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Viability of Ulpotha Micro-cascade Rehabilitation with its Indigenous Irrigation Systems-Sri Lanka

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Abstract

The main purpose of this article is to study the viability of Ulpotha micro-cascade rehabilitation with its traditional irrigation system. Rehabilitation of Ulpotha with its natural resources was started on pilot basis in 2005 and completed in the year 2010. This is the high time to study the impacts of Ulpotha rehabilitation with its traditional irrigation system. Extensive studies on traditional irrigation practices were commenced in 2013 and more positive impacts of the Ulpotha rehabilitation and the use of traditional irrigation were noted. The traditional irrigation system is more appropriate for this location as paddy is the main cultivation in Yala and Maha. Traditional flood irrigation also supports environment, ecology, biodiversity, agriculture in addition to socio-cultural and religious / spiritual values.

Keywords: Cascade; Cropping intensity; Water run-off; Ecology; Endemic; Cultivation calendar; Cultivation meetings

Introduction

Galkiriyakanda cascade is located in the northern part of Kurunegala District in Sri Lanka. The main axis from north and south is around 10 kilometres and stretches through two divisional secretariat divisions namely Ehatuwewa and Polpithigama. This cascade covers more than 1,100 hectares in the vicinity. Galkiriyakanda is also a meso-cascade or a catchment due to its geotechnical features. Under this meso-catchment, a number of micro-cascades (catchments) are located. Among them "Ulpotha micro cascade" is the largest one and it has been selected to study the impacts of its renovation done by the 'Sri Lanka Australia Natural Resource Management Project (SLANRMP) (Figure 1).

Objectives of the Study

Main objectives of this study could be categorised as general and specific. Initially, the big picture of the selected topic is covered by the general objective and is overarching the entire scope of the study.

General objective

The main objective of this study is to assess the viability of Ulpotha micro-cascade rehabilitation with its traditional irrigation system [1].

Specific objectives

The specific areas of the study and the intervention needed are covered under following specific objectives.

- To identify the root causes of cascade / forest degradation [2].
- To study whether the traditional irrigation system fits with community needs and the Ulpotha micro-cascade.

Note: The traditional irrigation network is best suit with the geo-technical aspects of Ulpotha micro-cascade. This system was developed naturally over the years and micro tanks assist to store and release water as and when necessary for cultivation works. Rehabilitation of traditional irrigation network in Ulpotha is technically viable and financially feasible (Source – SLANRM Office, 2011).

Ulpotha Micro-cascade (The Study Area)

A number of micro-cascades (catchments) are visible surrounding the Galkiriyakanda meso-cascade. Among them "Ulpotha is the key micro-cascade with more than 50 micro tanks, irrigation canals and water streams. Ulpotha micro-cascade is located in the south western part of Galkiriyakanda meso-cascade and supports a number of villages and communities to carry out their agricultural livelihood (Figure 2). Based on the importance and the (medium) size, Ulpotha micro-cascade has been selected for the renovation. According to irrigation experts, Ulpotha micro-cascade is also a 'Leaf Shape Cascade' due to its geotechnical features and functional shape (Figure 3).

Ulpotha micro-cascade also enriches nearly 56 tanks through its irrigation networks of micro-cascade. All drainage flow water ends in the middle size reservoir called 'Maha Gala Wewa'. The significant features of this irrigation network in micro-cascade are:

- Small Tanks (Kuluwewas) are being used to improve biodiversity while promoting paddy cultivation and other crops in Maha season.

Figure 1: A distance view of Galkiriyakanda.

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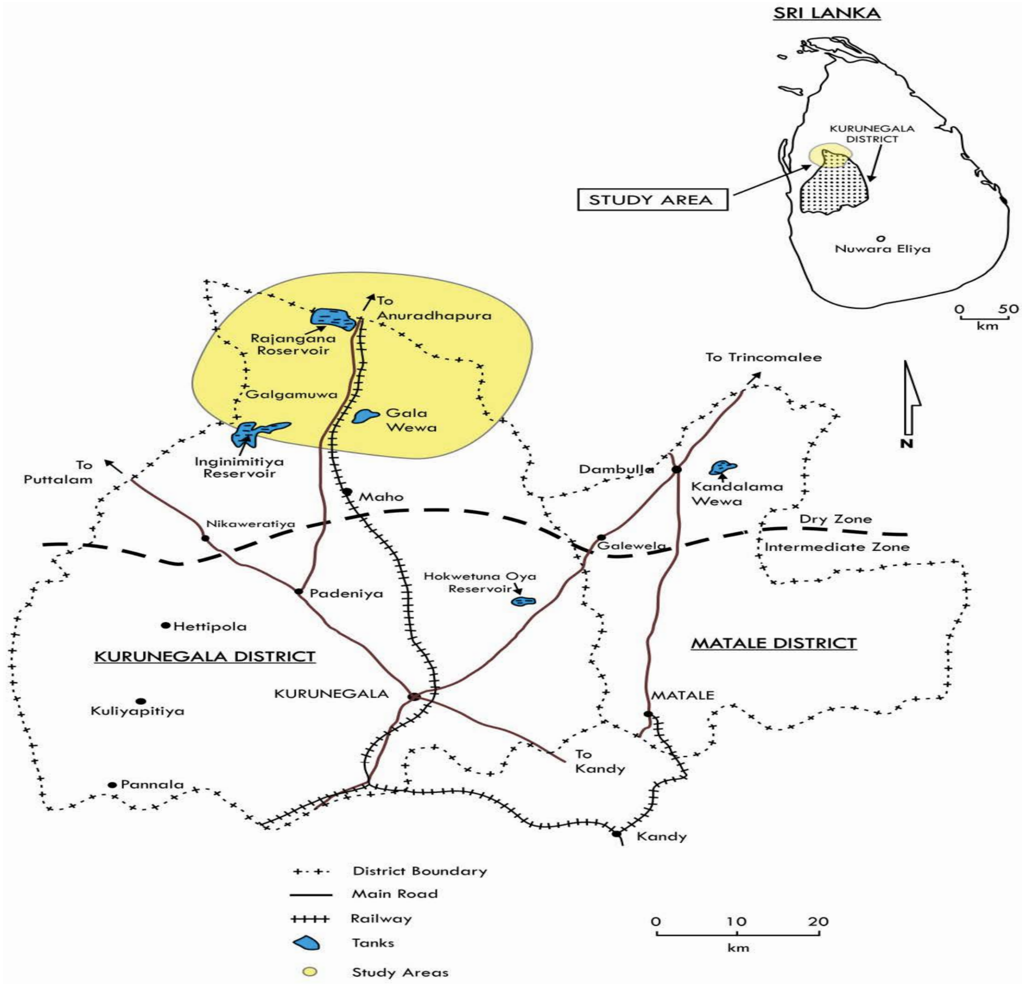

Figure 2: Location of the study area.

