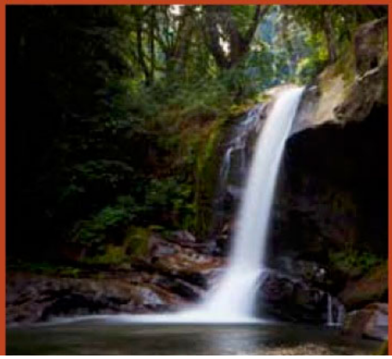
Tanzania:
The Measure of a Land

Low-Resolution Version

John Mendelsohn, Tony Robertson & Alice Jarvis



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Tanzania:

The Measure of a Land

Foreword

Feeding the growing world population will require an estimated 70 - 100% increase in food production, but agricultural activities are degrading ecosystems – and the benefits they provide for people – faster now than ever before. There is an urgent need for better data and risk management approaches to guide sustainable agricultural intensification and ensure healthy and resilient livelihoods and ecosystems.

Launched in 2012 with a US$10 million grant from the Bill & Melinda Gates Foundation to Conservation International, the Vital Signs monitoring system is co-led by Conservation International, the Council for Scientific and Industrial Research in South Africa and the Earth Institute, Columbia University. Vital Signs addresses the need for open access data and for consistent, quantitative, multi-scale, co-located metrics on agriculture, ecosystem services and human well-being. A key objective is to provide a small set of relevant, scientifically valid indicators to assess and manage risk and to support policy.

Tanzania developed the pilot project for Vital Signs - Vital Signs Tanzania is a partnership with the Tanzania Forest Conservation Group and with the National Bureau of Statistics. Vital Signs field teams collect data on agricultural management and productivity, ecosystems and human well-being. Field data are integrated with data from satellites and are analysed to provide diagnostic tools for leaders in Africa and the world.

This book, together with an online atlas, with downloadable data (www.vitalsignstanzania.org/atlas), provides a baseline of available environmental, demographic and agricultural information for Tanzania, including the Southern Agricultural Growth Corridor (SAGCOT).

Sandy Andelman PhD, Cheryl Palm PhD & Bob Scholes PhD

Vital Signs Technical Council

A note on sources: Brief notes on the sources of data are provided on each double-page spread. These should be read in conjunction with the Endnotes which give full details of all sources, together with citations and additional useful information.

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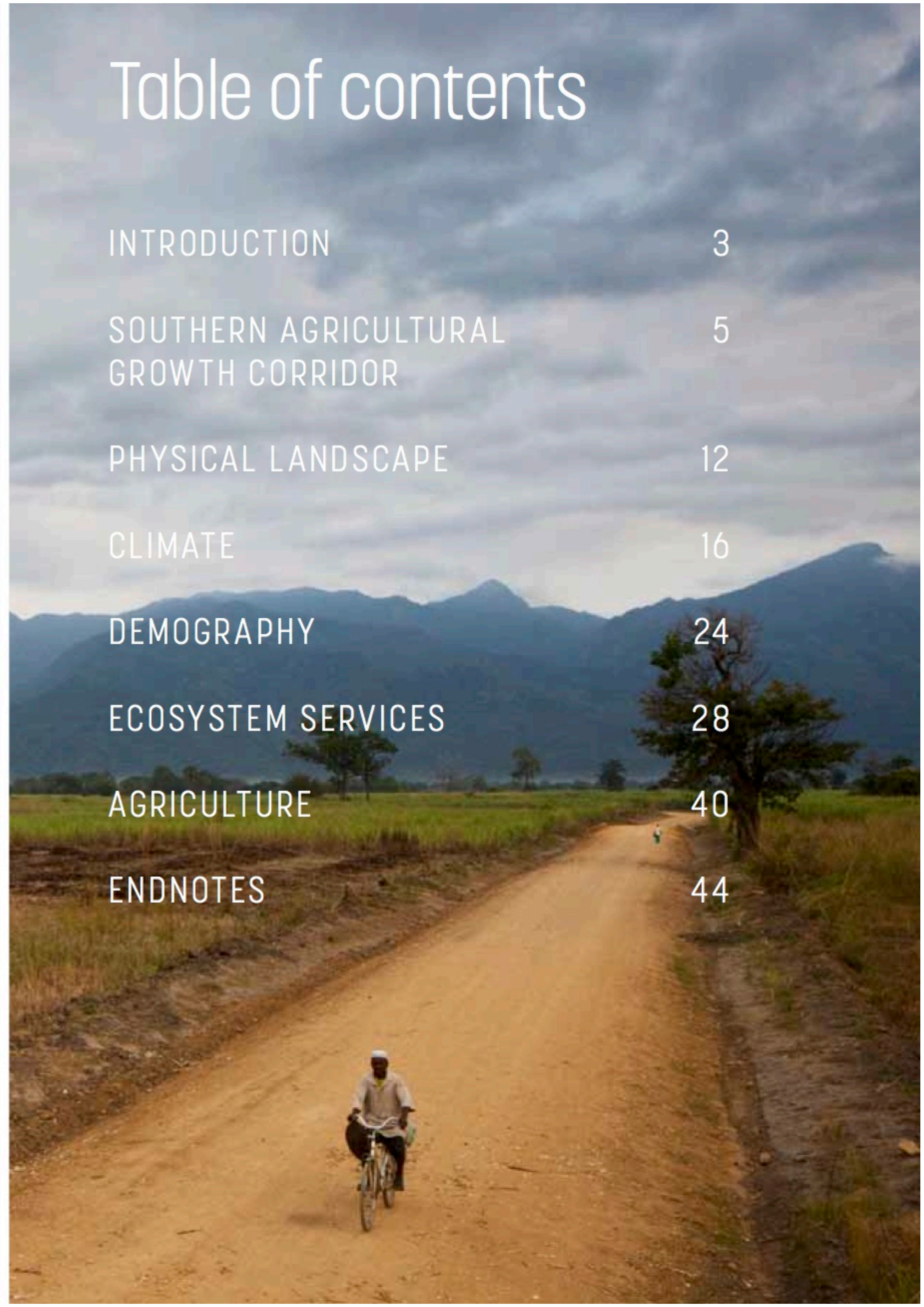


Introduction

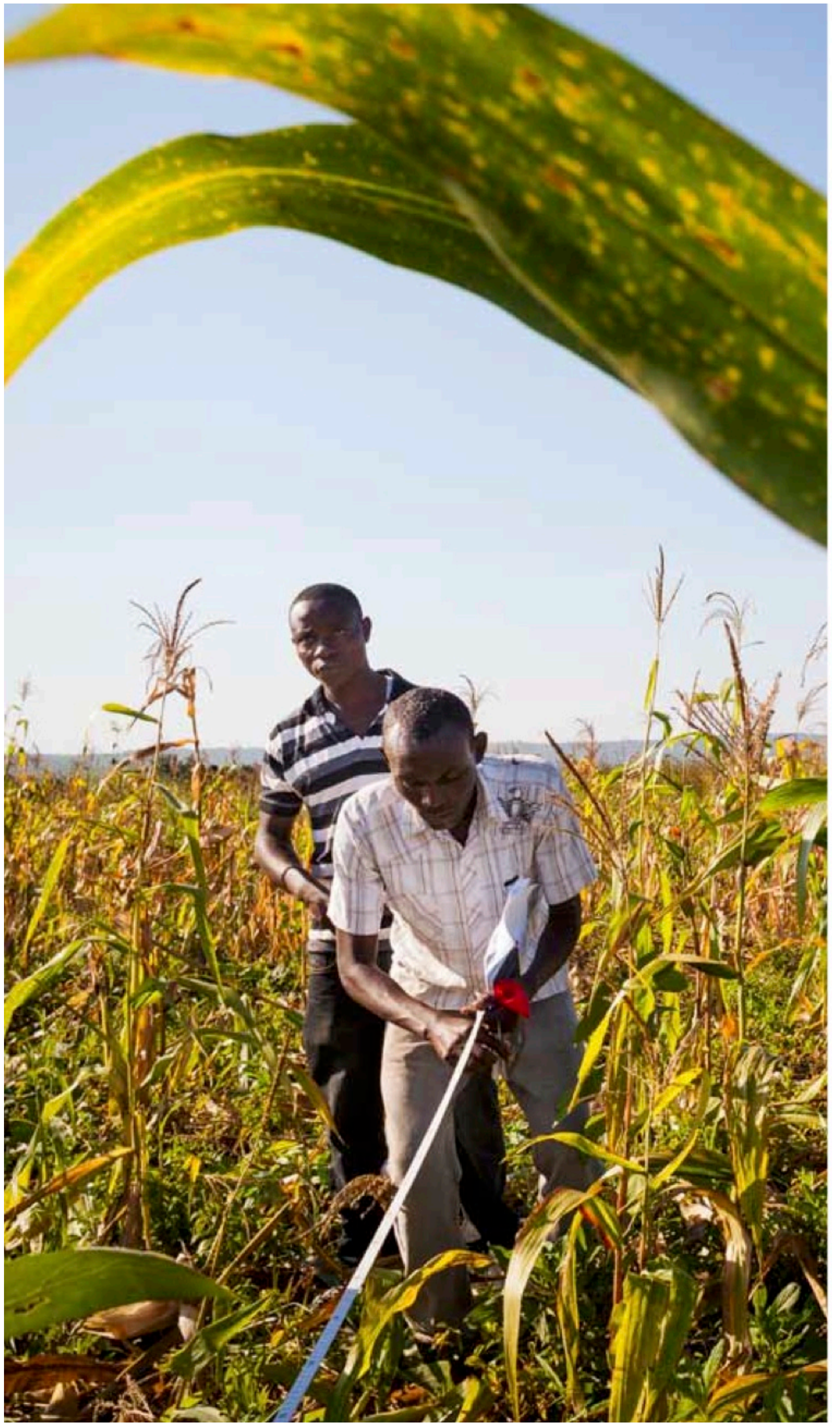
THE UNITED REPUBLIC OF TANZANIA IN BRIEF

Geographical extent	Covers 945,203 square kilometres, of which 6.2% is open water, principally Lake Victoria, Lake Tanganyika and Lake Nyasa.
Coast line	About 1,940 kilometres (including bays and major estuaries).
Major islands	Unguja (1,598 square kilometres), Pemba (991 square kilometres) and Mafia (445 square kilometres).
Frontiers with	Kenya and Uganda (north); Rwanda, Burundi and the Democratic Republic of Congo (west); Zambia, Malawi and Mozambique (south).
Recent history	The nation of Tanzania was created when mainland Tanganyika merged with Zanzibar/Pemba on 26 April 1964, after Tanganyika became independent on 9 December 1961 and Zanzibar/Pemba on 10 December 1963.
Administration	Tanzania is a federal and constitutional republic, with its seat of central government in the capital of Dodoma. It is divided into 30 regions and 169 districts. Of these, 34 are urban units which are administered by city, municipal, or town councils. Rural districts are administered by village councils or township authorities.
Population	44,928,923 in 2012, estimated to be 47,400,000 in 2014; 70% in rural and 30% in urban areas. Life expectancy at birth in 2012: 56 years. The under-15 age group makes up 44% of the total population.
Gross Domestic Product	US$73.5 billion and US$1,700 per capita in 2012; growth of 6.9% in 2012. Contribution to GDP in 2009: agriculture 26.6%; industry (including mining) 22.6%; services (including tourism) 50.8%.
Exports	US$9 billion in 2012; main exports: gold, coffee, tobacco, cashew nuts, tea, cloves, cotton, tourism, diamonds; main export partners: India, China, Japan, Germany, United Arab Emirates.
Imports	US$11 billion in 2012; main imports: consumer goods, machinery and transportation equipment, industrial raw materials, crude oil; main import partners: China, India, Kenya, South Africa, United Arab Emirates.

Source: National Bureau of Statistics, 2013

Regions

Districts



The Southern Agricultural Growth Corridor

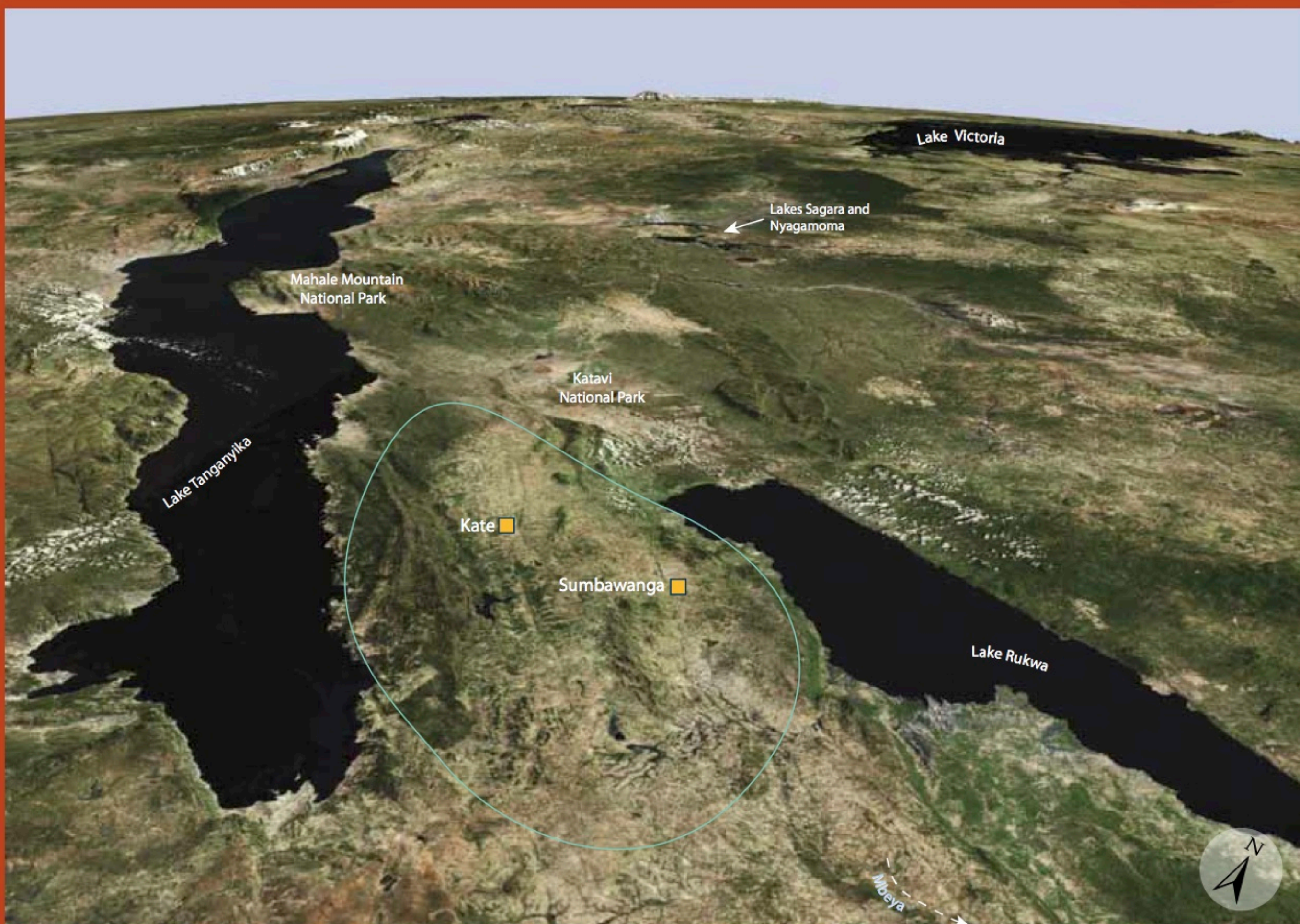
The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) is a multi-stakeholder partnership, including the Government of Tanzania, farmers, and the private sector. Launched in 2010, SAGCOT aims to attract some US$3 billion of investment which will promote food security, reduce poverty, stimulate economic growth in the Corridor and develop Tanzania into a major exporter of food. Investments are expected from international and local businesses, international development partners and the Tanzanian government.

The Corridor covers about 300,000 square kilometres, or close to one third of the country, and stretches between the Indian Ocean and the borders of Malawi, Zambia and the Democratic Republic of Congo. Major centres in the Corridor include Dar es Salaam, Morogoro, Iringa, Mbeya and Sumbawanga. The TanZam railway and main road between Dar es Salaam and the Zambian border are major assets to facilitate economic development, especially to transport food exports.

In addition to intensive commercial enterprises, small-scale farmers and the rural poor will be major beneficiaries of SAGCOT which aims to develop 350,000 hectares into productive farmland. Annual farming revenues are expected to increase by US$1.2 billion. It is also hoped that the livelihoods of some two million people in about 450,000 farming households will be improved and enriched. SAGCOT recognises the value of environmental conservation and natural resource management as critical to the Corridor's long-term economic development. Contributions made by Vital Signs are thus important for the success of SAGCOT.

SAGCOT activities and investments will be largely concentrated in six development clusters across the Corridor, which are described in the pages ahead.

Sumbawanga Cluster



Sumbawanga Cluster straddles the highlands that lie between Lake Rukwa in the east and Lake Tanganyika to the west. The only major commercial centre is the town of Sumbawanga, and most people in the area live in rural areas where they farm, predominantly with maize, sorghum and various legumes. Much of the cluster has soils that are well suited to crops (see page 28), and so large areas have been cleared of natural vegetation.

Annual rainfall is usually between 900 and 1,000 millimetres, and falls largely between November and April.

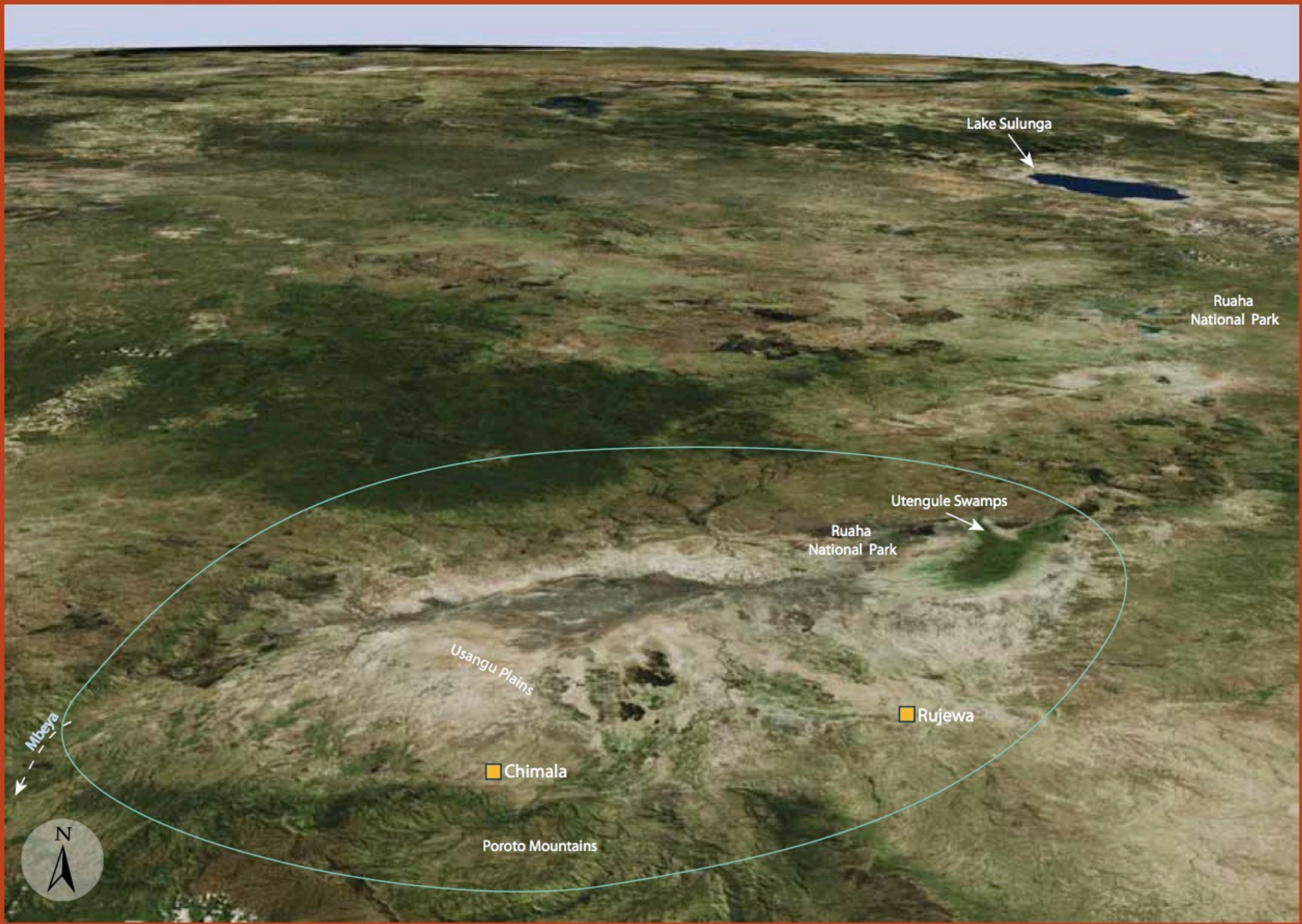
Several small forest reserves are the only protected areas in the cluster, but two of Tanzania's most famous conservation areas lie to the north: the Katavi and Mahale National Parks. These are best known for large populations of buffalo, hippo and crocodiles in Katavi and chimpanzees in Mahale.

Mbarali Cluster

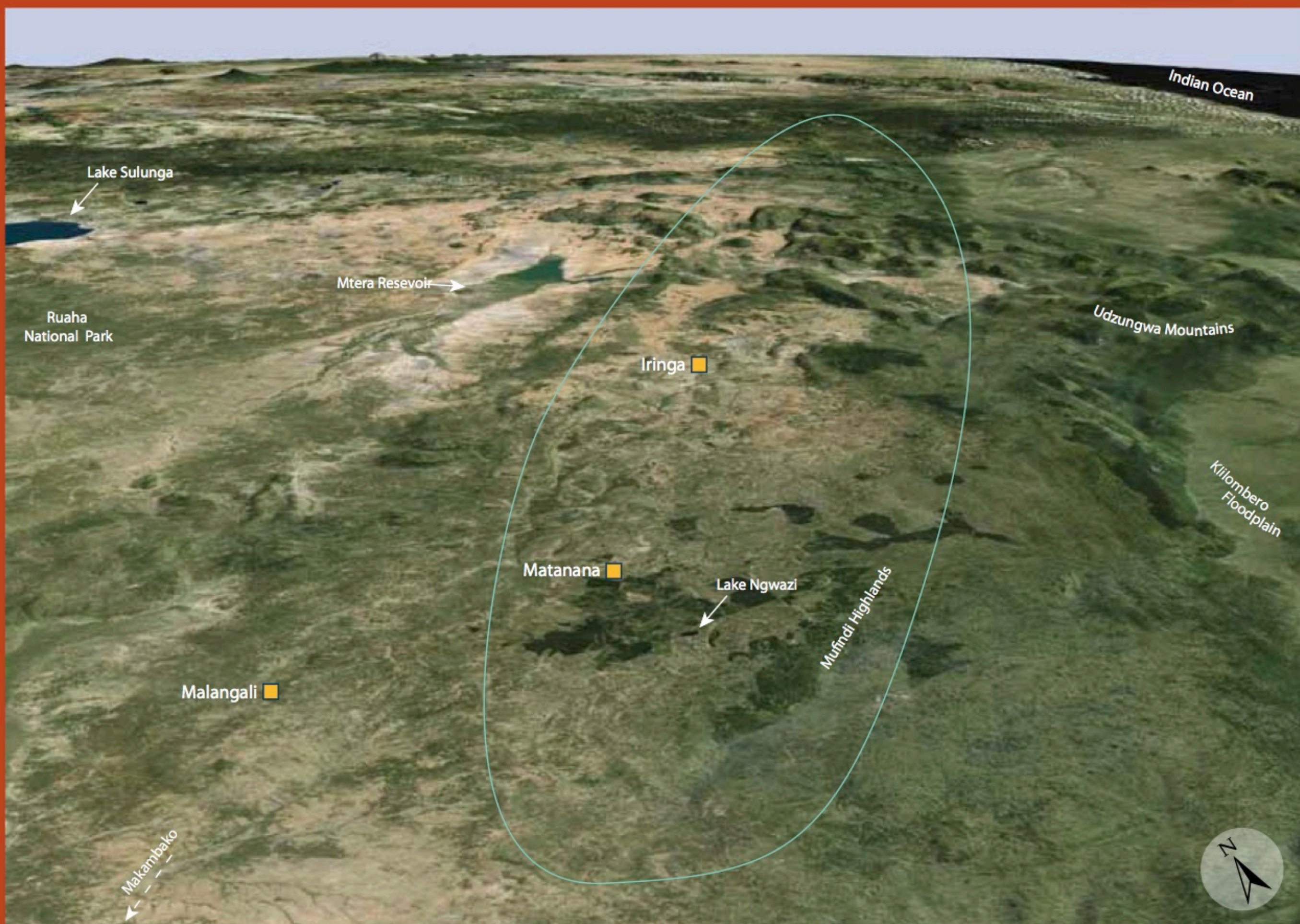
The Usangu Plains form the centerpiece of Mbarali Cluster. Tributaries of the Great Ruaha River drain the Poroto and Mbeya highlands to the south and west of the floodplain. The tributaries converge in the floodplain and it is from here that the Great Ruaha River flows north-east, first into the Utengule (or Ihefu) Swamps and then on to the Mtera and Kidatu dams and their hydroelectric plants. Mtera has a capacity of 80 megawatts and Kidatu 200 megawatts.

