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Contents

Medicinal Value of Ghee – The Ayurvedic Perspective <i>J. I. D. Diddeniya and N. D. Kodithuwakku</i>	01-12
Banana Leaf Meal, A Tamil Traditional Way of Eating <i>M. Sivakaran</i>	13-19
The Lotus: Symbolic Studies in Intercultural Communication (නෙළුම: අන්තර් සංස්කෘතික සන්නිවේදනයේ සංකේතාර්ථ අධ්‍යයනය) <i>A. Lokumannage</i>	20-27
Role of Museums for the Preservation of Kantha Embroidery - A Traditional Culture of Bengal <i>A. Ghosh</i>	28-41
A Studies of Native Male Body In British Colonial Photographs: 1843-1948 (යටත්විජිත ශ්‍රී ලාංකේය වාර්තා ඡායාරූපවල නිරූපිත ස්වදේශික පුරුෂ රූපය පිළිබඳ පාඨනයක්: ක්‍රි.ව 1843-1948) <i>S. M. D. G. Suriyabandara</i>	42-58
<i>Declining of a Traditional Craft industry: An observational Study on Mat-Weaving Industry in Induruwa, Southern Sri Lanka. (විශ්ලේෂණීය යන සාම්ප්‍රදායික හස්ත කර්මාන්තයක් ලෙස පත් කර්මාන්තය පිළිබඳ විමර්ශනාත්මක අධ්‍යයනයක්)</i> <i>U. D. R. S. Thilakarathna</i>	59-72
A Study of the Medical Treatment for venom in the Indigenous Medicine of Ancient Societies (අතීත සමාජයෙහි පැවති දේශීය වෛද්‍යමෙහි අන්තර්ගත සත්ත්ව විෂ උදෙසා සිදු කළ ප්‍රතිකර්ම පිළිබඳ අධ්‍යයනයක්) <i>M. Nishanthi</i>	73-82
Understanding social constructs of the Kandyan period: An examination of apparel accessories depicted in temple murals belonging to the Kandyan period: A study conducted on selected temples of the Kandyan period <i>L. D. M. Premaratne, M. Nishanthi, N. M. Neththasinghe</i>	83-94
A Study of the Poem "Ath Bandanaya" Displays in the "Kuruwe Rajakari Kramaya" of "Kiri Madu" Ritual (කිරි මදු ශාන්තිකර්මයේ ඇතුළත් ඇත් බන්ධනයෙන් ප්‍රකට වන කුරුවේ රාජකාරි ක්‍රමය පිළිබඳ අධ්‍යයනයක්) <i>C. M. R. P. Chandrasekara</i>	95-104
Study on the Existence of God's Temples and Sri Lankan Caste System (With Reference to the Balangoda Region) සිංහල කුල - ධුරාවලිය හා දේවාලයන්හි පැවැත්ම පිළිබඳ විමර්ශනාත්මක අධ්‍යයනයක් (බලංගොඩ ප්‍රදේශයට විශේෂිතව) <i>G. D. Maddhumage</i>	105-119
An Explorative Study on The Use of Dwarf Images in The Sacred Buildings of The Anuradhapura Era (අනුරාධපුර යුගයේ පූජනීය ගොඩනැගිලිවල වාමන රූප භාවිතය පිළිබඳ විමර්ශනාත්මක අධ්‍යයනයක්) <i>T. S. Martin</i>	120-133
An Anthropological Study of People's Attitudes and Beliefs on High Traffic Accident Locations (ඔහුලව රිය අනතුරු සිදුවන ස්ථානයන් සම්බන්ධයෙන් මිනිසුන් තුළ පවතින ආකල්ප හා විශ්වාස පිළිබඳ මානව විද්‍යාත්මක අධ්‍යයනයක්) <i>M. A. D. G. D. Munaweera, N. Kanthilatha</i>	134-146
An analysis of internal geophysical factors for the evolution of the micro-irrigation system; (Based on the dry Zone in Sri Lanka) <i>H. H. A. Karunarathna</i>	147-161
Hot water bath building and its activities in Rajagala, Sri Lanka <i>M. D. I. K. Abeynayake</i>	162-174



An Analysis of Internal Geophysical Factors for the Evolution of The Micro-Irrigation System; (Based on the Dry Zone in Sri Lanka)

