

## Article

# Traditional Water Governance Practices for Flood Mitigation in Ancient Sri Lanka

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**Abstract:** The tank cascade system, which emerged as early as the fifth century BC in Sri Lanka's dry zone, has been portrayed as one of the oldest water management practices in the world. However, its important function as flood management has not yet been thoroughly examined. In this paper, we argue that the main principle behind the tank cascade system is not only to recycle and reuse water resources by taking advantage of natural landscapes but also to control floods. This paper examines the evolution of traditional water management and flood mitigation techniques that flourished in pre-colonial Sri Lanka. This historical examination also sheds light on recent policies that exhibited renewed interests in revitalizing some aspects of the tank cascade system in Sri Lanka's dry zone. This paper shows how ancient Sinhalese engineers and leaders incorporated traditional scientific and engineering knowledge into flood mitigation by engendering a series of innovations for land use planning, embankment designs, and water storage technologies. It also discusses how this system was governed by both kingdoms and local communities. Water management and flood control were among the highest priorities in urban planning and management. The paper thus discusses how, for centuries, local communities successfully sustained the tank cascade system through localized governance, which recent revitalized traditional water management projects often lack.

**Keywords:** tank cascade system; dry zone; water governance; flood control; traditional knowledge; community participation; Sri Lanka



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## 1. Introduction

Water management is one of the fundamental requirements for the survival and prosperity of civilizations. Historically each civilization developed its unique water management practices that reflected the surrounding topography, climate, soil and utility purposes [1,2]. The traditional water management system that developed in the dry zone of Sri Lanka more than 2500 years ago is one of the oldest known water management systems in the world [3]. This ancient hydraulic civilization uniquely engineered storage dams [4] and water distribution systems [5,6].

According to the *Mahavamsa*, an earliest known chronicle that depicted ancient Sri Lanka, when Indian Prince Wijaya landed Sri Lanka from India in 543 BC, he observed irrigation practices among Indigenous Sinhalese people. At the port of Mannar, where he landed, the prince found many water tanks (or reservoirs) with cool water that replenished a great garden [5].

In the twenty-first century, this traditional water management is still in practice to some extent although much of it has been disrespected due to the introduction of Western water management systems under the colonial regime as well as in the age of the more contemporary international cooperation regime. However, somewhat reversing this trend, the Sri Lankan government has recently acknowledged the importance of historically

practiced water management and reinstalled some in rural regions for flood protection and irrigation purposes.

Some scholars have reexamined Sri Lanka's traditional water management system partly for the purpose of enhancing modern day climate resilience actions. Some emphasized the implications for drought mitigation and rain water harvesting [7–11], agricultural developments [5,12,13], ecosystem management [2,14–17], and socio-economic development [4,18–20]. Literature shows that a similar tank system existed in semiarid southern India, but its main purpose was to provide water for paddy cultivation [21,22]. Qanat is another traditional irrigation water management practices that existed in semi-arid regions of Morocco, Spain, Syria, Iran, and Central and Eastern Asia. Ancient societies developed underground networks for the transportation of water [1].

Looking at this growing trend of studies, what is missing is a linkage between traditional water management and flood mitigation practices in Sri Lanka and elsewhere. Some researchers did mention about traditional flood mitigation functions in Sri Lanka [2,13,22–25], but the question remains as to the extent to which traditional water management practices were systemically arranged for improving or supplementing flood protection. In other words, we argue, flood mitigation has long been integral part of Sri Lanka's water management system.

This paper, therefore, seeks to understand Sri Lanka's traditional flood mitigation functions and technologies that evolved through time in its dry zone. This said, some may argue that this type of examination requires hydrological modeling or engineering investigation to truly understand the effectiveness of ancient flood mitigation infrastructure [26]. However, our main focus in this paper is rather to trace how past practices took shape in time, given urgent needs of local Sri Lankan farmers to mitigate flood risks. The IPCC report and other recent studies on climate change adaptation and disaster mitigation emphasized the importance of better understanding locally developed adaptation and mitigation practices as a way to enhance local disaster response capacity and participation [6,13,22,27–30].

In the following discussion, we first look at the development process and functions of the traditional system. Then, we examine water and flood management practices in ancient cities. Finally, we discuss the water governance system and its sustainability. For our examination, we used historical records, secondary sources, institutional reports, and audiovisual sources. In March 2019, the authors visited several ancient water management sites, including Sigiriya and Polonnaruwa to collect documentary and visual information. We also collected information in Colombo in the same year to find out what has already been known in the country about its ancient water management system.

## 2. Development of the Tank Cascade System in the Dry Zone of Sri Lanka

In Sri Lanka's dry zone annual mean precipitation is about 1750 mm whereas annual mean evaporation ranges from 1700 mm to 1900 mm [31]. About 80% of the annual rainfall occurs during the northeast monsoon season from November to February when flash floods often occur. Seasonal rivers and so-called *Villu* (wetland ecosystem in floodplains) are natural water bodies that emerge during these months. The earliest inhabitants were recorded in the lowland areas such as Anuradhapura and north central parts of Sri Lanka in the ninth century BC [32,33]. They lived along rivers and water bodies, collecting and storing water partly for drinking and irrigation purposes [2,6].

The earliest available information on hydraulic civilization of Sri Lanka dated back to the sixth to fifth century BC [4,5]. Archaeological studies show a network of tanks that were interconnected by streams and waterways. Today, this water network is commonly known as the tank cascade system [5,8,9,34–36]. The main hydrological principle behind the tank cascade system is to recycle and reuse water through a network of small to large scale tanks within a catchment. It also considers storing, transporting and distributing water for mitigating floods and droughts [2]. The International Union for Conservation of Nature in Sri Lanka identified four main functions of these ancient structures: (1) capturing rainwater to minimize floods; (2) storing rainwater; (3) recycling used water; and (4) mitigating

drought impact [25,27]. Other than these, the cascade system sustained the local ecosystem as ancient engineers carefully used natural landscapes to enhance water storage [37].

