WORKING PAPER

CROP PRODUCTION PRACTICES IN VILLAGE TANK SYSTEMS IN DRY ZONE SRI LANKA

W.H.A SHANTHA
G.G. de L.W. SAMARASINHA

HARTI

Hector Kobbekaduwa
Agrarian Research and
Training Institute

Crop Production Practices in Village Tank Systems in Dry Zone Sri Lanka

W.H.A. Shantha
G.G. de L.W. Samarasinha

Working Paper No: 14 August 2021

Hector Kobbekaduwa Agrarian Research and Training Institute
114, Wijerama Mawatha
Colombo 07
Sri Lanka

First Published: 2021

Final typesetting and lay-out by: Niluka Priyadarshani de Silva

ISBN:

Suggested citation: Shantha, W.H.A. and Samarasinha, G.G. de L.W., 2021. Crop Production Practices in Village Tank Systems in Dry Zone Sri Lanka. HARTI Working Paper No: 14, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

FOREWORD

In Sri Lanka, farming is an indispensable part of the rural economy. To date rural communites largely depend on farming and various related activities to generate a decent income. The village level small scale tank cascades which support large scale irrigation systems is a unique feature of the country's hydraulic civilization. However, there is a large number of village tanks in abandoned state as well as sedimented condition due to a range of anthropogenic activities in tank catchment area. Tank sedimentation is a major threat that affects the small tank systems in most parts of the dry zone. Tank capacity reduction due to sedimentation has led to substantial productivity loss in the lowland cropping system in the respective command areas, resulting in serious negative effects on the environment as well as household economies.

Restoration of the small irrigation system is much desirable due to impending adverse impacts of global climate change such as high incidence of droughts and floods. Therefore, in this context restoration of village tank systems may prove highly beneficial in terms of increased cultivated extent, availability of water for other needs including livestock, domestic purposes, aquaculture, environmental services and many more.

Therefore, studying on village tank systems in the climate vulnerable dry zone is very timely and useful in understanding the contemporary agricultural production processes. I wish to congratulate the authors of this report for undertaking this valuable piece of study which provides useful insights for policymakers and relevant authorities to revive the traditional village irrigation system.

Malinda Senevirathne
Director/CEO

ACKNOWLEDGEMENTS

We are much thankful to former Directors of Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), Mr. Haputhanthri Dharmasena, Mr. K.W.E. Karalliyadda, Mr. K. Udage, Dr. K.B. Kotagama, Mr. W.H.D. Priyadarshana (Acting Director), Senior Prof. Ranjith Premalal de Silva and the present Director Mr. Malinda Seneviratne for the excellent guidance and assistance provided to complete this study successfully. Authors are also thankful to former Additional Directors of HARTI Mr. J.K.M.D. Chandrasiri and Mr. R.L.N. Jayatissa, the present Additional Director Dr. W.A.R. Wickramasinghe for their support and guidance rendered.

The technical advice and various support offered by Eng. D.D. Prabhath Vitharana, Head, Water Management Division, Department of Agrarian Development for this study is greatly appreciated. We highly appreciate the support given in various ways by the respondent farmers, field level officers attached to the Department of Agrarian Development, Department of Agriculture and Department of Irrigation by allocating their valuable time, which was instrumental for the successful completion of the study.

The continuous supervision by Mr. Sidath Bandara, Head, Environmental and Water Resources Management Division (EWRMD) for the conduct and publication of this study is highly appreciated. We also wish to thank Mr. A. Rathnasiri, Statistical Officer, Mr. N.L.M. Nalim, former Statistical Assistant of EWRM Division and the graduates who served as Investigators for the study, Mr. H.L. Sampath, Ms. K.S.H.M. Subasinghe, Ms. B.W.H.D.B. Witharana, Ms. W.B.G. Kaushalya, Mr. B.P.S. Jayampathi, Ms. H.E.N. Sandamali and Ms. W.H.K. Lakmali, for all the assistance given during the field data collection.

We also appreciate Ms. Niluka Priyadarshani de Silva, Acting Office Secretary, Ms. Uthpala Jinadari and the rest of the staff of EWRM Division for the support given throughout this study. Our sincere thanks are also extended to Mrs. K.S.N. Perera, Editor, HARTI for her expert editorial assistance. Finally, our appreciation goes to Mr. S.A.C.U. Senanayake, Head/Publication Unit of HARTI for proofreading the final report and to Dr. N.P.G. Samantha, Head/Communication Division for making arrangements to print the report. We appreciate the cheerful assistance extended by the printing staff of HARTI as well.

W.H.A. Shantha
G.G. de L.W. Samarasinha

EXECUTIVE SUMMARY

A total of around 16,000 small tanks, both operational and abandoned are scattered across 70 well defined river basins in the dry zone of Sri Lanka. In the North Western (NW) and North Central (NC) Provinces, about 20 - 30 percent of the storage of small tanks are sedimented, and hence their storage potential has declined. The rate of sedimentation has become extremely high compared to the past and it can be attributed to the increasing rate of upland cultivation in the tank catchments. Although a large number of studies have been carried out on sedimentation of large reservoirs located within the upper catchment areas of the country and its impact on different aspects of the economy, scant attention is paid to the small tanks and other reservoirs in the drier parts of the country. Therefore, this study was conducted to identify the recent land use changes and current pattern of crop cultivation in sedimented village tank systems in the dry zone of Sri Lanka.

