Scientific Validation of some Traditional Land and Water Management Practices under Village Tank Cascade Systems

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Abstract

Many recent writings on indigenous knowledge and practices in Sri Lanka appear to be largely descriptive than analytical, and incline to stress the virtues of ancient wisdom with a slant towards romanticising the past. Any attempts towards looking at these traditional practices from a scientific view point are hard to come-by. Some indeed believe that, indigenous knowledge systems cannot and need not be assessed from a scientific perspective. However, probing into the scientific bases of such practices is necessary to ensure their continued application as well as their very survival. The paper attempts to report the results of a study undertaken recently in the north western part of the Anuradhapura District with sites in close proximity to Maha Willachchiya, Tanthirimale and Medawachchiya. It encompassed an examination of a few village tank clusters, their cascade systems and associated environmental characteristics. In particular, the attention was focused on a few traditional water management and land use practices such as those associated with laterally connected tanks (baendi wew or aendutu wew), cistern sluices (keta or kumba horow), salinity interceptor belts (kattakaduwa) and on water circulation patterns in the cascades. An attempt is also made to bring out some implications of the findings of the study for future planning and technical design.

Introduction

Small tanks or reservoirs that store water for dry seasons, have always formed the life line of village economies and human well-being in the Dry Zone of Sri Lanka. They are of multiple use (for irrigation, domestic use and livestock) and supports aquatic ecosystems and human settlements in a geo-physical environment that would have otherwise been left parched and desolate. It has been demonstrated that, these tanks are not isolated entities, but often found in clusters forming part of a hydrologically integrated system that is now known as a 'cascade'. A 'cascade' is defined as a ***"connected series of tanks organised within micro- (or meso) catchments of the dry zone landscape, storing, conveying and utilising water from an ephemeral rivulet"*** (Madduma Bandara, 1985, Panabokke, 2002) (Fig.1). However, there is no evidence to suggest that all these tank systems were fully functional or operational at all times in history. Some tanks remain abandoned or in a poor state of repair at different times. Similarly, not all the tanks in the cascades apparently were meant for irrigation, but also used as silt traps (*isweti*) for fishing or for the benefit of domesticated animals and even wild life. In addition, now they are being absorbed to the natural landscape and has become a part of adjacent terrestrial systems.

As a reputed Director of Irrigation during the colonial days (Kennedy, 1936) observed **"..Every Village Irrigation work has an individuality of its own, and when located on the topographic map, the engineer has ... to acquire the 'sense and substance' of that individuality"**. In other words Kennedy was searching for that elusive 'sense and substance' in order to better grasp and understand the essential nature of small village tank systems (Panabokke, 2002). The cascade concept has obviously advanced this philosophical thought further, as is evident in its definition itself.

Method of Approach

Five village tank cascade clusters in three administrative Divisions of Maha Wilachchiya, Nuwaragam Palata Central and Medawachchiya came within the purview of this study (Table 1).

A reconnaissance field investigation undertaken at the beginning of the study has revealed some features that deserved further probing:

i. Circulation of water within the cascade system: both along the cascades and across the basins. It was obvious that water circulation patterns were different in different cascades. Lateral connections among the tanks (as at Ethdathkalla and Pandiggama) as well as the longitudinal relations along the valleys could be seen at several places.

ii. Along with water-flows, aquatic biota -both plant and fish species also seemed to circulate in the cascades in both upstream (fish) as well as downstream directions. Agricultural wastes and pollutants

