DOI: 10.21276/sjhss

Saudi Journal of Humanities and Social Sciences
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6256 (Print)
ISSN 2415-6248 (Online)

Evolution of Tank Cascade Studies of Sri Lanka

Dr. Muditha Prasannajith Perera
Senior Lecturer, Department of Geography, University of Peradeniya, Peradeniya, Sri Lanka.

***Corresponding Author:**
Dr. Muditha Prasannajith Perera
Email: mudithpras@gmail.com , mudithpp@pdn.ac.lk

Abstract: Some of the British agents have wondered due to view of thousands of tanks in low country dry zone of Sri Lanka. The first topographical survey conducted in 1897 and the first systematic study on small tanks within a limited area in 1923 marked the turning point of studying the unique tank system in the country. After this a lot of researchers and professionals both local and foreign, attempted to explore and analyze these systems. Understanding the strategies, water management techniques and issues, anthropological background, ecological settings, organizational behavior of tanks, as well as the current issues and management approaches, were also analyzed within the past period. In addition to the tank based studies, there were a number of studies in relation to “set of tanks” or “combined group of tanks with its catchments as well as command areas”. This paper identifies the evolution of these study disciplines, as well as relevant study periods on different perspectives in relation to tank cascades.

Keywords: Small Tanks, Cascade Systems, Catchments, Command Area, Food Security, Water Flow, Groundwater, Hydro-ecology.

INTRODUCTION

The historical hydraulic civilization of the Dry Zone of Sri Lanka since the 6^{th} century B.C. has created a number of unique strategies for water resources management in the Dry Zone as well as to maintain the hydraulic culture. These empirical knowledge and indigenous techniques of building thousands of tanks and management practices, which prevailed in the Dry Zone of the country, could be considered as one of the oldest and successful resources management practices in the world. But all the knowledge behind these systems has not been revealed until the recent past.

The objective of this paper is to review the evolution of the study background, which is relevant to the tank systems of the Dry Zone of Sri Lanka. Even though, Nianthi and Jayakumara [1] reported about the progress of research on cascade irrigation systems, this study covers the tank and cascade based overall significant studies from the history and identified the different study aspects with relevant study periods.

HISTORICAL ATTENTION OF THE BRITISH GOVERNMENT (1855-1897)

Sir Emerson Tennent contributes his opinion on the unique tank irrigation system in the Dry Zone of Sri Lanka by saying “The stupendous ruins of the reservoirs are the proudest monuments which remain of the former greatness of the country”. In one of the ablest reports on irrigation published by order of the Ceylon Government in 1855, Bailey, who was the Assistant Government Agent of Badulla district said that “It is possible, that in no other part of the world are there to be found within the same space, the remains of so many works of irrigation, which are, at the same time, of such great antiquate, and of such vast magnitude as in Ceylon. Probably no other country can exhibit works so numerous, and at the same time so ancient and extensive within the same limited area, as this island [2].

Until the topographical survey in 1897, very little was known of the exact sites of even the larger reservoirs and practically nothing of the catchment areas. “There was no conception until the maps were issued that the eastern and northern potions of the island contained so many remains of old irrigation works, ranging from the small village tank to schemes, which assumed gigantic proportions” [2].

FIRST SYSTEMATIC STUDIES (1923-1926)

However, the systematic studies on small tanks were started in 1923 [3]. This proves the writings of Arumugam’s as follows; “The railway disaster due to breaching of village tanks of 1923 forcibly directed attention to the potential danger that every village tank lying above the railway constituted. As a result, it was decided that the Irrigation Department should conduct a full investigation in to the safety of every village tank whether worked or abandoned, that was in any way a potential danger to the railway between Polgahawela Mannar and Jafna. The investigation of these 354 tanks on the original list was commenced by Emerson and Biddel in October1923 and was subsequently completed by Kennedy in 1926. Apart from pursuing its original object, namely the safety of the railway from floods caused by the breaching of village tanks, the investigation soon revealed the great possibilities of development that many of the tanks offered, and its scope accordingly extended. In this investigation, knowledge of the subject of village tanks was for the first time systematically collected and collated on scientific lines and the foundation of systematic study soundly established." [3]

OUTSTANDING DOCUMENTING (1933-1970)

Kennedy gave the most important and significant message to irrigation engineers in Sri Lanka, in1933. According to him, "Every village irrigation work in the island has an individuality of its own and when identified a tank on the topographic map, the engineer has to acquire the sense and substance of that individuality of each tank" [4]. This quote is applicable to Sri Lanka because Sri Lanka had a highly skilled and flourishing tank and irrigation system even as far back as 3rd Century AD.

Brohier's view of the Irrigation heritage of Sri Lanka, was "If you explore the low country Dry Zone of Ceylon, you will find for a mile around, striking evidence to denote the extent of paddy cultivation and the colossal nature of the system of artificial irrigation, which under circumstances we have considered, unquestionably occupied the spaces [2].

Then, Cook [5] studied about the spatial distribution of the village tanks and she prepared a map for the first time to indicate the tank distribution. According to her findings the highest tank density occurs within the southern segment of the North Western province and the central segment of the North Central Province follows this. Since each topography sheets shown in this figure covers 950 km^2 the presence of 800 tanks within a topography sheet, would indicate a tank density of approximately one tank per 1.2 km^2 in the high-density region, and approximately one tank per 12.0 km^2 in the low-density region of the eastern province.

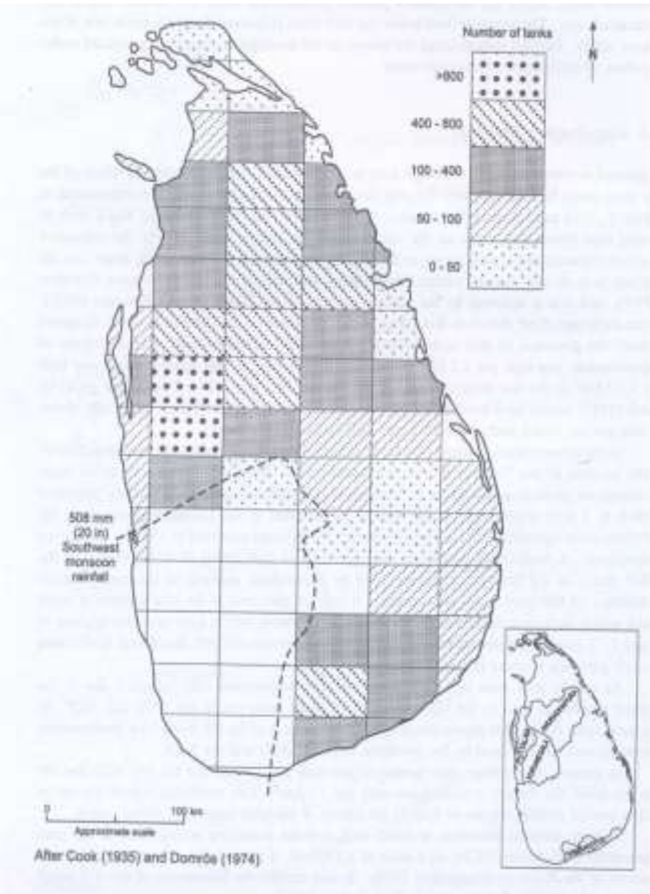

Fig-1.1: Tank distribution pattern of Sri Lanka
Source: Cook, 1935 and modification by Domros 1974

According to Panabokke [6] in general, the average tank density is one tank per 2.6 km^2 for the North Central Province, Northern Province, and Southern Province. For the North Western Province the density is around one tank per 1.2 km^2. This confirms both the nature of the overall rainfall regime as well as the nature of the geomorphology of the region.

