

Small Hydro Resource Mapping in Tanzania

# HYDROPOWER ATLAS: FINAL REPORT

January 2018

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This report was prepared by [SHER](#) in association with Mhylab, under contract to [The World Bank](#).

This is the **final output** from the small hydro **resource mapping component of the activity “Renewable Energy Resource Mapping and Geospatial Planning – Tanzania”** [Project ID: P145287]. This activity is funded and supported by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund administered by The World Bank, under a global initiative on Renewable Energy Resource Mapping. Further details on the initiative can be obtained from the [ESMAP website](#).

The **Final Report** relating to the Hydropower Atlas for Tanzania summarizes the project and the results obtained. The **Hydropower Atlas** has been **validated** through field-based surveys and has been **internally peer-reviewed**. It will be published via The World Bank’s main website and listed on the ESMAP website along with the other project outputs – please refer to the corresponding country page.

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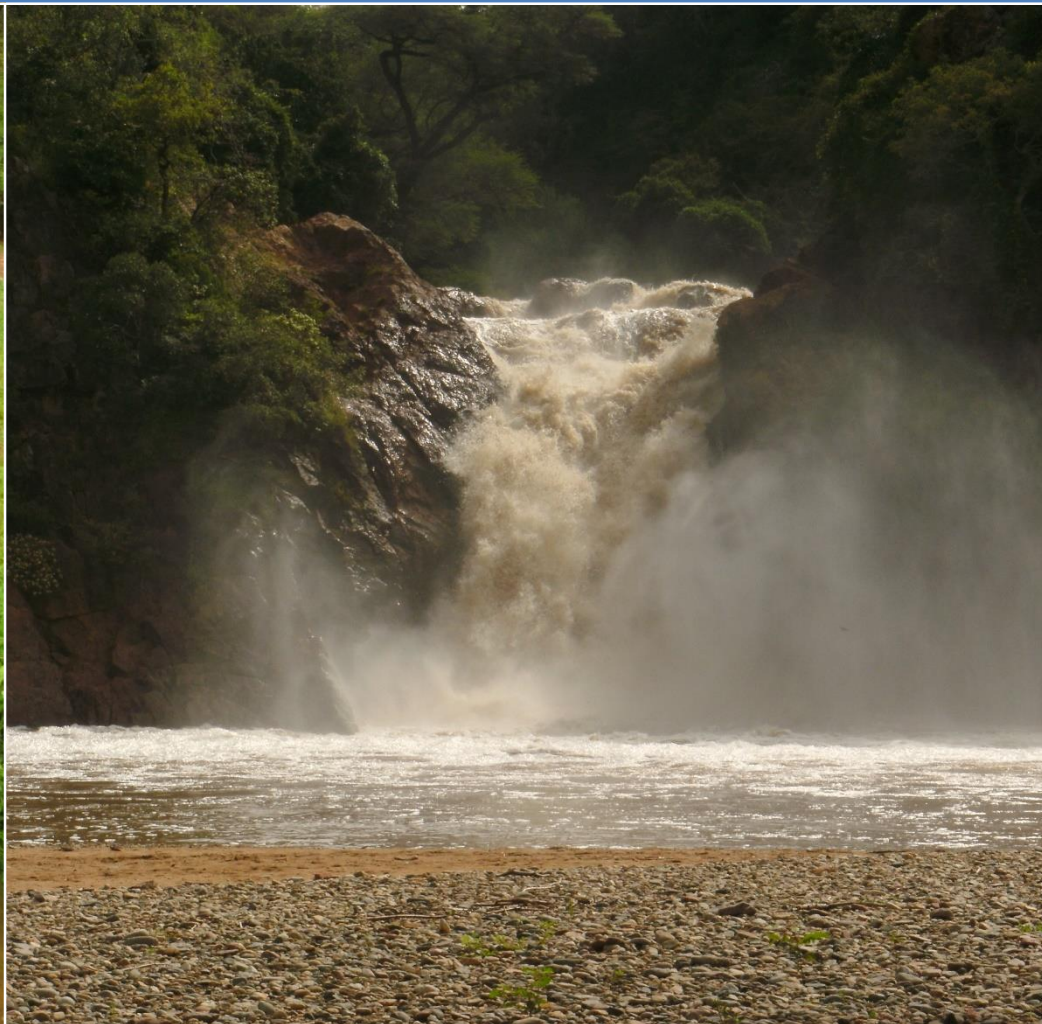
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# Atlas of the Hydropower Resource of Tanzania



In association with





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- January 2018 -

*« The small hydropower potential of Tanzania is important and largely underexploited. It is unevenly distributed across the country and opportunities exist in all capacity ranges »*

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## Acronyms

AFTG1	Africa Energy Practice 1	Mhylab	Mini-hydraulics laboratory
CCI	Climate Change Initiative	NASA	National Aeronautics and Space Administration
DEM	Digital Elevation Model	NCAA	Ngorongoro Conservation Area Authority
DSM	Digital Surface Model	RE	Renewable Energy
ESA	European Space Agency	REA	Rural Energy Agency
ESMAP	Energy Sector Management Assistance Program	SHER	SHER Ingénieurs-Conseils (Artelia Group)
EWURA	Energy and Water Utilities Regulatory Authority	SPPs	Small Power Producers
FAO	Food and Agriculture Organization (of the United Nations)	SRTM	Shuttle Radar Topography Mission
FNR	Forest Nature Reserve	TANAPA	Tanzania National Parks
GHG	Greenhouse Gas	TANESCO	Tanzania Electric Supply Company
GIS	Geographic Information System	TAWA	Tanzania Wildlife Management Authority
GLI	Global Legal Insights	TFS	Tanzania Forest Services
GoT	Government of Tanzania	UN	United Nations
IPPs	Independent Power Producers	UNESCO	United Nations Educational, Scientific and Cultural Organization
IRENA	International Renewable Energy Agency	USAID	United States Agency for International Development
IWRM	Integrated Water Resources Management	WMB	Water Management Basin
LCOE	Levelized Cost Of Energy		
MERIS	Medium Resolution Imaging Spectrometer		

## Units

### Length

1 km = 1,000 m  
 1 mile = 1.56 km  
 1 foot = 0.3048 m

### Volume

1 dm<sup>3</sup> = 1 liter = 0.001 m<sup>3</sup>  
 1 hm<sup>3</sup> = 1,000,000 m<sup>3</sup> = 0.001 km<sup>3</sup>  
 1 km<sup>3</sup> = 1 billion m<sup>3</sup>

### Area

1 are = 100 m<sup>2</sup> = 0.01 ha  
 1 ha = 10,000 m<sup>2</sup>  
 1 km<sup>2</sup> = 1,000,000 m<sup>2</sup> = 100 ha  
 1 acre = 4,047 m<sup>2</sup> = 0.4047 ha

### Capacity and energy

1 MW = 1,000 kW = 1,000,000 W  
 1 GWh = 1,000 MWh = 1,000,000 kWh

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- The implementation of this study has been endorsed by the World Bank team led by Fehrat Esen, as well as by the teams from the Rural Energy Agency (REA).
- The results presented in this report are based on comprehensive data and information from a large number of stakeholders, whom we thank for their valuable knowledge and inputs. The main contributors were the Rural Energy Agency, TANESCO, the Ministry of Energy and Minerals and the Tanzania Water Basin Offices.
- This project has been made possible thanks to the support of the Energy Sector Management Assistance Program (ESMAP) administered by the World Bank and supported by 11 bilateral donors.



# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)



SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Lakes: SRTM, National Geospatial-Intelligence Agency (NGA).

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



## Preface

- The small hydropower potential of Tanzania is good and largely untapped. Opportunities exist in all power capacity ranges. The development of this potential is however hampered by the size of the country and the poor state of the road network and tracks in remote areas. Soil degradation and erosion is worrying and may question the feasibility of some hydraulic projects. This context of catchment degradation and suspended sediments management must be considered in every future development of hydropower projects, whether large or small. Any new infrastructure development must be part of an Integrated Watershed Resources Management (IWRM) process in order to preserve the natural water resources of Tanzania in a sustainable way.
- Small hydro projects have the advantage of a faster development process (~2.5 to 4 years), a better progression in meeting the increasing electricity demand and a more easily available funding compared to the large hydro. The latter requires a longer development process, complex financial closure and may encounter severe socio-environmental constraints. Given the opportunity to replace expensive and polluting production from thermal power plants and the future increase in energy demand on the main grid and mini-grids, small hydro projects remain appealing even when a larger project is developed.
- Expansion of the existing power grids should continue, as planned in the Power System Master Plan 2016. The development should rely on accurate and transparent mapping highlighting the priorities and timeframes for their development. Consequently, the economic attractiveness of remote hydropower projects could strongly increase due to the expected reduced costs associated with the transmission lines and access roads. Those remote projects could hence become competitive compared to thermal production.
- In the light of a growing energy demand, the future development plans will have to integrate all the known and studied hydropower sites distributed across the country, the most promising hydropower projects selected in this study and the other renewable energy sources (solar, wind, ...) which will constitute a complete portfolio of renewable energy projects.
- In a context of climate change and high seasonal variabilities of streamflow in the rivers, development of reservoir projects should be further analyzed to provide more flexibility of the power system. Also, cascade development of hydropower projects (including an upstream reservoir for daily or seasonal regulation) are particularly relevant in Tanzania. Economy of scale, particularly in terms of access roads and transmission lines, are possible for such projects.

*« The small hydropower potential of Tanzania is important and largely underexploited. It is unevenly distributed across the country and opportunities exist in all capacity ranges »*





## SECTION A. INTRODUCTION AND CONTEXT

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- Introduction
- General geography
- Energy sector in Tanzania

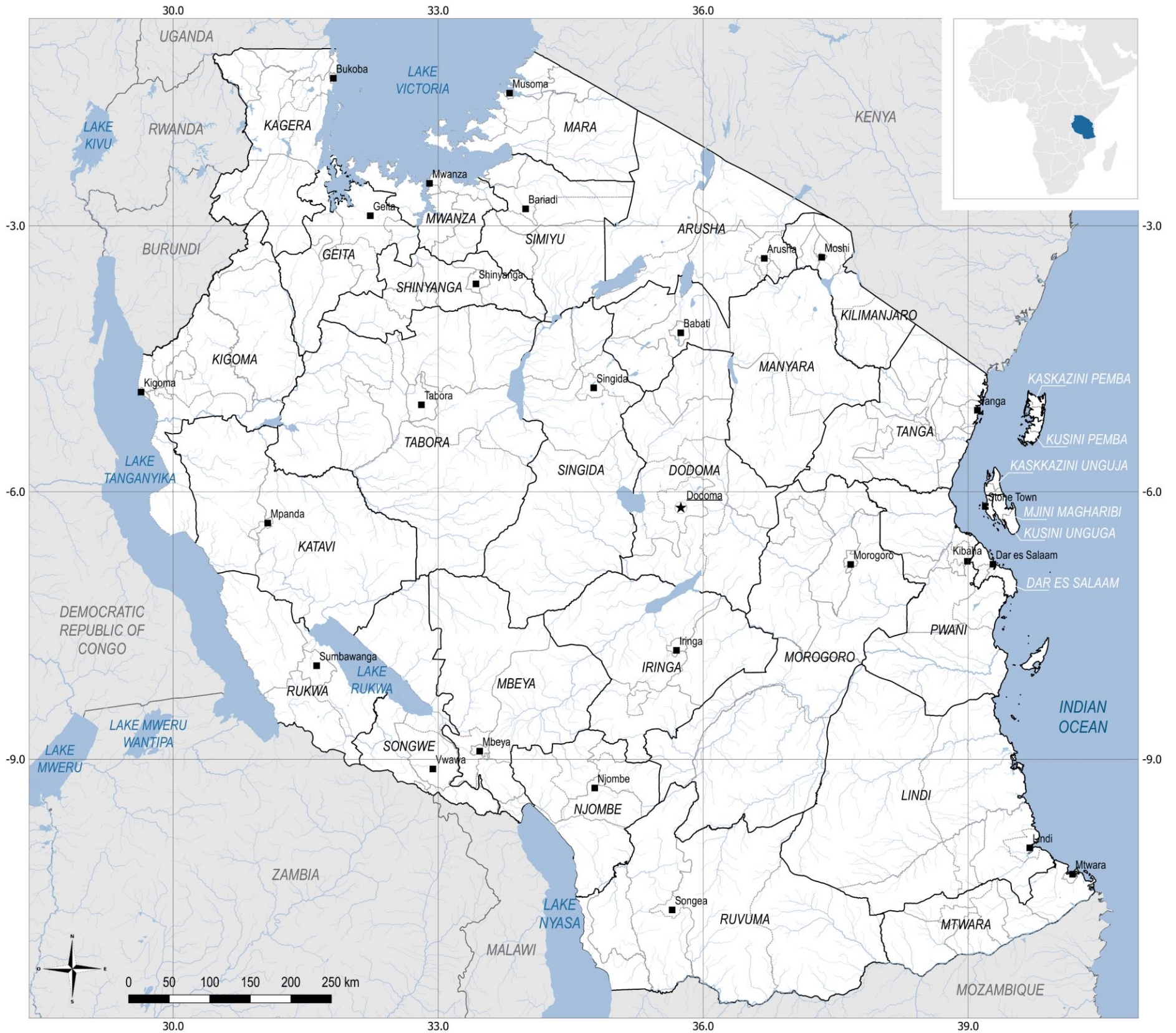


# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

### ADMINISTRATIVE BOUNDARIES

Tanzania is located in the Great Lakes region of East Africa between latitudes 0°59' and 11°45' South of the equator. North, the country shares a border with Kenya and Uganda, part of which is Lake Victoria. North-West, Rwanda and Burundi are the neighboring countries before Lake Tanganyika forms the border with the Democratic Republic of the Congo. Zambia, Malawi and Mozambique are the south neighboring countries while Indian Ocean forms the east border where are located the islands of Zanzibar and Pemba. With an area of 947,300 km<sup>2</sup>, Tanzania is the thirteen largest country of Africa. The territory is divided into thirty one administrative regions.



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries
- District boundaries

SHER Ingénieurs-Conseils s.a., 2017  
**Small Hydropower Resource Mapping Tanzania (0.3-10 MW)**

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).





# Chapter 1.

## Introduction

### 1.1. GENERAL CONTEXT OF THE ESMAP PROGRAM

- ESMAP (Energy Sector Management Assistance Program) is a technical assistance program administered by the World Bank and supported by 11 bilateral donors. In January 2013, ESMAP has launched an initiative that will support country-driven efforts to improve awareness about renewable energy resources (RE), to implement appropriate policy frameworks for RE development, and to provide “open access” to resources and geospatial mapping data.
- This initiative will also support the IRENA-Global Atlas by improving the availability and quality of the data that can be consulted through the interactive Atlas.

### 1.2. STUDY OBJECTIVES AND SCOPE OF WORK

- The objectives of the present study "Renewable Energy Mapping: Small Hydro Tanzania" are the following:
  - ◆ The improvement of the quality and availability of information on Tanzania's small hydropower resources;
  - ◆ Provide the Government of Tanzania (GoT) and commercial developers with ground-validated maps that show the varying level of hydropower potential throughout the country ;
  - ◆ Highlight several sites most suited for small hydropower projects development.
- The objectives of the resource maps are:
  - ◆ To contribute to a detailed comprehensive assessment and to a geospatial planning framework of small hydro resources in Tanzania;
  - ◆ To verify the potential for the most promising sites and prioritized sites to facilitate new small hydropower projects and ideally to guide private investments into the sector;
  - ◆ To increase the awareness and knowledge of the Client on RE potential.
- The expected results from the study are:
  - ◆ Assembled data in a geographical database (GIS);
  - ◆ A thematic atlas on hydropower in Tanzania with a particular emphasis on small hydro; and
  - ◆ Recommendations to develop the small hydropower sector in Tanzania.
- The 3 phases of the ESMAP study are :
  - ◆ **PHASE 1:** Initial scoping and preliminary mapping of the resources based on spatial analysis and site visits ;
  - ◆ **PHASE 2:** Field data collection and validation ;

- This "Renewable Energy Mapping: Small Hydro Tanzania" study, is part of a technical assistance project, ESMAP funded, being implemented by Africa Energy Practice 1 (AFTG1) of the World Bank in Tanzania (the 'Client') which aims at supporting resource mapping and geospatial planning for small hydro.
- It is being undertaken in close coordination with the Rural Energy Agency (REA) of Tanzania, the World Bank's primary Client country counterpart for this study.

- ◆ **PHASE 3:** Production of a validated Atlas of the resources combining spatial data and field measurements.
- All reports produced in the framework of this study are available for download on the ESMAP website at <https://www.esmap.org>.

Figure 1. Reconnaissance of potential sites near the Malagarasi River.



### 1.3. FRAME OF THE HYDRO-ATLAS OF TANZANIA

- This **Hydro-Atlas of Tanzania** is a document that contains all the information directly or indirectly related to hydropower and collected during Phase 1 and Phase 2 of this study. The information has been compiled and processed in a **Geographic Information System (GIS)** and is presented as thematic maps, tables, graphs and various illustrations. The Hydro-Atlas also includes the results of the prioritization of promising sites, as discussed during the Phase 1 and presented in the Hydro Mapping Report of April 2015.
- The information of this Atlas presents the hydropower potential of Tanzania including the new potential sites identified by the **consulting engineering firm SHER (ARTELIA Group)** within the framework of this study, using the SiteFinder tool as well as the existing hydropower sites. The creation of the Atlas started with Phase 1 of the study. The Atlas has been updated at the end

### 1.4. HYDROPOWER BASICS

- Hydropower uses the difference in energy of a water body between two points at different elevations. The elevation difference is called the gross head and is expressed in meters (m). A hydropower project aims to recover this energy in order to generate electricity. In the absence of a hydropower scheme, this energy is dissipated in the natural course of the river through the internal and external friction which is responsible for the river bed erosion.
- The production of hydropower results from the conversion of the kinetic energy of moving water (in a river or a lake) into mechanical energy by one or more hydraulic turbines. This mechanical energy is finally transformed into electrical energy by generators. The conversion of energy is carried out in a hydropower station (powerhouse) which houses in particular the turbines and alternators (Figure 2).
- The capacity of a hydropower plant  $P$ , expressed in megawatts (MW), is mainly a function of the gross head  $H$  (m) and the flow rate  $Q$  ( $m^3 \cdot s^{-1}$ ) passing through the turbines according to the following equation:

$$P = \rho \times g \times Q \times H \times \eta$$

with  $\rho$  the water density ( $kg \cdot m^{-3}$ ),  $g$  the acceleration of gravity ( $m \cdot s^{-2}$ ) and  $\eta$  (-) the global efficiency of the conversion of mechanical energy into electrical energy (product of the efficiency of the turbines, the alternator and the transformer).

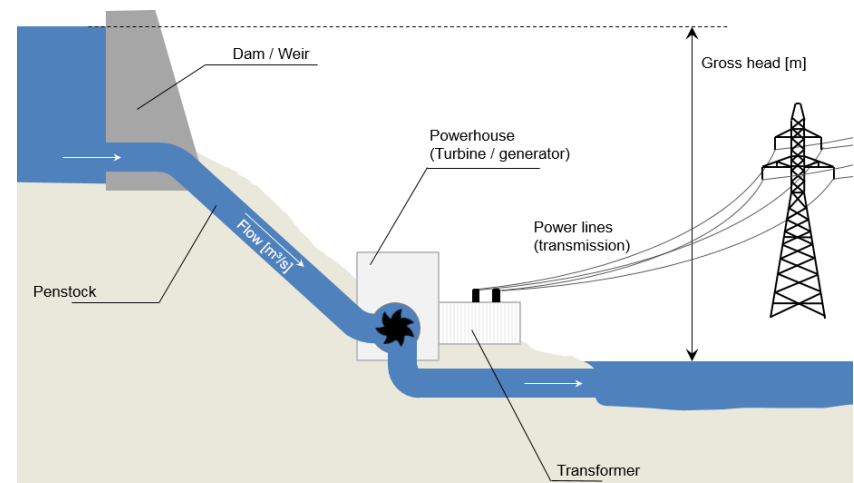
- The *energy* is the ability of a system to perform work while the *power* expresses the energy transfer per unit of time. The energy corresponds to the capacity produced by a power plant for a certain period. For example, 1 MWh is the electrical energy produced by a 1 MW (1,000,000 W) power plant in one hour.
- The hydropower is a renewable energy.
- There are two main types of hydropower schemes:

of Phase 3, by including new information collected on the field and updating the contextual information.

- The Geographic Information System has been designed to meet the compatibility and standardization requirements defined in the terms of reference so that geographic data can be easily published on the World Bank GIS platform. In addition, the consultant used the free of charge GIS software QuantumGIS for processing and publishing the geographic data, which makes it possible to disseminate and transfer the data free of charge during the training sessions carried out at the end of Phase 1.
- The present Hydro-Atlas of Tanzania focuses exclusively on potential sites in the range of capacities between 0.3 and 10 MW.

- **Storage hydropower:** In this type of scheme, the hydropower plant benefits from the regulating capacity of the reservoir to modulate the quantity of water conveyed to the turbines and consequently its energy production. This type of project therefore allows a production that can be modulated according to the energy demand on the grid. In addition, if the storage capacity of the reservoir is large enough, it can store the excess water during the wet season (or year) to redistribute it during the dry season (year). This type of projects and its operation are therefore one of the key elements of adaptation strategies to the effects of climate change.
- **Run-of-the-river hydropower:** In this type of scheme, the hydropower plant is directly supplied by an intake or diversion structure in the river and has only a very limited or zero storage capacity. In this case, the available power is mainly a function of the streamflow in the river.
- In the context of this study focusing on small hydro, only run-of-the-river projects have been considered.

Figure 2. Schematic layout of run-of-the-river hydropower.



# Chapter 2.

## General geography

### 2.1. TOPOGRAPHY: ALTIMETRY AND SLOPES

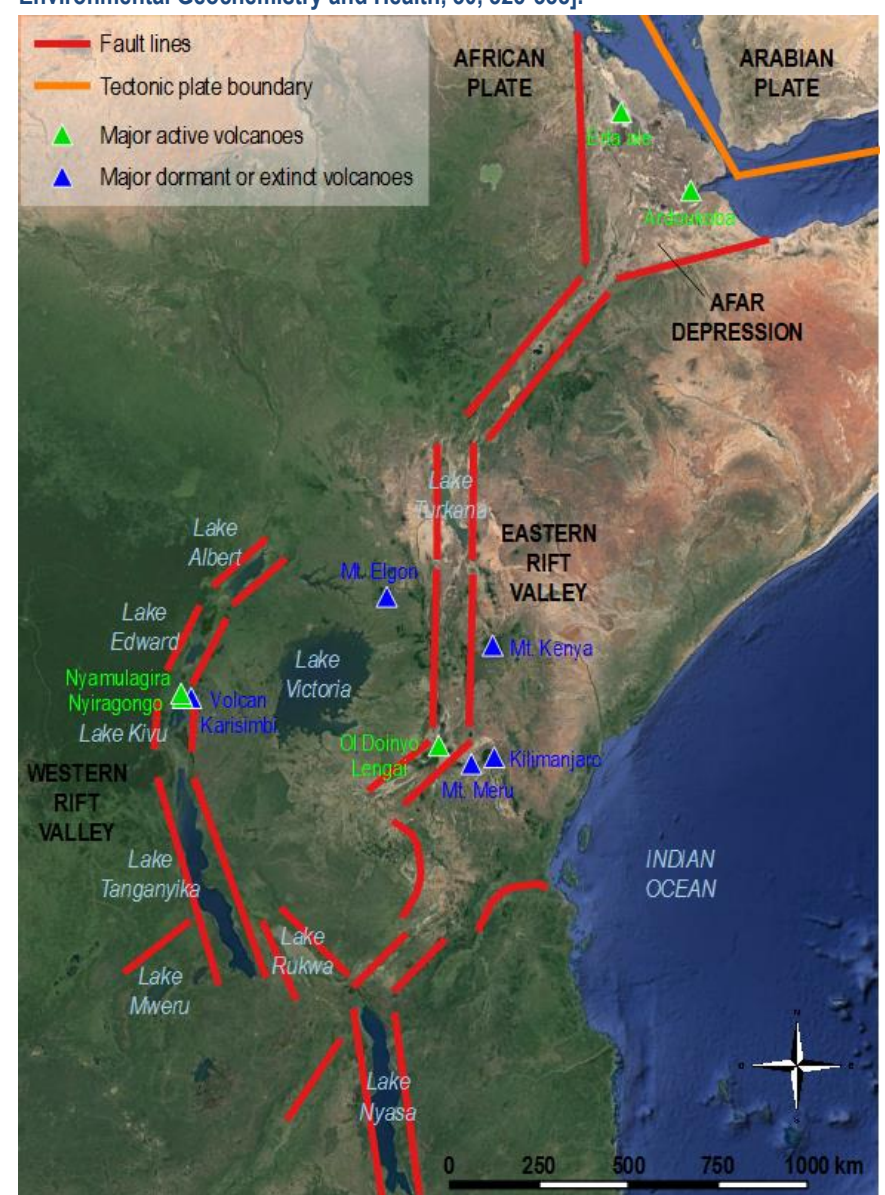
- The United Republic of Tanzania consists of the Mainland and Zanzibar, and is located in the Great Lakes region of East Africa between latitudes 0°59' and 11°45' south of the equator (**Map 2**).
- North, the country shares a border with Kenya and Uganda. Lake Victoria forms a natural border with Uganda. North-West, Rwanda and Burundi are the neighboring countries. The country is bounded to the West by the Lake Tanganyika, which separates it from the Democratic Republic of the Congo. Zambia, Malawi and Mozambique are the South neighboring countries. Indian Ocean forms the East border. Tanzania is the thirteen largest country of Africa with a total surface area of 947,300 km<sup>2</sup>.
- Most of the country is located in the East African Rift Valley formed by the separation of the African and Arabian tectonic plates. The movement of the tectonic plates began about 35 million years ago and created a combination of several rifts and volcanoes in the region, the most famous of which is Kilimanjaro, the highest mountain in Africa (5,895 m) located North-East of Tanzania. [Source: Davies, T. (2008). *Environmental health impacts of East African Rift volcanism*. Environmental Geochemistry and Health, 30, 325-338]. The Western and Eastern rift valleys form the Tanzanian Central Plateau. Along the coast, the terrain is composed by plains.
- Tanzania can be divided into four main orographic units:
  - the Western Rift Valley;
  - the Central Plateau;
  - the Eastern Rift Valley;
  - the Eastern Oceanic side.
- The Digital Surface Model (DSM) used in the frame of this study is the « *Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global* », published by NASA in 2014. These data have been acquired by the American Space Agency (NASA) through radar measurements from the space shuttle *Endeavor* in February 2000 and have a spatial resolution of 1 arc-second (about 30 m at the equator). This set of elevation data is particularly well suited for the delineation of hydrographic watersheds, the identification of river systems and the calculation of slopes. The altimetry of Tanzania is shown in **Map 3**.
- The map of slopes (**Map 4**) has been calculated from the DSM described in the previous paragraph and highlights the important

### 2.2. HYDROGRAPHY

- The Tanzania's topography features a series of internal drainage basins (endorheic basins) which outlets are the series of endorheic lakes in the Northern part of the country, along the Eastern Rift Valley (**Map 5**).
- The rainy season starts in November/December which results in an increase of river flows and a rise of lakes water level. The flood period occurs in March-April. Then, a recession period starts in May and finishes in October/November. Many of the larger rivers have flood plains, which extend far inland with grassy marshes, flooded forests and oxbow lakes [Source: FAO-AQUASTAT].
- Tanzania shares six international lakes, five international rivers and seven international aquifers. Three of the largest African river basins (Nile, Congo and Zambezi) run through the country. Lakes

elevation changes and elevation gradients. The steeper slopes are situated along the Western and Eastern branches of the rift with a difference of elevation that can be more than 1,500 m on a few kilometers distance (slopes > 30%). There is also a steep slopes line, the Rukwa fault, along the west side of Lake Rukwa. These regions have topographical features particularly favorable for hydropower development.

Figure 3. Location and tectonics of the Great Rift System in Africa. [Adapted from: Davies, T. (2008). *Environmental health impacts of East African Rift volcanism*. Environmental Geochemistry and Health, 30, 325-338].



and rivers form a large part of the country's borders. There are the Ruvuma River with Mozambique, Lake Tanganyika with the Democratic Republic of the Congo, Lake Nyasa and the Songwe River with Malawi, the Kagera River with Rwanda and Uganda and Lake Victoria with Uganda and Kenya. As a result, Tanzania plays a key role in managing transboundary institutions and agreements on transboundary water resources [Source: FAO-AQUASTAT].

- Tanzania is divided into nine major water management basins (WMB). A brief description of these basins is given below [Source: Ministry of Water and Irrigation of the United Republic of Tanzania]:

- ◆ **Lake Victoria Basin:** is an African Great Lake, source of the White Nile and is the world's second-largest freshwater lake and the largest lake in Africa. On Tanzania side, the main rivers draining into the lake include Kagera, Simiyu, Mbaraget, Grumet, Mara and Mori Rivers. Along the west side of the lake, the Western branch of the rift creates some large waterfalls.
- ◆ **Lake Tanganyika Basin:** is an African Great Lake part of the Congo basin situated in the Western part of the country. All the catchments that drain in the lake constitute the Lake Tanganyika basin. The land surface of the basin on Tanzania side is 151,000 km<sup>2</sup> and the lake has an area of 32,000 km<sup>2</sup>. The main river, the Malagarasi originates at about 1,750 meters above the sea level in the Burundian mountainous area from where it runs northeasterly through hilly and mountainous landscape and then southward into the Malagarasi Swamps. Its major tributaries, the Myowosi and Igombe Rivers meet the Malagarasi in the seasonal Lake Nyamagoma. The Ugalla and Ruchugi Rivers join the main river downstream of Lake Nyamagoma. The river then runs west, through the Misito Escarpment where it forms rapids and waterfalls before entering the lake like the Kalambo Falls, one of the tallest uninterrupted falls in Africa.
- ◆ **Internal Drainage Basin:** is described by rivers draining into a group of inland water bodies (lakes) which are located around the north-central part of the country. The system, composed mainly of troughs and faults runs southward from Lake Natron at the border with Kenya to central Tanzania in the Bahi depression. Total basin area on Tanzania side is about 153,800 km<sup>2</sup>. The major drainage systems in this basin includes: Lake Eyasi System, which drains areas in North Tabora Region and East Shinyanga by the Wembere and Manonga river systems, Lake Manyara system and Bubu complex where important features are the Bubu and Bubu swamps. There are several other small independent lakes and swamps with no outlet existing in this basin such as Lake Basuto and Lake Natron.
- ◆ **Pangani Basin:** is comprised of five sub basins: Pangani, Uмба, Msangazi, Zigi and Coastal Rivers including Mkulumuzi, all of which are independent and drain to the Indian Ocean. The Pangani River has two main tributaries, Kikuletwa and Ruvu Rivers, which join at Nyumba ya Mungu dam, a large man-made reservoir with a surface area of 140 km<sup>2</sup>. Mt. Kilimanjaro and Mt. Meru provide the source of Kikuletwa river flow, while the Ruvu, Mkomazi and Luengera Rivers drain part of Kilimanjaro, Pare and Usambara mountains and the springs emerge from the Kenyan side.