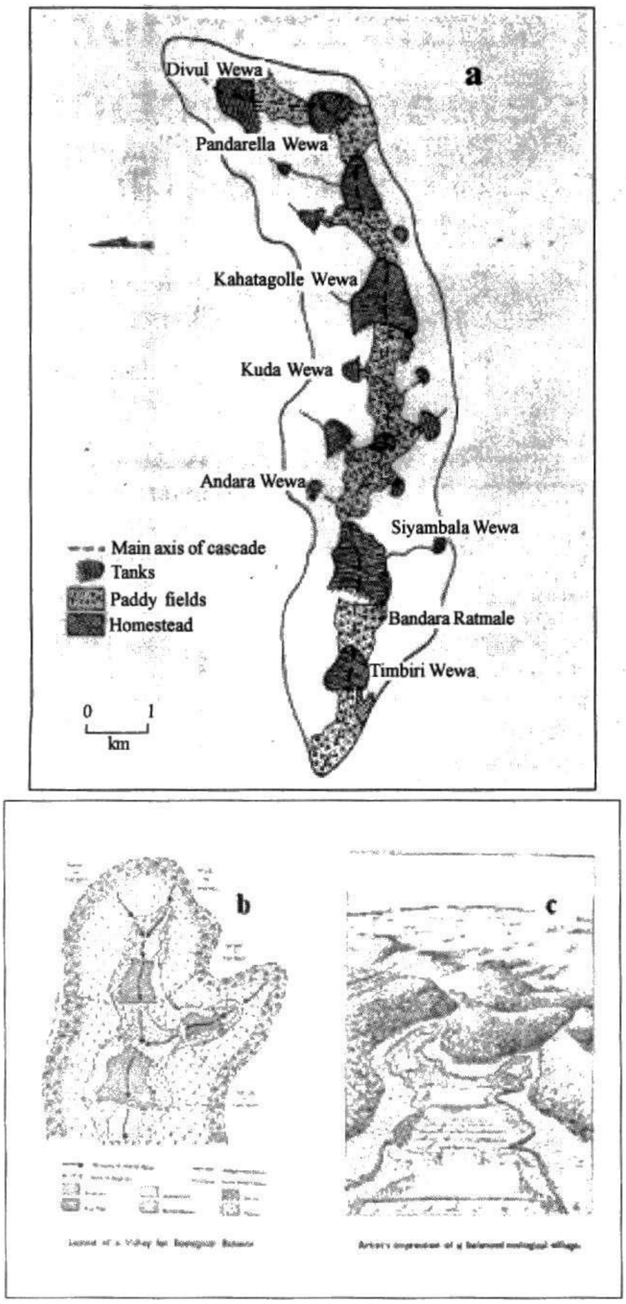

Fig.1 : (a) Bandara Ratmale Cascade near Mihintale (After Madduma Bandara, 1985), and (b) & (c) Impressions of a Cascade System (After Ratnatunge, 1970)

Table 1: Cascade Clusters, Cascades and Tanks in the Study

Cascade Cluster	Name of Cascade	Total No. of Operational Tanks
Parana Halmillewa	Parana Halmillewa	14
	Etaweeragollewa	06
	Galegama	04
Navodagama	Navodagama	09
Sandamal Eliya	Sandamal Eliya	12
Kahagollewa	Kahagollewa	06
	M. Katukeliyawa	05
	Wanni Palugollewa	02
Puwarasankulama	Madagalla	02
	Parasangaswewa	02
Total - 05	**10**	**62**

Table 2: Sources of Data and Information

Cartographic Maps and Field Sketches:

- ABMP* Maps - 1:10,000
- Topographic Map 1:50,000
- One Inch Topographic Map : 1:63.360
- Satellite Images : Google 2009 (Image date 2003)
- Aerial Photographs (1956,1992)
- Land Use Maps of cascades prepared by the District Land Use Division
- Field sketch maps

Water quality investigations

Engineering level measurements

*** ABMP : Agricultural Base Mapping Project**

also seemed to circulate along the cascades.

iii. Crop calendars and the sequence of agricultural activities in each tank in the cascade appeared to have some relationship with water availability.

iv. New development efforts, as well as emerging disputes, revealed the need for review of several prevailing legal regimes related to land and water at village and cascade levels.

v. Certain traditional cascade management practices such as protecting or re-introducing *kattakaduwa* and demarcating *Jalagilma* areas were incorporated in some rehabilitation processes.

vi. Sociological patterns of village settlements in different parts of the cascade also seemed to impinge on any attempts towards cascade-wide institutional developments.

vii. New agri-roads and other infrastructure, appeared to address the emerging needs with the advent of modern agricultural technologies such as combined harvesters *(Sunami)*

Sources and Nature of Data Collected

Some details of data sources used are given in Table 2.

Field visits for engineering level measurements were undertaken on 2/12/2009 (Kadawath Rambewa) Katukeliyawa (4/12/2009) Parana Halmillewa (12/12/2009) Maha Katukeliyawa (29/12/2009) and Ethdathkalla (15/01/2010). Similarly, field visits for water quality measurements took place from 12 to13 December and from 19 to 20 December 2009, at which water samples were collected from tanks and *kattakaduwas* sites below the tank bund. Therefore, the period of field visits fell within the wet season in the area.

Tools and Methods

Some issues identified during the reconnaissance survey and appeared amenable to scientific assessment, were examined further in each cascade system with the help of:

- Available land use and topographical maps at different scales
- Aerial photographs and satellite images where feasible

• A household survey was undertaken in all selected tank clusters using a questionnaire

• A few Case studies to understand lateral flows, and spill level measurements

• A few scientific investigations of water quality undertaken in selected cascades

• Some laboratory analyses of collected water samples undertaken to determine a few selected chemical properties such as conductivity, salinity and pH.

Cascades in the Survey

Some 5 'tank clusters' in 3 different Divisions geographically separated from each other, came within the purview of the study. Each cluster is comprised of a number of cascades and each cascade has a number of tanks. A list of these 'tank clusters' and 'cascades' is given in Table 1. A brief description of each cascade cluster is presented below:

Parana Halmillewa cascade cluster

As indicated in Fig. 5 below, this cluster is located in the Medawachchiya Division along the Kebitigollewa Road. This comprises of at least 3 distinct cascades, namely, Parana Halmillewa, Galegama and Etaweeragollewa. Kadawath Rambewa is considered as a single tank draining directly into the main stream below Peddegama Tank. The upper-most tank in the cascade is Indigahawewa belonging to Pandiggama systems at the top end of the cascade. From there, water flows into Pandiggama Kuda wewa, and then to Ethakada, and from there to Tikiri Kumbugollewa, Peddegama and finally to Parana Halmillewa located at the lowest end of the cascade. Altogether, a total of 35 tanks both operational as well as abandoned were recorded in the baseline survey completed in April 2009 (Jayakumara et al., 2009). With the Gallehewa small tank that we found in the upper reaches of Pandiggama Kudawewa, the total number of tanks at Paranahalmillewa cascade (excluding Galegama but including Etaweeragollewa) came up to 36.

