Assessment of Surface Water Quality for Irrigation in Ulagalla Cascade, Sri Lanka

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***Abstract*- Tank cascade systems in the dry zone are considered as one of the traditional land water management systems and have evolved in order to manage the surface water resources efficiently. Ulagalla cascade is a prominent cascade located in Anuradhapura district with nineteen small tanks and highly utilized for agricultural purposes. Therefore, a systematic monitoring of surface water quality is vital. This study was conducted to assess the variation of surface water quality in Ulagalla cascade and its suitability for irrigation. Water samples were collected once a month during October, 2015 to February, 2016 from each tank for chemical analysis. Electrical conductivity (EC), pH, concentrations of sodium, potassium, magnesium, calcium, alkalinity, nitrogen (NO_3^--N), and available phosphorous (PO_4^{3-}-P) were tested. Salinity, sodium adsorption ratio (SAR) and sodium percentage (Na %) were calculated using the measured parameters. Based on the sodium percentage 5%, 90% and 5% of the tanks water were categorized as excellent, good and permissible for irrigation respectively. As per the US salinity hazard diagram 5% of the tanks had low salinity low sodium (C1S1) water while, 95% of the tanks had medium salinity low sodium (C2S1) water. Surface water in Ulagalla cascade can be used to irrigate most crops provided with considerable amount of leaching.**

***Keywords* - Ulagalla cascade, water quality, irrigation, salinity hazard, eutrophication**

I. INTRODUCTION

Surface water is the primary source of water for agricultural, industrial, and human consumption uses in many regions all over the world. The quality of surface water affect the human health and ecological systems [1]. It has been known that the quality of irrigation water directly influences the quality of soil. [2]. During last century, due to the rapid population growth, the demand for agricultural land and products has increased. Hence demand for irrigation water also increased specially in the regions where agriculture is the main livelihood. Due to the insufficient freshwater resources available at global level, long term sustainable use of water resources to enable the agricultural and industrial purposes has become a growing concern [3].

Sri Lanka is characterized by three contrasting climatic zones known as wet, intermediate, and dry zone[4]. The mean annual rainfall in the dry zone is less than 1750 mm. This implies the limited water availability in the dry zone[5]. Around 63% of rainfall is received during Maha season and second inter-monsoon is the highest contributor (38%) to the annual rainfall in the dry zone[6]. Therefore, the ancient communities in the dry zone stored the rainfall and runoff water in man-made tanks called "wewa"[7].The tanks and related water conveying structures were particularly developed in the dry and intermediate climate zones of Sri Lanka [8,9]. Tank cascade systems were evolved by connecting series of tanks together for storing, conveying and utilizing water from an ephemeral rivulet and they operated as an ideal water management technique [10,11]. Due to the intensive use of irrigation water for agricultural purposes and the use of excessive amounts of chemical fertilizers and agrochemicals has led the surface water deterioration in dry zone of Sri Lanka [12–15]. Several studies have been conducted to assess the water quality parameters in tank cascade landscape in dry zone of Sri Lanka[16–18]. As it is difficult to explain the overall condition of water quality by assessing each and every parameter separately combine use of these water quality parameters were implemented[19–21].

Wijesundara et al.,[16] reported that elevated concentration of nutrients (NO_3^--N and PO_4^{3-}) were observed in Thirappane and Mahakanumullacascades which are adjacent to Ulagalla cascadein the dry zone of Sri Lanka. Hence the objective of this study was to assess the surface water quality in Ulagalla cascade for irrigation.

II. METHODOLOGY

Ulagallacascade is located in low country dry zone (DL_{1b}) agro-ecological region of Sri Lanka. Nineteen tanks located in Ulagalla cascade named as *Diwulwewa, Galviharawewa, Heenukwegamawewa, Itikattiyawewa, Ihalawewa, Karambayagamawewa, KudaItikattiyawewa, Mannakkulamawewa, Maradankadawalawewa, Pahalawewa, Periyakulamawewa, Pudukkulamawewa, Seththikulamawewa, Thodamaduwawewa, Halmillewawewa, Ulagallawewa, Ulankulamawewa* and *Wagayakkulamawewa* were selected for the study (Fig.1).

