# A World Geography of Irrigation

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CHAPTER 9

# SOUTH-WEST ASIA

The broad sweep of land from Afghanistan to Egypt, generally known as South-west Asia, is, by contrast with South-east Asia, an arid zone with few and limited humid areas. As a consequence, irrigation is essential for cultivating crops at almost all times of the year. Like other arid regions, South-west Asia suffers from the absence of large, level areas with readily available supplies of water. The only region which comes into this category is the Tigris-Euphrates Valley. Moreover, primitive methods of carrying and lifting water are still very widespread, while evaporation and seepage are prohibitive in their consumption of valuable water. In the area as a whole, there is considerable variation in the proportion of cultivated land under irrigation. It is highest in the more arid areas, so that whereas only about eight per cent of the cultivated land of Turkey is irrigated, it is approximately seventeen per cent in Syria, forty per cent in Iran, sixty-five per cent in Afghanistan and virtually one hundred per cent in Saudi Arabia.

TABLE 4

| Countries | Irrigated Areas ('000s of Acres) | Year |
|---|---|---|
| Afghanistan | 509 | 1961 |
| Iran | 4,900 | 1960* |
| Iraq | 7,195 | 1958* |
| Israel | 311 | 1959 |
| Jordan | 79 | 1954 |
| Lebanon | 175 | 1959 |
| Saudi Arabia | — | — |
| Syria | 1,176 | 1959 |
| Turkey | 4,912 | 1957 |

**South-west Asia: Irrigated Areas**

(Based on figures cited in *Economic Developments in the Middle East, 1959-61*, United Nations, New York, 1962, p. 99; and *Economic Survey of Asia and the Far East*, United Nations, 1963, p. 125.)

* Figures issued by national governments.

In South-west Asia as a whole, probably twenty per cent of the cultivated area is irrigated.[1]

The figures in Table 4 are only approximations. The United Nations publishes figures which are supplied by each country but makes no attempt at evaluation. In the absence of accurate surveys and precise data, it is impossible to judge the accuracy of the statistics. In addition, conflicting figures of the areas under irrigation are issued, frequently referring to the entire area which is occasionally supplied with water. The only countries in South-west Asia with considerable extents of irrigated land are Iraq, Turkey and Iran.

The most common methods of irrigating are by furrow and basin, although terrace irrigation is also found in places. Kanats or karez are also widespread, especially in Iran and Afghanistan, and although difficult to construct and restricted to certain types of terrain, they are more efficient than other methods of irrigation because they do not suffer loss by evaporation.

Afghanistan has approximately half a million acres under irrigation, of which about two-thirds are irrigated by water taken from rivers; one-eighth is irrigated by water from springs and the rest from underground water. At present, more than half of this irrigated land is in the northern piedmont, where rivers flowing north from the hills enter the plain to form irrigated tracts at levels generally between 1,200 and 1,500 feet, on which wheat, fruit and maize are grown. In the south-west desert area, kanats are common in oases like Farah, Girish and Kandahar, where they support a variety of field and market-garden crops; in the west, in valleys around Herat, rice and cotton are grown on narrow, irrigated strips along the riverbanks. In recent years Afghanistan has undertaken a number of large-scale projects, such as that in the Helmand valley where new construction, including the Kajakai Dam on the Helmand River and the Arghandab Dam on the Arghandab River, has led to a considerable extension of the irrigated area (Fig. 20). The forty-three-mile Jalalabad Canal east of Kabul will provide water for 75,000 acres in the Kabul valley.

In Iran only eleven per cent of the land is under cultivation, but since large tracts are constantly kept as fallow land, the actual land under various crops is less than four per cent, or approximately twelve and a half million acres. Of this, only about forty per cent, or 4·9 million acres, is irrigated, though it yields more



than half the total agricultural products. In the next few years it is hoped to increase Iran's irrigated area to over six million acres. Most irrigated farming currently relies mainly on wells, kanats and crudely formed channels leading from rivers and streams. The most important agricultural area in the country is in north-central Iran, in the Elburz Mountains and Caspian Plain region, where

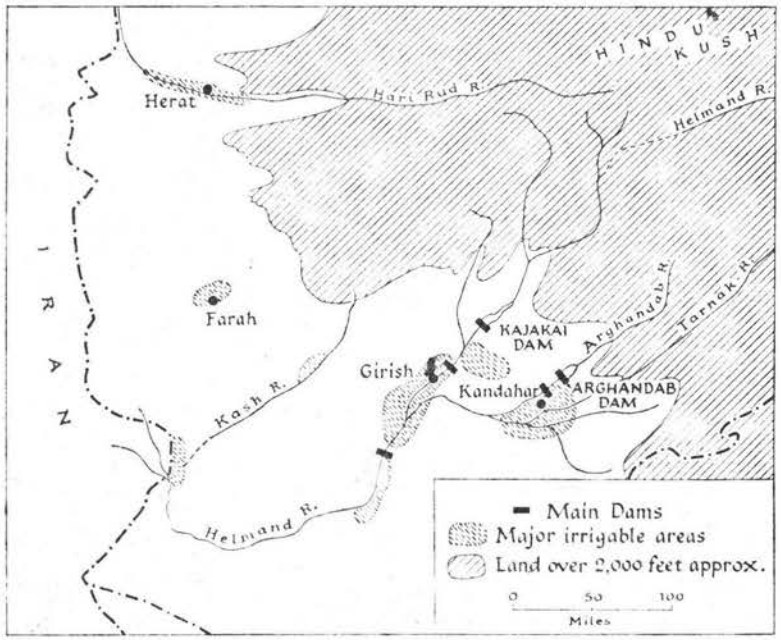


FIG. 20. Irrigation in the Helmand Basin, Afghanistan.

irrigation is used principally to grow grains, cotton and rice. Farther to the north-west is the Azerbaijan region where irrigation is normally essential and where, fortunately, adequate supplies of water are available from streams. Wheat is the major crop there. The largest but least developed region of Iran is the arid Central Plateau, which supports very little agriculture except in a number of peripheral oases and irrigated alluvial fans at the base of the central Elburz Mountains, where cereals, fruit and vegetables are grown.

The most promising area in Iran for the development of large-scale irrigated agriculture is the Plain of Khuzestan in the south-

west. Part of the Tigris-Euphrates lowland, it is the only plain of any size in the country and is approximately 16,000 square miles in extent. Formerly the site of an ancient, large-scale irrigation system, until recently it supported only a few irrigated areas along the riverbanks, in which rice, wheat, dates and fruit were grown. It was thought that the whole area could be irrigated by the construction of one major irrigation system, and it was with this object in view that the Greater Dez irrigation project was recently inaugurated. Since 1961, approximately 50,000 acres in this region have been brought under irrigation, and the success of this pilot scheme has encouraged the government to plan on making another 250,000 acres irrigable. In March 1963 the Muhammed Reza Shah Pahlevi Dam on the Dez River, built where the river flows rapidly through the Zagros Mountains before debouching into the plain, was dedicated. With a height of 647 feet, at present the highest dam in the Middle East, it will cost more than twenty million pounds and provide year-round irrigation, hydroelectricity and flood control. From the dam a network of concrete channels will release irrigation water to fifty-eight villages in a pilot project, and when the canal system is completed it will measure twenty-one miles in length and provide water for 360,000 acres. Higher upstream on the Dez near Hamadan, another dam, the Shahnaz, was inaugurated in June 1963 and marks a further stage in the project (Fig. 21).

Other dams completed in the last few years include the Karaj Dam near Tehran and the Sefid Rud Dam on the Gilan Plain in northern Iran. The Karaj Dam was inaugurated in 1961 and, with an associated diversion dam near Bilghan and a canal network, will help to alleviate Tehran's water shortage and make possible the irrigation of a considerable area. The Sefid Rud Dam, built at the confluence of the Sefid Rud and Ghezel Ozan rivers, was inaugurated in 1962 and will provide water for about 300,000 acres, mainly for the cultivation of rice. An associated canal system is under construction and is due for completion in 1967.

A government-sponsored scheme for drilling wells has also helped to increase the area of irrigated land. Between 1960 and 1964 almost 1,500 wells were drilled, and others are planned, especially in the Garmsar, Qazvin and Neishabour areas in the general region of Tehran. The normal irrigation capacity of these wells is between 175 and 250 acres of land, but as few



peasants own more than between twelve and twenty-five acres, they are encouraged to form co-operatives to run the wells, which are developed with the aid of government loans. Although considerable progress is being made in some parts of Iran, yet the development of irrigation in the country as a whole faces many difficulties: water resources are unevenly distributed, much of the

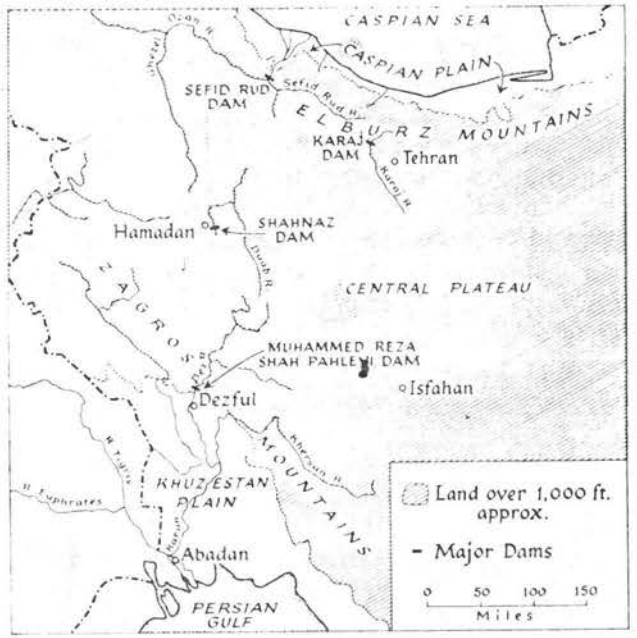


FIG. 21. Major dams in Iran.

terrain is unfavourable, and development schemes are costly. Further, insufficient technical knowledge on the part of both planners and farmers, such as their ignorance of soil types and the effect of irrigation upon them, has frequently resulted in short-sighted planning and inefficient irrigated farming. Consequently, the expansion of irrigated agriculture in Iran will be a slow and costly process.

