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Ethnoscience and Indigenous Hydraulic Technology in Asian Civilizations with Special Reference to Precolonial Sri Lanka

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Abstract: A field that was most representative of Asian technology catered to a vital concern shared by civilizations in China, Western Asia, and South Asia. Recurrent floods threatened some of these regions, while in others the major threat stemmed from the inadequacy of natural rainfall for food production. The flowering of civilization within such regions and in some cases, even their very existence depended on the construction of large-scale public works designed to prevent and divert floods, conserve water, and transfer water from one area to another. Owing to its unique strategic location in the middle of the Indian Ocean and the important role it played in regional commerce, Sri Lanka developed close ties with several major ancient civilizations in Europe and Asia. Hydraulic technology in Sri Lanka reached a remarkably high level of technical skill and sophistication. As a highly specialized branch of technology, hydraulics is a field in which advocates of diffusionism could expect to find ample support for their theoretical positions. This study employed a qualitative historical approach using archival and library-based sources and comparative analyses of Asian hydraulic technologies. The study demonstrates that ancient Sri Lanka achieved a pioneering and technologically advanced irrigation system marked by large-scale interlinked reservoirs, sophisticated surveying, low-gradient canals, and innovative cistern sluices, surpassing contemporaneous developments in South India. Despite close regional contacts, hydraulic technologies evolved along distinct local paths, challenging diffusionist models and highlighting the role of selective technological adaptation shaped by environmental, political, and social contexts.

Keywords: Asian Society, Ethnoscience, Hydraulic Engineering, Precolonial Sri Lanka

Introduction

Interest in Asian society among men of learning in the lands of the Western civilization has a very old history, and it goes back to the time of the Greeks. In our own times, collaborative activity in the study of Asia has brought into the world of learning a vast corpus of knowledge, documentation and theory, which has contributed to deepening our understanding of man and to broadening our horizons by enabling us to think of civilization and the heritage of the human race in its global context. Here, one should hasten to emphasize the fact that the work of some modern scholars has also contributed to the rise of a number of myths about Asian society. The exaggerated view of the "otherness" of Asian society, accompanied by a failure to observe and comment upon similarities and linkages, is representative of their impact. As in the refrain from *Rudyard Kipling's* popular ballad on East and West, Asia and

Europe came to be increasingly perceived as two regions with cultures marked by bipolarity, and separated by a great divide. It is particularly interesting to note that Asia came to be seen not as an area which could have been associated with technological achievements in an earlier era, but as an area of mystery which had been, and was being, hampered in its development by the burden of its own spirituality. Despite the phenomenal growth of Japan as a major industrial power in our times, the view has proved to be durable in its influence, and has produced a myopic vision of Asia's past. Even today, it is not easy to find textbooks on the general history of technology which focus attention on technology in precolonial Asia.

Literature Review

It is interesting to note that medieval Europeans did not share this view of Asia. When the Englishman Adelard from the city of Bath decided to further his knowledge of Mathematics and Astronomy, it was not to a center of learning in the European continent that he went. He proceeded instead to Syria where he learned Arabic and developed a sufficient proficiency in that language to translate several treatises on Mathematics and Astronomy, including the astronomical tables of *Al Majriti*, into Latin. This respect for Arab scientific learning was shared by other scholars from the twelfth century like *Alfred Sareschel*, Robert of Chester and *Michael Scot* who took great pains to translate into Latin other Arab manuscripts found in Spain. The respect for Asian achievements in science and technology disappeared in the period after the industrial revolution, and the relative stagnation of Asia in contrast to industrializing Europe was too easily transposed into the past.

