**ORIGINAL RESEARCH**

# Water quality for Agriculture and Aquaculture in *Malwathu Oya* Cascade-I in Sri Lanka

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**Abstract**

Malwathu Oya cascade-I is a prominent cascade system in Malwathu Oya river basin which is not evaluated yet, in terms of water quality and quantity. This study was conducted to find the spatial and temporal variation of salinity and some selected nutrients, related to irrigation water quality, and also to ascertain similar variations of some selected physical and chemical water parameters, related to the inland fish production, within the cascade system. Compared to the wet period, significantly higher dissolved oxygen, water temperature, turbidity, EC and alkalinity levels were recorded in dry period.

During the study period lower order tanks showed slight to moderate restriction level throughout the year. Middle order tanks also recorded slight to moderate restriction level during the dry period. The water temperature levels during the dry period recorded quite higher than the optimum range and although no deaths of fishes were observed the temperature stress could affect the growth and development of fishes. Turbidity, pH and alkalinity level of the tanks in the cascade did not exceed the critical levels for irrigation or inland fisheries during the period. Total nitrate nitrogen and ammoniacal nitrogen level of the tanks in the cascade were within the ususal range. Both spatial and temporal variation of water quality parameters can be seen in the cascade during the study period. However water quality is still good for irrigation even in dry period in upper and middle parts of the cascade.

**Key words:** Inland Fisheries, Irrigation, *Malwathu Oya* cascade-I, Water Quality

## Introduction

Village tank cascade system is an ancient small scale irrigation technology adopted especially in North Central dry zone of Sri Lanka. A cascade is defined as a connected series of small irrigation tanks organized within a meso catchment of the dry zone landscape; storing, conveying and utilizing water from an ephemeral rivulet[1]. It is usually made up of four to ten individual small tanks, with each tank having its own micro-catchment. The advantage of such a system is that excess water used from one tank in its command area is captured by the next downstream tank, by which this water is put to use again in the next command area. Accordingly, such water becomes continuously recycled or reused up to end of the cascade. This system helps to surmount irregularly distributed rainfall, non-availability of large catchment areas and the difficulty of constructing large reservoirs.

Major drawback of this system is farmer activities in upper parts of the cascade directly affecting the water users in lower lying tanks. The drainage water released from upper segments draining down to the low lying segments of the cascade may contain pollutants such as pesticides, fertilizers and sediments that originated from agricultural activities, as well as from industrial effluents and household activities. These pollutants can negatively affect crop production, aquaculture and the environment.

Aquaculture is considered as one of the most important sources of animal protein production for meeting the world's increasing demand for protein, especially in rural areas. Aquaculture in rural areas of dry zone in Sri Lanka, is mainly dependant on water availability during the dry seasons and water quality of small tanks.

In Malwathu Oya river basin, 179 cascade systems have been identified[2]. Of these, few cascades have been already evaluated in terms of quality and quantity of water. Malwathu Oya Cascade-I is located in $DL_{1b}$ agro ecological region of Sri Lanka which is a meso catchment of Nuwara Wewa catchment in Malwathu Oya river basin. It belongs to Nuwaragam Palatha - East and Mihintale Divisional Secretariat areas. This cascade system consists of twelve small tanks namely Maha Kalaththewa, Kuda Kalaththewa, Halmillawewa, Bandialankulama, Kammalakkulama, Thariyan kulama, Nelumkanniya, Sattambikulama, Halmillewa, Palugaswewa Illuppukanniya and Kudawewa surrounded by villages (Figure 1).

The total extent of the cascade is about 25 $Km^2$. As this cascade is not adequately evaluated yet in terms of water quality and quantity related to agriculture and aquaculture, this study was aimed to fill the existing vacuum. This study was conducted to find the spatial and temporal variation of salinity and some selected nutrients related to irrigation water quality and to ascertain similar variations of some selected physical and chemical water parameters, related to the inland fish production within the cascade system.

**Materials and Methods**

Water samples from Maha Kalaththewa, Kuda Kalaththewa, Halmillawewa, Bandialankulama, Kammalakkulama, Thariyankulama, Nelum kanniya, Sattambikulama, Halmillewa, Paluga swewa and Illuppukanniya tanks in Malwathu oya cascade-I were collected monthly from February 2011 to January 2012.

