J. Ind. Geophys. Union (November 2017)
v.21, no.6, pp: 535-542

Types of Irrigation and Historical development - a comprehensive compilation

P.R.Reddy
Director Grade Scientist (Retd), CSIR-NGRI, Hyderabad- 500007, Telangana State
parvatarreddy@gmail.com

INTRODUCTION

We often read in Newspapers, see in TV programs and hear in political circles about lack of sufficient irrigation facilities, leading to deceleration of food production. The word irrigation, many a time, is wrongly used as we are not exposed to various facets of irrigation and apt use of proper irrigation technique that is area specific. As our economy is agriculture based and as monsoon aberrations have introduced number of problems in properly applying irrigation in time and space, it is essential for all those interested in our country`s economy and there by wish to contribute to sustainable development of our economy and in turn their own wellbeing, to learn about irrigation. An attempt is made here to introduce the reader to irrigation and its importance in enhancing agriculture/ horticulture output. Since the topic requires coverage of various facets of irrigation and as readers may feel fatigued in reading a lengthy write up I have sub divided the contents in to 3 parts, viz, 1) Introduction, types of irrigation and Historical development; 2) Present Irrigation practices and their applicability & limitations 3) Irrigation in India and needed strategies to strengthen irrigation facilities. The first part is covered below. The rest will be presented later.

WHAT IS IRRIGATION?

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost, suppressing weed growth in grain fields and preventing soil consolidation. In contrast, agriculture that relies only on direct rainfall is referred to as rain-fed or farming. Irrigation systems are also used for dust suppression, disposal of sewage, and in mining. Irrigation is often studied together with drainage, which is the natural or artificial removal of surface and sub-surface water from a given area. Irrigation has been a central feature of agriculture for over 5000 years. Probably one of the oldest methods of irrigating fields is surface irrigation (also known as flood or furrow irrigation), where farmers flow water down small trenches running through their crops. Humans' first invention after learning how to grow plants from seeds was probably a bucket. For most of human history, people did not have mechanized spray irrigation systems to apply water to crop fields.

Sources of irrigation water can be groundwater extracted from springs or by using wells, surface water withdrawn from rivers, lakes or reservoirs or non-conventional sources like treated wastewater, desalinated water or drainage water. A special form of irrigation using surface water is spate irrigation, also called floodwater harvesting. Spate irrigation areas are in particular located in semi-arid or arid, mountainous regions. (Source: http://en.wikipedia.org/wiki/Irrigation)

TYPES OF IRRIGATION:

Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little.

Surface Irrigation: In surface (furrow, flood, or level basin) irrigation systems, water moves across the surface of agricultural lands, in order to wet it and infiltrate into the soil. Surface irrigation can be subdivided into furrow, border-strip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land and still is in most parts of the world.

a) Furrow Irrigation: Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. This method is suitable for all row crops and for crops that are affected in water for long periods such as 12-24 hours.

b) Basin Irrigation: Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields.

Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides. Trees can also be grown in basins, where one tree is usually located in the middle of a small basin.

In general, the basin method is suitable for crops that are unaffected by standing in water for long periods such as 12-24 hours.

c) Border Irrigation: Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips. Irrigation water can be fed to the border in several ways: opening up the channel bank, using small outlets or gates or by means of siphons or spiles. A sheet of water flows down the slope of the border, guided by the bunds on either side.

Localized Irrigation: Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods.

Subsurface textile irrigation: Subsurface Textile Irrigation (SSTI) is a technology designed specifically for subsurface irrigation in all soil textures from desert sands to heavy clays. A typical subsurface textile irrigation system has an impermeable base layer (usually polyethylene or polypropylene), a drip line running along that base, a layer of geotextile on top of the drip line and, finally, a narrow impermeable layer on top of the geotextile. Unlike standard drip irrigation, the spacing of emitters in the drip pipe is not critical as the geotextile moves the water along the fabric up to 2m from the dripper.

