

## REGIONAL DISTRIBUTION OF RIVERS AND STREAMS IN AFRICA

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### Summary

Africa is a continent of contrasting landscapes. About a half of its territory is occupied by deserts and semi-deserts, including the world largest tropical desert, the Sahara, of about 8 million sq. km. The central part of the continent, the Congo River basin (Zaire), is occupied by subtropical rain forests and the Congo River is the most full-flowing river in the eastern hemisphere.

Runoff resources of the continent, representing the renewable fresh water resources, are approximately equal to 4050 cu. km/year. This is 9.5% of the total world river runoff. According to specific indices (per sq. km and per capita) Africa is related to the continents with the least river water availability: together with Australia on areal water availability and together with Asia on river runoff per capita. The water availability of Africa is 2.4 times lower than that of the world land area (without Antarctica).

Meanwhile, some of the world's largest lakes are on this continent (Victoria, Tanganyika, Nyasa) and the world largest reservoirs have been constructed there. Four (out of five) of the largest reservoirs are in Africa.

The extremely uneven spatial distribution of water resources is not coincident with the distribution of population and economics (i. e. fresh water demands). According to physiographic and economic conditions, the continent is divided into five physiographic and economic regions: Northern, Western, Central, Eastern and Southern Regions. Each region consists of 7 to 16 countries.

The most arid Northern Region has 4.5% of river water resources of the continent; water use in this region is equal to 51% of the total water use. The opposite situation is observed in the most humid Central Region where these values equal 46% and 1.2%, respectively.

If we consider water availability for population needs in these regions, we see that the present water availability in the Central Region is 5-7 times greater than that in the Eastern, Western and Southern Regions, and it is 44 times greater than that in the Northern Region. By 2025 it is possible to expect 1.5 times higher water use in Africa and halving of water availability, as a result of high population growth. Meanwhile, the extremely uneven spatial distribution of water availability would be largely unchanged.

Problems for future studies in the field of water resources include a more detailed study of river runoff formation and its use, more reliable assessment and forecast of future water use, investigation of the anthropogenic climate effects on water resources and on water availability, and development of multipurpose projects.

## **1. Introduction: General Information about the Continent**

Africa is the second largest (after Eurasia) continent in the world. Its area, together with the adjacent islands, is 30.1 million sq. km (29.2 million sq. km without islands); Madagascar is the largest island (590 000 sq. km). The continent extends 8000 km from north to south and 7500 km from west to east (its northern part). Africa is situated northward and southward from the equator between 37°20' N and 34°52' S. If compared with Eurasia and North America, the configuration of the continent is simple, the coastal line is only slightly indented. The Gulf of Guinea, the largest gulf, is in the central part of the west coast; the largest peninsula, i. e. the Somali Peninsula is on the east (opposite) side of the continent.

There are more than 50 independent countries in Africa; most of them are developing countries and they gained their independence in the second half of the twentieth century. The Republic of South Africa (RSA) at the southern extremity of the continent is the only developed agricultural and industrial country. The following countries occupy large areas: Sudan (2 506 000 sq. km), Algeria (2 382 000. sq. km), Zaire (2 345 000 sq. km), Libya (1 760 000 sq. km), Chad (1 284 000 sq. km), Nigeria (1 267 000 sq. km). Most of these territories are occupied by sparsely populated deserts and jungle.

In 1995 the population of Africa was 750 million; the highest population number is in

Nigeria (112 million), Egypt (62.9 million), Ethiopia (55.0 million), the Democratic Republic of the Congo (43.9 million) and the RSA (41.5 million).

Due to its geographic situation near the equator, Africa receives much heat. Air temperatures are high all the year round; winter and summer mainly differ in conditions of moistening, i.e. rainy season in summer and dry season in winter.

Landscape contrasts are typical of Africa. Deserts and semi-deserts occupy about half of the continent, including the Sahara Desert, the world's largest tropical desert of about 8 million sq. km. Tropical rain forests are extending in the central part of the continent in the Congo River basin (Zaire).

Africa is rich in many different minerals; some of the mineral deposits are the world's largest.

## **2. Factors Determining Development of the Hydrographic Network and River Runoff Regime**

### **2.1. Relief**

The surface relief of Africa is gentler than that of the other continents. There are no high and extensive mountain ranges like the Cordilleras in North America, the Andes in South America or the Himalayas in Asia. Plains and plateaus prevail; lowlands are few.

The geology is characterized by slow movements and shifts of the Earth's crust. The results of these movements are upshifts formed on the margins of the continent, i. e. the Atlas Mountains in the north (the largest peak is 4165 m), the Drakensberg Mountains in the south (the highest peak is 3482 m), the Ethiopian Highlands (4620 m) and Mount Kilimanjaro (5895 m).