The two cascades, Mahameruwa cascade in Mi Oya river basin in Kurunegala district and Maha Kumbukwewa cascade in Malwathu-Oya river basin in the Anuradhapura district that consist of minor tanks where sedimentation has been reported to be a problem affecting the livelihoods, were selected as study sites. The entire farmer households (312 households) practicing paddy cultivation in the fields fed by tanks in two village cascades were interviewed. It comprised 179 households from Mahameruwa cascade and 133 households from the cascade in Malwathu Oya river basin.

Long-term negligence and lack of attention in terms of rehabilitation and regular operation and monitoring (O&M) activities have further deteriorated the irrigation capacities of village tanks. Tank sedimentation resulting low capacity has led to issues such as shrinking of the cultivated area particularly in the dry *Yala* season and water scarcity for other activities including domestic purposes and livestock. Though, the entire command area of respective tanks is cultivated during rainy *Maha* seasons with paddy, the majority of the lands are not cultivated in *Yala* seasons. Because the food security is the foremost priority of farm households in the minor irrigation schemes, farmers whose lands are irrigable even in the dry seasons tend to grow paddy. The upland farming including the home gardening are mostly limited to rainy *Maha* seasons due to unavailability of supplementary irrigation facilities.

Rehabilitation of silted tanks while increasing the storage capacities of the operational tanks have been practiced by raising the spill and tank bund instead of adopting widely recommended partial desiltation methods. Selection of solitary tanks for rehabilitation work is practiced rather than using effective cascade-based approach in the study locations.

Due to lack of financial, technical and institutional capacities with the Farmer Organizations, tank rehabilitation activities are out-sourced to third party contractors, thus, the expected level of work quality and the standards cannot be expected. Therefore, it is recommended to provide training and awareness programs to enhance the capacities of FOs in terms of financial management, basic technical know-how on regular O&M activities and minor rehabilitation works.

In the absence of continuous supervision of the relevant officials, misconduct and malpractices are taking place in tank rehabilitation processes. Therefore, continuous supervision by officials with technical expertise should be ensured throughout the process, through which frequently occurring wrongful acts associated with tank desiltation could be controlled to a large extent.

TABLE OF CONTENTS

	Page No.
FOREWORD	i
ACKNOWLEDGEMENTS	ii
EXECUTIVE SUMMARY	iii
LIST OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	viii
ABBREVIATIONS	ix
CHAPTER ONE	1
Introduction	1
1.1 Background	1
1.2 Small Village Tanks	4
1.3 Research Problem	10
1.4 Research Objective	11
1.5 Research Methodology	11
1.5.1 Study Area	11
1.5.1.1 Mi Oya River Basin	12
1.5.1.2 Malwathu Oya River Basin	15
1.5.2 Data Collection and Analysis	19
1.5.2.1 Sample Distribution	19
1.5.3 Data Processing and Analysis	20
1.5.4 Limitations of the Study	20
CHAPTER TWO	21
Literature Review	21
2.1 Rainfall Distribution in Sri Lanka	21
2.2 Village Tank Cascade Systems of Sri Lanka	22
2.2.1 Issues of Cascaded Village-Tank Systems	28
2.2.2 Significance of Restoring the Cascade System	29
2.2.3 Village Tank Restoration and Rehabilitation Processes	32
CHAPTER THREE	37
Results and Discussion	37
3.1 Introduction	37
3.2 Demographic Information of the Farmer Households	37
3.2.1 Family Size	37
3.2.2 Gender Ratio	38

3.2.3 Age Distribution of Sample Farmers 38
3.2.4 Level of Education of Respondent Farmers 39
3.2.5 Farming Experience 40
3.2.6 Occupation.. 41
3.2.7 Type of Engagement in Farming 43
3.3 Crop Production Systems 44
3.3.1 Type of Lands Cultivated.. 44
3.3.2 Crop Cultivation in Home Gardens 45
3.3.3 Crop Cultivation in Lowlands 46
3.3.4 Upland Cultivation 50
3.3.5 *Chena* Cultivation... 53
3.4 Land Use Changes in the Study Areas 55
3.5 Reasons for Diminished Services of Village Tanks 62

CHAPTER FOUR 67
Conclusions and Recommendations 67
4.1 Major Findings, Conclusions and Recommendation 67

REFERENCES 69

LIST OF TABLES

Page No.

Table 1.1: Distribution of Study Sample ____ 20

Table 2.1: Tank Cascade Zones in Sri Lanka ____ 23

Table 2.2: State of Village Tanks in the Country ____ 25

Table 2.3: The State of Operation of Small Tanks in Major Dry Zone Provinces ____ 27

