

Chapter 2

Hydrology of the Nile and Ancient Agriculture

M.N. Noaman and D. El Quosy

2.1 General Overview of the Nile

The Nile is the longest river in the world. Its length from the remote sources to the mouth on the Mediterranean Sea is about 6800 km, which makes it 300 km longer than the Amazon, 800 km longer than the Mississippi and more than 2000 km longer than the Congo River. The Nile catchment area covers 2.9 million km² (Dumont 2009), approx. 10% of the area of the African Continent.

The Nile spreads over eleven sovereign countries: Rwanda, Burundi, Democratic Republic of Congo, Kenya, Uganda, Tanzania, South Sudan, Democratic Republic of Sudan, Ethiopia, Eritrea and the Arab Republic of Egypt. Figure 2.1 is a map of the Nile Basin. The state of Eritrea (capital city, Asmara) became independent from Ethiopia in May 1993, and the state of South Sudan (capital city, Juba) was separated from the Democratic Republic of Sudan in July 2011.

2.2 Topography of the Nile Basin

The Nile Basin can be divided into three sub-basins: the Equatorial Lakes, Bahr El Ghazal, and the Ethiopian Highlands. Water flows from the River Luvironza and River Kagera to Lake Victoria, falling from 2000 + elevation to 1100 m. Lake

M.N. Noaman (✉)

Field Crops Research Institute (Molecular Breeding), Agricultural Research Center,
Giza, Egypt

e-mail: mahernoaman@yahoo.com

D. El Quosy

Water Management Research Institute (Water Resources Engineering),
National Water Research Center, Delta Barrage, Egypt

e-mail: lmewp2000@gmail.com

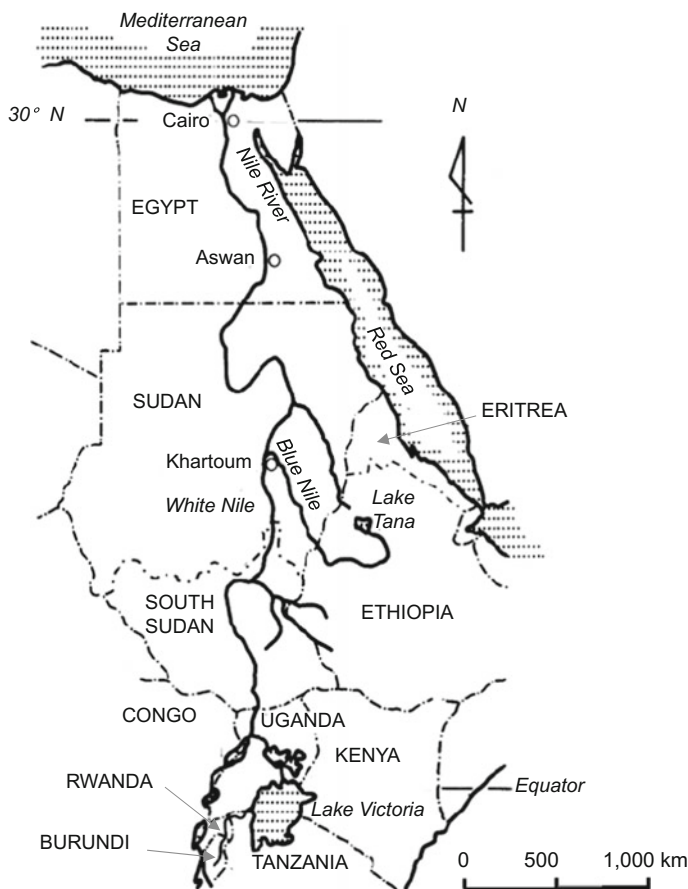


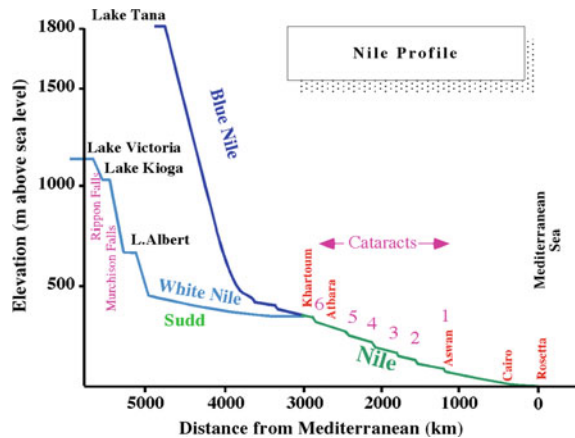
Fig. 2.1 The Nile river basin. Source Abu-Zeid (1983) (Partly revised by author)

Edward is located at 1150 m elevation and connected to Lake Albert at 600 m elevation via River Semiliki. Lake Victoria is connected to Lake Kioga at 1000 m elevation.

The water of the Equatorial Lakes flows through the city of Nimule to the cities of Mongalla and Boor to the Sudd region where the Nile meets with River Sobat, a tributary of River Baro originating from the Ethiopian Highlands. Both rivers connect close to the city of Malakal, forming the White Nile. The water level at this point ranges between 400 and 450 m above mean sea level (MSL).