Drip irrigation: Drip (or micro) irrigation, also known as trickle irrigation, functions as its name suggests. In this system water falls drop by drop just at the position of roots. Water is delivered at or near the root zone of plants, drop by drop. This method can be the most water-efficient method of irrigation if managed properly, since evaporation and runoff are minimized. The field water efficiency of drip irrigation is typically in the range of 80 to 90 percent when managed correctly.

Sprinkler Irrigation: In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a solid-set irrigation system. Sprinklers can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems known as traveling sprinklers may irrigate areas such as small farms.

Center pivot Irrigation: Center pivot irrigation is a form of sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the center of the arc. These systems are found and used in all parts of the world and allow irrigation of all types of terrain. Newer systems have drop sprinkler heads

Lateral move (side roll, wheel line) Irrigation: A series of pipes, each with a wheel of about 1.5 m diameter permanently affixed to its midpoint and sprinklers along its length, are coupled together at one edge of a field. Water is supplied at one end using a large hose. After sufficient water has been applied, the hose is removed and the remaining assembly rotated either by hand or with a purpose-built mechanism, so that the sprinklers move 10 m across the field. The hose is reconnected. The process is repeated until the opposite edge of the field is reached.

Sub-irrigation: Sub-irrigation has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Sub-irrigation is also used in commercial greenhouse production, usually for potted plants.

Automatic, non-electric using buckets and ropes: Besides the common manual watering by bucket, an automated, natural version of this also exists. Using plain polyester ropes combined with a prepared ground mixture can be used to water plants from a vessel filled with water.

Using water condensed from humid air: In countries where at night, humid air sweeps the countryside, water can be obtained from the humid air by condensation onto cold surfaces. This is for example practiced in the vineyards at Lanzarote using stones to condense water or with various fog collectors based on canvas or foil sheets.

In-ground irrigation: Most commercial and residential irrigation systems are "in ground" systems, which means that everything is buried in the ground. With the pipes, sprinklers, emitters (drippers), and irrigation valves being hidden, it makes for a cleaner, more presentable landscape without garden hoses or other items having to be moved around manually. (**Source:** http://en.wikipedia.org/wiki/Irrigation)

SELECTION OF IRRIGATION METHOD:

To choose an irrigation method, the farmer must know the advantages and disadvantages of the various methods. He or she must know which method suits the local conditions best. Unfortunately, in many cases there is no single best solution: all methods have their advantages and disadvantages. Testing of the various methods - under the prevailing local conditions - provides the best basis for a sound choice of irrigation method.

The suitability of the various irrigation methods, i.e. surface, sprinkler or drip irrigation, depends mainly on the following factors:

1)natural conditions 2)type of crop 3)type of technology 4)previous experience with irrigation 5)required labour inputs 6) costs and benefits.

Even though all the factors cited above are useful to select a type of irrigation Natural Conditions play crucial role in selecting the best possible method. Some specifics are detailed below:

Natural Conditions:

The natural conditions such as soil type, slope, climate, water quality and availability, have the following impact on the choice of an irrigation method:

Soil type: Sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. On loam or clay soils all three irrigation methods can be used, but surface irrigation is more commonly found. Clay soils with low infiltration rates are ideally suited to surface irrigation. When a variety of different soil types is found within one irrigation scheme, sprinkler or drip irrigation are recommended as they will ensure a more even water distribution.

Slope: Sprinkler or drip irrigation are preferred above surface irrigation on steeper or unevenly sloping lands as they require little or no land levelling. An exception is rice grown on terraces on sloping lands.

Climate: Strong wind can disturb the spraying of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.

Water availability: Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation and so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.

Water quality: Surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems. If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods. Sprinkler systems are more efficient than surface irrigation methods in leaching out salts. (**Source**: http://www.fao.org/docrep/s8684e/s8684e08.htm)

HISTORY-GLOBAL SCENARIO:

Historically, civilizations have been dependent on development of irrigated agriculture to provide agrarian basis of a society and to enhance the security of people. A prerequisite in the rise of the first state societies seems to have been the development of complex farming systems involving labour intensive irrigation, in which cereals and grain legumes were usually the main crops. Ancient irrigation is, however, often difficult to identify directly because of the destruction of associated ground structures. As an alternative, other methods have been proposed to assess irrigation. One indirect method takes into consideration the development of seeds; for example, from the size of charred flax seeds which may occur in an archaeological assemblage of plant remains. A more direct method for identifying ancient irrigation is based on the increased deposition of silica in cereal plants when they grow under irrigation. Comparison of the resulting distinctive characteristics of the phytoliths produced by crops under irrigation with rain-fed ones has been proposed in mid 1990s as a method to assess the presence of ancient irrigation in cereal cultures. In one such study this method was applied to investigate whether ancient irrigation was practiced in the southeast Iberian Peninsula. Whereas in the Near East, irrigation has been inferred archaeologically from the early stages of civilization .Indirect evidence for irrigation in the western Mediterranean basin is scarce and inconclusive until the Roman period. There is a strong debate about when irrigation started in the south-eastern part of the Iberian Peninsula (Spain), one of the regions of the western Mediterranean basin in which advanced social structures first appeared. Although there is agreement among archaeologists that irrigation in the south-east of Spain spread after the end of the 3rd millennium BP, no clear picture emerges from earlier times. In this context some of the current theories adduced to explain the strong cultural development of the southeast of the Iberian Peninsula during the Copper and Bronze Ages (5th and 4th millennia BP) have placed great importance on the control of the environment, because attempts to control it (for example, by hydraulic works) could lead to an organized (i.e. hierarchical) society. From different theoretical approaches and on the assumption that the environment has not changed substantially, scientists have proposed that intensive agriculture based on irrigation was necessary to maintain a growing population in an arid zone such as the south-east of the Iberian Peninsula. They point out that water control and hydraulic works such as irrigation channels, canals, dams and cisterns were among the most valued elements in these societies. Indeed, if the information on early agricultural sites in the Near East may be considered as a guide, it could be assumed that cultivation whenever possible was based on sowing on alluvial fans and terraces as well as on the edges of freshwater swamps where the water table was always high and the soil fertilized by silt deposited by periodic floods. However, the occurrence of irrigation at these times remains controversial. (**Source**: Jose´ Luis Araus et al., 1997, Journal of Archaeological Science (1997) 24, 729–740). Such an environment was indeed present in Harappa and Mohenjo-Daro region (Indus Aryan Civilization).

Archaeological investigation has identified evidence of irrigation where the natural rainfall was insufficient to support crops. Perennial irrigation was practiced in the Mesopotamian plain whereby crops were regularly watered throughout the growing season by coaxing water through a matrix of small channels formed in the field. Ancient Egyptians practiced *Basin irrigation* using the flooding of the Nile to inundate land plots which had been surrounded by dykes. The flood water was held until the fertile sediment had settled before the surplus was returned to the watercourse. There is evidence of the ancient Egyptian pharaoh Amenemhet III in the twelfth dynasty (about 1800 BCE) using the natural lake of the Faiyum Oasis as a reservoir to store surpluses of water for use during the dry seasons, the lake swelled annually from flooding of the Nile. The Ancient Nubians developed a form of irrigation by using a waterwheel-like device called a sakia. Irrigation began in Nubia sometime between the third and second millennium BCE. It largely depended upon the flood waters that would flow through the Nile River and other rivers in what is now the Sudan. In sub-Saharan Africa irrigation reached the Niger River region cultures and civilizations by the first or second millennium BCE and was based on wet season flooding and water harvesting.

