

REGIONAL DISTRIBUTION OF RIVERS AND STREAMS IN ASIA

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Summary

Asia is the largest continent in area and population size. The large territory of the continent extending over 10 000 km from north to south covers all geographic belts from the Arctic to the equatorial belt, and includes almost all types of climate, vegetation and soils observed on the Earth.

Total annual river runoff in Asia is estimated to be 13 500 cu. km which is 32% of the world's renewable water resources. River runoff in Asia is the largest in the world but the specific indices per unit area are lower those in the Americas. As regards river runoff per capita, it is minimum in Asia if compared with the other continents.

About 50% of renewable water resources on the continent occur in South East Asia, which occupies only 16% of the continent. Rather rich water resources are also available in Siberia and the Far East of Russia and in South Asia; these three natural-economic regions include 87% of the renewable water resources of the continent. The

largest rivers of Asia flow there (the Ganges and Brahmaputra and Meghna, Yangtze, Yenisei, Lena, Mekong, etc.). Lake Baikal (Russia)—the world largest freshwater storage—is also found there. Concurrently, there are vast areas with extremely limited renewable water resources (Central Asia and Kazakhstan, West Asia and Arabian Peninsula).

Irrigation is the main freshwater user in Asia; it takes 80% of the total water withdrawal and 92% of water consumption on the continent. Moreover, 67% of the total water withdrawal is used in two regions, i.e. South East Asia (including the major area of China, Indonesia, Japan and other countries) and South Asia (including India, Pakistan, Bangladesh and other countries). Seventy-six percent of the population inhabit these two regions and 70% of irrigated lands are cultivated there.

As to the load on water resources, which is usually estimated as a ratio between the total water use and renewable water resources, the most unfavourable situation is observed in the following regions: Central Asia and Kazakhstan (68%), West Asia (48%) and South Asia (41%).

In South East Asia, with extremely abundant water resources, the load on water resources is not great and equals about 8%, but the lowest load is observed in Siberia and the Far East (about 1%).

If we consider the continent as a whole, the present volume of total water withdrawal is 16% of the total river runoff and may reach 23% before 2025. In the regions of Central Asia and Kazakhstan, West Asia and South Asia these values may attain 60-70%. This is one of the highest loads on water resources among all continents and natural-economic regions in the world.

Proceeding from the above, the problem of more effective water resources use and development of projects on water supply in regions with high freshwater deficits in Asia are of the utmost importance. In future, with predicted global climate warming, this problem will be more acute because the negative results of warming may be extremely serious for regions with water deficits.

1. Introduction: General Information about the Continent

Asia is the largest continent by area (43.4 million sq. km) and population size (3445 million persons in 1995). Together with Europe it forms Eurasia. The boundary between Europe and Asia runs along the Urals, the Ural river valley, the Caspian Sea, the Caucasus Range, the Black Sea, the Bosphorus and the Dardanelles. Asia is separated from Africa by the Suez Canal, and from North America by the Bering Strait. There are many islands adjacent to Asia, with a total area of 2 million sq. km. The largest islands are Northern Land, Sakhalin Island, the islands of Japan, Taiwan, Philippine Islands, Malay Archipelago and Sri Lanka.

There are more than 50 countries in Asia, each with different physiographic features, socio-economic and political situations, area and population size. The following occupy the largest area: Russia (its Asian part is 12 760 000 sq. km), China (9 561 000 sq. km),

and India (3 288 000 sq. km). The total area of these three countries is 59% of the total area of Asia. Most people in Asia (63%) inhabit two countries: 1221 million persons in China and 936 million in India.

The vast territory of Asia extends from north to south over 10 000 km across all physiographic belts from the Arctic region to equatorial latitudes. All the kinds of climate, vegetation and soils ever observed on Earth may be found in Asia. The nature of Asia is characterized by a widely developed continental climate. In the west of the continent, a continental tropical air mass prevails and causes arid landscapes. The nearby Pacific and Indian Oceans stimulate formation of the world's largest monsoon area, and a vast territory of about 11 million sq. km in the north is a permafrost area. Climate differences are intensified by contrasting topography.