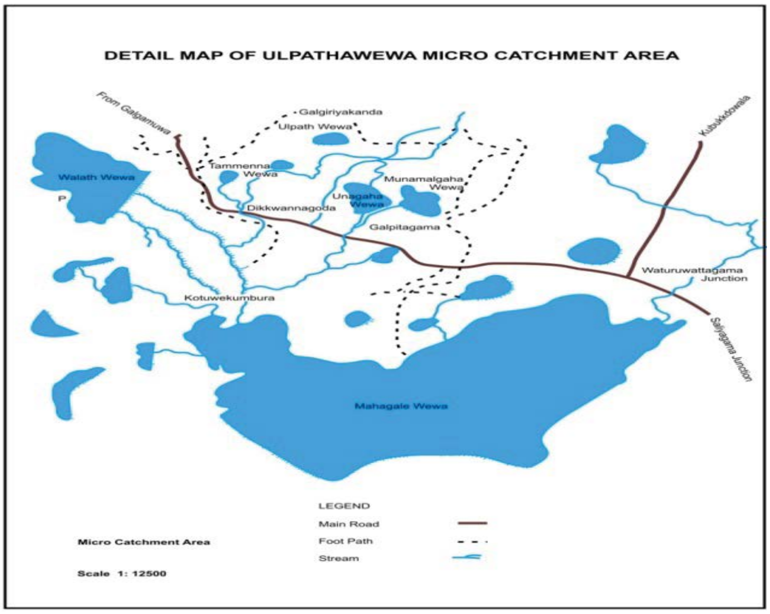

Figure 3: Leaf Shape Ulpotha Cascade.

- Chena cultivation (slash and burn) also practices during the Maha season in upland areas. Supplementary water use for Yala cultivation.
- Small tanks (Kuluwewas) will not hold sufficient water for Yala cultivation due to siltation.
- During Yala season, communities engage in paddy cultivation under the Maha Gala Wewa. Farmers do not cultivate any crops under this tank in Maha season and keep water for Yala (season) cultivation.
- If sufficient water is not available in Maha Gala Tank for Yala cultivation, farmers practice 'Bethma System' in order to support all members of the farmer organisation. According to the Bethma system, farmers divide the cultivable area equally among the number of farmers. This enables each and every farmer to cultivate at least 0.5 acre under the tank even with the low water capacity in the tank.
- Communities cultivate vegetable and fruits in their home gardens in both Yala and Maha. Village home gardens are rich with fruit, food and timber trees.

This system proves that communities in this area could live comfortably if all components of irrigation networks and cascade operate properly. Damages in the cascade system will harm the community life pattern as well as food security aspects [3].

As explained by Bandara et al. [4], several types of small tanks (Kuluwewas) and traditional irrigation systems could be seen in a cascade and the same features are visible in Ulpotha micro-cascade as well. Some of the tanks in this cascade are not for cultivation purpose. But they help irrigated agriculture in the downstream by storing and releasing water at a given time. The various types of micro tanks and irrigation networks operate in Ulpotha micro cascade (Figure 3).

Results of the Field Study

Under this section, results of the field level studies and surveys are being discussed under two categories. These two areas specifically selected to cover the two main objectives of the study.

- Identification of root causes for cascade degradation.
- Study the viability of micro-cascade renovation with its traditional irrigation.

The Galkiriyakanda Cascade has been degraded over the years due to many reasons. The main reason for cascade degradation was the reduction of forest cover. As a result of this, soil erosion and water run-off was high. As such, similar reasons identified have been impacted on forest degradation and as well as cascade degradation. Forest is the main protective cover for other cascade resources like soil, dams (tank bunds), irrigation network and other creatures. In addition to forest destruction, community encroachments, mega development programs, forest fire, weak monitoring and management, poverty level of adjacent communities and internal conflicts or war situation also impacted on cascade destruction.

Forest destruction and degradation

Forest decline is interpreted as deforestation, forest degradation or a combination of both. The FAO defines deforestation as the "Sum of all transitions from natural forest classes (continuous and fragmented) to all other classes" by FAO [5]. FAO also suggests that a minimum of 0.5 hectares is needed to qualify as a forest and therefore loss of crown cover to less than 10% for at least this area would presumably qualify as deforestation (FAO, 1994). Anyway, this is not a universally accepted definition. In addition, to deforestation, forest degradation is also a major source of forest decline. It is noted that forest degradation takes different forms and shapes, particularly on natural causes or human activities. These reasons are common factors in Kurunegala district as well (North Western Environment Authority - 2002).

The present forest cover in the district is about 212,770 hectares or 44.2% of the total land area. But the forest cover in the district was around 300 hectares in 1990 this shows the rapid deforestation in the district (Table 1).

The preliminary work in the area from 2006 to 2009 revealed a continued tendency for degradation of the cascade causing a decrease in livelihood opportunities for the people dependant on it and reduction of fauna and flora.

Rural infrastructure development

Implementation of major development programs has caused a major threat to forest and forest resources. Rural infrastructure development projects, housing, industrial development/expansion have made severe damage to the forest (FD-1990). Among them major irrigation development/rehabilitation and road development or expansion programs are significant in forest destruction. It is also observed that "greatest single cause of deforestation (responsible for 75% of the total) in Sri Lanka has been done by the accelerated Mahaweli Development Program" [6]. This observation is valid to Kurunegala district as well. The forest cover of the northern part of the district was damaged due to several irrigation development programs, road development and housing programs.

Forest fire

The Forest wild fire is also a common issue in forest degradation in the dry zone of the country. Even in Kurunegala district forest fire is a common practice by people due to various reasons. Following are the main reasons for forest fire in Kurunegala district (Figures 4a and 4b).