The flood mitigation of the tank cascade system entailed engineering techniques of water and sedimentation flow control along with the protection of banks from erosion. Ancient Sinhalese people constructed granite structures and pillars. In order to protect the embankment from breaching and flooding, with improved technologies for metallurgy, iron was used to strengthen the structure [5]. The knowledge of iron metallurgy was introduced to Sri Lanka as early as the tenth century BC. The archaeological sites of Aligala, Sigiriya and Anuradhapura show evidence of iron smelting in the ninth century BC [38]. The construction of large tanks emerged in the fourth century BC. At the time of increasing water levels, tanks had spillways to safely release excess water from one tank to another. Small tanks were built in low plains between hills by connecting them with embankments [36]. For example, *Basawakkulama* tank, the earliest recorded large-scale tank was built in the Malwathu Oya Basin in about 430 BC. With over 3000 feet in length and 21 feet in height, the dam had storage capacity for cultivating 350 acres. A large number of small tanks were built in the same basin to avoid possible disasters from flooding [4].

Mahatantila et al. [39] identified three main components of tanks: (1) upper periphery, (2) bund/embankment and (3) tank body. However, in the following discussion, we add one more component, which is especially important for flood management; that is, the lower periphery of the tank where human settlements with paddies were located. Figure 1 shows how these components were typically laid out. Paddy cultivation was the main livelihood practiced by early inhabitants. The paddy cultivation of Sri Lanka dates back to the ninth to sixth centuries BC. During this period, ancient farmers domesticated cattle. Cattle were used for harrowing paddy fields [32,33,40].



Figure 1. Main components of the tank.

In the upper periphery of the tank running water in streams was filtered through forests with patchy water holes or bogs. Rain-fed farms were located here [2]. The ancient law prohibited felling trees as forests were important to manage water quantity and quality. Ancient people developed water holes (*godawala*) partly to prevent sediments from entering the tank [19,23]. Below these water holes, a water filtering area called *perahana* was created with water grasses like reeds [23,27].

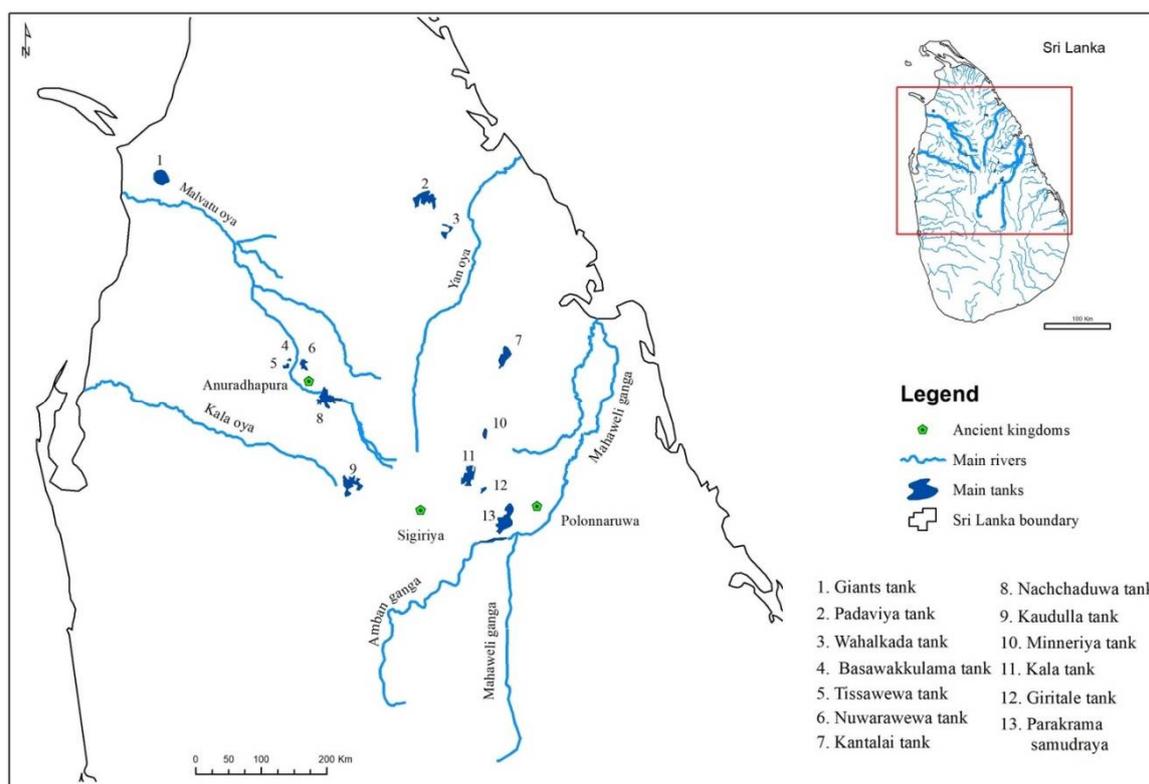
Ancient Sinhalese protected the embankment from wind, heavy rain and waves by building stone liners on embankment walls [2,20]. The tank embankment was basically made of earth and granite rocks. Large-scale embankments with 30–40 feet deep reservoirs consisted of unique and intricate engineering innovations. The height of the embankment was carefully designed not to flood the upper stream area [14]. The embankment was installed with a sluice gate (*sorowwa*), valve pit (*bisokotuwa*), water level indicator (*diyakata pahana*), spillway (*pitawana*) and embankment protector (*ralapanawwa*). The main purpose of sluice gate (*sorowwa*) was to regulate water release without flooding lower stream areas. The water level indicator helped decide when to release water. The valve pit or *bisokotuwa*, which was attached to the sluice gate on the bottom of the embankment, was basically a rectangular buffer room that was created to temporarily gather water from the lake through the sluice. When the level of gathered water in the room was raised above the sluice gate level but below the reservoir water level, water was released toward the lower periphery through the other gate(s). The location and arrangement of these water gates differed by region and embankment, showing engineering diversity [16,41]. The *bisokotuwa* is still in operation at Kalawewa, one of the largest tanks built in 477AD during the period of Anuradhapura kingdom [2].