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Abstract

Considering the technical and structural preparation of affairs in micro-irrigation, a study can be carried out itself on its evolution. The evolution of irrigation affairs from the beginning of the early historic stage to the historic stage can be authenticated by observing both the creative environment and its physical environment. However, there is a vacuum in the field of research between the periods from prehistoric to the early historic stage. The intention of this dissertation is to disclose the internal geophysical variables that affected the evolution of irrigation affairs during the periods from prehistoric to the early historic stage. The fact that water was contained in tanks that were formed according to a network between the early historic stage, and the aforementioned tanks being free of the network between the period from prehistoric to the early historic stage is being discussed in this paper as the research problem. The upper valley of the border between Kala Wewa and Thisa Wewa and the lower valley of Malwathu Oya are selected as the research area. The Coring and analysis of the soil sample method, studying contour maps and layers of the cross-section in the test pit, utilizing the GIS technology, and analyzing the soil particles were applied as the research method. Research results were attesting the prehistoric settlements and affairs in the micro-irrigation of those areas, constructing the connection between the underground water circulation and internal geophysical factors, classification of micro water resources and confirming the primitive industrial affairs. The conceptual frame of the research is noted as the period of prehistoric-stage settlements, and it is clearly identified that the root cause for the migration from upper layers to lower layers is the failure of water circulation between groundwater and agricultural lands.

Key Words: Irrigation, Settlement, Micro Water Resources, Geophysical facts, Underground Water.

1. Introduction

Water is recognized as one of the basic biological needs that determine the existence of human culture. Since the main way of life of prehistoric man was based on food gathering, there was no need to store it in one place. They fulfilled their water needs from natural springs, water retention, and from waterways. Man had entered agriculture in the protohistoric stage; the "Iron Age". Since the man in the protohistoric age used to live in permanent houses and bade farewell to the itinerant lifestyle, consequently they paid special attention to selecting the most satisfactory places fit for containing water (Karunarathna, 2018). The environmental experiences retrieved from the itinerant lifestyle were grounded to select the settlement lands. The protohistoric stage is the closest stage that enables the revealing of prehistoric irrigation affairs. In order to confirm this, micro-irrigation affairs were authenticated, which were created comparatively to the prehistoric settlements. With the aim of storing water, *Pathas* were located in landscapes, where the lands were with slight valleys. Since the production process was increased with the continuous development of village tanks, consequently, it delivered the chance to store water in a greater capacity. Thus this research was censored on revealing the relationship of micro-irrigation with *Pathas* and Village tanks.

With the advent of iron consumption, ponds were formed in the areas where water was naturally accumulated (Fernando, 1982:48). Further, he demonstrates that the earlier hunters could get their water supply from these ponds and earlier irrigation affairs were completely centralized around these water sources. Later the ponds in which these sediments were deposited accordingly were based to invent tanks upon the requirement of water (Brohier, 1957: 200).

Pathas were initially identified in the protohistoric settlements and later evolved into village tanks in the prehistoric stages. The Ibbankatuwa Wewa - Ibbankatuwa Settlement, Machchagama Wewa - *Maanaawa* Settlement, Yapahuwa Pin Wewa, Kokebe Wewa- Kokebe Settlements are the foremost examples (Jayarathna, 2015: 68-78; Karunarathna 2018:128). These tanks were formed by combining several *Pathas* (Karunarathna, 2018). When studying habitat distribution through the theoretical approach, the irrigation industry has evolved by combining several systems of sub-subjects. The continuous flow of complexity of society, knowledge through experience, technology, and methods of dependence have influenced to strengthen this process. Factors like environment, climate, and technology; including the technological wisdom derived from foreign cultures, affected the growth of these settlements. Also, simultaneously, the irrigation industry and cultural determinants of inter-settlement settlements were also influenced by this, revealing technological wisdom.

The beginning of the Sri Lankan Iron Age is identified as the period between 1000-500 B.C (Deraniyagala, 1972). Origin of the irrigation industry could be traced back to the period between 1500-500 B.C. At that time, with the use of iron tools, small lakes had been built for the requirement of basic needs (Panabokke, 2009:64). When studying the landscape of the Megalithic Culture, it could be observed that a considerable number of small tanks existed. As the needs and land consumption were immensely increased, by the end of the iron age and the beginning of the

historic age, these lakes were assumed to be converted into complex village tanks. Thennakon speculates that this process might have occurred in the medieval Iron Age (Thennakon, 2014:50). Pre-irrigation affairs related to this period can be identified through the areas associated with various geographical backgrounds. Brohier has recorded that these typical tanks had existed, which were assumed to be created before 500 B.C. Moreover, these lakes had been avoided from being introduced as tanks (Brohier, 1934). When studying the Megalithic tombs associated with the area of Pomparippu, Wimala Begley has attempted to inspect the relationship between those tanks (Begly, 1981:59). The data found in chronicles, especially the stories of designing the ponds with the aim of storing the water, the pond in the *Wijeya Kuweni* story, and the *Thimbiri Yahanwila* pond in the *Pandukabhaya* story reveal the above facts (Sumangala; Batuwanthudawe, 1967:47-48). It was revealed from this that before the construction of village tanks, lakes had existed at the developmental levels with more complex water-containing structures than the '*Pathas*'. Materialistic culture and technological wisdom that influenced the dissemination of irrigation affairs are comprehensible through the cultural environment. Resource-utilization in Sri Lankan Historical Iron Production Research indicates that in the prehistoric age, centralizing small tanks, iron extraction had been done in irrigation affairs and also in relation to village tanks (Thantilage; Vithanage, 2015:64).

