

MOZAMBIQUE

Area: 783,000 km²

Population: 13.3 million (1983 estimate)

I. BACKGROUND

Mozambique has about 2,800 km of coastline of the Indian Ocean facing Madagascar. In the south and as far as Beira, the country consists of a vast plain lying between 200 and 500 m above sea level and dominated in the west by the high plateaus of Natal, Swaziland, Transvaal and Zimbabwe. The coastal area is swampy.

In its centre along the Zambezi, which is one of Africa's biggest rivers, Mozambique is wedged between Zimbabwe and Zambia in the high plateaus country; in the north, east of Lake Malawi, it slopes fairly regularly down towards the Indian Ocean for 400 to 500 km from the eastern rim of the Rift Valley which is often more than 1,500 m above sea level.

Large rivers cross the country from west to east. These are, from north to south: the Ruvuma, Louria, Zambezi, Save and Limpopo.

There are several different levels descending from the western highlands to the Indian Ocean:

- The high plateaus: 700 to 99 m;
- The plateaus: 300 to 400 m;
- The coastal plain: from 200 m to sea level.

The high plateaus have fair amounts of rainfall and good soils; they are therefore suitable for very diversified agriculture, with both tropical and mediterranean crops. From north to south, these plateaus are called Lichinga, Mozambique, Angonis, Moravia and Chimoia. The traditional non-irrigated crops include cotton, maize, cassava (mapira) and peanuts.

The sandy coastal plains are less suitable for agriculture; the crops include cashew nuts, date, coconut and oil palms, peanuts (low yield) and cassava. Close to the banks of the rivers the flood plains are argillaceous and suitable for intensive agriculture, in particular sugar cane and rice. The best areas are the final sections of the rivers Pangué, Buzi, Limpopo and Incomati, and especially the Zambezi, where most of the country's sugar cane plantations are located; yet only a small part of this territory is cultivated.

Except in a few southern areas, the country has an annual rainfall in excess of 500 mm and even over 1,000 mm close to the coast and in the north, especially in the vicinity of Lake Malawi. The rainfall can be as high as 1,800 mm at the highest points in the country. It is subject to wide variations, in space as well as in time (20 to 40 %).

The climate varies from region to region:

Arid type: Western part of Gaza province, around the town of Tete.

Semi-arid and sub-humid dry type: Average annual temperatures of over 20 °C and potential evapotranspiration of over 1,200 mm. This includes the whole of the coastal zone, the area along the Zambezi River, and the area south of the Buzi and Save Rivers.

Sub-humid to humid type: Average annual temperatures of 15-25 °C and potential evaporation of 1,000-2,000 mm. This includes the north and the interior of the country, the highest areas north of the Zambezi, the higher central parts of Manica, and a small area in the Limbombo mountains.

Humid to tropical humid type: Potential evapotranspiration of 1,000 mm: northern plateaus (around Lichinga and Gurue), Tete province, high land in the centre of the country.

For an annual average rainfall of 968 mm, i.e. 750 billion m³ of water, the surface flows total 80 billion m³, i.e. about 10 % of the rainfall. The hydrographic network is very well developed, with about 100 main drainage basins and several international rivers which rise in the plateaus of Central Africa and flow into the Indian Ocean. The main rivers are:

Rovuma:	800 km
Zambezi:	800 km (in Mozambique alone)
Save:	310 km
Limpopo:	520 km
Incomati:	270 km

The most important national rivers are the Lurio (605 km), the Licungo (336 km) and the Messalo (530 km). Except in the case of the very small watercourses which drain the sandy areas close to the coasts, the flows are very irregular.

The surface flows entering Mozambique from neighbouring countries in the rivers Maputo, Umbeluzi, Incomati, Limpopo, Save, Pungue, Zambezi and Rovuma amount to about 95 billion m³, of which 87 billion (85 %) are carried by the Zambezi alone.

The surface flows occur mainly (70 %) in the rainy season. In 1982 the country had 231 measuring stations, of which 86 took regular readings; 77 of these stations have automatic recording equipment and the others have limnimetric gauges.

II. GEOLOGY

Mozambique has two large geological systems: (i) the Precambrian crystalline basement in the west of the country, north of the Save River, covering an area of 540,000 km²; (ii) the Paleozoic to Recent formations covering 240,000 km² in the south and east of the country.

The Precambrian system is subdivided into a base complex more than 2,000 million years old and an Upper Precambrian complex ("Mozambique belt") produced by successive orogenies, the last of which, the "Pan African", occurred 500 million years ago and has left well preserved evidence.

The base complex consists mainly of green schists with strata of ferruginous quartzites, limestones, greywackes and conglomerates.

The Upper Precambrian system can be subdivided into three provinces with different structures: Mozambique, Nyassa and Middle Zambezi. These provinces have certain characteristics in common: metamorphic katazone facies, north-south direction, and age range of 400 to 700 million years. The whole complex was lifted by the last "Pan African" orogeny.