Galegama tank in the northern part of the cluster flows into a different cascade where water flows from Galegama, down to Kongollewa, Lolugaswewa, and finally to Aluth Halmillewa before joining Boo Oya (Fig. 5). Etaweera Gollewa is a small cascade with two main tanks where Pahala Tammennawa form the lower tank from which water drains into drainage channel in the main axis of the cascade. A satellite image (Google 2008) shows the location of the lower part of the cascade cluster where some of the selected tanks are situated.

Navodagama cascade

This is single cascade system with five main tanks, namely, Navodagama, Wanni Helambawewa, Maha Helambawewa, Ethdath kalla and Millawetiya, located in the Wilachchiya Division. It also has at least 7 abandoned tanks, out of which a few have been recently renovated. The largest of these abandoned tanks is Muththankulama located at the down end of the cascade that drains directly into the Wilachchiya Major Irrigation Tank. In the historical past, Muththankulama, would have functioned as the biggest tank in the Navodagama cascade. Today, it cannot be renovated, because people have settled in its tank-bed and a part of its old paddy tract if asweddumised gets inundated by the water spread of Wilachchiya Major Irrigation tank downstream. Older maps indicate that even Ethdathkalla and Millawetiya were abandoned tanks that have been renovated in recent times. One of the most interesting features of the cascade is the existence of three parallel connected tanks, namely, Millawetiya, Ethdathkalla and Maha Helamba wewa. These are not connected now as in the past (as depicted on old topographic maps), because they have been renovated as single tanks. However, the wisdom of disintegrating the ancient system remains questionable.

Sandamal Eliya cascade

This is a cascade covering a large area with numerous abandoned tanks, situated close to Wilpattu National Park, and mostly in the Miocene Limestone area (Fig. 2). Plan Sri Lanka has renovated 6 village tanks within this cascade, namely, Dalukpotana, Pahala Gonewa, Maha Viharagama, Manewa, Kuda Kumbuk Gollewa and Helambagaswewa. Some of these tanks do not appear even in recent Topographic Maps at the Scale of 1:50,000, and it appears that Plan Sri Lanka has responded to requests from respective village communities in choosing them for rehabilitation. This cascade also drains into Moderagam Aru joining it about 2km below the bund of the Maha Wilachchiya Major Tank.

Kahagollewa cascade cluster

There are three cascades in the Kahagollewa cluster, namely Kahagollewa, Katukeliyawa and