The Iron Age (1000-500B.C) analysis indicates that, in the confirmation of the cultural stages, it was identified that the entrance is about 10 feet deep from the excavation surface. Also, factors related to the horse and cow who were participants in agriculture were discovered. Moreover, according to the silt radiocarbon dating of the deposit, it belonged to the period of 700 B.C. (75 Radio Carbon date) (Deraniyagala, 2002).

Based on this evidence, it could be surmised that the Sri Lankan water management affairs were originated in the period between 1000-500 B.C., which belongs to the protohistoric stage (Deraniyagala, 2002). The exploration of the settlements and irrigation background of the intermediate valley between *Daduru Oya*, *Mee Oya* and *Kala Oya*, uncovered that water management had been functioning through *Pathas* located in the *Andaragama* Village of protohistoric settlements (Withanachhi, 2019:141). The village tanks were further expanded successfully through micro-irrigation. Some of them are *Kulu Wewa*, *Olagan Wewa*, *Kayan Wewa* and Village Tank. *Kulu Wewa* resides on the upper valley of the *Wewa*, and temporarily stores the water coming from the upper lands. It is also called the '*Boru Wewa*', as it is excluded from the operation of a tank (Dharmasena, 2017:01).

2. Materials and Methods

For the study of the micro-irrigation affairs, the upper valley of the *Kala Oya* and the lower valley of the *Malwathu Oya* were under observation. Fourteen parts were selected (A-N) from the upper valley of *Kala Oya* to its lower valley. The data was collected through observation, and a GPS software was used to map the settlements and micro-irrigation management affairs.

The research was focused on the identification of micro-irrigation affairs. The micro-irrigation prior to village tanks, which was originated and associated with protohistoric settlements were taken into consideration. Since the landscapes had changed, it was difficult to come to conclusions about the structural attributes of this context. This micro-irrigation was built at an altitude below the settlement lands.

Observing the structural setting of the internal physical factors that affected the continuous flow of the irrigation affairs is the aim of this research paper. To achieve that goal, soil samples were collected. The soil samples collected by digging the ground are demonstrated in Map 1. The samples were collected from the upper valley to the lower valley which had a 200m*200m scale. The components contained in the soil samples contributed to the analysis of the para-terrestriality when they are reacting with water. The findings are as follows;

Table 01. Altitude distribution of the soil according to soil samples

Range/No	A	B	C	D	E	F	G	H	I	J	K	L	M	N
0-20	5	8	5	15	9	10	13	3	7	5	15	13	15	15
20-40	20	30	23	25	38	21	24	16	26	39	25	29	35	36
40-60	48	40	50	53	55	48	56	53	52	54	48	55	53	53
60-80	75	65	63	74	65	78	73	77	69	80	65	63	75	78
80-100	90	88	94	85	87	92	87	90	94	99	89	90	98	88
100-120	118	115	103	150	120	118	115	109	116	115	119	105	116	115
120-140	130	138	123	135	140	138	134	138	133	128	124	130	136	108

The ground contours were incorporated in the study to further analyze both internal geophysical factors and external physical factors. When observing the contours of the micro-irrigation that lay between the Kala Oya upper valley, it was identified that the contours had a spreading pattern of 100-110. Due to the slightly sloped structure of the upper valley zone, and the dispersion of the contours with rough slopes in the inter-valley zones, there is a gap between the soil-water level and the groundwater level. An equal mechanism was observed in the soil water level and the groundwater level in the rough slope zone. This directly affects the evolution of water sources.

Rajarata landscape has a nature of ripple valleys. So, by observing its cross-section, the dispersion of the soil layers was studied. Thus, in comparison to the causes for the structural formation of both the ground layer of the upper valley and internal soil layers, the operation of the groundwater and the upper groundwater were identified.

3. Results and Discussion

3.1 The Evolution of Micro-Irrigation

Pathas, Kulu Wewa, Olagam Wewa, Kayan Wewa, Kanchi Wewa, Village Tanks were revealed as micro-irrigations. In this paper, they are presented as the five stages of micro-irrigation. According to the landscape of micro-irrigation evolution, a sequence from the upper valley to the lower valley was recognized. Also, the internal geophysical factors have affected the formation of the micro-irrigation. The research

study specially explored the principalities of soil layers and their permeability with water and how it affected the structural constructions.