- Chase wild animals for poaching.
- Burning for chena cultivation (Negligence of chena cultivators).
- To obtain tender grass for cattle grazing.
- Accidental fires created by visitors.

Chena cultivation (Shifting or slash and burn)

The Forest Department of Sri Lanka has identified "Chena Cultivation" (Swidden agriculture or Slash and Burn method) as a destructive factor on forest cover. "Chena cultivation is the most widespread traditional farming system in the tropics" (FAO, 1984). Following are the main reasons for Chena cultivation:

- High community dependency on Chena for food security.

Description	Whole District	% of Total Land Area	Dry Land Area	% of Total Dry Land Area
Total land area (ha)	481,280	100%	160,400	33%
Area of natural forest (ha)	212,770	44.2%	85,108	40%
Area cultivated (Including home gardens and chena (ha)	241,830	50.2%	107,700	45%
Area of not cultivated (ha)	26,680	5.5%		

Table 1: Land use Statistics in Kurunegala.

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a b

Figure 4: How forest fire extended to catchment areas: a) Mana Enter into the forest, b) Fire enter into the forest with Mana.

- Major supplementary source of income for small farmers and lack of other sustainable income source.
- Landlessness of the people (no other land available for rain fed farming).
- Traditional attitudes to continue Chena farming practice.
- Production of the specific grains, vegetables and nutritious food.
- Low cost and low risk farming option.
- Encroachment possibilities of state lands for practicing Chena cultivation.

Increased population and encroachment

An encroachment of forest areas by people and over grazing of livestock are related matters in which local people and Forest Department often clash (Figure 5). Some people with the blessing of politicians and powerful traders/ businessmen encroach, the buffer zones of forest areas. "Since there was no strong community involvement in forest management, out-siders could deploy people to encroach the buffer zones especially in the "Island Forest" areas. The other reason for the encroachment is the increase of rural population. "The average size of a rural family is four to five" (Statistical Hand Book). The annual rural population growth is around 1.5%. Sri Lanka is one of the most densely populated countries in the world, ranking 19 in population density [4]. The per capita forest land has declined from 0.32 ha in 1956 to 0.09 ha in 1992 and 0.86 in 2010. The annual forest cover loss between 1990 and 2005 is estimated at about 1.3%. The factors related to encroachment are:

- Landlessness of the people in the vicinity of the forest.
- Lack of alternative private lands for settlements and cultivation.
- Requirement of extending lands for second generation. Source-Forest Department of Sri Lanka [7].

Poverty and environment

The link between poverty and environment degradation could be identified easily. Using community indicators, three categories of poverty have been noted in surrounding villages. They are the poorest, the poor and the non-poor.

The data show about 50% of the people consists of the poorest and the poor (Table 2). In Ihalathimbiriyawa village, most people are poor and more catchment / forest destruction also could be seen in this village. This shows us that there is a strong link between poverty and cascade/forest destruction. The forest degradation is relatively low in Walathewe village and poverty level is also comparatively low than Ihalathimbiriyawa (Box 1).

> When tree cover declines, soil fertility and water retention are reduced, soils dry out are eroded, siltation of rivers decreases storage capacity of dams (tanks) and further reduce water flow, crop yields decline as soil fertility and moisture retention declines, income and food supplies decrease.

Box 1: The Poverty-environmental cycle.

Internal conflicts and war situation

Conflict situation in Sri Lanka also badly affected the environment and forest resources. Both Army and Militants have cleared or encroached, forest not only for fighting but also for protection and training purposes. The forest along the main roads has been cleared to avoid planting bombs and anti-personal mines. Both sides have used forest timber to strengthened their bunkers and camps. This situation was a real threat for forest resources, animals and eco-systems as well. "Armed conflict frequently erupt in or near tropical forests" which are often remote from centres of government, rich with natural resources and capable of concealing armed forces.

With the experience of Sri Lanka, it is observed that more damage for forest occurred Post-war situation. With the completion of war in 2009, all displaced communities due to war situation have returned to their original villages. Then they found their houses and other properties were destroyed due to the war. Even their paddy fields were full of land mines and government was compelled to resettle them in

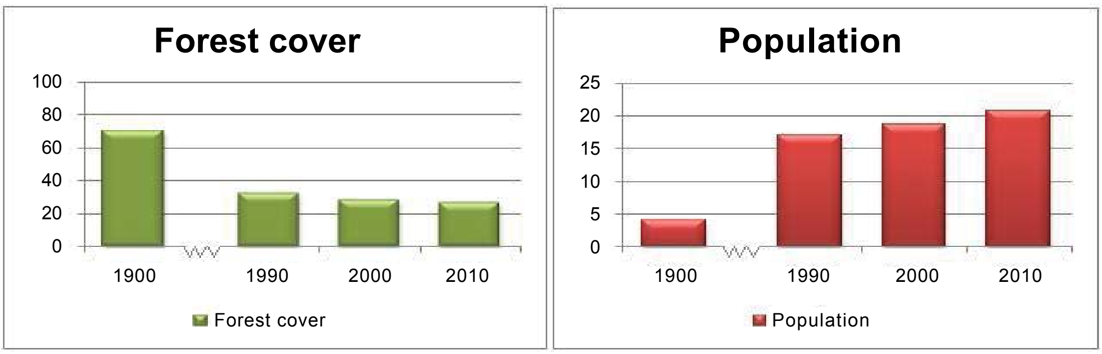

Figure 5: Forest cover against Population.

Village	Poverty Status		
	Poorest	Poor	Non-poor
Walathewa	4 (44)	3 (60)	11 (61)
Ihalathimbiriyawa	5 (56)	2 (40)	7 (39)

Table 2: Distribution of People by their Poverty Status.

alternative places. The government has identified lands in the buffer zone to resettle these families after constructing temporary houses. Again they need to clear more lands for permanent housing as well. On the other hand to improve the economic conditions of resettled families, they were given a portion of land to recommence their agricultural activities. Accordingly, large extents of lands were cleared for housing and agricultural activities (Figure 6).