There are two unique lakes in the basin namely Jipe and Chala which are transboundary water bodies.

- ◆ **Wami/Ruvu and its associated Coast Rivers Basin:** is located in the eastern part of Tanzania. The basin has two major rivers, Wami and Ruvu, and it has coastal rivers flowing into Indian Ocean, most of which are located in Dar es Salaam Region. The source of Wami River is Chandama highland in the northern Tanzania and Ruvu River originates from Mt. Uluguru.
- ◆ **Rufiji Basin:** covers an area of 183,800 km<sup>2</sup> (about 20% of Tanzania). The river drains into the Indian Ocean. The Rufiji Basin comprises of four major rivers namely: Great Ruaha, Kilombero, Luwegu and Rufiji (the lower part of main river) Rivers. The climate in the basin differs from the coast to the highlands in the upper parts of the catchments. For instance, except for the lower parts of the basin, which experience two rainy seasons, the largest portion is characterized by unimodal rainfall.
- ◆ **Ruvuma and Southern Rivers Basin:** occupies the Ruvuma, Mtwara and Lindi Regions of southeastern Tanzania. The entire area of Ruvuma River basin is about 152,200 km<sup>2</sup> of which 34% is in Tanzania. The Ruvuma River is a perennial river and its main tributaries at its headwaters are Lucheringo, Likonde and Lugenda Rivers in Mozambique and the Matogoro Mountains.
- ◆ **Lake Nyasa Basin:** forms the southwestern part of Tanzania with common borders of Mozambique and Malawi territories. The total area covered is approximately 165,100 km<sup>2</sup>, inclusive of lake waters (33,457 km<sup>2</sup>). The basin covers all land whose rivers drain water into Lake Nyasa. The main rivers that pour their water into Lake Nyasa from the Tanzania side include Ruhuhu, Songwe, Kiwira, Rufirio and Lumbira Rivers.
- ◆ **Lake Rukwa Basin:** is characterized by an extensive network of seasonal and perennial rivers that feed and drain several small lakes and large expanses of swamps and wetland systems before discharging into Lake Rukwa. The lake is fed by seventeen rivers, ranging in size from big perennial rivers to small seasonal rivers. The major rivers draining the basin include: the Rungwa River, which drains into Lake Rukwa from the North; Lupa, Chambua and Songwe Rivers, which drain the Mbeya Range and flow into the lake from the South; and the Momba River, which flows into the lake from the West. Other rivers include Luiche and Katuma that originate from the Ufipa plateau and several ephemeral rivers that flow into the lake during the wet season.

« *The topography along the Great Rift in Tanzania is particularly favorable for hydropower development. However abundant annual precipitations across the country are unevenly distributed during the year* »

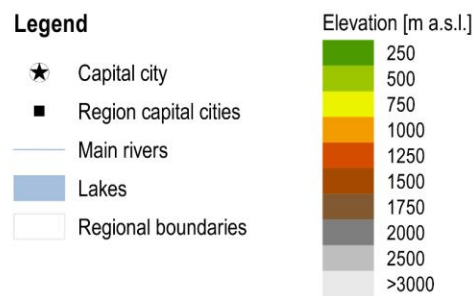
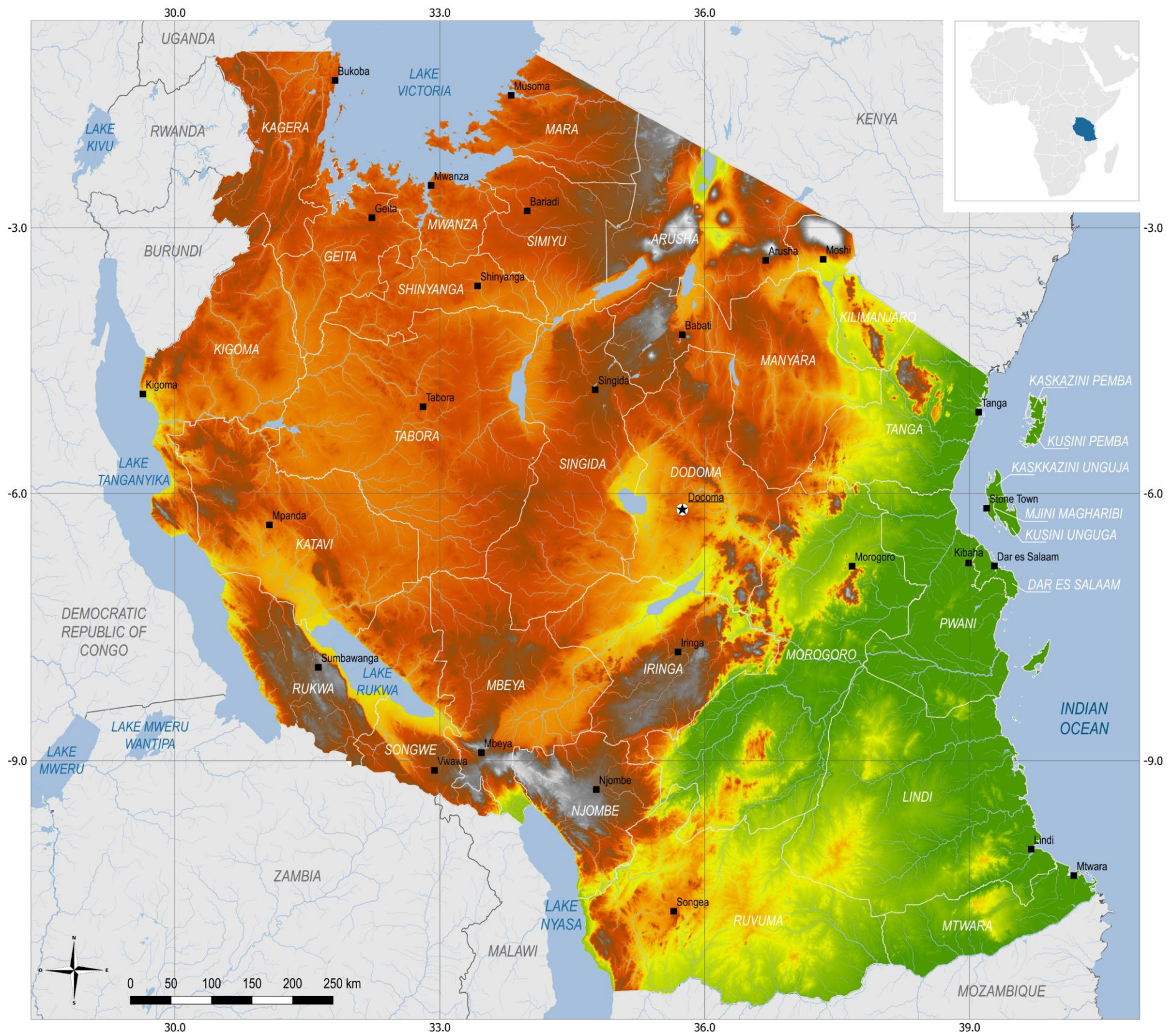


# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

### TOPOGRAPHY: ELEVATION

This map highlights the different orographic regions of Tanzania mainly formed by the East African Rift crossing the territory. On the Western branch, the landscape is characterized by a mountainous area with hill-tops that can reach more than 2,000 m. A similar landscape can be observed on the Eastern branch with a volcanuous activity more intense. The mountains reach very high altitudes with the highest peak of Africa, Mt. Kilimanjaro culminating at 5,895 m. Between both branches of the rift, the Central Plateau is characterized by a hilly landscape with elevation varying between 1,100-1,200 m. Finally, the Eastern Ocean side of the country is characterized by a much flatter landscape.



SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources :  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Elevation: Digital Surface Model (DSM) - SRTM 1 arc-second, NASA 2014.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA

## TOPOGRAPHY: SLOPES

### Atlas of the Hydropower Resource (0.3-10 MW)

This map highlights the elevation gradient across Tanzania. The steeper slopes are encountered along the Western and Eastern branches of the East African Rift with a difference of altitudes which can reach more than 1,500 m on a few kilometers distance (slopes > 30%). In addition, the Rukwa fault along the west side of Lake Rukwa causes a steep slopes line. These regions feature favourable topographical conditions for hydropower development.



**Legend**

- ★ Capital city
  - Region capital cities
  - Main rivers
  - Lakes
  - Regional boundaries
- | Slopes [%] |       |
|------------|-------|
|            | 0-5   |
|            | 5-10  |
|            | 10-15 |
|            | 15-20 |
|            | >20   |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Slopes: Digital Surface Model (DSM) - SRTM 1 arc-second, NASA 2014.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).

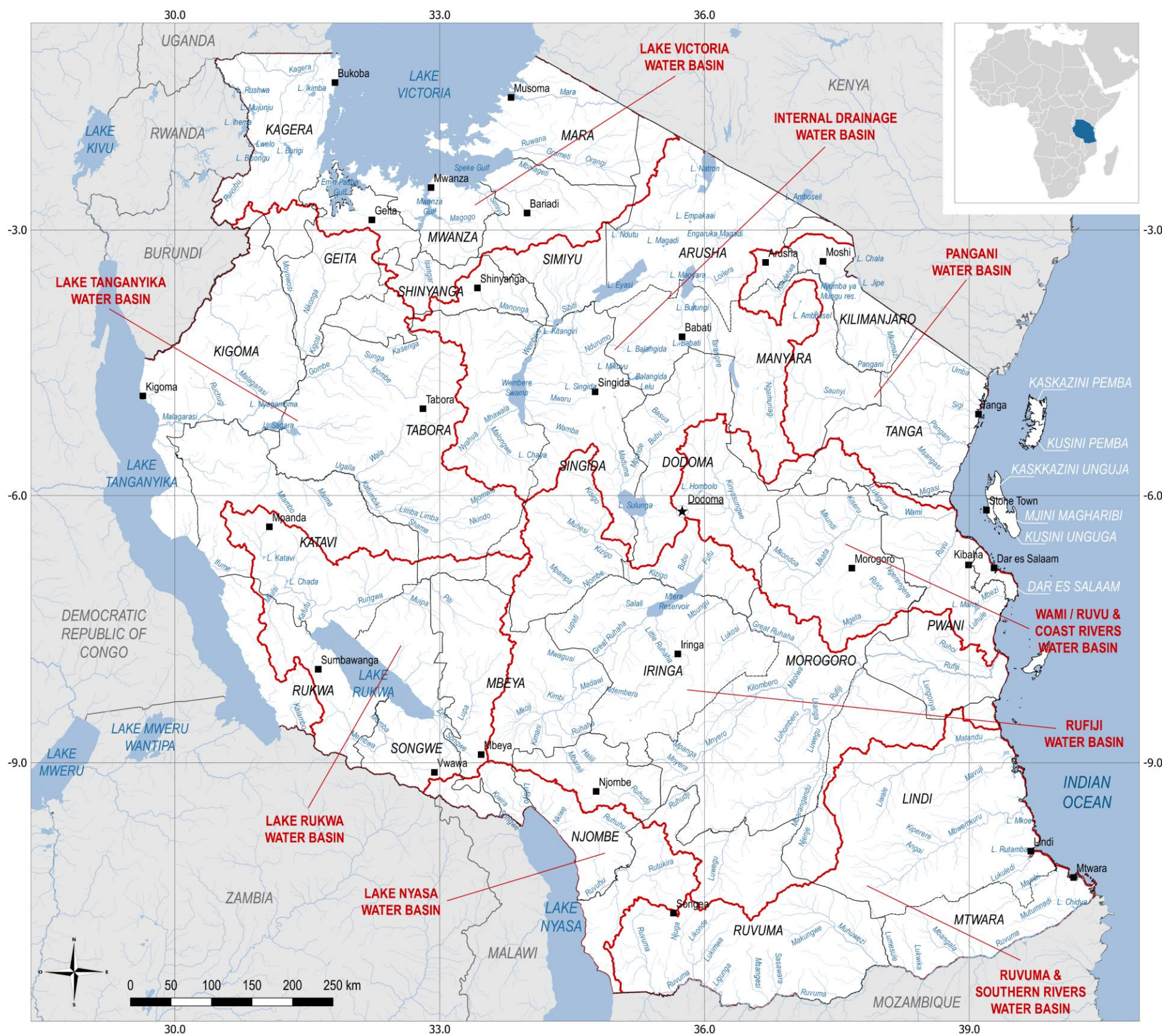


# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

### HYDROGRAPHIC NETWORK

The Tanzania's topography features a series of internal drainage basins (endorheic basins) which outlets are the series of endorheic lakes in the Northern part of the country, along the Eastern Rift Valley. The rainy season starts in November/December which results in an increase of river flows and a rise of lakes water level. The flood period occurs in March-April. Then, a recession period starts in May and finishes in October/November. Many of the larger rivers have flood plains, which extend far inland with grassy marshes, flooded forests and oxbow lakes Tanzania shares six international lakes, five international rivers and seven international aquifers. Three of the largest African river basins (Nile, Congo and Zambezi) run through the country. Lakes and rivers forms a large part of the country's borders.



- Legend**
- ★ Capital city
  - Region capital cities
  - Main rivers
  - Lakes
  - ▭ Regional boundaries
  - ▭ Water management basins [9]

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources :
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Cities: Open Street Map (OSM), 2013.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Rivers and Lakes names: Tanzania - Rwanda - Burundi, Nelles Map, Ed. 2012.
  - Water management basins: Ministry of Water and Irrigation of the United Republic of Tanzania.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



### 2.3. GEOLOGY

[Source: Sika Resources Inc. (2011), A brief introduction to the geology and mining industry of Tanzania].

- The geological framework of Tanzania is a good representation of the whole geologic history of the African continent. Archean evolution, its modification through metamorphic reworking and accretion of other continental rocks, in turn covered by continentally derived sediments; all these events have shaped the nature of the soil.
- Pre-rift magmatism followed by active rifting has also left a major mark upon the Tanzanian landscape.
- In the past, geological mapping programs have been undertaken and have contributed to the identification of several major litho-structural provinces from Archean (Precambrian) to recent age. The **Archean (Tanzanian) Craton** covers a large area of the western part of the country. It is approximately delimited by the East African Rift to the East. Archean rocks contain various elements such as kimberlite pipes where there used to have lodes of diamond and gold deposits. The Archean basement terrain is bounded to the East and West by a series of Proterozoic mobile belts. This area, on the East side in particular, hosts most of the country's wide variety of colored gemstone deposits. Some recent research suggests that portions of this assumed Proterozoic terrane may actually consist of Archean crust that has endured a later phase of higher-grade metamorphism.
- The Phanerozoic is represented by a series of **sedimentary units** of Paleozoic to Mesozoic age (Jurassic and Cretaceous). This was followed by a pre-rift period of kimberlitic and related, alkalic, mantle-derived intrusive and extrusive activity that presaged active rifting. Rocks related to this event intrude up to Upper Mesozoic and Lower Cenozoic sedimentary formations. Next, came a period of rift-related intrusive and extrusive activity. This activity was concentrated in the Arusha area in the northeast and Mbeya area in the southwest that led to the formation of mountain-sized volcanoes such as Mt. Meru and Mt. Kilimanjaro. Finally, a wide variety of recent and largely semi- to unconsolidated wind, water, and weathering-derived recent formations are found across the country, a number of which host alluvial gold, diamond, and colored gemstone deposits.
- In the modern times, the typical weather of Tanzania is characterized by a hot climate, long periods of steady rain during the monsoon period (March through May) followed by a stretch of hot, dry weather, which has led to the development of deeply weathered rock formations and thick overlying lateritic and related soil horizons.
- The long, evolved drainage history of the country, considerably affected by sudden and dramatic changes in geomorphology due to tectonic events in the past, have led to a complex series of fluvial, elluvial and alluvial deposits, which host a wide variety of placer deposits (gold, diamonds, colored gemstones, etc.).



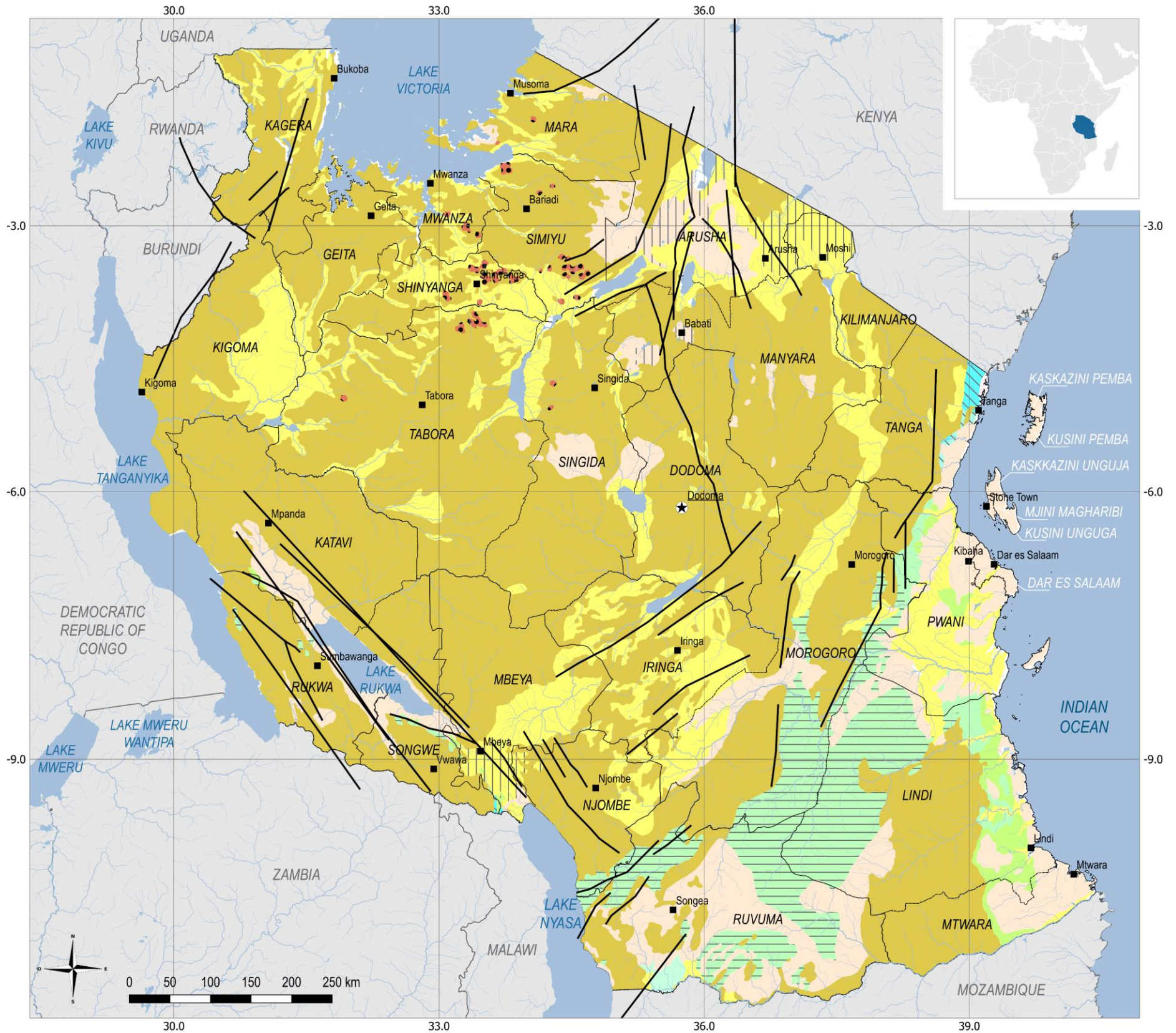


# TANZANIA

## GEOLOGY

### Atlas of the Hydropower Resource (0.3-10 MW)

This map presents the geological characteristics of Tanzania and the main faults formed by the East African Rift System. The geological framework of Tanzania reflects the geologic history of the African continent as a whole. Its present appearance is a result of a series of events that began with evolution of Archean shield, followed by its modification through metamorphic reworking and accretion of other continental rocks, in turn covered by continentally derived sediments. Pre-rift magmatism followed by active rifting has also left a major mark upon the Tanzanian landscape.



<b>Legend</b>		<b>Geology</b>	
★ Capital city	■ Region capital cities	— Faults	■ Pleistocene
— Main rivers	■ Lakes	■ Cretaceous	■ Precambrian
— Regional boundaries		■ Holocene	■ Quaternary (undivided)
		■ Jurassic	■ Quaternary Igneous
		■ Jurassic-Carboniferous	■ Tertiary
		■ Jurassic-Triassic	■ Tertiary Igneous
		■ Kimberlites	■ Triassic
		■ Paleozoic-Precambrian	■ Triassic-Permian

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Geological layers: U.S. Geological Survey, 2002.
  - Faults: Global Faults layer by ArcAtlas (ESRI), 2014.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



## 2.4. CLIMATE

### 2.4.1. Climate factors

[Sources: United Republic of Tanzania (Vice President's Office), National Climate Change Strategy, 2012; FAO, 2006].

- The climate is diverse within the country due to its size (wide elevation range which governs temperature and latitude) and is affected by the ocean and inland lakes.
- It is characterized by two main rain seasons namely the long rains and the short rains. They originate from the southward and northward movement of the Inter-Tropical Convergence Zone. The long rains (Masika) begin in the mid of March and end at the end May, while the short rains (Vuli) begin in the middle of October and continue to early December. The northern part of the country including areas around Lake Victoria Basin, North-Eastern Highlands and the Northern Coast experience a bimodal rainfall regime. Central, South and Western areas have a prolonged unimodal rainfall regime starting from November, continuing to the end of April. More details are given in the table below (Table 1).

### 2.4.2. Rainfall and temperature

- Annual rainfall varies from 500 mm/y to 1,000 mm/y in most parts of the country. The highest annual rainfall of 1,000 mm to 3,000 mm occurs in the Northeast of the Lake Tanganyika Basin and in the Southern Highlands. In these areas, mean annual rainfall is 1,071 mm. Zanzibar and the coastal areas are hot and humid, and average daily temperatures are around 30°C. October-March is the hottest period. Sea breezes however temper the region's climate and the period of June-September is the coolest with temperatures falling to 25°C. In the Kilimanjaro area, temperatures vary from 15°C in May-August to 22°C in December-March [Source: FAO, 2016].
- **Map 8** shows the duration of the dry periods across the country represented by the number of months with precipitations below 10 mm/month (on average). It reveals that abundant annual precipitations across the country are unevenly distributed during the year: some regions feature high precipitations during the wet season and an extended dry period with very small amount of rain.
- Sixty percent (60%) of the country (548,290 km<sup>2</sup>) experiences at least four months with precipitations below 10 mm/month every year (on average). Forty percent (40%) of the country (380,000

### 2.4.3. El Niño

- El Niño is a natural event characterized by the abnormal warming of the sea surface temperatures in the central and eastern regions along the equatorial line of the Pacific Ocean. On average, it occurs every 2 to 7 years and can last up to 18 months. El Niño has significant environmental and climate impacts on a global scale. In some areas, this can lead to reduced rainfall and drought, while other areas are subject to intensive rainfall and flooding. Climatologists have announced that the El Niño event 2015-2016 could be the most severe ever recorded [Source: FAO, 2016].
- The last El Niño event (from 2015 to 2016) has affected Tanzania. About 25,000 households have been directly affected by floods in six regions namely Arusha, Dodoma, Mara, Morogoro, Mwanza, and Shinyanga [Source: FAO, 2017].
- It has also impacted temperatures from October to December 2015 and the beginning of year 2016. Temperatures during that period reached up to 36°C, approximately 1.7 - 2.0°C above the monthly average temperature, in particular on the coastal areas and Northeastern highlands. This deviation from the average is

Table 1. Seasons in Tanzania. [Source: FAO, 2006].

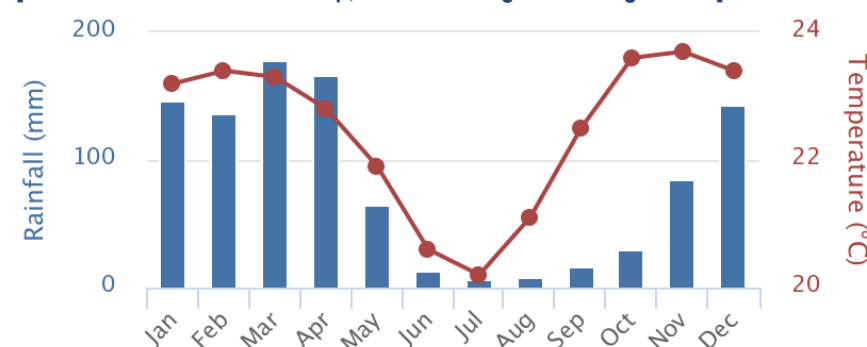
MONTH	WIND DIRECTION	SEASON	ZONE		
			North	Central	South
December to March	NE	Kaskazi	Dry	Dry	Wet
March to May	Variable	Masika	Wet	Wet	Wet
June to September	SE	Kusi	Dry	Dry	Dry
October to November	NE	Vuli	Wet	Wet	Wet

- The table shows typical seasons in Tanzania but it may vary. High evapotranspiration rate can reduce the effectiveness of rainfall, especially in the semi-arid areas (PLDPT, 1984).
- The combined influences of altitude, latitude, rainfall and soil determine the climatic zones of East Africa. Pratt and Gwynne (1977) classify Tanzania into five agro-ecological zones: afro-alpine, humid to dry sub-humid, dry sub-humid to semi-arid, semi-arid and arid.

km<sup>2</sup>) experiences at least four months with precipitations below 5 mm/month every year (on average).

- Most of the areas with extended dry periods are mainly in the Center (Dodoma, Iringa, Mbeya, Sumbawanga, Tabora) and in the South (Songea, Tunduru) of the country. The situation is less severe in the Northern (around Lake Victoria) and Eastern oceanic zones.
- Those long dry period regions are more likely to feature seasonal rivers and streams that are less favorable for hydropower development.

Figure 4. Average Monthly Temperature and Rainfall for Tanzania from 1901-2015. [Source: The World Bank Group, Climate Change Knowledge Portal].



the highest in the country historical records [Source: Tanzania Meteorological Agency, 2016].

- These extreme hazards have had severe repercussion on the livelihood of the affected population. They have lost crops, agricultural inputs and tools, animals, pasture land and other sources of income such as agriculture casual labor, in addition to houses properties [Source: FAO, 2017].

Table 2. Main natural hazards experienced by the Tanzanian communities (% of respondents). [Source: FAO, 2016].

TYPE OF HAZARDS	FREQUENCY			
	RARELY	REGULARLY	SEASONALLY	YEARLY
Drought	13.5%	14.5%	29.5%	70.0%
Floods	73.0%	14.5%	26.5%	0.0%
Frost	0.0%	0.0%	3.0%	0.0%
Hail	0.0%	0.0%	3.0%	0.0%
Others	0.0%	0.0%	0.0%	10.0%
Pest / diseases	13.5%	71.0%	3.0%	0.0%
Storm	0.0%	0.0%	35.0%	20.0%

#### 2.4.4. Climate change

[Sources: United Republic of Tanzania (Vice President's Office), *National Climate Change Strategy*, 2012; The World Bank Group, Climate Change Knowledge Portal].

- Climate change has impacted Tanzania and threatens the majority of Tanzanian who depend on natural resources. In order to face this problem, the country has to develop adaptation strategies in various areas including agriculture and water resource management, such as irrigation, water saving, rainwater harvesting; coastal protection; alternative clean energy sources; sustainable tourism activities and community awareness programs in public health.
- Analysis of climatological data notice signals of increased climate variability and climate change over most parts of the country. Observations from local communities point in the same direction. Recent climatic disturbances such as increasing temperature, notably over highland areas are observed in most parts of the country, late rainfall onset and early withdraw (cessation),

decreasing rainfall amount and seasonal shift in rainfall patterns are becoming more common. Most parts of the country, particularly the Central and Northern Zones, which are semi-arid will be more likely vulnerable to the projected increase in frequency and amplitude of extreme climate events (URT, 2007).

- The National Climate Change Strategy presents Tanzania with an opportunity to address climate change adaptation and participate in the global efforts to reduce GHG emissions in the context of sustainable development. The commitment of the country to the conservation of its forests is appropriate considering that Tanzania has over 33.5 million hectares of forestry reserves and sizable rural land under forest cover. This natural reserve can play an important role to sustainable development and act as a sink of greenhouse gases produced elsewhere. Every decisions and actions that will be taken to reduce climate change will have beneficial consequence for the nation and communities.

*« Hydropower: a renewable source of energy whose development must contribute to adaptation strategies to climate change »*

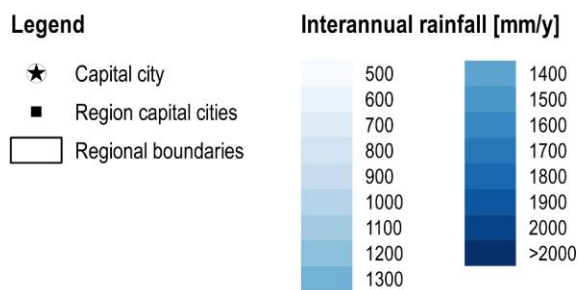
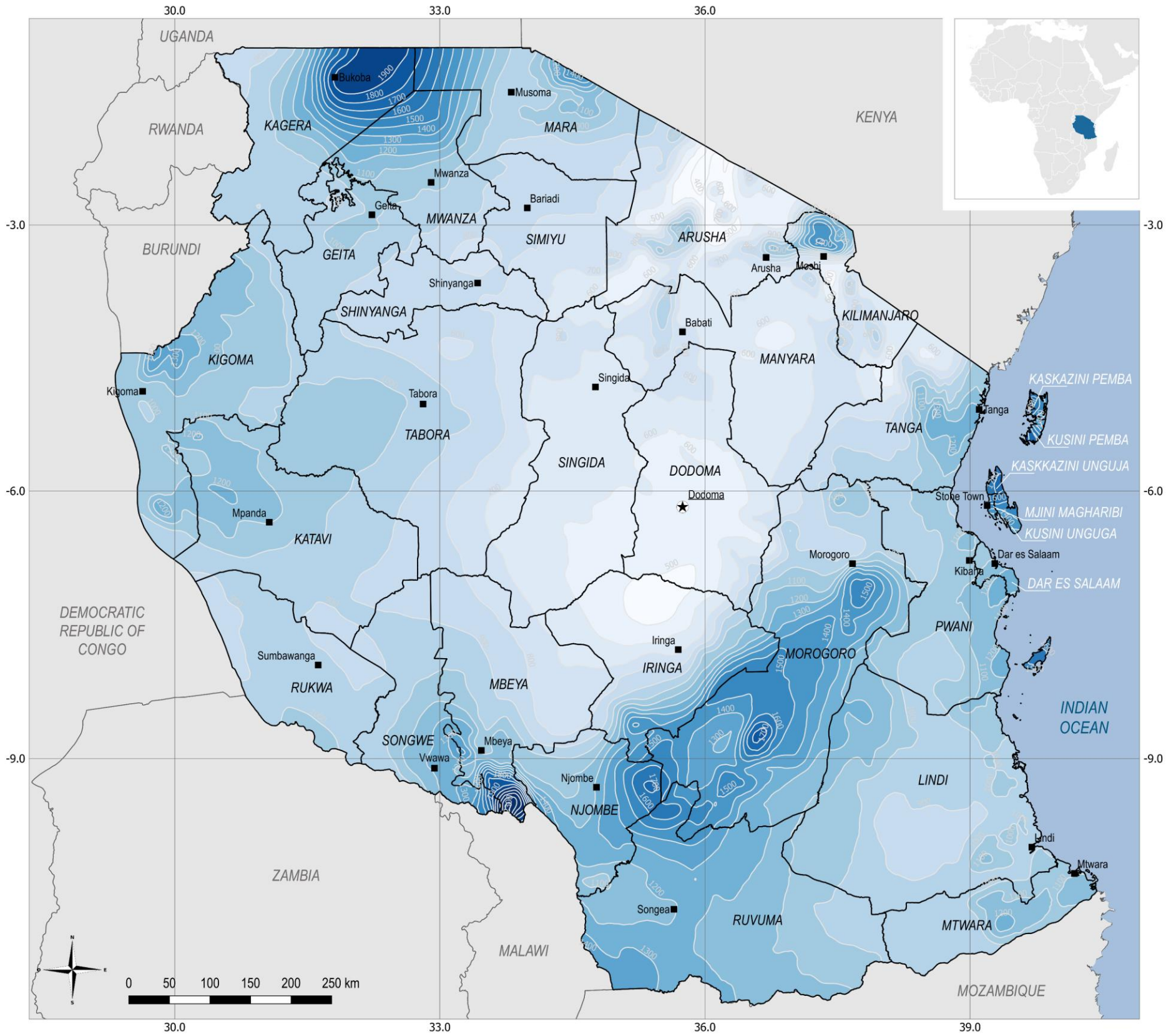


# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

### RAINFALL: INTERANNUAL AVERAGE

Annual rainfall varies from 500 mm/y to 1,000 mm/y in most parts of the country. The highest annual rainfall of 1,000 mm to 3,000 mm occurs in the northeast of the Lake Tanganyika basin and in the Southern Highlands. In these areas, mean annual rainfall is 1,071 mm. Zanzibar and the coastal areas are hot and humid, and average daily temperatures are around 30°C. October-March is the hottest period. Sea breezes however temper the region's climate and the period of June-September is the coolest with temperatures falling to 25°C. In the Kilimanjaro area, temperatures vary from 15°C in May-August to 22°C in December-March [Source: FAO, 2016].



SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Cities: Open Street Map (OSM), 2013.  
 - Rainfall: WorldClim v2, 30 arc-seconds, 2017.

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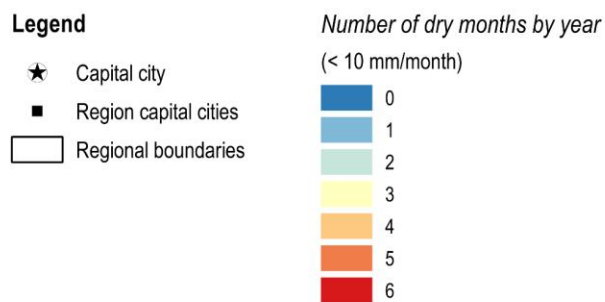
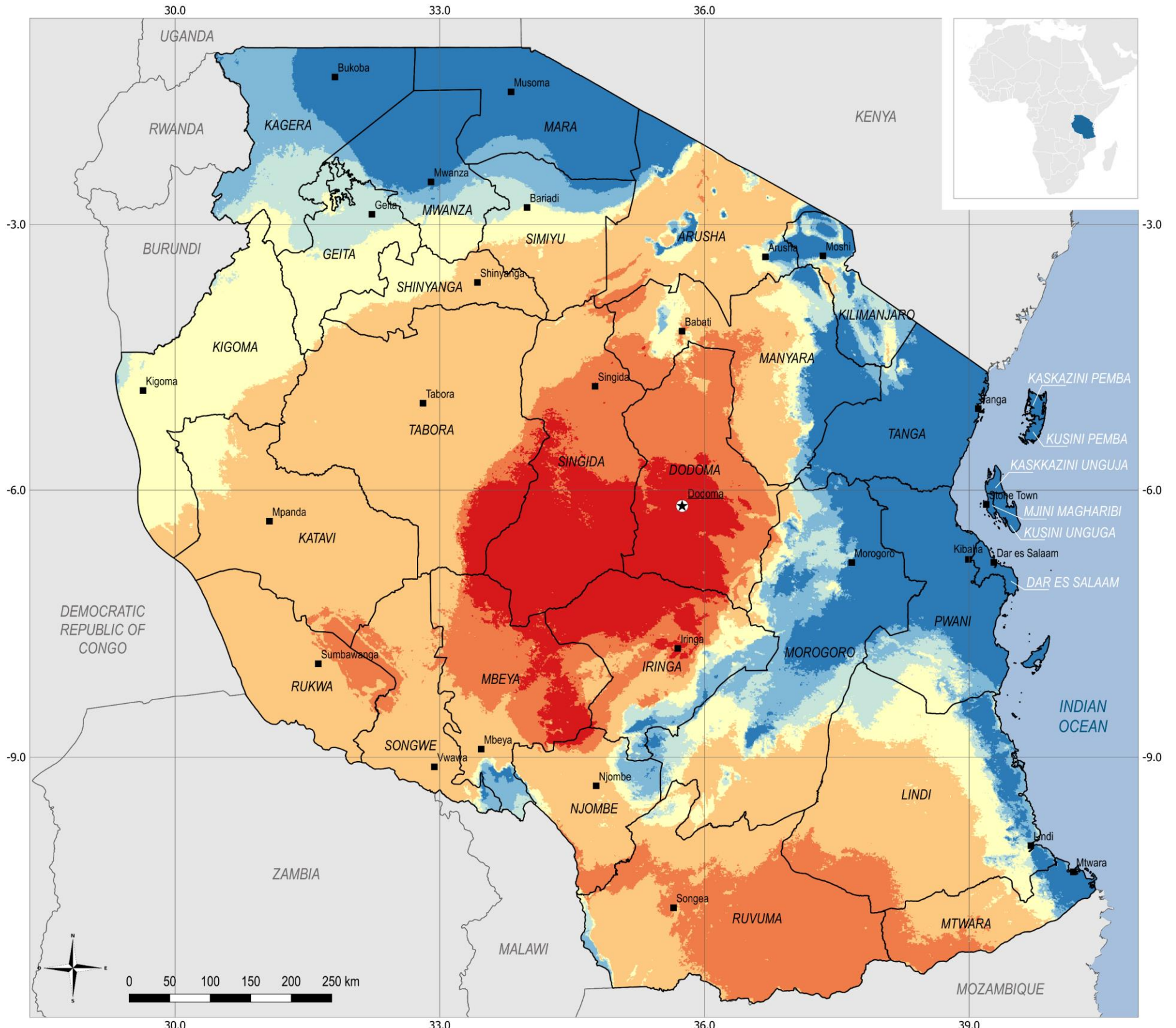


# TANZANIA

## RAINFALL: SEASONAL VARIABILITY

### Atlas of the Hydropower Resource (0.3-10 MW)

This map aims at highlighting the spatiotemporal variability of precipitations in Tanzania. Abundant annual precipitations across the country are unevenly distributed during the year: some regions feature high precipitations during the wet season and long period or several months with precipitations below 10 mm/month. Those regions are characterized by the presence of seasonal rivers and streams that are less favorable for hydropower development.



SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Cities: Open Street Map (OSM), 2013.  
 - Rainfall: WorldClim v2, 30 arc-seconds, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



## 2.5. LAND COVER

- The land cover presented in **Map 9** is a result of the CCI Land Cover (© ESA Climate Change Initiative - Land Cover project 2016) which is a well-known source of land cover information worldwide. These data are the result of the integration of five years (2008-2012) of satellite images acquired by the European Space Agency (ESA) MERIS instrument (MEdium Resolution Imaging Spectrometer).
- A very abundant vegetation cover composed mainly by forests, which cover about 40% of the territory, characterizes the country. Croplands, alone or in association, account for about 30% of the land cover classes. Then, the grasslands and shrublands together represent a little less than 25% of the country's surface whereas water bodies a little more than 5%.
- The spatial distribution of the land cover of the country is mainly characterized by a natural vegetation (forest and shrub) which covers half part of the central plateau (western, southern and northeastern parts) and the eastern ocean side (plains) whereas the other part of the central plateau (central and northern parts) is mainly distinguished by agricultural areas.
- The Landsat satellite image presented in **Map 10** shows the distinction between the diverse vegetation cover.
- The general evolutionary trend leads to a deforestation in favor of agriculture.

Table 3. Land cover classes of Tanzania (ESA-CCI).

LAND COVER CLASS	AREA	
	[km <sup>2</sup> ]	[%]
Tree cover broadleaved deciduous open (15-40%)	193,200	20.5%
Shrubland	150,400	16.0%
Cropland rainfed - Herbaceous cover	117,000	12.4%
Tree cover broadleaved deciduous closed to open (>15%)	116,000	12.3%
Cropland rainfed	91,170	9.7%
Water Bodies	60,020	6.4%
Shrub or herbaceous cover flooded fresh/saline/brackish water	45,130	4.8%
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	27,600	2.9%
Grassland	27,050	2.9%
Mosaic cropland (>50%) / natural vegetation (tree/shrub/herbaceous cover) (<50%)	25,070	2.7%
Tree cover mixed leaf type (broadleaved and needleleaved)	20,700	2.2%
Cropland irrigated or post-flooding	16,540	1.8%
Tree cover broadleaved evergreen closed to open (>15%)	11,460	1.2%
Mosaic natural vegetation (tree/shrub/herbaceous cover) (>50%) / cropland (<50%)	10,680	1.1%
Others classes (with < 1% of total area)	28,572	3%
<b>TOTAL</b>	<b>940,592</b>	<b>100%</b>



## 2.6. PROTECTED AREAS

[Sources: Tanzania National Parks (TANAPA), 2017; Ngorongoro Conservation Area Authority (NCAA); Tanzania Wildlife Management Authority (TAWA), 2016; Tanzania Forest Services (TFS) Agency, 2016; The Ramsar Convention Secretariat; Marine Parks and Reserves Tanzania, 2015].

▪ The President of Tanzania, in agreement with the relevant authorities, has approved the designation of protected areas on the land and at sea. This decision is part of Tanzania's wildlife conservation strategy. The designation of protected areas aims to maintain the biological diversity, the natural and cultural resources of these places through legal or other effective means. Among the protected areas, many sites are listed as UNESCO World Heritage Sites. Consequently, special rules and regulations apply for these areas, e.g. related to settlement, tourism, hunting and other activities. Depending on their status, the areas are divided into the following categories:

- ◆ **National Parks:** The Tanzania National Parks (TANAPA) consists of 16 national parks and are part of the country's rich natural heritage. The conservation of its fauna and flora is a priority. Hence, these areas are subject to a particular protection against the human activity that may threaten their biodiversity and ecosystem.
  - ◆ **Conservation Areas** such as the Ngorongoro Conservation Area (NCA) are polyvalent lands where human development is realized in accordance with the conservation of natural resources. For example, in the Ngorongoro Conservation Area, the interests of indigenous residents are respected and tourism is promoted while maintaining the conservation of natural resources.
  - ◆ **Game Reserves** are categories of wildlife protected areas which are declared for the purpose of conservation. Both consumptive and non-consumptive wildlife utilization are allowed after permit has been obtained from the Director of Tanzania Wildlife Management Authority (TAWA). No human activities are allowed, unless, with permit granted by the Director of TAWA.
  - ◆ **Wildlife Management Areas** are areas of communal land which are not part of protected areas, voluntarily set aside as habitat of wildlife by local community members.
  - ◆ **Game Controlled Areas** are declared for conservation of wildlife outside village land where activities that could negatively affect wildlife are prohibited.
  - ◆ **Forest Nature Reserves** (FNR) are state-owned and are managed by the Tanzania Forest Services (TFS) Agency. Animals and trees are protected in these places. These reserves are generally restricted to research, education and nature-based tourism.
  - ◆ **Ramsar Sites:** The Convention on Wetlands, called the Ramsar Convention, is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. There are two sites in Tanzania identified as Ramsar sites: Lake Natron and Kilombero valley. Wetlands are among the most diverse and productive ecosystems. They provide essential environmental services and represent important resources of fresh water.
  - ◆ **Marine Reserves** are protected areas that are strictly set aside to protect biodiversity and are always small areas where human residence is not allowed. The use of their resources and their impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
  - ◆ **Marine Parks** are a specialized version of a marine reserve where various community users and habitation is encouraged through a strict zonation scheme, and emphasis on education, recreation and preservation is highly recommended through participatory management approaches.
- Protected areas represent a little less than 40% (361,300 km<sup>2</sup>) of the total terrestrial area of Tanzania and 3% (7,300 km<sup>2</sup>) of the marine area (**Map 11**). These areas are distributed throughout the territory.

« *The environmental impacts of small hydropower development are generally lower* »

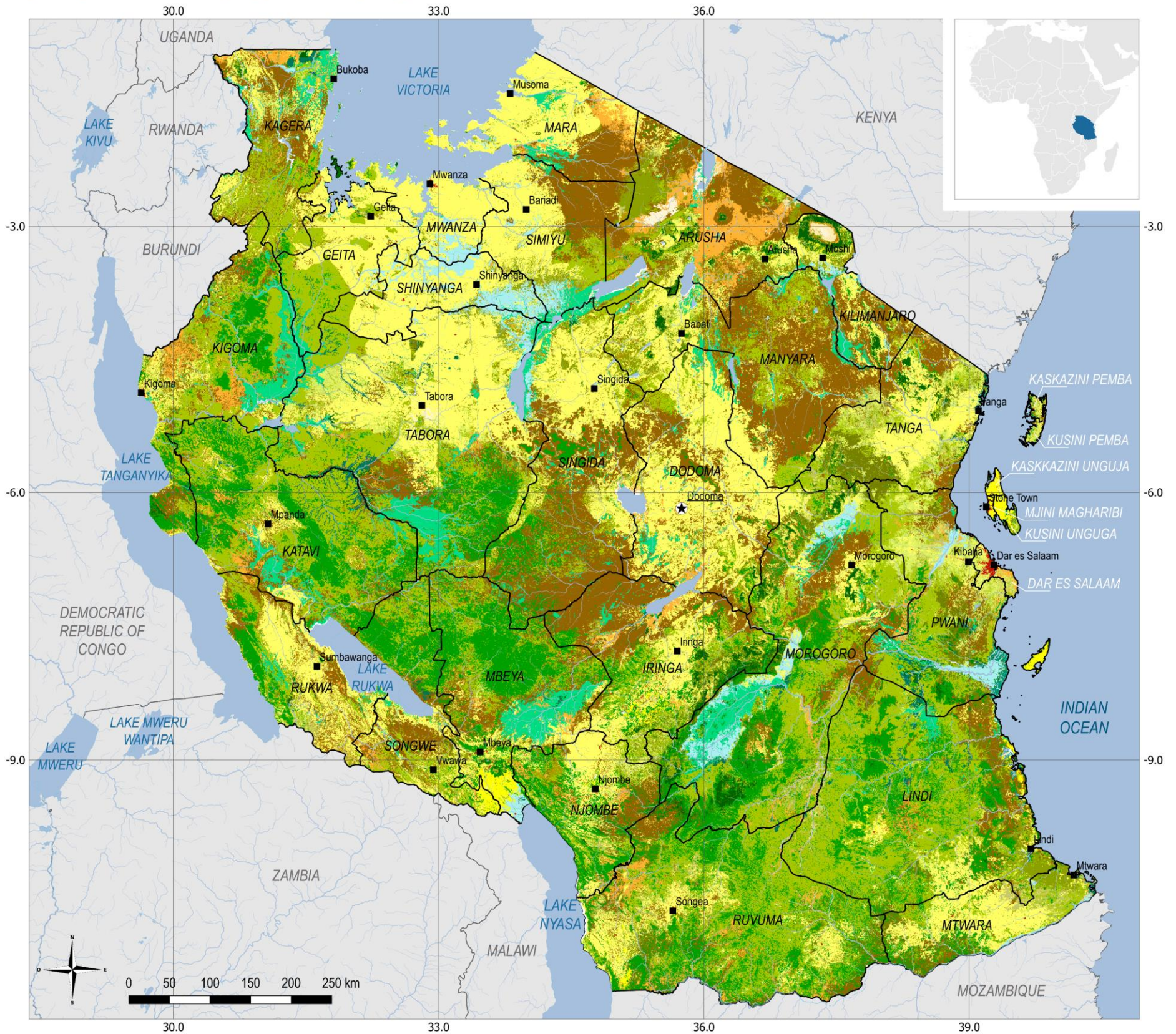


# TANZANIA

## LAND COVER

### Atlas of the Hydropower Resource (0.3-10 MW)

A very abundant vegetation cover composed mainly by forests, which cover about 40% of the territory, characterizes the territory of Tanzania. Croplands, alone or in association, account for about 30% of the different land cover classes. Then, the grasslands and shrublands together represent a little less than 25% of the country's surface whereas water bodies a little more than 5%. The spatial distribution of the land cover of the country mainly concerns a natural vegetation (forest and shrub) which characterizes a half part of the central plateau (western, southern and northeastern parts) and the eastern ocean side (plaines) whereas the other part of the central plateau (central and northern parts) presents mainly an agricultural areas.



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries

**Land cover (ESA-CCI)**

- Cropland rainfed
- Cropland rainfed - Herbaceous cover
- Cropland rainfed - Tree or shrub cover
- Cropland irrigated or post-flooding
- Mosaic cropland (>50%) / natural vegetation (<50%)
- Mosaic natural vegetation (>50%) / cropland (<50%)
- Tree cover broadleaved evergreen closed to open (>15%)
- Tree cover broadleaved deciduous closed to open (>15%)
- Tree cover broadleaved deciduous closed (>40%)

- Tree cover broadleaved deciduous open (15-40%)
- Tree cover needleleaved evergreen closed to open (>15%)
- Tree cover needleleaved deciduous closed to open (>15%)
- Tree cover mixed leaf type (broadleaved and needleleaved)
- Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
- Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
- Shrubland
- Shrubland deciduous
- Grassland
- Sparse vegetation (tree/shrub/herbaceous cover) (<15%)

- Sparse herbaceous cover (<15%)
- Tree cover flooded fresh or brakish water
- Tree cover flooded saline water
- Shrub or herbaceous cover flooded
- Urban areas
- Bare areas
- Consolidated bare areas
- Unconsolidated bare areas

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

Data sources :  
- Administrative boundaries: Global Administrative Areas (GADM), 2015.  
- Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
- Cities: Open Street Map (OSM), 2013.  
- Land cover: ESA Climate Change Initiative - Land cover Project 2015.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).





# TANZANIA

## SATELLITE IMAGERY

### Atlas of the Hydropower Resource (0.3-10 MW)

The Landsat satellite imagery illustrates the spectral information from the Earth's surface in Tanzania collected on October 4, 2013. It shows the presence of a dense and abundant vegetation across the country. Drier areas are clearly identified by brown patterns mainly in the extreme Northeastern and central parts of the country. Landsat imagery is used to contribute to resources assessment and to monitor the environmental changes such deforestation, land use change and population growth through the analysis of time series of images.



- Legend**
- ★ Capital city
  - Region capital cities
  - Main rivers
  - Lakes
  - Regional boundaries

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Satellite imagery: Google Earth, October 2013.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).

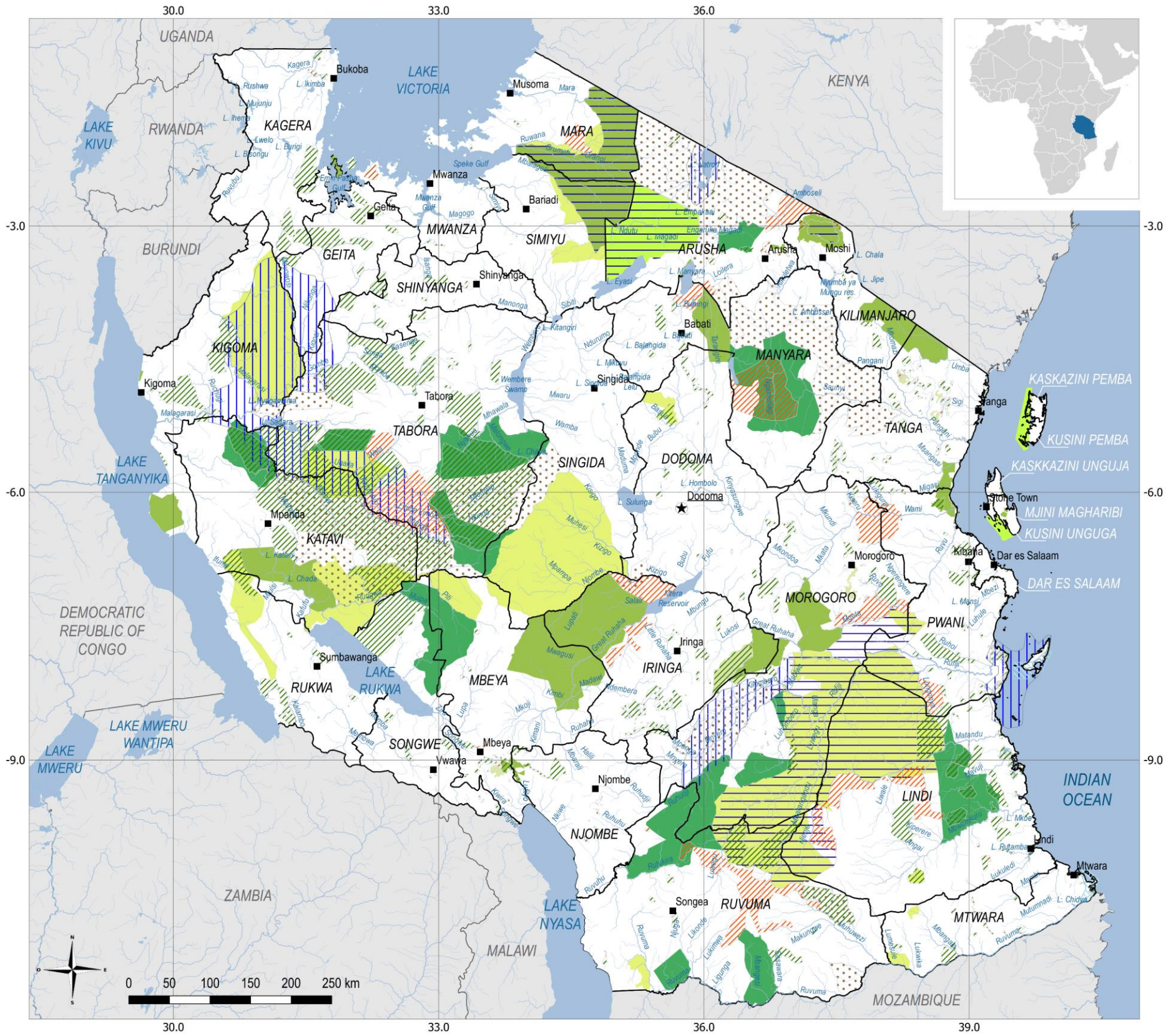


# TANZANIA

## PROTECTED AREAS

### Atlas of the Hydropower Resource (0.3-10 MW)

The President of Tanzania, in agreement with the relevant authorities, has approved the designation of protected areas on the land and at sea. This decision is part of Tanzania's wildlife conservation strategy. The designation of protected areas aims to maintain the biological diversity, the natural and cultural resources of these places through legal or other effective means. Among the protected areas, manysites are listed as UNESCO World Heritage Sites. Protected areas represent a little less than 40% (361,300 km<sup>2</sup>) of the total terrestrial area of Tanzania and 3% (7,300 km<sup>2</sup>) of the marine area. These areas are distributed throughout the territory.



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries

**Protected areas**

- ▨ Ramsar Site, Wetland of International Importance
- ▨ World Heritage Site
- ▨ Forest Plantation
- ▨ Forest Reserve
- ▨ Wildlife management area
- ▨ Marine Reserve
- ▨ Marine Park
- ▨ Game controlled area
- ▨ Conservation Area
- ▨ Game reserve
- National Park
- Nature Reserve
- Open area
- Sanctuary and Closed Forest Reserve

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

Data sources:  
- Administrative boundaries: Global Administrative Areas (GADM), 2015.  
- Cities: Open Street Map (OSM), 2013.  
- Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
- Rivers and Lakes names: Tanzania - Rwanda - Burundi, Nelles Map, Ed. 2012.  
- Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# Chapter 3.

## Energy sector in Tanzania

### 3.1. GENERAL INFORMATION

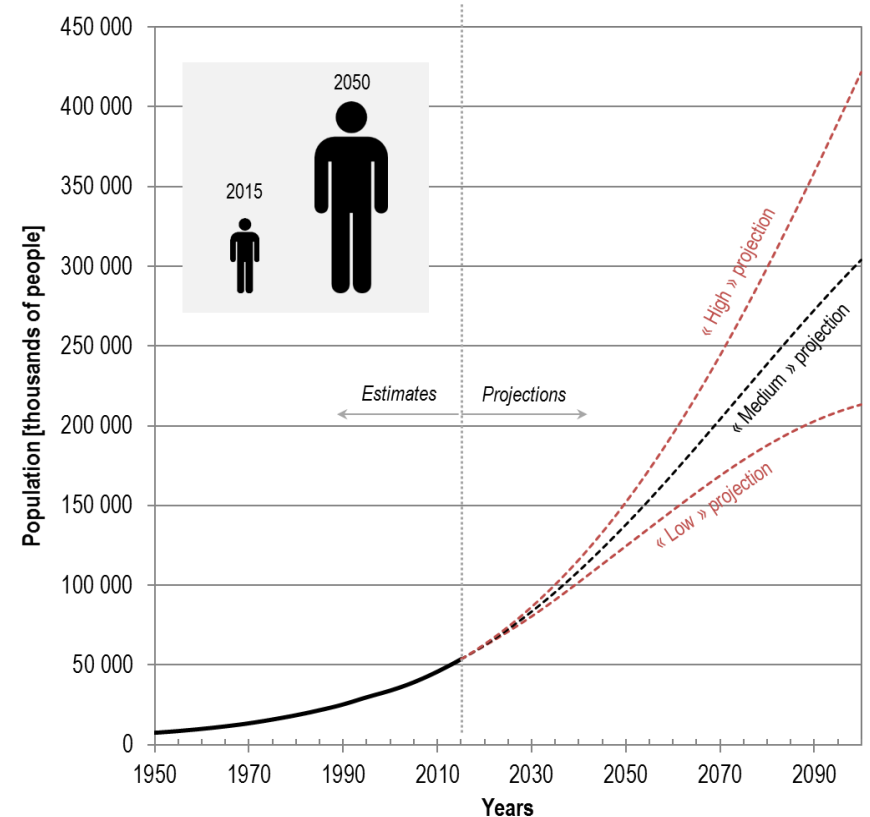
[Sources: U.S. Agency for International Development (USAID); SHER Ingénieurs-Conseils, *Small Hydro Mapping Report*, 2015; African Development Bank Group, *Renewable Energy in Africa - Tanzania country profile*, 2015]

- Tanzania is endowed by a variety of energy resources from coal and natural gas to renewable energy sources like biomass, hydropower, geothermal, solar and wind. Most of this potential remains currently untapped, despite the expansion of the power capacity and grid extension led by the Government of Tanzania (GoT). The continued development of Tanzania's energy sector is critical to the country's ability to grow economically, attract foreign direct investment, and increase industrialization.
- The development of the renewable resources available in the country would contribute significantly to Tanzania's energy supply and contribute moving the country closer to achieving middle-income status, as envisioned in the Tanzania National Development Vision 2025.
- For many years, the Tanzanian electric system has not been able to satisfy the growing demand for electricity. Supply of electricity is not keeping pace with demand causing frequent load shedding and power outages. Consequently, the electricity demand is supply-driven, and it is hence difficult to estimate the actual demand in a context of sufficient supply. Government estimates are that demand for electricity is on average growing between 10 % and 15 % per annum.
- During the last 10 years, various important reforms were implemented in the electricity sector. The main stakeholders in the Tanzanian Electric Sector are the following: The Ministry of Energy and Minerals responsible for "electricity matters" (as it is designated in the Electricity Act, 2008), the Energy and Water Utilities Regulatory Authority (established under EWURA Act, Chapter 414), the Rural Energy Agency (REA) (established under Part IV of the Rural Energy Act, 2005) and the utility Tanzania Electric Supply Company Limited (TANESCO). Other Ministries also have a role in the energy sector activities such as the Ministry of Environment.
- Recognizing the potential contribution of renewable energy to the country's future energy mix, the GoT is committed to promote the development of low-carbon energy initiatives, by harnessing the country's renewable energy resource. Renewable and clean sources of energy can be utilized to improve access to sustainable, modern and cleaner energy services. Deployment of renewable energy technologies has the potential to contribute to job creation, income generation and the improved livelihoods for vulnerable population groups, particularly women and children in rural areas.
- Tanzania is impacted by climate change, facing increasingly unreliable rainfall patterns and more frequent and prolonged drought periods over the past two decades. These have affected the country's power sector due to its strong dependence on hydropower, as presented in Section B hereafter. This situation has created power crises and increased dependence on expensive and environment polluting fossil fuels most of which are imported. This unsustainable situation is an opportunity to

boost the development of renewable energy and diversify the energy mix to attain a more robust and resilient energy supply that is less subject to oil price shocks.

- Tanzania's energy sector faces a number of significant challenges amongst which:
  - ◆ Increasing electricity demand;
  - ◆ Risk of load shedding, power outages and associated electricity price shocks due to the increasing unpredictability of hydropower generation;
  - ◆ Financing of the energy sector;
  - ◆ Low access to reliable electricity;
  - ◆ The size of the country associated with scattered population makes grid extension expensive for many remote areas;
  - ◆ Health risks and degradation of the environment from household reliance on biomass energy.
- In June 2014, considering the supply and financial crisis known by the country in recent years, the GoT adopted the "Electricity Supply Industry Reform Strategy and Roadmap 2014 – 2025".
- Population dynamics is one of the key factors influencing the future demand for energy and capacity. As illustrated in Figure 5, the number of inhabitants of the country will increase from 53.9 million in 2015 (estimate) to 138.1 million in 2050 (median projection).

Figure 5. Population growth in Tanzania between 1950-2100 [Source: UN, World Population Prospects, The 2017 Revision].



