# Economic Value of an Ancient Small Tank Cascade System in Sri Lanka

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DOCTORAL RESEARCH SERIES
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**Economic Value of an Ancient Small Tank Cascade System in Sri Lanka**

**By Shamen Prabhath Vidanage**

Thesis submitted to the University of Colombo in fulfilment of the requirement for the degree of Doctor of Philosophy in Economics

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## ABSTRACT

Sri Lanka is well known for its hydraulic civilization, and the Small Tank Cascade Systems (STCS) are part of that heritage of the country. Investment into restoration of degraded STCS are often considered financially not feasible due to narrowly defined assessment of benefits of these systems. The main reason for such a thought trend is the bulk of the multiple benefits generated by STCS belong to ecosystem goods and services, which are not provided through the market system; hence not reflected in the market determined monetary value. This research is undertaken to elicit the Willingness to Pay (WTP) for restoration and sustainable management of a representative small tank cascade system, to assess Marginal Willingness to Pay (MWTP) for selected cascade attributes and to develop and validate a Benefit Cost Analysis (BCA)[1] framework for decision-making in restoration and sustainable management of small tank cascade systems.

This research is conducted on the Pihimbiyagollewa and Kapiriggama small tank cascades in Malwathu Oya basin in Anuradhapura district of Sri Lanka. The study has pioneered the use of state-of-the-art non-market valuation technique to a small tank cascade taking "the entire cascade" as the unit of analysis. Furthermore, this is also the first application of Choice Experiment (CE) non-market valuation technique in small tank cascade systems in Sri Lanka.

The research concludes that both on-site as well as off-site communities have positive WTP for restoration and sustainable management of the cascade as an integrated unit. Results indicate that, the people from the cascade have a higher total WTP compared to an off-site sample (LKR 78,865 per season per household vs. LKR 54,260 per season per household). Estimates for marginal improvements of different attribute levels of the cascade demonstrated the differences in preferences of two communities sampled. The on-site sample community, depending on the cascade for their day to day sustenance, has placed a highest value on water for paddy followed by water for other uses and the cascade biodiversity (LKR 25,507, LKR 16,366 and LKR 5,880) respectively with attributing



[1] In this thesis Benefit Cost Analysis has been used throughout which is identical to the Cost Benefit Analysis used in other literature

LKR 31,109 for the all the other factors outside of the four attributes considered. All estimates are per season per household. It is noted that the cascade dependent community's consideration for the level of cascade ecosystem in their assessment, was irrelevant as the attribute estimate was turned out to be statistically insignificant.

On the contrary, the off-site community sample - who didn't have direct benefits from the cascade, placed water for other uses as the highest priority, while cascade biodiversity, water for paddy and cascade ecology were identified as decreasing priorities for willingness to pay for marginal change (values were LKR 17,995, LKR 8,921, LKR 8,234 and LKR 4,000 per household per season respectively). It is noted that they consider all four attributes in their valuation including the cascade ecology which has not emerged as significant in such valuations by the on-site communities.



The findings suggest that both cascade dependent, as well as other communities, are willing to pay for cascade level restoration and sustainable management of small tanks. The conventional Benefit Cost Analysis performed with on-site benefits of restoration indicate that the paddy related incremental benefits alone cannot justify cascade-wide restoration investment. However, extended benefits of irrigated agriculture, including non-irrigation benefits arising from other uses of water in cascades and benefits associated with biodiversity in them clearly justify cascade level restoration as a feasible investment option even after taking into account the vulnerabilities usually associated with small tank irrigated agriculture in the Dry Zone. The estimated selection criteria (Benefit Cost Ratio -BC ratio, Net Present Value - NPV and Internal Rate of Return -IRR) demonstrate the economic feasibility of investment with sensitivity analysis performed. Base case BC ratio was 2.24, while NPV was LKR 204,920,854 with an IRR of 24%. With cross sensitivity of 40 % cost overrun and 40 % unrealized benefits over the project period of 20 years, resulted a BC Ratio of 1.47, and a NPV of LKR 108,729,307 and an IRR of 17%.

The study demonstrates that the restoration benefits of small tank cascade, in taking cascade as an integrated unit of decision-making, overweigh the cost of such restoration. This result tends to promote such cascade wide restoration as the policy for small tank restoration in Sri Lanka.



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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **AIC** | Akaike Information Criterion |
| **APA** | American Psychological Association |
| **ASC** | Alternative Specific Constant |
| **BCA** | Benefit Cost Analysis |
| **BIC** | Baysian Information Criterion |
| **BV** | Bequest Value |
| **CBD** | Convention on Biological Diversity |
| **CE** | Choice Experiments |
| **CL** | Conditional Logit |
| **CPR** | Common Property Resource |
| **CVM** | Contingent Valuation Method |
| **DAD** | Department of Agrarian Development |
| **DSD** | Divisional Secretariat Division |
| **DUV** | Direct Use Value |
| **EBCA** | Extended Benefit Cost Analysis |
| **EV** | Existence Value |
| **FO** | Farmer Organization |
| **GND** | Grama Niladhari Division |
| **HPM** | Hedonic Price Method |
| **IIA** | Independence of Irrelevant Alternatives |
| **IUCN** | International Union for Conservation of Nature |
| **IUV** | Indirect Use Value |
| **IWRM** | Integrated Water Resources Management |
| **LKR** | Sri Lankan Rupees |
| **MEA** | Millennium Ecosystem Assessment |
| **MMDE** | Ministry of Mahaweli Development and Environment |
| **MMNL** | Mixed Multi Nomial Logit |
| **MWTP** | Marginal Willingness to Pay |
| **NCPCP** | North Central Province Canal Project |
| **NTFP** | Non-Timber Forest Products |
| **NUV** | Non Use Value |
| **OV** | Option Value |
| **PDoI** | Provincial Department of Irrigation |
| **RP** | Revealed Preferences |
| **RPL** | Random Parameter Logit |
| **SANDEE** | South Asia Network for Development and Environment Economics |
| **SP** | Stated Preference |
| **STCS** | Small Tank Cascade Systems |
| **TCM** | Travel Cost Method |
| **TEEB** | The Economics of Ecosystems and Biodiversity |
| **TEV** | Total Economic Value |
| **UV** | Use value |
| **VIRP** | Village Irrigation Rehabilitation Programme |
| **VIS** | Village Irrigation System |
| **WTA** | Willingness to Accept |
| **WTP** | Willingness to Pay |

# CHAPTER ONE
# INTRODUCTION

Chapter one provides an overall introduction to the thesis. The chapter begins with the background information covering the foundation and the focus to the research objectives. Followed by research problem and gaps in knowledge. The research objectives are presented next. Followed by the research questions formulated based on the research issues identified, which is supported by the hypotheses to be tested in the research. Both null and alternative hypotheses formulated for testing the research is presented in this chapter. Relevance, usefulness and contributions to the discipline and society are briefly explained under the rationale and justification. An account of methodological approaches, data collection and analysis is provided under the section on methodology. Lastly, the scope of the study with geographic boundary of the research followed by a description on the structure of the thesis is presented.



## 1.1 Background

This research is on assessing the Willingness to Pay (WTP) for restoration and sustainable management of a Small Tank Cascade System (STCS) – the clusters of hydrologically interconnected small irrigation reservoirs in the Dry Zone of Sri Lanka (Madduma Bandara, 1985). WTP is estimated for the direct dependents (on-site) of the STCS as well as for the indirectly dependent community who lives far away (off-site) from the cascades but has appreciation for STCS for their indirect benefits. These STCS are considered unique in many facets; the hydro-ecological engineering aspects, the design and the management by farmers for nearly two millennia are key contributory factors for such considerations. Panabokke, Tennakoon & Ariyabandu (2001) highlighted that though the small tanks in a system physically differs from one another, they follow a certain pattern determined by the hydrology, and the society. They remain economically and socially beneficial eco-friendly pools of water, integral to the Dry Zone of Sri Lanka. They further highlighted that the Sri Lankan systems are unique and unparalleled to any other system although they have some resemblance to those in South India.

Panabokke, et al., (2001) further elaborated the need for quantification and valuation of non-market functions of tanks:

> It is even argued that non-economic purposes for which tank water is used are more important than for economic uses. This finds support from villages' decision at times, to forego irrigated cultivations (in seasons of deficit rainfall) in favour of the use of tank water to meet social needs - drinking, bathing and washing. Though the importance of non-economic functions to which tank water is put into are often inventorised and stressed by many scholars, quantified values of those functions have not yet been scientifically ascertained and demonstrated (Panabokke, et al., 2001, p. 2).



Current efforts for restoring small tanks in STCS in Sri Lanka is targeting the individual tanks[2] of degraded cascades, without taking the cascade as the unit of intervention. As the cascade is a hydro-ecologically functional system such interventions on components of a system is expected to yield sub-optimal results in restoration. The main justification behind such tank level intervention is the cost of investment over expected benefits of restoration. In this situation, the authorities are mostly accounting for irrigation as the only benefit which has a direct market value.

[2] There were few project-based pilot interventions which can be considered exceptions, notably Plan Sri Lanka, Mahaweli Authority of Sri Lanka and IUCN together with Department of Agrarian Development delivered cascade-wide restoration cases.

However, it is assumed that most of the benefits of cascades are non-marketed[3] and therefore, this research is expected to test the hypothesis on non-market values of the STCS by generating WTP for restoration of cascades and their sustainable management by direct cascade dependant (on-site) and others who are far away from cascades, who do not directly dependant on cascades (off-site).

These estimates will provide guidance to the authorities about how the community would value these systems by taking the economic value based on Total Economic Value (TEV) principles related to cascades into account. In addition, the research will generate the marginal willingness to pay for different attributes of the cascades for appropriate policy guidance. The WTP estimation was done using Choice Experiment as the main valuation method taking *Pihimbiyagollewa* cascade in *Kahatagasdigiliya* and *Rambewa* Divisional Secretariat divisions of the Anuradhapura District of North Central Province of Sri Lanka as a case study.



## 1.2 Introduction to Small Tank Cascade Systems in Sri Lanka

Small tank cascade systems are unique soil-water conservation systems invented by our forefathers about two millennia ago. As explained by Madduma Bandara (2007), these tank cascade systems are linked with a diverse ecological and socio-economic subsystem within which they evolved, covering the following:

i. The ecological system with catchment forests, aquatic habitats, and the commons
ii. Land use zoning systems

[3] Most of the environmental goods and services are not traded in the market. Therefore, how much people would be willing to pay for those are not determined in a market transaction, hence their economic values are not revealed in the market prices.

iii. Various crop combination systems

iv. Elaborate water management systems including, sluices, spills, water control weirs (Karahankota) with rotational water distribution systems

v. Management systems such as Velvidane (Irrigation Headman) system that dates back to pre-colonial times.

Madduma Bandara (2007) further elaborated that for the emergence and continued existence of village tank cascade systems, there was the need for a sustainable irrigation and water management technology to meet the challenge of recurrent water shortages and drought conditions in a seasonally dry environment. Despite adverse effects of various socio-economic, institutional and political changes experienced over centauries, these systems still sustain and provide services at a lower scale to what they were capable of mainly on the biophysical, socio-economic and ecological principles on which they were created. Further details on STCS are provided in the chapter 4, Schematic diagram of a cascade and distribution of cascades in Malwathu oya basin is provided below (Figures 1.1 and 1.2 respectively).

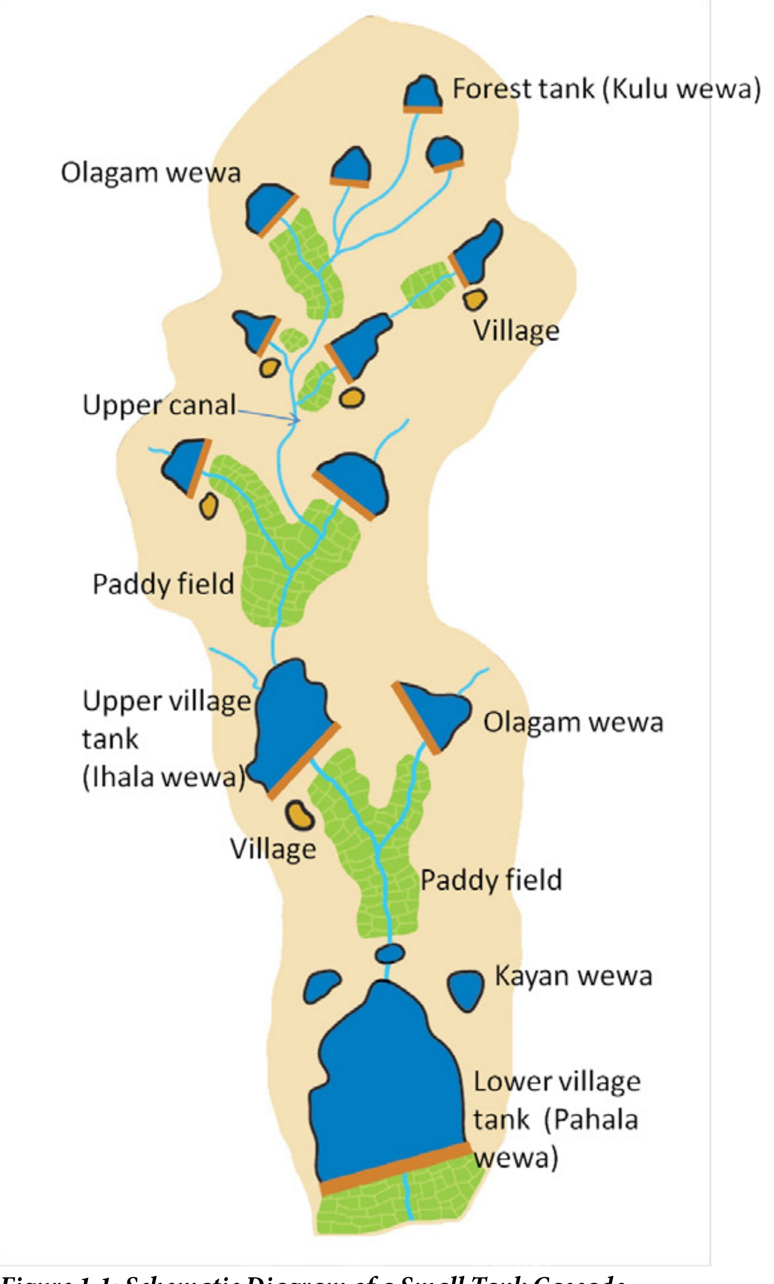


***Figure 1.1: Schematic Diagram of a Small Tank Cascade***
Source: IUCN, 2016

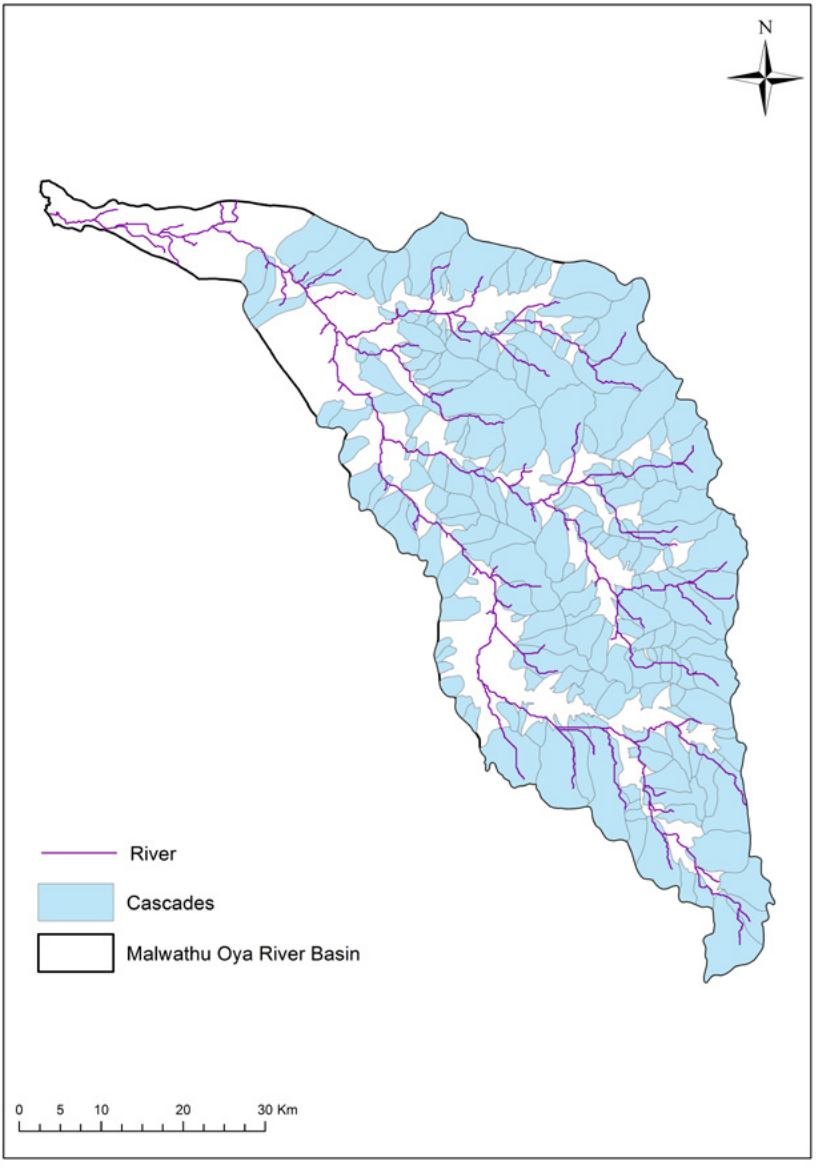


***Figure 1.2: Distribution of STCS in Malwathu Oya Basin***
Source: DAD Small Tank Database

## 1.3 Research Problem

Due to various socio-economic and political reasons, the maintenance of small tank cascade systems have been neglected over a long period of time. The fundamental reason is the lack of recognition of their true value as a multipurpose and multifunctional system. Their worthiness has been assessed purely on their irrigation potential. The reason for missing values is that the bulk of the multiple benefits generated by tank systems belong to ecosystem goods and services. Ecosystem goods and services are not provided and valued through the market system; therefore, they have no apparent monetary value reflected and has not been recognised by formal economic investment analysis tools nor informal political decision-making processes.



Also, the lack of understanding of cascade dynamics, ad hoc restoration of individual tanks (part of the system) without looking at a cascade as a functional system/unit also have given rise to negative results. Various poorly planned development activities such as catchment deforestation, and land alienation also disturb these systems. Poor understanding of the values that small tank cascades provide as a multipurpose system is argued as the main issue for not drawing attention of the policy makers on these systems. Therefore, the research problem and gaps in knowledge related to this research can be summarised as;

i. Not having comprehensive estimates of benefits related to STCS of Sri Lanka

ii. Lack of recognition of STCS as an interconnected system in design, analysis and planning of small tank restoration in Sri Lanka.

iii. Poor adaptation to changing ecological, economic and social conditions.

## 1.4 Research Objectives

In addressing the above research problem, the research is designed in a way in which it addresses the main objective by eliciting the values for WTP for restoration and sustainable management of a representative cascade system in the Dry Zone of Sri Lanka by the direct dependants of cascades and those who are far away from cascades. These values will be based on the multiple benefits provided by small tank cascade systems and they will be useful in the decision-making processes relating to restoration and sustainable management of them. The specific objectives of the research are listed below.



i. To elicit the Willingness to Pay (WTP) for restoration and sustainable management of a representative small tank cascade system in the *Malwathu Oya* basin for cascade dependent on-site community and off-site community who are not directly dependent on the cascade, taking cascade as the unit of decision-making.

ii. To assess the Marginal Willingness to Pay (MWTP) for different cascade attributes for on-site and off-site communities.

iii. To develop and validate a Benefit Cost Analysis (BCA) framework for decision-making in restoration and sustainable management of small tank cascade systems using the findings of the research.

In addition to above three specific research objectives, two methodological research objectives too were addressed in this research as sub research objectives. They are: to assess how the payment mode (monetary vs labor) and survey format (group vs individual) impact the estimated values.

## 1.5 Research Questions and Hypotheses

The small tank cascades are largely regarded as relatively low productive systems. Therefore, it is believed that investing in them does not yield reasonable returns due to narrowly defined assessment of these systems. They are assessed just for irrigation purposes, without looking at them as multipurpose and multifunctional systems. There is therefore, a need for identification, quantification and valuation of other benefits of these systems to understand the true value to people – the total economic value of cascades, taking cascades as the unit of analysis in contrast to the tanks as the unit in present planning. Based on this premise the following research questions were formulated for the research.



### 1.5.1 Research Questions

i. How much the small tank cascade dependant on-site communities and distant off-site communities are willing to pay for restoration and sustainable management of a selected small tank cascade system, in the Malwathu Oya basin?

ii. What is the marginal willingness to pay by these communities for different attributes of the cascade being studied?

iii. Whether and how the elicited values can be objectively used in better decision-making in relation to restoration and sustainable management of small tank cascades in Sri Lanka?

In addition to above three main research questions, two methodological research question too were addressed in this research as sub research questions, they are:



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a. What would be the impact of payment attribute on estimates when comparing labour verses cash?
b. Whether there is any effect on the group verses individual introduction of the survey on estimates?

### 1.5.2 Hypotheses

The research is designed to test the following hypothesis.

Null hypothesis ($H_0$)

Both the small tank cascade dependant on-site communities as well as the off-site communities, who are living further away from these systems, do not have a positive willingness to pay for restoration and sustainable management of cascade systems.

Alternative hypothesis ($H_1$)

Both the small tank cascade dependant on-site communities as well as the off-site communities, who are living further away from these systems, have a positive willingness to pay for restoration and sustainable management of cascade systems.

## 1.6 Rationale and Justification

Most small tank cascade systems in the Dry Zone were created several centuries ago giving us an initial experience of integrated water resources management with spatial planning at landscape scale. They demonstrated the ability to manage those as socio-ecological systems for the multiple benefits for on-site communities including economic, ecological and spiritual values. However, due to changes that took place since the long colonial rule up to the creation of institutions to manage these systems, replacing the community participation aspects, believed to have contributed to the commencement of the degradation of small tank cascade systems.

At times, the implementation of mega development programmes such as Accelerated Mahaweli Development Programme also interfered with the functionality of these systems. Therefore, many of these systems at present are either abandoned or not functioning to their full potential. Table 1.1 provides the distribution of small tanks in Sri Lanka at province level with their functional status according to Panabokke, 2002[4].

***Table 1.1: Operational and Abandoned Small Tanks within each Province***

| **Province and area (km²)** | **Number of small tanks** | | **Total** |
|---|---|---|---|
| | Operating | Abandoned | |
| Northern 3,709 | 608 | 896 | 1,424 |
| North Central 10,365 | 2,095 | 1,922 | 4,017 |
| North Western 7,760 | 4,200 | 2,273 | 6,473 |
| Southern 2,849* | 653 | 757 | 1,410 |
| Lower Uva 2,901* | 16 | 543 | 559 |
| Eastern (South of Mahaweli) 3,885* | - | 1,017 | 1,017 |
| Eastern (North of Mahaweli)* | 48 | 425 | 473 |
| Total | 7,620 | 7,753 | 15,373 |

**Includes only the Dry Zone part of the province.*

Source: Panabokke, 2002

A unique feature, in these systems, is that water falling in a small watershed is captured by a hydrologically interconnected system of tanks (eg. *Pihimbiyagollewa* and *Kapiriggama* Cascade systems consist of 19 and 21 small tanks respectively) collecting most of the rainwater during the rainy

[4] There is no agreement on the exact number of small tanks in Sri Lanka as various authors have indicated different numbers ranging from about 12,000 to 20,000. Therefore, relevant reference is given where a number is referred in the thesis.

season and use them in the dry season for the benefit of local communities and surrounding environment. As the water passes through from upstream to downstream tanks of the cascade, the water is used and reused several times before they leave the cascade. *Kapiriggama* cascade is a recently restored cascade, adjoining and similar to the *Pihimbiyagollewa* cascade, in *Rambewa* DSD. Restoration cost of *Kapiriggama* cascade was used as a proxy for the cost of *Pihimbiyagollewa* restoration in economic analysis. Key features of two cascades are provided in Table 1.2 and 1.3. Maps of the two cascades are provided in Figure 1.3 and 1.4.



Assuming that one of the objectives of STC management is to maximise the social value of these systems to people, an improved knowledge of the marginal benefits of extending or reducing some attribute levels could result in more efficient decisions. The full economic implications of managing STCS in alternative ways then be taken into account.

Even though these systems are meant to generate multiple benefits to local economy, and actually does so, the planners/decision-makers tend to take only the irrigation benefits of these systems for assessing feasibility in restoration of degraded systems as they are the only market values available. They often conclude that restoration of entire STCS is not financially and or economically feasible. Hence, the tendency is to rehabilitate/restore one or two tanks in a given system ignoring what it means to the cascade system of tanks as a whole. However, as they were designed to work as interconnected systems of tanks, such rehabilitations of few tanks in isolation do not bring about the expected results. It may even contribute to de-stabilise the systems.

The purpose of this research is to elicit the values of restoration and sustainable management of a selected cascade as an integrated system taking the multiple benefits of STCS by the on-site and off-site communities. At the same time, to demonstrate a framework to integrate multiple benefits in a Benefit Cost Analysis framework using a selected cascade system of tanks in the *Malwathu Oya* basin as the case. It is expected that the research findings will have immediate applications in assessing feasibility of cascade tank restoration by incorporating multiple benefits that they generate.

***Table 1.2: List of Tanks in Pihimbiyagollewa Small Tank Cascade with Capacities***

| Tank identification number | Name of the tank | Tank surface area in ha at FSL | Tank surface area as a % of the cascade | Command area in ha |
|---|---|---|---|---|
| 1 | *Palippothana wewa* | 19.58 | 8.03 | 31 |
| 2 | *Italawetuna wewa* | 9.19 | 3.77 | 40 |
| 3 | *Hendegama wewa* | 3.82 | 1.57 | 15 |
| 4 | *Ihalakolongas wewa* | 5.53 | 2.27 | 19 |
| 5 | *Pahalagama wewa* | 4.06 | 1.66 | 19 |
| 6 | *Kuda thambalagollewa wewa* | 16.51 | 6.77 | 28 |
| 7 | *Thambalagollewa wewa* | 47.76 | 19.59 | 87 |
| 8 | *Welpothu wewa* | 0.72 | 0.30 | 6 |
| 9 | *Badu wewa* | 5.40 | 2.21 | 12 |
| 10 | *Tharamahalmillewa wewa* | 27.17 | 11.14 | 34 |
| 11 | *Hakuruketiyawa wewa* | 5.47 | 2.24 | 17 |
| 12 | *Kirimetiyawa wewa* | 5.47 | 2.24 | 7 |
| 13 | *Kudawewelketiya wewa* | 2.19 | 0.90 | 13 |
| 14 | *Wewelketiya wewa* | 43.87 | 17.99 | 60 |
| 15 | *Lolugas wewa* | 10.45 | 4.29 | 24 |
| 16 | *Pahalakolongas wewa* | 3.17 | 1.30 | 23 |
| 17 | *Ihala wewa* | 4.66 | 1.91 | 19 |
| 18 | *Balahonda wewa* | 23.79 | 9.76 | 59 |
| 19 | Balahondakuda wewa | 5.05 | 2.07 | 20 |
|  | ***Totals*** | ***243.86*** | ***100.00*** | ***533*** |

Source: Survey Department 1:10,000 maps and DAD database

Department of Agrarian Development and Provincial Department of Irrigation (PDoI) have the jurisdiction over these systems and the findings will be relevant for them to take cascade systems as units of planning and implementation for the management of small tanks in the Dry Zone of Sri Lanka.

***Table 1.3: List of Tanks in Kapiriggama Small Tank Cascade with Capacities***

| Tank identification number | Name of the tank | Tank surface area in ha at FSL | Tank surface area as a % of the cascade | Command area in ha |
|---|---|---|---|---|
| 1 | *Aluthgama wewa* | 17.04 | 8.65 | 50 |
| 2 | *Aluwaketuwala wewa* | 8.98 | 4.56 | 52 |
| 3 | *Galkadawala wewa* | 27.20 | 13.81 | 85 |
| 4 | *Karuwalagas wewa* | 4.00 | 2.03 | 20 |
| 5 | *Kayan wewa* | 1.91 | 0.97 | 10 |
| 6 | *Kayangollawa wewa* | 1.17 | 0.59 | 15 |
| 7 | *Kikilige wewa* | 1.65 | 0.84 | 15 |
| 8 | *Kohombagas wewa* | 1.90 | 0.96 | 20 |
| 9 | *Konakumbuk wewa* | 34.77 | 17.65 | 110 |
| 10 | *Kuda kadiyawa wewa* | 6.58 | 3.34 | 35 |
| 11 | *Kurundugoda wewa* | 2.38 | 1.21 | 42 |
| 12 | *Maha kadiyawa wewa* | 6.60 | 3.35 | 85 |
| 13 | *Mailagammana wewa* | 10.20 | 5.18 | 54 |
| 14 | *Mailagammana kuda wewa* | 1.19 | 0.60 | 8 |
| 15 | *Massalawa wewa* | 24.49 | 12.43 | 60 |
| 16 | *Palugonamariyawa wewa* | 9.97 | 5.06 | 22 |
| 17 | *Peenagama kuda wewa* | 5.60 | 2.84 | 45 |
| 18 | *Peenagama maha wewa* | 24.34 | 12.35 | 130 |
| 19 | *Puliyankulama wewa* | 5.50 | 2.79 | 38 |
| 20 | *Wanniyankulama wewa* | 0.47 | 0.24 | 10 |
| 21 | *Galkadawala kayan wewa* | 1.08 | 0.55 | 30 |
| | ***Totals*** | ***197.02*** | ***100.00*** | ***784*** |

Source: IUCN, 2016, Survey Department 1:10,000 maps and DAD database

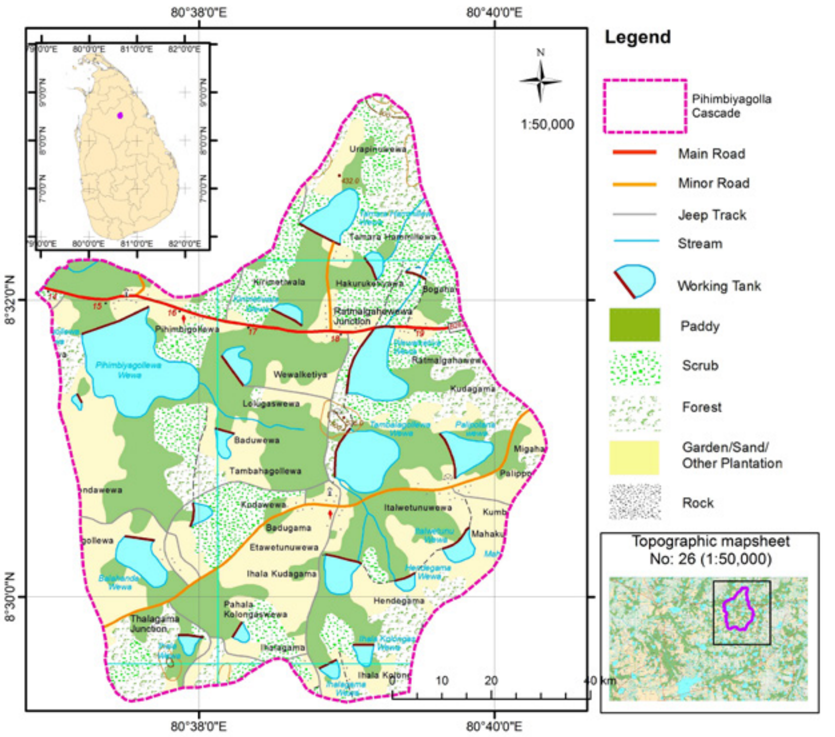



*Figure 1.3: Distribution of Small Tanks in Pihimbiyagollewa Cascade*

Source: Survey Department 1:10,000 maps and DAD database

It is also expected that the findings of this research will lead to an objective analysis of restoration of degraded STCS looking at their multiple benefits. It will also increase the climate resilience for the tank associated communities as the well-functioning restored systems would prove to be an adaptation measure for climate change vulnerability. National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025 has identified (MMDE, 2016) participatory cascade management programmes in selected village tank catchments as one of the sector actions in its water resources action plan. Further, the government of Sri Lanka is expecting funds under the Green Climate Fund for 'Strengthening the resilience of

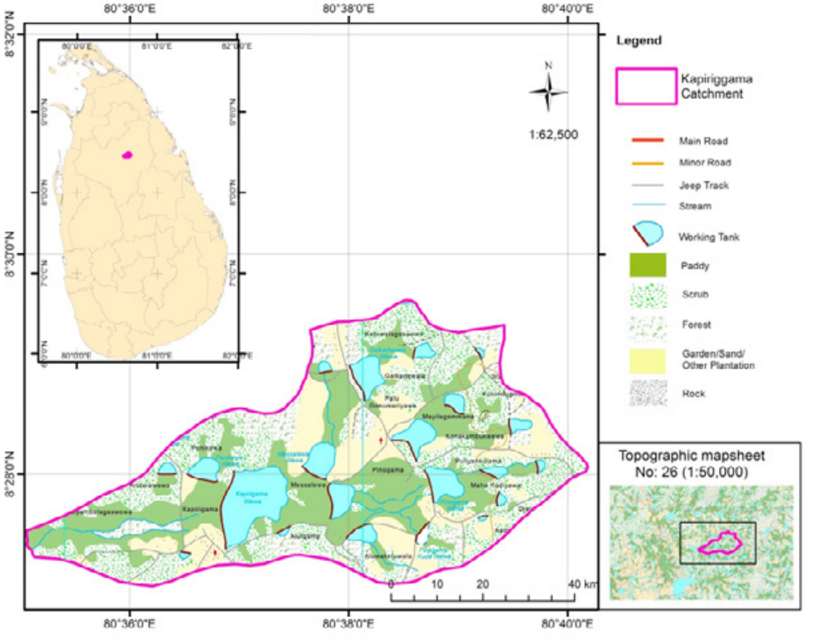



*Figure 1.4: Distribution of Small Tanks in Kapiriggama Cascade*

Source: Survey Department 1:10,000 maps and DAD database
(with updated landuse maps in 2015)

smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management to restore 17 cascades consisting 320 small tanks amongst other things covered in the Project (Green Climate Fund, 2017). There are other initiatives such as feeding cascades in the North Central Province while conveying water from Moragahakanda and Kaluganga Reservoirs through Upper Elahera Canal of the North Central Province Canal Project (NCPCP) to the North (Mahaweli Authority of Sri Lanka, 2015).

***Table 1.4: Comparison of Two Cascades on Land Use and Land Cover Categories***

| | ***Pihimbiyagollewa cascade*** | | ***Kapiriggama cascade*** | |
|---|---|---|---|---|
| | **Area (ha)** | **Area (%)** | **Area (ha)** | **Area (%)** |
| Barren land | 3.58 | 0.12 | 1.93 | 0.08 |
| Forest | 907.22 | 30.34 | 552.27 | 23.92 |
| Homestead | 240.59 | 8.05 | 247.96 | 10.74 |
| Water | 417.34 | 13.96 | 215.32 | 9.32 |
| Marshland | 25.97 | 0.87 | 13.06 | 0.57 |
| Other crops | 49.89 | 1.67 | 0.18 | 0.01 |
| Paddy | 1,027.07 | 34.35 | 1,072.41 | 46.44 |
| Scrub land | 316.26 | 10.58 | 204.99 | 8.88 |
| Rock | 1.90 | 0.06 | 1.00 | 0.04 |
| | **2,989.82** | **100.00** | **2,309.11** | **100.00** |

Source: Survey Department of Sri Lanka, 1:10,000 maps



## 1.7 Methodology and Data in Brief

The research strategy adopted to address the three research objectives stated above includes a mix of quantitative and qualitative approaches, and the data collection is cross-sectional looking at a particular representative small tank cascade system in Sri Lanka as a case study. The research design covers a field survey of on-site communities directly dependent on the *Pihimbiyagollewa* cascade - the selected sample cascade system of tanks in the *Malwathu Oya* basin in Anuradhapura district as well as off-site communities who are far away from the selected *Pihimbiyagollewa* cascade, not enjoying any direct benefits of the selected STCS. In order to assess the economics of restoration of *Pihimbiyagollewa* cascade, cost of restoration of recently restored *Kapiriggama* cascade was used. Research methods include review of previous studies, consultation of experts and officials, interview of key informants, focus group discussions of cascade dependant community and individual questionnaire surveys of on-site and off-site communities (on-site survey questionnaire is given as Annex 5A and off-site survey questionnaire is given as Annex 5B). Official statistics, official documents and all accessible literature on the subjects related to the research were also consulted. Selected community from the *Pihimbiyagollewa* cascade were interviewed during August 2016 through face-to-face interviews using a structured questionnaire as they were the primary beneficiaries of the cascade.

As these systems are valued by people living outside the cascade, a similar face-to-face interviews were conducted in selected GN divisions of Colombo district during December 2016. Both surveys were conducted with trained final year University undergraduate students from the Rajarata University of Sri Lanka and the Colombo University as enumerators. As presented in detail in the methodology chapter, questionnaires were carefully developed to gather all required information needed for analysis to address three research questions and the research hypothesis.

As described previously, the case study approach is used in this research to investigate into the WTP by local on-site communities as well as off-site communities. The valuation technique used to elicit WTP - the discrete choice modelling required to establish the present status of the cascade through selected attributes and their levels as well as the two cascade improvement scenarios which the respondents will choose the best alternative with a price tag in a market created under the choice experiment survey procedure. These scenarios or alternatives can be meaningfully developed and with realistic attributes and their levels when particular valuation object is selected. Hence, the case study approach is best suited to this research.

Considering the heterogeneity in the cascades, a stratified random sampling method based on population distribution was used in selecting the on-site sample. Sample size was 500 households covering approximately 50% of the cascade population. The sample households for the cascade level survey were drawn from *Balahondawewa, Ihalakongaswewa, Pihimbiyagollewa, Thamarahalmillawa* and *Wewelketiya* GNDs of the *Rambewa* DSD and *Palipothana* GND of the *Kahatagasdigiliya* DSD, of Anuradhapura district. In the off-site sample, 200 households were randomly selected from Pagoda, Grama Niladhari Division of *Sri-Jayawardanapura Kotte* Divisional Secretariat Division, *Kurunduwatta* GND of *Thimbirigasyaya* DSD and *Sri Subhoothipura* and *Malabe North* GNDs were selected from Kaduwela DSD covering a mix of high, medium and low income earning communities for the 'off-site' sample identified.



Non-market valuation tools need to be used when there are no well-functioning markets for the goods and services to be valued. It is a process of estimating value of goods and services when there is no market, or limited market, or an incomplete market. The main non-market valuation technique used in this research is Choice Experiments (CE) as detailed in chapter three.

Ecosystem services are the benefits that people, society and the economy receive from the nature. For example: water provision and purification, flood and storm control, carbon storage and climate regulation, food and materials provision, scientific knowledge, recreation and tourism (Millennium Ecosystem Assessment, 2005); The Economics of Ecosystems and Biodiversity (TEEB), initiative has demonstrated the usefulness of presenting evidence on the values of nature and targeting the messages to different audiences (TEEB, 2010 and 2013). Those principles were followed in valuation of ecosystem goods and services related to STCS. Understanding and communicating the economic, social and cultural value of ecosystem services (many of which nature provides for "free") is crucial to fostering a better management, conservation and restoration of practices (TEEB, 2013).

Findings were used in performing a Benefit Cost Analysis (BCA) to demonstrate and to find out the economics of cascade tank restoration after taking ecosystem goods and services of these systems in addition to taking traditional irrigation benefits. The cost of tank restoration was obtained from recently completed project in *Kapiriggama* STCS implemented jointly by the Department Agrarian Development and the International Union for Conservation of Nature (IUCN). The multiple benefits of restoration were assessed by the research. The basic idea behind BCA is that better decisions could be reached if all associated costs and benefits (economic and environmental) in a project were identified, measured, valued and compared.



## 1.8 Scope of Study and Limitations

The scope of study covers the *Pihimbiyagollewa* STCS as a representative STCS selected in the Anuradhapura District within *Malwathu Oya* basin (Figures 1.5 and 1.6). Figure 1.6 indicates the higher density of small tanks and small tank cascades in Anuradhapura district compared to those within Mannar and Vavunia districts of the same river basin. While *Malwathu Oya* basin has the largest number of cascades in any given river-basin in Sri Lanka (Panabokke et al., 2002), the selection of *Pihimbiyagollewa* cascade was done in consultation with DAD officials, cascades experts and preliminary field studies. It is a representative cascade which has not been subject to restoration in the recent past and the cascade features were still intact. A choice experiment survey conducted through a questionnaire designed based on the *Pihimbiyagollewa* cascade's present status and two levels of alternative improvements proposed. Surveys were conducted in

*Pihimbiyagollewa* cascade as well as four Divisional Secretariat divisions of Colombo district to elicit willingness to pay for cascade restoration options. Restoration cost associated data was obtained from DAD/ IUCN project site – *Kapiriggama* STCS, which has three GN Divisions (*Konakumbuk wewa, Peenagama* and *Kapiriggama*) of Rambewa Divisional Secretariat Division (DSD) of the Anuradhapura district which is bordering the *Pihimbiyagollewa* cascade with similar number of small tanks and socio-economic features.

Main limitation of the study is approximation of restoration cost of adjoining cascade of the *Pihimbiyagollewa* cascade, the *Kapiriggama* cascade.



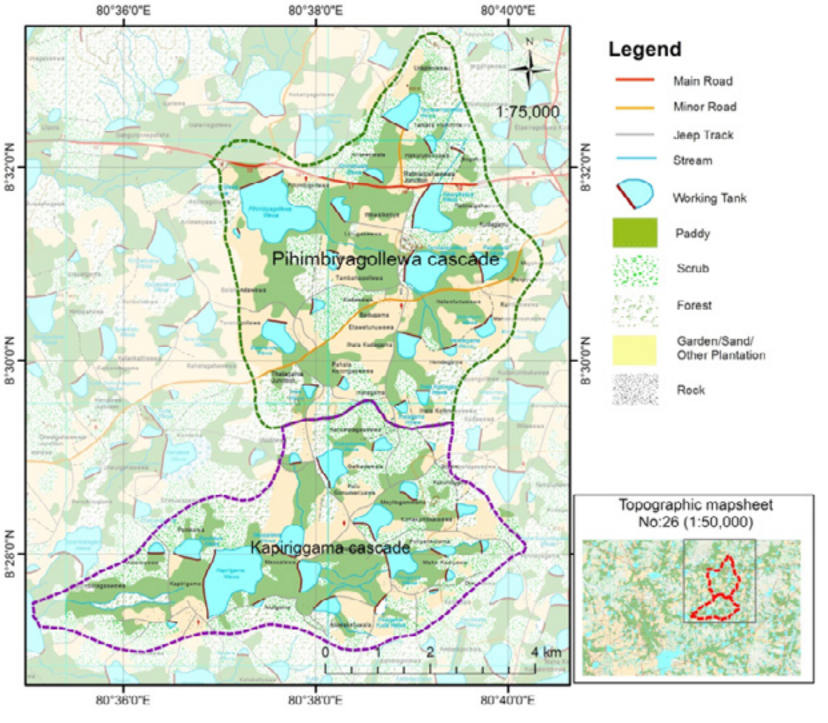



***Figure 1.5: Relative Location of the Pihimbiyagollewa and Kapiriggama Cascades***
Source: Survey Department 1:10,000 maps and DAD database

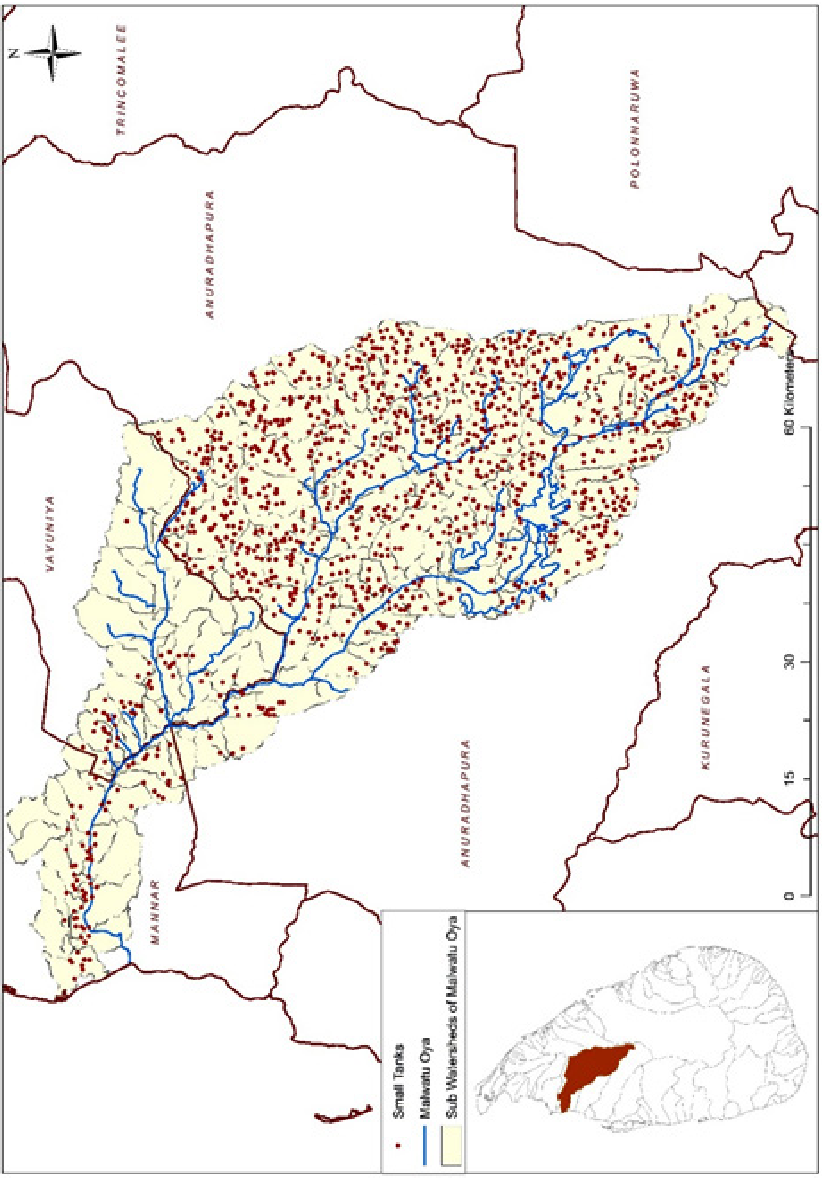



***Figure 1.6: Distribution of Small Tanks in Malwathu Oya***

Source: IWMI and DAD data base

The study assessed WTP by cascade based local communities as well as WTP of the selected off-site communities for restoration and sustainable management of *Pihimbiyagollewa* cascade. The assessed MWTP of different attributes of cascade determines the value of the cascade and demonstrate the BCA framework for cascade restoration based on the research findings to guide cascade-wide decision-making for other cascades in Sri Lanka. There are 1,166 identified cascades in Sri Lanka (DAD, 2005). The findings are expected to be policy relevant for small tank cascade restoration and sustainable management in Sri Lanka.