Plains and lowlands are widespread in the central part of the continent where they are surrounded by plateaus and look like bottoms of huge depressions. In the south, an extensive arid plateau contains the Kalahari Desert and the large Zambezi River; northward there is large Congo lowland occupied by the Congo river system. To the north of the Congo lowland there is the Chad basin with the endorheic Lake Chad in the centre. To the east of Lake Chad there is the White Nile river valley and to the west of the low-lying area contains the middle reaches of the Niger river. Lowlands occupy both continental and coastal areas.

Vast areas of Africa are occupied by deserts. The Sahara Desert extends from the Atlantic coast to the Red Sea shore. In the centre of this desert there are the Ahaggar Mountains, Tibesti Mountains and Darfur Plateau with the highest peaks at 3000 to 3500 m. The second largest desert is the Kalahari, which is 0.9 million sq. km, in the south of the continent.

The northern ranges of the Atlas Mountains were built during the formation of the young Alpine folding. The remaining area is related to the African Platform which is composed of Precambrian crystalline and metamorphic rocks. A meridional belt of

faults extending from West Asia across the Red Sea and the eastern part of Africa intersects the eastern margin of the continent for a distance of more than 6000 km (the longest Rift Valley on the planet) to the Mozambique coastal plain (to the south of the Zambezi lower reaches). There are several deep hollows on the surface of this belt, in most of which large lakes were formed (Lake Victoria, Tanganyika, Nyasa, etc.). Active and extinct volcanoes rise high above along the faults line, e. g. the Kilimanjaro volcanic massif (with its highest peak of 5895 m) and Mount Kenya (5199 m). The mean elevation of Africa above the ocean level is 750 m.

## 2.2. Climate and Vegetation

Climate characteristics, precipitation and air temperature in particular, are the major factors which determine (together with the relief) the river network density, areal distribution of rivers and streams, river runoff regime by months and seasons and extreme values.

Africa occupies three climate zones. Most of the continent is within the tropical latitudes; a minor part is within the equatorial belt. The northwest and southeast margins are within the subtropics. The continent receives much heat during the year; it is the continent with the highest mean annual air temperature, at about 20 °C.

Africa extends north and south of the equator, so the seasons in the north and in the south are opposite: The summer period in the northern hemisphere corresponds to the winter period in the southern hemisphere, and vice versa. The temperature difference is insignificant, the nature and quantity of moistening, however, differs greatly during a year. A water deficit is observed on the major part of the continent; dry (winter) and wet (summer) seasons are quite distinctive on a large area but the duration of these seasons differs greatly.

The climate is constantly affected by high pressure areas, i.e. the Azores and South Atlantic anticyclones over the Atlantic Ocean and South-Indian anticyclone over the Indian Ocean. A transfer of tropical air by trade winds (northeast wind in the northern hemisphere and southeast wind in the southern hemisphere) is the main circulation process.

Total annual precipitation on most of the area within the equatorial latitudes exceeds 1000 mm/year; it tends to decrease in eastern regions where west winds transport less moisture. On the coast of the Gulf of Guinea and in the Congo River basin, precipitation exceeds 1500 mm/year. The wettest area in Africa (9600 mm/year) is here, at the foot of Mount Cameroon. Precipitation above 3000 mm/year occurs on the wind-exposed mountain slopes on the Atlantic coast in West Africa, in Liberia, Sierra Leone and on the east coast of Madagascar affected by southeast trade winds. A narrow stripe with water surplus during the whole year extends from the west coast (between the Niger river delta and the equator) across the middle part of the Congo river basin to the reef system in East Africa. The Somali Peninsula is the most arid region of the equatorial belt.

A permanent hot climate with air temperature of 25-26 °C during the year is observed

on the coast of the Gulf of Guinea and in the Congo depression. Air temperature difference between the warmest and coldest months is from 1-2 °C to 4-5 °C. A cooler climate is observed in the highlands of east Africa; there are glaciers on the peaks of the highest mountains, i.e. Kilimanjaro and Kenya (the snow line is at an elevation of 4400-5000 m).

Northward and southward the equatorial climate gradually turns into subequatorial (equatorial monsoons) with a wet summer and a dry winter. The duration of the dry winter season tends to increase from 2 months to 10 months. Annual precipitation tends to decrease from 1800 mm to 300 mm.

Northward of 20°N and southward of 18°S the climate is tropical; in the northern hemisphere it is very arid. In the Sahara Desert precipitation decreases to 100 mm/year and less. The eastern Sahara is the most arid region; precipitation in the Libyan and Nubian Deserts is 10-20 mm/year. Along the west coast of the Sahara Desert, the climate is oceanic with a relatively high air humidity. To the south of the equator the tropical belt is subdivided into three sectors, i.e. oceanic desert in the west, continental moderately dry and dry climate in the centre, marine climate with trade winds and summer precipitation maximum in the east.