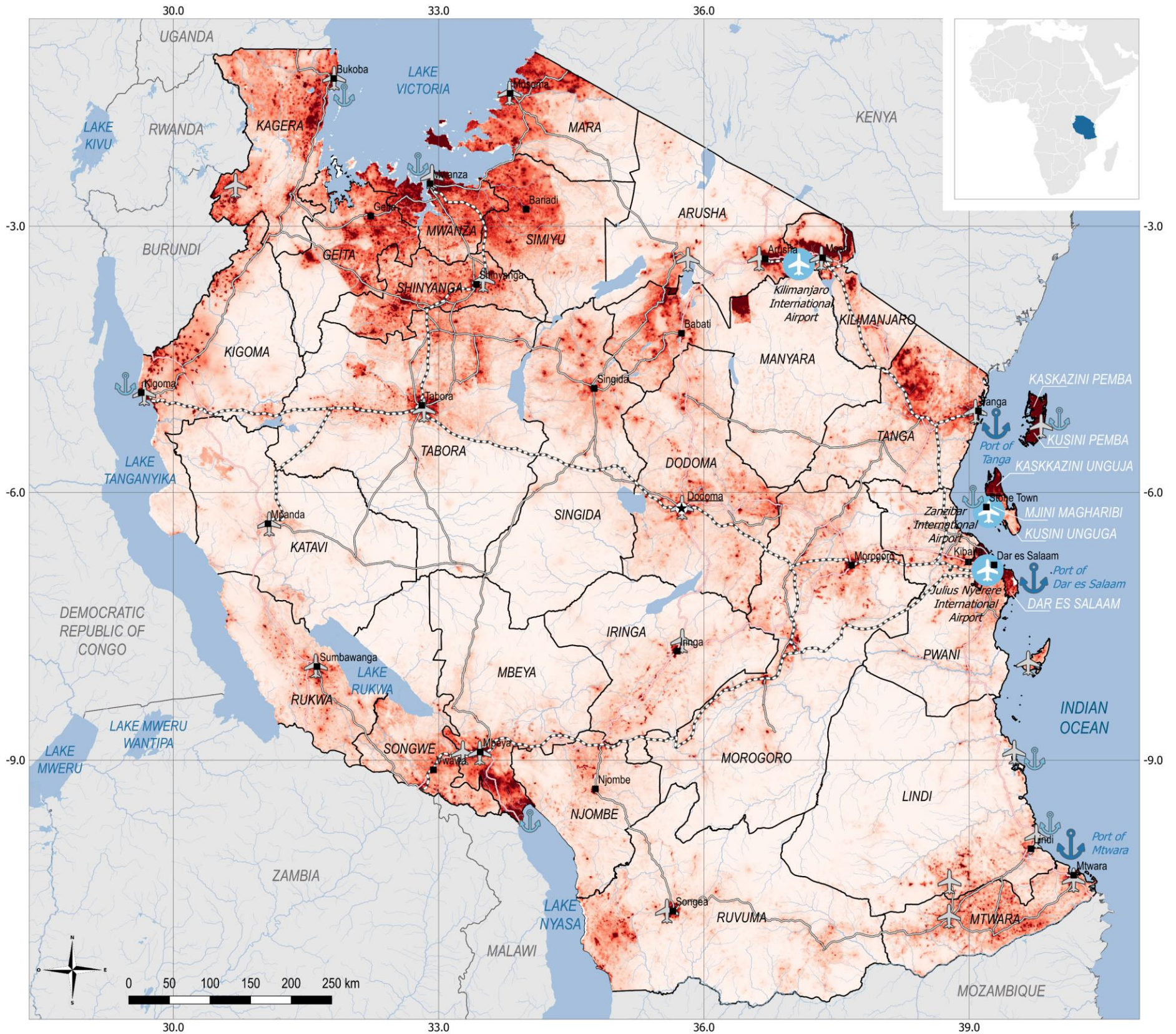
- According to the census 2012, on the Mainland, the population is mainly distributed on the northern border (Lake Victoria) and eastern coast with the highest density in Dar es Salaam (over 3,000 persons per square kilometer). Zanzibar has also a high-density population with over 2,500 persons per square kilometer in the Mjini Magharibi region (**Map 12**).

# TANZANIA

## POPULATION & TRANSPORT

### Atlas of the Hydropower Resource (0.3-10 MW)

According to the 2012 census, the population is mainly distributed along the northern border (Lake Victoria) and eastern coast with the highest density in Dar es Salaam. With a total population of 44,928,923 inhabitants (census 2012), the density is higher than 1000 inhabitants per square kilometer around the major cities. According to the Road Act (2007), there are 86,472 km of classified road in Tanzania. The National Road Network consists of 12,786 km of trunk roads (out of which 5,130 km are paved) and 21,105 km of regional roads (amongst which 840 km are paved). Dar Es Salaam is (with Mombasa in Kenya) one the key player in the container sector on the East coast of Africa. The port is connected by rail and road to the main cities across the country.



Legend		Road network	Port & Airport infrastructure	Population density [pers./km <sup>2</sup> ]
★ Capital city	— National roads	⚓ Major ports	0	
■ Region capital cities	— Regional roads	⚓ Secondary ports	50	
— Main rivers	⋯ Railways	✈ International airports	100	
■ Lakes		✈ Regional airports	150	
□ Regional boundaries			200	
			250 and more	

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Road network: World Bank, Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Airports infrastructure: Tanzania Airports Authority (TAA).
  - Ports infrastructure: Tanzania Ports Authority (TPA).
  - Population density: AfrPop v2b (adjusted to match UN national estimates), 2015.

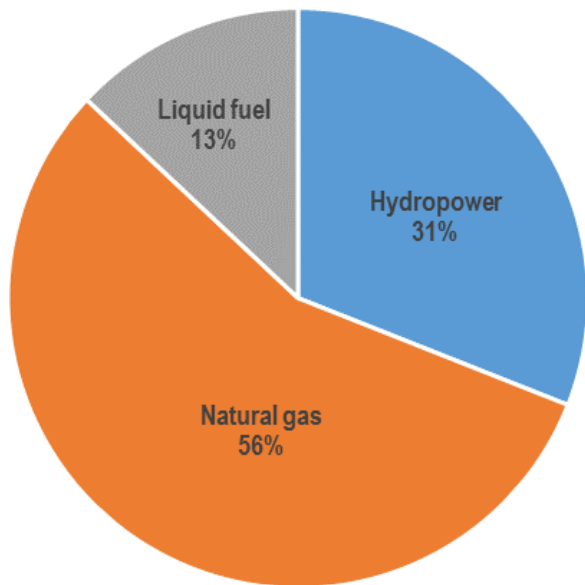
This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



### 3.2. ENERGY MIX, DISTRIBUTION AND MAIN PRODUCTION UNITS

- Biomass is the major source of energy in Tanzania. It is primarily used domestically, in the form of charcoal and firewood [Source: Global Legal Insights (GLI), *Energy 2018*]. More than 80% of energy delivered from biomass is consumed in rural areas. Heavy use of biomass as the main energy source contributes to deforestation, while the importation of oil costs about 25% to 35% of the nation's foreign currency earnings [Source: TANESCO, *Current status of energy sector in Tanzania*, 2013].
- According to the EWURA's annual report (2016), Tanzania has an installed power capacity of 1,442 MW, of which 1,358 MW supplying the Main Grid and 84 MW in Isolated Grids across the country. The electricity generation mix consists of 31% from hydropower and 69% from thermal (natural gas 56% and liquid fuel 13%) as shown in Figure 6. During the financial year 2015-2016 a total of 6,449 GWh were available for sale from TANESCO plants (61%), Independent Power Producers (IPPs, 37%), Small Power Producers (SPPs, 0.8%) and imports from neighboring countries (1.3%).

Figure 6. Electricity generation mix in Tanzania. [Source: EWURA, *Annual Report for the year ended 30<sup>th</sup> June, 2016*].



- Most of the thermal power is installed around Dar es Salaam with a total of 757 MW representing approximately 80% of the total thermal installed capacity of the country (2013).
- Hydropower generation which used to represent the bulk of the overall electricity generation declined by nearly two-thirds between 2002 and 2006 (from 98% to 40%), and now stands at 31% of the available capacity. This situation resulting notably from periods of extended droughts has caused extensive load shedding and the use of expensive thermal power plants as main electricity source to compensate the reduced output from hydropower plants. [Source: African Development Bank Group, *Renewable Energy in Africa*, 2015].

Figure 7. Mtera dam and reservoir (Source: Google Earth).



Table 4. Main existing hydropower plants [Source: Ministry of Energy and Minerals, *Power System Master Plan – 2016 Update*, December 2016].

NAME (LOCATION)	TYPE	NUMBER OF UNITS	INSTALLED CAPACITY [MW]	ANNUAL ENERGY GENERATION [GWh]	INSTALLATION YEAR
<b>Owned by TANESCO</b>					
Hale (Korogwe)	Run-of-the-river	2	21	36	1964
Nyumba Ya Mungu (Mwanga)	Reservoir	2	8	22	1968
New Pangani (Muheza)	Run-of-the-river	2	68	137	1995
Kidatu (Kilombero-Morogoro)	Reservoir	4	204	558	1975 (2 units) 1980 (2 units)
Mtera (Kilolo)	Reservoir	2	80	167	1988
Uwemba (Njombe)	Run-of-the-river	3	0.8	2	1991
Kihansi (Kilombero-Iringa)	Run-of-the-river	3	180	793	1999 (1 unit) 2000 (2 units)
<b>Owned by Small Power Producers (SPPs)</b>					
Mwanga (Mufindi)	Run-of-the-river	1	4	17	2012
Darakuta (Magugu)	Run-of-the-river	N/A	0.5	N/A	2015
Yovi (Kisanga)	Run-of-the-river	1	1	N/A	2016
Tulila (Songea)	Run-of-the-river	2	5	N/A	2015
Ikondo (N/A)	Run-of-the-river	3	0.6	N/A	2015
Mbangamao (Mbinga)	Run-of-the-river	1	0.5	N/A	2014

Figure 8. Penstock of an existing hydropower scheme.



**Table 5. Percentage distribution of households (HHs) connected (C) and not connected (NC) to electricity by region and place of residence [Source: Rural Energy Agency (REA), *Energy Access Situation Report 2016, 2017*].**

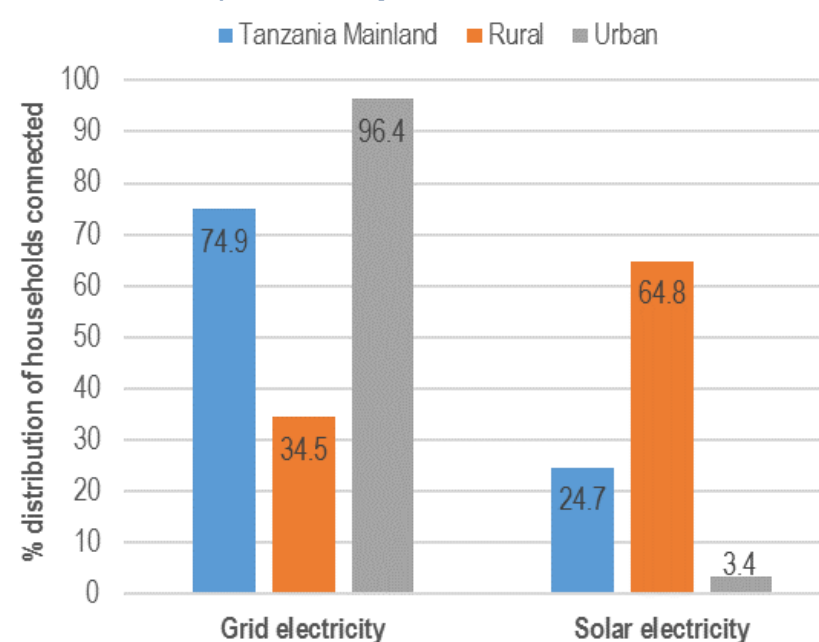
REGION	TOTAL			RURAL		URBAN	
	TOTAL HHs	C	NC	TOTAL HHs	C	TOTAL HHs	C
Arusha	469,204	39.7	60.3	306,509	25.1	162,694	67.4
Dar es salaam	1,417,251	75.2	24.8	-	-	1,417,251	75.2
Dodoma	590,106	23.5	76.5	499,290	16.9	90,817	60.0
Geita	76,553	14.0	86.0	62,706	10.3	13,847	30.6
Iringa	289,324	39.5	60.5	211,231	29.5	78,094	66.7
Kagera	678,574	24.6	75.4	600,054	16.2	78,520	88.7
Katavi	103,890	40.0	60.0	75,873	31.5	28,016	62.8
Kigoma	483,363	16.2	83.8	391,543	6.7	91,820	56.7
Kilimanjaro	499,128	42.6	57.4	383,952	32.4	115,176	76.7
Lindi	293,907	20.0	80.0	237,279	18.0	56,628	28.0
Manyara	354,642	20.6	79.4	299,895	9.4	54,747	81.8
Mara	403,837	21.3	78.7	325,812	14.2	78,024	50.7
Mbeya	412,915	34.1	65.9	254,064	12.9	158,851	68.0
Morogoro	655,833	24.3	75.7	453,798	11.8	202,036	52.4
Mtwara	448,463	33.0	67.0	337,833	24.1	110,630	60.3
Mwanza	630,094	32.8	67.2	387,434	17.9	242,659	56.6
Njombe	221,565	50.5	49.5	161,848	45.9	59,717	62.8
Pwani	333,150	32.8	67.2	216,087	22.5	117,063	51.8
Rukwa	259,632	8.7	91.3	199,587	3.3	60,045	26.6
Ruvuma	392,519	31.8	68.2	286,460	23.2	106,059	55.2
Shinyanga	339,428	12.8	87.2	260,910	7.0	78,517	32.2
Simiyu	298,960	11.5	88.5	287,419	9.3	11,541	66.5
Singida	334,525	22.3	77.7	295,744	15.0	38,780	77.6
Songwe	412,608	15.9	84.1	317,343	6.0	95,264	48.9
Tabora	483,265	21.8	78.2	408,880	13.9	74,385	65.0
Tanga	572,083	30.5	69.5	439,666	19.3	132,417	67.8
<b>Total</b>	<b>11,454,819</b>	<b>32.8</b>	<b>67.2</b>	<b>7,701,217</b>	<b>16.9</b>	<b>3,753,598</b>	<b>65.3</b>

### 3.3. POWER GRID

- The transmission and distribution network of Tanzania are owned and operated by TANESCO. The transmission system consists of 647 km of 400 kV lines, 2,745 km of 220 kV lines, 1,626 km of 132 kV lines and 580 km of 66 kV lines.

- According to a recent survey (*Energy Access Situation Report 2016*), the regional differentials in electricity distribution are still noticeable within and among all regions of Tanzania (**Map 13**). Dar es Salaam region has the highest proportion of households connected to electricity (75%) followed by Njombe (50%), Kilimanjaro (43%) and Katavi (40%). Regions which has less than 20% of households connected to electricity include Rukwa (9%), Simiyu (12%), Shinyanga (13%), Geita (14%), Songwe (16%) and Kigoma (16%).
- Rukwa region is poorly served by electricity with only 3% of its rural households connected to the electricity in 2016. Other regions with less than 10% of their rural households connected to electricity include: Songwe (6%), Kigoma (7%), Shinyanga (7%), Simiyu (9%) and Manyara (10%). The situation is different for urban areas where the percentage of connected households to the electricity ranges from 27% (Rukwa region) to 89% (Kagera region).
- The electrification rate is much higher in urban (65.3%) than in rural areas (16.9%). Disparities on sources of energy are significant between rural and urban residents. Figure 9 shows that, households connected to grid electricity are lower in rural (35%) than urban areas (96%). On the other hand, households connected to solar power was higher in rural (65%) than in urban areas (3%). Private entity/individual electricity generated from owned sources (excluding solar) is the least source of electricity among rural households (0.6 percent).

**Figure 9. Percentage distribution of households connected to electricity by source of energy and place of residence [Source: Rural Energy Agency (REA), *Energy Access Situation Report 2016, 2017*].**



- In addition, transboundary transmission lines exist between Tanzania and Uganda (132 kV) and between Tanzania and Zambia (66 kV) to import power to Tanzania.

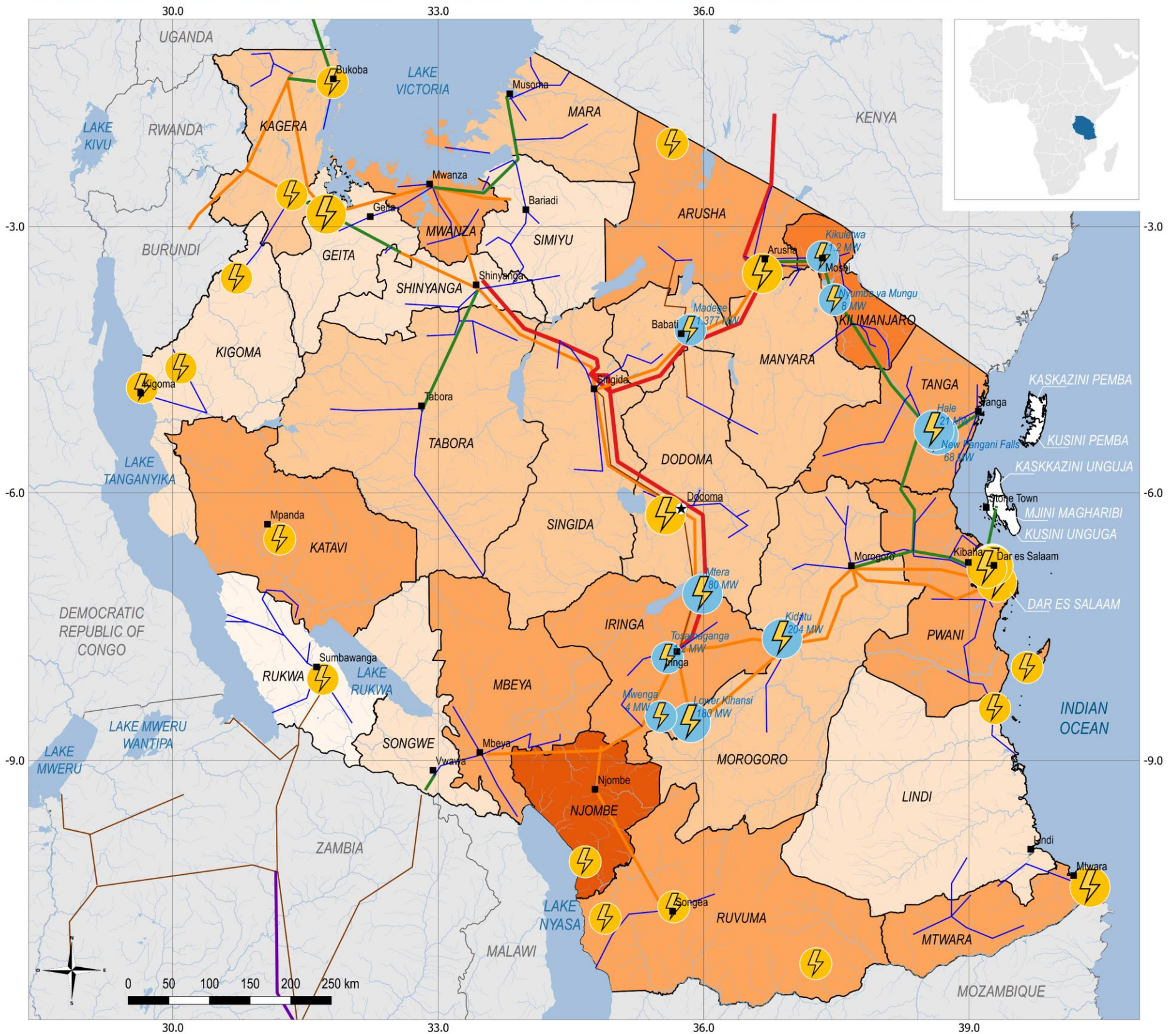
Beside the national grid exists a series of isolated grid supplied by an aggregate power capacity of 84 MW.

# TANZANIA

## ACCESS TO ELECTRICITY

### Atlas of the Hydropower Resource (0.3-10 MW)

According to a recent survey (Energy Access Situation Report 2016), the regional differentials in electricity distribution are still noticeable within and among all regions of Tanzania (Map 13). Dar es Salaam region has the highest proportion of households connected to electricity (75%) followed by Njombe (50%), Kilimanjaro (43%) and Katavi (40%). Regions which has less than 20% of households connected to electricity include Rukwa (9%), Simiyu (12%), Shinyanga (13%), Geita (14%), Songwe (16%) and Kigoma (16%). Rukwa region is poorly served by electricity with only 3% of its rural households connected to the electricity in 2016. Other regions with less than 10% of their rural households connected to electricity include: Songwe (6%), Kigoma (7%), Shinyanga (7%), Simiyu (9%) and Manyara (10%). The situation is different for urban areas where the percentage of connected households to the electricity ranges from 27% (Rukwa region) to 89% (Kagera region)



**Legend**

★ Capital city	Existing transmission lines (schematic)	Main Thermal power plants	Main Hydropower plants (> 1MW)	Access to electricity (by region)
■ Region capital cities	— 33 kV	⚡ > 10 MW	⚡ > 10 MW	(% of households connected)
— Main rivers	— 66 kV	⚡ 1-10 MW	⚡ 1-10 MW	0% - 10%
— Lakes	— 132 kV			10% - 20%
▭ Regional boundaries	— 220 kV			20% - 30%
	— 330 kV			30% - 40%
	— 400 kV			40% - 50%
				50% - 60%
				60% - 70%
				70% - 80%

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

**Data sources:**

- Administrative boundaries: Global Administrative Areas (GADM), 2015.
- Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
- Cities: Open Street Map (OSM), 2013.
- Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
- Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
- Electricity distribution: Rural Energy Agency (REA), 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



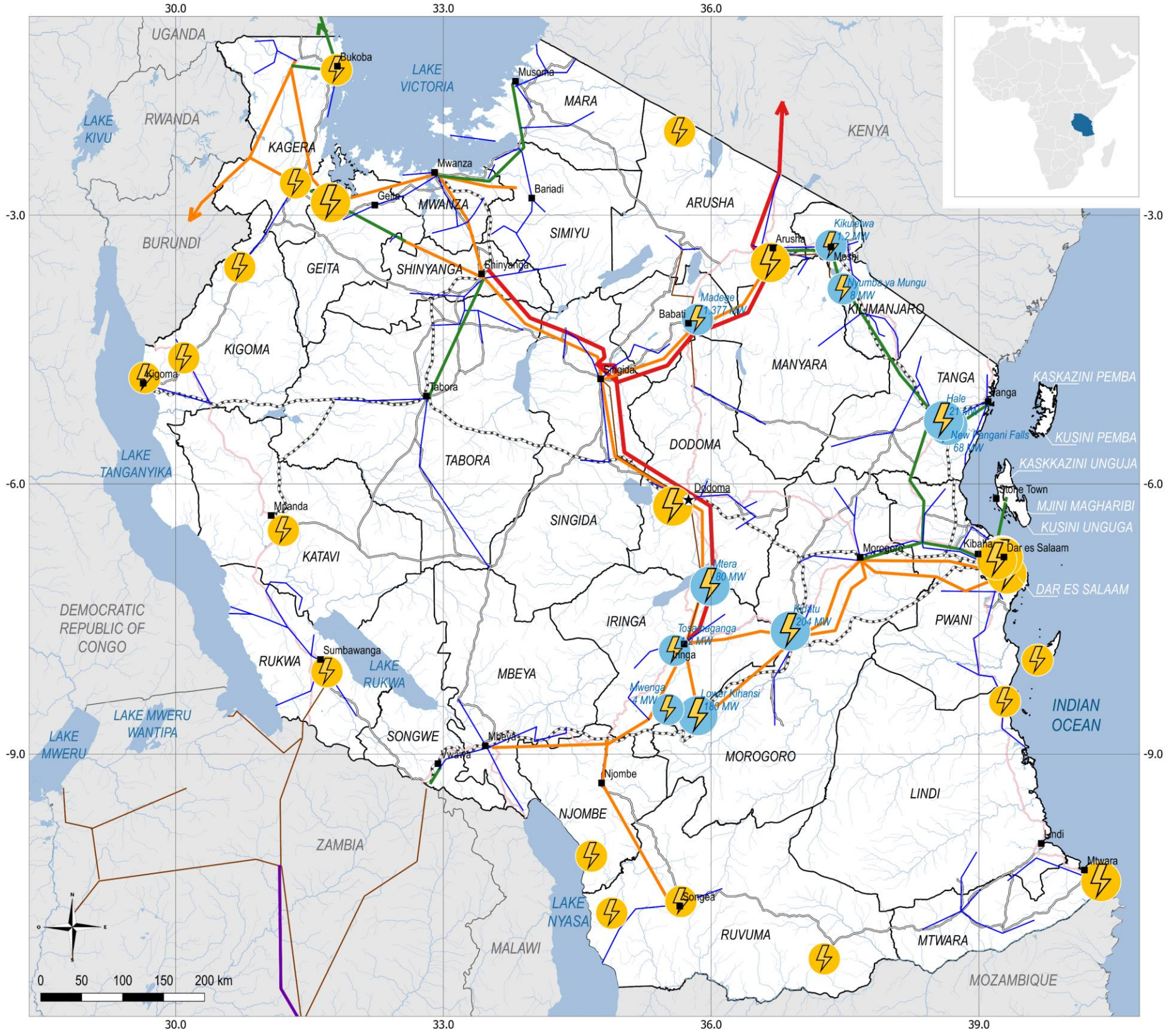
Map 13

# TANZANIA

## EXISTING POWER SYSTEM

### Atlas of the Hydropower Resource (0.3-10 MW)

According to the EWURA's annual report (2016), Tanzania has an installed power capacity of 1,442MW, of which 1,358MW supplying the Main Grid and 84MW in Isolated Grids across the country. The electricity generation mix consists of 31% from hydropower and 69% from thermal (natural gas 56% and liquid fuel 13%). During the financial year 2015-2016 a total of 6,449GWh were available for sale from TANESCO plants (61%), Independent Power Producers (IPPs, 37%), Small Power Producers (SPPs, 0.8%) and imports from neighbouring countries (1.3%).



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries

- Road network**
- National roads
  - Regional roads
  - - - Railways

**Existing power system**

- Transmission lines**
- 33 kV
  - 66 kV
  - 132 kV
  - 220 kV
  - 330 kV
  - 400 kV

- Main Thermal power plants**
- ⚡ > 10 MW
  - ⚡ 1-10 MW

- Main Hydropower plants (> 1MW)**
- ⚡ > 10 MW
  - ⚡ 1-10 MW

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).





## SECTION B. HYDROPOWER RESOURCE (0.3-10 MW)

---

- Methodological approach
- Small hydro potential in Tanzania (0.3-10 MW)



# Chapter 4.

## Methodological approach

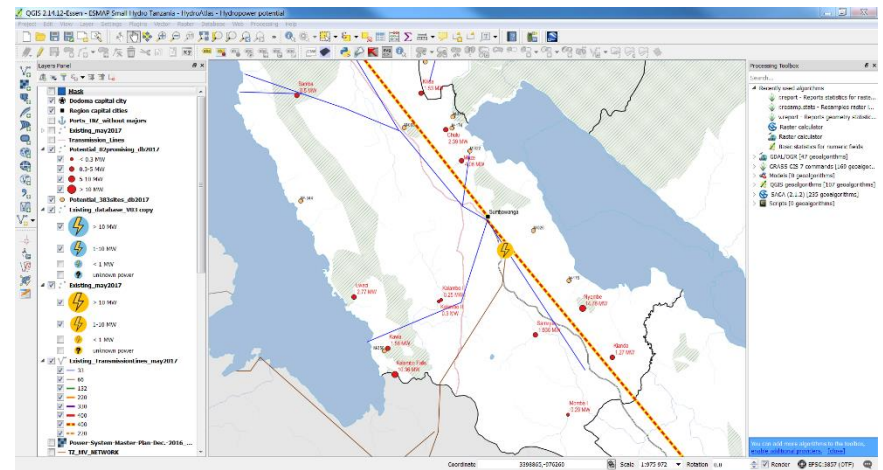
### 4.1. INTRODUCTION

- The present Atlas of Hydropower Resources focuses on potential hydropower sites with an installed capacity between 0.3 and 10 MW.
- The identification of new potential hydropower sites at the country or regional scale relies on the following three-stage approach:
  1. **Screening of the study area** using a dedicated tool that calculates hydropower potential along a network of rivers based on the rainfall and topography. This tool, SiteFinder, has been developed by SHER Ingénieur-Conseils.
  2. **Desk-based analysis** of the results of the screening phase based on the analysis of satellite imageries and topographic maps. It aims at identifying the actual location of potential hydropower site along the river stretch and carrying out a first estimate of the site key features.
  3. **Field visits** are integral part of the potential site identification process to validate the key features expected from the previous stage.
- The database of potential hydropower sites is complemented by the sites that have been already studied and that are available from the literature, studies or lists from the Ministries and other stakeholders of the energy sector.
- The development of the Hydro-Atlas, including the associated Geographic Information System, is an essential tool for the responsible Tanzanian agencies in charge of the planning and

development of the energy sector (Figure 10). The Hydro-Atlas is indeed a unique tool that integrates all the information coming from the different institutions involved in the hydropower sector. It provides an overview of the sector in terms of both existing and potential projects, allowing a better understanding of the energy demand and candidate projects that need to be developed.

- The Hydro-Atlas should be a **dynamic and evolving tool** that must be updated according to future development of the hydropower sector in Tanzania and the increasing availability of information (hydrological measurements, update of site surveys, etc.).

Figure 10. Geographic Information System associated with the Hydro-Atlas of Tanzania.



### 4.2. SITES IDENTIFIED BASED ON EXISTING INFORMATION

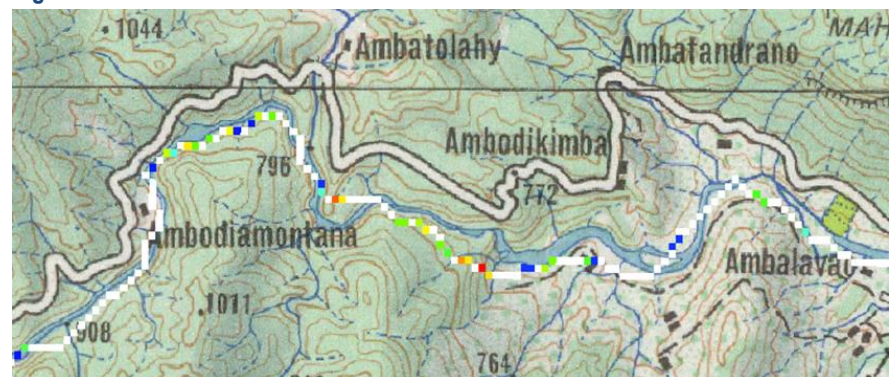
- More than 100 documents were collected and reviewed during the Study. Those documents embrace a large scope of fields related to the electricity sector in Tanzania and from all kinds of authors ranging from government officials to international consultants and agencies. The sources of information on potential sites were the following:
  - ◆ potential sites from the lists of the **World Bank**;
  - ◆ potential sites reported in the archives of the **Ministry of Energy and Minerals, REA, TANESCO**;
  - ◆ potential sites described in different studies from Consultants.

- These lists, which contain common potential sites, present geographical coordinates and some technical information such as installed capacity, gross head or design flow.
- It is important to remember that the lists are often summaries of several documents. Most of the time, these documents are not or not anymore available. Very often, there are significant errors on the positioning and/or technical parameters, and it is not possible to trace the source or to correct them. There is also uncertainty about the technical parameters, when they are mentioned, as we generally do not have information on the assumptions used to determine them.

### 4.3. NEW POTENTIAL SITES: CONTRIBUTION OF SITEFINDER

- *SiteFinder* is a screening tool that calculates hydropower potential along a network of rivers. The result of SiteFinder is a set of river stretches that appear to be relevant for the development of small hydropower scheme i.e. river stretches that features the combination of a high gradient of the river slope and favorable hydrological conditions. The analysis relies on a Digital Elevation Model (DEM) and climatic and/or hydrological data.
- **SiteFinder contributes to add 174 potential sites** to the final spatial database of hydropower. It is worth mentioning that potential stretches that have not been visited may eventually not be favorable for hydropower development.

Figure 11. Illustration of SiteFinder.