Starting from Mongalla and Boor through the Sudd Region, the Bahr El Gazal Sub-basin (which is now part of the state of South Sudan) dominates. The Blue Nile starts from Lake Tana on the Ethiopian Highlands, which is 1800 m above MSL in elevation. It flows through extremely steep sloping land that conveys water from

Fig. 2.2 Topography of the Nile. *Source* The river Nile home page, <https://www.utdallas.edu/geosciences/remsens/Nile/intro.html>



1800 m above MSL to meet with the White Nile at the City of Khartoum in Sudan at 400–450 m above MSL.

The last tributary of the River Nile starts from the Ethiopian Highlands and flows through River Atbara inside the Sudanese territories until it meets with the Main Nile north of Khartoum. The Main Nile then proceeds to Aswan, where the water level upstream of the High Aswan Dam is generally within 150–180 m above MSL. Figure 2.2 shows the topography of the Nile Basin from different sources until it reaches the Mediterranean Sea.

2.3 Precipitation: Run-off and Natural Flows

Half of the course of the River Nile flows through countries with no effective rainfall. Almost all surface runoff is generated on an area of no more than 20% of the total area of the basin. The remaining 80% of the basin area is located in arid and semi-arid regions where precipitation is limited and evaporation and seepage losses are extremely high. Figure 2.3 shows the distribution of rainfall in the Nile Basin, which gradually changes from almost 3500–3750 mm/y in parts of the Upper Nile Region to less than 250 mm/y in the northern parts of the Sudan Democratic Republic and less than 100 mm in the whole of Egypt.

Figure 2.4 is a schematic diagram of the Nile's mean natural flows. The rainfall on Lake Victoria Basin amounts to 100 BCM/y. Only 5.5 BCM enters the Lake, as 94.5 BCM are lost. The lake receives 18 BCM from River Kagera, making the input to Lake Kyoga 23.5 BCM. Three BCM inflow to Lake Kyoga whereas 4.0 BCM are lost, making the net flow 22.5 BCM to Lake Albert, which also receives 6.5 BCM from its own catchment and loses 2.5 BCM, leaving a net of 26.5 BCM to enter the Sudd Region plus 4.8 BCM from other sources than Lake Albert. The Bahr El Ghazal sub-basin feeds the Sudd Region with 14.6 BCM more of water;

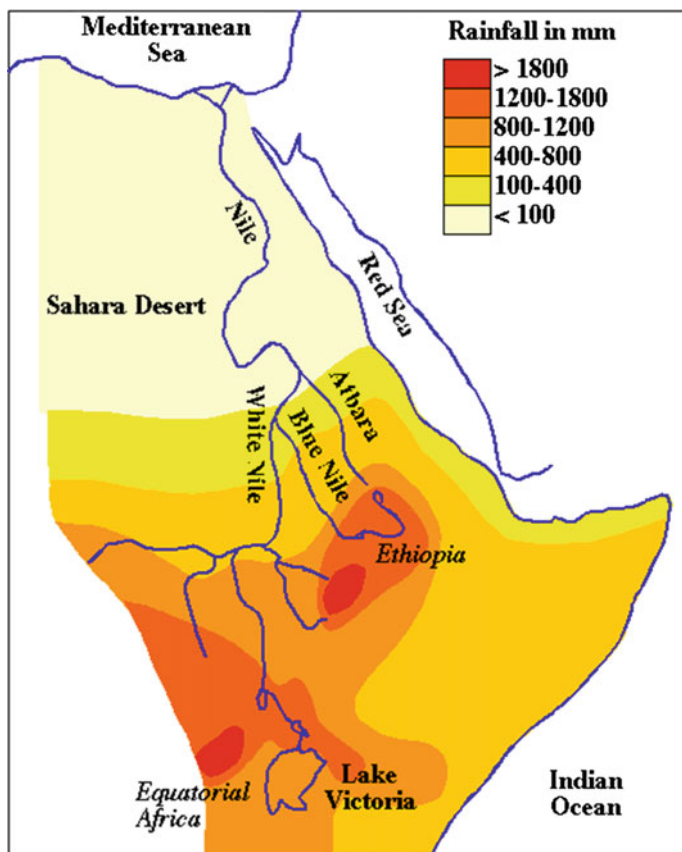


Fig. 2.3 The distribution of rainfall in the Nile basin. *Source* The river Nile home page <https://www.utdallas.edu/geosciences/remsens/Nile/intro.html>

however, a huge amount of water is lost in the Sudd by evaporation from the free water surfaces (lakes, marshes and swamps) and through evapotranspiration (from vegetated cover). The losses amount to almost 31 BCM, bringing the contribution of the White Nile to the Main Nile at this point to no more than 15 BCM/y.

From the Ethiopian Highlands, River Sobat carries 13.5 BCM to South Sudan from both River Baro and River Bipor, bringing the total flow of the Nile at this point to 28.5 BCM.