In the upper edge of tanks, a so-called tree belt (*gasgommana*) had a number of planted trees partly to protect the embankment. It also provided the habitat for fish and other aquatic species [2,23]. The trees became partly submerged in water during the heavy rain period. This tree belt also acted as a wind barrier and reduced the waves in the tank.

In the lower periphery of the tank, when water was released from a sluice gate through a valve pit it ran through an interceptor (*kattakaduwa*). The interceptor is a reserved land for the purpose of controlling soil erosion and water contamination. Villagers took drinking water below the interceptor. It also provided water to farms. The surrounding village was protected from water inundation with a hamlet buffer area (*thisbambe*), shrub land (*landa*) and drainage (*kivoul ela*). The trees that have high heavy metal and salt absorption capacity with a strong root system were planted [2,23]. Being in the high elevated areas near the interceptor, villagers could observe flooding or damages to the embankment. The hamlet was surrounded by the hamlet buffer area that was used for common perennial cultivation (e.g., mango, coconut) and resting places for buffaloes [20,23]. Paddy fields below the interceptor functioned as wetlands during heavy rains to keep temporary flood water. When water is not enough for the whole paddy lands, all farmers cultivated equally (*Bethma cultivation*), limiting the paddy area to be irrigated [13,15]. The villagers used the shrub land for home gardening, such as chena cultivation. The excess water of the paddy fields flowed to the drainage area that was used for common village purposes to absorb salt and other contaminations [23,27]. Through the drainage and other natural streams, water reached the next tank.

### 3. Flood and Water Management Techniques in Ancient Kingdoms in Sri Lanka

In planning cities, villages and monastery complexes, ancient Sinhalese engineers carefully considered water sources, water uses and landscapes [42]. Flood control is one of the main requirements of city planning. Figure 2 shows the locations of the ancient kingdoms, main tanks and rivers. The historical records show that water was used not only for drinking and irrigation purposes but also for public bath and recreational activities. Traditional knowledge on rainfall patterns, land use planning and landscape helped ancient people maximize the use of water resources [17].



**Figure 2.** The locations of the ancient kingdoms, main tanks and rivers.

For example, in the early fifth century BC, the city of Anuradhapura adopted the ancient Indian “Nandyavarta plan” for water resource management [42]. It laid out the city in a circular shape. The central area was surrounded by walls with four gates that faced each cardinal direction. Anuradhapura was established along the Malwathu Oya (or river), the main river of the area. Anuradhapura’s engineers constructed five large tanks around the city in about 437 BC. In order to protect the city from floods and droughts, they also constructed many small tanks in the same valley. Between the river and the tanks, three green parks were established mainly for recreational purposes [42]. These parks acted as water retention facilities during floods. Villages and king’s palace were located below *Basawakkulama* tank. Its L-shaped embankment was designed to take advantage of the surrounding landscape. It supplied both drinking and irrigation water. Bathing also became important part of Anuradhapura residents’ lifestyle [42].

Sigiriya fortress, the present-day UNESCO World Heritage site, is another example to show a complex outlook of water management in an ancient city. The annual rainfall is the only possible water source here [8,17]. The fortress, which was built on the top of a gigantic rock as well as its surrounding areas, was built by King Kassapa in the fifth century AD (477–495). Human settlements began in this area as early as the third to the first century BC [43–45]. These early settlements were basically for monks who lived in caves of Sigiriya Rock. The rock walls just above caves were carved out like a gutter to keep out rainwater from flooding dwelling areas [43,45]. The cave entrances were then plastered for further protection. Archeologists identified about thirty such locations [43].

Later, King Kassapa developed an urban complex here [43,45]. Residents took water from the Sigiriya Oya and stored in a tank near Sigiriya Rock. Engineers at the time built storage tanks, cisterns, water-courses, underground and surface drainage to managed water in the city. All storage ponds and bathing pools were paved with marbles and pebbles to enhance water retention. In addition, natural depression areas were used to collect rainwater. The city was designed to control flow velocity, runoff discharge, and flow distance. For example, non-structural depression areas and drainage patterns were

used to direct rainwater to the structural ponds located in lower elevations. During the process, water was filtered and velocity was reduced to control soil erosion [17]. Sigiriya also had water gardens and fountains [17,45]. The pools in the water gardens and Sigiriya tank were interconnected through underground drainage. This helped fill the pools automatically [8,42]. During the rain, the water garden can function as a water storage facility. In maintaining pools for bathing purposes, water was supplied from storage tanks, and the used water was released to moats through a separate drainage. The fountains were connected to special underground channels [42]. The moats were located in the lowest area of the land and excess water flows into the moats by reducing floods (Figure 3).



**Figure 3.** A water storage tank in the Sigiriya complex, Photo courtesy: Kenichi Matsui.

King's palace and the rock garden were located on the three-acre rock summit area about 360 m above the sea level [43]. Roofs were designed to collect and transport rainwater to the main water storage area. A drainage outlet was constructed to dispose excess water and prevent flooding. The surface area was terraced with the western side as the highest point [42].

After the demise of Sigiriya city, the Anuradhapura kingdom was reestablished in the 5th century AD about 80 km northwest from the rock. In its monastery site called Abayagiri, twin ponds were created in a low-lying area partly for monks to bathe. It is considered one of the best hydrologic engineering marvels of ancient Sri Lanka [46]. Underground pipelines were established to connect the ponds to Tissawewa, Basawakkulama, and Nuwarawewa tanks around the city by drawing water from the Malwathu Oya [42]. These pipelines ran through a number of small sediment/debris control tanks [47]. An enclosing wall was built around the ponds to control the possible spillage [46]. Also, wastewater outflows ran through wetlands for purification. Then the water was released back to the same river [8]. Each component of the ponds was carefully designed to protect the monastery complex from flooding.