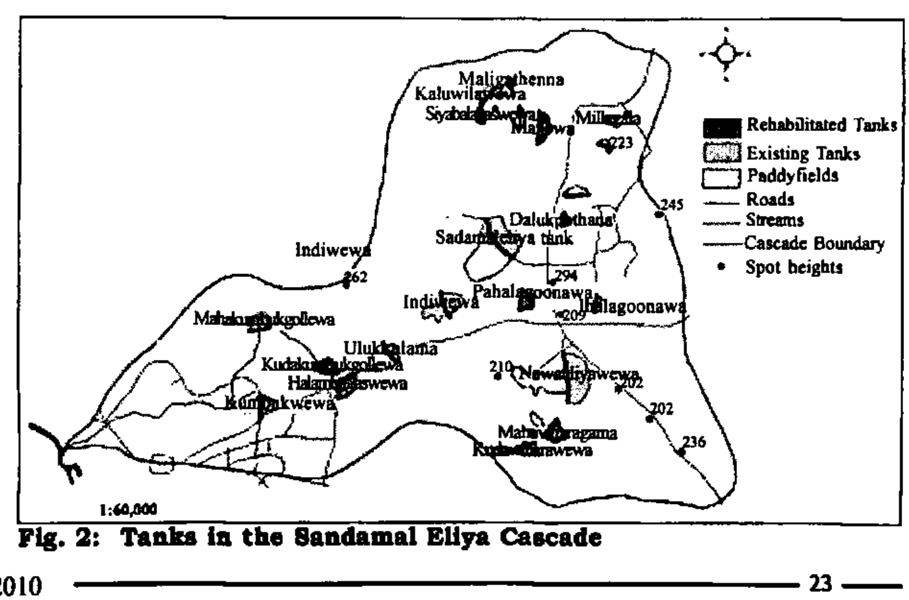

Fig. 2: Tanks in the Sandamal Eliya Cascade

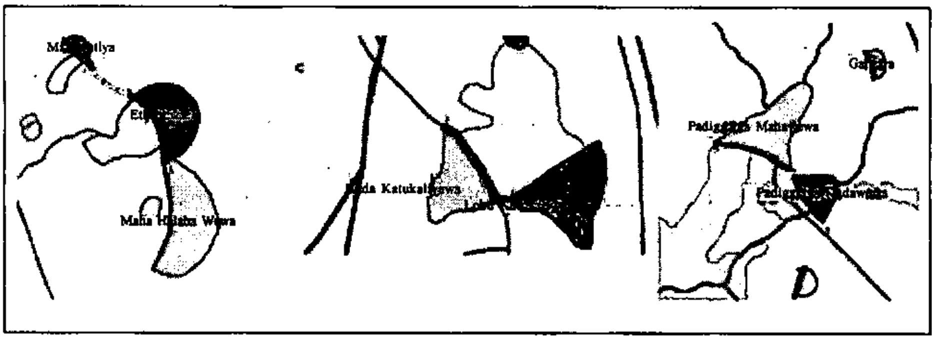

Fig.3: Levelling points at three tank systems with lateral relations

both ways (e.g., Pahala Parasangaswewa). In some tanks people had to use nets across spillways to prevent such movement (e.g., Katukeliyawa). This brings out the need to take the whole cascade into account in introducing fish fingerlings. It also shows the need to re-design spill ways to facilitate fish movement through some form of 'fish-ladders'.

Wanni Palugollewa. This area is predominantly a Muslim settlement except for a few Sinhala Villages such as Wanni Palugollewa and Kokpetiyawa. Wanni Palugollewa has one operational tank with an elongated paddy tract. As could be surmised from cascade considerations, somewhere near the middle of this paddy tract, there are ruins of an old tank bund indicating the existence of another small tank in the historical past.

Puwarasankulama cascades

A few minor tanks were developed by Plan Sri Lanka near the medium-sized tanks of Puwarasankulama and Paniyankadawala, falling within two micro-catchments, namely, the Madagalla and Parasangaswewa cascades. Tanks rehabilitated were Madagalla and Elapathgama in the former and Pahala Parasangaswewa in the latter. These were indeed abandoned small tanks before taking up for rehabilitation. Despite their small size, they display some characteristics common to rehabilitated cascades elsewhere.

There were hardly any permanent settlements under these tanks earlier. After rehabilitation, second generation settlers from neighbouring settlements of Puwarasankulama and Paniyankadawala received land and began cultivation under the tanks.

Tanks Affected by Material Received from Upstream Catchment Areas

As part of the household survey conducted, people were asked whether their tanks are affected by upstream flows of fish, other fauna and flora as well as agricultural wastes. The responses received are summarised in Table 3.

As could be seen, nearly 30% of the respondents reported that such flows affects their tanks in a significant way. The most affected tanks appear to be Navodagama, Parana Halmillewa and Kuda Kumbugollewa. One common feature in the last two tanks is their location in the lower parts of the respective cascades. Sometimes, the effects are not necessarily negative. At least in a few cases, it has been reported that fish introduced to upstream or even downstream tanks, ended up in a different tank, because they migrate

Trans-migration of aquatic flora and fauna and agricultural wastes appears to produce more negative than positive results. Colonisation of tanks with unprecedented volumes and varieties of aquatic plants such as lotus, *'minneri lavan'* and even the traditional *'ramba'* may be considered as signs of eutrophication. Of course, lotus - an edible plant with flowers used for worship, is useful if it does not reduce tank water capacities significantly. However, its unprecedented profuse growth in recent years is exceptionally noticeable. Similarly, *'ramba'* as seen at Pandiggama is a good elephant feed. On the other hand, *'minneri lavan'* not only reduces tank capacity as it forms a 'floating mat', but also discourages people from bathing in the tanks due to its itchy effect on the skin. At Tikiri Kumbugollewa, people were seen collecting them and burning large heaps on the tank bed.

Table 3 : Tanks reported as receiving significant quantities of fish, aquatic plants, and agricultural wastes from upstream areas

Cascade Cluster	Cluster-level responses	Tanks reported receiving	Tanks reported Receiving fish, wastes,etc. from upstream areas
Parana Halmillewa	21	Parana Halmillewa	08
		Hinguruwewa	04
		Pahala Tammennewa	04
		Kudawewa	03
		Galegama	01
Navodagama	15	Navodagama	14
Sandamal Eliya	20	Kuda Kumbkgollewa	08
		Pahala Gonewa	05
		MahaViharagama	03
		Helambagaswewa	03
		Dalukpotana	01
Kahagollewa	01	Kahagollewa	00
		Katukeliyawa	01
		Wanni Palugollewa	00
Puwarasankulama	05	Madagallewa	02
		Parasangaswewa	02
	62 (29.8%)		**59 (28.36%)**

Role and Relationships of Lateral Tanks (*baendi wew or aenduthu wew*) in the Cascade

Water circulation in a cascade is not only longitudinal along the cascade from upstream to downstream, but also it happens sometimes between parallel lateral tanks. Brohier (1937) has discussed the inter-connectedness of larger ancient reservoirs. Nevertheless, this aspect has not received adequate attention in tank rehabilitation and cascade studies in the past. It is undoubtedly an element of our ancient tank irrigation technology that reflects some enlightened attempts towards optimising the use of scarce water resources in small catchments in the Dry Zone. In our study areas, we have come across several places where this technology is still in practice or there is some evidence on ground that it has been used in the past. These include Ethdathkalla, Millawetiya and Maha Helambawewa tank system, Aliyawetuna wewa, Loku Katukeliyawa and the Pandiggama subsystems. At Sandamal Eliya cascade too Mahaviharagama and Kaluvila tank systems display some lateral relations. We have undertaken some engineering level measurements in a few such places to ascertain the possible lateral water flows and their results are given in Fig.3.