Arumugam [3] has documented a lot of writings including the "Development of Village Irrigation Works" on behalf of the Ceylon Irrigation Department. He has explained that the integration between the "Tank" and "Village System" was unbelievable. According to Arumugam [3], "A tank means a village and a village means a tank and not just a collection of houses. The tank is a provider of all the material needs of village life: when the tank breaches the village migrates particularly in the Dry Zone".

Leach [7] revealed that there were three categories of small tanks. The first category deemed to be on crown land. It was the general policy of the British administration to presume that, in the absence of very specific evidence to the country, all village tanks belong to the crown. The "*ancient rajakariya system*[1]" also implemented to maintain the tank in good condition. *"Pul Eliya*[2]*"* tank also falls into this category. Secondly there are tanks which belong to temple authorities. The income of these tanks belong to the temple and these tanks did not receive the financial assistance from the government irrigation department. The third category of tanks is known as "*olagama tanks"* which are still in existence in the jungle. It has long been official policy that anyone who goes to the trouble and expense of repairing such a small tank shall be entitled to them. They entitled not only to the land of the tank itself but also to any area of land belong it which can be irrigated.

According to Arumugam's [8] writing, "the Village tank is an artificial reservoir storing rain water for use during non-rainy months and maintenance of these tanks are fundamental to sustain life in the dry low country villages. Nearly 160,000 ha of rice cultivation and 35 % of total irrigable area in Ceylon are supplied with water conserved in small irrigation works all over the island. These minor (or village) irrigation works are small water conservation storage tanks or stream diversion anicuts looked after by the beneficiaries under the care of cultivation committees, who are responsible for their maintenance and upkeep".

Ratnatunga [9] contributed Wewas and Reservoir album with contains a most comprehensive and up-to date description of all existing and abandoned tanks of all sizes. He completed this task using 3 volumes covering North Central Province, North Western Province and southern province. Further he has described the tank and the village as "eco-villages" in the Dry Zone.

TANK BASED ANALYSIS (1979-1999)

Agrarian Service Department of Sri Lanka paid attention on tank system as well as to the irrigation systems in the island. Although there were three types of tanks including "Large tanks" (more than 400 ha of Irrigated area) and "Medium scale tanks" (400-80 ha of Irrigated area) constructed by the ancient heroes of the country, All minor irrigation works have an irrigated command area of 80 ha or less, define as "small tanks" by the Agrarian Service act No. 59 of 1979. They have also been referred to as "Village tanks" in official records and published literature [6].

According to Abesinghe's studies [10], the tank based villages were the most stable settlement system that exists in the Dry Zone of Sri Lanka. There was a proper balance between the farming operations and environment under these systems. The "Tank", the "Paddy Track", the "Homestead / Gangoda" and the "Chena" are the four major components that constitute a tank village. The major component of the tank village system is a man made tank which receives the water from various combinations of catchments run-off, temporary reverlets or river diversion. Water management in these systems is generally the responsibility of the village community, which organized by paddy landowners others wise by all villages.

A study carried out in 1990 showed that three small tanks; Paindikulama, Siwalagala and Marikaragama in the Nachchaduwa major watershed have reduced the capacity due to sedimentation by 35, 30 and 23 percent respectively [11]. Siltation of tanks not only causes reduction of storage capacity but also leads to alter the tank bed geometry. Present rehabilitation works, where the capacity is regained by raising the spill and the tank bund have led to form shallow water bodies spreading over larger surface areas. This makes a complex situation creating several other problems.

Some of the basic hydrological principles also have been developed using the tanks. As example, Arumugam [3] has developed a formula to gain an average small tank capacity or volume as V=0.4 AD

[1] Maintaining tank bund and canal system through community participation or through subsidy programme organized by the government.

[2] "*Pul Eliya*" is a ablest anthropologic study on a village tank, written by Leach (1961)

V= 0.4 AD where

V is the Volume,

A is the surface area at full supply level,

D is the depth from full supply level to the sill level of the tank sluice and

The tank water budgeting concept was introduced specially for irrigation purposes and identifying the real situation of water storage in individual tanks. Somasiri (1979) [12] developed a tank water balance model for efficient utilization of tank water and to pay attention on the importance of understanding the hydrology of the village tanks. Further, to manage this resource for achieving higher production. Somasiri calculated the tank storage by reducing tank outflow from the tank inflow for a given period as follows.

$$S = (Rf + Ro + If) – (I + Do + Ds + Eto)$$

S = (Rf + Ro + If) – (I + Do + Ds + Eto) where

S = Tank storage

Rf = Rainfall, direct in to the tank

Ro = Runoff

If = Sub-surface flow from catchment

I = Irrigation issues

Somasiri’s studies were carried out at Walagambahuwa tank in the Anuradhapura district during 1976/77 and 1977/78 periods [12]. Somasiri identified some of the alternative cropping seasons under the village tanks for maximum utilization of the water resources as a hydrological unit, considering the inflow and outflow relationship and water storage status.

Later Dharmasena [13] also developed a tank water budgeting methodology (S f = Si + Ro + Rd - UNL – I) where Sf is storage at the end, Si is initial storage, Ro is catchment runoff, Rd is direct rainfall to the tank, UNL is usual net loss of the storage and I is irrigation releases. The aim of the study was identifying the optimum utilization of the storage in village tanks.

Shakthivadivel *et al.* [14] attempted to determin some of the engineering oriented applications including They have confirmed the formula of Depth – Area-Volume relationship (S_t= 0.4 X A_t X d) previously proposed by Arumugam) [3]. S_t is the storage capacity of the tank, A_t is the surface area at full supply level,and d is the deptrh from full supply level to the sill of the tank sluice(effective tank depth). They have used 14 representative tanks for their exercise (IIMI, 1994). Accordingly, Shakthivadivel *et al.* (1997) made a model for the tank water adequacy for command area, using depth-area-volume realationship for the small tanks and both area under the command and water surface. Nachchaduwa catchment the ratio, Tank command area (Atco) to tank water spread area (Atws) describes the adequacy of the tank storage capacity to serve the command area. This ratio should be less than 2 in order to serve the command well [14].