Wastewater is a significant threat to health, particularly during flood events [28,48,49]. Ancient Sinhalese developed and practiced wastewater management. In Anuradhapura and Polonnaruwa different types of lavatories were developed [50]. Here urinals were collected in pits through terracotta pipes. Sands, lime powder and charcoals were used to purify wastewater [8,50]. In some places, separate septic tanks were used to store

wastewater. These places were kept some distance from residential areas in order to avoid wastewater spillage during floods.

In the reign of King Parakramabahu (1153–1183 AD), water management technologies were further refined [5]. His engineers built several large-scale tanks and irrigation systems [23]. They constructed more than 163 major tanks, 2376 minor tanks, 165 anicuts and 3910 diversion channels [51]. The capital was located in present-day Polonnaruwa city, about 50 km east from Sigiriya. King's palace was located very close to the tank called *Parakyama Samudraya* (Figure 4) that had nine-mile-long embankment. In order to protect the palace from floods, huge brick walls were constructed along the tank side of the palace. There were several non-structural natural drainage facilities inside the walls to temporarily store water. The ground was also covered with grass to reduce soil erosion and trap debris. A few sluice gates were installed along the brick walls. A drainage canal was installed in the other side of the palace. *Kumara Pokuna* near King Parakramabahu's palace was one of bathing ponds that might have functioned as flood control structure (Figure 5). Similar to the Anuradhapura pipeline system it was connected with several drainages to purify water [17]. Even today this system is functioning well.



**Figure 4.** View of *Parakrama Samudraya* Photo courtesy: Kenichi Matsui.



**Figure 5.** *Kumara Pokuna* in Polonnaruwa Photo courtesy: Kenichi Matsui.

#### 4. Water Governance in Ancient Sri Lanka

The ancient chronicles of *Mahavamsa*, *Dipavamsa* and *Culavamsa* as well as remaining cave, rock and slab inscriptions show evidence of Sri Lanka's water governance from the fourth century BC to the thirteenth century AD [3]. Some of these documents tell us how early Anuradhapura kingdom governance practices emerged with professionals and water ownership. The government imposed an income tax and other rules on using water [52]. These rules basically relied on community participation and involvement [10,13,17]. Later, the governance system gradually changed from a community-based system to a centralized one although the small-scale tank cascade system remained under community management [3].

From the fourth century BC to third century AD, water rights in general were held by individuals, kings, elites, local chiefs and families [3]. Kings and elites could grant water rights to monks mainly in the period between the second century BC and eighth century AD. Buddhist temples then administered water allocations. Until the second century BC, the management of tanks, including flood control and maintenance, were mainly undertaken at the village level, which mainly consisted of farmers [3,13]. Works for repair, desiltation and cleaning of the tank during the dry season were shared among farmers proportionately to the land ownership. Each farmer provided his or her service free on certain days [20]. The community also planted trees to strengthen the stability of the tank embankment and the interceptor (*Kattakaduwa*). In times of water shortage, the *Bethma* rules made farmers share water for paddy cultivation. This set of rules are still practiced today among some farmers during water shortage [13]. Here the village head or prominent leader decide the area for cultivation each year based on water availability in the tank. Farmers then received equity-based water allocation based on land ownership [13,20,40,53].

In the second century BC, localized water governance was gradually replaced with a centralized system. Different professions emerged as a result, such as flow operators (*Naguli*), canal officials, and proprietors of ferries (*Parumaka Thota Bojhaka*), and proprietor of tanks (*Parumaka vapihamika*). This institutionalized governance made it possible to sustain the food supply of a large population [3]. In the ninth century AD, the last phase of kingdom of Anuradhapura further institutionalized water governance by establishing specialized committees to maintain large-scale tanks [3].

Water rites, rituals, and customs played an important role in ancient water governance. For example, the king granted water rights through the "ceremony of golden vase", in which water was poured from a golden vase into farmers' hands [3]. The king also participated in festivals that sent a signal to commence ploughing, sowing, and harvesting. *Pen Pidima* ceremony offered fresh water of a tank to Buddha statues to pray for fertility [18].

#### 5. Abandonment of Dry Zone Water Governance to Contemporary Water Governance

By the mid-13th century AD with the collapse of the Polonnaruwa kingdom, the centralized large-scale tank cascade governance was largely abandoned in many parts of the dry zone [3,4,31,54]. Although community-driven small-scale cascade systems remained in practice with varying degrees until the end of the 15th century [31]. European colonization under the Portuguese, Dutch, and British from the 16th through 18th centuries systemically and gradually disempowered traditional local authorities for water governance [4].

In 1832, about 17 years after the British established its colonial government in Kandy, it abolished the Kandyan *rajakariya* system, which imposed compulsory labor for public works, claiming that it resembled a form of slavery [3,31]. At the time many villages governed local affairs through *Gansabhawa*, a council composed of representatives of villagers. This council depended largely on the availability of village labor under the *rajakariya* system. As the British colonial regime further tightened restrictions on it, canals and other traditional water management works gradually fell into serious decay [54]. This change led to the deterioration of the community tank cascade system in many parts of the dry zone [3,31].

The British then empowered the Temple Land Commission (1856) and the Service Tenure Commission (1870) to govern tanks and surrounding villages where village heads used to control local affairs [3]. From 1870 to 1897, the colonial government repaired and restored a large number of village tanks, including *Kalawewa*, one of the largest tanks built in 477AD and Giant's Canal (*Yoda ela*), which was built in 459AD. Village communities provided their labor in voluntary basis for these tasks [54]. In 1900, as more educated Sri Lankan elites had been brought into civil services by then, the colonial government hired many of them and established the Department of Irrigation, which took control over public works. This department remains as one of the oldest departments in Sri Lanka. One of its mandates was flood protection [4,55]. During its 50-year operation, it restored almost all large-scale tanks and anicuts [4].