Viability of Ulpotha Micro-cascade Renovation with its Traditional Irrigation System

Results of the study emphasised that indigenous irrigation in this micro-cascade is appropriate and this was validated through technical measurements as well. At the grassroots level, farming communities living around the cascade have validated the rehabilitation of Ulpotha with its traditional irrigation as a successful effort. They further said that the rehabilitated cascade improved its functions and provide sustainable benefits to downstream communities. This proves the practical application of indigenous irrigation ensures improved cascade functions with reliable cultivation practices. The validity of restoration of Ulpotha micro-cascade with its traditional irrigation was studied under following four criteria.

- Engineering viability of traditional irrigation.
- Ecological viability of traditional irrigation.
- Managerial viability of traditional irrigation.
- Financial and economic viability of traditional irrigation.

Initially, it is important to understand the nature of indigenous irrigation with its functions. It is clearly observed that traditional irrigation system in Galkiriyakanda cascade evolved over the years naturally or without any intervention by outsiders. This proves that 'traditional irrigation practices are shaped and emerged from understanding of local conditions and are modified in response to changes in ecological, geological and geographical requirements'. This has widened the functions and usage of irrigation systems in different societies. The ultimate finding was that irrigation is not limited to its physical structures, water, soil and land itself. Traditional / indigenous irrigation or hydrological system goes beyond just irrigation of crops or soil and covers environmental/ecological, agricultural, socio-economic and socio-cultural requirements of hydrological societies. Irrigation water (streams and rivers) is important for indigenous communities for their economic, religious and cultural values as well.

Engineering viability of indigenous irrigation

Traditional engineering principles and practices developed in the past are still appropriate for tropical localities and agree with modern technologies as well. Diversions, weirs, canals layout, sluice gates and spill ways are accurate irrigation structures developed in appropriate locations after considering environmental and geological conditions such as soil, slope of the land and speed of water flow (run-off). In addition to the irrigation designs and plans, the quality of materials used for construction was met with required specifications and standards for a long-term sustainability.

During transect walks in the upper cascade the study team has clearly observed the (old) traditional hydrological networks. Collection, storing and releasing of rain water through canals connected with small tanks (Kuluwewas) were the other features noted. All these constructions were done without damaging the ecological, geological and hydrological balance in the cascade. All structures have been done with earth (soil) and granite or other stones. There are no invasive materials introduced to the upper catchment. The main functions of Kuluwewas are storing and releasing of water by reducing its speed of flow (run-off) in order to minimise erosion in the catchment while enriching the eco-system. A cross section of the upper catchment presented in the diagram (Figure 7).

It should be noted that indigenous irrigation systems have been tested for many years (more than 1,000 years) and proved the efficiency and sustainability of the system. Even technically, performance of indigenous irrigation is impressive. In most cases, water losses from main canal to secondary canals are low. The main structural challenges face by irrigation engineers in rehabilitating such cascade systems include:

- Degree of slope of the land.
- Rain intensity and occurrence.

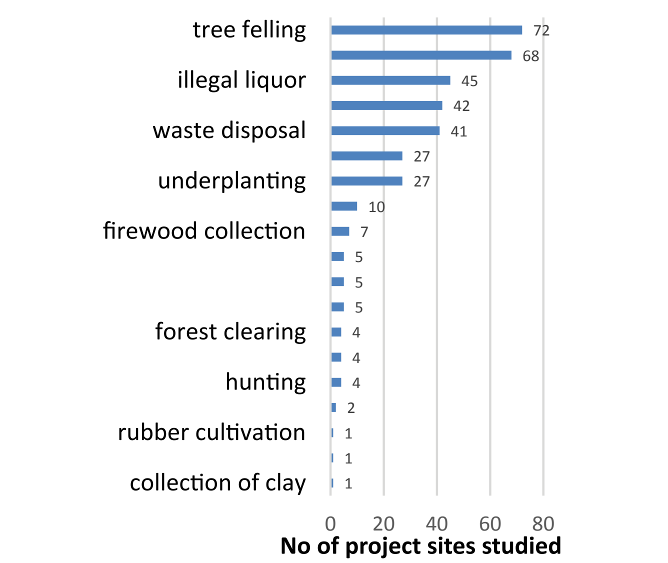

Figure 6: Threats for Forest.

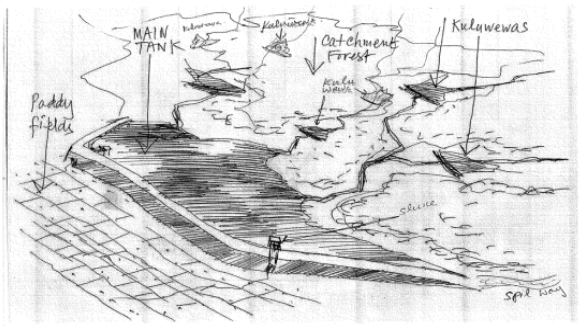

Figure 7: A cross section of the upper catchment.

- High or speedy water run-off.
- Calculation of depth of canals.
- Alignment and layout of canals.

Irrigation duty

Under this method, direct water releases and usages is being calculated. Actual water usage from channel to farms has been calculated. This method calculates the usage without adding other supplementary water sources or usage. Even rain water drainage is also not calculated. This method also illustrates that during the rainy season, water releases from channels could be reduced. This is helpful to calculate actual crop water requirements from the reservoir direct. Then Irrigation Engineers could calculate the actual water requirement and restore the balance water in reservoirs for another crop. Similarly, engineers also reduce the releases during the rainy season without wasting stored water in reservoirs (Table 3).

Water duty

Generally, water duty calculates supplementary water addition to the field. Rain water collection is also considered in this calculation. If the field receives more rain water then the irrigation duty could be reduced and it will save tank water for another crop season. The water duty in several tanks in Ulpotha cascade is given (Table 4).

Increased paddy harvest–Ihala thimbiriyawa

With restoration of cascade and proper water management results an additional harvest and additional income for rural farmers. Table 5 illustrates the incremental acerage under selected tanks and the additional income received by farmers. This shows that cascade restoration is feasible in financial terms.

Increased harvest in walathwewa

A clear increased harvest could be seen in Walathwea as well. Due to the restoration of cascade, the cultivation area has been expanded. On the other hand, an effective water management resulted in higher production or harvest. Ultimate benefits have gone to rural farmers to compensate their additional burden and risk factors (Table 6).

