DISTRIBUTION OF IRRIGATED LANDS AND WATER CONSUMPTION

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Summary

At the end of the twentieth century the world's irrigated land comprised 2.72 million km^2 (272 million hectares) and about 60% of this belonged to four countries: India, China, the United States, and Pakistan. Irrigation of agricultural lands is one of the main causes of water consumption in the world, along with other human activities such as industry, transport, and domestic use. During the last decades of the twentieth century, irrigation worldwide consumed about 2500 km^3 of fresh water annually, or approximately 70% of the total human use of this natural resource. The practice of irrigation may have negative ecological impacts, including the exhaustion or contamination of natural water resources. Irrigation is required where and when precipitation is insufficient. The main function of water use by plants is to prevent overheating, especially during hot days. The water absorbed from soil by plant roots is mainly lost to the atmosphere through evaporation from plant leaves. Irrigated lands occupy about 18% of the total cultivated agricultural land worldwide and yield about a

third of the global agricultural crop production. The principal crops are grains (mainly rice and wheat), cotton, oil crops (e.g. soybeans), vegetables and fruits. Taking into account the growing global demand for food and raw industrial materials and the corresponding need for more irrigation water (approximately an additional 60 km^3 of water per year by 2025), future conflicts among water users are certain to occur, especially in regions where water is a scarce resource. According to predictions developed by the International Water Management Institute, a third of the world's population will experience severe water scarcity by the year 2025, which will likely be a destabilizing force for the development of some countries. Fortunately, there are a number of ways to reduce water consumption and negative ecological impacts in irrigated lands.

1. Irrigation Development from Ancient to Modern Times

It is well known that water is as important as air and food for mankind. Therefore, the history of the development of human society cannot be separated from the issue of water conservation. Historically, civilization has followed the development of irrigation. As the FAO has acknowledged, "the early story of irrigation developments is buried in the oblivion of ancient unrecorded history. Since civilizations have risen on irrigated lands, the antiquity of irrigation is well documented throughout the written history of mankind."

One of the oldest citations is in the Bible. Genesis mentions Amraphel, King of Shinar, a contemporary of Abraham, who developed the "laws of Hammurabi," which indicate that the people had to depend upon irrigation for existence. Further mention of irrigation is found in Second Kings 3:16–17: "And he said, Thus saith the Lord; Make this valley full of ditches. For thus saith the Lord, Ye shall not see wind, neither shall ye see rain; yet that valley shall be filled with water, that ye may drink, both ye, and your cattle, and your beasts."

Irrigation canals believed to have been built under an ancient Assyrian Queen, who supposedly lived before 200 BC, are still delivering water today. Thus, there are records and evidence of continuous irrigation for thousands of years in the valleys of the Nile and for comparatively long periods in Syria, Persia, India, Java, and Italy (see *History of Land Improvement*).

Egypt claims to have the world's oldest dam, built 5 000 years ago, which is more than 100 meters long and 12 meters high, and is used to store water for drinking and irrigation. Irrigation introduced on the Nile about 3300 BC "still plays an important part in Egyptian agriculture."

The 4000 years of written records of the irrigation systems on the Tigris, from 2600 BC to 1400 AD, have been studied jointly by the Director-General of Antiquities in Iraq and the Oriental Institute of the University of Chicago. They include a series of recorded disasters from salinization (see *Drainage of Irrigated Lands*). Salinity surveys are recorded from about 2400 BC. Control of salinization by leaching and drainage appears to have been practiced.

The history of irrigation, drainage, and flood control in China can be dated back over 5000 years, nearly 3000 years of which is recorded history. In China flood control work began in about the twentieth century BC. In the early stages of the first century BC, the great litterateur Sima Qian wrote a special volume entitled “Hequshu,” in his historical works “Shiji.” It was a record of the rivers and canals. In the book he recorded the important events of water conservancy from the flood control works of the Great Yu in the twentieth century BC to his own time. After describing in detail the closure of a breach on the Yellow River ordered by Emperor Hanwu, he exclaimed: “What a role the water plays in the people’s life whether it is beneficial or harmful.” After him, the tradition of keeping special historical records about water conservancy continued for more than 2000 years to the present. These records supply a rich experience of water conservancy for our work in this day and age. The famous Tu-Kiang Dam, still an effective dam today, was built by a man named Mr. Li and his son in the Chin dynasty (200 BC) and still provides irrigation water for more than 2 000 km^2 (200 000 hectares) of rice fields. The water ladder, a widely used pumping device in China and neighboring countries, is believed to have been invented about the same time. Country carpenters worshiped its inventor as a god. The Grand Canal, 1125 meters long, was built in the Sui Empire, AD 589–618.