Soon after independence in 1948, the government of Sri Lanka attempted to improve water management. For example, in 1952, it constructed the nation's largest reservoir called *Senanayaka Samudraya* [29]. As the Gal Oya basin often experienced floods and droughts [55], disaster mitigation was one of the main components of the project. However, the project ultimately failed to achieve its initial goals due largely to top-down decision making where community participation was not incorporated [29].

In the 1950s, the Sri Lankan government began to place more emphasis on regional tank cascade governance. The Paddy Lands Act of 1958, for example, authorized the Department of Agrarian Services to maintain all small-scale water works. This act placed village tank cascade systems directly under the Department of Agrarian Services, a central government authority. It led the restoration and rehabilitation of small-scale village tanks including canals and flood mitigation structures [31].

In 1977, the Sri Lankan government undertook a comprehensive basin development called the Mahaweli Accelerated Development Project in the Mahaweli River Basin and created the Mahaweli Authority [4]. Flood control in the lower Mahaweli River was one of the main objectives [56,57]. It constructed new Western-style water reservoirs such as Kotmale, Victoria, and Maduru Oya. Kotmale reservoir was specifically designed for flood control by making it possible to transfer flood water from Polgolla to the dry zone where restored ancient tanks are located (e.g., *Parakrama Samudraya*, *Minneriya*, *Kantale*, *Kaudulla*, *Kalawewa* and *Giritale*) [58]. After the construction of this reservoir was completed in the mid-1980s, the flood inundation risk in the downstream of the Mahaweli River was significantly reduced [58]. The Mahaweli Authority also reestablished ancient river connections among Sudu Ganga, Amban Ganga, and Dambulla Oya in central province [59].

In the 1980s, the government undertook projects to restore ancient water management by mobilizing local people. In 1981, the Gal Oya Left Bank Rehabilitation Project hired community labor and collected local knowledge about water management [29,60]. It created farming organizations to control local water use for domestic and agricultural purposes. It also funded channel maintenance by these organizations. As farmers in the dry zone are the ones to experience flood damage to their crops, these farmer organizations were expected to play active roles in flood management [29]. In 1982, for example, the Village Irrigation Rehabilitation Project and National Irrigation Rehabilitation Project aimed to repair and maintain minor tanks with community participation [37].

In 1991, the Agrarian Services Act induced the concept of joint water management between farmers' organizations and a government agency [31]. In order to promote participatory planning and management, stakeholders were engaged in *kanna* meetings (pre-seasonal meetings of farmers). Even today, these meetings are the most important decision-making bodies in operating local tanks. Their tasks include the joint maintenance of flood control bunds, sluices, and channels [31].

Post-independent tank rehabilitation programs were mainly for repair, maintenance and physical development of individual tanks rather than the whole network of the tank cascade system. This shortcoming resulted in tank sedimentation, water leakage, land degradation, biodiversity loss, and floods and soil erosion [37]. In the 1990s, the Shared Control of Natural Resources in Watersheds Project adopted an ecosystem approach through

community-based participatory watershed management. It expressed its strong interests in environmental sustainability and productivity improvement [60]. The project was implemented in northcentral province and southern province. It introduced farming companies to work independently in watershed management [61]. The project took the novel approach to address watershed issues by creating mini-projects among local communities and NGOs. This provided a sense of ownership for the parties involved in the project [62]. For example, in the Nilwala watershed, deforestation in the upper stream often flooded the lower basin due to sedimentation. To prevent soil erosion and sedimentation, the project attempted to protect existing forests and rehabilitate degraded forests. At villages, agroforestry practices were encouraged [63].

## 6. Conclusions

This paper has examined how Sri Lanka's traditional flood and water management evolved in its dry zone. Our goal was not to suggest that all traditional forms of flood control and community participation were effective. However, to better understand how Sri Lanka's flood management practices exist today in a hybrid form, which has incorporated traditional, colonial and modern technologies and practices, we found it imperative to clarify historical changes in flood management practices. Without knowing this complexity, locally viable flood mitigation measures cannot be sustainable. Therefore, it is important to understand how, in Sri Lanka, societies developed unique flood control practices, including governance frameworks and laws to ensure safety from disasters and equitable access to water. The tank cascade system is the result of their traditional knowledge on watershed and disaster management.

To demonstrate some recorded practices, this paper looked at how the tank cascade system captured rainwater, stored it, minimized flood impacts, maintained public health and conserved/nourished biodiversity. It somewhat resembled modern-day integrated water resources management. The traditional knowledge regarding engineering and metallurgy evolved and resulted in large-scale embankments for flood control along with sluice gate (*Sorowwa*), valve pit (*Bisokotuwa*), water level indicator (*Diyakata pahana*), spillway (*Pitawana*), and embankment protector (*Ralapanawa*).

Anuradhapura, Sigiriya, and Polonnaruwa cities developed both structural and non-structural water infrastructures. Multiple-purpose structures were designed for flood mitigation, irrigation, purification, drinking, and recreation. For centuries, the tank cascade system was largely governed by the community. Experienced community leaders played a vital role in decision making. Community voluntary support for managing the commons is an important feature in water governance. Rights to water resources were shared among elite groups, monks, community and individuals. The development of water professionals, taxes and rules in managing water systems emerged when centralized water governance under kingdoms began to exert more control over water resources. Along with these institutional development, monks and people developed water rituals and customs that considerably influenced traditional water governance.