#### 4.4. CREATION OF A CONSOLIDATED DATABASE

- All the 700+ potential sites that were identified from the sources described above were analyzed based on satellite imagery, topographic and geological maps, and regional hydrological studies in order to assess if the site is favorable or not for hydropower development.
- This analysis confirmed the presence of hydraulic head, the river catchment area, the absence of obvious development constraints due to the presence of villages, protected areas, military sites, etc.
- The geological maps gave a first indication on the nature of the rocks, the possible tectonic events and the presence of geological faults which could make the implementation of a hydropower project more complex.
- This analysis has eliminated duplicates and sites with inconsistent data, for which no exploitable information was available.
- The result is a consolidated database containing 455 potential hydropower sites distributed across Tanzania.

#### 4.5. PROMISING HYDROPOWER PROJECTS FOR SHORT TERM INVESTMENT (0.3-10 MW)

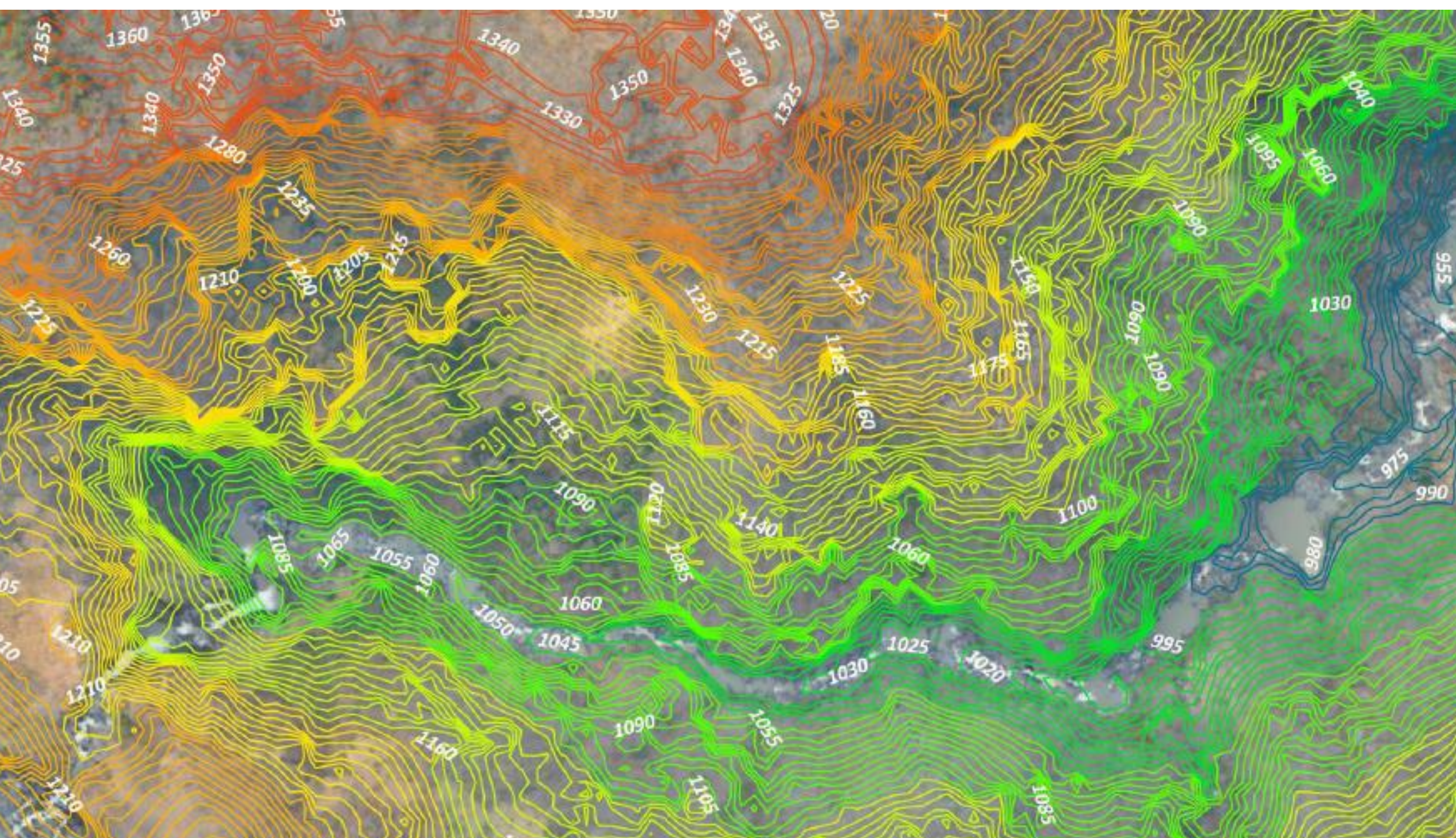
- A substantive work has been carried out to establish a portfolio of hydropower projects that meet the criteria of the study: **the promising hydropower projects**. This work was conducted in close consultation with REA and the World Bank Experts.
- This selection is the result of a complex multicriteria analysis, based on:
  - ◆ Estimated power capacity between ~300 kW and 10 MW corresponding to the scope of this study;
  - ◆ Economic criteria: estimation of the Levelized Cost of Energy (LCOE), including the costs related to the access roads and transmission lines;
  - ◆ Environmental criteria: lack of major environmental constraints that may jeopardize the development of the project;
  - ◆ Adequacy between energy demand and size of candidate projects;
  - ◆ Technical criteria: assessment of the geological risk and the hydraulic and hydrological characteristics of the site, including sediments transport.
- An estimate of the potential capacity of each project was carried out, considering a design flow corresponding to the median flow of the river, which was estimated based on a regional hydrological study.



#### 4.6. RECONNAISSANCE STUDY AND FIELD INVESTIGATIONS

- The objective of this stage is to study, at the level of Reconnaissance study, the most promising potential sites for small hydro in Tanzania.
- In total, 85 promising sites have been visited from which 82 have a confirmed potential for hydropower development. Amongst those 82 promising projects, a subset of 20 was selected and constitutes the list of the top 20 priority hydroelectric projects for short-term development in Tanzania.
- Additional field investigations (surface geology, topography, hydrology and socio-environment) were carried out on the top 20 priority projects:
  - ◆ Additional site visits by experts in hydropower design;
  - ◆ Topographic surveys based on the processing of ortho-photogrammetric images acquired by drone;
  - ◆ Characterization of the surface geology;
  - ◆ Description of the socio-economic and environmental context;
  - ◆ Visit of the nine Water Basins Offices for hydrological data collection in order to perform additional hydrological modelling.
- The reconnaissance and field investigations took place between September 2016 and July 2017. They were carried out by teams of experienced engineers and technicians with a solid background in the following areas:
  - ◆ Hydropower design;
  - ◆ Hydrology;
  - ◆ Hydraulics;
  - ◆ Geology;
  - ◆ Geotechnics;
  - ◆ Environmental and social impacts;
  - ◆ Economics;
  - ◆ Topography.
- The Consultant's team of Experts have frequently worked in difficult conditions due to the difficulty of access to many sites. These experts had to show endurance during the long hikes in addition to the sections by motorcycle, canoe, pirogue and accommodation under sometimes precarious conditions.
- The data and information collected during the site investigations of the top 20 prioritized potential hydroelectric projects were used to prepare a preliminary layout for each site including a preliminary bill of quantities and investment costs. The preliminary design of the potential hydropower schemes, their energy performance analysis and eventually the economic modelling are detailed in dedicated project fiches consolidated in the *Site Investigations Report*.

Figure 12. Investigations of the surface geology.



# Chapter 5. Small hydro potential in Tanzania (0.3-10 MW)

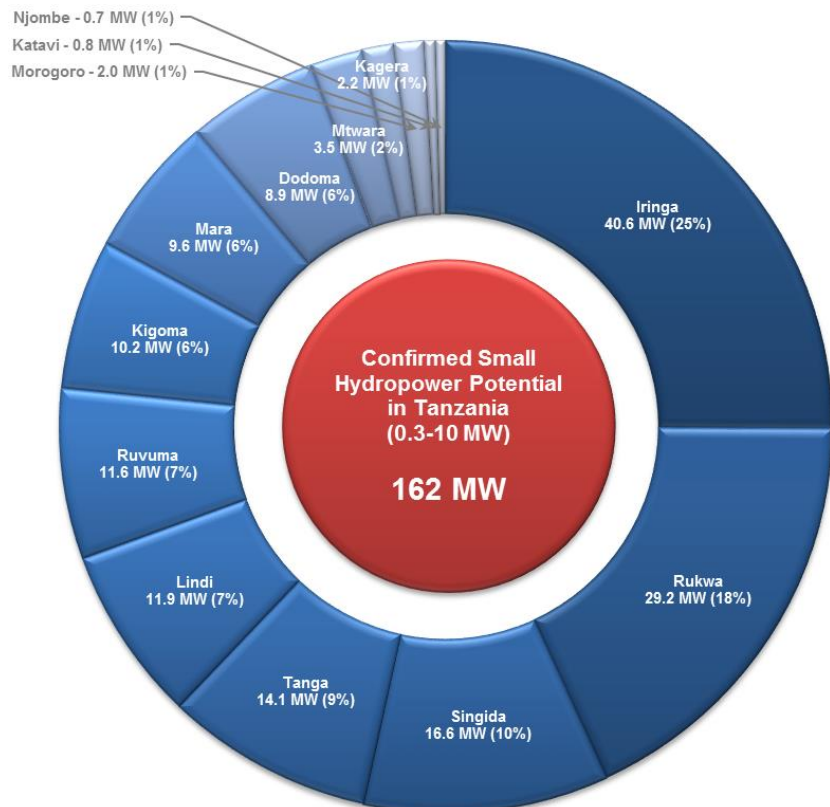
## 5.1. CONSOLIDATED SMALL HYDRO POTENTIAL

- The hydropower potential of Tanzania is still largely untapped. Opportunities exist in all power capacity ranges.
- The analysis shows that Tanzania has a good small hydro potential for private or government investments.
- Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites from 0.3 to 10 MW. Eighty-two (82) potential projects were visited with a **cumulated capacity of approximately 162 MW (confirmed small hydropower potential)** (Figure 13).
- 43% of the confirmed hydropower potential is concentrated in the regions of Iringa (25%) and Rukwa (18%), whose favorable topographic characteristics were highlighted in Chapter 2. These two regions have a confirmed total potential of 69.8 MW.
- 57% of the small hydropower potential is concentrated in three water basins: Rufiji (27%), Lake Tanganyika (16%) and Internal Drainage (14%).
- The spatial distribution of the small hydro potential is presented in details below. Table 6 and Figure 13 illustrate the breakdown by administrative region while Table 7 and Figure 14 present the results by water basin. Detailed maps for each of the regions with hydropower potential are presented in **Maps 16-1 to 16-20**. These maps illustrate in detail the location of the potential hydropower sites and their features.

Table 6. Small hydropower potential (0.3-10 MW) confirmed by site visits: breakdown by region.

Region	Confirmed small Hydropower Potential	
	[MW]	[%]
Iringa	40.6	25.1%
Rukwa	29.2	18.1%
Singida	16.6	10.3%
Tanga	14.1	8.7%
Lindi	11.9	7.3%
Ruvuma	11.6	7.2%
Kigoma	10.2	6.3%
Mara	9.6	6.0%
Dodoma	8.9	5.5%
Mtwara	3.5	2.2%
Kagera	2.2	1.3%
Morogoro	2.0	1.3%
Katavi	0.8	0.5%
Njombe	0.7	0.4%
<b>TOTAL</b>	<b>162</b>	<b>100.0%</b>

Figure 13. Small hydropower potential (0.3-10 MW) confirmed by site visits: breakdown by region.



« Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites ranging from 0.3 to 10 MW. The small hydro potential confirmed by field visits represent a cumulated power capacity of ~162 MW »

Table 7. Small hydropower potential (0.3-10 MW) confirmed by site visits: breakdown by water basin.

Water Basin	Small Hydropower Potential	
	[MW]	[%]
Rufiji	43.6	27.0%
Lake Tanganyika	25.6	15.8%
Internal Drainage	22.5	13.9%
Ruvuma & Southern Rivers	17.2	10.7%
Lake Rukwa	14.5	9.0%
Pangani	14.1	8.7%
Lake Victoria	11.8	7.3%
Lake Nyasa	10.4	6.4%
Wami/Ruvu and Coast Rivers	2.0	1.3%
<b>TOTAL</b>	<b>162</b>	<b>100.0%</b>

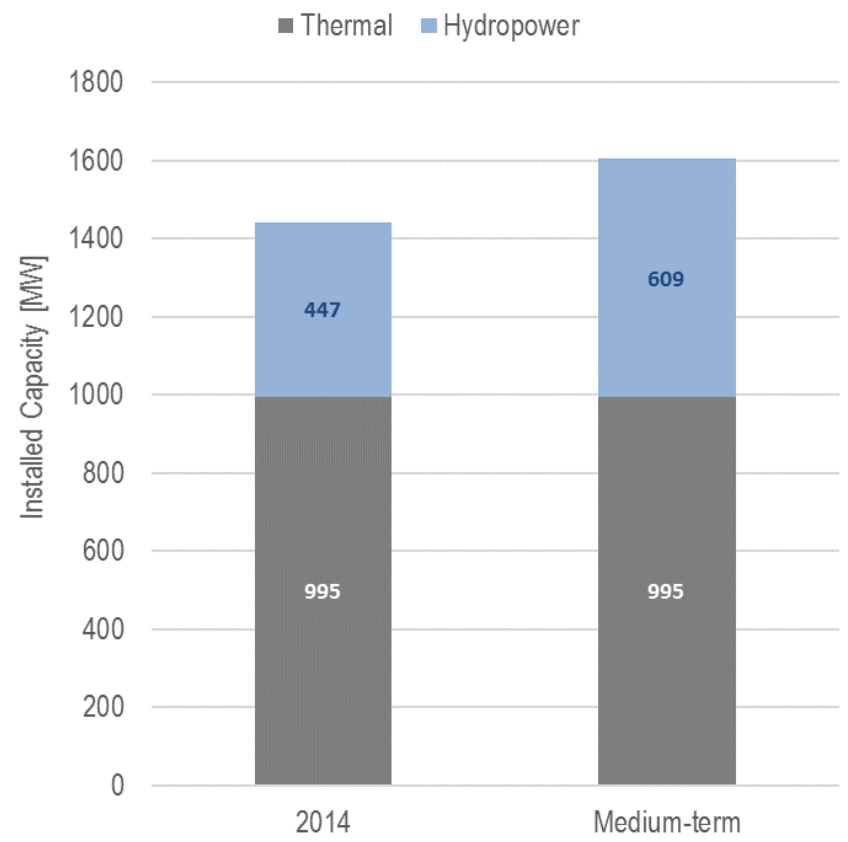
Figure 14. Small hydropower potential (0.3-10 MW) confirmed by site visits: breakdown by water basin.



## 5.2. CONTRIBUTION OF SMALL HYDRO TO THE ENERGY MIX IN TANZANIA

- As presented in the previous chapters, Tanzania’s potential for small hydro development is important.
- Small hydropower has the advantage of a faster project development process (~ 2.5 to 4 years), a better progression in meeting the growing electricity demand and an easier financial closure compared to large hydro. The latter requires a longer development process (6 to 10 years), significant funding and may encounter severe socio-environmental constraints. Given the opportunity of thermal substitution and the future increase in energy demand on the main grid and mini-grids, small hydro projects remain appealing even when a larger project is developed.
- Figure 15 highlights the contribution of small hydropower in the energy mix of Tanzania. This figure compares the energy mix in 2016 (source: EWURA’s Annual Report 2016), as detailed in Chapter 3, and a medium term projection with the implementation of the top 20 priority hydropower projects identified and selected for this study (section 4.5). This figure considers that the sources of thermal generation remain identical. The data on other renewable energies are not available.
- The contribution of these top 20 priority projects is 162 MW, which represents an increase of 36% (from 447 MW to 609 MW) of the available hydropower power capacity.
- These figures show the importance of small hydro development to achieve the country’s objectives in terms of energy security and economic development.

Figure 15. Medium-term contribution of small hydro to the energy mix in Tanzania.



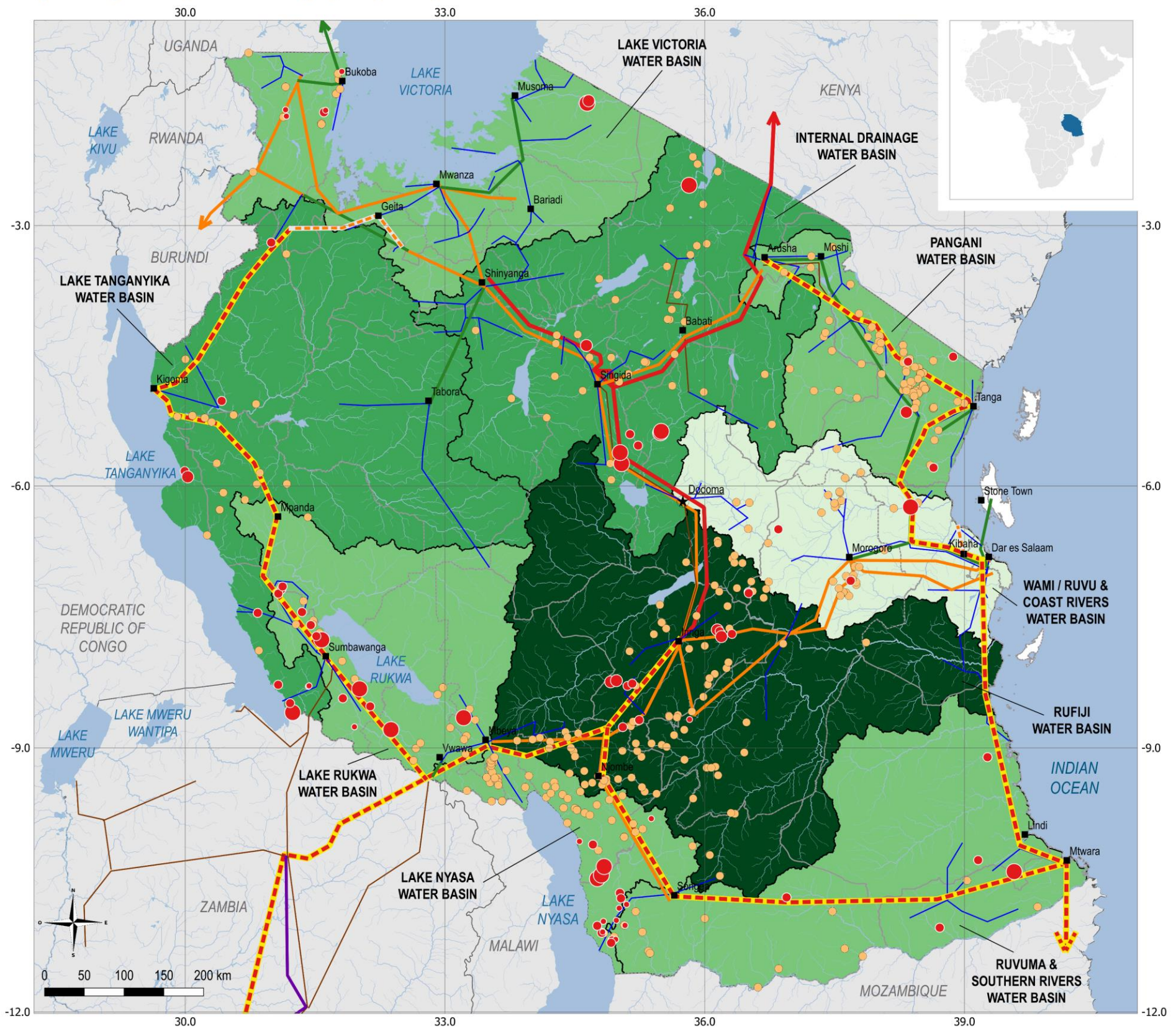
« Small hydropower has the advantage of a faster development (~ 2.5 to 4 years), a better progression in meeting the electricity demand and a more easily available funding than for the large hydro »

# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

### SMALL HYDROPOWER POTENTIAL BY WATER MANAGEMENT BASIN

This map illustrates the hydropower potential by water management basin considering projects in the range 0.3 - 10 MW only. Potential hydropower projects with a power capacity larger than 10 MW are however mentioned on the map. The hydropower potential of Tanzania is still largely untapped. Opportunities exist in all power capacity ranges. The analysis shows that Tanzania has a good small hydro potential for private or government investments. Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites from 0.3 to 10 MW. Eighty-two (82) potential projects were visited with a cumulated capacity of approximately 162 MW (confirmed small hydropower potential).



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries
- Water Management Basins

**Transmission lines (schematic)**

- | Existing | Planned  |
|----------|----------|
| — 33 kV  | — 220 kV |
| — 66 kV  | — 400 kV |
| — 132 kV |          |
| — 220 kV |          |
| — 330 kV |          |
| — 400 kV |          |

**Small Hydropower Potential by Water Management Basin**

- |  |   |
|--|---|
| <p>SHP potential (0.3-10 MW) confirmed by site visits</p> <ul style="list-style-type: none"> <li>□ No confirmed potential</li> <li>□ &lt; 5 MW</li> <li>□ 5-10 MW</li> <li>□ 10-20 MW</li> <li>□ 20-30 MW</li> <li>□ 30-40 MW</li> <li>□ &gt; 40 MW</li> </ul> | <p>Potential sites (not visited) [383]</p> <ul style="list-style-type: none"> <li>● &lt; 0.3 MW</li> <li>● 0.3-5 MW</li> <li>● 5-10 MW</li> <li>● &gt; 10 MW</li> </ul> <p>Promising sites (visited) [82]</p> |
|--|---|

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84  
Data sources :  
- Administrative boundaries: Global Administrative Areas (GADM), 2015.  
- Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
- Cities: Open Street Map (OSM), 2013.  
- Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.  
- Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a.(Artelia Group).



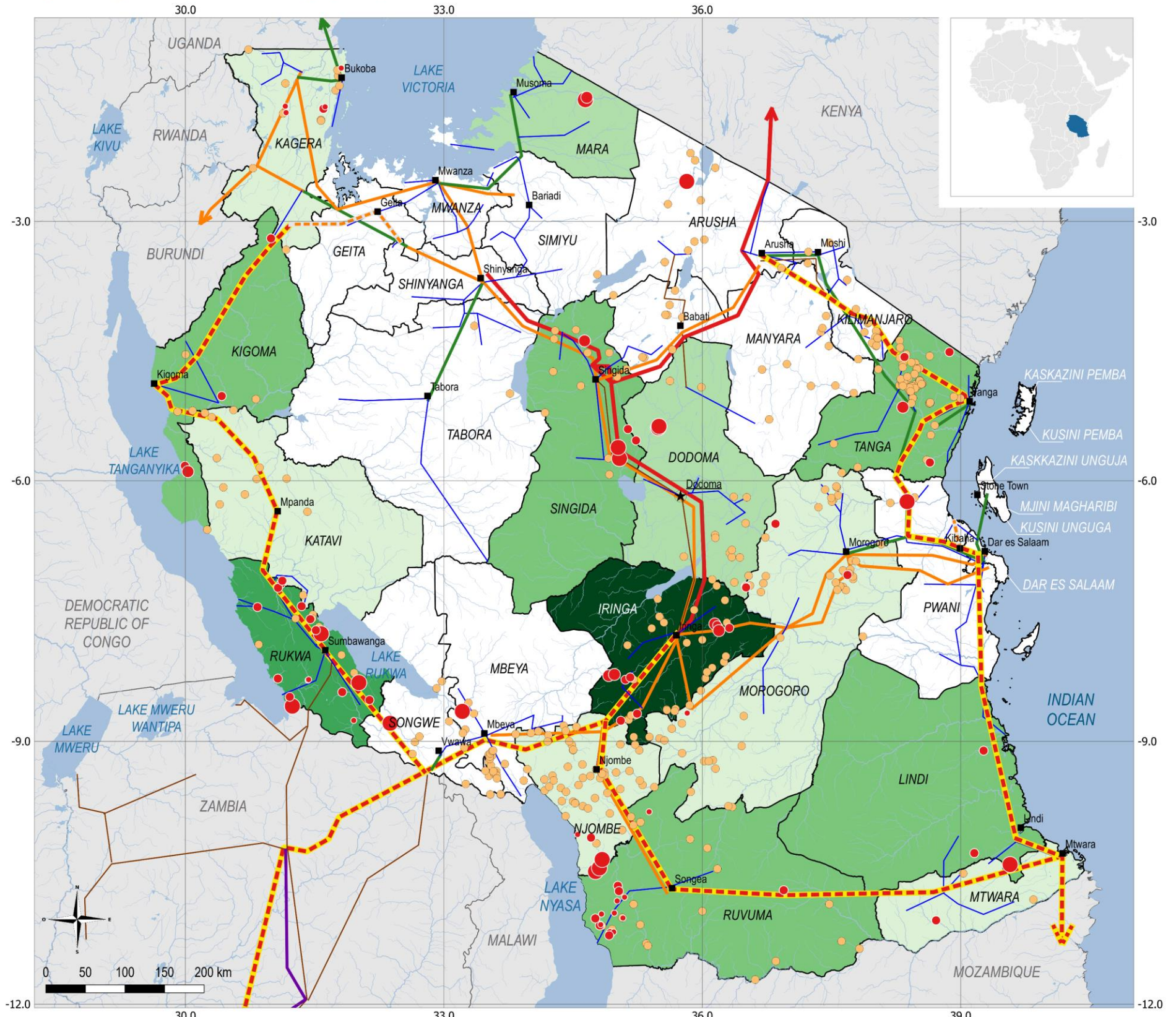


# TANZANIA

## Atlas of the Hydropower Resource (0.3-10 MW)

## SMALL HYDROPOWER POTENTIAL BY REGION

This map illustrates the hydropower potential by administrative region considering projects in the range 0.3 - 10 MW only. Potential hydropower projects with a power capacity larger than 10 MW are however mentioned on the map. The hydropower potential of Tanzania is still largely untapped. Opportunities exist in all power capacity ranges. The analysis shows that Tanzania has a good small hydro potential for private or government investments. Without technical or economic considerations, the small hydro potential in Tanzania consists of more than 400 potential sites from 0.3 to 10 MW. Eighty-two (82) potential projects were visited with a cumulated capacity of approximately 162 MW (confirmed small hydropower potential).



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- ▭ Lakes
- ▭ Regional boundaries

**Transmission lines (schematic)**

- |          |          |
|----------|----------|
| Existing | Planned  |
| — 33 kV  | — 220 kV |
| — 66 kV  | — 400 kV |
| — 132 kV |          |
| — 220 kV |          |
| — 330 kV |          |
| — 400 kV |          |

**Small Hydropower Potential by Region**

- SHP potential (0.3-10 MW) confirmed by site visits
- No confirmed potential
  - < 5 MW
  - 5-10 MW
  - 10-20 MW
  - 20-30 MW
  - 30-40 MW
  - > 40 MW

- Potential sites (not visited) [383]
- Promising sites (visited) [82]
- < 0.3 MW
- 0.3-5 MW
- 5-10 MW
- > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.  
 - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Arusha

## Atlas of the Hydropower Resource (0.3-10 MW)

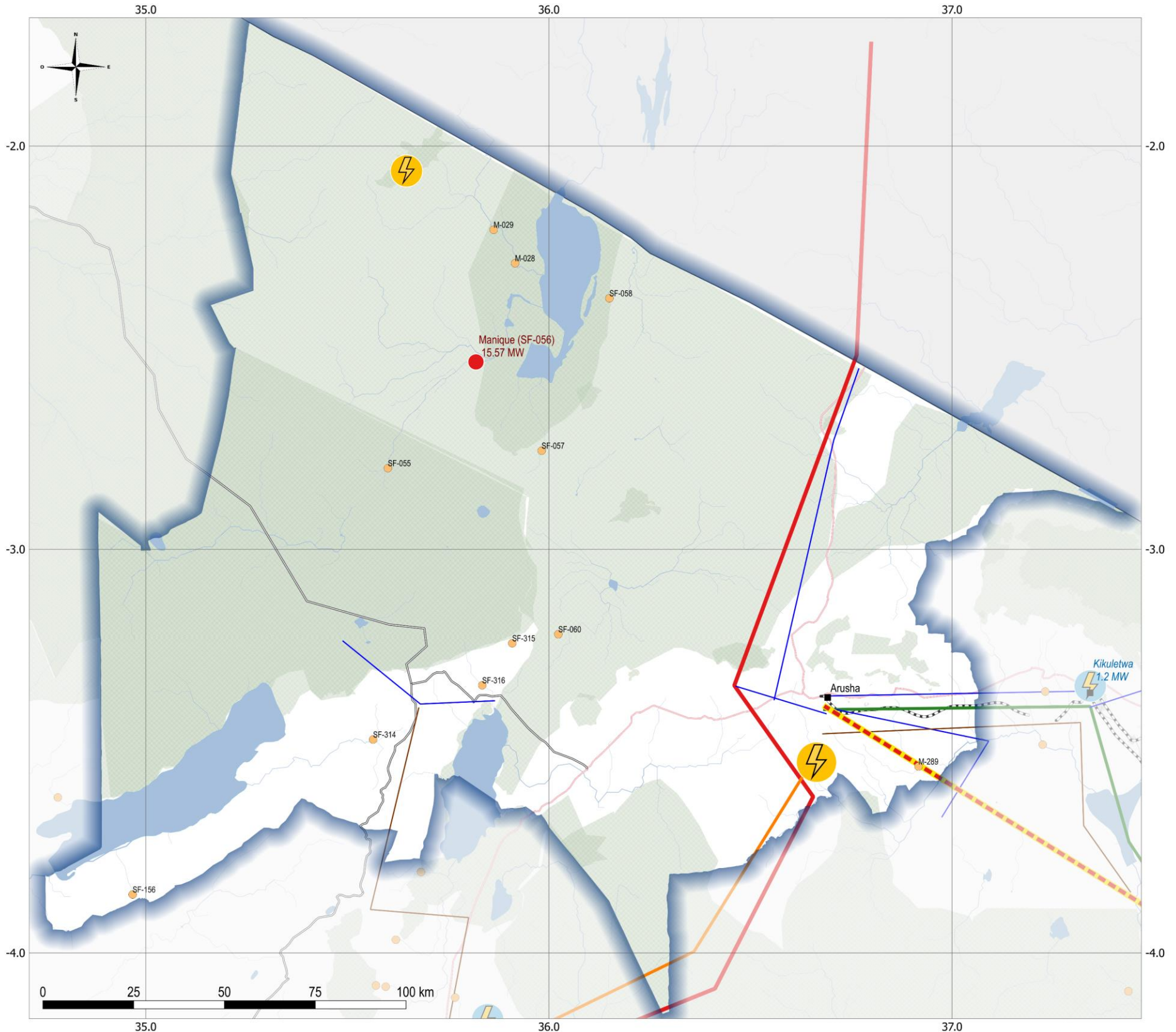
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Arusha

Number of promising sites (visited): 1

Number of potential sites (not visited): 11

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- |                         |                                    |                                |                                 |
|-------------------------|------------------------------------|--------------------------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | — 33 kV                        | ● Promising sites (visited)     |
| ■ Lakes                 | Main existing Hydropower plants    | — 66 kV                        | ● < 0.3 MW                      |
| ⋯ Regional boundaries   | > 10 MW                            | — 132 kV                       | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 220 kV                       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 330 kV                       | ● > 10 MW                       |
| — National roads        |                                    | — 400 kV                       |                                 |
| ⋯ Railways              |                                    |                                |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.  
 - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.  
 - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.  
 - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.  
 - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Dodoma