At the time of sampling, temperature, dissolved oxygen level and turbidity were measured using methods presented in Table 1. The samples for laboratory analysis were collected to polyethylene bottles which were prior rinsed with same tank water. Preservation of water samples was done following the APHA guidelines[3]. The samples were stored in a cool box and transported within 3 - 4 hours to the Soil and Water Science, Faculty of Agriculture, Rajarata University of Sri Lanka and refrigerated below $4^0C$ for further analysis. Electrical conductivity, pH, ammonium nitrogen and nitrate nitrogen concentrations of each and every water sample were measured/determined using the methods given in Table 1. Daily rainfall data of Anuradhapura meteorological station during the study period were collected and monthly rainfall values were computed.

Further assessments, were made by clustering the tanks into three groups as top, middle and lower order. Top order tanks are receiving water from the upper catchment area and the direct rainfall to which Bandialankulama, Kammalakkulama, Illuppukanniya, Sattambikulama, and Paluga swewa tanks belong. Middle order tanks of the cascade areas receiving water from direct rainfall and their individual catchment areas including drainage water of top order tanks are Halmillawewa, Thariyankulama, Halmillewa and Nelumkanniya.

Lower order tanks are receiving water from direct rainfall and their own catchment areas including drainage water from top and middle order tanks comprising of Maha Kalaththewa and Kuda Kalaththewa tanks. Finally all the drainage waters of Maha Kalaththewa and Kuda Kalaththewa merged together entered the Nuwara Wewa located in the vicinity of the city of Anuradhapura.

Statistical analysis was carried out using data analysis tool pack of Microsoft Excel to detect the water quality changes between wet and dry

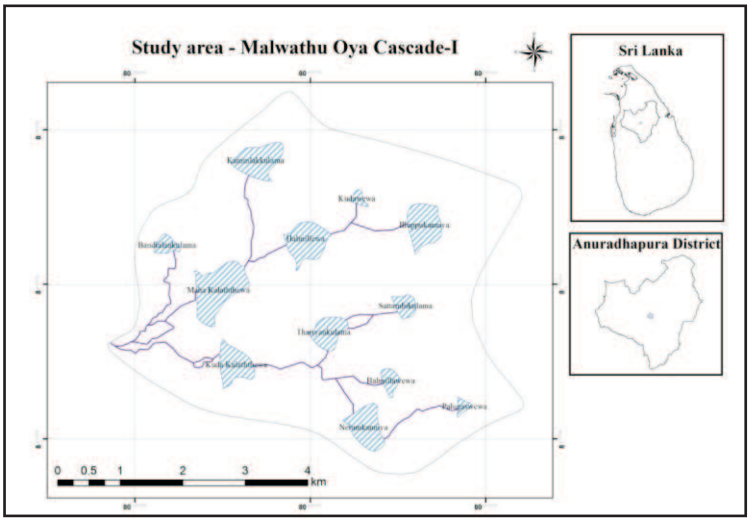


Figure 1. Map of study area - *Malwathu Oya* Cascade-I

Table 1. Instruments and methods used for water quality analysis

| Water quality parameter | Instrument / Method |
|---|---|
| Temperature | DO meter (EUTECH, CyberScan DO 300) |
| Dissolved Oxygen | DO meter (EUTECH, CyberScan DO 300) |
| Turbidity | Turbidity meter (EUTECH, TN 100) |
| pH | Multi parameter analyzer (HATCH, Sension 156) |
| Electrical Conductivity (EC) | Multi parameter analyzer (HATCH, Sension 156) |
| Ammonium nitrogen | 4500 $NH_3$ F Phenate method |
| Nitrate nitrogen | Salicylic Acid method |
| Alkalinity | Potentiometric Titration |