European colonial regimes, however, gradually eroded this intricate water governance practices. The abolition of the *rajakariya system* under the British rule led to the disuse of communal tanks as it became difficult to obtain local labor. After independence, the government of Sri Lanka showed its renewed interests in traditional water governance and undertook several large-scale water management projects, such as the Gal Oya Irrigation Project and Mahaweli Accelerated Development Project with renewed interests in locally viable traditional water management. In the 1990s, Sri Lanka's watershed restoration policy began to emphasize community participation and led to some positive results. More water governance projects are planned to take advantage of traditional systems and mobilize local participation although the overall impact of their effectiveness for flood control under escalating climate change conditions remain to be determined in the future.

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## References

- Behailu, B.M.; Pietilä, P.E.; Katko, T.S. Indigenous Practices of Water Management for Sustainable Services: Case of Borana and Konso, Ethiopia. Special Issue-Traditional Wisdom. *SAGE Open* **2016**, *6*, 2158244016682292. [CrossRef]
- Geekiyana, N.; Pushpakumara, D.K.N.G. Ecology of ancient Tank Cascade Systems in island Sri Lanka. *J. Mar. Isl. Cult.* **2013**, *2*, 93–101. [CrossRef]
- Abeywardana, N.; Bebermeier, W.; Schütt, B. Ancient Water Management and Governance in the Dry Zone of Sri Lanka Until Abandonment, and the Influence of Colonial Politics during Reclamation. *Water* **2018**, *10*, 1746. [CrossRef]
- Irrigation Department of Sri Lanka. Hydraulic Civilization and Water Resources in Sri Lanka. In Proceedings of the Hydro ASIA Fifth International Conference on Water Resources and Hydro Power Development in Asia, Colombo, Sri Lanka, 11–13 March 2014.
- Brohier, R.L. *Ancient Irrigation Works in Ceylon. Part II. Northern and North-Western Sections of the Island*; Superintendent of Surveys; Ceylon Government Press: Colombo, Sri Lanka, 1935.
- Dharmasena, P.B. Indigenous Water Resources Management in Sri Lanka. In Proceedings of the Conference on Environment and Humanity, Colombo, Sri Lanka, 19–20 August 2012.
- Dharmasena, P.B. Indigenous Irrigation Practices. National Science Foundation, Sri Lanka. *Vidurava* **2004**, *32*, 3–7.
- Turpin, T. *Traditional Water Management in Sri Lanka & Its Relevance to the UK for Climate Change*; Winston Churchill Memorial Trust: Colombo, Sri Lanka, 2006.
- Jayasena, H.A.H.; Chandrajith, R.; Gangadhara, K.R. Water Management in Ancient Tank Cascade Systems in Sri Lanka: Evidence for Systematic Tank Distribution. *J. Geol. Soc. Sri Lanka* **2011**, *14*, 29–34.
- Gangadhara, K.R.; Jayasena, H.A.H. *Rainwater Harvest by Tank Cascades in Sri Lanka Was It a Technically Adapted Methodology by the Ancients?* Department of Geology, University of Peradeniya: Peradeniya, Sri Lanka, 2014.
- Piyadigama, T.M. Indigenous Water Resource Management in Sri Lanka. 2017. Available online: [https://www.researchgate.net/publication/330957196\\_Indigenous\\_Water\\_Resource\\_Management\\_in\\_Sri\\_Lanka](https://www.researchgate.net/publication/330957196_Indigenous_Water_Resource_Management_in_Sri_Lanka) (accessed on 14 December 2019).
- Dharmasena, P.B. Sustainability of Small Tank Irrigation Systems in Sri Lanka at the 21st Century. In *Traversing No Man's Land*; Godage International Publishers (Pvt) Ltd.: Matara, Sri Lanka, 2009; pp. 233–252.
- Marambe, B.; Pushpakumara, G.; Silva, P. Biodiversity and Agrobiodiversity in Sri Lanka: Village Tank Systems. In *The Biodiversity Observation Network in the Asia-Pacific Region: Toward Further Development of Monitoring. Ecological Research Monographs*; Nakano, S., Yahara, T., Nakashizuka, T., Eds.; Springer: Tokyo, Japan, 2012. [CrossRef]
- Panabokke, C.R. *The Small Tank Cascade System of the Rajarata*; Mahaweli Authority of Sri Lanka: Colombo, Sri Lanka, 2000.
- Perera, M.P.; Chandima, D. Ancient Watershed Management Strategies in the Dry Zone of Sri Lanka. In Proceedings of the 3rd International Conference on Water & Flood Management (ICWFM), Dhaka, Bangladesh, 8–11 January 2011.
- Dharmasena, P.B. Water Resources Management for Agriculture in the Dry Zone of Sri Lanka. A Review of the Journal of Tropical Agriculture. 2012. Available online: [https://www.academia.edu/14024262/Water\\_Resource\\_Management\\_for\\_Agriculture\\_in\\_the\\_Dry\\_Zone\\_of\\_Sri\\_Lanka\\_A\\_Review\\_of\\_the\\_Journal\\_of\\_Tropical\\_Agriculture](https://www.academia.edu/14024262/Water_Resource_Management_for_Agriculture_in_the_Dry_Zone_of_Sri_Lanka_A_Review_of_the_Journal_of_Tropical_Agriculture) (accessed on 20 December 2020).
- Gunaseena, C. Structural and Non-Structural Water Management Concepts and Community Participation in Managing Land and Water Resources in Ancient Sri Lanka. Acedemia. 2018. Available online: [https://www.academia.edu/36990554/Structural\\_and\\_nonstructural\\_water\\_management\\_concepts\\_and\\_community\\_participation\\_in\\_managing\\_land\\_and\\_water\\_resources\\_in\\_ancient\\_sri\\_lanka](https://www.academia.edu/36990554/Structural_and_nonstructural_water_management_concepts_and_community_participation_in_managing_land_and_water_resources_in_ancient_sri_lanka) (accessed on 20 December 2020).
- Abeyasinghe, A. Historical Evidence of Water Management in Ancient Sri Lanka. *Econ. Rev.* **1980**, *6*, 6–7.
- Wijesekera, S. Importance of Cascade Systems (Ancient Irrigation Systems) in Sustainable Development of Rural Communities in the Dry Zone of Sri Lanka (a Review of the Previous Studies). University of Kelaniya, Sri Lanka. 2015. Available online: <http://repository.kln.ac.lk/handle/123456789/17710> (accessed on 14 December 2019).
- FAO. *A Proposal for Declaration as a GIAHS. The Cascaded Tank-Village System (CTVS) in the Dry Zone of Sri Lanka*; Ministry of Agriculture, Food and Agriculture Organization of the United Nations: Colombo, Sri Lanka, 2017.
- Gunnell, Y.; Krishnamurthy, A. Past and Present Status of Runoff Harvesting Systems in Dryland Peninsular India: A Critical Review. *Ambio* **2003**, *32*, 320–324. [CrossRef]