Ecological viable in traditional irrigation

An efficient water management system has been developed in the Ulpothe cascade through effective indigenous irrigation principles [5]. Kuluwewas or micro tanks will store rain water and release time to time as and when necessary by down-stream farming communities [8]. Similar to the upper cascade area, a well-balanced ecological landscape has been developed in main valleys and in the down-stream. These ecological balanced layouts create enabling environment for farming and rearing animals. Forest, river, tanks, pasture for cattle, paddy fields and home gardens are the important components to balance ecology in valleys and in the down-stream.

In addition, individual tank catchments and tank components were established in an eco-friendly manner. Tank catchments were developed with forest cover and close to the water spread areas were cultivated with creeping grass varieties to prevent the soil erosion. In the downstream close to the tank bund, nearly 25 to 50 feet has been allocated along the bund as a Kattakaduwa or a vulnerable area for possible damages to the tank bund from seepage and other threats. Cascade systems have an important role to manage eco-systems with flora and fauna and protection and promotion of biodiversity is the other role of a well-balanced cascade system (Figure 8).

There are a number of endemic species live in Galkiriyakanda cascade. Restoration of this cascade with its traditional hydrology system will help to protect endemic species in their home land. Any improvement to the cascade should reduce possible adverse impacts to the endemic species in the Galkiriyakanda cascade (Table 7 and Figure 9).

Management of these software items of ecology is the key result of traditional irrigation systems in cascades. And these were the results of centuries-long structural irrigation network development.

It is clear that declining of cascade resources invariably impact on the biodiversity and eco-system in a locality. Tree density with richness and composition, biodiversity indices and spread of invasive species are the other main factors (in addition to water) impact on ecology in the area. The impact of cascade resources decline could be measured by using different diversity indexes. The Simpson Diversity Index

Tank	2012/13 Maha	2013 Yala	2013/14 Maha (Less irr. water use in some parts)	2014 Yala	2014/15 Maha (Less irr. water used)	2015 Yala
Kandubodagama	3.8	5.5	NA	4.0	1.7	4.6
Ranamukgama	3.0	4.2	2.5	2.8	0.7	3.1
Walpaluwa Maha	2.6	3.8	2.5	3.2	2.17	3.5
Palurambewa	4.2	3.85	4.2	3.0	1.8	3.5
Ihalathimbiriyawa	3.0	4.4	3.8	4.2	0.7	4.5
Dematagama	4.0	5.11	4.85	4.0	1.6	5.1
Wera wewa	3.5	4.02	3.25	3.8	2.0	4.2

Table 3: Irrigation Duty in selected tanks in the cascade.

Tank	2012/13 Maha	2013 Yala	2013/14 Maha	2014 Yala	2014/15 Maha	2015 Yala
Kandubodagama	4.5	5.56	NA	4.2	3.92	5.12
Ranamukgama	NA	4.20	2.8	3.0	2.87	4.3
Walpaluwa Maha	4.48	3.99	2.8	3.5	4.34	4.7
Palurambewa	NA	3.85	4.5	3.3	3.97	4.7
Ihalathimbiriyawa	NA	4.40	4.0	4.5	2.92	5.02
Dematagama	NA	5.11	5.0	4.2	3.8	6.3
Wera wewa	NA	4.02	3.4	4.0	4.1	5.4

Table 4: Water Duty in selected tanks.

	Name of the Tank	Area Cultivated prior to restoration - (ac)	Current cultivation - (ac)	Incremental acreage	Additional production
1	Kandubodagama	7	15	8	
2	Vitharangama	4	12	8	
3	Ranamukgama	3	18	15	
4	Athaudagama Maha	12	20	8	
5	Athaudagama Ulpath	8	16	8	
6	Ihalathimbiriyawa	16	25	9	
7	Wera	7	15	8	
8	Walpaluwa Maha	13	22	9	
9	Walpaluwa Kuda	3	17	14	
10	Asirigama	3	12	9	
	Total	76	172	96	3.360kg × 96 = 332,560 kg

Table 5: Additional harvest and income in Ihala Thimbiriyawa.

	Name of the Tank	Area Cultivated prior to restoration - (ac)	Current cultivation – (ac)	Incremental acreage	Additional Production
1	Mahagalewewa	120	150	30	
2	Walathwewa	47	60	13	
3	Ulpothawewa	30	40	10	
4	Galketikammennawewa	28	35	7	
5	Rancheyagodawewa	30	38	8	
6	Thuththripitiyawewa	12	22	10	
7	Harakwetunawewa	4	15	11	
8	Midellagahawewa	8	20	12	
9	Halpangalawewa	6	14	8	
10	Dambagahawewa	6	16	10	
	Total	291	410	119	3,360 × 119 =399,840 kg

Table 6: Additional harvest and income in Walathwewa.

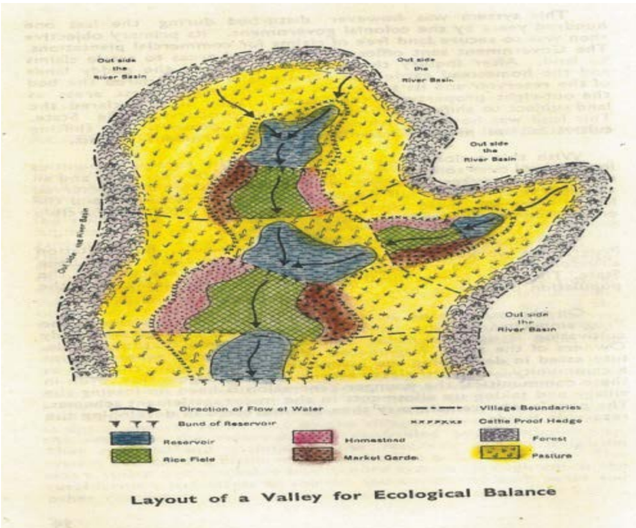

Figure 8: Layout of an ecological balanced valley.

Species	Number
Animal Endemic	5
Plant Endemic	17
Nationally Threatened Animals	5
Globally Threatened Animals	74
Globally threatened Plants	73
Birds	38

Table 7: Endemic and threatened species in Galkiriyakanda Cascade.

is mostly used by foresters to measure the biodiversity changes. The formula for Simpson Diversity Index is shown below.