Again, Dharmasena & Goodwill [15] prepared a annual tank water balance sheets by quantifying inflow and outflow components (S f = Si + Ro + Rd - UNL – I) using eight tanks in Nachchaduwa catchment. The tanks were Puliyankulama, Borawewa, Puswellagama, Aliyawetunuwewa, Kolongaswewa, Vembuwewa, Thamarankulama, and Siwalakulama. Direct rainfall contribution was found for many tanks in the range of 25-30 percent of annual total inflow. Evaporation from water surface area ranged from 22 to 33 percent. High evaporation losses were reported in tanks where area/head ratio was high. Percolation from tank and seepage from the tank bund have given an average of 27 percent of total outflow. In general it was found that 50 % volume stored in a tank is lost through evaporation, percolation and seepage leaving other 50 % for irrigation.

Although these study has genereted useful hydrologic information on small tanks, they were limited in extenet and scope. Therefore, there was a need to conducting further systematic studies at tank cascade level [14].

ORIGIN OF THE TANK CASCADE CONCEPT (1985)

Tanks are not individual resource units. At the first, Ievers revealed that this spatial pattern of small tanks in the dry zone of Sri Lanka as a chain of tanks. He described the laying of these tanks as "Chain of small tanks (*wew rehen*) along the small valleys in undulating landscape in the dry zone" [5]. Then, Brohier [2] explained that "these tanks were built in orderly method at slightly varying elevations so that there often was a series of tanks to take the overflow from the one above it". Later Cook [5] also proved that the above pattern of tanks can identify in the dry zone of Sri Lanka.

Madduma Bandara [16] scientifically defined this pattern as a "Tank Cascade System [3] ", and according to him, the "Tank Cascade system is a connected series of tanks organized within a micro-catchment of the dry zone landscape, storing conveying and utilizing water from an ephemeral rivulet". He has shown that, there should be at least 2 tanks to make up a "Tank cascade".

A shift in research emphasis from single small tanks to tank cascades followed Madduma Bandara's [16] study of tank cascades in the Dry Zone of Sri Lanka. His approach emphasized the treatment of the total tank cascade rather than the individual tanks within a cascade as the more logical focus for any study of small tank systems [16]. However, Panabokke *et al.* [6] Well explained this pattern as follows; "these patterns are located within mini basins with second order or first order ephemeral streams. Further these systems were refined over several centuries in order to match the capricious nature of rainfall, along with the special geomorphological attributes of the landscape". Further Panabokke [6] described the main elements of a tank cascade as follows (Figure 1.8);

i. The watershed boundary of the meso-catchment
ii. The individual micro catchment boundaries of the small tanks
iii. The main vally and side valleys in the cascade.

[3] According to the Madduma Bandara's (1985) definition, At least two currently functional tanks were considered necessary to make a cascade and mean size of the catchment area of a cascade is 6.42 km^2.

Then he revealed that a close examination of the 1 inch to 1 mile topo sheets of the survay department covering the dry zone regions would show that more than 90% of the small tanks are clusterd in to cascades.

A LOCAL TERM FOR THE TANK CASCADE

There are a few local terms identified by Dharmasena such as "*Wew Panthiya*", "*Wew pokura*" and "*Wew Punjaya*" considering the behaviour of tanks within a cascade. The term "*Ellangawa*", identified by Thennakoon [17] and it has found among the local communities at several areas of the Dry Zone. Accordoing to Thennakoon *Ellangawa* is a small vally among the highland ridges. The lower end of the ellangawa may be a stream/ river or tank / reservoir. The small tanks system are situated in it and comparetively smaller tanks situated in upper part.

Perera [18] further explained this pattern as "*Wew mandulla*"[4] as a local name, considering the

i. Lenier system of tanks,
ii. Drendertic locationalization of tank and
iii. Parelel - network behaviour of tanks

He explained that, these tanks have been interlinked within a mini basin and act as a combined group of tanks.

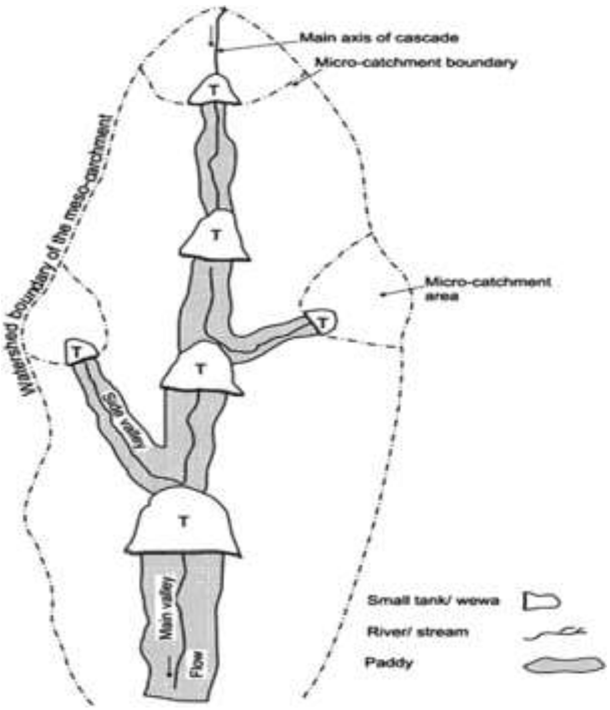

Fig-1.2: Scematic representation of a typical tank cascade system
Source: Panabokke *et al*. 2002, p.6

[4] Muditha Prasannajith Perera, 2010

CASCADE BASED BASIC ANALYSIS (1993-2009)

Itakura and Abernethy [19] mentioned that "the tank cascade irrigation systems have developed as ultimate stock-type irrigation systems. These systems are interconnected storage and regulating reserviours, which serve multiple functions of resources management including irrigation, domestic supply, water for livestock and subserface water for perrennial cropping. Some of these tanks have very long histories which date back toover a thousend years and wewe once the backbone of an ancient hydraulic civilisation which flourished in the north central part of the country".Shakthivadivel *et al.* [14] attempted to develop a criterian to assess the cascade water availability in the North Central ry Zone. They select the Anuradhapura District and used 76 tank cascades. The changes in water availability in tank cascades can thus affect the availability of ground water for irrigation. Further water deficit in relation to total demand, there may be a serious effect on the water availability to downstream users as well as ecological functions of the cascades.

The initial task was to determine the overall water availability within the cascade by estimating the cascade water surplus. That was the "Initial Cascade Screening" (ICS). The first step in cascade screening was to use standard 1: 50,000 topographic maps of Anuradhapura District to identify the cascade and make key measurements. Then for each cascade the total surface area, the total tank surface area, and the total command area were measured. In addition to that, a rapid assessment technique to collected data on the initially selected cascades, participatory appraisal techniques for further investigations and computer simulation model to determine the expected out flow were also used [14]. The second step was the rapid assessment methods to collect information on agricultural land use pattern, population details, Rainfall, tank physical details (Depth –Area-Volume relationship $St= 0.4 X A_t X d$) and ground water use to estimate the cascade water surplus standard values. Finally they have developed criteria as follows:

For cascade water surplus,

- The ratio of cascade area (Ac), to the total tank water surface area in the cascade (Acws) should exceed 8

$$\frac{Ac}{Acws} = > 8$$

The ratio of cascade command area (Acca), to the total tank water surface area in the cascade (Acws) should be less than 2

$$\frac{Acca}{Acws} = < 2$$

According to them, the following relation gives a direct way to estimate the cascade out flow from area mesurments for the cascade.