The first serious challenge to the deep-seated Eurocentric approach to the history of technology was posed by the work of *Joseph Needham* of the University of Cambridge, a renowned scientist who had been elected a Fellow of the Royal Society for his outstanding contributions in the field of biology. In his monumental work, Science and Civilization in China, *Needham* has documented the progress made in China in premodern science and technology in a wide range of disciplines. On the basis of his researches, *Needham* asserts that, between the third and the thirteenth century, China maintained "a level of scientific knowledge unapproached in the West." "Chinese technological inventions," he observes, "poured into Europe in a continuous stream during the first thirteen centuries of the Christian era, just as later the technological current flowed the other way." The early Chinese inventions include not only items we are generally familiar with and associate with China, like the art of printing, and the manufacture of paper, porcelain and gun powder, but also many other items such as the rudder, the magnetic compass, canal lock gates, the segmental arch bridge, the cardon suspension, the crossbow and metallurgical blowing machines. They were a series of innovations which mark important mileposts and had significant implications for the development of technology in general. Perhaps more than any other work of our times, *Needham*'s contribution directs our attention to the need to make a radical departure from the Eurocentric approach to the study of the history of technology. (“as discussed by Needham [2]”)

Owing to its unique, strategic location in the middle of the Indian Ocean and the important role it came to play in the commerce of the region, Sri Lanka developed close ties with some of the major ancient civilizations in Europe and Asia. These contacts helped to create the intellectual milieu necessary for technological progress, and enabled this small island to develop and improve upon the common South Asian heritage so that in certain periods it even seems to have had the leading edge within the Indian Ocean region in certain specific branches of science and technology. A good example to illustrate this point is to be found in a fifth-century century Sri Lankan text which provides a remarkable, stage-by-stage description of the development of the embryo and a discussion on the functions of the umbilicus. A second example is to be found in the observation of *Li Chao*, a mandarin in charge of foreign trade under the *T'ang* dynasty, that ships from Sri Lanka were the largest among the vessels which came each year to the Chinese ports. This is indeed a significant statement because this was a time when Indian and Persian ships as well as the famed *Khun-lun* ships of Southeast Asia which had been the technical marvels up to that time, were still touching at Chinese ports. And, as Needham's researches have revealed, Chinese of the times were themselves building large ships of "nearly 600 tuns" in burthen. Li Chao's statement carries the implication that, for a brief span between 713 and 825 A.D., Sri Lankan nautical technology had captured the lead. (“as discussed by Needham [4]”)

Extensive scholarship has documented the development of hydraulic technology in South and East Asia, highlighting its centrality to the growth of precolonial civilizations. Among these studies, the work of *R. A. L. H. Gunawardana* stands out for its detailed analysis of Sri Lankan irrigation systems and their ethnoscientific foundations. *Gunawardana*’s research, including Ethnoscience and Technology in Precolonial Sri Lanka and Cistern Sluices and Piston Sluices, provides in-depth descriptions of reservoir construction, canal networks, and innovative sluice mechanisms, demonstrating the technical sophistication and localized adaptation of hydraulic knowledge. Further studies by *Gunawardana* explored the social, political, and intersocietal dimensions of hydraulic technology addressing issues of technological transfer, administrative control, and the organization of labor in large-scale irrigation works. Complementary perspectives from *Wilson, Needham* and *Wittfogel* situate these Sri Lankan developments within broader Asian technological traditions illustrating both regional connections and independent innovation in water management practices. Collectively, this body of literature underscores the significance of indigenous technological knowledge or ethnoscience in shaping the environmental, social, and political landscapes of precolonial Asian societies.

Materials and Methods

Hydraulic technology reached a remarkably high level of technical skill and sophistication in Sri Lanka. The study of hydraulic technology in this island and in the neighboring subcontinent is important not merely to gain an awareness of the achievements made in these areas but also to understand the processes and problems involved in the transfer of technology and the factors behind the development of technology, operative in the ancient world. Further, it was in South Asia that some pioneer British engineers gained valuable first-hand experience in irrigation engineering in the nineteenth century when they began the important task of providing irrigation facilities. It was here that these European engineers gained access to irrigation works of considerable magnitude and complexity, and the lessons they learned about the design and structures of earthwork dams and methods of releasing water from massive reservoirs without endangering such dams were incorporated in the technology of the profession as practiced in tropical lands. Here we see an instance of an ancient technology reaching across the gulf of many centuries and making contact with a developing branch of modern technology to leave an impact on it. By this time more than six centuries had passed since the collapse of hydraulic civilization in Sri Lanka. In several instances, when the British engineers surveyed a site suitable for a reservoir, they found that a dam had been already built long ago at the very place they chose for it. Similarly, when they decided on the best locations for a sluice to release water from a reservoir, they would often find a sluice already built there. Only a few years ago, the engineers who planned the Mahaweli irrigation project decided to locate one of their largest reservoirs at a site in the valley of the river *Maduru Oya*. ("as discussed by Gunawardana [9]") The Canadian engineer who started work on the project found that their ancient counterparts, who lived more than a thousand years ago, had already built a very large reservoir at the site. The river had broken through the dam, but a section about 300 yards in length, still remained. When earth-moving machinery was used to prepare the foundation of the new dam, the remains of an old sluice were found. Here again, the sluice was at the same location where the modern engineer had decided to locate their sluice. To quote the report made by a Canadian engineer attached to the project, "The location of one of the irrigation outlets for the new dam is almost in exact alignment with the ancient sluice. The similarity of the ancient and modern projects is startling". ("as discussed by Gunawardana [9]")