Table 3.1: Gender Distribution of the Sample ____ 38

Table 3.2: Age Distribution of Sample Farmers ____ 39

Table 3.3: Education Level of Sample Farmers ____ 40

Table 3.4: The Primary Occupation of Respondent Farmers ____ 42

Table 3.5: The Secondary Occupation of Respondent Farmers ____ 42

Table 3.6: Type of Farming Practiced by the Sample Farmers ____ 43

Table 3.7: Types of Lands Cultivated by Respondent Households ____ 44

Table 3.8: Source of Water for Home Gardening ____ 46

Table 3.9: Number of Lowland Parcels Owned by Households ____ 47

Table 3.10: Cultivation Patterns in Lowland Plots ____ 48

Table 3.11: Source of Water/Irrigation for Lowlands ____ 49

Table 3.12: Distribution of Upland Plots among Sample Households ____ 50

Table 3.13: Number of Upland Parcels Owned by Sample Households _ 51

Table 3.14: Distribution of Water Source in Uplands ____ 52

Table 3.15: Cropping Patterns in Uplands ____ 52

Table 3.16: Number of *Chena* Land Parcels Owned by Sample Households ____ 53

Table 3.17: Water Source for *Chena* Cultivation ____ 54

Table 3.18: Changes in Land Use Types in Mahameruwa Cascade ____ 59

Table 3.19: Changes in Land Use Types in Maha Kumbukwewa Cascade 62

Table 3.20: Reasons for Reduced Services from Village Tanks ____ 63

LIST OF FIGURES

		Page No.
Figure 1.1:	Distribution of Village Tanks in the Dry and Intermediate Zones	6
Figure 1.2:	Mi-Oya and Malwathu-Oya River Basins	12
Figure 1.3:	Mi-Oya River Basin	14
Figure 1.4:	Malwathu Oya River Basin	16
Figure 1.5:	Mahameruwa Cascade Area	17
Figure 1.6:	Maha Kumbukwewa Cascade Area	18
Figure 2.1:	Climatic Zones of Sri Lanka	21
Figure 2.2:	A Graphical Representation of a Small Tank Cascade System	24
Figure 2.3:	The density and distribution of small village tanks in the Dry and Intermediate Zones	26
Figure 3.1:	Number of Family Members in the Study Area	38
Figure 3.2:	Farming Experience of the Respondent Farmers	41
Figure 3.3:	Types of Lands Cultivated by Respondent Households	45
Figure 3.4:	Distribution of Lowlands by Extent	48
Figure 3.5:	Distribution of Uplands by Land Size	51
Figure 3.6:	Distribution of *Chena* Lands by Land Extent	54
Figure 3.7:	Land Use Map of Mahameruwa Cascade in 1983	56
Figure 3.8:	Land Use Map of Mahameruwa Cascade in 2018	57
Figure 3.9:	Land Use Map of Mahameruwa Cascade in 2018 (Sketch)	58
Figure 3.10:	Land Use Map of Maha Kumbukwewa Cascade in 1983	60
Figure 3.11:	Land use Map of Maha Kumbukwewa Cascade in 2018	61

ABBREVIATIONS

A/L	-	Advanced Level
ASC	-	Agrarian Services Centre
CC	-	Cultivation Committee
CVTS	-	Cascaded Village-Tank System
DAD	-	Department of Agrarian Development
DL	-	Low Country Dry Zone
DoA	-	Department of Agriculture
DS	-	Divisional Secretariat
FAO	-	Food and Agriculture Organization of the UN
FGD	-	Focus Group Discussion
FO	-	Farmer Organization
GA	-	Government Agent
GCE	-	General Certificate of Education
GIS	-	Geographical Information System
GN	-	Grama Niladhari
HH	-	Household
ID	-	Irrigation Department
ITCZ	-	Inter-Tropical Convergence Zone
MoA	-	Ministry of Agriculture
NC	-	North-Central
NCP	-	North-Central Province
NGO	-	Non-Governmental Organization
NW	-	North-Western
NWP	-	North-Western Province
OFC	-	Other Field Crop

O/L	-	Ordinary Level
O&M	-	Operation and Maintenance
PWD	-	Public Works Department
RS	-	remote Sensing
SP	-	Southern Province
SW	-	South-West
TCEO	-	Territorial Civil Engineering Organization

CHAPTER ONE

Introduction

1.1 Background

Sri Lanka is well known for her rich and proud history of irrigation development with hydraulic civilization over 2000 years. The reservoir tanks and a large number of derivatives of water channels still being used today from ancient times testifies the brilliance of the highly developed hydraulic engineering heritage in Sri Lanka (Mogi, 2007). The historical hydraulic civilization of the dry zone of Sri Lanka since the 6th century B.C. has created and developed a number of unique strategies for water resources management as well as to maintain the hydraulic culture (Perera, 2017). The evolution of water civilization in Sri Lanka has links to the latter part of the early Iron Age. The early settlers who were earning their living as hunters and gatherers in the dry zone had to live closer to the natural water holes called *villus* to meet the domestic water needs, as seasonal water paths and small streams ran dry during the rainless periods (Tennakoon, 2017).

The rudimentary iron implements are believed to be used by the people to dig the shallow *villu* bottoms and increase the water storage to some extent. Thus, in the latter part of the early Iron Age, with the improvements of the quality of the iron implements the settlers were able to dig *villus* and remove the dug-out earth from them (Panabokke, 2009; Dharmasena 2010b). Tennakoon (2017) established the fact that the continuous and gradual improvements of iron implements during the final stage of the Iron Age enabled the people also to clear small patches of forest, particularly with the use of socket axe to grow some dry grains which very much later gave rise to the highland farming practices of slash-and-burn type *chena* cultivation in which finger millet, mustard and gingerly were cultivated in short rainy seasons.