## 1.9 Structure of the Thesis

The thesis is presented in eight main sections including six chapters, references and annexes. Preliminary pages covering title page to acronyms and abbreviations were presented according to the guidelines issued by the Department of Economics, University of Colombo. Brief outline of the contents covered in the rest of the chapters are provided below.

The second chapter is the Literature Review, which covers the literature relevant to the research problem outlined in this chapter. It covers the evolution of conceptual and theoretical framework, the gaps in knowledge and a justification of the current research. Furthermore, this section presents the theory of value, rationale for using non-market valuation for valuing ecosystem goods and services, application of different non-market valuation techniques/methods in similar situations. Details on non-market valuation methods and their applicability for the given situations are discussed in detail.

The third chapter is the Methodology. It presents the detailed methodology covering conceptual framework, theoretical foundation, econometric model, research design, experimental design, sampling strategy, data collection methods of both on-site and off-site samples and an introduction to the data analysis. Choice Experiment as the principle valuation method, a detail account on steps related to design and application of CE in the research is also provided. The chapter four devoted to provide a detail account of STCS in Sri Lanka.

The fifth chapter is on Data Analysis and Findings, which covers the details of data handling for the use in choice modelling, specific models used for WTP estimation, how different treatments such as explaining the survey in groups verses individuals, cash payment attribute verses labour contribution attribute behaves in on-site sample and how on-site sample results compare with off-site sample, how the marginal WTP for different attributes varies in off-site and on-site sample is examined and interpreted. Statistical tests performed and interpretation of results and the findings are presented in this chapter.



The final chapter is on Summary and Conclusions. It is devoted for discussing the main results of the study, how they address the research problems. Further the conclusions reached are highlighted with potential policy relevant findings of the study on guiding decisions towards restoration and sustainable management of small tank cascades in the Dry Zone of Sri Lanka is dealt in this chapter. Further this chapter discusses the limitations of the present study and provides the avenues for furthering the research undertaken.

A complete list of cited references is presented in the next section devoted for References. The American Psychological Association's (APA) 6th referencing, and citation style was used throughout the thesis for citation and referencing. The final and the seventh section of the thesis is devoted for Annexes. This section provides useful additional materials used in the research including the following. The experimental design, sample of choice profiles, survey questionnaires, graphs related to key demographic features of the samples and excel files of the BCA as referred to in the six chapters of the thesis.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 Introduction

The previous chapter provided the background to the research. It covered the identification of the research problems for investigation, gaps in knowledge, formulation of the research objectives and the research question, hypotheses to be tested in the research with relevance, usefulness and contributions to the discipline and to the society. It also introduced the rationale and justification of the research with the backing of review of relevant literature. The chapter two deals with the review of literature relevant to this research covering conceptual, theoretical and empirical studies positioning the identified research questions related to small tank cascade systems in Sri Lanka.



The subject of STCS is relatively new to the readers of economics. Hence, this chapter begins with a review of some key literature on small tank cascades in Sri Lanka, covering the history and the present context of small tanks, small tank cascades as a multiple benefit system and finally the economic studies undertaken on small tank cascades and small tank cascades as a common property resource. It also outlines and reviews the conceptual, theoretical and empirical studies with setting the background for the theoretical foundation for this research.

## 2.2 Main Concepts Associated with the Research

This research is on the investigation into the economic value of traditional small tank cascade systems in Sri Lanka. Several concepts have been used in this work drawing from both natural and social science disciplines. To begin with the STCS are considered socio-ecological systems.

A socio-ecological system consists of a 'bio-geo-physical' unit and its associated social actors and institutions. Socio-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context. Cascades are evolved within hydrological boundaries, taking a large unit (STCS) as the unit of planning where small tank is considered just a component of a system. These systems can be considered as early demonstration of the concepts such as integrated water resource management and landscape scale spatial planning experiences that Sri Lanka offered to the world a couple of millennia ago. Due to various issues related to socio-political, policy and management, overtime these STCS systems degraded. Concept of governing them at cascade level – keeping systems intact as against dealing with components (tanks) disappeared overtime as a result. Now trying to re-establish such, the values of ecosystem services provided by STCS failed to appear in decision-making table on these systems as they are not traded in the market.

A question often asked now is whether such investment in cascade level management and restoration will pays off? Hence, the concept on non-market valuation has been used in this research to elicit such values which do not come to play naturally in decision-making. Non-market valuation technique – Choice Experiment was used to create those values based on the principles of consumer choice theory. The total economic value of STCS is estimated through people's willingness to pay for restoring a cascade from present status is assessed using discrete choice analysis – choice experiments in short. The theory behind choice experiments is closely linked to two economic theories known as Lancaster's Characteristic theory of value (Lancaster, 1966) and the Random Utility theory (Thurstone, 1927; McFadden, 1974). According to Lancaster's approach to consumer theory, consumers derive their utility not from the product as such, but from the attributes by which the product can be described. The estimated benefits (non-market values) of STCS by way of WTP was included in benefit cost analysis framework for economic evaluation of cascade wide restoration.

## 2.3 Historical, Cultural and Socio-economic Significance of STCS

As brought out by Panabokke (2004) the small[5] (interchangeably used minor or village tank for small tanks) tank marks the beginning of organised human settlement in Sri Lanka. He further stated that in the second century BC, North Central Region became the more favoured area for evolution and spread of small tank settlements. Subsequently, by the fifth and sixth century AD, both small and large tank settlements fully developed across the Dry Zone of Sri Lanka.

There are over 18,000 small tanks scattered throughout the Dry Zone of Sri Lanka (Panabokke, 2004 & Ratnatunge, 1979). Though these small tanks originally thought to have distributed randomly, research in late 1980s established that the distribution pattern of village tanks in capturing rainwater received are in well-defined micro catchments through their strategic location in the macro landscape (Madduma Bandara, 1985; Panabokke, 1999; Panabokke et al., 2002). Moreover, individual small tanks constitute the component units of larger systems of rainwater harvesting units known as 'cascades'. The cascades are clusters of hydrologically interconnected village tanks that help to harvest rainfall received by larger watershed units called meso-catchments (Madduma Bandara, 1985; Panabokke et al., 2002; Tennakoon, 2001).



[5] Tanks which have a command area less than 80ha are considered as small tanks belonging to minor irrigation category. They are also referred to as village tanks as well as minor tanks.

Minor irrigation systems[6] are officially defined as tanks and anicuts with command areas of 80 ha or less (Agrarian Services Act 58, 1979). These were largely under the administration of the Department of Agrarian Development. With the devolution of powers to Provincial Councils under the 13th Amendment to the Constitution, management of minor irrigation became a devolved subject which comes under the Provincial Departments of Irrigation. However, in many places PDoI has not demonstrated that they actively take part in small tank management mainly due to capacity constraints. Hence, in practice the DAD is broadly taking the lead in small tank management in Sri Lanka. However, as reported by Wijeratne et al., (2016), in some places there are conflict of interests between the central government agency (DAD) and the provincial administration (PDoI) on minor irrigation rehabilitation, maintenance and water management. Furthermore, Wijeratne et al. (2016), elaborated the need for integrating and coordinating the functions of these two separate and independent entities to avoid duplication and overlapping of their activities.



The subject that is being addressed in this research is on small tanks or village tanks (*wewa* in Sinhala), specifically the small tank cascade (*ellangawa* in Sinhala) systems.

Interest to study small tank irrigation is somewhat recent with the comprehensive mapping exercise done by Ratnatunga (1979). Sakthivadivel et al., 1996 in their IIMI Country Paper 13 on "Nature of small tank cascade systems and framework for rehabilitation of tanks within them" provides a commentary on the scientific studies conducted on small tanks in Sri Lanka. It concludes that the past studies beginning with Kennedy's seminal work titled 'Evolution of scientific development of village irrigation

[6] Minor irrigation schemes are those that irrigate less than 80ha (or 200ac) of command area. These include village/small/minor tanks and anicuts (river diversions).

works' in 1933 to Madduma Bandara's pioneering work presented in 1985 as "Catchment ecosystems and village tank cascades in the Dry Zone of Sri Lanka, a time-tested system of land and water resource management", all scientific work done in small tanks in Sri Lanka, have been done as individual small tanks rather than the whole tank cascade. Shift in emphasis from individual tanks to more holistic, interconnected system of tanks in a given watershed –called tank cascade took place following Madduma Bandara (1985).

As highlighted by Senaratne & Wickramasinghe (2011), the causal factors that have transformed the traditional systems are broad sweeping and powerful forces of social change. The production system being evolved as a result of these factors has the potential for high level of productivity and higher income than the system it is replacing. Given the circumstances, it seems that the on-going transformation is irreversible and there is no reverting back to the past system how much environmental-friendly it may be. Instead, we need to identify the strengths, weaknesses, and gaps in knowledge in the emerging system so that we can make it more sustainable than the present. Further, Senaratne & Wickramasinghe recommends that "any technical/institutional interventions or policies should aim at finding a sustainable path of transformation rather than preserving or re-establishing the old order".



The setting and distribution pattern of small tank cascades across the Rajarata landscape has been described by Panabokke (2009). Altogether a total of 457[7] small tank cascades have been identified and demarcated over 50 sub-watersheds that make up the nine river basins of Rajarata. A summary statement of the total number of sub-watersheds present within

[7] Total for the country is estimated at 1,166 cascades

each main watershed, together with the total number of cascades present within each sub-watershed is given in Table 2.1. As could be seen in this table, the highest number of cascades is found within the *Malwathu Oya* basin followed by the *Kala Oya* and *Yan Oya*. The *Malwathu Oya* basin can, therefore, rightly be considered as the cradle of the hydraulic civilisation. It should be noted that there is a small percentage of small tanks that do not occur within a cascade, but as individual tanks with their own independent catchment. A well-known example is that of the *Pul Eliya* village tank close to *Medawachchiya,* studied by Leach (1961).

*Table 2.1: Distribution of Rajarata Small Tank Cascades*

| Main Watershed Basin | Number of Sub Watersheds | Number of Cascades |
|---|---|---|
| Malwathu Oya | *15* | 179 |
| Kala Oya | *12* | 68 |
| Yan Oya | *7* | 74 |
| Ma Oya | *4* | 40 |
| Parangi Aru | *4* | 34 |
| Modaragam Aru | *3* | 42 |
| Pankulam Aru | *3* | 11 |
| Kaddikkaddi Aru | *1* | 8 |
| Mee Oya | *1* | 1 |
| **Total** | ***50*** | ***457*** |

Source: Panabokke, 2009.

## 2.4 Small Tank Cascades as Systems with Multiple Benefits

Small tanks have been part of the Dry Zone culture. A tank cascade is a connected series of tanks that stores, conveys, and utilises rainwater from first or second order temporary streams (see Figure 2.1). Excess water flowing from one tank in the cascade is captured in the next tank downstream, which is an efficient system of water management. When examining, it is clear that these cascades were built with the indigenous knowledge taking watershed boundary as the boundary of the cascade, demonstrating the early lessons on the Integrated Water Resources Management (IWRM), the idea came in to practice much later in the modern world.

Furthermore, these systems demonstrate the key features in landscape approach to planning and management being popularised in recent times.

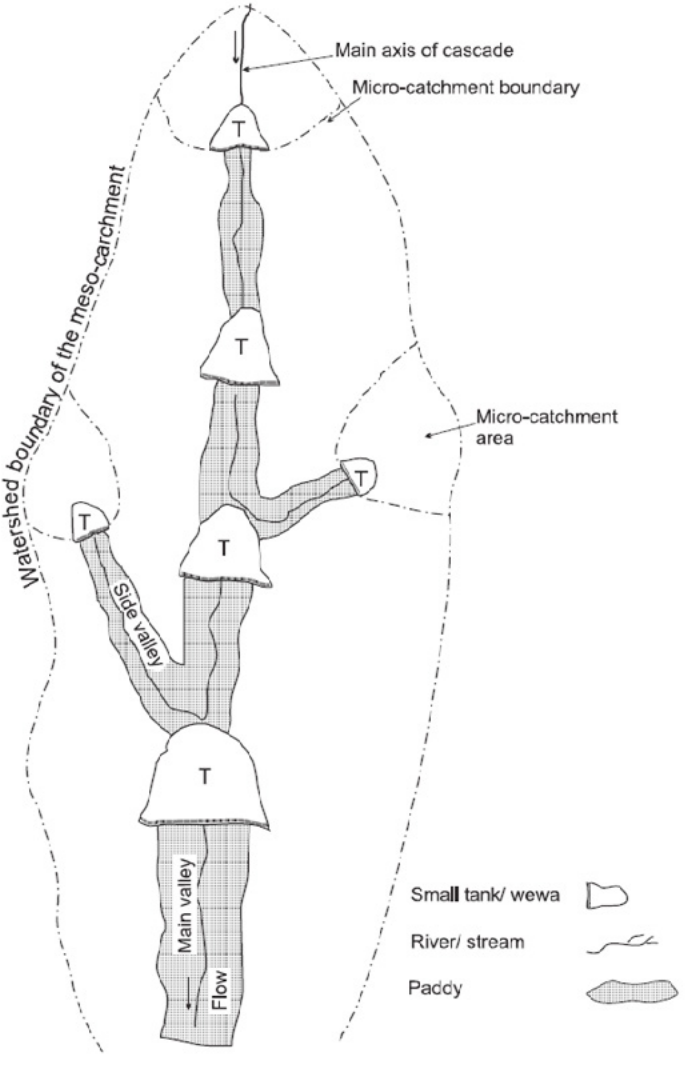
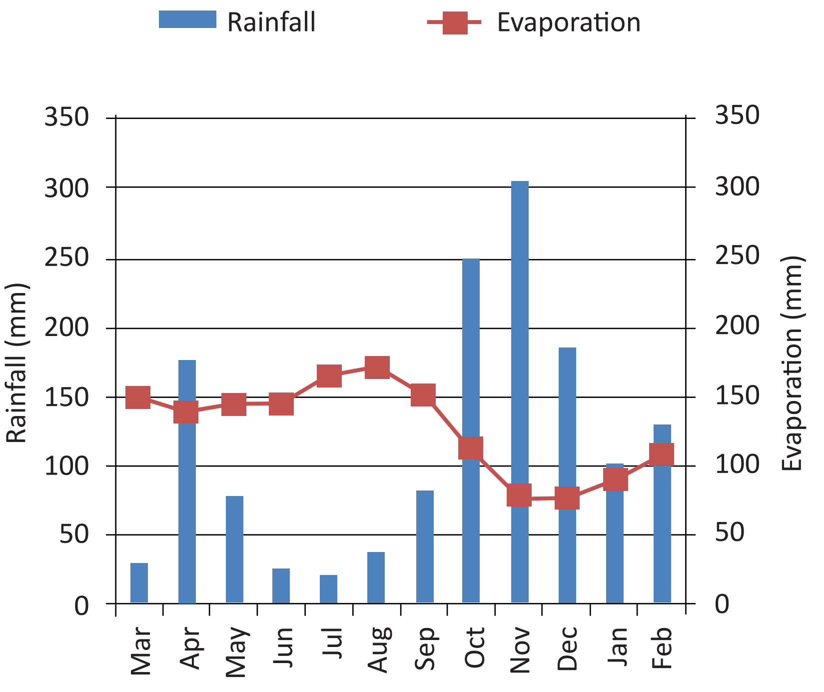



***Figure 2.1: Schematic Diagram of a Cascade Water Course***
Source: Panabokke, 2009, p. 6

Most of these small tanks go dry during the peak dry (Yala) season (July-September) that coincides with the rainfall pattern (see Figure 2.2). However, they continue to provide some ecosystem services even during the dry season as most of these small tanks continue to hold water in their dead-storage *(madakaluwa)* which cannot be removed from the sluice *(sorowwa)* for irrigation due the level difference by design. According to climate change vulnerability mapping conducted in 2010 by the Ministry of Environment in partnership with the Asian Development Bank, parts of the Dry Zone have been identified as high vulnerable areas for rainfall fluctuation and temperature changes (Ministry of Environment, 2010). One of the most cited and apparent impacts would be erratic nature of rainfall, where intensity and distribution pattern and timing of rainfall would change. Some of these changes are being already observed by farmers. Small tank cascades in the Dry Zone of Sri Lanka, if properly managed would be one of the best adaptation measures for such vulnerability as they could hold extra water when available, nourish the surrounding ecosystems in the catchment and provide water for other uses as and when available.



The economic value related to environmental resource derives from various sources. The use of the environmental resources (use values), capture both commercial as well as non-commercial uses or from its mere existence - even in the absence of use (non-use value). A broad array of values included under this approach is captured by the Total Economic Value (TEV) framework to identify potential sources of this value. Use of the TEV framework helps to provide a checklist of potential impacts and effects that need to be considered in valuing ecosystem services as comprehensively as possible (Figure 2.3). Therefore, this research is an attempt to understand the economic aspects of small tank cascade systems with particular interest to capture non-market benefits generated by these systems.




1.1 (a): rainfall and evaporation

***Figure 2.2: Rainfall Distribution in the Anuradhapura District***

Source: Senaratne, 2013

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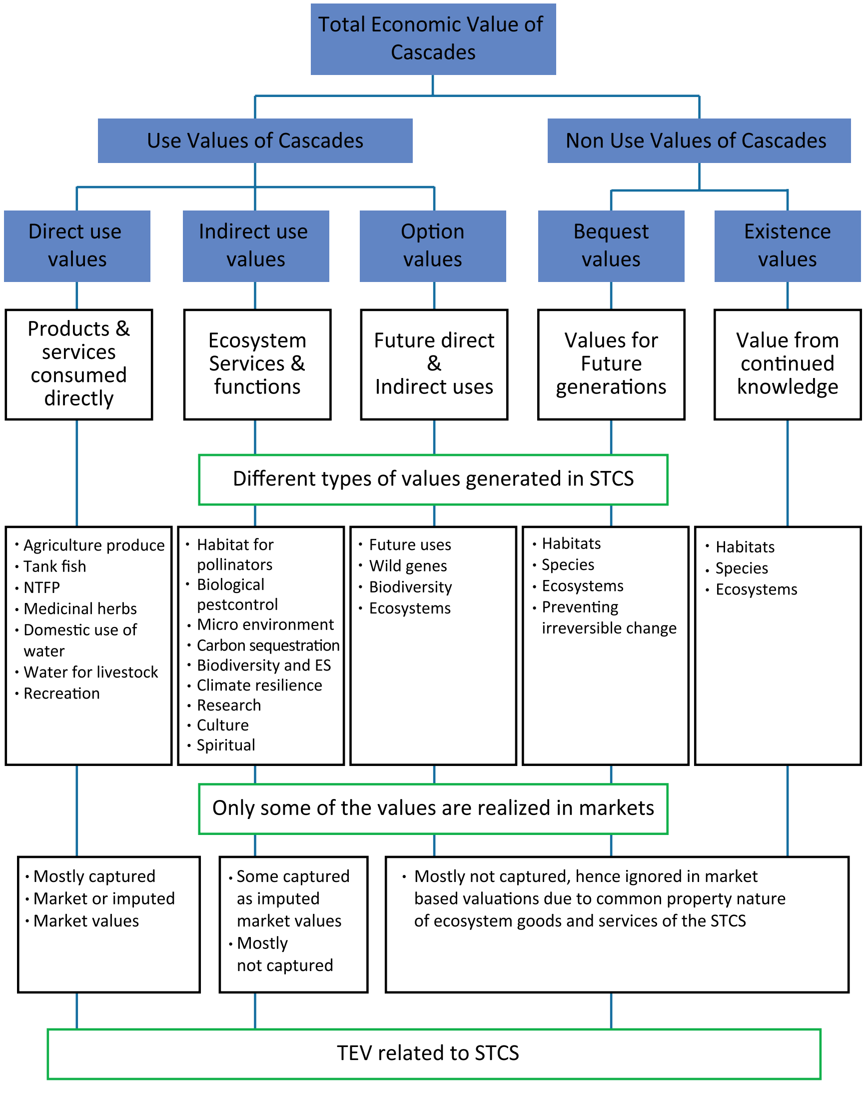


***Figure 2.3: Total Economic Value diagram for STCS***

Source: Modified after Kotagama, H.B., Ranawana, S., Vidanage, S.P., & Dahanayake, 1997; Vidanage, Perera, & Kallesoe, 2005; Dayananda, 2007

The concept of TEV is discussed further in the latter part of this chapter where the economic aspects are discussed as this builds the foundation for environmental valuation. The Table 2.2 provides the multiple benefits from small tanks and STCS identified within the TEV framework.

***Table 2.2: Total Economic Value of a Village Tank***

| Value type | Sub type | Definition | Examples | MEA[8] Category |
|---|---|---|---|---|
| Direct use | Consumptive | Outputs directly consumable | Tank products - water for domestic use, tank fish, lotus flowers, lotus roots, NTFP, livestock - water and grazing, wild varieties of food - wild plants and animals, thatching materials, medicine, fruits and vegetables, poles, timber, fuel wood, rattan, bathing and washing for people | Mostly Provisioning Services |
| | Productive | Outputs used in production | Agriculture output - paddy & other, wild gene for plant breeding, brick making, habitat for pollinators and biological pest control agents | Mostly Provisioning Services |
| | Non-consumptive | Not depleting due to use | scientific research value, recreation value, religious and spiritual, aesthetics, leisure, tourism, educational, place for cultural and religious rituals | Mostly Cultural Services |
| Indirect use | | Functional benefits | Micro-climate stabilization, external ecosystem support, gene pool conservation, carbon sequestration, nutrient cycles, ground water recharge, nutrient retention, flood and drought regulation, water table maintenance, maintenance of biodiversity and tank ecology, cultivation using agro /tube wells and adaptation to climate change | Mostly supporting services |
| Option values | | Future direct and indirect use values | Preserving for future use, future value of drugs, improvements to crops and identifying new crops | Mostly Provisioning Services |

[8] MEA Categories – Ecosystem services categories proposed by Millennium Ecosystems Assessment, (2005)

| | | | | |
|---|---|---|---|---|
| Bequest values | | Values derived from the knowledge that others might benefit in the future | Habitats, sentimental value and prevention of irreversible changes | Mostly Cultural Services |
| Existence Values | | Value from knowledge of continued existence | Habitats, species and ecosystems | Mostly Cultural[9] Services |

Sources: Adapted from Pearce and Moran, 1994; Kotagama et al., 1997; Vidanage et al., 2005; Dayananda, 2007.



Village tank is a man-made ecological construction, which includes several components of natural resources management. According to Dharmasena (2004), the village tank systems have provided due consideration to the micro land uses in addition to the macro land uses of '*Gangoda*' (home garden), 'Chena' (shifting cultivation), and '*Welyaya'* (lowland paddy cultivation). Micro land uses include '*Gasgommana*' (the upland land strip above the tank bed, where water stagnates only when spilling and also as a wind barrier), '*Godawala*' (a water hole to trap silt before water enters the tank bed), '*Perahana*' (a meadow developed under the '*Gasgommana*' to filter sediment coming from upstream 'Chena'), '*Iswetiya*' (upstream soil ridge on either side of tank bund to prevent entering eroded soil from upper land slopes), '*Kattakaduwa*' (reserved land below the tank bund consisting of diverse vegetation to absorb salinity) and '*Kivul ela*' (natural stream utilizes as a common drainage) Dharmasena (2004).  The key components of small tank cascade systems are indicated in the Figure 2.4.

[9] Cultural services include recreational, aesthetic, and spiritual benefits according to the Millennium Ecosystems Assessment, 2005. Social coherence and harmony resulting in village tank culture also can be considered under this service category of MEA.

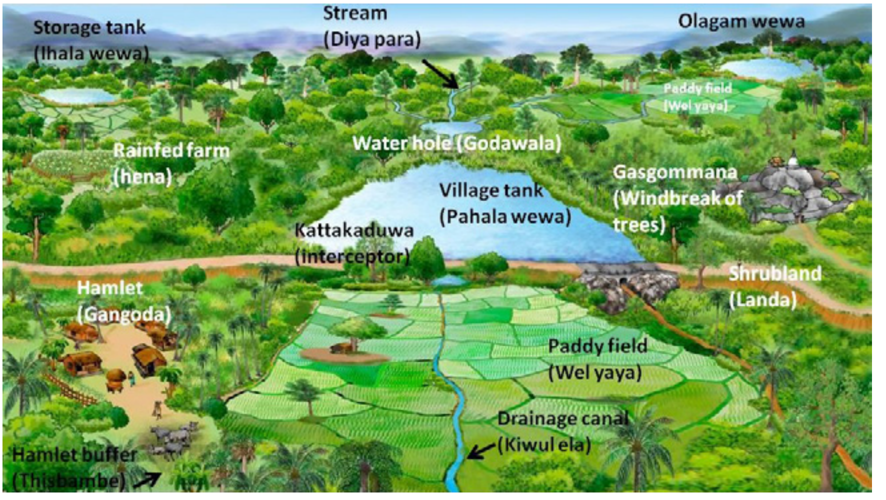


***Figure 2.4: Components of a Typical Small Tank Cascade System***

Source: IUCN, 2016

The above-mentioned ecological components of cascades harbour unique biodiversity found in the Dry Zone of Sri Lanka. The recent assessments conducted in the *Kapiriggama* Cascade in the vicinity of the *Pihimbiyagollewa* cascade provides an indication of the diversity of life these STCS harbour. The Table 2.3 provides the list of threatened plants recorded in *Kapiriggama* cascade.

***Table 2.3: Threatened Plant Species Recorded from Kapiriggama[10] STCS***

| Family | Botanical name/Sinhala name | NCS |
|---|---|---|
| Amaryllidaceae | *Crinum latifolium* L. /Godamanel | VU |
| Apocyanaceae | *Anodendron paniculatum* A.DC. /Aswel | VU |
| Apocyanaceae | *Gymnema sylvestre* (Retz.) R. Br. ex Schult. /Masbedda | VU |
| Apocyanaceae | *Heterostemma tanjorense* Wight & Arn. ex Wight /Palakeera | VU |
| Aponogetonaceae | *Aponogeton crispus* Thunb. /Kekatiya | VU |
| Basellaceae | *Basella alba* L. /Gam nivithi | EN |
| Celastraceae | *Salacia reticulata* Wight /Kothala himbutu | EN |
| Ebenaceae | *Diospyros ebenum* Koenig /Kaluwara | EN |
| Lauraceae | *Alseodaphne semecarpifolia* Nees /Wevaraniya | VU |
| Loganiaceae | *Strychnos nux-vomica* L. /Godakaduru | VU |
| Loranthaceae | *Taxillus courtallensis* (Gamble) Danser / Niliwel | VU |
| Malvaceae | *Corchorus olitorius* L. /Goni gas | VU |
| Menispermaceae | *Pachygone ovata* (Poir.) Hook.f. & Thoms. /Pilila | VU |
| Menispermaceae | *Tinospora cordifolia* (Willd.) Hook.f. &Thoms. / Rasakinda | VU |
| Moraceae | *Plecospermum spinosum* Trecul /Katu thimbol | VU |
| Nymphaeaceae | *Nymphaea nouchali* Burm.f. /Manel | VU |
| Orchidaceae | *Vanda tessellata* (Roxb.) Lodd.ex G. Don /Reththa | VU |
| Phyllanthaceae | *Margaritaria indicus* (Dalz.) Airy Shaw /Karau | VU |
| Poaceae | *Aristida adscensionis* L. /Theli thana | VU |
| Poaceae | *Coix lacryma-jobi* L. /Kirindi | VU |
| Poaceae | *Dichaetaria wightii* Nees ex Stude. /- | VU |
| Rubiaceae | *Tamilnadia uliginosa* (Retz.) Tirv. & Sastre / Et kukuruman | VU |
| Rutaceae | *Chloroxylon swietenia* DC. / Burutha | VU |
| Sapindaceae | *Lepisanthes erecta* (Thw.) Leenh. / - | VU |
| Sapotaceae | *Manilkara hexandra* (Roxb.) Dubard /Palu | VU |

Source: Goonatilake, S. de A., Ekanayake, S.P., Perera, N., Wijenayake, T. and A. Wadugodapitiya (2015).

Where VU – indicates vulnerable species, EN – indicates endangered species according National Red List, Sri Lanka, 2012

The Table 2.4 provides the threatened animals found in *Kapiriggama* cascade

[10] Detailed fauna and flora studies are not available for Pihimbiyagollewa cascade. As there are many similarities between Kapiriggama and Pihimbiyagollewa cascades it is expected to have similar species richness in Pihimbiyagollewa cascade.

***Table 2.4: Threatened Animal Species Recorded in Kapiriggama STCS***

| | Scientific Name | English Name | Sinhala Name | NCS |
|---|---|---|---|---|
| 1 | *Pethia melanomaculata* | Tic-tac-toe barb | *Depulliya / Tith-pethiya* | VU |
| 2 | *Crocodylus porosus* | Saltwater crocodile | *Gata kimbula* | EN |
| 3 | *Rostratula benghalensis* | Greater Painted-snipe | *Raja Ulu-kaswatuwa* | VU |
| 4 | *Charadrius alexandrinus* | Kentish Plover | *Kenti Oleviya* | VU |
| 5 | *Pipistrellus coromandra* | Indian pipistrel | *Indu Koseta-vavula* | VU |
| 6 | *Prionailurus rubiginosus* | Rusty-spotted cat | *Kola Diviya / Balal Diviya* | EN |
| 7 | *Lutra lutra* | Otter | *Diya-balla* | VU |
| 8 | *Elephas maximus* | Elephant | *Etha / Aliya* | EN |

Source: Goonatilake et al., 2015

Where VU – indicates vulnerable species, EN – indicates endangered species according National Red List, Sri Lanka, 2012



## 2.5 Review of Environmental Valuation Related to STCS

Since Ratnatunga (1979), substantial amount of research work has been conducted on technical, bio-physical and socio-economic aspects of individual small tanks with relatively less research on economics. As elaborated above, emphasis of such studies was on individual tanks and not on cascades of tanks.

Hence, it is clear from the literature that the economic aspects of the cascades have not been sufficiently studied in Sri Lanka, especially taking cascades as the unit of analysis.

Apart from the gap in studies related to economics of small tank cascades, most of the studies conducted on individual tanks were based on conventional BCA taking the market transacted components of the benefits and costs. Some of the early studies on economic aspects of small tanks were on restoration of small irrigation tanks under the Village Irrigation Rehabilitation Programme (VIRP) where the marketed aspects of tank benefits (agricultural production) were taken in Benefit Cost Analysis against cost of restoration (Gunadasa, Wickramasekera, & Herath, (1980), 1981; Sivayoganathan, Herath, Pinnaduwage, & Bogahawatte, (1985).

There have only been limited research carried out on the economic aspects of the small tanks as cascade systems. These studies have limited to the examination of the direct use values. Both individual small tanks as well as small tank cascade systems, being ecological constructs, provide numerous ecosystem goods and services for which values are not determined by the market mechanism. Hence, those values are missed out in conventional BCA.

However, interpretation of how villagers of small tank systems appreciate non-market values of small tanks as they sometimes forgo economic benefits by not cultivating paddy for conserving water for other uses such as drinking, bathing and washing has been reported by Panabokke et al., (2001). He further elaborated highlighting the need for capturing nonmarket values indicating that "quantified values of those functions have not yet been scientifically ascertained and demonstrated".

Dharmasena (2004) argued that the cost/benefit methodology cannot be successfully applied to measure the manifold economic and social benefits of tanks to the individuals, communities and to the nation. Yet an appropriation can be made by intuiting values to the manifold social benefits. Then it will be found that those benefits far exceed the costs of de-silting tanks to improve their water storage capacity which gives cumulative benefits indefinitely. If the small tanks were successfully used for two thousand years or even more, it should be the benefit which these tanks accrued to people, over the cost, which convinced them to continue it to the present day as source of productive input – that is water. The need for the cascade-based small tank development cannot, therefore, be ignored for farming (Dharmasena, 2004). Dharmasena further explains that the partial de-silting[11] will not be economical if the whole purpose of de-silting is to increase the storage of water just for paddy farming (or irrigation).

Jayawardena, (2010) has done an economic assessment of the cascade system with regards to the ancient period with the help of historical evidence. It revealed the effect of cascade systems to the economy in macro level at ancient times. The system functioned as a response to water demand from the people and people paid for the service they received from the government. This economic relationship helps to sustain the cascade system as it ensures the continuity of the system. His paper analyses the potential of the ancient irrigation system as a means of wealth creation and also has analysed the taxation methodology coupled with ancient water use (Jayawardana, 2010). The types of revenues were identified as *dakapathi*, payment to the state in the form of a tax and the *bojakapathi*, payment to the supplier of water. He further claims that all minor and major canals and tanks, built by the King, were the property of the state and their income in the form of taxes on water and fish yield was absorbed by the royal treasury. However, Madduma Bandara disagrees with the proposition that all small tanks were built and owned by the king, especially when there is evidence for existence of *vapi-hamika* and temple tanks[12].



[11] Partial-desilting is removal of silt in tanks filled with sediments in a way that increase the water holding capacity by changing the geometry of the tank.

[12] Madduma Bandara personal communication

Large reservoirs are the constructions of kings and belonged to the government and acted as a public good. But according to Siriweera (2001), he identifies the term *vapi-hamika* found in the Brahmi inscriptions from the third century B.C. onwards as denoting a 'tank-owner'. The *Thimbiriwewa* inscription of the third century A.D. refers to a reservoir owned by a family, *tumaha kula sataka*. Jayawardana (2010) emphasised that ownership of the tank can vary from a single individual, families, institutes like monasteries or to the government (the King). According to Jayawardana (2010), the farmer's share of water was called *diyamura* and for this he had to pay a stipulated amount to the water supplier. Owners of a single component of a cascade could earn by supplying water or fish to the downstream users. At the same time, they had to pay for water received from upstream suppliers (Jayawardana, 2010).



Goonatilake et al., (2015) reported that the *Konakumbukweva* rock inscription in *Kapiriggama* cascade provides evidence of donating the *Konakumbukweva* tank by a donor called "*Vasaya Sivika*" to maintain in proper condition to a *Mehenavara* (Buddhist nunnery). Citing *Paranavitana*, (2001) the authors indicated that the inscription can be dated back to the second to third century A.D. The *Kapiriggama* is the adjoining cascade to the *Pihimbiyagollewa* cascade selected as the on-site sample for this study.

Cascade systems have been assessed from an economic viewpoint covering different facets. Kularatne, (2011) examined whether water allocation becomes more productive when it is re-allocated from 'low' to 'high' efficient alternative uses in village irrigation systems in Sri Lanka. Institutional suggestions have been given to the problem by assessing both rice farming and fish farming groups in Anuradhapura and Kurunegala administrative districts. Inter-sectoral optimal allocation shows that the estimated inefficient volume of water in rice farming, which can be re-allocated for fish farming is 32%. The existing inter-sectoral inefficient volume of water use in tail-end fields and head-end fields can potentially be removed by reducing water use and re-allocating this to middle fields. Kularatne, (2011), emphasises that the total productivity of reservoir water can be increased by responsible village level institutions and primary level stakeholders.

Plan Sri Lanka presented the cost and benefits of cascade restoration work they have undertaken in five cascades during 2004 – 2010. However, Benefit Cost analysis has not been performed for the restoration that they undertook (Plan Sri Lanka, 2012). Vidanage, et al., (2005) assessed the direct use values in economic terms for selected small tanks of Kala Oya basin covering small tanks cascades as well as isolated small tanks (occurring as solitary tanks outside the cascades). The estimates are provided in the Table 2.5 in 2003 US$ per ha of water spread area of a small tank. Their study showed that the agricultural production of small tanks is just around 20% of the direct use values that the villages are enjoying from a small tank.

***Table 2.5: Direct Use Values of Small Tanks in Kala Oya Basin***

| | **Economic value[13] (US$/ha/year)** | |
|---|---|---|
| Product | *Giribawa cascade* | Isolated tanks |
| Paddy | *290* | 161 |
| Banana | *54* | 209 |
| Coconut | *149* | 216 |
| Other field crops | *7* | 39 |
| Domestic use | *2,276* | 1,469 |
| Livestock | *949* | 335 |
| Fishery | *171* | 351 |
| Lotus flowers | *15* | 72 |
| Lotus roots | *0* | 107 |
| Industrial use | *0* | 12 |
| Sedge | *0* | 0.6 |
| Total | *3,911* | 2,972 |

Source: Vidanage et al., (2005)

They also evaluated the indirect benefits of these small tanks qualitatively assessing their services in terms of ground water and subsurface water recharge, nutrient and sediment retention and biological diversity related services. Their work provided following scenarios for small tank management decision-making based on prevailed practices. The results are tabulated below in Table 2.6;

i. Option 1 - Keep the tanks as they are – here, the sedimentation loads remain the same if not increasing and tank wetland continue to deteriorate.

ii. Option 2 - Raise the level of the spill in tanks – here, the water body will grow, and additional land will be flooded but sedimentation loads will remain the same if not increase.

[13] Economic values were calculated for a unit area of the tank water spread measured in ha

iii. Option 3 - Raise the level of the spill in tanks and manage the reservation properly – here, the water body will grow, and additional land will be flooded and future sedimentation loads reduced, thus prolonging the lifespan of the wetlands.

iv. Option 4 - Desilt the tanks and manage the reservation properly– here, the original tank capacity and seasonality is restored and future sedimentation loads reduced, thus prolonging the lifespan of the wetlands and restoring its environmental goods and services.

*Table 2.6: Management Scenario for Small Tanks Based on Economic Reasoning*

| Management Scenarios for small tanks | Incremental NPVs of direct uses | Qualitative estimates of indirect uses | Value of the accumulated natural capital |
|---|---|---|---|
| Option 1<br>Keep the tanks as they are – here, the sedimentation loads remain the same if not increasing, and tank wetland continue to deteriorate | 0 | *7-* | NC 1 |
| Option 2<br>Raise the level of the spill in tanks – here, the water body will grow, and additional land will be flooded, but sedimentation loads will remain the same if not increase | 2.4 | *4-* | NC 2 |
| Option 3<br>Raise the level of the spill in tanks and manage the reservation properly – here, the water body will grow, and additional land will be flooded and future sedimentation loads reduced, thus prolonging the lifespan of the wetlands | 6.4 | *6+* | NC 3 |
| Option 4<br>Desilt the tanks and manage the reservation properly – here, the original tank capacity and seasonality is restored, and future sedimentation loads reduced, thus prolonging the lifespan of the wetlands and restoring its environmental goods and services | 11.95 | *7+* | NC 4 |

Source: Vidanage et al., 2005

Where NC refers to accumulated natural capital estimated for tanks for selected management option after 30 years of decision-making and NC4 > NC3 > NC2 > NC1

In this work Vidanage et al., assessed the prevailed management options, however decision-making at cascade level has not been part of their study. Subsequently, Dayananda (2007) expanded small tank valuation by including some of the non-market values and attempted Benefit Cost Analysis of village tank rehabilitation. Dayananda concluded that the economic justification of small tank restoration is only possible when non-paddy benefits are included to the BCA.  The values they estimated were LKR 159 million/year for an average small tank from a cascade and LKR 381 million/year for an isolated tank of the sample they used in Hambantota district of Sri Lanka.   However, their research too has been focussed on individual tanks. They have used 7 isolated tanks and 3 tanks of a given cascade for their research. Therefore, they too have not assessed cascade-wide values for the small tank cascades of Sri Lanka.



Vidanage, (2017) concluded the importance of considering cascades as a unit of analysis for small tank restoration by analysing secondary data of 400 small tanks in 50 cascades of the *Malwathu Oya* basin in the Anuradhapura District of North Central Province of Sri Lanka. Findings indicated that the "the upstream tanks with tree girdles (*gasgommana*) helps preserving the downstream tank capacity and continuous 'shifting cultivation' (chena) of upstream tanks of the STCS contribute to reduction in downstream tank capacity. Further, the study showed that in tanks where there is vegetation buffer (*thisbambaya*) between the tank and the village enhances the preserving the tank capacity. Furthermore, the upstream tanks silt holding capacity shows a positive relationship to preserving downstream tank capacity preservation recommending cascades as a better candidate for planning of small tank restoration compared to individual tanks within a cascade. However, the research has not provided an economic justification for such recommendation, hence; the current research is expected to fill in this gap.



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### 2.5.1 Small Tank Cascades as a Common Property Resource

Small irrigation tanks are one of the oldest and most important communal property water resource in the Dry Zone of Sri Lanka. In addition to their role as the main source of water for agriculture, domestic and livestock raring related purposes, these tanks are important from an ecological perspective because they serve as a geographically well-distributed mechanism for the conservation of soil, water and biodiversity (Balasubramanian & Selvaraj, 2003). Further, the small tanks play a central role in socio-cultural and spiritual aspects of the village life in the Dry Zone of Sri Lanka. They create an 'oasis effect' that attracts a wide variety of aquatic life as well as avifauna and other animals[14].



Senaratne & Wickramasinghe (2011), discussed that the tanks and common lands in tanks were traditionally governed by customary law. The homesteads and home gardens located at '*gangoda*' were under some form of private tenure in the villages. They further elaborated that the British rulers brought those commonly held lands under the Crown in 1840 but continued as *de facto* common property. However, in the recent past, there is increasing evidence of people encroaching into these lands for personal benefits and making them '*de facto*' private property disregarding the local customs and the rules. Authors then argued that community management and collective action is largely confined to village tanks and not so much in other parts of the small tank cascades. The British recognized traditional management practices in a limited context such as in irrigable areas under the Irrigation Ordinance No 32 of 1946 (see section 11of the Ordinance). The present-day lack of respect towards commons in small tank systems can be largely attributable to the lack of enforcement of the law by respective authorities and formalisation of encroachments due to political reasons by successive governments.

[14] Madduma Bandara personal communication

Ulluwishewa (1997), clearly indicated the degradation of traditional common property resource management system in villages in general and village tank system is no exception. However, Madduma Bandara emphasised the distinction between private property and common property is not so well defined in traditional tank villages. Therefore, the application of the 'law of commons' has to be attempted with caution[15]. Different property regimes and their definitions are provided in the Table 2.7.

***Table 2.7: Definition of Property Regimes***

| **Type of property** | **Definition** |
|---|---|
| State | Individuals have a duty to observe the rules of use determined by the controlling agency. The agency has the right to determine those rules |
| Private | Individuals have a right to undertake socially acceptable uses and a duty to refrain unacceptable uses. Others have a duty to respect individual rights |
| Common | A management group has the right to exclude non-members. Non-members have a duty to abide by that exclusion. Co-owners comprise the management group and have rights and duties related to the use of resources |
| Open access | No uses or owners are defined. Individuals have the privilege but not the right to use resources |

Source: Pearce & Warford, 1993



[15] Madduma Bandara personal communication

## 2.6 Review of Environmental Valuation

Ariza, Galan, & Serrano (2007), studied water tanks as ecosystems in South India, where they focused on the theoretical framework of strong sustainability under the interdisciplinary approach of ecological economics. In addition, they focused on extended peer review process to capture different social values and different views of the scientific reality. As highlighted by several writers (Ostrom, 1990; Agrawal, 2003; Senaratne & Wickramasinghe, 2011) small tank cascade systems possess elements of common property or common pool of resources. Where there are some non-rival and non-excludable goods and services provided and needing collective action for their governance. However, others argue these features are very few in present day tank village systems confined to limited non-consumptive uses[16].



### 2.6.1 Theory of Pubic Goods

Brundtland Commission's Report, 1987 challenged the entire world to recognize that we all are sharing a common future and the need for sustainable development (World Comission on Environment and Development, 1987). Almost two decades later Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005), indicated that their first finding was that there was an unprecedented rate of change to ecosystems during the last half century than that of any comparable period in human history. Their second major finding was that while these changes have led to substantial net gains in economic development and human well-being, the gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes and the exacerbation of poverty for some groups of people. These problems unless addressed, will substantially diminish the benefits that

[16] Madduma Bandara, personal communication

future generations obtain from ecosystems. Hence, sustainable utilization of natural resources becomes vital.

As stated by Ostrom (2008) the common-pool resources that are sufficiently large is difficult, but not impossible to define who the recognized users are and to exclude others. Further, each person's use of such resources is subtractive of benefits that others might enjoy. Fisheries and forests are given as two common-pool resources that are of great concern in this era of major ecological challenge. Irrigation systems, ground water basins, pastures and grazing systems are given as other examples.



Dasgupta, (2008) explained the difference between the economic theory of open-access and common property resources (CPR). He further proved that if a CPR is unmanaged and the uses are large it can approximate to an open-access resource. Dasgupta further explained that for success for CPR management four conditions need to be fulfilled, they are; 1. Mutual affection – parties care about one another sufficiently, 2. Pro-social disposition – it should be common knowledge that those making promises are trust worthy, 3. Incentives to keep promises – devise an institution to keep agreement in an equilibrium, 4. External enforcement – rely on external enforcer. An econometric study conducted in Tamil Nadu, India revealed that the increase in number of private wells in tank irrigation systems has a negative impact on both the persistence of traditional irrigation institutions and collective action for tank management (Balasubramanian & Selvaraj, 2003).

