In Praise of Traditional Technologies

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1. Introduction

There are two conflicting dynamics in the economic literature as regard to the role and contributions of traditional technologies for the progress and development of nations. W.W. Rostow (1960) argues that development is only possible if and only when countries seeking growth and progress are able to unload the traditions of the past and accept and adopt the calculus of compound interest as well as the institutions of modernity. The past is a heavy burden that delays and prevents "take off" of the country to the open and accessible space of modernity and progress. The only way an economy is able to take off and achieve progress, however, is when it is able to jettisons its past, traditions and old values and accepts the norms, values and institutions of modern societies.

Rostow's (1960) concept of a traditional society is one whose structure is developed within limited and archaic functions of production, based on pre-Newtonian science and technology, and on pre-Newtonian attitudes towards the physical world. The central tenet of the modernists is that in the traditional society there is a ceiling on the level of attainable output per head, progress and change. This ceiling resulted from the fact that the potentialities which flow from modern science and technology were either not available or not regularly and systematically applied. Traditional technologies within this perspective are unproductive or limit the possibilities of introducing more productive alternatives. In traditional societies the level of productivity is limited by inaccessibility to modern science, its applications, and its frame of mind.

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Progress in the modernists' conception of history is defined as leaving the traditional structures and values behind and transitioning into the preconditions for take-off phase. This second stage of growth in the Rostovian framework embraces societies in the process of transition; that is, the period when the preconditions for take-off are developed. The issue is that it takes time to transform a traditional society in the ways necessary for it to exploit the fruits of modern science, to fend off diminishing returns and to enjoy the blessings as well as choices opened up by the march of compound interest.

This conception of progress as departing from a laggard, constraining past and embracing a liberating, dynamic and efficient future is, at variance, with the historical record and march of time. It dismisses glibly the achievements of the past and the many breakthroughs that our ancestors made that laid firmly the foundations for the progress and achievements realized by the advancing societies. It also underestimates and minimizes the many difficulties some of the new technologies have brought in their wake. This is no where more blatantly refuted as in the case of traditional water technologies that the Assyrians, Nabetians, Egyptians, Romans, Chinese, and the Incas have built and continue to survive today. There is no question about the incredible efficiency and effectiveness of aqueducts that transported and preserved water over thousands of kilometers or the ingenuity of reversed siphons invented by the Romans or the qanats built by the Arabs and Nabetians or the hanging gardens constructed by the Babylonians.

The real problem in the Rostovian conception of history and progress is its linear structure, the disconnect between the stages and the implicit superiority of and preference for western values, technologies and systems.

In a number of influential studies Hayami and Ruttan (H-R) (1971;1973) have postulated an alternative framework to Rostow's that is based on the concept of the "innovation possibility curve" developed by Ahmad (1966; 1967a; 1967b).

The basic tenet of this framework is that progress and efficiency need not be the same for all nations as it is implicitly assumed in the Rostovian system. Actually H-R argue that the United States and Japan both achieved high agricultural productivity using different technologies that suited their different factor endowments. In other words road to progress and development can be different in different countries and regions. That there is no one single way or road to progress. On the contrary, those that imitate (fail to innovate) or adopt the technologies developed by others in response to different factor endowments will suffer and not realize higher productivity. Progress is finding suitable and special solutions to indigenous problems. The accent is not on modern versus traditional technology but on appropriate technology. Appropriate in the sense that it reflects and is designed to deal with specific and local conditions and reflect the local endowments.

2. Alternative Technologies

Let us begin by expressing agricultural output per worker as the product of two components, namely land area per worker and land productivity.

$$Y/L = (A/L)\,(Y/A)$$

Where

- Y = Agricultural output
- L = Labour
- A = Land or arable land
- Y/L = Labour productivity
- A/L = Land area per worker
- Y/A = Land productivity.

Thus labour productivity in agriculture can be improved by the use of different technologies or methods (mechanization or land reclamation) that increase the land available for farming per worker, and/or those (e.g., the use of fertilizers and new seed varieties) that increase output per unit of land.

Japan and the United States are characterized by extreme differences in factor endowments. In 1880, the total amount of agricultural land per male farm worker was 36 times larger in the United States than in Japan. This difference has widened over the time with the opening of more land in the Western United States for agricultural purposes. By 1960, the total amount of agricultural land per male farm worker was 97 times larger in the United States than in Japan. Naturally, the relative prices of land and labour differed in the two countries. In 1880, a Japanese farm worker had to work 9 times as many days as a U.S. farm worker in order to purchase a hectare of arable land. This difference has also widened over time, particularly between 1880 and 1920, when the wages of labour rose more sharply relatively to the price of land in the United States. By 1960, a Japanese farm worker had to work 30 times as many days as his U.S. counterpart in order to acquire a hectare of arable land.

Despite these marked differences in factor endowments and factor prices, both countries experienced rapid and persistent rates of growth in agricultural productivity throughout the entire period of eighty years between 1880 and 1960. This has been ascribed by Hayami and Ruttan (1971; 1973) to the two nations' remarkable adaptation of agricultural technology to suit their contrasting factor endowments. Japan employed biological (including chemical) innovations, whereas U.S. farmers focused more on mechanical methods. In both cases, the process of innovation increased efficiency of whichever factor and was scarce in the given country. Only in the last several decades there has been technological convergence between the two countries, with the United States making a greater use of biological methods and Japan rapidly assimilating mechanical technology.