- $\text{Log } Rc = 1.4582 + 0.0003(Ac - Acws - Acca)$

(1.4582, 0.0003 are regration values acording to the above analysis)

Then the answerwe should define cascade outflow per unit area (Re) as the cascade out flow (Rc) divided by the total area of the cascade (Ac)

Senaratne's studies [20] revealed a few findings which important to groundwater use in cascades including, Cascade is a closed system and water is contributed to a cascade only through rainfall. Later Panabokke [21] identified the entire part of the Rajarata (North Central Dry Zone) consists of nine river basins and 50 sub watersheds in it. these sub watersheds consisted of 457 tank cascade systems. A detailed description of small tank system occuring within each of the nine river basins has given by panabokke using 1: 250,000 scale map. Jayatilaka *et al.* [22] attempted to measure the water availability in tank cascade systems using cascade water balence model. Dharmasena emphasised that the existence of smal tanks in a "cascade pattern" is an advantageous feature in many ways, including surface water bodies that are spread over an area can maintain the ground water level closer to the land surface. In addition to that Mahatantila *et al.* [23] attempted to identify the spatial and temporal changes of hydo-geochemestry in tank cascade systems.

Further, Bandaranayake [24] studyied on the differentiation of cascades on the basis of size, shape and destination points of water flow. He discussed the location and positioning of the cascades to designate the most efficient cascades in the sense of water availibility, using the cascade system approach.

CASCADE LEVEL WATER FLOW STUDIES (1993-UP TO DATE)

Itakura *et al.* [25] carried out a water balence and water flow study for 4 small tanks in Thirappane tank cascade in Anuradhapura District. He recordes that average runoff was 30 percent and 12 percent of the rainfall for two maha seasons and two yala seasons it was 10 percent and 4.5 percent respectively. Itakura also mesured drainage return flow from upstream to downstream tanks. For the maha seasons, drainage return flows averaged approximately 29 percent for the tank located at the lowest end of the main valley, and 12 percent for the tanks loketed at the lower end of the side valley. Return flow values for yala seasons were zero [15]. Further, Matsuno *et al.* [26] attempted to study the water circulation in a cascade including ground water movement along the cascade.

Another study carried out at the *Parana Halmillawewa* cascade in anuradhapura district by Paranavithana [27] revealed that thereis a lateral formation of tanks at the same elevation adjacent to each other. These tank systems can be considerd as Lateral Cascade Systems. The basicreason behind these lateral cascade relations is to store water as much as possible among the relatives of the village without allowing spillage of tanks going to down stream tanks. These lateral relations were established by lateral spill relations or by single embankment type contour canal connections. These canals were behaving as elongated reservoirs connecting lateral tanks.

Madduma Bandara [28] discribe as "If the water in a cascade is limited in relation to total demand, there may be serious implications in terms of water availability for downstream users. The increased use of agro-chemicals for agriculture in recent years, and aquaculture development has further complicated this situation. This means that the hydrology of the entire cascade needs to be understood and assessed in order to make the best use of the available water resources withing the cascade. The value of the cascade consept, and its potential for future applications will ultimately be decided by its scientific validation and by the synergis it can generate in terms of socio-economic benifits and long term sustainability.

After the Matsuno's [26] finding, Perera [29] again revealed that the shallow ground water flow is occurring along the cascade but not across the cascades even within a cascade cluster. After preparing the water table contour maps from sea level, it was revealed that water table movement occurred along the tank cascade within a climatic year, following the geomorphologic landscape and natural gradient.

CASCADE LEVEL WATER QUALITY STUDIES (2010-UP TO DATE)

One of water quality study at Paranahalmilla wewa cascade, conducted by Yatigammana [30] revealed, "most of environmental variables show a marked spatial variation along the cascade. The most importantly evapoconcentration of ions was noted along the downstream direction and terminal tanks in the cascades show the highest salinity and specific conductance values. In addition, in all the reservoirs the salinity interceptor belts (Kattakaduwa) showed high concentration of ions and in some tank systems salinity level is above the freshwater boundary. Thus the kattakaduwa could be compared with a dilute brackish water system where both chemical and biological characteristics similar to lagoon and mangrove environments". Further results suggested that the tanks are showing environmental stress especially along the downstream direction in the cascade.

The most recent cascade based water quality study had been conducted by Wijesundara, Nandasena and Jayakody [31] at Mahakanumulla cascade in the north central Dry Zone. This study has shone special variations from the upper most Siwalagala tank to the lower most Mahakanumulla tank. Temporal variations also showd over the study period and showed a bimodal pattern which was coincided with the bimodal rainfall of the Dry Zone. The highest NPK and Cd concentrations have recorded during the rainy months of April, October and November comparatively to the drier months. But N, P, K, Concentrations didn't exceed the permissible level for water quality standards of World Health Organization.

Tank Cascade Level Groundwater Table and Groundwater availability Studies (1973-up to date)

Although Panabokke [32] reported the groundwater levels in the dry zone of Sri Lanka at first, Madduma Bandara [33] Senaratne [20], Dharmasena [34], [35], Panabokke [36, 6], Perera [37] and Kikuchi *et al.* (2003) [38] studied the groundwater table behavior in tank cascade areas and they analyzed these data in different perspectives including annual fluctuations. Further, Perera, Nianthi and Madduma Bandara [29] examined the ground water table fluctuations in tank cascades for fifteen months to find out the groundwater extraction impacts. However Dharmasena and Goodwill [15], Senarathne [20], Panabokke [36], and Perera discuss the groundwater availability, limitations and impacts in tank cascades of the dry zone of Sri Lanka.

Tank Cascade Level Groundwater Table Mapping (1973-up to date)

At the first, Madduma Bandara [33] studied the water table behavior of hard rock areas using groundwater maps in the Polonnaruwa area. Later, Dharmasena & Goodwill [15] produced a ground water map for the Siwalakulama area, in the Malwathu Oya basin and he also proved that the ground water level was closer to the land surface in the vicinity of tanks. Then Perera, Nianthi and Maddumabandara [29] examined the ground water table fluctuations in tank cascades due to ground water extraction through Agro-wells using groundwater table maps. This groundwater table behavior test was conducted using GIS maps analysis based on Geo Eye – 1 Satellite images and field measurements carried out for sixteen months. Further Perera produced monthly "water table elevation contour maps form sea level" for three tank cascades covering a climatic year to observe the groundwater flow pattern. For this purpose, 44 Agro-well elevation data were used and "Kriging Interpolation Method" was used to assume the un-sample points to create groundwater elevation contours.