As a floodplain filled with alluvial sediments (mainly ferralic cambisols), Usangu offers fertile soils, which have attracted extensive agriculture. Crops predominate in the southern areas of Usangu where the principal products are maize, beans, rice, and vegetables. Rice and vegetables are mainly produced under irrigation, while other crops are usually rain-fed. Up to 20,000 hectares of rice can be irrigated every year. Usangu also supports many goats and sheep, as well as large numbers of cattle and donkeys.

The use of water for irrigation and livestock led to the Great Ruaha River drying up over long periods during the 1980s and 1990s. This created shortages of water for wildlife in Ruaha National Park (home to some 21,000 elephants; the largest population in East Africa) and for power generation at Mtera and Kidatu. The shortages also interrupted flows in the lower Rufiji River and Delta. To limit livestock numbers and therefore increase water supplies from Usangu, the Ruaha National Park was enlarged in 2008 to cover a larger area of the floodplain.



Ihemi Cluster



The Ihemi Cluster covers much of the belt of the Mufindi Highlands that lie along a southwest – northeast axis (see page 12). Elevations in the Highlands range between 1,500 and 2,000 metres above sea level in most areas. The climate is cool and comparatively wet, as a consequence of high rainfall (1,300 - 1,600 millimetres per year) and low rates of evaporation. Unlike areas to the east and north with bi-modal seasons, Ihemi cluster has rainfall in a single season extending from November to April.

The southern edge of these Highlands is marked by a distinct scarp which forms the edge of a rift valley formed about 250 - 300 million years ago. That is about 10 times older than the Great Rift Valley elsewhere in Tanzania.

Originally, vegetation in the cluster consisted largely of miombo woodlands at relatively low elevations, and wooded grasslands at higher elevations. Nowadays, much of the indigenous plant life has been cleared to produce the great variety of crops found in Ihemi. These include vegetables for commercial production - potatoes, onions and tomatoes - along with maize and sorghum as the main cereals. Much of Tanzania's tea is grown south of Mafinga, and many of the country's pine and eucalyptus plantations are here.

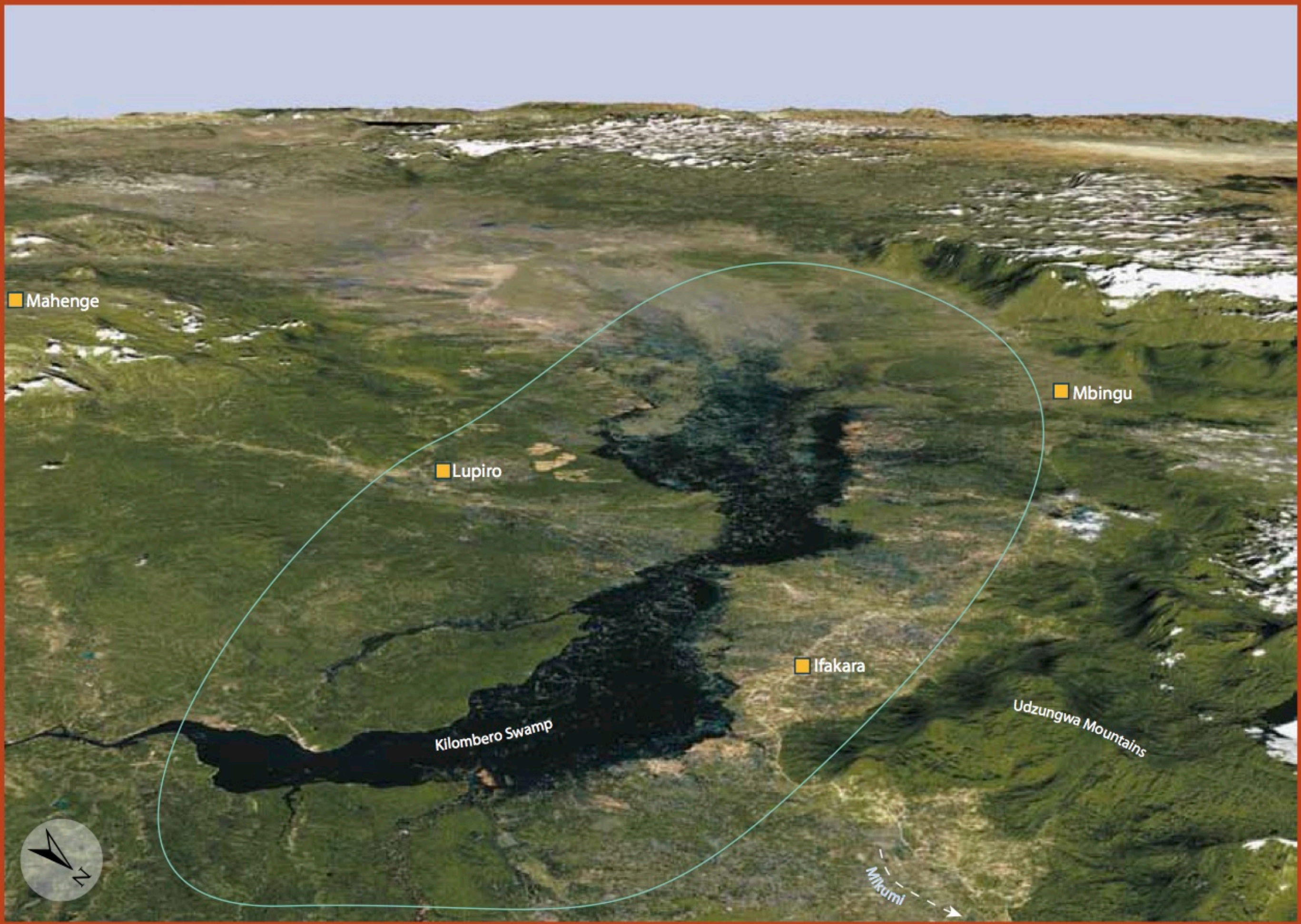
Kilombero Cluster

The broad valley and floodplain of the Kilombero Cluster extend southwest to northeast between the Udzungwa Mountains to the north and the hills of the Mahenge Highlands to the south. The floodplain is watered by the Ruhudji, Mnyera and Pitu rivers, and dozens of small streams that flow off the Udzungwa Mountains.

Kilombero is one of the largest freshwater floodplains in East Africa, and therefore has high ecological value in providing habitat to many wetland species of plants and animals. The floodplain also helps to regulate water flows into the Rufiji River. The Kilombero Valley Flood Plain Ramsar Site was designated in April 2002.

A high proportion of the world's puku antelope live in Kilombero, and several species of birds are endemic to the valley. Many large wildlife species move into the valley during the dry season. Tens of thousands of buffalo were counted there in the 1980s, as well as thousands of elephants and hippo. Populations of these large mammals have since declined several fold.

Soils in Kilombero are generally well-suited to various crops. Considerable areas have thus been used for small and large-scale farming, and several new large-scale irrigation schemes have been planned. These include 14,000 hectares of rice, 20,000 hectares of sugar plantations, and 13,250 hectares of mixed cropping.



Rufiji Cluster

The Rufiji Cluster extends inland from the coast some 140 kilometres to Stiegler's Gorge on the Rufiji River. Mafia Island lies some twenty kilometres offshore the Rufiji Delta. The climate in this area is normally hot and humid since the elevation is low - less than 60 metres above sea level - and onshore winds bring moist air onto the coastal plain.

Annual rainfall is highest near the coast (about 1,300 millimetres), lowest in the central areas of the cluster (about 950 millimetres) and somewhat higher in the west (about 1,000 millimetres). The two rainy seasons are quite distinct, with early rains falling between November and December, and later falls occurring from March to April. June to October are the driest months.

The inland area of the cluster is built on marine sediments, predominantly covered by woodland and forest interspersed with grasslands and swamps. About one quarter of the vegetation in the Delta is mangrove, making this the most extensive area of mangrove forest in eastern Africa. Five species of globally threatened marine turtles occur in the Delta, and two of them nest there. Small numbers of dugong survive in the Delta. About 80% of all prawns harvested in Tanzania come from the Rufiji Delta. The Delta and Mafia Island Marine Park are a designated RAMSAR area.

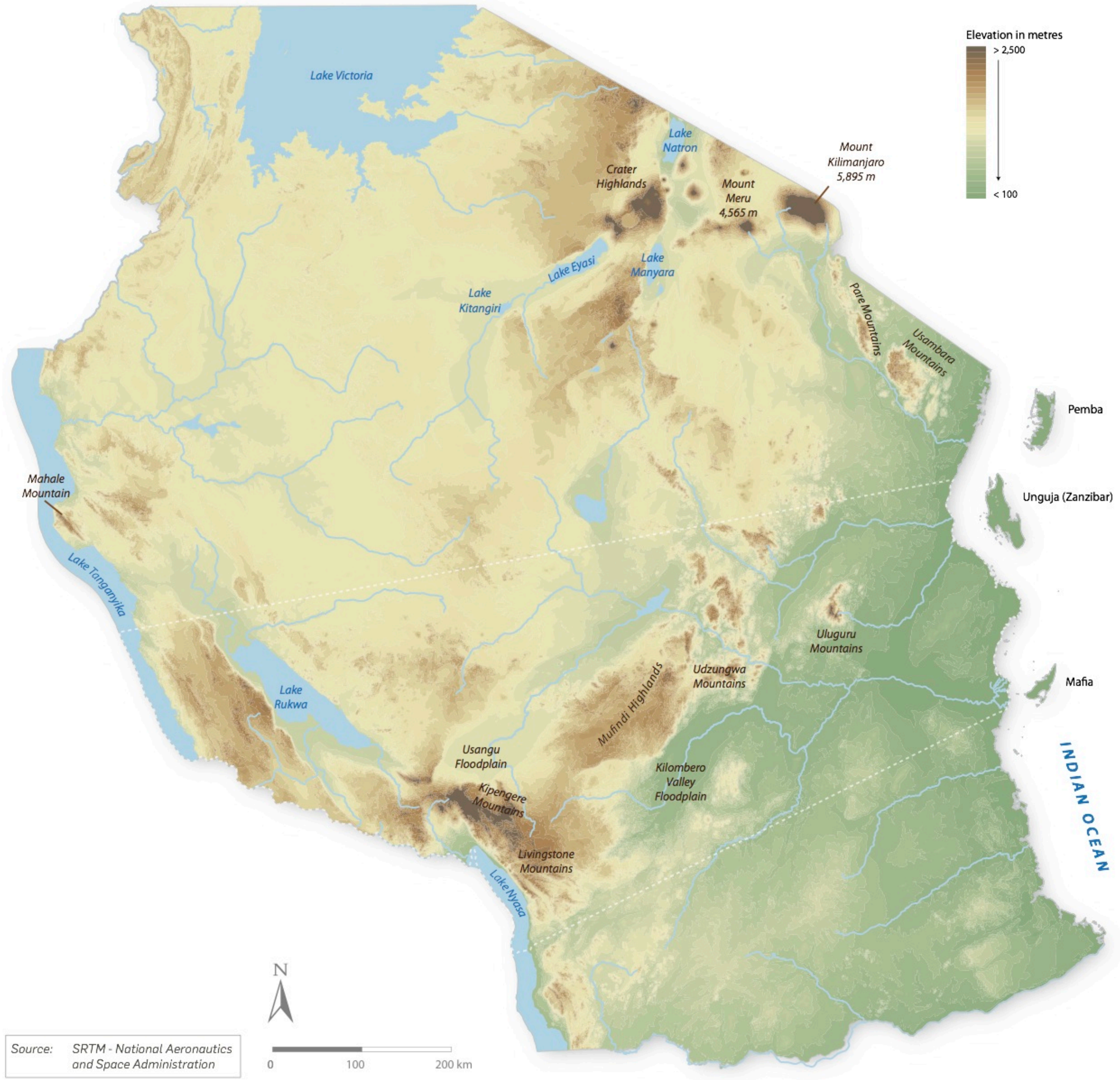
Ludewa Cluster

The Ludewa Cluster lies to the east of Lake Nyasa and on the southern slopes of the Livingstone Mountains. The cluster also covers a substantial part of the Lake Nyasa River Basin and lies within the administrative region of Njombe.

At higher elevations, montane forest and grasslands predominate, while drier miombo woodlands and grasslands are found at lower elevations. Riverine forests and woodlands grow alongside rivers and streams. Rainfall is highest in the northern areas of the cluster, where annual falls average about 1,300 millimetres. Further south in the cluster about 1,000 millimetres of rain falls each year. Most rain is received between December and April.

The cluster is fairly sparsely populated, at least compared with many other areas in Tanzania. The total population of Ludewa District, which covers an area about double the size of the cluster, was 133,218 in 2012. Most people are small-holder farmers who live in villages dispersed fairly evenly across the area. Their major cereal crops are maize, sorghum and rice. The are four forest reserves in the cluster: Mdandu, Sakaranyumo, Mushola and Madenge.

Physical landscape



TOPOGRAPHY

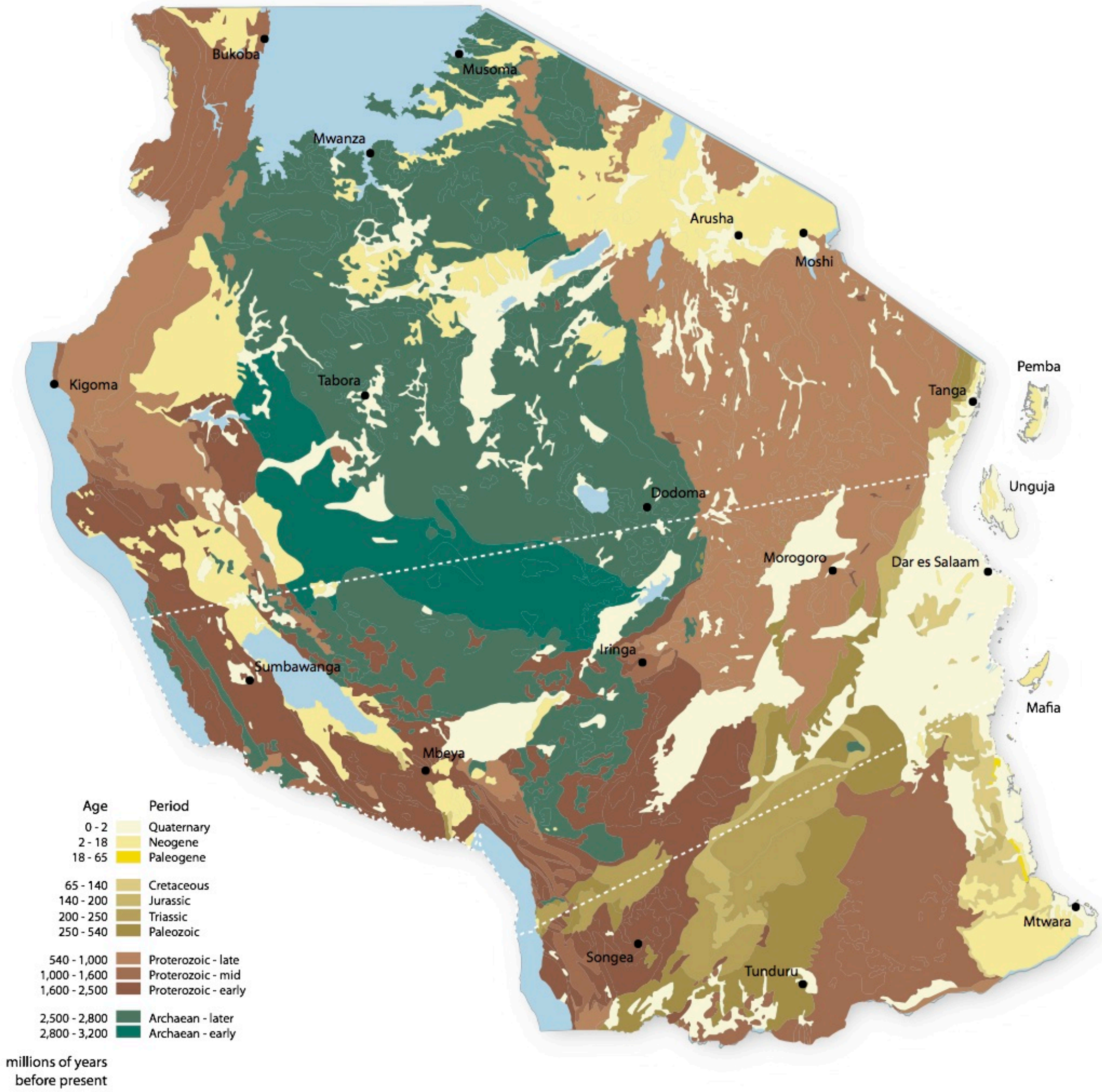
Large areas of Tanzania consist of relatively flat countryside or gently rolling hills. This is true for most of the central areas, the broad coastal plains and the southeast. However, these even landscapes are broken in places by hills, mountains and valleys, all of which lend diversity and spectacle.

There are two main groups of hills and mountains. The first are those built by volcanic outpourings, the most prominent being Mount Kilimanjaro, Mount Meru and the Ngorongoro Crater highlands. The second group consists largely of belts of hardy old metamorphic rocks that have withstood erosion over hundreds of millions of years. They make up the Eastern Arc Mountains (Pare, Usambara, Uluguru, and Udzungwa) and Southern Highlands (Kipengere, Poroto, Rungwe, Njombe, Mbeya and Livingstone).

There are also two main groups of valleys. The first are ancient rift valleys that formed between 300 and 250 million years ago, the most conspicuous remaining as the Kilombero Valley, which is bounded by a distinct scarp rising onto the Udzungwa Mountains and Mufindi Highlands. The second is the Great East African Rift Valley system, consisting of the Albertine Rift in the west (in which lie lakes Tanganyika, Rukwa and Nyasa) and the Gregory Rift in the east (containing lakes Natron, Manyara and Eyasi).

GEOLOGY

Period and age of rocks



Source: Maps - adapted from Council for Geoscience

Much of Tanzania's centre formed during Archaean times between 3,200 and 2,500 million years ago. The rocks here are largely granitic and form the Tanzanian Craton, which is an ancient stable mass of continental rock. This Craton thus forms Tanzania's geological foundation, on which other rock formations have been built more recently.

Rocks of the Proterozoic eon formed between 2,500 and 540 million years ago, and largely surround the ancient craton. They consist mainly of metamorphic rocks formed from igneous or sedimentary rocks. The most extensive of these are gneisses, amphibolites, metasediments and shales.

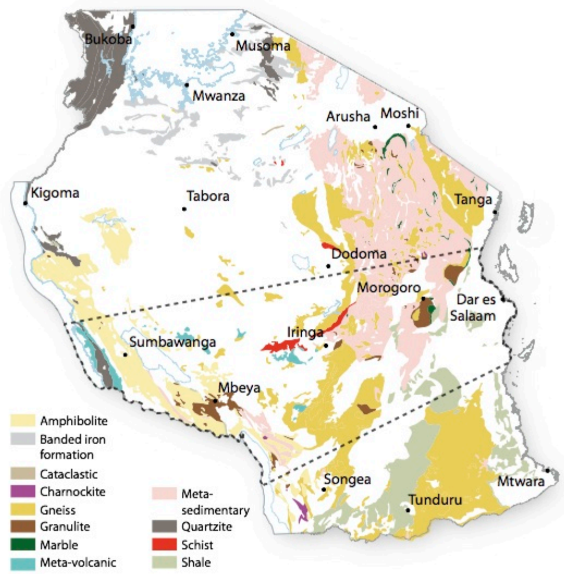
The Palaeozoic era followed between 540 and 250 million years ago when various sedimentary rocks were formed, largely along a belt from Tanga south along the coast and south-westwards to the Mozambique border around Tunduru. The sediments are mainly sandstones and mudstones, but tillites were also deposited by glaciers.

The Triassic, Jurassic and Cretaceous together form the Mesozoic era between 250 and 65 million years ago; the end of the Mesozoic marks the time when most dinosaurs became extinct. As in the Palaeozoic, this was an era of deposition and all the rocks of the Mesozoic are sedimentary sandstones and conglomerates. They, too, lie along a belt southwest and south of Tanga.

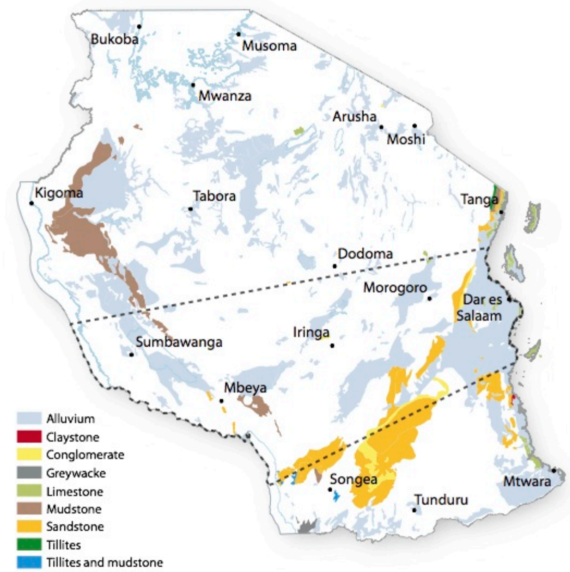
The youngest rocks belong to the Cenozoic era that began 65 million years ago and continues today. This era is further divided into the Paleogene, Neogene and Quaternary, the last covering the last 2 million years. It is during the Cenozoic that the Great East Rift Valley opened between 35 and 25 million years ago. The rifting of the crust created fissures through which molten rock spewed to build Tanzania's great volcanoes, such as Mount Kilimanjaro and the volcanic highlands near Mbeya. Some of the most fertile soils, intensive farming and highest densities of people owe their existence to that volcanism. Other than the volcanic rocks, all other Cenozoic rocks are of sedimentary origin, mainly from alluvial or marine origins. The latter form large areas of the coastal plain, while others were deposited in lowlands scattered across Tanzania.

Rock type

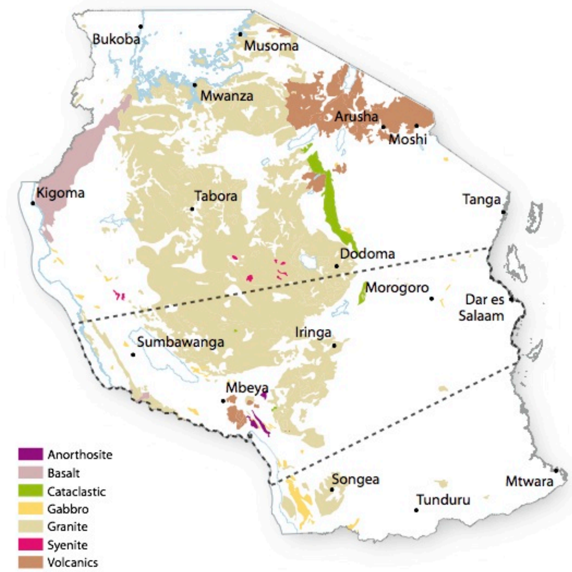
Metamorphic

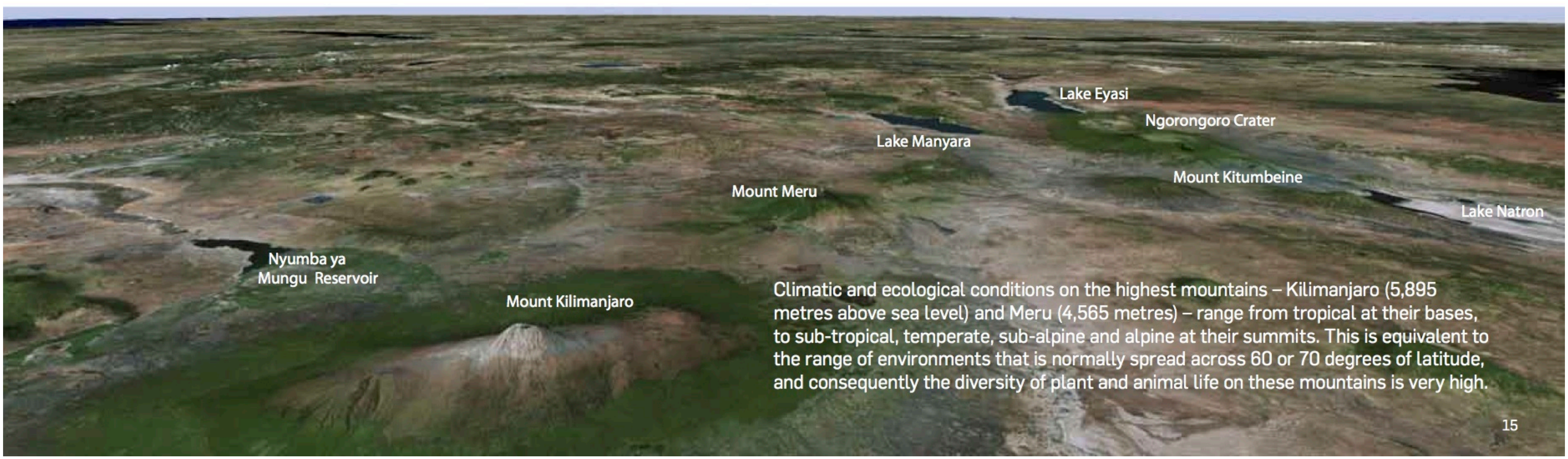


Sedimentary



Igneous





Climatic and ecological conditions on the highest mountains – Kilimanjaro (5,895 metres above sea level) and Meru (4,565 metres) – range from tropical at their bases, to sub-tropical, temperate, sub-alpine and alpine at their summits. This is equivalent to the range of environments that is normally spread across 60 or 70 degrees of latitude, and consequently the diversity of plant and animal life on these mountains is very high.

