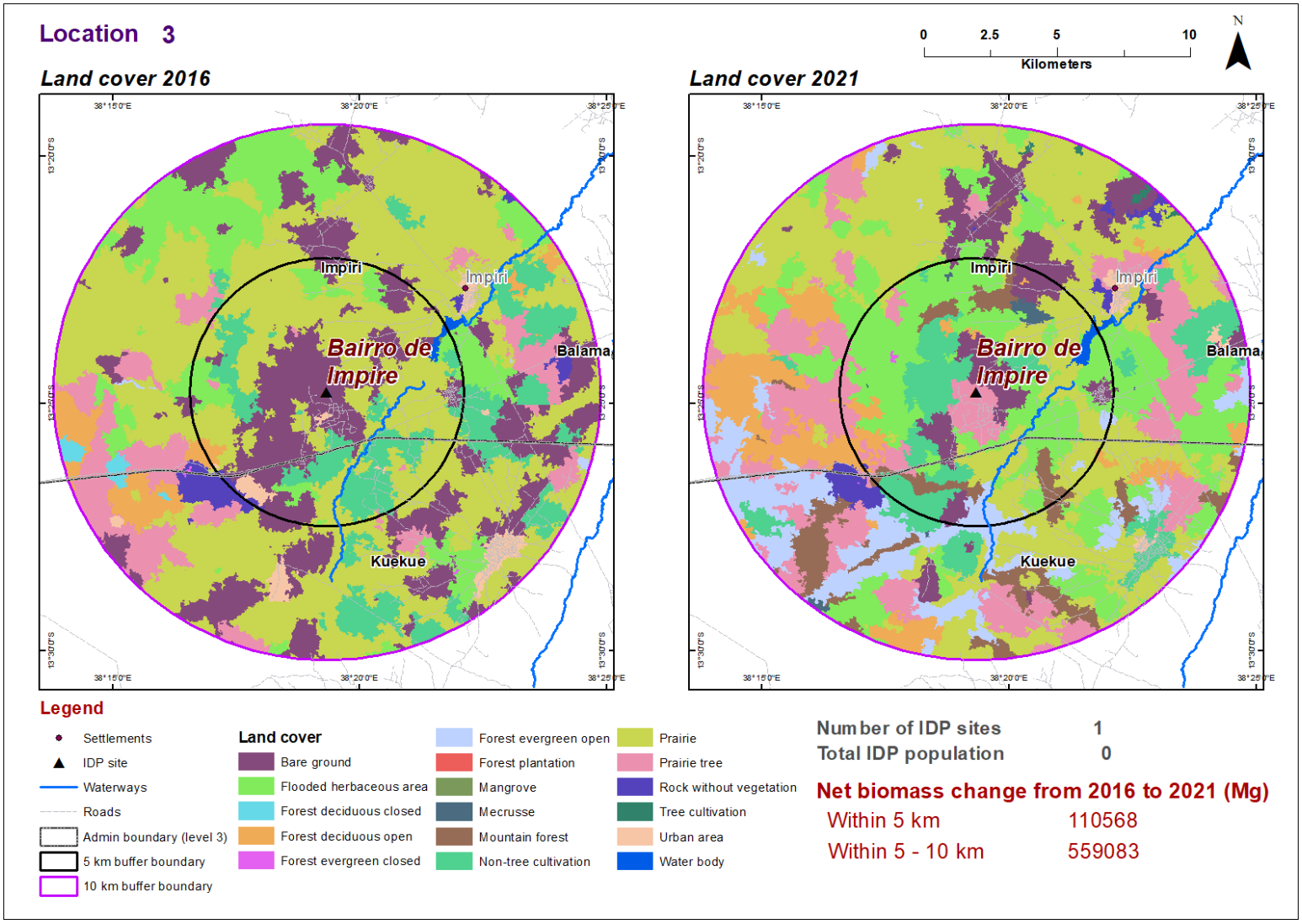

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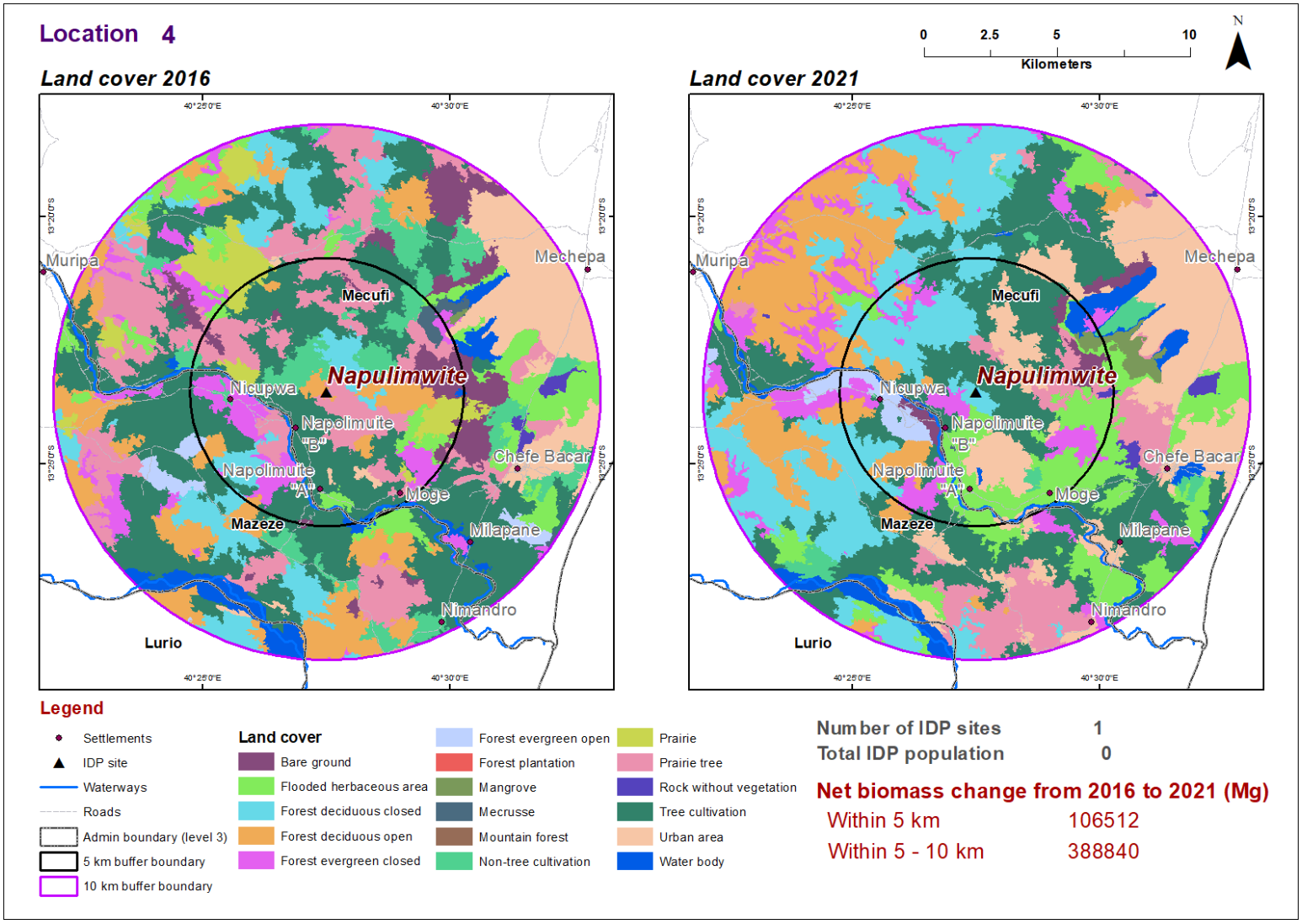