Table 2. Water quality characteristics of *Malwathu Oya* cascade-I

| Water quality parameter | Study period Average | | Dry period (September) | | Wet period (December) | |
|---|---|---|---|---|---|---|
| | Value | SD | Value | SD | Value | SD |
| Temperature ($^{0}$C) | 29.8 | 1.9 | 31.6 | 2.3 | 26.8 | 1.0 |
| Dissolved Oxygen (ppm) | 5.6 | 2.8 | 10.3 | 5.2 | 4.8 | 0.9 |
| pH | 7.4 | 0.5 | 7.6 | 0.5 | 7.5 | 0.4 |
| Electrical Conductivity (dS/m) | 0.53 | 0.47 | 1.48 | 0.95 | 0.33 | 0.12 |
| Turbidity (NTU) | 9.7 | 17.3 | 57.5 | 47.2 | 6.4 | 6.8 |
| Ammoniacal nitrogen (ppm) | 1.05 | 1.03 | 0.92 | 0.56 | 1.55 | 0.17 |
| Nitrate nitrogen (ppm) | 2.01 | 1.61 | 0.91 | 0.13 | 1.64 | 0.25 |
| Alkalinity (ppm) | 110 | 33 | 143 | 33 | 91 | 37 |

## Results and Discussion

***Electrical Conductivity (EC):***

Electrical conductivity of the water is due to the presence of dissolved salts in the water. Significantly higher ($p<0.05$) EC values were recorded during September, which represents the dry period as compared to December, which represents the wet period. Increased conductivities during the dry period could be expected due to higher total ionic concentration aggravated by low rainfall and high evapotranspiration [4,5,6].

During the study period, significant increase ($p<0.05$) of EC levels from top to lower order tanks were identified. This result agreed with the previous studies conducted at Navodagama Kahagollewa and Paranahalmillewa cascades [7]. Based on EC values of water, restriction levels to use as an irrigation water source can be classified as, no restriction (<0.7 dS/m), slight to moderate restriction (0.7 – 3.0 dS/m) and severe restriction (>3.0 dS/m)[8]. There is a slight to moderate restriction to use tank waters in lower order tanks in both wet and dry periods. In middle order tanks, there is a slight to moderate restriction to use tank waters in dry period but no restriction during the wet period. There is no restriction to use tank waters in top order tanks for irrigation in both wet and dry periods. Variation of EC of three orders of tanks during the study period are shown in Figure 2.

Different fish species act differently on maintaining osmotic pressure; therefore optimum range of electrical conductivity for fish production differs from species to species. However some ranges as “desirable range” (0.1- 2 dS/m) and “acceptable range” (0.3 - 5 dS/m) are recommended[9]. Considering the EC values, all tank waters can be classified as desirable or acceptable for aquaculture.