The relief of Asia is characterized by predominance of highlands, mountains and plateaus occupying 75% of the continent. More than 28% of Asian territory are areas of inland runoff.

The hydrographic network is well developed in the north, east and south of the continent. Some of the world's largest river systems are in Asia: the Ganges and Brahmaputra, Yangtze, Yenisei, Lena, Ob, Amur and Mekong.

2. Factors, Affecting Development of the Hydrographic Network and Runoff Regime

2.1. Relief, Landscapes

Asia is the second highest continent in the world (after Antarctica). Mean elevation of the continent is 950 m above sea level. About 75% of the land area is mountains and highlands. A belt of very high mountain systems extends across the central part of Asia (Hindu Kush, Karakoram, Himalayas, etc.), intercepting moisture from the Indian Ocean and partly from the Atlantic and Pacific Oceans. A system of ranges (Pamir, Tian Shan, Altai, Sayans, etc.) and Bolshoy Hingan in the east explain the almost complete orographic closure of the plateaus and highlands of the central part of Asia within which deserts and semi-deserts occupy large areas (Takla Makan, Alashan, Gobi, etc.). Peaks of many ridges in the central part of Asia rise above 7000 m and even 8000 m. The other mountain ranges generally do not rise above 4000 m. The highest peak Chomolungma (Mount Everest) in the Himalayas rises to 8848 m above sea level. This is the highest peak in the world.

There are two great mountain belts in Asia, one of which is of a latitudinal strike from Asia Minor to East China and the Malay Archipelago; the other belt extends from southwest to northeast, from the northern edges of the central part of the Asia highlands to the Chukchi Peninsula. Another mountain belt runs across the islands of East Asia.

Within the highlands in central and south-west Asia, adjacent to the Mediterranean Sea, there are elevated plains tied to interfluvial depressions (Dzungar, Kashgar, and other plains). There are vast plateaus in Asia (the Gobi, Central Iranian plateau, Anatolia) that

are elevated at about 1000 m. In Tibet, Tian Shan and Pamirs there are plateaus at elevations above 4000 m.

Lowlands occupy about 20% of the continent. In the northwest there is the world's largest lowland, the West Siberian Lowland. Eastward of the Caspian Sea there is the Turanian Lowland. Other lowlands occupy coastal margins of the continent, piedmont depressions (Mesopotamia, Indo-Gangetic Plain), some isolated depressions in East Asia (Penzhina and Anadyr Plains, lowlands along the Amur river, Great Plain of China and Manchurian Plain) and the Arctic Ocean coast (Yana-Indigirka Plain, North-Siberian Plain).

Due to the long latitudinal strike and variable climates, all landscape zones are available in Asia, i.e. from the Arctic zone to the equatorial one.

The north of Asia (Siberia) forms a wide slope to the Arctic Ocean, into which the largest Siberian rivers discharge. Large plains alternate with plateaus and mountain ranges; landscapes of tundra turn to forest-tundra, taiga, subtaiga, forest-steppe and steppe in the latitudinal direction. Permafrost areas occupy a large territory of about 11 million sq. km.

The east of Asia covering the Pacific coastal extremity of the continent is characterized by monsoon seasonal cycles of thermal regime and moistening, i.e. a rainy summer and a dry winter.

From north to south the landscapes change from subarctic, taiga, subtaiga, broad-leaved forest, subtropical to tropical forests.

The inner territory of Central Asia is the most arid region on the continent. This is the region of inland runoff. Deserts of the temperate belt prevail. In the south the landscapes change to subtropical. In mountains the landscape types depend on elevation and slope exposure relative to winds transporting moisture.

South West Asia is characterized by variable topography, covering arid highlands and plateaus at subtropical and tropical latitudes; desert landscapes prevail here. Mediterranean and submediterranean landscapes occur on the wind-exposed slopes of the outmost boundaries of the mountain ranges.