Hayami and Ruttan (1971; 1973) have marshalled two types of evidence to support their contentions. Firstly, they showed that there is a link between high agricultural productivity and a high output per hectare in Japan and between high productivity and a high land area per worker in the United States. The second type of evidence comes from the result obtained by testing and hypothesis that variations in factor proportions (land-labour, power-labour, and fertilizer-land rations) are explained by variations in factor price ratios.

Although H-R places a strong emphasis on the ability of Japan and the United States to acquire the appropriate "modern" technology to expand productivity in agriculture, they do not distinguish between "modern"(e.g., machinery/power and fertilizer) and "traditional" (e.g., land and labour) inputs. Furthermore, because they were considering two highly developed and more or less "market-oriented economies," they felt no need to distinguish between market prices and true scarcity prices.

In dealing with various developing countries, this distinction cannot be avoided. The divergence of existing prices from "optimal prices" and the differences in responses of farmers to variations in traditional as opposed to modern factor proportions and their corresponding prices must be considered if one is to have a full understanding of the problems of development. In this paper we will focus on the analysis of the problems of response. Four types of responses are distinguished. First, there is the response of traditional factors to their own factor price ratios. Second, there is the response of traditional factors to the modern factor price ratios. Third, there is the response of modern factors to their own prices, and fourth, there is the response of modern factors to the factor price ratios of traditional inputs. The first and third type of responses is referred to as direct and second and fourth type of responses is referred to as indirect.

Generally, one expects to find the following pattern of responses of factors proportions to changes in factor prices ratios (see Table 1). If the relative cost of a given, say, traditional factor goes up, it seems reasonable that its use would decrease relative to that of other factors; similar considerations would hold for modern factors. If the relative cost of, say, a traditional factor were to soar then one would think that farmers would step up their use of those modern factors that are substitutes for the now expensive traditional input, and decrease their use of modern inputs that are complements to the costly factor. A similar argument is obtained by exchanging the words "traditional" and "modern" for each other in the receding sentence.

Table 1: Responses to factor Prices of Traditional and Modern Inputs

Response to / Response of	Traditional Factor Price Ratio	Modern Factor Price Ratio
Traditional factor Ratio	– (1) (Substitute) (Complement) +	(Substitute) (Complement) + - (2)
Modern Factor Ratio	- (4)	- (3)

Source: Atif Kubursi (1983), "Arab Agricultural Productivity: A New Perspective", in Ibrahim (ed.), *Arab Resources*, Croom Helm, London, pp. 71-104.

The following results emerge when these predictions are compared to the H-R findings for the United States and Japan. For the United States, all responses are generally as expected as far as the signs are concerned, but the statistical significance of the results is more notable in cases (2) and (3) than in cases (1) and (4) and invariably (4) dominates (1).

In the case of Japan, there is a striking difference between the results for modern and for traditional inputs. The signs of the responses (traditional factor proportion for traditional factor's own relative prices) are the opposite of what Table 1 predicts, whereas all the other types of responses have correct signs and are generally statistically significant.

This result lends support to a stronger (more specific) version of the H-R hypothesis, namely, that agricultural productivity depends primarily on induced adjustment in modern inputs. This new formulation is especially important from the perspective of the developing countries which must compare their current performances and strategies not with the current performances and strategies of the developed economies, but with the strategies and performances of these countries when they were on the threshold of economic development.

It turns out that developing countries have been more successful in adjusting the traditional inputs and have failed to adjust appropriately and to the extent expected when it came to modern inputs. In Egypt and Syria as in India and several other countries large productivity gains were realized on appropriate responses to the prices and other signals of traditional inputs. These productivity gains were not realized on modern inputs (Kubursi, 1983; Ahmed and Kubursi, 1978)

3. The Innovation Possibility Curve

The idea of induced innovation is essentially an extension of the idea of factor substitution in response to changing factor prices, when such a change not only causes factor substitution, given the production function, but also determines the choice of a new production function.

Generally, a country may simply import technology embedded in a given technique or machine. In that case it takes the factor proportions embedded in the technique or in the use of the machine as given. This is the case of an imitating country.

Alternatively, the receiving country may strive to be free to choose its factor proportions and to adapt the technique or machine to suit its own factor endowments. This is the case of an adapting country. But a country may choose to invent its own technology and develop machines that suit best its factor endowments. This is the case of an innovating country. The differences between the three conditions and their implications are clarified using Figure 1.