Clearly, the standards of levelling and surveying should have been quite high to enable such an accomplishment. Even in the nineteenth century, the British engineers developed a healthy respect for their ancient counterparts. The greater majority of irrigation projects undertaken in Sri Lanka in the nineteenth century and the early part of this century involved the restoration of old hydraulic works rather than the construction of new ones. The ancient reservoirs were repaired by reconstructing the dam where it had been breached by the river. In some cases, the original design was modified by increasing the height of the dam or by extending the spillway. In most cases, the old design, including the old sluices, was retained, the main innovations being the introduction of modern sluice-gates, operated by chains or shafts with geared wheels.

Initially, Sri Lanka came to possess a rudimentary irrigation technology which it shared with the people living in the Southern or the peninsular part of India. The simple technology related to the construction of small reservoirs and canals, each of which served a single village settlement. The earliest reservoirs are associated with the Megalithic Folk who built a distinctive type of large tomb for the leading figures among their ancestors, had access to iron tools and produced a type of pottery called Black and Red Ware. They were widely spread over a good part of the Indian subcontinent and Sri Lanka. It seems most likely that the Megalithic Folk were responsible for the dissemination of this elementary irrigation technology, and that they brought it with them from India to Sri Lanka. Thus, a transfer of proto-historic technology had been accomplished through a migration of peoples.

So, this study employed a qualitative, historical research approach drawing on both primary and secondary sources to investigate ethnoscience and indigenous hydraulic technology in precolonial Sri Lanka. Data were collected through systematic archival research at institutions such as the National Archives of Sri Lanka, as well as through extensive library-based studies. Particular emphasis was placed on the works of *Gunawardana*, including Ethnoscience and Technology in Precolonial Sri Lanka and Cistern Sluices and Piston Sluices: Some Observations on the Types of Sluices and Methods of Water Distribution in Precolonial Sri Lanka, which provided detailed analyses of reservoir construction, canal systems, sluice mechanisms, and the underlying principles of indigenous hydraulic knowledge. Additional insights were drawn from comparative studies of Asian civilizations and theoretical frameworks, including the works of *Needham* on Chinese science and technology [2, 4], *Wittfogel* on hydraulic societies [3], and Wilson on South Asian irrigation [1]. Collected data were analyzed using qualitative content analysis and comparative historical interpretation to identify patterns of technological innovation, environmental adaptation, and the selective transfer of knowledge across regions. Through this approach, the study reconstructed the technological, social, and administrative factors that contributed to the development of precolonial Sri Lankan hydraulic systems, while situating them within the broader context of Asian civilizations [5–10].

Results and Discussion

The pace of change in ancient irrigation technology was initially very slow. Attempts were made in India even from about the fourth century before Christ, to construct large-scale irrigation works like the Nanda canal in Orissa and the *Sudassana* reservoir in the western part of the subcontinent, but such attempts were few. It is very interesting to note that the crucial transition from the level of single, small-scale reservoirs irrigating up to about fifty acres of land to the level of irrigation complexes of interlinked large-scale reservoirs took place not in the Indian subcontinent but in Sri Lanka. The construction of the *Minneri* reservoir in the third century A.D. marks the beginning of a new stage in the development of hydraulic technology. The *Minneri* is best described as an artificial lake and has a circumference of about 25 miles. The modern engineers who attended to its repairs in the early part of this century estimated its capacity to be about 87 million cubic meters. It was capable of irrigating more than 10,000 acres of rice fields, equivalent to many times the area irrigated by any of the reservoirs built earlier in Sri Lanka. At the time it was completed, the *Minneri* appears to have been the largest irrigation reservoir in South Asia. In neighboring South India, it is only after the rise into power of the *Pallava* dynasty in the seventh century that the construction of reservoirs of a comparable scale was undertaken. ("as discussed by Wilson [1]") The largest of the *Pallava* work was the *Kaveripakkam* reservoir with an estimated capacity of about 39.6 million cubic metres, i.e. less than half the capacity of the *Minneri*.