In 1958 Iraq had about seven million acres under irrigation, most of it in the plain of the Tigris and Euphrates rivers. Although the development of large-scale perennial irrigation has gathered momentum in recent years, the older, more primitive

forms of inundation and flood irrigation are still predominant. In the lower valleys, flood irrigation is most important, and annually the rivers inundate large areas devoted to rice-growing. Unfortunately, much of the land, particularly in the delta area, suffers from wasteful and inefficient irrigation farming and is subject to salinity. It is estimated that as much as twenty per cent of the cultivated land in this region has been made worthless in this way, resulting in 'long streches of poor barley, without apparent limits, alternating with long stretches of camel thorn, derelict salt-encrusted land and expanses of last year's flood water'.[2]

Higher up the valleys, primitive channels are dug to lead the water by gravity from the rivers into the fields, in which barley and wheat are grown. In many areas only one crop a year can be grown, as the summer level of the river may be too low. As an encouragement to double cropping, pumps are increasingly used to provide a more certain year-round supply, and they enable barley, millet and wheat to be grown in winter and rice in summer. The main factor limiting the use of such pumps is their high cost.

In recent years, strenuous efforts have been made to establish an over-all co-ordinated scheme of large-scale perennial irrigation on the Tigris-Euphrates plain to replace, for the first time in the modern era, the present makeshift system. The scheme requires a great deal of capital investment, provided partly by oil royalties and partly by foreign aid. It was announced in March 1965 that the Soviet Union would help Iraq to finance the construction of a dam and power station on the Euphrates costing an estimated fifty million pounds. The only major irrigation works constructed before the war were the Hindiya Barrage in 1913 and the Kut Barrage in 1939. During the last decade, three other major water-control schemes have been completed: the Wadi Tharthar flood-control scheme on the Tigris, the Habbaniya flood-control and irrigation scheme on the Euphrates, both inaugurated in April 1956, and the Dokan Barrage on the Lesser Zab, inaugurated in 1958 (Fig. 22.) The Wadi Tharthar scheme includes a new barrage at Samarra and the Habbaniya scheme has a new barrage at Ramadi. In addition, the Derbendi Khan Dam on the Diala River near the Iranian border was initiated in 1961 and, with a storage capacity of three million cubic metres, will control flooding on the Diala River, eliminate water shortages, and expand the area under summer cultivation. A number of drainage projects have also



recently been inaugurated to reduce waterlogging and salinity in lands presently irrigated.

In December 1961 the Iraq government issued a detailed economic plan aimed at doubling the national income in about ten years. The plan envisages considerable expenditure on irrigation


FIG. 22. Major irrigation works in Iraq.

and drainage projects, water storage and drilling. Among the major projects are (*a*) the Dibbis Dam on the Lesser Zab, presently under construction and the key structure in a scheme designed to irrigate large areas in the Kirkuk and Hawija region; (*b*) the Eski-Kalak project on the left bank of the Greater Zab River, half-way between Arbil and Mosul, now under construction and designed to irrigate more than 30,000 acres; (*c*) the Gharraf project and associated Shattra drainage west of Amara, on which work is under way and which, it is hoped, will eventually render more than 175,000 acres cultivable; (*d*) an artesian well programme

in the northern and southern deserts, where over 800 wells had been drilled by 1962 and where an additional thousand are intended.[3]

While large areas of land could certainly be made cultivable if water could be stored for irrigation, possibly as much as five million acres in all, it is open to question whether the extension of cultivation is the most effective way of developing the country's agricultural potential. As Doreen Warriner writes in her excellent book, *Land Reform and Development in the Middle East*, 'The tendency to regard the extension of cultivation as the main aim of development derives from the engineer's approach which has dominated most thinking about the future of the country. Yet the immediate need is not to add to the area already cultivated but to get better cultivation on the land already in use.'[4] Lord Salter has argued that the present water storage works are sufficient and that no new, big dam scheme should be implemented. He advocates a complete change of policy whereby drainage would take priority and money would be invested not in new works but in increasing agricultural productivity on lands already farmed.[5]

Syria, unlike Iraq, has few extensive irrigation schemes but many small irrigated areas instead. A recent estimate places the extent of irrigated land at approximately one and a quarter million acres.[6] The most extensive and probably the oldest irrigated tract in the country is the Damascus oasis, comprising about 400 square miles, which is supplied with water from the Barada River and its tributaries flowing down from the Anti-Lebanon and Herman ranges to the west. Intensively cultivated, it produces vegetables, citrus fruit, cereals and cotton. Irrigation is also important along the Euphrates valley (Fig. 23), where it is hoped that water from the Euphrates will eventually provide for the irrigation of more than 800,000 additional acres.

A number of projects are in hand there, including that at Youssef Pasha where wheat, rice and cotton are the principal crops. Another recent project is that along the coast on the Sinn River near Latakia, where more than 13,000 acres are being brought under irrigation. Along the Orontes valley the area of irrigated land has been extended in the last thirty years by the construction of a barrage raising the level of Lake Homs and irrigating 60,000 acres by means of gravity channels running between Homs and Hama. A comparable area in this region is irrigated by private



pump-schemes, which provide water for the cultivation of wheat, cotton and sugar beet, while the increasing use of pumps to tap deep artesian wells enables cotton to be grown around Aleppo. Below Hama in the Ghab, a government reclamation scheme that is well advanced will eventually make more than 170,000 acres irrigable. In February 1961 the Rastan Dam was completed there, making more than 60,000 acres irrigable, and in 1962 the Mahared

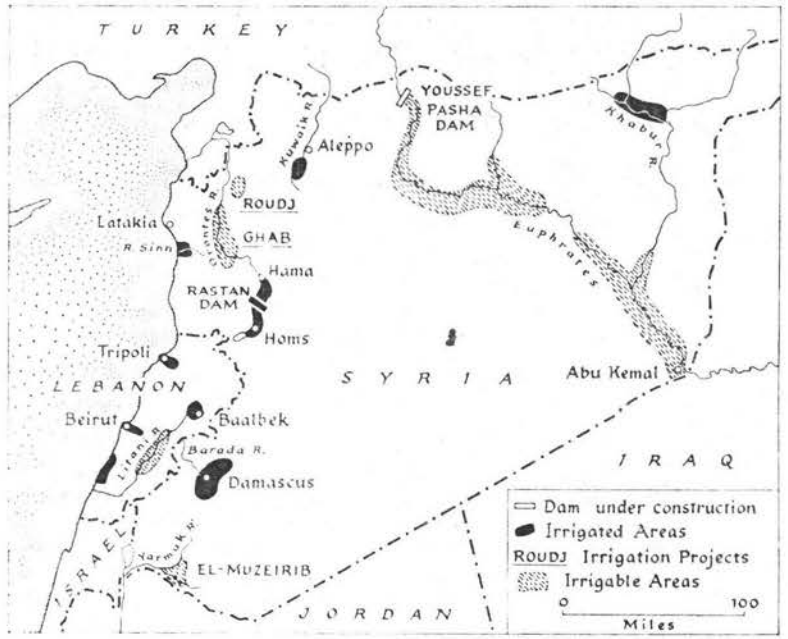


FIG. 23. Irrigated areas in Syria and Lebanon.

Barrage was inaugurated which will supply water for a similar area when completed. The Roudj project, south-west of Aleppo, was one-third completed by June 1963 and will eventually irrigate nearly 12,500 acres. Other state-operated schemes include those along the Khabur River, where some 10,000 acres are irrigable, and along the Kuwaik River, south of Aleppo, with over 30,000 acres. In southern Syria, along the Jordan border, a recent development that is part of the Great Yarmuk project is a headwater irrigation programme to provide controlled winter irrigation and expanded summer irrigation in the El-Muzeirib region; it is hoped

eventually to make 16,500 acres irrigable. As Syria is predominantly an arid land, any considerable extension of agriculture will depend upon further irrigation developments; given substantial capital investment, Syria could conceivably triple her present irrigated area.[7]

Because of a more adequate supply of rainfall, Lebanon is less dependent upon irrigation than Syria and has a smaller irrigated acreage, estimated at slightly more than 90,000 in 1950 and 175,000 in 1959.[8] The most important agricultural area is the humid coastal plain, backed by limestone massifs which act as natural reservoirs and release water in the form of springs feeding perennial streams. These supplies of water make irrigation possible both on the coastal plains, where wheat, vegetables and fruit are grown, and at much higher levels where the occurrence of impervious beds brings the water near the surface, where it is led into a system of terraces on which vines, bananas and oranges are grown. Beyond the coastal range is the Bekka, a fault valley lying between the western ranges and the Anti-Lebanon and Herman ranges to the east. Because the climate is dry, cultivation is only possible where infrequent springs provide water for small, widely separated oases, but it is an area in which irrigation could be greatly extended. Lebanon has a number of schemes for extending her area of irrigated land, including the multi-purpose Litani project which is under construction and participation in a project for changing the courses of some of the headstreams of the Jordan River, a scheme which has caused considerable friction with Israel.