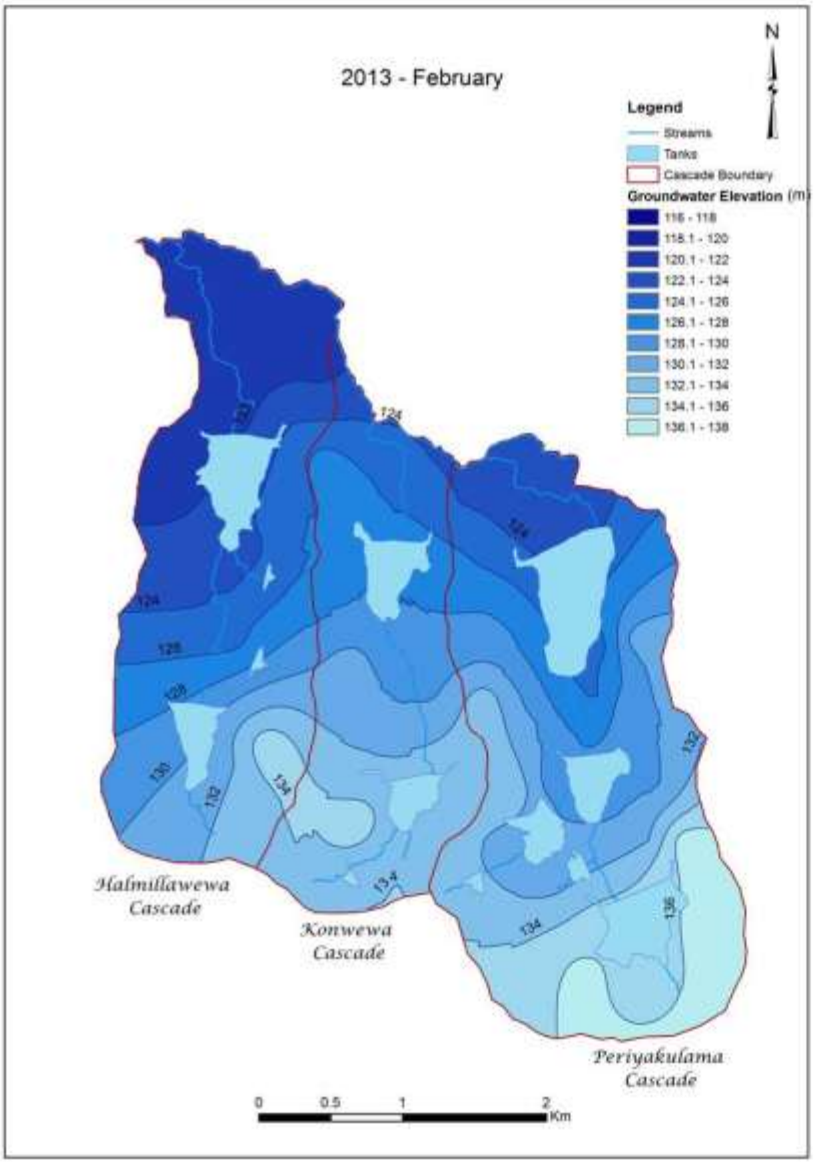

Figure 1.3: Groundwater mapping
Source: Perera (2016)

PRODUCTIVITY AND SOCIO-ECONOMIC STUDIES IN TANK CASCADE ENVIRONMENTS (2000 - 2012)

The first conference on small tank systems organized on 9th September of 2000 to discuss the food security in relation to tank system in Sri Lanka [39]. Aheear *et al.* [40] and Pathmarajah [41] studied the productivity and profitability of tank irrigation agriculture and compared with other types of agricultural activities such as Agro-well based farming. Further Aheear [40] studied the socio-economic aspects of agricultural activities related to tanks environments. Perera revealed that land equivalent ratio of some lands of tank cascades have been high due to the Agro-well intervention. Further, Jayasena [42] studied about the Socio-technical aspects of tanks environments.

ECOLOGICAL STUDIES WITHIN THE CASCADES (1970 – UP TO DATE)

The first attempt of the biological analyzing of the tank was the Ratnatunga's [9] "Eco-Village" concept to describe the Ecological /Biological status of tanks in the dry zone are as in Sri Lanka.

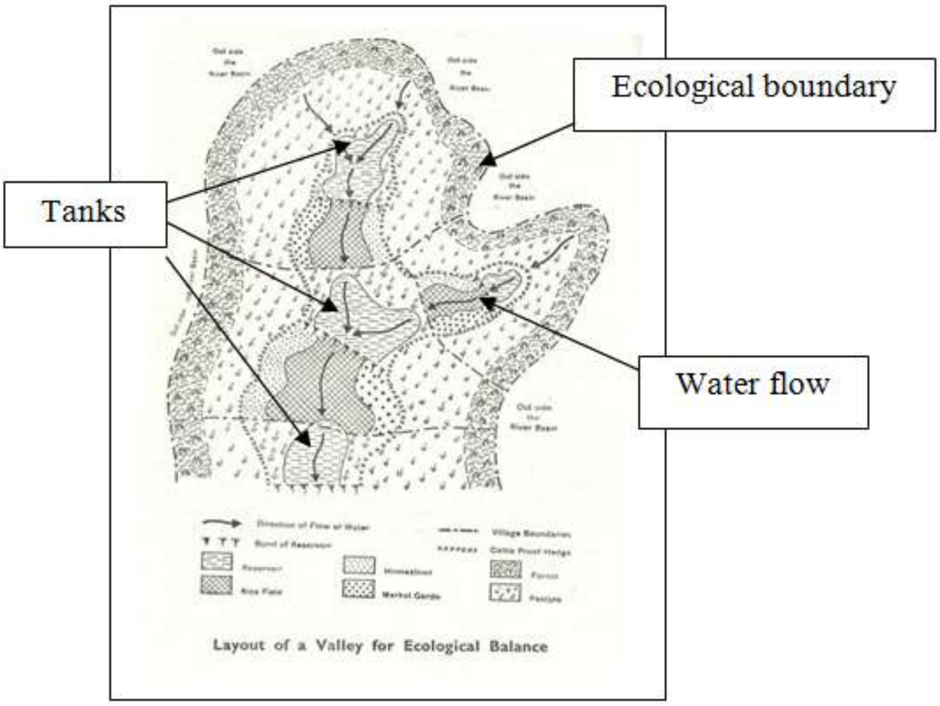

Figure 1.4: the concept of Eco Village
Source: (Ratnatunga, 1970)

Madduma Bandara [28] explained, that "the traditional village tank systems in Sri Lanka support biodiversity as they provide mixed, heterogeneous landscapes: small tanks, irrigated paddy fields, forests, and villages in small areas".