Construction of irrigation complexes on such an extensive scale was possible partly because, by this time, a state with the capacity to mobilize and divert the resources necessary for this purpose had come into being. By the third century, the kings of Sri Lanka, ruling from their fortified capital, had at their disposal an administrative organization which enabled them to collect taxes, to operate a system of judicial courts and to implement decisions taken at Anuradhapura in distant parts of the island. The second major factor, one might even say, the more important factor, was the growth of technology - the development accomplished in the field of hydraulic technology. The technological heritage accumulated over many centuries through construction of irrigation works of a smaller scale and of large religious monuments, some of which have been compared with the Egyptian pyramids of an earlier era, external influence brought in through trade contacts that the island had developed with many lands including China in the East and Persia and Rome in the West, and a capacity among those involved in hydraulic activity to experiment and innovate, all helped to bring about this development.

It is very clear that the men who designed these complexes of irrigation works possessed remarkable skills at selecting suitable sites for their reservoirs. They had done so after carefully observing the physical characteristics of the land. Several of the reservoirs have been carefully located in such a manner that natural rock formations provide the foundations for the embankments. When this was not possible, they tried to find a natural rock formation at least for the spillways. In a number of instances, the location had been selected in a manner that would enable these engineers to minimize the construction work on the dam. The *Minneri* provides one of the best examples to demonstrate this skill. The capacity of ancient reservoirs was generally related to the length of their dams, which could be even up to 12 miles in length, but the gigantic reservoir at *Minneri* was created by a dam which was less than one mile in length ("as discussed by Gunawardana [8]"). A second area in which there was a remarkable development of technical skill pertained to techniques of surveying and levelling. The creation of the western hydraulic complex involved linking two river valleys and the diversion of water from one valley to the other. For this purpose, a canal, 53 miles in length, was built in the fifth century. It becomes easily clear to a modern visitor to the site of the canal that it would have been extremely difficult for the man who designed this canal to decide that the water would flow in the intended direction and to the intended area by visual observation alone: Only by careful surveying and levelling would it be possible to establish that the beginning of the canal is located at a point higher than the place at the other end of the canal, which is about fifty miles away across what is relatively flat terrain. In fact, the canal had to be built at an unusually low gradient. For the first seventeen miles of its course, this canal flows at a gradient of only 6 inches in a mile. The construction of a canal at such a remarkably low gradient was a complex technical accomplishment, even when judged by the criteria of modern technology in this field. ("as discussed by Gunawardana [10]")

The construction of durable reservoirs of large proportions also involved the successful solution of several relevant problems. Wave action is common in large reservoirs. Waves would have an erosive effect on an earthwork dam and eventually destabilize it. Literary works of this period refer to such damage caused by waves. To counteract wave action, large, irregular stones were placed along the inner side of the dam, and here, we find the beginning of the use of what is called "pitching" which has become a regular feature of earthwork dams built in more recent times. There are two other features which are necessary for the safety of a reservoir. One helps to protect the reservoir in times of flood. It is a type of safety-valve which permits the excess water to flow out and prevents what engineers call "overtopping." If flood waters rise above the level of the earthwork dam and flow over it, the dam would be destabilized, and a breach would be most likely. The need to provide such a safety-valve in the form of a spillway was realized very early and the spillway became an invariable element in all the major reservoirs.