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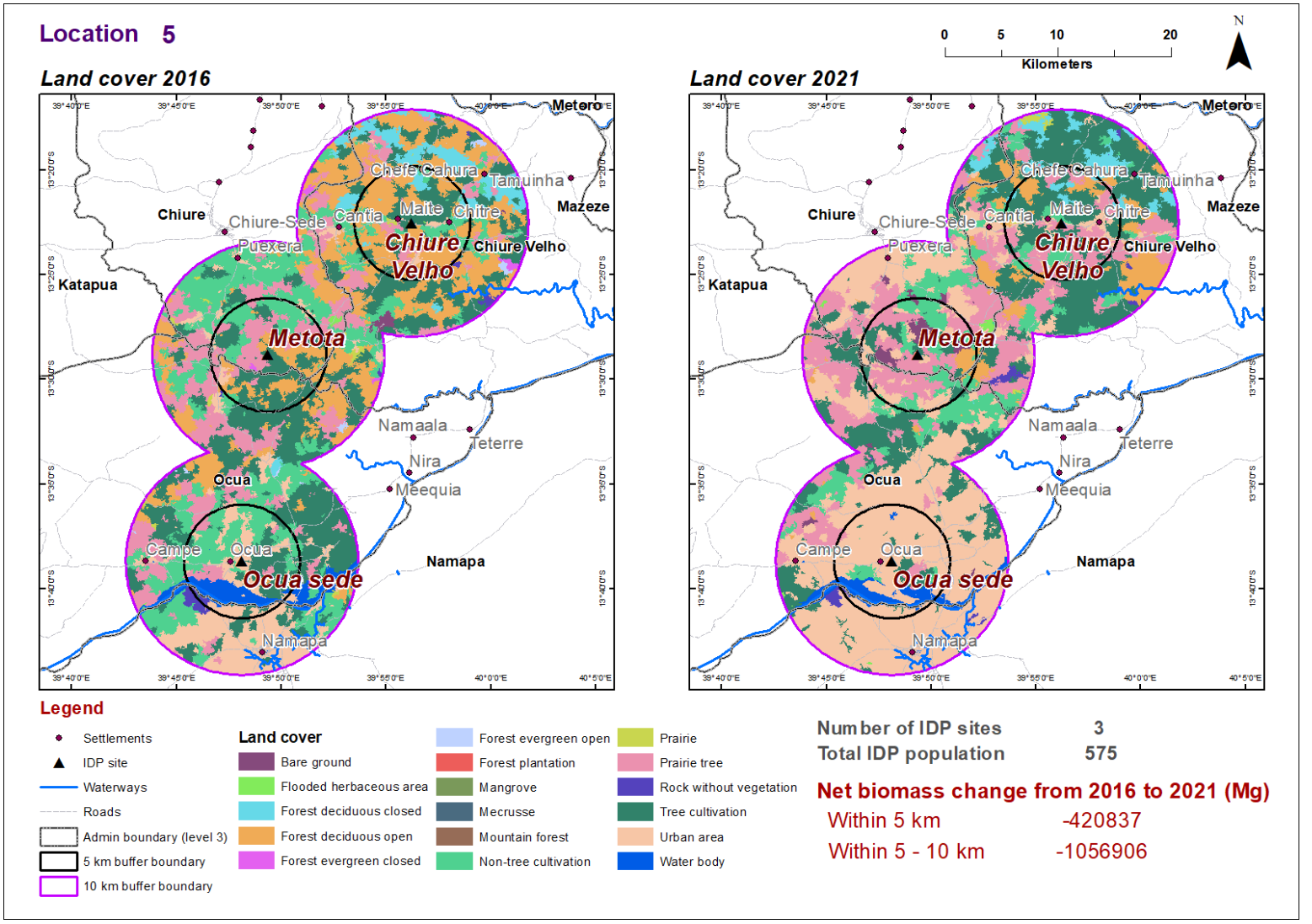

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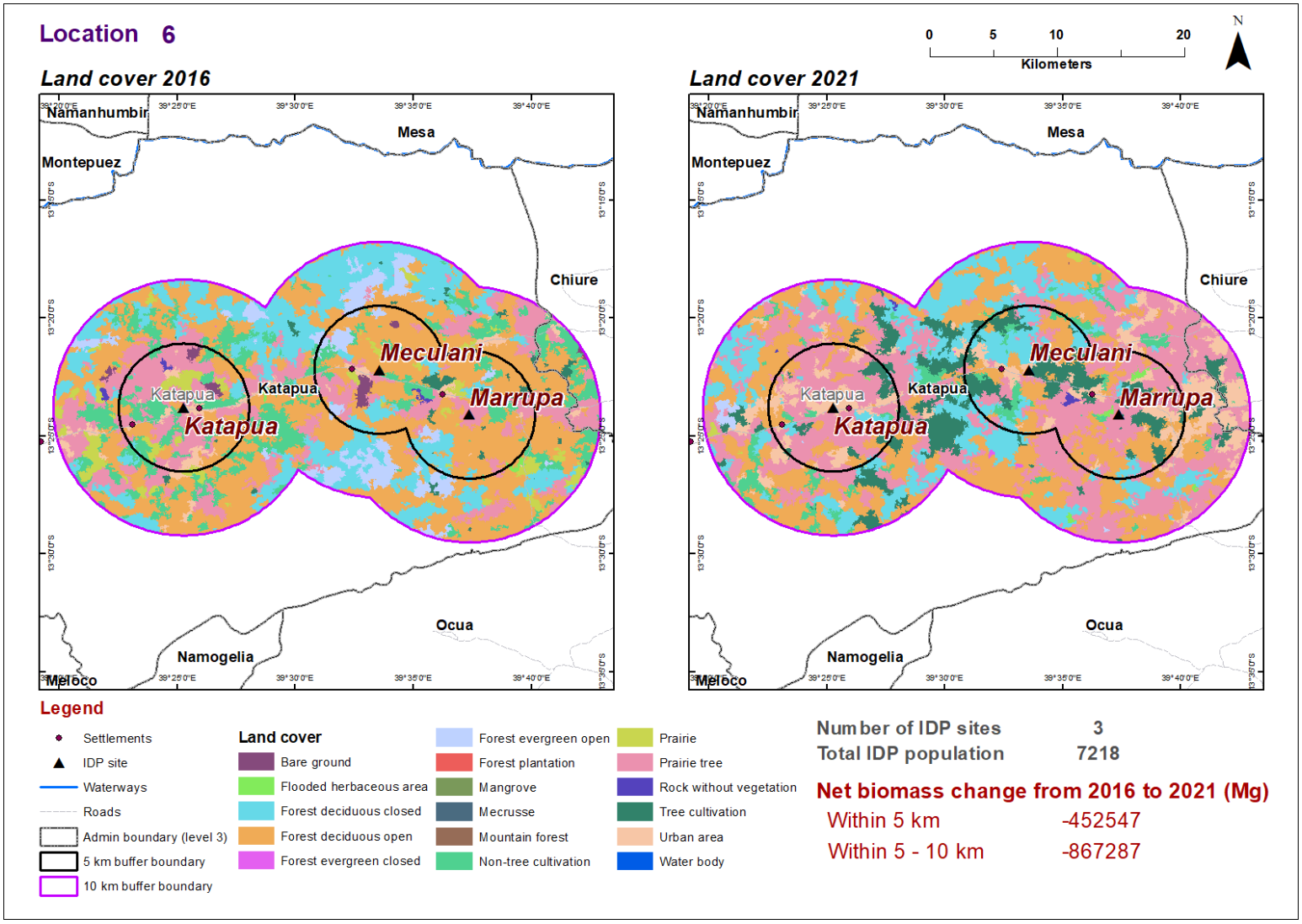