Israel has about 340,000 acres under irrigation, based chiefly on water derived from wells and pumps in the areas around Tel Aviv, in the upper Jordan valley, along the Kishon River and in parts of the southern Negev Desert. The major crop is citrus fruit, and sprinkler irrigation, using modern, Californian sprinkler equipment, is becoming increasingly common. As the southern two-thirds of the country is arid, it has been necessary to transfer water to it from the humid northern area. Unfortunately, Israel is nearing a point at which its water resources will be taxed to the limit, since apart from the Jordan the country is poorly endowed with rivers, and storage is often difficult because of the porous nature of the soils. Moreover, evaporation and transpiration cause considerable wastage of water, and excessive pumping of ground water in the Central Plain has brought about a decline in the water



table and has accelerated salt-water intrusion near the coast. In an effort to conserve water, Israel has had to resort to reclaiming sewage effluent and to damming gullies to intercept floodwaters in the rainy months. For future demands, only two major sources of water are available, the salt water of the Mediterranean and Red seas and the fresh water of the River Jordan.

Mekorot, Israel's national water authority, has estimated that the country's water needs will rise by 500 million cubic metres by 1980, when the population is expected to be about four million. Three-fifths of this demand will be met by tapping remaining conventional and semi-conventional sources, including the Jordan River, Lake Tiberias, unused ground-water supplies, intercepted floodwaters and reclaimed sewage. For the rest, desalinated water will be required to make up the deficit and to dilute brackish waters which would otherwise be unfit for irrigation. There is little doubt that it is technically feasible to produce a desalination system extensive enough to provide the necessary water. The chief problem is to reduce production costs sufficiently to make such a system an economic proposition.[9]

Realising the urgency of the problem, the Israeli government, in partnership with an American corporation, has set up a desalination demonstration plant at Eilat on the Red Sea, using a process by which water is frozen in a vacuum to produce salt-free ice crystals, which are then melted. At present, this is far too expensive to be economic, but it is hoped that substantial reductions will soon be possible.

Another joint study by technologists of Israel and the United States recommends the construction of a nuclear plant on the Mediterranean coast, south of Tel Aviv, to produce 200 megawatts of electricity and desalt 100 million cubic metres of sea water a year. Other proposals have been put forward to carry desalinated water inland to a reservoir of Israel's national water grid, so that it can then be delivered throughout the country.

Other research projects include an electrodialysis plant at the Negev Research Institute, where salt is separated from brackish water by drawing electrified particles through membranes by means of electric fields. Much work is also being done in the field of water conservation, including experiments to reduce evaporation in reservoirs and to store water underground. In the Negev Desert a new method of irrigation has been introduced whereby water is

brought directly to the roots of plants by means of narrow, underground plastic pipes. In this way, there is little wastage of water, and it is estimated that this method will save up to thirty-five per cent of the water for further use in irrigation.

As far as a supply of surface water is concerned, Israel, like Jordan, will have to depend primarily on the River Jordan and its tributaries. Any scheme to utilise this source will also affect Lebanon and Syria, as some of the headwaters of the Jordan originate in these countries. The most effective use of the water resources of the Jordan would undoubtedly be achieved by developing the valley as a whole. Several plans along these lines have been put forward, including the Jordan Valley Plan or the Unified Water Plan, drawn up in 1955 by Eric A. Johnston. Although his proposal was accepted by the Israelis, it was finally rejected by neighbouring Arab nations because of their intense hostility towards Israel. As a result, Israel and Jordan have decided to proceed independently with separate aspects of the unified plan, with American financial assistance. The danger of open conflict over the water of the Jordan has grown more acute recently as a consequence of an Arab plan to divert several of the headwaters of the Jordan before they reach Israel.

Israel regards the development of the Jordan River as an integral part of her national water system, which at present consists of three main sections: (*a*) the Yargon-Negev section, completed in 1955 and fed by wells east of Tel Aviv to provide irrigation for the Lakhish area south of the city, (*b*) water from north Galilean creeks to irrigate the inner portions of the Esdraelon valley, and (*c*) an area around Lake Huleh, which has been drained and reclaimed. In order to link these and other existing systems together as well as to extend irrigation south into the Negev Desert, Israel has begun the construction of a trunk line, the National Water Carrier, to take water directly from Lake Tiberias, which is fed by the Jordan, and to carry it 125 miles south into the Negev (Fig. 24). As Lake Tiberias is below sea level, the water has to be lifted by three electrically driven intake pumps 812 feet through a penstock 1·3 miles long. It then enters a canal eleven and a half miles long and so into a storage reservoir, from which it passes into the pipeline. When the system becomes fully operational in 1970, it is intended to carry an average water flow of 320 million cubic metres annually. Because Lake Tiberias features prominently in



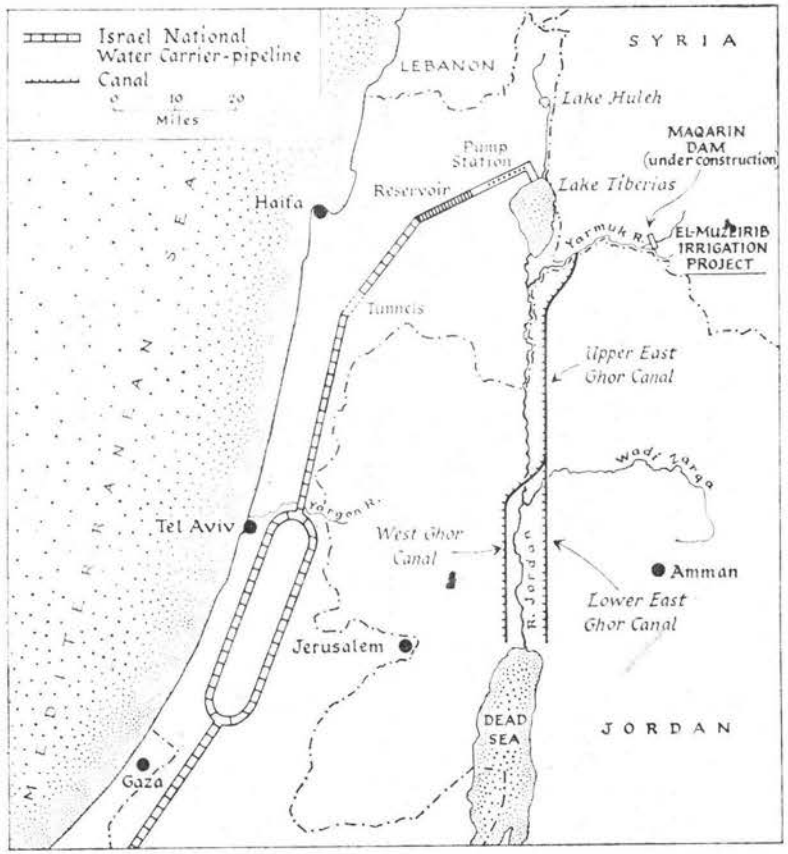


FIG. 24. The Israel National Water Carrier and Jordan Valley Plan.

this scheme as a means of water storage, it will be necessary to reduce its present high degree of salinity by capturing saline springs which now flow into the lake and diverting them into the Dead Sea.

Jordan is currently using the waters of the Jordan's main tributary, the Yarmuk, in her Great Yarmuk project which she is carrying out in co-operation with Syria. It has three main components: (*a*) a headwater irrigation programme to provide irrigation for the El-Muzeirib region of southern Syria, (*b*) the Upper East Ghor Canal system, presently under construction, to divert water from the Yarmuk along the foothills of the eastern Jordan valley,

in order to irrigate some 30,000 acres of previously marginal and undeveloped land between the Yarmuk and the Wadi Zarqa, about forty miles to the south, and (*c*) the Maqarin Dam, to be constructed across the Yarmuk on the Jordan-Syria border to store and control the total winter flow of the river (Fig. 24). The scheme will lead to the generation of hydroelectricity, to be shared by Jordan and Syria, and the provision of irrigation water, mainly for Jordan, to irrigate 125,000 acres along the lower Jordan valley. By the end of 1965 the first stage of the East Ghor Canal was completed and was reputedly providing water for the cultivation of 40,000 acres. It is interesting to note that the separate endeavours of both Jordan and Israel are largely in tune with the Unified Water Plan, whose provisions have been very closely followed because of the physical realities upon which they were based.[10]

In 1958, Jordan had approximately 120,000 acres under irrigation,[11] the bulk of which was along the east bank of the Jordan in valleys formed by perennial streams flowing into the main river. In these relatively small tracts, highly specialised, intensive fruit-farming is carried on, involving a heavy application of capital and labour to the land in order to obtain maximum yields. The water is brought to the orchards through concrete and masonry conduits and flumes. Vegetables, planted in terraces, are double-cropped and intercropped, and bananas and citrus fruit are produced to be marketed all year round. In the past ten years, private well-boring in the Jordan valley around Jericho has led to the intensive cultivation of about 40,000 acres, also for orchard and market-garden crops. This kind of agricultural economy provides a complete contrast with the bulk of Jordanian agriculture, which is non-irrigated and extensive, lacking in mechanisation and the use of fertilisers and giving relatively low yields. Other small irrigated areas include an interesting project of the Arab Development Society, a private, philanthropic society which has succeeded in irrigating and cultivating 6,200 acres of salt desert land near Jericho.[12] The government has sponsored a number of small-scale projects, including one for the proper control of run-off water in the more humid north, a scheme that has made considerable amounts of water available for livestock in areas where it has not previously been available. In addition, a number of schemes have been proposed for wadis leading into the Jordan valley and



near springs and wells farther inland. Several such operations have been carried out, making 12,800 acres of irrigable land available for cultivation, while others have been abandoned either because they could not be put into effect successfully or because it was found advisable to consider them as integral parts of the Jordan valley scheme.