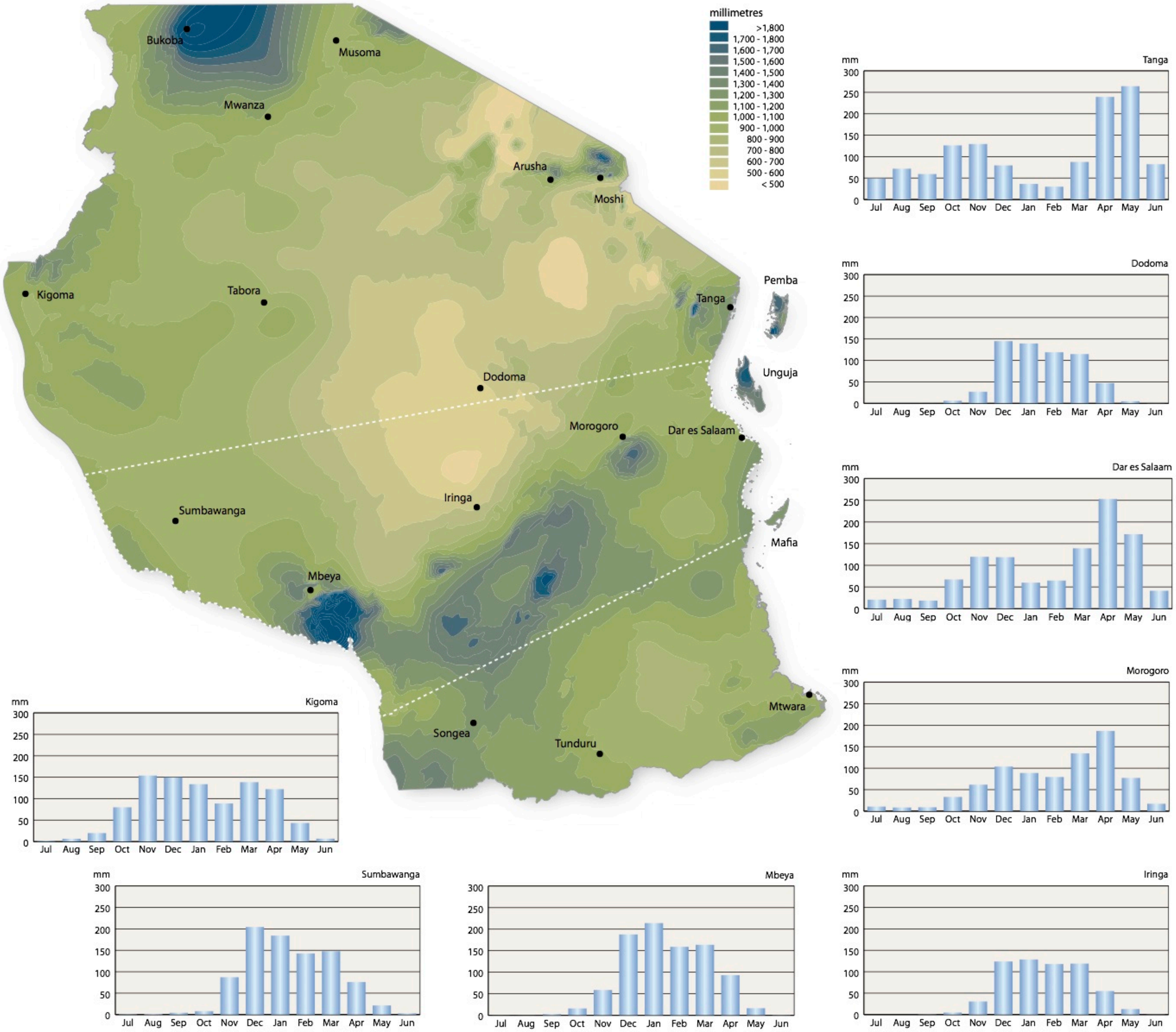
Climate

RAINFALL

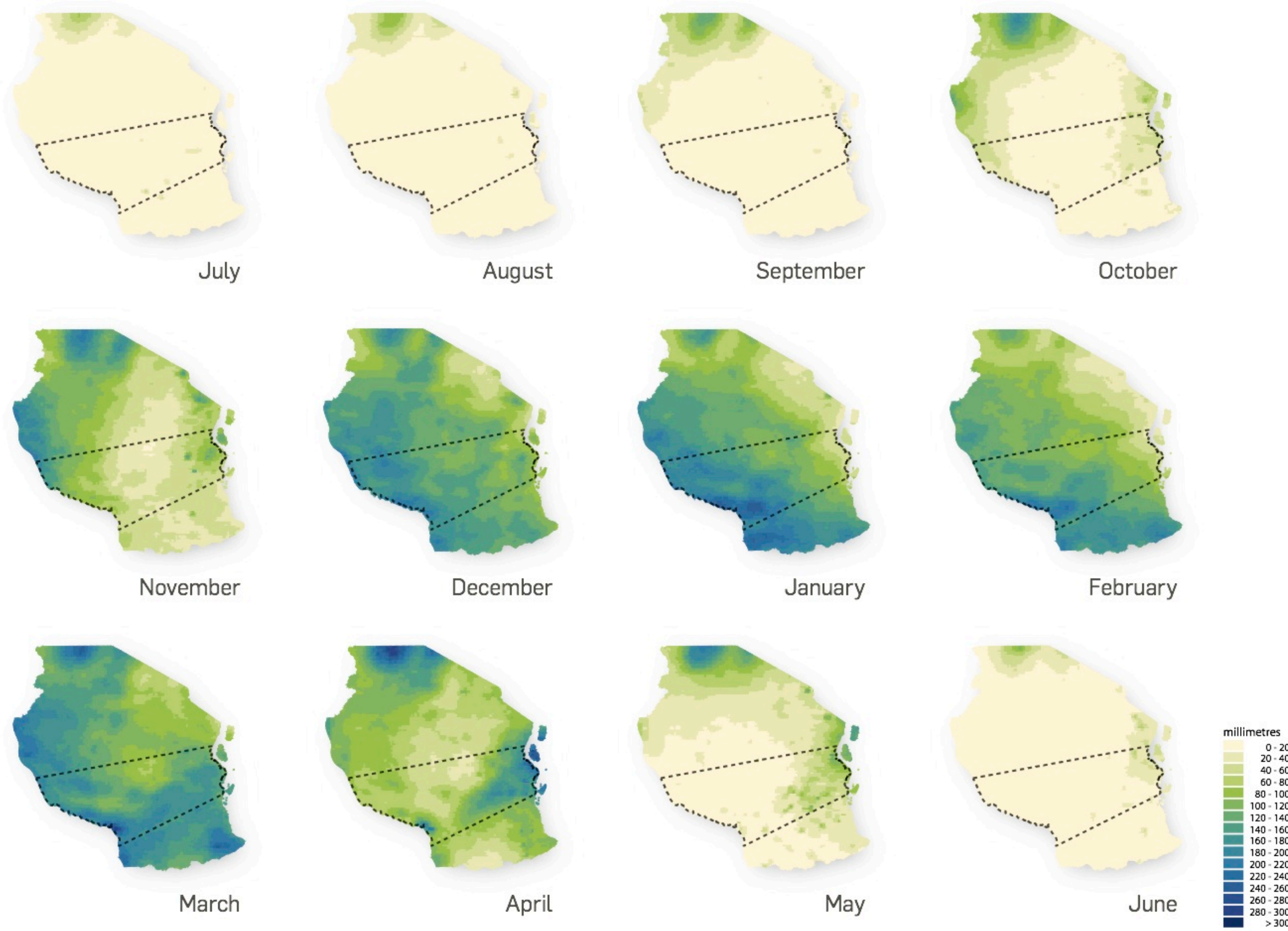
Average annual rainfall

Annual rainfall in Tanzania varies between less than 500 millimetres in the centre of the country to over 1,800 millimetres over Lake Victoria and the Southern Highlands near Mbeya. There is also substantial local variation in rainfall associated with topography, so highlands and mountains receive much more rain than lower, surrounding ground. This is particularly evident on the western sides of highlands, since much of the rain is carried into the country on easterly winds from the Indian Ocean. As the moist air rises, it cools and condenses, causing rain to fall over the high ground. Air moving onto the west is drier.

The graphs show the average rainfall recorded each month at a selection of stations. Annual averages at these stations are: Iringa 593; Dodoma 603; Morogoro 810; Sumbawanga 856; Mbeya 912; Kigoma 944; Dar es Salaam 1,097; and Tanga 1,255 millimetres.



Average monthly rainfall



These maps show how rain shifts from month to month, starting in July which is the driest month everywhere. Rainfalls then gradually increase and expand from the northwest, while a separate zone of rainfall expands westwards from the northeastern coast in October. December is the wettest month everywhere. Then follows a short drier season in January and February which is most pronounced along the coast. March is again wet in most areas, and then rainfall diminishes until July.

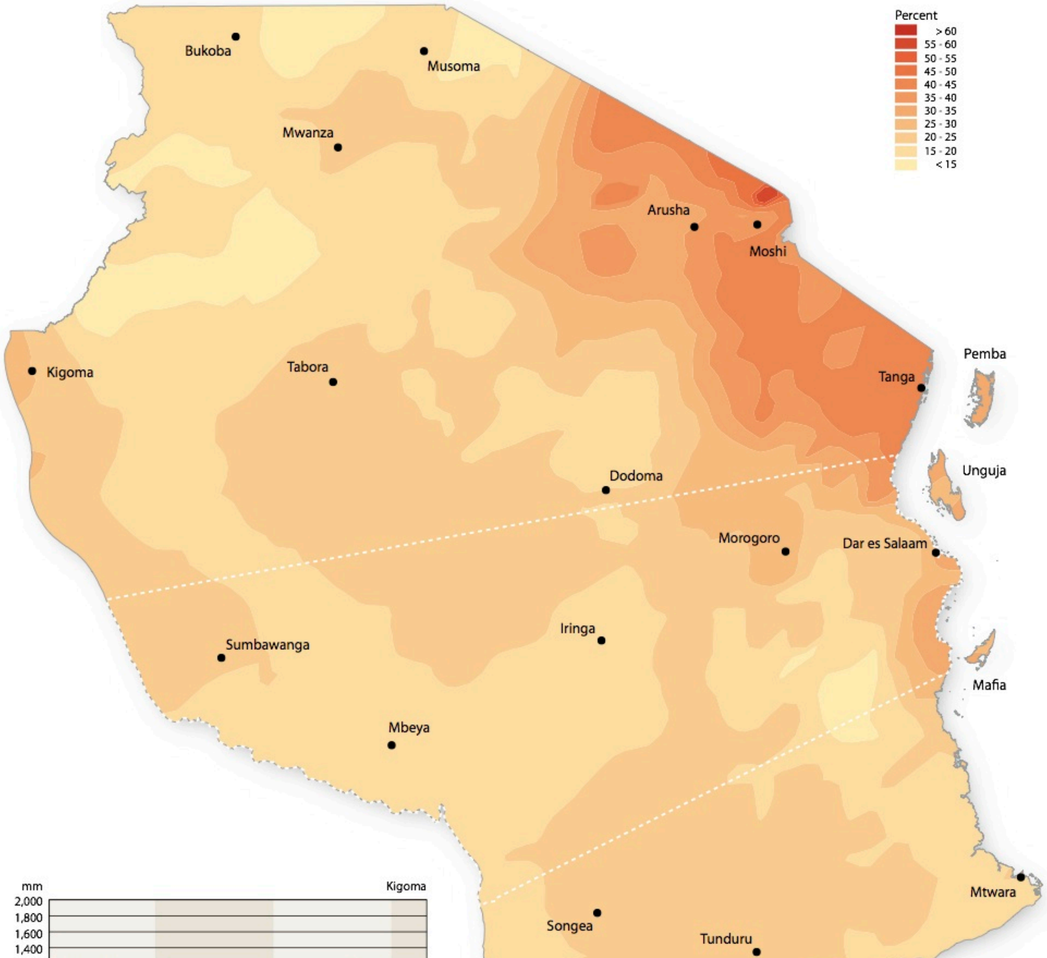
The seasonal patterns are a consequence of movements of the Inter-tropical Convergence Zone (ITCZ). The Zone begins to shift south in October, reaching southern Tanzania in January and February, and then moves back north. The so-called short rains (locally called *vuli*) occur during the shift south, while the long rains (*masika*) fall during the movement northwards.

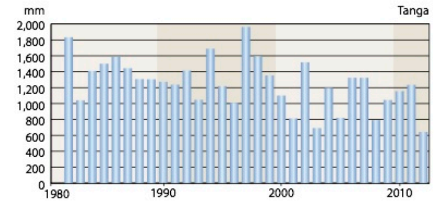
Sources: *Annual map - WorldClim representation of 1950 - 2000*
Monthly maps - Famine Early Warning System Network, 1996 - 2013
Graphs - Ministry of Agriculture, Food Security and Cooperatives & Tanzania Meteorological Agency, 1982 - 2012

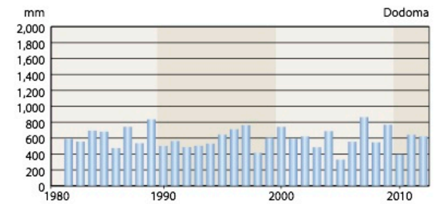
Rainfall variability

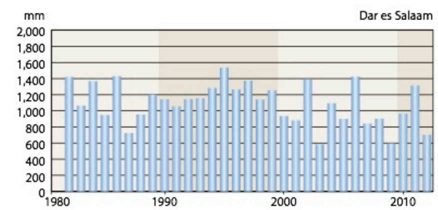
Total rainfalls vary more from year to year in the northeastern areas than elsewhere, as shown in the map of the coefficient of variation of annual rainfall. This is the part of the country where the short and long rains are most clearly defined.

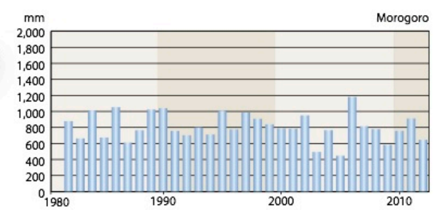
The graphs of annual rainfall at eight stations also indicate the extent to which rainfall varies between years, with Tanga having much greater variation than, for example, Dodoma and Mbeya. The lowest total recorded between 1980 and 2012 at Tanga was 644 millimetres in 2012, which was three times less than the wettest year in 1997, when 1,963 millimetres was measured.

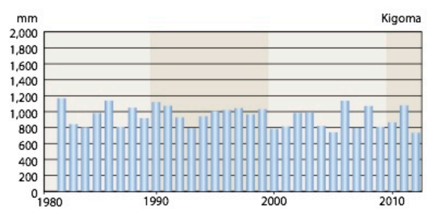




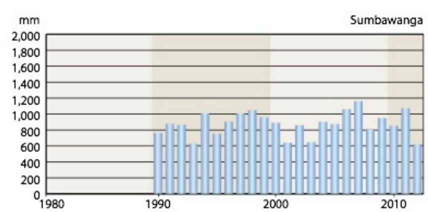


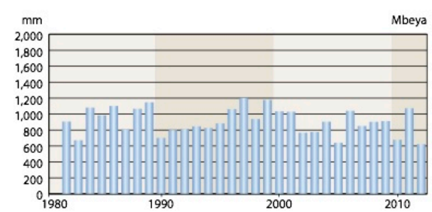


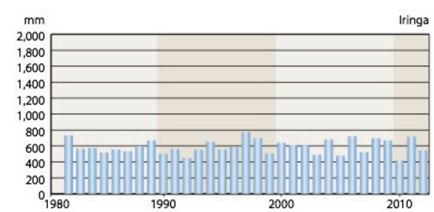




Sources: *Map of variability - Famine Early Warning System Network, 1996 - 2012*
Map of evaporation - MODIS Global Evapotranspiration Project, 2000 - 2010
Graphs - Ministry of Agriculture, Food Security and Cooperatives & Tanzania Meteorological Agency, 1982 - 2012



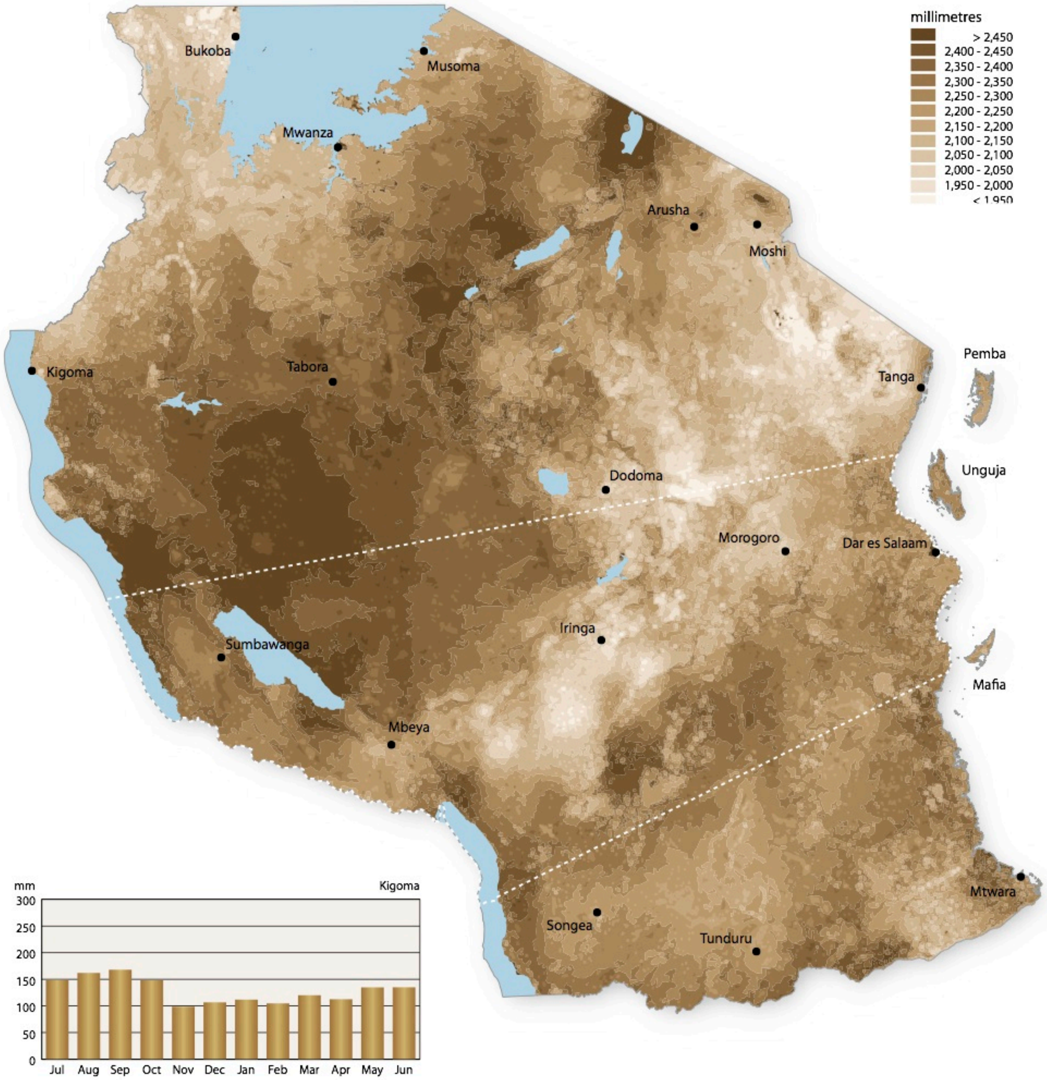


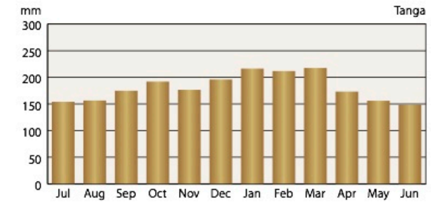


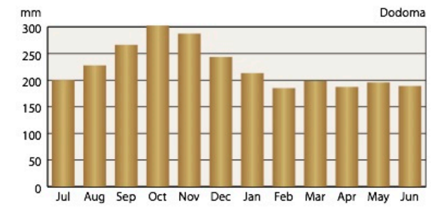
EVAPORATION

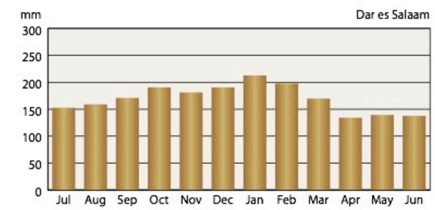
Potential evapotranspiration shown in the map provides a measure of the amount of water that is potentially lost annually to the atmosphere through evaporation and the transpiration of water by plants. The highest rates are in central western Tanzania and in the Rift Valley around Lake Natron and Lake Eyasi.

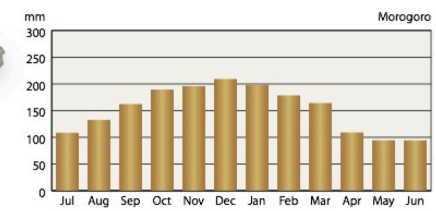
The series of graphs provide measures of evaporation from pans at various weather stations each month. Changes during the year are closely related to temperature, such that the highest evaporation rates along the coast are in the warmest months of February and March. Further inland, most water evaporates during the hottest months of September, October and November.

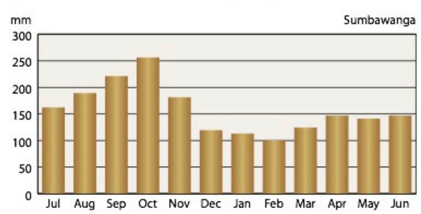


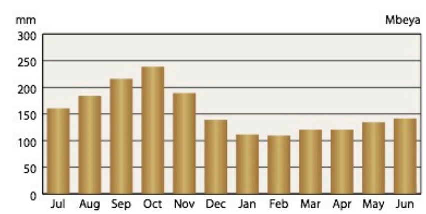


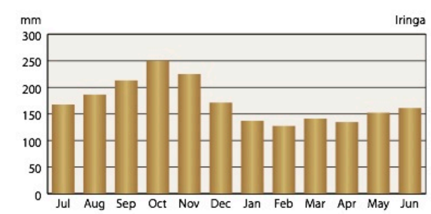












TEMPERATURE

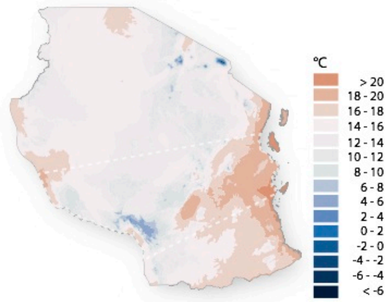
Temperatures in Tanzania vary largely in relation to elevation. The very coldest sub-zero temperatures are thus on top of Mount Kilimanjaro, while the hottest areas are at low elevations along the coast and in the Rift Valley.

The hottest months are between September and November in the southern and western regions, whereas February and March are warmest along the coast. July is the coldest month everywhere, as well as the driest month (see page 17).

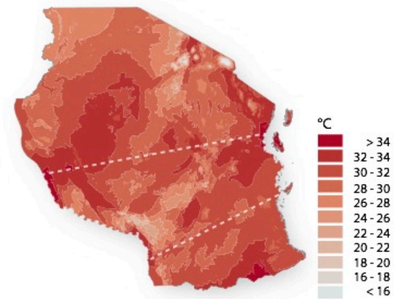
The maps of minimum and maximum temperature show the average lowest and highest temperature across the country during the coldest and warmest months, respectively.

Annual range is the difference in average temperature between the warmest and coldest months of the year. The greatest differences – of more than 15°C – are in the eastern and southern parts of Tanzania.