At first, economists focused on the two poles of a spectrum of goods; pure public goods and pure private goods. Private goods can be parcelled out among individuals and efficiently allocated by markets, whereas public goods cannot be divided among individuals, owing to non-rivalry of benefits and non-excludability problems. Collective provision was first thought essential for these public goods. As given in Corner & Sandler (1999) "Indeed, a very clear statement of what we would recognize as a public good problem was provided, more than 30 years before Smith's Inquiry into the Nature and Causes of the Wealth of Nations, by his friend David Hume. One passage from Hume's Treatise of Human Nature, first published in 1739, states the problem so clearly that it is worth reproducing:

> Two neighbours may agree to drain a meadow, which they possess in common; because it's easy for them to know each other's mind; and each must perceive, that the immediate consequence of his failing in his part, is, the abandoning of the whole project. But it's very difficult, and indeed impossible, that a thousand persons should agree in any such action; it being difficult for them to concert so complicated a design, and still more difficult for them to execute it; while each seeks a pretext to free himself of the trouble and expense, and would lay the whole burden on others. Political society easily remedies both these inconveniences. Hume, D. (1976, p. 538)" as given in Cornes & Sandler, 1999.



A public good, as defined by economic theory, is a good that once produced or naturally available and can be consumed by an additional consumer at no additional cost. A second characteristic is sometimes added, specifying that consumers cannot be excluded from consuming the public good once it is produced. A public good is a good having one or both of the characteristics of non-excludability and non-rivalry in consumption. Non-excludability means that it is difficult to keep people from consuming the good once it has been produced and non-rivalry in consumption means that one's consumption doesn't affect the utility of others up to the capacity constraint.

Small tank cascades too have elements of public goods in them; therefore, they need to be treated differently to private goods. Senaratne & Wickramasinghe (2011) argues that the village tanks are common property resources (CPR). The use rights for water in commonly owned village tanks are usually held by well-defined agrarian communities that own or cultivate paddy fields in the command areas of tanks. These communities make decisions on the use of tank water through institutional mechanisms involved with Farmer Organizations (FO). The prevalence of common property (partially or fully) elements in STCS provides justification for valuation of public goods attributes of tank cascades.

STCS are common pool renewable resources, they are having sustainable limits for extraction for the healthy functioning of the system. However, lack of collective action and control mechanisms to manage individual maximisation of benefits from the system can lead to a degradation of the system. As presented by Hardin (1968), in absence of such controls, a communal property like STCS generating rewards to individuals eventually can diminish beyond its capacity to regenerate – a phenomena that Hardin explained as 'the tragedy of the commons[17]'.



[17] The tragedy of the commons is an economic theory of a situation within a shared-resource system where individual users acting independently according to their own self-interest behave contrary to the common good of all users by depleting or spoiling that resource through their collective action.

*Table 2.8: Status of Property Rights in STCS*

| # | Ownership Elements or components | Private | Common/ Commu-nal | Both private and com-munal | Status Uncertain | Pangu/ sharing | Remarks on the ownership |
|---|---|---|---|---|---|---|---|
| 1 | Village tank | Temple tanks are private | ✓ | ✓ | | ✓ | Tank Water: A Common resources with a share of water proportionate to the share of paddy Land (as reflected in the sharing of fish catch) |
| | Water for agriculture | ✓ | ✓ | | | ✓ | Water in own paddy field can be considered private, all the other cases it can be considered communal. When there is insufficient irrigation water available in the tank amount is shared by way of the area to be cultivated. special case of *bethma* |
| | Water for non-consumptive uses | | ✓ | | | | Bathing, washing, water for animals husbandry and wildlife are communal |
| | Lotus flowers and seeds | | ✓ | | | ✓ | Lotus flowers and seeds communal – there are cases of leasing out of flowers collection and revenue goes to FO |
| | Tank fish | ✓ | ✓ | ✓ | | ✓ | Fishing is usually leased out and revenues shared. Occasional private fishing is not prevented |
| | Aesthetic benefits | | ✓ | | | | Aesthetic benefits can be considered common |
| | Biodiversity | | ✓ | | | | (Animals, Birds and Fish as well as wild products as edible leaves fruits and firewood) Biodiversity benefits can be considered common |
| | Cultural and religious | | ✓ | | | | Cultural and religious benefits can be considered communal |
| | Removal of clay for bricks | ✓ | ✓ | | | | Usually private |
| 2 | Other tanks/tank components | | ✓ | | | | Sorowwa, Vaana, bisokotuwa etc. except in private tanks |
| 2.1 | *Kulu wewa* | ✓ | ✓ | | | | Usually communal |
| 2.2 | *Godawala* | | ✓ | | | | Usually communal |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Tank bunds | | ✓ | | | | Usually common - anyone can use as a road |
| 4 | Upper catchment | | | ✓ | Govt? | | |
| 4.1 | Forest land above FSL | | ✓ | | Govt? | | Usually communal |
| 4.2 | Between tank water and FSL | ✓ | ✓ | | | | Some cultivate as de-facto private property, largely use as a communal property |
| 5 | Paddy fields | | | | | | |
| 5.1 | Paddy fields (Purana) | ✓ | ✓ | ✓ | | ✓ | Largely private, in instances of bethma – they are temporarily shared |
| 5.2 | Paddy Fields (Akkara wel) | ✓ | | | Govt? | | |
| 6 | *Kattakaduwa*/Interceptor | | ✓ | ✓ | | | Usually communal |
| 7 | *Gasgommana*/Wind break | | ✓ | | | | Usually communal |
| 8 | *Perahana/ Wew Pitiya* | | ✓ | | | | Usually communal |
| 9 | *Thisbambe*/hamlet buffer | ✓ | ✓ | | | | Usually communal |
| 10 | *Gangoda*/hamlet | ✓ | | | | | Private property |
| 11 | *Hena*/Rainfed upland farmlands | ✓ | | | Govt? | | *de-facto* private property |
| 12 | *Landa*/Shrubland | | ✓ | | Govt? | | Usually communal |
| 13 | *Kivul ela*/Drainage canal | | ✓ | | | | Usually communal |
| 14 | Agro-wells | ✓ | | | | | Private property |
| 15 | Temples and Devale lands | ✓ | ✓ | | | | 'Pin kumburu' are lands donated to the temple |
| 16 | Rocks and Rock outcrops, Minerals and sands etc | | ✓ | | Govt? | | |

Source: Common knowledge and consultative discussions with experts ✓ indicates presence;

### 2.6.2 Introduction to Economic Value

There are many facets of value, as found in Dhamma Pada, Buddha teaching refers to wealth "*Arogya parama labha - santutti paramam dhanam. Vissasaparama nati - nibbanam paraman sukham*," meaning "Health excels all gains. Contentment excels all wealth. Trustworthiness is best of relatives. Nibbana is the ultimate happiness."

The concept of value in Buddhist tradition differs that of conventional economics. Happiness according the Buddhist tradition is not an attachment to goods and services, but a feeling as the result of the serious work of inner reflection and compassion toward others. The 'Buddhist Economics' was put forward by Schumacher (1973), since then it has been getting momentum in explaining aspects such limits to growth and sustainability. Buddhist economics suggests people to think mindfully as they go about their daily activities and offers a way to appreciate how their actions affect the well-being of those around them including the environment.



The economic concept of value has been broadly defined as any net change in the welfare of society. This concept does not restrict environmental values to benefits from the direct use of a resource. For example, the benefits received from environmental resources (such as enjoyment of national parks and clean air) add to an individual's well-being, as do the benefits obtained from the consumption of goods (such as steel and sawn timber). The benefits that individuals obtain in satisfying altruistic desires that arise from their own moral beliefs also have economic value. From an economic perspective, values can be associated equally with the consumption of goods and services purchased in markets and with the services from environmental amenities for which no payments are made. In this sense, anything from which an individual gains satisfaction is deemed to be of value, so long as the individual is willing to give up scarce resources for it (Freeman, 1999).

Monetary values are readily observable for commodities regularly exchanged in the marketplace. However, because many environmental resources such as clean air, wilderness and the existence of wildlife are not often exchanged in markets they are unpriced. Nonetheless, these non-market resources have monetary value if people are willing to trade some of their income and wealth for them. In this way, monetary values do not depend upon whether people trade money for the benefits received.

In economic theory, an economic value of any good or service is determined by its price- that is the quantity of money for which it will be exchanged. But the value of a benefit is not simply the price of that product on the open market. It is, rather, the individual's willingness to pay for the benefit. Therefore, economic valuation in the environmental context is about measuring the preferences/ choices of people for an environmental benefit or against environmental degradation.



**2.6.3 Changes in Welfare and Market Based Valuation**

Neo classical economics assumes that individuals, not the government, are the best judges of what they want. Thus, the theory of economic valuation is based on individual preferences and choices. People express their preferences through the choices and trade-offs that they make, given certain constraints, such as those on income or available time. The economic value of a particular good, for example a loaf of bread, is measured by the maximum number of other things that a person is willing to give up to have that loaf of bread. Thus, economic value is measured by the willingness to give up in other goods and services in order to obtain a good, service or a state of the world (Freeman, 1993). This is often referred to as "willingness to pay." In general, when the price of a good increases, people will purchase less of that good. This is referred to as the law of demand. People demand less of something when it is more expensive (assuming prices of other goods and peoples' incomes have not changed). By relating the quantity demanded and the price of a good, we can estimate the demand function for that good. From this, we can elicit the demand curve, the graphical representation of the demand function.

Kotagama et al., (1997) explained how values (preferences) of individuals aggregate to decide societal values on resources in market economy when property rights defined and ownership enforced in a perfectly competitive market, where markets would allocate resources efficiently through prices (unit values) determined by the market in coordinating desires of consumers (demand) and production possibilities (supply). However, they further elaborated that despite the strengths of the markets, they fail in allocating environmental resources efficiently due to inherent weaknesses in markets. Notably, barriers to perfect competition, deficiencies in defining property rights, prevalence of public goods and externalities and missing preferences require non-market approaches as well in defining environmental values (Kotagama et al., 1997).

In general, the direct use of marketed products of ecosystems is easier to measure since marketed products exist and their prices may be adjusted for distortions. In contrast, ecological functions, such as groundwater recharge or discharge may have indirect use values, which are reflected in the economic activities these functions support. Usually, changes in the well-being or social welfare are used to define and quantify economic value. Therefore, valuing a good or service requires one to study the change in a person's welfare due to a change in the availability of the resource. The purpose of economic valuation is to reveal the true costs of using scarce environmental resources.

Valuation of environmental resources is related to changes in social welfare. The magnitude of social welfare change is centred on the concept of consumer surplus associated with a price change. But compensating variation and equivalent variation can also be used to measure the welfare change associated with other changes.

### 2.6.4 Consumer Surplus and Producer Surplus

It is often incorrectly assumed that a good's market price measures its economic value. However, the market price only tells us the *minimum* amount that people who buy the good are willing to pay for it. When people purchase a marketed good, they compare the amount they would be willing to pay for that good with its market price. They will only purchase the good if their willingness to pay is equal to or greater than the price. Many people are actually willing to pay more than the market price for a good and thus their values exceed the market price. In order to make resource allocation decisions based on economic values, what we really want to measure is the net economic benefit from a good or service (Kwang, 1979).



The economic benefit to individuals is often measured by consumer surplus (Figure 2.5). This is represented by the area under the demand curve for a good, above its price. The economic benefit to individuals or consumer surplus, received from a good will change if its price or quality changes (Freeman, 1999). For example, if the price of good increases but people's willingness to pay remains the same, the benefit received (maximum willingness to pay minus price) will be less than before. If the quality of a good increases, but price remains the same, people's willingness to pay may increase and thus the benefit received will also increase (Winpenny, 1991).

Marshall defined consumer surplus as 'the excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay'. Marshall used the triangular area under the demand curve and above rectangle representing the actual money expenditure of the consumer.

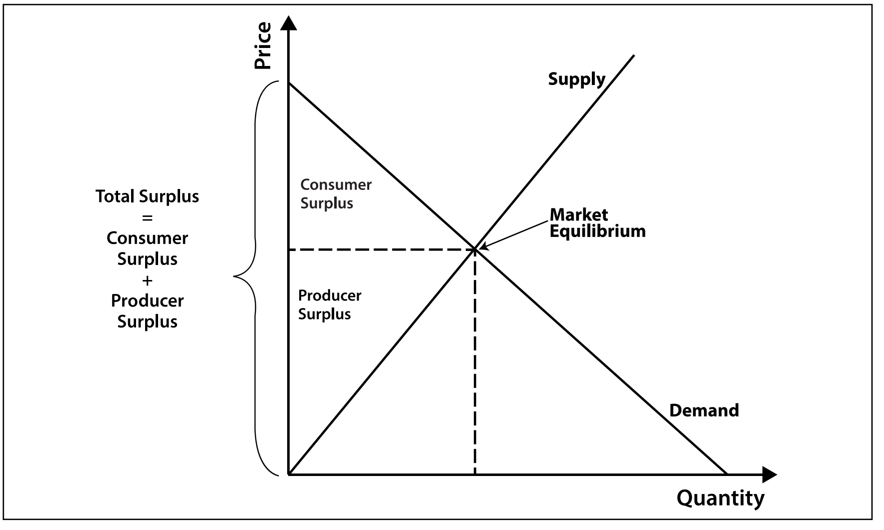


*Figure 2.5: Depiction of Consumer and Producer Surpluses*

Source: IUCN, 2016

Producers of goods also receive economic benefits based on the profits they make when selling the good. Economic benefits to producers are measured by producer surplus; the area above the supply curve and below the market price. The supply function tells how many units of a good the producers are willing to produce and sell at a given price. The supply curve is a graphical representation of the supply function. Because producers would like to sell more at higher prices, the supply curve slopes upward. If producers receive a higher price than the minimum price they would sell their output for, then they receive a benefit from the sale called the producer surplus. Thus, benefits to producers are similar to benefits to consumers, because they measure the gains to the producer from receiving a price higher than the price, they would have been willing to sell the good for. When measuring economic benefits of a policy or initiative that affects an ecosystem, economists measure the total net economic benefit. This is the sum of consumer surplus plus producer surplus, minus any costs associated with the policy or initiative.

Market based valuation principles can be used when the demand and supply curves for commodities are known. This method is not used to value environmental resources very often. However, understanding these methods is important as many non-market valuation techniques are imitated or approximated to market valuation methods. In a well-functioning market system, the question of valuation does not arise because market price change with value changes and as described above, these price changes lead to a series of changes in resource allocation. Since this process takes place automatically there is no need to know the value of each commodity and consciously allocate them to the right sectors. However, many natural resources and environmental services do not have markets. If there are markets, then the prices are often distorted. The lack of appropriate prices leads to inefficient resource allocation. Environmental valuation attempts to impute prices for natural resources and environmental services to guide proper allocation of these resources.

## 2.7 Review of Similar Systems in other Countries

This section introduces very briefly the historical background to irrigation development in the world and an introduction to ancient small irrigation systems from selected countries which have some similarities to the STCS capturing the flavour of ancient/traditional small scale irrigation systems.

### 2.7.1 Brief History of Irrigation Development in the World

Irrigation has been practiced for thousands of years in the Nile Valley. Egypt claims to have the world's oldest dam built about 5000 years ago to supply drinking water and for irrigation. Irrigation has been practiced in Egypt, China (Huang Ho and Chang Jiang basins), India (Indus Valley) and other parts of Asia including Sri Lanka for a very long period of time. India and Far East have grown rice using irrigation nearly for 5000 years. The Nile valley in Egypt, the plain of Euphrates and Tigris in Iraq were under irrigation for 4000 years. Irrigation is the foundation of civilization in numerous regions. Egyptians have depended on Nile flooding for irrigation continuously for a long period of time on a large scale. The land between Euphrates and Tigris, Mesopotamia, was the breadbasket for the Sumerian Empire. Civilization developed from centrally controlled irrigation system.

It is also reported that irrigation in China was begun about 4000 years ago. Shannon and Manawadu (2007) stated that there were reservoirs in Sri Lanka more than 2000 years old. Other indicator for irrigation development is found in the stony-gravel limestone desert of the Negev area in old Israel Kingdom. Remnants of these ancient irrigation systems date back from the Israelite period (about 1000 BC) and from the Nabattean- Roman-Byzantine era (300 BC to 600 AD). In the absence of permanent water sources, the ancient farmers developed 'runoff' farm systems that used sporadic flash floods for irrigating.

All these early civilizations were based on flood recession agriculture which is entirely different to the Dry Zone hydraulic civilisation of Sri Lanka and to some extent to the South India, where rainwater harvesting and reuse was the key.

### 2.7.2 Ancient Small Irrigation Systems of the World

Defining what ‘makes’ a small tank/reservoir is not simple, as the criteria used to define them (size, stored volume, embankment height, type of infrastructure, governance modality, planning approaches, number of users served, irrigated area, etc.) vary widely from one place to another (Payen, Faurès and Vallée, 2012). The word ‘ancient’ literally means ‘belonging to the very distant past and no longer in existence’. In this thesis we were looking at systems which are very old but still functional deviating from the literal meaning of the word ‘ancient’ as the STCS are still functional since their invention in about two millennia ago. Therefore, the subjects discussed in this sub section has given prominence to the ancient systems which are still functional and most relevant to the area researched in this thesis.



In South Asia, small reservoirs or tanks have traditionally been one of the most important sources of irrigation water. They are mostly managed together with communities and provide open bodies of standing water that can be used for domestic needs, livestock and fish.

Over 60 percent of the world’s irrigated area is found in Asia. Approximately two thirds of this is devoted to cereal grain production, rice and to a lesser extent wheat (Barker and Molle, 2004). According to Brohier (1935), the earliest medium-scale irrigation reservoir that could be traced back in Sri Lanka with certainty is the present *Basavakkulama* tank. Which has a water spread area of 107 ha and expected to have built around 300 B.C.

All the well-known other ancient major irrigation works in this country are expected to have been constructed after this period. It was suggested by Shah, Samad, Ariyaratne, and Jinapala (2012) that among all ancient rice irrigation civilizations, the three most celebrated ones are Tanjore (in today's Tamil Nadu), Cambodia and Sri Lanka. While rice irrigation institutions in Tanjore and Cambodia have metamorphosed, small tank irrigation in Sri Lanka's dry zone is the only ancient irrigation culture that can boast of an unbroken history over millennia, undisturbed by rise and fall of states.



#### *2.7.2.1 Experience from Cambodia*

Out of the three ancient rice irrigation civilisations, the Khmer Empire (or Angkorean Empire) lasted for around six centauries (A.D. 802-1432), Dinh (undated). In their 'hydraulic city' hypothesis they also built artificial lakes called 'barays', which translates to mean "large pool or reservoir". Archaeologists uncovered three enormous 'barays' in abandoned Angkor city, the largest which measures to be eight kilometres by three kilometres. This "West Baray," believed to have started between 975 and 1020 and was completed in 1050, was created by making 10 meter high ramparts which extended for over 20 kilometres. In their mapping exercise, Fletcher et al., (2008) have shown that in the first half of the second millennium the inhabitants of Angkor were clearly able to engineer the distribution of water, meticulously and systematically across the landscape, on an enormous scale. The water management network depended on elaborate configurations of channels and embankments built from huge quantities of clayey sand, the available bulk material on the Angkor plain. The structures would have reduced the flow rate of the incoming water, dispersed it, allowed the concentration of masses of still water and enabled its redirection across the landscape. The water storage system perfected over several hundred years at Angkor was one of the great accomplishments of the Khmer civilization.

Apart from those very large irrigation structures, according to Liere (1980) the millions of small plots, neatly levelled and bunded to keep the rainwater on the land, and the thousands of small devices to manipulate water in the wet season at village and farm level, reshaped the lowlands of the lower Mekong Basin, and of many other rivers in south-east Asia, transforming them into productive, well populated human habitats, truly man-made landscapes. These small-scale irrigation systems servicing less than 200ha of farming land compared to less than 80ha in Sri Lanka for the same category of small scale irrigation. Ponds with a surface area on the order of 400 m2 and a depth of 2-3 meters typically can provide water for irrigation through much of the dry season, particularly for application at critical times in the growth cycle (FAO, 2005). Liere (1980) further claims that Cambodia traditionally had two separate and independent systems of water management. Where, one at the level of the productive, profane farmer and one at the level of the theocratic superstructure. He further qualifies that the 'both systems were quite sophisticated in the past. However, there was no connection between the two, and the water management schemes of the theocratic superstructure did not contribute to agricultural production in a technical sense'.



Angkor became a lost city due to invasions in the 15th Century. Modern irrigation systems were first developed in the period 1950-1953. Many of the structures built during that period functioned until 1975. Most of these structures, including the 'colmatage'[18] canals, have become non-functional as a result of the network of irrigation and drainage systems built during the period of the Democratic Kampuchea (1975-1979) without appropriate knowledge and plans.

[18] The 'colmatage' system uses dykes and sluices to provide controlled annual inundation. Intake and drainage are controlled, allowing a fertile layer of silt to settle on the fields. The annual irrigated area in 1993 for these schemes is an estimated 46 599 ha in the wet season and 31 225 ha in the dry season (FAO, 2005).

### *2.7.2.2 Experience from India*

Other closest systems to what we have in Sri Lanka is found in Tamil Nadu state of India. Which was mainly ruled by the 'Crowned Kings' of the Chera, the Chola, the Pallava and the Pandyan lineage and a number of minor chieftains. Agriculture flourished in all these kingdoms well patronised by these kings and chieftains (Indian National Committee on Irrigation and Drainage –INCID, 2001). Similar to the Dry Zone of Sri Lanka, the South Indian State of Tamil Nadu is equally proud of the indigenous and extensive system of tanks which have been designed many centuries ago to utilise river and rainwater for agriculture. However, the beginning of small tanks in Tamil Nadu is not very clear as some referred to as they existed at the beginning of the Christian era (INCID, 2001) and some relate them to the Cholas period date back to the Sangam period (second century B.C to second century A.D), Rathika (2016). Furthermore, Rathika indicates that Cholas disappear from the south Indian scene at the end of it till the 9th century A.D. The Cholas were responsible for development of Thanjavur, a predominantly deltaic area lying along the west of the Bay of Bengal, is known as the 'rice bowl of Tamil Nadu state'

By far the most important irrigation structure that was built sometime in the second century AD by the King Karikala Chola is the Grand Anicut across river Cauvery 16 km east of the Tiruchirapalli town. This anicut is really grand as it has been named later, in that it is perhaps the oldest hydraulic structure built on permeable foundation in the world which is still functioning at the head of the Cauvery delta.

It is interesting to note the reference to the use of Sri Lankan manpower in irrigation works in Tamil Nadu in History of Irrigation in Tamil Nadu:

> The whole work might have been done employing native labour with a religious zeal utilising whatever experience they had at that time in tackling river problems. King Karikala Chola is said to have inflicted crushing defeat upon the joint forces of Chera and Pandya rulers and also successfully invaded Ceylon (Sri Lanka). It is on record that thousands of slave labour brought from Ceylon (now Sri Lanka) were employed on this work, after Cholas' conquest of Ceylon (Sri Lanka) using his powerful navy (INCID, 2001, p. 15)



It is not very clear whether the Cholas just used Sri Lankan labour or skills as the Sri Lankan have been mastered the subject of tank building by the time King Kalinga Chola ruled south India.

Organising small tanks in cascades have not been well reported in India as done in Sri Lanka. However, there are references to interconnected tanks, closest reference to something similar to cascade is:

> One can see a dense spread of these tanks most of them in chain in the coastal plains of Tamil Nadu barring the Cauvery delta. A low earthen bund thrown across the natural shallow valley creates the tank which holds the run off from its catchment above until the tank is full and the surplus overflowing over a simple spill structure is led into the tank immediately below in the falling contour and this is repeated one below the other in a chain until perhaps the last tank spills into a drain or a river (INCID, 2001, p. 15).

According to Bandopadhyay (1992), tanks in Indian context are classified into two categories, the system and non-system. The system tanks receive



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water from major streams or reservoir in addition to the run-off from their own catchments. Non-system tanks depend on rainfall and are not connected to a river system. Originally most tanks were non-system tanks. This is quite contrast to the system in Sri Lanka where tanks are identified as solitary or in cascades, as mentioned elsewhere in Sri Lankan small tanks about 90% are organised as cascades. Work by Krishnaveni, Sankari, & Rajeswari, (2011) indicates that they have used remote sensing, GPS and GIS technology for searching irrigation tank cascade systems for their rehabilitation planning referring to work by Panabokke et al., (1999), (Sakthivadivel et al., 1996) and Madduma Bandara (1985).



There appears to be many similarities in expected management approaches of individual small tanks in Sri Lanka and Tamil Nadu. As highlighted by Sastri (1935), historically the small tanks in Tamil Nadu where:

(a) village sabhas were desilting of small tanks before rains, if necessary, by creating special maintenance funds
(b) the water rights went with the land when land was sold or gifted
(c) villages were collectively fined when they did not do desilting and
(d) several stone inscriptions mention of strengthening tank bunds, closure of breaches in tanks and community efforts to give irrigation facility to lands belonging to temples.

It is noteworthy to highlight the enactment of the (Tamil Nadu) Compulsory Labour Act, 1858 as an Act to make lawful compulsory labour for the prevention of mischief by inundation and to provide for the enforcement of customary labour on certain works of irrigation in the State of Tamil Nadu (INCID, 2001). This may have been influenced by the bitter lessons learned in Sri Lanka by British with the abolishing of the *Rajakariya* system in 1832.

### *2.7.2.3 Experience from Thailand*

The traditional irrigation system can be seen where people in a community get together to form a group as one entity in order to manage irrigation water resources. The main concept is to apply their social culture, which consists of knowledge, beliefs, and customs as well as all other local knowledge to manage the natural resource used (Sordalen, 2011). The *muang fai* irrigation system is one ex ample of a traditional, small-scale, communal irrigation system that has been practised for centuries in northern Thailand. There are various types of institutional arrangement ranging from government controlled to market based (North et al. 2002; Williamson 1986). As discussed below, there are also many levels of farmer involvement. *Muang fai* is a communally based irrigation institution that has limited government involvement, and a high level of farmer participation in the management of the scheme. There is also communal supply of labour in the maintenance of the canal system.



In general, traditional irrigation systems are constructed to control water flow by using locally available natural materials that are easy to find, such as stones, sand, bamboo sticks, wooden poles, and bundles of branches. The materials are laid to obstruct the waterway to form a weir that is well adapted to the local environment, and technically efficient in performance (Laan, 1984).

The traditional process is applied in the case of the *muang fai* irrigation system, which uses mainly rocks and sticks to build the headwork weir. In principle it is like other systems even though materials may vary to suit local conditions. Prior to constructing a traditional irrigation system, the characteristics of topography such as the slope of the hill, speed of water flow, fluctuation of water height, erosion, flooding level, and water requirements for farming are generally considered (Tarang, 2001). Thus,



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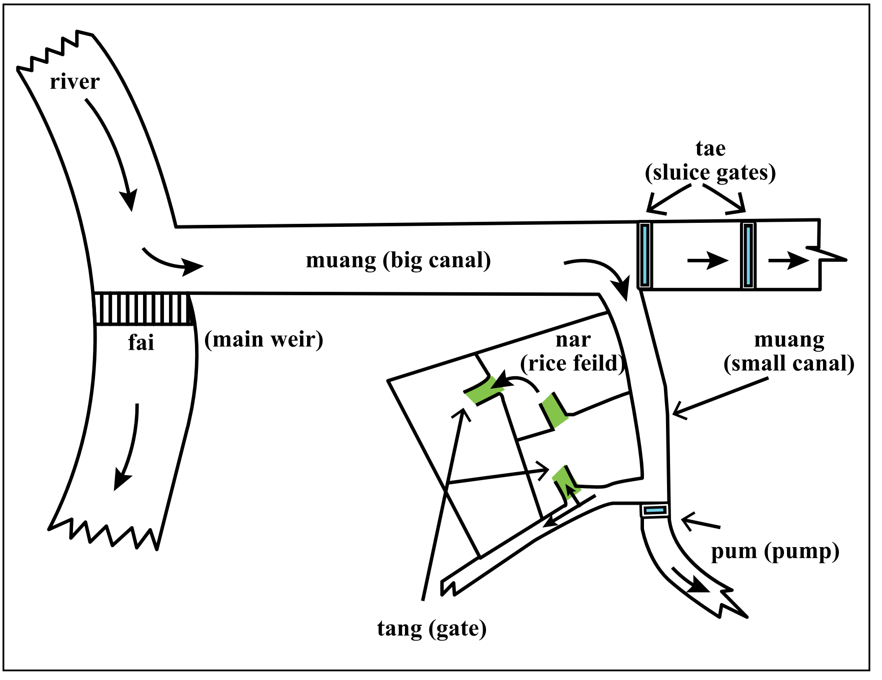


***Figure 2.6: Illustration of a Muang fai system***

Source: Mungsunti, 2014

the topographical characteristics play an important part in choosing the most suitable location to build these systems. As in the case of the *muang fai* system in northern Thailand, the most suitable topography to build the weir is mainly where there are high mountains and steep river valleys. This also applies to various farmer-managed irrigation systems in Nepal, where the systems rely heavily on surface water from rivers and streams (Bastakoti et al., 2010).

Additionally, farmers also take into account local native knowledge to consider the conditions of soil, climate, topography and hydrology in order to make a decision on how to operate and maintain the irrigation system contributing to long-term existence of such systems.

### *2.7.2.4 Experience from Bali, Indonesia*

According to UNESCO, cultural landscape of Bali Province: the *Subak* System as a manifestation of the *Tri Hita Karana* Philosophy. The cultural landscape of Bali consists of five rice terraces and their water temples that cover 19,500 ha. The temples are the focus of a cooperative water management system of canals and weirs, known as *subak*, That dates back to the 9th century. Included in the landscape is the 18th-century Royal Water Temple of Pura Taman Ayun, the largest and most impressive architectural edifice of its type on the island. The *subak* reflects the philosophical concept of *Tri Hita Karana*, which brings together the realms of the spirit, the human world and nature. This philosophy was born of the cultural exchange between Bali and India over the past 2,000 years and has shaped the landscape of Bali. The *subak* system of democratic and egalitarian farming practices has enabled the Balinese to become the most prolific rice growers in the archipelago despite the challenge of supporting a dense population (UNESCO World Heritage Centre, 2018).



Sordalen (2011) presents that *subak* is a technological unit, referring to the dam and channels, a physical unit in the landscape, a social unit upheld by cooperation, a religious unit, as it has its own temple, and a legal unit involving laws and regulations written down in a book called "awig-awig". He further explains the structure of the *subaks* as a corporate body, a social system, and a cultivation regime. The *subak* is an institution separate from the village, as the association consists of all the farmers that acquire water from the same canal. The *subak* is such an efficient water user association due to the structure between the different above-mentioned units.

However, as Geertz (1972) notes, the main characteristic is the one-dam-one-*subak* relationship. First of all, the subak system does not involve artificial tanks or storage of water, thus is dependent on seasonal flow of water from rivers which varies from wet to dry season (Lansing, 1991). Weirs are located one underneath the other down the canal which brings the water to the *subak*, often in long tunnels (Geertz, 1972). When the water enters the *subak,* it is divided by many adjusted bamboo 'tubes' spread around the *subak*, in a way that what was a single incoming channel is now divided into numerous bamboo veins into the terrace field (Geertz, 1972). A *subak* includes a main water inlet and a complex system of collectively owned, compound units. Like STCS gain recognition as a Globally Important Agriculture Heritage System (GIAHS) through FAO in 2018, *Subaks* recognised by UNESCO as a cultural World Heritage Category in 2012.



***2.7.2.5 Other Ancient Irrigation Systems Experience in Brief***

Systems discussed above are truly small scale traditional/ancient systems related to STCS. Examples briefly discussed here too belong to the ancient category but their scale is relatively large though they are being called 'small' in comparison to the STCS in Sri Lanka. These experiences are mainly coming from African continent. Irrigation plays a minor role in African agriculture. The irrigated area, extending over 6 million hectares, makes up just 5 percent of the total cultivated area, compared to 37 percent in Asia and 14 percent in Latin America. Two-thirds of that area is in three countries: Madagascar, South Africa, and Sudan (You, 2008).

The sub-Saharan Africa (SSA) has witnessed increased public and scholarly interest in small-scale irrigation in general and small dams in particular in post-independence. Numerous small reservoirs were constructed in the 1950s and early 1960s, primarily for livestock watering and soil and water conservation purposes (Nkhoma, 2011). The focus shifted through the mid-1980s to drought proofing, largely promoted by the World Bank and other Development Agencies in response to severe droughts in the 1970s, and later, in the 1990s to irrigation development. However, these 'Small dams' are much larger systems to STCS, as given in Zimbabwe case – small dams are water storage structures whose capacity is less than 1million m3 with a maximum height above a cleared foundation level is 8m (Kabell, 1986). In Burkina Faso, small dams are ones with the dam height less than 10 m. In Zambia, small reservoirs are earthen or cement dams that are less than 7.5 meters high. They can store up to 1 million cubic meters of water and sometimes have a downstream adjacent irrigation area of less than 50 hectares (FAO, undated).

In Zambia, most of the approximately 3,000 small low cost earth dams with recent origin are situated in the drought prone semi-arid areas of the Eastern, Lusaka, Central and Southern provinces, where water needs to be stored for sustainable livestock, agriculture and domestic use. In a recent survey by the Ministry of Energy and Water Development, many dams have suffered from irregular maintenance and repair and are considered to be in a state of disrepair (African Water Facility, 2012).



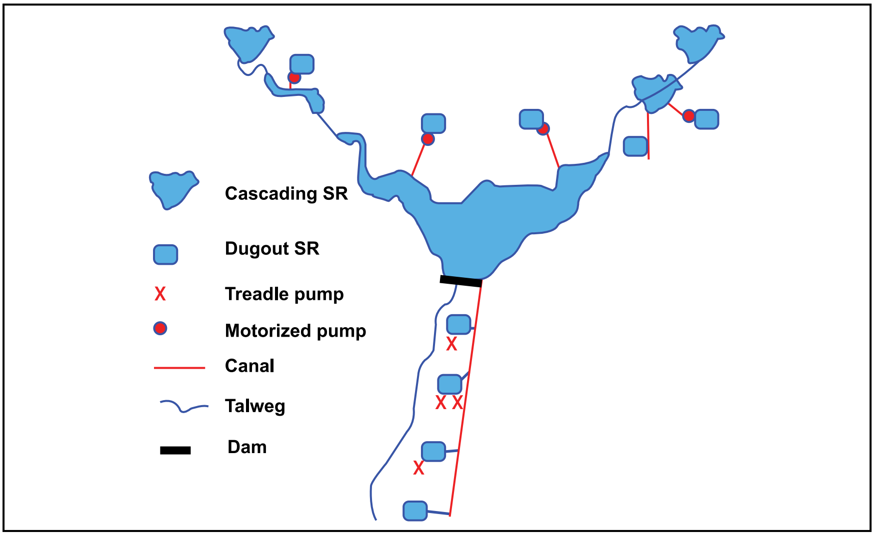


***Figure 2.7: Schematic Diagram of Small Reservoir Network***

Source: Payen, Faurès and Vallée, 2012

Looking back to the ancient systems in Africa, Westerberg *et al.,* (2010) discovered ancient irrigation system by using climate data from Empakaai Crater in northern Tanzania. Which helped understanding establishment, development and decline of the ancient irrigation system at Engaruka covering the last 1200 years. They established a shift from a comparatively humid climate to drier conditions in the 1400s prompted the establishment of irrigated agriculture at Engaruka, and a flourishing long-distance trade increased its value as a water and food source for passing caravans. Once established, the land-use system at Engaruka was sufficiently resilient to survive and even intensify during much drier climate from c. 1500 to 1670 CE (Common Era) and during the decline of caravan trade between c. 1550 and 1750. The ancient land-use system probably reached its maximum extension during the humid conditions between 1670 and 1740, and was deserted in the early to mid-1800s, presumably as a result of the added effects of climate deterioration, the Maasai expansion, and change of livelihood strategies as agriculturalists became pastoralists. Towards the end of the 1800s irrigated agriculture was again established at Engaruka, in part driven by the transfer from pastoral to agricultural livelihoods caused by the Rinderpest (Westerberg et al., 2010).

## 2.8 Environmental Economic Valuation

The value of environment from an economic viewpoint differs from what it means from an ecological viewpoint. The latter considers goods or services as valuable when it contributes to some system goal. These ecological values are derived purely from ecological functions that can be measured objectively and described using biophysical models. Ecological models tend to disregard human preferences when considering 'values' (Bockstael, Costanza, Strand, Boynton, Bell, & Wainger, 1995). In neoclassical economics, on the other hand, a good or service has an economic value because it contributes to the individual utility (Straton, 2006). Many of the benefits generated from ecosystem goods and services are not traded in conventional markets (Kragt, 2009) and therefore, different non-market valuation techniques have evolved which are briefly introduced in the latter part of this chapter.

The basic strategy for environmental valuation is the 'commodification' of the services that the natural environment provides (Perman, McGilvery & Common, 2003). The services are used by households and firms and are treated as arguments in the utility and the production functions respectively. Most of the environmental valuation literature is about the goods and services which flow to households rather than to firms and present study also emphasises on the households which get benefits from village tank ecosystems.

The purpose of environmental economic valuation is to strengthen the links between the environment and the economy, while traditionally the environment and the economy have been regarded as separate and distinct. They are now seen as closely interrelated. Ecologically sustainable development requires an integration of environment, economic and social issues. Applying economic valuation to environmental assets through various valuation techniques is one method to promote this integration.

Economists measure environmental values in terms of an individual's willingness to pay or accept for compensation. For environmental resources to have an economic value, a person must be willing to pay an amount of money to obtain the resource or willing to accept an amount of money as compensation for its loss. Environmental effects clearly have a value in economic terms because they increase or decrease welfare even though they may not be traded in markets with monetary prices. In financial analyses, environmental effects are considered only when they directly affect the revenue streams or cost outlays.  Hence, these values are often ignored in the analysis.



In economic valuation, value is used in its economic sense of a change in welfare and valuation is used to mean the process of valuing or estimating the change in welfare. The emphasis that economics places on maximising social welfare requires an awareness of all benefits and costs and so includes those environmental values such as clean water or species preservation that are not fully or even partially revealed in financial markets. While these unpriced values are difficult to reveal, they have an economic meaning nonetheless because anything or an action from which individuals gain satisfaction is deemed to have a value.

### 2.8.1 The Concept of Benefits and Value in Welfare Economics

The natural environment is a prerequisite for human existence. The absolute value of the nature is thus infinite. Therefore, it only makes sense to value marginal changes in the quality of nature and environment. What is to be considered as marginal changes depends on, e.g. physical and biological assumptions about the tolerance thresholds of nature and ethically defined comprehensions of what human beings should or should not do in relation to nature. In a welfare economics point of view, the value originates from individual preferences for various goods that are, marketed or not and the willingness to substitute for another (Freeman, 1993). The value of a unit, of a given good, is measured as the amount of another general good which the individual is ready to relinquish in order to obtain an extra unit of the good in question. The general good used for measuring value is usually money. This is not because money holds value in itself, but rather money is a numeraire for a large variety of items in the bundle of consumer goods. Accordingly, the objective of economic valuation is not to attach a (market) price to all non-priced (non-marketed) goods, but rather to reveal the social value of the non-market goods.



### 2.8.2 Valuation versus Pricing

There are different theoretical approaches to monetisation of non-market goods; preference based and non-preference based. The methods based on preferences attempt to estimate behavioural relationships in the form of demand functions or marginal willingness to pay functions. This indicates the connection between the price level and the amount demanded (a relationship which could be observed empirically if the goods were traded in a market). In other words, valuation methods attempt to disclose people's willingness to pay (e.g. through taxes) for goods with no market price. The estimated willingness to pay function reflects individual's rate of substitution between the non-market and the relevant bundle of market goods. The value of a given environmental undertaking is computed in terms of welfare measures. Which means the changes in consumer surplus due to changes in the quality or amount of the environmental benefits in question. Let us consider an example of measures taken to limit the pollution of groundwater. To evaluate such a policy, one must elicit the maximum amount of income (purchasing power) people are willing to give up maintaining a certain level of groundwater quality.

The non-preference based methods can be described as pricing. Pricing methods are not based on the economic behaviour of individuals, but usually on the costs connected with realizing a given environmental objective. If we use the groundwater example again a policy requiring a certain standard for the nitrate content in groundwater can be priced as the social cost incurred by realizing this standard. Cost relations are of course extremely relevant when assessing an environmental policy. But pricing does not show whether the people's willingness to pay meets the costs nor if there is a willingness to pay for even a greater effort. Thus, pricing does not answer the fundamental question of how scarce resources should be allocated between the environmental objectives on the one hand and fulfilment of other human needs on the other.



### 2.8.3 Pricing Methods

When monetising environmental benefits based on market prices, there are two main approaches;

(a) *Opportunity cost method:* This monetises the benefits of a non-market environmental resource based on the costs of ensuring similar benefits through alternative activities. For example, the "price" of pure groundwater for drinking water supplies can be calculated as the treatment costs of removing nitrate and various chemicals from groundwater. The method does not show whether consumers' preferences/willingness to pay for the purity of groundwater is larger or smaller than the costs of maintaining the current standard.

(b) *Replacement costs:* The price of an environmental benefit can be considered equal to the cost of producing a similar environmental benefit in other ways. If a pond is destroyed due to construction work, the loss of this amenity can be priced as the cost of establishing a similar pond in a nearby-area. This method is limited to environmental resources that can be recreated with qualities, which are reasonably similar to those lost. Even when this is physically possible it is not certain that the affected individuals are willing to pay an amount equal to the cost of replacement.

Pricing methods are usually easier to apply than the preference-based valuation methods but, from a welfare economics point of view, pricing is not necessarily the correct way of measuring the social value of benefits connected with environmental policy initiatives.



### 2.8.4 The Total Economic Value

The concept of total economic value became one of the most widely used frameworks for identifying and categorizing ecosystem benefits (Barbier, Acreman & Knowler, 1997). Total Economic Value distinguishes between the use values and non-use values. The latter referring to those current or future (potential) values associated with an environmental resource, which rely merely on its continued existence and are unrelated to use. Typically, the use values involve some human interaction with the resource, whereas non-use values do not. The total economic valuation framework as applied to village tanks is in Table 2.8. It also provides the categorisation of ecosystem services according the four categories of ecosystem services as suggested by the MEA (2005).

### 2.8.5 Use and Non-use Benefits

The total economic value of environmental amenities comprises explicit use benefits as well as implicit non-use benefits. Use benefits are those that accrue from the physical use of environmental resources such as visiting a national park or recreational fishing. The benefits from productive activities such as agriculture, forestry or fisheries are also included in this category.

Use benefits also comprise benefits unaccompanied by market exchanges or explicit activities. For example, people may derive use benefits simply from experiencing a place without participating in any explicit activities.

*Direct use values* are the most tangible and relate to the products and benefits that can be derived from the use of a village tanks. In contrast, various regulatory ecological functions of village tank may have important *indirect use values*. Their values are derived from supporting or protecting economic activities that have directly measurable values. Direct use values can be further divided into consumptive, productive and non-consumptive use values (Table 2.2). *Option values* are another special category of values. It arises because an individual may be uncertain about his or her future demand for a resource and/or its availability in village tank in the future (Barbier, Acreman & Knowler, 1997). Option value approximates an individual's willingness to pay to safeguard an asset for option of using it at a future date (Pearce & Moran, 1994).

*Non-use benefits*, on the other hand, refer to the benefits individuals may obtain from environmental resources without directly using or visiting them. They are classified into existence value (EV) and bequest value (BV). Existence value is the welfare obtained from the knowledge that an environmental resource exists. The concept may also include the benefits obtained from knowing that culturally important resources are protected. There are individuals who do not currently make use of wetlands but nevertheless wish to see them preserved 'in their own right'. Such an 'intrinsic' value is often referred to as *existence value*. Existence values are unrelated to current use or option values and it is the value derived from the knowledge that any particular asset exists. For example, an individual's concern to protect the blue whale although he or she has never seen one and is never likely to be an example of existence value.

*Bequest value* on the other hand, measures the benefit of accruing knowledge about the tank by an individual that others might benefit from it in the future. As explained by (Barbier, Acreman, & Knowler, 1997) bequest values may be high among the local populations currently using village tanks. In that they would like to see the village tank and their way of life that has evolved in conjunction with it passed to their heirs and to the future generations in general.

Thus, the total economic value (TEV) could be expressed as,

TEV = UV + NUV = (DUV + IUV + OV) + (BV +EV)

Where;

TEV is Total Economic Value, UV is Used Values, NUV is Non-used Value, DUV is Direct Use Value, IUV is Indirect Use Value, OV is Option Value, BV is Bequest Value and EV is Existence Value.

Both use and non-use values can reside in the host nation or globally[19] (all nations other than the host nation). Therefore, the above equation can be rewritten as,

TEV = DUVn + DUVg + IUVn + IUVg + OVn + OVg + BVn + BVg + EVn + EVg

Here n denotes national and g denotes global (Dayananda, 2007).

[19] g denotes global and n denotes national values

## 2.9 Non-market Valuation of Environmental Goods and Services

Non-market values associated with environmental goods can be divided into two major sections: use value and non-use value. Use values include consumptive use values such as hunting and fishing and non-consumptive use values such as hiking and sightseeing. Non-use values include existence value, bequest value and option value. Existence value is the value of simply knowing that an environmental amenity of particular quality exists, while bequest value arises from intergenerational altruism and is the value an individual derives from preserving environmental quality for future generations. Option value is the value an individual places on preserving the option to make use of an environmental amenity in the future (Sun, 2006).