Table 2. The distribution of soil layers from upper valley to the lower valley

No	Range	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	Soil Color
1	0-20	13	15	18	14	14	14	14	13	13	13	13	12	12	Brown
2	20-	30	38	38	37	35	38	32	35	33	30	32	30	30	Reddish Brown
3	40-	45	55	55	57	53	50	53	58	50	52	55	50	53	Reddish Yellow
4	60-	68	75	75	75	75	64	72	70	73	75	70	70	75	Dark Brown
5	80-	85	90	90	90	65	92	85	93	95	90	100	83	85	Red brown
6	100-	105	110	110	115	115	110	95	105	100	110	105	105	113	Red yellow
7	120-	125	130	133	130	123	128	109	115	120	130	120	120	120	Bedrock

3.1.1 Pathasa or Pathaha

The initial factors related to micro-irrigation were disclosed in the protohistoric settlements. It was identified as *Pathasa*, and was initially confirmed in the research zone of the *Maanewa* Megalithic Settlements. This micro-irrigation had been used as a water management medium in the protohistoric age. One example would be the right slope of the *Kala Oya* which has a high altitude. Almost 15 *Pathas* can be found around this settlement. According to the quantitative analysis of *Pathas*, the mean depth value is about 5-6 feet, and their volumes were different from each other. Majority of these *Pathas* were oval-shaped.

Several fundamental features were identified in the internal physical structure of the *Pathas*. *Pathas* were often located **in lands with no mountains**, and places where the land of the valley is depressed, (ex: pre-settlement lands with low elevation). The edges of the *Pathas* being depressed with a minimum elevation to the internal side could also be seen as a salient feature. Also, multiple *Pathas* were arranged in the same land according to the landscape. In most cases, arrangements were made for the extra water to be overflowed from a place of high elevation, while facilitating

groundwater leakage in a high volume. Water could be retained to a maximum of three days in the soil zone of *Pathas* which could store rainwater adequately, as *Pathas* were dried soon due to the **rapid evaporation**. The fact that the areas around *Pathas* having a high level of texture was also given attention. It was observed that the water management associated with micro-irrigation had been far ahead of their time, in the protohistoric Period.

The soil at the farthest depth of *Pathas* was dark brown in color (humus). The common characteristics of this soil are; having a high level of sand and clay ratio in the soil composition, laying on the slopes of wavy terrains, not being able to retain water as the granular openings are abundant, contributing to the increase of the gravitational force of water, and being 3-4 feet thick in areas with slight slopes. The water contained in micro space of soil is often insufficient due to the dry climate. All these phenomena had affected the water retention period of the *Pathas*. The main reason for this is that the zones with *Pathas*, which have obtained satisfactory internal soil conditions, are challenged by the factors of macro space.

These *Pathas* are only activated in the rainy season. Based on the dry zone climatic and environmental factors, they are distinguished by the dissimilarities of water retention. Specifically, the speed of the water leakage is measured by the soil structure. The speed of the water leakage is at a high level since the soils have a granular form in the seasons in which *Pathas* are constructed. Though the water is stored temporarily in *Pathas* in rainy seasons, the water is mixed with groundwater at a high rate. Also, the water leakage speed is determined according to the soil texture. The water in *Pathas* is mixed with groundwater within a short period of time since the sand percentage is higher than the clay percentage of the *Pathas* zones.

To study the soil in *Pathas*, soil samples collected from drilling the ground were tested. Though soil samples were collected extending **to the level of the mother rock**, the composition of the soil variation of the soil layer in *Pathas* zone was confirmed only after accurately determining the depth of *Pathas*.

Table 3. Contents of the soil profile (components of soil layers collected from A, B, C, D, E, F places)

Soil	Sand]	Clay]	Loam]	Gravel]	Other]
Brown soil	60	10	20	05	05
Dark Brown	50	15]	20	10	05
Reddish yellow	20	60	10	05	05
Strong Brown	20	65	15	05	05

Table 4. The depth of micro-irrigation

Micro-Irrigation	High
<i>Pathasa</i>	7-10 ft
<i>Olagan wewa</i>	10-15ft
<i>Kayan wewa</i>	15-20ft
<i>Kanchi wewa</i>	20-25ft
<i>Village Tank</i>	20-30ft