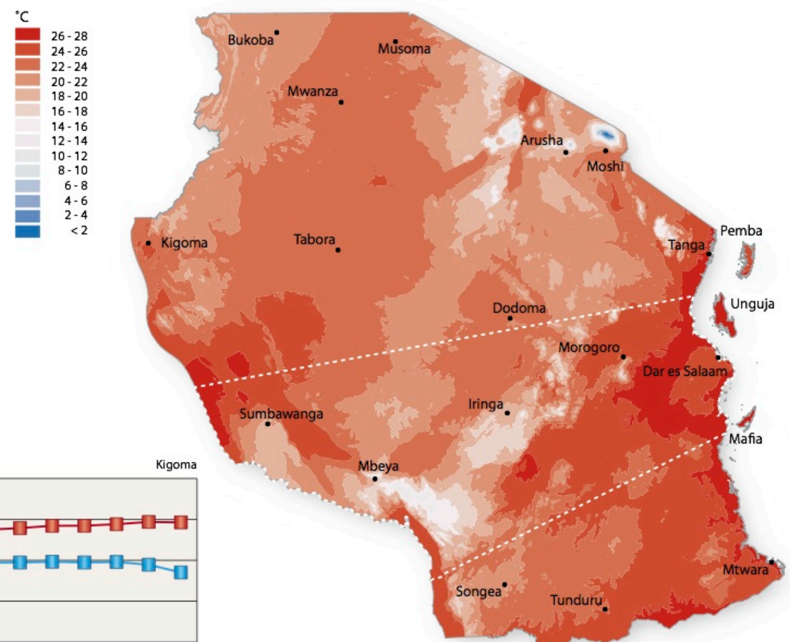
Minimum temperature



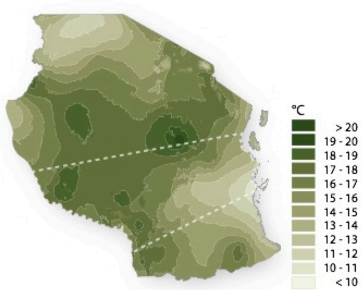
Maximum temperature

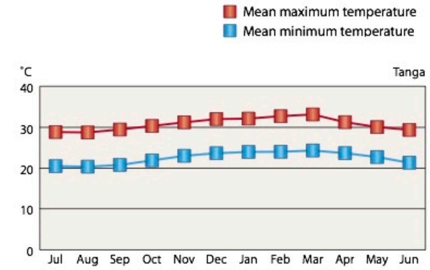


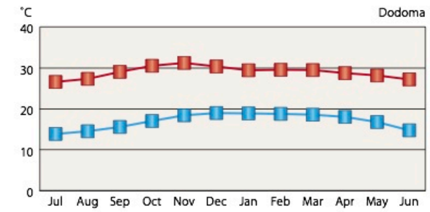
Average annual temperature

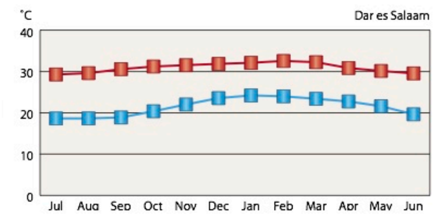


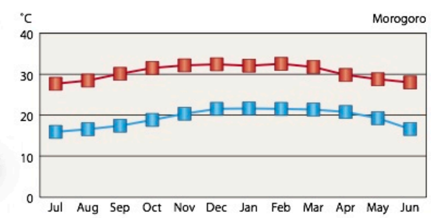
Annual range

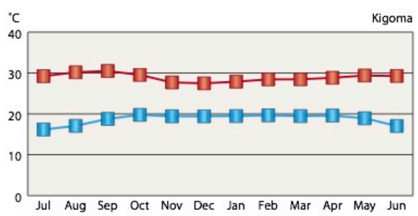


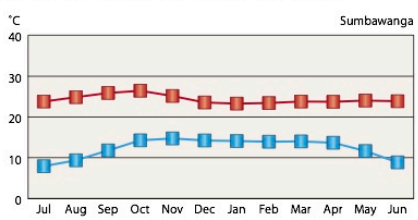


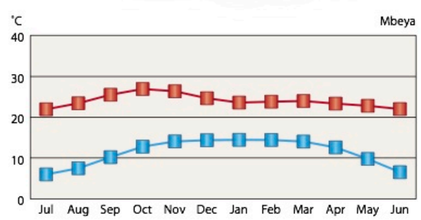


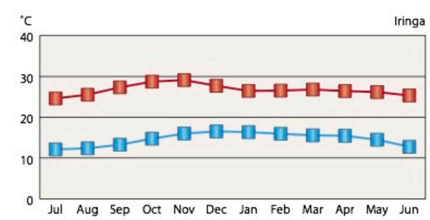








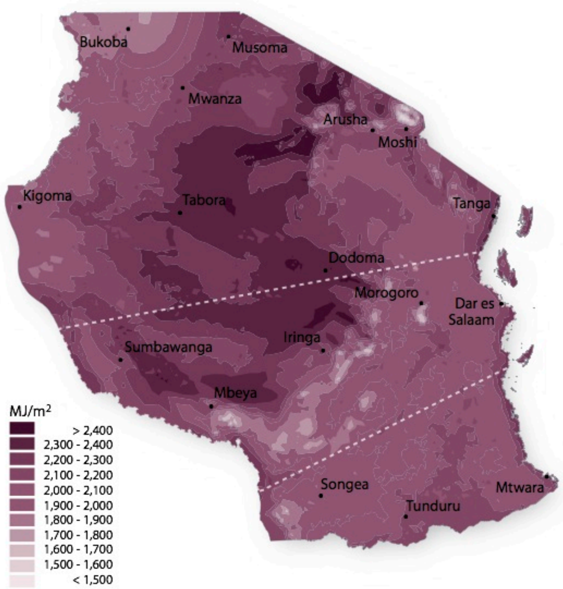




RADIATION

Being close to the equator, Tanzania is potentially bathed in sunlight (and thus solar radiation) for about 12 hours each day throughout the year. However, solar radiation (measured in megajoules per square metre) is often limited by cloud cover (see page 39), particularly at high elevations and in the south-eastern third of the country.

Average annual solar radiation

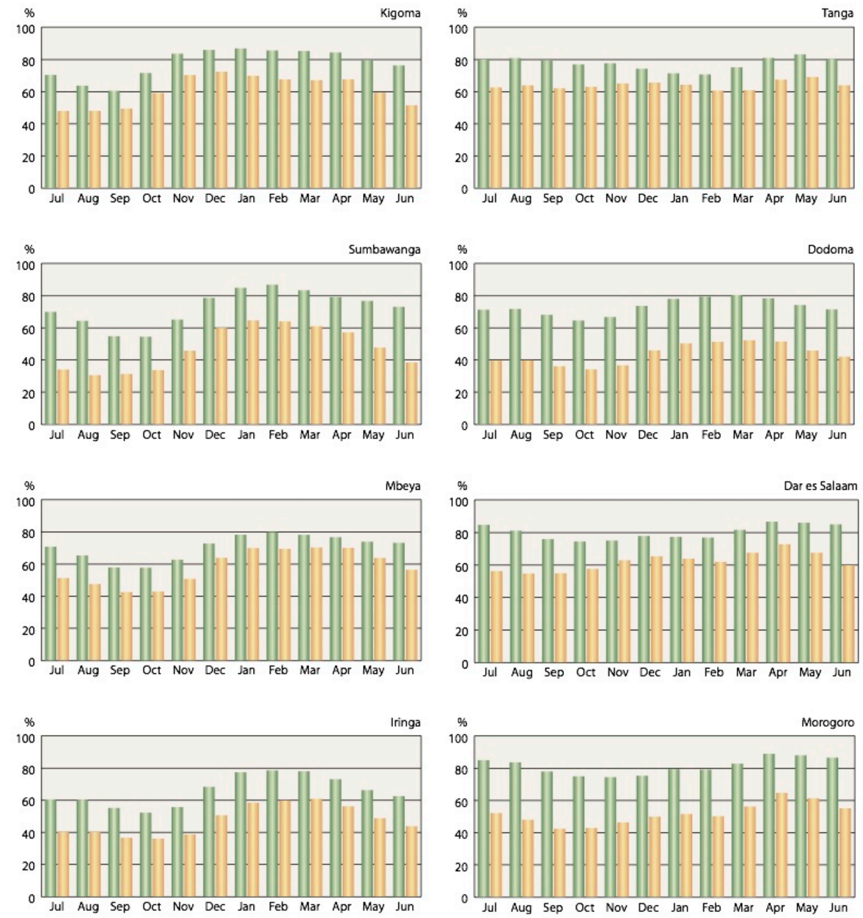


Sources: *All temperature maps - WorldClim, 1950 - 2000*
Temperature graphs - Ministry of Agriculture, Food Security and Cooperatives & Tanzania Meteorological Agency, 1982 - 2012
Radiation - Joint Research Centre, European Union, 1998 - 2011
Humidity graphs - Tanzania Meterological Agency, 1982 - 2012
Bioclimate maps - United States Geological Survey

HUMIDITY

Relative humidity is a measure of the amount of water held in air relative to its saturation point and is thus influenced by temperature. Higher measures are typically recorded when it is cool early in the morning (06h00), decreasing as the air temperature rises towards mid-day (12h00).

The graphs show how relative humidity changes during the year. Close to the coast (Tanga, Dar es Salaam and Morogoro), humidity is strongly influenced by onshore flows of moist air coming off the warm waters of the Indian Ocean. Humidity in these parts is high throughout the year with the highest levels from April to June as a result of the lower temperatures in the winter months. Inland, the highest humidity levels occur during the rainy months between December and March.

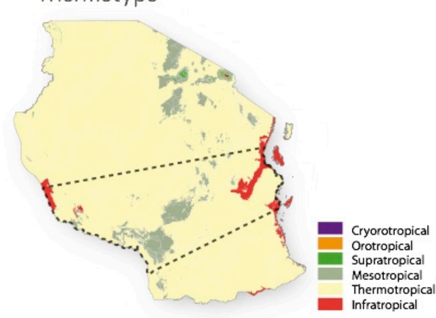


06h00 12h00

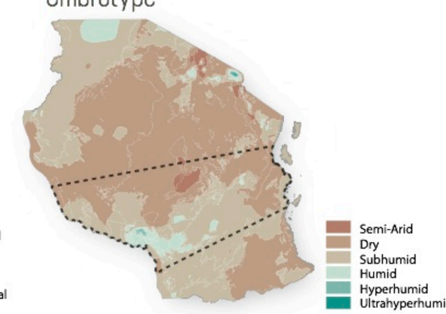
BIOCLIMATE

Bioclimate zones exhibit distinctive climatic features which strongly influence vegetation types and structures. Thermotypes are defined by temperature while ombrotypes are classified on the basis of rainfall and temperature.

Thermotype



Ombrotype



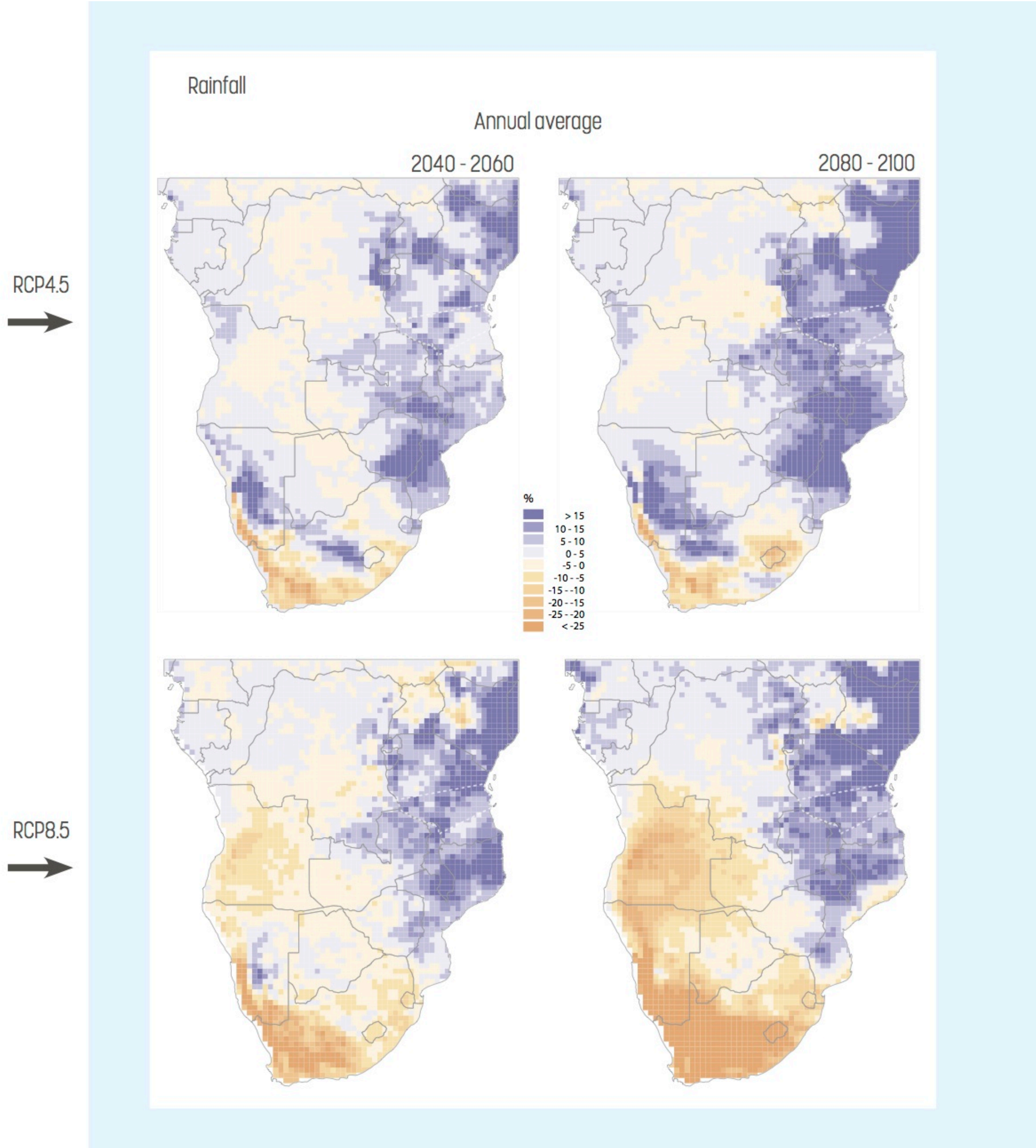
CLIMATE CHANGE

Climatologists are certain that the earth is getting warmer which alters patterns of air circulation around the globe. In turn, that is leading to changes in rainfall and other aspects of the earth's climate which have implications for agriculture and ecosystems.

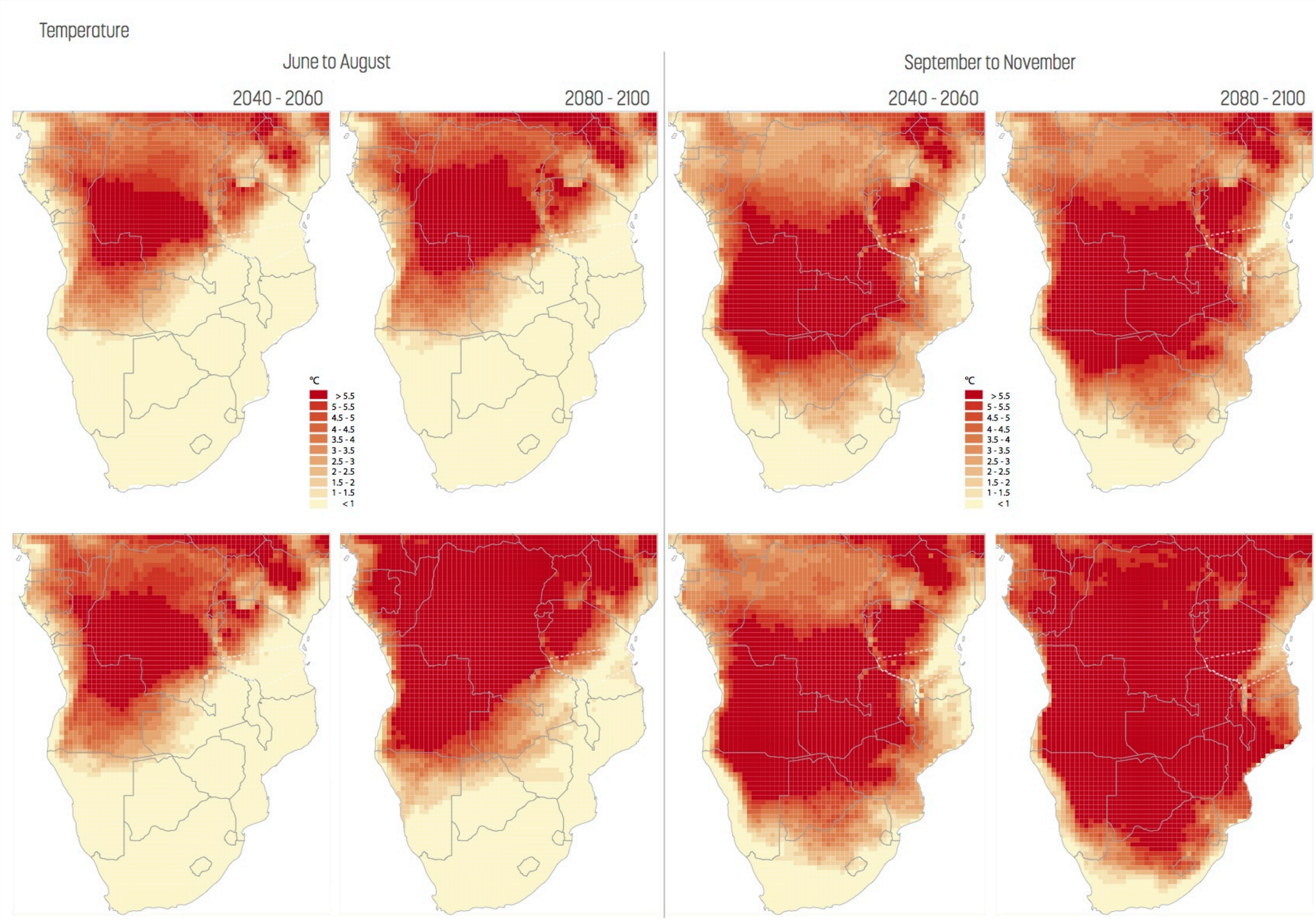
These maps present projected changes in rainfall and temperature by 2040 - 2060 and 2080 - 2100. Two RCP (Representative Concentration Pathways) scenarios were used for the projections. The RCP scenarios are based on emission levels associated with differences in radiant energy received by, and radiated from, the earth. RCP 8.5 is based on the assumption that the *rate of increase* of emissions of carbon dioxide will continue throughout the 21st century. By contrast, it is assumed for RCP 4.5 that emission levels will remain relatively stable up to 2050 and decline thereafter to below current levels. If controls can be implemented as much as anticipated by the 4.5 scenario, emissions of carbon dioxide in 2100 could be several times lower than those projected by the 8.5 scenario.

The rainfall maps show the percentage change between current annual totals and those projected in 2040 - 2060 and 2080 - 2100. Both scenarios show increased rainfall over much or all of Tanzania, with the 8.5 scenario projecting increases sooner and to a greater extent than the 4.5 scenario. Rainfall over much of Tanzania in 2100 is projected to be more than 15% higher than it is now.

Projected temperature changes are shown for the coolest months (June - August) and warmest months (September - November) of the year. Both scenarios indicate that the western half of Tanzania will become hotter in the two seasons, but more so between September and November, and more so in terms of the 8.5 than the 4.5 scenario. By 2100, both scenarios project that much of Tanzania will be 5.5°C or hotter than currently. The eastern and coastal areas of the country are projected to be less affected by temperature increases.



Source: Modelled by CSIR South Africa, baseline data 1970 - 2005

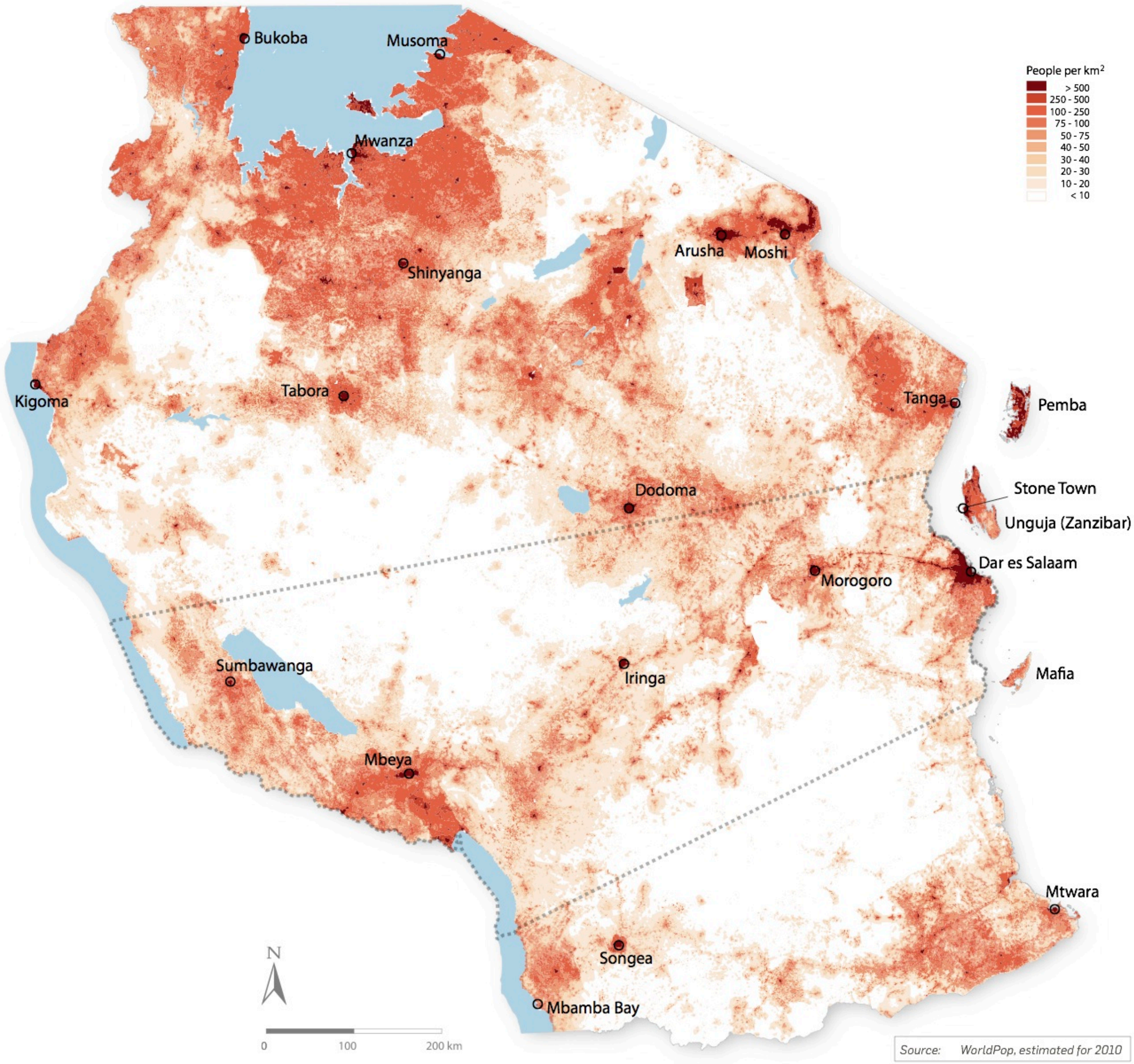

Temperature
June to August
September to November
2040 - 2060
2080 - 2100
2040 - 2060
2080 - 2100
°C
> 5.5
5 - 5.5
4.5 - 5
4 - 4.5
3.5 - 4
3 - 3.5
2.5 - 3
2 - 2.5
1.5 - 2
1 - 1.5
< 1

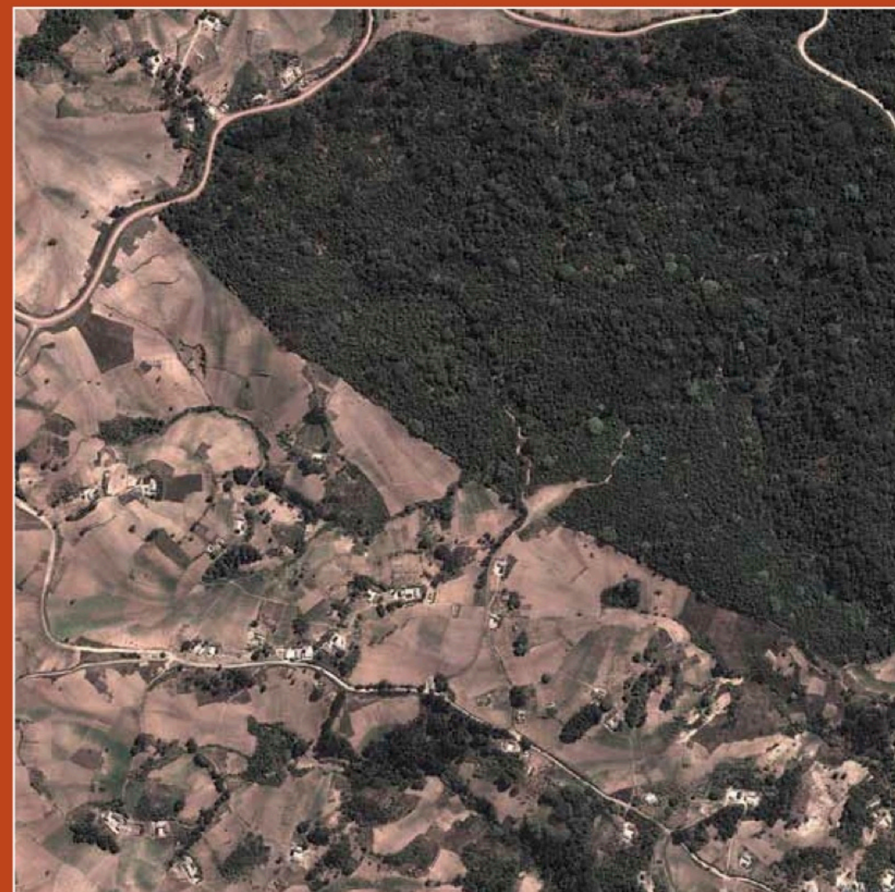
Demography

POPULATION DISTRIBUTION

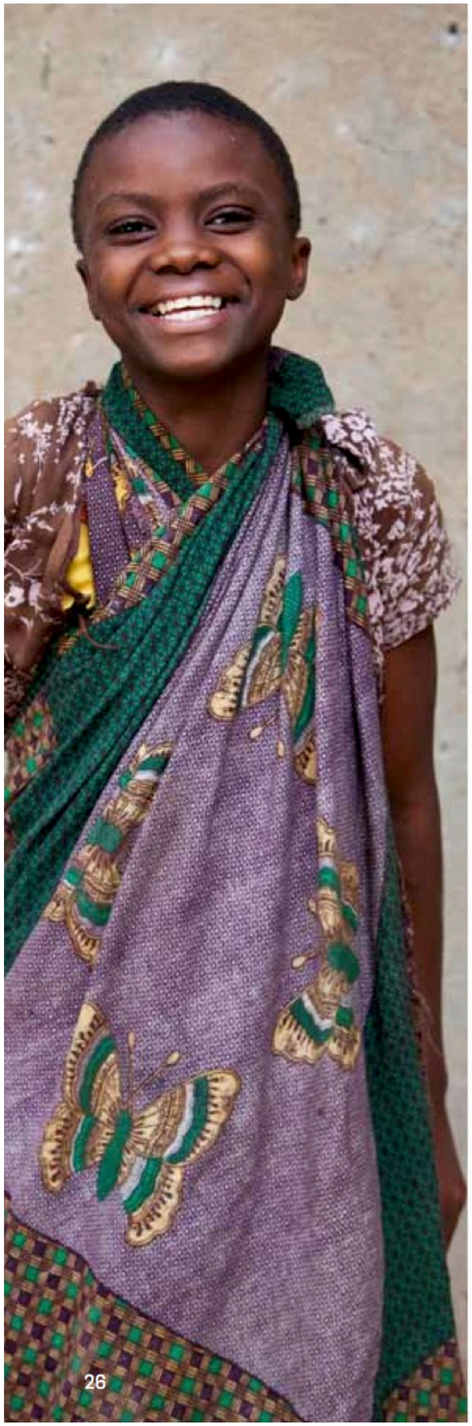
By far the greatest concentrations of people are in and around towns and cities, Dar es Salaam being the biggest and most visible at the scale of this map. Over 10% of the country's population was living in Dar es Salaam and its surrounding metropolitan area in 2012.