## 2.10 Benefit Cost Analysis as a Decision-making Tool

As Boardman, Greenberg, Vining, & Weimer, (2006) suggests, the Benefit Cost Analysis[20] is a key input for the ex-ante evaluation of public projects and policies. An ideal BCA analysis incorporates all the social costs and benefits of a project for all members of a society. BCA has its basis on Paretian welfare economics (neo-classical economics). Welfare economics is the analysis of the optimal behaviour of individual consumers at the level of society as a whole. In here, just as at individual level, there is a need for a subjective ranking of bundles of goods dependent on the consumer's taste, the economic states which usually rely on subjective or normative criteria (judgments of taste about how society should look). Welfare economics is based on the view that an economic system should be efficient in satisfying human wants. Its basic tenet is that welfare cannot be at a maximum if it is possible to make any individual better off without making another worse off. This is called Paretian optimality and it operates

[20] Benefit Cost Analysis and Cost Benefit Analysis means the same tool

under a set of restrictive assumptions such as perfect information, absence of externalities etc. A similar rule is the Paretian improvement.

A Paretian improvement is said to occur when a change in the use of resources makes some individuals better off without anyone else being made worse off. Any change that brings a Paretian improvement is regarded as socially desirable. In practice, however this is not easy to achieve. The potential Paretian improvement (Kaldor-Hicks compensation approach) was suggested as a means of dealing with this problem. According to this criterion, a change is considered to be socially beneficial if the gainers could secure sufficient benefits to compensate the losers and still have some net gain left over. If the compensation is equal to what the gainers have as net benefit while losers are indifferent. This actual compensation need not to be paid to the losers. If compensation is paid, then this reduces to the Paretian criterion. The criterion of potential Pareto improvement is the underlying basis of Benefit Cost Analysis (Pearce & Turner, 1990).



When BCA is used for social choices, benefits and costs should be evaluated in a social context and take account of any externalities arising from adoption of a particular action. Therefore, when analysing complex environmental assets such as village tanks, it needs to assess both direct and indirect benefits of conservation or proposed actions. In a broader perspective, to assess a complex natural asset, a wider range of cost and benefits would be needed. These costs and benefits should be identified, measured and the end monetary value must be assigned. Major limitations of BCA include, potential inaccuracies in identification and assessing benefits and costs, increased subjectivity in assessing intangible benefits and costs, and inaccuracies related to converting future values to present values by using the concept of discounting.

## 2.11 Valuation Methods

Valuing environmental changes economically is about analysing the trade-offs that individuals are prepared to make between the environment and other resources. Economic theory suggests that such trade-offs reveal the influence that environmental changes have on human wellbeing. In other words, economists measure the influence of an environmental change on wellbeing as the resources individuals would be willing to give up to have the change (or prevent the change). Another word for willingness to give up resources is WTP. In some situations, it is more relevant to study another kind of trade-off, namely what people require as compensation if the environmental change takes place (or is prevented), which is their WTA compensation.



WTP and WTA are closely linked to the concept of consumer surplus. Consumer surplus is the difference between the maximum amount an individual is willing to pay for consuming a good and the amount that actually has to pay for the good. Economic theory suggests that changes in wellbeing can be measured as changes in consumer surplus. These changes can be defined in somewhat different ways, which explains the fact that there are several measures of changes in consumer surplus available: e.g., changes in the Marshallian consumer surplus, compensating variation, equivalent variation, compensating surplus and equivalent surplus (Freeman, Herriges, & King, 2014; Johansson, 1993). The change in *profits* (or producer surplus, which is almost the same thing,) is the corresponding measure for changes in firms' "wellbeing". Since economic values are about trade-offs that individuals are willing to make, economic values depend on the individuals' preferences. Which is their more or less fixed opinions about how important (or unimportant) different goods and services are for their wellbeing. The focus on individuals' preferences in economics reflects an anthropocentric ethical point of departure and


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also the importance of the principle of consumer sovereignty. Meaning the individual is the sole person who can judge what is good or bad for him/her. However, it should be noted the view that economic values are determined by individuals' preferences implies that the results from valuation studies are not more informed than the individuals themselves are (Daily, Söderqvist, Aniyar, Arrow, Dasgupta, Ehrlich, … Walker, 2000). This fact has probably played an important role in the discussion among, for example, ecologists and economists about the reasonableness of economic valuation of environmental change.

Sometimes ecosystem goods and services are subject to free trade and pricing on markets. In such occasions they resemble market goods or services. In such situations it is straightforward to use data on consumer's and firm's market behaviour to estimate the demand and supply. These relationships can in turn be used for estimating changes in consumer surplus and profits. However, the ecosystem services are not typically traded nor priced on any market. For being able to compute the economic value of environmental changes influencing also such nonmarket goods or services, special valuation methods have been developed within environmental economics. These valuation methods can be divided into three main groups:

i. Revealed preference (RP) methods
ii. Stated preference (SP) methods
iii. Other valuation methods, less firmly rooted in economic theory

Each of these groups of methods is briefly described below.

### 2.11.1. Revealed Preference Methods

RP methods make use of linkages between ecosystem services and one or more market goods. This means that they are all based on consumers or firms' actual market behaviour, which is usually viewed as an important advantage. The four most important valuation methods within this group are:

i. The production function method

ii. The travel cost method

iii. The hedonic price method (often also called the property value method)

iv. The defensive expenditure method



*The production function method* can be applied, when it is known how ecosystem services contribute to the production of some market good. Ecosystem services are often such an input to production. For example, some fish species are very dependent on the availability of suitable coastal habitats as nursery areas. If there is a change in the quality or quantity of these habitats, this might influence the stock of these fish species, which in turn might reduce the catch (or "production") in commercial fisheries and thus the supply of these fish species on the market for fish will fall. If there is information on these relationships, it is also possible to use the production function method for putting an economic value of the habitat change. Production function method is therefore, an important method for valuing ecosystem services economically, but its application is often limited because of insufficient knowledge of how the nature works as a production factor.

*The travel cost method* provides an opportunity to value the recreational opportunities provided by the nature. The willingness to pay for visiting a recreational area may be estimated if there are enough data on how much money and time people would spend for travelling to the area. Early travel cost method applications were used to value the recreational access to the areas such as nature reserves in the United States. A more modern version of the method is used to analyse how different characteristics of a recreational area affect the demand for recreation. For example, the number of people visiting a beach might partly depend on its water quality. If knowledge is available on how water quality is manifested and if the effect of water quality on recreational demand can be isolated from that of all other factors influencing demand (travel cost, income, services on site, etc.), then a possibility exist to estimate the WTP for improved water quality.



*The hedonic price method* is based on the idea that the supply of ecosystem services might play a role for property values. A summer house situated by a beach, characterized by poor water quality, might have a lower market price than a summer house situated by a beach with clean water, even if the houses and the surroundings are identical in all other aspects. If data exist on the property values and the characteristics influencing the property values (including water quality), an indirect market price on water quality might be estimated and in some cases even the WTP for an improved water quality.

*The defensive expenditure method* uses data on people's market behaviour when they try to compensate themselves for a reduced supply of some ecosystem service. One example is when people install some equipment to protect themselves from an environmental deterioration, for example, a coal filter for cleaning the drinking water coming from contaminated groundwater. From a drinking water perspective, such a filter works as a substitute for clean groundwater if the filter preserves the quality of the drinking water. For a small change in the supply of an ecosystem service such defensive expenditures may give information on the WTP for the change.

### 2.11.2. Stated Preference Methods

Sometimes there is a weak, poorly explored or there is no linkage between the ecosystem service, one wishes to value economically, and a relevant market good. With the help of Stated Preference (SP) methods, this problem can be solved by estimating the WTP for the ecosystem service directly by creating a hypothetical market situation. This way of gaining information about the economic value of ecosystem services has been increasingly applied during the last two decades. Two main SP methods are the following:

i. The contingent valuation method (CVM)
ii. Choice experiments (CE)

The contingent valuation method uses interviews or mail surveys that describe a scenario of a change in the supply of an ecosystem service and illustrated for a (usually) random sample of individuals. The scenario is followed by questions about the respondents' WTP for a realization of the change. According to Smith (2004), this is a debated method. The requirements are substantial regarding the design of text, pictures and other things which are used in the questionnaire for communicating information about the considered change in the supply of the ecosystem service. Moreover, CVM and other SP methods do not use data on individuals' actual market behaviour. As a consequence, the main question is whether the individuals would actually pay the WTP inferred from their responses if the scenario becomes a reality. This and the other questions related to SP methods have been subject to extensive testing and therefore, much is known today about how a SP method should be applied for maximizing reliability and validity. The hypothetical setting used by SP methods makes it possible to also approach people who at least at present do not use the ecosystem service but might still be willing to pay something for an increased provision of the service. RP methods cannot provide information on such a non-use value of ecosystem services. For example, only values held by visitors are taken into account if an improved environmental quality in a recreational area is valued using travel cost method. However, it is not unlikely that non-visitors also care for the environmental quality in the area. A CVM study can be used for capturing the WTP of these non-visitors.

Choice experiments is a technique under the group of Choice Modelling techniques, which includes other techniques. Namely, contingent ranking, contingent rating and paired comparisons in addition to CE. This set of SP techniques are based around the idea that any good can be described in terms of attributes or characteristics and the levels of those attributes take. However, not all these four techniques are in line with the theory of welfare economics, only the CE technique fits in (Bateman et al, 2002). The CE is somewhat similar to CVM, but is based on how respondents make repeated choices among at least two alternatives. The alternatives differ with respect to the levels of attributes characterizing the ecosystem service and the payment requirements for the respondent. The WTP for the environmental attributes can be derived from the choices made by the respondents. In addition, the marginal WTP for the individual attributes can also be derived by these methods, where useful information in designing efficient solutions for cascade restoration and management is generated. Further, as the choice experiments are closely linked to two economic theories known as Lancaster's Characteristics theory of value and the Random Utility theory was selected as the preferred method of valuation for this research.

### 2.11.3. Other Valuation Methods

All methods mentioned so far are characterized by the fact that they can all be justified by economic theory. However, also other valuation methods are used for valuing environmental changes but these are less firmly rooted in economic theory. This might make it difficult to interpret the results produced by these methods, of which three are briefly described below:

i. The replacement cost method
ii. The human capital method
iii. The costs of realizing political decisions ("political WTP")



*The replacement cost method* is typically based on data about the costs for socially coordinated actual or hypothetical projects rather than data on people's actual trade-offs at a market. One example might be a study of the costs of stocking fish to compensate at least partly the loss of natural coastal habitats which are needed for stocking the fish species. Another example is the construction of sewage treatment plants to compensate for the lost water cleaning capacity when wetlands are ditched. Replacement costs thus refer to the costs of replacing the loss of an ecosystem service.

These costs can be interpreted as the economic value of the ecosystem service given that the following conditions hold: (i) the man-made replacement system provides services of equally high quantity and quality as the ecosystem service, (ii) the man-made replacement system is the cost-effective way of replacing the ecosystem service, and (iii) people would in fact be willing to pay the costs for the replacement system if the ecosystem service is no longer available (Freeman et al., 2014).

The human capital method is based on, inter alia, the idea that a person's value is what he/she produces and that wages give information about productivity. HCM provides a basis for using data on production losses to value illness. Costs of medical treatment are usually added to the production losses. Such data are interesting and might in some cases be motivated by the fact that they provide information on the lower boundary of economic damage. However, the method should be used cautiously because it might give results that are not defensible, for example, that retired people have no value. The cost of realizing political decisions provides some valuation possibilities by using cost data. It is doubtful whether such decisions reveal "society's WTP" for a changed supply of ecosystem services because the decisions do not necessarily reflect people's WTP. However, this does not imply that there are no cases where people's preferences are relatively strongly reflected. The decision was perhaps preceded by an intensive discussion in which the opinions of many groups were expressed and also converged. A valuation through the cost of realizing political decisions has some similarities with replacement cost method, which suggests that the three conditions mentioned above for replacement cost method are again applicable.



#### 2.11.4 Valuation Advancements

The global interest in ecosystem services has risen since the launch of the Millennium Ecosystem Assessment (MEA) in 2005. Later "The Economics of Ecosystems and Biodiversity" (TEEB) developed a framework for capturing ecosystem services values based on the findings of MEA. According to TEEB, ecosystem services are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). Some ecosystem processes provide direct benefits to human, but many of them provide benefits primarily via indirect interaction.

As originally proposed by MEA, ecosystem services categorized into four main categories:

*Provisioning Services:* are the products obtained from ecosystems which provide direct benefits and often with a clear monetary value such as food, water, woods, fibre, fish from ocean, rivers and lakes genetic resources and medicines.

*Regulating Services:* are defined as the benefits obtained from the regulation of eco system processes which are often of greater value but generally not given a monetary value in conventional market such as climate regulation, natural hazard regulation, water purification, waste management, pollination, pest control and erosion prevention & soil fertility.

*Supporting Services:* are the services that has no direct benefit to people but essential to the functioning of ecosystems and therefore, indirectly responsible for all other processes such as soil formation and plant growth.

*Cultural Services:* include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values and tourism.

Biodiversity is not regarded as an ecosystem service itself but rather as a pre-requisite underpinning each of them. The precise link between the natural diversity and the capacity of ecosystem to provide services is a complex one and an area in which the science is still developing (TEEB, 2013).

Figure 2.6 provides how the changes in ecosystem service related to constituency of a human well-being developed by TEEB based on MEA.

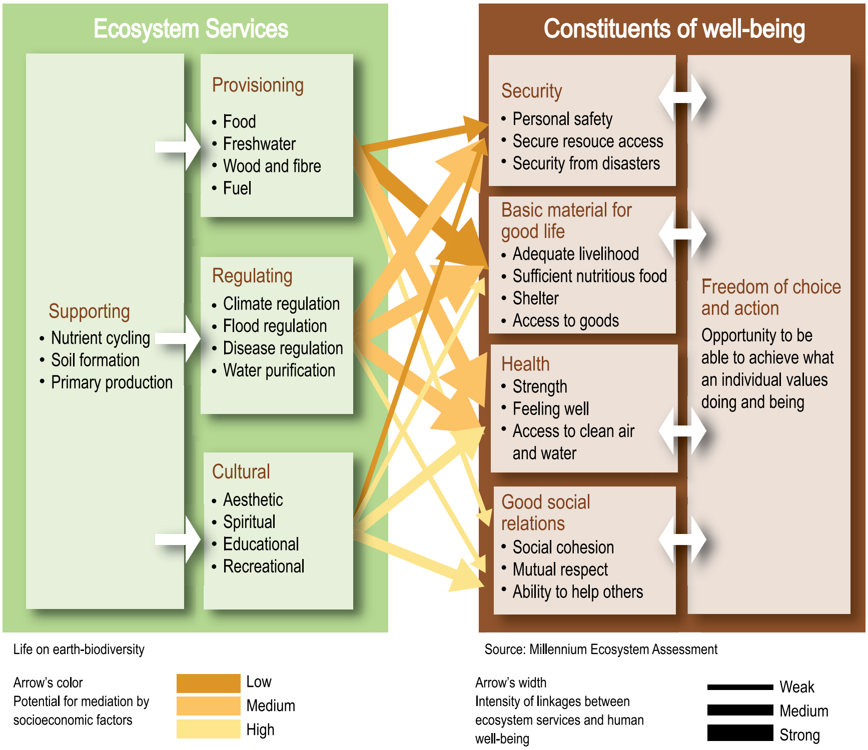


***Figure 2.8: Consequences of Ecosystem Change for Human Well-being***

Source: TEEB, 2010

***Table 2.9: Small Tank Related Goods and Services with Possible Valuation Methods***

| **Value type** | **Small tank goods and services** | **Possible Valuation methods** |
|---|---|---|
| | Direct use | |
| MEA Category | | |
| Mostly Provisioning Services | water for domestic use, tank fish, lotus flowers, lotus roots, NTFP, livestock - water and grazing, wild varieties of food - wild plants and animals, thatching materials, medicine, fruits and vegetables, poles, timber, fuel wood, rattan, bathing and washing for people | Market Price, Imputed Market Value |
| Mostly Provisioning Services | Agriculture output - paddy & other, wild gene for plant breeding, brick making, habitat for pollinators and biological pest control agents | Market Price, Imputed Market Value Opportunity Cost Approach |
| Mostly Cultural Services | scientific research value, recreation value, religious and spiritual, aesthetics, leisure, tourism, educational, place for cultural and religious rituals | Contingent Valuation Travel Cost |
| | Indirect use | |
| Mostly supporting services | Micro-climate stabilization, external ecosystem support, genepool conservation, carbon sequestration, nutrient cycles, ground water recharge, nutrient retention, flood and drought regulation, water table maintenance, maintenance of biodiversity and tank ecology, cultivation using agro /tube wells and adaptation to climate change | Preventive Expenditure Replacement Cost Contingent Valuation |
| | Option values | |
| Mostly Provisioning Services | Preserving for future use, future value of drugs, improvements to crops and identifying new crops | Contingent Valuation |
| | Bequest values | |
| Mostly Cultural Services | Habitats, sentimental value and prevention of irreversible changes | Contingent Valuation |
| | Existence Values | |
| Mostly Cultural Services | Habitats, species and ecosystems | Contingent Valuation |
| | Total Economic Value (TEV) | |
| All 4 types | Estimation of TEV encompassing all above values | Contingent Valuation Choice Experiments |

Sources: Adapted from Vidanage et al, 2005 and Dayananda, 2007

There is renewed interest in assessing ecosystem service values for better decision-making. The Table 2.9 provides STCS related ecosystem goods and services while the Table 2.10 provides a list of global initiatives and databases related to ecosystem valuation extracted from Natural Capital Coalition (2014).

***Table 2.10: Global Initiatives and Databases Related to Ecosystem Valuation***

| No. | Global initiatives and databases related to ecosystem valuation |
|---|---|
| 1 | Artificial Intelligence for Ecosystem Services (ARIES) |
| 2 | Co$ting Nature |
| 3 | Ecologically base Lifecycle Assessment |
| 4 | Green Infrastructure Valuation Toolkit (GIVT) |
| 5 | Natural Capital Project InVEST |
| 6 | National Value Initiative (NVI) |
| 7 | Total Impact Measurement and Management (TIMM) |
| 8 | Simple Effective Resource for Valuing Ecosystem Services (SERVES) |
| 9 | Systain |
| 10 | Techno-Ecological Synergy (Eco-Synergy) |
| 11 | Total Contribution |
| 12 | True Cost Natural Capital Analyzer |
| 13 | WBCSD Business Guide to Water Value |
| 14 | WBCSD Business Guide to Water Value |
| 15 | WRI WBCSD Corporate Ecosystems Review (ESR) |
| 16 | B Team |
| 17 | Climate Earth Natural Capital Management System (NCMS) |
| 18 | Environmental Risk, Opportunity and Valuation Assessment (EROVA) |
| 19 | Externality Valuation Assessment Tool (E.Valu. A.Te) |
| 20 | Natural Capital Declaration (NCD) |
| 21 | True Price |
| 22 | University of Oxford's Smith School Standard Assets Program |
| | **Databases** |
| 1 | Earth Economics: Ecosystem Valuation Toolkit (EVT) |
| 2 | Ecosystem Service Valuation Database (ESVD) |
| 3 | ENVALUE |
| 4 | Environmental Valuation Reference Inventory (EVRI) |
| 5 | Eye on Earth |
| 6 | FAO databases |
| 7 | Global Ecosystems Model (GEM) and Madingley Model |
| 8 | Group on Earth Observation (GEO) – System of Systems and Biodiversity Observation Network (GEOSS & GEO BON) |
| 9 | Integrated Biodiversity Assessment Tool (IBAT) |
| 10 | IUCN Knowledge Products – IUCN Red List of Threatened Species, Protected Planet, Key Biodiversity Areas and IUCN Red List of Ecosystems |
| 11 | Natural Capital from Space |
| 12 | Proteus Partnership |
| 13 | World Conservation Monitoring Centre |

Source: Natural Capital Coalition, 2014

As indicted before, Panabokke et al., (2001) criticised the common belief of economic feasibility of small tank restoration by comparing the cost of restoration verses the resultant paddy benefits. The small tanks are multipurpose, and they argue further the so-called 'non-economic' uses of small tanks are the more important benefits than the paddy yield. Hence, the communities at times forgo paddy cultivation keeping water for other purposes. They stressed the need for a scientific assessment and demonstration of those 'non-economic' values of small tanks for better decision-making on their restoration and sustainable management. Since then a few studies were undertaken on the economic aspects of small tanks addressing the main concerns raised by Panabokke. However, as indicated in the literature review presented in this chapter, clearly demonstrates that there is a research gap in assessing the cascade-wise values for small tanks cascade systems in Sri Lanka. This research is hence, formulated to address this gap in knowledge.



As brought out in above paragraph, the small tank cascades systems are multifunctional, multiple benefit generating a common property system in Dry Zone of Sri Lanka. Rural life in STCS fed areas are highly dependent on those systems for everything. Yet these systems are being degraded progressively. Amongst the plethora of reasons inadequate investment owing to non-realisation of true value of STCS and governance issues are the key for degradation. STCS being a common property resource, many of their benefits fall into non-market category of values. Hence, the returns to investment in cascade restoration are expected to be greater than their direct market based benefits. Therefore, this research is attempting to assess the WTP for restoration and sustainable management of *Pihimbiyagollewa* cascade - a representative STCS in *Malwathu Oya* basin using choice experiment as a non-market valuation technique and also to assess the worthiness of such restorations using an appropriate cost benefit framework.

Table 2.11 provide the types of values generally found in STCS, whether those values are reflected in markets and the reasons if the values are not reflected in markets. It is clear that market fails in expressing STCS values due to market failures such as prevalence of public goods, prevalence of common property regimes, externalities and poorly defined property rights with lack of non-attenuated[12] private property in STCSs. Therefore, for most of the goods and services generated by STCS are not having market determined values. CE is providing the tools for assessing total economic value of STCS in consistent with economic theory (Hanley, Mourato, and Wright, 2001).



***Table 2.11: STCS Values and Reasons for their Non-reflection in Market Prices***

| # | Elements or components of STCS values | Reasons for non-reflection of some of the value categories in markets |
|---|---|---|
| 1 | Village tanks in a STCS | Tank Water: A Common resource with a share of water proportionate to the share of paddy Land (as reflected in the sharing of fish catch) |
| 1.1 | Water for agriculture | Water in own paddy field can be considered private, all the other cases it can be considered communal. When there is insufficient irrigation water available in the tank amount is shared by way of the area to be cultivated. special case of *bethma* |
| 1.2 | Water for non-consumptive uses | Bathing, washing, water for animal husbandry and wildlife are communal |
| 1.3 | Lotus flowers and seeds | Lotus flowers and seeds communal – there are cases of leasing out of flowers collection and revenue goes to FO |
| 1.4 | Tank fish | Fishing is usually leased out and revenues shared. Occasional private fishing is not prevented |
| 1.5 | Aesthetic benefits | Aesthetic benefits can be considered a public good |
| 1.6 | Biodiversity | (Animals, Birds and Fish as well as wild products as edible leaves fruits and firewood) Biodiversity benefits can be considered common |
| 1.7 | Cultural and religious | Cultural and religious benefits can be considered public goods |
| 1.8 | Removal of clay for bricks | Usually private which has negative externalities |

21 An attenuation of a property right is a restriction placed on the use or transfer of property.

| | | |
|---|---|---|
| 2 | Other tanks/tank components | *Sorowwa, Vaana, bisokotuwa* etc. are common property except those in private tanks |
| 2.1 | *Kulu wewa* | Usually communal conversion of these to other uses have negative externalities |
| 2.2 | *Godawala* | Usually communal conversion of these to other uses have negative externalities |
| 3 | Tank bunds | Usually common - anyone can use as a road |
| 4 | Upper catchment | Partly government (public) and partly communal, encroachment has negative externalities |
| 4.1 | Forest land above FSL | Usually public goods violations will have negative externalities |
| 4.2 | Between tank water and FSL | Some cultivate as *de-facto* private property, largely use as a communal property exerting negative externalities to STCS |
| 5 | Paddy fields | Private |
| 5.1 | Paddy fields (*Purana*) | Largely private, in instances of *bethma* – they are temporarily shared |
| 5.2 | Paddy Fields (*Akkara wel*) | Largely private, in instances of *bethma* – they are temporarily shared |
| 6 | *Kattakaduwa*/ Interceptor | Usually communal property |
| 7 | *Gasgommana*/ Wind break | Usually communal property |
| 8 | *Perahana/ Wew Pitiya* | Usually communal property |
| 9 | *Thisbambe*/ Hamlet buffer | Usually communal property |
| 10 | *Gangoda*/ Hamlet | Private property |
| 11 | *Hena*/ Rain fed upland farmlands | *de-facto* private property exerts negative externality |
| 12 | *Landa*/ Scrubland | Usually communal property |
| 13 | *Kivul ela*/ Drainage canal | Usually communal property |
| 14 | Agro-wells | Private property |
| 15 | Temples and Devala lands | '*Pin kumburu*' are lands donated to the temple |
| 16 | Rocks and Rock outcrops, Minerals and sands etc. | Owned by the government |
| 17 | STCS as an integrated system | Communal property |

Source: Common knowledge and consultative discussions with experts

## 2.12 Theoretical Foundation

Individuals maximize utility by selecting the best among different alternative options, which represent the hypothetical outcomes of a proposed program. Alternatives are made up of a set of attributes, which in turn are differentiated by levels. Therefore, choice is a function of attributes presented in multiple choice sets (Rai, Nepal, & Bhatta, 2014). Choice experiments are closely linked to two economic theories known as Lancaster's characteristics theory of value (Lancaster, 1966) and the random utility theory (McFadden, 1974). In choice experiments, respondents are presented with a series of alternative profiles of environmental goods or policies and asked to choose their most preferred choice (Bateman et al., 2002). These profiles are set out in terms of the attributes (characteristics) of these goods and policies (Hanley, et al., 2002).

In discrete choice models the respondents' choices are described from a set of alternatives. The alternatives must be mutually exclusive, whereby, choosing one alternative necessarily implies not choosing any of the other alternatives. Discrete choice models are usually derived under the premise of a utility maximizing consumer and therefore, use the random utility theory. The objective of this research is to estimate the values of alternative levels of cascade benefits (considered as outcomes of alternative management strategies) through assessing the TEV of such benefits.

A choice question in a CE typically includes several alternatives including a 'baseline' scenario. Each alternative is described in terms of different levels of cascade management with associated non-market attributes and a cost / payment attribute. Respondents are asked to choose their preferred option from these scenarios, allowing the researcher to observe the relative importance of the different attributes to the stakeholders.

For the Benefit Cost Analysis framework attempted in this research, cost of restoration was assessed based on recently completed restoration of a STCS named *Kapiriggama* by IUCN and DAD. The *Kapiriggama* Cascade in *Rambewa* DS division which is the adjoining and of similar in size to *Pihimbiyagollewa* cascade (see Figure 1.3). Table 1.4 shows a comparison of the land use and land cover extents and as percentages of the total cascade area in *Pihimbiyagollewa* and *Kapiriggama* cascades. As they are similar adjoining cascades, cost of restoration of *Kapiriggama* cascades from a recent IUCN/DAD project has been used as an approximate cost of restoration of *Pihimbiyagollewa* cascade. Economic value of restored cascade was estimated by way of willingness to pay for restoration of *Pihimbiyagollewa* cascade in this research for attempting economic evaluation of STCS restoration using BCA framework.

# CHAPTER THREE
# METHODOLOGY

## 3.1 Introduction

The previous chapter dealt with review of literature relevant to the research being undertaken covering conceptual, theoretical, and empirical studies related to the identified research questions on the small tank cascades in Sri Lanka. Chapter 3 presents the details related to the methodology covering the conceptual framework, the theoretical foundation, the econometric model, the research design, the sample selection, the data collection methods and an introduction to the data analysis.

The specific objectives of the research are listed below.

i. To elicit the Willingness to Pay (WTP) for restoration and sustainable management of a representative small tank cascade system in the *Malwathu Oya* basin for cascade dependent on-site community and off-site community who are not directly dependent on cascade, taking cascade as the unit of decision-making.

ii. To assess the Marginal Willingness to Pay (MWTP) for different cascade attributes for on-site and off-site communities.

iii. To develop and validate a Benefit Cost Analysis (BCA) framework for decision-making in restoration and sustainable management of small tank cascade systems using the findings of the research.

## 3.2 Conceptual Framework

Cascade systems of tanks provide multiple benefits to the communities that depend on them as well as others who are not directly dependent on these systems. Apart from the most obvious irrigation benefits, there are a number of other benefits which local communities enjoy over time even though many such benefits are not traded in markets. When the small tank cascades were traditionally managed by the local communities, all the direct beneficiaries of these systems participated in the operation and maintenance of the cascade system under the customary practices of management (under the *rajakariya* system). However, when the operation and maintenance shifted from people to formal institutions, small cascade tank systems were not managed to the same extent as they were in the past mainly due to losing the sense of ownership by the community of this communal property. Since the British ruling, over about one and a half century, these systems gradually degraded to the present state, needing large investments to restore them with removal of silt and some repair works. A question often asked now is whether such investment in cascade management and restoration will pays off?



Even though there are a few studies conducted in assessing non-market values of small tanks in Sri Lanka, none have attempted to capture the cascade wide benefits by taking small tank cascade as the unit of analysis, recognising it as the unit of planning and implementing. The main reason being many of the multiple benefits are ecosystem services by the nature, which are not monetised, as such not captured in economic decision-making process and hence, neglecting the investments into restoration and management of cascades. Conceptual framework is presented in Figure 3.1.

Small tank cascades systems are socio-ecological systems[22] generating multiple benefits to local communities. They are largely neglected, as their multipurpose nature is not reflected in irrigation dominated market-based valuation currently being used. Assessment of different aspects of value of a small tank cascade systems is the main area of work in this research. The total economic value of STCS is estimated through people's willingness to pay for restoring a cascade from present status is assessed using discrete choice analysis – choice experiments in short. The theory behind choice experiments is closely linked to two economic theories known as Lancaster's Characteristic theory of value (Lancaster, 1966) and the Random Utility theory (Thurstone, 1927; McFadden, 1974). The estimated benefits of STCS by way of WTP was used in BCA framework for economic evaluation of cascade wide restoration.



[22] A socio-ecological system consists of a 'bio-geo-physical' unit and its associated social actors and institutions. Socio-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context.

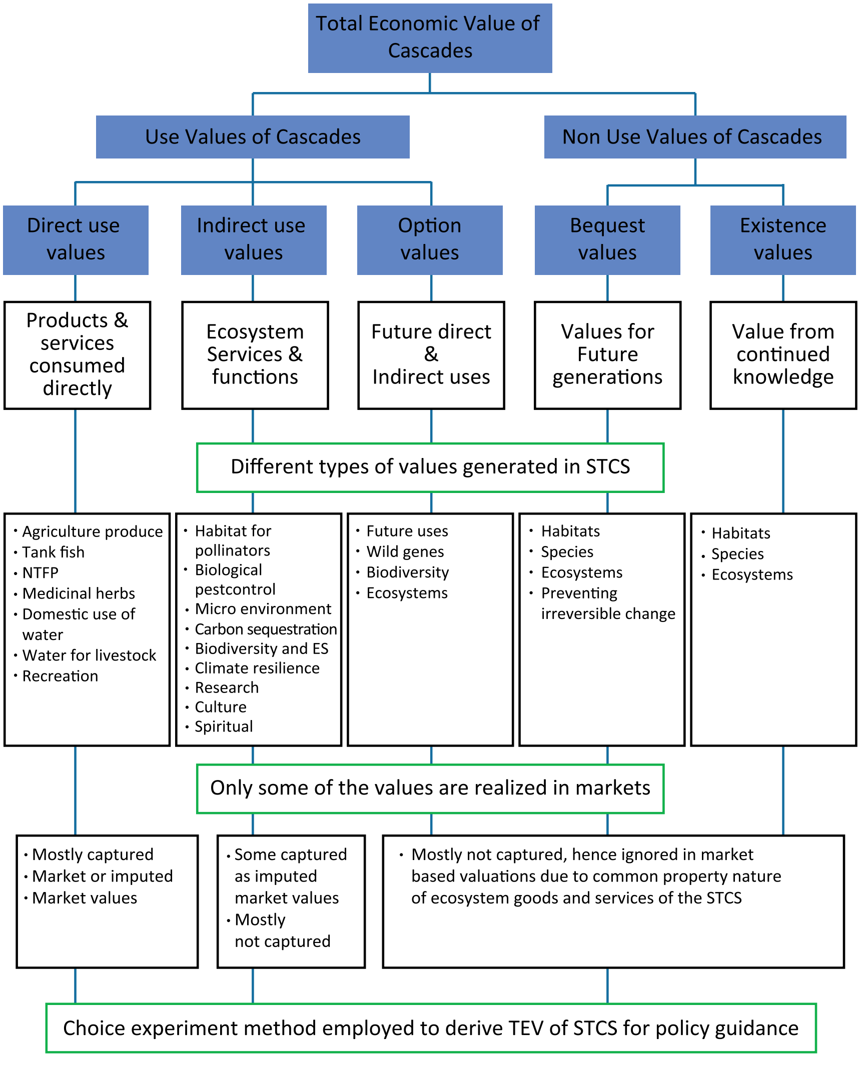


*Figure 3.1: Conceptual Framework*

Discrete choice modelling in economic theory complies with Lancaster's approach to the individual utility maximization problem in consumer theory (Lancaster, 1966) and with the random utility theory (McFadden, 1974). According to Lancaster's approach to consumer theory, consumers derive their utility not from the product as such, but from the attributes by which the product can be described.

The conceptual framework (Figure 3.1) for the research is built on the Lancaster's characteristic theory of value where, STCS provides its values to users through various ways which can be captured through their inherent characteristics. The total economic value of STCS is not reflected in market transactions due to market failures as discussed later in this chapter. Hence, in this research, Choice Experiments will be used as the main valuation technique to elicit non-market values of the system of small tank cascade. In Choice Experiments, the respondents are provided with number of alternative choices to choose their preferred alternative in a Stated Preference survey.



Apart from strong linkage to economic theory, the CE method allows respondents to think in terms of trade-offs, which may be easier than directly expressing monetary values as in other SP methods such as Contingent Valuation. The trade-off process may also encourage respondent introspection and make it easier to check for consistency of responses. In addition, respondents may be able to give more meaningful answers to questions about their behaviour (indicates whether they prefer one alternative over another), than to questions that ask them directly about the dollar value of a good or service or the value of changes in environmental quality. Thus, an advantage of this method over the contingent valuation method is that it does not ask the respondent to make a trade off directly between environmental quality and money. Respondents are generally more comfortable providing qualitative rankings or ratings of attribute bundles that include prices, rather than monetary valuation of the same bundles without prices, by de-emphasizing the price as simply another attribute.

Survey methods may be better at estimating relative values than absolute values. Thus, even if the absolute dollar values estimated are not precise, the relative values or priorities elicited by a contingent choice survey are likely to be valid and useful for policy decisions. The method minimizes many of the biases that can arise in open-ended contingent valuation studies where respondents are presented with the unfamiliar and often unrealistic task of putting prices on non-market amenities.



### 3.3 Econometric Model

The econometric model used by Rai et.al (2014) on estimating demand for watershed services in Koshi basin in Nepal was adopted for the present research. In a CE, the utility derived by individual (i) from an alternative (j) is not limited to the attributes (x) given in the experiment. Several unobservable factors can influence utility, which are captured by a random part (ε). Consistent with the random utility theory (Hensher, Rose, & Greene, 2015), the random and unobservable term are assumed to enter the utility function additively. Therefore, individual (i)'s utility (U) from choosing alternative j is expressed as follows:

$$U_{ij} = X_{ij} + \varepsilon_{ij} \ldots \qquad (1)$$

In order to ensure internal consistency, a CE contains multiple choice sets. Each choice set includes the *status quo*, representing no change in the prevailing levels of different attributes (x), and two (or more) alternatives scenarios; noting that each alternative identifies different levels of a number of attributes. Therefore, individual (i) selects alternative j over alternatives j' when expected utility (U) is greater than expected utility from all other options (U). The probability (Pr) that individual i will choose alternative j over other alternatives j' in a complete choice set R is given by:

$$Pr\ (j \backslash R) = Pr\{(U_{ij} > U_{ij}', \text{s.t.} \forall j' \in R, \text{and } j \neq j')\} \ldots \quad (2)$$

In order to identify the most preferred alternative, equation (2) can be econometrically estimated based on responses to a household or individual survey. Assuming that the error term is Identically and Independently Distributed (IID) and indirect utility (V) is linear in attributes (x), then equation (2) can be estimated with a conditional logit (CL) model (McFadden, 1974). The CL model is expressed as:

$$V_{ij} = ASC + \beta_{ij} \ldots \quad (3)$$

Where, V refers to indirect utility obtained by the ith individual for the jth alternative and β is the coefficient of the attributes (x) included in the experiment. The Alternative Specific Constant (ASC) captures the effect of unobservable factors on the selection of alternatives relative to the *status quo*. In this analysis, ASC is a dummy variable that is coded as 1 for 2 hypothetical alternatives in the choice set, and as 0 for the *status quo.* A random parameter logit (RPL) model can also be estimated by relaxing some of the constraints associated with the IID assumption in the CL model. In the RPL model, the observed component (βx) is decomposed into two parts: the sum of the population mean (ϒ) and the individual deviation of the random parameter (η). In this model, socioeconomic variables (s) are introduced to detect sources of heterogeneity. Further, the interaction terms in γ identify the impacts of individual-specific characteristics on selected alternatives and the ASC. The RPL model is expressed as:

$$V_{ij} = ASC + \Upsilon x_{ij} + \eta x_i + \gamma s_i \ldots \quad (4)$$

### 3.4 Research Design

As explained in the introductory chapter, this research was conducted as a case study by selecting a representative cascade from the Dry Zone of Sri Lanka. *Pihimbiyagollewa* cascade was selected from the *Malwathu Oya* basin – the river basin which has the most number of cascades in Sri Lanka (Panabokke et al., 2002) as the representative cascade for the research, *Kapiriggama* cascade from the same basin was used to get restoration cost estimates for the BCA (see Figure 3.2 and 3.3).

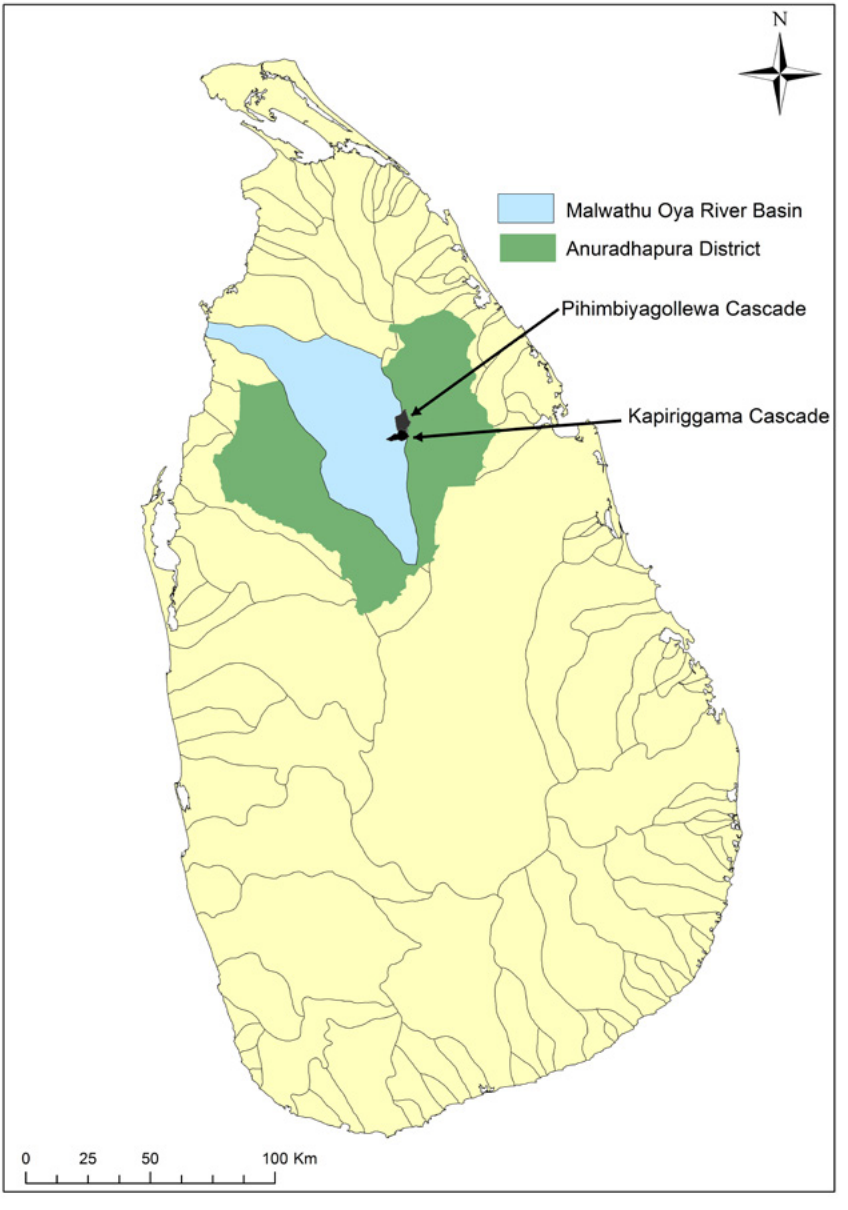


***Figure 3.2: Location of Pihimbiyagollewa Cascade***

Source: IWMI database

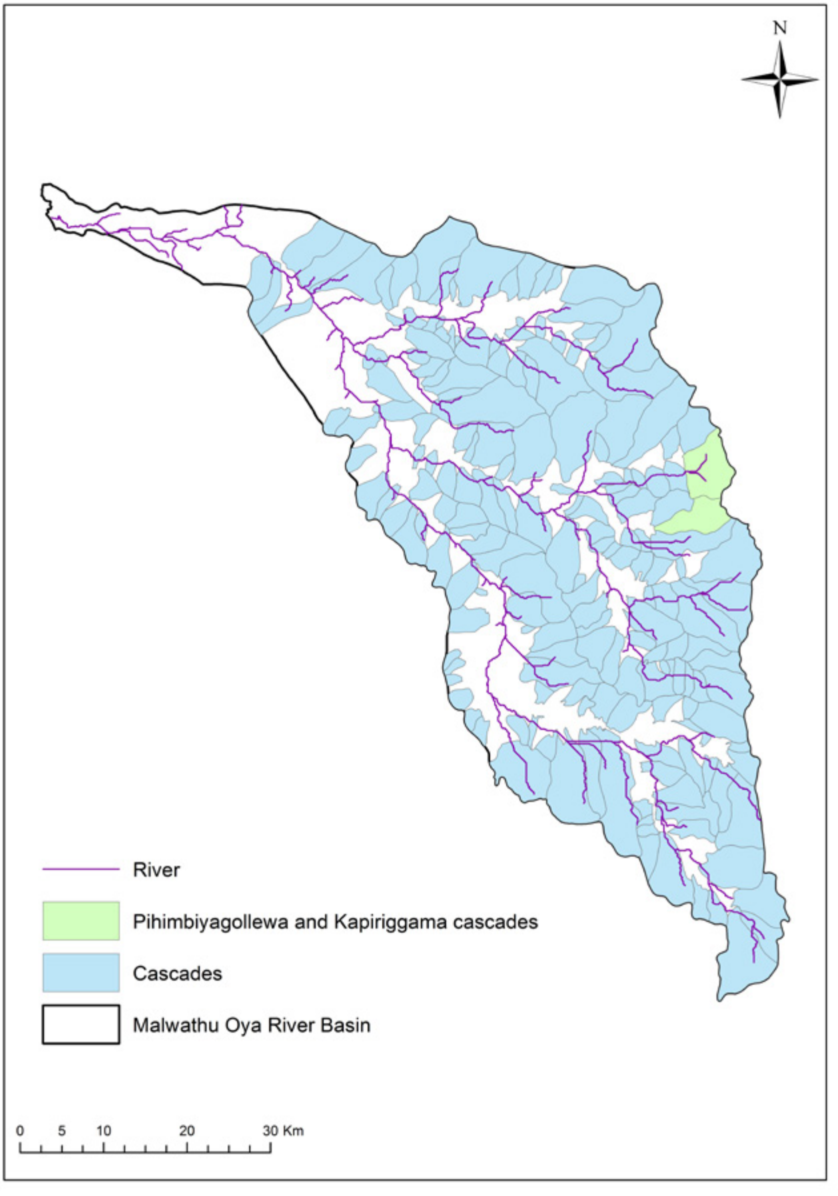


***Figure 3.3: Positioning of Sample Cascades in Malwathu Oya Basin***

Source: DAD and IWMI databases

The selection of the cascade was done in consultation with experts on STCS, institutional representatives mandated for managing cascades, local communities and undertaking a reconnaissance visit to few prospective cascades. The main criteria in selecting the cascade includes; that the potential cascade has to be a functional cascade, which has not been recently restored, preserve its main cascade features with having active Farmer Organisations of a medium size cascade. The selected *Pihimbiyagollewa* cascade situated in *Rambewa* and *Kahatagasdigiliya* Divisional Secretariat divisions of Anuradhapura district of the North Central Province of Sri Lanka (see Figure 3.4). Cascades are socio-ecological systems that provide benefits to people living in and around the cascades as well as people living in distant areas.