In the Arabian peninsula, cultivation is based very largely on oases like Medina, near the Red Sea, and Riyadh and Anaiza farther north. Saudi Arabia, a true desert country, has less than two per cent of its area under cultivation, of which eighty per cent is entirely under irrigation.[13] Three main types of irrigation are in use: (*a*) perennial irrigation, by far the most common, in which water is lifted in skin bags from pits and wells by donkeys and camels, though a number of turbine and centrifugal pumps are currently in use, (*b*) the drawing of water from springs through tunnels in the hillsides, and (*c*) the construction of earthen diversion dams to divert occasional floodwaters through ditches into prepared bordered or dyked areas. Cultivation is based mainly on tree crops, including dates, deciduous and citrus fruits and coffee; and grains, principally millet, wheat and rice. Dates are by far the most important single crop and occupy a sizable percentage of the total irrigated area. A number of large-scale projects have been planned, including the Akramah Dam which was completed in 1959 and the Wadi Jiza Dam which has been under construction since 1960 and which, when completed, will supply water to 50,000 acres of newly irrigated land near the Yemen border. It is also intended to reclaim many ancient dams which have fallen out of use. Unfortunately, methods of irrigation are too often rudimentary and inefficient, and it is not uncommon for the Arabian farmer to use far more water than is necessary to grow his crops, with the result that waterlogging and salinity have already become very evident and some areas have degenerated into malaria-infested bogs. Proper drainage exists in only a very few areas, and there is an urgent need for adequate drainage systems. Moreover, the indiscriminate pumping of wells at Riyadh has caused a serious lowering of water tables.[14]

Irrigated agriculture is very limited in the sheikdoms of the Persian Gulf. Bahrain is best supplied with water, and free-running springs promote the cultivation of date palms, fruit, cereals and fodder crops. In Qatar a few wells support gardens

and date palms, and in Trucial Oman artesian water supplies are used for irrigation in a few oases like Sharjah and Buraimi. Muscat and Oman are more favoured and use water from springs and wadis running down the north and east slopes of the Jebel Akhdar Mountains, and in the Yemen wells and tanks allow some cultivation at higher levels, usually above 4,500 feet.

Until recently, irrigation in Aden was restricted to a few limited areas in valleys, using water from laboriously dug wells worked by animal power. Kanats are also found in some places, and cultivation in the Wadi Hadhramaut relies partly on springs which emerge from the base of the cliffs. Traditional crops are largely subsistence and include sorghum, millets, sesame and dates, with wheat, barley and some coffee at higher altitudes. Since the end of the war, efforts have been made to extend and improve irrigation by the establishment and development of farmers' co-operatives, which now undertake major irrigation works. The pilot scheme for such associations was begun in the nineteen-forties in the Abyan Plain, utilising the floodwaters of the Wadi Bana and the Wadi Hasan. Earth dams were constructed and long-staple cotton was introduced as the principal crop. The irrigated area was gradually extended and it now covers more than 50,000 acres. Since then, a similar association has been set up in the Lahej area to use the floodwaters of the Wadi Tiban, and cotton is now being grown there. In other parts of the Protectorate, particularly in the Wadi Hadhramaut, sakia are gradually being replaced by oil pumps, and a number of tube wells have been installed near Zinjibar. Further extension of the irrigated area is possible, and a survey has been undertaken at Beihan with a view to using the floodwaters of the Wadi Behan.

Turkey has an irrigated area of approximately five million acres, representing ten per cent of the cultivated land. It is doubtful, however, if the whole of this area is utilised, since inadequate drainage and salination in some places have discouraged farmers from changing from dryland to irrigation farming. Moreover, where irrigation farming is practised, it is often done by means of unsuitable crop rotations and the wasteful use of water with primitive techniques. Nonetheless, in the last fifteen years the government has invested considerable capital in the development of Turkey's abundant water resources. In recent years a number of large dams have been completed, including the Seyhan



Dam near Adana, the Sariyar Dam on the Sakarya River near Ankara and the Gediz Dam in western Turkey (Fig. 25). Some doubt has been expressed as to the wisdom of using Turkey's scant financial resources on a few large projects, and a recent report of the International Bank recommends that the government should restrict itself to a programme of small-scale irrigation based on earthen dams and the use of underground water.[15]

The largest irrigated area in Turkey is along the southern coast in the Seyhan Plain, where the recent systematic irrigation of an


FIG. 25. The water resources of Turkey.

area of 30,000 acres, based upon a dam constructed just north of Adana, has resulted in the cultivation of cotton, maize and rice. There are plans to reclaim and irrigate further sections of the Seyhan lowlands and to extend irrigation to about 350,000 acres. Along the western Aegean coast, irrigation canals are under construction to provide water for an area that will eventually exceed that of the Adana irrigation scheme. At present, however, irrigation is more common in the northern coastal valleys, where rice, cotton, sugar beet and vines are grown. Farther inland, two dams have been constructed on the Menderes River below Danizli, which provide water for over 100,000 acres, and there is a scheme to build a dam on the Porsuk River above Eskesehir to water an interior valley on the margins of the plateau. On the Central Plateau itself, large-scale irrigation is most difficult and has not been very successful mainly because many of the rivers are heavily charged with silt, so that storage reservoirs fill up rapidly and become useless, and also because few of the rivers are suitable for irrigation, being deeply incised into the plateau. As a consequence,

small-scale irrigation is more common. One of the few large barrages is the Sariyar Dam near Ankara, which provides water for the cultivation of cereals and vegetables. In eastern Turkey, the Malatya region on the upper reaches of the Euphrates is an important fruit-producing area, where it is hoped eventually to irrigate 250,000 acres. Higher up the Euphrates, thirty miles north-west of Elazig, is the site of the proposed Keban dam and hydroelectric project. The cost of the project will be at least £125 million, and Turkey has recently been trying to raise money in Western Europe to finance the scheme. Although it is primarily designed to meet increasing power needs and to lay a basis for the creation of heavy industry in eastern Turkey, it will also provide irrigation for a large area of arid land.

Cyprus had approximately 200,000 acres under irrigation in 1959,[16] of which thirty per cent was in the form of perennial irrigation. The remainder was irrigated seasonally, in winter and spring. Although perennial irrigation is limited in extent, it is much more important than seasonal irrigation and promotes the cultivation of cereals, market-garden produce, especially citrus fruit and vegetables, and vines. Mechanical devices for lifting water have been increasingly used in recent years, including water-wheels, windmills and pumps. Also common in Cyprus are chains-of-wells, some of which have been in use for centuries and which are similar to the kanats of Iran and Afghanistan. They tap shallow aquifers and commonly lead water down conduits which are constructed at a gentler inclination than the fall of the surface above so that the water will eventually reach the surface. Many chains-of-wells were constructed in the latter half of the nineteenth century and in the early years of the twentieth. Springs are also important local sources of water, notably in the Kyrenia Range. Undoubtedly, irrigation practice in Cyprus could be more efficient but there are considerable difficulties, including complicated land tenures and water rights, the common practice of flood rather than furrow irrigation, with its wasteful use of water, water losses due to leaky, silted and overgrown channels, and a general lack of technical knowledge.[17]



*Bibliographical References*


1. Cressey, G. B., *Crossroads, Land and Life in Southwest Asia* (Lippincott, Chicago), 1960, p. 159.
2. Warriner, D., *Land Reform and Development in the Middle East* (Oxford University Press), 1962, p. 115.
3. *The Iraqi Revolution in Its Fourth Year* (High Commission for the Celebrations of 14th July, Baghdad), 1962, p. 176 *et seq.*
4. Warriner, *op. cit.*, p. 116.
5. Lord Salter, *The Development of Iraq, A Plan of Action* (Caxton, London), 1955, p. 49.
6. Walker, D. S., *The Mediterranean Lands* (Methuen, London), 1962, p. 442.
7. Fisher, W. B., *The Middle East* (Methuen, London), 1961, p. 418.
8. Ginsburg, N. (Ed.), *The Pattern of Asia* (Constable, London), 1960, p. 807.
9. 'Finding Water for the Promised Land', *The Times*, London, March 24, 1965, p. 13.
10. Garbell, M. A., 'The Jordan Valley Plan', *Scientific American*, CCXII, No. 3, March 1965, pp. 23-31.
11. Pateau, R., *The Kingdom of Jordan* (Princeton University Press, New Jersey), 1958, p. 121.
12. Harris, G. L., *Jordan*, Survey of World Cultures Series (Hraf Press, New Haven), 1958, p. 154.
13. Twitchell, K. J., *Saudi Arabia* (Princeton University Press, New Jersey), 1958, p. 21.
14. Lipsky, G. A., *Saudi Arabia*, Survey of World Cultures Series (Hraf Press, New Haven), 1959, p. 214.
15. Eren, N., *Turkey, Today and Tomorrow* (Pall Mall Press, London), 1963, p. 118.
16. *Cyprus, 1959* (Her Majesty's Stationery Office, London), 1961, p. 70.
17. Christodoulou, D., *Cyprus: The Evolution of the Rural Land Use Pattern* (Geographical Publications, Bude), 1959, p. 114 *et seq.*

CHAPTER II

# AFRICA

In 1963 Africa had approximately fourteen million irrigated acres, representing only 3·8 per cent of the world's total irrigated acreage. Although there are large tracts of land which are arid and semi-arid and which would consequently benefit from irrigation, Africa is unfortunate in having few alluvial valleys whose river regimes or surface contours are as favourable as those in the Nile Valley. Nor, apart from the Nile Valley, is there any long-standing, traditional irrigated agriculture. Therefore, the Nile Valley is by far the most important single irrigated area in Africa, with more than eight million irrigated acres, three-quarters of them in Egypt and the rest in the Sudan. Elsewhere irrigation is relatively limited and sporadic, with the main areas being along the Mediterranean coast of North-west Africa, along parts of the Niger and Senegal rivers in West Africa, in Rhodesia, in the Union of South Africa and in Madagascar (Table 10).