South East Asia covers the Hindustan and Indochina Peninsulas and the adjacent groups of islands within the lower subequatorial and equatorial latitudes. The relief here depends on the latitudes of the landscapes: subequatorial forest landscapes are observed on wind-exposed mountain slopes, and landscapes of subequatorial savanna type prevail in more arid regions.

In most cultivated regions of Asia the natural landscapes are greatly disturbed by human activity. For example, the major forested areas have been clear-cut or replaced by less productive sparsely leaved shrubs; different types of agricultural landscapes form the basic landscape structure. Negative processes caused by human impact such as intensive

erosion and deflation, soil degradation, secondary salinization, anthropogenic desertification, etc., are developed quite intensively.

The Indo-Gangetic Plain is one of the most cultivated areas and it has been ploughed intensively. The Plain was overgrown by forests long ago but at present these forests have been almost completely clear-cut. The landscapes of the plain and piedmont areas of Indochina were subject to great changes, too. Alluvial lowlands have been ploughed for rice fields. Forests here are replaced by savannas as a result of human activity. The Malay Archipelago, despite the dense population living there, is the most forested region in the south of the continent.

2.2. Climate

Climate characteristics, primarily precipitation and air temperature, are the main factors which determine, together with topography, the river network density, distribution of rivers over the land, river runoff regime by months and seasons and runoff extreme values. The vast territory of Asia extending from the Arctic latitudes to equatorial latitudes and the complicated orography of the continent explain the extremely variable climate conditions in different parts of the continent. In addition, almost all the land is characterized by contrasting conditions of moistening connected with oceanic moisture interception by mountain ranges. High mountain ranges close to the sea explain not only high humidity on the wind-exposed slopes but arid and semi-arid conditions in inner areas or in coastal regions in the “rain shadow”.

Arctic, moderate and tropical air masses are transported above the continent through the year. Over most of Asia, in inner areas in particular, continental air masses are formed in winter and summer; these masses are cool in winter and warm in summer. Annual air temperature variations are significant. Strong seasonality is a specific climate feature in Asia; it depends on the thermal regime in Arctic, subarctic and moderate latitudes; at equatorial and tropical latitudes it depends on the precipitation regime. This seasonality is strongest in the central part of Asia. Despite total annual precipitation changing within wide limits, precipitation regime variations during a year are rather homogeneous on most of the continent.

During the cold season anticyclonic weather with little precipitation prevails over most of Asia (except the southwest). In many regions not more than 10% of annual precipitation is observed during three winter months. Mean air temperatures in January vary from -32°C or -36°C in the north, in the coastal areas of the Arctic Ocean, to $+25^{\circ}\text{C}$ in pre-equatorial regions. South of the tropic of Cancer negative temperatures are observed only at altitudes above 1500-2000 m. In equatorial regions a typical minimum is $+20^{\circ}\text{C}$ or $+22^{\circ}\text{C}$, and mean January air temperatures are $+24$ to 25°C .

In the summer time the rainfall situation is quite opposite. Most regions affected by monsoons, i.e. East and South Asia, as well as most of northern and central areas of the continent, are characterized by predominance of summer rainfalls (40-70% of annual precipitation). During this period low precipitation (5-10%) is observed only in the southwest of the continent.

Temperature differences between north and south of the continent are greatly smoothed. On most of Asia mean air temperatures in July are within 16 to 24 °C. On the Arabian Peninsula, however, as well as in West and South Asia they vary within 24 to 32 °C and greater. In the mountains of Central Asia mean monthly air temperatures during the warmest month vary from 8 to 12 °C. The lowest air temperatures are observed in the mountains of North Mongolia, Tibet and the adjacent mountain ranges. On the islands of Japan mean monthly air temperature in July is 20 to 26 °C; in high mountains it falls to 18-20 °C. On the Philippine Islands it rises to 27 °C. On the Malay Archipelago, Sri Lanka and Taiwan, the air temperatures vary within 24 to 28 °C.