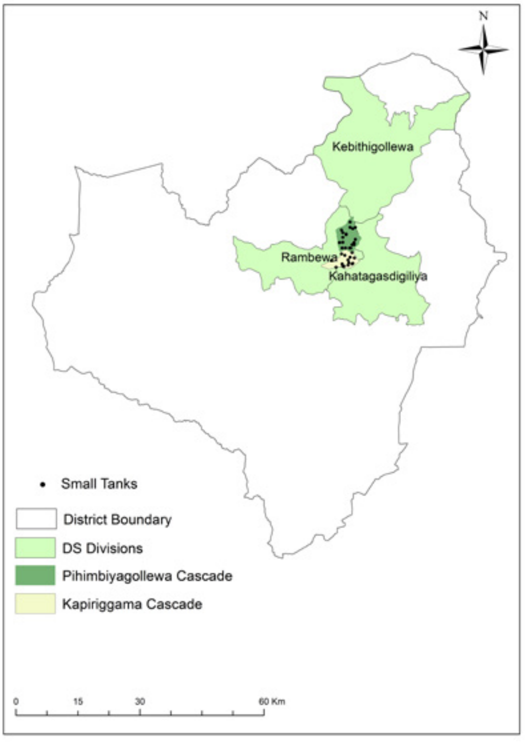


***Figure 3.4: DSDs of Pihimbiyagollewa STCS***

Source: Survey Department

This research is expected to capture the values of the cascade both, from the 'on-site' – community in *Pihimbiyagollewa* cascade and from the 'off-site' – selected communities outside of the *Pihimbiyagollewa* cascade. The purpose of having off-site sample was to capture the values that they place on restoration of STC, the relative importance of attributes between the two samples in determining value and to explore the potential use of the values in policy guidance on STCS restoration. Off-site sample was selected from three DS divisions of Colombo district.

**3.4.1 Designing the Choice Experiment (CE)**

Following main steps in designing the choice experiment was adopted from Blamey et al., 1997.

i. Problem Identification – issues associated with the STCS operation and the maintenance were well studied, with google maps, consultation of experts and local communities (See Annex 1) and field surveys. All above collectively helped to establish the current status of the cascade, threats to their sustenance, and the stakeholders involved.

ii. Policy scenarios – identified two management actions as alternatives for restoring and sustainable management of the cascade from the current state using the attributes chosen and their levels. With the *status quo*, altogether three policy scenarios were considered for the research.

iii. Selection of attributes – as described in detailed below, the attributes relevant to the cascade under consideration for valuation were identified. The identification of attributes was done in consultation with the relevant stakeholders (mainly experts on STCS, officials) and they were finalised through four Focus Group Discussions conducted for cascade dependent communities in *Pihimbiyagollewa*.

iv. Assigning levels to attributes - the levels of the attributes determined for the *status quo* scenario and alternative policy scenarios. These were also agreed upon with proper literature review, expert opinion, use of maps, field visits and with stakeholder consultation.

v. Experimental design – as four attributes with three levels and one attribute with five levels, a full factorial design became too large to administer. Therefore, an experimental design was used to arrive at a manageable number of choice sets required for reliable estimates.

vi. Survey delivery - choosing the survey tool, the sample size, locations and the surveying procedure are covered in Section 3.6.3 on data collection.
vii. Analysis of the survey results - different econometric models specifically developed to analysing discrete choice data were used to get estimate for the trade-offs made between the attributes



### 3.4.2 Selecting Attributes for the CE Questionnaire

The key task in any CE exercise is the selection of the attributes, and their levels, used to describe the impacts of alternative policy scenarios (Kragt, 2009). The attributes chosen to describe the change has to be relevant to both decision makers and to the respondents of the questionnaire. Therefore, in determining the relevant attributes for the *Pihimbiyagollewa* cascade, an extensive literature review, consultation with experts/scientists working on cascades, use of google maps and focus group discussions of cascade dependent stakeholders were utilized. The following section provides the attributes and the levels decided based on the literature survey, expert consultations, focussed group discussions and field observations for the selected cascade in *Malwathu Oya* basin.

### *3.4.2.1 Alternatives, Attributes and their Levels*

With above background, a choice experiment survey was planned by describing three cascade-wide restorations and sustainable management alternatives/options to get respondent preferences in a structured questionnaire survey. The three alternatives included the *status quo* or the 'baseline', and two scenarios of improvements. Each alternative was described in terms of different levels of cascade management with associated attributes and a cost attri bute. Respondents were asked to choose their preferred option from these scenarios, allowing the research to observe the relative importance of the different attributes to the stakeholders. These cascade restoration alternatives are made up of a set of attributes, which in turn are differentiated by levels. These attributes and their levels were determined based on literature, expert consultation, use of google maps (Figures 3.5), focus group discussions with communities living in cascades and field testing of those through focus discussion with cascade communities.

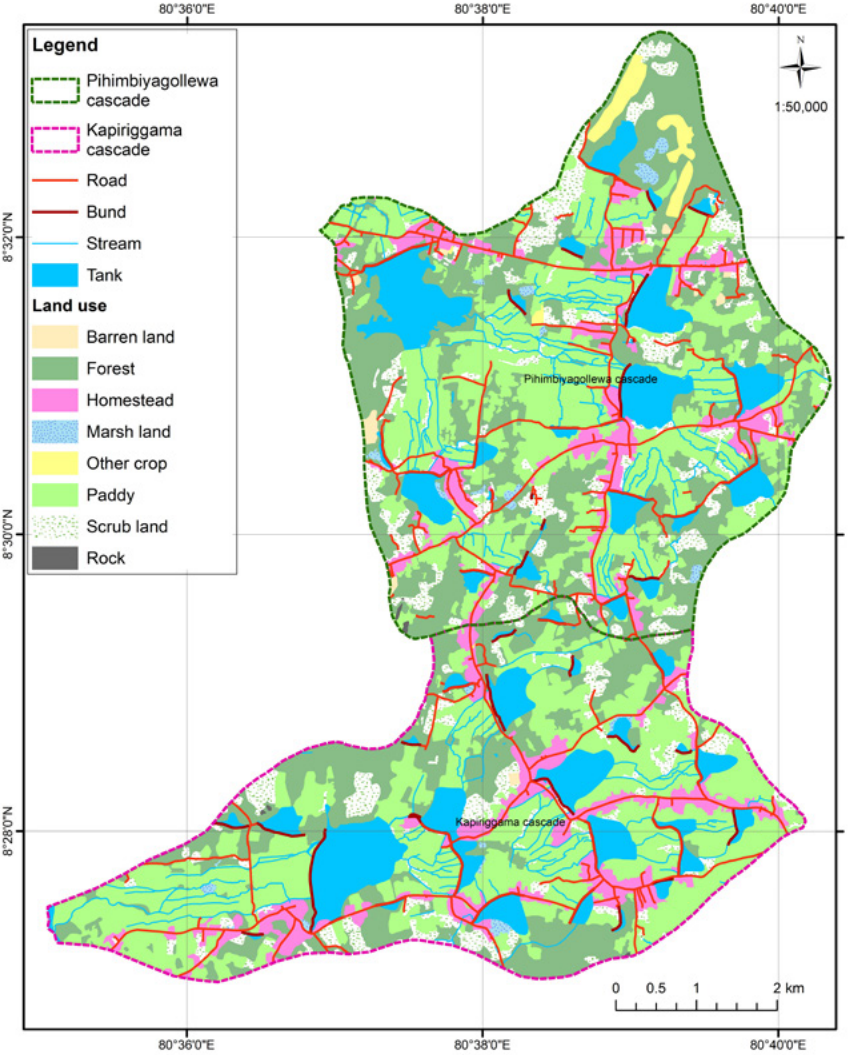


*Figure 3.5: Land Use Map of the Study Area*

Source: Survey Department

The Table 3.1 provides the attributes and their levels used in the research. Detailed attribute descriptions are provided in Annex 2.

***Table 3.1: Attributes and their Levels***

| Attribute Name | Attribute Levels in a normal year |
|---|---|
| Availability of irrigation water in the cascade for cultivating paddy during the dry season (Yala[23]) | 1. Water will be available for cultivating entire paddy fields in the cascade.<br>2. Water will be available for cultivating three fourth of paddy fields in the cascade.<br>3. Water will be sufficient to cultivate for about half of paddy fields in the cascade. |
| Availability of water for other purposes in the cascade during dry season (Yala) | 1. Water will be available throughout the year in cascade for other purposes.<br>2. Water will be available at least 10 months of the year in cascade for other purposes.<br>3. Water will be available at least 8 months of the year in cascade for other purposes. |
| Extent of unique cascade ecological components | 1. Cascade ecosystem components collectively fully covered with forest/natural vegetation of the entire cascade area<br>2. Cascade ecosystem components collectively cover two third areas with forest/natural vegetation of the entire cascade area<br>3. Cascade ecosystem components collectively cover one third areas with forest/natural vegetation of the entire cascade area |
| Cascade biodiversity | 1. About 12 types of bird groups found in the cascade during Yala season<br>2. About 8 types of bird groups found in the cascade during Yala season<br>3. About 4 types of bird groups found in the cascade during Yala season |
| Respondent contribution to cascade restoration and management | For Cash - In LKR/season/household 2,000, 4,000, 6,000, 8,000, 10,000 and 12,000<br><br>For Labour – in days /season/household 2, 4, 6, 8, 10, 12<br>(Level 0 was used for Cash and Labour only in business as usual case) |

Attributes and their levels were identified with literature, expert opinion, google maps and field observations. They were fine-tuned in consultation

[23] Water deficit dry cultivation season depends on the availability of tank water.





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with cascade-based communities at Kapiriggama and Pihimbiyagollewa cascades through a series of focus group discussions. Hence, attributes and their levels including the payment attribute levels are realistic (see details in Annex 2).

### 3.4.3 Experimental Design

Discrete choice models describe respondents' choices among a set of alternatives. In this research, the alternatives are the different cascade restoration options. One of the alternatives to choose from will be the present status of the cascade (alternative A, the *status quo* or business as usual) for which respondents do not have to pay any additional payment if they wish to select that as their choice. Alternatives will have different levels of the five attributes, designed as add-ons to Alternative A.



Levels of attributes for other two alternatives were generated in an experimental design. A design with four attributes with three levels and a six-level payment attribute, will result in a full factorial design with 486 (34x6) different combinations of attributes. Therefore, a manageable fractional factorial design was created with 54 unique choice profiles (see Annex 3 for experimental design) as, a subset of all possible combinations. SAS statistical package was used to generate orthogonal main effects design using 100% D-efficient design following Kuhfeld (2010). Even the 54 sets of choices were too many for the respondents in the survey. Therefore, these, were blocked into nine sets of choice profiles. As found in literature, for better understanding of the choice set, the first and the second choices in a profile were repeated at the end making the choice set per respondent as eight. Hence, in this survey each respondent got eight sets of choice questions within which six unique choices were administered within a choice set. In the analysis, the first two choice responses were discarded as they are captured in the last two responses in a choice set.

These attribute levels were illustrated graphically and used in producing printed colour cards of choice profiles to be given to respondents to make their choices. There were a total of 72 choice cards (6x9 = 54 unique cards + 2x9 = 18 repeated cards) per each payment attribute (either cash or labour). One respondent faced either cash or labour survey as determined in the survey design. Sample choice cards for labour and cash are in Annex 4.

In the survey, nine sets of choice cards repeated amongst respondents in a way that each set is equally distributed amongst the sample in both cash and labour versions where applicable. Each respondent faced just a one set out of the nine sets either in cash or labour in the on-site sample and just cash in the off-site sample. The labour contribution from the off-site sample to the cascade was evaluated as impractical. Therefore, only the in-cash surveys were selected for the off-site sample



### 3.5 Data Collection

The tool for primary data collection of the research was a structured survey questionnaire, drafted with preliminary research undertaken and improved through consultations. Finally, it was field tested in *Kapiriggama* Cascade adjoining *Pihimbiyagollewa* cascade with the enumerators before finalising. There were two formats of the survey questionnaires; a more detailed one for the on-site sample and a variant of the same for the off-site sample (see Annex 5A and 5B for choice experiment and demographic questions presented in two questionnaires). The questionnaire comprised of four sections. The first section is about the general information on the survey, which included the confidentiality of the information collected, the consent of the respondent and that the respondents can leave the survey at any point and finally, a detailed background to the issues to be addressed in the survey. Section two was devoted to introducing the attributes, their levels and graphical representation of them in the choice cards and the third section was on the choice cards and getting choice responses. The final and the fourth section was on the respondent's socio-economic information.

As the choice experiment surveys are somewhat complex, the enumerators (in both locations *Pihimbiyagollewa* and Colombo) were provided with detailed training. The training covered an introduction to the subject of STCS (enumerators for *Pihimbiyagollewa* were taken to the cascade as part of the training), training on the CEs, survey methods, and on field testing of the survey for them to get a better understanding before they undertook the survey proper. They were also given a chance to role play by administering few surveys amongst themselves before they were exposed to field testing. In addition to the survey questionnaire, a set of colour printed materials were provided to the enumerators as a survey aid. It included the materials for introducing the survey, complete set of labour and cash choice cards (72x2=144) methodically arranged in hardcover ring binder folders.



### 3.5.1 Field Surveys

As highlighted before, the primary data collection surveys were conducted targeting two communities. The main one was at the *Pihimbiyagollewa* cascade in Anuradhapura district, the on-site survey. Cost of restoration of adjoining *Kapiriggama* cascade was accessed from IUCN as a proxy for restoration of *Pihimbiyagollewa* cascade in the BCA. The on-site survey was conducted with 10 final year undergraduate students as enumerators from the faculty of Humanities, Rajarata University of Sri Lanka supported by an experienced survey coordinator. The on-site sample was selected from residents of *Pihimbiyagollewa* cascade covering six Grama Niladhari divisions in two Divisional Secretariat divisions of the Anuradhapura district. They were *Pihimbiyagollewa, Wewelketiya, Thamara Halmillawewa, Balahondawewa, Ihalakolongaswewa* GNDs of *Rambewa* DSD and *Palippothana* GND of *Kahatagasdigiliya* DSD (Figure 3.6).

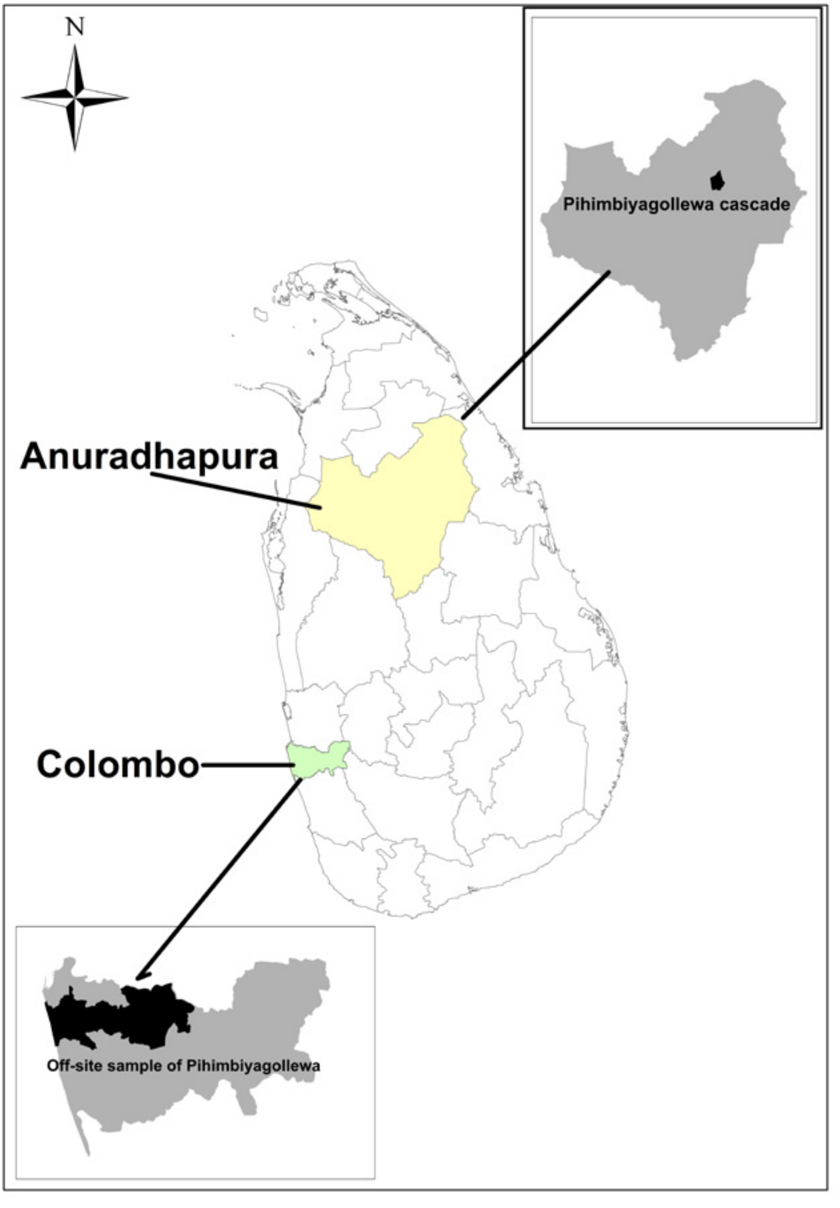


***Figure 3.6: On-site and off-site Sampling Sites***

Source: Survey Department

The *Pihimbiyagollewa* off-site sample was selected from Colombo district covering four GNDs in three DSDs. Selection of Colombo district for the off-site sample was based on the ability to reach out to a cross section population covering high, medium and low-income categories within the same district. The selected GNDs were *Kurunduwatte* GND of *Thimbirigasyaya* DSD, *Pagoda* GND of *Sri Jawardenapure* DSD and *Sri Subuthipura* and Malabe South GNDs of Kaduwela DSD (Figure 3.6). Similar to the on-site survey, the off-site also done with university students after providing them with training. Five final year undergraduate students of the Department of Economics, Faculty of Arts, University of Colombo were used as enumerators. They too were supported by an experienced survey coordinator.



The on-site survey in *Pihimbiyagollewa* cascade conducted in August/ September 2016. The surveys were of two types, one was with payment attribute in cash and the other was with labour as the payment attribute. In addition, the introduction to the survey for the respondents were done in two ways;

i. As a group: for approximately 50% of the respondents, the survey (both cash and labour) introduction was done in a group of 10 respondents by one enumerator using visual aid and then they were surveyed individually by 10 enumerators. The 10 enumerators took turns in introducing the survey to the groups ensuring that each enumerator approximately got equal number of chances introducing group surveys.
ii. As individuals: this way the introduction to the survey was done individually at the upfront of the survey by the respective enumerator using the visual aid provided individually.

The idea of administering individual surveys after two types of introductions (respondents in a group and on individual basis) was a novel concept. The reason for doing that was to understand whether there is any impact on responses based on the way the survey was introduced (group vs individual learning). Therefore, the *Pihimbiyagollewa* sample has following categories depending on the combination they faced.

i. Individual cash survey
ii. Individual labour survey
iii. Group cash survey
iv. Group labour survey



Further, in analysis there were two additional sub categories created as below

v. Cash combined (Individual + Group)
vi. Labour combined (Individual + Group)

The off-site survey in Colombo district was conducted entirely as individual cash surveys. As their labour contribution to be given for a far-away cascade was not practical and also due to their unavailability for group introduction, all surveys at off-site were conducted individually with cash as the payment attribute.

A stratified random sample of 516 households was surveyed in *Pihimbiyagollewa* covering approximately 50% of the cascade community in six Grama Niladhari divisions of the two Divisional Secretariat divisions. Stratification was done to capture variability in upstream, mid catchment area and the downstream of the cascade. Off-site survey of *Pihimbiyagollewa* cascade was conducted in four GN divisions in three Divisional Secretariat divisions of Colombo district. Survey was originally planned as a random sample using the voters list, however in conducting the survey it was found impractical as there were many instances of changed house numbers and inaccessibility to selected householders' due to locked gates preventing enumerators engagement. Therefore, the survey in Colombo was done by interviewing pre-determined number of respondents of a given lane in selected GNDs. Total number of surveys conducted in Colombo was 206 households.

### 3.5.2 Description of Sample Sites

*Pihimbiyagollewa* cascade selected as the on-site sample for the study is one of the five representative cascades studied by Panabokke et al., 2002. The illustration used by them is given in Figure 3.7 with the list of constituent small tanks numbering to 23. According to them, out of the total 23 tanks, 18 were in either fairly good or good condition as a result of their rehabilitated at least once since 1970. Fifteen of them having been rehabilitated after 1991. The five tanks which were in relatively bad state then were in a moderate state of repair. Those were very small tanks that have either never been rehabilitated or have been rehabilitated once in the early 1970s.

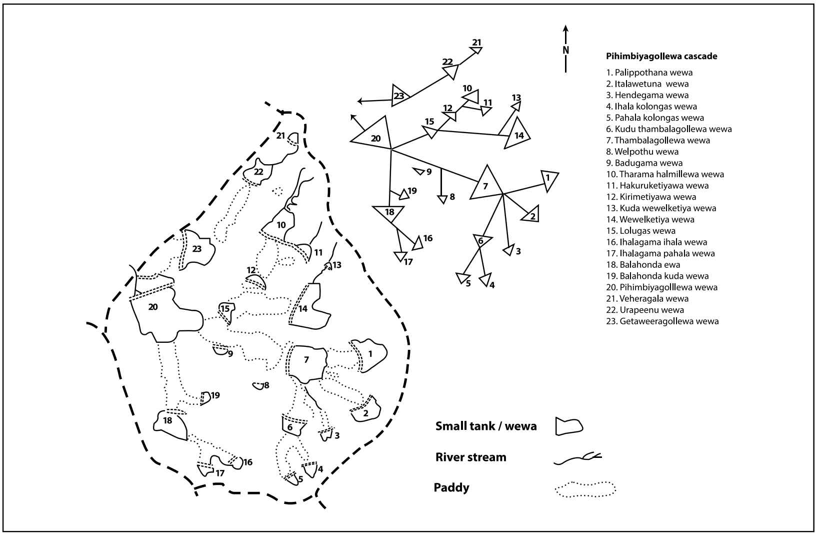


***Figure 3.7: Schematic map of Pihimbiyagollewa Cascade***

Source: Panabokke et al., 2002, p.22



Table 3.2 provides the size class distribution of tanks in the cascade

***Table 3.2: Size Class Distribution of Tanks in Pihimbiyagollewa Cascade***

| | Water Spread Area (ha) | | | | |
|---|---|---|---|---|---|
| | >80 | 40-80 | 20-40 | 10-20 | <10 |
| No of Tanks | 1 | 2 | 5 | 2 | 13 |

Source: Panabokke et al., 2002

Table 3.3 indicates how the population in the cascade change over time.

***Table 3.3 Population Dynamics in Pihimbiyagollewa Cascade***

| Year | 1900 | 1998 | 2016 |
|---|---|---|---|
| No of families reported in cascade | 70 | 132 | 1050 |

Source: Panabokke et al., 2002 and DAD database

As indicated in Figure 3.7, the tanks 21 to 23 were considered a separate linear cascade. Therefore, those three tanks were excluded in the present study.

The *Pihimbiyagollewa* cascade administratively lies on three Divisional Secretariat Divisional areas namely *Rambewa, Kahatagasdigiliya* and *Kebithigollewa*. Great majority of the cascade falls in *Rambewa* DSD with *Kahatagasdigiliya* DSD occupying a negligible area falls within *Kebithigollewa* DSD (Figure 3.8). Socio-economic characteristics of the on-site sample is provided in Table 5.1.

Off-site sample for the study was selected from three DSDs, namely Thimbirigasyaya DSD, Kaduwela DSD and Sri Jayawardenapura Kotte DSD of Colombo district covering high, middle and low income earning segments of the population studied away from the cascade being valued (Figure 3.9). Socio-economic characteristics of the off-site sample is provided in Table 5.2.

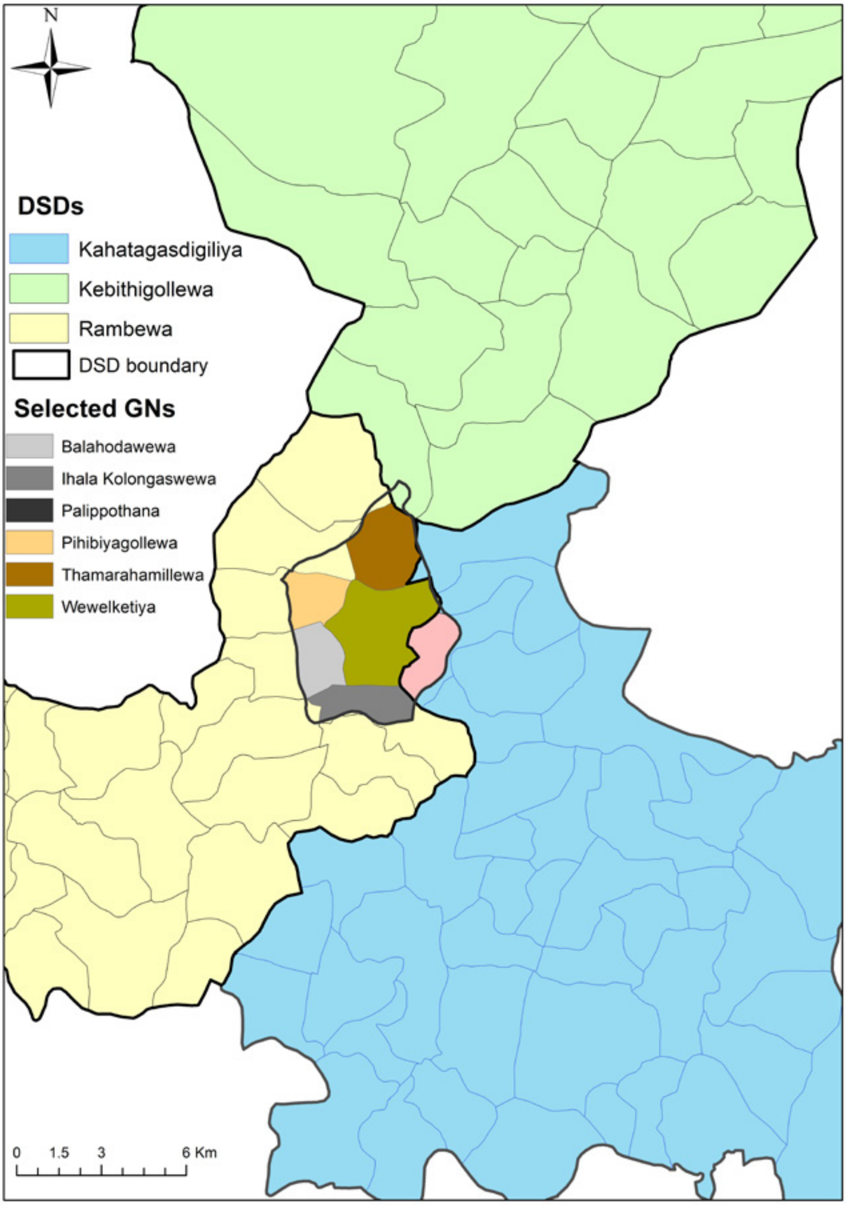


***Figure 3.8: Grama Niladhari Divisions of the on-site Sample***

Source: Survey Department

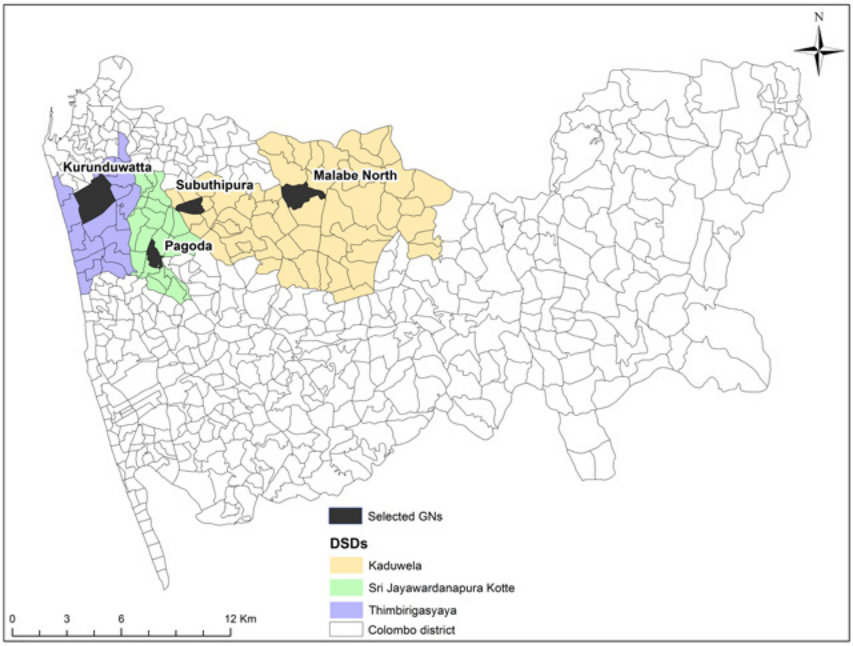


*Figure 3.9: DSD of the off-site Sample*

Source: Survey Department



## 3.6 Introduction to Data Analyses

Data from CE survey is analysed using logit regression models. Standard Multinomial Logit Model (also referred to as Conditional Logit Model) was used initially and then the Mixed Multinomial Logit – MML Model (also called Random Parameter Logit – RPL Model) was used by relaxing some of the assumptions. Stata 14 SE statistical package was used in the data analysis in estimating the TEV through WTP by the stakeholders for different segments of the sample. Details related to models used and estimation is discussed in the next chapter. Sample choice set used in CE is given in Table 3.4.

***Table 3.4: Sample Choice Set***

| Attribute | Availability of irrigation water for cultivating paddy during the dry season in the cascade (*Yala*) | Availability of water for other purposes in the cascade during dry season (*Yala*) | Extent of unique cascade ecology components | Cascade biodiversity | Your contribution to cascade management (cash or labour) | I would Choose |
|---|---|---|---|---|---|---|
| Alternative A | No change to the present scenario ½ of the paddy lands in cascade are cultivated with paddy | *Status quo* maintained – water will be available at least 8 months of the year for other purposes | *Status quo* maintained – cascade ecological components collectively cover 1/3 of the cascade area | *Status quo* maintained – about 4 types of bird groups found in cascade during *Yala* | No additional contribution | □ A |
| Alternative B | Water will be available for cultivating about ¾ of the paddy lands in *Yala* season | water will be available at least 10 months of the year for other purposes | *Status quo* maintained - Cascade ecosystem components collectively cover 1/3 of the cascade area | *Status quo* maintained – about 4 types of bird groups found in cascade during *Yala* | In LKR 1,000 per year | □ B |
| Alternative C | Water will be available for cultivating the entire paddy lands in *Yala* season | water will be available throughout the year for other purposes | Cascade ecosystem components collectively cover 2/3 of the cascade area | about 12 types of bird groups found in cascade during *Yala* | In LKR 10,000 per year | □ C |

Alternative A: Status quo – some interventions by the government and community, at individual tank level – Choice A
Alternative B: Cascades are restored and managed taking cascade as the planning and management unit – Choice B
Alternative C: Cascades are restored and managed taking cascade as the planning and management unit – Choice C

# CHAPTER FOUR

# SMALL TANK CASCADE SYSTEMS IN SRI LANKA

As the subject of STCS is less familiar to the economics readership, a separate chapter is devoted on the STCS of Sri Lanka. In this chapter, STCS are introduced, their historical, socio-economic, environmental and institutional aspects and their present status is presented

## 4.1 Background to Small Tank Cascade Systems

The irrigation systems of Sri Lanka are broadly categorized into minor, medium, large and those under special projects – such as Mahaweli and Walawe systems (Murray & Little (2000). Of these, the minor irrigation systems also referred to as village or minor irrigation works as well - the subject of this study are officially defined as the tanks with command areas of 80 ha or less. Work by Panabokke, Sakthivadivel & Weerasinghe (2002) indicates that these tanks are not occurring randomly but organized in a manner that collects rainwater from well-defined micro catchments. These individual tanks are components of large systems or units called 'cascades' (Madduma Bandara, 1985; Panabokke et al., 2002; Tennakoon, 2002). Madduma Bandara (1985) defined cascades as 'a connected series of village irrigation tanks organized within a micro - (or meso-) catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet'.

Cascade systems comprise with number of components including many types of tanks; *maha wewa*[24], *olagam wewa*[25], *kulu wewa*[26], *godawala*[27] and *pinwewa*[28] (Tennakoon, 2004). Multiple uses are generating from irrigation water, rather than crop irrigation (Renwick, 2001). Fisheries and livestock (Renwick, 2001), flood prevention, soil erosion control, water quality control and water storage of irrigation (Schütt, Bebermeier, Meister, & Withanachchi, 2013), climatic vulnerability with drought and condition of changing climate patterns, human integrity, retaining soil health (Senanayake, Wijesekara, & Hunter, 2010) are some of the direct and indirect agricultural benefits. Mendis (2002) referring to the functions of the ancient irrigation works in Sri Lanka notes, in addition to the much-known hydraulic engineering supremacy, the existence of a well-established water and soil conservation aspects in ecosystem perspective.



These systems are hydrologically and socio-economically interlinked (Sakthivadivel, Fernando, Panabokke, & Wijeratne, 1996). These tanks need to be rehabilitated as a system considering the cascade connections (Aheeyar, 2013), and need to be assessed in socio-economical terms (Begum, 1987). The changes made to the system may have an impact on the socio-economic stability of the adjoining communities (Jayakody, Mowjood, & Gunawardena, 2004). Senanayake et al., (2010), has emphasized that the tanks are losing its functionality due to various social, economic, environmental and physical reasons. This rich resource can be

[24] *Maha wewa* is the larger tanks in villages used for irrigation and other domestic purposes

[25] *Olagam wewa* means the tank without a village, cultivation from the tank is done by villages from an adjoining village tank

[26] *Kulu wewa* is a small tank constructed on upstream for the purpose of trapping silt brings down by runoff water. Usually there are no settlements or paddy field for these tanks

[27] *Godawala a*re the water holes in forest areas above tanks, mainly for the wild animals around which lush vegetation too prevails.

[28] *Pinwewa* are constructed closer to the temples to meet their water needs. These tanks were not used for irrigation purposes earlier, but paddy cultivation seen in recent times.

used as a tremendous multi-beneficiary treasure for the development of on-site community's livelihood. Turner, Georgiou, Clark, Brouwer, & Burke (2004) identified that despite the number of functions it provides, a common problem is the ignorance of the values of water resources that leads to depletion and degradation of the resource.

Poor management of the STCS has caused drastic changes in the cascade systems. After the independence, Walawe river basin was recolonized. Without considering the hydrology of the tanks, the command area had been increased. Water shortage, abandonment of tanks, impeding the natural recruitment of migratory fish stocks were the consequences of it. Reducing soil cover by *chena* (slash and burn) cultivation lead to soil erosion and sedimentation of tanks and streams, drying up of streams and degradation of tank ecosystem (Somaratne, Jayakody, Molle, & Jinapala, (2005); Murray and Little, (2000)).



There is a wide variation in the size-class a nd geometry of these small tank systems across the Dry Zone landscape (Panabokke et al., 2002). Distribution of small tanks in Sri Lanka is presented in Figure 4.1.

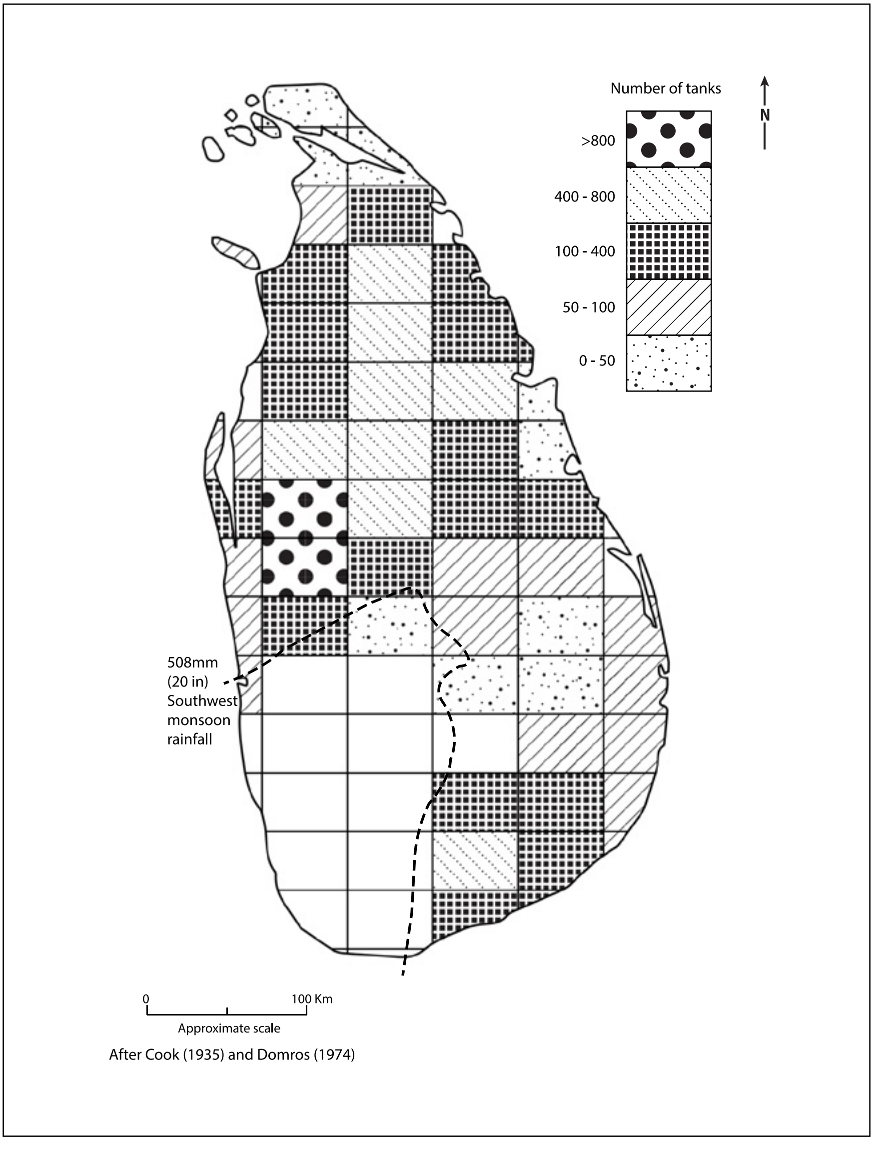


***Figure 4.1: Distribution of Small Tanks in Sri Lanka***

Source: Cook (as cited in Panabokke et al., 2002, p. 4)

According to Panabokke et al., (2002) the technology of construction of these small village tanks had been simple and straightforward and certainly within the capacity of village resources as well as their construction skills. At the same time, the design and construction of the major irrigation works had reached a certain level of maturity and there is no reason to doubt that the expertise that had by then developed for major construction works would have been applied with some modification to the construction of the smaller village tanks as well. Further they refer a body of empirical relationships on rainfall, run-off and storage must have been known by 350 AD when very advanced hydraulic structures were being built (Panabokke, 2009).

Different scholars suggested different figures for the total number of small tanks in Sri Lanka. Dharmasena (2004) suggested that over 30,000 small tanks are in existence in Sri Lanka where others like Panabokke believed in a much lower number. Panabokke (2004) estimated it as around 18,000 small tanks, both operational and abandoned distributed across 70 well defined river basins in the Dry Zone of Sri Lanka. Approximately 40 percent of these small tanks are located within the North Western Province, 26 percent within the North Central Province and 10 percent within the Southern Province and Northern Province.

Nearly 90% of these small tanks were found to be organised as clusters or cascades (Panabokke et al., 2002 and Madduma Bandara, 1985). Total number of remaining cascades in Sri Lanka were estimated as 1,166 (DAD, 2005), out of which 457 cascades are found in North Central Province of Sri Lanka (Panabokke et al., 2002). Figure 4.2 provides an illustration on how the small tanks in *Pihimbiyagollewa* and *Kapiriggama* cascades – meso catchments are contributing to the *Malwathu Oya* river through *Sangilikandara oya* and *Kadahathu oya* streams sub basins respectively.

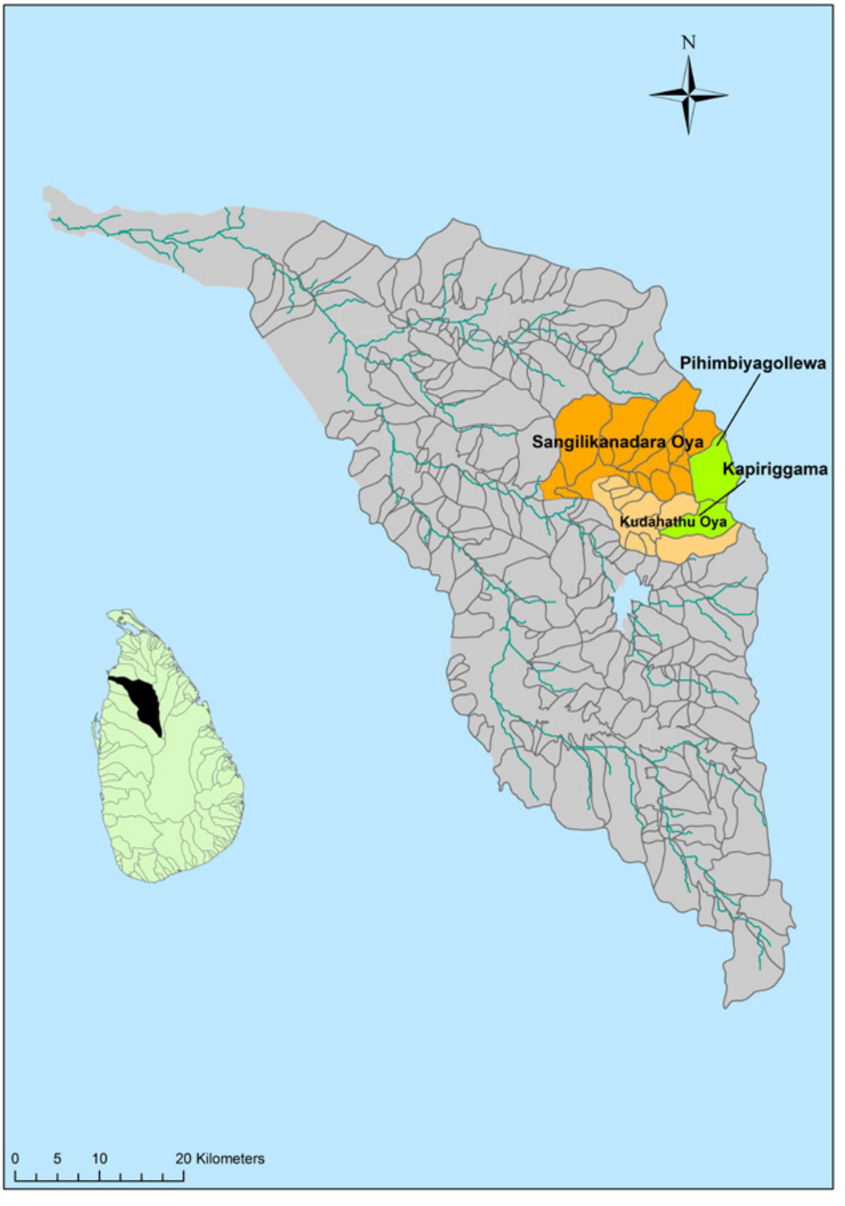


***Figure 4.2: Malwathu Oya basin with study area***

Source: IWMI and DAD databases

Schematic diagram of a STCS is provided in Figure 4.3 helps visualising how the small tanks at various levels in cascades are organised and drains to a large tank downstream.

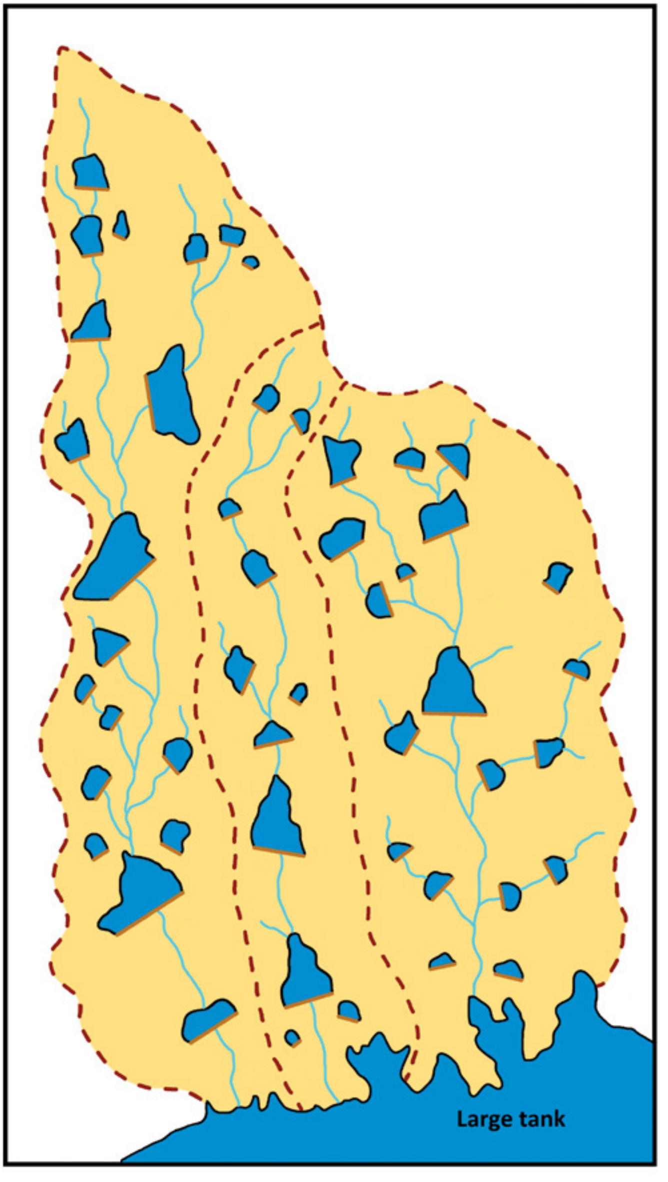


***Figure 4.3:Illustration of Small Tanks in a Cascade Drains to a Larger Tank***

Source: IUCN, 2016

As described by Panabokke et al., (2001), the micro-morphological features of Dry Zone such as *heennas*[29] and *mudunnas* have had a great influence in the distribution, density, alignment, size, shape and use of small tanks within cascades. They further explained that though the small tanks within a cascade differs physically from one another, these eco-friendly pools of water have a hydrologically and socially determined pattern to be economically and socially beneficial. After about 2 millennia of their invention, the STCS are still an integral part of the Dry Zone of Sri Lanka serving the present generation in economic, socio-cultural and ecological fronts with a hope to serve the future if well managed. Cross section of a cascade is depicted in Figure 4.4, where relative positions of cascade components are shown in undulated landscape.