Simpson Diversity Index

$D=N(N-1)/\Sigma n(n-1)$

D=Diversity index

N=Total number of organisms of all species

n=Total number of organisms of each species

The higher the value of D, the more diversity

The condition classes assigned in relation to this baseline such that CDF=20%; HDF=21%–40%; MDF=41%-60%; LDF ≥ 61%

The forestry research centre has classified forest degradation to four (4) levels (Table 8). Critically degraded areas will have only 20% of forest cover while lightly degraded areas comprise of 61% of forest cover. Highly degraded and moderately degraded areas will have 21% to 40% forest cover and 41% to 60% forest cover respectively.

Based on the above classification, studies have been done in selected eight (8) sample plots in the Galkiriyakanda and results in 2016 were given in the Table 9. (These sample plots were established during the transect walk in the cascade). This shows that critically degraded areas have been reduced in 2016 with the influence of the Action Research Program while enhancing the community awareness on importance of ecological balance in the cascade. In 2016, critically degraded areas reduced to 18 from 26 in 2014. Highly degraded areas also reduced to 16 in 2016 from 18 in 2014. But moderately degraded area has been increased to 8 in 2016 from 2 in 2014. No lightly degraded areas in 2014 and these were increased up to 4 in 2016. This clearly shows that when critically degraded and highly degraded areas reduced, moderately and lightly degraded areas will increase. However, still some threats to the forest and cascade resources could be seen in several plots due to the negative attitudes of few community members. The next challenge is the winning of these few families.

The biodiversity monitoring done by Forest Department shows that cascade and forest degradation in Ulpotha is decreasing (Table 9) and forest cover is increasing gradually. Generally, the regeneration of forest cover is very slow and takes a number of years to recover from damages. During this recovery period, ecology in the area is also changing. As per Forest Department observations, the rainfall of the area has been increased and water springs have been regenerated. Accordingly, now there is no scarcity of water in rehabilitated locations. Down-stream farmers receive sufficient water for their crops including paddy. The wet climate attracts wild animals and now monkeys, snakes,

Figure 9: Degraded Galkiriyakanda Cascade during the dry season.

Degradation level	Abbreviation	AGB stock is in Mgha-1 in relation to this baseline
Critically degraded forest	CDF	=20%
Highly degraded forest	HDF	=21%-40%
Moderately degraded forest	MDF	=41%-60%
Lightly degraded forest	LDF	≥ 61%

Table 8: Identifying degradation levels which impacts on Ecology / biodiversity.

Permanent Sample Sites	Degradation levels – 2014 to 2016							
	CDF		HDF		MDF		LDF	
	2014	2016	2014	2016	2014	2016	2014	2016
Sample 1 (out of 5 plots)	4	2	1	1	--	1	--	1
Sample 2 (out of 5 plots)	4	2	1	2	--	1	--	--
Sample 3 (out of 4 plots)	3	2	1	2	--	--	--	--
Sample 4 (out of 5 plots)	2	2	3	2	--	1	--	--
Sample 5 (out of 6 plots)	3	3	3	2	--	1	--	--
Sample 6 (out of 8 plots)	4	3	3	3	1	1	--	1
Sample 7 (out of 7 plots)	3	2	3	2	1	2	--	1
Sample 8 (out of 6 plots)	3	2	3	2	--	1	--	1
Total (46 plots)	26	18	18	16	2	8	--	4

Table 9: Levels of Cascade Degradation.

Resource	% of households	Value per HH (US$/HH/Yr)	Value per Unit Area (US$/ha/Yr)
Highland Paddy cultivation (Rain-fed)	23%	377	181
Vegetable cultivation	17%	96	39
Banana cultivation	13%	1,150	209
Coconut cultivation	15%	238	216
Domestic water	93%	226	1,469
Livestock water	13%	369	335
Commercial water	2%	132	12
Fishery	16%	309	351
Lotus flowers	10%	106	72
Lotus roots	7%	235	107
Different income generation avenues		**TOTAL**	**2,991 (LKR 415,000)**

Table 10: Different income generation avenues around Ulpotha.

deer, elk, peacocks and birds came back to the cascade. Accordingly, ecological balance is gradually improving in the cascade.

Managerial viability of traditional irrigation

The management roles of indigenous irrigation and cascade systems involve with many government, semi-government and community organisations. Generally, the current management aspect of cascade with its resources is not a strong one. At the present context, the Department of Agrarian Development (DAD) has the full responsibility of construction, rehabilitation and maintenance of minor irrigation schemes. Respective Government Agent's (District Secretaries) are also responsible for some lands in their respective districts. However, it is not clear who is actually responsible for major cascade systems like Galkiriyakanda. In Sri Lanka, there are many agencies to share the responsibilities on cascade management. The Forest Department (FD) is mainly responsible for tree cover in cascades. Their main role is to protect forest cover while reducing forest destruction and degradation. The Department of Wild Life (DWL) is also responsible to conserve protected forest areas as animal sanctuaries and game parks. The Irrigation Department and Mahaweli Authority are responsible to protect and promote catchments of major reservoirs such as Kalawewa, Thabbowa and Inginimitiya. The coordination among these agencies is not encouraging.

Even though there are rules and regulations, it is not easy to stop forest destruction and degradation in catchments. Even today, Sri Lanka loses around 0.05 ha of forest per annum due to many reasons. This situation invariably impact on cascade resources and sound management practices are also absent for small tank systems. No proper or regular maintenance system operates under DAD. On the other hand, Farmer Organisations (FOs) do not have sufficient funds and technical know-how to establish effective maintenance systems (Figure 10).

The study also noted some positive traditional environmental and resource management systems operate within Ulpotha cascade. The 'Bethma' cultivation system is the best example for managing water resources while practicing paddy cultivation. Under the Bethma system, cultivation area reduces according to availability of water in the tank and the land divide equally among farmers. Accordingly, each farmer cultivates a small portion of land and this system provides equal benefits to all members. Ensuring reasonable harvest, reducing risk of water requirements and preventing social issues on extent of land for cultivation are the main benefits of this system. This proves that traditional environment and resource management systems could be used in a modified way within the current context. However, early actions should be taken to promote effective systems for cascade management as the current systems are weak.