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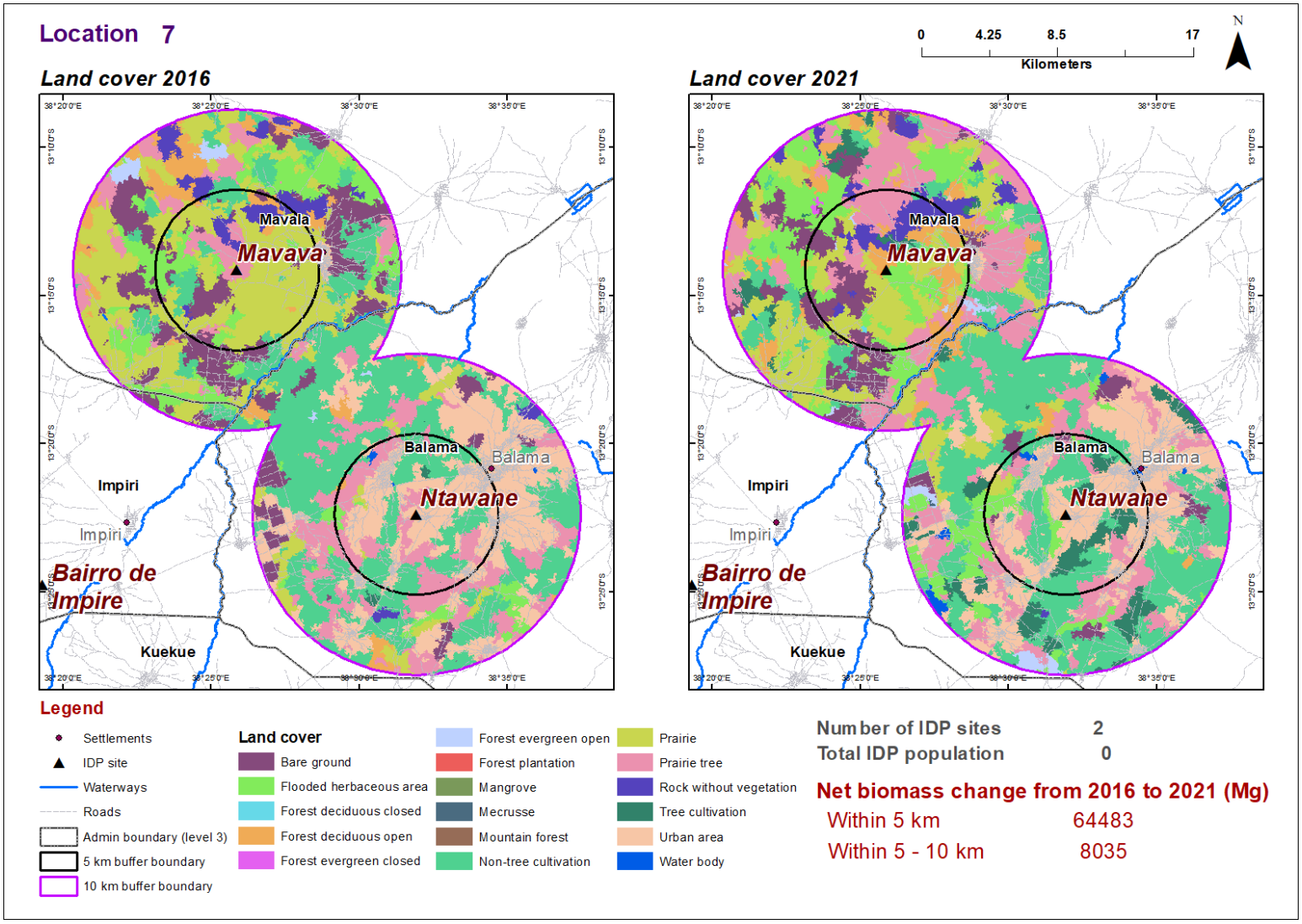

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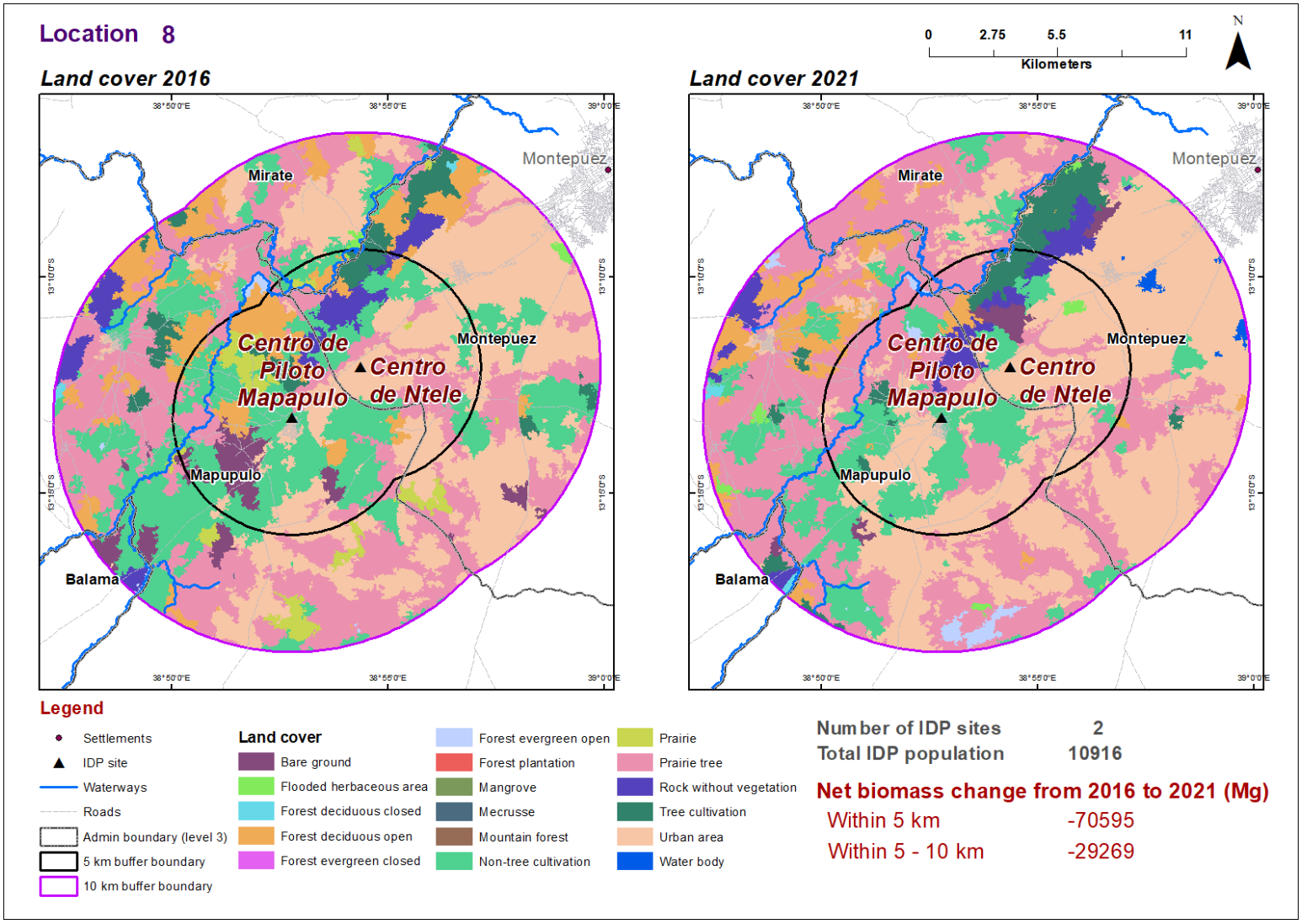