The major contribution to the Nile flow comes from the Blue Nile, which reaches its maximum at the convergence with the White Nile at the city of Khartoum. The average flow of the Blue Nile at this point is 54 BCM, increasing the Nile flow to 82.5 BCM. River Atbara, the last tributary of the Nile, connects north of Khartoum with a flow of 12 BCM, making the total flow of the river 94.5 BCM. Of this flow, 10.5 BCM is lost due to evaporation from the surface and seepage along the main stem of the Nile from Khartoum until Aswan, resulting in a net average natural flow

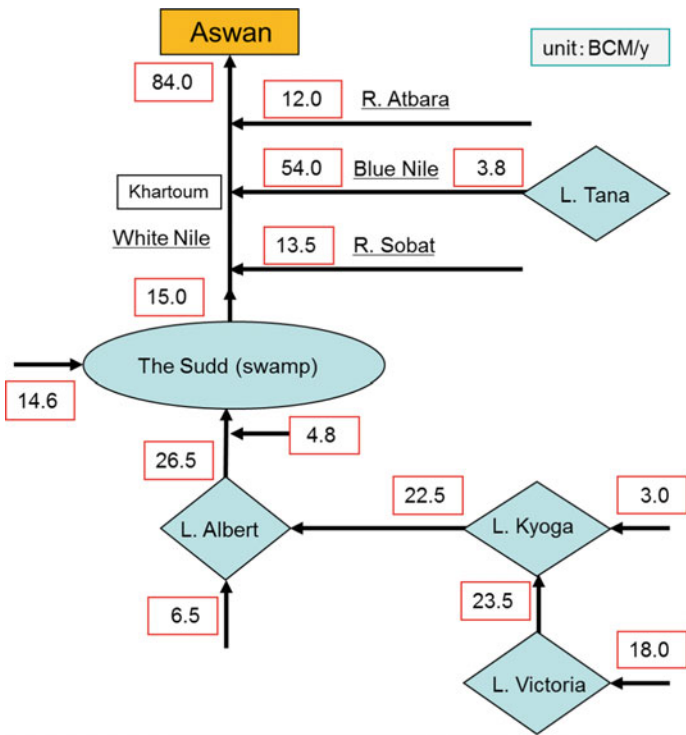


Fig. 2.4 Schematic of the Nile’s mean natural flows

at Aswan of about 84 BCM/year. The detailed distribution of river flow discharges in the Nile basin is presented by Shahin (1985).

The 1959 agreement signed between Egypt and Sudan distributes the natural flow as one-quarter for Sudan (18.5 BCM) and three-quarters for Egypt (55.5 BCM) out of a net of 74 BCM/year — after deducting 10 BCM/year for evaporation from Lake Nasser, which extends 350 km inside Egypt and 150 km inside Sudan and has a width of 12 km on average.

2.4 Annual Flows of the Nile

Figure 2.2 shows the monthly change in the discharge of the Nile at Aswan, with the range of discharge for each month. It suggests that the Nile flood starts in August and continues until October, while the flood discharge fluctuate much from year to year. The 1959 agreement was based on historic natural flow data covering more than 100 years starting from the water year 1870–71 to 1957–58. However, the measurement years during the 19th century are considered lower-accuracy, and

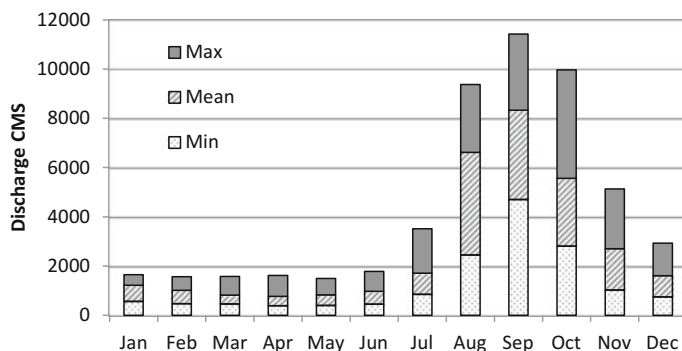


Fig. 2.5 Monthly discharge of the Nile river at Aswan (1900–1963). *Data Source* Vorosmarty et al. (1998)

therefore the average of 1900–1958 was used to divide the water flows. This average was taken as 84 BCM at Aswan. A recent statistical analysis was conducted for the period 1900–2000, from which 20-year time spans were examined. The result was that the average of the 100 years was 84 BCM, and the average of each separate 20-year span was also 84 BCM; within each 20-year span, the number of years above the average was seven, the number of years below the average was seven, and the number of years around the average was 6 years (Fig. 2.5).

High flood years were observed in 1878–1879 (150 BCM) as a record maximum; however, 133, 131, 131, 129, 125, 122, 122, and 121 BCM were observed in the years 1894–95, 1870–71, 1892–93, 1879–80, 1874–75, 1895–96, 1896–97 and in 1875–76, respectively.