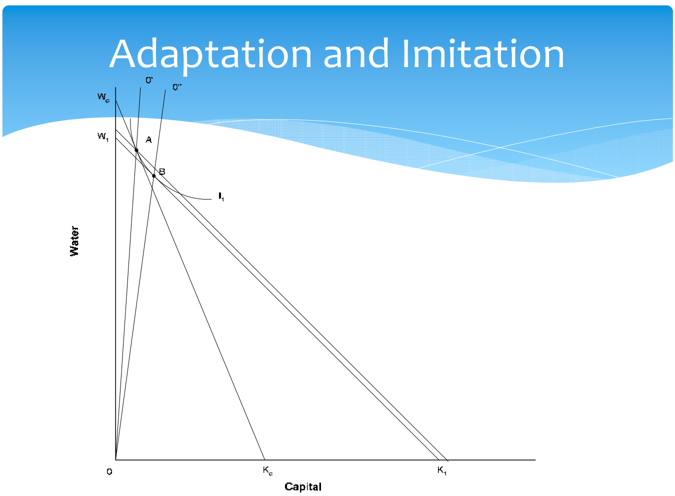

Figure 1 – Innovation and Imitation

In Figure 1, the two axes represent two factors of production, namely capital and water. Now let I_1 be the isoquant (equal product curve) representing one unit of output. This isoquant was developed in response to the price ratio of the factors represented by W_0K_0. At point A (a tangency point) the producers minimize cost. But if the price ratio changes to W_1K_1 and the economy is technically free to choose its factor proportions, then it will choose point B where W_1K_1 is tangent to the isoquant. If for some reason the economy is not able to move to point B, then the economy would loose K_0K_1 in terms of capital for its inability to choose and adapt the factor proportions to the new price ratio.

Innovation would allow the country to choose its isoquant to minimize cost the point of tangency W5K5 because now it adjusts the factor proportions to take advantage of the lowest iso-cost possible which is at point C in Figure 2. The reductions in the cost of water or capital (both factors are scarce) would optimize the resources of the economy.

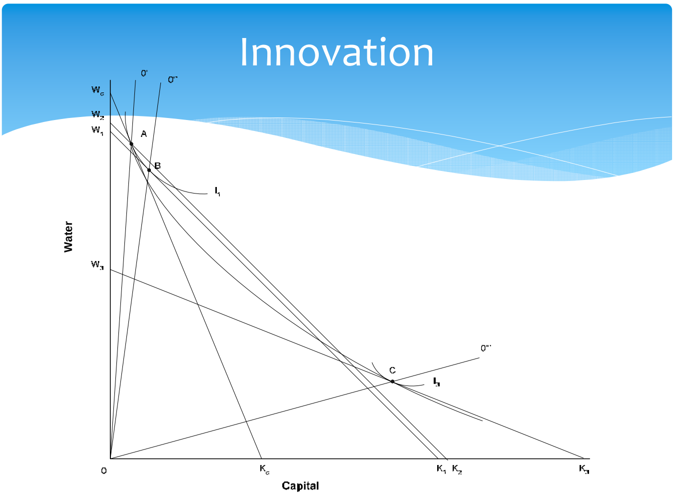

Figure 2 - Innovation

The adapting economy saves scarce resources and moves along a given isoquant to minimize cost within the given production costs. The savings are positive but limited. When the country is free to invent its own technology to match its factor endowments reflected in the domestic price ratio of the factors, it would save a considerably higher proportion of factors. This is illustrated also in Figure 3 where the envelopes of all possible innovations that are open to the economy are considered. The isoquant chosen will be the one that minimizes the total cost (appoint of tangency) between the isoquant and the isocost.

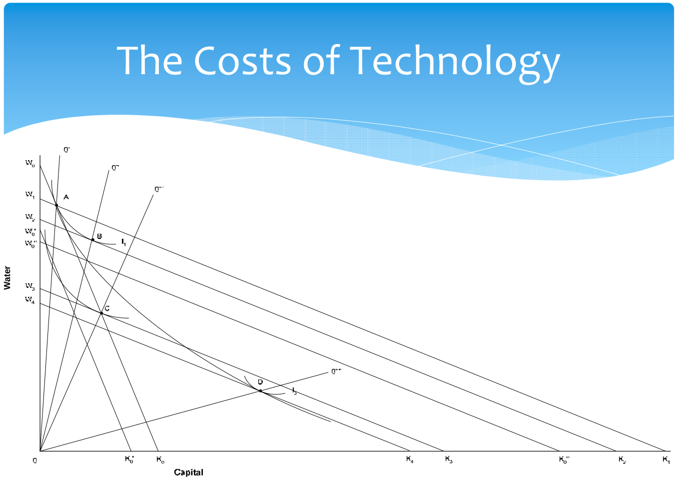

Figure 3 – The Cost and Advantages of Innovation

4. Traditional Technologies

The record of innovation in old civilization is a testimony to the capacity of ancient people to innovate technologies that best suited their environments and endowments. The quest was efficiency and in that regard is finding the relevant innovation possibility curve and the relevant isoquant given the prevailing factor price ratios captured by the prevailing isocost.

A synopsis of some of these old water technologies is presented below to highlight the adaptations and innovations of these civilizations.

4.1. The Ancient Roman water System

The Romans had developed highly sophisticated water supply and sanitation systems. The use of tunnels, high bridges over valleys, or inverted siphons across deep depressions was a last resort when difficult conditions could not be met in any other way. For example, in the system of aqueducts serving the city of

Rome, only 5 percent of the distance was carried by bridges. Below 50 meters, the Romans crossed a valley by bridging it; above that height they constructed an inverted siphon.[1]

Figure 4 – The Ancient Roman Water System

In Roman water supply systems, aqueduct channels generally followed the sides of valleys between the source and destination, maintaining a shallow downward gradient. When subsidiary valleys were encountered the channel would follow the contour into the valley, and then cross to the other side by means of a specially-constructed bridge.