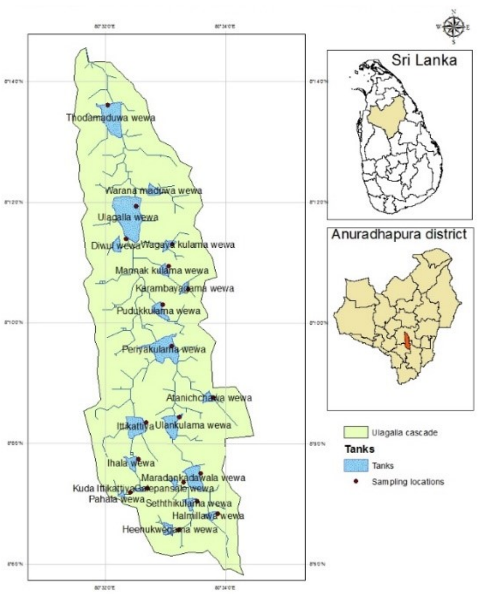

Figure 1. Surface water bodies in Ulagalla cascade

A. Collection of surface water samples

Water samples from each tank in the study area were collected during October 2015 to February 2016. Water samples were collected in monthly intervals from three locations of each tank. Samples were collected in to 500ml of clean plastic bottles after rinsing two or three times with the water to be sampled. These bottles were tightly closed and labeled. All the water samples were brought to the laboratory of soil and water science, Faculty of Agriculture, Rajarata University of Sri Lanka for the chemical analysis and stored at 4^0C.

B. Analysis of surface water samples

Electrical conductivity (EC), and pH of the water samples were measured in-situ. Filtered water samples were used for the chemical analysis. Sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), available phosphorus (PO_4^{3-}-P),alkalinity, and nitrate-nitrogen (NO_3^--N) were determined in the laboratory using standard analytical techniques. Table 1 shows the parameters monitored and the method of analysis.

C. Assessment of Hazards

Salinity, sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and sodium percentage (Na %) were calculated using measured quality parameters and those calculated parameters were used to assess the suitability of tank water for irrigation.

Table 1: Methods of Water Samples Analysis

Water quality parameter	Instrument / Method
pH	Multi parameter analyser (HQ 40 d)
Electrical Conductivity (EC)	Multi parameter analyzer
Sodium	Flame Photometer
Potassium	Flame Photometer
Calcium	Flame Photometer
Magnesium	Atomic absorption spectrophotometer
Nitrogen (NO_3^--N)	Salicylic Acid method
Available Phosphorus	Ascorbic acid method
Alkalinity	Acid-base Titration

1) Salinity hazard: Classification of water based on salinity hazard was assessed according to the recommendation of Wilcox[22] as excellent (0.1-0.25 dS/m), good - (0.25-0.75 dS/m), doubtful (0.75 2.25 dS/m), and unsuitable (>2.25 dS/m).

2) Sodium Adsorption Ratio (SAR): SAR was calculated using Equation 1 which was proposed by Richards [23] where all the concentrations are in meq/l.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \qquad (1)$$

Irrigation water was categorized as 0 to10 –excellent, 10 to 18- good, 18 to 26- doubtful, and >26 unsuitable.

3) Residual Sodium Carbonate (RSC): RSC was calculated using Equation 2 where all the concentrations are expressed in meq/l. Accordingly the irrigation water was classified as < 1.25 (meq/L)- good, 1.25 to 2.5 (meq/L)- doubtful, and >2.5 (meq/L)–unsuitable.

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \qquad (2)$$

4) Sodium Percentage (Na %): Na% was calculated using Equation 3 where all the concentrations are expressed in meq/l. Classification of water based on Na% was done according to the recommendation of Wilcox [22] as <20-excellent, 20to 40-good, 40 to 60- permissible, 60 to 80-doubtful, and >80- unsuitable.

$$Na\% = \frac{(Na^+)*100}{(Ca^{2+}+Mg^{2+}+Na^++K^+)} \qquad (3)$$

III. RESULTS AND DISCUSSION

A. pH

pH of the water is considered as a basic water quality parameter as it determines the solubility and biological availability of chemical constituents in water [24,25]. As can be seen in Fig. 2, average pH of the selected tanks varied from 6.79 to 7.47, the highest pH was recorded in *Ulankulama*wewa and lowest pH was recorded in *Ihalawewa*. According to Ayers and Wescot[26], the optimum pH range for irrigation water is 6.5 to 8.4. Therefore, based on pH, all the tanks had good quality water for irrigation.