## Atlas of the Hydropower Resource (0.3-10 MW)

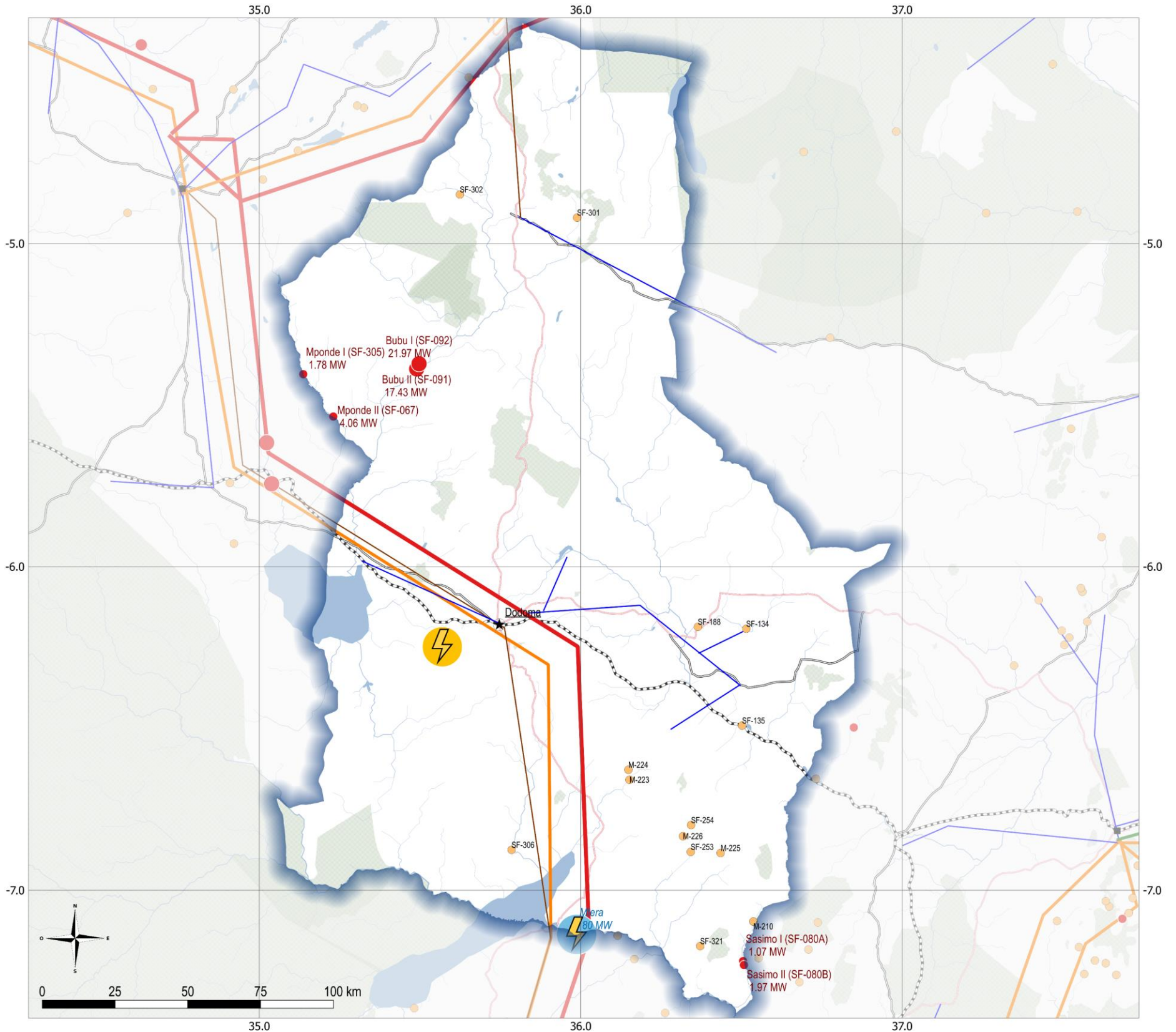
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Dodoma

Number of promising sites (visited): 6

Number of potential sites (not visited): 15

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 8.9 MW



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- ▭ Lakes
- ▭ Regional boundaries
- ▭ Protected areas
- Regional roads
- National roads
- ⋯ Railways
- ⚡ Main existing Thermal power plants
  - > 10 MW
  - 1-10 MW
- ⚡ Main existing Hydropower plants
  - > 10 MW
  - 1-10 MW
- Transmission lines (schematic)
 

<i>Existing</i>	<i>Planned</i>
— 33 kV	— 220 kV
— 66 kV	— 400 kV
— 132 kV	
— 220 kV	
— 330 kV	
— 400 kV	
- Small Hydropower Potential
  - Potential sites (not visited)
  - Promising sites (visited)
    - < 0.3 MW
    - 0.3-5 MW
    - 5-10 MW
    - > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Iringa

## Atlas of the Hydropower Resource (0.3-10 MW)

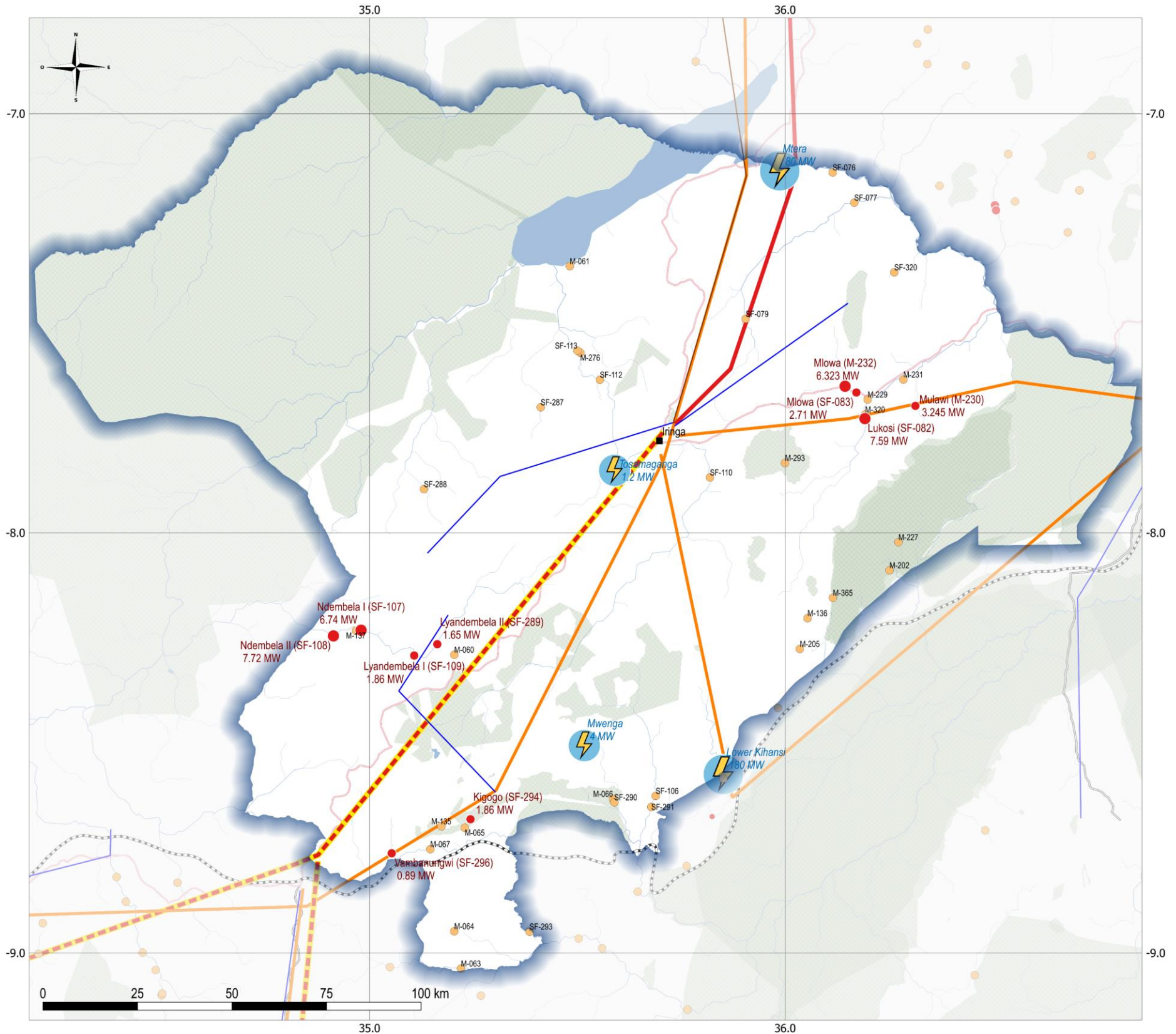
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Iringa

Number of promising sites (visited): 10

Number of potential sites (not visited): 32

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 40.6 MW



**Legend**

- |                         |                                    |                                |                |                                 |
|-------------------------|------------------------------------|--------------------------------|----------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) |                | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | <i>Planned</i> | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | — 33 kV                        | — 220 kV       | Promising sites (visited)       |
| ■ Lakes                 | Main existing Hydropower plants    | — 66 kV                        | — 400 kV       | ● < 0.3 MW                      |
| --- Regional boundaries | > 10 MW                            | — 132 kV                       | — 220 kV       | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 220 kV                       | — 330 kV       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 400 kV                       | — 400 kV       | ● > 10 MW                       |
| — National roads        |                                    |                                |                |                                 |
| --- Railways            |                                    |                                |                |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Kagera

## Atlas of the Hydropower Resource (0.3-10 MW)

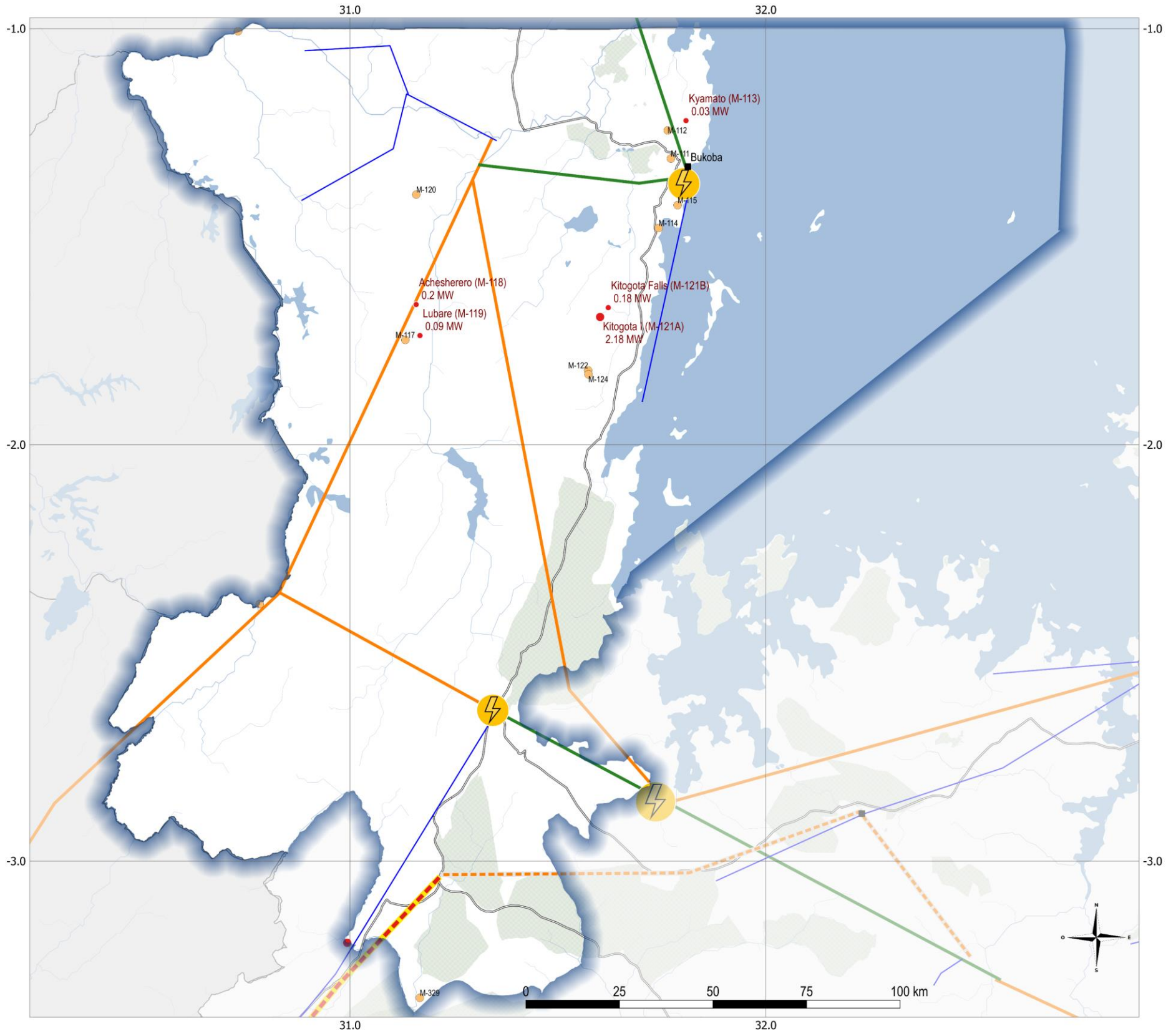
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Kagera

Number of promising sites (visited): 5

Number of potential sites (not visited): 10

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 2.2 MW



#### Legend

- ★ Capital city
  - Region capital cities
  - Main rivers
  - Lakes
  - Regional boundaries
  - Protected areas
  - Regional roads
  - National roads
  - Railways
- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>⚡ &gt; 10 MW</li> <li>⚡ 1-10 MW</li> </ul> | <ul style="list-style-type: none"> <li>⚡ &gt; 10 MW</li> <li>⚡ 1-10 MW</li> </ul> |
|---|---|
- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li>Existing</li> <li>33 kV</li> <li>66 kV</li> <li>132 kV</li> <li>220 kV</li> <li>330 kV</li> <li>400 kV</li> </ul> | <ul style="list-style-type: none"> <li>Planned</li> <li>220 kV</li> <li>400 kV</li> </ul> |
|--|---|
- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>● Potential sites (not visited)</li> </ul> | <ul style="list-style-type: none"> <li>● Promising sites (visited)</li> <li>&lt; 0.3 MW</li> <li>0.3-5 MW</li> <li>5-10 MW</li> <li>&gt; 10 MW</li> </ul> |
|---|---|

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Katavi

## Atlas of the Hydropower Resource (0.3-10 MW)

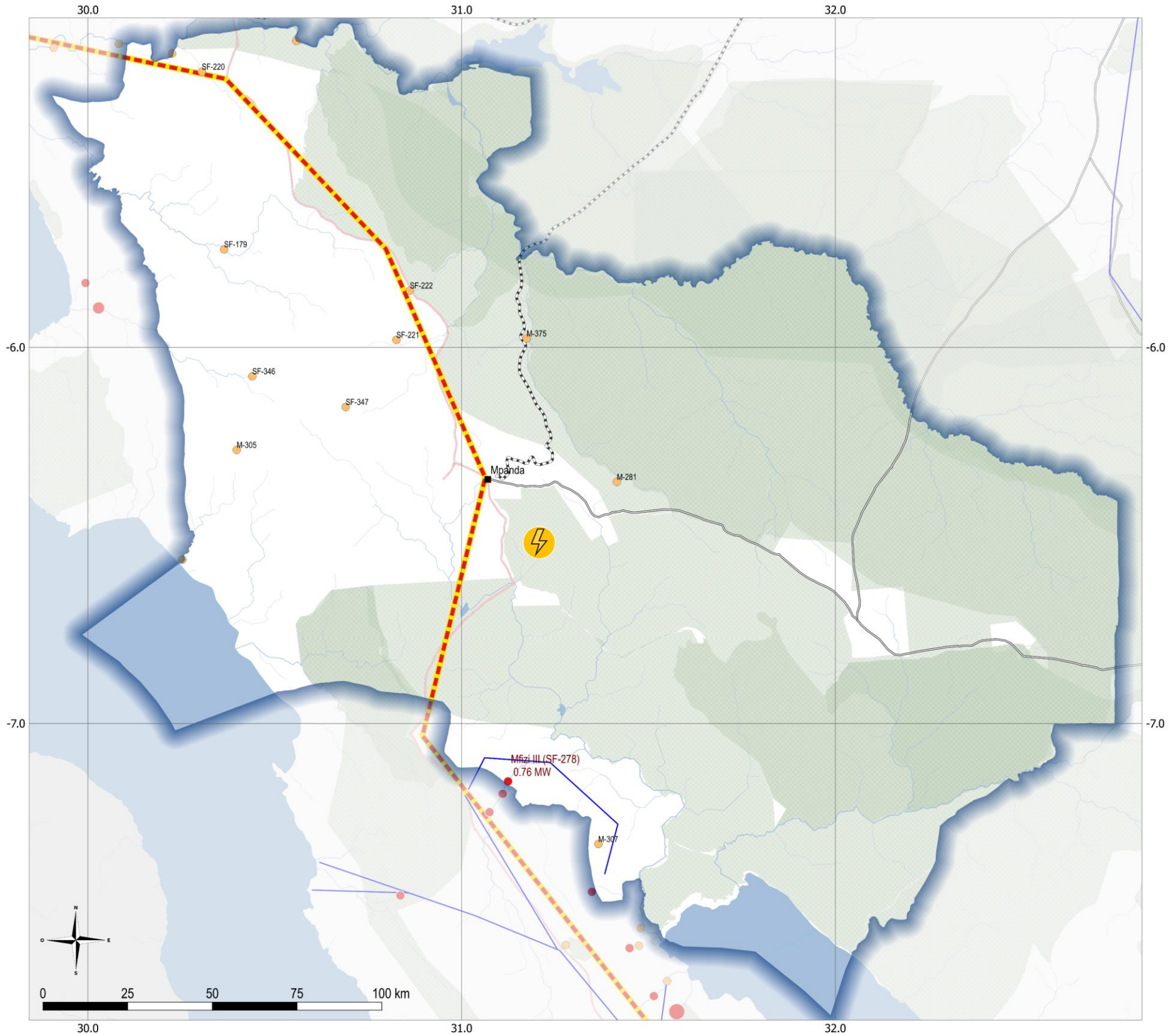
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Katavi

Number of promising sites (visited): 1

Number of potential sites (not visited): 10

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0.8 MW



**Legend**

- |                         |                                    |                                |                                 |
|-------------------------|------------------------------------|--------------------------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | — 33 kV                        | ● Promising sites (visited)     |
| ■ Lakes                 | Main existing Hydropower plants    | — 66 kV                        | ● < 0.3 MW                      |
| ⋯ Regional boundaries   | > 10 MW                            | — 132 kV                       | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 220 kV                       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 330 kV                       | ● > 10 MW                       |
| — National roads        |                                    | — 400 kV                       |                                 |
| ⋯ Railways              |                                    | <i>Planned</i>                 |                                 |
|                         |                                    | — 220 kV                       |                                 |
|                         |                                    | — 400 kV                       |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Kigoma

## Atlas of the Hydropower Resource (0.3-10 MW)

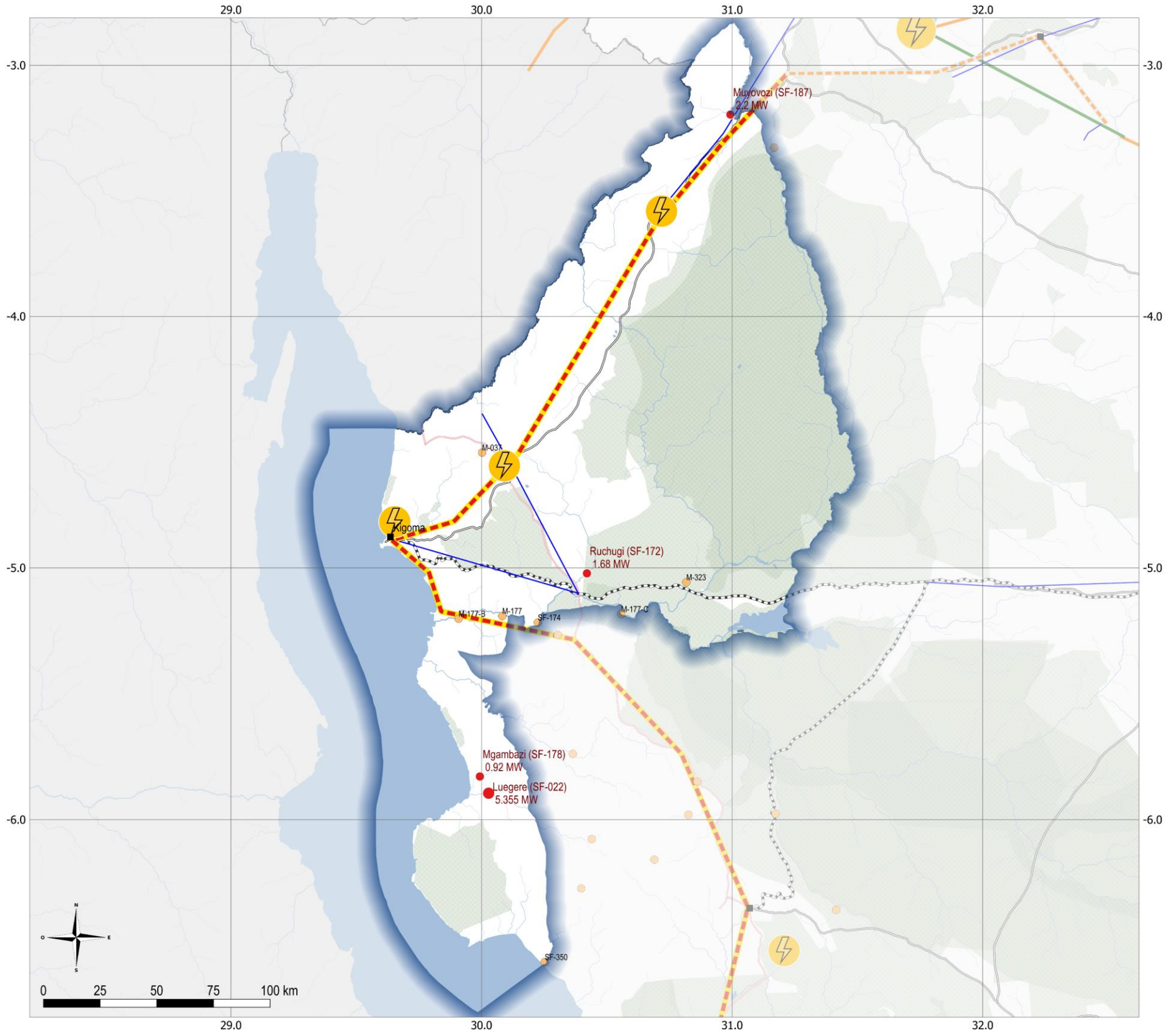
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Kigoma

Number of promising sites (visited): 4

Number of potential sites (not visited): 7

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 10.2 MW



**Legend**

- |   |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
|---|--|--|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|---|
| <ul style="list-style-type: none"> <li>★ Capital city</li> <li>■ Region capital cities</li> <li>— Main rivers</li> <li>■ Lakes</li> <li>--- Regional boundaries</li> <li>■ Protected areas</li> <li>— Regional roads</li> <li>— National roads</li> <li>--- Railways</li> </ul> | <p><b>Main existing Thermal power plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p><b>Main existing Hydropower plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p><b>Transmission lines (schematic)</b></p> <table border="0"> <tr> <td><i>Existing</i></td> <td><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p><b>Small Hydropower Potential</b></p> <ul style="list-style-type: none"> <li>● Potential sites (not visited)</li> <li>● Promising sites (visited)</li> <li>● &lt; 0.3 MW</li> <li>● 0.3-5 MW</li> <li>● 5-10 MW</li> <li>● &gt; 10 MW</li> </ul> |
| <i>Existing</i>   | <i>Planned</i>   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 33 kV   | 220 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 66 kV   | 400 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 132 kV  |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 220 kV  |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 330 kV  |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 400 kV  |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Kilimanjaro

## Atlas of the Hydropower Resource (0.3-10 MW)

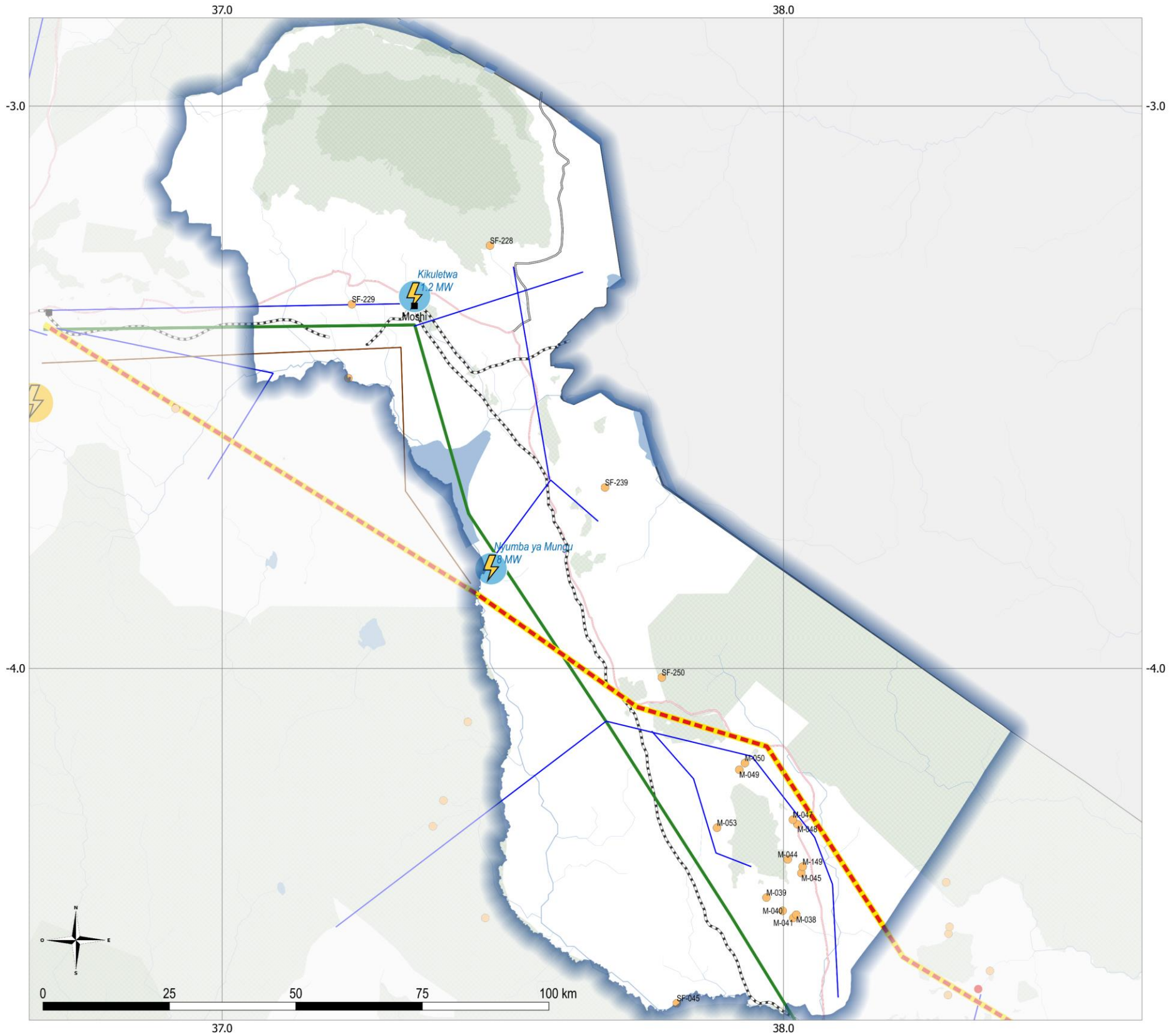
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Kilimanjaro

Number of promising sites (visited): 0

Number of potential sites (not visited): 17

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



#### Legend

- ★ Capital city
  - Region capital cities
  - Main rivers
  - Lakes
  - Regional boundaries
  - Protected areas
  - Regional roads
  - National roads
  - Railways
- | <p><b>Main existing Thermal power plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p><b>Main existing Hydropower plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p><b>Transmission lines (schematic)</b></p> <table border="0"> <tr> <th>Existing</th> <th>Planned</th> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | Existing | Planned | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p><b>Small Hydropower Potential</b></p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> <li> Promising sites (visited)</li> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
|--|--|----------|---------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|---|
| Existing   | Planned  |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 33 kV  | 220 kV   |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 66 kV  | 400 kV   |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 132 kV   |  |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 220 kV   |  |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 330 kV   |  |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 400 kV   |  |          |         |       |        |       |        |        |  |        |  |        |  |        |  |   |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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# TANZANIA - Manyara

## Atlas of the Hydropower Resource (0.3-10 MW)

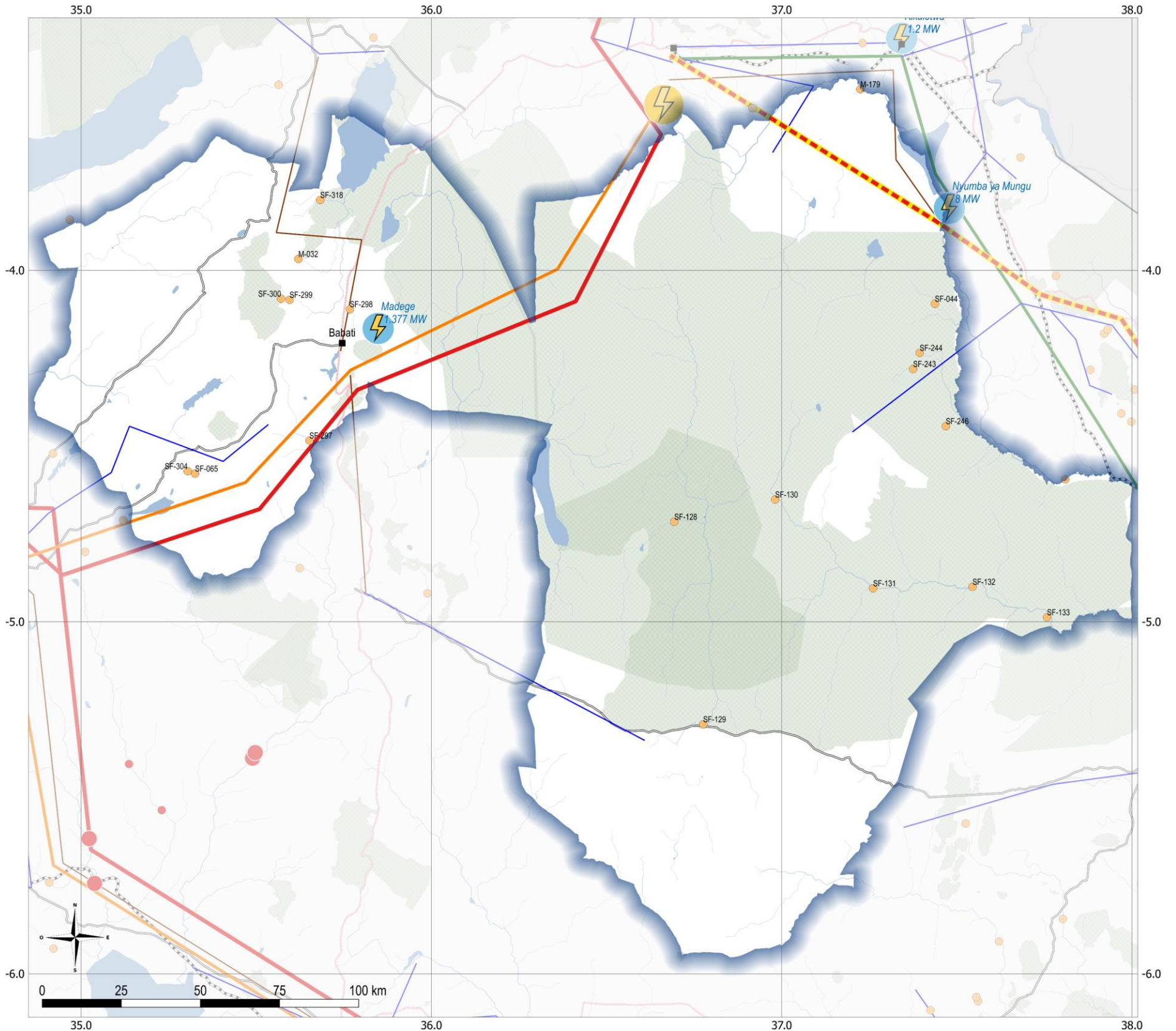
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Manyara