With the increase of population, the water demand for domestic use from the *villus* also increased. This situation compelled settlers to deep *villus* further and pile the dug-out earth along the lower parts of the *villu* rim to increase the water retention capacity of *villus* converted to 'pools' (Tennakoon, 2017). The seasonal small water paths and tributaries in the interior areas of the dry zone were also begun to be converted into small water pools to be used in the rainless period. As per FAO (2017), the modifications introduced to *villus* was the forerunner of the commencement of construction of small tanks in Sri Lanka.

In addition to nature (characterized by the climate) and the local landscapes (geography) with which settlers tied in developing their own culture and lifestyles, the social, political and economic interactions with neighboring countries have also interfered in entire process of evolution including the ancient water civilization in Sri Lanka (Mogi, 2007; Dharmasena, 2010b). By the arrival of 'Aaryan' colonists around 500 BC, small scale irrigation systems were already operational in Sri Lanka (FAO, 2017). Land and water became the most important resources for the early colonists who settled in the northern dry zone where there were ample opportunities for crop cultivation (Seneviratne, 1987). Introduction of wet paddy cultivation that provides higher crop yields in comparison to the finger millet grown in uplands, to meet the ever increasing demand for food from the increased population was the key driver for people to improve and modify water pools to provide improved irrigation facilities (Tennakoon, 2017).

The availability of water resources, particularly for wet paddy cultivation was the key factor taken into consideration in the spread of early settlers from northern dry zone areas to dry zone localities in the south-eastern part. Thus, villages of the early settlers are mostly found along the rivers. Thambapanni on the southern bank of the Aruvi Aru; Upatissagaama on the Kanadara Oya; Anuradhagaama by the Malwathu Oya; Vijitanagara close to the Mahaweli Ganga; Uruvela near to the mouth of Kala Oya; Dighavapi on the Gal Oya and Maagama by the Kirindi Oya are a few such places (Seneviratne, 1987).

According to Dharmasena (2020), the early societies of water civilization have thrived on small irrigation systems with unique assemblages of land uses and agricultural attributes. Possibly, these systems have evolved from the early rainfed shifting agriculture into small-scale irrigation systems that in turn have led to major irrigation systems. Since the building of *Abayawewa* in 3rd century BC, the first large irrigation tank in the recorded history, Sri Lankan tank builders have developed a remarkable expertise on controlling large bodies of water which allowed them to build massive reservoirs to irrigate large extent of paddy fields and meet the water demand from the emerging urban centers like Anuradhapura (FAO, 2017). Fernando (1979) has identified 44 ancient major irrigation reservoirs covering a surface area of approximately 39,000 ha. Civilizations whose agriculture and culture were dependent upon minor as well as large-scale waterworks for irrigation, flood control and water supply are referred to as "hydraulic civilizations". The conditions that prevailed in the dry zone Sri Lanka fitted into this description quite well (Maddumabandara, 2009). The sedentary way of life facilitated by this hydraulic base has led to land tenure, property inheritance, and social organizations that persisted for centuries (Dharmasena, 2020).

The ancient irrigation development in the dry zone of Sri Lanka, thus, have gradually evolved over centuries. Jayasena & Selker (2004) pointed out that it has been technically evaluated and refined with a time tested remodeling activities more than thousand years and in this sense the water system evolved rather than being put in as an externally-conceived, untested complete system. Over the time, the changes in water regime in the dry zone had developed the irrigation systems consisting of a large number of village tanks to gigantic reservoirs and an intrinsic network of water canals connecting these tanks while supplying water to farming lands (FAO, 2017).

Dharmasena (2020) summarizes the evolution of ancient irrigation system in Sri Lanka. Accordingly, a number of stages of the development of irrigation systems have been identified, First stage - collection of rainwater in a pond or valley, lift irrigation using primitive implements to irrigate the surrounding paddies; Second stage - development of low artificial embankments or weirs built across the valleys of small ephemeral rivulets, such a tank would have a depth of 2.5 m, tank followed downstream by yet another tank and paddy fields; Third stage - improvement of the former type, the bunds strengthened; extent of irrigable land improved but still not part of a complex network of tanks; Fourth stage - damming of the bed of comparatively large non-perennial rivers, e.g. Kala Oya (Dhatusena, 459 AD), water distribution capabilities increased, special channels constructed to transmit water, catchments linked; Fifth stage - construction of reservoirs on large, ephemeral rivers and tributaries and linking these to anicuts built on rivers having catchment areas of perennial water supply in the wet zone, e.g. anicut at Elahera across the Amban Ganga (tributary of Mahaweli Ganga), built by Vasabha (65–109 AD), later enlarged and diversified by Mahasena (276–303 AD), feeds the Minneriyawewa. This stage was also characterized by building of spills and sluices; Sixth stage - trans-basin transfer of water from a perennial catchment to an ephemeral catchment-based reservoir, e.g. Amban Ganga catchment linked with Kala Oya catchment, highest complexity by the eighth century AD.