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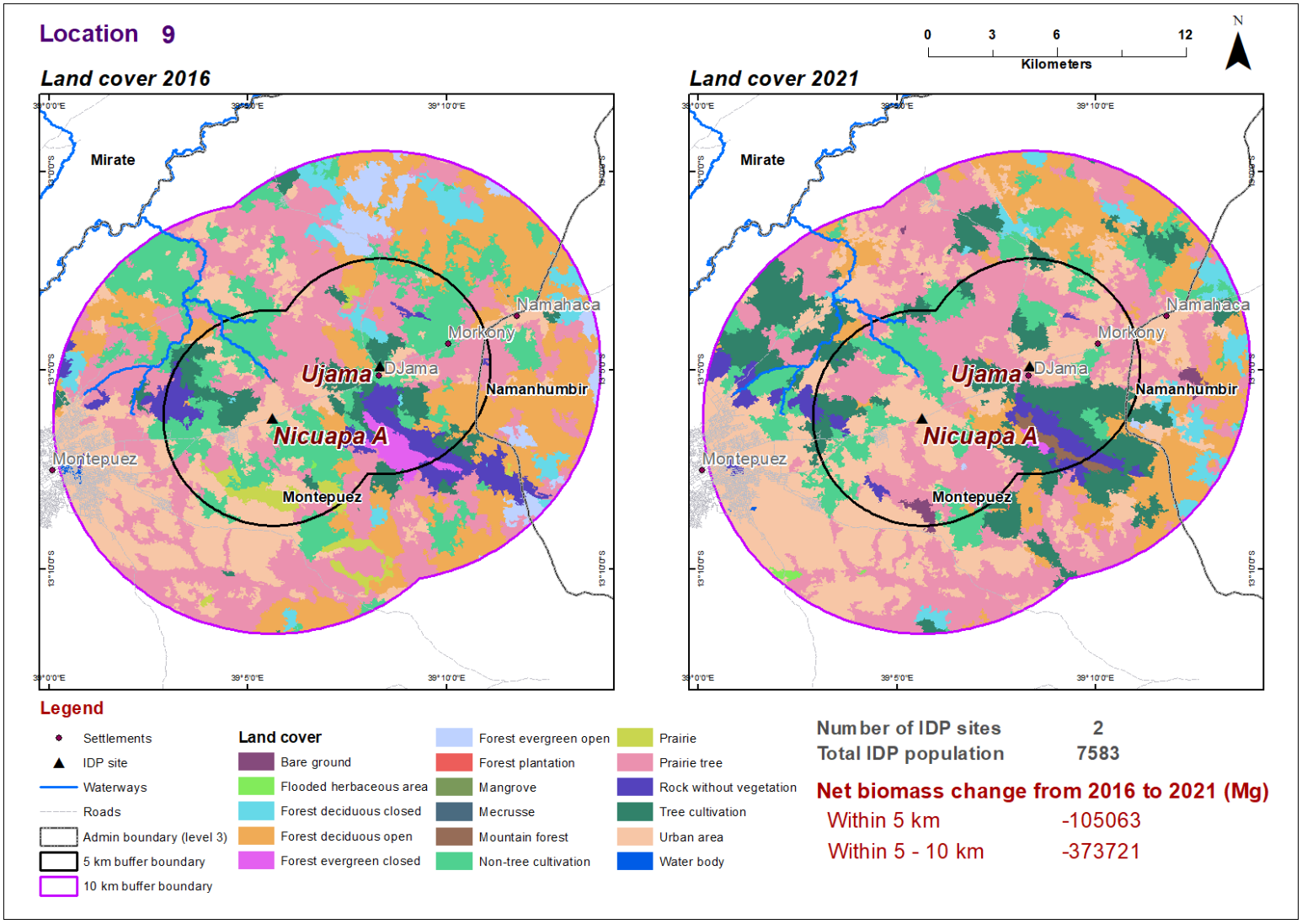

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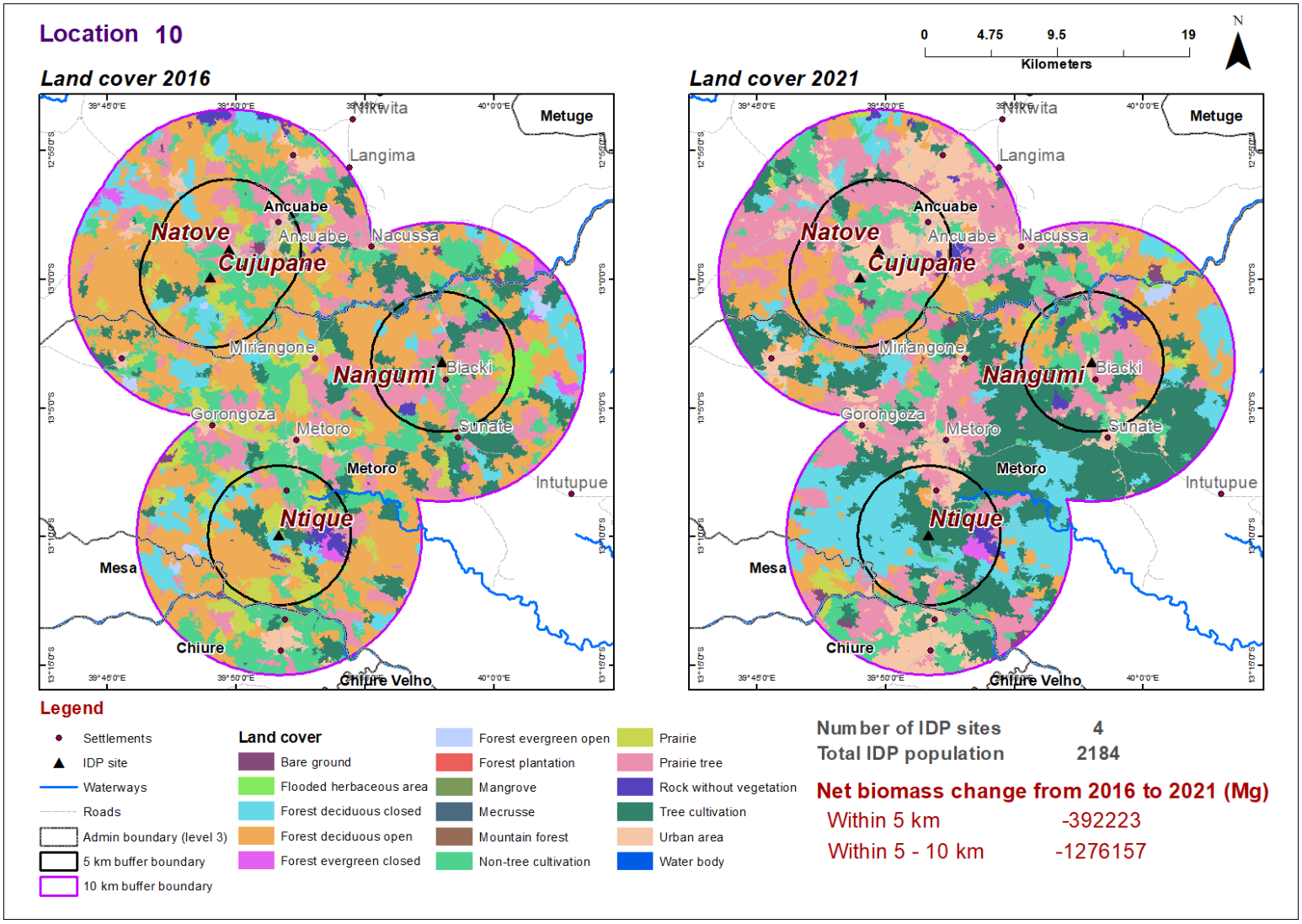

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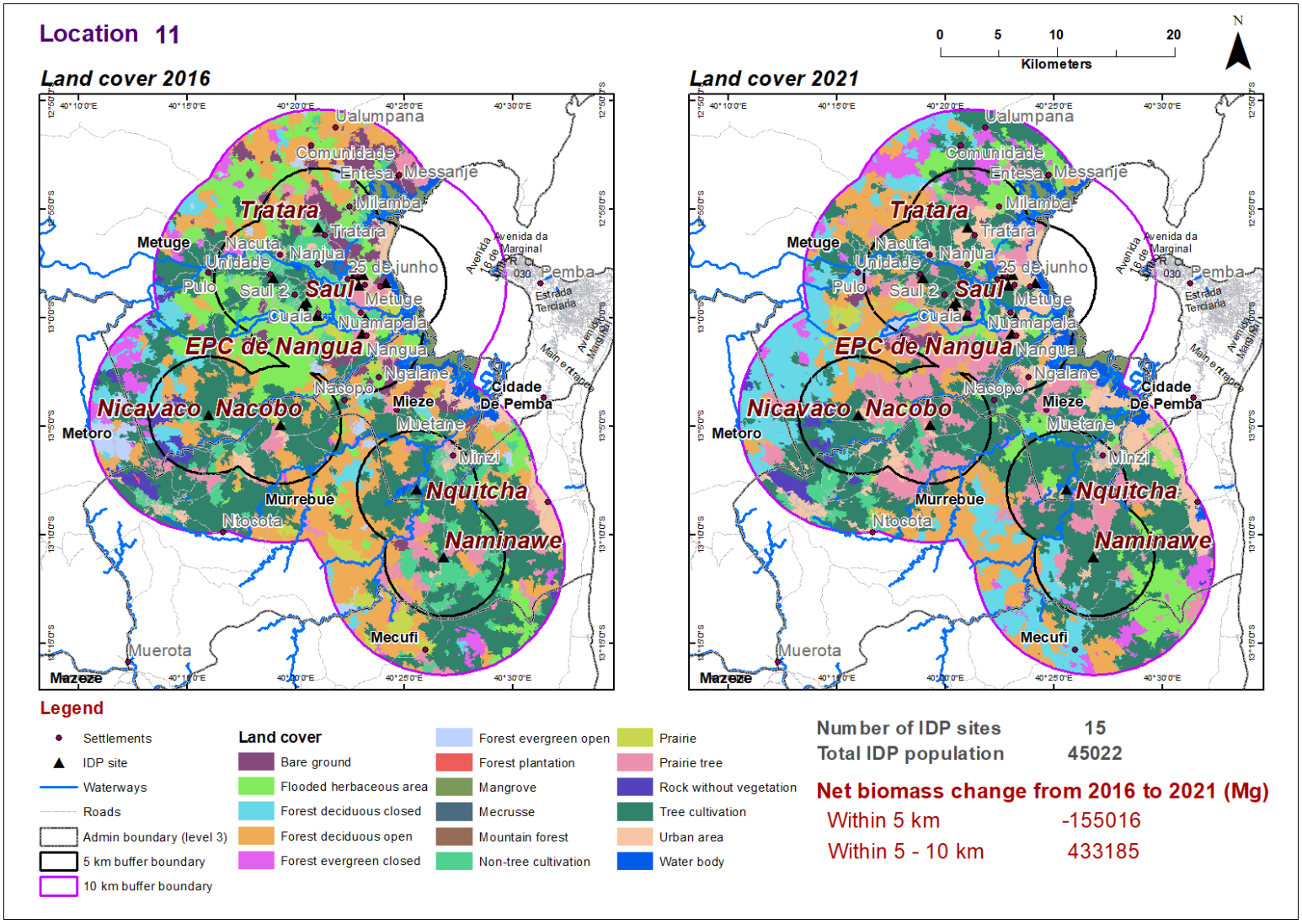