Many aqueduct bridges survive in the forested central areas of the system, where their remoteness has aided their preservation. Around 60 have been identified along the 250km line, and 19 of these are more or less in tact. From our studies of the topography we can probably suggest that at least another 40 bridges are unaccounted for. Most are single tier, but there are

[1] From: http://www.waterhistory.org/gallery/romanwater

five 2 tier bridges and one or possibly two with three tiers. [2]
This artist concept illustrates the most probable configuration of the 16 overshot waterwheels at Barbegal. The ancient Romans used an impressive variety of structures in their water supply systems.

4.2. The Incas' Water System

The Peruvian Incas first found the source of water, planned the city – built a clay model to see how it will work – one side was planned settlement and the other side was agricultural land.

The Machu-Picchu in Peru had also developed a sophisticated water delivery and control system. Kenneth R. Wright's (President and chief engineer of Wright Water Engineers in Denver, CO USA assembled a team of engineers that examined and reported on the Incas' water system). The Wright Team's research revealed that the Inca must have planned the city carefully before building it. First, the Inca engineers had to determine the exact location of the spring and whether it would meet the needs of the anticipated population. They also found that the spring, on the steep mountain slope to the north of Machu-Picchu, is fed by a 16.3 ha tributary basin. After conducting an inflow-outflow evaluation, the team also concluded that the spring draws on drainage from a much larger hydro-geographic catchment basin.

The Inca enhanced the yield of the spring by building a spring collection system set into the hillside. The system consists of a stone wall about 14.6 m long and up to 1.4 m high. Water from the spring seeps through the wall into a rectangular stone trench about 0.8 m wide. Water from a secondary spring enters the canal about 80 m west of the primary spring. The Inca also built a 1.5 to 2 m wide terrace to allow easy access for operating and maintaining the spring works. The condition of the spring works surprised Wright. "The spring works was still intact and still

[2] From: http://museums.ncl.ac.uk/long_walls/Water/bridges.htm

working," he says. "It was still yielding a water supply after all these centuries of abandonment."

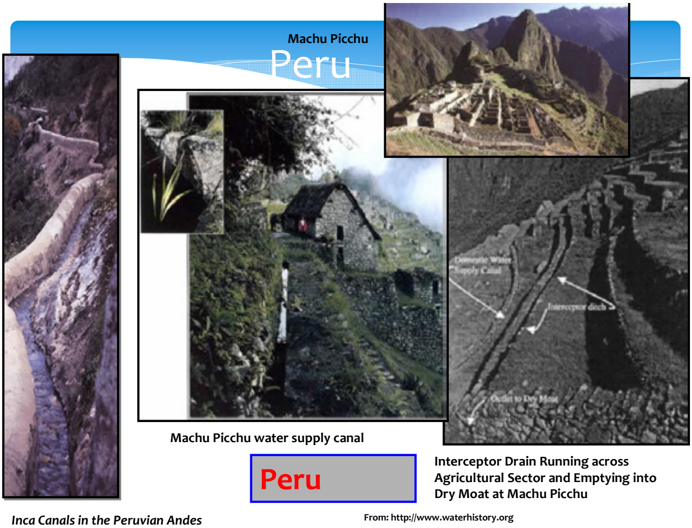

Figure 5 – The Incas' Water System

Before the city could be built, however, the Inca engineers had to plan how to convey the water from the spring–at an elevation of 2,458 m–to the proposed site on the ridge below. They decided to build a canal 749 m long with a slope of about 3 percent. With the city walls, the water would be made accessible through a series of 16 fountains, the first of which would be reserved for the emperor. Thus the canal design, says Wright, determined the location of the emperor's residence and the layout of the entire city of Machu-Picchu.[3]

The Inca built the water supply canal on a relatively steady grade, depending on gravity flow to carry the water from the spring to the city center. They used cut stones to construct a channel that typically ranged from 10 to 16 cm deep and 10 to 12 cm wide at the bottom. Wright's team concluded that the nominal design

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[3] See www.waterhistory.org.

capacity of the channel was about 300 L/min, or more than twice the typical 25 to 150 L/min yield of the primary spring

In 1450 the best example of Incan civil engineering, Machu-Picchu, was constructed. The famous lost Inca city is an architectural remnant of a society whose understanding of civil and hydraulic engineering was both advanced and complete. At 8,000 feet (2,400 m) in the Andes Mountains, the city planners had to consider the steep slopes of the site as well as the 2,000 mm of rainfall per year. Making models out of clay before beginning to build, the city planners remained consistent with Inca architecture and laid out a city that separated the agriculture and urban areas. Before construction began the engineers had to assess the spring and whether it could provide for all of the city's anticipated citizens. After evaluating the water supply, the civil engineers designed a 2,457-foot (749 m)-long canal to what would become the city's center.

The Incans built the canals on steady grades, using cut stones as the water channels. Most citizens worked on the construction and maintenance of the canal and irrigation systems, using bronze and stone tools to complete the water-tight stone canals. The water then traveled through the channels into sixteen fountains known as the "stairway of fountains", reserving the first water source for the emperor. This incredible feat supplied the population of Machu-Picchu, which varied between 300 and 1000 people when the emperor was present, and also helped irrigate water to the farming steppes. The fountains and canal system were built so well that they would, after a few minor repairs, still work today.