Sustainability aspect of system management

The sustainability of irrigation structures and components is a key factor in the management of cascade and irrigation systems. Maintenance of concrete structures as well as earth bunds and canals should be done after each cultivation season. Motivation of farmers or users, farmer organisations and relevant government authorities is essential for an effective maintenance process. A new sustainability approach has been introduced to cascade communities and basic concept could be explained by the following diagram (Figure 11).

Economic and financial viability of traditional irrigation

The rural communities rely predominantly on agriculture as their main source of income. The traditional cultivation systems mostly follow natural farming practices which supported the ecological balance in the locality. Paddy cultivation was traditionally done on a consumption level. With the development of market economy, paddy cultivation also turns to the income generation path. Harvest of irrigated paddy cultivation is almost double than the rain-fed or

Figure 10: Indigenous Water Storing Practices.

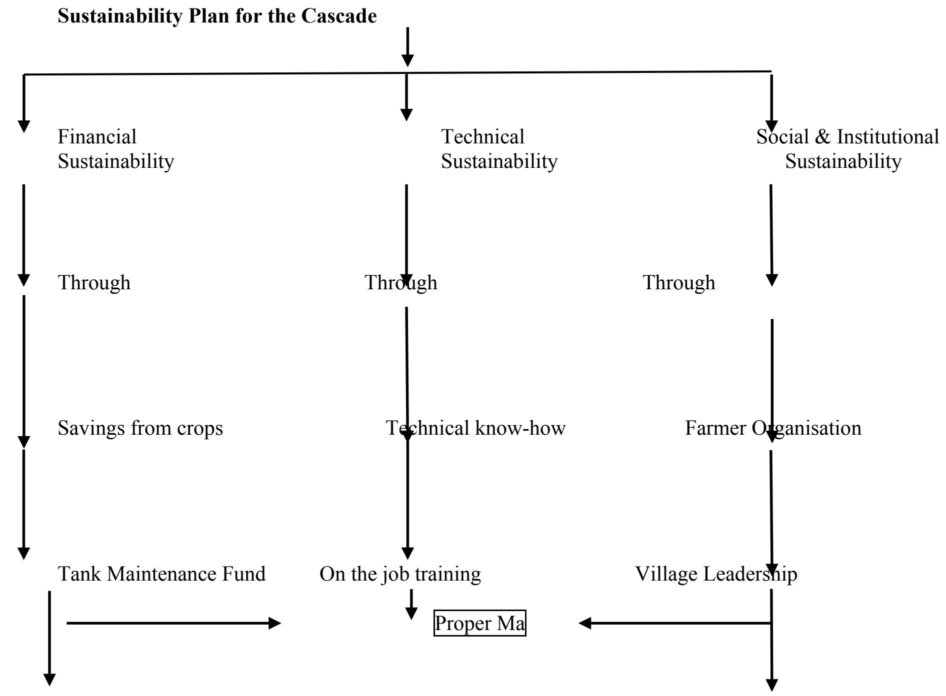

Figure 11: Sustainability of Cascade System.

normal cultivation. Fertilizer and chemicals are also used to increase the harvest per acre. In addition, high yield seed paddy varieties were also introduced to increase farmer income. These changes were well suited to irrigation systems in an operational cascade. This proves that 'water has an economic value and need to recognise as an 'economic good' (Dublin Principles). Since it is an economic good, efficiency and equity are the main principles to follow for better use. Since irrigated water resources are limited or inadequate to meet the entire demand, alternative sources could be identified in the downstream and this leads to study on 'opportunity cost' factor as well. Opportunity costs are the forgone benefits that could have been generated if water was allocated. The irrigation water available in the downstream is the resource generates by the Ulpotha micro-cascade and the Mee Oya river basin. The Mee Oya river basin crosses one district (Kurunegala) and flows to the sea in the Puttlam district. Therefore, trans-boundary water management is important for equity and fair distribution. Fortunately, both Kurunegala and Puttlam districts come under one province (North Western Province - NWP) and the Chief Minister with his bureaucrats will be able to manage to reduce any possible conflicts. On the other hand, NWP has their own 'Provincial Environmental Act' to manage environmental issues and promote income sources. Accordingly, trans-boundary water issues could be handled in a better way in the province. Economic analysis of Chena cultivation revealed that 'Chena is important as a source of income as well as the provision of nutritious food for rural family units. Home gardens are mainly cultivated with perennial crops and other timber trees. Both food and fruit trees are cultivated in a well-planned home garden. Coconut, mango, orange, breadfruit, jack and papaya are the popular species in home gardens. According to the recent estimates, nearly 25% of fire wood and 75% of wood are collected from home gardens. Accordingly, Chena and home gardens are also important economic units of the rural life [9].

Generally, water provides four kinds of economic benefits namely, commodity benefits, waste assimilation benefits, religion and aesthetic benefits and recreational benefits. Commodity benefits could enjoy as individuals and collective groups. Farming always categorise under collective usage of water through irrigation. Fresh water fish provides more economic value and nutrition value for rural folks. Fishing is a good income for people living around tanks and rivers. Water also works as a waste disposal tool by pushing and diluting and carry away wastes. Religious and aesthetic value of water is not strong in Sri Lanka as in India. Manik River in Kataragama is the most popular river among communities for religious or spiritual values. According to the current trend, water front hotels and eco-resorts are very popular among tourists and it is a lucrative business to earn foreign exchange. The world famous 'Ulpotha eco-resort' is located within the Ulpotha cascade and this is also a water front lodge with natural beauty. Ulpotha eco-resort provides a different flavour of tourism combine with yoga (Figures 12a and 12b). Generally, this flavour is expensive and Ulpotha eco-resort charges around 250 Sterling pounds per day. The SPA is managed by a local Ayurveda Doctor. This is an isolated tourist lodge without electricity or telephone facilities. But chemical free healthy local food is available for tourists. This activity provides direct and indirect benefits to community living in the area by offering jobs and purchasing their paddy, vegetable and fruits etc.

The environmental or ecological benefits are rarely included in economic analyses in cascades due to the difficulty of quantifying and/or valuing the impacts. Although the cascade systems generate a range of environmental benefits, such analysis includes only in economic benefits while ignoring environmental and ecological benefits.

A reduction in soil erosion will occur as a result of:

- A reduction in the destructive cultivation methods such as slash and burn (Chena) cultivation.