Ethdathkalla lateral tank system

Older one-inch topographic maps, clearly indicate that all three tanks in the system, namely, Ethdathkalla, Maha Helambawea and Millawetiya were connected through a continuation of the same tank bund. Level points taken by us at critical points indicate a flow direction towards Ethdathkalla from the two lateral tanks on either side, indicating water deficits at Ethdathkalla. However, in view of the fact that, all tank bunds were obviously built on the same contour, and the almost imperceptible level differences at respective spills, it would have also

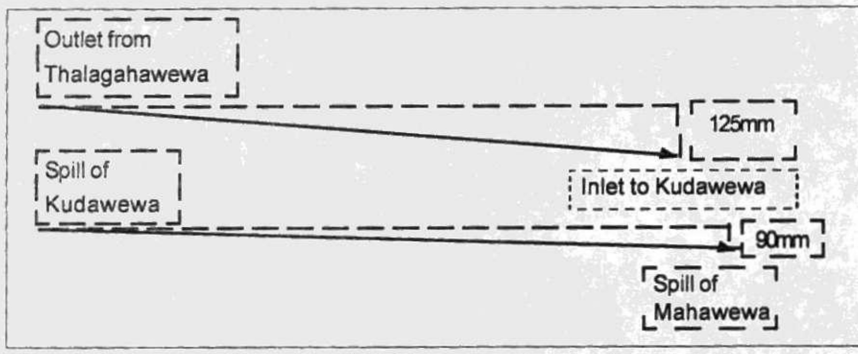

Fig. 4: Imperceptible level differences in the Pandiggama lateral tank system

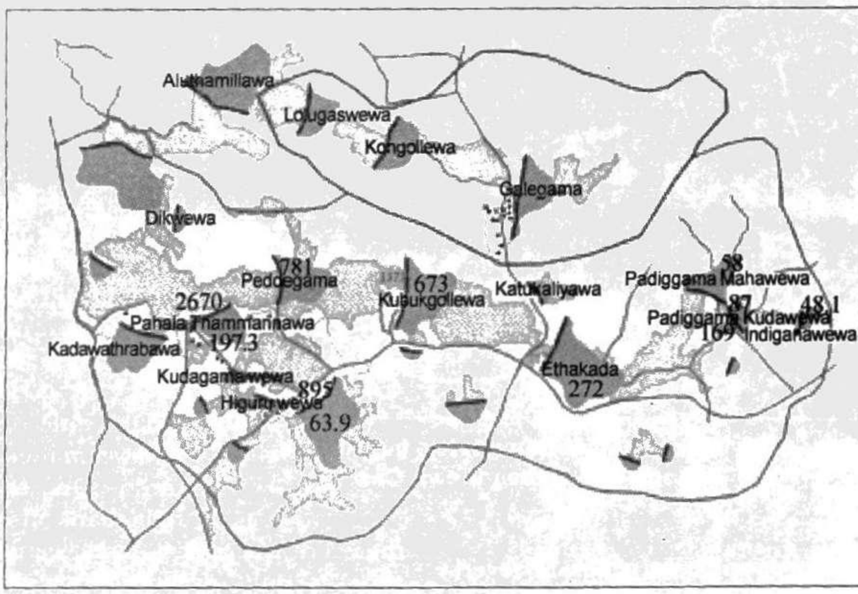

Fig. 5(a): Electrical conductivity variations along the Paranahalmillewa Cascade; Figures in black inside the tanks indicate salinity of tank water; Those below the bunds indicate salinity in *Kattakaduwa* areas