Annual precipitation distribution is extremely uneven because of specific temperature regimes and global circulation processes. Maximum annual precipitation (2000-4000 mm and more) occurs on the southern slopes of the Himalayas, west mountain slopes of the Hindustan Peninsula and Indochina, on the islands of Indonesia. Charrapunji, one of the rainiest places in the world (more than 11000 mm/year) is found here.

Vast areas of West, South West and Central Asia are regions of a great water deficit. The deserts of the Arabian Peninsula, with total annual precipitation of less than 100 mm, as well as the Takla Makan Desert and inner Mongolia (Gobi Desert), are the most arid places in Asia. There are some places with annual precipitation less than 50-70 mm. The coast along the Arabian Gulf is an exceptionally arid place. Here the dry climate is accompanied by high air temperatures (absolute maxima attain 50-55 °C). Precipitation less than 100 mm is observed in the deserts of the lower Indus river reaches. Low precipitation (150-200 mm) is also observed on the plains of Central Asia. The most arid regions are: Kara Kum, Kyzyl Kum and Betpak Dala, the west shore of Lake Balkhash and the Sarakamysh Depression, where annual precipitation is less than 100 mm.

To the north of 65°N in Siberia, precipitation is lower than that at the same latitude in Europe. Precipitation tends to decrease eastward, which is explained by the continental climate. The exception is the northeastern pre-oceanic part of the continent.

In the Arctic zone precipitation ranges from 250 mm on the coast to 100 mm in the Yana and Indigirka interfluve and Verkhoyansk Depression. Precipitation to 200-250 mm occurs in Yakutia due to an anticyclonic regime in winter and the protecting effect of the mountains there. Precipitation attains 400-500 mm/year on the wind-exposed mountain slopes.

Distribution of precipitation in the east of the continent greatly depends on the monsoon circulation. Precipitation is distributed quite unevenly here because of the vast area and broken topography. Along the east coast of the continent precipitation tends to increase from north to south (from 500-600 mm to 2000-2400 mm). On the islands of Japan it is 1000-3200 mm; a great precipitation decrease is most evident westward, off the sea.

On the rest of Asia annual precipitation ranges from 400 to 1000 mm; in mountains it increases to 1200-2000 mm and higher on wind-exposed slopes. On the islands of South East Asia precipitation is higher, at 4000-5000 mm. On average, annual precipitation on

the continent (without islands) is 630 mm, and on the islands it is 2400 mm/year. The figure for the whole continent including the islands is 740 mm/year.

2.3. Human Activity

Human activity is one of the factors greatly affecting the hydrographic network and hydrological regime of water bodies. Its influence is most evident in the arid and semi-arid regions of Asia where much surface and subsurface water is used for irrigation, causing sharp changes in the hydrological regimes of river systems. Irrigation is connected with construction of numerous man-made water bodies: reservoirs, canals, main drains and different structures for water diversion and discharge. In 1995 irrigated lands in Asia occupied 175 million ha or about 70% of all irrigated lands on the planet. Moreover, about two thirds of irrigated lands are concentrated in three countries: China (about 50 million ha), India (about 50 million ha) and Pakistan (17.3 million ha). The natural hydrographic networks and hydrological regimes in these countries in the regions of intensive irrigation development have been transformed practically completely. For example, according to an approximate assessment, the total length of all irrigation canals in the Indus river basin exceeds 60 000 km; some main canals transport water from a river as far as 300 km.

Since the middle of the twentieth century the area occupied by irrigated lands in Asia has increased 2.4 times. It is possible to assume that irrigation will be further developed intensively on the continent. This is mainly explained by the following objective reasons: rapid population growth and widespread climate where farming cannot be developed without irrigation. Man-made reservoirs greatly contribute to the hydrographic network on the continent; the amount of water in these reservoirs is the largest in the world, if compared with the other continents. The total number of the reservoirs exceeds 16 000. The basic water storage (more than 90%) is concentrated in reservoirs with a capacity of more than 100 million cu. m; the number of such reservoirs exceeds 600. The total water volume in these reservoirs attains 1700 cu. km. Table 1 gives data on the 20 largest reservoirs of the continent.