Kokebe, Pomparippuwa, Ibbankatuwa and Galsohon Kanaththa (Researches related to this - Beragala Kalupahana Waththa - 400 B.C, Haldhumma - 1750, Ranchamadama -1359 B.C, Ibbankatwa - 700-400 B.C, Ihala KalawellaUlpatha -520 B.C, Galgamuwa AndaraWewa- 500 B.C, ThammannaGodalla- 490 B.C, Nikawalamulla - 400 B.C) which were similar to the above-mentioned settlements, was also critical in analyzing the cultural environment of those settlement lands. The mean value of the depth of *Pathas* is 5-6 ft, which was revealed from the *Maanawa* protohistoric settlement lands of the research area. When comparing the structural and cultural landscape, it had been similar to the *Mahaandara Wewa* protohistoric settlement lands (Withanaachchi, 2019:141). The structural formation of this is similar to the *Pathas* (depth 3-4 ft), which was revealed from the observation of the research area. It was understood that the origin of the tank, which is called '*Maha-Andara Wewa*'² at present, had been a developmental phase of these previous actions (Withanaachchi, 2019:141).

It was concluded that the medium-sized tanks found in these settlements evolved as primary phases of *Pathas* or as village tanks. When W. Begly was researching on Megalithic burials near *Pomparippu*, she has focused on studying the relationship between tanks around the settlement lands (Begly, 1981:59). Though these *Pathas* were used for water management near the settlement lands in the protohistoric stage, later, with the advancement of the material culture and technology, they had evolved as village tanks. The way in which the space of the settlements had been organized was vital for this study.

Ibbankatuwa settlement land, *Pinwewa-Galsohohn* Tomb settlement land, *Kokebe* Settlement lands were taken into consideration for this study (Karunaratna, 2018:128). *Maanawa* is among the research areas of protohistoric settlements. Since *Maanawa* was centralized for its spread, it was verified that there is a similarity in the cultural landscape, when comparing its cultural landscape with inter-premises settlements.

The process of *Pathas* being developed as village tanks is a result of continuous evolution from the protohistoric stage to materialistic culture. Daraniyagala pointed out that 1000-500 B.C is the time frame of the origin of the Sri Lankan Iron Age (Deraniyagala, 1972). Resource Utilization in Sri Lanka Historical Iron Production has presented a comparative comment on village tanks being created during the iron age, by considering the Slag identified near village tanks (Thanthilage; Vithanage, 2015:64). Village tanks evolved during the peak phase of the water management process, which was initially centralized to *Pathas*. Also, lakes had been formed as a water retention medium parallel to this.

Brohier mentions that the sediments in ponds were later utilized in the construction of tanks (Brohier, 1975). Panabokka points out that with the advent of iron usage, lakes were developed into village tanks between the periods of 1500-500 B.C. (Panabokka, 2009:64). Further Thennakon proposes that this process could have happened in the medieval iron age [The medieval Iron Age between 500-300 B.C. is recognized as the premature period of building tanks. (Thennakon, 2012:11)] (Thennakon, 2012:50). It is speculated that lakes or *Pathas* were constructed during this period. Although lakes were used as village tanks during this period, when

investigating later resources, conclusions were drawn that they were continuously named as lakes based on pragmatic evidence. The "*Thimbiriyahan Vila*" ["*Chethiya*" Yakinni who lived in Dumrakgala, walks in disguised as a mare (Sumanala Himi and Batuwanthudawe Dhewarakshitha, 1967:47 p)] mentioned in the *Pandukabhaya* story, and the pond mentioned in the *Wijaya- Kuweni* story confirm this assumption. (Rev.Sumangala and Batuwanthudawe Dewarakshitha, 1967:47-48). D.L.O Mendis points out seven evolutionary stages [Rain-fed agriculture, River diversion from a flowing river Ganga. Oya, Ara, development of permanent river diversion structure, construction and Operation of Spillways, Invention of the sluice, construction of small medium and large Storage, damming Operation system. (Mendis, 2002:111)] of micro-irrigation and identifies 'rainfall agriculture' as the initial stage. Further, he clarifies that there is a similarity between *Pathas* and other ponds in the protohistoric stage. Accordingly, it shows the independence in the formation of the cultural landscape which is revealed through the prehistoric settlement lands of the research area.

In the study of the settlement enlargement of the protohistoric and early historic stage, factors related to Intra-Spatial Settlement patterns [A rural settlement is a place where a group of people live more or less permanently allowing them to share problems of shelter, defence cultivation and service as well as to enjoy social activities (Brain Knapp" 1994:440p)] are discussed (Jayaratne, 2015). They demonstrate a common spread pattern which was centralized in a village tank located in the shape of mountains and plains. *Kokebe* settlements which were centralized in *Kokebe* Mountain, *Yapahphuwa*, *Galsohon* Cemetery centralized in *Pinwewa* and mountain valleys, *Ibbankatuwa* centralized in *Ibbankatuwa* and mountain, have similar geophysical distribution to the *Machchagama* *Maanawa* protohistoric settlements.