1.2 Small Village Tanks

Maddumabandara (2009) has described village tank settlements as the back-bone of the hydraulic civilization in Sri Lanka. Small tanks or village tanks are also intermittently called minor irrigation systems (Aheeyar, 2013). According to Panabokke (1999), two main traditions of Sri Lanka's irrigation heritage, the small village-based tank and anicut systems belong to the Greater Tradition (*Mahasammatha*) against the *Chulasammatha* or the Lesser Tradition which emerged from the construction and management of the large storage reservoirs and canal complexes have evolved. The greater tradition contains the elements associated with the wide spread paddy cultivation-culture based on the village tanks and anicut systems. It along with norms, customs and rules governing water management for paddy-based crop production and ecosystems services has endures intervening centuries up to the present. The irrigation technology and institutional base of the management of lesser tradition, however, that represents the later and higher evolutionary steps in irrigation development in Sri Lanka have not survived. Panabokke (1999) particularly argued that the major irrigation works have been much sensitive to foreign invasions, civil strife and physical hazards that periodically disrupted central authority of the ancient kingdoms. However, as the building and operation and management of small tanks have been carried out by the local communities, the survival of those systems and continued usage were guaranteed even amidst external stresses.

According to Seneviratne (1987), in the ancient times, the small village tanks have mostly been privately owned by people called *Vavihamika* belonging to the noble class, *Parumukas.* Further, *Gamika* and *Gaamani* were also said to be the nobles having the ownership and commanding over village small tanks. Panabokke (1999) pointed out that the capital in terms of labour efforts and material invested in building of small village tanks were colossal and it represented the continuous development and management efforts by the generations of village communities over centuries. Such efforts and investments have developed the strong common property sense over the use of village water resource. This common property sense has generated and developed appropriate institutional set ups to maintain the order and stability of these systems (Panabokke, Shakthivadivel & Weerasinghe, 2002).

The water management systems associated with the ancient hydraulic civilization have been adapted to furnish diverse water needs for anthropological and environment functions as water was the essence for the survival (Jayasinghe & Rambodagedara, 2019). Thus, building of village tanks were largely meant for meeting the water demand from domestic purposes and irrigation, village tanks provide water for animals (both the livestock and wild animals) and for the other ecosystem functions of the surrounding environment. Siriweera (2002) emphasizes that inland fishing in fact was much prevalent in small tanks and it used to be an important protein source for the rural communities. Thus, small village tanks in the ancient times are considered the major contributor to the food security levels of the agrarian societies. Therefore, the village tanks have been providing direct and indirect economic benefits and environmental services for the sustenance of the natural and socio-cultural systems in the dry zone landscapes.

In the early stage of the water civilization, the major irrigation systems were developed involving Malwathu-Oya, Kala-Oya and Mahaweli river and the tributaries of these prominent rivers in the dry zone. These large scale irrigation systems were immensely supported by well distributed village level small scale tank systems in the dry zone areas (Murray and Little, 2000). Approximately, a total of 12,000 - 16,000 small tanks, both operational and abandoned, are presently found distributed across 70 well defined river basins in the dry zone (Figure 1.1). However, the realistic numbers of small tanks in operation and dilapidated/abandoned conditions should be much difference against these approximations (Panabokke, Tennakoon & Ariyabandu, 2001; Panabokke, Shnkthivadivel & Weerasinghe, 2002).

Source: Tennakoon (2017)

Figure 1.1: Distribution of Village Tanks in the Dry and Intermediate Zones

The village tanks distributed in the Dry Zone are not isolated entities and they are not randomly located (Aheeyar, 2013). Though they have physical differences from one another these tanks are within certain patterns that are hydrologically and socially determined. They have been remaining economically and socially beneficial and eco-friendly 'pools' of water which have become acclimatized to the extent that they have become an integral part of the dry zone environment (Panabokke, Tennakoon and Ariyabandu, 2001). Maddumabandara (1985) proposed the term ***Tank Cascade*** with a definition to the series of such interconnected village tanks. Thus, tank cascade is a 'connected series of tanks (irrigation reservoirs) organized within a micro-catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet and is considered as one of the traditional land water management systems which has obviously been developed on the basis of catchment ecosystems. Later, Panabokke (IIMI-SLFO 1994; Shakthivadivel et al., 1996) proposed some minor refinements to the terminology of the above definition.

However, Dharmasena (2017a) observed that with the advancement of understanding the perception of the Dry Zone landscape, the tank cascade definitions by previous scholars have shown limitations to describe the whole concept of cascade formation on the landscape and specific features evolved subsequently due to the human adaptation and nature's contribution to the system equilibrium. Thus, the tank cascade is defined as 'an ecosystem, where land and water resources are origanized within the micro-catchments of the dry zone landscape, providing basic needs to human, floral and faunal communities through water, soil, air and vegetation with human intervention on sustainable basis'. Therefore, the socio-cultural attributes and ecosystem features and their functions relating to a series of village tanks located in a common micro (meso) catchment are considered to be a cascaded village-tank system (CVTS).

The tank cascade systems are associated with a variety of ecological and socio-economic subsystems that include (a) the ecological system with catchment forests, aquatic habitats, and the commons (b) land use zoning systems (c) various crop combination systems (d) elaborate water management systems including, sluices, spills, water control weirs (*Karahankota*) with rotational water distribution systems (e) management systems such as *Velvidane* (Irrigation Headman) system that dates back to pre-colonial times.