22. Bebermeier, W.; Meister, J.; Withanachchi, C.R.; Middelhaufe, I.; Schütt, B. Tank Cascade Systems as a Sustainable Measure of Watershed Management in South Asia. *Water* **2017**, *9*, 231. [[CrossRef](#)]
23. Dharmasena, P.B. Evolution of Hydraulic Societies in the Ancient Anuradhapura Kingdom of Sri Lanka. In *Landscapes and Societies*; Martini, I.P., Chesworth, W., Eds.; Springer: Dordrecht, The Netherlands, 2010; pp. 341–352. [[CrossRef](#)]
24. Schütt, B.; Bebermeier, W.; Meister, J.; Withanachchi, C.R. Characterisation of the Rota Wewa tank cascade system in the vicinity of Anuradhapura, Sri Lanka. *Die Erde J. Geogr. Soc. Berl.* **2013**, *144*, 51–68.
25. IUCN. Ecological Restoration of Kapiriggama Cascade Tank System. 2016. Available online: <https://www.youtube.com/watch?v=DapXzbHLykQ> (accessed on 14 December 2019).
26. Pedro, P.d.S.; Tavares, A.O. 2015. Basin Flood Risk Management: A Territorial Data-Driven Approach to Support Decision-Making. *Water* **2015**, *7*, 480–502. [[CrossRef](#)]
27. IUCN. *Restoring Traditional Cascading Tank Systems for Enhanced Rural Livelihoods and Environmental Services in Sri Lanka*; Cascade Development Project Information Brief No. 1; IUCN: Colombo, Sri Lanka, 2015.
28. Hughes, J.; Cowper-Heays, K.; Olesson, E.; Bell, R.; Stroombergen, A. Impacts and implications of climate change on wastewater systems: A New Zealand perspective. *Clim. Risk Manag.* **2021**, *31*, 100262. [[CrossRef](#)]
29. Uphoff, N. *Learning from Gal Oya: Possibilities for Participatory Development and Post-Newtonian Social Science*; Intermediate Technology Publications Ltd.: Rugby, UK, 1996.
30. IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*; Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC); Cambridge University Press: Cambridge, UK, 2014.
31. Panabokke, C.R.; Sakthivadivel, R.; Weerasinghe, A.D. *Evolution, Present Status and Issues Concerning Small Tank Systems in Sri Lanka*; International Water Management Institute: Colombo, Sri Lanka, 2002.
32. Kulatilake, S. The Peopling of Sri Lanka from Prehistoric to Historic Times: Biological and Archaeological Evidence. In *A Companion to South Asia in the Past*; Schug, G.R., Walimbe, S.R., Eds.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2016; pp. 426–436.
33. Premathilake, R. Relationship of environmental Changes in central Sri Lanka to possible prehistoric land-use and climate change. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2006**, *240*, 468–496. [[CrossRef](#)]
34. Piyadasa, R.U.K.; Weerasinghe, M.; Weerakoon, L.; Somadewa, R.; Vipulasena, M.P. Sustainable Ancient Water Management and Resilience to Climate Change in Sri Lanka. In Proceedings of the International Conference on Climate Change Impacts and Adaptation for Food and Environment Security, Los Baños, Philippines, 21–22 November 2012.
35. Dharmasena, P.B. Water Balance of a Tank Cascade System in The Dry Zone. In *54th Annual Session of SLAAS*; Part 1:123; Sri Lanka Association for the Advancement of Science: Colombo, Sri Lanka, 1998.
36. Madduma Bandara, C.M. Tank cascade systems in Sri Lanka: Some thoughts on their development implications. In *Summaries of Papers Presented at Irrigation Research Management Unit Seminar Series during 1994*; Haq, K.A., Wijayarathne, C.M., Samarasekera, B.M.S., Eds.; IIMI: Colombo, Sri Lanka, 1995.
37. Dharmasena, P.B. *Guidelines for Tank Cascade Development*; Concept Note Submitted to Plan Sri Lanka for Tank Cascade Development Programme; Department of Agriculture, Field Crops Research and Development Institute: Maha Iluppallama, Sri Lanka, 2005.
38. Solangaarachchi, R. History of Metalurgy and Ancient Iron Smelting. Postgraduate Institute of Archology. University of Kelaniya. *Vidurava* **1997**, *19*, 30–40.
39. Mahatantila, K.; Chandrajith, R.; Jayasena, H.A.H.; Ranawana, K.B. Spatial and temporal changes of hydro geochemistry in ancient tank cascade systems in Sri Lanka: Evidence for a constructed wetland. *Water Environ.* **2008**, *22*, 17–24. [[CrossRef](#)]
40. Dharmasena, P.B. Water use in Ancient Era. *Vidurava* **2001**, *29*, 3–9.
41. Peiris, K.; Wijesinghe, S. Introduction to the Function of Bisokotuwa in Ancient Vewa. *Engineer* **2008**, *41*, 24–28. [[CrossRef](#)]
42. Udalamatta, S.S. The Use of Water and Hydraulics in the Landscape Design of Sigiriya. Master's Thesis, Department of Architecture, University of Moratuwa, Moratuwa, Sri Lanka, 2003.
43. Bopearachchi, O. *The Pleasure Gardens of Sigiriya-A New Approach*; Godage International Publishers: Colombo, Sri Lanka, 2006.
44. Mandawala, P.B. *Buffer Zones in World Cultural Heritage Sites Sri Lankan Examples in Urban and Natural Setting*; President ICOMOS Sri Lanka; International Council on Monuments and Sites: Colombo, Sri Lanka, 2006.
45. Dumas, D.K. Sigiriya: An Early Designed Landscape in Sri Lanka. *Orientalia* **2018**, *49*, 112–121.
46. Karunachandra, T.D. Kuttam Pokuna (Twin Ponds). Acedemia. University of Moratuwa. Sri Lanka. 2018. Available online: [https://www.academia.edu/42989540/KUTTAM\\_POKUNA\\_twin\\_ponds\\_email\\_work\\_card=view-paper](https://www.academia.edu/42989540/KUTTAM_POKUNA_twin_ponds_email_work_card=view-paper) (accessed on 5 April 2022).
47. Allceylon. Kuttam Pokuna (Twin Ponds). All Ceylon Tourism and Directory. Updated 20 October 2017. Available online: <https://www.allceylon.lk/place/95-Kuttam-Pokuna-Twin-Ponds> (accessed on 12 December 2019).
48. Han, J.; He, S. Urban flooding events pose risks of virus spread during the novel coronavirus (COVID-19) pandemic. *Sci. Total Environ.* **2021**, *755*, 142491. [[CrossRef](#)]
49. EPA. *Flood Resilience: A Basic Guide for Water and Wastewater Utilities*; EPA 817-B-14-006; Environmental Protection Agency: Washington, DC, USA, 2014.
50. Siriweera, W.I. Sanitation and Health Care in Ancient Sri Lanka. *Sri Lanka J. Humanit.* **2004**, *XXIX & XXX*, 1–12.
51. Jayasundera, M. Ancient Sri Lankan Economic Systems. *Financ. Mark. Inst. Risks* **2017**, *1*, 24–27. [[CrossRef](#)]