Densities of people vary greatly in rural areas. Sparsely populated places include national parks and game reserves, as well as inhospitably cold mountains and arid areas where water is not locally available. By contrast, several rural areas have high densities of more than 300 people per square kilometre. The highest concentrations are where soils are most productive (see pages 28-29), especially the highly fertile soils of volcanic origin around Moshi and Arusha, and southeast of Mbeya.





These photographs show different patterns of settlement and land uses in two areas, each of which covers one square kilometre. Tens of thousands of people live in this area of Dar es Salaam while only a few hundred people are in this village and farming area near Mbeya. The nearby forest gives an idea of what the environment looked like before it was cleared for small-scale agriculture.

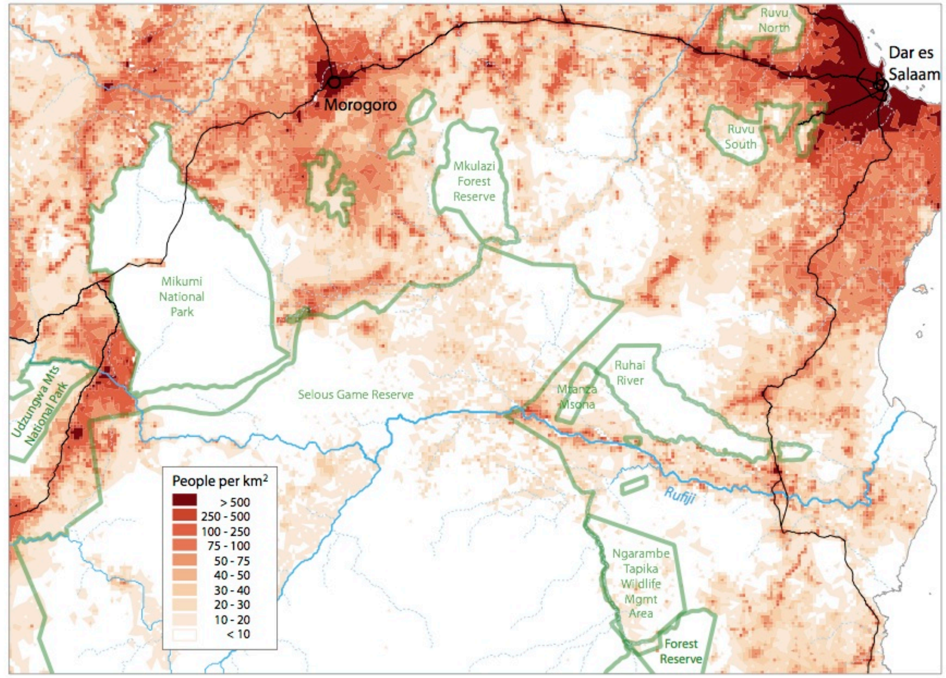


FACTORS INFLUENCING POPULATION DISTRIBUTION

This map focuses on one area of Tanzania to provide more detailed perspectives on factors that influence the distribution of people. First, densities along the major roads are high because they offer access to markets that are otherwise rare in rural areas. Rural residents can sell to passing motorists or, better still, load their produce and charcoal in bulk onto trucks going to markets in large urban areas.

Second, the presence of more fertile alluvial soils and water to support people is clear along the lower Rufiji River where many more people live and farm than away from this riverine lifeline.

Third, people do not live in national parks – as shown here in Mikumi – while settlement in other areas managed for conservation is discouraged, for example in many forest reserves.



POPULATION GROWTH AND STRUCTURE

The graph at the bottom right shows how the population has grown, effectively quadrupling between 1967 and 2012. The annual growth rate between 2002 and 2012 was 2.7%, and if the population continues to grow at that rate, the population will be about 47,400,000 in 2014 and 58 million by the next census in 2022.

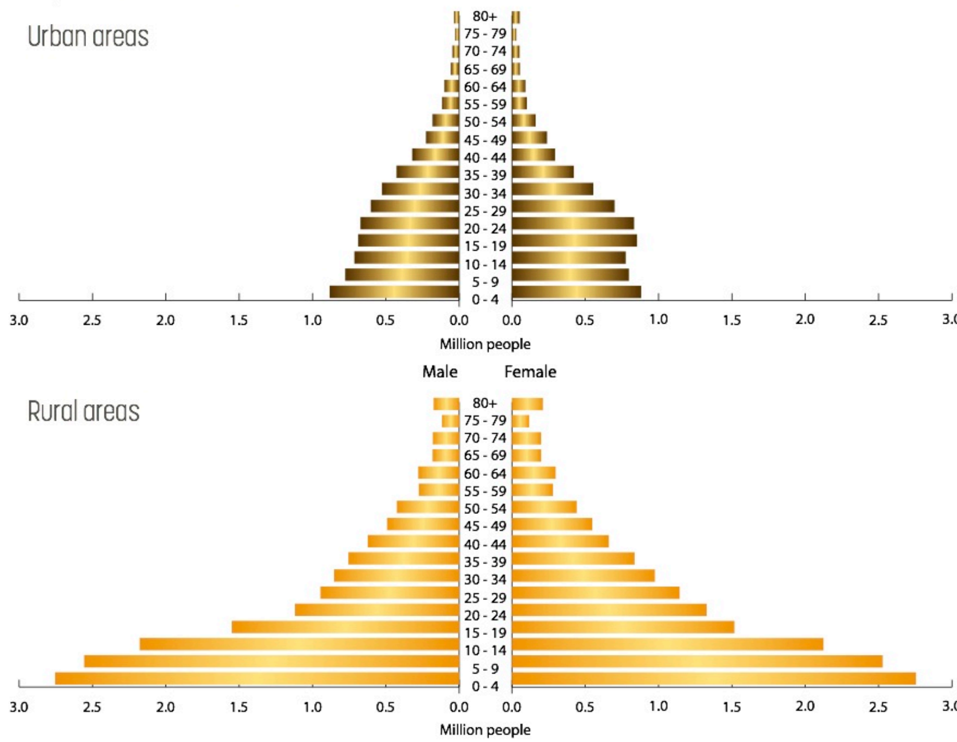
More and more people choose to live in towns simply because access to services and cash incomes is much greater than in most rural environments. As a result, 30% of all Tanzanians were living in towns and cities in 2012, compared to 23% in 2002 and 18% in 1988. The annual growth rate in urban areas was 6% between 2002 and 2012, while the number of people in rural areas increased annually by only 2% over the same period.

The two maps of population density in each district in 2002 and 2012 provide another perspective on the distribution of people. The number of districts increased from 129 to 169 and the borders of many districts changed over this period.

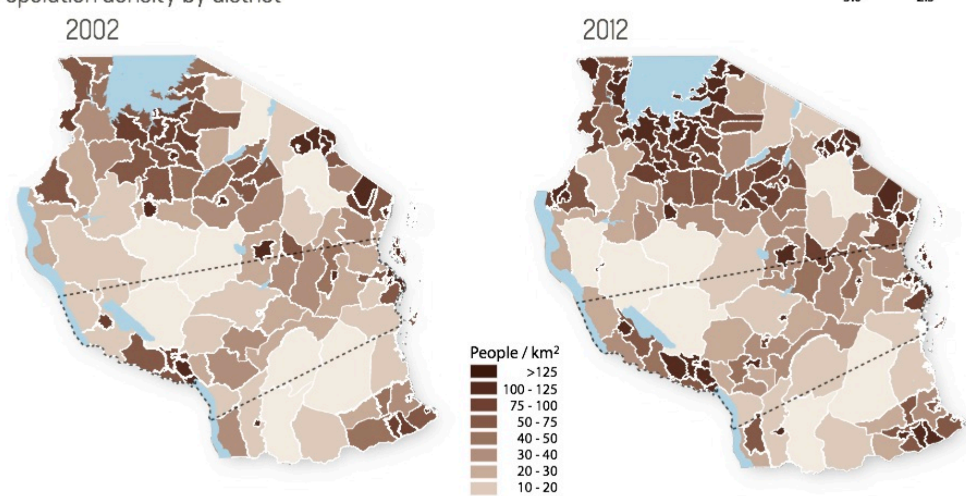
The age pyramids show the number of males and females in 5-year age groups in 2012 in urban and rural areas. Urban populations have relatively higher proportions of students and working-age people, while rural populations have greater numbers of children and older people. In the whole country, 44% of all people are younger than 15 years.

Sources: Distribution map - WorldPop, estimated for 2010
District maps, population pyramids and growth chart - national census data from National Bureau of Statistics, 2012

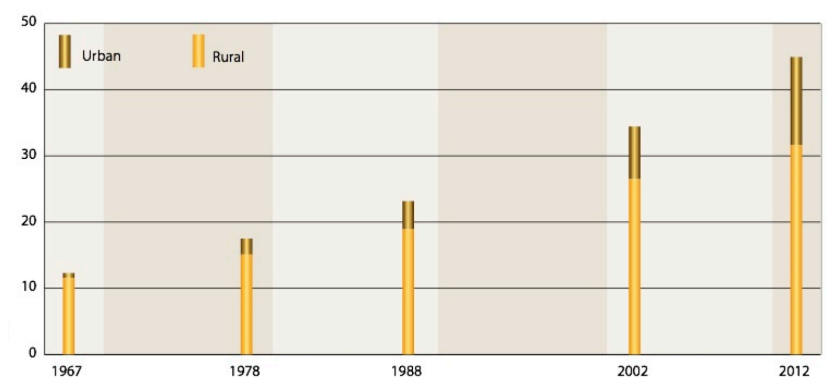
Population structure in 2012



Population density by district



Population growth in the last 5 decades



Ecosystem services

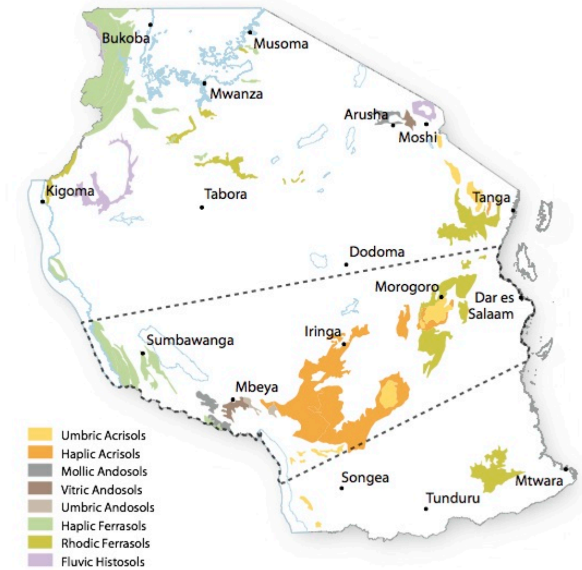
SOILS

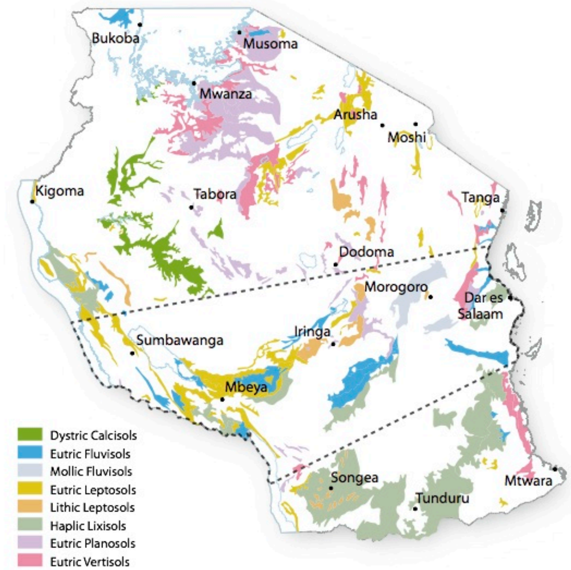
The suitability or capacity of soil for plant growth is determined by many factors, but water availability and the properties of soils are usually the most important. Where one of these is in good supply, such as water in high rainfall areas, it is usually the other that limits vegetation growth.

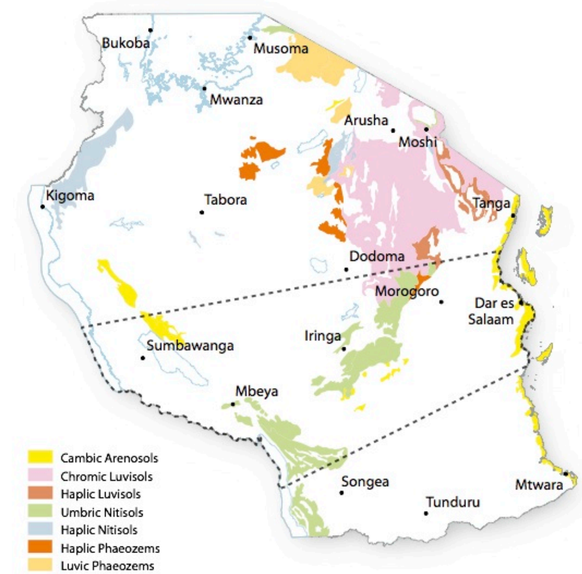
The first of the two names given to each type of soil reflects its chemical and physical structure, for instance ferralic means that the soil has high levels of oxides of iron and aluminium. The second name derives from the soil's origins, as a fluvisol deposited by water or leptosol formed from the local weathering of underlying rock, for example.

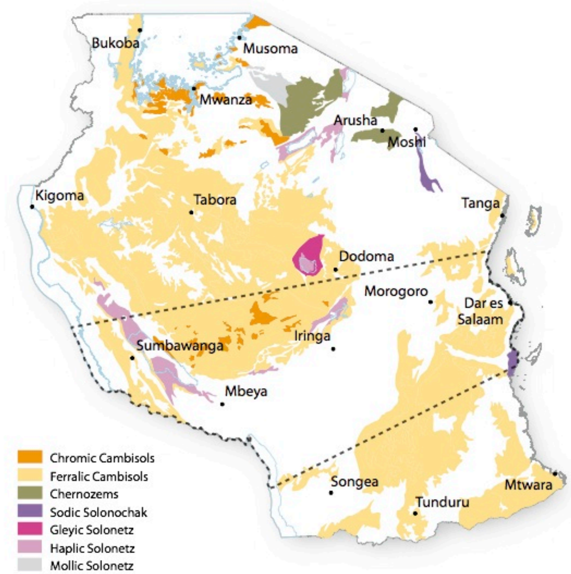
These four maps show the broad distributions of 30 types of soils in Tanzania. However, soils in any area are usually heterogeneous and many farmers have keen eyes to find the best patches of soils for their crops.

Sources: Soil types - Ministry of Agriculture, Food Security and Cooperatives
Soil properties - International Soil Reference and Information Centre









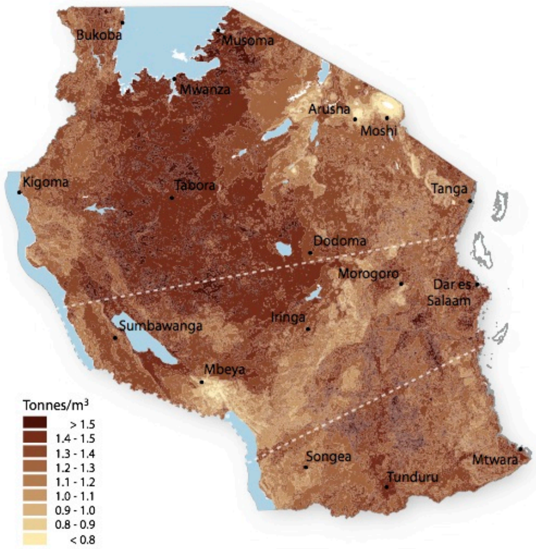
Soil fertility depends on its structure, moisture and nutrient content. The best soils are structured in ways that retain water in appropriate amounts, allow air to circulate and roots to penetrate. One measure of structure is bulk density which is the weight of soil divided by its volume. Compacted soils usually have high density.

Soils with high organic carbon content are fertile because nutrients are available from decomposing organic material, which also helps to retain water and create tiny spaces for roots to penetrate. Another important measure of fertility is cation exchange capacity, which reflects the concentration and availability of many key nutrients for plants. Soils of volcanic origin in the central north and southeast of Mbeya have among the highest levels of organic carbon and cation exchange capacities.

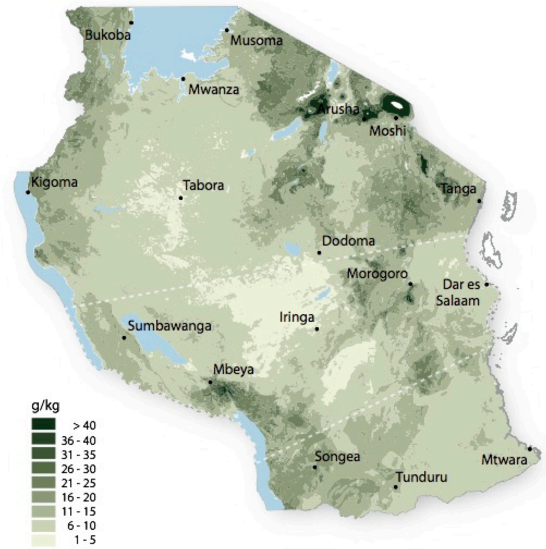
pH is a measure of how acidic or alkaline a soil is, and this affects chemical processes that make nutrients more or less available to plants. For most plants pH values between 7 and 5.5 are best.

Soil particles are of different sizes. Clay is the smallest, then silt and sand, and their content in soil affects a range of properties. For example, clays have greater moisture retention and nutrients than sandier soil.