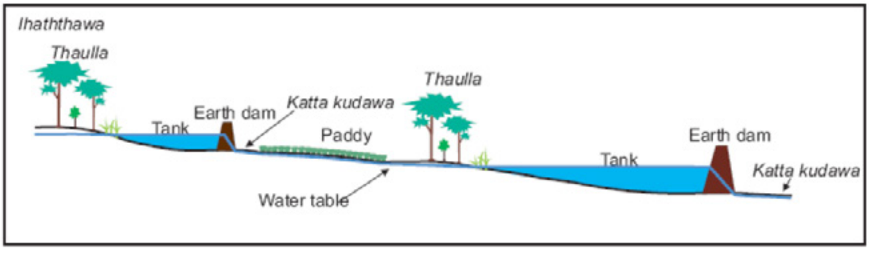


***Figure 4.4: Cross Section of a STCS***

Source: Mahatantila, 2007

Figure 4.5 depicts the cross section of an individual tank of a cascade

[29] *Heennnas and mudunnas are micro-morphological characteristics of the areas where cascades are constructed. Inside low ridges within sub watershed boundaries are called heennas while summits within those sub watersheds are called mudunnas. Tennnakoon, (2001)*

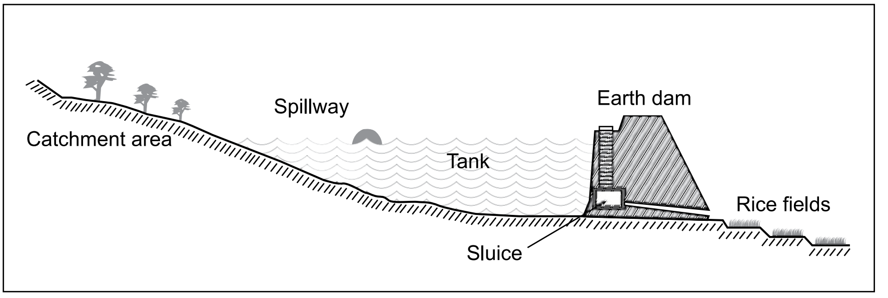


***Figure 4.5: Cross Section of a Present-Day Small Tank***

Source: Panabokke et al., 2002

As shown in the map collection titled 'The Hydrography of the Rajarata' (Panabokke, 1999) a high density of small tanks occurs in the upper watershed regions of the main river basins such as the *Malwathu Oya*, *Kala Oya* and *Yan Oya*, as well as the major tributaries such as the *Maminiya Oya*, *Kanadara Oya* and *Kadahatu Oya*. This conforms to the normal process of landscape evolution where a higher drainage density occurs in the upper aspects of a watershed, thus resulting in a higher tank density in its upper reaches. In contrast, a lower density of small tank cascades occurs across all the lower reaches of the sub-watershed of the *Malwathu Oya*, *Kala Oya*, *Yan Oya* and *Modaragam Ara*. Also, lower basin area is underlain by Miocene limestone creating a different environment compared to upper basin. Tank technology has adapted to this condition remarkably as reflected by the Giant tank system[30].



[30] *Madduma Bandara personal communication*

Another important feature of this region is the very 1ow incidence of abandoned tanks. There is also an oral tradition in this region that it was never totally abandoned even during the disturbed period between the thirteenth and nineteenth centuries and it is said to have had an unbroken history of continuous settlement over the last 2,000 years or more. It is also claimed that during the heyday of the Anuradhapura civilization, this region had a very close symbiotic association with the main capital city, and it was also its main source of food sustenance.

## 4.2. Historical Perspective and Evolution of STCS



According to Shannon & Manawadu (2007), the first planned settlement in Sri Lanka was recorded in 1000 BC in the Dry Zone. Left bank of the *Kadambha nadi* (now *Malwathu oya*) was selected by Aryan's to establish the settlement 'Anuradhagama', in 623 BC. Due to the seasonality of watercourses, the settlements were suffered from water scarcity. Tanks were built to conserve rainwater to overcome the same (Shannon & Manawadu, 2007). There are many articles on the history of hydraulic civilization of Sri Lanka and the following quote illustrates the salient features of the nation's hydraulic civilization:

> Sri Lanka is well-known for its ancient hydraulic civilization. The earliest reservoir referred to in the Mahavamsa, the great chronicle of the history of the island, was the Jayavápi built in the reign of King Pandukabhaya (377-307BC). The construction of larger scale reservoirs initiated at the time of King Vasabha (65-109AD) and by 500AD, very advanced hydraulic structures which would have required a sound knowledge of key hydraulic principles pertaining to rainfall, runoff and storage volumes had been designed and constructed. That trend continued until the reign of King

> Parakramabahu I (1153-1186AD). This long development phase had established a widely spread mosaic system of reservoirs and canals regulating the water flow either extracted from natural streams or received from direct rainfall (Jayawardena, 2010, p. 128).

Scientific documentation of irrigation works of Sri Lanka believed to have started during British Colonial period by irrigation engineers served in then Ceylon for the British Crown. Henry Parker (1849-1926), Robert Wilson Ievers (1850-1905), Richard Leslie Brohier (1892-1980) and Cyril Wace Nicholas (1898-1961) can be considered pioneers as Panabokke's recent book, "Small Tank Systems of Sri Lanka: their Evolution, Setting, Distribution and Essential Functions" has been dedicated to those four people by identifying them as the 'the true pioneers in the scientific field study of the country's ancient irrigation works' (Panabokke, 2009). As highlighted by Senaratne and Wickramasinghe (2011), Farmer, Leach, Ratnatunge, Madduma Bandara, Panabokke, Tennakoon, Somasiri, Itakura, Abernethy, Sakthivadivel, Handawala, Ulluwishwa, Dharmasena, Begum, Abeyratne and Perera were the post-colonial period scholars who studied further into the various aspects of small irrigation systems in Sri Lanka. The subjects they covered include both bio-physical and socio-economic aspects of irrigation systems in Sri Lanka. Witharana, Aheeyar, Senaratne, Weligamage, Piyadasa and Kularatne are some relatively recent contributors to the subject worth mentioning. It is evident, a considerable amount of work has been done in the past about small, medium and large reservoirs in Sri Lanka.

Brohier (1934) mentions of the belief that small tank technology in Sri Lanka dates back to the pre-Aryan settlements (fifth century BC) but their further technical development and wider usage are evident mostly from Anuradhapura period (from circa 12th Century AD) onwards. The term tank is derived from the Portuguese word 'tanque' also meaning a small man-made reservoir. It has been demonstrated that these tanks are not isolated entities but often form part of a hydrologically integrated system known as a 'cascade'. A cascade is defined as a 'connected series of tanks organized within a meso-catchment of the Dry Zone landscape, storing, conveying and utilizing water from an ephemeral rivulet' (Madduma Bandara, 1985; Panabokke, 2002; Plan Sri Lanka, 2012).

It is further highlighted that the small tanks are not unique to Sri Lanka, they are also found in South India, China, Thailand and Indonesia (Plan Sri Lanka, 2012) with some differentiation. Brohier (1934) in his monumental work on Ancient Irrigation Works, referred to these amazing clusters of tanks [cascades] in the following words:



> "So careful were the inhabitants in husbanding the liquid resources on which their very existence depended, that even the surplus waters from one tank would spill to the next, when water was plentiful, were not allowed to escape. The tanks were built in an orderly method, at slightly varying elevations so that there often was a series of reservoirs to take the overflow from one above it… (Brohier, 1934, p. 2.)"

Aerial view of *Kapiriggama* cascade as given in the page 3 of the Annex 5A demonstrates some of the features highlighted by Brohier in the above paragraph.

It has been further commented that the evolution of minor tank systems through long period of history, spanning several millennia, has resulted in the accumulation of a considerable wealth of indigenous knowledge in the field of irrigation and agriculture (Plan Sri Lanka, 2012). At the same time, evolution of tanks had its own vicissitudes with times of recession and desolation. It is believed the bigger tank systems often collapsed due to a numerous factor, ultimately leading to the collapse of entire 'hydraulic civilization' in the Dry Zone. In contrast, when population increased, the small tanks expanded in number within their cascades and they contracted when the population decreased. Thereby, the minor tank systems displayed greater resilience and proved more sustainable than the bigger ones and therefore, survived through the centuries (Plan Sri Lanka, 2012).

It is evident, that a considerable amount of work has been done in the past about small, medium and large reservoirs in Sri Lanka. Paranagama & Mendis (n.d) referring to the functions of the ancient irrigation works in Sri Lanka notes, "in addition to the much known hydraulic engineering supremacy, the existence of a well-established water and soil conservation aspects in ecosystem perspective" is evident. According to Witharana (2004), traditional Sri Lankan village tank is the heart of the village settlement in the Dry Zone and he further described village tank as one of the "most successful ecological constructions" by ancient people for soil and water conservation.



Shah, Samad, Ariyaratne, & Jinapala (2013) concludes "Sri Lanka's Dry Zone is the only ancient irrigation culture that can boast of an unbroken history of local management of village tanks for rice irrigation over millennia". They further interpreted the "ancient Sinhalese kingdom of Anuradhapura in today's North Central Province fell to Chola invasions during the 11th century". However, during the 20th century several scholars described that the social organisation around small and large tanks to have remained intact. After couple of millennia of establishing the small tanks in cascades, they are still providing many ecological, cultural, spiritual, aesthetic and economic benefits. However, they are being degraded or their functionality has disturbed due to other un-planned development activities taking place at an alarming rate. As our political boundaries are not overlapping with hydrological boundaries, dissection of cascades into different administration units also may have contributed to degradation though it has not been well researched.

From available accounts, it is clear that the spread of these small village tanks would have taken place concurrently with the construction of well-known major irrigation works, especially those of King Mahasen, during late second and early third century AD (Brohier, 1934 & Panabokke, 2002). It is believed however, that the small-scale village irrigation systems as the precursor to large irrigation systems (Panabokke, 2002). The country had now arrived at a stage where the potential for construction and spread of major tanks is almost exhausted. In the past, it was a state driven enterprise under the direction of the ruling monarchs, while the small village tanks construction was largely undertaken and implemented by the local village communities as in neighbouring Tamil Nadu.



### 4.3 Environmental Conditions of STCS

STCS are man-made socio-ecological systems and can be regarded as early applications of landscape approach to spatial planning. This is an agricultural production system that functions in harmony with the ecology within a hydrological boundary. Small tanks, the individual components of STCS are easier to study than cascades. Work by Dharmasena (2004) on small tanks indicates that the village tank systems have been developed to cater diverse micro as well as macro land uses by having different components such as *gangoda*, *chena*, *welyaya*, *gasgommana*, *godawala*, *perahana*, *iswetiya*, *kattakaduwa* and *kivul ela*. According to Somasiri (1991), the small tanks are probably the most important source of water that recharges for the shallow groundwater aquifers of hard rock areas of Dry Zone that supplies potable water for the inhabitants. Restoration of degraded cascades has been identified as a key climate change adaptation mechanism in National Adaptation Plan for Sri Lanka (Ministry of Mahaweli Development and Environment [MMDE], 2016).

Tennakoon states that small cascade-based tank systems had been a classic example of man's ability to maintain a long lasting symbolic relationship of man with available water, vegetation, climate, soil characteristics, animals domesticated and wild being a partner of a well renowned hydraulic civilization. Its revival, therefore, is urgently called for (Tennakoon, 2001). Furthermore, Mendis (2007) articulated that when viewed from an ecosystem's perspective, the ancient irrigation works may be correctly recognised as water and soil conservation mechanism. As investigated by Mahatantila, Chandrajith, Jayasena & Ranawana (2008), the upper periphery of STCS consists of a gentle sloping land - locally known as 'Thaulla' behaves as a constructed wetland that removes excess nutrients and suspended particles in water that drains into the tank.



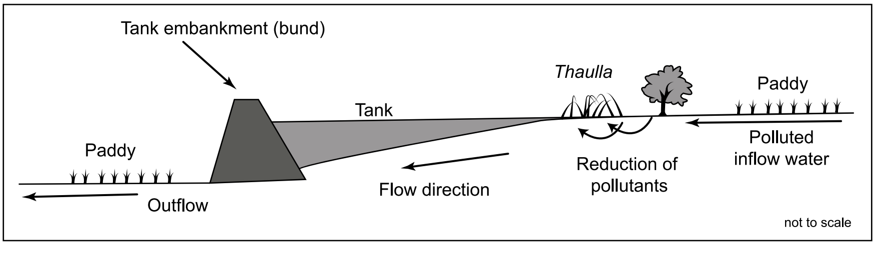


***Figure 4.6: Conceptual Model on Pollution and Flow Regulation in STCS***

Source: Mahatantila, 2008

## 4.4 Economic Aspects of STCS

For small tank associated agrarian societies, the tank is the most important asset as the tank provides numerous services in addition to supplying water for irrigation. They provide water for other purposes such as drinking, washing bathing, livestock and wildlife, helps maintaining groundwater and micro environment. In addition, tank fish has been the main source of protein for small tank associated communities. There are many more food items (Non-Timber Forest Products - NTFP) such as lotus root, seeds, *kekatiya* and other edible aquatic plants that they get from small tanks.



It is worth mentioning the conclusion of the manual on 'Development of Village Irrigation Works' by Arumugam (1957), then the Deputy Director of Irrigation about the small tanks and how they were important to the country. He stated "in the midst of large scale national agricultural development, the village cultivation still stands as the country's backbone and his [villager] village irrigation work is his priceless possession. To him it is the provider of all material needs for existence. The village irrigation works irrigates over 50% of Ceylon's irrigated paddy" (Arumugam, 1957). The rehabilitation or reconstruction of a minor tank is often beyond the capacity of poor communities inhabiting tank villages although, they fully recognize their importance for survival and for the improvement of their living conditions. In the recent decades, increasing uncertainties of rainfall and water availability associated with on-going climate changes have also further discouraged the farming communities from investing their meagre resources towards tank rehabilitation. It is in this context that both the governmental as well as several international agencies came forward to undertake minor irrigation tank rehabilitation during the last few decades (Plan Sri Lanka, 2012 & Aheeyar, 2013).


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As highlighted by Wijekoon, Gunawardena & Aheeyar (2016) based on the Department of Census and Statistics, village tank systems contributed to 26% of the 2014/15 *Maha* season paddy extent cultivated (203,836 ha out of total extent of 772,626ha of paddy) in Sri Lanka. Similarly, they reported that the village tanks contribution to 2015 *Yala* season was 25% covering 123,375ha out of total the 480,662ha paddy land cultivated. Wijekoon et al., (2016), further estimated that the minor irrigation systems represent 28% of 2014/15 total *Maha* season production and 24% of total *Yala* paddy production in 2015. It is noted that small tank related values capturing their environmental aspects were presented in the chapter two were at individual tanks level, cascade level such values are yet to be estimated.



The rice cultivation under the large/major tanks was promoted by the rulers of that period largely for the State income generation. These major tank constructions have taken place under the patronage of the rulers at the time. The smaller and medium size tanks were constructed by the village communities as well as by influential local chieftains and village leaders. These smaller scale hydro projects have served as centres for settlement and in seasons when adequate rains were received rice cultivation was possible (Panabokke, 2004).

It is also now being increasingly recognized that the use of water for several other essential purposes such as inland fisheries, livestock needs during the dry season, replenishment of groundwater conditions, domestic bathing needs and environment amelioration during the enhanced dry months from July - September should all collectively be assigned an economic and social value.

## 4.5 Social and Institutional Setting of STCS

Though the cascades have been explained in hydrological context, there is no literature available on existence of cascade level governance mechanism. As Madduma Bandara noted (1985, 2007), this may be due to the fact that the early management systems of small tanks buried in the historical past still remains poorly understood. However, it is well documented that the small tanks were owned and managed by local communities in pre-colonial era (Aheeyar, 2001 and Madduma Bandara, 2007). As Aheeyar further elaborated, the people performed the specific irrigation development and management tasks in ancient time through the feudal system of *Rajakariya* until that was abolished by the British rulers in 1832. Since then the functions of *Gamsabawa* (the Village Council) headed by *Gamarala* (Village Headman) became inactive and customary rules and regulations became malfunctioning related to management of small tanks by people. As institutions introduced in 1900 to manage small tanks community ownership and the role in management further distanced. Currently, the farmers are organised as Farmer Organisations (FO) at tank level and interacting with Department of Agrarian Development (DAD) in deciding on when, what and the extent to be cultivated in a given season through *Kanna* meeting (seasonal meeting). Witharana, 2001 argues that the best solution identified by the society to establish and regulate individual as well as group activities in village tanks systems were customs and traditions. He further commends *bethma*[31] as a classic example of traditional system existed in sharing of limited resources using equality principles, which he thought such equality principles may not have been present even in socialist countries. However, as Senaratne &

[31] *System practiced to share community owned resource – the tank water, in a water deficit season in an equitable manner relaxing private property rights of the land under cultivation. A part of the command area is cultivated based on water availability, by sharing it amongst farmers of the tank proportionate to their land holding in the command area. Begum, (1987).*

Wickramasinghe, (2011) highlighted, overtime people in small tanks lost the sense of ownership and increasingly trying to maximise individual or private benefits as against contributing to manage small tanks as common property.

During the pre-colonial era, the village irrigation systems were farmer managed systems with customary laws and traditions evolved over centuries. These systems were well managed under "*Rajakariya'* system. As highlighted by Aheeyar (2001) these management actions were governed by '*Gamsabawa*' (village council) headed by '*Gamarala*' (village headman). With the abolishment of Rajakariya system in 1832 by the British rulers, the customary regulations and traditions in managing the small tanks by the local community begun to collapse. The vacuum in the management created by the British rulers in maintaining small irrigation systems (Aheeyar, 2001) contributed to the degradation of STCS in Sri Lanka. Subsequent interventions by British rulers such as Paddy Lands Irrigation Ordinance No. 9 of 1856 introducing '*Velvidane*' (irrigation headman) in place of *Gamarala* and establishment of Irrigation Department in 1900 contributed more towards centralizing and introducing bureaucracy to once well community managed system. During the post-colonial era, the subject of managing small tanks changed hands between Irrigation Department and the Department of Agrarian Development, established in 1958 under the *Paddy Lands Act*. With this act *Velvidane* position was abolished and a *Govi Karaka Sabha* (farmer committee council) with a *Palaka Lekam* (administrative secretary) was appointed. With this, the mode of compulsory labour maintenance virtually collapsed, but in most places the voluntary *Velvidane* system was able to continue. After several misguided attempts, the Farmer Organization (FO) system came into operation in the late 1980s, and this has continued up to now with the FOs functioning with the help of the former *Velvidane* (Panbokke et al., 2002). Overtime, the institutional arrangements for small irrigation systems changed from community owned well managed small irrigation systems to a government institution led dual management system today with not clear community ownership.

As found in literature, the small tank cascades have evolved several millennia ago incorporating the principles of Integrated Water Resources Management (IWRM), and landscape approaches into planning and possibly in governance. Due to various historical and socio-cultural reasons, these systems were neglected over long period of time. Cascades were 're-discovered' as interconnected system of tanks by Madduma Bandara (1985), however, there are no records on governance of these systems. Hence, over time we have been managing individual tanks instead of cascade which, is only a part of a complex system. If these unique soil and water management systems based on hydrological and ecological principles for benefiting humans for thousands of more years, urgent attention to governing the cascades as systems is warranted.



### 4.6 Sustainable Management Issues of STCS

As highlighted in previous chapters, maintenance of small tank cascade systems has been neglected over a long period of time. One of the fundamental reasons for this is not knowing the ecosystem values relating to the STCS, this encourages people to disregard ecological components of the system to just productive components - tanks. This further aggravated when there is no governance mechanism in place today to take care of the entire cascade. Tanks are managed individually by Farmer Organisations devoid of their linkages between them and other ecological components.

As ecosystem goods and services are not provided and valued through the market system; they have no apparent monetary value reflected and



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has not been recognised by formal economic investment analysis tools nor informal political decision-making processes. This coupled with loss of social values towards seeing the STCS as a communal property, individuals try to maximize private benefits by engaging activities which are detrimental to sustaining STCS as a functional unit.

Also, the lack of understanding of cascade dynamics, *ad hoc* restoration of individual tanks (part of the system) without looking at a cascade as a functional system/unit also have given rise to negative results. Various poorly planned development activities such as catchment deforestation, and land alienation also disturb these systems. Poor understanding of the values that small tank cascades provide as a multipurpose system is argued as the main issue for not drawing attention of the policy makers on these systems. Therefore, the research problem and gaps in knowledge related to this research can be summarised as;



i. Not having comprehensive estimates of benefits related to STCS of Sri Lanka.

ii. Lack of recognition of STCS as an interconnected system in design, analysis and planning of small tank restoration in Sri Lanka.

iii. Poor adaptation to changing ecological, economic and social conditions.

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# CHAPTER FIVE

# DATA ANALYSES AND FINDINGS

## 5.1 Introduction

The previous chapter of the thesis dealt with the methodology covering the conceptual framework, the theoretical foundation, the econometric model, the research design, sample selection, an introduction to data collection methods and an introduction to data analysis. This chapter presents the details of data collection, data cleaning, data handling, data analyses and the results.

For better presentation, number of maps were prepared with GIS expert assistance. The main data sources for mapping were the land use map extracted from 1:10000 scale topographic data of survey department. Study area lies on topographic sheet numbers (2603, 2604, 2608, 2609, 26013 and 26014) and 1:5000 topographic sheet number 26 Medawachchiya. Land use area and percentage extent within each study catchment has been calculated using 'add geometry attribute' feature class tool of data management tool box using ArcGIS (Ver 10.31) software under 'UTM Zone 44 - Kandawala datum' spatial reference. In addition, IWMI's Malwathu Oya hydrology study data and DAD's cascade shape files were used in preparing specific detailed maps.



## 5.2 Data Processing and Handling for Analyses

The *Pihimbiyagollewa* survey (on-site survey) was completed first. The survey data were entered to Excel manually having a data entry format to match the data format needed for analysis with Stata statistical package. On-site survey data collection was completed in late September 2016, and review and preliminary data cleaning were completed subsequently. There were 516 surveys collected as completed, out of which 489 of them were finally qualified to be used in the next step. Similarly, *Pihimbiyagollewa* off-site data entry and cleaning were completed next where, out of 205 completed surveys, only 197 were qualified for the analysis. Both datasets were re-examined for possible data entry errors, and finally various summary statistics for the entered data were produced in order to correct any data entry errors previously not detected. Two datasets (on-site and off-site of *Pihimbiyagollewa* cascade) were then used for the statistical analysis as two separate samples.



There were three seemingly protest responses by respondents in the off-site sample, strategically responding either to the status quo or to one of the two cascade improvement options repeatedly disregarding the variability demonstrated in attribute levels of the choice sets served to the respondent. They were removed from the analysis together with incomplete responses in the collected questionnaires. Questionnaires used for analysis was therefore reduced to 489 for *Pihimbiyagollewa* on-site sample and 197 for *Pihimbiyagollewa* off-site sample.

Data entered in Excel as they were recorded in the survey questionnaires having observation per row containing all eight choice responses per respondent in one row. These were transposed using Stata 14 SE by expanding one observation (row) into 24[32] rows making each new row a choice response related to respondents. With the data transpose, 489 observations of the on-site data became 11,736 choices while in the off-site sample, the original 197 observations increased to 4,728 choices.

[32] *Each respondent faced 8 choice sets with each one having three alternatives (8x3=24).*

## 5.3 Analyses of Field Data

The statistical software package used for analyses was Stata 14 SE. As described under econometric methods above, Conditional Logit (CL) or Multinomial Logit Model (MNL) and Random Parameter Logit or Mixed Logit / Mixed Multinomial Logit (MMNL) models were used for analyzing data. With three alternatives in this experiment for restoration and sustainable management of cascades (A – *Status quo*, B and C are improvements to the *status quo*), the model considered for the analysis was multinomial logit model (having more than two alternatives to choose from). Socio-demographic characteristics of the two samples were provided on tables 5.1 and 5.2.



***Table 5.1: Socio-demographic Characteristics of the on-site Cascade Sample***

| Characteristic | Subdivision | Count | Percentage |
|---|---|---|---|
| Age (n=501) | 0-19 | 6 | 1.2 |
| | 20-34 | 85 | 16.9 |
| | 35-49 | 172 | 34.2 |
| | 50-64 | 178 | 35.4 |
| | 65-79 | 57 | 11.3 |
| | 80 and over | 5 | 1.0 |
| Gender (n = 501) | Male | 206 | 41.1 |
| | Female | 295 | 58.9 |
| Education (n= 499) | No formal education | 17 | 3.4 |
| | Primary education | 112 | 22.4 |
| | Secondary education | 361 | 72.3 |
| | Tertiary education | 8 | 1.8 |
| Income (n=495) | Less than LKR 10,000 | 86 | 17.4 |
| | LKR 10,001 - 20,000 | 123 | 24.9 |
| | LKR 20,001 - 50,000 | 200 | 40.4 |
| | LKR 50,001 - 100,000 | 75 | 15.2 |
| | LKR 100,001 - 150,000 | 9 | 1.8 |
| | LKR 150,001 - 200,000 | 2 | 0.4 |
| | More than LKR 200,000 | 0 | 0.0 |

Source: STCS Survey Data, 2016



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*Table 5.2: Socio-demographic Characteristics of the off-site Sample*

| Characteristic | Subdivision | Count | Percentage |
|---|---|---|---|
| Age (n=202) | 0-19 | 1 | 0.5 |
| | 20-34 | 44 | 21.8 |
| | 35-49 | 56 | 27.7 |
| | 50-64 | 63 | 31.2 |
| | 65-79 | 32 | 15.8 |
| | 80 and over | 6 | 3.0 |
| Gender (n = 202) | Male | 102 | 50.5 |
| | Female | 100 | 49.5 |
| Education (n= 202) | No formal education | 1 | 0.5 |
| | Primary education | 14 | 6.9 |
| | Secondary education | 91 | 45.1 |
| | Tertiary education | 96 | 47.5 |
| Income (n=198) | Less than LKR 10,000 | 2 | 1.0 |
| | LKR 10,000 - 20,000 | 11 | 5.6 |
| | LKR 20,001 - 50,000 | 79 | 39.9 |
| | LKR 50,001 - 100,000 | 61 | 30.8 |
| | LKR 100,001 - 150,000 | 33 | 16.7 |
| | LKR 150,001 - 200,000 | 3 | 1.5 |
| | More than LKR 200,000 | 9 | 4.6 |

Source: STCS Survey Data, 2016



### 5.3.1 Conditional Logit Model

Conditional Logit Model (McFadden, 1974; Greene, 2012) assumes that the observable utility function would follow strictly additive form (Birol, Karousakis, & Koundouri, 2006). The model was specified so that the probability of selecting a particular cascade restoration and management scenario was a function of attributes of that scenario and of the Alternative Specific Constant (ASC), which was specified as 1 when either management scenario B or C was selected, and as 0 when 'neither management scenario option was selected. Conditional Logit Model was used to analyze the 11,736 choices elicited from 489 *Pihimbiyagollewa* on-site respondents and 4,728 choices elicited from 197 *Pihimbiyagollewa* off-site respondents.

The Conditional Logit Model assumes the Independence of Irrelevant Alternative (IIA) property, which states that the relative probability of the two options being chosen are unaffected by the introduction or removal of the other alternative. If the IIA property is violated, then the Conditional Logit will be biased and hence, a discrete choice model that does not require IIA property such as Random Parameter Logit (RPL) model should be used instead.

### 5.3.2 Random Parameter Logit Model

As explained in the previous paragraph, by relaxing IIA property, a model such as Random Parameter Logit / Mixed Multinomial Logit can be used. In addition to IIA, one other limiting assumption that CL assumes is that the homogeneous preference across respondents which usually does not hold. Therefore, in RPL model both IIA and the preference homogeneity are relaxed. As per Greene, (1997), accounting for IIA and preference heterogeneity enables RPL to produce unbiased estimates of individual preferences of demand, participation, marginal, and total welfare. Furthermore, accounting for heterogeneity enables prescription of policies that take equity concerns into account. An understanding of who will be affected by a policy change in addition to understanding the aggregate economic value associated with such change is necessary (Boxall and Adamowicz, 2002). The random parameter logit model (Train, 1998), which accounts for unobserved, unconditional heterogeneity, should be used in order to account for the preference heterogeneity in a pure public good (Konotoleon, 2003).

Applications of the RPL model has shown that this model is superior to the CL model in terms of overall fit and the welfare estimates (Konotoleon, 2003; Morey and Rossmann, 2003). However, as Lancsar, Fiebig & Hole (2017) highlighted, in choice modeling, it is natural to start with classical multinomial logit model, but it is linked to a random utility model established by McFadden (1974). Hence, Conditional Logit Model too was estimated in this research prior to estimating Random Parameter Logit Model..

Estimation equations used are provided below;



1. For Conditional Logit

$$U_j = \sum_{k=1}^{K} \beta_k x_{kj} + \beta_p p_j + \varepsilon_j$$

Homogeneous utility for alternative j with k attributes

The marginal value of attribute k is the ratio between the parameter $\beta_k$ and $\beta_p$

$$MWTP_k = -\frac{\beta_k}{\beta_p}$$

2. For Mixed Multinomial Logit

$$U_j^i = \sum_{k=1}^{K} \beta_{ki} x_{kj} + \beta_{pi} p_{ij} + \varepsilon_{ij}$$

Utility for individual *q* choosing alternative *j* with *k* attributes

Models preference heterogeneity; deals well with repeated choices

### 5.3.3 Random Parameter Logit Model with Interactions

Even if unobserved heterogeneity can be accounted for in the RPL model, the model fails to explain the sources of heterogeneity (Boxall and Adamowicz, 2002). One solution to detect the sources of heterogeneity while accounting for unobserved heterogeneity is by including interactions of respondent specific social, economic and attitudinal characteristics with choice specific attributes and/or with ASC in the utility function. This enables the RPL model to pick up the preference variation in terms of both unconditional taste heterogeneity (random heterogeneity), and individual characteristics (conditional heterogeneity), and hence it improves the model fit (e.g., Revelt & Train, 1998; Kontoleon, 2003). However, the interactions tested for model attributes with selected socioeconomic characters (education level and income level) were non-convergent in both on-site and off-site RPL models, hence failed to estimate a RPL model with interactions leaving RPL main effects model as the best model.



### 5.3.4 Different Strata for Analysis

The two types of samples used for data collection in the survey were *Pihimbiyagollewa* on-site and *Pihimbiyagollewa* off-site. The on-site survey in *Pihimbiyagollewa* was conducted in August/September 2016. The surveys were of two types, one was with payment attribute in cash and the other was with labour as the payment attribute. In addition, the introduction of survey was done in two different ways; for approximately 50% of the sample surveyed (both cash and labour) the introduction was done in a group of 10 respondents and then they were individually surveyed by 10 enumerators The other way was the introduction was done individually at the upfront of the survey by the enumerator before beginning the survey. Considering all variations of the survey, the surveys were administered as face-to-face individual surveys. Therefore, the *Pihimbiyagollewa* on-site sample has following categories depending on the combination of payment modality and the survey introduction they faced.

i. Individual Cash (IC)
ii. Individual Labour (IL)
iii. Group Cash (GC)
iv. Group Labour (GL)

Further, in analysis, there were two additional sub categories created as below to assess the responses per payment attribute irrespective of the way the survey was introduced.



v. Cash combine, covering individual and group (I+GC)
vi. Labour combine, covering individual and group (I+GL)

In the off-site sample, all the surveys were conducted as individual cash surveys.

In survey administering, each block of choice sets (out of nine sets each for cash and labour for on-site sample and nine sets of cash choices for off-site sample) were used equally. This was done by the enumerators beginning with different choice sets and continuing in an orderly manner thereafter, with close supervision of the survey coordinator who maintained a survey register / survey log.

### 5.3.5 Benefit Cost Analysis

Costs were approximated from a recently completed cascade restoration project of a similar cascade (*Kapiriggama* cascade) which shares a boundary with the *Pihimbiyagollewa* cascade having many similarities as mentioned in the previous chapter.

Direct financial costs, labour contribution and agency contribution provided by DAD for restoration were included in the total costs of restoration. As observed in the project, the restoration costs were spread over a period of three and a half years. The experience from the *Kapiriggama* project has been used as it is for the recipient site (*Pihimbiyagollewa*) cost stream. The total cost of the restored project was assumed to have met only 70% of the full restoration based on consultations with Project Manager of the *Kapiriggama* restoration project. Hence costs used for *Pihimbiyagollewa* was 100/70 times of the *Kapiriggama* cascade restoration costs to account for a full restoration.

Annual Operation and Maintenance (O&M) cost of the cascade to keep its high level of performance was assumed to be 5% of the total restoration cost. Periodic Maintenance cost was assumed as 20% of the total restoration cost to be invested in every five years. Cost estimates used in the BCA is provided in Table 5.3.

***Table 5.3: Cost Estimates for Pihimbiyagollewa Cascade Restoration***

| **Kapiriggama costing summary in LKR** | **Yr 1** | **Yr 2** | **Yr 3** | **Yr 4** | **Total** |
|---|---|---|---|---|---|
| Annual totals cash | 11,721,881 | 22,344,282 | 35,553,062 | 5,384,937 | 75,004,161 |
| Labour contribution | 774,208 | 1,548,416 | 2,064,555 | 774,208 | 5,161,387 |
| DAD contribution | 1,172,188 | 2,234,428 | 3,555,306 | 538,494 | 7,500,416 |
| Total cost (70% restoration) | 13,668,277 | 26,127,126 | 41,172,922 | 6,697,639 | 87,665,964 |
| Full restoration cost | 19,526,109 | 37,324,466 | 58,818,461 | 9,568,055 | 125,237,091 |
| O&M annual (5% of the full cost) | | 6,261,855 | | | |
| Periodic maintenance every 5 yr (20% of the full cost) | | | | 25,047,418 | |

Source: IUCN, 2016; Assumptions made for the research



It is assumed that the restoration will bring additional 100ha to be cultivated with paddy/year. They will gradually be available after completion of the project in 3.5 years, the cascade will begin to give full benefits on extended cultivation fully on the 6$^{th}$ year onwards (25%, 50% and 75% of 100ha will come in 4$^{th}$ to 6$^{th}$ year. There after the full extent will be available). Average yield for the cascade is assumed at 4,000kg/ha. Price for paddy is assumed to be LKR 40/kg.

In conventional BCA, just the incremental paddy yield was taken as the benefit. As there are no clear demarcation for some of the benefits that the cascade produces, just the on-site sample estimates were used in the Extended Benefit Cost Analysis (EBCA). In EBCA benefits were taking from the finding of the CE estimates for cash combine sample (Individual and group) of the on-site sample. As we are interested on the incremental benefits in the BCA (applying with and without scenario in project analysis) value for ASC was not taken in as benefit. Which gives *status quo* benefits of the cascade. However, the ASC was used previously in estimating the TEV of the cascade as it relates to the total benefits of the restored cascade.

Economic discount rate of 8% was used in analyses. Shadow pricing and other aspects of economic analysis were not attempted due to the aggregate nature of the cost data used (see Annex 7 for details).

## 5.4 Findings

Summary findings are presented in tables 5.4 to 5.13 covering on-site cash, on-site labour and off-site (cash only) sample respectively. Each table provides the model estimates for a given category of sample with attribute coefficient estimates, the level of significance, standard errors related to estimates, sample size, log likelihood estimates, chi-square value and the pseudo $R^2$ where appropriate. Marginal willingness to pay estimates for attributes under each model is given in the next table for the given category of the sample.

***Table 5.4: Estimates of Pihimbiyagollewa on-site Individual Cash Survey***

| | (1) | (2) |
|---|---:|---:|
| | CLogit IC | MMNL IC |
| Mean | | |
| ASC | 0.987*** | 3.865*** |
| | (4.22) | (5.80) |
| Water for Paddy | 2.726*** | 5.545*** |
| | (7.44) | (5.84) |
| Water for Other uses | 0.323*** | 0.547*** |
| | (6.59) | (4.92) |
| Cascade Ecological components | 0.102 | 0.106 |
| | (0.52) | (0.32) |
| Cascade Biodiversity | 0.0324 | 0.0578* |
| | (1.90) | (2.01) |
| Contribution | -0.0000987*** | -0.000205*** |
| | (-5.70) | (-4.77) |
| SD | | |
| ASC | | -2.791*** |
| | | (-6.28) |
| Water for Paddy | | 5.399** |
| | | (4.87) |
| Water for Other uses | | -0.710*** |
| | | (-5.62) |
| Cascade Ecological Components | | 0.944 |
| | | (1.19) |
| Cascade Biodiversity | | 0.0408 |
| | | (0.95) |
| Contribution | | 0.000288*** |
| | | (6.22) |
| N | 2,016 | 2,016 |
| Log likelihood | -494.58 | -393.61 |
| Chi-square | 487.37 | 201.93 |
| Pseudo $R^2$ | 0.3301 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

***Table 5.5: Estimates of Pihimbiyagollewa on-site Group Cash Survey***

| | (3) | (4) |
|---|---|---|
| | CLogit GC | MMNL GC |
| Mean | | |
| ASC | 1.807*** | 4.186*** |
| | (6.55) | (5.60) |
| Water for Paddy | 2.823*** | 4.883*** |
| | (8.00) | (6.07) |
| Water for Other uses | 0.243*** | 0.525*** |
| | (5.00) | (4.68) |
| Cascade Ecological components | 0.406* | 0.520 |
| | (2.15) | (1.48) |
| Cascade Biodiversity | 0.0748*** | 0.130*** |
| | (4.56) | (3.95) |
| Contribution | -0.000107*** | -0.000211*** |
| | (-6.42) | (-4.89) |
| SD | | |
| ASC | | -1,690** |
| | | (-2.99) |
| Water for Paddy | | -4.202*** |
| | | (-3.69) |
| Water for Other uses | | 0.677*** |
| | | (5.50) |
| Cascade Ecological Components | | -1,898** |
| | | (-3.08) |
| Cascade Biodiversity | | 0.188*** |
| | | (3.39) |
| Contribution | | 0.000302*** |
| | | (5.13) |
| N | 2,268 | 2,268 |
| Log likelihood | -486.51 | -427.62 |
| Chi-square | 688/07 | 117.78 |
| Pseudo $R^2$ | 0.4142 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016





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***Table 5.6: Estimates of Pihimbiyagollewa on-site Combined Cash Survey***

| | (5) | (6) |
|---|---|---|
| | CLogit I+GC | MMNL I+GC |
| Mean | | |
| ASC | 1.342*** | 5.942*** |
| | (7.66) | (4.05) |
| Water for Paddy | 2.754*** | 4.872*** |
| | (10.90) | (8.60) |
| Water for Other uses | 0.279*** | 0.521*** |
| | (8.13) | (6.86) |
| Cascade Ecological components | 0.270* | 0.377 |
| | (2.00) | (1.73) |
| Cascade Biodiversity | 0.0549*** | 0.0936*** |
| | (4.69) | (4.61) |
| Contribution | -0.000104*** | -0.000191*** |
| | (-8.69) | (6.71) |
| SD | | |
| ASC | | -4.556*** |
| | | (-5.26) |
| Water for Paddy | | -4.024*** |
| | | (-5.96) |
| Water for Other uses | | 0.585*** |
| | | (5.68) |
| Cascade Ecological Components | | -1.042** |
| | | (-2.68) |
| Cascade Biodiversity | | -0.0966** |
| | | (-2.68) |
| Contribution | | -0.000240*** |
| | | (-6.24) |
| N | 4,284 | 4,284 |
| Log likelihood | -898.77 | -825.14 |
| Chi-square | 1,158.09 | 329.27 |
| Pseudo $R^2$ | 0.3691 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

***Table 5.7: MWTP of Pihimbiyagollewa on-site Cash Sample***

| | MWTP in LKR/season/family | | | | | |
|---|---|---|---|---|---|---|
| Attribute | CLogit IC | MMNL IC | CLogit GC | MMNL GC | CLogit I+GC | CLogit I+GC |
| ASC | 10,000 | 18,853 | 16,887 | 19,838 | 12,903 | 31,109 |
| Water for Paddy | 27,619 | 27,048 | 26,383 | 23,142 | 26,480 | 25,507 |
| Water for other uses | 19,635 | 16,009 | 13,626 | 14,928 | 16,096 | 16,366 |
| Cascade Ecological components | 1,033 | 517 | 3,794 | 2,464 | 2,596 | 1,973 |
| Cascade Biodiversity | 3,939 | 3,383 | 8,388 | 7,393 | 6,334 | 5,880 |

Source: STCS Survey Results, 2016

Note – 1.Parameter estimates of the Attributes related to shaded MWTP figures were not significant at 10%
Abbreviations are explained at the end of the table 4.8.

Note – 2. MWTP figures estimated are per unit of defined attribute levels, for paddy and ecology the defined units were full extent. Whereas for other uses and biodiversity units were months and bird groups respectively. Therefore, the marginal values generated were for per month and per bird group. Therefore, they were adjusted to get full six-month (seasonal) levels by multiplying these two MWTP by 6 and 12 respectively.

***Table 5.8: Estimates of Pihimbiyagollewa on-site Survey Individual Labour Respondents***

| | (1) | (2) |
|---|---|---|
| | CLogit IL | MMNL IL |
| Mean | | |
| ASC | 0.931** | 2.802** |
| | (2.85) | (2.69) |
| Water for Paddy | 1.838*** | 3.344*** |
| | (4.51) | (4.31) |
| Water for Other uses | 0.335*** | 0.459*** |
| | (5.64) | (4.79) |
| Cascade Ecological components | 0.883*** | 1.119*** |
| | (3.85) | (3.52) |
| Cascade Biodiversity | 0.0915*** | 0.0972*** |
| | (4.63) | (3.44) |
| Contribution | -0.0606** | -0.0795** |
| | (-3.03) | (-2.83) |
| SD | | |
| ASC | | 2.211* |
| | | (2.40) |
| Water for Paddy | | 3.729*** |
| | | (3.96) |
| Water for Other uses | | 0.365** |
| | | (2.70) |
| Cascade Ecological Components | | -0.772 |
| | | (-1.23) |
| Cascade Biodiversity | | -0.0803 |
| | | (-1.48) |
| Contribution | | 0.102 |
| | | (1.74) |
| N | 1,494 | 1,494 |
| Log likelihood | -330.85 | -307.78 |
| Chi-square | 416.50 | 62.15 |
| Pseudo $R^2$ | 0.3806 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

***Table 5.9: Estimates of Pihimbiyagollewa on-site Survey Group Labour Respondents***

| | (3) | (4) |
|---|---|---|
| | CLogit GL | MMNL GL |
| Mean | | |
| ASC | 1.855*** | 4.075*** |
| | (5.68) | (3.67) |
| Water for Paddy | 2.404*** | 4.398*** |
| | (8.16) | (6.29) |
| Water for Other uses | 0.357*** | 0.658*** |
| | (8.87) | (7.24) |
| Cascade Ecological components | 0.262 | 0.486 |
| | (1.63) | (1.93) |
| Cascade Biodiversity | 0.0538*** | 0.0671** |
| | (3.98) | (2.91) |
| Contribution | 0.00788 | 0.0130 |
| | (0.56) | (0.62) |
| SD | | |
| ASC | | -2.644** |
| | | (-2.86) |
| Water for Paddy | | -4.936*** |
| | | (-5.69) |
| Water for Other uses | | 0.555*** |
| | | (5.78) |
| Cascade Ecological Components | | -1.270** |
| | | (-2.79) |
| Cascade Biodiversity | | 0.136*** |
| | | (3.41) |
| Contribution | | -0.0723 |
| | | (-1.43) |
| N | 3,024 | 3,024 |
| Log likelihood | -595.28 | -537.79 |
| Chi-square | 1,024.22 | 114.98 |
| Pseudo $R^2$ | 0.4624 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

***Table 5.10: Estimates of Pihimbiyagollewa on-site Survey Combined Respondents***

| | (5) | (6) |
|---|---|---|
| | CLogit I+GL | MMNL I+GL |
| Mean | | |
| ASC | 1.432*** | 3.065*** |
| | (6.44) | (4.97) |
| Water for Paddy | 2.206*** | 4.069*** |
| | (9.31) | (7.63) |
| Water for Other uses | 0.340*** | 0.555*** |
| | (10.33) | (8.93) |
| Cascade Ecological components | 0.497*** | 0.732*** |
| | (3.81) | (3.62) |
| Cascade Biodiversity | 0.0642*** | 0.0767*** |
| | (5.82) | (4.38) |
| Contribution | -0.0171 | -0.0249 |
| | (-1.51) | (-1.50) |
| SD | | |
| ASC | | 2.079*** |
| | | (4.10) |
| Water for Paddy | | 5.197*** |
| | | (7.61) |
| Water for Other uses | | 0.474*** |
| | | (6.74) |
| Cascade Ecological Components | | -1.326*** |
| | | (-3.47) |
| Cascade Biodiversity | | 0.105** |
| | | (3.08) |
| Contribution | | 0.0726* |
| | | (2.20) |
| N | 4,500 | 4,500 |
| Log likelihood | -944.58 | -849.96 |
| Chi-square | 1,406.67 | 189.23 |
| Pseudo $R^2$ | 0.4268 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

***Table 5.11: MWTP of Pihimbiyagollewa on-site Labour Sample***

| | MWTP in Labour days/season/household | |
|---|---|---|
| Attribute | CLogit IL | MMNL IL |
| ASC | 12 | 46 |
| Water for Paddy | 30 | 55 |
| Water for other uses | 33 | 45 |
| Cascade Ecological components | 14 | 18 |
| Cascade Biodiversity | 18 | 19 |

Source: STCS Survey Results, 2016

Note. 3. MWTP calculated only for Individual Labour sample as contribution attribute was not statistically significant in both Group and combined (I+G) labour samples.