TABLE 10

| Country | Irrigated Land ('000s of Acres) |
|---|---|
| Algeria | 500 |
| Egypt | 6,400 |
| Ethiopia | 74 |
| Kenya | 17 |
| Libya | 250 |
| Madagascar | 1,625 |
| Mali | 150 |
| Morocco | 540 |
| Rhodesia | 40 |
| Somalia | 50 |
| South Africa | 1,500 |
| South-west Africa | 25 |
| Sudan | 2,500 |
| Swaziland | 28 |
| Tanzania | 100 |
| Tunisia | 120 |

**Africa: Major Irrigated Areas**

(Based partly on figures cited in Richard M. Highsmith, Jr., 'Irrigated Lands of the World', *Geographical Review*, LV, 1965, pp. 385-86.)



It has been estimated that the extent of irrigation in Africa could be tripled, partly by extending the present irrigated areas and partly by bringing new areas under irrigation. The latter are mainly the perennial and seasonal swamps, which are a striking feature of Africa, covering about 125,000 square miles and including the Niger delta, Lake Chad, the freshwater swamps of Nigeria, the Congo Basin and the Kafue Flats in Zambia. But if such immense areas are ever to be reclaimed, vast pumping and drainage schemes will be required, at great cost.

Other areas of potential development are in the vast desert and semi-desert regions of Africa, where water is frequently available from underground sources, which most usefully occur in troughs between fixed sand dunes, in alluvial fans at the foot of mountains and in the beds of seasonal streams. Although sand-dune water is frequently used by pastoral tribes, alluvial fan water remains, in the words of G. H. T. Kimble, 'probably the one underexploited source of ground water in arid Africa. It is not every society that has acquired the knack of tapping this underground supply at its most rewarding points or of using what it taps with efficiency.'[1] In these parts of Africa the so-called dry streams or wadis are probably the most widespread source of water. However, many wadis are unreliable and may either dry up entirely or are subject to occasional flooding, though they frequently retain water in the subsoil, which can be reached by digging shallow wells. In the true desert the only major sources of water are either rivers, which rise in wetter areas and may, like the Nile, sustain their courses across the desert; or underground water, which moves beneath the desert from distant sources. Where the water-bearing rocks are sufficiently close to the surface, the water can be obtained by wells and boreholes, frequently in sufficient quantities to support oases. While it is almost certain that the underground water resources of the African deserts are considerable, their development faces certain problems. Firstly, it is often very difficult to locate the water, which being underground may leave no clue on the surface of a featureless desert. Besides, once it has been located, the ground water may be too hot for use with growing plants; some of the water from the deeper Nile Valley wells exceeds 100°F. in temperature.[2] Finally, if ground water is to be utilised on a large scale, a great deal of capital will be required. In spite of these difficulties, the desert and semi-desert areas of Africa are not

without their promise for the future, and Egypt, for example, has begun to explore the possibility of tapping the vast water table of the Sahara. As the demand for water grows in these areas, similar projects are likely to become more common elsewhere.

Perhaps just as important as finding new supplies of irrigation water is managing to conserve and use efficiently the water presently available. In too many areas, both in Africa and elsewhere, water is used wastefully, and salinity and waterlogging have resulted. Nor are large irrigation schemes by themselves any guarantee of increased agricultural productivity. In Morocco, instead of bringing about much needed agricultural expansion, such schemes have further favoured speculation and large landholdings, and in the newly irrigated lands of Imfout, farmers have simply cultivated less land better, leaving the rest fallow, thus keeping the same standard of living at considerable expense to the state.[3] A more successful way of extending and improving irrigated agriculture in many areas might be by installing simple, small-scale, water-conserving dams rather than constructing large, expensive projects. One of the most common simple devices is the 'subsand dam', consisting of a cement barrier placed across the sand bed of a river which is underlain at no great depth by an impervious formation. The barrier retains some of the water, which is then drawn off through pipes and similar devices. In addition, as the water percolates through and lies below the surface of the sandy bed, the sand will rise in time to the top of the barrier, so that the loss due to evaporation from the surface will be less than in the case of the conventional dam and reservoir. Since 1954, hundreds of these dams, which are cheap and simple to build, have been constructed in the former British territories of East and Central Africa.[4]

## EGYPT AND THE SUDAN

In Egypt, which has a total irrigated area of about 6·4 million acres, virtually the entire agricultural economy is dependent on irrigation based on the Nile waters. Modern Egypt is largely the creation of irrigation engineers, who maintain a highly complicated and efficient system of water distribution and who plan and execute its further development on behalf of the government. Each year, plans for seasonal water budgets and programmes for water control



at the various dams and barrages are drawn up, taking into account the acreages under the principal crops, the particular needs of these crops and the amount of water available at any given time. These plans are co-ordinated by two inspectors-general, one in Upper Egypt and one in Lower Egypt.[5]

However, if the methods of storing and distributing water on a large scale are complex and efficient, irrigated farming as practised by Egyptian peasants remains primitive compared with the highly mechanised and scientific agriculture of the developed countries. Crop rotations are practised and large quantities of fertiliser are used, but equipment is primitive or lacking, holdings are usually small, and crop yields are often low.

There are two main forms of irrigation along the Nile Valley, basin irrigation and perennial irrigation. Basin irrigation is now confined to little more than 700,000 acres, largely restricted to Upper Egypt. It has few mechanical requirements, but being dependent on flooding, it is largely devoted to single cropping. Exceptionally, oil pumps have been installed in a few basins to raise water for use in the dry season. Perennial irrigation, on the other hand, involves a complex, large-scale system of storage reservoirs, barrages, regulators and canals (Fig. 34), and is preferred to basin irrigation for a number of reasons. It enables a wider range of crops to be produced, including those which require a constant supply of water throughout their growing season, and it increases crop yields considerably. The completion of the Aswan High Dam should enable those areas in Upper Egypt at present given over to basin irrigation to be converted to perennial irrigation. Among the consequences of the introduction of perennial irrigation into Egypt by British engineers during the past century have been the reintroduction and rise of cotton, rice and sugar cane, the introduction of maize, and the decline of wheat, flax, indigo and saffron. In general, summer cash crops have become dominant at the expense of food crops.

The development of perennial irrigation has not been without its problems, however. Overcropping and consequent soil exhaustion, salinity and waterlogging, and declining fertility resulting from lack of silt have all followed in its wake. Salinity and waterlogging are perhaps the most pressing and immediate problems and can only be reduced by an efficient drainage system. This is not necessary in basin irrigation, as the water is allowed to drain

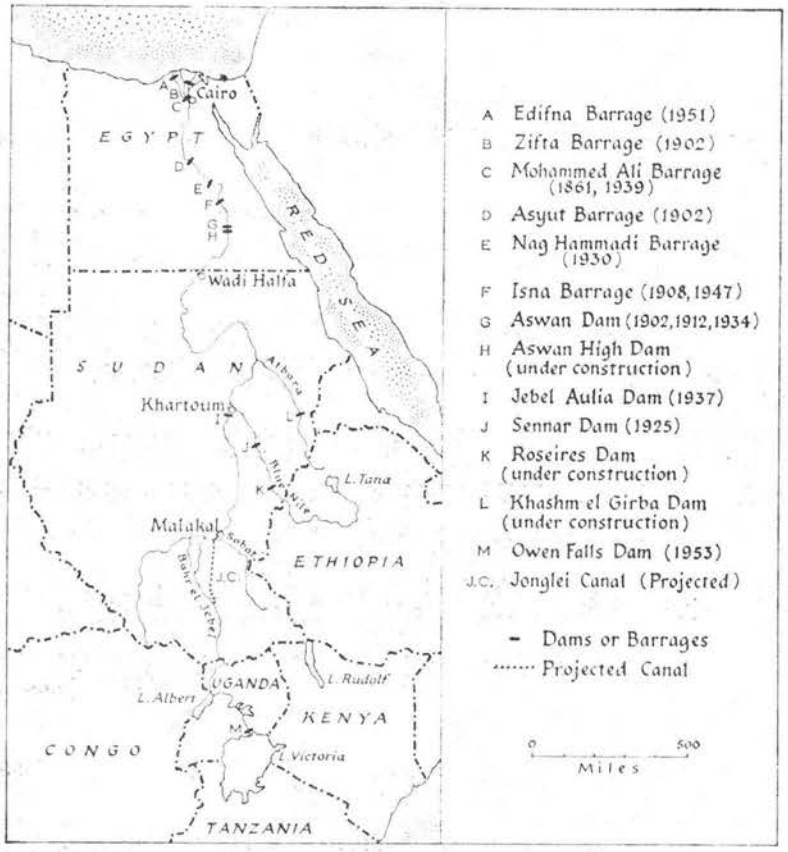


FIG. 34. Major control structures in the Nile Basin.

back into the river of its own accord, but it is essential with perennial irrigation because the silt is clayey and not sufficiently permeable to allow the water to seep quickly down to its lowest layers. The problem is most acute in the low-lying delta, where the canal system is relatively old and where perennial irrigation was introduced before the importance of a proper drainage system was fully realised. The greater part of the delta is still drained by a series of wide ditches; this wastes both time and water and is expensive to maintain. Experiments are being made with small-bore tile drains of porous cement, which are laid below root level and are inclined very gradually in the direction of the main drains. But since their



use involves a considerable capital outlay, they are not as yet very widespread.