Perhaps the more formidable problem was to devise a means by which water could be released from large reservoirs. In earlier times, it had been the practice to release water from reservoirs by cutting the dam in the dry season when water would be needed in the rice fields and rebuilding it before the rainy season. Obviously, such an arrangement was unsuitable for releasing water from reservoirs of large proportion. The response to this problem was a device which the *Gunawardana* has called "*the cistern sluice*."(“as discussed by Gunawardana [6]”). It is interesting to note that these designers were clearly aware of the relationship between head and pressure of water. They used this knowledge to furnish a simple solution to deal with problems arising from the levels of the pressure of water in these large reservoirs. They placed their sluices at different levels of the dam: The first sluice would be at a depth of about 4 to 10 feet, and the rest at similar intervals lower down. They would first operate the topmost sluice, and, when the level of water receded below that sluice, the next sluice would be operated, and so on. This meant that though the total depth of a reservoir was considerable, at each releasing operation, they were handling water at a level of pressure which did not cause serious problems for the dam. Further, the cistern sluice was constituted of elements which would ensure dissipation of energy through friction and eddy formation before the water would flow through the dam. The remains of sluices at ancient reservoirs reveal attempts at improving their design through experiments involving variations of length, size, shape, and orientation. They also varied the tapering of the inlets and outlets of the sluices. Today, on looking back at their work, we can detect one serious shortcoming. Unlike the modern designers who have access to information on long-term rainfall patterns and are able to estimate the amount and variation of the supply of water to their reservoirs, the ancient designers did not possess a reliable understanding of the intensity of the floods and the resultant pressures their reservoirs would have to face. Consequently, they sometimes failed to provide adequately large spillways to ensure the safety of their reservoirs. But, on the whole, their work reflects an innovative approach which enabled the Sri Lankans to attain a leading position in ancient hydraulic technology. Unfortunately, we do not know any of the names of the innovators. This technology was the product of a caste society in which technical excellence rarely brought adequate compensation in social terms. It is only the names of kings and of leading men who mobilized the labor and other resources that were recorded for posterity.

An important question which confronts us at this point is whether Sri Lankan hydraulic technology wielded an influence on subsequent developments in the neighboring South Indian kingdoms with which Sri Lanka maintained close political, cultural and commercial contacts. It is possible that the feasibility and the value of large-scale reservoirs gained acceptance on the basis of Sri Lankan examples. There are also certain basic similarities in design, but, as regards a crucial element, there is a clear difference. The South Indian reservoirs have a highly distinctive sluice mechanism, which is widely distributed over this region. The operation of this sluice was based on a piston which was raised to open the sluice and release water and lowered to close it. Unlike the Sri Lankan sluice, the South Indian sluice, which the *Gunawardana* has termed the "*piston sluice*," was located on the bed of the reservoir, away from the dam (“as discussed by Gunawardana [6]”). Operation of the sluice would have been rather cumbersome. One had to use a boat to reach it. On the other hand, it is possible to suggest that such a location of the sluice reduced the risks of seepage of water into the dam. Seepage was a common cause behind the failure of dams. It also discouraged theft of water, a serious problem in irrigation society. At the same time, apart from the inconvenience of operating the piston sluice, the volume of water it could handle was quite meagre when compared with the Sri Lankan sluices. Consequently, Reservoirs in South India were constructed with considerably more sluices than Sri Lankan reservoirs of comparable size. While some large South Indian reservoirs include as many as twenty-three sluices, major Sri Lankan reservoirs typically contain fewer than five. In the eleventh century, when the northern parts of Sri Lanka were conquered by a Cola king from South India, there was an attempt to introduce the Sri Lankan type of sluice to South India. But it is interesting to note that this sluice was modified later on, and the traditional South Indian type of "piston sluice" was fitted inside it.