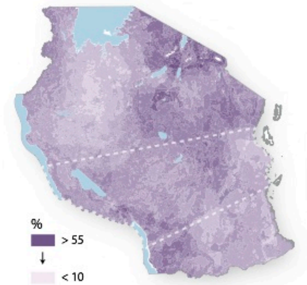
Bulk density



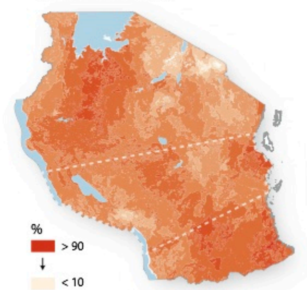
Organic carbon



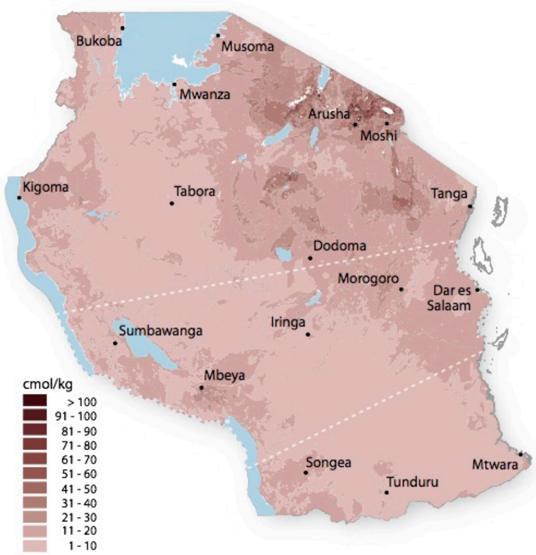
Clay content



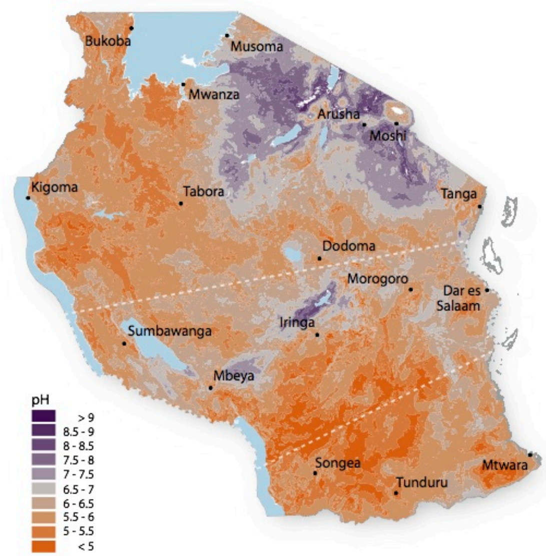
Sand content



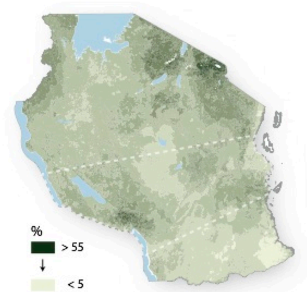
Cation exchange capacity



pH



Silt content

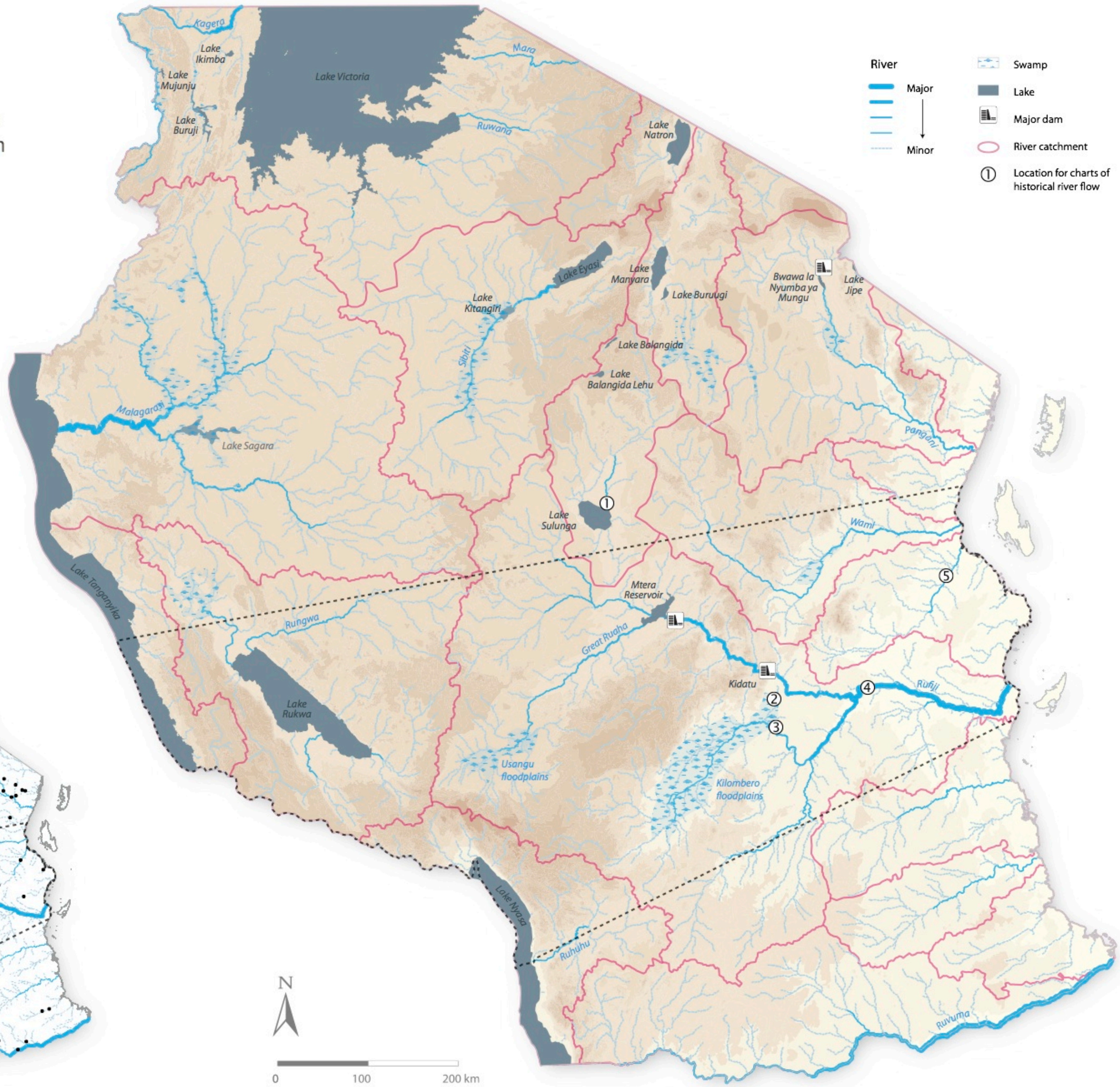


SURFACE WATER

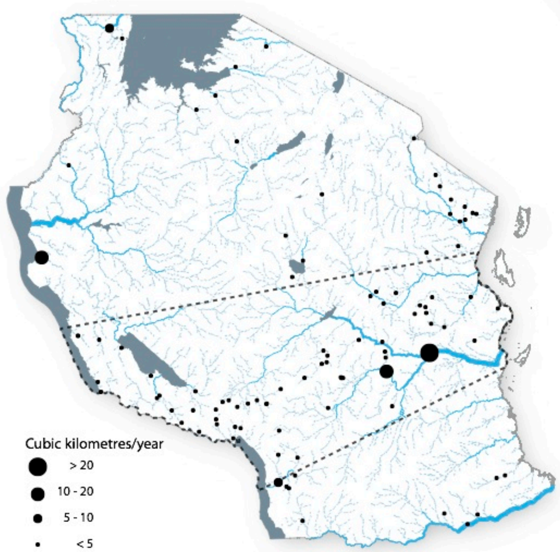
Rivers, lakes and major dams

There are 21 major river catchment areas in Tanzania. Ten of them flow east to the Indian Ocean and drain about half the country's surface. All other catchments are internal drainages, and therefore do not reach the coast. Most of them flow into lakes in the Rift Valley, particularly in the central-north and into Lakes Tanganyika and Nyasa. The largest river and catchment is that of the Rufiji River which collects water from about 20% of Tanzania's land surface.

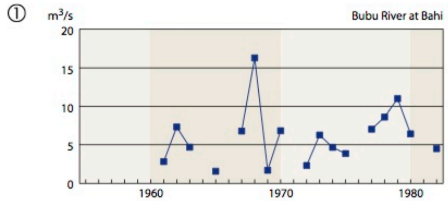
Flow volumes vary considerably, as reflected by the thicknesses of the river lines in the map to the right, and the dot sizes in the map below. The dots show the gauging stations where flows were measured.

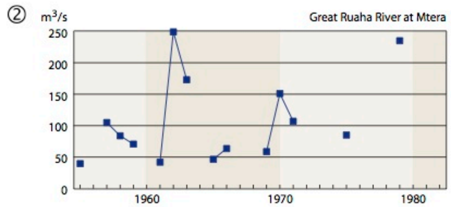


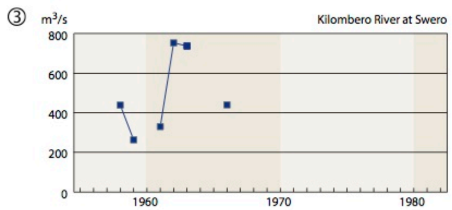
Average annual river flow volume

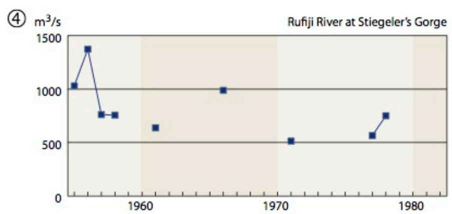


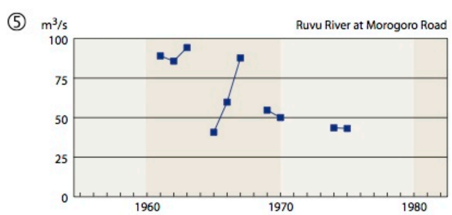
Historical river flows











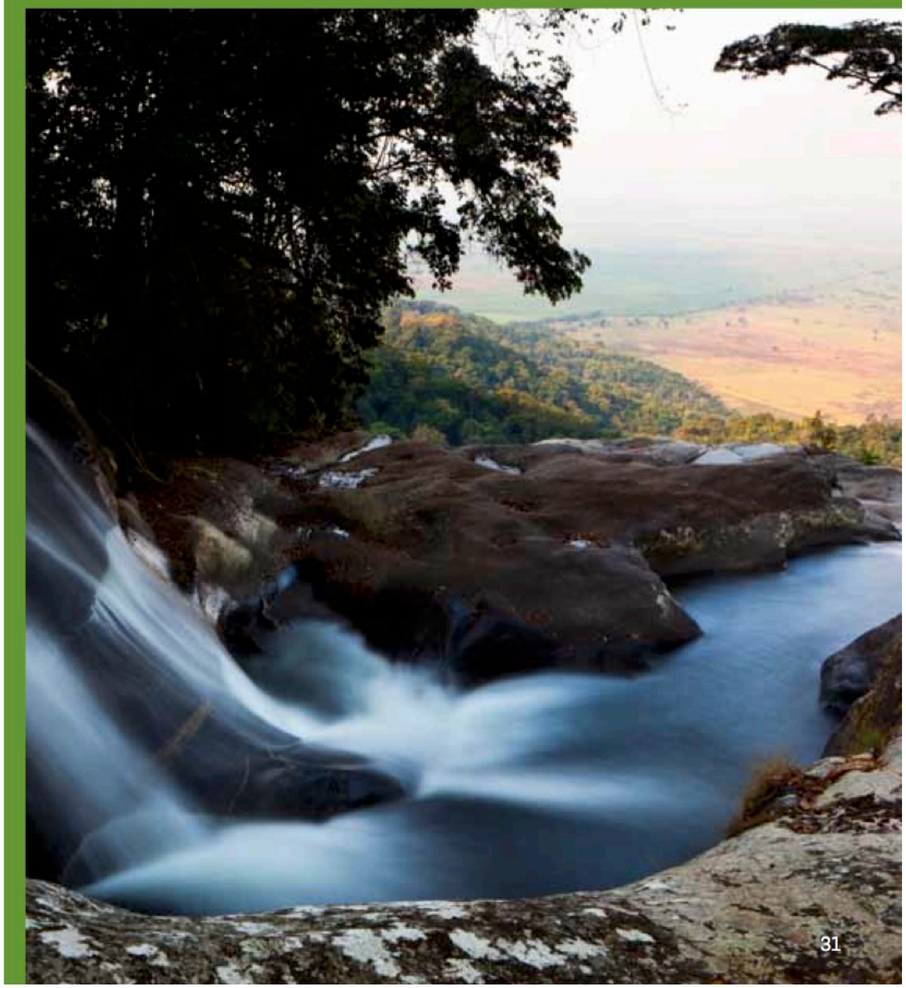
As these graphs show, water flows vary greatly from year to year, largely as a result of varying rainfall. The locations of the gauging stations where these flows were recorded are numbered on the facing map.

There is consensus that the patterns of flow and water quality in many rivers have been changed by the loss of forest cover in their catchments. Examples of these changes are reported in the Kilombero floodplains, into which some 78 streams flow from their small catchments on the surrounding Udzungwa plateau. The photograph to the right is of one such stream, its flow of clear water dropping to the plains of sugar cane below.

All of the streams used to flow throughout or for the greater part of the year, and their water was clear. Nowadays, however, it is reported that about half of the streams seldom flow. When they do have water after heavy rain, the flows are hurried surges of water muddied by the erosion of areas stripped of forest and other plant cover.

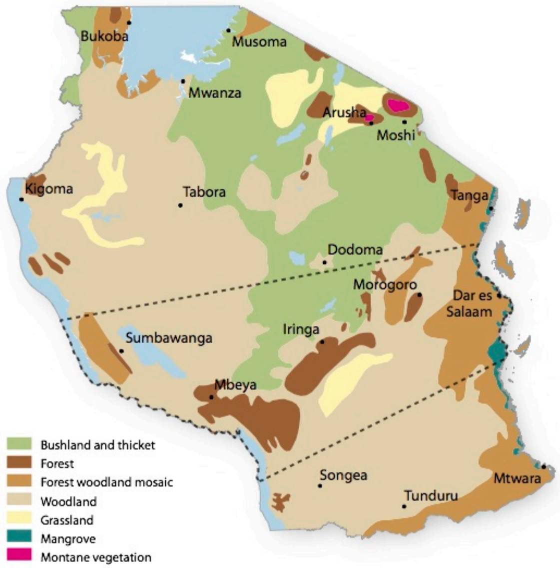
By contrast, streams that still drain the forested areas remaining in the Udzungwas do not have these erosive flows. Heavy rain is largely trapped in the forest cover, the water permeating gradually into layers of leaf litter and deep soils. From there, the water is filtered through the soil and continuously seeps out to supply a flow of clear water into the streams throughout the year.

Sources: Map of river flows - Global Runoff Data Centre
Map of surface water - RAISON, from multiple sources
Charts - Global Runoff Data Centre, 1954 - 1984



VEGETATION STRUCTURE AND TYPES

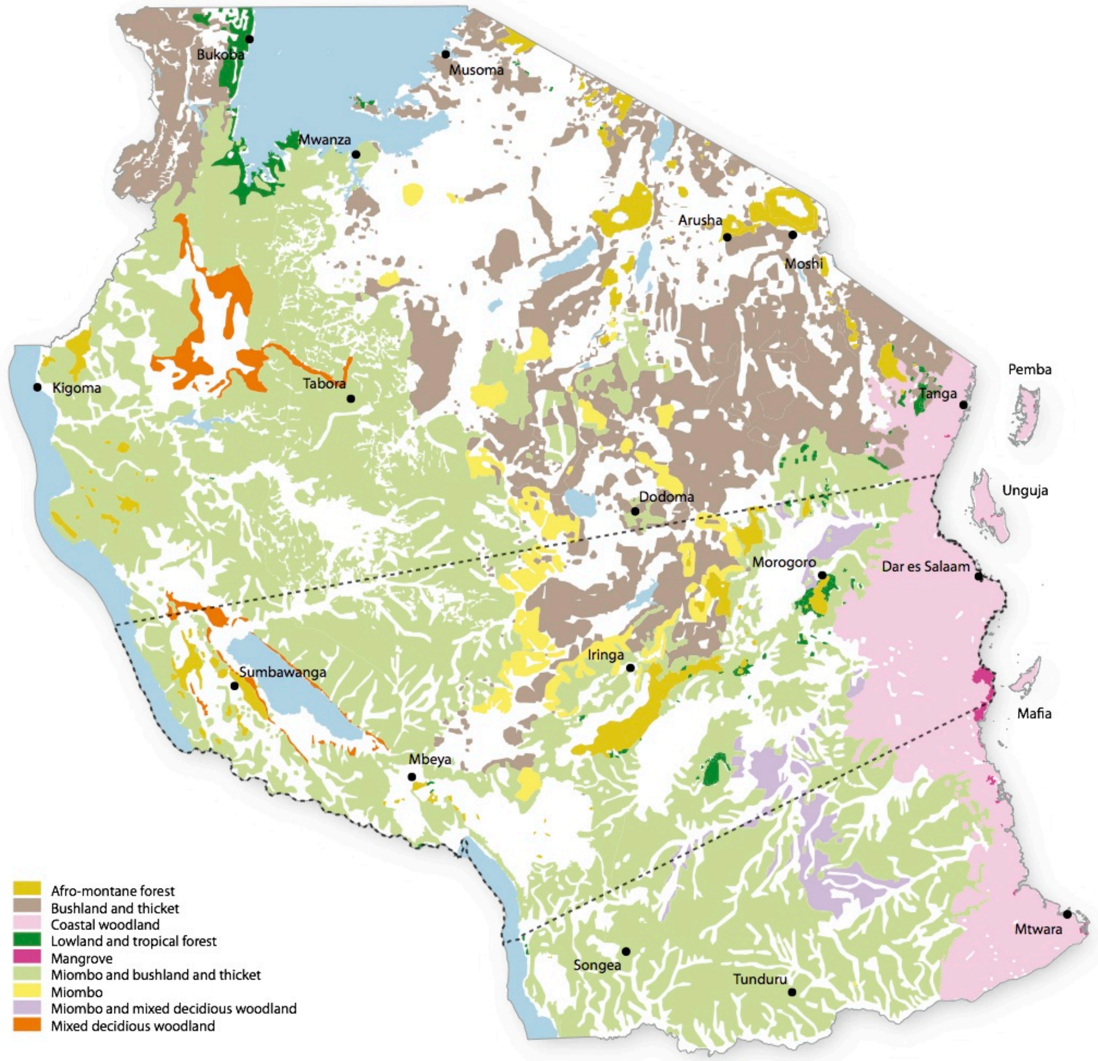
Structure



The small map provides a simplified perspective on the structure of vegetation. The largest areas consist of woodland, where the trees are generally more than 8 metres high and the tree canopy covers 40% or more of the area. Bushlands and thickets are dominated by smaller bushes, sometimes clumped in thickets, and are generally found in areas of lower rainfall (see page 16). Grasslands dominate in and around wetlands, while those on drier soils are often accompanied by a sparse cover of woody plants.

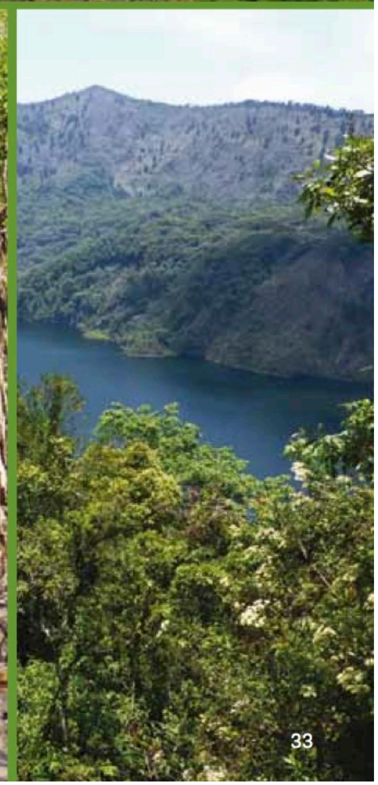
More details on structures and types of vegetation are presented in the large maps, one focusing on plant communities dominated by woody trees and shrubs, and the second showing types characterised by non-woody plants. The details of these two large maps cannot be presented here, but interested readers can view the map and its detailed legend in Google Earth by obtaining the necessary kml file from http://vegetationmap4africa.org.

Woody vegetation



Sources: Vegetation structure map - World Agroforestry Centre
Vegetation types maps - van Breugel et al., Version 1.1, 2012

Non-woody and mixed vegetation



Top: Much of the country's woodland is miombo, a community of broad-leaved trees that covers large areas across southern-central Africa. Bottom left: Mangroves occur only along the coast where they are the only trees that can grow in salt water. Bottom right: Typical Afro-montane forest around Lake Ngozi.

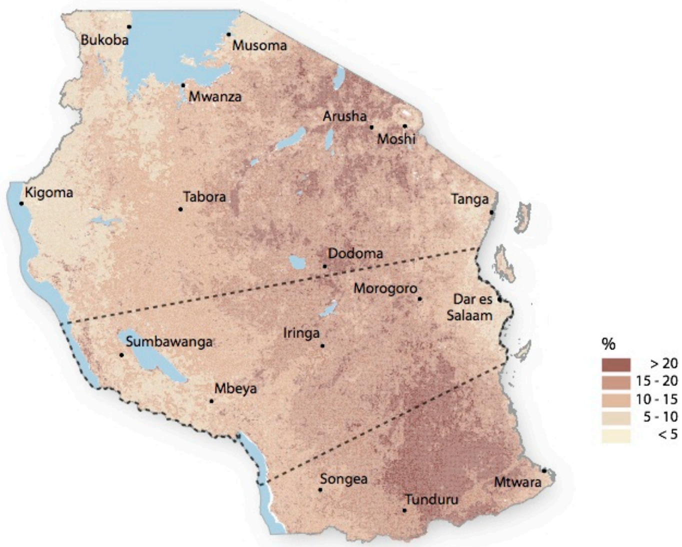
VEGETATION COVER AND PRODUCTION

Vegetation cover varies a great deal, between dense, tall forest to open woodlands and to arid lands with scattered grasses and herbaceous plants.

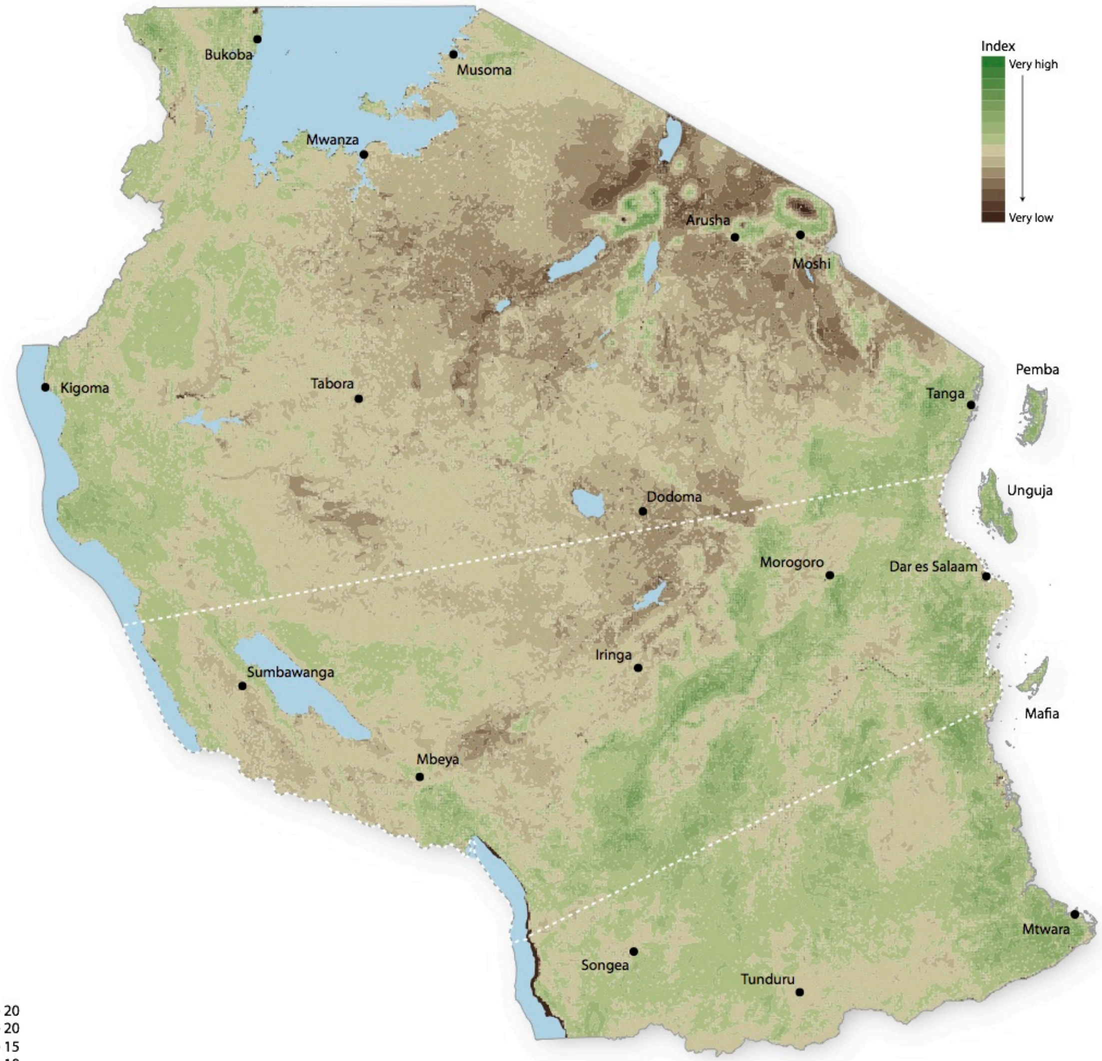
One measure of cover is provided in the map to the right. This Enhanced Vegetation Index (EVI) is an average of leaf cover over 12 years, from 2000 to 2012. Several features are clear, for example forest patches in the Eastern Arc Mountains, forest surrounding Mounts Kilimanjaro and Meru, and the borders of certain protected areas. Vegetation cover is much greater inside these areas where vegetation cannot be cleared for farmland. A particularly visible example is inside and outside Kigosi Game Reserve to the northwest of Tabora.

Vegetation cover also varies from year to year, being least in dry years and greater in years with abundant rain. A measure of annual variation - the co-efficient of variation of Net Plant Production - is shown below. Broadly, variation is lowest in the western and coastal areas, while patches of dense cover (high EVI) show the greatest variation.

