Sustainable Management of *Malwathu Oya* Cascade-I: Present Status and Future Needs

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***Abstract*—Village tank cascade System is an old age art of irrigation technology presence, especially in North Central dry zone of Sri Lanka. Some of these cascades were already evaluated but most of them are not yet. In *Malwathu Oya* Cascade-I, no any comprehensive study was carried out yet, therefore this study aimed conduct a comprehensive study of *Malwathu Oya* cascade-I including demarcation of meso and micro catchments of this cascade, understanding of characteristics and hydrological endowment of the cascade, estimating tank water storage, runoff and irrigation water demand etc. Catchment, water spread and commanding areas of the individual tanks were measured and tank storage, effective runoff to tanks, irrigation water demand and cascade outflow were estimated. With the results, cascade was evaluated for hydrological endowment of the cascade, cascade water surplus and potential water availability.**

***Malwathu Oya* cascade-I is a branched type large cascade with the form index of 3.6. The total area of the cascade is 25.88 square kilometers with overall length of 7.1 kilometers. Total water spread area of the tanks and total commanding area of the tanks are 2.57 and 2.81 square kilometers respectively. Tank water supply adequacy showed that, cascade has adequate source of water to cater the irrigation requirement of the command area. All the individual tanks in the cascade except *Kudawewa, Palugaswewa* and *Sattambikulama* showed adequate storage capacity. According to the ratio of cascade area to the total tank water surface area of the cascade and ratio of cascade command area to the total tank water surface area, the cascade can be identified as a cascade with good hydrological endowment and stability. According to the cropping intensity of the cascade, cascade can be categorized as a well performing cascade.**

***Index Terms*—cascade, cropping intensity, form index, hydrological endowment**

I. Introduction

WATER scarcity is one of the most prominent constraints for agricultural cropping in the dry zone of Sri Lanka. Hence, historically as well as during the past few decades, the agricultural cropping was practiced using either rainwater or water collected in village tanks and water diverted from the wet zone by major irrigation schemes. However, trans-basin diversions are limited only to some areas of the dry zone, village tanks are playing major role in dry zone agriculture. As evidence, large number of village tanks (over 15000) that are distributed across the landscape of the dry zone. Distribution of these tanks in dry zone undulating landscape doesn't show any random pattern; rather they are orderly placed to form a cascade. Village tank cascade system is an ancient small scale irrigation technology presence, especially in North Central dry zone of Sri Lanka. As defined by Madduma Bandara (1985), cascade is 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. A cascade of tanks is usually made up of 4 to 10 individual small tanks, with each tank having its own micro-catchment, but where all of the tanks are situated within a single meso-catchment basin. The advantage of such a system is that excess water from a reservoir along with the water used in its command area is captured by the next downstream reservoir and is thus put to use again in the command area of the second reservoir. This water is thus continuously recycled. This system helps to surmount irregularly distributed rainfall, non-availability of large catchment areas and the difficulty of constructing large reservoirs.

In *Malwathu Oya* river basin, around 180 cascade systems in 15 sub watersheds were already identified. Some of these cascades were already evaluated but most of them are not yet. *Malwathu Oya* Cascade-I is located in DL_{1b} agro ecological region of Sri Lanka which is a meso catchment of *Nuwara Wewa* catchment (part of *Malwathu Oya* river basin). It belongs to *Nuwaragam Palatha - East* and *Mihintale* divisional secretariat areas in Anuradhapura district close proximity to the city of Anuradhapura. This cascade system consists of twelve small tanks (*viz: Maha Kalaththewa, Kuda Kalaththewa, Halmillawewa, Bandialankulama, Kammalakkulama, Thariyankulama, Nelumkanniya, Sattambikulama, Halmillewa, Palugaswewa Illuppukanniya and Kudawewa*) surrounded by villages. No any comprehensive study of this cascade was carried out yet, therefore this study aimed to conduct a comprehensive study on this cascade including demarcation of meso and micro catchments of this cascade, understanding of characteristics and *hydrological endowment of the cascade, estimating*

DOI: 10.5176/0000-0000_1.1.9

tank water storage, runoff and irrigation water demand etc.

II. Materials and Methods

A. Catchment, water spread and commanding areas

Total area of the cascade, water spread area of individual tanks and catchment area of individual tanks were demarcated using satellite images and tools using Google Earth Pro software and verified using Megelan 300 GPS instrument and field observations. Measured catchment area, water spread area and commanding area of each tank are shown in Table 01.