To go along with the Incans' advanced water supply system, an equally impressive drainage system was built as well. Machu-Picchu contains nearly 130 outlets in the center that moved the water out of the city through walls and other structures. The agriculture terraces are a feature of the complicated drainage system; the steppes helped avoid erosion, and were built on a slope to aimed excess water into channels that ran alongside the stairways. These channels carried the runoff into the main drain, avoiding the main water supply. This carefully planned drainage system, which was more advanced than European cities, shows the Incans' concern and appreciation for clean water. Water engineer Ken Wright and his archaeological team also found the emperor's bathing room complete with a separate drain that carried off his used bath water so it would never re-enter Machu-Picchu's water supply.

4.3. The Water System in Ancient Egypt

In ancient times, Egyptian society depended upon the Nile River for its existence. Society flourished for approximately 3000 years because of the Egyptian people's ability to harness the power of the river for agricultural purposes, social events, community projects, religious purposes. The central importance of the river in the Ancient Egyptian's daily life is evident in history and is reflected in their art, religion, writings, politics, and social life. The river shaped nearly every facet of their existence.[4]

After the unification of Upper and Lower Egypt by King Menes (3200 BC) and the establishment of the capital at Memphis, he is credited for beginning construction of basins to contain the flood water, digging canals and irrigation ditches to reclaim the marshland. By 2500 BC an extensive network of canals, ditches, dikes, and levees are built.

Agriculture in Egypt was almost totally dependent on the Nile. The fertile strip of the Nile offers the only possible resource. The people congregated on the steep banks of the river despite its annual floods and shifting marshlands. The dependency on the Nile is not only for the irrigation necessary to raise crops, but also for the topsoil deposited annually by the floods. Every year from July to October the Nile River valley was gradually flooded. Its annual cycle of flooding and the depositing of silt created a

[4] From: http://carbon.cudenver.edu/stc-link/AE/culture.html

new layer of topsoil each year. This topsoil is rich in organic nutrients and nitrogen. By October the waters begin to recede, leaving behind pools of water in depressed areas of the floodplain. After the water subsides enough to let the remaining water be absorbed by the soil, the Egyptians would plant their crops in the mud (http://www.waterhistory.org).

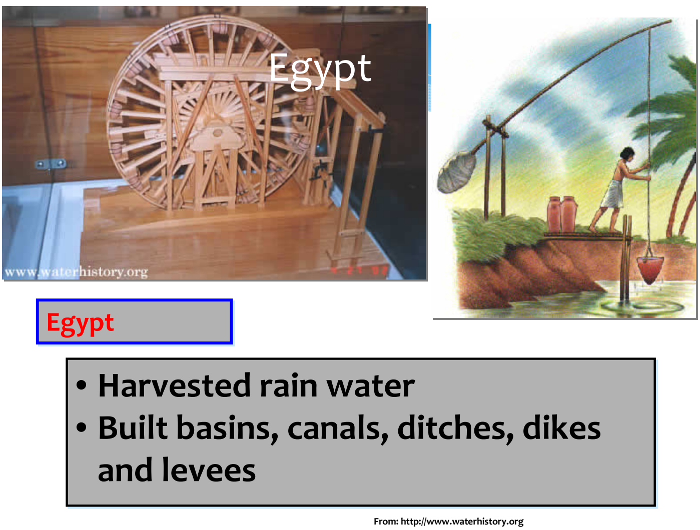

Figure 6 – The Ancient Egyptian Water System

Overall, Ancient Egypt's system of basin irrigation proved inherently more stable from an ecological, political, social, and institutional perspective than that of any other irrigation-based society in human history. Fundamentally, the system was an enhancement of the natural hydrological patterns of the Nile River and not a wholesale transformation of them.

4.4. China's Ancient water System: A lesson worth repeating!

An underground irrigation system, differing from a normal aqueduct in that the water is already there and being tapped. A qanat is constructed by tunneling into a cliff, scarp or base of a mountainous area, following a water-bearing formation. The purpose is to bring water to the surface where it can be utilized in irrigation of agricultural areas. Note, the water is not brought UP to the surface but rather OUT to the surface. The tunnels are roughly horizontal, with a slope to allow water to drain out.