In areas where canal irrigation is not provided or where water cannot be guaranteed throughout the year, various methods of lifting and pumping water from rivers and wells are used. These include primitive lifting devices as well as modern pumps driven by steam, diesel or electricity, which are usually owned by the wealthier landowners or the government. Such lifting devices are found either in small areas bordering the river, which are often too high to be reached by canals except at the height of the floods, or in the delta on land normally watered by canals from gravity flow. In the latter case, pump irrigation is usually limited to the early part of the flood, when the demand is so great that not all the canals can be supplied with enough water to reach all parts of any particular section of the system. It is anticipated that when all the new barrage and drainage projects have been fully developed, lift and pump irrigation will practically disappear.

The urgent need to expand Egypt's irrigated agriculture in order to feed her rapidly growing population has led the government to inaugurate a long-term development programme for irrigation. How best to achieve this expansion has been a matter of considerable debate, involving problems of both a technical and a political nature. As Egypt contributes none of the Nile floodwater, international co-operation, particularly with the Sudan, is essential. Under normal conditions, the flow of the Nile is insufficient to irrigate even the present acreage of cultivated lands, while during the flood period there is much more water than can be used. At present, the Egyptian barrages provide only annual storage, and if the area under irrigation is to be extended and basin irrigation replaced by perennial irrigation, then long-term storage facilities will have to be provided. An international, long-term plan for the storage and control of the water of the Nile Basin has been in existence for some time, and measures in accordance with this plan include the Owen Falls Dam in Uganda, completed in 1953 to control the outflow of Lake Victoria and generate hydroelectricity, and the Jebel Aulia and Sennar dams in the Sudan. The Jebel Aulia Dam, completed in 1937, is operated largely for the benefit of Egypt; the Sennar Dam, finished in 1925, provides a reservoir and barrage to raise the level of the Blue Nile sufficiently to allow the water to flow into the Main Gravity Canal of the

Gezira scheme, for the benefit of the Sudan. In November 1959 a new agreement was signed by Egypt and the Sudan allocating to the Sudan a greater share of the water stored behind the Sennar Dam. To complete the harnessing of the Nile waters, the co-operation of the Congo, Tanzania and Ethiopia as well as that of Uganda, the Sudan and Egypt would be essential, since complete

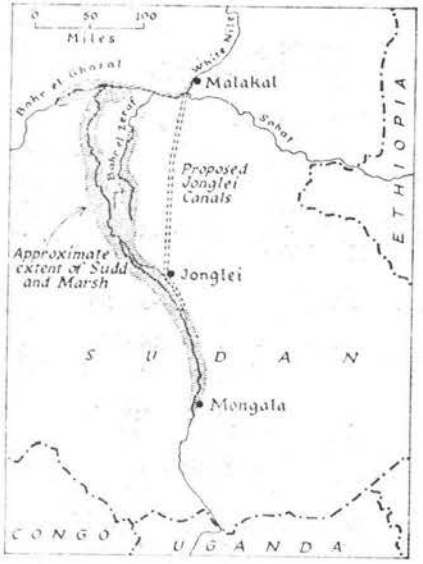


FIG. 35. The Jonglei scheme.

water control would involve the regulation of lakes Albert and Victoria in East Africa, Lake Tana in Ethiopia and the Bahr el Jebel swamps in the Sudan.

The most feasible and rewarding of these measures would probably be the one regulating the swamps of the southern Sudan, where large quantities of water are now lost to evaporation in the Sudd between Mongala and Malakal. Much of this water could be conserved and the flow of the White Nile increased by implementing the project known as the Jonglei scheme (Fig. 35). This consists of two major, interdependent phases: (*a*) the use of Lake Victoria as a reservoir for long-term storage, with sufficient water being held in it by means of the Owen Falls Dam and other regulating devices to make up for any deficiencies in the annual



flow; and (*b*) the improvement of the existing Nile channel between Mongala and Jonglei by dredging and excavating and by the construction of a duplicate Jonglei canal. The storage capacity of Lake Victoria could be greatly increased by raising its maximum level about four feet, which would also increase the volume delivered to Bahr el Jebel. By building the Jonglei canal, from Jonglei to a point downstream between the mouths of the right-bank tributaries of the Bahr el Zeraf and the Sobat, about half the water which normally goes into the Sudd would be directed into the White Nile, and evaporation would be enormously reduced. The scheme would be a complicated and expensive one, calling for co-operation between the countries concerned. Moreover, although it is estimated that it would increase the water available by an amount equal to the expected loss due to evaporation from the Aswan High Dam, the scheme is not without its social and economic difficulties. For example, it would likely result in a loss of pasture and fisheries that would directly affect 600,000 Nilotic pastoralists and indirectly another 400,000.[6] In any case, general political considerations have led Egypt to set aside indefinitely this more comprehensive scheme in favour of the national project at Aswan. It may be, however, that the enormous cost of the Aswan project and the uncertainty concerning its ability to provide sufficient storage capacity to keep pace with Egypt's mushrooming population may at some time in the future cause the Egyptian government to reconsider the wider Jonglei scheme.

In the meantime, the Aswan High Dam (*Sadd-el-Aali*) (Fig. 36) has become the cornerstone of the Egyptian government's plans for extending the country's cultivated area. Situated four miles upstream from the present Aswan Dam, it will be 364 feet high and 11,480 feet long. When full, its reservoir, to be called Lake Nasser, will be 282 miles long. It will flood much of Nubia, including important archaeological sites, as well as the Wadi Halfa region of the Sudan, and will have a total capacity of 127 million acre-feet and a usable capacity of 62 million acre-feet annually. In 1960 work began on the dam, which will take at least ten years to complete, though the first and perhaps most difficult stage was finished in May 1964 when the Nile was diverted from its original course by the sealing of the barrier across the river. It is difficult to estimate the total cost of the project but it will probably exceed

£400 million. It is intended to store sufficient water to irrigate as much as two million additional acres and to convert the present 700,000 acres under basin irrigation to perennial irrigation. In addition, the dam will both provide the total cultivated area with supplemental water during periods of low-water supply and store sufficient reserves of water to meet deficits in years of low flood.


FIG. 36. The Aswan High Dam project.

The controlled flow of the Nile will make it possible to distribute the proper amounts of water to the various crops at the right time, and the enormous storage capacity of the reservoir will eliminate the possibility of periodic overflooding. By curtailing the free flow of water at the height of the flood season, the dam should also lower the ground-water table and reduce the dangers of water-logging. Last but by no means least, power stations on the site will provide great quantities of hydroelectricity primarily to power Egypt's industrial development. On the other hand, there is no doubt that a dam of this sort, situated in the middle of the Sahara Desert, will lose a great deal of water by evaporation, estimated



at almost twice that of the capacity of the present Aswan Dam reservoir.[7]

The project has also caused an enormous social upheaval. Almost the entire Nubian population, some 60,000 people, has been dispossessed of its ancient home, which will disappear under the waters of Lake Nasser. In order to rehouse the Nubians, evacuated from more than forty villages, about seventy-five government townships have been built on the land soon to be irrigated, including Kalabashi, New Daboud and Nasser City, which will be the new Nubian capital to replace the old one, Ineiba. These developments represent the construction of a new Nubia on an area of about 170,000 acres in the vicinity of the sugar-refining town of Kom Ombo.

Another way in which the Egyptian government hopes to increase the cultivated area is by the reclamation of desert lands away from the immediate vicinity of the Nile. In the pre-Christian era the Mediterranean coast of Egypt was celebrated for its grains and wines. But since then, the southern limit of Mediterranean rain has moved north, and the water table is now much lower than it was two thousand years ago. Nevertheless, reclamation possibilities exist in the desert areas, and the government has established a number of experimental stations in the Western Desert and the Sinai Peninsula. In the former region, 54,000 acres were set aside for irrigation in 1954, east of the old Cairo-Alexandria road, where fruit and vegetables are grown with the aid of Nile water brought by means of a specially built canal. This project labours under a number of difficulties, however, including the high cost of production and the fact that not enough water will be available until the Aswan High Dam is completed. Another scheme is designed to reclaim lands on the sites of present and former oases in the Western Desert by drilling for underground water, but its success will depend partly on the availability of such water and partly on the amount of capital invested in pumping equipment. The great cost of the Qattara Depression scheme, estimated at more than £100 million, is also likely to bring about its eventual postponement. This scheme entails boring and operating wells on the floor of the Qattara Depression in order to tap the Saharan water table. The depression, which is only 120 miles west of the delta, occupies an area of about 7,000 square miles and has a bed averaging 150 feet below sea level. It is estimated that by drawing in

Mediterranean water by means of a canal leading to the northern tip of the depression, sufficient electricity could be generated to make deep pumping a practicable, if expensive, proposition.[8] In the Sinai Peninsula a number of reservoirs have been built to capture as much as possible of the meagre supply of rainfall. Together with auxiliary supplies from wells, sufficient water is available to enable fruit to be grown around El Arish. In the north-western part of the peninsula, 50,000 acres may be made irrigable by the transfer of fresh water from the Ismailia Canal under the Suez Canal.