The lowest natural flow measured was in the water year 1913–14, estimated at 42 BCM. Other low flows are 62, 66, 66, 68, 69, 69, and 70 BCM, registered during the water years 1899–1900, 1907–08, 1940–41, 1941–42, 1918–19, 1925–26 and in 1915–16, respectively.

The conclusion is that although the average natural flow of the Nile at Aswan at 84 BCM/year is believed to be valid in the long term, records as high as 150 BCM (almost twice the average) as well as records as low as 42 BCM (almost half the average) were observed. This variation in the annual flow was behind the idea of having a long-term storage dam to replace the yearly storage of Old Aswan Dam, which was a one-year storage dam even after being heightened twice to increase its capacity from 1.0 BCM to 2.5 BCM and eventually to 5.0 BCM.

The storage of 5.0 BCM can augment the flow at most only 450 m³/s over a half-year, which is rather large compared to the average natural flow around 800 m³/s, but it is not sufficient even within one year. This limitation may be one of the reasons for the construction of the Aswan High Dam (AHD).

2.5 The Pharaohs' Water Management Systems (3500 BC–640 AD)

At the dawn of Egypt's history, the Nile Valley consisted of arid plains, sand dunes and marshy jungles with spots of reclaimed enclosures only on high-lying lands. Every seven to ten years the valley was swept with a devastating flood that inundated both high and low lands, leaving most of the country under water, although in some years the flood was modest and allowed people to raise crops and make a reasonable living. The third alternative was a low flood that might still result in famine and the starvation of humans and animals. Despite the floods, the first regular state in the history of humanity was born in Egypt.

During the nomadic Stone Age, Egyptians started introducing controlled basin irrigation by cultivating the part of the flood plain of the river where fertile sediments settle on both sides of the river (Egyptian Commission for Irrigation and Drainage 1983), as shown in Fig. 2.6. These spots were further protected from floodwater by levees surrounding them; tail escapes were also located at the end of a number of plots to allow surplus water to flow back to the river when the flood receded. The tail escape was then closed by stone and earth to keep water inside the basin. This process could be maintained within small communities, but the establishment of the huge number of basins of wider areas between the river flood plain and the desert could only be carried out by capable governments supported by strong institutions and assisted by many people willing to work and serve their communities for a better living standard and a brighter future.

Basin irrigation was not the only available system for land cultivation. Inundated swamps and low-lying lands on both sides of the river were exploited by digging small holes and lifting subsurface water during non-flooding times. The pictures of primitive lifting devices like the *shaduf* and *tanbour* provide evidence of the irrigation of highlands by the use of surface and subsurface water not only during the flood periods but also during the rest of the year when upstream flows come to an end.

Menes (3000 BC) was the first king to rule United Egypt, i.e., Upper Egypt and Lower Egypt. Menes closed a branch of the Nile running through the Western

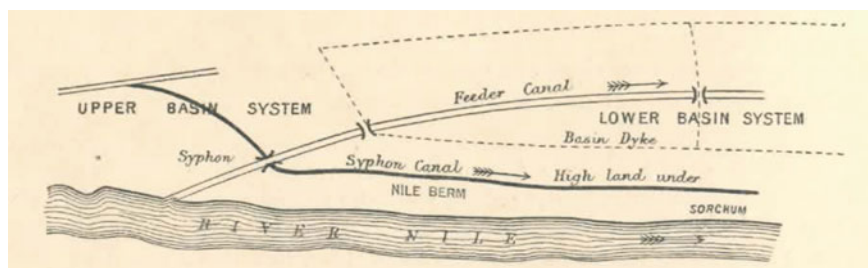


Fig. 2.6 Diagram of a basin irrigation system in the Nile valley. *Source* Willcocks and Craig (1913)

Desert depression (which is now an oasis). He also widened and deepened the branch running through the Valley and the Delta and strengthened its embankments not only to secure water for agriculture but also to establish communities and protect their towns and cities from high floods.

In 1885 Al Kofra Dam was discovered by the German geographist Georg Schweinfurth on Wadi El Garawy located in Helwan at the outskirts of Cairo, 30 km to the south. This dam was constructed on a tributary stream on the right side of the Nile to store the flash flood water from the eastern hills. Over the years 1915–1982, a number of scientists investigated the age of the dam, and they concluded that it was built about 2600–2700 BC. The Al Kofra Dam is composed of an impermeable core of gravel and broken stones, surrounded on all sides by large stones covered by graded parts of crushed stone.

Following the maintenance of the river between two strong embankments, the Fayoum Depression (70 km southwest of Cairo) was used as a powerful tail escape, as it can accommodate excess water from high floods together with water collected in low-lying lands on both sides of the river. Water in “Lake Moeris” (the ancient name of Fayoum) would flow back to the river when dangerously high floods were over.

Basin irrigation held water for almost 45 days every year. The average depth of the water in the basin would be approx. 1 m but never less than 30 cm even at the highest elevation of the basin. Retention of water in the basin for 6 weeks would cause the complete saturation of the sub-soil, and this moisture would be sufficient for maturing some crops and growing others.