Variation in annual plant production

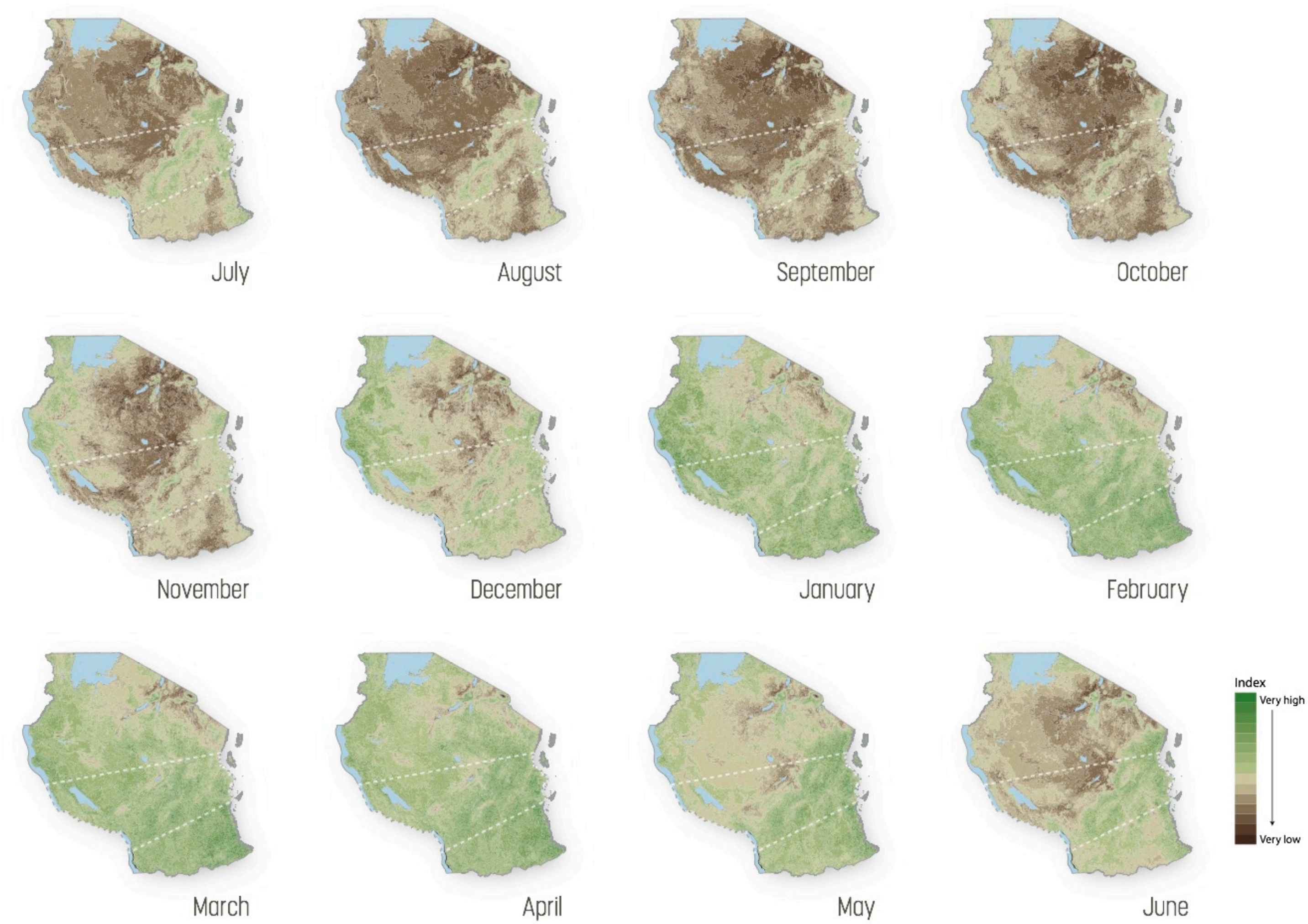


Annual average enhanced vegetation index



Source: Africa Soil Information Service, 2000 - 2012

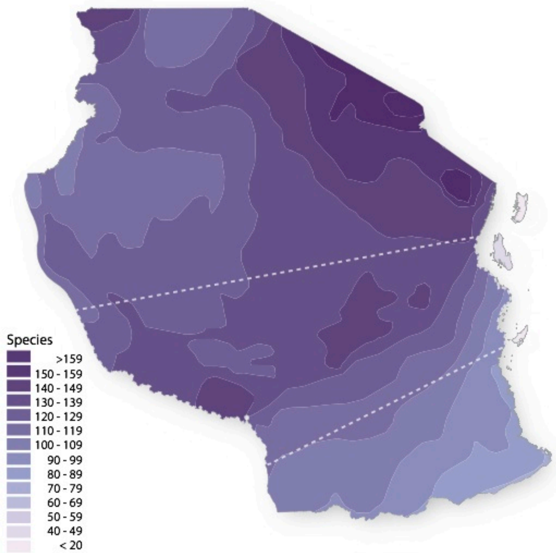
Monthly average enhanced vegetation index



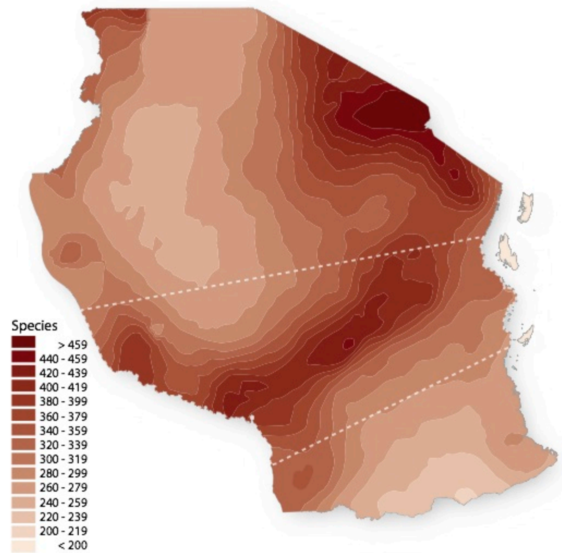
These maps show changes in leaf cover during the year, starting in July, through the rainy season to June. Most changes in cover occur in response to rain, and many plants only start to grow after the early rains in October (see page 17). Other changes, particularly in areas where tree cover is high, are determined to a greater extent by changing day length and temperature; as the days warm and lengthen, deciduous trees begin to leaf and evergreens grow new leaves.

BIODIVERSITY

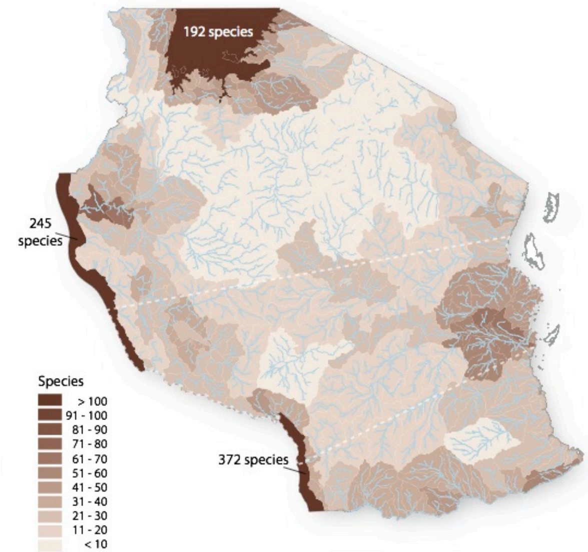
Mammals



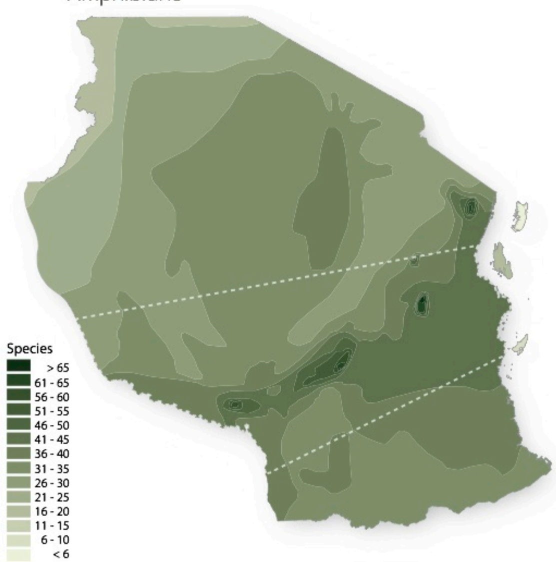
Birds



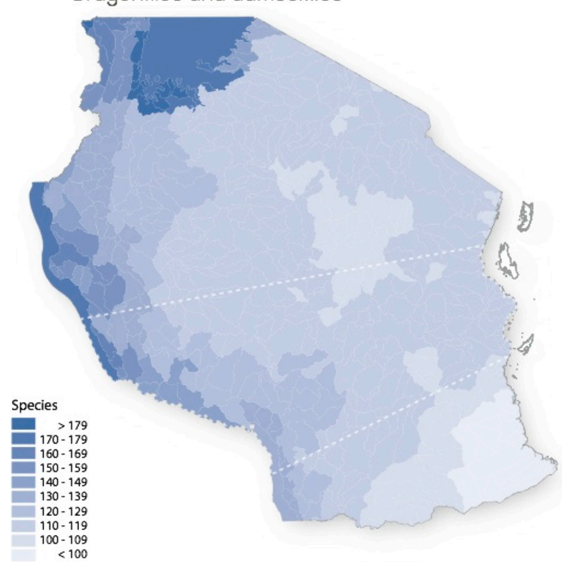
Freshwater fish



Amphibians



Dragonflies and damselflies



Being in the tropics means that Tanzania is rich in life, as reflected in the maps of species diversity to the left. The maps to the right show the number of endemic species (species found nowhere else in the world) recorded in the Eastern Arc Mountains.

In total, about 1,100 bird species, 2,000 fish, 414 mammals, 194 amphibians, and 180 dragonflies and damselflies have so far been recorded in Tanzania. The highest levels of species-richness among birds, mammals and amphibians are in a broad zone running from the central-north (Arusha and Kilimanjaro Regions) southwards to Morogoro and then southwest along the highlands to the Mbeya area.

The southern regions of Ruvuma, Lindi and Mtwara and the more arid areas of the central areas of the country have relatively fewer species. The diversity of dragonflies and damselflies is highest in the western areas of the country.

Lakes Tanganyika and Nyasa are world renowned for their very high numbers of fish species, particularly species in the family of cichlids. These lakes have more species of fish than any other freshwater body on earth and most of those species occur nowhere else.

Frequently referred to as the African Galapagos, the forests of the Eastern Arc Mountains have persisted for over 30 million years. During the last 10 million years, these forests – now highly fragmented – have become isolated from the forests of the Congo Basin. This isolation has created an exceptionally diverse group of endemic species which make these forests among the highest priorities for conservation.

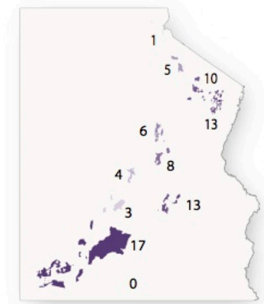
The Kipunji was discovered in 2003 at Mount Rungwe, south-east of Mbeya, the first new genus of primate to be discovered anywhere in the world since 1923. In many ways, the Kipunji symbolises the unusual and special features of the Eastern Arc Mountains: it is extremely rare and its numbers are isolated in small populations that live in forests separated across the Eastern Arc. The Kipunji is also considered to be among the 25 primate species most in danger of extinction in the world.

Sources: Maps of diversity - International Union for Conservation of Nature and biodiversitymapping.org
Maps of endemism - Burgess et al., 2007

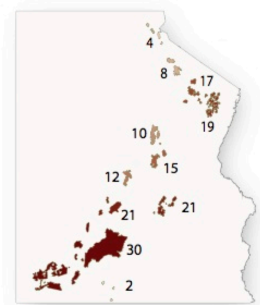
ENDEMISM

Species recorded at different locations in the Eastern Arc Mountains

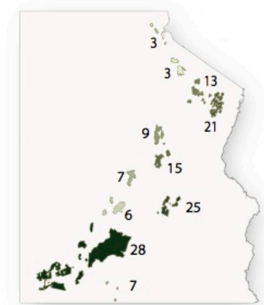
Mammals



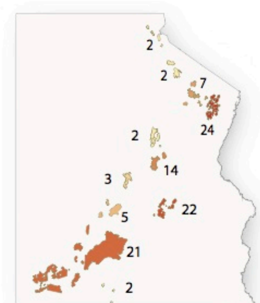
Birds



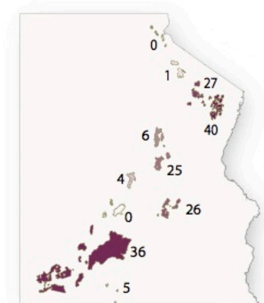
Amphibians



Reptiles



Trees

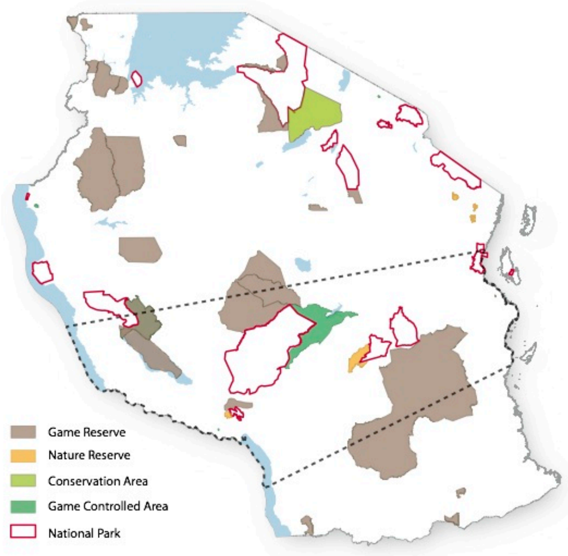


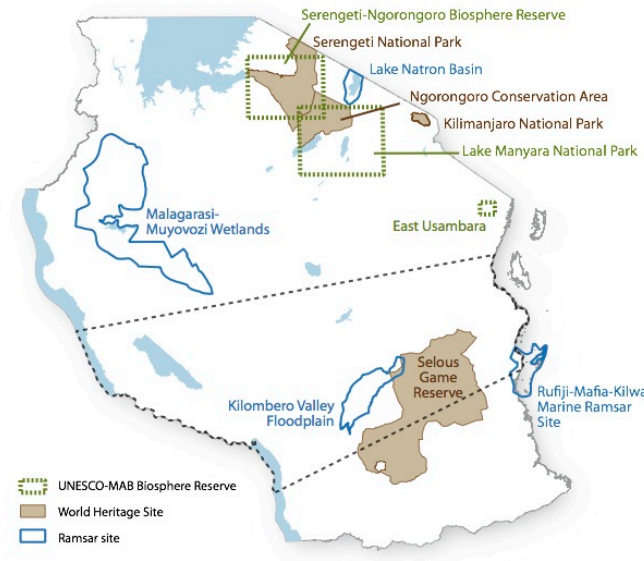
PROTECTED AREAS

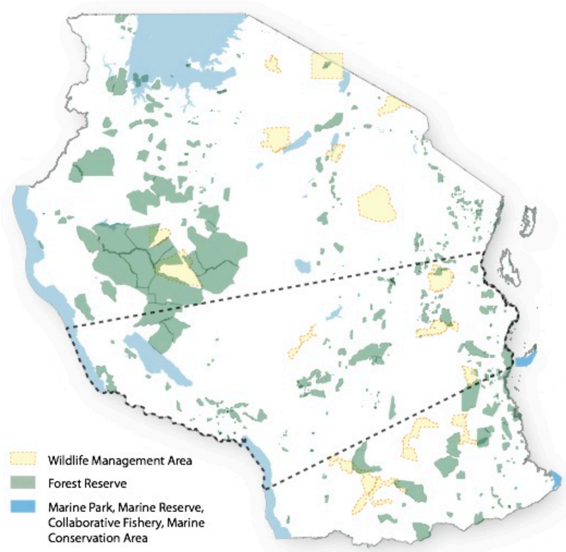
Tanzania is renowned for its large network of protected areas. Depending on the definition, degree and nature of protection, between 32.2 and 40.5% of the country is managed for conservation and biodiversity.

The protected areas are managed by different central and district government offices, agencies and local associations. The ways and purposes for which protected areas are managed also varies. No extraction of resources or hunting is allowed in national parks or nature reserves, for example, but different forms of hunting are allowed in game reserves, game controlled areas and wildlife management areas. Forest reserves are protected or managed for resource use to various degrees by the central government, district councils or village associations.

Over and above the areas designated for protection by Tanzanian authorities, several protected areas enjoy international recognition. These are Man and Biosphere (MAB) Reserves recognised by UNESCO (United Nations Educational, Scientific and Cultural Organisation), wetlands declared to be of international significance in terms of the Ramsar Convention, and UNESCO World Heritage Sites. Zanzibar Stone Town, the ruins of Kilwa Kisiwani and Songo Mnara, and the Kondoa rock paintings are also declared World Heritage Sites for their cultural value.







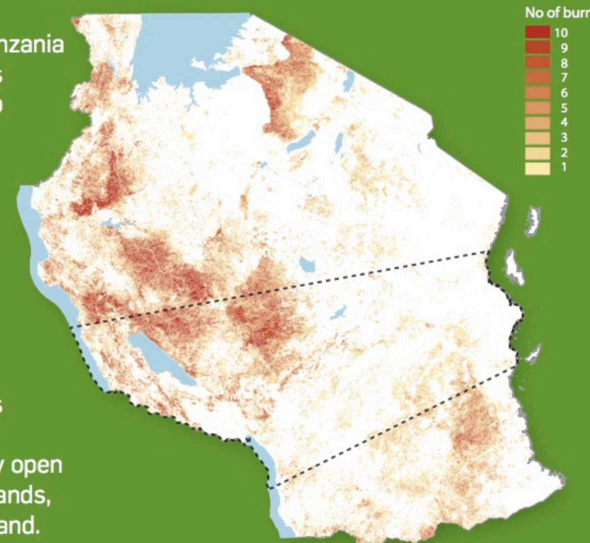
The large areas of Tanzania that are protected offer a variety of benefits that offset the limitations on using those areas for farming or harvesting plants and animals. Most importantly, protected areas sustain the provision of ecosystem services, such as food, water, climate regulation and soil nutrients. Protected areas also conserve biological resources and fulfil many consumptive, moral and recreational purposes.

Protected areas provide substantial value for Tanzania's economy. Tourism contributes about 17% of GDP and provides 42% of foreign exchange earnings. It is also estimated that about 377,000 people are employed within the tourism sector, while another 1,124,000 jobs (11.2% of total employment) have been created in sectors that support tourism.

Sources: *Maps of protected areas - World Database on Protected Areas, 2013*
Maps of burning frequency and cloud cover - derived by Archibald from MODIS Burnt Area products produced by Roy, 2000 - 2010

FIRE

Frequency of fires

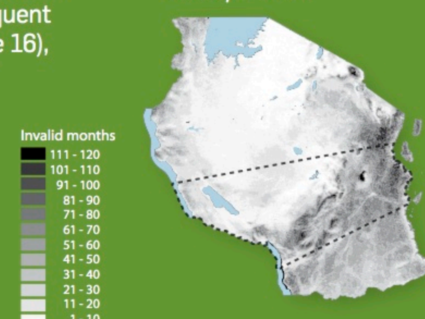


Large areas of Tanzania burn each year, as shown in this map of the frequency of burns over a 10-year period, from 2000 to 2010. While many areas never burned, others burned often, and some every year. Places that burned most often were largely open or wooded grasslands, or miombo woodland.

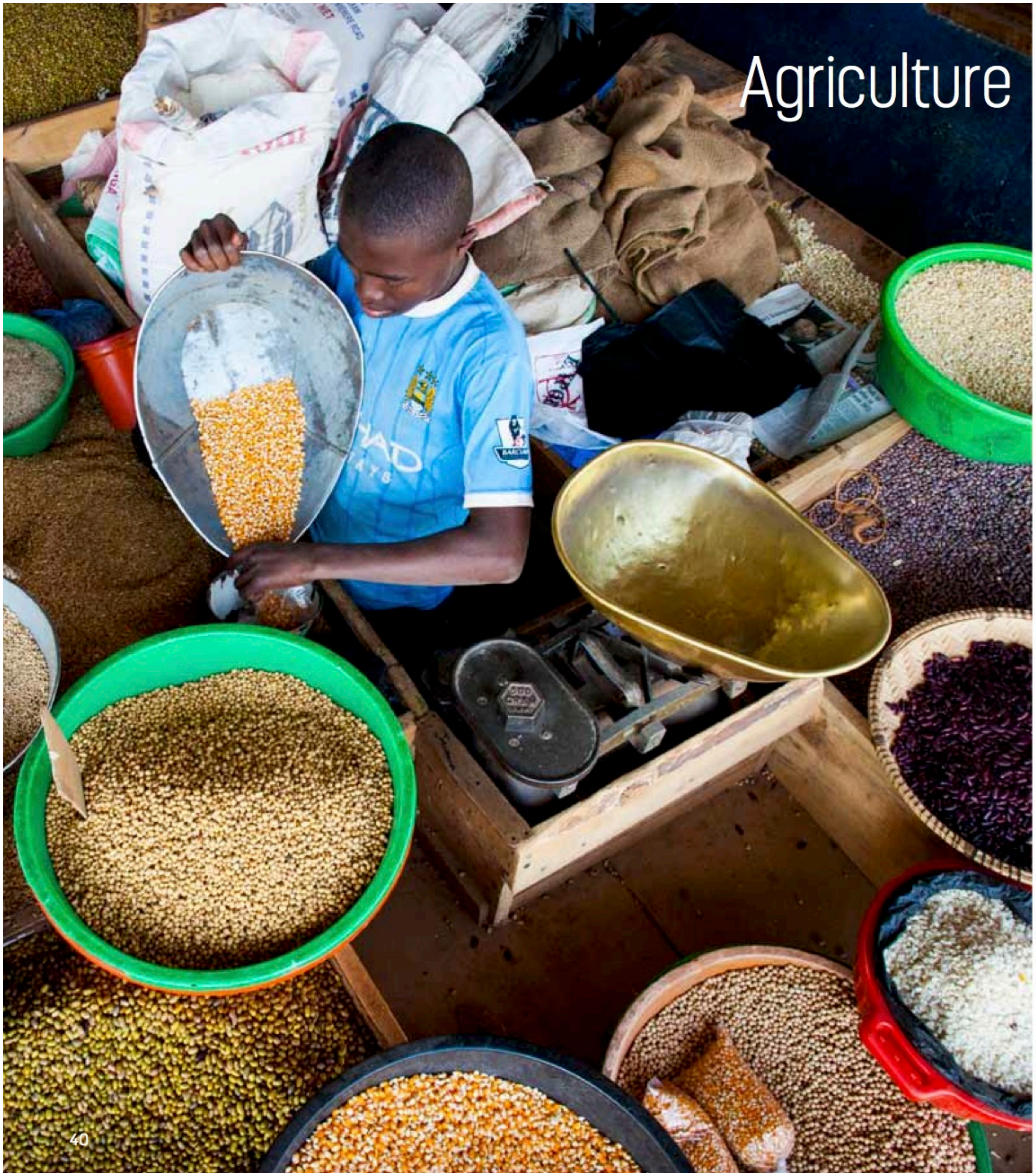
The burns were detected in satellite images, but fires could only be seen when conditions were cloud-free. Fires burning beneath cloud cover were thus not mapped, and so these are minimum estimates of burning frequency. The effects of cloud cover in potentially hiding fires were obviously more prevalent in places that were often cloudy.

The small map shows the number of months (out of a maximum of 120) which were too cloudy for fires to be seen. Cloud cover was generally most frequent in high rainfall areas (see page 16), and especially over the highlands of the Eastern Arc Mountains and the Mufindi Highlands (page 12). Coastal areas were often cloudy too, as were the southern regions of Ruvuma, Mtwara and Lindi.

Cloudy months



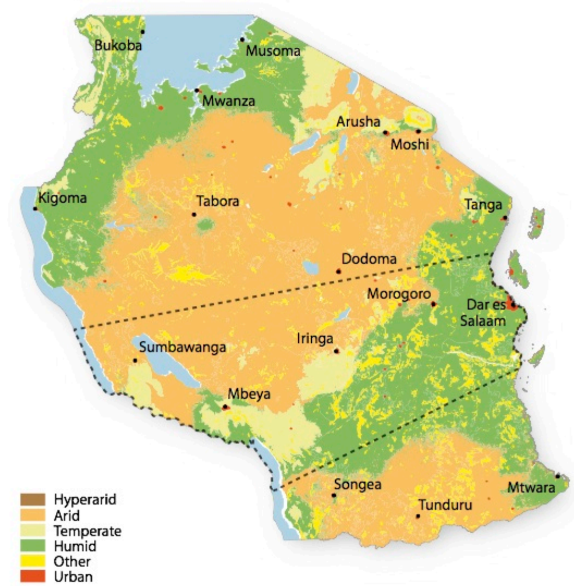
Agriculture



Farming is an extremely important activity in Tanzania: most food consumed is produced locally, the 70% of all Tanzanians who live in rural areas make much or all of their living from farming, and agriculture contributes about 26.6% to GDP.

It is also a very diverse activity which produces a wide variety of types of food for domestic consumption and export. While most farming is by small-holders, there are also over a thousand large-scale farms. The majority of crops and livestock are produced by small-holders, while large-scale farms produce most of Tanzania's sisal, cut flowers, sugar cane and tea for export.