In these various ways, Egypt could probably double her present cultivated area. But even if the most ambitious projects are realised, it is likely to be a long, slow and costly business. In the near future, the conversion of areas presently under basin irrigation to perennial irrigation will likely lead to greater productivity.

In 1959 the Sudan had approximately 2·5 million acres under irrigation, representing only five per cent of an estimated fifty million potentially irrigable acres. Since then, a number of extensions have taken place and others are planned. The most important irrigated area is the celebrated Gezira scheme (Fig. 37), based on the triangular plain between the White and Blue Niles. The Gezira is supplied with water by a main canal which leads from the reservoir above the Sennar Dam, completed in 1925. When the scheme first came into operation, the irrigable area was 300,000 acres; with the opening of the north-west extension in 1952, the total became nearly one million acres. The Gezira is especially well suited to irrigation because it consists of heavy clay soil, which retains the water at the surface and supports the growth of long-staple cotton, the major crop of the area. Developed under the British administration, the Gezira has become the model for similar agricultural developments in other countries.

Since Sudanese independence in 1959, a number of extensions to the Gezira have been planned to increase the Sudan's agricultural productivity and to relieve overpopulation in the northern part of the country. An important extension is the Managil project to the south of the Gezira, which is a product of the Nile Waters Agreement of 1959. By this agreement, which reallocated the waters of the Nile, the Managil area now receives twenty-five per cent of the water with an additional margin for evaporation. In return, the Egyptian government received an eighteen-year



'loan' of unused Sudanese water and permission to flood the Wadi Halfa region consequent upon the backing up of water behind the Aswan High Dam. Other important extensions are the Kenana project, based upon the new Roseires Dam on the Blue Nile, 132 miles upstream from the Sennar Dam, which was made possible by the Nile Waters Agreement and a loan of thirty-two million

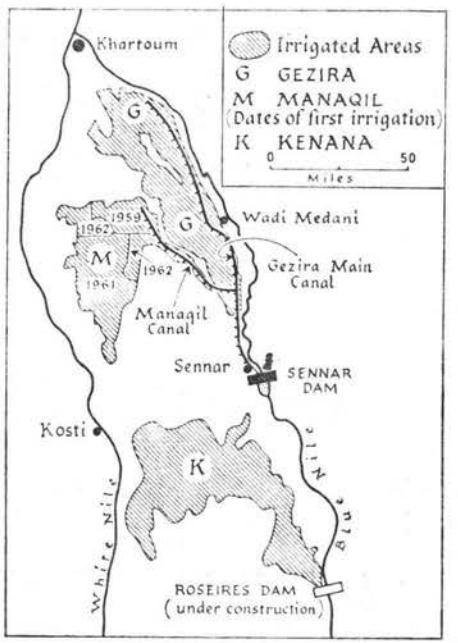


FIG. 37. Irrigated areas between the White and Blue Niles, Sudan.

dollars from the World Bank; and the dam at Khashm el Girba on the Atbara, which is designed primarily to provide cultivable land for farmers dispossessed by the flooding of Wadi Halfa. In addition to these large-scale, government-sponsored schemes, there has also been considerable private investment in irrigation facilities in recent years.

A number of schemes for irrigating alluvial terraces with the aid of diesel pumps have been developed in recent years along the Nile below Khartoum, and in central Sudan along both the Blue and White Niles.[9] In Kassala Province in north-eastern Sudan, floodwaters of the Gash and Baraka rivers enable cotton to be

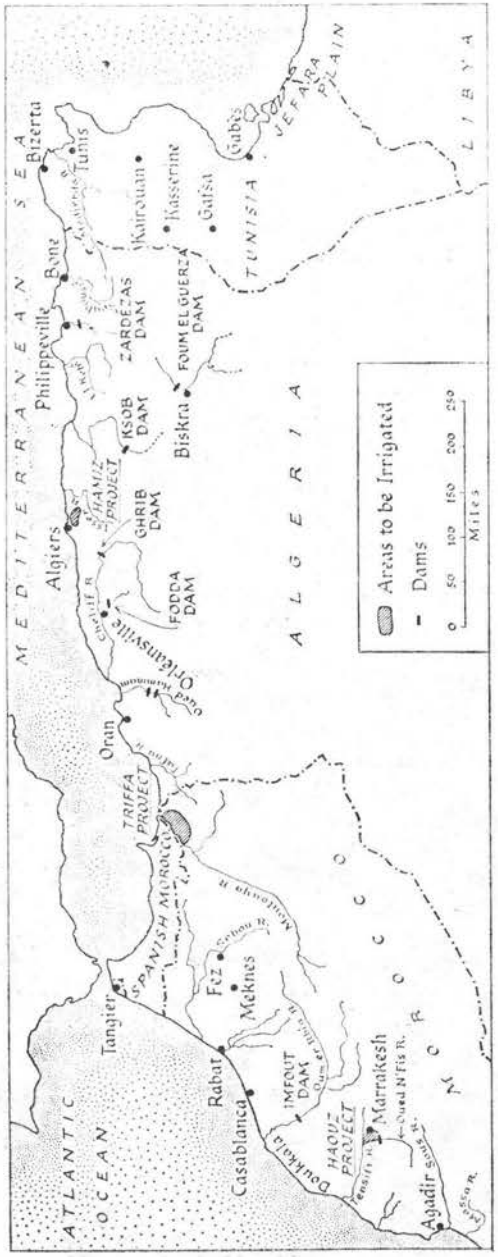


FIG. 38. Water resources in North-west Africa.



grown on approximately 150,000 acres in the Gash and Tokar deltas.

### NORTH AFRICA

In North-west Africa, irrigation has been most important and successful in the Mahgreb, the Mediterranean coastal region of Morocco, Algeria and Tunisia, where it has been practised for thousands of years. In Morocco, which at present has an irrigable area of about 540,000 acres, a very small proportion of the total cultivated area is under irrigation, and the government is making great efforts to increase the irrigated acreage by sponsoring a number of large-scale schemes based on the construction of dams along some of the rivers flowing down from the High Atlas into the Mediterranean, notably the Sebou, Moulouya and Oum er Rbia rivers (Fig. 38).[10]

In all these areas the irrigation water is used for the cultivation of cereals, vines and citrus fruits. However, reclamation has been difficult and expensive, as the low-lying coastal areas suffer from waterlogging and salinity, especially in the late spring and early summer when the snow melts from the mountains and floods the lower courses of the valleys. Consequently, irrigation has hitherto been restricted to the zone along the junction of the mountain and plain above the coastal marshes; with water taken from wadis, farmers cultivate olive groves and citrus orchards.

Even more difficult to bring under cultivation are the semi-arid steppes between the High and Anti Atlas, where the flow of wadis is too capricious to support a stable agriculture on a large scale, though there is some limited cultivation. It may be possible to exploit underground water supplies in these regions, such as those which underlie the Tadla Depression between the Meseta plateau and the Middle Atlas. It is estimated that the present irrigated area of approximately 50,000 acres could be enlarged five times, but such a project would be very expensive. Along the southern desert margins of the Saharan Atlas, there are a number of oases which utilise artesian waters located in Tertiary and Cretaceous aquifers. This area of the northern Sahara has considerable potential, as a number of aquifers have recently been found which could support considerable agricultural development. Perhaps the most important of these is the one in the Inter-Calary Continental Albienne Nappe, the most prolific aquifer yet discovered.

Algeria also has a relatively limited irrigated acreage, probably about 500,000 acres. Future development will be very expensive, and the Algerian government has apparently decided to invest its limited capital resources in industrial expansion. As in Morocco, the most important irrigated areas are in the coastal foothills above the poorly drained coastal plains. There, water is available from wadis and springs and is used by peasant farmers to cultivate olive groves and citrus fruit orchards, largely with the aid of primitive devices. In addition, there are a few fairly large-scale irrigation projects, based on barrages and dams constructed by the French. These include the Oued Hammam Basin south-east of Oran, the Cheliff valley around Orléansville based on the Ghrib and Fodda dams, the Hamiz project east of Algiers designed to serve an area of more than 35,000 acres, the Ksob Basin based on the Ksob Dam, the coastal area east of Philippeville supplied by the Zardézas Dam and, in the interior, the Biskra area served by the Foum el Guerza Dam.

Tunisia, with a total of approximately 120,000 irrigated acres, has only a very small proportion of her cultivated area under irrigation but is planning a considerable development of irrigated agriculture in the next few years. The only river capable of supplying large amounts of water for irrigation is the Medjerda, and a large-scale scheme on the lower Medjerda is now nearing completion. Furthermore, work is expected to begin shortly on an irrigation and drainage project in the Lake Ichkeul area near Bizerta. The key structure will be the Oued Kasseb Dam across the Rhazala River, and in 1970, the estimated completion date, it will provide water for about 50,000 acres. As Tunisia is unsuited to the construction of large dams, underground water is generally more important at present, and a number of pumping schemes are planned, notably in the Kairouan Plain, on the coast near Gabès, at Gafsa and at Kasserine.[11] The most important irrigated areas at present are the coastal plains behind Bizerta, where citrus fruit is the chief crop.