Awsadahami [43] explains, "The villagers who lived by these tank systems were the guardians of these environments. The tree covered watersheds of the tank systems were strictly conserved and guarded by those who benefited from the tanks. The encroachments and slashing of these protected lands for agriculture were made taboo by the traditions, which had passed from generation to generation not on mere mythical grounds but by insight, fortitude and understanding. These communities were fostered by the traditions and practices aimed at conserving forest cover of the watersheds, conserving soil and water, preserving the rich bio-diversity and maintaining responsible social structures".

Rekha Nianthi [44] attempted to examine the adjustments, preparation, and adaptation to climate change of farmers lived in Dry Zone tank cascades. The study carried out in selected cascades at *Mahawilachchiya*, *Nuwaragampalatha-Central*, and *Medawachchiya*. Some of the climate adaptation practices relevant to biological environment and agricultural practices, including Bethma Practice, Use of drought tolerence varaities, Short duration paddy varieties, Changing crop calanders and seasonal water suppling system were checked. The evaluation has high ligted varios levels of effectiveness in addressing these strategies are potenally negative. The study identified the need to focus onthe implications of climate change on water resources in irrigation systems not only at macro-level but at micro-level as well as at cascade level.

All the tank systems consist of its own unique ecosystem, flora and fauna, and indigenous knowledge that fulfill a unique function within the system [35]. Further he produced a model to represent the ecological behavior in the vicinity of tanks.

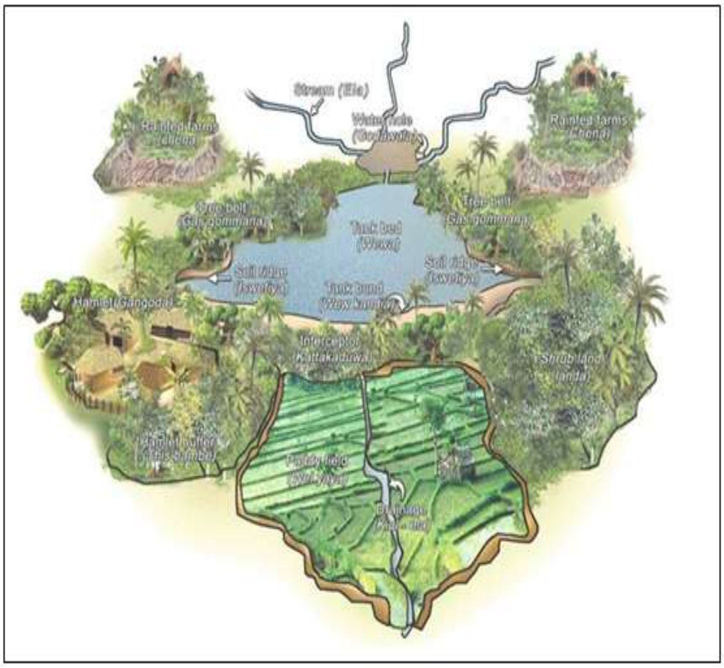

Fig-1.5: Components of a small tank system in Sri Lanka
Source: Dharmasena, 2010

According to several studies, including Dharmasena [35], Madduma Bandara [28], Perera [18,45], Marambe *et al.* [46], the tank ecosystems play a vital role such as maintaining the biodiversity, wiled fruits, protecting herbal plants, and supplying handloom materials including mat-grass and rattan in addition to maintaining the water source habitat units for a number of fauna species. Further, tank reservations around the tanks, especially "*Gasgommana*[5]", "*Perahana*[6]", and "*Kattakaduwa* [7]" play a significant role for the sustainability of the tank as well as the maintaining the biological diversity spots in the dry zone. Further Perera [18] who is author of this paper made a model to represent the ancient tank reservations around the tank.

Forest reservation is a one of essential components in a tank cascade and it has been contributing a lot of services to the watershed processes. The mountainous and high land areas should be covered by the forest and this environment acts as a sponge to capture rain water in the rainy season and released water in the dry season to the down streams. It is very essential to maintain the river base flow, ground water recharge at the lower areas and for the survival of bio- diversity within a tank cascade. Even in the history, there was a large forest patch in the mountainous catchments (upper part of the tank cascade) named as "Mahamukalana" at the Rajarata. It is the dense forest in the hills or the upper watershed area which has covered about 12 - 25% according to a study conducted in five tank cascades in Yan Oya Basin and Malwathu Oya Basin [47].

[5] Strip of large trees located around the tank, roughly near the full supply level and serving as a windbreak to reduce the evaporation losses.
[6] Strip of bushes as acts as a filter around the tank.
[7] Reserved land strip with well-rooted trees located between the tank bund and the paddy field, acting as a salinity interceptor belt.

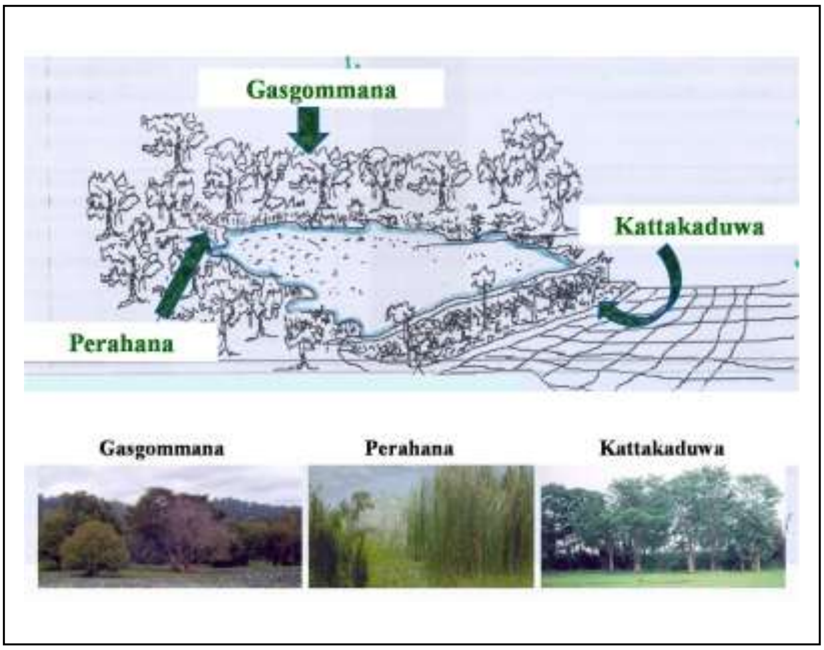

Fig- 1.6: Ancient Tank Reservations
Source: Perera (2010)

HYDRO-ECOLOGICAL STUDIES WITHIN THE CASCADE (2010 – UP TO DATE)

With a lot of environmental issues in tank cascades due to the human involvements, researchers paid attention through different perspectives covering both hydrological and ecological aspects.