India also has a long history of irrigation. There are reservoirs in Sri Lanka, to the south of India that are more than 2000 years old. Writings in 300 BC indicate that the whole country was under irrigation and very prosperous because of the double harvests that the people were able to reap each year. Wells, tanks, and inundation canals from rivers were well-known sources of irrigation water in India thousands of years ago.

More recently, at the beginning of the sixteenth century, the Spaniards on their entrance into Mexico and Peru found elaborate provisions for storing and conveying water supplies that had been used for many generations. Their origin was almost lost even to tradition. In the southeast of Mexico, the remains of canals and drains were found close to the ruins of Edzna, from the antique Maya culture. By the middle of the fifteenth century, Netzahualcoyotl, King of the Chichimecas, poet and engineer, constructed dams, canals, and flood control works in the Valley of Mexico. Some of these constructions can still be seen today close to the city of Texcoco.

Extensive irrigation works also existed in the southwestern United States. The early Spanish missionaries brought knowledge of irrigation from their Mediterranean homes. Trappers, miners, and frontierspeople in many places in the western United States practiced irrigation also, although no effort was made to develop an agricultural economy based on irrigation until the Mormon Pioneers entered the Salt Lake Valley in northern Utah in July 1847.

Even though irrigation is as old as civilization itself, until the beginning of the nineteenth century the number of works built and the irrigated areas of the world were of relatively minor significance as a total part of agriculture. It has been estimated that the total irrigated area in the world was then about 80 000 km^2. But during the early part of the nineteenth century a number of fairly large irrigation projects were constructed in different parts of the world. In the latter half of the nineteenth century, there was considerable development of irrigation in India. Among the important works constructed, those worthy of mention include the Ganga canal completed in 1854, and the Godavari and Krishna Delta Systems completed towards the end of the century. The Lower Chenab Canal (now in Pakistan) was built in the 1890s, and in addition a large number of inundation canals on the Indus and its tributaries were improved and extended. In the western United States numerous small irrigation works were built, mainly by private enterprise. Among these may be mentioned the efforts of the Mormons in Utah, the Greely colony in northeastern Colorado, and the Anaheim community in southern California. In Italy, the Cavour canal was built in 1852, followed by the Villoresi and Mariano canals, which were built between 1887 and 1891. It has been estimated that the total area irrigated in the world by the end of the nineteenth century was about 400 000 km^2. In other words, the irrigated area was five times as large as at the beginning of the century. The more important developments of the century, however, were advances in the science of hydraulics and the development of techniques in the planning, construction, and operation of large projects. By the turn of the century, millions of hectares of once desert lands had been converted into green fields, new towns had appeared, and there was new life where there had been little before.

In the early years of the twentieth century irrigation planners began to develop very large-scale projects to improve agriculture production as well as to populate wastelands. New types of machinery, new methods of construction, new advances in hydraulics, and new developments in large dam construction all contributed to transforming agricultural production. Irrigation acreage increased at an exponential rate.

World agriculture is the main consumer of fresh water, using significantly more than other activities such as industry and transportation. In recent decades the irrigation of fields has annually consumed about 70% of all the fresh water used by humans. The irrigated area of the world and fresh water consumption in irrigated fields increased significantly during the twentieth century (Table 1).

By the end of twentieth century, the irrigated area of the world covered about 18% of the cultivated total and contributed about a third of the world's food production. In some countries, like Egypt, China, and Pakistan, irrigated lands contribute much more than 50% of the national food production, as shown in Table 2. Irrigation contributed to the eradication of famine in the countries with the biggest populations, such as China, India, and Pakistan.

Year	Area (Million ha)	Volume (Km^3)
1800	8	75
1900	48	450
1950	94	865
1960	140	1288

1970	198	1822
1985	250	2300
1995	267	2459
2000	272	2502

Source: FAOSTAT (2000)

Table 1. Development of irrigated area and annual water consumption for irrigation in the world. Source: FAOSTAT (2000).