Terrace irrigation is evidenced in pre-Columbian America, early Syria, India, and China. In the Zana Valley of the Andes Mountains in Peru, archaeologists found remains of three irrigation canals radiocarbon dated from the 4th millennium BCE, the 3rd millennium BCE and the 9th century CE. These canals are the earliest record of irrigation in the New World. Traces of a canal possibly dating from the 5th millennium BCE were found under the 4th millennium canal .Sophisticated irrigation and storage systems were developed by the Indus Valley Civilization in present-day Pakistan and North India, including the reservoirs at Girnar in 3000 BCE and an early canal irrigation system from circa 2600 BCE. Large scale agriculture was practiced and an extensive network of canals was used for the purpose of irrigation in Ancient Persia (modern day Iran) as far back as the 6th millennium BCE, where barley was grown in areas where the natural rainfall was insufficient to support such a crop. The Qanats, developed in ancient Persia in about 800 BCE, are among the oldest known irrigation methods still in use today. They are now found in Asia, the Middle East and North Africa. The system comprises a network of vertical wells and gently sloping tunnels driven into the sides of cliffs and steep hills to tap groundwater. The noria, a water wheel with clay pots around the rim powered by the flow of the stream (or by animals where the water source was still), was first brought into use at about this time, by Roman settlers in North Africa. By 150 BCE the pots were fitted with valves to allow smoother filling as they were forced into the water. The irrigation works of ancient Sri Lanka, the earliest dating from about 300 BCE, in the reign of King Pandukabhaya and under continuous development for the next thousand years, were one of the most complex irrigation systems of the ancient world. In addition to underground canals, the Sinhalese were the first to build completely artificial reservoirs to store water. Due to their engineering superiority in this sector, they were often called 'masters of irrigation'. Most of these irrigation systems still exist undamaged up to now, in Anuradhapura and Polonnaruwa, because of the advanced and precise engineering. The system was extensively restored and further extended during the reign of King Parakrama Bahu (1153–1186 CE).The oldest known hydraulic engineers of China were Sunshu Ao (6th century BCE) of the Spring and Autumn Period and Ximen Bao (5th century BCE) of the Warring States period, both of whom worked on large irrigation projects. In the Szechwan region belonging to the State of Qin of ancient China, the Dujiangyan Irrigation System was built in 256 BCE to irrigate an enormous area of farmland that today still supplies water. By the 2nd century AD, during the Han Dynasty, the Chinese also used chain pumps that lifted water from lower elevation to higher elevation. These were powered by manual foot pedal, hydraulic waterwheels, or rotating mechanical wheels pulled by oxen. The water was used for public works of providing water for urban residential quarters and palace gardens, but mostly for irrigation of farmland canals and channels in the fields. In 15th century Korea, the world's first rain gauge, *uryanggye* was invented in 1441. It was installed in irrigation tanks as part of a nationwide system to measure and collect rainfall for agricultural applications. With this instrument, planners and farmers could make better use of the information gathered in the survey. In North America, the Hohokam were the only culture to rely on irrigation canals to water their crops, and their irrigation systems supported the largest population in the Southwest by AD 1300. The Hohokam constructed an assortment of simple canals combined with weirs in their various agricultural pursuits. Between the 7th and 14th centuries, they also built and maintained extensive irrigation networks along the lower Salt and middle Gila rivers that rivaled the complexity of those used in the ancient Near East, Egypt, and China. These were constructed using relatively simple excavation tools, without the benefit of advanced engineering technologies, and achieved drops of a few feet per mile, balancing erosion and siltation. The Hohokam cultivated varieties of cotton, tobacco, maize, beans and squash, as well as harvested an assortment of wild plants. Late in the Hohokam Chronological Sequence, they also used extensive dry-farming systems, primarily to grow agave for food and fiber. Their reliance on agricultural strategies based on canal irrigation, vital in their less than hospitable desert environment and arid climate, provided the basis for the aggregation of rural populations into stable urban centers. (**Source:** http://en.wikipedia.org/wiki/Irrigation)

A set of carefully-constructed ditches, thought to be the earliest evidence of Roman irrigation in Britain, have been discovered by archaeologists working as part of a £1 billion development by the University of Cambridge in an area occupied by settlements since Prehistoric times. A lost medieval village is now being pursued by experts at the northern end of the North West Cambridge site, where they hope to investigate how civilisation has adapted to living in an area isolated from river valley water supplies. The area has a ridge-way where the gravels meet the clay. Cambridge University findings from excavating around the ridge-way have unearthed zebra-like stripes of Roman planting beds that are encircled on their higher northern side by more deep pit-wells. The gully-defined planting beds were closely set and were probably grapevines or possibly asparagus. Extraordinarily, after carefully peeling off the clays, archaeologists saw a series of ditches lining the wells and the horticultural beds. Clearly, in dry spells, water could have been poured from the pit-wells into the ditches to reach the beds. This is a tremendously significant find that reflects the area's intense agricultural regime from the Roman period. The findings suggest communities lived in the area from as early as the later Neolithic period, between 2800 and 2200BC, and through the later Bronze, Iron and Roman ages. (**Source**:http://www.culture24.org.uk/history-and-heritage/archaeology/art473068-Earliest-evidence-Roman-irrigation-found-by-archaeologists-near-medieval-village).