Reservoir	Country	River basin	Year of filling up	Dam backwater, m	Total capacity, km ³
Bratskoye	Russia	Angara	1967	106	169.3
Krasnoyarskoye	Russia	Yenisei	1967	100	73.3
Vadi-Tartar	Iraq	Tigris	1956-1976	-	72.8
Zeiskoye	Russia	Zeya	1974	98	68.4
Ust-Ilimskoye	Russia	Angara	1977	88	59.4
Boguchanskoye	Russia	Angara	1989	70	58.2
Upper	India	Wainganga	1987	43	50.7
Wainganga	Kazakhstan	Irtysh	1960-1967	67	49.6
Bukhtarminskoye	Turkey	Euphrate	1995	175	48.7
Ataturk	Russia	Viliuy	1965-1972	68	35.9
Vilyuiskoje	China	Hwang Ho	1960-1962	90	35.4
Sanmenhia	Turkey	Euphrates	1974-1976	190	30.6
Keban	Russia	Yenisey	1980-1987	220	29.1
Sayanskoye	Kazakhstan	Ili	1970	41	28.1
Kapchagaiskoye	Iraq	Euphrate	1970	15	26.0

Razzaza Dyke	China	Hwang Ho	1990	172	24.7
Longyangxia	Russia	Khantaika	1970-1975	50	23.5
Khantaiskoye	China	Xinanjia	1960	100	21.6
Xinanjia	Kyrgyzstan	Naryn	1974	180	19.5
Toktogulskoye	Thailand	Quae Yai	1981	140	17.8
Srinagarind					

Table 1. The largest reservoirs in Asia

The total water area of all the reservoirs in Asia is 115 000 to 120 000 sq. km.

The distribution of reservoirs over the continent is not even. Most have been constructed on the Indochina and Hindustan Peninsulas, in China and on the edges of the Arabian Peninsula. The maximum number of reservoirs are to be found in China and India, but maximum water volume accumulated in the reservoirs is in Russia. More than 560 cu. km of river water are accumulated in the reservoirs of the Asian part of Russia. Most reservoirs in Asia were constructed in river valleys for seasonal and (more seldom) long-term runoff control. In some countries many reservoirs were made for flood control. For example the Vadi-Tartar Reservoir (the largest reservoir in Iraq) was made to divert flood water from the Tigris River.

The very first reservoirs were made on the continent many centuries ago on vast arid lands in Central, South and South West Asia. Before the middle of the twentieth century reservoirs were mainly made for irrigation and flood control. Later the reservoirs were made not only for irrigation but also for power generation. Many reservoirs have been constructed since the 1970s for these purposes in China, Vietnam, Laos, Indonesia, Malaysia, India, Pakistan, Bangladesh, Iran, Afghanistan and Turkey. At that time the largest multi-purpose reservoirs (for power generation, in particular) were made on large Asian rivers in Russia; the capacity of many reservoirs there exceeds 20 cu. km. There are also reservoirs in Asia made for fishery, navigation and recreation.

During recent years systems of multi-purpose reservoirs have been constructed in many countries of Asia, e.g. the system of four reservoirs on the Krishna river (India), a system of nine reservoirs on the Saskarya river (Turkey) and a system of reservoirs on the Angara-Yenisei rivers (Russia). Construction of multi-purpose reservoirs and intensive development of irrigation and urbanization provide the basis for development of complex water management systems. These consist of reservoirs and canals which not only provide river runoff control in time but also redistribute river runoff spatially, among different regions and river basins.

For example, by the beginning of the 1990s in India, the length of canals for water transfers exceeded 3200 km and more than 50 cu. km of fresh water were transferred by these canals every year. In the countries of Central Asia and Kazakhstan more than 40 cu. km of fresh water are transferred by ten long canals every year over a distance of 2800 km. The Great Kara-Kum Canal made during the 1960s is 1100 km long and takes about 11 cu. km/year of water off the Amu Darya river every year. Numerous canals extending over many hundreds of kilometers long have been made and are being built in China, Pakistan and in other countries of Asia where irrigation development is intensive.

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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).