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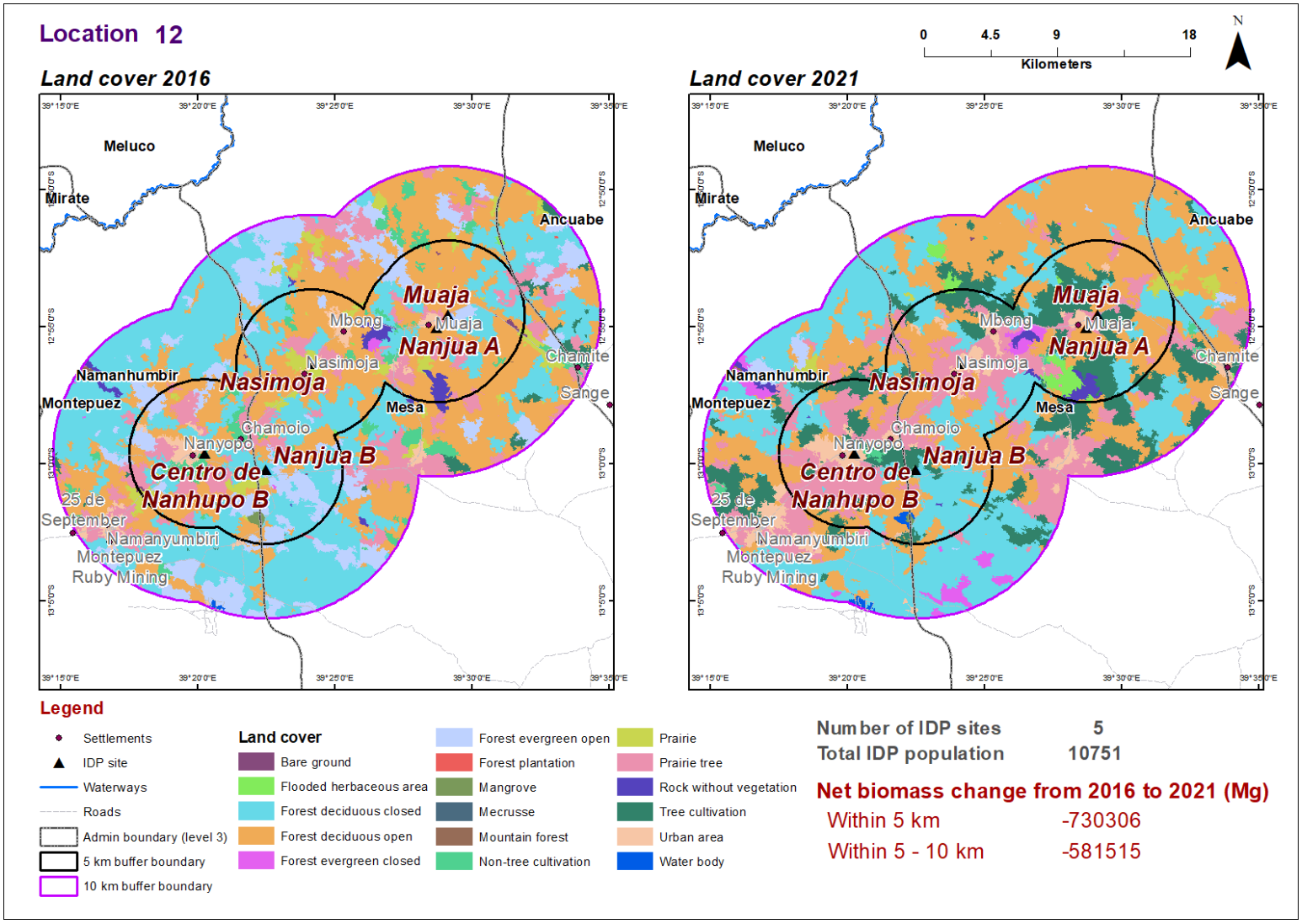

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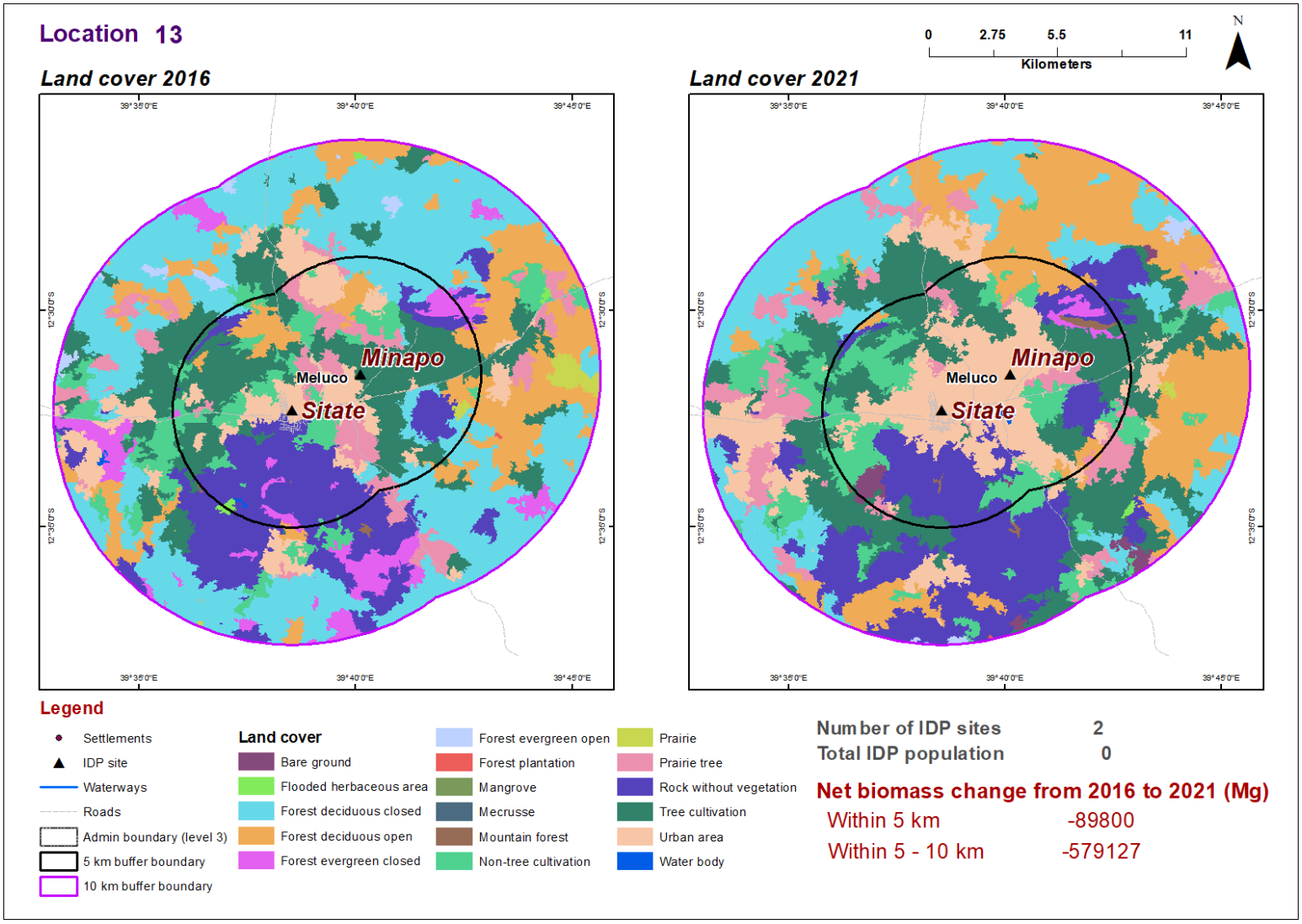