Madduma Bandara [28] explained the tank environment as an "Amphibian Environment" of the Dry Zone. These concepts are enough to understand the status of the biological value of the tank environments. The most important fact is that, these hydro-logically and ecologically integrated tanks have shown a specific spatial pattern. Due to the Agro-wells are diffused in the vicinity of these kinds of tanks, identifying the distribution pattern of these tanks and its' characteristics are very important. Further, Dharmasena [35] linked the tank cascade based surface as well as groundwater level and survival of the floral resources.

According to Marmbe *et al*. [46] tank systems in a cascade contribute to biodiversity providing mixed and heterogeneous landscapes and these systems provide an appropriate environment for restoration, use and proper management of biodiversity. Poor understanding on the function of this complex ecosystem had led to either ignorance or inadvertent destruction of the ancient tank systems during the various development projects.

The term "Hydro-ecology" is defined by M. Pfaundler, [48] as the hydrological and ecological status of an area. Accordingly at the first time, the term "Hydro-ecology" used for a tank cascade study by Perera / author of this paper [29,46,49,50,51] to examine the hydro-ecological impacts of Agro-well development in tank cascades of the north central dry zone of Sri Lanka.

CONCLUSION

Historical attention on studying the tank systems was started in 1855 and the first systematic studies started with a breaching of village tanks in 1923. Later several outstanding documents were produced by different researchers. However after the tank based analysis period, the attention has been changed towards the tank cascade level studies due to more logical reasons associated with natural endowments. Accordingly tank cascade based basic principles, water flow, water quality, groundwater availability and table fluctuations, groundwater mapping, Socio-economic studies, ecological studies as well as hydro-ecological studies were identified with relevant study periods.

According to the research findings, surface drainage patterns as well as shallow groundwater flow patterns depends on the geo-morphological characteristics within a tank cascade. All the basic relationships of tanks depends on the tank components, climatic features as well as resources use patterns. Not only that, floral eco-systems have been organized according to the surface drainage pattern as well as tank cascade pattern. Therefore the tank cascade based studies being more complex in recent years, with the understanding of tank cascades as "hydro-ecological units" rather than "hydrological units".

ACKNOWLEDGEMENTS:

Author gratefully acknowledges the financial supports given by the International Research Centre, University of Peradeniya, Sri Lanka (Grants Reference Number: InRC/RG/13/06) and National Centre for Advance Studies in Humanities and Social Sciences, Sri Lanka (Grants Reference Number: 14/NCAS/PDN/Geo/37).

REFERENCES

1. Nianthi, K.W.G.R., & Jayakumara, M.A.S., (2010), *Progress of Research on Cascade Irrigation Systems in the Dry Zone of Sri Lanka*. In Shaw, R., & Thaitakoo, D., (eds), Water Communities, Emerald Publishing, Japan (pp. 109-137).
2. Brohier, R. L., (1934), *Ancient Irrigation Works in Ceylon*, Ministry of Mahaweli Development, Colombo (pp. 1-4).
3. Arumugam, S., (1957), *Development of Village Irrigation Works*, Ceylon Irrigation Department, Colombo.
4. Kennedy, J.S., (1933), *Evolution of Scientific Development of Village Irrigation Works*, in proceedings of Engineering Association of Ceylon, Colombo (pp. 229-320).
5. Cook, E. K., (1935), *Ceylon its Geography, Resources and People*, University of Colombo, Colombo.
6. Panabokke, C. R. (2002). *Small tanks in Sri Lanka: evolution, present status, and issues*. IWMI.
7. Leach E.R., (1961), *Pul Eliya; A Village in Ceylon*, Cambridge University Press, Cambridge.
8. Arumugam, S., (1969), *Water Resources of Ceylon; Its Utilization and Development*, Water Resources Board, Colombo.
9. Ratnatunga, P.U., (1970), *Sri Lanka Wewas and Reservoirs Album*, Sri Lanka Freedom from Hunger Campaign, Colombo.
10. Abesinghe, A., (1982), *Minor Irrigation in the Agricultural Development of Sri Lanka* In Economic Review (Vol- 8), Peoples Bank, Colombo (pp. 22-28).
11. Dharmasena, P.B., (1994), *Conservation Farming Practices for Small Reservoir Watershed*: A Case Study from Sri Lanka, Agroforestry Systems. Maha Illuppallama Agricultural Research Center, Maha illuppallama.
12. Somasiri, S., (1979), *Village Tank as an Agricultural Resource in the Dry Zone of Sri Lanka*, in Tropical Agriculturist, Department of Agriculture, Peradeniya (pp. 33-46).
13. Dharmasena, P.B., (1989), *Optimum Utilization of the Storage in Village Tanks*, Tropical Agriculturist, Department of Agriculture, Peradeniya (pp. 1-11).
14. Sakthivadivel, R., Fernando, N., & Brewer, J. D. (1997). *Rehabilitation planning for small tanks in cascades*. IIMI Research Report 13. Colombo, Sri Lanka: International Irrigation Management Institute.
15. Dharmasena, P.B., and Goodwill I.M, (1999), *Use of Ground Water in Minor Tank Irrigation Schemes* of Sri Lanka. In Proceedings of 17th International Congress on Irrigation and Drainage, Granada, Spain (pp.175-194).
16. Madduma Bandara, C.M., (1985), *Catchment Eco-systems and Village Tank Cascades in the Dry Zone of Sri Lanka*, in 'The Geo-Journal', Reidel publishing company, Dortrecht.
17. Tennakoon, M.U.A., (2005), *Ellangawa* (Sinhala Version). Godage and Sons, Colombo, Sri Lanka.
18. Perera, M.P., (2010), *Irrigation Heritage of Sri Lanka* (Sinhala Version), Center for Environmental Justice, Colombo.
19. Ithakura, J. And Abernethey C., (1993), *Water Management in a Tank Cascade Irrigation System in Sri Lanka* (IIMI Working Paper 24), International Irrigation Management Institute, Colombo.
20. Senaratne, A., (2002), *Groundwater Exploration in Sri Lanka* , in Pathmarajah,s.(ed), Use of Groundwater for Agriculture in Sri Lanka-Symposium Proceedings, Agricultural Engineering Society of Sri Lanka, Peradeniya.
21. Panabokke, C.R., (1999), *The Small Tank Cascade Systems of the Rajarata: their Setting, Distribution Pattern and Hydrology*. Mahaweli Authority of Sri Lanka - International Irrigation Management Institute, Colombo.
22. Jayatilaka, C. J., Sakthivadivel, R., Shinogi, Y., Makin, I. W., & Witharana, P. (2001). *Predicting water availability in irrigation tank cascade systems: the cascade water balance model* (Vol. 48). IWMI.
23. Mahatantila, K., Chandrajith,R., Jayasena,H.A.H., & Ranawana K.B., (2008), *Spatial and Temporal Changes of Hydro-geochemestry in Ancient Tank Cascade Systems in Sri Lanka: Evidence for a Constructed Wetland*. (*http// www3 interscience.wiley.com*)
24. Bandaranayake, G.M., (2009), *A Geographical Analysis of Positonining and Functionality of the Tank Cascade Systems of the North Central Province*, Sri Lanka (PhD Thesis), University of Sri Jayewardenepura.
25. Itakura, J., (1995), *Water Balance Model for Planning Rehabilitation of a Tank Cascade Irrigation Systems in Sri Lanka* (Working Paper No. 37), International Irrigation Management Institute, Colombo (P. 5)
26. Matsuno, Y., Tasumi, M., van der Hoek, W., Sakthivadivel, R., & Otsuki, K. (2003). Analysis of return flows in a tank cascade system in Sri Lanka. *Paddy and water environment*, *1*(4), 173-181.