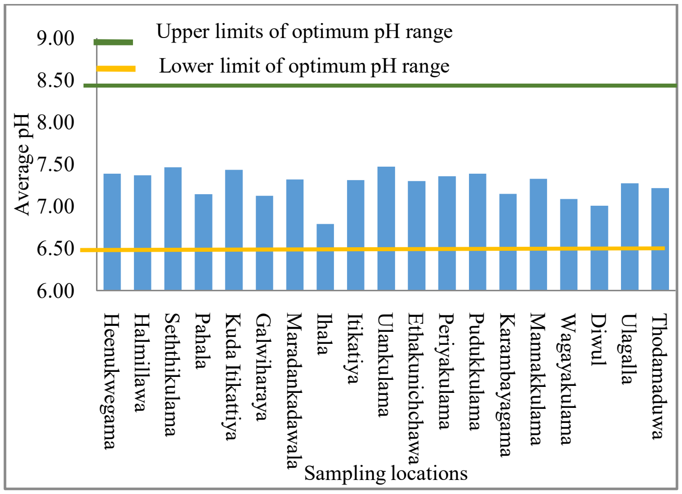

Figure 2. Average pH values of sampling locations

B. Salinity

Salinity has been identified as one of the major constraint in dry zone agriculture [27,28]. Therefore, salinity was assessed using EC in Ulagalla cascade (Fig. 3). Based on the results average EC of the study area varied from 0.56 to 0.24 dS/m while, the highest EC was recorded in *Thodamaduwawewa* situated at the lower end of the cascade. This is supported by the findings of Mahatantila et al [29]and Kumari et al [18],where all the agricultural and domestic pollutants in the particular water divide entered to the waterway, and accumulate in the end member of the cascade. Lowest EC level was recorded in *Galwiharayawewa* due to the deposition of silt and dilution effect. According to Ayers and Wescot[28] all the tanks were within the permissible limit for irrigated agriculture.

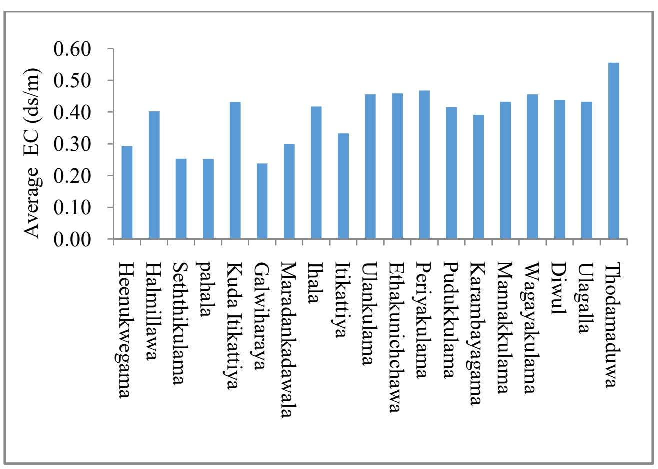

Figure 3: Average EC values of sampling locations in Ulagalla cascade

C. Nutrient concentration of surface water in Ulagalla cascade

Based on average NO_3^--N concentration in Ulagalla cascade, all the tank waters in the cascade did not exceed the critical level (<5mg/l) for irrigation during the study period whereas, all the tank waters in the cascade did not exceed the critical level of nitrate nitrogen concentration (<10mg/l) for irrigation during the study period.

The results revealed that the available phosphorous in the surface water is well below the critical level of 2 mg/l. It varied between 0.02 -0.34 mg/l (Fig. 4). Highest and the lowest concentration were recorded in Thodamaduwawewa and Itikattiyawewa respectively. Since phosphorus is the major macro nutrient responsible for eutrophication, occurrence of eutrophication was assessed using the critical value (0.08 mg/l) suggested by environmental protection agency (EPA)[30]. Accordingly, *Heenukwegama, Kudaitikattiya, Galwiharaya,Ihala, Ethkunichchawa, Maradhankadawala, Pudukkulama, Ulagalla* and *Thodamaduwa* exceed the critical value during sampling period. Therefore, there is a possibility for occurrence of eutrophication in the future due to the enrichment of phosphorus in tank waters of the Ulagalla cascade.