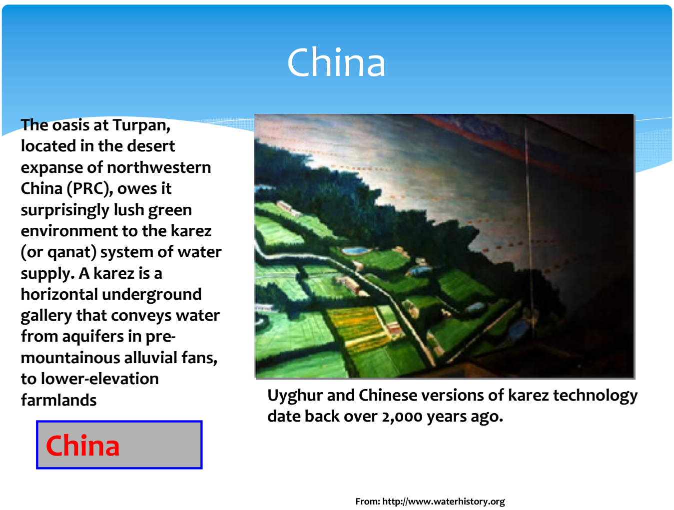

Figure 7 – The Ancient Chinese Water System

About four-fifths of the water used in the plateau regions of Iran is subsurface and is brought into use in this way. There are literally hundred of miles of qanat in Iran, and many hundreds more throughout the Arab world. The result is a sort of oasis in an otherwise arid area, creating a pleasant oasis of date palms or other crops. Indeed, an oasis could be considered a natural 'qanat', although there is no tunnel, just a spring. At the exit of a typical qanat you see a tunnel similar to a mine entrance, which is exactly what it is. The 'mineral' mined is water

Most of the qanats are found in Iran, around the extensive plateau which forms central Iran. However, there are also qanats in western China, Afghanistan, and on the North African continent, from Libya and Algeria to Morocco. It is unknown for sure where the idea originated, but it is fairly certain the idea was first used by Arabs

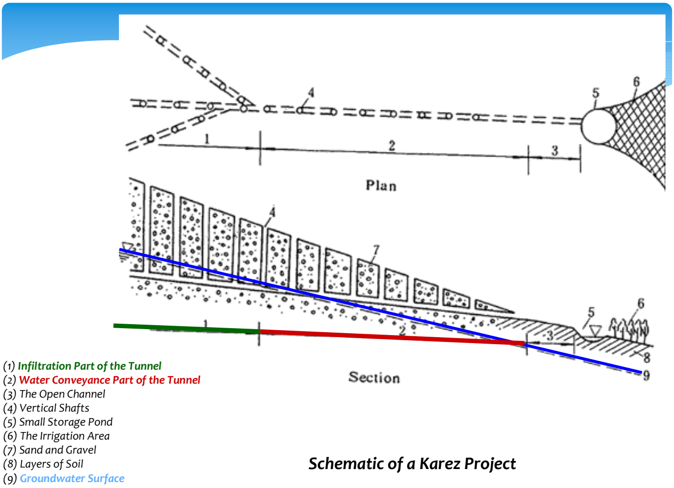

Figure 8 – Schematic of a Karez Project
From: http://www.ancientroute.com/water/qanat.htm.

First, damp areas are often noticed along the base of a cliff or escarpment, or on the floor of an otherwise dry wash. These can be tunneled back, keeping the slope slightly uphill to facilitate water drainage outward. As one goes deeper, the water volume generally increases. When sufficient depth has been reached, branches are sent in opposite directions to increase the drainage area.

Or, second, a well can be sunk in the hills, up on the plateau, until water is struck. A tunnel is then constructed in a slightly downhill manner to the face of the escarpment nearest the village. [Or the village is moved to the exit point of the water.] Once the water is draining well, further branches can be constructed at the collection point to increase the water drainage area.

In both methods, air shafts are constructed to the surface, both for air and removal of mined dirt. The dirt is brought up to the surface by rope and leather bucket, and placed around the rim of the air hole. This dirt mound keeps rare surface floods from washing soil back into the shaft. These holes are often lined up every 50-150 feet along a line several miles long. This is what is seen from the surface, and remarked on as "a line of ant-hills, stretching for miles", or other such comments by the uninitiated.

The repair work is done by the farmers who will eventually benefit from the water supply. In traditions handed down over generations from father to son, every spring the qanats are cleaned out. Many methods are used but an example would be as follows. A small boy is let down by rope and windlass to the bottom, riding the leather bucket. Every now and again the father pulls bucket up and unloads a small amount of dirt and debris. When the qanat is cleaned in one shaft, they move to the next. In this way, several groups of farmers can cover the entire area, and are available if a problem arises

In many arid countries, life would unsustainable without a water supply. The infrequent rains soak into the underlying soil rapidly, leaving the wadis dry for the better part of the year. However, if an aquifer [water-bearing layer] underlies an extensive area, it can be tapped by a qanat and directed to an area where it can be used. It is the same thing done by drilling a well and pumping the water to a field. However, in many technology-poor areas, a qanat replaces the drilling.

The volume of water produced by a qanat [or drilled well] depends upon several factors:

- The extent of the aquifer, or rather the acre-feet of available water-bearing formation.
- The type of aquifer; a sand seam, a fractured limestone, a buried riverbed conglomerate. Each will holds its own volume of water per acre. And each rock type will allow the water to drain out at a fixed rate.
- The recharge volume. All the water must be replaced annually or the qanat will dry up. This is done by rains in the surrounding hills or perhaps in the mountains several hundred miles away. Wherever the water comes

from, the annual use cannot exceed the annual recharge or the qanat will dry up.

Petra solved water supply and distribution problems in an arid area with a system of springs, small aqueducts, separate distribution systems for drinking water and other water.

5. Struggling between tradition and modernity: the Indian difficult path towards innovation

The Indian case is another interesting example to discuss, as it exemplifies the often contradictory development pattern caught between a strong push towards modernity and deep roots in tradition.