Figure 12: a and b) Ulpotha Forest Eco-resort.

- A reduction of water run-off through small tanks (Kuluwewas) and proper canals system and irrigation networks.
- A reduction in fire and increased forest cover in the cascade.
- Soil conservation measures in down-stream and home gardens.

Research conducted in the Upper Mahaweli catchment in 1992 estimated the quantity of soil erosion between 0.3 and 1.0 tonnes per hectare per year in dense natural forest, compared to 10 tonnes per hectare per year in degraded natural forest.

The environmental benefits from reduced erosion have been valued by assuming that it leads to a reduction in the siltation of tanks, and therefore maintain paddy yields [9] at a higher level than without restoration. An estimate of the decline in yields was obtained from Walathewa (a village [10] in the Ulpotha cascade), where the rehabilitation of a tank [11] resulted in an increase in yields from 80 to 100 bushels per acre. It is assumed that this decline would occur over a 30 year period where the cascade and forests were degraded, but effective soil and water conservation measures would reduce the level of erosion and halve the annual rate of decline in paddy yields. The resulting difference in yields is illustrated in Figure 13.

The environmental benefit from reduced erosion therefore equals the difference in the value of production between the 'with project' and 'without project' scenarios. The reduction in soil erosion is applied to a total area of 12 hectares of paddy, as in the example from Walathewa. The internal rate of return of the cascade rehabilitation program, including the above environmental benefits, is estimated at 19%. The cascade is also expected to increase the availability of water for agricultural purposes, which should also boost agricultural yields. The estimate of the value of environmental benefits is therefore considered to be conservative.

Another study has been conducted in 2008 in Kala Oya basin to calculate the benefits enjoyed by the farmers from 23 tanks close to Galkiriyakanda area [12,13]. In terms of tank area including water-spread area, the direct use value of ecosystem services are worth US$ 2,991 per hectare per year (Table 10). This is a significant contribution to the people's livelihood as most of the population is considered to be poor, and having an income of less than US$ 15 per month.

The studies done in 2015 showed that the farmer income has been increased after the renovation of cascade. This is mainly due to the increase of paddy and other cultivation areas. The increased paddy harvest and the increased income of farmers indicate in the following Tables 11 and 12. It shows that farmer's income has been increased more than double. As Indicated, the harvest will be double under the irrigated agriculture and this statement justified by the following figures.

These statistics show that farmers are enjoying many benefits after the cascade restoration and improvement. Among them financial benefits are the major factor to increase their income levels and the livelihood.

Conclusion

Irrigation (water) requirements are mainly fulfil by water sources in main catchments or cascades through its irrigation networks. Catchments also need sufficient rain to enrich water sources within cascades. Then only indigenous irrigation systems naturally develop or enhance their capacities. In the meantime, cascade with its irrigation system should be in good condition to improve efficiency of the system. The most traditional cascades including Galkiriyakanda were damaged due to various reasons and therefore downstream farmers face many challenges. This situation creates opportunities to criticise the traditional irrigation systems as ineffective systems to provide optimum benefits to downstream communities. But the correct picture is different and traditional irrigation systems operate as an appropriate local technology and very well suit to the local environmental conditions.

The rehabilitated Galkiriyakanda cascade provides many benefits to communities, wildlife, environment and ecological systems. Well-functioning cascade protects biodiversity with it creatures and endemic species. It is clear that objectives of traditional irrigation go beyond just irrigation and cover cultural and spiritual requirements of adjacent communities. Accordingly, traditional irrigation addresses broader issues of resource use and environmental sustainability in the long-run. The Ulpotha micro-cascade which was rehabilitated recently proved

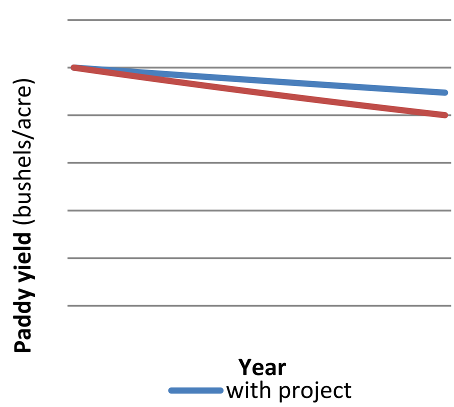

Figure 13: Comparison of Paddy Yields under with and without cascade improvement.

Ihala Thimbiriyawa			
Before restoration	3,360 × 76	255,360 kg × LKR 38	LKR 9,703,680
After restoration	3,360 × 172	577,920 kg × LKR 38	LKR 21,960,960
Increased harvest / Income		322,560 kg × LKR 38	LKR 12,257,280 (US$ 88,820)

Table 11: Increased Harvest and the Income.

Walathwewa			
Before restoration	3,360 × 291	977,760 kg × LKR 38	LKR 37,154,880
After restoration	3,360 × 410	1,377,600 kg × LKR 38	LKR 52,348,800
Increased harvest / Income		399,840 kg × LKR 38	LKR 15,193,920 (US$100,100)

Table 12: Increased Harvest and the Income.

that traditional irrigation system is strong enough to address water related issues in the catchment and in the downstream as well. Now all most all tanks and canals are in operation and communities cultivate their paddy fields and highland crops. Income level of communities has been improved with sustainable agriculture due to the sufficient water availability for all crops including paddy. The positive changes occurred in environmentally and economically are clearly visible in the area. However, strengthening of management is important for the sustainability of cascade and irrigation systems. Finally, it has proved that rehabilitation of cascade with its traditional irrigation is:

- Technically viable.
- Ecologically viable.
- Financially and economically feasible.

Recommendations

- The rehabilitation of cascades with its traditional irrigation systems is recommended based on the positive results and best practices experienced. The rehabilitated Galkiriyakanda traditional irrigation system operates with an appropriate technology and very well suit to the local environmental and physical conditions in the area. It is also cost effective and easy to maintain with community participation.
- The Government of Sri Lanka (GOSL) should introduce innovative systems for O&M and reforms are necessary to handover the systems to Farmer Organisations (Water Users). In this regard, reforms for existing legislations are also essential.
- Finally, the restoration of water cascades with its traditional irrigations systems is technically viable and financially feasible and therefore recommended to replicate in other water/ irrigation cascades especially in the dry zone.

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