B. Estimation of tank storage

Total tank capacities were estimated using the empirical relationship (Equation 01), proposed by Arumugam (1957) and confirmed by Sakthivadivel *et al.* (1994). Effective tank water depths were measured using a rod. Estimated tank storages at full supply level are shown in Table 02.

$$S_t = 0.4 \times A_t \times d \quad (01)$$

S_t - Storage capacity of the tank
A_t - Surface area at full supply level
d - Depth from full supply level to the sill of the tank sluice (effective tank depth)

C. Estimation of effective runoff to tanks

Since no gauging is practiced in village tanks, it is hard to collect actual runoff data of village tanks. After studying of 50 cascades and 699 tanks in Anuradhapura district, Sakthivadivel *et al.* (1996) proposed relationships to estimate the effective runoff for an individual tank (R_o) using easily measurable parameters such as tank catchment area (T_{ca}) with appreciable accuracy. The relationship between R_o and T_{ca} (Equation 02) was used to estimate the effective runoff to individual tanks of the cascade. Estimated effective runoffs to the individual tanks of the cascade are shown in Table 02.

$$R_o = 0.2738T_{ca} - 1.4861 \quad (02)$$

D. Estimation of irrigation water demand

Estimation of irrigation demands leads to better water management and crop security. However, there are no proper water measurement techniques or records about water releases in village tanks. Sakthivadivel *et al.* (1996) proposed a relationship to estimate tank system irrigation water demand (I_t) using tank command area (A_{co}) in village tanks (Equation 3). Estimated irrigation water demands of the individual tanks of the cascade are shown in Table 02.

$$I_t = 5.7947 + 0.7078A_{co} \quad (03)$$

E. Estimation of cascade outflow

Sakthivadivel *et al.* (1996) also proposed a relationship to estimate the cascade outflow (R_c) using total cascade area (A_c) total tank water surface area in the cascade (A_{ws}) and the total command area in the cascade (A_{co}) with the following regression equation.

$$\log R_c = 1.4582 + 0.0003(A_c - A_{ws} - A_{co}) \quad (04)$$

F. Evaluation of cascade water surplus

Cascade water surplus plays vital role in terms of environmental protection. Calculation of cascade water surplus also provides an idea about scale of water use within the cascade. Therefore for better management of cascade it is vital to estimate the cascade water surplus. To evaluate the cascade water surplus, cascade outflow per unit area (R_e) to be determined (Equation 05) using the ratio of the cascade outflow (R_c) and total area of the cascade (A_c) as proposed by Sakthivadivel *et al.*(1996).

$$R_e = R_c/A_c \quad (05)$$

Sakthivadivel *et al.* (1996) also proposed a relationship (Equation 06) to estimate cascade water surplus (W_{sc}) using cascade outflow per unit area (R_e) and mean annual rainfall (R_{50}).

$$W_{sc} = R_e/R_{50} \quad (06)$$

When considering the mean annual rainfall in Anuradhapura district as 1200 mm, Sakthivadivel *et al.* (1996) estimated that if W_{sc} is greater than 0.05, the cascade has surplus water. Moreover, in any cascade where the water surplus is less than 0.05, no tank expansion or augmentation can be considered.

G. Hydrological endowment of the cascade

The ratio of cascade area (A_c) to the total tank water surface area in the cascade (A_{ws}) and ratio of cascade command area (A_{co}) to the total tank water surface area (A_{ws}) can be used to understand the hydrological endowment and system stability of a cascade. Sakthivadivel *et al.* (1994) and Sakthivadivel *et al.* (1996) developed limits for aforesaid ratios for individual tanks and generalized to cascades as, ratio of A_c to A_{ws} should be grater 8 and ratio of A_{co} to the A_{ws} should be less than 2.

H. Tank water supply adequacy

Though the cascade is hydrologically well endowed, individual tanks within the cascade may not be so. Therefore it is vital to estimate water supply adequacy of a tank. Water supply adequacy is evaluated using the ratio of the effective runoff to the tank (R_o) and irrigation requirement (I_t), in the main season of cultivation (Sakthivadivel *et al.*, 1997). As explained by Sakthivadivel *et al.*, (1997), R_o/I_t is greater than 1, the tank has adequate water supply to meet the irrigation requirement; otherwise, additional water is needed to meet this requirement.

I. Tank storage adequacy

The storage capacity of a tank (S_t) represents the capability of the tank to store the runoff water and release it to meet the irrigation requirement (I_t). Tank storage adequacy can be evaluated using the ratio of S_t and I_t as explained by Sakthivadivel *et al.,* (1997). After analyzing of field observations and farmer perceptions, Sakthivadivel *et al.,* (1997) proposed that, the ratio of S_t and I_t should be greater than 0.3 to provide adequate water supply to meet the irrigation requirement. Tank storage adequacy of individual tanks of the *Malwathu Oya* cascade I was also assessed using aforesaid procedure and limits.