In the tropics of North Africa the air temperatures are the highest on the continent. In summer in north Sudan and in the Sahara Desert mean monthly air temperatures vary within 30-32 °C; in the day time the temperature rises to 40 °C. The highest air temperature has been recorded in the Libyan Desert (57.8 °C). Dry air and a cloudless sky stimulate intensive heating of the underlying surface (in the deserts the sand temperature reaches 70 °C). In winter northward and southward of the tropics, as well as in some mountain regions, frosts are observed.

On the west coast of the Sahara Desert and in Namibia, deserts are formed adjacent to oceans with lower air temperatures than the inland continental areas (the Namib Desert with precipitation of 25 mm/year in places, is the driest area in Africa south of the equator). Moistening of the surface by dew and fogs in the main source of moisture in these deserts. In summer the air temperature on the Mediterranean coast is usually 20-25 °C; in winter it is 10-15 °C. On the summits of the Drakensberg Mountains (in the far south of the continent) frontal cyclones in winter cause severe snowfalls; frosts may attain -6 °C.

The margins of Africa are in the subtropical belt. In the north, the climate is Mediterranean, with rain occurring during the cold season. In the Atlas Mountains and in Sinai there are places with snow coverage; the air temperatures falls below 0 °C. Air humidity in the coastal areas tends to a gradual decrease with increase of distance from the Atlantic coast eastward; precipitation tends to decrease, too (from 500-1000 mm/year in Morocco and Algeria to 100-250 mm/year in Egypt). In the southern hemisphere the Mediterranean type of climate is observed in the southwest only; eastward a summer precipitation maximum is observed. In general, precipitation is quite sufficient here; heavy rains (to 2000 mm) fall on the wind-exposed slopes of the Drakensberg Mountains and in the mountains of Madagascar.

Periodically repeated droughts are typical of the continent. Of particular note is the droughts in the so-called Sudan-Sahelian zone south of the Sahara Desert as a wide stripe occupied by 15 countries. The most severe droughts were observed in this zone during 1968-1973 and in the 1980s. The drought in 1969-1973 resulted in an advance of the south Sahara boundary 350-500 km southward and a significant shift of plant zones (desertification of savannas, savannisation of forests).

At present, savannas occupy about 33% of the territory of Africa; deserts and semi-deserts occupy 40%. The other territories (about 27%) are occupied by forests and thin forests. In general, tropical vegetation prevails in Africa. Non-tropical species grow on small areas—in the far north, in the far south and in high mountains. In areas with wet and hot climate, equatorial and tropical evergreen and mixed rain forests grow. The largest forest areas are concentrated on the coast of the Gulf of Guinea and in the Congo River depression. More than 3000 tree species grow in the rain forests of Africa. The trees are 40-50 m high. Bushes do not usually grow, and the grass cover is thin.

Southward and northward of the equatorial and tropical rain forests, as precipitation tends to be lower and the dry period tends to be longer (to 2 or 3 months) periodically rain tropical forests are extending.

Dry forests, light forests and shrubs occupy vast areas in South Africa (to 20 °S) mainly on high plateaus where the dry period is 5 to 7 months long. Trees are 7 to 25 m high, and evergreen undergrowth is available.

Depending on the duration of the rainy season and amount of precipitation, savannas are subdivided into rain high-grass savannas, arid low-grass savannas and tropical semi-desert zones, regularly replaced northward of the equator. To the south of the equator, dry forests, thin forests, shrub communities and tropical semi-desert zones are widespread.

The plant cover of deserts greatly depends on the specific features of the ground. In the Sahara Desert thin tree and bush species with deep roots grow in rocky deserts. Pebble deserts and shifting sandhills have no vegetation. In the deserts of South Africa plants with succulent leaves and stems prevail.

Mediterranean plant species are observed in North Africa within the Atlas Mountains and on a narrow coastal strip from Tunisia to the Nile rivermouth. Subtropical sclerophyllous evergreen forests are widespread here.

The distribution of vegetation is closely connected with the moistening of territories. Rain evergreen tropical and equatorial forests occur in areas with heavy precipitation (exceeding 2000 mm) evaporate about 1000 mm/year. These are favourable factors for river runoff formation and the hydrographic network is best developed here.

### **2.3. Human Activity**

Human activity associated with the use of water bodies for construction of reservoirs, canals and different structures for water intake and discharge may cause great changes

in the hydrographic network and river runoff regime.

Reservoirs are an important component in the hydrographic network in Africa. Before the 1950s there were no large reservoirs in Africa; during 1954-1977 the world's largest reservoirs were constructed on this continent. Four (out of five) of the largest reservoirs are in Africa, including Lake Victoria, where the Owen Falls dam was made. Data on the largest reservoirs of Africa are given in Table 1.