The development of water control systems in the Asian region began from a small- scale/community system to become an integrated larger system of a kingdom. Technological development had been in line with the accumulation of knowledge and wisdom in the local areas. Over the years, resource endowments have led to different paths of development for rice- producing countries. All rice-exporting countries in Asia (Thailand, Myanmar, Cambodia and Vietnam) have major river deltas, and water control in these areas requires huge investment and management capacity. Such development did not begin until the arrival of the colonial powers in the nineteenth century. Rice cultivation in Thailand, Myanmar and Cambodia remains extensive, with large areas under rain-fed lowland or deep water cultivation. Vietnam is moving into the second stage of developing its delta areas with an increased share of irrigation and better control of water, resulting in a higher yield level. There are differences between the Asian and Western approach to development. The Western approach tends to be dominating and controlling, placing more emphasis on engineering theory and making light of traditional wisdom or human/institutional factors. The Asian approach, on the other hand, is more flexible and is in harmony with nature and the socio-cultural environment

(**Source**: The evolution of irrigation development in monsoon Asia and historical lessons by Nobumasa Hatcho et al; DOI: 10.1002/ird.542. Irrigation and Drainage, Special Issue: Selected Papers of the 20th ICID Congress, Lahore, Pakistan, Volume 59, Issue 1, pages 4–16, Feb 2010).

Ancient China remains an important case to investigate the relationship between statecraft development and 'total power.' While important economic and social developments were achieved in the late Neolithic, it was not until the late Bronze Age (first millennium BC) that state-run irrigation systems began to be built. Construction of large-scale irrigation projects, along with walls and defensive facilities, became vital to regional states who were frequently involved in chaotic warfare and desperate to increase food production to feed the growing population. Some of the irrigation infrastructures were brought into light by recent archeological surveys. We scrutinize fast accumulating archeological evidence and review rich historical accounts on late Bronze Age irrigation systems. While the credibility of historical documents is often questioned, with a robust integration with archeological data, they provide important information to understand functions and maintenance of the irrigation projects. We investigate structure and organization of large-scale irrigation systems built and run by states and their importance to understanding dynamic trajectories to social power in late Bronze Age China. Cleverly designed based on local environmental and hydrological conditions, these projects fundamentally changed water management and farming patterns, with dramatic ecological consequences in different states. Special bureaucratic divisions were created and laws were made to further enhance the functioning of these large-scale irrigation systems. We argue that they significantly increased productivity by converting previously unoccupied land into fertile ground and pushed population threshold to a new level. A hypothesis should be tested in further archeological research. (**Source:** WIREs Water 2017, 4:e1217. doi: 10.1002/wat2.1217)

HISTORY OF IRRIGATION DEVELOPMENT IN INDIA:

Ministry of Water Resources , Govt. Of India, on its web site briefly explains the history of irrigation development in India which can be traced back to prehistoric times. The history of irrigation development in India can be traced back to prehistoric times. Vedas and ancient Indian scriptures made reference to wells, canals, tanks and dams which were beneficial to the community and their efficient operation and maintenance was the responsibility of the State. Civilization flourished on the banks of the rivers and harnessed the water for sustenance of life. According to the ancient Indian writers, the digging of a tank or well was amongst the greatest of the meritorious acts of a man. Brihaspathi, an ancient writer on law and politics, states that the construction and the repair of dams is a pious work and its burden should fall on the shoulders of rich men of the land. Vishnu Purana enjoins merit to a person who patronages repairs to well, gardens and dams.