52. Abeywardana, N.; Pitawala, H.M.T.G.A.; Schütt, B.; Bebermeier, W. Evolution of the dry zone water harvesting and management systems in Sri Lanka during the Anuradhapura Kingdom; a study based on ancient chronicles and lithic inscriptions. *Water Hist.* **2019**, *11*, 75–103. [[CrossRef](#)]
53. Dharmasena, P.B. Essential Components of Traditional Village Tank Systems. In Proceedings of the Seminar on Cascade Irrigation Systems for Rural Sustainability, Colombo, Sri Lanka, 9 December 2010.
54. Mills, A.L. *Ceylon Under British Rule 1795-1932: With an Account of the East India Company's Embassies to Kandy 1762-1795*; Frank Cass and Co. Ltd.: London, UK, 1933.
55. Government of Sri Lanka. *Flood Protection Ordinance. Flood Protection Ordinance No 4 of 1924*; Government of Sri Lanka: Colombo, Sri Lanka, 1924.
56. Mohamed, Z. Development of Integrated Water Resources Management Plan for Eastern Dry Zone in Sri Lanka: The Case of Gal Oya River Basin. 2019. Available online: [https://www.pwri.go.jp/icharm/training/master/img/2019/synopses/08\\_Zuhail\\_synopsis.pdf](https://www.pwri.go.jp/icharm/training/master/img/2019/synopses/08_Zuhail_synopsis.pdf) (accessed on 14 December 2019).
57. Chandrathilaka, W.A. Water Resources Management in Mahaweli and Adjoining River Basins in Sri Lanka. Engineer in Charge. Kotmale Dam and Reservoir. Mahaweli Authority of Sri Lanka. 2013. Available online: <http://k-learn.adb.org/system/files/materials/2013/12/201312-water-resources-management-mahaweli-and-adjoining-river-basins-sri-lanka.pdf> (accessed on 20 December 2020).
58. Rathnayake, U.; Weerakoon, S.B.; Nandalal, K.D.W.; Rathnayake, U. Flood Modeling in the Mahaweli River Reach from Kotmale to Polgolla. In Proceedings of the International Conference on Mitigation of the Risk of Natural Hazards, Colombo, Sri Lanka, 25–26 March 2007.
59. Weeraratne, S.; Wimalawansa, S.J. A Major Irrigation Project (Accelerated Mahaweli Programme) and the Chronic Kidney Disease of Multifactorial Origin in Sri Lanka. *Int. J. Environ. Agric. Res.* **2015**, *1*, 16–27.
60. Somasiri, H.P.S. Participatory Management in Irrigation Development and Environmental Management in Sri Lanka. *J. Dev. Sustain. Agric.* **2008**, *3*, 55–62.
61. Wijayarathne, C.M. Shared Control of Natural Resources (SCOR): An Integrated Watershed Management Approach to Optimize Production and Protection. *Sri Lankan J. Agric. Econ.* **1994**, *4*, 60–97.
62. Wijayarathne, C.M.; Jayawardena, K. Shared Control of Natural Resources (SCOR): A Market Oriented Watershed Management Strategy. Executive Summary. Paper 73 of Session 10. CGSpace. 1998. A Repository of Agricultural Research Outputs. Available online: <https://cgspace.cgiar.org/handle/10568/37999> (accessed on 19 December 2021).
63. Elkaduwa, W.K.B.; Sakthivadivel, R. *Use of Historical Data as a Decision Support Tool in Watershed Management: A Case Study of the Upper Nilwala Basin in Sri Lanka*; Research Report 26; International Water Management Institute: Colombo, Sri Lanka, 1998.