The average area of each basin was approximately 2900 ha, varying from 840 to 16,800 ha. Five to eight basins connected in a series were served by one main canal. The last basin (which is the lowest in elevation) and the largest in area were both equipped with a tail escape that allowed water to flow back to the river when the flood period is over. The canals serving the basins had an average width of 10 m, but some were up to 75 m wide (Fig. 2.6).

Basin irrigation continued over the age of Pharaohs (3500–332 BC), Ptolemy (332–31 BC) and the Romans (31 BC–640 AD), and on to the beginning of the 19th century. During the Arab reign (640–1517), cultivated land increased from 0.6 mil. ha to 1.2 mil. ha. During this era, the excavation of new canals, widening of existing canals and the construction of regulating structures were carried out on a regular basis. The remains of a Lahoun head regulator in Fayoum, an Abu-El-Menega regulator in Kalub (15 km north of Cairo) and an elevated canal carrying water from the Nile at the center of Cairo to irrigate the green cover surrounding the Citadel was originally named the Amir El Mo'menin Canal (the official name of the country's ruler). The canal is 5 km long and 15 m above ground level. All of these structures are good examples of masonry control structures built during the 10th, 11th and 16th centuries. The Roda Nilometer (built in 711 AD) is still in use, and its records have been continuously collected for more than 1300 years, with only a few gaps.

It should be mentioned here that during the rule of the Othman Empire, irrigation was not given the attention it needed, and thus the area irrigated at the end of the

18th century shrank to less than 2 million acres (0.84 million ha). It seems possible that the ancient Egyptians, who traded with communities as far as the Red Sea and the land of Punt (Somali Land) and up the Nile to Khartoum and beyond, did not know, at that time, about the sources of the Nile.

As mentioned earlier, the Nile Basin consists of three distinct sub-basins: the Equatorial Lakes, Bahr El Ghazal and the Ethiopian Highlands. Rain falls almost equally on these sub-basins at about 1600 BCM/y. However, the contribution of the Equatorial Lakes plateau to the Main Nile's natural flow is no more than 14%. The Ethiopian Highlands contribute 86% to the Nile flow, whereas all of the rain that falls on Bahr El Ghazal is lost through evaporation from free water surfaces (swamps and marches) and from the evapotranspiration of flora and vegetation, where wild fauna are spreading all over. Both the Equatorial Lakes and Bahr El Ghazal are generally flat or mild sloping lands, but the Ethiopian Highlands is characterized by its steep slopes.

The Ancient Egyptians established the first Central state worldwide when they learned from individuals how to manage floodwater through very small to extremely large basins inside which floodwater was allowed to enter, bringing sediment. When each flood was over, the basins allowed the water to flow back into the river. This process added to the fertility of the soil (because when the water was stored in the basins, most of the silt in the water was deposited in the fields), and it enabled the saturation of the soil profile, which made the cultivation of a mono-crop possible.

When water collected in low-lying lands infiltrated the soil surface, it was possible to use primitive lifting devices to bring water up again for different purposes. The relevant government system during the time of the Pharaohs consisted of three entities: (1) the central royal financial and public works department; (2) the farms along both sides of the river divided into large plots managed by separate management bodies called "agricultural houses," a part of which was the irrigation management section called "water houses," and (3) lands on both right and left desert fringes which were not subject to regular flooding and were used only for grazing and the cultivation of short-age crops such as vegetables.

2.6 Ancient Egyptian Agriculture

The civilization of ancient Egypt was indebted to the Nile River and its dependable seasonal flooding. The river's predictability and the fertile soils it provided allowed the Egyptians to build an empire based on great agricultural wealth. Egyptians are credited as being one of the first groups of people to practice agriculture on a large scale. This was possible because of the cleverness of the Egyptians as they developed basin irrigation. Their farming practices allowed them to grow staple food crops, especially grains such as wheat and barley, and industrial crops, such as flax and papyrus.

The River Nile flows from Lake Victoria and Lake Tana north into the Mediterranean Sea, as was mentioned above. The river provided a fertile oasis in the middle of great deserts, which allowed the Egyptians to develop into a powerful state. Egypt's dependence on a river as its life source was not unique. This dependence was characteristic of several ancient races, including the Mesopotamia, Indus and Yellow River civilizations that relied on the Tigris/Euphrates, Indus and Yellow Rivers, respectively.

Egyptian irrigators did not experience many of the troublesome problems that overwhelmed other historic irrigation societies. The single season of planting did not overly deplete the soil, and fertility was naturally restored each year by the return of the silt-laden floodwaters. In some basins, farmers planted grains and nitrogen-fixing legumes in alternative years, which helped maintain the soil's productivity.

The summer water table remained at least 3–4 m below the surface in most basins, and the period of inundation prior to planting pushed whatever salts had accumulated in the upper soil layers down below the root zone. With salt buildup naturally checked and fertility constantly restored, Egyptian agriculturists enjoyed not only a productive system, but also a sustainable one.