3.2 The Formation of the Internal Geophysical Structure of *Kulu* Tanks

Kulu tanks can be demonstrated as the second phase of the evolution of micro-irrigation. The facts about these tanks were confirmed based on contour data analysis of the land, the structural preparation of internal geophysical variables, and cultural landscape and soil profile test.

Kuluwewa had been located at a lower altitude than *Pathas* and a higher altitude than *Olagamwewa*. According to the analysis of internal geophysical variables, *Kulu* tanks had also been utilized as temporary water retainers. As a result of the difference in the depth between the underground water level and the *Kulu* tank, which is 20-25 ft, the gravitational force is of a high intensity. Since there is a gap between the internal soil position and underground water level in the areas where the *Kulu* tanks were distributed, it instantly extracted the surface water into the interior. Generally, the depth of a *Kuluwewa* is expanded within 12-15 ft. As a result, *Kuluwewa* had been impotent in functioning as a permanent source of water. When examining the depth of the center of a *Kulu* tank, soil zones belonging to two soil layers were identified. The first layer was identified in the structural preparation of the internal geophysical variables of *Pathas*. The *Kulu* tank had been spread up to red and podzol soil in the second layer. There were several salient characteristics identified such as; considerably deep soil composition, weak soil conditions due to the excessive water

to retain the groundwater required for agricultural purposes. As a solution to this issue, water resources were developed centralizing land zones with low inclination. Since the human settlements became more complex over time, microbial water resources were constructed in the inter-valley zone to increase the water capacity.

These specific tanks were located considerably deeper and lower than *Pathas*, so the water retention was at a higher rate. Even though it could not be utilized as a permanent resource of water either, it contributed commendably towards the protection of soil water levels. Chandana Withanachchi has classified tanks based on several aspects, such as; the capacity of the tank and the location and the utility. The classifications are; *Wawkotu*, village tanks, large tanks, *Samudra* tanks, ***Biso*** tanks, ***Katakulu*** tanks, Karati tanks and *Aanduthu* tanks. (Withanachchi, 2017:58-67). According to this categorization, *Kotuwewa* and *Katuluwewa* are micro water sustainers. Udula Awsadahami has identified *Iskuluwewa* as *Katakulu*, *Mahaihawewa* **based on the localization** of Kuluwewa as a Gamwewa, or a tank that is of a moderate size (Awsadahami, 2015: 60).

Accordingly, *Katakuluwewa* and *Karawita Wewa* were recognized as types of *Kulu* tanks. They are often found in landscapes with high inclination and forests. They store rainwater, while controlling the sediments in water flowing from higher areas. (Dharmasena, 2017:1-5).

Kuluwewa is mostly found near forests and scrubs. It has the capability of functioning as a temporary rainwater retainer as well. Furthermore, Kuluwewa; as a micro water sustainer contributed to the water management of settlements and Gamwewa prior to the establishment of Yoda Ela. The *Kuluwewa* has been introduced as '*Boruwewa*' by Awsadahami in his research work, 'Wewa'. According to him, it does not only co-operate in controlling sediments but also in maintaining the underwater level of the tank at a higher rate, by storing rainwater in the tank surface (Awsadahami, 2015;60). These micro water sustainers were identified in the area around Yoda Ela. They have nurtured the village tank prior to the formation of Yoda Ela. Eventually, with the development of the late prehistoric and early prehistoric periods, the village tanks were connected as an embankment system, making the mother tanks, the sustainers. Researches show that rural tanks were created as a result of micro-aquifers associated with prehistoric settlements in the *Udawatha* regions, and the water management practices introduced during those periods.

Some examples for *Kulu* tanks would be; *kurundakulama*, *wellamudawa*, *Ulankulama*, *Siyambalagaswewa*, *Kuttikulama*, *koodarikulama*, *Wagayakulama*, *Kaduruwewa*, *Gonapathirawa*, *Dikwewa*, *Koonwewa*, which had been established as sample tanks. These tanks which were constructed in a slightly larger scale have the water capacity of several *Kuluwewas*. Dharmasena proposed a classification of these micro water sustainer tanks; *Kuluwewa* in the upper reaches of a rural lake and *Olagam wewa* in the lower reaches. A *Kayan* tank was the collection of several *Olagam* tanks. Agricultural activities were carried out in the vicinity of *Olagam* tanks. (Dharmasena, 2017:1-2). Although researches conducted during the 20th century had focused on the village tank and the cascade system, micro water sources had received a minimal attention. This is confirmed in this paper by comparing the results of this study with previously completed studies. Literary and archaeological sources were explored in

this study. Also, in Jetavana inscriptions suggest a classification, as ‘Wewa’, ‘Village tank’, ‘Maha wewa’ and ‘Danawew’ (Senevirathna, 1998). But, this classification does not include information regarding micro water sustainers, which is discussed in this paper.