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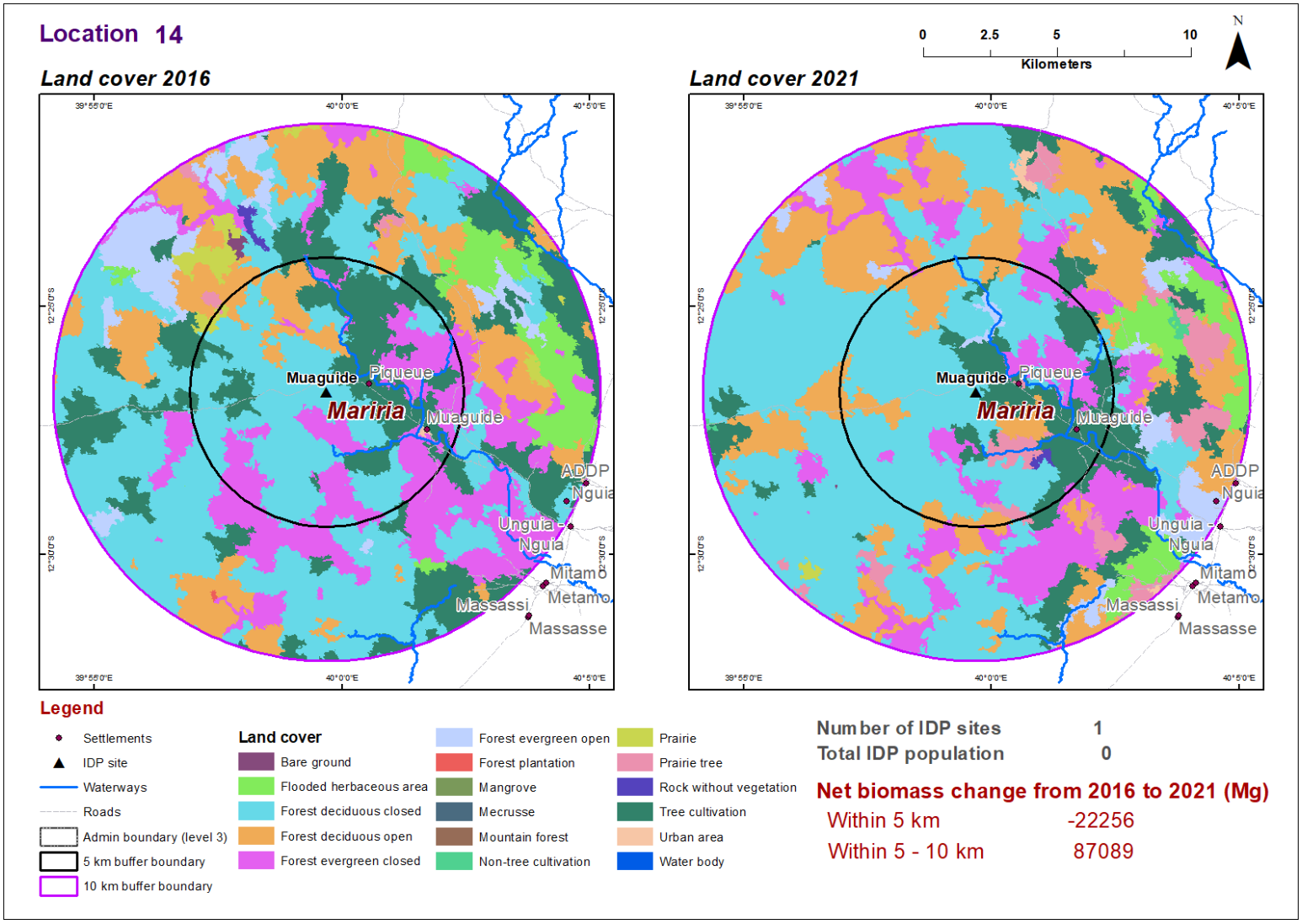

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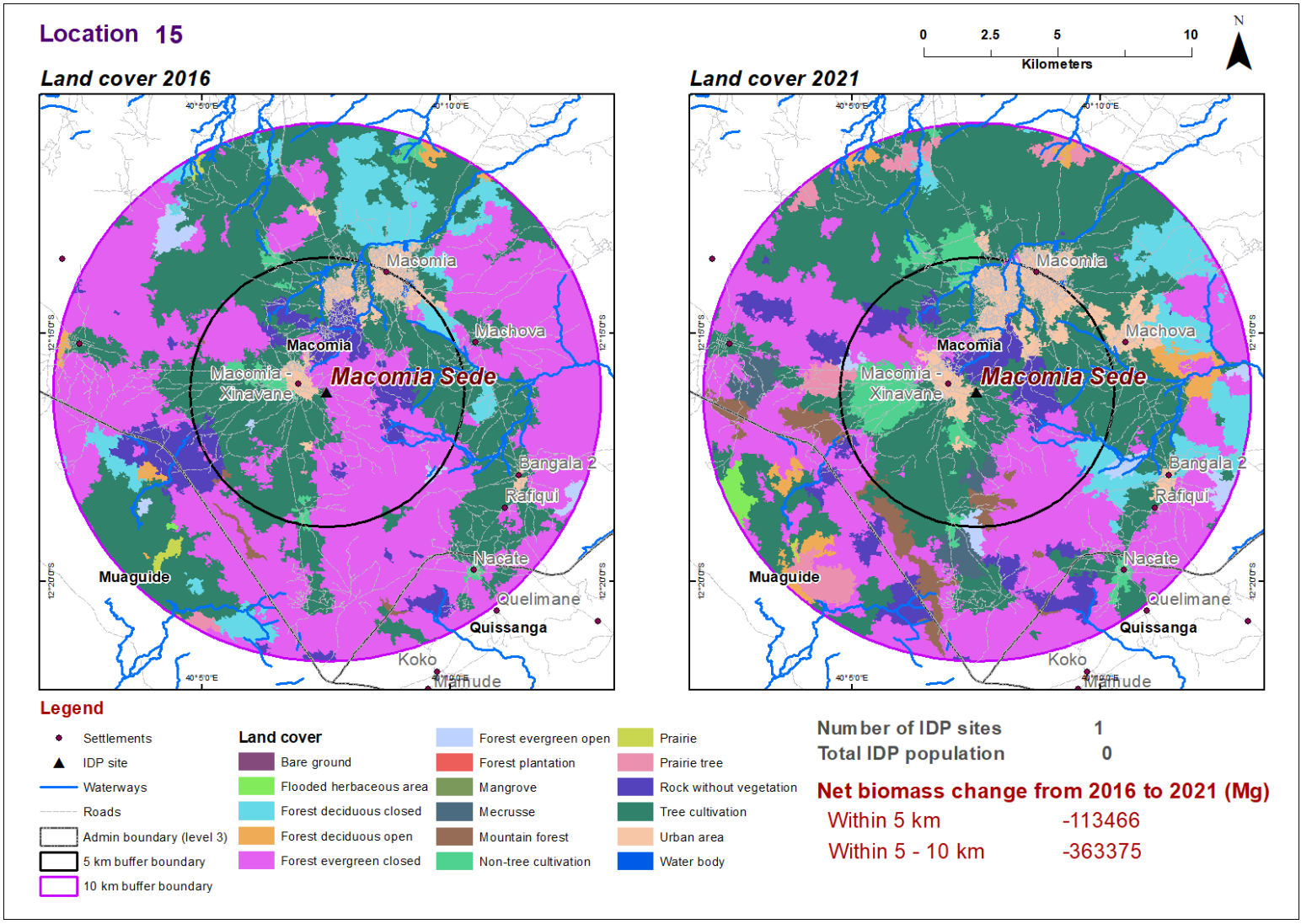