Irrigated agriculture is also very limited in Libya. About 250,000 acres are under irrigation in three main areas: the Jefara Plain in Tripolitania, the Barce Plain in Cyrenaica and a number of scattered oases in the desert to the south (Fig. 39). The most important of these is the Jefara Plain between Misurata and the Tunisian border in the north-western part of the country. There,



an irregular line of coastal oases produces dates, olives and oranges. In the plain backing the coast, farmers have in recent years switched from dry to irrigated farming with the aid of pumps which tap excellent supplies of underground water. The emphasis is on cash crops, mainly groundnuts, which have become the

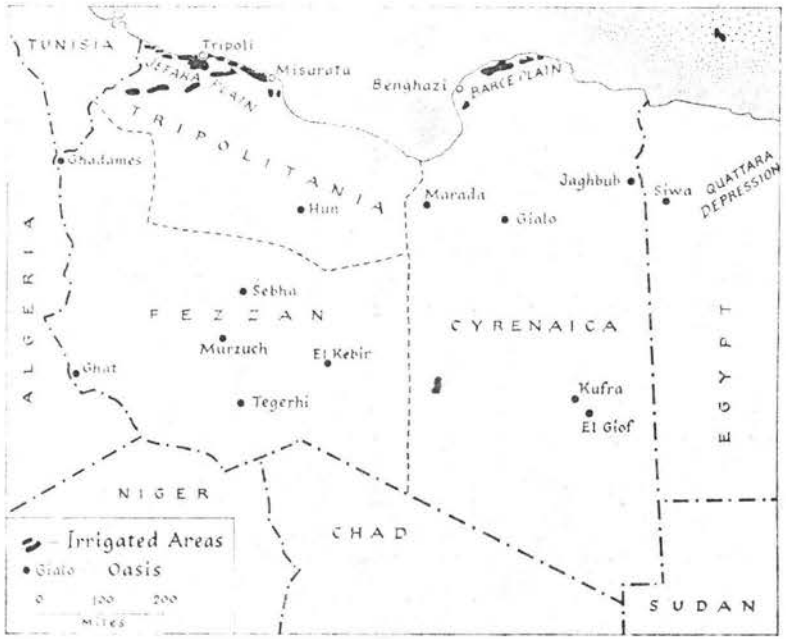


FIG. 39. Main irrigated areas in Libya.

leading agricultural export of the country, potatoes and citrus fruit. As these crops consume a great deal of water, excessive pumping has taken place, causing a serious drop in underground water levels.[12]

## WEST AFRICA

The major irrigated areas in West Africa are based on the Niger and Senegal rivers in the semi-desert, or Sahel, zone between the savanna to the south and the Sahara proper to the north. There, large-scale irrigation projects installed by French engineers have had some success in redeeming land for sedentary agriculture.

The Niger River project (Fig. 40) in the north-central part of the Mali Republic is an ambitious scheme begun by the French in 1932. The key structure consists of the barrage at Sansanding.

Originally, the French planned to develop the enormous inland delta of the Niger primarily for irrigated cotton and secondarily for rice, but despite considerable expenditure, these objectives have never been attained. Even by 1960 fewer than 150,000 acres were actually irrigated and fewer than 50,000 people were settled on the project area, though they were enjoying an income far

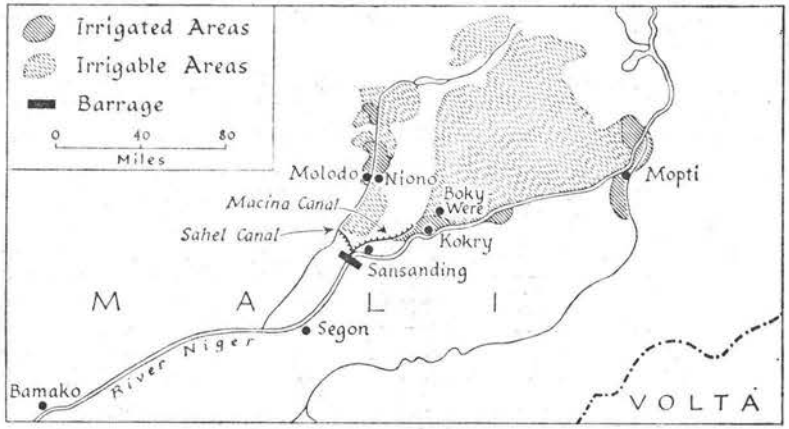


FIG. 40. The Niger River project, Mali.

greater than the average per capita income of Mali. According to Sir John Russell, this 'disparity between expectation and achievement' was the result of a lack of basic knowledge arising from inadequate preparatory surveys; excessive overhead charges owing to the proliferation of European staff; and the reluctance of African natives to move to new sites as well as their lack of industry and knowledge of irrigation farming.[13] The French administration of the Niger River project had little understanding of the problems of the Mossi tribe, whose indigenous culture they seemed to regard as 'little more than a compendium of savage rites upon which European usages need only be imposed in order to prevail. Such an approach reveals a failure to comprehend both the complexity and tenacity of the Mossi cultural heritage.'[14] On the other hand, a recent sociological study of the resettlement of some 5,000 members of the Mossi tribe concludes that the Mossi adapted



themselves fairly easily to their new environment and in time mastered the new technology of irrigation farming. But acute social problems arose as a result of their removal from a cultural setting which had been relatively undisturbed by the influence of European civilisation to one in which the economic situation was formed and directed by Europeans.

Perhaps a more fundamental reason for the disappointing results of the Niger project is that over much of the area the soil

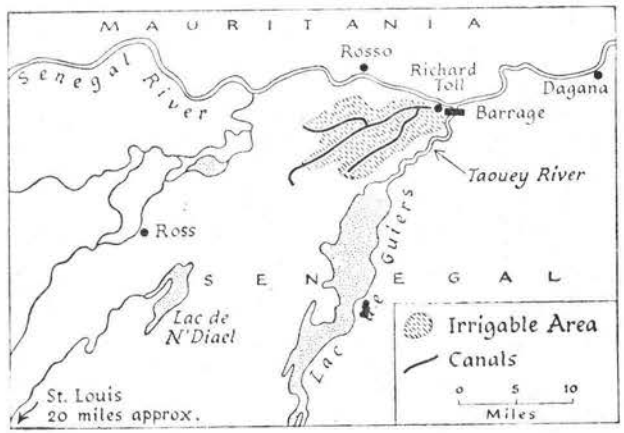


FIG. 41. The Richard Toll project, Senegal. The barrage stores water in Lac de Guiers, and a pumping station lifts the water into canals, from which it is led into the irrigated area.

is poor. The project has also suffered from aerial attacks by locusts and swarms of birds. Consequently, only a small proportion of the original project area has come into full operation, with rice being a more important crop than cotton.

Another costly regional development scheme sponsored originally by the French government is the Richard Toll project (Fig. 41) on a large inland delta at Richard Toll in north-west Senegal. Work began in 1946 but by 1957, after the expenditure of a great deal of money, only 14,000 acres had been brought under cultivation, mainly for rice. Since independence, the project has been taken over by Senegal.

Both the Niger and Senegal rivers could support considerable extensions of irrigated agriculture if the necessary capital were available for the construction of dams and canal networks. A study

of the potential of the Senegal River has been in progress since July 1962, sponsored jointly by Senegal, Mali, Mauritania and Guinea, and in October 1963 a draft agreement to undertake the economic development of the Niger River throughout its length was signed by Mali, Niger, Upper Volta, Guinea, the Ivory Coast, Dahomey, Cameroun, Chad and Nigeria. The agreement provides for the development of the river's resources, including fishing, irrigation, power and navigation. If these schemes are ever to be converted into reality, they will require expenditures far beyond the means of the West African countries, and thus considerable foreign financial assistance will be essential.

The only other irrigated areas of any note in former French West Africa are quite small, based on more than 600 wells and some 200 irrigation dams built by the French between 1949 and 1954 in Mauritania, Sudan, Upper Volta and the Niger. One of the by-products of this venture was the outbreak of sporadic fighting between the sedentary settlers for whom the water was intended and the nomads who coveted it. The governments of the newly independent territories hope that the progressive settling down of the nomadic tribes will eventually result in peace with the sedentary farmers.

In former British West Africa the only major potential area of irrigated agriculture is the Accra Plain in Ghana, a gently undulating area of open scrub between the Akwapim Hills and the sea, with an unusually dry climate for that part of the world. A pilot scheme has been established on a small tract near Kpong to test the suitability of the area for intensive irrigated farming, and it is hoped that the Volta River scheme will render irrigable hundreds of thousands of acres of savanna that are unused at present. There are few irrigated areas in Nigeria, except along streams in the Sudan zone around Kano, where together with easily accessible ground-water supplies, they provide water for the cultivation of foodgrains and groundnuts. Such areas in north and central Nigeria could be considerably expanded and could make possible both the cultivation of specialised crops such as rice, sugar cane and vegetables and the extension of dry-season cropping.

Another area of potential development is the Lake Chad region, and a scheme has been mooted to dyke the dry-season shoreline of the lake and utilise the impounded water for irrigating 10,000 acres of land south of the lake.