Olagam Tanks

When compared to *Kuluwewa*, *Olagam Wewa* is located at a slightly lower inclination. The depth and volume of *Olagam* tanks are wider than *Pathas* and *Kuluwewa*. Here, the soil water level is deep and the median depth of the *Olagam* tank is about 20 feet. As a result, soil water cannot be retained for a long period of time. Neither the environment nor the state of soil is conducive to agricultural purposes. *Olagam* tanks can be identified in intermediate valleys with a higher elevation.

Several specific characteristics were identified in *Olagam* tanks. Often, exiting gates located at a lower elevation. These tanks are mostly nurtured only by rainwater. However, there are instances where *Olagam* tanks are nurtured by *Kulu* tanks as well. The *Olagam* tanks belong to the soil zone of red-brown latosol and comprise some physical characteristics as follows: basic saturation value is 40% and it increases up to 70% when the profile depth increases, found to be slightly moist when spreading into the depth, not a saturated soil, gravity remains at a moderate level, and based on the nature of the slope the thickness of the soil level differs.

Table 6. The depth of underwater level and *Olagam* tanks

					Depth of <i>Olagam wawe's</i>							
A	B	C	D	E	F	G	H	I	J	K	L	M
10.08	13.02	10.05	11.09	12.5	10.5	11.03	14.01	14.02	15.01	15.05	14.04	14.06
15.02	11.02	12.10	6.9	13.03	12.05	15.04	12.12	15.08	10.8	14.10	13.03	13.05
12.10	12.05	15.10	15.01	14.05	14.04	12.02	14.08	14.01	14.5	15.0	14.05	13.05
13.07	14.02	13.5	14.05	14.09	10.05	13.04	13.05	12.5	15.01	13.08	14.10	15.00
13.04	13.04	14.08	12.04	14.09	10.08	14.05	12.10	12.01	12.02	14.05	14.10	15.0
15.04	12.06	12.05	11.05	15.01	10.05	13.08	14.11	10.03	11.10	13.45	12.05	15.0

The *Olagam* tanks were recognized as suitable structures to store water for a longer period of time than *Pathas* and *Kulu* tanks. The main reason for this is the distribution of inter-geophysical variables and pre-micro water resources. The *Udawatha* area in this region had been influenced by this structure, to maintain a high density of *Kulu* tanks. The soil layers were slightly inclined, as the outlet of the *Olagam* tank is located in a valley with a minimum elevation. The absence of canals to drain the excess water from the *Olagam* tanks led to the passing of excess water over the bund.

Kayan Tanks

Kayan tanks can be identified as the fourth stage of the distribution of micro water resources. *Kayan* tanks were formed with the concatenation of several *Olagam* tanks spreading over a considerable wide area near the *Olagam* tanks. As per the contour data analysis, these micro water resources had been located at a lower elevation in the intertidal zone. Even though its depth had been approximately 18-20 feet, *Kayan* tanks had been spread up to the fourth soil zone of the internal geophysical

distribution. The brown fur soil belonging to this particular area is enriched with some distinctive features such as; the vertical thickness of the soil profile is between 15-25, the color of the soil varies from dark brown to dark grey, slightly acidic soil, action exchange capacity is between 10-20, while the saturation of the soil is 50-60. Due to the high permeability of the specific area, it had been possible to retain more water. The permeability depends on the elements contained in the soil structure.

Table 7. The underwater level and the depth of Kayan tanks

A	B	C	D	Depth of Kayan tanks					J	K	L	M
				E	F	G	H	I				
14.08	17.02	17.05	11.09	12.5	18.5	19.03	17.01	18.02	19.01	20.05	19.04	19.06
17.02	18.02	19.10	16.9	17.03	18.05	18.04	15.12	17.08	19.08	16.10	18.03	19.05
18.10	18.05	18.10	19.01	14.05	15.04	19.02	18.08	17.01	19.5	19.0	19.05	17.05
18.07	20.02	20.5	20.05	14.09	16.05	18.04	17.05	16.05	18.01	13.08	16.10	18.00
19.04	19.04	19.08	18.04	19.09	16.08	19.05	20.10	16.01	20.02	18.05	18.10	20.0
17.04	12.06	18.05	19.05	18.01	17.05	19.08	16.11	10.03	20.10	15.45	20.05	19.0

Kanchi Tanks

Kanchi tank can be identified as the fifth stage of the evolution of micro water resources. *Kanchi* tanks were formed with a network of several *Kayan* tanks and has spread in intermediate valleys. The location of this landscape had affected the water retention for a long period of time which was more than *Olagam* tanks and *Kayan* tanks. As per the location of internal geophysical variables, this soil zone extends up to a depth of 20-25 feet. The diffusion of the interior landscape have influenced the soil layer structure to remain partially active even in the present.