Number of promising sites (visited): 0

Number of potential sites (not visited): 19

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- ▭ Lakes
- ▭ Regional boundaries
- ▭ Protected areas
- Regional roads
- National roads
- Railways
- ⚡ Main existing Thermal power plants
  - > 10 MW
  - 1-10 MW
- ⚡ Main existing Hydropower plants
  - > 10 MW
  - 1-10 MW
- Transmission lines (schematic)
 

<i>Existing</i>	<i>Planned</i>
— 33 kV	— 220 kV
— 66 kV	— 400 kV
— 132 kV	
— 220 kV	
— 330 kV	
— 400 kV	
- Small Hydropower Potential
  - Potential sites (not visited)
  - Promising sites (visited)
    - < 0.3 MW
    - 0.3-5 MW
    - 5-10 MW
    - > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Mbeya

## Atlas of the Hydropower Resource (0.3-10 MW)

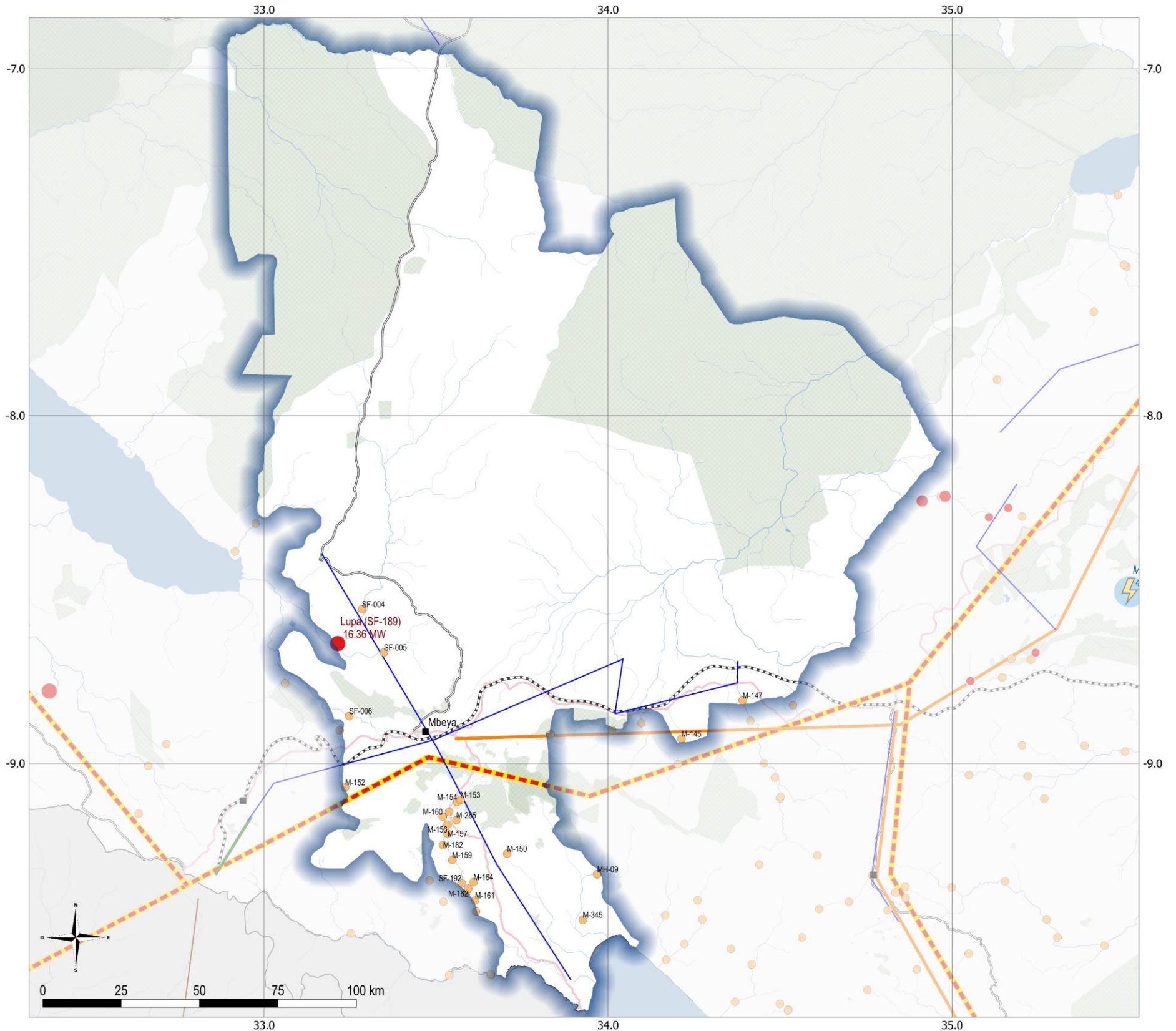
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Mbeya

Number of promising sites (visited): 1

Number of potential sites (not visited): 22

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



#### Legend

- |                         |                                    |                                |                                 |
|-------------------------|------------------------------------|--------------------------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | <i>Planned</i>                 | ● Promising sites (visited)     |
| ■ Lakes                 | Main existing Hydropower plants    | — 33 kV                        | ● < 0.3 MW                      |
| --- Regional boundaries | > 10 MW                            | — 66 kV                        | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 132 kV                       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 220 kV                       | ● > 10 MW                       |
| — National roads        |                                    | — 330 kV                       |                                 |
| --- Railways            |                                    | — 400 kV                       |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Morogoro

## Atlas of the Hydropower Resource (0.3-10 MW)

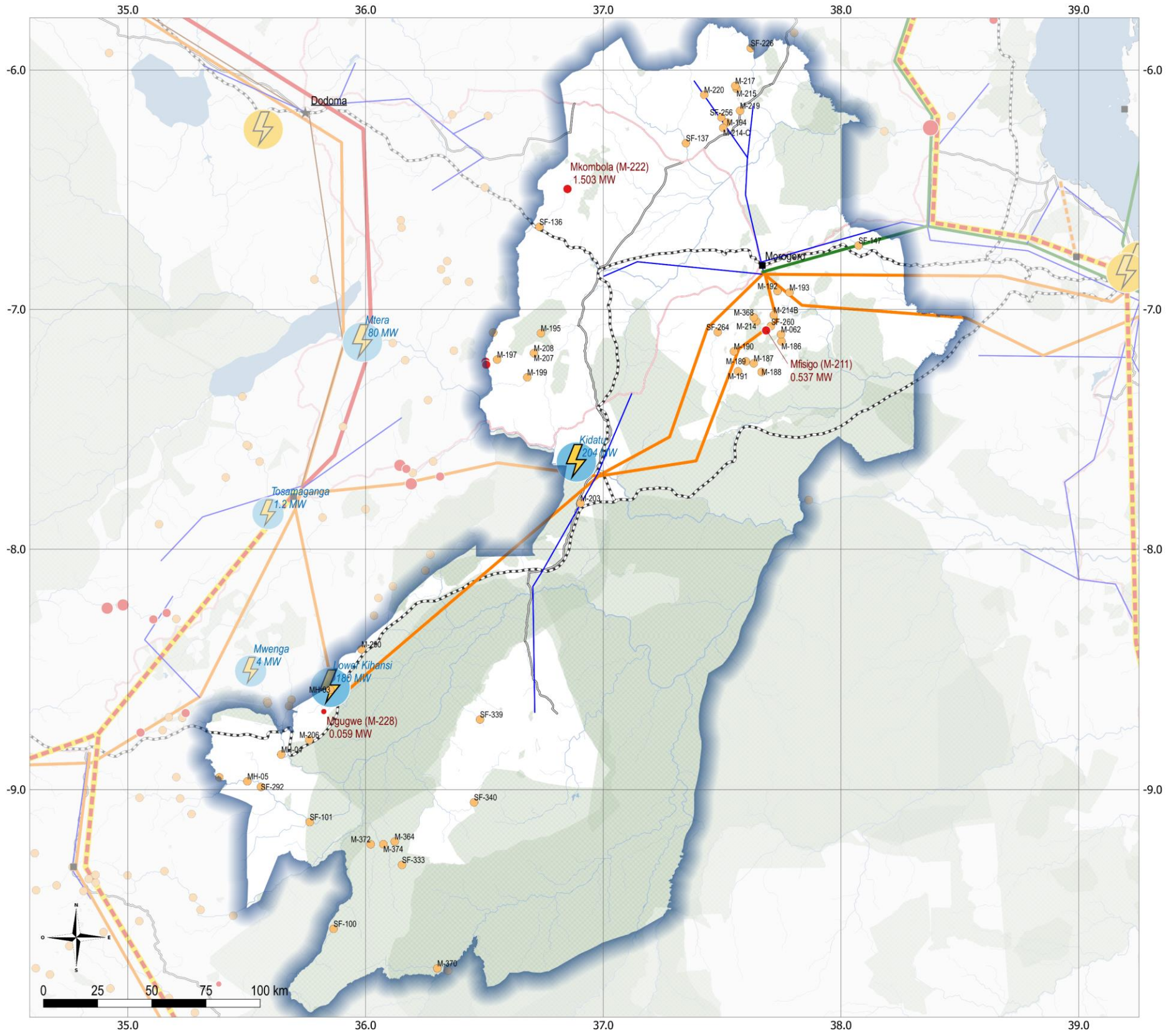
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Morogoro

Number of promising sites (visited): 3

Number of potential sites (not visited): 48

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 2 MW



#### Legend

- |   |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
|---|--|---|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|--|
| <ul style="list-style-type: none"> <li>★ Capital city</li> <li>■ Region capital cities</li> <li>— Main rivers</li> <li>▭ Lakes</li> <li>▭ Regional boundaries</li> <li>▭ Protected areas</li> <li>— Regional roads</li> <li>— National roads</li> <li>— Railways</li> </ul> | <p>Main existing Thermal power plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p>Main existing Hydropower plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p>Transmission lines (schematic)</p> <table border="0"> <tr> <td><i>Existing</i></td> <td><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p>Small Hydropower Potential</p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> </ul> <p>Promising sites (visited)</p> <ul style="list-style-type: none"> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
| <i>Existing</i>   | <i>Planned</i>   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 33 kV   | 220 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 66 kV   | 400 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 132 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 220 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 330 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 400 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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# TANZANIA - Mtwara

## Atlas of the Hydropower Resource (0.3-10 MW)

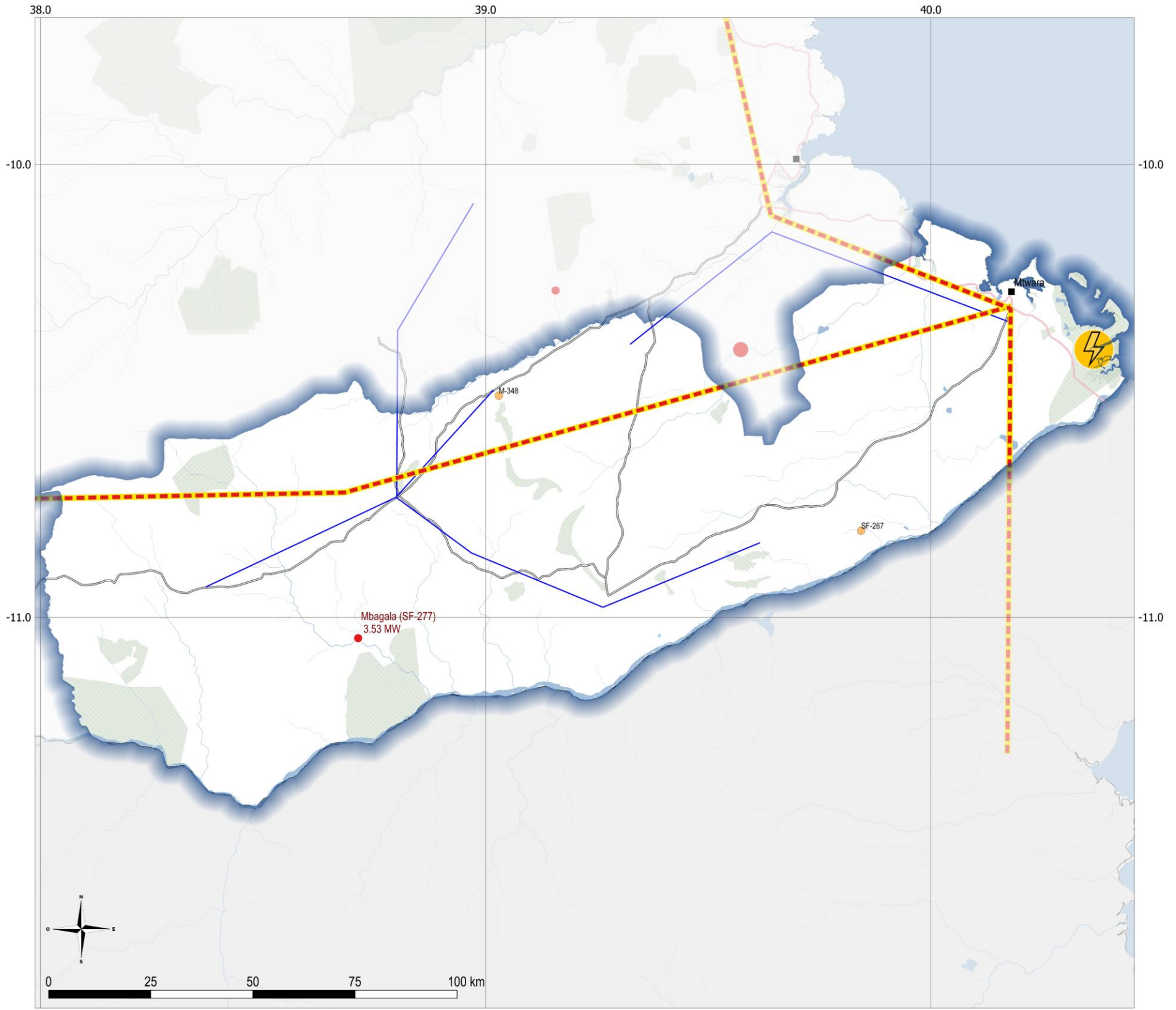
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Mtwara

Number of promising sites (visited): 1

Number of potential sites (not visited): 2

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 3.5 MW



**Legend**

- |                         |                                    |                                |                                 |
|-------------------------|------------------------------------|--------------------------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | — 33 kV                        | Promising sites (visited)       |
| ■ Lakes                 | Main existing Hydropower plants    | — 66 kV                        | ● < 0.3 MW                      |
| ⋯ Regional boundaries   | > 10 MW                            | — 132 kV                       | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 220 kV                       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 330 kV                       | ● > 10 MW                       |
| — National roads        |                                    | — 400 kV                       |                                 |
| ⋯ Railways              |                                    | — 400 kV                       |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Njombe

Atlas of the Hydropower Resource (0.3-10 MW)

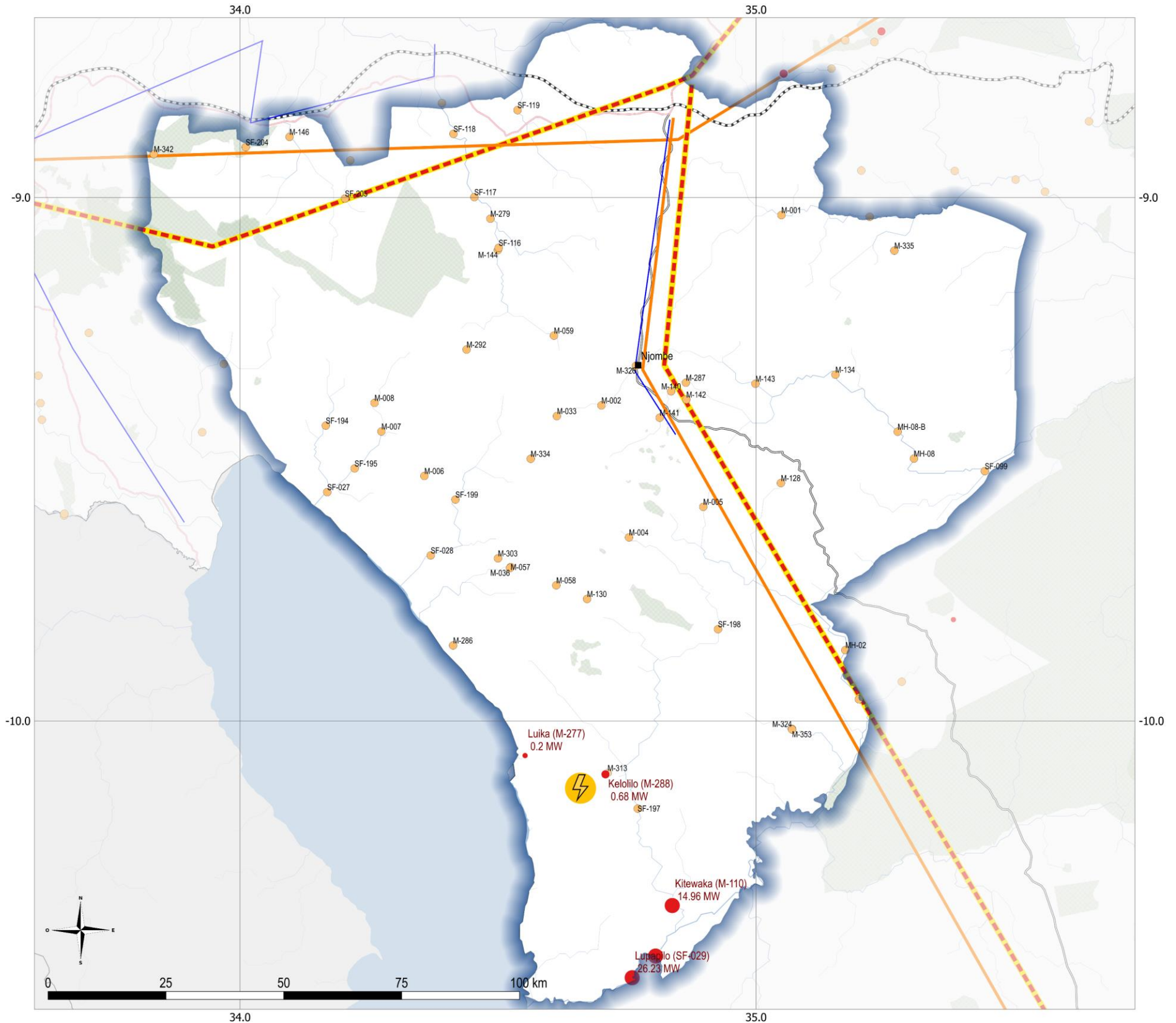
## SMALL HYDROPOWER POTENTIAL BY REGION

Region: Njombe

Number of promising sites (visited): 4

Number of potential sites (not visited): 50

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0.7 MW



### Legend

- |   |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
|---|--|---|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|--|
| <ul style="list-style-type: none"> <li>★ Capital city</li> <li>■ Region capital cities</li> <li>— Main rivers</li> <li>▭ Lakes</li> <li>▭ Regional boundaries</li> <li>▭ Protected areas</li> <li>— Regional roads</li> <li>— National roads</li> <li>— Railways</li> </ul> | <p>Main existing Thermal power plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p>Main existing Hydropower plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p>Transmission lines (schematic)</p> <table border="0"> <tr> <td><i>Existing</i></td> <td><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p>Small Hydropower Potential</p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> </ul> <p>Promising sites (visited)</p> <ul style="list-style-type: none"> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
| <i>Existing</i>   | <i>Planned</i>   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 33 kV   | 220 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 66 kV   | 400 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 132 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 220 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 330 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 400 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Pwani

## Atlas of the Hydropower Resource (0.3-10 MW)

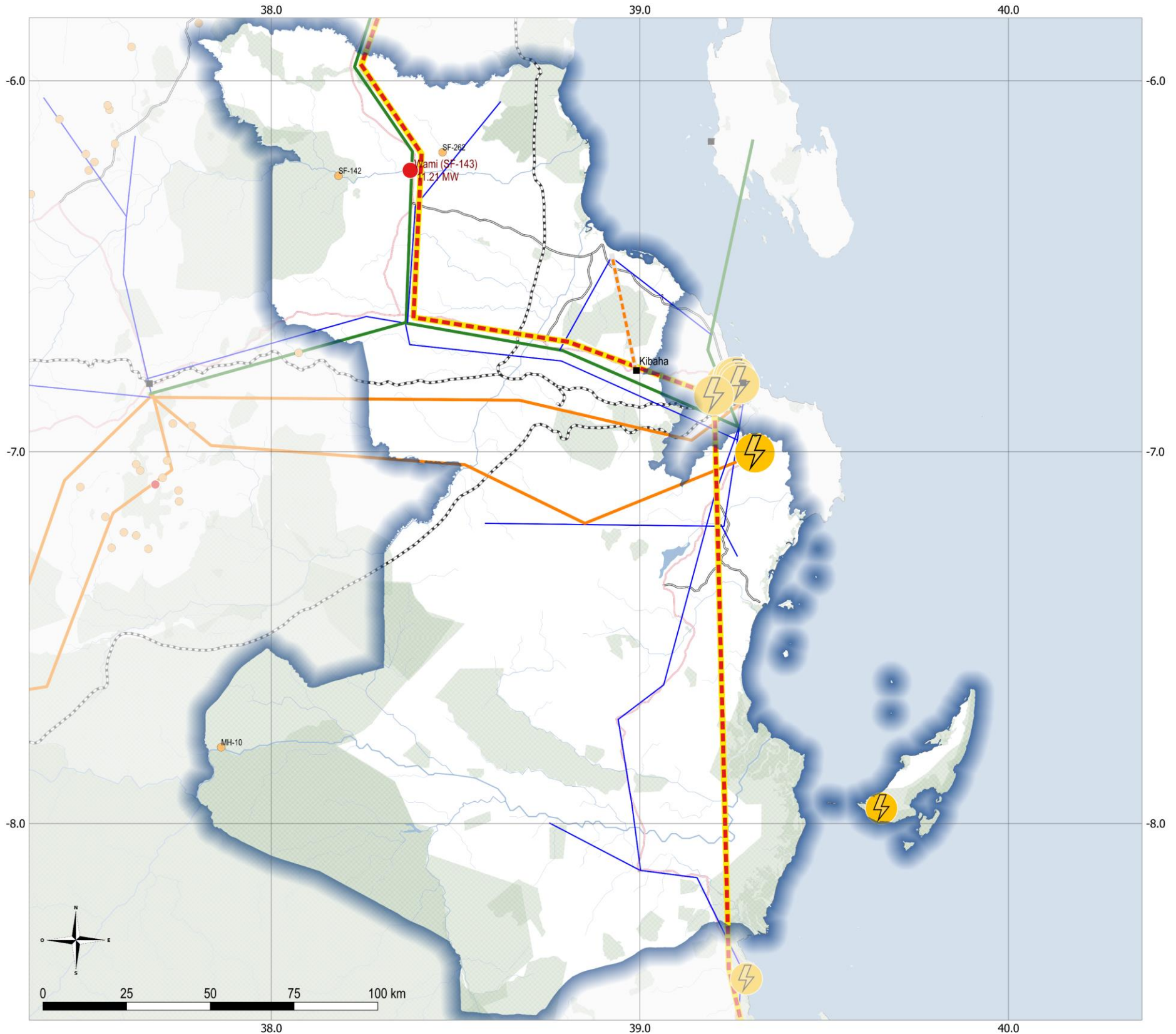
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Pwani

Number of promising sites (visited): 1

Number of potential sites (not visited): 3

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- ▭ Lakes
- ▭ Regional boundaries
- ▭ Protected areas
- Regional roads
- National roads
- Railways
- ⚡ Main existing Thermal power plants
  - > 10 MW
  - 1-10 MW
- ⚡ Main existing Hydropower plants
  - > 10 MW
  - 1-10 MW
- Transmission lines (schematic)
 

<i>Existing</i>	<i>Planned</i>
— 33 kV	— 220 kV
— 66 kV	— 400 kV
— 132 kV	
— 220 kV	
— 330 kV	
— 400 kV	
- Small Hydropower Potential
  - Potential sites (not visited)
  - Promising sites (visited)
    - < 0.3 MW
    - 0.3-5 MW
    - 5-10 MW
    - > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Rukwa

## Atlas of the Hydropower Resource (0.3-10 MW)

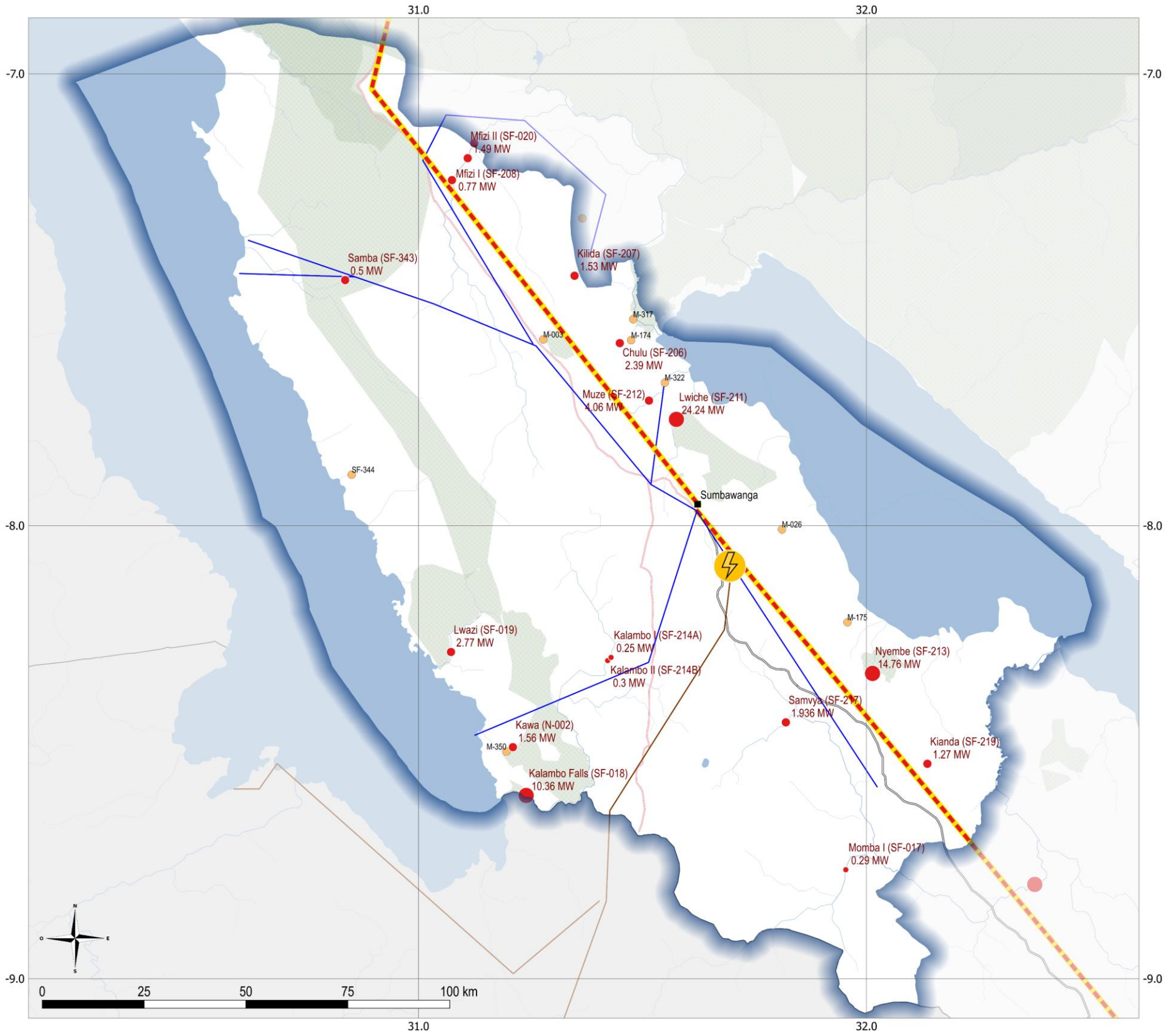
## SMALL HYDROPOWER POTENTIAL BY REGION

Region: Rukwa

Number of potential sites (not visited): 8

Number of promising sites (visited): 16

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 29.2 MW



### Legend

- |   |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
|---|--|---|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|--|
| <ul style="list-style-type: none"> <li>★ Capital city</li> <li>■ Region capital cities</li> <li>— Main rivers</li> <li>■ Lakes</li> <li>▭ Regional boundaries</li> <li>■ Protected areas</li> <li>— Regional roads</li> <li>— National roads</li> <li>— Railways</li> </ul> | <p>Main existing Thermal power plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p>Main existing Hydropower plants</p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p>Transmission lines (schematic)</p> <table border="0"> <tr> <td><i>Existing</i></td> <td><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p>Small Hydropower Potential</p> <ul style="list-style-type: none"> <li>● Potential sites (not visited)</li> <li>● Promising sites (visited)</li> <li>● &lt; 0.3 MW</li> <li>● 0.3-5 MW</li> <li>● 5-10 MW</li> <li>● &gt; 10 MW</li> </ul> |
| <i>Existing</i>   | <i>Planned</i>   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 33 kV   | 220 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 66 kV   | 400 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 132 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 220 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 330 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 400 kV  |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |

SHER Ingénieurs-Conseils s.a., 2017  
Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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# TANZANIA - Ruvuma