The first deliberate attempt to follow a Rostovian pattern of development was clearly made upon Independence, when the Gandhian strategy of development based on a traditional village economy was defeated by the Nehru's strategy to transform India into a modern economy. In that context, water definitely became one of the key means for this transition. Modern hydraulics became the means to make water abundant and available throughout the country as a precondition to support a main turn from subsistence to a modern agriculture; a turn that would enable India to generate surplus and growth. It was at that time that dams became the "temples of modern India", as Nehru liked to define them. Nehru believed that these dams would free Indian people from hunger and poverty (Gidwani, 2002).

As a consequence of this strong push to imitate a western type of development in the water sector, strong alliances between India and Western donor countries were drawn up (Black, 1998; Hirschman, 1967) and India became one of the largest builders of dams in the world. Worldwide, about 40% of large dams are in India (Roy, 2002). But not only dams were used to increase the access of water throughout the country. At the time of independence, there were only 3.000 wells equipped with electric pumps for water extraction in India. Fifty years later, there were 20 million (GOI/WB, 1999).

This large use of modern hydraulics and technologies, which entailed huge groundwater pumping and large scale diversion, had obviously deep impacts on water ecosystems and on traditional technologies (Guha, 2000; Escobar, 1995; McCully, 1998; Roy, 2002). They were generally considered to be the cause of the displacement of indigenous people from their home land, the loss of their cultural and social traditions, the production of huge environmental damage (Postel, 2000; McCully, 1996), and the predation of local ecologies and knowledge (Shiva, 2001). The Narmada project alone, which is one of the largest Indian multi-dam projects in between the states of Gujarat, Maharashtra and Madya Pradesh, will require the relocation of about 25 million people, 60% of which are tribal people upon final completion (Roy, 2002). Groundwater table in India is now dropping as fast as 3 meters per year in some areas.

This fast growing pace of resource exploitation and the deep changes in socio-economic structures and community water use practices, together with the growing conviction that modern hydraulics was the only way towards progress, increasingly led to the collapse of traditional systems, whose functioning required the preservation of local water ecosystems and the capacity of local communities to maintain them (Agarwal et al., 1997).

But how are local communities and the government reacting to this? The extensive use of modern technologies has caused a huge increase in the cost of production of water as the falling of water table is requiring deeper drilling, more electricity, and more expensive pumps; at the same time, interregional diversion schemes are becoming even more necessary in the face of the cumulative reduction of groundwater. However, this means longer diversions and more expensive schemes. Despite all of this, the trust in the capacity of modernity to bring progress seems unchallenged by key players in the field and the mainstream recipe for growth remains the same: modernity.

Higher modern input costs have thus not prompted the government to search for a traditional substitutes for them; instead the government has decided to subsidise modern inputs. This is particularly the case of the Indian state of Gujarat, where the electricity costs for the extraction of water from wells is today mainly subsidised by the government. Moreover, in those regions where water is scarcer, special tax reduction regimes are introduced in order to compensate the higher water extraction costs. But apparently the possibility to have these tax reductions led farmers to grow water-intensive crops in these water scarce regions, thus contributing to the disruption of water equilibrium (Grassini 2003).

Critiques of the irrationalities of the present situation initially came from researchers and activists trying to demonstrate how knowledge rich technological systems from the past could be adequately revived to present viable solutions to current water problems (Agarwal et al., 1997; Mishra, 1994; Sridhar, 2001). This was supported by several small scale initiatives at local level, which tried to rehabilitate traditional technologies in support of alternative development projects. Several other critiques developed building on the earlier critiques which tried to demonstrate the irrationalities of the uncritical transposition of techno-institutional solutions from the Western world to the developing contexts and to India in particular (Shah et al., 2003).

These initial critiques also nurtured reflections in several other fields and disciplines. They contributed to the development of a large literature on political ecology (Braun et al., 1998; Peet et al., 1996; Escobar, 1996), which tried to challenge the assumption that the rural poor were somebody else's development strategy and the passive subjects of development programs instead of being active originators of their own development patterns. The acknowledgement of the intrinsic rationality of traditional systems strongly supported the recognition of the importance of the indigenous knowledge embedded in those technologies and its deep roots in local ecologies (Shiva et al., 2001). This also led to the mushrooming of critiques, within the field of the epistemology of science (Borri et al., 2010), that non-Western reasoning was irrational and subjective as opposed to the western system of thought (Millar et al., 1999; Kloppenburg, 1991), thus trying to demonstrate the intrinsic value of indigenous knowledge as a system of thought (Agrawal, 1995).

Despite the valuable contributions made by these researches, their attempt to challenge the mainstream modern thinking ran the risk of constructing an alternative paradigm based on a somehow idealistic and simplistic conception of indigenous people and traditional system of knowledge, which sometimes led to uncritical faith in traditional technologies and an exaggerated critique of technological modernization (Baviskar, 1997; Babington, 1996).

At the same time, while most of these studies seemed to look at the past as a more or less static viable repository of solutions for the future, some interesting research also developed trying to look at the possibility to use that repository as the starting point for creative development of new solutions for the future. In so doing, researchers tried to highlight the way grassroots innovations develop from local people ingenuity, based on their traditional knowledge (Gupta 2007a, 2007b), and the way western science can try to support them to enhance the productivity of local knowledge (Bonthakur, 2009). Interesting hybridizations of traditional and modern technologies are increasingly put to the attention of the international debate as examples of new ways to produce innovations (Barbanente et al., forthcoming). These studies deeply rely on case studies in local contexts, where the process of innovation is grasped and analysed. How innovations develop, how they are rooted in traditional knowledge, how modern science can support it?