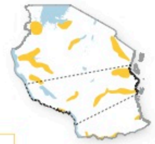
Agroclimatic zones



Sources: *Map of agroclimatic zones - Food and Agriculture Organisation of the United Nations*
Maps of production systems - compiled by RAISON from multiple sources
Maps of livestock density - HarvestChoice, 2005

PRODUCTION SYSTEMS

Nine major farming or production systems are recognised:



Rice/sugar cane: throughout the country on alluvial soils in river valleys

Cashew/coconut/cassava: in coastal areas on poor soils

Bananas/coffee/horticulture: intensive farming mainly on soils with high fertility around Kilimanjaro-Arusha, Kigoma-Kagera and Mbeya

Maize/legumes: widespread in areas where shifting cultivation occurs: maize is usually intercropped with legumes

Horticulture: mainly in cooler high areas where a variety of vegetables are grown, as well as deciduous fruit, maize, tea and potatoes

Tea/maize/pyrethrum: in the cooler Southern Highlands where potatoes and beans are also widely grown

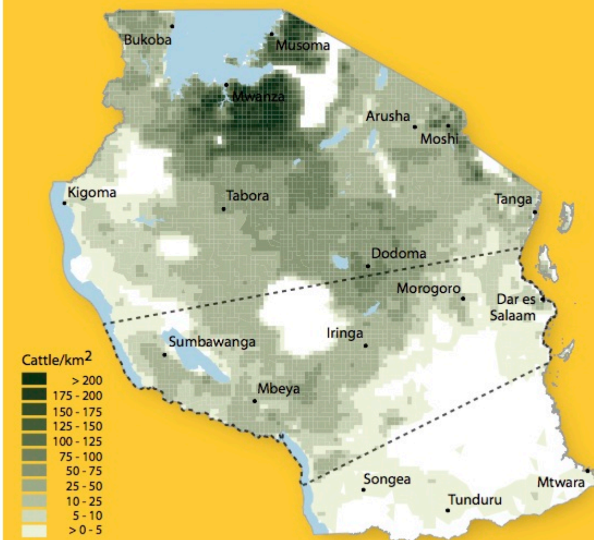
Cotton/maize: mainly in the northern regions; livestock is also important here and other crops include sorghum, groundnuts and sweet potatoes

Sorghum/millet/livestock: south of Lake Victoria where populations are dense and soil fertility has declined

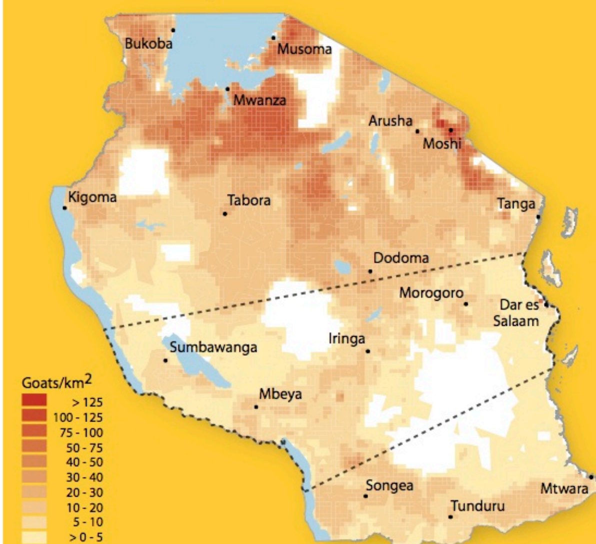
Pastoralist and agro-pastoralist: cattle and goats predominate in the semi-arid central regions. Some sorghum and millet are also produced here

LIVESTOCK PRODUCTION

Cattle density

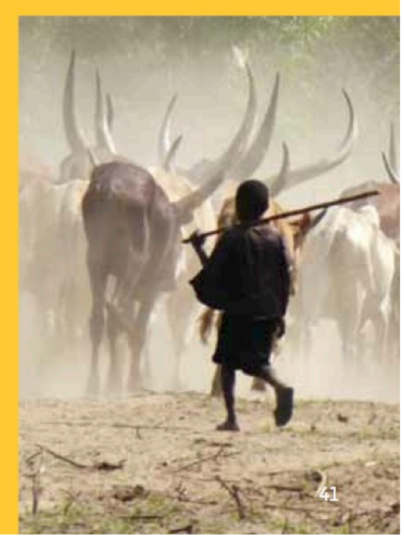


Goat density

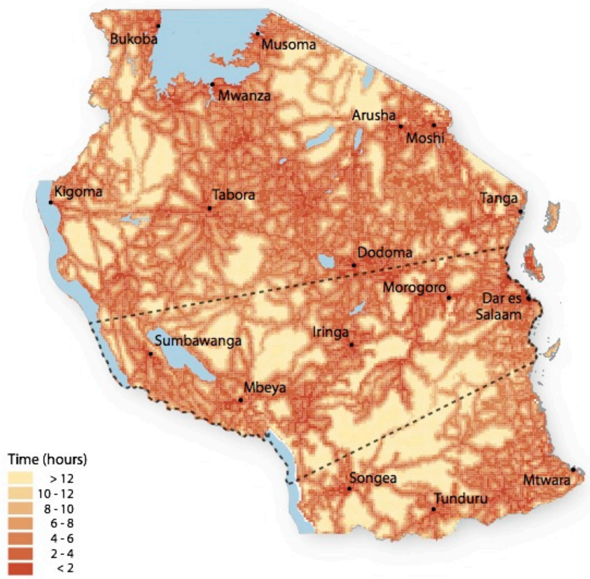


These maps show the distribution of cattle and goats. In 2007/2008 there were an estimated 21 million cattle, 15 million goats, 6 million sheep, 1.5 million pigs and 44 million chickens in Tanzania.

Apart from products such as meat, milk, manure and hides, many animals (especially cattle) provide a store of wealth and security that can be drawn upon when needed. In total, some 2.3 million households kept livestock in 2007/2008. Ownership was skewed, however, with the top 20% of cattle owners keeping more than 80% of all animals. The number of livestock on large scale farms amounts to about 0.1% of all animals.



Access to markets

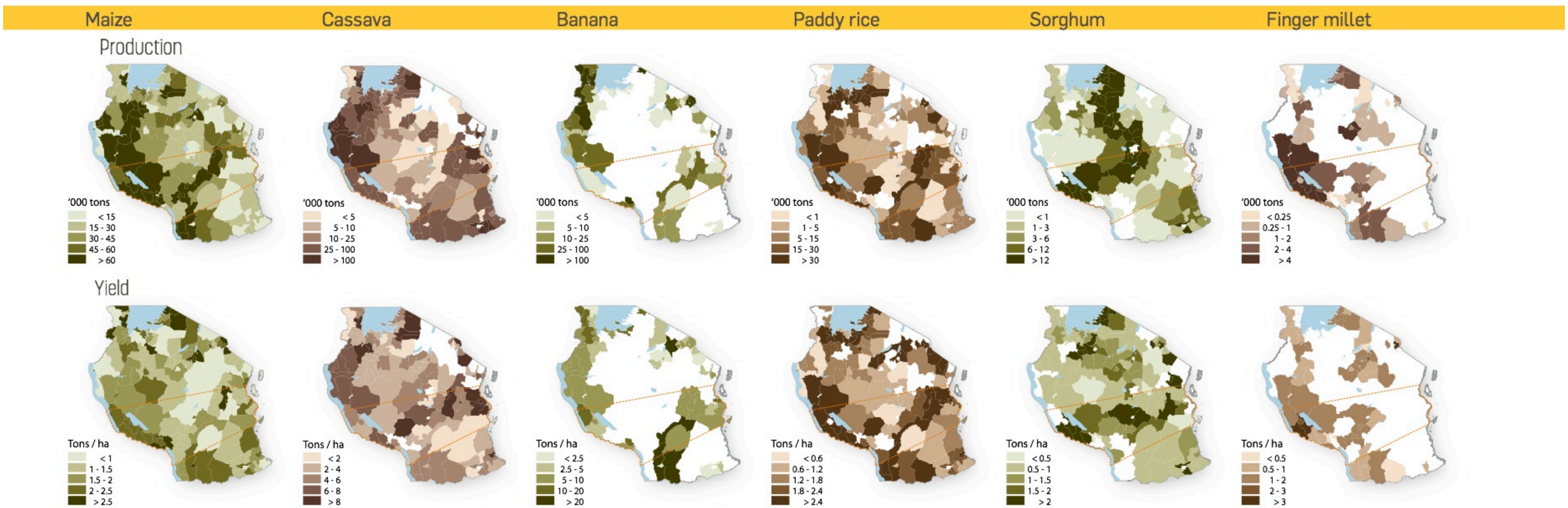


CROP PRODUCTION

Most small-holder farmers cultivate small areas, generally between 1 and 3 hectares. Irrigated farms and those on very fertile soils are usually smaller than dry-land farms or those in less productive areas. On average, 67% of production is used for domestic consumption, 30% is sold and the remainder is used for other purposes. However, the proportions sold and kept for domestic use vary greatly from home to home, area to area and between crops. Such factors as market access, demand, prices, domestic needs and production volumes influence decisions on what can be sold. As can be seen from the adjacent map, large areas of the country do not have ready access to urban markets or roads from where their produce can be carried to markets.

Maize and cassava are the most important staple crops, followed by bananas, rice, sorghum and millet. These crops are also sold, but the predominant cash crops are cashew nuts, beans, vegetables, tea, coffee, oil seeds and cotton. Yields are limited primarily by low soil quality, poor rainfall and pests. Other important constraints include poor access to inputs and mechanisation, labour shortages, and low profitability which limits incentives to invest in the management of crops. About 70% of croplands are cultivated with hand hoes, 20% with ox-drawn ploughs and 10% with tractors. Only 3% of all cultivated land is irrigated.

The series of maps below show the production and yields of a selection of crops, as recorded during the 2009/2010 Agriculture Sample Census.



Area under production (thousands of hectares) and production (thousands of tons)

Staples & grains	Area	Production
Maize	3,051	4,733
Cassava	873	4,548
Banana	418	3,156
Paddy rice	1,136	2,650
Sorghum	618	799
Bulrush millet	253	235
Finger millet	93	116
Wheat	55	62
Barley	8	15

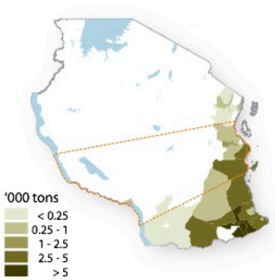
Legumes	Area	Production
Bean	1,209	868
Groundnut	482	465
Cow pea	258	152
Pigeon pea	187	139
Garden pea	28	40
Chick pea	45	38
Bambara nut	32	30
Green gram	6	5
Soya bean	4	3

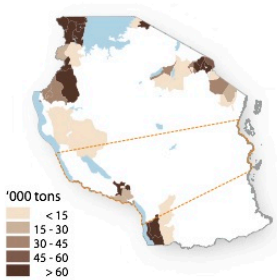
Exports	Area	Production
Cotton	421	267
Sesame	203	144
Cashew nut	249	74
Tobacco	79	61
Coffee	224	40
Tea	11	33
Pyrethrum	5	3

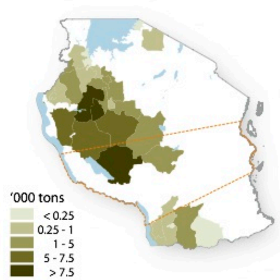
Other	Area	Production
Sweet potato	576	2,424
Irish potato	173	1,473
Tomato	26	321
Sunflower	432	313
Coconut	26	41
Oil palm	15	16

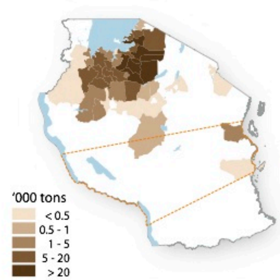
Sources: *Map of access to markets - Joint Research Centre, European Commission*
Tables and maps of crop production - 2009 / 2010 Agriculture Sample Census data from Ministry of Agriculture, Food Security and Cooperatives

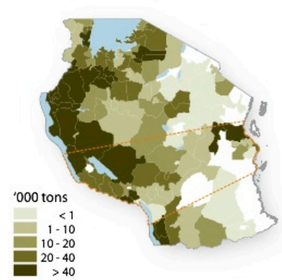
Cashew | Coffee | Tobacco | Cotton | Sweet potato | Groundnut

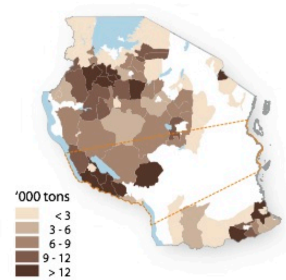


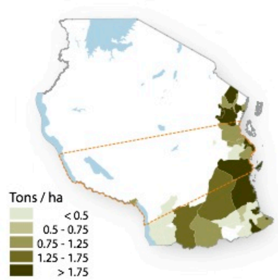


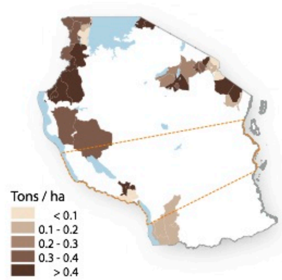


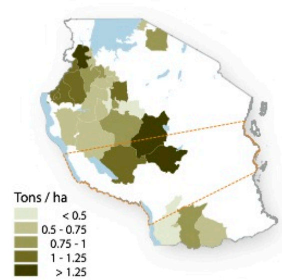


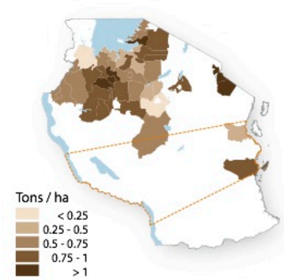


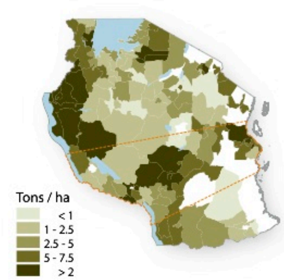


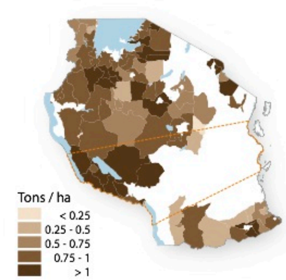












ENDNOTES

Data Sources

Page 4
Map data for regions and districts from National Bureau of Statistics, Dar es Salaam http://www.nbs.go.tz

Text: National Bureau of Statistics. 2013. *Tanzania in Figures 2012*. Government of Tanzania http://www.nbs.go.tz and http://en.wikipedia.org/wiki/Tanzania

Pages 6-11
Images created from satellite images provided by http://www.bing.com/maps through TerraIncognita http://www.zubak.sk and SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA) http://www2.jpl.nasa.gov/srtm

Page 12
Mosaic of images provided by http://www.bing.com/maps through TerraIncognita http://www.zubak.sk

Page 13
Topography: SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA) http://www2.jpl.nasa.gov/srtm

Page 14 and 15
Maps adapted from the Council for Geoscience's map of geology for the SADC (Southern African Development Community) area. Information on types of rocks is available from http://www.ucl.ac.uk/es/impact/geology/london/glossary/rocks

Text: partly based on Howard A. 2011. *A brief introduction to the geology and mining industry of Tanzania*. Report by Nebu Consulting LLC, Colorado for Sika Resources, Toronto. http://sikaresources.com/wp-content/uploads/2011/09/Tanzania-Backgrounder.pdf

Page 15
Image created from satellite images provided by http://www.bing.com/maps/ through TerraIncognita http://www.zubak.sk and SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA) http://www2.jpl.nasa.gov/srtm

Page 16
Map of annual average rainfall from WorldClim data set which covers the period 1950 to 2000. http://www.worldclim.org. Worldclim interpolated layers are derived using major climate databases (GHCN, FAO, WMO, CIAT, R-HYdronet) as well as the SRTM elevation database. Resolution is 30 arc seconds.

Graphs of rainfall records provided by the Ministry of Agriculture, Food Security and Cooperatives and the Tanzania Meteorological Agency, covering 30 years (1982-2012). http://www.agriculture.go.tz

Page 17
Maps created from rainfall estimates from 1996 to 2013 produced by FEWS NET (Famine Early Warning System Network) http://earlywarning.usgs.gov/fews. Resolution is 8 km.

Page 18
Map created from estimates of rainfall from 1996 to 2013 produced by FEWS NET (Famine Early Warning System Network) http://earlywarning.usgs.gov/fews. Resolution is 8 km. Average annual rainfall was calculated for the rainfall season July to June for each year in the period 1996 to 2013. The standard deviation in annual totals was then calculated to produce the coefficient of variation (standard deviation as a percentage of the mean).

Graphs of rainfall records provided by the Ministry of Agriculture, Food Security and Cooperatives and the Tanzania Meteorological Agency, covering 30 years (1982-2012). http://www.agriculture.go.tz

Page 19
Map created from data provided by MODIS Global Evapotranspiration Project (MOD16), http://www.ntsg.umt.edu/project/mod16 which covers the period from 2000 to 2010. Resolution is 1 km.

Graphs of monthly data between 1982 and 2012 from the Tanzania Meteorological Agency.

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Map of average temperature from WorldClim data set which covers the period 1950 to 2000. http://www.worldclim.org. Resolution is 30 arc seconds.

Graphs of maximum and minimum temperatures provided by the Ministry of Agriculture, Food Security and Cooperatives and the Tanzania Meteorological Agency, covering 30 years (1982-2012). http://www.agriculture.go.tz

Maps of minimum and maximum temperature and annual range from WorldClim data set which covers the period 1950 to 2000. http://www.worldclim.org. Resolution is 30 arc seconds.

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Map of solar radiation from data covering the period 1998 to 2011, from Joint Research Centre, Institute for Energy and Transport, European Union. http://re.jrc.ec.europa.eu/pvgis/download/solar_radiation_cmsaf_download.html. Resolution is 1.5 arc minutes.

Graphs of relative humidity 1982 and 2012 from the Tanzania Meteorological Agency.

Maps of bioclimate zones from http://rmgsc.cr.usgs.gov/ecosystems/dataviewer.shtml and see http://pubs.usgs.gov/sim/3084 and Rivas-Martínez S, Sánchez-Mata D & Costa M. 2004. *Synoptical Worldwide Bioclimatic Classification System*: http://www.globalbioclimatics.org/book/bioc/tabla3.htm

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Maps were produced by the CSIR Natural Resources and the Environment: Climate Studies, Modelling and Environmental Health, South Africa for two emission scenarios: RCP 4.5 and RCP 8.5 modelled at 0.5 degree resolution. Each scenario comprised 2 and 3 models respectively and the mean (RCP 4.5) and median (RCP 8.5) of each set was used for each time period. The RCP 4.5 and 8.5 data were not bias-corrected and were therefore adjusted relative to A2 scenario baselines for rainfall and temperature. For rainfall maps, percentage change was calculated between baseline projections (1970 - 2005) and modelled projections for the periods 2040-2060 and 2080-2100. Annual rainfall totals were derived by summing the four seasonal totals JAS, OND, JFM and AMJ for each model in each time period. For temperature maps two seasons were selected containing the coolest and warmest months across the majority of the country i.e. JJA and SON. For each model, average seasonal temperature was calculated as the midpoint between the average seasonal maximum and minimum temperatures for model periods 1970-2005, 2040-2060 and 2080-2100. Maps depict temperature change in degrees Celsius for the periods 2040-2060 and 2080-2100. For more information see: Engelbrecht FA, Landman WA, Engelbrecht CJ, Landman S, Bopape MM, Roux B, McGregor JL & Thatcher M. 2011. Multi-scale climate modeling over Southern Africa using a variable-resolution global model. *Water SA* 37: 647–658, Malherbe J, Engelbrecht FA & Landman WA. 2013. Projected changes in tropical cyclone climatology and landfall in the Southwest Indian Ocean region under enhanced anthropogenic forcing. *Climate Dynamics* (Impact Factor: 4.23). 40(11-12). DOI:10.1007/s00382-012-1635-2, DEA (Department of Environmental Affairs). 2013. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa*. Climate Trends and Scenarios for South Africa. Pretoria, South Africa.

Page 24 and 26
Map of population densities in 2010, compiled by and available from WorldPop Project http://www.worldpop.org.uk

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Graphs and age pyramids from 2012 census data compiled by the National Bureau of Statistics http://www.nbs.go.tz

Graph of population growth from data of the National Bureau of Statistics http://www.nbs.go.tz

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Maps of soil types from Ministry of Agriculture, Food Security and Cooperatives http://www.agriculture.go.tz/agricultural%20 maps/Tanzania%20Soil%20Maps/Soil%20maps.htm. Detailed information on the characteristics of each soil type is available from http://www.fao.org/docrep/w8594e/w8594e00.htm and in the Soil Atlas of Africa, which can be downloaded from http://eusoils.jrc.ec.europa.eu/library/maps/africa_atlas

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Maps of soil properties from International Soil Reference and Information Centre (ISRIC) World Soil Information African Soils Information Service (AfSIS) http://www.isric.org/data/soil-property-maps-africa-1-km. Resolution is 1 km.

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Map of river flow volumes: Global Runoff Data Centre (GRDC) http://www.bafg.de/GRDC/EN/Home/homepage_node.html

Map of rivers and catchments compiled by RAISON from multiple sources including HydroSHEDS data http://hydrosheds.cr.usgs.gov, satellite images and vegetation types data (page 32).

Page 31
Graphs of river flows from Global Runoff Data Centre (GRDC) http://www.bafg.de/GRDC/EN/Home/homepage_node.html

Page 32
Vegetation structure map adapted from: The Useful Tree Species for Africa tool developed by the World Agroforestry Centre (ICRAF) and Forest and Landscape Denmark under the UNEP-GEF Carbon Benefits Project. http://www.worldagroforestrycentre.org/our_products/databases/useful-tree-species-africa

Pages 32 and 33
Vegetation type maps adapted from: van Breugel P, Kindt R, Lillesø JPB, Bingham M, Demissew S, Dudley C, Friis I, Gachathi F, Kalema J, Mbago F, Moshi HN, Mulumba, J, Ngda H, Namaganda M, Ruffo CK, Védaste M, Jamnadass R and Graudal L. 2012. *Potential Natural Vegetation Map of Eastern Africa: An interactive vegetation map for Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia.* Version 1.1. Forest and Landscape (Denmark) and World Agroforestry Centre (ICRAF). Visit http://vegetationmap4africa.org to obtain updated maps and detailed information on the characteristics of each vegetation type.

Page 34
Map of variation in annual plant production derived from data for 2000 to 2012 obtained from Africa Soil Information Service (AfSIS) http://www.africasoils.net/data/datasets?page=1. Resolution is 1 km.

Map of Enhanced Vegetation Index (EVI) derived from data for 2000 to 2012 obtained from Africa Soil Information Service http://www.africasoils.net/data/datasets?page=1. Resolution is 250 m.

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Maps of bird, mammal, freshwater fish, amphibian, dragonfly & damselfly diversity from IUCN (*International Union for Conservation of Nature*) data obtained from http://www.iucnredlist.org/technical-documents/spatial-data and http://www.biodiversitymapping.org

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Maps of endemism from data in Burgess ND, Butynski TM, Cordeiro NJ, Doggart NH, Fjeldså J, Howell KM, Kilahama FB, Loader SP, Lovett JC, Mbilinyi B, Menegon M, Moyer DC, Nashanda E, Perking A, Rovero F, Stanley WT & SN Stuart. 2007. The biological importance of the Eastern Arc Mountains of Tanzania and Kenya. *Biological Conservation* 134, 209-231

Text from http://uu.diva-portal.org/smash/get/diva2:615493/FULLTEXT01.pdf and http://en.wikipedia.org/wiki/Kipunji#Distribution

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Maps show protected areas in 2013, from World Database on Protected Areas (WDPA) http://www.wdpa.org

Text from Burgess N & Rodgers A. 2004. *Protected Area Categories: Why they matter for the Eastern Arc and coastal forests in Tanzania – Briefing Note.* Report for the Conservation and Management of the Eastern Arc Mountain Forests Project; Kijazi AJH (Director General-Tanzania National Parks). Undated. National overview of protected areas in Tanzania and their tourism potentials. http://ccs.infospace.com; http://data.worldbank.org/indicator/ER.LND.PTLD.ZS; Carbon Tanzania: http://www.carbontanzania.com/forests/forests-and-communities.htm and Wapalila GJ. 2006. *Protected areas, local people livelihoods and conflicts: a case study of Mikumi National Park in Tanzania.* Master's thesis, Norwegian University of Life Sciences; Chape S, Spalding M & Jenkins MD. 2008. The World's Protected Areas. UNEP World Conservation Monitoring Centre. University of California Press. Berkeley, USA.

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Maps of burning frequency from Sally Archibald, and Modis Burnt Area products produced by David Roy, for the years 2000 to 2010, at 500 metre pixel resolution; available from http://wamis.meraka.org.za/products/fire-frequency-map; and described by Archibald S, Scholes R, Roy D, Roberts G & Boschetti L. 2010. Southern African fire regimes as revealed by remote sensing. *International Journal of Wildland Fire*, 19 (7) 861-878.

Page 40
Map of agroclimatic zones from Food and Agriculture Organisation of the United Nations http://www.fao.org/ag/againfo/resources/en/glw/GLW_prod-sys.html

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Maps of production systems compiled by RAISON from maps on pages 42 and 43, and Derksen-Schrock D, Anderson CL & Gugerty MK. 2011. Tanzania: Agricultural Sector Overview. EPAR Brief No. 133. Evans School Policy Analysis and Research; and Makoi J. Undated. Description of cropping systems, climate, and soils in Tanzania. http://www.yieldgap.org/tanzania

Maps of cattle and goat density: HarvestChoice. Data are for 2005, published in 2011. http://harvestchoice.org/products/map/104%2C68. Resolution is 5 arc minutes.

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The map of access to markets shows the travel time using land- or water-based travel to cities of 50,000 people or more in 2007 - 2008. Compiled by Andy Nelson and available from the Joint Research Centre of the European Commission http://bioval.jrc.ec.europa.eu/products/gam/index.htm

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Maps on crop production derived from district level data from the 2009 / 2010 Agriculture Sample Census, obtained from the Ministry of Agriculture, Food Security and Cooperatives http://www.agriculture.go.tz

Tables on crop production derived from data from the 2009 / 2010 Agriculture Sample Census, obtained from the Ministry of Agriculture, Food Security and Cooperatives http://www.agriculture.go.tz

Text from Covarrubias K, Nsiima L & Zezza A. 2012. *Livestock and livelihoods in rural Tanzania: A descriptive analysis of the 2009 National Panel Survey.* Joint report of the World Bank, FAO, AU-IBAR, ILRI and the Tanzania Ministry of Livestock and Fisheries; Government of Tanzania. 2012. *National Sample Census of Agriculture 2007/2008 Small Holder Agriculture Volume II: Crop Sector – National Report.* National Bureau of Statistics, and Government of Tanzania. 2012. *National Sample Census of Agriculture 2007/2008 Small Holder Agriculture Volume III: Livestock Sector – National Report.* National Bureau of Statistics.

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