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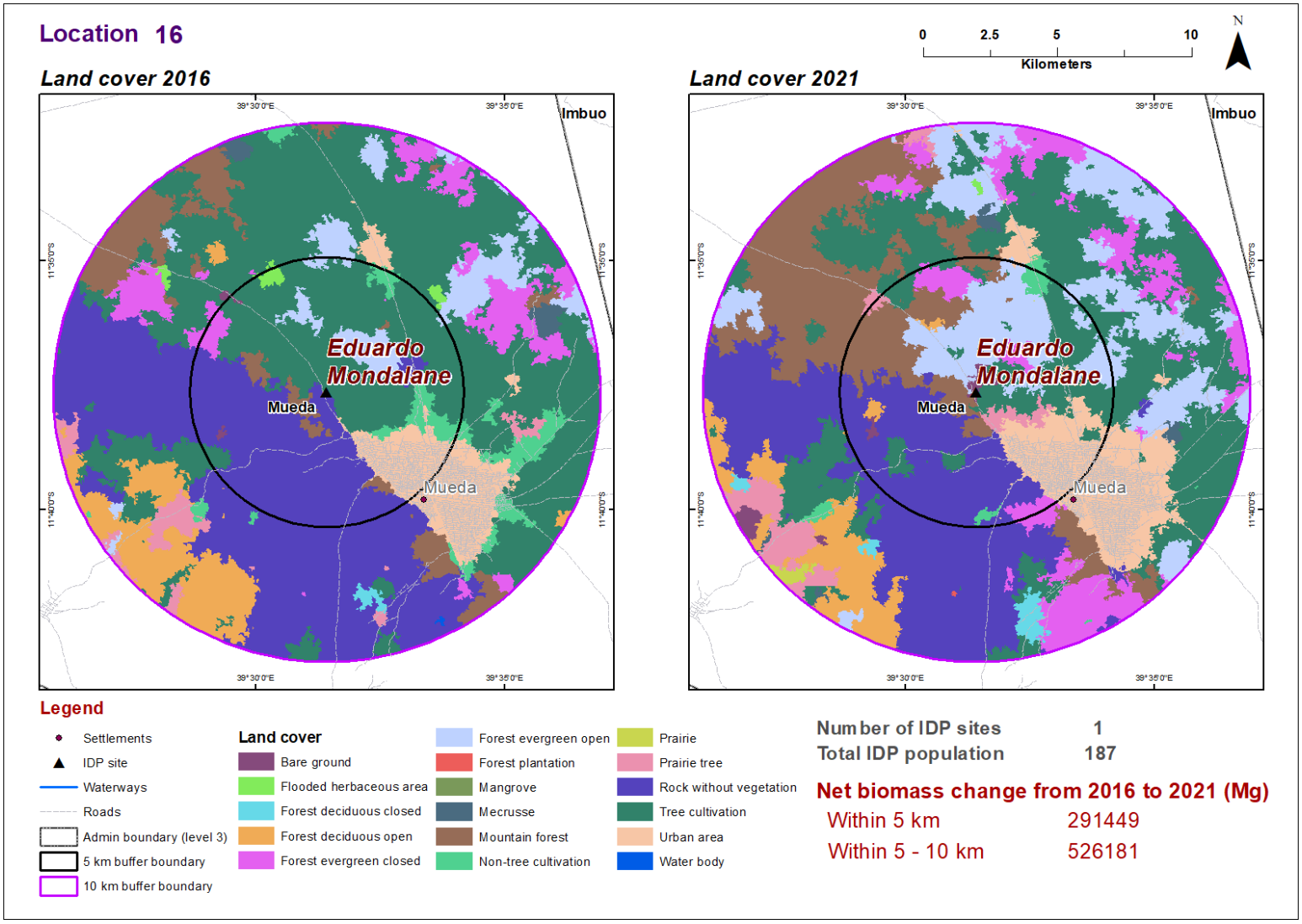

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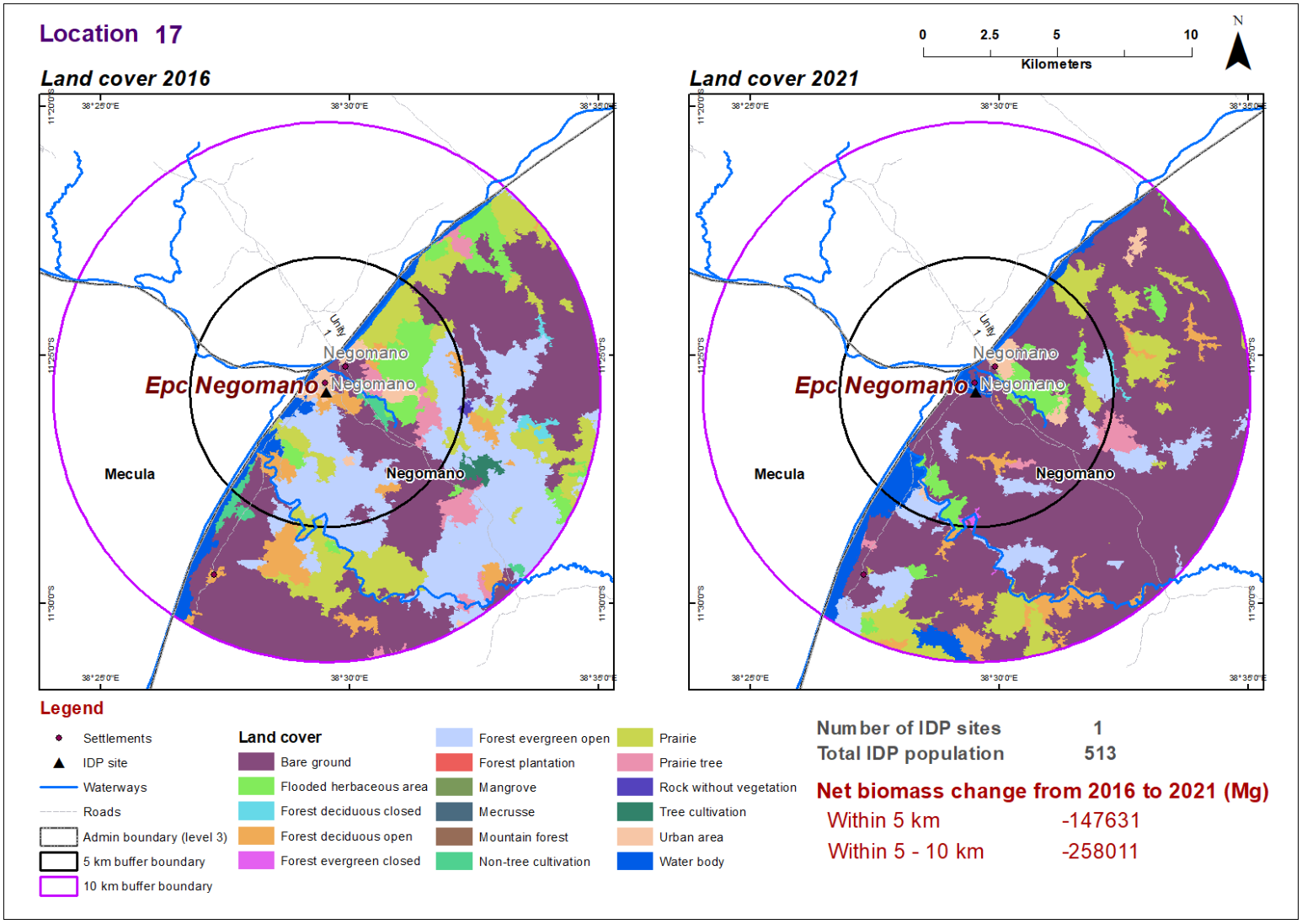