27. Paranavithana, G.N., (2010), *Some Civil Engineering Aspects of Village Tanks*, In Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability, Central Environmental Authority and Plan Sri Lanka, Colombo (p.16).
28. Madduma Bandara, C.M., *et al*. (2010), *Scientific validation of some traditional land and water management practices under Village Tank Cascade Systems*, in Economic Review (Vol. 36) People's Bank, Colombo.
29. Perera, M.P., Nianthi, K.W.G.R. and Madduma Bandara C.M. (2016), *Agro-well Development and its Impact on Groundwater Table Depletion in Tank Cascades in the Dry Zone of Sri Lanka*, in International Journal of Arts and Commerce (Vol.5-No.5), South Shields, United Kingdom. http://www. 1929-7106 www.ijac.org.uk 66-77.
30. Yatigammana, S., (2010), *Water Quality Variations in Village Tank Cascade Systems*, in Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability, Central Environmental Authority and Plan Sri Lanka, Colombo (pp.19-20).
31. Wijesundara,W.M.G.D., Nandasena K.A. and Jayakody A.N., (2012), *Seasonal and Spatial Variations of N,P,K, and Cd Concentrations in Water of the Mahakanumulla Cascade in the Dry Zone of Sri Lanka,* in Twenty Fourth Annual Congress Proceedings, PGIA, Peradeniya (p. 41).
32. Panabokke, C.R., (1959), *A Study of Soils in the Dry Zone of Ceylon*, Soil Science Publication Colombo (pp. 55-74).
33. Madduma Bandara, C.M., (1973), *Groundwater Resources in the Dry Zone Hard Rock Areas,* Annual Sessions of the Ceylon Association for the Advancement of Science, Colombo.
34. Dharmasena, P.B., (2002), *Integrated Management of Surface and Ground Water Resources in Tank Cascade Systems.* In Pathmarajah, S. (ed), Use of Ground Water for Agriculture in Sri Lanka - Symposium Proceedings, Agricultural engineering society of Sri Lanka, Peradeniya (pp. 53-65).
35. Dharmasena, P.B., (2010), *Essential Components of Traditional Village Tank Systems. In: Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability*. Central Environmental Authority, Colombo.
36. Panabokke, C.R., (2001), *Groundwater Management in Sri Lanka*, in Economic Review: Water and Life, Peoples' Bank, Colombo.
37. Perera, M.P., (2011), *The Nature of the Surface and Groundwater Use in the Dry Zone Subwatersheds*, in Sambhawana (Vol.v-No.1), University of Peradeniya, Peradeniya.
38. Kikuchi, M. *et al.,* (2003), *Agro-well and Pump Diffusion in the Dry Zone of Sri Lanka* (Research Report–66), International Water Management Institute, Colombo (pp. 1-25).
39. Gunasena, H.M.P. (ed), (2000), *Food Security and Small Tank Systems in Sri Lanka Workshop Proceedings*, National Science Foundation, Colombo.
40. Aheeyar, M.M.M., and Ariyabandu R.D.S. (2002), *Socio-economic Issues Pertinent to Agro-well Farming in Sri Lanka.* In Pathmarajah, S. (ed), Use of Ground Water for Agriculture in Sri Lanka - Symposium Proceedings, Agricultural engineering society of Sri Lanka, Peradeniya.
41. Pathmarajah, S., (2002), *Use of Groundwater for Agriculture in Sri Lanka*, In Pathmarajah, S. (ed), Use of Ground water for agriculture in Sri lanka - Symposium Proceedings, Agricultural engineering society of Sri Lanka, Peradeniya.
42. Jayasena, H.A.H., (2012), *Socio-technical Aspects of Water Management in Sri Lanka: The Past and the Present*, Ceylon Journal of Science (Physical Sciences) - Vol-16, University of Peradeniya (pp.19-30).
43. Ausadahami, U.B., (2010), *the Ancient Irrigation Systems: Past and Present.* In Proceedings of the "National Conference on Cascade Irrigation Systems for Rural Sustainability", Central Environmental Authority and Plan Sri Lanka, Colombo (pp.23-24).
44. Nianthi, K.W.G.R., (2010), *Adaptation to Climate Change in Village Tank Cascade Systems in the Dry Zone of Sri Lanka*, in Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability, Central Environmental Authority and Plan Sri Lanka, Colombo (pp. 25-28).
45. Perera, M.P., (2011), *Beyond the Truth: Potential for Re-establishment of Ancient Tank Reserves in the Dry Zone of Sri Lanka*, National Geography Conference, University of Sri Jayewardenepura, Nugegoda.
46. Marambe, B., Pushpakumara, G., Silva, P., (2012), *Biodiversity and Agrobiodiversity in Sri Lanka: Village Tank Systems*. In: Nakano, S.I., Yahara, T., Nakashizuka, T., Yamamoto, S. (Eds.), Biodiversity Observation Network in the Asia-Pacific Region. Springer, Japan.
47. Perera, M.P. and Nianthi, K.W.G.R. (2016), The Impact of Agro-well Development on Floral Diversity in Tank Cascades in the Dry Zone of Sri Lanka, in International Journal of Science and Research (IJSR), (Vol.5 - Issue 6). http://dx.doi.org/10.21275/v5i6.NOV164764.
48. Pfaundler, M., (2011), *Module Hydrology (HYDMOD) the Swiss method for assessing and classifying the natural state of the rivers` flow regime,* Federal Office for the Environment FOEN, Vienna.

49. Perera, M.P., (2016), *Development of Agro-well Lands and Its impact on Soil Salinity in the North Central Dry Zone of Sri Lanka*, in International Journal of Science and Research (IJSR), (Vol.5- Issue 7). DOI: 10.21275/v5i7.ART2016217,
50. Perera, M.P., (2016), *The Hydro-ecological Impact Assessment Scoring: A New Participatory Method to Grasp Hydro-ecological Impact of Agro-well Development of Sri Lanka*, in International Journal of Advanced Research and Review, (Vol.1- Issue 7). DOI: IJARR, 1(7), 2016; 01-10
51. Perera, M.P., (2017), Stream *Reservations are at Risk?: A Case Study on the Agro-well Development in the Dry Zone of Sri Lanka*, in International Journal of Science and Research (IJSR), (Vol.6- Issue 6). DOI: 10.21275/ART20174619.