Nearly 1500 years ago, Egyptian farmers cultivated about 800,000 hectares under this system of basin irrigation. The *shaduf*, the water-lifting device already in use in Mesopotamia, appeared in Upper Egypt sometime after 1500 BC (Fig. 2.7). This technology enabled farmers to irrigate crops near the riverbanks and canals during the dry summer. This would have allowed the cultivated area to expand by 10–15% in summer. A similar increase might have been afforded by the water-wheel, introduced sometime after 325 BC. Thus, by the time Egypt had become a breadbasket for the Roman Empire, some 1 million hectares of land were effectively under cultivation in the course of a year.

The blessings of the Nile were many, but they did not come without some costs. A low flood could lead to famine, and too high a flood could destroy dikes and other irrigation works. Even a 2-meter drop in the river's flood level could leave as much as a third of the floodplain un-watered.

Because of the link between the Nile's flow level and Egypt's well-being, early on the ancient Egyptians developed a system for measuring the height of the Nile in various parts of the country. This monitoring allowed them to compare daily river levels with years past and to predict with some accuracy the coming year's high mark. At least 20 "nilometers" were spaced along the river (Fig. 2.7), and the maximum level of each year's flood was recorded in the palace and temple archives.

The central government imposed a tax on the peasant farmers of about 10–20% of their harvest, but the basic administration of the agricultural system remained local. The collapse of government and the turnover of dynasties did little to undermine irrigation and agricultural production on the local level.

Overall, Egypt's system of basin irrigation proved inherently more stable from ecological, political, social, and institutional perspectives compared to any other

Fig. 2.7 The *nilometer* on Elephantine island, Aswan, consisting of stairs and staff gauges. (By M. Satoh)



irrigation-based society in human history. Fundamentally, the system was an enhancement of the natural hydrological patterns of the Nile River, not a wholesale transformation of them. Although the system was not always able to prevent large losses of human life due to famine following the Nile floods, the system sustained an advanced civilization through numerous political disturbances and other destabilizing events over some 5000 years. No other place on Earth has been provided continuous cultivation of the same crops for so long (Postel 1999).

2.7 Ancient Egyptian Irrigation Methods

The earliest and most famous reference to irrigation in Egyptian archaeology was found on the mace head of the Scorpion King, which was dated to roughly 3100 BC. In order to fully utilize the waters of the River Nile, the ancient Egyptians developed systems of irrigation for a variety of purposes. As described above, irrigation granted them greater control over their agricultural practices, but irrigation was also used to provide drinking water. In addition, although irrigation was crucial to the country's

agricultural success, there were no statewide regulations on water control in ancient times; instead, irrigation was the responsibility of local farmers or villages.

The Egyptians depended on the annual Nile flood to cover their fields with black silt and irrigate their crops. They measured the flood to determine their taxes. They built canals and dams so that water could be transported from the Nile to distant areas for irrigation and drinking. The Egyptians invented or adapted several tools to help collect water from the Nile to the surface fields, including the *tanbour*, the *shaduf*, and the *saqia*.

2.7.1 *Tanbour*

The *tanbour* is a tool for raising water (Fig. 2.8). Increasing the water level from the Nile to the surface of agricultural land was a very important activity in Egypt. The invention of the tanbour made this task easier. The well-known scientist Archimedes invented the tanbour during his stay in Alexandria and named it the “Archimedes screw” (Kantert 2008). It consists of a piece of wood in the form of a screw surrounded by a nested disk. The lower part of the tanbour is placed in the water and rotated, causing the water to rise to higher levels. The tanbour has been adopted by many generations of Egyptians, and today farmers still use it in times of low water levels.

2.7.2 *Shaduf*

The *shaduf*, also spelled *shadoof*, is a hand-operated device for lifting water (Fig. 2.9), invented in ancient times and still used in India, Egypt, and some other

Fig. 2.8 A *Tanbour*. Source El-Sherif (2012)



Fig. 2.9 A *shaduf*. Source El-Sherif (2012)



countries to irrigate land. Typically, it consists of a long, tapering, nearly horizontal pole mounted like a seesaw. A skin or bucket is hung on a rope from the long end, and a counterweight is hung on the short end. The operator pulls down on a rope attached to the long end to fill the bucket and allows the counterweight to raise the bucket. To raise water to higher levels, a series of *shadufs* are sometimes mounted one above the other.

2.7.3 *Saqia*

A water wheel, or *saqia*, is a machine for converting the energy of free-flowing or falling water into useful forms of power, often in a watermill. A water wheel consists of a large wooden or metal wheel with a number of blades or buckets arranged on the outside rim forming the driving surface. Most commonly, the wheel is mounted vertically on a horizontal axle, but the tub or Norse wheel is mounted horizontally on a vertical shaft. Vertical wheels can transmit power either through the axle or via a ring gear and typically drive belts or gears; horizontal wheels usually directly drive their load.

The *saqia*, or Egyptian water wheel, is thought to be the first vertical water wheel in history. It dates from the early Roman Empire, around 700–600 BC, and was primarily used by the empire in Egypt. A *saqia* was set on a transverse axis in such a way as to submerge the lower portion of the wheel. Functioning in much the same way as the chain of pots, it was rotated to raise the water in the buckets to the level of the top of the wheel. A *saqia* was normally driven by animals such as donkeys and oxen (Fig. 2.10).