In a monsoon climate and an agrarian economy like India, irrigation has played a major role in the production process. There is evidence of the practice of irrigation since the establishment of settled agriculture during the Indus Valley Civilization (2500 BC). These irrigation technologies were in the form of small and minor works, which could be operated by small households to irrigate small patches of land and did not require co-operative effort. Nearly all these irrigation technologies still exist in India with little technological change, and continue to be used by independent households for small holdings. The lack of evidence of large irrigation works at this time signifies the absence of large surplus that could be invested in bigger schemes or, in other words, the absence of rigid and unequal property rights. While village communities and co-operation in agriculture did exist as seen in well-developed townships and economy, such co-operation in the large irrigation works was not needed, as these settlements were on the fertile and well irrigated Indus basin. The spread of agricultural settlements to less fertile and irrigated area led to co-operation in irrigation development and the emergence of larger irrigation works in the form of reservoirs and small canals. While the construction of small schemes was well within the capability of village communities, large irrigation works were to emerge only with the growth of states, empires and the intervention of the rulers. There used to emerge a close link between irrigation and the state. The king had at his disposal the power to mobilize labour which could be used for irrigation works.

Man`s knowledge in developing water storage structures, especially in areas that are environmentally hostile is exhibited in Dholavira. Dholavira is an archaeological site at Khadir bet in Bhachau Taluka of Kutch District. Khadir bet island is in the Kutch Desert Wildlife Sanctuary in the Great Rann of Kutch. The site contains ruins of an ancient Indus Valley Civilization/ Harappan city. It is one of the five largest Harappan sites and most prominent archaeological sites in India belonging to the Indus Valley Civilization. The site was occupied from c.2650 BCE, declining slowly after about 2100 BCE. The most striking feature of the city is that all of its buildings, at least in their present state of preservation, are built of stone, whereas most other Harappan sites, including Harappa itself and Mohenjo-daro, are almost exclusively built of brick. Dholavira is flanked by two storm water channels; the Mansar in the north, and the Manhar in the south. The kind of efficient system of Harappans of Dholavira, developed for conservation, harvesting and storage of water speaks eloquently about their advanced hydraulic engineering, given the state of technology in the third millennium BCE. One of the unique features of Dholavira is the sophisticated water conservation system of channels and reservoirs, the earliest found anywhere in the world, built completely of stone. The city had massive reservoirs, three of which are exposed. They were used for storing fresh water brought by rains or to store water diverted from two nearby rivulets. This clearly came in response to the desert climate and conditions of Kutch, where several years may pass without rainfall. A seasonal stream which runs in a north-south direction near the site was dammed at several points to collect water. The inhabitants of Dholavira created sixteen or more reservoirs of varying size . Some of these took advantage of the slope of the ground within the large settlement, a drop of 13 metres (43 ft) from northeast to northwest. Other reservoirs were excavated, some into living rock. Recent archaeological excavation work has revealed two large reservoirs, one to the east of the castle and one to its south, near the Annexe. The reservoirs are cut through stone vertically, and are about 7 m (23 ft) deep and 79 m (259 ft) long. They skirt the city, while the citadel and bath are centrally located on raised ground. There is also a large well with a stone-cut trough connecting it to a drain meant for conducting water to a storage tank. The bathing tank had steps descending inwards. In October 2014 excavation began on a rectangular step-well which measured 73.4 m (241 ft) long, 29.3 m (96 ft) wide, and 10 m (33 ft) deep, making it three times bigger than the Great Bath of Mohenjo-Daro. This finding clearly exhibits the significant knowledge of Harappans and may motivate present day inquisitive irrigation engineers to use the architectural finer points in serving individual small urban hamlets in environmentally difficult and hostile terrains.

In the south, perennial irrigation may have begun with construction of the Grand Anicut by the Cholas as early as second century to provide irrigation from the Cauvery River. Wherever the topography and terrain permitted, it was an old practice in the region to impound the surface drainage water in tanks or reservoirs by throwing across an earthen dam with a surplus weir, where necessary, to take off excess water, and a sluice at a suitable level to irrigate the land below. Some of the tanks got supplemental supply from stream and river channels. The entire land-scape in the central and southern India is studded with numerous irrigation tanks which have been traced back to many centuries before the beginning of the Christian era. In northern India also there are a number of small canals in the upper valleys of rivers which are very old.