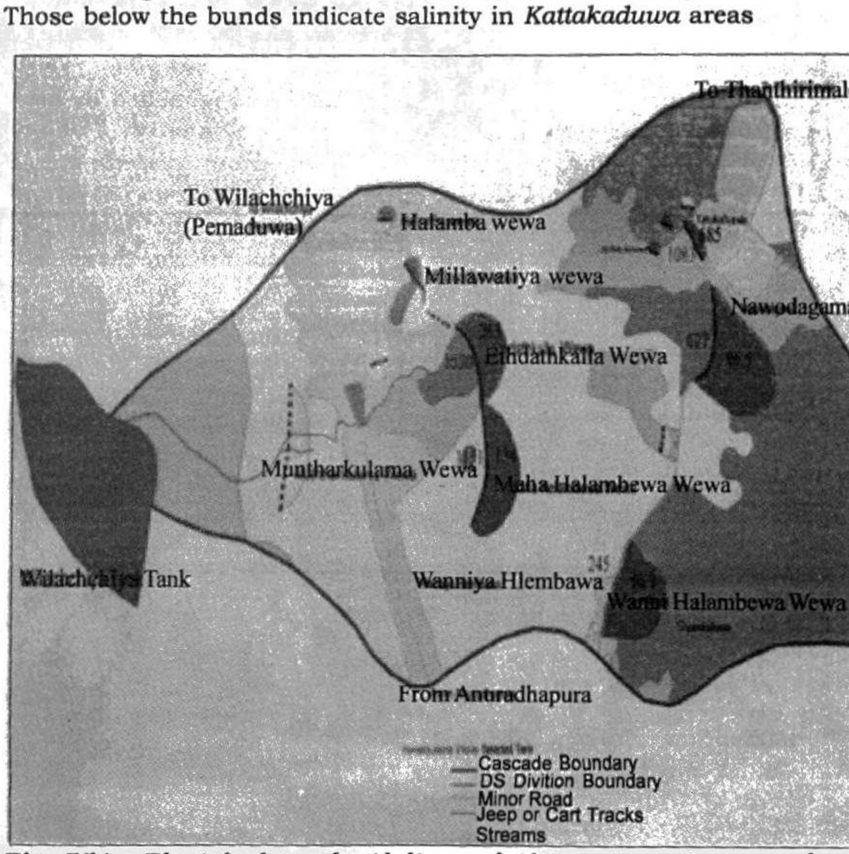

Fig. 5(b) : Electrical conductivity variations along the Navodagama Cascade

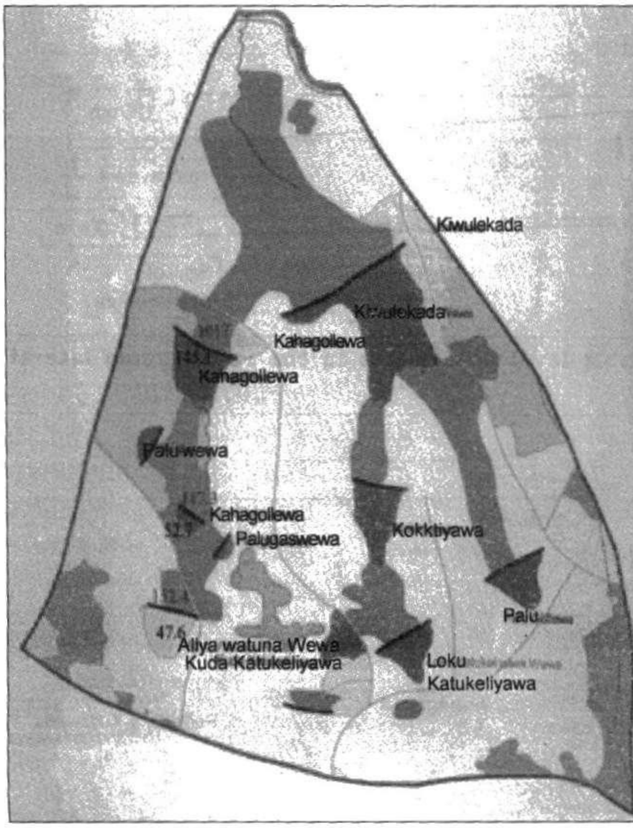

Fig. 5(c): Electrical conductivity variations along the Kahagollewa Cascade

been possible to generate reverse flows, when Ethdathkalla received excessive water from high rains. The canal that connected Millawetiya and Ethdath kalla is still seen in ruins near latter's recently constructed spill. This old lateral canal between Millawetiya and Ethdathaklle tanks, possess a level difference of only 50mm (2 inches) and could be considered as a level crossing between these two tanks. Maha Helambawewa tank is located at a slightly higher elevation according to the levels obtained, causing water to flow form it to Ethdathkalle along an old lateral link between those to tanks. It is likely that, not only the existence of such a link canal was not recognised by the engineers, but also they have effectively destroyed it in order to build the new spill-way.

Katukeliyawa tank system

The lateral flow between Loku and Kuda Katukeliyawa tanks is still operational during the rainy seasons. Here, the flow is from Loku Katukeliyawa to Kuda Katukeliyawa that shows some water deficits.

Aliyawetunuwewa tank system

Aliyawetunuwewa is a small tank on the head of a cascade from which water flows down to Ihala and Pahala Kahagollewa tanks respectively. On the left bank of the tank, there is a feeder canal from a small forest tank nearby. This was renovated by the elders of the village some years ago, but was not considered in the rehabilitation of Aliyawetunuwewa tank. On the right bank also, there are traces of a forest canal, that brought overland flows of water from the rains in upper catchment areas.

Pandiggama tank system

Pandiggama is inhabited by people who call themselves *Wanniye Minissu,* and take pride in the fact that, they belong to the original inhabitants of the Island who descend from Kuveni, the queen of ancient Sri Lanka. Pandiggama is served by a cluster of 7 small tanks. The bunds of three bigger tanks, namely, Mahawewa, Kuda Wewa and Thalgaswewa are located on the same contour. These three tanks were connected laterally in the historical past. Water flow direction was from Thalgaswewa to Kuda Wewa and then to Mahawewa. About 20 years ago, Mahawewa and Kudawewa were reconnected by restoring the old link. The villagers requested the Plan to connect the other two tanks (Thalgaswewa) as well, but this was not taken up due to dearth of funds. The level measurements we made at critical points indicate that, the spill levels of these three tanks have surprisingly small level differences in elevation of less than 15cm. These minor level differences between tanks lateral canals were possibly maintained allowing excess water from one tank to be shared with other parallel tanks at the same elevation. Here too, it is possible that there could have been reverse lateral flows, depending on the intensity of rains that brought water to the tanks.