The Precambrian rocks are found in complex series of granitogneiss, paragneiss, metamorphic schists, quartzites, crystallized limestones, granites, migmatites and amphibolites and in metasedimentary series. The Precambrian system is overlain by formations of the Karroo, Jurassic, Cretaceous, Cenozoic and Quaternary periods.

Karoo: Dating from 180 to 300 million years ago, with the upper part consisting of the Beaufort, Ecca and Dwyka series: tillites, sedimentary sandstones and schists with coal seams. These continental sediments were deposited on the floor of subsidence basins bounded by major faults. The Karroo is divided into:

- Tete province in parts of the Zambezi valley, 7,500 m thick: from south of Chioco to Mucumbura;
- Manica province: in the Espungabera area and between Villa Machado and the Lupata gorge in the Zambezi valley;
- Niassa province, with the Lake Nyassa area delimited by the courses of the Bunho and Jugo; and the Lugenda valley area;
- Gaza and Maputo provinces, with the Limbombo mountains.

Jurassic: The formations date from 135 to 180 million years ago and include sandstones, conglomerates and limestones. They are found in small outcrops in Lupata, Nampula and Cabo Delgado provinces.

The Cretaceous rocks date from 70 to 135 million years ago and have the following stratigraphic sequence:

- Calcareous sandstones of the Grudja formation;
- Sandstones and conglomerates of the Sena formation;
- Calcareous sandstones and sandy limestones;
- Maconde strata;
- Lupata sandstones.

They are found in the Sena area, the Cabo Delgado coastal zone, south of Espungabera, at the edge of the volcanic formations of the Limbombo mountains, and along the course of the Buzi.

Cenozoic: 1.6 to 70 million years old, with the following stratigraphic sequence:

- Sandstones and conglomerates of the Mazamba formation;
- Calcareous sandstones and limestones of the Jofane formation;

- Calcareous sandstones, limestones and nummulitic limestones of the Cheringoma formation.

These Cenozoic formations are found in the coastal region of Cabo Delgado in the vicinity of Inhaminga, along the Save and Limpopo Rivers and also along National Road No. 1 between Mapunhane and Massinga.

Quaternary: This series consists mainly of unconsolidated formations:

- Sand or sand-clay alluviums, colluviums and eluviums;
- Terraces;
- Lacustral limestones;
- Sand dunes.

III. GROUND WATER

It is in the south and the far north of the country where water supply problems are most serious and ground-water research has been most intensive, especially since the end of the 1950s. A national inventory of water resources has been drawn up and a first regional hydrogeological study made of the part of the country south of the Save, with the assistance of a team of hydrogeologists from BURGEAP.

In the south, the unconfined aquifer is extensive and continuous, receiving considerable recharge by direct infiltration of rainwater; but the water often has a high mineral content, except in a few places where there are accumulations of surface sands. In fact, the Cretaceous and Tertiary sandstone-clay formations have poor permeability - in a country with intense evapotranspiration. The alluvial reservoirs contain abundant and easily accessible fresh water.

The karstified Miocene limestones which cover about 25,000 km² south of the Save contain a fractured stratum, with water of low mineral content, which furnishes high unit yields. The water table is at a depth of 50 m. Further south, the aquifer is also continuous and can be exploited on a large scale in the vast region of Recent dunes. The water has a low mineral content and its chemical composition is complex and variable; it does not bear any direct relationship to the nature of the formations in which it is contained.

In areas of metamorphic and eruptive crystalline rocks (basement, Upper Karroo and Precambrian), the wells have the following yields:

- In orthogneiss, granites and paragneiss with low ferromagnesian content and thick surface alteration strata, the wells yield 4-8 m³/h on average and up to 10-12 m³/h, with 25 m³/h in exceptional cases. The water has a low mineral content (under 300 mg/l);
- In paragneiss rich in ferromagnesian elements and generally impermeable, the few inclusions (quartz and peridotite veins) supply only modest yields. The alteration stratum itself is argillaceous and barren:

- In the rhyolites, which contain small stocks of water in their fractures and, in a few places, springs discharging a few hundred litres an hour, the wells yield 1 m³/h on average. The situation is similar in the case of the basic and ultrabasic rocks. However, some boreholes in the basalts can yield up to 25 m²/h;
- In the Karroo and post-Karoo formations of the interior, where the tillites, schist-sandstones and clay-sandstones are mostly impermeable, the best wells yield a few cubic metres an hour.

The water is of acceptable quality from the standpoint of its salt content. The ground water is found mainly in areas of fractures and faults. For the water supply of Tete airport at Matundo, 4 l/s was obtained after several attempts from boreholes 60 m deep which encountered more or less fractured schistoid limestones of the Tete series.