The foundation for the largest part of the country's agricultural production, the village tanks host a remarkable heritage of agro-biodiversity and wild biodiversity and constitute a unique buffer against natural disasters and climate change. The significance of this system is high due to the practical solution it provides to absorb shocks of natural disasters such as floods which can be controlled by storing water, and drought by reducing the water loss from tanks due to existence of the surrounding ecosystem. The Cascaded Tank-Village System also contributes to efficient water management with water from one tank flowing to another, through a network of tanks and streams (FAO, 2017). Taking the facts that the CTVSs have long played, and continue to play the crucial role at global, regional and national level for food security and sustainable development in the context of climate change, it was declared as Globally

Important Agricultural Heritage Systems (GIAHS) by the Food and Agriculture Organization of the United Nations (FAO) in 2018.

The ancient, century old hydraulic civilization of the dry zone disappeared after the 12th century AD (Jayasena & Selker, 2004; Abeywardena, Bebermeier, & Schütt, 2018) largely owing to the changes in climate, malaria, depletion of soil fertility, foreign invasions, and famine and etc. Paranavithana (1960) and Dharmasena (2010b) have reported that the annihilation of the *Kulinas* (the dry zone nobility who possessed irrigation expertise) by invading South Indian forces may have resulted breakdown of the efficient irrigation management systems. Tennakoon (2017) refers the period from 1250 – 1850 AD as the *Dark Age* of the Sri Lankan hydraulic civilization during which the state sponsorship and the attention on building of irrigation structures and maintenance of related systems has not been offered.

From 1850, under the British rule there was a revival of irrigation activities in the Dry Zone and the systematic renovation of ancient village irrigation (Tennakoon, 2017). Since then the responsibility of regular renovations, rehabilitation and maintenance of village tanks have been on the state agencies such as Irrigation Department, Department of Agrarian Development. However, owing to the negligence of the regular maintenance and inappropriate activities and operations in and around village tank cascade systems the sustainability of CVTS have been threatened.

The village tank-based farming system had traditionally been three-fold, namely '*gangoda'* (home garden), '*chena'* (shifting cultivation) and *'welyaya'* (lowland paddy cultivation). These crop production systems were considered as a more stable settlement to averse the risk of vagaries of weather and subsistence nature of production. Thus, the sustainability of the village tank systems is vital for enhancing farm level income and household food security (Aheeyar, 2013). Further, it is emphasized the importance of the role of upland farming and *chena* cultivation as the major sources of household income in order to ensure future sustainability of such farming systems. Maddumabandara (2009) has also highlighted the importance of farming systems evolved around the village tank systems as a sustainable system. Therefore, whatever produced from the local resource base in the village tank system was sufficient for an egalitarian life style, with rice (from lowland paddy fields) for all meals supplemented with finger millets and vegetables from *chena* (swidden) cultivation and freshwater fish from the tanks. The village had been virtually self-sufficient except in a few items like salt. Murray & Little (2000) also emphasized the pivotal role that has been played by small village tanks in providing a major portion of protein requirement of the rural communities.

Panabokke, Tennakoon & Ariyabandu (2002) described that the natural equilibrium of the settlements, the resources and the socio-economic set ups in village tank systems have threatened largely due to the anthropogenic activities. In the distant past based on rain-fed *chena* farmers, lowland rice cultivation, homestead mixed garden farming, cattle grazing and herding, tank fishing and food gathering game and tree harvesting, there was a traditionally self-sufficient and inward looking contended life style in equilibrium in tank associated village settlements. This equilibrium having been subjected to external influences has gradually brought about a great disequilibrium, demanding a changed but sustainable production threshold, though the resource base remains limited. Due to *chena* lands being converted to settled rainfed settlements a high degree of land degradation, soil erosion, tank siltation has taken place. The earlier equilibrium that existed in relation to the tank capacity irrigated area and tree covered catchment area too have been severely altered, thus resulting in severe stress and conflicts both in respect of irrigated rice cultivation and upland rainfed *chena* cultivation. Furthermore, production systems too have become different in that they have to be responsive to the prevailing challenges of the open market forces in operation. This also makes it difficult to ascertain realistic production thresholds of both rainfed and irrigated farming systems in the small tank cascade systems (Ibid).

Traditional communities that largely depended on these small scale irrigation systems made every attempt to conserve soil, water, and natural habitats with sustainable resource utilization practices. Cultivation of the upper tank bed area (*thavulu govithena*) during extremely dry seasons taking adequate precaution to prevent sediment flow into tank is an example of their cultivation wisdom (Dharmasena, 2009). However, over exploitation of natural resources in the last century with the commencement of large scale settlement schemes, clearing and cultivation in the catchments practiced by the farmers/settlers of those schemes caused severe damage to the village tank systems.

Madduma Bandara (2009) and Dharmasena (2010a) have highlighted that, the various anthropogenic activities including agro-well development, residential and industrial activities resulting degrading of flora and fauna communities, loss of fertile soils, destruction of the village ecosystems, were the most prominent factors that have made adverse impacts on the tank cascade systems of Sri Lanka. Further, Marambe, Pushpakumara & Silva (2012) observed that during the past few decades there has been a drastic reduction in forest cover and degrading of flora and fauna communities due to various development activities in tank cascades.