Conclusion and Recommendation

The discussion of sluice technology outlined above draws attention to several broader issues, particularly the restricted explanatory strength of diffusionist theory in interpreting technological development in precolonial South Asia. Hydraulic engineering represents a highly specialized field in which proponents of diffusionism would reasonably anticipate strong empirical support for their perspective. Nevertheless, although Sri Lanka developed advanced hydraulic innovations most notably extensive networks of interconnected reservoirs that surpassed comparable developments in South India these technological advances were not wholly transferred to neighboring regions. A close analysis of sluice structures demonstrates how two culturally related societies, operating within similar environmental conditions, formulated distinct technological responses to an identical fundamental challenge. While there was some degree of technological exchange between them, each culture maintained unique methods in relation to critical components of hydraulic engineering. It may be proposed that political considerations contributed to limiting technological diffusion. Large-scale irrigation initiatives facilitated population concentration, and demographic expansion was a central factor in the political rivalries of the period. Consequently, rulers were generally reluctant to promote irrigation development beyond their own territories and carefully protected their hydraulic knowledge. This protective stance is illustrated in a Sri Lankan literary source that recounts a royal decree forbidding subjects from traveling to South India to participate in irrigation construction. Conversely, the receiving societies also demonstrated caution, retaining their established practices and selectively adopting only certain external techniques. Although such conservatism might appear restrictive, it represented a deliberate and discerning approach to technological adaptation, offering a model that remains relevant even for contemporary societies.

It may be relevant here to examine un passing the theories of *Wittfogel* cited in an early context and to pursue the theme of the relationship between technology and power. Following *Max Weber*, *Wittfogel* maintained that, in hydraulic societies the construction and maintenance of all irrigation work as well as the distribution of irrigation water were in the hands of a massive bureaucracy. This massive bureaucracy, *Wittfogel* theorized, was used by the king to keep the entire non-official population under rigid control. In *Wittfogel*'s hydraulic state, private property was weak ("as discussed by Wittfogel, [3]"). There were little trade and no merchant class. Thus, there were no social groups who could challenge the power of a despotic king. The influence of this line of thought can be traced in the noteworthy writings of the late Professor *Harry Benda* who defined the hydraulic state as "virtually complete control over the agrarian economy, the absence of a substantial landowning class and political power channeled through an appointive quasi-bureaucratic nobility." *Benda* counterposed the hydraulic state to the commercial state characterized by the presence of "a trading bourgeoisie possessing financial resources and some degree at least of countervailing political power." In the Sri Lankan case, however, the hydraulic state was also a trading state. In fact, the period of most intense hydraulic activity in the island was also a period of notable commercial activity. Prosperity brought in by commerce enabled kings to undertake massive public works.

Wittfogel assumed that irrigation was a monopoly of the state. This was certainly not so in Sri Lanka. While the 66 large-scale reservoirs mentioned earlier were built by kings, it has been estimated that there are about 12,000 small-scale irrigation reservoirs in Sri Lanka. As late as in 1931, sixty-five percent of the total irrigation needs of the island were being met by these small-scale irrigation works ("as discussed by Wittfogel, [3]"). Hence, though the massive irrigation works are technologically impressive, the role of the small-scale irrigation works in the agrarian economy should not be underestimated. These works were constructed and maintained not by the king but by village communities, private individuals and even Buddhist monasteries. In many cases small-scale irrigation works were maintained by the joint labour of the community. The participation in such communal activities strengthened the solidarity of the community. Further, in this society there were social groups wielding power and influence which was based, at least partly, on the ownership of irrigation works and land. It is relevant to note that, even in the case of large irrigation works, while the state intervened to construct them and to repair them after major calamities, the everyday maintenance was not always in state hands. Some of these larger works had been donated to Buddhist monasteries and were maintained by them. Religious institutions, played an important role in helping to maintain the traditions of hydraulic technology. Their ideology emphasized the need for harmony between man and nature and the need to avoid injury to life of humans as well as animals: it was not a force opposed to development of hydraulic technology.

A field which was most representative of Asian technology was one which catered to a vital concern shared in common by civilization in China, in the western parts of Asia as well as in South Asia. In one way or another, these regions were seriously affected by problems connected with water. Recurrent floods threatened civilization in some of these regions. In other regions, the threat stemmed from the inadequacy of water, of natural rainfall, for the production of food. Paradoxically enough, there was a third category of which was threatened by both flood and drought. The flowering of civilization within such regions, in some cases, even their very existence, depended on the construction of large-scale public works designed to keep out and divert floods, to conserve water or to transfer water from one area to another. The construction of flood-protection schemes, of reservoirs and canals to help increase food production, and the repair of these hydraulic works were among the major functions of the polity in these civilizations. It is for these reasons that, in his well-known work, *Wittfogel* began to use the term hydraulic civilization with reference to these civilizations.

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