Country	Irrigated Area/ Cultivated Area (%)	Food Production in Irrigated Lands/ Total Country's Food Production (%)
Egypt	100	100
Pakistan	65	80
China	50	70
Chile	35	55
Peru	35	55
India	30	55
Mexico	30	55
Indonesia	40	50

Source: Rangely (1987)

Table 2. Contribution of irrigation to food production in selected countries in 1985. Source: Rangely (1987).

The most important irrigated crops in the world are a range of cereals (such as rice, wheat, corn, sorghum, and barley), forage grass (principally alfalfa), cotton, vegetables, and some orchard produce. Rice is the most important irrigated crop in the world. It occupies about 45% of the world's irrigated area. In China almost two-thirds of the national irrigated area is used for rice (paddy fields). The distribution of the principle irrigated agricultural crops in the world is presented in Table 3.

Crops	Area (Million ha)	Area (%)
Cereals	175	64.4
Oil seeds	19	6.7

Forage & Fodder	17	6.4
Fruits	16	6.0
Vegetables	15	5.6
Leguminous	9	3.4
Sugar Crops	4	1.5
Other crops	17	6.0
Total	272	100

Source: FAOSTAT (2000)

Table 3. Irrigated area of principle groups of agricultural crops in the world at the end of the twentieth century. Source: FAOSTAT (2000).

Since the late 1970s the expansion of irrigated land has slowed down markedly. This has occurred for several reasons, including low prices for food commodities and comparatively high energy costs. In addition, the general economic conditions since the middle of the 1980s have discouraged agricultural investment. A related cause of the slowdown was that the rising cost of irrigation capacity growth in many countries made it harder to justify investments in irrigation on economic grounds. At the same time, increasing water scarcity, overexploitation of aquifers, and problems related to the drainage and salinity of irrigated lands have also reduced the growth of the irrigated area. The production of such important crops as cereals and fibers (principally cotton and linen) in irrigated lands decreased towards the end of twentieth century because their price was falling (in comparison with escalating energy prices), and investment in new irrigated areas diminished.

Some irrigated lands also use wastewater from sewage, agricultural runoff, or municipal supplies, in treated or even untreated form (but diluted with fresh water) (see Table 4). Drainage water or runoff from irrigated lands is the principal type of agricultural sewage water (see *Drainage of Irrigated Lands*). Wastewaters are frequently used for irrigation because of the growing deficit of fresh water, the high cost of agricultural fertilizers, and the presence in wastewaters of organic matter and plant nutrients such as nitrogen, phosphorus, and potassium (see *Irrigation* and *Irrigation Systems—Techniques and Technology* and *Water Resources—Quality and Supply*). At the end of the twentieth century, Central Asia was reportedly the primary region where agricultural runoff water was being re-used for irrigation, with an estimated 4500 km^2. An additional 2500 km^2 is irrigated with domestic and industrial wastewaters.

Country or region	Area (Million ha)
China	1.33
Central Asia (Aral Sea Basin)	0.70
Mexico	0.34

India	0.09

Source: Duncan and Cairncross (1990); FAO UNESCO (1997)

Table 4. Principal consumers of wastewater for irrigation in 1990. Sources: Duncan and Cairncross (1990); FAO UNESCO (1997).

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Biographical Sketches

Iourii Nikolskii-Gavrilov was born in Moscow in 1941. He qualified as a hydrotechnical engineer at the Moscow Institute of Drainage and Soil Water Management in 1964, and gained his Ph.D. in Technology (Soil Water Management and Drainage) in 1969 at the same institute where, in 1989, he also attained a Doctorate of Science in Ecological Aspects and Optimization of Irrigation and Drainage.

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Enrique Palacios-Vélez was born in Mexico City in 1933. He qualified as an Agronomy Engineer in 1956 at the National Agricultural School, Mexico, and gained his M.Sc. in Technology (Irrigation and Drainage) in 1972 at the Post Graduate College in Agricultural Science, Mexico. In 1976 he was awarded his Ph.D. in Technology (Water Resources Administration) at the University of Arizona, Tucson.

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