In the Moatize area boreholes were drilled over 100 m deep and penetrated a number of strata, but they yielded less than 1 l/s. Lastly, in the Caldas Xavier region yields of 2 to 3 l/s were obtained from boreholes 30 to 40 m deep in contact zones between the Karroo sandstones and the dolerite dykes. Before these boreholes were drilled, water had to be brought by tanker truck from Beira.

The aquifers in the formations of the crystalline complex are of only local size. They furnish low unit yields, rarely in excess of 2 l/s. The aquifers are divided into separate lenticular units and are found in:

- The deep alteration zone of the rocky substratum;
- Contact zones between rocks of different types;
- Faulted, fractured or crushed zones.

In the Cretaceous and post-Cretaceous formations south of the Save the wells installed in the past 20 years have very variable yields, from very low up to 30 l/s. The salinity of the water is also very varied, from sweet water up to 4,000-10,000 mg/l. The salinity of the water taken from a number of boreholes in the area of Dindiza, Chigubo and Alto Changane has had a salt content of 3,000-45,000 mg/l.

In other sectors the systematic use of geophysical prospecting has produced satisfactory results. This prospecting was carried out between 1971 and 1974 along the main roads linking Chokue and Maqueze, Dindiza, Chigubo, Mabete, Maxaita, Mapai, Combomune and Mabalane; the geoelectric method was used (AB 5-10 km). Wells yielding 2 to 3 l/s were drilled between Mabete and Maxaita, and 20 to 30 l/s in the Chigubo and Cocone areas, with water of acceptable quality.

North of the Save there are no large-yield boreholes, and even holes yielding 2 to 3 l/s are fairly rare. The water is usually of acceptable salinity, except in the lower part of the Pungue basin. In some places it is necessary to drill to depths of 100-150 m.

North of the Pungue on the Inhaminga plateau the aquifers are found at depths below 80 to 100 m; the yields are about 3 l/s. In Cabo Delgado province the boreholes in the Cretaceous and Cenozoic plateaus of Manica and Mueda had to be drilled more than 100 m deep before finding water. The yields are very variable but rarely in excess of 2 to 3 l/s. There is a borehole 301 m deep on the Mueda plateau.

The coastal sedimentary basin in the north has a number of springs: at Cabo Delgado, for example, 43 springs with a total yield of over 100 l/s have been inventoried.

Work has been carried out recently with a view to exploiting the water of the alluviums of temporary watercourses for urban supplies. The plans include the extraction of 24,000 m³/day from the alluviums of the Umbeluzi to supply Maputo. The alluviums of the Monapo are exploited to supply other locations - Ilha de Moçambique, Lundo, Chocas and Mossuril - with expected yields of 5,000 m³/day. It is also hoped that it will be possible to extract 12,000 m³/day from the aquifers to supply Pemba. At Qualimane the plan is to extract 3,000 m³/day from the alluviums of the Licuari. The lower course of the Lincomati is also to be exploited to supply Maputo (70,000 m³/day). It may also be possible to exploit the potential of the Pungue alluviums to supply Beira.

Generally speaking, study of the ground water of this vast and sparsely and unevenly populated country is at the stage of inventory and reconnaissance. Owing to the relatively widespread presence of saline water containing more than one gramme of NaCl per litre, hydrochemical and geophysical (electrical prospecting) studies have been carried out on a considerable scale in Mozambique. There is no doubt that the country's ground water, especially in the south, represents a natural resource of considerable potential.

The drilling of boreholes for water supplies is the responsibility of GEOMOC E.E., a public corporation of the National Water Department (DNA). The first step is to make a photogeological study of the zone, using the aerial photographs available, usually on scale 1:40,000; the existing geological maps are also studied. All the structures visible on the photographs are recorded: contacts, faults, fractures, probable dykes, direction and slope of strata, interruptions of slope, escarpments, hydrographic network, and drainage zones. A field survey is then made to verify the observations and identify the limits of the alluvial zones by study of the colour and texture of the soil. If necessary, geophysical prospecting is then carried out: the geoelectrical method is the commonest used, but sometimes additional magnetometric prospecting is carried out.

It is usually sufficient to make vertical electrical soundings 200 m apart along previously established profiles. If necessary, the soundings are made closer together. The geomagnetic method is faster; when this method is used in conjunction with the geoelectric method, it is possible to identify intensely fractured zones and zones traversed by dykes, to distinguish zones of sweet water from zones with a high mineral content, and to study the alluviums hidden beneath the surface deposits.

The electrical soundings are made by the Schlumberger ABEM quadripole method. The installation of a borehole requires about three days of work at the site. An old type of drilling rig (Mangold) and down-the-hole hammer rigs (Rotamec Foraco) are available for drilling work.

GEOMOC does not have sufficient equipment and staff to meet the demand.