Reservoir	Country	Basin	Year of filling up	Capacity, km <sup>3</sup>
Owen Falls (Lake Victoria)	Uganda, Kenya, Tanzania	Victoria-Nile	1954	205
Nasser	Egypt	Nile	1970	169
Kariba	Zambia,	Zambezi	1959	160
Volta	Zimbabwe	Volta River	1965	148
Cabora Bassa	Ghana	Zambezi	1977	62
Kossou	Mozambique	Bandama	1972	28
Suanity	Côte d'Ivoire	Konkure	1961	17.2
Kainji	Guinea	Niger	1968	15

Table 1. Principal reservoirs of Africa

At present in Africa about 20 very large reservoirs are under operation or construction with a capacity of more than 5 km<sup>3</sup> and more than 100 reservoirs with capacity exceeding 100 million m<sup>3</sup>. The total capacity of the reservoirs exceeds 1000 km<sup>3</sup> which is about 20% of the capacity of all the reservoirs in the world. The greatest number of reservoirs has been constructed in the RSA, then Morocco and then Algeria. But the reservoirs in these countries are not large; the largest reservoirs have been constructed in the countries listed in Table 1.

In general, reservoirs are made for power generation because the power-generation resources are great in the rivers of Africa. Africa is the second continent (after Asia) in the world according to this factor. The Congo and Zambezi Rivers have the greatest capacity for power generation. R reservoirs are also used for irrigation, flood control, water supply and fishery.

Large reservoirs greatly affect the hydrological river regimes, increasing possible use of river runoff and providing flood control. Being located in a region of hot and dry climate, however, the reservoirs may greatly reduce the total water resources in rivers due to intensive evaporation from water surfaces. This is very important in Africa because practically all large and mid-sized reservoirs are made in plains and on plateaus and their water surfaces are significant. Only in RSA, Morocco and Algeria have reservoirs been constructed in mountain areas.

According to the character of river runoff control, most African reservoirs are of seasonal, weekly and daily storage. Among reservoirs of carry-over storage, the Nasser Reservoir in the Nile River must be mentioned; it was made in the 1970s and its importance for the economy of Egypt is great.

Not only reservoirs, but a great number of canals have been constructed for irrigation, urban water supply and navigation. Irrigation development is accompanied by construction of numerous canals, which require much water. The present irrigated lands in Africa occupy more than 12.4 million ha and this requires 140 km<sup>3</sup>/year of fresh water; the major portion of this is diverted from rivers, lakes and reservoirs and delivered to the fields by canals. The most extensive irrigated lands are in Egypt (more than 3.3 million ha), Sudan (1.9 million ha), RSA (1.3 million ha), in Morocco (1.2 million ha) and on Madagascar (1.1 million ha). Irrigation development is quite intensive on the continent; during the last 30 years irrigated lands have increased threefold. There is some ground to assume that in future irrigation development will be intensive, too. This is explained by the following factors: very rapid population growth and difficult climate conditions; on most of the continent cultivation cannot be practiced without irrigation.

Construction of multipurpose water management systems including reservoirs and canals for river runoff redistribution in time and space (including between different river basins) is the most effective means of management for the hydrographic network.

The largest multipurpose water management system in Africa with water transfers is under operation in RSA. This complicated hydraulic system consists of a reservoir, canals, tunnels, and pumping stations; it connects the Orange and Limpopo Rivers and other coastal rivers and it is intended to improve water supply of industrial centres and irrigation development. The amount of water transferred by this system is 3 or 4 km<sup>3</sup>/year, and the distance it is transferred is several hundreds of kilometers.

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### **Biographical Sketch**

**Igor Alexeevich SHIKLOMANOV** was born in February 1939. In 1961 he graduated from the Leningrad Hydrometeorological Institute (Hydrological Faculty). From 1961 to the present he has been working at the State Hydrological Institute in St. Petersburg (Russia) in different appointments. Since 1981 he has been the Director of the State Hydrological Institute.

In 1967 I.A. Shiklomanov defended his theses for a candidate's degree and in 1975, a thesis for a doctor's degree on "Hydrology and Water Resources. Since 1985 he has been a professor on "Water Resources", since 1991 – a Corresponding Member, and since 2000 – Academician of the Russian Academy of Natural Sciences on "Hydrology".

The scientific interests of I.A. Shiklomanov include water resources, water balance, water use, the global hydrological cycle, and effects of human activity and anthropogenic climate change on water resources and hydrological regime. He has published about 200 scientific papers, including 9 monographs.

I.A. Shiklomanov has made a notable contribution to international cooperation within the framework of UNESCO, WMO, IAHS, and IPCC: during 1992-1994 he was the Chairman of the Inter-Governmental Council for the IHP (UNESCO), from 1992 to the present he has been a member of the Advisory Working Group, Commission of Hydrology WMO; since 2000 he has been Chairman of the Working Group on Water Resources of the Commission of Hydrology (WMO).