Fig. 2.10 A *saqia* driven by a donkey still used in 1990. (West Delta, by M. Satoh)

2.8 Farming System

The Egyptians took advantage of the natural cyclical flooding pattern of the Nile. Because this flooding occurred predictably, the Egyptians were able to develop their agricultural practices around the floods. The water levels of the river would rise in August and September, leaving the floodplain and delta submerged by 1.5 m of water at the peak of flooding. This yearly flooding of the river was known as inundation. As the floodwaters receded in October, farmers were left with well-watered and fertile soil in which to plant their crops. The soil left behind by the flooding, which was known as silt, was brought mainly from the Ethiopian Highlands by the Blue Nile and the main Nile. Planting took place in October once the flooding was over, and crops were left to grow with minimal care until they ripened between the months of March and May.

2.9 Crop Plants

2.9.1 Food Crops

Knowledge of crops of ancient Egypt can be deduced from the artistic record, but definite proof comes from the desiccated remains of plants themselves. Many archeological remnants of both plants and animals can be viewed in the newly reconstructed Ancient Egyptian Agricultural Museum in Cairo.

The chief ancient grain crops, used for bread and beer, were barley and various wheats including the diploid einkorn (AA genome), the tetraploid emmer and durum wheats (AABB), and the hexaploid spelt and bread wheats (AABBDD). The vegetable crops of ancient Egypt included a number of root crops, leafy salad crops, legumes, and various cucurbits. The ancient root crops such as the pungent alliums, garlic (*Allium sativum*) and onion (*A. cepa*), as well as radish (*Raphanus sativum*) continue to be very popular in modern Egypt. Among the leafy salad crops were lettuce (*Lactuca sativa*) and parsley (*Petroselinum crispum*). There were a number of pulses such as cowpea (*Vigna sinensis*), faba (broad) bean (*Vicia faba*), chickpea (*Cicer arietinum*), and lentils (*Lens culinaris*). The cucurbits included cucumber (*Cucurbita sativa*), melons (*Cucumis melo*), gourds (pumpkins) (*Lagenaria* spp.), and later watermelon (*Citrullus lanatus*).

The fruit crops of Egypt were expanded throughout the centuries. The date and doum palm as well as the sycamore fig are considered pre-dynastic Egyptian fruits and the sycamore is not indigenous. The fig and grape were known since the Old Kingdom, the carob and pomegranate were introduced in the Middle Kingdom, the olive and apple appeared in the New Kingdom, and the peach and pear date to the New Kingdom.

Fruits were a common motif of Egyptian artwork, suggesting that their growth was also a major focus of agricultural efforts as the civilization's agricultural technology developed. Unlike cereals and pulses, fruit required more demanding and complex agricultural techniques, including the use of irrigation systems, cloning, propagation and training. The first fruits cultivated by the Egyptians were likely indigenous, such as the palm date. Grapes and watermelon were found throughout pre-dynastic Egyptian sites.

2.9.2 Industrial and Fiber Crops

Egyptians relied on agriculture for more than just the production of food. They were creative in their use of plants, using them for medicine, as part of their religious practices, and in the production of clothing. Herbs perhaps had the most varied purposes; they were used in cooking, medicine, as cosmetics and in the process of embalming. Over 2000 different species of flowering or aromatic plants have been found in tombs. Papyrus was an extremely versatile crop that grew wild and was also cultivated. The roots of the plant were eaten as food, but it was primarily used as an industrial crop. The stem of the papyrus plant was used to make boats, mats and paper. Flax was another important industrial crop that has several uses. Its primary use was in the production of rope and fine linens, which were used domestically and also exported. Henna was grown for the production of dye. The textile industry was still a hand-made process. People worked in their own homes or in groups in workshops.

2.9.3 Horticulture

Orchards and gardens were also developed in addition to field planting in the floodplains. This horticulture generally took place further from the floodplain of the Nile, and as a result, it required much more work. The perennial irrigation required by gardens forced growers to manually carry water from either a well or the Nile to water their garden crops. Additionally, while the Nile brought silt, which naturally fertilized the valley, gardens had to be fertilized by pigeon manure. These gardens and orchards were generally used to grow vegetables, vines and fruit trees.

The ancient Egyptians also loved flowers, as evidenced by murals portraying court women wearing Egyptian lotus blooms, container-grown plants, and funeral garlands.

2.10 Cultivation Technology

2.10.1 Farm Tools

The basic tools of agriculture, i.e., the ax, the hoe, and the plow, are independent Egyptian inventions (Fig. 2.11). The prototype hoe can be seen as a modification of a forked branch, while the more developed form has a handle and wooden blade. The plow was at first a modification of the hoe, originally drawn through the ground; perhaps first by a man with a rope, but by the time of the Old Kingdom it was drawn by a pair of oxen. Metal plowshares were eventually created. In the New Kingdom, handles were lashed by ladder-like crosspieces, and the shaft was bound to a double yoke over the oxen's horns.