***Table 5.12: Estimates of Pihimbiyagollewa off-site Survey*[33]**

| | (1) | (2) |
|---|---|---|
| | CLogit UC | MMNL UC |
| Mean | | |
| ASC | 0.730*** | 4.075*** |
| | (4.05) | (6.38) |
| Paddy_lvl | 0.750** | 2.215*** |
| | (2.89) | (3.58) |
| Otheruse_lvl | 0.368*** | 0.805*** |
| | (9.61) | (7.55) |
| Ecology_lvl | 0.623*** | 1.076** |
| | (4.34) | (3.24) |
| Biodiversity_lvl | 0.101*** | 0.200*** |
| | (7.83) | (5.96) |
| Contribute_lvl | -0.0000978*** | -0.000269*** |
| | (-7.74) | (-5.91) |
| SD | | |
| ASC | | 2.113*** |
| | | (4.62) |
| Water for Paddy | | 3.742*** |
| | | (4.17) |
| Water for Other uses | | -0.677*** |
| | | (-5.38) |
| Cascade Ecological Components | | 2.325*** |
| | | (4.25) |
| Cascade Biodiversity | | 0.243*** |
| | | (5.17) |
| Contribute_lvl | | 0.000542*** |
| | | (7.48) |
| *N* | 3,546 | 3,546 |
| Log likelihood | -914.29 | -710.31 |
| Chi-square | 768.52 | 407.96 |
| Pseudo $R^2$ | 0.2959 | - |

Standard errors are in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: STCS Survey Results, 2016

[33] In off-site survey, all surveys were conducted as individual cash surveys

***Table 5.13: MWTP in Pihimbiyagollewa off-site Sample (Cash)***

| Attributes | MWTP in Rs/season/household | |
|---|---|---|
| | Clogit | MMNL |
| ASC | 7,464 | 15,148 |
| Water for Paddy | 7,668 | 8,234 |
| Water for other uses | 22,576 | 17,955 |
| Cascade Ecological components | 6,370 | 4,000 |
| Cascade Biodiversity | 12,392 | 8,921 |

Source: STCS Survey Results, 2016

Annex 6 gives some demographic features of the two samples in graphical form.

***Abbreviations***

CL Results from Conditional Logit Model
MMNL Results from Mixed Multinomial Logit Model (or Random Parameter Model – RPL) with main effects
I Responses from those respondents to whom the survey was introduced individually
G Responses from those respondents to whom the survey was introduced in groups
I+G Inclusion of both categories of survey introduction - individually and as groups (covers full sample in labour or cash)
C Include only the surveys conducted for in cash contribution
L Include only the surveys conducted for in labour contribution
IC Individually explained surveys with contribution attribute in cash
GC Group wise explained surveys with contribution attribute in cash
IL Individually explained surveys with labour contribution attribute
GL Group wise explained surveys with labour contribution attribute

***Attributes***

1. Availability of irrigation water for cultivating paddy during the dry season (Yala) in the cascade
2. Availability of water for other purposes in the cascade during the dry season
3. Extent of unique cascade ecological components in the cascade (during Yala)
4. Cascade biodiversity (presence of representative groups of birds in cascade during Yala)
5. Contribution to restoration and management of cascade (C – by cash, L – by labour)

Conventional BCA and EBCA estimates for restoration and sustainable management of *Pihimbiyagollewa* cascade is given in Tables 5.14 and 5.15.

***Table 5.14: Estimates of Conventional BCA of Cascade Restoration***

| | |
|---|---|
| BC Ratio | 0.60 |
| Net Present Value (NPV) in LKR | (56,618,945) |
| Internal Rate of Return (IRR) | -2.01% |

Source: STCS Survey Results, 2016

***Table 5.15: Estimates of the EBCA for STCS Restoration***

| Sensitivity Analysis for the *Pihimbiyagollewa* cascade EBCA (values in LKR) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Base Case | | | Costs Increased by 40% | | | Benefits Decreased by 40% | | | Costs increased by 40% & Benefits Decrease 40% | | |
| | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV |
| Paddy Benefits | 2.24 | 24% | 204,920,854 | 1.60 | 15% | 139,044,834 | 1.35 | 11% | 57,076,493 | 0.9% | 3% | (8,799,527) |
| Non-irrigation Benefits of water | 1.44 | 13% | 72,462,577 | 1.03 | 5% | 6,586,558 | 0.86 | 1% | (22,398,473) | 0.62 | -10% | (88,274,493) |
| Total Restoration Benefits | 3.43 | 41% | 400,802,244 | 2.45 | 30% | 334,926,225 | 2.06 | 25% | 174,605,327 | 1.47 | 17% | 108,729,307 |

Source: STCS Survey Results, 2016

### 5.4.1 Findings of *Pihimbiyagollewa* on-site Cash Sample

Conditional Logit and Random Parameter Logit model results for the on-site cash sample is given in Table 4.3. In all models related to the on-site cash sample, the coefficients for paddy level and other uses level attributes were positive and statistically significant at 1% alpha level. The biodiversity attribute was statistically significant in on-site group cash and combine models at 1% alpha level, while on-site individual cash RPL model was statistically significant at 5% alpha level. The same was not statistically significant on-site individual CL model. The ecology level, the other cascade restoration and management attribute considered was statistically significant only in two models (CL group and CL combine sample) of *Pihimbiyagollewa* on-site survey. All the cascade restoration and management related attributes were having positives coefficients (even the ones which are insignificant at 10% alpha level or less), indicates the higher the levels of any single attribute will increase the probability of the selected management scenario. In other words, respondents prefer those cascade restoration and management scenarios, which resulted in higher level of paddy cultivation, other uses, biodiversity and ecosystem levels. The payment coefficient was negative as expected, indicating that the effect on utility of opting for a choice set with a higher payment level is negative.

When payment attribute is used as the normalising variable, the paddy level stands out as the most important attribute for choosing cascade restoration and management option for the respondents in *Pihimbiyagollewa* on-site cash sample followed by other uses, biodiversity and ecology. The positive sign and the statistical significance of the ASC coefficient implies that the utility is higher for the improved alternatives over the *status quo* (Alternative A).

### 5.4.2 Findings of *Pihimbiyagollewa* on-site Labour Sample

Conditional Logit and Random Parameter Logit model results for on-site labour sample is given in Table 4.5. Labour contribution attribute became statistically insignificant at 10% alpha level or less in all models with group explanations related to on-site labour sample. Therefore, only the individual cash surveys were used in the results. Cascade restoration and management related attribute coefficients for paddy level, other uses level, ecology and biodiversity were positive and statistically significant at 1% alpha level. All the cascade restoration and management related attributes were having positive coefficients, indicating the higher the levels of any single attribute will increase the probability of the selected management scenario. In other words, respondents preferred those cascade restoration and management scenarios, which result in a higher level of paddy cultivation, other uses, biodiversity and ecosystem levels. The payment coefficient was negative as expected, indicating the effect on utility of opting for a choice set with a higher payment level is negative.

When payment attribute is used as the normalising variable, the paddy level stands out as the most important attribute for choosing cascade restoration and management option for the respondents in on-site cash sample followed by other uses, ecology and biodiversity. The positive sign and statistical significance on the ASC coefficient imply that the utility is higher for the improved alternatives over the *status quo* (Alternative A).

### 5.4.3 Findings of Pihimbiyagollewa off-site Sample

Conditional Logit and Random Parameter Logit model results for off-site sample (all were cash and individually explained surveys) is given in Table 4.7. In both models related to off-site sample, the coefficients of all cascade restoration and management attributes were positive and statistically




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significant at either 1% or 5% alpha level. All the cascade restoration and management related attributes were having positives coefficients, indicating the higher the level of any single attribute will increase the probability of the selected management scenario. In other words, respondents preferred those cascade restorations and management scenarios, which resulted in a higher level of paddy cultivation, other uses, biodiversity and ecosystem levels. The sign of the payment coefficient was negative as expected, indicating that the effect on utility of opting for a choice set with a higher payment level is negative.

When payment attribute is used as the normalising variable, the paddy level stands out as the most important attribute for choosing cascade restoration and management option for the respondents in off-site cash sample followed by ecology, other uses and biodiversity. The positive sign and the statistical significance on the ASC coefficient imply that the utility is higher for the improved alternatives over the *status quo* (Alternative A).



### 5.4.4 Post-estimation Analysis

When dealing with revealed preference data, a constant threat is omitted variable biases. This means the effects of interest may be very sensitive to the variables not included in the model. However, in stated preference data this threat is minimal. Especially in Choice Experiment survey, where the effects of interest are typically associated with the attributes that are created as part of the experimental design. These designs are done in a way that there is no correlation between attributes and no reason to believe they will be correlated with respondent characteristics (Lancsar et al., 2017).

The Conditional Logit Model assumes the Independence of Irrelevant Alternatives (IIA) property, which states that the relative probability of the two options being chosen are unaffected by the introduction or removal of the other alternative. Hausman specification test was performed to assess whether the IIA property is violated. As the test proves that the IIA property doesn't hold for the given data set, the Conditional Logit model is determined to be biased and hence, the discrete choice model that does not require IIA property – the Random Parameter Logit (RPL) model has been selected as the suitable model for estimating WTP. Akaike Information Criterion (AIC) and Baysian Information Criterion (BIC) were also used to discriminate between alternative models used in the analysis. As Conditional Logit Models were ruled out for not holding the IIA property AIC and BIC also reconfirmed the RPL models as the best models for all sample strata used.

## 5.5 Estimation of Willingness to Pay

The Choice Experiment method is consistent with utility maximisation and demand theory (Bateman et al., 2002). When the parameter estimates are obtained from the appropriate model, welfare measures, in the form of marginal willingness to pay, can be determined by estimating the marginal rate of substitution between the change in the cascade restoration and management attribute in question and marginal utility of income represented by the coefficient of the payment attribute.

### 5.5.1 Willingness to pay in *Pihimbiyagollewa* on-site Cash Sample



The Marginal Willingness to Pay or implicit prices for all selected attributes of cascade restoration and sustainable management in on-site cash survey (Table 4.4) were calculated using Wald procedure (delta method), dividing respective attribute coefficients by payment coefficient in all the models. In models where attributes were not statistically significant, respective MWTP figures were shaded in Table 4.4. Results showed that the highest MWTP per unit change in the attribute level was highest for paddy in the on-site cash sample, followed by other use, biodiversity and ecology. This order was consistent in over the six combinations of the two models considered.

### 5.5.2 Willingness to Pay in *Pihimbiyagollewa* on-site Labour Sample

The Marginal Willingness to Pay or implicit prices for all selected attributes of cascade restoration and sustainable management in on-site labour survey sample (Table 4.6) was calculated using Wald procedure (delta method), dividing respective attribute coefficients by payment coefficient in all the models. In models where payment attributes were not statistically significant no MWTP were calculated. Therefore, only CL and RPL models were relevant to individual labour samples of the on-site survey. The results showed that the highest MWTP in Conditional Logit model was for the other uses while paddy became the second in MMNL model. Per unit change in the attribute level was highest for paddy in the on-site labour individual sample, followed by the other uses. In both models biodiversity and ecology were the next highest levels respectively. In this sample first and second highest MWTP were inconsistent in the two models but the last two followed the same pattern.

### 5.5.3 Willingness to Pay in Pihimbiyagollewa off-site Sample

The Marginal Willingness to Pay or implicit prices for all selected attributes of cascade restoration and sustainable management in off-site survey (all individual cash surveys, Table 4.8) were calculated using Wald procedure (delta method), dividing respective attribute coefficients by payment coefficient in all the models. Results showed that the highest MWTP per unit change in the attribute level was for the other uses in the off-site cash sample, followed by paddy, biodiversity and ecology. This order was consistent in both models considered for the off-site sample.



The next chapter provides the interpretation of results, post estimation statistics, discussion on findings, conclusions reached with some policy implications related to findings of the study in restoration and sustainable management of small tank clusters in the Dry Zone of Sri Lanka.

# CHAPTER SIX

# SUMMARY AND CONCLUSION

This research is on assessing total economic value of a representative small tank cascade system in Anuradhapura district within *Malwathu oya* river basin. The rationale for the research was to find economic solution to the degradation of STCS in Sri Lanka. Despite their multiple benefits to local community, sustained over millennia, these time-tested traditional irrigation systems are fast degrading. The major reasons for accelerated degradation were lack of local level management and insufficient investment on STCS for restoration and maintenance. In a resource constrained environment, such investments are rarely justified as the market-based returns (benefits) are much less than the associated investment.

This chapter begins with a reflection of materials brought out in chapters one to four of the thesis by way of a summary. Then it brings out an assessment of delivering the stated objectives of the thesis. The next is the conclusions reached, followed by the recommendations based on the research with a few policy relevant suggestions for the restoration and sustainable management of small tank cascade systems in Sri Lanka to conclude the chapter.

## 6.1 Introduction

STCS in Sri Lanka can be considered as part of our ancient irrigation heritage. STCS believed to have developed around a couple of millennia ago by our forefathers. In doing so they adhered to a landscape scale spatial planning in addressing socioeconomic needs while integrating ecological considerations within them. These magnificent systems designed to address the needs at the time of their inventions, may have contributed immensely to the civilisation in the Dry Zone of Sri Lanka which was based on rain water harvesting as compared to river basin based civilisations known elsewhere. One of the unique features in these time-tested socio-ecological systems is that this ecosystem's based design is still capable of addressing the social-economic and environmental challenges of the 21st century. One such benefit is their ability to adapt to the climate change associated impacts in the Dry Zone of Sri Lanka, provided the STCS are properly restored and sustainably managed. STCS are also known for harbouring critical Dry Zone biodiversity of Sri Lanka in its ecological components.



Therefore, there is a strong justification to investigate into the feasibility of conserving STCS as a sustainable water infrastructure for the current as well as for the future use. However, it was revealed that STCS are fast degrading despite above mentioned significance to the local community as well as to the country. According to literature consulted as well as experts revealed, there are numerous direct and indirect benefits generates to the people living within those cascades and those who are living outside the cascades. However, only a fraction of those values are reflected in market transactions. These are mostly seen in direct commercial values of few goods and services of STCS. These are minute in compared to the plethora of goods and services produced by them in terms of their total economic value. Hence, those are not reflected in the market-based valuation of STCS as benefits to give economic rationale for STCS restoration and sustainable management investments. This has led to non-optimal investment into STCS restoration in recent times leading to their continuous degradation. Photo catalogue related to research is provided at Annex 8.

Investigating into the aspects mentioned above has been the main area of interest of this thesis and they were investigated under the three specific research questions listed below:

1. How much the small tank cascade dependant on-site communities and distant off-site communities are willing to pay for restoration and sustainable management of a selected small tank cascade system, in the *Malwathu Oya* basin?

2. What is the marginal willingness to pay by these communities for different attributes of the cascade being studied?

3. Whether and how the elicited values can be objectively used in better decision-making in relation to restoration and sustainable management of small tank cascades in Sri Lanka?



In addition to the above three main research questions, two methodological research questions were also addressed in this research as sub research questions. They are;

i. What would be the impact of payment attribute on estimates when comparing labour verses cash?

ii. Whether there is any effect on the group verses individual introduction of the survey on estimates?

The above-mentioned research questions were answered using primary data collected from direct dependent community of the *Pihimbiyagollewa* cascade ('on-site' sample) and from a community indirectly dependent on the *Pihimbiyagollewa* cascade ('off-site sample). The three specific objectives of the research successfully delivered in this thesis is listed below.

1. To elicit the willingness to pay (WTP) for restoration and sustainable management of a representative small tank cascade system in the *Malwathu Oya* basin for cascade dependent on-site community and distant off-site communities using cascade as the unit of decision-making.

2. To assess the marginal willingness to pay (MWTP) for different cascade attributes for off-site and on-site communities.

3. To develop and validate a Benefit Cost Analysis framework for decision-making in restoration and sustainable management of small tank cascade systems using the findings of the research.



In line with the two sub research questions mentioned above, two methodological sub research objectives also covered in this research. They are to assess the payment mode (money vs labour) and survey format (group vs individual) impact on the estimated values.

The first objective was the key objective in this research, which subsequently contributed to meet the other two objectives. The methodology for addressing Objective one was chosen in a way to capture the total economic value of STCS. It was evident that the economic value of restoration and sustainable management of STCS can only be assessed based on a comprehensive identification and capturing of environmental and social values of the ecosystem services that the STCSs provide. It has been presented in this research that most of the identified TEV components of the STCS were not traded in the market due to market failures such as prevalence of common property, public goods, and externalities. Furthermore, since the accrual of benefits of conservation of components of cascades such as *Kattakaduwa* and *Gasgommana* being long term, only activities that bring short-term benefits have been favoured against their conservation. The latter is also leading to inter-generational equity issues. Therefore, to assess the TEV of a STCS, a stated preference method, the Choice Experiment was chosen as the revealed preference methods failed in capturing the TEV of STCSs due to above mentioned reasons. The key advantages of the CE over other SP methods are the CE is consistent with consumer theory and rather than stating an amount by the respondent, the CE allows the respondent to select between three options of different levels of five attributes of the cascade and amongst them one of the attributes is related to the payment.

In CE, respondents choose from the two selected samples (on-site and off-site) were presented with carefully designed series off choice sets consisting three alternative options comprising five STCS related attributes with varying attribute levels. The fifth attribute was the payment attribute which was presented as labour or cash for approximately in 50:50 share of the (on-site) sample. The respondent's choice of alternatives in each choice sets were obtained to derive TEV in terms of WTP using econometric procedure. As described under chapter three, using the experimental design and the analytical procedures, CE estimated the respondent's personal costs to be bone for implementing STCS management strategy. With the choices made by respondents, it was possible to deduce the trade-offs that they are willing to make between money (or labour for on-site sample) and STCS restoration options.

## 6.2 Summary of the Findings

This section is devoted to the interpretation and the discussion of the findings which were introduced in the previous chapter. Summary of the findings are given below relating to different categories of the sample. In addition to interpretation, major conclusions reached with some recommendations, policy implications related to findings of the study in restoration and sustainable management of small tank clusters in the Dry Zone of Sri Lanka and finally the limitations of the research with suggested future studies are presented in this section.



### 6.2.1 Estimates Related to *Pihimbiyagollewa* on-site Sample

CE design and methodology executed carefully to obtain estimates that are consistent with economic theory. The estimated coefficients for attributes, 'availability of irrigation water for cultivating paddy during the dry season (Yala) in the cascade (paddy level)' and the 'availability of water for other purposes in the cascade during the dry season -Yala (other uses level)' were positive in all models related to on-site survey, and they were significant at 1% alpha level. The 'presence of representative groups of birds in cascade during Yala (cascade biodiversity)' attribute was significant at various levels for all models except for estimates for on-site cash from the Conditional Logit Model. In all instances the sign of the biodiversity attribute was also positive. The other cascade restoration and management attribute, 'extent of unique cascade ecological components in the cascade during Yala (ecology level)' was significant only in few instances compared to other three attributes used. Wherever the 'ecology level' was significant the sign was positive like other attributes. All the cascade restoration and management related attributes having positive coefficients indicated that the higher the levels of attribute will increase the probability of the selected management scenario. In other words, respondents prefer those cascade restoration and management scenarios, which resulted in a higher level of paddy cultivation, other uses, biodiversity and ecosystem levels. The coefficient of the payment attribute was negative as expected and statistically significant in all instances of the on-site cash sample implying that the effect on utility of opting for a choice set with a higher payment level is negative.

When payment attribute is used as the normalising variable, the paddy level stands out as the most important attribute for choosing cascade restoration and management option for the respondents in the on-site cash sample followed by the other uses and biodiversity. The attribute ecology was not statistically significant. The positive sign and the statistical significance on the ASC coefficient imply that a positive utility impact will occur in any move away from the present status of the cascade. However, in on-site labour sample, the payment attribute which is the labour contribution for restoration and sustainable management was not significant in many models used. This indicates that the labour was not an effective contributing attribute like cash for the respondents in *Pihimbiyagollewa*. This may be due to outmigration of youth for occupations outside of cascade making labour as a scarce resource at cascade level.

Marginal Willingness to Pay or implicit prices for all selected attributes of cascade restoration and sustainable management in on-site cash survey showed that the highest MWTP per unit change in the attribute level was for paddy in the on-site cash sample, followed by the other use, biodiversity and ecology. This order was consistent over the six combinations of two models considered for on-site cash sample.

### 6.2.2. Estimates Related to Pihimbiyagollewa off-site Sample

In both models related to off-site sample, the coefficients of all cascade restoration and management attributes had a positive sign and a statistical significance at either 1% or 5% alpha level. All the cascade restoration and management related attributes had positive coefficients indicating the higher the levels of any single attribute will increase the probability of that selected management scenario. In other words, respondents preferred those cascade restoration and management scenarios, which resulted in a higher level of paddy cultivation, other uses, biodiversity and ecosystem levels. The payment coefficient was negative as expected, indicating that the utility of opting for a choice set with a higher payment level is negative.



When payment attribute was used as the normalising variable, the water for paddy level stands out as the most important attribute for choosing cascade restoration and management option for the respondents in off-site cash sample followed by ecology, water for other uses and biodiversity. The positive sign and the statistical significance of the ASC coefficient implies that a positive utility impact will occur in any move away from the *status quo.*

***Table 6.1: MWTP for on-site Cash and off-site Cash Samples in MMNL Models***

| Attributes | On-site Cash | Off-site Cash |
|---|---|---|
| | In LKR/season/household | |
| ASC | 31,109 | 15,148 |
| Water for Paddy | 25,507 | 8,234 |
| Water for other uses | 16,366 | 17,955 |
| Cascade Ecological components | 1,973 | 4,000 |
| Cascade Biodiversity | 5,880 | 8,921 |

Source: STCS Survey Results, 2016



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As given in the Table 6.1, the Marginal Willingness to Pay or implicit prices for all selected attributes of cascade restoration and sustainable management in on-site and off-site cash surveys, the highest MWTP per change in the attribute level differed in on-site and off-site samples. LKR 25,507 was the highest MWTP for the on-site sample estimated for cultivating paddy in full extent of the cascade per season per family, followed by LKR 16,366 for having water for other uses covering all six months and LKR 5,880 for biodiversity represented by having all 12 groups of birds respectively for the on-site sample per household per season. The MWTP for ecology was statistically insignificant for the on-site sample meaning there is no consideration placed by on-site sample in ecological aspects of cascades.

In contrast, the off-site sample placed the attribute other uses of cascades as the highest MWTP for them with an estimated value of LKR 17,995 per family per season, followed by biodiversity with LKR 8,921, paddy LKR 8,234 and ecology with LKR 4,000. Order as well as the absolute values of MWTP for cascade related attributes differs between two samples where on-site sample MWTP is highest for paddy, followed by other use then biodiversity with ecology being insignificant. Whereas the off-site sample placed the highest MWTP for other use followed by biodiversity, paddy and ecology.

Total WTP for restoration of *Pihimbiyagollewa* cascade by the community in the same cascade (referred to as the on-site sample elsewhere) is estimated as LKR 78,865 per season per household whereas the total WTP for off-site sample is estimated at LKR 54,260 per season per household. All statistically significant MWTP values for attributes and MWTP for ASC were aggregated to arrive at total WTP values mentioned above. Aggregate WTP for restoration and sustainable management was calculated based on the sampled populations as given in Table 6.2.

***Table 6.2: Population Data Related to on-site and off-site Samples***

| Divisional Secretariat | Grama Niladhari Division | GND no | GND no | Number of Families |
|---|---|---|---|---|
| *Rambewa* | *Pihimbiyagollewa* | 81 | 1,049 | |
| *Rambewa* | *Wewelkatiya* | 82 | 1,032 | |
| *Rambewa* | *Thamarahalmillewa* | 83 | 520 | |
| *Rambewa* | *Balahondawewa* | 86 | 699 | |
| *Rambewa* | *Ihalakolongaswewa* | 87 | 554 | |
| *Kahatagasdigiliya* | *Palippothana* | 224 | 592 | |
| **On-site Sample totals** | | | **4,446** | **998** |
| *Sri-Jayawardanapura Kotte* | *Pagoda* | 519A | 5,407 | |
| *Thimbirigasyaya* | *Kurunduwatta* | | 9,873 | |
| *Kaduwela* | *Sri Subhoothipura* | 492 | 2,558 | |
| *Kaduwela* | *Malabe North* | 476B | 7,689 | |
| **Off-site Sample totals** | | | **25,527** | **5,110** |

Source: Department of Census and Statistics, 2015

***Table 6.3 Total WTP for the Sample***

| Description | On-site Amount in LKR | Off-site Amount in LKR |
|---|---|---|
| WTP individual household / season | 78,865 | 54,260 |
| WTP for total sample | 78,707,190 | 277,269,724 |

Source: STCS Survey Results, 2016

The individual family level WTP estimates were used to derive WTP values for the GNDs covered by the survey by multiplying the individual WTP by total number of families in the sampled GNDs. These estimates provide total WTP by the population of the sample site per season (see Table 6.3).

As there is no clear demarcation for the boundary of the off-site benefits of STCS due to its common property nature, in economic evaluation (in BCA), the off-site values were not considered. However, it is clear that off-site communities enjoy some benefits of having STCS and they are willing to pay for restoration and sustainable management of STCS as demonstrated in the selected off-site sample. These values may extend even to global scale owing to unique features of STCS. Due to unclear boundaries of such values and difficulty in apportioning such values by off-site community to a particular cascade amongst the population of STCS, off-site values were not used in the BCA.

### 6.2.3 Economic Evaluation of STCS Restoration

The Benefit Cost Analysis is used as the economic evaluation tool for STCS restoration as the final task in the thesis. BCA is a method use in determining the economic impact of a policy, program or a project. It encompasses the quantifying incremental economic impacts, which determines the net value of the investment. The results of the evaluation will be useful for decision making on small tank restoration at cascade level. In conventional BCA, economic evaluation is performed based on goods that are commonly traded in competitive markets. In the Extended BCA non-market benefits too were incorporated into the analysis which were generated in the CE. The cost estimates were obtained from recently concluded ecological restoration of *Kapiriggama* small tank cascade project of IUCN and DAD. The 'donor' cascade – *Kapiriggama* STCS is of similar size and adjoining to the *Pihimbiyagollewa* cascade which is being researched in this thesis.

#### *6.2.3.1 Conventional Benefit Cost Analysis*

Conventional BCA demonstrated that the incremental benefit of paddy alone is not sufficient to justify the investing on cascade level restoration. Which supports the common belief on cascade restoration feasibility. As indicted in the chapter four, BC Ratio is 0.60 (less than one), NPV (65,618,455) (less than zero) and IRR is -3.10% (less than market interest rate).

#### *6.2.3.2 Extended Benefit Cost Analysis (EBCA)*

The extended benefit cost analysis performed with the cascade-wide benefits assessed using CE. The results indicate the cascade restoration is economically feasible when non-market benefits are taken into account. The incremental benefits from cultivating paddy in a restored cascade assessed using CE appears to be higher than the benefits calculated using incremental production related benefits in the conventional BCA. However, in sensitivity analysis paddy only benefits failed to justify restoration investment when cross sensitivity option is used (cost of restoration increase by 40% with benefits decreased by 40%). Looking at the realities in the Dry Zone agriculture such cost over runs, and forgone benefits are very common. Hence, we can assume paddy alone is not justifying cascade restoration taking the vulnerabilities of the Dry Zone small tank systems. However, extended benefits of irrigated agriculture, non-irrigation benefits arising from the other uses of water in cascades and benefits associated with biodiversity in cascades clearly justifies cascade level restoration as a feasible investment option even after taking the vulnerabilities of the Dry Zone STCS based farming. Base case BC ratio was 2.24, NPV was LKR 204,920,854 with IRR of 24% with cross sensitivity of 40 % cost overrun and 40 % unrealized benefits over the project period gave a BC Ratio of 1.47, NPV of LKR 108,729,307 and IRR of 17%.

### 6.3 Conclusion

The research undertaken on the *Pihimbiyagollewa* small tank cascade together with *Kapiriggama* cascade in *Malwathu oya* basin in *Kahatagasdigiliya* and *Rambewa* DSDs of Anuradhapura district of North Central Province of Sri Lanka contributes to the small tank cascade valuation literature by applying a state-of-the-art non-market valuation technique to a small tank cascade system. Most probably this is one of the first valuation study of small tank cascade system taking the cascade as the unit of analysis. Furthermore, this also be the first application of choice experiment non-market valuation technique in small tank cascade system.

The study concludes that both the cascade dependent people as well as people away from the cascade with no direct benefits receiving from the cascade have positive WTP for restoration and sustainable management of the cascade as a whole. The total value estimated is the benefits (TEV) of the restoration of *Pihimbiyagollewa* STCS. The research methodology adopted helped estimating the welfare changes to the society generated by the restoration and sustainable management of STCS using heterogeneous respondents from two distinctly different samples. Further, the BCA proved that the economic evaluation (B/C) of investments on restoration and sustainable utilization of STCS could be justified when considering TEV of a cascade vis-à-vis considering only direct values of individual irrigation tanks. As demonstrated in *Pihimibiyagollewa* cascade, the restoration benefits of small tank cascade in taking cascade as the unit of decision-making, overweigh the cost of such restoration. In other words, permitting STCS to degradation will result in welfare loss to the society.

People from the cascade has a higher willingness to pay compared to the off-site sample (LKR 78,865 per season per family vs. LKR 54,260 per season per family). Estimates for marginal improvements of different attribute levels of the cascade demonstrated the differences in the preferences of the two sampled communities. The on-site sample, who depends on the cascade for their day to day sustenance placed the highest value on cascade water for paddy followed by cascade water for other uses and cascade biodiversity (LKR 25,507, LKR 16,366 and LKR 5,880 for respectively). It is interesting to note that the cascade dependent community did not consider the level of cascade ecosystem as important in their assessments. This may be due to the practice of encroaching ecological components such as *Kattakaduwa* by farmers for cultivation.



On the contrary the off-site community sampled, who did not have direct benefits from the cascade, placed cascade water for other uses as the top priority, while cascade biodiversity, cascade water for paddy and cascade ecology were identified as decreasing priorities for willingness to pay for marginal change (values were LKR 17,995, LKR 8,921, LKR 8,234 and LKR 4,000 per family per season respectively). It is noted that they considered all four attributes in their valuation including the cascade ecology.

The findings suggest that both cascade dependent as well as other communities are willing to pay for cascade level restoration and sustainable management of small tanks and EBCA performed based on the on-site benefits suggests that such cascade restoration is economically feasible.

Assuming that one of the objectives of STCS management is to maximise the social value of these systems to people, improved knowledge of the marginal benefits of extending or reducing some attribute levels could result in a more efficient solution. Full economic implications of managing STCS in alternative ways will then be taken considered.



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## 6.4 Policy Implications

The research findings suggest that cascade dependent as well as off-site community have a high WTP for restoration and sustainable management of STCS being studied. It also proves that careful design and administration of CE applications can provide robust findings for policy guidance. Therefore, appropriate policy relevant recommendations can be formulated based on the findings of this research. The following policy relevant recommendations can be proposed to reconsider the current practices of managing small tanks in isolation without considering them as parts of the cascade system, in planning and management for sustenance of the services they provide.

i. *Cascade as a functional unit for planning* - Consider the cascade system as a functional socio-ecological system, as well as the unit of planning/intervention, in recognition of the interconnected nature of the tanks and other ecological components within it.

ii. *Governance of small reservoir clusters* - currently there is no system of governance at the cluster or cascade level. To reap the maximum benefits of these multifunctional time-tested systems, a cascade level governance mechanism needs to be formulated. Such system of governance at cascade level has to be legally established to consider cascades as the unit of planning and management. Systems benefits of cascades then be enjoyed continually as opposed to the current tank-based governance system. The structure of the governance system needs to be determined in consultation with DAD, FOs, related cascade level stakeholders and experts, taking all 1,100 cascades into account.





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iii. *Awareness raising* - raise awareness about the cascades and engage all stakeholders in sustainable use of these systems in addressing present day problems including adaptation to climate change impacts.

iv. Explore wider Co-benefits of STCS - Investigate further and manage their other benefits such as carbon fixation, enhancement of biodiversity and positive contribution to the microenvironment.

v. *Integrate in to practice* -Policy guidelines based on the points discussed above should be issued by the Department of Agrarian Development in order to ensure that cascades are used as the unit for planning in the development of the national small tank restoration programme.

vi. *Learning from the past for future* - Study key elements of small tank cascade systems and associated traditional knowledge related to cascades in order to learn and use them in addressing present day socio-economic and environmental challenges faced by Dry Zone farmers.



### 6.5 Limitations of the Research

Limitations of the study is discussed below with some ideas to furtherance of the current research.

i. Assessment of WTP using contingent valuation was included as a part of this study for comparison purpose. However, it was not performed due to time limitations. If that was done the WTP generated by Choice Experiments could have been compared.

ii. Original sampling strategy for off-site sample had to be changed as many houses selected in Colombo 7 were not accessible as they did not open their gates for enumerators. Hence, more samples were taken from sub-urban off-site areas of Colombo.


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iii. Lengthy nature of the survey prevented spending adequate time on discussing the establishment of a trust fund for cascade restoration and sustainable management.

iv. Benefit cost framework applied used the cost estimates from a similar adjoining cascade. While the approximation appears to be justifiable, cost estimates for the same site would have given more precise estimates.

## 6.6 Future Research

Following are suggestions for further related research on small tanks cascades in Sri Lanka.

i. Updated national level database on cascades and individual tanks.

ii. Research on establishment of a trust fund for cascade restoration and sustainable management.

iii. Fine-tune benefit cost framework for small tank cascade restoration using restoration costs based on estimates for the same tank cascade system to be valued.

iv. Assessment of total economic value of cascades using other valuation techniques.

v. Further work on property rights of different components of small tank cascades and assessment of their ecosystem service values.

vi. Investigate into a cascade level governance model for agrarian purposes, deviating from usual administrative boundaries often cutting across cascades. In such a model the local community should play a key role with authorities delegating more powers to Farmer Organisations.

vii. Off-site estimates of values indicated that there are WTP from people living outside of the cascade identified for restoration. However, due to lack of clarity on deciding principles for the boundary for a given project. Those values were not used in BCA. Further work on methodology for determining project boundary for BCA in accommodating off-site values will be useful to explore.

viii. Sustainability of small tank cascades beyond their restoration is a matter of concern, further studies into effective cascade level management mechanisms with the participation of cascade dependent stakeholders and mandates agencies will be of great importance. Findings of this research may be used for evaluating restoration options for other cascades with appropriate benefit transfer methods.

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# ANNEXES

## Annex 1: List of Stakeholders Consulted

| # | Name of the person/ group consulted[34] | Stakeholder category | Engagement | Date |
|---|---|---|---|---|
| 1. | Dr. P.B. Dharmasena (Freelance Consultant Soil and Water Resources) | Expert on STCS | Consultation on the overall concept<br>Review of attributes and their levels<br>Selection of appropriate cascade for the research<br>Focus group discussion with cascade community<br>Clarification of concepts on STCS | 03/06/2015<br>11/11/2015<br>12/11/2015<br>12/11/2015<br>Continuous through out |
| 2. | Prof. C.M. Madduma Bandara (Emeritus Professor of Geography, University of Peradeniya) | Expert on STCS | Consultation on overall concept<br>Survey methods<br>Detailed discussion after the review of 1st three draft chapters<br>Consultation on property rights applica-ble to STCS | 15/12/2015<br>28/07/2016<br>05/07/2016<br>22/03/2017 |
| 3. | Eng. P. Witharana Head Water Resources Management, DAD | Expert / Official on STCS | Consultation on the overall idea<br>Consultation of selecting a cascade for research | 10/06/2015<br>05/11/2015 |
| 4. | Dr. Lal Mutuwatte (IWMI) | Expert hydrologist and spatial planner | Consultation on spatial planning | 30/11/2015<br>14/05/2016<br>05/09/2017 |
| 5. | Dr. Harsha Kadupitiya Department of Agriculture | Expert / Official GIS/RS | Consultation on feasibility of comparing *Kapiriggama* and *Pihimbiyagollewa*<br>GIS mapping | 30/11/2015<br>18/06/2016<br>12/07/2016 |
| 6. | Sampath Goonatilake Senior Programme Officer, IUCN | Expert Biodiversity | Consultation on bio-diversity and ecology attributes and their levels | 18/06/2016 |

[34] Two supervisors were not included though they were consulted throughout the study period

| | | | | |
|---|---|---|---|---|
| 7. | Naalin Perera<br>Programme Officer, IUCN | Expert Biodiversity | Consultation on bio-diversity and ecology attributes and their levels | 18/06/2016 |
| 8. | Prof. D.N.K. Pushpakumara (University of Peradeniya) | Expert Agri-culture | Consultation on overall concept | 10/11/2015 |
| 9. | Dr. Athula Senaratne (IPS) | Expert Environmen-tal Economist | Consultation on the overall approach to the research | 20/12/2015 |
| 10. | M.A.M. Aheeyar (IWMI Formerly HARTI) | Expert STCS institutional | Attributes and their levels | 15/06/2015 |
| 11. | Viraj Perera<br>Deputy Commissioner, DAD Anuradhapura | Official DAD | Consultation on the overall idea | 11/11/2015 |
| 12 | Dr. Sahan Dissanayake<br>Colby College, USA. | Expert CE | Assistance in enumera-tor training<br>Preparation on Choice cards<br>Planning FGS with farmers<br>CE analysis | 30/11/2015<br>12-13/08/2016<br><br>Continuous throughout |
| 13. | Famers in *Kapiriggama* and *Pihimbiyagollewa* cascades | Community from STCS studied | FGS on attributes and their levels<br>Pretesting of questionnaires | 27-28/07/2016<br>05-06/08/2016 |
| 14. | Mr. Karunaratne and Mr. Ruwan of Plan Sri Lanka, Anuradhapura | Officials Plan Sri Lanka | Consulted on their experience in STCS restoration | 12/11/2015 |
| 15. | Mr. Lakshman and Mr. Buddhika Provincial Agriculture Department, Anuradhapura | Official | Consultation on the overall idea | 12/11/2015 |
| 16. | Mr. Lalith Alwis<br>Director Provincial Irrigation Department, Anuradhapura | Official | Consultation on the overall idea | 12/11/2015 |
| 17. | Prof. L.H.P. Gunaratne<br>University of Peradeniya | Expert on non-market valuation | Discussion on possible methods | 30/11/2015 |

# Annex 2: Attribute Descriptions used in CE

| Attribute Name | Description |
|---|---|
| Availability of irrigation water in the cascade for cultivating paddy during the dry season (Yala) | Portion of paddy fields that can be cultivated out of entire paddy lands in the cascade with available water in the cascade during the dry (Yala) season[35] |
| Availability of water for other purposes in the cascade during dry season (Yala) | Cascade wide availability of water for other non-irrigational uses like drinking, bathing, washing, recreation and for livestock during the dry season |
| Extent of unique cascade ecological components | Unique cascades ecology represented by cascade ecosystem components *Kattakaduwa* and *Gasgommana*. They contribute to the species diversity, availability of NTFP[36] for local community and controls soil erosion.<br>Extent will be taken as full (100%) if the entire areas of these ecosystem components are covered with forest/natural vegetation according to latest google image. |
| Cascade biodiversity | Different type of bird groups were selected as an indicator of the biodiversity of the cascade area. Number of different bird groups found in the cascade during Yala season. |
| Contribution to cascade management | Cash contribution that your household will have to pay every season (twice a year) for restoration and sustainable management of cascade at the selected option<br>Cash contribution per season (twice a year) |



[35] Water deficit dry cultivation season depends on tank water

[36] Water deficit dry cultivation season depends on tank water

# Annex 3: Experimental Design

Since the first two attributes are linked, they were combined as one attribute in the design

X1 – 6 levels

| Water Household | Water Irrigation | Design Level for X1 |
|---|---|---|
| 1 – 4 months shortage | 1 50% | 1 |
| 2 – 2 months water shortage<br>2 – 2 months water shortage | 1 50%<br>2 75% | 2<br>3 |
| 3 – 0 months water shortage<br>3 – 0 months water shortage<br>3 – 0 months water shortage | 1 50%<br>2 75%<br>3 100% | 4<br>5<br>6 |