In one of our recent projects in India[5], we also could find interesting examples of innovations made on traditional technologies. In this case, we found several cases where local communities in rural villages in India are trying to rehabilitate traditional technologies while innovating and improving them from the inside. In so doing, they are trying to root technological development in their specific country endowment, i.e. the presence of monsoon water, which led to the development of interesting examples of rainwater harvesting technologies in the past[6].
But at the same time, people are trying to recreate and improve those ancient technologies to make them able to solve current water problems, which have different hygienic and social components than in the past. Because of this, some purification systems are often added and the combination of traditional sources of water and modern distribution systems within the village is supporting the possibility to get water at each house's door, thus a more convenient way to access resources than the traditional practices of fetching water from communal sources through long distance walks.

For example, while the use of traditional technologies like ponds was widespread in the past and may still be revived today as a viable source of water, the possibility to use it as a source of drinking water is strongly questioned today. Water quality in these ponds is generally poor due to a large variability of pollutants, which may come from the catchment area (pesticides, organic pollutants and microbiological contaminants from humans and animals). High risk variability is also linked to consumers' practices. Nevertheless, some interesting examples of innovative revival of these technologies could be observed in

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[5] Acknowledgement goes to the EU-FP6 CA project ANTINOMOS "A knowledge network for solving real life water problems in developing countries: Bridging contrasts" (April 2007-December 2010).
[6] Monsoon water was traditionally harvested to recharge groundwater or to fill storage tanks, while reducing flooding risks; these technologies were then abandoned to adopt less efficient and more costly technological paradigms from western science.

India, where water form the pond is not fetched directly from its surface but used to recharge a well through a horizontal filter from its bed. Water is then extracted from the well with a hand pump and then distributed into a village network after passing through a vertical sand filter.

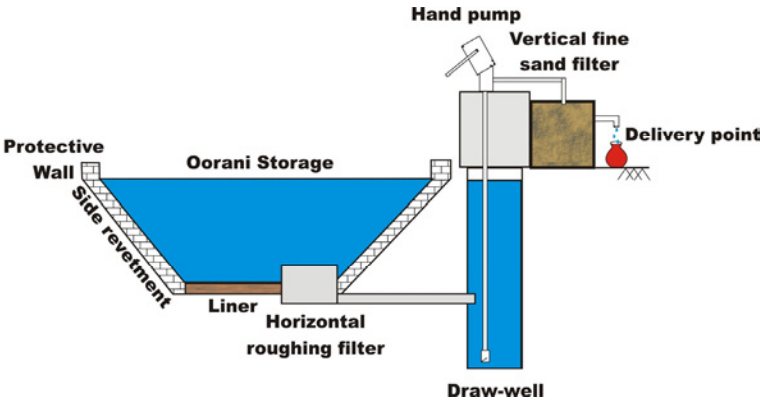

Figure 9 - Improved *Oorani* observed in Pattikadu village, Tamil Nadu, India

Sample testing of the quality of water obtained from this source in the Pattikadu village in Guajarat, although insufficient to make any final judgement on the hygienic risk variability due to the stop-check basis of the sampling, still indicates that the system is able to make a huge reduction of the microbial contamination level. While this was very high in the original pond, which is called *Oorani* in Gujarati language (around 5000 faecal coli forms and 500 E coli at the time of sampling), after the full filtration process there was a 2 log reduction and E coli was not detected (Borri and Grassini 2010)[7].

Another interesting example of innovation of traditional technologies comes from the Rudraprayag village in Uttrannchal.

[7] Within the joint work on which this project report is based, the hygienic risk assessment for this case study was done by Thor-Axel Stenström (SMI) with support from R K Srinivasan (CSE). Figure 9 above is from CSE.

In this case, traditional recharging practices, through which farmers used to divert monsoon water to the aquifer, were aided and innovated upon with the support of modern isotope techniques. Through these techniques the best point of recharge were identified by tracing the correct origins of the springs. Various tanks, check-dams and trenches were thus built by farmers in those areas in order to collect rainwater to recharge the spring. Spring water then is collected downstream and used for domestic purposes. Support to this initiative was given by scientists from the Bhabha Atomic Research Centre and proved to have deep impact on the level of recharge of the spring (Borri and Grassini, 2010)[8].

In conclusion, in the Indian case the transfer of modern technologies – originally developed in other countries and tailored to different factor endowments – clearly seems to have led to less efficient and more costly response to water needs. The return to traditional technologies was then discouraged by the decision of the government to subsidise those costs, which led to a further increase in the use of modern technologies. This led, in turn, to a further increase in the ecological and production costs. In this context, only very recently some communities are trying to revert back to traditional technologies while innovating them. Although complete evaluations of these attempts still need to be made, they look promising in relation to the water quality standards, social acceptance and ecological performance.

[8] Within the joint work on which this project report is based, this specific case studies was carried out by R.K. Srinivasan (CSE).

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