## Atlas of the Hydropower Resource (0.3-10 MW)

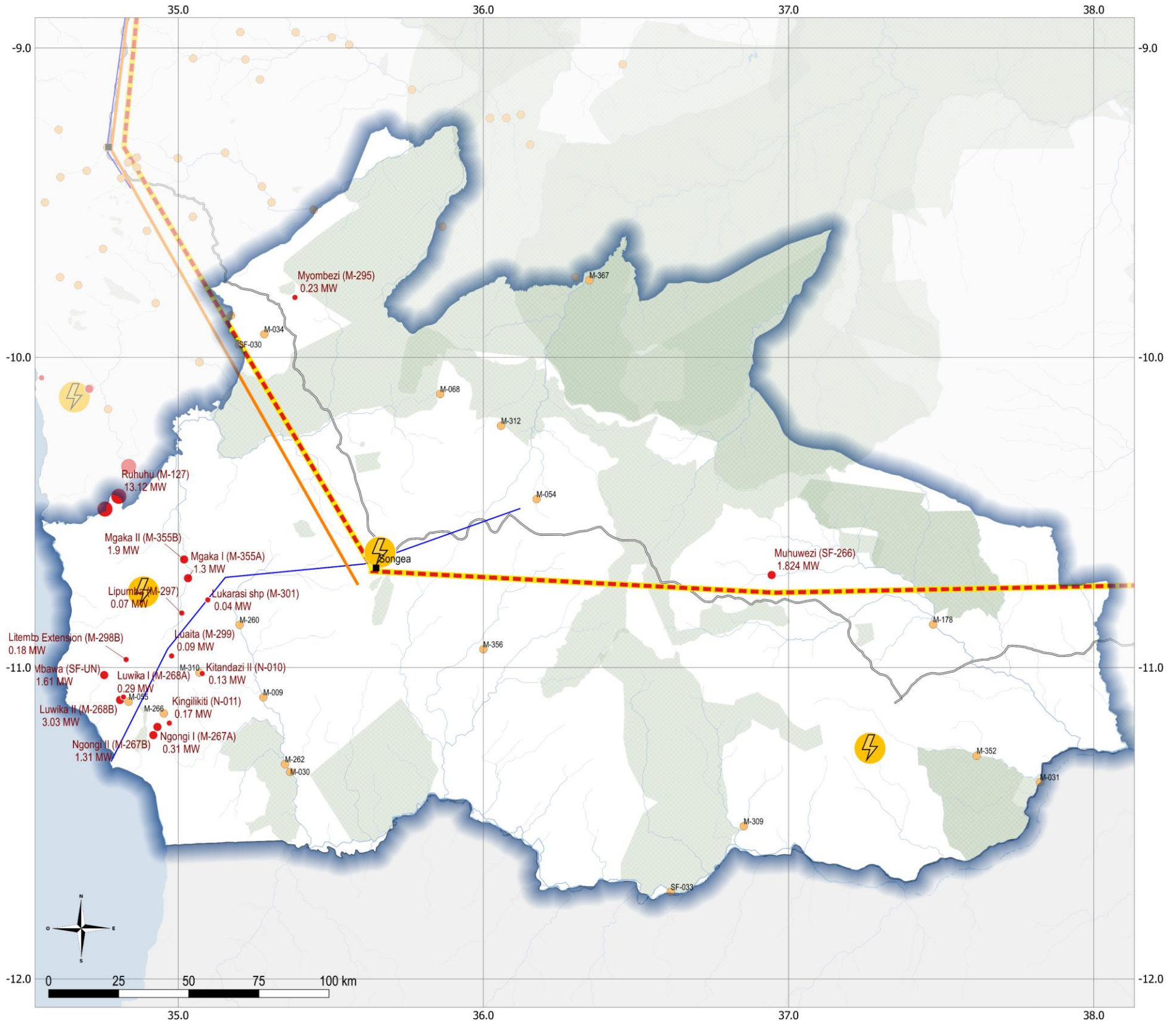
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Ruvuma

Number of promising sites (visited): 16

Number of potential sites (not visited): 19

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 11.6 MW



**Legend**

- ★ Capital city
  - Region capital cities
  - Main rivers
  - ▭ Lakes
  - ▭ Regional boundaries
  - ▭ Protected areas
  - Regional roads
  - National roads
  - Railways
- |  |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
|--|--|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|---|
| <p><b>Main existing Thermal power plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p><b>Main existing Hydropower plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p><b>Transmission lines (schematic)</b></p> <table border="0"> <tr> <td><i>Existing</i></td> <td><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p><b>Small Hydropower Potential</b></p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> <li><b>Promising sites (visited)</b></li> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
| <i>Existing</i>  | <i>Planned</i>   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 33 kV  | 220 kV   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 66 kV  | 400 kV   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 132 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 220 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 330 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |
| 400 kV   |  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |   |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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# TANZANIA - Simiyu

## Atlas of the Hydropower Resource (0.3-10 MW)

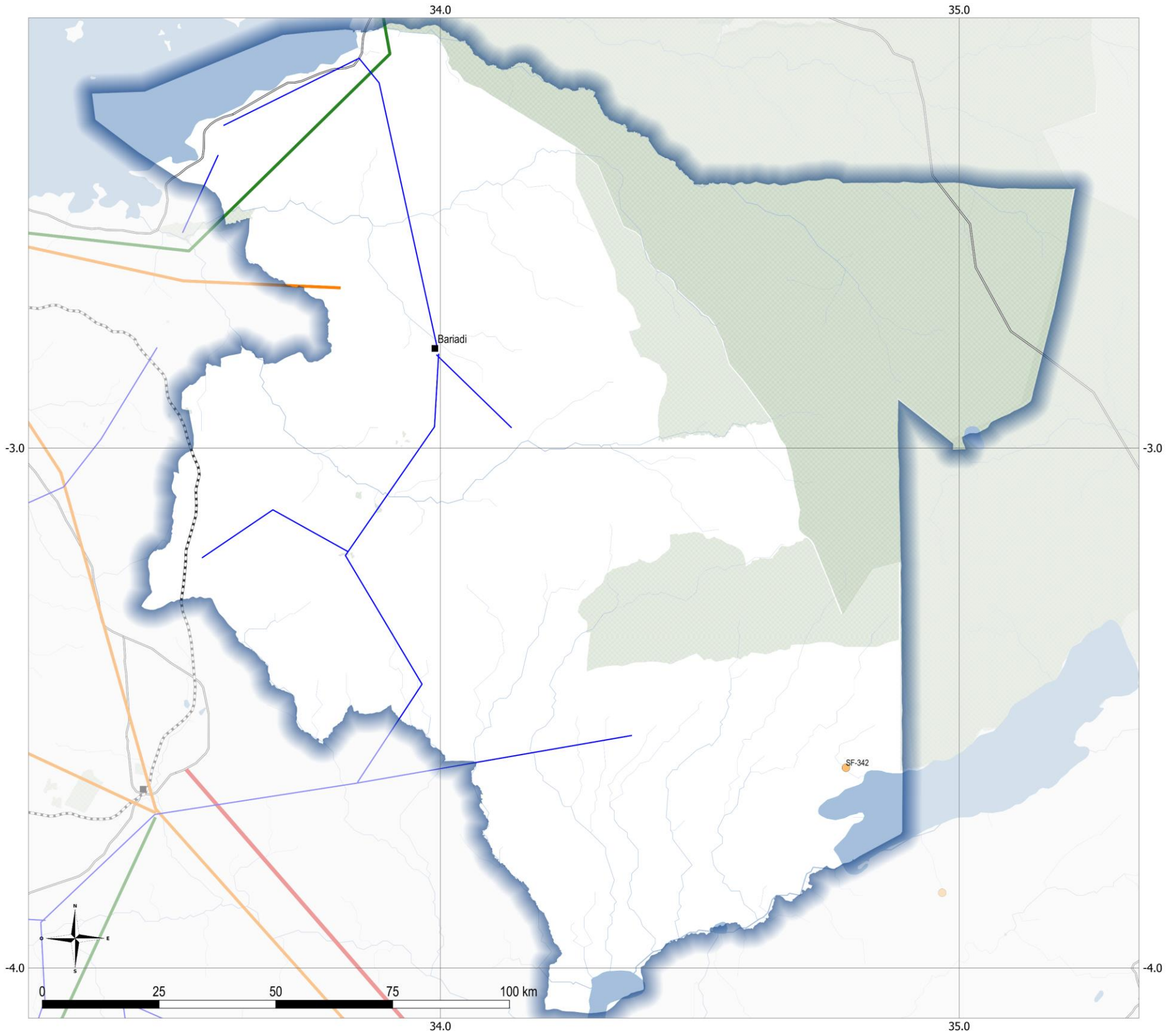
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Simiyu

Number of promising sites (visited): 0

Number of potential sites (not visited): 1

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries
- Protected areas
- Regional roads
- National roads
- Railways
- ⚡ Main existing Thermal power plants
  - > 10 MW
  - 1-10 MW
- ⚡ Main existing Hydropower plants
  - > 10 MW
  - 1-10 MW
- Transmission lines (schematic)
 

<i>Existing</i>	<i>Planned</i>
— 33 kV	--- 220 kV
— 66 kV	--- 400 kV
— 132 kV	
— 220 kV	
— 330 kV	
— 400 kV	
- Small Hydropower Potential
  - Potential sites (not visited)
  - Promising sites (visited)
    - < 0.3 MW
    - 0.3-5 MW
    - 5-10 MW
    - > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Singida

## Atlas of the Hydropower Resource (0.3-10 MW)

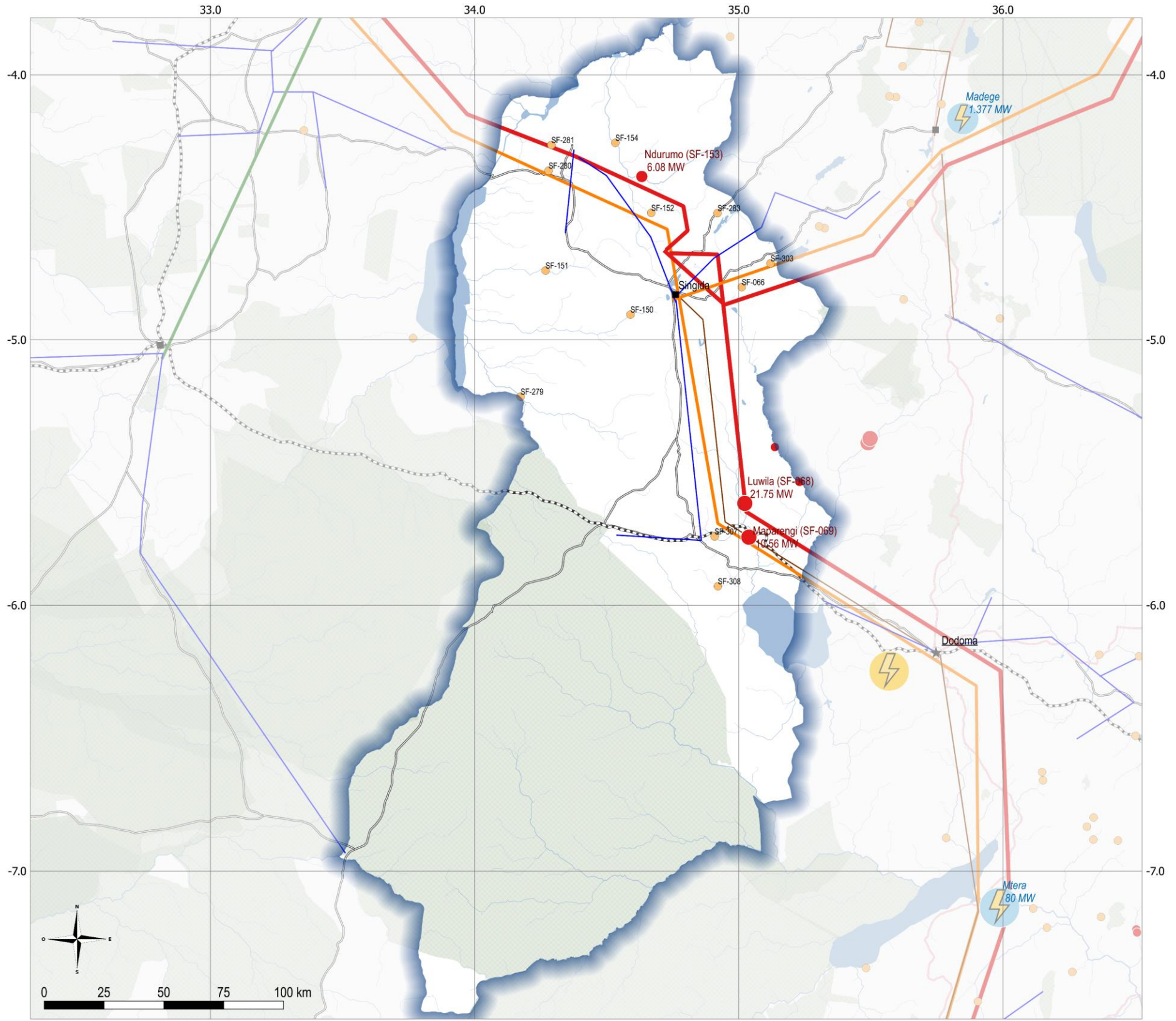
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Singida

Number of promising sites (visited): 3

Number of potential sites (not visited): 12

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 16.6 MW



**Legend**

- |                         |                                    |                                |                                 |
|-------------------------|------------------------------------|--------------------------------|---------------------------------|
| ★ Capital city          | Main existing Thermal power plants | Transmission lines (schematic) | Small Hydropower Potential      |
| ■ Region capital cities | > 10 MW                            | <i>Existing</i>                | ● Potential sites (not visited) |
| — Main rivers           | 1-10 MW                            | — 33 kV                        | ● Promising sites (visited)     |
| ■ Lakes                 | Main existing Hydropower plants    | — 66 kV                        | ● < 0.3 MW                      |
| ⋯ Regional boundaries   | > 10 MW                            | — 132 kV                       | ● 0.3-5 MW                      |
| ■ Protected areas       | 1-10 MW                            | — 220 kV                       | ● 5-10 MW                       |
| — Regional roads        |                                    | — 330 kV                       | ● > 10 MW                       |
| — National roads        |                                    | — 400 kV                       |                                 |
| ⋯ Railways              |                                    |                                |                                 |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Songwe

## Atlas of the Hydropower Resource (0.3-10 MW)

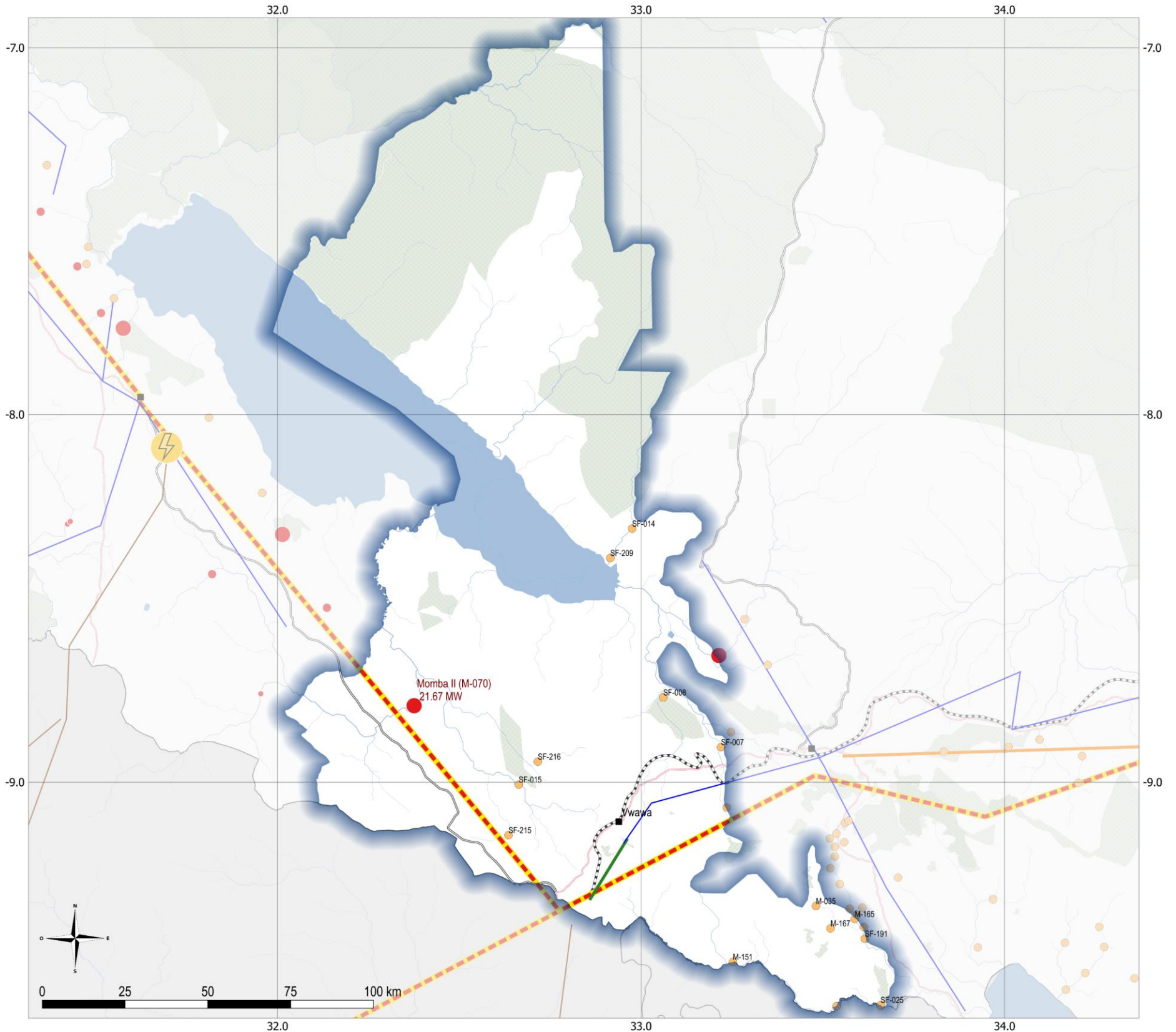
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Songwe

Number of promising sites (visited): 1

Number of potential sites (not visited): 13

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- ★ Capital city
  - Region capital cities
  - Main rivers
  - ▭ Lakes
  - ▭ Regional boundaries
  - ▭ Protected areas
  - Regional roads
  - National roads
  - ⋯ Railways
- |  |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
|--|---|-----------------|----------------|-------|--------|-------|--------|--------|--|--------|--|--------|--|--------|--|--|
| <p><b>Main existing Thermal power plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p><b>Main existing Hydropower plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p><b>Transmission lines (schematic)</b></p> <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;"><i>Existing</i></td> <td style="width: 50%;"><i>Planned</i></td> </tr> <tr> <td> 33 kV</td> <td> 220 kV</td> </tr> <tr> <td> 66 kV</td> <td> 400 kV</td> </tr> <tr> <td> 132 kV</td> <td></td> </tr> <tr> <td> 220 kV</td> <td></td> </tr> <tr> <td> 330 kV</td> <td></td> </tr> <tr> <td> 400 kV</td> <td></td> </tr> </table> | <i>Existing</i> | <i>Planned</i> | 33 kV | 220 kV | 66 kV | 400 kV | 132 kV |  | 220 kV |  | 330 kV |  | 400 kV |  | <p><b>Small Hydropower Potential</b></p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> </ul> <p><b>Promising sites (visited)</b></p> <ul style="list-style-type: none"> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
| <i>Existing</i>  | <i>Planned</i>  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 33 kV  | 220 kV  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 66 kV  | 400 kV  |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 132 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 220 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 330 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |
| 400 kV   |   |                 |                |       |        |       |        |        |  |        |  |        |  |        |  |  |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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# TANZANIA - Tabora

## Atlas of the Hydropower Resource (0.3-10 MW)

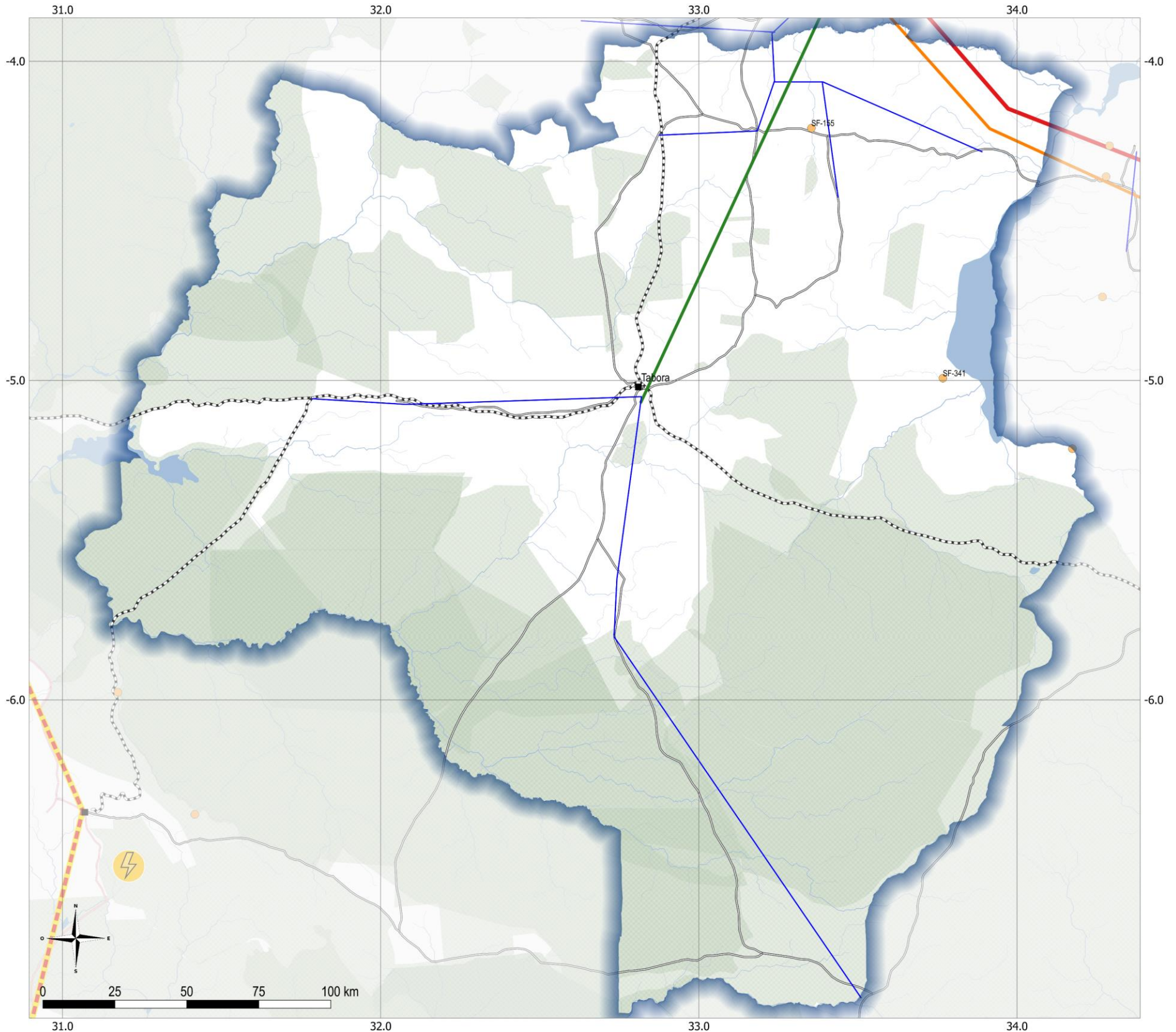
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Tabora

Number of potential sites (not visited): 2

Number of promising sites (visited): 0

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 0 MW



**Legend**

- ★ Capital city
- Region capital cities
- Main rivers
- Lakes
- Regional boundaries
- Protected areas
- Regional roads
- National roads
- Railways
- Main existing Thermal power plants
  - ⚡ > 10 MW
  - ⚡ 1-10 MW
- Main existing Hydropower plants
  - ⚡ > 10 MW
  - ⚡ 1-10 MW
- Transmission lines (schematic)
 

<i>Existing</i>	<i>Planned</i>
— 33 kV	--- 220 kV
— 66 kV	--- 400 kV
— 132 kV	
— 220 kV	
— 330 kV	
— 400 kV	
- Small Hydropower Potential
  - Potential sites (not visited)
  - Promising sites (visited)
    - < 0.3 MW
    - 0.3-5 MW
    - 5-10 MW
    - > 10 MW

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

Data sources:  
 - Administrative boundaries: Global Administrative Areas (GADM), 2015.  
 - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.  
 - Cities: Open Street Map (OSM), 2013.  
 - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.  
 - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.  
 - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.  
 - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.  
 - Small Hydropower Potential: SHER, 2017.

This map is made available by the World Bank, financed by ESMAP and prepared by SHER Ingénieurs-Conseils s.a. (Artelia Group).



# TANZANIA - Tanga

## Atlas of the Hydropower Resource (0.3-10 MW)

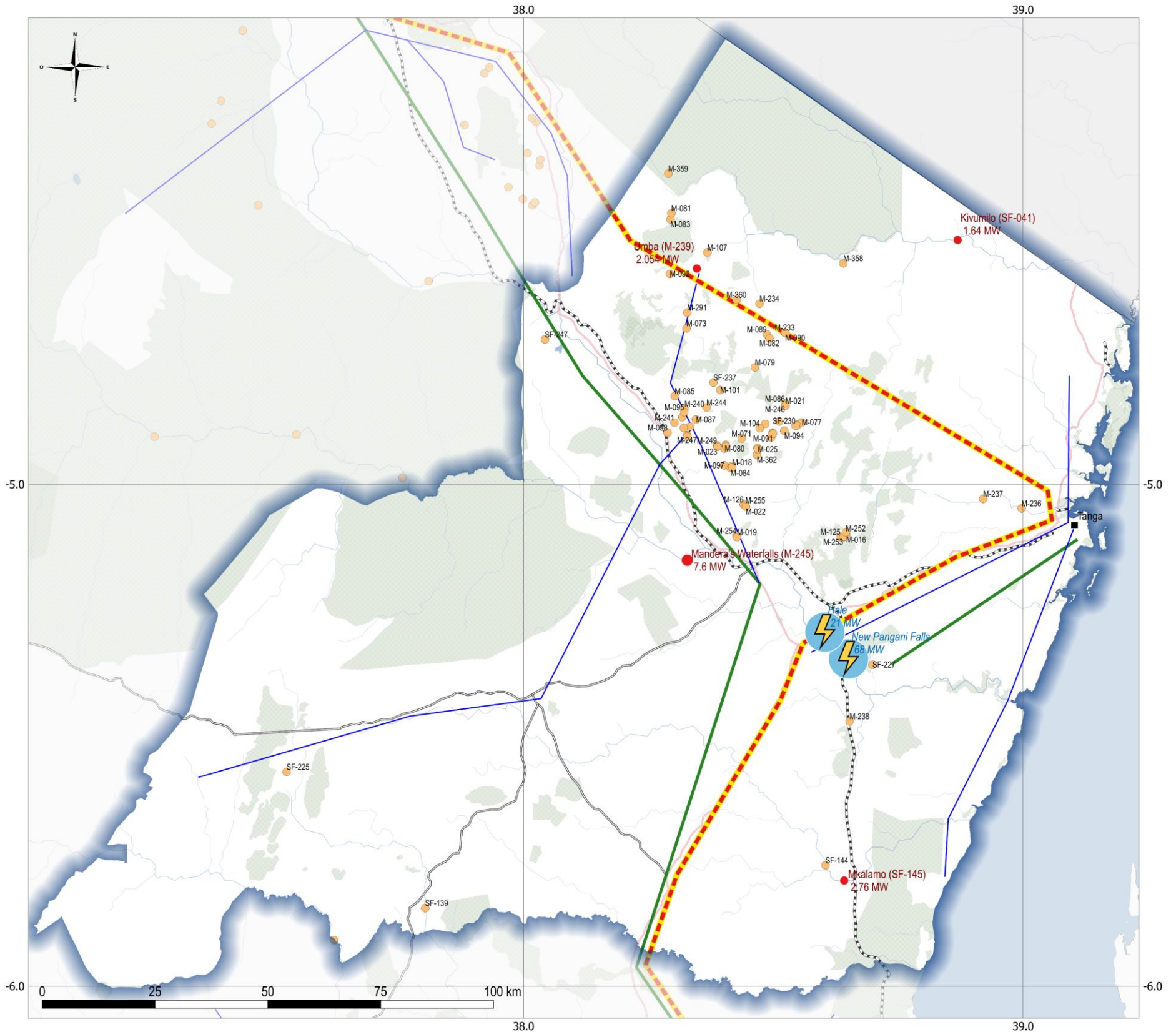
### SMALL HYDROPOWER POTENTIAL BY REGION

Region: Tanga

Number of promising sites (visited): 4

Number of potential sites (not visited): 77

Small Hydropower Potential (0.3-10 MW) confirmed by site visits: 14.1 MW



**Legend**

- ★ Capital city
  - Region capital cities
  - Main rivers
  - ▭ Lakes
  - ▭ Regional boundaries
  - ▭ Protected areas
  - Regional roads
  - National roads
  - ⋯ Railways
- |  |   |   |  |  |
|--|---|---|--|--|
| <p><b>Main existing Thermal power plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> <p><b>Main existing Hydropower plants</b></p> <ul style="list-style-type: none"> <li> &gt; 10 MW</li> <li> 1-10 MW</li> </ul> | <p><b>Transmission lines (schematic)</b></p> <table border="0" style="width: 100%;"> <tr> <td style="vertical-align: top;"> <p><i>Existing</i></p> <ul style="list-style-type: none"> <li> 33 kV</li> <li> 66 kV</li> <li> 132 kV</li> <li> 220 kV</li> <li> 330 kV</li> <li> 400 kV</li> </ul> </td> <td style="vertical-align: top;"> <p><i>Planned</i></p> <ul style="list-style-type: none"> <li> 220 kV</li> <li> 400 kV</li> </ul> </td> </tr> </table> | <p><i>Existing</i></p> <ul style="list-style-type: none"> <li> 33 kV</li> <li> 66 kV</li> <li> 132 kV</li> <li> 220 kV</li> <li> 330 kV</li> <li> 400 kV</li> </ul> | <p><i>Planned</i></p> <ul style="list-style-type: none"> <li> 220 kV</li> <li> 400 kV</li> </ul> | <p><b>Small Hydropower Potential</b></p> <ul style="list-style-type: none"> <li> Potential sites (not visited)</li> </ul> <p><b>Promising sites (visited)</b></p> <ul style="list-style-type: none"> <li> &lt; 0.3 MW</li> <li> 0.3-5 MW</li> <li> 5-10 MW</li> <li> &gt; 10 MW</li> </ul> |
| <p><i>Existing</i></p> <ul style="list-style-type: none"> <li> 33 kV</li> <li> 66 kV</li> <li> 132 kV</li> <li> 220 kV</li> <li> 330 kV</li> <li> 400 kV</li> </ul>  | <p><i>Planned</i></p> <ul style="list-style-type: none"> <li> 220 kV</li> <li> 400 kV</li> </ul>  |   |  |  |

SHER Ingénieurs-Conseils s.a., 2017  
 Small Hydropower Resource Mapping Tanzania (0.3-10 MW)

Geographic Coordinate System (GCS): WGS 84  
 Datum: WGS 84

- Data sources:
- Administrative boundaries: Global Administrative Areas (GADM), 2015.
  - Hydrographic network: Rivers of Africa (derived from HydroSHEDS), FAO, 2014.
  - Cities: Open Street Map (OSM), 2013.
  - Protected areas: World Database on Protected Areas (WDPA), IUCN and UNEP-WCMC, 2017.
  - Road network: Africa Infrastructure Country Diagnostic (AICD), 2009.
  - Existing power plants: TANESCO, 2016; The World Bank Group, 2017; SHER, 2015.
  - Transmission lines: The World Bank Group (IBRD 42944), May 2017; TANESCO.
  - Small Hydropower Potential: SHER, 2017.

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