J. Cropping Intensity

Agricultural performance of a tank is a measure of the extent to which the command area of a tank is cultivated with irrigation water successfully in *maha* seasons. It is evaluated using the average *maha* season cropping intensity (TCI_m) for the past few consecutive seasons (Sakthivadivel *et al.,* 1997). Cultivation data of last 5 years (2007-2011) of the cascade were collected from the records of farmer organizations. Using average cultivated area (A_{cu}) of individual tanks for last 5 years and commanding area (A_{co}) of individual tanks, TCI_m were calculated (equation 07). Cascade cropping intensity (CCI_m) was calculated as weighted average of TCI_m to provide better representation (Equation 08).

$$TCI_m = \frac{A_{cu}}{A_{co}} \tag{07}$$

$$CCI_m = \frac{\sum_{i=1}^{N} TCI_{mi}.A_{coi}}{\sum_{i=1}^{N} A_{coi}} \tag{08}$$

Sakthivadivel *et al.,* (1997) reported that if any individual tank or cascade in Anuradhapura district recorded CI_m (or CCI_m) more than 60%, the tank or cascade can categorize as well performing tank or cascade.

K. Potential water availability

Potential water availability for a tank could be evaluated using two easily determined ratios. The ratio of tank catchment area (T_{ca}) to tank water spread area (T_{ws}) represents the hydrologic potential of the tank. If this ratio is greater than 7.5, then the tank usually has sufficient water to improve its cropping intensity. The second ratio, tank command area (T_{co}) to T_{ws}, describes the adequacy of the tank storage capacity to serve the command. This ratio should be less than 2 in order to serve the commanding area well (Sakthivadivel *et al.,* 1997). Potential water availability and adequacy of the tank storage to serve the commanding area of each tank of the cascade were assessed and results were shown in Table 01.

L. Rainfall

Mean annual rainfall, seasonal rainfall, annual and seasonal dependable rainfall values were calculated using a set of homogeneous data over 40 years from 1971 to 2010.

M. Present status

Present status of the cascade was assessed using participatory rapid appraisal tools.

III. Results and Discussion

A. Characteristics of the cascade

The total area of the *Malwathu Oya* cascade-I is 25.88 square kilometers with overall length of 7.1 kilometers. Total water spread area of the tanks and total commanding area of the tanks are 2.57 and 2.81 square kilometers respectively. A classification of small cascades has been proposed by Sakthivadivel *et al.* (1994) based on its size class and form of the cascade. Size class of the *Malwathu Oya* cascade-I is large (meso catchment area is between 5000 – 7500 acres*) (*1 acre = 0.40469 ha). The cascade is a branched type cascade with the form index (Overall area of the catchment to its overall length) of 3.6. Since this cascade has two prominent main axis as water flow through the *Maha Kalaththewa* tank and water flow through the *Kuda Kalaththewa* tank, form index of *Malwathu Oya* cascade-I is quite higher than the average form index of cascades (1.15-2.5). Due to this nature some authors mentioned this area as two cascades named *Maha Kalaththewa* cascade and *Kuda Kalaththewa* cascade. However, drainage waters of both *Kuda Kalaththewa* and *Maha Kalaththewa* tanks are merged before it reached to the *Nuwara Wewa.* Therefore in this study, areas under both main axes are demarcated as a single cascade called *Malwathu Oya* cascade-I.

B. Hydrological endowment of the cascade

The ratio of cascade area (A_c) to the total tank water surface area of the cascade (A_{ws}) is 10.1. The ratio of cascade command area (A_{co}) to the total tank water surface area (A_{ws}) is 1.1. With these two values, the cascade can be identified as a cascade with good hydrological endowment and stability.

C. Tank water supply adequacy

Tank water supply adequacy of individual tanks of the *Malwathu Oya* cascade-I was assessed using aforesaid procedure and limits. Results revealed that, since all the individual tanks in the cascade recorded values greater than 1 for aforesaid ratio, cascade has

adequate source of water to cater the irrigation requirement of the command area.

D. Tank storage adequacy

Results revealed that, since all the individual tanks in the cascade except *Kudawewa*, *Palugaswewa* and *Sattambikulama* recorded values greater than 0.3 for aforesaid ratio, tanks have adequate storage capacity to cater the irrigation requirement of the command area.

E. Cropping Intensity

Cropping intensity of the cascade (CCI_m) was 90%. Results revealed that the cascade can be categorized as a well performing cascade.