X2 – 3 levels for cascade ecology

X3 – 3 levels for biodiversity

X4 – 6 levels for contribution

We want to include interaction for X2 and X3

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 4.61569 | 29 | 0.5 | 1 | 1 | 1 | 2 | 2 | 3 | 6 |
| | 1 | 4.61569 | 105 | 0.5 | 2 | 1 | 1 | 6 | 3 | 2 | 3 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 4.61569 | 28 | 0.5 | 3 | 1 | 1 | 2 | 2 | 2 | 4 |
| | 1 | 4.61569 | 42 | 0.5 | 4 | 1 | 1 | 3 | 1 | 3 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 4.61569 | 51 | 0.5 | 5 | 1 | 1 | 3 | 3 | 2 | 1 |
| | 1 | 4.61569 | 98 | 0.5 | 6 | 1 | 1 | 6 | 2 | 1 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 1 | 4.61569 | 17 | 0.5 | 5 | 1 | 1 | 3 | 3 | 2 | 1 |
| | 1 | 4.61569 | 97 | 0.5 | 8 | 1 | 1 | 6 | 2 | 1 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 4.61569 | 28 | 0.5 | 9 | 1 | 1 | 2 | 2 | 2 | 4 |
| | 1 | 4.61569 | 38 | 0.5 | 10 | 1 | 1 | 3 | 1 | 1 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1 | 4.61569 | 21 | 0.5 | 11 | 1 | 1 | 2 | 1 | 2 | 2 |
| | 1 | 4.61569 | 103 | 0.5 | 12 | 1 | 1 | 6 | 3 | 1 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 4.61569 | 67 | 0.5 | 13 | 1 | 1 | 4 | 3 | 1 | 3 |
| | 1 | 4.61569 | 75 | 0.5 | 14 | 1 | 1 | 5 | 1 | 2 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 4.61569 | 56 | 0.5 | 15 | 1 | 1 | 4 | 1 | 1 | 3 |
| | 1 | 4.61569 | 46 | 0.5 | 16 | 1 | 1 | 3 | 2 | 2 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 1 | 4.61569 | 78 | 0.5 | 17 | 1 | 1 | 5 | 1 | 3 | 6 |
| | 1 | 4.61569 | 99 | 0.5 | 18 | 1 | 1 | 6 | 2 | 2 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 1 | 4.61569 | 50 | 0.5 | 19 | 1 | 1 | 3 | 3 | 1 | 5 |
| | 1 | 4.61569 | 3 | 0.5 | 20 | 1 | 1 | 1 | 1 | 2 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 1 | 4.61569 | 64 | 0.5 | 21 | 1 | 1 | 4 | 2 | 2 | 6 |
| | 1 | 4.61569 | 91 | 0.5 | 22 | 1 | 1 | 6 | 1 | 1 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 1 | 4.61569 | 37 | 0.5 | 23 | 1 | 1 | 3 | 1 | 1 | 1 |
| | 1 | 4.61569 | 71 | 0.5 | 24 | 1 | 1 | 4 | 3 | 3 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 1 | 4.61569 | 96 | 0.5 | 25 | 1 | 1 | 6 | 1 | 3 | 3 |
| | 1 | 4.61569 | 86 | 0.5 | 26 | 1 | 1 | 5 | 3 | 1 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 1 | 4.61569 | 67 | 0.5 | 27 | 1 | 1 | 4 | 3 | 1 | 3 |
| | 1 | 4.61569 | 94 | 0.5 | 28 | 1 | 1 | 6 | 1 | 2 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 1 | 4.61569 | 13 | 0.5 | 29 | 1 | 1 | 1 | 3 | 1 | 1 |
| | 1 | 4.61569 | 48 | 0.5 | 30 | 1 | 1 | 3 | 2 | 3 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 1 | 4.61569 | 9 | 0.5 | 31 | 1 | 1 | 1 | 2 | 2 | 5 |
| | 1 | 4.61569 | 54 | 0.5 | 32 | 1 | 1 | 3 | 3 | 3 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 1 | 4.61569 | 94 | 0.5 | 33 | 1 | 1 | 6 | 1 | 2 | 6 |
| | 1 | 4.61569 | 43 | 0.5 | 34 | 1 | 1 | 3 | 2 | 1 | 3 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 1 | 4.61569 | 101 | 0.5 | 35 | 1 | 1 | 6 | 2 | 3 | 2 |
| | 1 | 4.61569 | 2 | 0.5 | 36 | 1 | 1 | 1 | 1 | 1 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 1 | 4.61569 | 64 | 0.5 | 37 | 1 | 1 | 4 | 2 | 2 | 6 |
| | 1 | 4.61569 | 23 | 0.5 | 38 | 1 | 1 | 2 | 1 | 3 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 1 | 4.61569 | 89 | 0.5 | 39 | 1 | 1 | 5 | 3 | 3 | 1 |
| | 1 | 4.61569 | 8 | 0.5 | 40 | 1 | 1 | 1 | 2 | 1 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 1 | 4.61569 | 44 | 0.5 | 41 | 1 | 1 | 3 | 2 | 1 | 6 |
| | 1 | 4.61569 | 60 | 0.5 | 42 | 1 | 1 | 4 | 1 | 3 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 1 | 4.61569 | 74 | 0.5 | 43 | 1 | 1 | 5 | 1 | 1 | 6 |
| | 1 | 4.61569 | 102 | 0.5 | 44 | 1 | 1 | 6 | 2 | 3 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 1 | 4.61569 | 107 | 0.5 | 45 | 1 | 1 | 6 | 3 | 3 | 3 |
| | 1 | 4.61569 | 61 | 0.5 | 46 | 1 | 1 | 4 | 2 | 1 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 1 | 4.61569 | 69 | 0.5 | 47 | 1 | 1 | 4 | 3 | 2 | 2 |
| | 1 | 4.61569 | 8 | 0.5 | 48 | 1 | 1 | 1 | 2 | 1 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 1 | 4.61569 | 85 | 0.5 | 49 | 1 | 1 | 5 | 3 | 1 | 2 |
| | 1 | 4.61569 | 42 | 0.5 | 50 | 1 | 1 | 3 | 1 | 3 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 1 | 4.61569 | 19 | 0.5 | 51 | 1 | 1 | 2 | 1 | 1 | 1 |
| | 1 | 4.61569 | 82 | 0.5 | 52 | 1 | 1 | 5 | 2 | 2 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 1 | 4.61569 | 40 | 0.5 | 53 | 1 | 1 | 3 | 1 | 2 | 4 |
| | 1 | 4.61569 | 31 | 0.5 | 54 | 1 | 1 | 2 | 3 | 1 | 3 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | 1 | 4.61569 | 16 | 0.5 | 55 | 1 | 1 | 1 | 3 | 2 | 5 |
| | 1 | 4.61569 | 80 | 0.5 | 56 | 1 | 1 | 5 | 2 | 1 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 1 | 4.61569 | 5 | 0.5 | 57 | 1 | 1 | 1 | 1 | 3 | 3 |
| | 1 | 4.61569 | 98 | 0.5 | 58 | 1 | 1 | 6 | 2 | 1 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 1 | 4.61569 | 15 | 0.5 | 59 | 1 | 1 | 1 | 3 | 2 | 1 |
| | 1 | 4.61569 | 73 | 0.5 | 60 | 1 | 1 | 5 | 1 | 1 | 3 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 1 | 4.61569 | 108 | 0.5 | 61 | 1 | 1 | 6 | 3 | 3 | 6 |
| | 1 | 4.61569 | 27 | 0.5 | 62 | 1 | 1 | 2 | 2 | 2 | 3 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 1 | 4.61569 | 79 | 0.5 | 63 | 1 | 1 | 5 | 2 | 1 | 3 |
| | 1 | 4.61569 | 36 | 0.5 | 64 | 1 | 1 | 2 | 3 | 3 | 5 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 1 | 4.61569 | 22 | 0.5 | 65 | 1 | 1 | 2 | 1 | 2 | 3 |
| | 1 | 4.61569 | 65 | 0.5 | 66 | 1 | 1 | 4 | 2 | 3 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 1 | 4.61569 | 87 | 0.5 | 67 | 1 | 1 | 5 | 3 | 2 | 4 |
| | 1 | 4.61569 | 29 | 0.5 | 68 | 1 | 1 | 2 | 2 | 3 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 1 | 4.61569 | 104 | 0.5 | 69 | 1 | 1 | 6 | 3 | 1 | 4 |
| | 1 | 4.61569 | 81 | 0.5 | 70 | 1 | 1 | 5 | 2 | 2 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **36** | 1 | 4.61569 | 66 | 0.5 | 71 | 1 | 1 | 4 | 2 | 3 | 4 |
| | 1 | 4.61569 | 32 | 0.5 | 72 | 1 | 1 | 2 | 3 | 1 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **37** | 1 | 4.61569 | 14 | 0.5 | 73 | 1 | 1 | 1 | 3 | 1 | 6 |
| | 1 | 4.61569 | 59 | 0.5 | 74 | 1 | 1 | 4 | 1 | 3 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **38** | 1 | 4.61569 | 4 | 0.5 | 75 | 1 | 1 | 1 | 1 | 2 | 5 |
| | 1 | 4.61569 | 29 | 0.5 | 76 | 1 | 1 | 2 | 2 | 3 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **39** | 1 | 4.61569 | 34 | 0.5 | 77 | 1 | 1 | 2 | 3 | 2 | 5 |
| | 1 | 4.61569 | 55 | 0.5 | 78 | 1 | 1 | 4 | 1 | 1 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **40** | 1 | 4.61569 | 70 | 0.5 | 79 | 1 | 1 | 4 | 3 | 2 | 3 |
| | 1 | 4.61569 | 1 | 0.5 | 80 | 1 | 1 | 1 | 1 | 1 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **41** | 1 | 4.61569 | 45 | 0.5 | 81 | 1 | 1 | 3 | 2 | 2 | 3 |
| | 1 | 4.61569 | 18 | 0.5 | 82 | 1 | 1 | 1 | 3 | 3 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **42** | 1 | 4.61569 | 88 | 0.5 | 83 | 1 | 1 | 5 | 3 | 2 | 6 |
| | 1 | 4.61569 | 19 | 0.5 | 84 | 1 | 1 | 2 | 1 | 1 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **43** | 1 | 4.61569 | 96 | 0.5 | 85 | 1 | 1 | 6 | 1 | 3 | 3 |
| | 1 | 4.61569 | 68 | 0.5 | 86 | 1 | 1 | 4 | 3 | 1 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 44 | 1 | 4.61569 | 12 | 0.5 | 87 | 1 | 1 | 1 | 2 | 3 | 3 |
| | 1 | 4.61569 | 19 | 0.5 | 88 | 1 | 1 | 2 | 1 | 1 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | 1 | 4.61569 | 33 | 0.5 | 89 | 1 | 1 | 2 | 3 | 2 | 4 |
| | 1 | 4.61569 | 11 | 0.5 | 90 | 1 | 1 | 1 | 2 | 3 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | 1 | 4.61569 | 77 | 0.5 | 91 | 1 | 1 | 5 | 1 | 3 | 4 |
| | 1 | 4.61569 | 52 | 0.5 | 92 | 1 | 1 | 3 | 3 | 2 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | 1 | 4.61569 | 58 | 0.5 | 93 | 1 | 1 | 4 | 1 | 2 | 6 |
| | 1 | 4.61569 | 47 | 0.5 | 94 | 1 | 1 | 3 | 2 | 3 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 1 | 4.61569 | 75 | 0.5 | 95 | 1 | 1 | 5 | 1 | 2 | 1 |
| | 1 | 4.61569 | 108 | 0.5 | 96 | 1 | 1 | 6 | 3 | 3 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 49 | 1 | 4.61569 | 84 | 0.5 | 97 | 1 | 1 | 5 | 2 | 3 | 5 |
| | 1 | 4.61569 | 52 | 0.5 | 98 | 1 | 1 | 3 | 3 | 2 | 2 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 1 | 4.61569 | 99 | 0.5 | 99 | 1 | 1 | 6 | 2 | 2 | 1 |
| | 1 | 4.61569 | 41 | 0.5 | 100 | 1 | 1 | 3 | 1 | 3 | 4 |

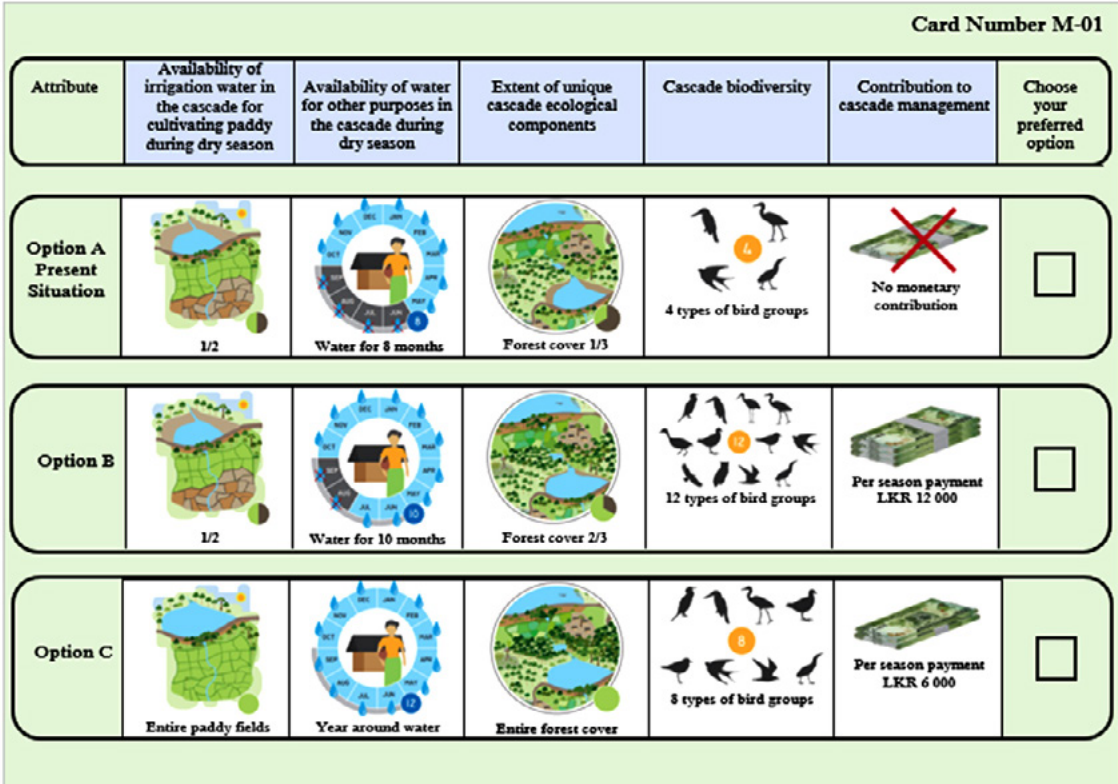
| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | 1 | 4.61569 | 11 | 0.5 | 101 | 1 | 1 | 1 | 2 | 3 | 1 |
| | 1 | 4.61569 | 93 | 0.5 | 102 | 1 | 1 | 6 | 1 | 2 | 4 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **52** | 1 | 4.61569 | 55 | 0.5 | 103 | 1 | 1 | 4 | 1 | 1 | 2 |
| | 1 | 4.61569 | 89 | 0.5 | 104 | 1 | 1 | 5 | 3 | 3 | 1 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **53** | 1 | 4.61569 | 90 | 0.5 | 105 | 1 | 1 | 5 | 3 | 3 | 2 |
| | 1 | 4.61569 | 58 | 0.5 | 106 | 1 | 1 | 4 | 1 | 2 | 6 |

| Set | Design | Efficiency | Index | Prob | n | f1 | f2 | x1 | x2 | x3 | x4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **54** | 1 | 4.61569 | 49 | 0.5 | 107 | 1 | 1 | 3 | 3 | 1 | 2 |
| | 1 | 4.61569 | 29 | 0.5 | 108 | 1 | 1 | 2 | 2 | 3 | 6 |

# Annex 4: Sample of a Choice Profile



# Annex 5A:
# Structure of the Questionnaire used in the on-site Survey

## Contribution of Small Tank Cascade Systems to Dry Zone Rural Economy of Sri Lanka: Capturing Non-Market Values

**Survey Information for Enumerators**

| | | | |
|---|---|---|---|
| 0.1 | Day: | 0.2 | Time: |
| 0.3 | Questionnaire No.: | 0.4 | Enumerator's Name |

## Section 1 – General Information on the Survey

### Background to the Survey

This survey is to study what people think about a small tank cascade (STC) system in Anuradhapura, their restoration and sustainable management. We are interested to know your feelings about possible restoration of small tank cascade systems. We have chosen *Pihimbiyagollewa* STC in Anuradhapura district for this survey. This cascade has 22 small tanks and located in *Rambewa* and *Kahatagasdigiliya* Divisional Secretariat divisions. Cascade area accommodates around 1000 families and spread out in 9 Grama Niladari divisions.

In section one of the survey, you will be provided with information about the survey, background information on cascades, their present status and restoration needs. The section two is on selected attributes of the tank system and their levels reflecting different status of cascades. The section three explains the choice experiment survey, where eight choice questions on cascade restoration and one question for contingent valuation will be presented.

In section four of the survey, there will be some short questions about you, to help us understand what factors affect the way people feel about small tank cascades and their restoration.

This research is part of Shamen Vidanage's postgraduate studies through the Department of Economics at the University of Colombo. The survey is designed and implemented in association with IUCN-Sri Lanka, Colby College, USA and South Asia Network for Development and Environmental Economics (SANDEE) with final year students of the Faculty of Humanities, Rajarata University of Sri Lanka.

Your participation and answers to this survey will be held confidential.

**Participation is voluntary and will take approximately 45-60 minutes.**

Informed consent is required by participating institutions for any person participating in research study that they sponsor. This study has been approved by the participating institutions for Research with Human Subjects. Since this is an anonymous survey by returning the survey you are providing consent to be a subject of the study and acknowledge that the researcher has provided you with:

A. An explanation of the study's general purpose and procedure.
B. Answers to any questions you have asked about the study procedure

You should only complete this survey if you are over 18 years old. No unusual risks are anticipated as a result of participating in this research. Please complete the survey to the best of your ability. You may choose not to answer specific questions or discontinue the survey at any time. Your decision to participate, decline, or withdraw from participation will have no effect on future relations with IUCN, the University of Colombo, Colby College or SANDEE.



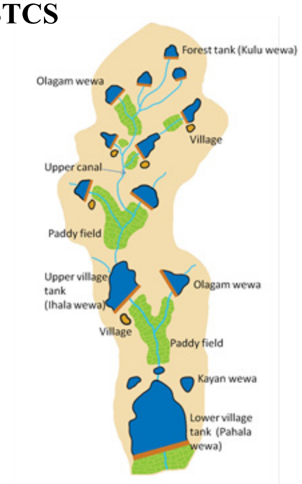
**Background Information on Cascades**

Small tank cascades systems are interconnected system of small irrigation tanks in Dry Zone of Sri Lanka believed to have started around 2500 years ago. They contribute directly to the rural lives and livelihoods of the Dry Zone and indirectly to the entire nation. These systems well managed in the past providing multiple benefits at highest level. However most of them are degraded today due to their poor maintenance over time

**Some of the well-known benefits of small tank cascade systems**

- Irrigation water for farming
- Water for bathing, washing and livestock
- Biodiversity and habitat conservation
- Medicinal plants, flowers, vegetables and fish
- Improvement of micro environment
- Recharge of ground water
- Adaptation to climate variability/change
- Carbon sequestration
- Building materials (bricks, poles and timber...)
- Water and soil conservation
- Medium for transport
- Flood and drought mitigation
- Educational benefits
- Cultural and spiritual values
- Recreation and tourism
- Other …

**Schematic diagram of a STCS**




Source: IUCN, 2016





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***Pihimbiyagollewa and Kapiriggama small tank cascades***

Source: Survey Department and Department of Agrarian Development

*Aerial photographs from Kapiriggama cascade (Photo credits: IUCN)*

If the present trend continues, these cascades will further degrade and the services they provide will disappear gradually. Therefore, cascade restoration and their sustainable management programme is proposed. We suppose to collect your ideas and get your contribution to design and implement such a programme.

***Pictures showing different uses of small tanks (various locations)***

Source: http://www2.ir3s.u-tokyo.ac.jp/icssasia2012/PDF%20files/S1-Srikantha%20Herath.pdf

Photo credits: IUCN

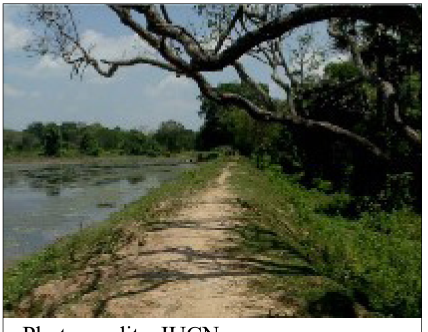


Photo credits: IUCN

Photo credits: IUCN

***Some of the benefits from small tank cascade systems***

**Small Tank Cascade Restoration and Sustainable Management**

Degraded cascades need to be scientifically studied as a single functional unit and interventions such as desilting, restoration of upper watershed, tank components such as *Kattakaduwa, Gasgommana, Perahana* and *Iswetiya* etc. to be undertaken keeping the overall functionality/ systems features of the cascade in mind. Similarly tank bunds, water management devices and canal systems needs restoration. Mandated technical agency like Department of Agrarian Development will have to take the technical lead while farmer organisations fully participate in the restoration and maintenance of these systems holistically thereafter for long term benefits of these systems

***Small tank (Messalewa wewa) dried up in dry season of 2012***

Photo credits: IUCN

DAD Surveying of Kapiriggama STC
Photo credit: IUCN

Removal of silt Kapiriggama STC
Photo credit: IUCN

Shrmadana in Kapiriggama STC
Photo credit: IUCN

Tree planting in Kapiriggama STC
Photo credit: IUCN

***Some of the events from cascade restoration programme in Kapiriggama***

If scientific restoration of cascade is undertaken, they will provide improved benefits to local communities directly dependent on these systems and to Sri Lanka as a whole as they conserve local biodiversity, provide educational, spiritual and aesthetic benefits to all including those who are not living in the locality.

## Section 2: Description of Attributes of Small Tank Cascades and their levels

### Features of cascade restoration

The table below provides selected characteristics or attributes of STC that represents quality of STC and their levels capable of measuring levels of STC quality.

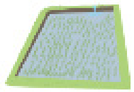
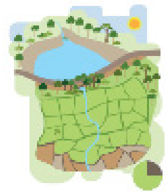
| Attribute Name | Description | Attribute Levels in a normal year |
|---|---|---|
| Availability of irrigation water for cultivating paddy during the dry season | Portion of paddy fields that can be cultivated out of entire paddy lands in the cascade with available water in the cascade during the dry (Yala) season[37] | -Water will be available for cultivating entire paddy fields.<br>-Water will be available for cultivating three fourth of paddy fields.<br>-Water will be sufficient to cultivate for about half of paddy fields. |
| Availability of water for other purposes in the cascade during dry season | Cascade wide availability of water for other non-irrigational uses like drinking, bathing, washing, recreation and livestock during the dry season | -Water will be available throughout the year for other purposes.<br>-Water will be available at least 10 months of the year for other purposes.<br>-Water will be available at least 8 months of the year for other purposes. |
| Extent of unique cascade ecological components | Unique cascades ecology represented by cascade ecosystem components *Kattakaduwa* and *Gasgommana*. They contribute to the species diversity, availability of NTFP[38] for local community and controls soil erosion.<br>Extent will be taken as full (100%) if the entire areas of these ecosystem components are covered with forest/natural vegetation according to latest google image. | -Cascade ecosystem components collectively fully covered with forest/natural vegetation of the entire cascade area<br>-Cascade ecosystem components collectively cover two third areas with forest/natural vegetation of the entire cascade area<br>-Cascade ecosystem components collectively cover one third areas with forest/natural vegetation of the entire cascade area |

[37] Water deficit dry cultivation season depends on tank water

[38] Non timber forest products

| | | |
|---|---|---|
| Cascade biodiversity | Different type of bird groups were selected as an indicator of the biodiversity of the cascade area.<br>Number of different bird groups found in the cascade during Yala season. | -About 12 types of bird groups found in the cascade during Yala season<br>-About 8 types of bird groups found in the cascade during Yala season<br>-About 4 types of bird groups found in the cascade during Yala season |
| Contribution to cascade management | Cash contribution that your household will have to pay every season (twice a year) for restoration and sustainable management of cascade at the selected option<br>Cash contribution per season | In LKR 0, 2,000, 4 000, 6,000, 8,000, 10,000 and 12,000 |

**Attributes and attribute levels by illustrated diagrams**

| | | | |
|---|---|---|---|
|  Availability of irrigation water for cultivating paddy during the dry season |  Water will be sufficient to cultivate for about half of paddy fields |  Water will be available for cultivat-ing three fourth of paddy fields |  Water will be available for cultivat-ing entire paddy fields |
|  Availability of water for other purposes in the cascade during dry season |   Water will be available at least 8 months of the year for other purposes |   Water will be available at least 10 months of the year for other purposes |   Water will be available thorough out the year for other purposes |



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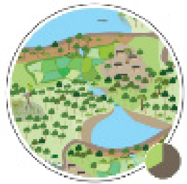
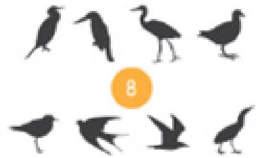
<table>
<tr><td><br>Extent of unique cascade ecological components</td><td colspan="2"><br>Cascade ecosystem components collectively cover one third areas with forest/natural vegetation of the entire cascade area</td><td colspan="2"><br>Cascade ecosystem components collectively cover two third areas with forest/natural vegetation of the entire cascade area</td><td colspan="2"><br>Cascade ecosystem components collectively fully covered with forest/natural vegetation of the entire cascade area</td></tr>
<tr><td><br>Cascade biodiversity</td><td colspan="2"><br>About 4 types of bird groups found in the cascade during Yala season</td><td colspan="2"><br>About 8 types of bird groups found in the cascade during Yala season</td><td colspan="2"><br>About 12 types of bird groups found in the cascade during Yala season</td></tr>
<tr><td><br>Contribution to cascade management</td><td><br>No monetary contribution</td><td><br>LKR 2,000 / season</td><td><br>LKR 4,000 / season</td><td><br>LKR 6,000 / season</td><td><br>LKR 8,000 / season</td><td><br>LKR 10,000 / season</td><td><br>LKR 12,000 / season</td></tr>
</table>

## Section 3: Introduction of Choice Sets and the Choice Experiment Survey

### Survey Instructions

This section of survey is designed to collect your ideas to restoration of the cascade or the tank system inclusive of your tank.

Your contribution will be asked to restore the previously mentioned *Pihimbiyagollewa* cascade to a better situation to design a programme to gain long term direct and indirect benefits to future generations as well. You can contribute by money/labour[39] and please consider the household level contribution while marking your choice.

Next, you were given the choice sets designed with different levels representing different attributes included in the cascade restoration. Your choice will be collected for 8 choice questions to identify the preferred restoration level and your contribution. Under each question, two options and the current situation (No any restoration) will be presented. Please carefully response to represent the whole cascade or the systems of cascade in your answers.



### 3.1. Choice experiment results

| Choice set number (Please mention whether the contribution is in cash (M) or by Labour (L) | | Selected option (A, B or C) |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |
| 6. | | |
| 7. | | |
| 8. | | |

[39] In the survey just one was given there was no option to select money/labour

## Section 4: General Information on the Respondents

In this section of the survey, there will be some short questions about you for us to understand what factors affect the way people feel about small tank cascades and their restoration.

Remember all your answers will be completely anonymous and strictly confidential.

### Personal Information

1. What is your gender?
   1. □ Male 2. □ Female

2. In which year were you born?

3. What is the highest level of education you have completed?
   1. □ No formal education 2. □ Primary education
   3. □ Secondary education 4. □ Technical education
   5. □ Bachelor's degree 6. □ Postgraduate degree

4. Where do you live in Pihimbiyagollewa cascade?
   4.1 Name of your village:
   4.2 Name of the GN division:
   4.3 GPS coordinates of the house:
   Latitude…………………. Longitude………………

5. Check the category that describe you well from the following.
   1.□ Full time farmer
   2.□ Part time farmer
   3.□ Other employment within cascade
   4.□ Other employment outside cascade
   5.□ Unemployed
   6.□ Retired

6. Household make up
   Details of respondents and family members





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| 6.1 Name | 6.2 Relationship with respondent[1] | 6.3 Age | 6.4 Sex[2] | 6.5 Marital status[3] | 6.6 Education[4] | 6.7 Main Occupation[5] |
|---|---|---|---|---|---|---|
| | Self | | | | | |
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**Codes:**

[1]1=Respondent, 2=Spouse (Wife/Husband/Partner), 3=Son/ Daughter, 4=Son/ Daughter (in law), 5=Grandchildren, 6= Father/Mother,7=Father/ Mother (In-law) 8=Sister/Brother (from birth/in law), 9=Uncle/Aunt, 10= Grandparents, 11=Other relatives, 12=Servant,13=Tenant

[2]1=Male 2=Female

[3]1=Married 2=Single 3=Divorced 4=Separated 5=Widowed 6=Other specify________

[4] 1=Illiterate 2= Literate or primary level 3= less than high school 4=high school

5=bachelor, higher than bachelor

[5]1=Agriculture 2=wage worker 3=business 4=Government service 5=NGO 6=Private sector 7=Student 8=Foreign employment 9=Elderly/disabled/ 10= household work 11= unemployed 12= other (specify)_________

7. Are you aware, that the most of the small irrigation tanks in Anuradhapura are not just isolated tanks but they constitute a part of a system of hydrologically interlinked system of tanks?
   1. □ Yes 2. □ No

8. Do you aware that these tank systems are named as Ellangawa before going through this survey details?
   1. □ Yes 2. □ No

9. Do you know of any other name being used for these systems? Please state the name

……………………………………………………………………………

10. In your opinion do animal biodiversity found in the cascade help or hurt your livelihood?
    1. Occasions of helping
    1.1..........................................................................
    1.2..........................................................................
    1.3..........................................................................

    2. Occasions of hurting
    2.1..........................................................................
    2.2..........................................................................
    2.3..........................................................................

    3. □ Don't know

11. What are the main benefits that you perceive from a restored cascade?
    1…………………………………………………………
    2…………………………………………………………
    3…………………………………………………………
    4…………………………………………………………
    5…………………………………………………………

12. Do you engage in fishing in small tanks?
    1.□ Yes 2. □ No

13. If you get water year around, do you engage in cultivating upland crops using agro wells?
    1.□ Yes 2. □ No

14. If the answer is yes to the above, how much money you make as net income per season

LKR ……………………………………

15. Does human-wildlife conflict in your area is increasing with decreasing availability of water in the cascade during dry season?
1. ☐ Yes 2. ☐ No 3. ☐ Not relevant

16. Explain your responses to control human-wildlife conflict.

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17. Do you think having well-functioning cascades contributes to better social cohesion?
1. ☐ Yes 2. ☐ No

18. Do you think controlling soil erosion as an important attribute of cascade quality?
1. ☐ Yes 2. ☐ No

19. How important is well managed cascades in improving water quality in tanks?
1. ☐ Important 2. ☐ Not Important 3. ☐ Do not know

20. According to your opinion, which statement explains most about the kidney disease condition in Ellangawa?
1. ☐ Main health problem
2. ☐ One health problem (out of many)
3. ☐ Don't know

21. Does your family have patients of kidney disease?
1. ☐ No 2. ☐ Yes





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22. According to your opinion, what makes the kidney disease abundant in Anuradhapura?

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23. Do you think these small tank cascades are valuable assets?
1. ☐ Yes 2. ☐ No

24. In your opinion, how would you describe the current state of Pihimbiyagollewa cascade?
1. ☐ Well-functioning 2. ☐ not well-functioning
3. ☐ do not know

25. If your response to above is 'not well-functioning' state the reasons for that and what you proposed to change the situation.
Reasons

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Suggestions to change the situation

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..............................................................................................

26. What are the periodic payments that you make currently?

| Type of payment | Amount (LKR) | Frequency (monthly, seasonally, annually) |
|---|---|---|
| 1. Farmer organisation | | |
| 2. *Maranadara samithiya* | | |
| 3. ………………………. | | |
| 4. ………………………. | | |

27. Please check the box indicates your monthly family income category.

1. ☐ Less than LKR. 10,000
2. ☐ LKR 10,001 - 20,000
3. ☐ LKR 20,001 – 50,000
4. ☐ LKR 50,001 – 100,000
5. ☐ LKR 100,001 – 150,000
6. ☐ LKR 150,001 – 200,000
7. ☐ More than LKR 200,000

28. Please mention your comments and ideas about this survey.
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# Annex 5B:
# Structure of the Questionnaire used in the off-site survey

## Contribution of Small Tank Cascade Systems to Dry Zone Rural Economy of Sri Lanka: Capturing Non-Market Values

## Survey on Appreciation of Small Tank Cascade Systems, their Restoration and Sustainable Management by Urban Community

**Survey Information for Enumerators**

| | | | |
|---|---|---|---|
| 0.1 | Day: | 0.2 | Time: |
| 0.3 | Questionnaire No.: | 0.4 | Enumerator's Name |



### Section 1 –General Information on the Survey

### Background to the Survey

Thank you very much for your interest in this survey. The survey is to study what people think about clusters of small irrigation tanks (reservoirs) in Dry Zone of Sri Lanka.

**Participation is voluntary and will take approximately 30 minutes.**

Informed consent is required by participating institutions of this research study as this study has been with Human Subjects. Since this is an anonymous survey by taking the survey you are providing consent to be a subject of the study and acknowledge that the researcher has provided you with:

A. An explanation of the study's general purpose and procedure.
B. Answers to any questions you have asked about the study procedure

You should only complete this survey if you are over 18 years old. No unusual risks are anticipated as a result of participating in this research. Please complete the survey to the best of your ability. You may choose not to answer specific questions or discontinue the survey at any time. Your decision to participate, decline, or withdraw from participation will have no effect on future relations with IUCN, the University of Colombo, Colby College or SANDEE.

The section one of this questionnaire will provide you with information about the survey, background information on cascades, their present status and restoration needs. The section two is on selected attributes of the tank system and their levels reflecting different status of cascades. The section three explains the choice experiment survey with options for you to choose. In section four of the survey, there will be some short questions about you, to help us understand what factors affect the way people feel about small tank cascades and their restoration.

This research is part of Mr. Shamen Vidanage's postgraduate studies through the Department of Economics at the University of Colombo. The survey is implemented with technical and financial support from IUCN-Sri Lanka, Colby College, USA, Department of Economics of the University of Colombo, South Asia Network for Development and Environmental Economics (SANDEE) and implemented by the final year students of the Department of Economics, University of Colombo, Sri Lanka.



Your participation and answers to this survey will be held confidential.

**Background Information on Cascades**

These clusters of tanks are called small tank cascade (STC) systems. The STC can be considered the life blood of Dry Zone civilization of Sri Lanka, over time these systems degraded, we are interested to find out about your perceptions on their restoration and sustainable management. We have chosen *Pihimbiyagollewa* STC in Anuradhapura district to represent STC systems of Sri Lanka for this survey. This cascade has 22 interconnected tanks and located in *Rambewa* and *Kahatagasdigiliya* Divisional Secretariat divisions. *Pihimbiyagollewa* cascade area accommodates around 1,000 families and spread out in 9 Grama Niladari divisions.

Small tank cascades systems are interconnected system of small irrigation tanks in Dry Zone of Sri Lanka believed to have started around 2500 years ago. They contribute directly to the rural lives and livelihoods of the Dry Zone and indirectly to the entire nation. These systems well managed in the past providing multiple benefits at highest level. However, most of them are degraded today due to their poor maintenance over time.

..........................................................................................

Note: Survey questionnaire from this point to Section 3 were identical in on site as well as off-site samples. Therefore, it has been omitted in this. Please refer to Annex 5A for complete questionnaire used for the on-site sample.

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**Section 3: Introduction of Choice Sets and the Choice Experiment Survey**

**Survey Instructions**

This section of the survey is designed to collect your choices on restoration options of the cascade or the tank system.

In this section your contribution will be asked to a given restoration option of the previously mentioned *Pihimbiyagollewa* cascade. Such restoration programme will provide long term direct and indirect benefits to present as well as future generations.

You will be given 8 sets of choice cards one after the other containing different levels of cascade attributes depicting different levels of cascade restoration. Under each choice card, two restoration options and the current situation/status quo (no any restoration) will be presented. Your choices per card will be collected to identify the preferred restoration levels and associated contributions. Please carefully respond having the whole cascade or the systems of tanks represented in your answers. Contribution that you indicate is from your entire family. The indicated contribution has to be made twice a year for a foreseeable future.



Please serve the appropriate Choice Card

> **Instructions to Enumerator:** there are nine sets of choice cards available to you. Each set contains 8 choice cards (CC), each one of the choice cards have three alternatives for cascade restoration with the present status as one of them. These 8 sets of CCs need to be used equally in the sample. Therefore, please start with the CC set number communicated to you by the survey coordinator for your first interview. Thereafter use the CC sets in ascending order one after the other for your interviews. In a survey issue one card at a time from the chosen CC set and record responses in the table 3.1.

### 3.1. Choice experiment results

| Choice set number with M letter | | Selected option (A, B or C) |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |
| 6. | | |
| 7. | | |
| 8. | | |



### Section 4: General Information on the Respondents

In this section of the survey, we will ask few short questions about you for us to understand what factors affect the way people feel about small tank cascades and their restoration.

Remember all your answers will be completely anonymous and strictly confidential.

**Personal Information**

1. What is your gender?
   1. ☐ Male 2. ☐ Female

2. In which year were you born?

3. What is the highest level of education you have completed?
   1. ☐ No formal education 2. ☐ Primary education
   3. ☐ Secondary education 4. ☐ Technical education
   5. ☐ Bachelor's degree 6. ☐ Postgraduate degree

4. Where do you live?
   4.1 Name the place of residence:
   4.2 Name of the district:
   4.3 GPS coordinates of the house
   Lat…………………. Long ………………..

5. What do you do for living?
   1. ☐ working in the government 2. ☐ working in private sector
   3. ☐ working in a NGO 4. ☐ self employed
   5. ☐ currently unemployed 6. ☐other

   ………………………………..

6. Please check the box indicates your monthly family expenditure category.
   1. ☐ Less than LKR. 20,000 2. ☐ LKR 20,001 - 50,000
   3. ☐ LKR 50,001 – 80,000 4. ☐ LKR 80,001 – 100,000
   5. ☐ LKR 100,001 – 150,000 6. ☐ LKR 150,001 – 200,000
   7. ☐ More than LKR 200,000

7. Before you went through this survey were you aware, that the most of the small irrigation tanks in Anuradhapura are not just isolated tanks but they constitute a part of a system of hydrologically interlinked system of tanks?
   1. ☐ Yes 2. ☐ No

8. Do you or your family members come from a part of Sri Lanka with cascade tanks?
   1. ☐ Yes 2. ☐ No

9. In the last five years have you visited to see any of the cascade tank systems in Sri Lanka?
   1. ☐ Yes 2. ☐ No

10. Are you expecting to visit to see cascade tank systems in near future?
   1. ☐ Yes 2. ☐ No

11. In your opinion what are the main values and benefits that people in urban areas may derive from these systems?

……………………………………………………………………
…….........................................................................................
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..................................................................................................
..................................................................................................
..........................................

12. Did you know about the word ellangawa/cascades before going through this survey details?
   1. ☐ Yes 2. ☐ No

13. Please check the box indicates your monthly family income category.

1. ☐ Less than LKR. 20,000
2. ☐ LKR 20,001 - 50,000
3. ☐ LKR 50,001 – 80,000
4. ☐ LKR 80,001 – 100,000
5. ☐ LKR 100,001 – 150,000
6. ☐ LKR 150,001 – 200,000
7. ☐ More than LKR 200,000

14. Please mention your comments and ideas about this survey.

……………………………………………………………………………………………
……………………………………………………………………………………………
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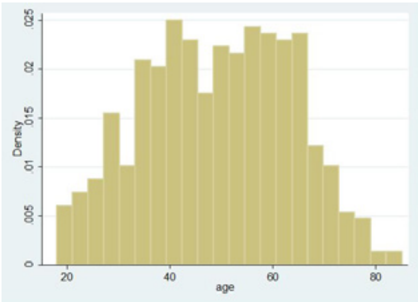
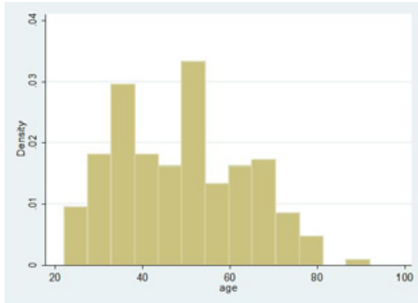
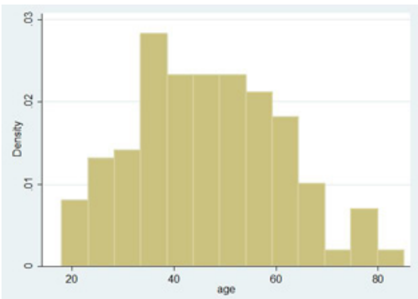
# Annex 6: Demographic Features of Sample Categories



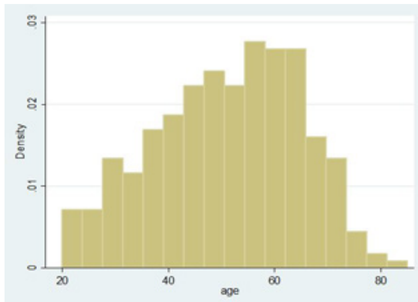

*Pihimbiyagollewa* on-site survey age distribution



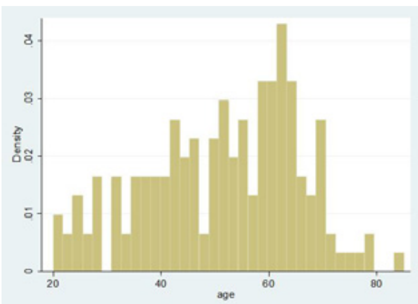

*Pihimbiyagollewa* off-site survey age distribution



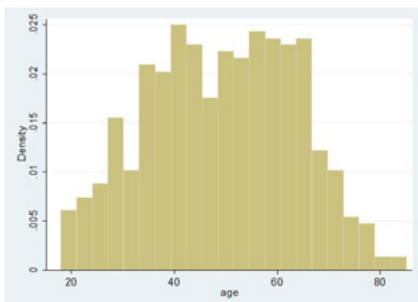

Age distribution Group – overall




Age distribution Individual – overall




*Pihimbiyagollewa* on-site Group Labour




*Pihimbiyagollewa* on-site Individual Labour

# Annex 7: Benefit Cost Analysis Data Sheets of *Pihimbiyagollewa* STCS

| **Conventional BC Analysis** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | | **Change %** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Cost | 125,237,091 | 1 | 19,526,109 | 37,324,466 | 58,818,461 | 9,568,055 | | | | |
| O&M annual & periodic | 156,546,364 | 1 | | | | | 6,261,854 | 6,261,855 | 6,261,855 | 6,261,855 |
| Total Cost | 281,783,455 | 1 | 19,526,109 | 37,324,466 | 58,818,461 | 9,568,055 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 |
| | | | | | | | | | | |
| Incremental Benefit (LKR/Year) | 248,000,000 | | | | | 4,000,000 | 8,000,000 | 12,000,000 | 16,000,000 | 16,000,000 |
| Increased paddy production (kg) | | | | | | 100,000 | 200,000 | 300,000 | 400,000 | 400,000 |
| Yield (kg/ha) | 4,000 | 1 | | | | | | | | |
| Increased hactarage of irrigation/yr | 100 | 1 | | | | | | | | |
| Market price of paddy (LKR/kg) | 40 | | | | | | | | | |
| | | | | | | | | | | |
| Net benefits (FV) | | | (19,526,109) | (37,324,466) | (58,818,461) | (5,568,055) | 1,738,145 | 5,738,145 | 9,738,145 | 9,738,145 |
| PV Benefits | 99,071,104 | | | | | | | | | |
| PV Costs | 164,690,049 | | | | | | | | | |
| BC Ratio | 0.60 | | | | | | | | | |
| NPV | (65,618,945) | | | | | | | | | |
| IRR | -3.10% | | | | | | | | | |



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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| | | | | | | | | | | | |
| 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 |
| 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 |
| | | | | | | | | | | | |
| 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 | 16,000,000 |
| 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 | 400,000 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| (9,047,418) | 9,738,145 | 9,738,145 | 9,738,145 | 9,738,145 | (9,047,418) | 9,738,145 | 9,738,145 | 9,738,145 | 9,738,145 | (9,047,418) | 9,738,145 |





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| ECBA | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | | **Change %** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Cost | 281,783,455 | | 19,526,109 | 37,324,466 | 58,818,461 | 9,568,055 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 |
| Incremental Benefit (LKR/year) | | | | | | | | | | |
| Paddy full extend (LKR/yea/household) | 51,014 | 1 | | | 11,478,150 | 22,956,300 | 34,434,450 | 45,912,600 | 45,912,600 | 45,912,600 |
| Water (LKR/year/household) | 32,732 | 1 | | | 7,364,700 | 14,729,400 | 22,094,100 | 29,458,800 | 29,458,800 | 29,458,800 |
| Biodiversity (LKR/year/household) | 11,760 | 1 | | | | | | 2,646,000 | 2,646,000 | 5,292,000 |
| Total benefits | | | - | - | 18,842,850 | 37,685,700 | 56,528,550 | 78,017,400 | 78,017,400 | 80,663,400 |
| No of households | 900 | | | | | | | | | |
| **Net Benefits stream in FV** | | | | | | | | | | |
| Paddy full extend Net Benefit FV | | | (19,526,109) | (37,324,466) | (47,340,311) | 13,388,245 | 28,172,595 | 39,650,745 | 39,650,745 | 39,650,745 |
| Water Net Benefit FV | | | (19,526,109) | (37,324,466) | (51,453,761) | 5,161,345 | 15,832,245 | 23,196,945 | 23,196,945 | 23,196,945 |
| Biodiversity Net Benefit FV | | | | | (11,478,150) | (22,956,300) | (34,434,450) | (43,266,600) | (43,266,600) | (40,620,600) |
| Total Net Benefit FV | | | (19,526,109) | (37,324,466) | (39,975,611) | 28,117,645 | 50,266,695 | 71,755,545 | 71,755,545 | 74,401,545 |

| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 | 6,261,855 | 6,261,855 | 6,261,855 | 25,047,418 | 6,261,855 |
| | | | | | | | | | | | |
| 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 | 45,912,600 |
| 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 | 29,458,800 |
| 5,292,000 | 7,938,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 | 10,584,000 |
| 80,663,400 | 83,309,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 | 85,955,400 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 20,865,182 | 39,650,745 | 39,650,745 | 39,650,745 | 39,650,745 | 20,865,182 | 39,650,745 | 39,650,745 | 39,650,745 | 39,650,745 | 20,865,182 | 39,650,745 |
| 4,411,382 | 23,196,945 | 23,196,945 | 23,196,945 | 23,196,945 | 4,411,382 | 23,196,945 | 23,196,945 | 23,196,945 | 23,196,945 | 4,411,382 | 23,196,945 |
| (40,620,600) | (37,974,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) | (35,328,600) |
| 55,615,982 | 77,047,545 | 79,693,545 | 79,693,545 | 79,693,545 | 60,907,982 | 79,693,545 | 79,693,545 | 79,693,545 | 79,693,545 | 60,907,982 | 79,693,545 |

| ECBA Results | BC Ratio | | IRR | NPV |
|---|---|---|---|---|
| PV Paddy Full Extent | 369,60,902.62 | 2.24 | 24% | 204,920,854 |
| PV of Water | 237,152,626.04 | 1.44 | 13% | 72,462,577 |
| PV of Biodiversity | 66,546,405.54 | 0.40 | na | (98,143,643) |
| PV of Total | 565,492,293.30 | 3.43 | 41% | 400,802,244 |
| PV Costs | 164,690,048.93 | | | |
| Discount Rate | 8% | | | |

**Sensitivity Analysis for EBCA**

| | Base Case | | | Cost Increased by 40% | | | Benefits Decreased by 40% | | | Cost Increased by 40% and Benefits Decreased by 40% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV | BC Ratio | IRR | NPV |
| Paddy Full Extend | 2.24 | 24% | 204,920,854 | 1.60 | 15% | 139,044,834 | 1.35 | 11% | 57,076,493 | 0.96 | 3% | (8,799,527) |
| Water for Other Users | 1.44 | 13% | 72,462,577 | 1.03 | 5% | 6,586,558 | 0.86 | 1% | (22,398,473) | 0.62 | -10% | (88,274,493) |
| Total Benefits | 3.43 | 41% | 400,802,244 | 2.45 | 30% | 334,926,225 | 2.06 | 25% | 174,605,327 | 1.47 | 17% | 108,729,307 |

**Cost Details**

| Kapiriggama costing summary | Year 1 | Year 2 | Year 3 | Year 4 | Total |
|---|---|---|---|---|---|
| Annual Totals Cash (LKR) | 11,721,881 | 22,344,282 | 35,553,062 | 5,384,937 | 75,004,161 |
| Labour Contribution | 774,208 | 1,548,416 | 2,064,555 | 774,208 | 5,161,387 |
| DAD Contribution | 1,172,188 | 2,234,428 | 3,555,306 | 538,494 | 7,500,416 |
| Total Cost (70% Restoration) | 13,668,277 | 26,127,126 | 41,172,922 | 6,697,639 | 87,665,964 |
| Full Restoration Cost | 19,526,109 | 37,324,466 | 58,818,461 | 9,568,055 | 125,237,091 |
| O&M Annual (5% of the Full Cost) | 6,261,855 | | | | |
| Periodic Every 5 Year (20% of the Full Cost) | 25,047,418 | | | | |

## Annex 8: Photo Catalogue

Photo credits for the above collection of pictures are given below, pictures are numbered starting from the top left corner and continue clockwise.

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The middle Photo: IUCN and all other photos: S.P. Vidanage





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# Economic Value of an Ancient Small Tank Cascade System in Sri Lanka

Shamen P. Vidanage

Small Tank Cascade Systems (STCS) are part of the heritage of the country. Investment into restoration of degraded STCS are often found financially not feasible due to narrowly defined assessment of benefits of these systems. The main reason for such is the bulk of the multiple benefits generated by STCS belong to ecosystem goods and services which are not provided through the market system; hence not reflected in the market determined monetary value. This research is undertaken to elicit the Willingness to Pay (WTP) for restoration and sustainable management of a representative small tank cascade system, to assess Marginal Willingness to Pay (MWTP) for selected cascade attributes and to develop and validate a Benefit Cost Analysis (BCA) framework for decision-making in restoration and sustainable management of small tank cascade systems.The study has pioneered the use of state-of-the-art non-market valuation technique to a small tank cascade taking "the entire cascade" as the unit of analysis. Furthermore, this is also the first application of Choice Experiment (CE) non-market valuation technique in small tank cascade systems in Sri Lanka.

About the Author: Shamen Vidanage is currently a Senior Lecturer at the Department of Zoology and Environmental Management, Faculty of Science University of Kelaniya. He was the Programme Coordinator at International Union for Conservation of Nature and Natural Resources (IUCN), Sri Lanka Programme, where he served over 17 years. Shamen graduated from University of Peradeniya with BSc (Hon) Degree in Agricultural Sciences, obtained his MSc in Environmental Economics from the Postgraduate Institute of Agriculture, University of Peradeniya, his Masters in Economics and PhD in Economics from the University of Colombo.

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