Figure 4 illustrates the level difference of the old canal, from Thalagahawewa to Kudawewa as 125 mm (5 inches). Further, it indicates that the level difference between the spill of Kudawewa to spill of Mahawewa is only 90mm (nearly 4 inches).

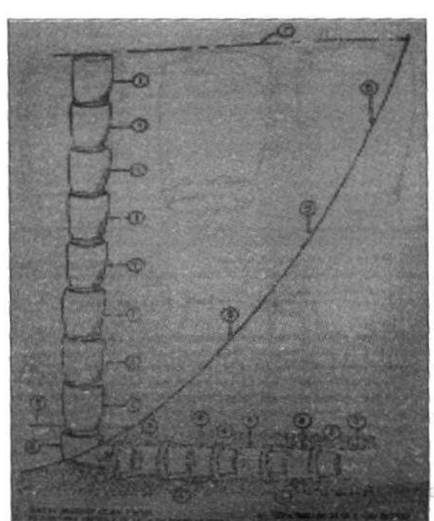

Fig. 6 (a): Plan of *Kumba Horowwa*

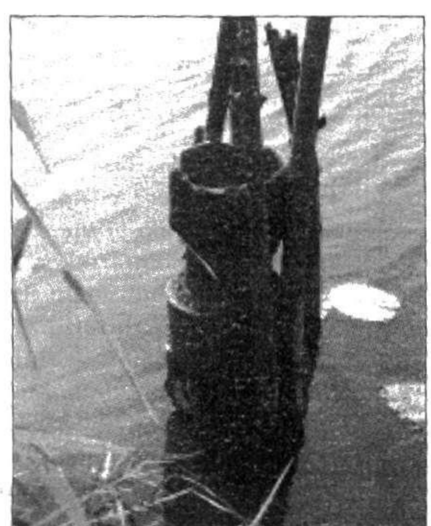

Fig. 6 (b): A Functioning *Keta Horowwa*

When global climatic changes and their local impacts are considered, the above-described lateral flow tank systems may prove valuable for rational water management in the future. This is particularly in view of the extremes patterns of localised rainfall (referred to as *salaka wessa* by some villagers) and dry spells that are likely to happen now with increased frequency.

Water Quality Variations in the Cascades

An attempt has been made to understand water quality variations along the cascades in order to understand their spatial patterns. It must be noted that, this is only a reconnaissance study with an extremely limited sampling frame and a limited number of selected parameters felt relevant for evaluation. A comprehensive water quality survey was beyond our purview in terms of available time and resources at our disposal. However, we suppose, such a comprehensive survey is a dire need in these times of high agro-chemical use.

The few cascades we selected for this exercise included, Navodagama, Kahagollewa and Parana Halmillewa. Water samples were collected and analysed in December 2009 at the height of the rainy season. Therefore, we presume that actual readings during dry weather conditions may prove different. Some results of our analyses are depicted on maps (Fig. 5. a, b, & c).

Variations in electrical conductivity

As could be seen in Fig. 5a, Electrical Conductivity (EC) values of tank water (marked in bold black) when plotted on a cascade map, shows a definite variation from top end to the bottom end of the cascade. Thus geographical distribution pattern of EC revealed 3 major features hitherto little known to science. These are:

i. Increasing EC in tanks along the cascade in a downstream sequence

ii. EC levels below the tank bund in *Kattakaduwa* (interceptor belts) area were several times higher

iii. EC at *Kattakaduwa* also showed a definite increase in a downstream direction

Implications of high EC which is an indicator of amount of ions, for tank rehabilitation are interesting and challenging. The decision made by some tank rehabilitating agencies such as Plan Sri Lanka to re-introduce *Kattakaduwa*, seem to be scientifically validated by these findings. Rice, being a salt sensitive crop, must be protected from even slightly saline waters to maintain high levels of productivity. It also reveals the ancient wisdom of leaving a belt of land below the tank bund, to absorb salinity appropriately called *Kattakaduwa* implying an area affected by salinity.

The observed tendency for salinity concentration in the *kattakaduwa* may be explained in terms of seepage from dead-storage areas inside the tanks, where there is a salinity build-up due to the vertical salinity gradient found in most tanks (Schiemer, 1983). Seepage lines normally tend to bend under the weight of tank bunds and perhaps reappear in *Kattakaduwa* areas.

The salinity distribution patterns were consistently similar in all the three cascades that we have selected, namely, Parana Halmillewa, Navodagama and Kahagollewa, that are geographically separated from each other (Fig. 5a, 5b & 5c). Therefore, we are inclined to conclude that, in general, this may be a recurrent phenomenon in almost all cascade systems.

It may be noted that, most modern mechanical sluices have been, perhaps designed to convey bottom saline water from tanks, for convenience, without a proper understanding the above fact. On the other hand, traditional *'keta' or 'kumba horowwa'* (Fig. 6a & 6b) carried the top surface water of a tank which is least affected by salinity. However, almost all *Keta* and *'kumba horowwas'*, have been destroyed and replaced by modern irrigation engineering in small tanks. Therefore, there is a challenge to develop a new sluice design that can combine the best features of both old and the new.