1.3 Research Problem

Due to increasing population pressure on land, the extent of *chena* where shifting cultivation is practiced declined with no fallow period between two cultivation seasons (Panabokke, Shakthivadivel & Weerasinghe, 2002). Gradually the *chena* land was converted to rain-fed or agro-well irrigated farming systems where the same plots of lands were frequently cultivated. This resulted in generation of high runoff and associated sediments were accumulated in tank beds. Tank sedimentation triggered by accelerated soil erosion is major threat posed to tank systems in most parts of the country. According to Dharmasena (1992) and Dharmasena and Joseph (1994), in the North Western (NW) and North Central (NC) Provinces, about 20 - 30 percent of the storage of small tanks have sedimented, resulting in a decrease in storage potential. The rate of sedimentation is extremely high compared to the past and can be attributed the increasing upland cultivation in the tank catchments (Dharmasena, 1992). Tank capacity reduction due to sedimentation has resulted in substantial productivity loss in the lowland cropping system in the respective command areas. Apart from inappropriate farming practices in the catchment areas other activities related to industrial, construction tourism as well as residential sectors have contributed in raising erosion to an alarming level.

Although a large number of studies have been carried out on sedimentation of large reservoirs located within the upper catchment areas of the country and its impact on different sectors of the economy, adequate attention has not been paid to the changes in land use and land cover of the catchments of small tank systems and the cropping systems under those tanks in the drier parts of the country, particularly on the existing crop production systems. Therefore, this study was conducted to examine present crop production systems under cascaded village tank systems in the dry zone area.

1.4 Research Objective

The general objective of this study was to identify contemporary crop production systems and related livelihoods in the cascaded village tank systems in the dry zone of Sri Lanka.

Specific research objectives:

1. To study the land-use and land cover changes in the catchments of selected village tank cascades in the Dry Zone.
2. To investigate the different crop production practices under village tank systems.
3. To propose policy recommendations for sustainable rehabilitation and operation and maintenance of village tank systems.

1.5 Research Methodology

1.5.1 Study Area

The main cascade zones that could be identified in Sri Lanka are north and north-central, north-western and south and south-eastern (Dharmasena, 2017b). Of the total village tank cascade systems (1162), over three fourth is located in the North-Central (NC) and North-Western (NW) provinces where the highest density of village tank cascade systems is also reported. Therefore, taking the CVTS density and the changes in the land use in the tank catchments, the Mi-Oya river basin from the NW province and the Malwathu-Oya river basin from the NC province were selected as the broader study locations of this study (Fig. 1.2). These river basins are among the most vulnerable to the vagaries of the climate, have a high presence of village irrigation systems on which poor and vulnerable farming populations depend for their livelihoods (UNDP, 2017).