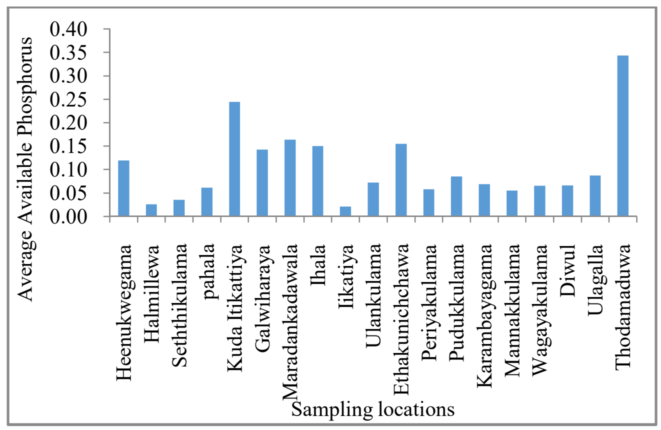

Figure 4: Average available phosphorus level in sampling locations in Ulagalla cascade

D. Irrigation water quality hazards

As per the classification based on average SAR values, all of the tanks water fall in to excellent category. Hence, surface water in Ulagalla cascade was suitable for irrigation with no danger of exchangeable sodium. Based on sodium percentage, 5 %, 90% and 5% had excellent, good, and permissible water quality for irrigation respectively. Moreover, all the tank water fall into good category for irrigation based on RSC.

E. Classification of Irrigation Water

The US salinity diagram [23] was used to classify the surface water suitability for irrigation. The combination of EC (salinity hazard) and SAR (sodium hazard) had been used in US salinity diagram. Out of selected tanks, 95% fall under C2-S1, indicating medium salinity and low sodium hazard. These wells can be used for irrigation with most crops on most soils with little danger of exchangeable sodium. Five percent (5%) of the tank water fall into C1-S1 category with low salinity and low sodium.

Based on all the measured water quality parameters 95% and 5% of the tanks fall into good and permissible category for irrigation respectively (Table 2).

IV. CONCLUSION

Based on EC, 95% of the tanks had good quality water and 5% of the tanks had excellent quality. It can be used for irrigation on all soils and on most crops but leaching is required in case of extremely low permeable soil.

As per the classification based on sodium percentage, 5% had excellent irrigation water quality, 90% had good irrigation water quality and 5% had permissible irrigation water quality in Ulagalla cascade. However, based on average SAR and RSC values, all the wells fall into excellent and good category respectively. According to the US salinity hazard diagram, 95% of the tanks had (C2-S1) medium salinity and low sodium hazard. Surface water of Ulagalla cascade can be used for irrigation with most crops on most soils with little danger of exchangeable sodium. Five percent (5%) of the tanks had (C1-S1) low salinity and low sodium hazard.

Moreover, 47 % of the tanks exceeded the critical level of available phosphorus for eutrophication during the study period. Based on all the measured water quality parameters 95% and 5% of tanks fall into good and permissible categories for irrigation respectively.

Table 2: Suitability of irrigation water based on the measured water qualityparameters

Tank	pH	SAR	Na%	Salinity	RSC	Suitability
Heenukwegama	Suitable	Excellent	Good	Good	Good	Suitable
Halmillawa	Suitable	Excellent	Good	Good	Good	Suitable
Seththikulama	Suitable	Excellent	Good	Good	Good	Suitable
Pahalawewa	Suitable	Excellent	Good	Good	Good	Suitable
KudaItikattiya	Suitable	Excellent	Good	Good	Good	Suitable
Galwiharaya	Suitable	Excellent	Good	Excellent	Good	Suitable
Maradankadawala	Suitable	Excellent	Good	Good	Good	Suitable
Ihalawewa	Suitable	Excellent	Good	Good	Good	Suitable
Itikatiya	Suitable	Excellent	Good	Good	Good	Suitable
Ulankulama	Suitable	Excellent	Good	Good	Good	Suitable
Ethakunichchawa	Suitable	Excellent	Good	Good	Good	Suitable
Periyakulama	Suitable	Excellent	Good	Good	Good	Suitable
Pudukkulama	Suitable	Excellent	Good	Good	Good	Suitable
Karambayagama	Suitable	Excellent	Good	Good	Good	Suitable
Mannakkulama	Suitable	Excellent	Good	Good	Good	Suitable
Wagayakulama	Suitable	Excellent	Good	Good	Good	Suitable
Diwulwewa	Suitable	Excellent	Excellent	Good	Good	Suitable
Ulagalla	Suitable	Excellent	Good	Good	Good	Suitable
Thodamaduwa	Suitable	Excellent	Permissible	Good	Good	Permissible

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