Sowing followed plowing. Often the sower scattered seed in front of the oxen, so that the oxen tread it into the ground, whereas fine seed such as flax was shaken directly into the furrows. If the seed was sown after flooding, sheep, goats, or swine were driven to trample the seed into the ground.

Fig. 2.11 Cultivating a field.
Source El-Sherif (2012)



2.10.2 *Harvest and Postharvest Technology*

Harvest and the postharvest handling of grain were favorite themes in Egyptian art. Early sickles, used to cut wheat, had flint teeth set in a wooden or bone haft followed by curved sickles with a short handgrip (Fig. 2.12). Metal sickles were common in the New Kingdom. Wheat was bound into bundles and loaded onto donkeys for storage or later carried in net baskets. Fruit was collected and packed in shallow baskets, artfully arranged.

Evidence of grain storage dates to Neolithic times in buried baskets or earthenware jars. Later the storage of grain and other provisions became a state function, and communal silos and granaries were constructed. The Roman world considered Egypt the “breadbasket of the world.”

2.10.3 *Viticulture*

Grapes were much appreciated in ancient Egypt, with abundant pictures of grapes, grape culture, and winemaking (Fig. 2.13).

Some reports indicate that vines were grown directly on the field surfaces, but there are also many representations of fencing and arbors. The round arbor was a common feature between the New Kingdom and the Greco-Roman Periods. Greek authors confirmed that various cultivars of vines (*Vitis vinifera*) were developed in Egypt. The biblical literature is rich with allusions to grapes and wine. Grapes were preserved by drying. Raisins became favorite foods in cooking, were considered to have medicinal properties, and were at one time used as a drying aid in embalming.

Fig. 2.12 Harvesting wheat.
Source El-Sherif (2012)



Fig. 2.13 Harvesting grape.
 Source El-Sherif (2012)



2.10.4 Ripening Induction

A system of ripening parthenocarpic fruit was developed that involves the scraping or wounding of the immature fruit. Wounding of fruit can induce speedy growth (3–4 days), and it can increase the weight and volume of figs by seven-fold, in a process now shown to be an ethylene response: the wounding process yields an induced parthenocarpic fruit that matures before the development of insect pests that make the figs inedible.

2.10.5 Biotechnology: Bread and Wine

The beginnings of biotechnology are traced directly to the manufacture of bread and wine. The harvest, threshing, grinding of grain to flour and subsequent sieving are abundantly illustrated in Egyptian art. Grain grinding was handled with a hand mill called a ‘saddle quern’ by housewives, but eventually grinding was carried out on a large scale by millers. Fermentation by the use of leaven, a mass of yeast, was a development that changed the making of bread. By 1200 BC, over 30 different forms of bread and cakes were mentioned.

Alcoholic fermentation was carried out in pots with bread or flour to make beer, or with sugary fruit juices (particularly grapes but also dates and pomegranates) to make wine. Wine is described as early as the first dynasty and was associated with Horus, the falcon-headed god, son of Isis, the Great Mother, loyal sister and wife of Osiris, god of the beneficent Nile. The first Pharaoh called his vineyard “The Enclosure of the Beverage of the Body of Horus” resonating with the subsequent relation of wine to the blood of Jesus Christ in the Eucharist.

After fermentation, the wine vessels were sealed with plugs of straw and clay designed to prevent bursting from gas accumulation and then impressed with official stamps showing the year of the king's rule, the district, the town, and the name of the wine. Wines were mixed by siphoning. Taxes were levied on imported and exported wine. By the Greco-Roman periods there were literally hundreds of wine types from grapes, indicating intense genetic selection.

2.10.6 Gardens and Ornamental Horticulture

Gardens in Egypt represent the beginnings of horticulture. They originated on the edge of the desert where the natural vegetation was sparse. There was no landscape to copy except that of the oasis. Thus, the first garden can be thought of as an artificial, protected oasis; such gardens still exist. Later gardens surrounded by walls were often terraced, containing enclosed pools to provide the "oasis" feeling and containing water plants. The gardens were filled with statuary and ornamental columns.

Plantings became ordered and set in straight rows because of irrigation requirements and the flatness of the land. Irrigation canals were a common feature. Plants were treated architecturally; trained on lattice structures to artificial shapes (referred to as arbors, bowers, or pergolas). Fruit trees, palms, and vines in symmetrical arrangements were common garden plants providing food and shade.

Egyptians gardens are the forerunners of our present-day formal gardens, which use plants as architectural elements. Because there was essentially no natural landscape, the Egyptians created one based on straight lines and symmetry. They represent human domination over plants and an ordered, artificial environment.

A study of Egyptian history underscores the ancient origins of agriculture. The modern world is in debt to this great civilization, which contributed many of our basic agricultural innovations, especially cultivation and irrigation technology and the horticultural arts. Ancient Egyptian agriculture is also shown to be the mother of science, providing the resources to enable the construction of vast public works and temples and a basic inspiration for progress.

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