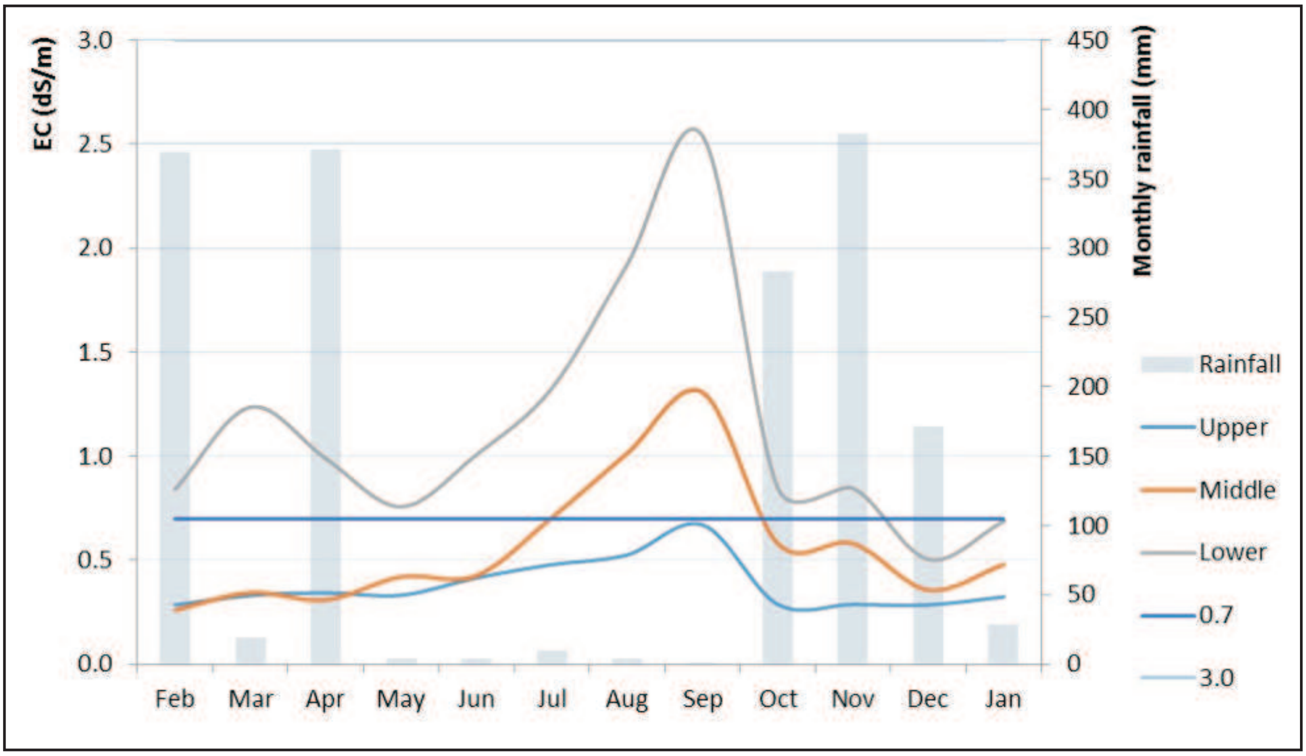


Figure 2. Temporal variation of EC in the *Malwathu Oya* Cascade-I

**Temperature**

Temperature exerts a major influence on biological activities and growth. The optimum temperature range for many species of warm water fishes is 24 to 30$^0$C. However, it is proved that, water slightly warmer than optimum provides better growth and food conversion of fishes, than low temperature[10] When considering the temporal variation of water temperature, dry period recorded significantly higher ($p<0.05$) temperature compared to the wet period. It resulted by hot environment with less amount of water in the tanks due to peak period of the dry season and relatively cool environment with water filled tanks up to full supply level (FSL) during the wet period. Although tanks were at FSL during March and April, water temperature was quite higher due to hot environment conditions. Months of June and July recorded relatively lower water temperature values, which may have resulted by heavy energy losses due to evaporation enhanced by high wind speeds recorded during that period. Most part of the year recorded good water temperatures vital for inland fisheries. Although, the water temperatures during the dry season were quite higher than the optimum range, no deaths of fishes were observed.

***Dissolved Oxygen***

Dissolved oxygen (DO) can be considered as the most important among the water quality parameters for trouble-free fish production. Sources of dissolved oxygen in the aquatic environment include the atmosphere and photosynthesis. This depends on its solubility while a loss of oxygen includes respiration, decay by aerobic bacteria and decomposition of dead decaying sediments [11]. Desirable concentration of dissolved oxygen for most fish is 5 ppm and above [12]. Among the tanks which has water year around, all tank waters except Nelumkanniya recorded average DO levels over 5 ppm. Nelumkanniya tank water recorded values less than 5 ppm of DO level for over 7 months during the study period. However, although, no deaths of fishes were observed; several complaints about low growth of fishes were received during the informal disscussions.

During the wet period, significantly lower ($p<0.05$) DO levels were recorded compared to the dry period. This depression in DO level could be due to chemical and biological oxidation process in water, encouraged by sediment inflows loaded with organic materials and lesser photosynthesis rates of aquatic plants, during rainy season as compared to the dry season [4,6,13,14].

***pH***

pH determines the solubility and biological availability of some nutrients as well. pH levels of tanks in the cascade varied without any specific pattern or trend. However, pH levels of the tanks in the cascade were not exceeding the critical levels for irrigation (6.5 – 8.4) or inland fisheries (6 - 9) during sampling period.

***Turbidity***

High variation of tubidity levels were recorded during the study period. During the dry period, significantly higher ($p<0.05$) turbidity levels were recorded as compared to the wet weriod. It was as a result of distubances made by the people and animals during the dry period when the water was scarce. However, turbidity levels of tanks in the cascade were not exceeding the critical levels for irrigation and inland fisheries during sampling period.