Irrigation during Medieval India

Ghiyasuddin Tughluq (1220-1250) is credited to be the first ruler who encouraged digging canals. Fruz Tughluq (1351-86) is considered to be the greatest canal builder. Irrigation is said to be one of the major reasons for the growth and expansion of the Vijayanagar Empire in southern India in the fifteenth century. Babur, in his memoirs called 'Baburnamah' gave a vivid description of prevalent modes of irrigation practices in India at that time. The Gabar Bunds captured and stored annual runoff from surrounding mountains to be made available to tracts under cultivation.

Irrigation Development under British Rule

Close to nineteenth century according to sources of irrigation; canals irrigated 45 %, wells 35 %, tanks 15 % and other sources 5 %. Famines of 1897-98 and 1899-1900 necessitated British to appoint first irrigation commission in 1901, especially to report on irrigation as a means of protection against famine in India. As a result of recommendations of first irrigation commission total irrigated area by public and private works increased to 16 Mha in 1921. From the beginning of 19th century to 1921 there was no significant increase in tube well irrigated area. During 1910 to 1950 growth rate of irrigation was estimated at 2.0 % per annum for government canal irrigation, 0.54 % per annum for well irrigation and 0.98 % per annum in respect of irrigation from all sources.

Irrigation Development at Time of Independence

At time of independence net irrigated area of India under British rule which include Bangladesh and Pakistan was 28.2 Mha. After partition net irrigated area in India and Pakistan being 19.4 Mha and 8.8 Mha respectively. (**Source**: Irrigation Development in India: History & Impact, PareshB. Shirsath,2009;http://indiairrigation.blogspot.com/2009/01/history-of-irrigation-development-in_01.html)& https://www.revolvy.com/main/index.php?s=Dholavira)

CONCLUSIONS:

From the archaeological information civilizations survived and thrived by optimally utilising water resources, adapting area specific irrigation practices. The scriptures clearly show that during ancient times realizing the value of water Man has taken needed decisions to optimally utilize water resources, for drinking and agriculture/ horticulture activities. Community Development was given importance by one and all starting from the King down to a peasant. Till the mechanized implements, for faster extraction and transmission, have come in to use Man has availed the natural resources, including water, in a limited way allowing the environment more or less undisturbed and safe from degradation. Man needs food. But, he needs to be satisfied and content with the food that is sufficient to keep him survive and grow. During historic and pre-historic times Man was satisfied with the products produced by him using apt irrigation practices. The needs were limited and people, in general, were content. The invention of less laborious mechanized systems has created more problems in meeting ever increasing demand for food products by ballooning population. Mechanized farming should basically aim at conservation of water and limited usage of unskilled labour, but not for over exploitation of natural resources, including water. The degradation and pollution of environment started surfacing with the focus diverted towards higher production of varied types of food products, without taking in to consideration the ill effects of disorganized irrigation practices. The age old irrigation practices, if continued, would have made the Man less avaricious. If not a reversal to the earlier irrigation practices, the basic objective behind optimum utilization of water resources through controlled irrigation practices need to be re-introduced to avoid total annihilation of our water resources. While optimally utilizing limited water resources (~ 3% of fresh water in entire globe) it is essential for the human race to use apt irrigation methods taking in to consideration various natural and artificial factors in locating a water source, extracting optimal quantities, storage of extracted and naturally available resources, distributing the available resources and optimally utilizing available waters to grow area specific agriculture/ horticulture products. In this exercise it is essential not only use mechanized irrigation practices but also age old successfully adapted irrigation practices.

ACKNOWLEDGEMENTS:

Even though it may not be categorized as a research article it is prepared to motivate earth scientists to use it for taking up an important societal research activity that can help the farming community in introducing a combination of historical and present day irrigation methods. I am thankful to Google and Yahoo search bases. The write up has been prepared mainly using internet inputs (Source links are duly referred in the text). My contribution is confined to properly link the available information and build a useful write up. This write up has been compiled mainly as my parting contribution to JIGU.