F. Potential water availability

Results revealed that, potential water availability in *Maha Kalaththewa, Bandialankulama, Nelumkanniya, Tariyankulama* and *Kammalakkulama* tanks were not satisfactory. Moreover, adequacy of the tank storage to serve the command in *Sattambikulama* and *Palugaswewa* tanks were also not in satisfactory level. Therefore no further expansion of commanding area or cropping intensity is recommended for the cascades except *Kuda Kalaththewa, Halmillewa, Halmillawewa, Illuppukanniya* and *Kudawewa*. However, according to the field observations and field survey data, *Kudawewa* and *Halmillewa* tanks haven't any water during dry seasons due to limited capacity resulted by heavy siltation of these tanks. Therefore, at present, no any provision to expand the cropping intensity in these two tanks. There was no rehabilitation of these tanks were carried out in recent past, immediate rehabilitation is recommended for these two tanks. Since water management was given least attention in all areas of the cascade, a practice in water management and attitudinal change on water and environmental conservation is urgently required.

TABLE I
POTENTIAL WATER AVAILABILITY AND ADEQUACY OF THE TANK STORAGE TO SERVE THE COMMAND

Tank	T_{ca} (ha)	T_{ws} (ha)	T_{co} (ha)	T_{ca}/T_{ws}	T_{co}/T_{ws}
Maha Kalaththewa	355.0	50.0	54.7	**7.1**	1.1
Bandialankulama	60.2	8.1	7.9	**7.4**	1.0
Kuda Kalaththewa	309.0	26.0	23.8	11.9	0.9
Nelumkanniya	165.3	28.7	38.2	**5.8**	1.3
Sattambikulama	110.2	9.8	19.9	11.2	**2.0**
Halmillewa	111.4	8.6	12.8	12.9	1.5
Halmillawewa	260.8	33.2	25.3	7.9	0.8
Palugaswewa	87.3	6.4	13.3	13.7	**2.1**
Illuppulanniya	240.5	30.5	19.2	7.9	0.6
Kudawewa	89.3	4.0	6.9	22.6	1.8
Tariyankulama	122.2	20.8	31.7	**5.9**	1.5
Kammalakkulama	156.7	31.3	27.1	**5.0**	0.9

TABLE II
ESTIMATED TANK STORAGES, EFFECTIVE RUNOFF AND IRRIGATION WATER DEMAND

Tank	Tank storage at FSL (ha.m)	Effective runoff (ha.m)	Irrigation water demand (ha.m)
Maha Kalaththewa	51.0	95.7	42.0
Bandialankulama	8.3	15.0	11.4
Kuda Kalaththewa	26.9	81.5	25.3
Nelumkanniya	21.4	46.2	32.8
Sattambikulama	9.1	28.7	19.9
Halmillewa	8.6	29.0	14.9
Halmillawewa	32.5	69.9	31.2
Palugaswewa	7.1	22.4	15.2
Illuppulanniya	37.1	64.4	21.4
Kudawewa	3.2	23.0	10.7
Tariyankulama	28.5	32.0	28.2
Kammalakkulama	28.4	41.4	28.9

G. Rainfall

Mean annual rainfall and dependable annual rainfall at 75% probability level in Anuradhapura over the period of 1971 – 2010 are 1255 mm and 1075 mm

respectively. The cascade area shows bimodal rainfall pattern with prominent peaks in months of November and April. However, month November shows relatively higher rainfall compared to the month April. First inter monsoon (FIM), south west monsoon (SWM), second inter monsoon (SIM) and north east monsoon (NEM) contribute 18%, 19%, 38% and 25% respectively to the mean annual rainfall in Anuradhapura. Due to high rainfall during the SIM and NEM, almost all tanks in the cascade are spilling out several times per year during the period of October to February.

H. Present status

The reservation areas or closer catchment of all the tanks were encroached by the people for housing and farming. Illegal sand mining, gravel mining and dumping of municipal waste were also can be seen within the cascade. Most of the tanks were covered with aquatic weeds such as *Salvinia molesta* and *Eichornia crassipes* and signs of eutrophication are also evident in most tanks. Farmers complained about reduction of water holding capacity due to heavy siltation of tanks. As a result, most of the tanks facilitating only for *Maha* season and lack of irrigation water has become a problem in *Yala* season. *Kattakaduwa* reservation area of the tank which is meant for salinity management is neglected and as a result the paddy fields show signs of high salinity.

IV. Conclusions And Recommendations

Malwathu Oya cascade-I is a branched type large cascade with the form index of 3.6. The total area of the cascade is 25.88 square kilometers with overall length of 7.1 kilometers. Total water spread area of the tanks and total commanding area of the tanks are 2.57 and 2.81 square kilometers respectively.

Malwathu Oya cascade-I can be identified as a cascade with good hydrological endowment and stability and can be classified as a well performing cascade. Though the cascade showed adequate source of water to cater the irrigation requirement of the command area, few individual tanks (*Kudawewa*, *Palugaswewa* and *Sattambikulama*) showed inadequacy of storage capacity to cater the irrigation requirement of the command area. Therefore, early attention on rehabilitation of these tanks is required.

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