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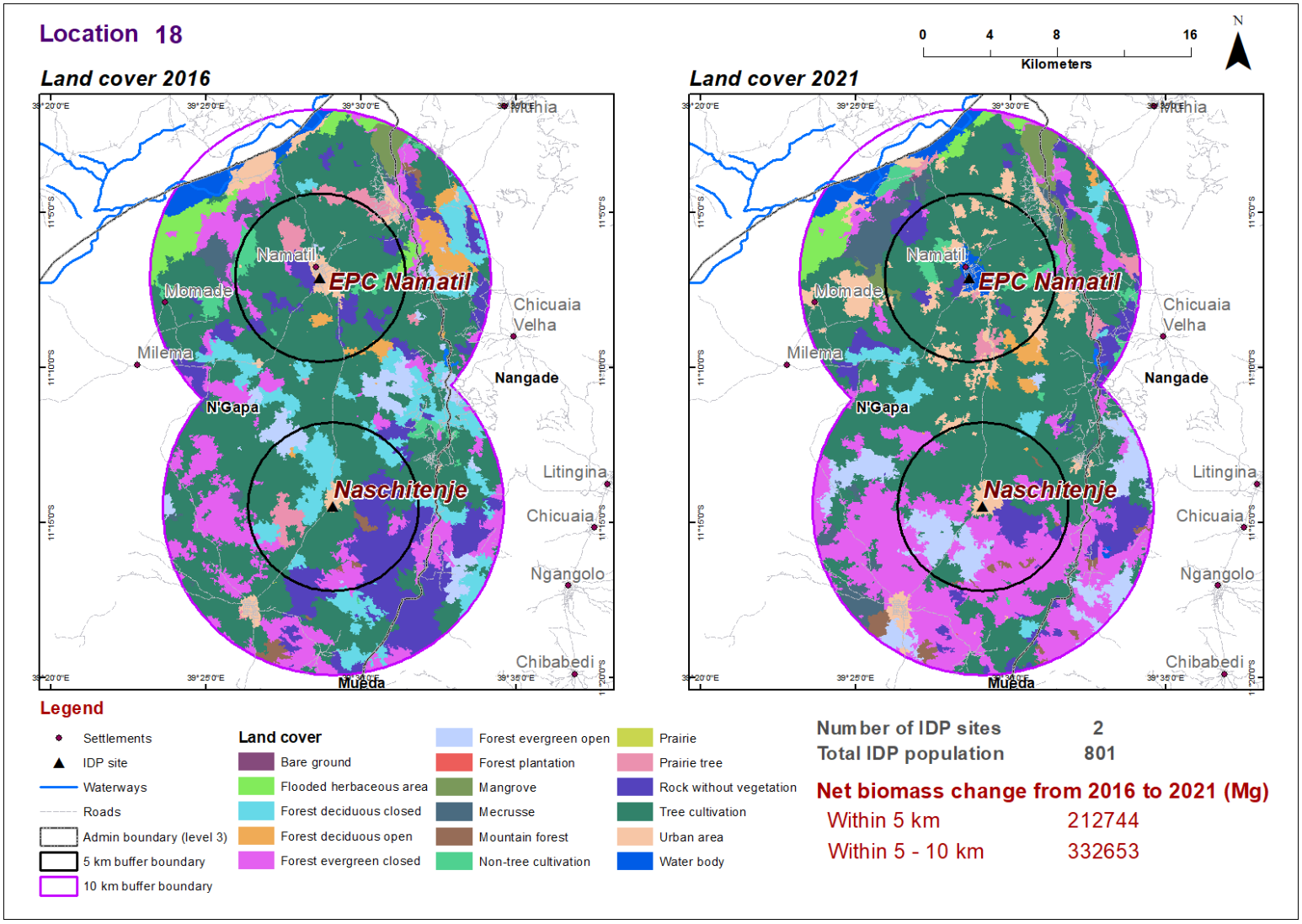

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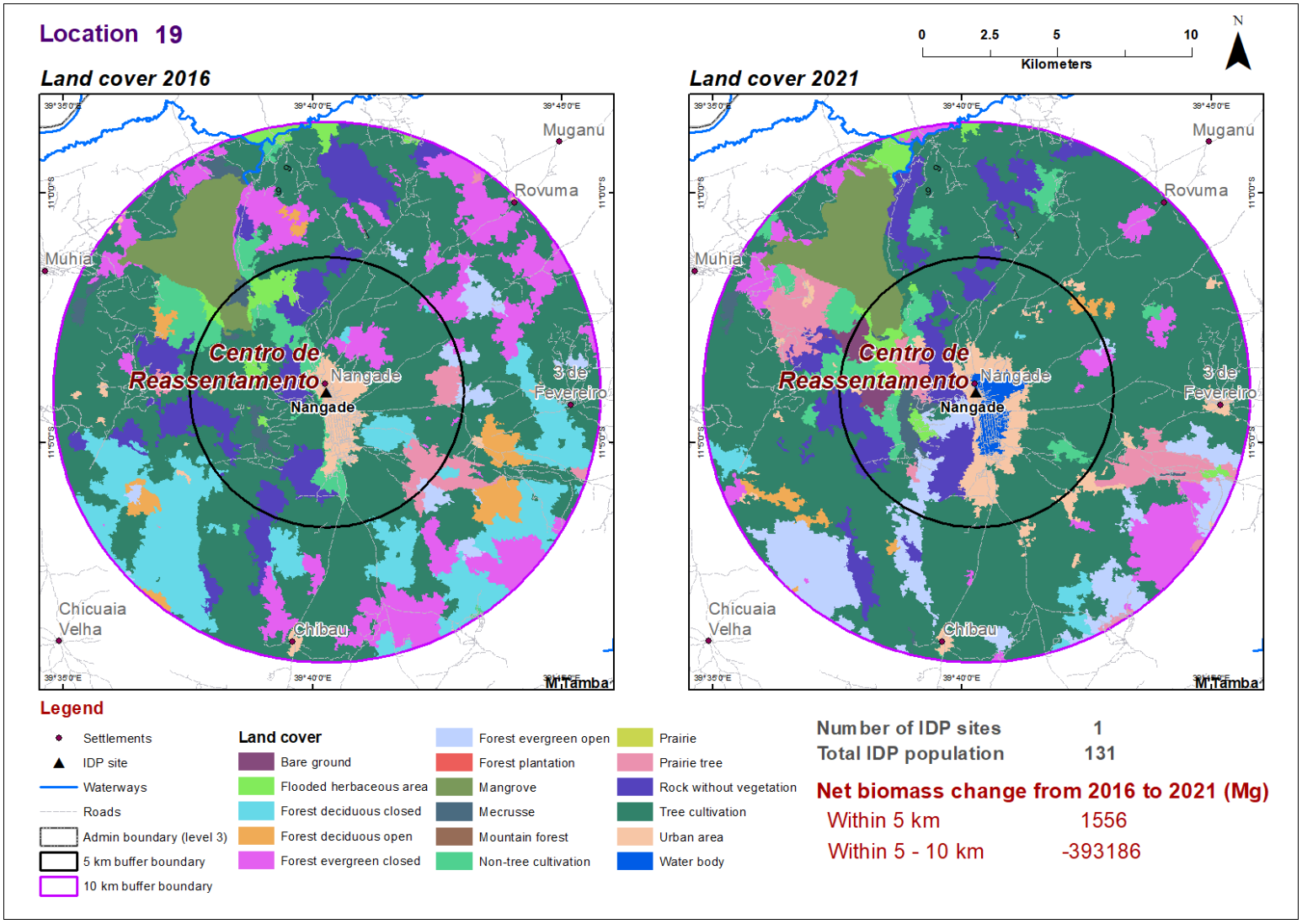

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A rapid geospatial analysis of Nampula and Cabo Delgado Provinces in Mozambique

Cabo Delgado and Nampula, located in the northernmost part of Mozambique, are among the most unstable provinces in the country and are affected by escalating conflicts and insurgencies, along with climatic shocks, impacting the agricultural sector and livelihoods in the area. In this context, the Food and Agriculture Organization of the United Nations (FAO) conducted a rapid geospatial assessment of Cabo Delgado and Nampula provinces, including the internally displaced population site areas, with a particular focus on key indicators related to access to energy (i.e. biomass), food (i.e., change of agricultural land) and water (i.e. agricultural drought). This assessment identified geographic areas and exposed households that are most affected by the changes in land cover, biomass and drought from 2016 to 2021.

This work aims to support current and future programmes related to improvement of agricultural system as an important prerequisite to improve the food security and minimize conflicts. For further improvement of similar geospatial assessment in the context of Mozambique, recommendations are made including the use of available standard for preparing and collecting data; updating of national data; validation and calibration of results based on ground data; use of high-resolution satellite imagery and latest geospatial technologies; and stakeholder engagement.

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