There are several specific characteristics of internal geophysical variables in the lands where *Kanchi* tanks were established. *Kanchi* tanks were nurtured by *Olagam* tanks and *Kayan* tanks in the *Udawatha* area, which were spread with a rough elevation of contours. When compared to other tanks, *Kanchi* tanks stored a higher level of underground water. The main reason for this was, maintaining the underground water level at a higher rate through rainwater and stored water. Since the *Kanchi* tanks were spread in a broad scope of land, they were more suitable for agricultural purposes than micro water resources. For this purpose, the internal soil structure of *Kanchi* tanks had been designed in a suitable manner. Water could be stored for a long period in this particular region is due to the internal soil structure which had minimum gap between the inner soil layer and the parent rock.

The specific characteristics of the soil layer which belonged to the area had affected the existence of *Kanchi* tanks. Especially, the inter-relation between underground water and soil water was identified in this area. The forces of adhesion and cohesion are required when the water flows through micro spaces. Due to the proximity of the mother rock and the formation of the intertidal rock, the water content of the soil in the region exhibited difficulties when adding to the groundwater.

Soil conditions of the interior geophysical variables belonging to this region were identified as immature reddish-brown soils. Its salient features are: the vertical thickness of the soil profile is between 15-25, the colour of the soil varies from dark brown to dark grey, slightly acidic soil, cation exchange capacity is between 10-20,

while the saturation of the soil is 50-60. The gravity is at a lower level. Also, a close relationship between the underground water and the minimal slope of the land was identified. Accordingly, the condition of the soil in the area is appropriate to store water.

What predominantly contributed to the failure of the early microbial water management system was heterogeneous physical factors. It was identified that the formation of plain valleys and low elevations were utilized as an alternative. As a result, the human settlements were displaced gradually towards the lower valleys. They moved to the semi-arid zones as a result of the introduction of agriculture during the latter part of the prehistoric period. The formation of the structure of the internal ground contributed to this phenomenon, as well.

Table 8. The underwater level and the depth of Kayan tanks

A	B	C	D	Depth of Kayan wawe's					J	K	L	M
				E	F	G	H	I				
22.08	24.02	24.05	20.09	22.5	24.5	24.03	23.01	24.02	19.01	20.05	19.04	21.06
24.02	25.02	24.10	22.9	25.03	23.05	24.04	25.12	24.08	19.08	24.10	20.03	22.05
21.10	23.05	23.10	19.01	21.05	24.04	20.02	24.08	22.01	19.5	25.0	24.05	23.05
23.07	24.02	24.5	20.05	23.09	20.05	22.04	25.05	21.05	18.01	23.08	24.10	24.00
25.04	20.04	21.08	20.04	19.09	24.08	20.05	20.10	23.01	20.02	24.05	23.10	20.0
24.04	24.06	22.05	19.05	20.01	17.05	22.08	21.11	24.03	20.10	25.45	24.05	24.0

Source: Based on the research study

4. Conclusion and Recommendations

The research revealed that the formation of internal geophysical variables had affected the evolution of micro-irrigational activities. The landscape of the *Kala oya* upper valley region which was the study area had been affected by the evolution of micro water sources. The specific water sources had been distributed from the *Udawatha* area with a high altitude, to the inter-valley zone with slight slopes. The evolution of the tanks were observed in five stages; as *Pathas*, *Kulu* tanks, *Olagam* tanks, *Kayan* tanks and *Kanchi* tanks. Village tanks had been created as the final phase of the this evolution. The crucial factors which had affected this process are; internal geophysical variables and their structural formation. To confirm the evolution of micro water sources, samples of internal ground soil were taken from *Udawatha* to the inter-valley zone, and their median depths were identified as 7-10, 12-15, 13-15, 15-20 and 20-25 feet respectively. As a result of the decline of the underground water due to the structure of the soil, it had been appropriate to store water from the *Udawatha* region to the inter-valley zone. It was observed that the micro water sources have evolved along with the settlements. Thus, the elements of solid condition, water, interchangeability, and communication preferences for agricultural purposes had become the driving forces behind the evolution of micro water sources.

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