***Alkalinity***

*A*lkalinity levels can vary with the location, season, plankton population and nature of bottom deposits[15]. During the dry period, significantly higher ($p<0.05$) alkalinity levels were recorded compared to the wet period. Similar results were reported by various authors with different conditions [5,15,16]. *I*ncreased conductivities during the dry period could be explained as higher total ionic concentration aggravated by low rainfall and high evapotranspiration. Acceptable level of alkalinity for fresh water aquaculture is reported as 40 – 200 ppm [15]. Alkalinity levels over 300 ppm have been reported to adversely affect the spawning and hatching of freshwater fish [11]. During the study period all the tanks reported alkalinity levels within the range of 40 – 200 ppm. Therefore all tanks can be identified as good potential areas for inland fisheries. All tank waters are within the usual range of alkalinity in irrigation water which is 0 – 600 ppm [8]

### *Nitrate Nitrogen*

High variation of nitrate nitrogen levels were recorded during the study period. During the wet period, significantly higher ($p<0.05$) nitrate nitrogen levels were recorded compared to the *dry period.* Lower order tanks in the cascade recorded relatively higher average nitate nitrogen level of 2.4±1.5 ppm compared to middle order tanks of 2.0±1.3 ppm and upper level tanks of 1.9±1.2 ppm. However, the variation between the three orders are not significant *($p>0.05$)*. Similar results have been reported in Thirappane and Mahakanumulla cascades [17]. High concentrations of nitrate nitrogen in wet period as well as in the lower order tanks of the cascade may have resulted due to washouts of fertilizers, and animal excreta from upper catchments. Even with higher water levels in the tanks, just after starting the croppping season, tanks shows relatively higher concentrations of nitrate nitrogen (May – 2.8±1.5 ppm, June – 3.1±1.6 ppm, October - 3.4±0.7 ppm, November – 2.9±0.8 ppm) compared to the other months. Similar results were reported in Thirappane and Mahakanumulla casecades [17]. These increments also proved that fertilizer and animal excreta washouts during the rainy season. However, all tank waters in the cascade did not exceed maximum limit of nitrate nitrogen level (30 ppm) during the study period. Heavy growth rate of nitrogeous plants like Salvinia were observerd in all tanks during the study period. Though most of the plants were washed out during the flood periods during late 2010, most tanks were again invaded within 2-3 monthsby these plants . This indicates that, these plants absorbed nitrate from the waters, which carry from catchment areas. Lower nitrate nitrogen levels of tanks could be a reflection of heavy growth rate of aquatic plants in the presence of ample amounts of other nutrients as well. [18]

### *Ammoniacal Nitrogen*

High variation of ammoniacal nitrogen levels were recorded during the study period. During the wet period, significantly higher ($p<0.05$) ammoniacal nitrogen were recorded compared to the dry period. The proportion of toxic ammonia to total ammonia is 2.5% in waters with pH level at 7.5 and temperature at $30^0$C [19]. Usually ammonia nitrogen is converted from toxic ammonia ($NH_3$) to nontoxic ammonium ion ($NH_4^+$) at pH below 8.0. Although little higher levels of total ammoniacal nitrogen were recorded, pH around 7.4 ensures that, there is minimal risk of ammonia toxicity (estimated ammonia level is "0.03 mg/l " range 0.00 - 0.14) in these tanks. Ammonia is highly toxic at levels less than 0.1 mg/l to several fishes, but tropical species (carps and tilapias) can withstand ammonia levels over 3 – 4 mg/l . Almost all tanks in the cascade reared tropical fishes that also ensured that there was minimal risk of ammonia toxicity for aquaculture in this cascade. Total ammonia nitrogen level of the tanks in the cascade were within the ususal range of ammoniacal nitrogen in irrigation water, which is 0-5 mg/l [8].

### Conclusion

Both spatial and temporal variation of water quality parameters can be seen in the cascade during the study period. Deterioration of water quality was recorded From top to bottom. This situation became worst during dry periods compared to wet period. However water quality is still good for irrigation even in dry period in top and middle parts of the cascade. Water resources at the bottom of the cascade showed slight to moderate salinity conditions during dry period. According to the measured water quality parameters, all the tanks except Nelumkanniya showed suitable conditions for inland fisheries. Nelumkanniya which belongs to the middle part of the catchment showed low dissolved oxygen level, which it may badly affect the fisheries sector.

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