Increasing salinity normally increases stress on seed banks of aquatic plants, and weeds. (Schiemer, F. (1983).Yatigammana, 2004). As a result, it may decrease the species richness of aquatic communities, resulting in some loss of biodiversity. The possible effect of higher levels of salinity on aquatic fauna may be more complex and remains less understood. Therefore, it would be necessary to make further inquiries to ascertain the actual impacts of salinity on fish breeding and aquaculture. Does the increasing levels of salinity make lower tanks in the cascade less suitable for aquaculture? Does it require a more circumspect choice of fingerling species that can adapt to salinity variations? In response to these questions, salt tolerant fish species such as *Etroplus suratensis* that are found in lagoons as well as reservoirs of Sri Lanka could prove to be the better adapted species in Kattakaduwa as well as the reservoirs, especially towards the lower end of cascades. Therefore, it may be suggested that, when introducing fish into reservoirs, the salinity levels of the systems must be taken into consideration to get better yields. Thus, it will facilitate the maximum use of high saline waters for the aquaculture.

Spatial patterns of other water quality parameters

Apart from EC and pH measurements, several other chemical parameters have also been determined from the samples. These included, Suphate, Ammonia, Nitrite, Nitrate, Phosphate, Dissolved Phosphorous, and Dissolved Oxygen. In addition, bio-indicators among which the zooplankton and phytoplankton groups also identified. The distribution patterns of some of these measured environmental variables indicate the following features:

i. In Parana Halmillewa Cascade, pH increases significantly downstream from Tikiri Kumbukgollewa to Parana Hallmillewa

ii. Both Phosphates and Sulphates seem to decrease downstream in the Navodagama cascade

iii. In the Parana Halmillewa Cascade, Sulphate increases from Indigahawewa to Ethakada Tanks and marks a slight drop thereafter; However, from Peddegama to Parana Halmillawe again there is an increase.

iv. Ammonia too increases downstream as Sulphates in the Navodagama Cascade

v. At Kahagollewa Cascade, there is definite increase in Nitrite levels downstream from Aliyawetunuwea to Pahala Kahagollewa

vi. In Parana Halmillewa Cascade, Nitrite levels seem to behave in the same manner as Sulphates as described under section ii above

vii. In the Navodagama Cascade, Nitrites appears to decrease downstream and behave in the same ways as Sulphates

viii. Zooplanktons seem to decreases downstream in the Kahagollewa Cascade

ix. Phyto-planktons seem to decrease downstream at Parana Halmillewa Cascade from Indigahawewa to Tikiri Kumbukgollewa.

The above results may be treated only as preliminary findings for reasons given earlier. However, their geographical variations along the cascades due to their significance, deserve some interpretation. In the Parana Halmillewa Cascade, Ethakada Tank (a medium-sized irrigation tank) appears to break the sequence of variations in Sulphates and Nitrates. This may perhaps be due to the uses of these nutrients by abundant macro-phytes and phyto-planktons of the system.

In general, almost all the above chemical parameters appear to display some increases downstream with the exception of Navodagama where some local factors may be at play. The downstream increases in Sulphates and Nitrites which are normally associated with heavy agro-chemical uses in rice fields, may accumulate and conveyed through running water, resulting in the distribution patterns described above. In addition, in reservoirs that appear to have less macro-phytes within the littoral region where the absorbance of nutrients by biota could be lower have different properties of water quality.

Some Implications of the Results of Study

The implications of the above findings on tank construction and rehabilitation planning may include the following:

a) Tanks at the lower end of the cascades deserve more regular vigilance and monitoring of impacts

b) Aquaculture development may have to take these findings in their plans to introduce fingerlings of different fish species with more salinity tolerant ones in downstream tanks of the cascades

c) The relationships between the above findings with weed growth and their control in tank systems deserves further investigation.

d) The use of agro-chemicals by farmers in the upper cascade areas may need to be monitored and controlled in order to protect the tank systems at the lower end of cascades. Possibilities of planting pollutant absorbing grass varieties or sedges along the drainage channels (or Kiul Ela), may prove helpful in controlling the inflow of agro-chemicals to reservoirs at least to some extent. Development of engineered wetlands on drainage paths and canals in the cascade system. Those wetlands to be designed as free surface wetlands. Cattail species (Taipha species) is proposed as the plant since it is suitable to the dry zone.

e) Any health impacts of changing water quality in the tanks for humans (for bathing and washing) as well as to domesticated animals (particularly to buffaloes, cattle and goats) and wild animals and aquatic birds and fish where necessary, need to be monitored.

f) Most modern mechanical sluices have been, perhaps designed to convey bottom water from tanks, for convenience, oblivious to their salinity implications. On the other hand, traditional *'keta' or 'kumba horowwa'* carried the top surface water of a tank which is least affected by salinity. However, almost all *'kumba horowwas'* have been destroyed and replaced by modern irrigation engineering in small tanks. Therefore, there is a challenge to develop a new sluice design that can combine the best features of both old and the new.

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