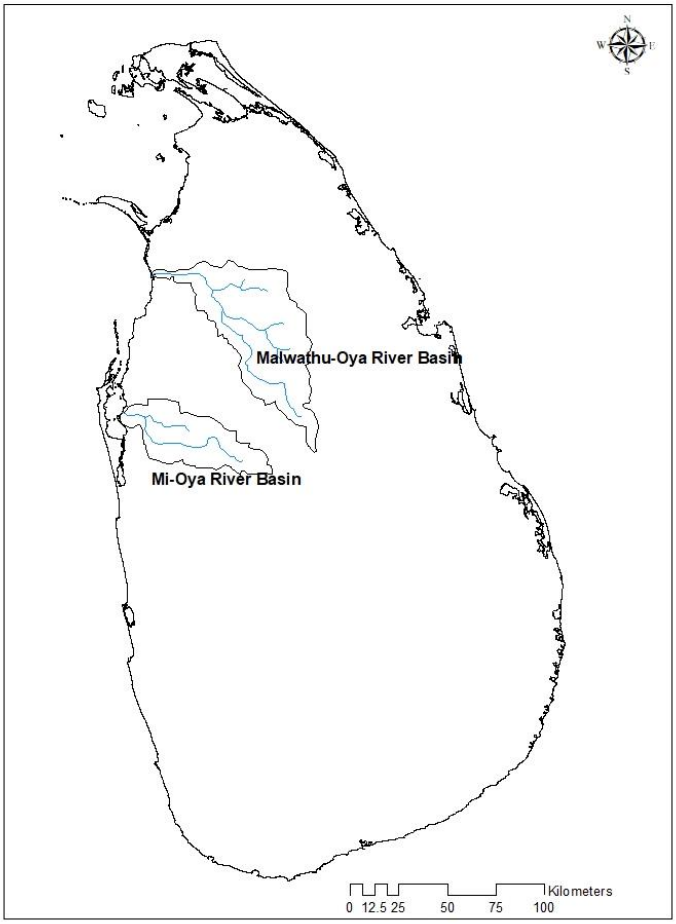
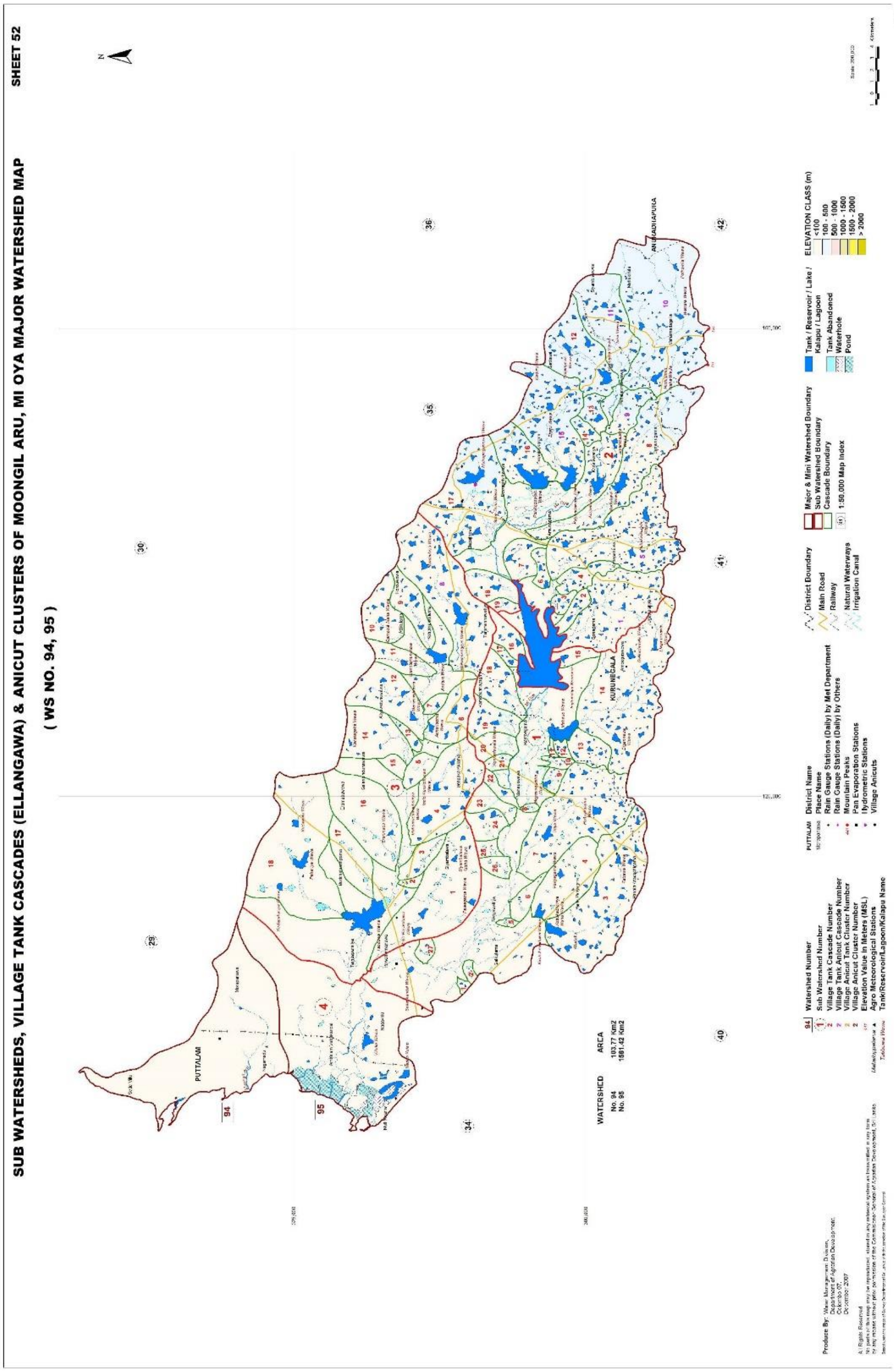


Figure 1.2: Mi-Oya and Malwathu-Oya River Basins

1.5.1.1 Mi Oya River Basin

The Mi Oya river is a 108 km long river, in North Western of Sri Lanka. It is the fifteenth-longest river in Sri Lanka, originating in Saliyagama areas and flowing northwest, emptying into the Indian Ocean through Puttalam. The total catchment area of the Mi Oya river basin is 1024 square kilometers. Its catchment area receives approximately 1,596 million cubic meters of rain per year, and approximately 3 percent of the water reaches the sea. One of the main features in Mi Oya river basin is it forms a cluster of small village tanks and cascade systems and anicuts which are scattered all over the basin. In these minor irrigation systems, the full extent under the scheme is cultivated during the *Maha* season. In the *Yala* season, cultivation is not practiced in most of the schemes, as water is a scarce resource. In this region, paddy yields range from 175-300 bushels per hectare in major schemes while yields reduce to 50-200 bushels per hectare in minor schemes. This variation in yields between seasons and among types of schemes is mainly determined on the water availability, particularly at the end of crop seasons (De Silva, 1988).

In a study by Bandaranayake & Kumara (2016), it is highlighted that in the case of Mi Oya, for a long time, it has been evident that there is a lack of water for a number of large irrigation reservoirs and hundreds of small tanks located in the lower basin. Hydrologically, the upper catchment of the Mi Oya river is the main source of water to the main flow in turn to the lower basin. When water from the upper catchment is drastically changed, it affects the lower basin water use. Thus, it is essential to adopt a better water management system. In the same study, it was revealed that the total volume of water produced by the upper catchment has been considerably decreased due to human activities. The prominent activity is the blocking out of small streams by farmers for their own purposes such as the construction of private tanks and newly made paddy fields. It is also evident that removing vegetation cover for *chena* cultivation has caused higher water evaporation from the soil resulting in low water discharge to the drainage system.

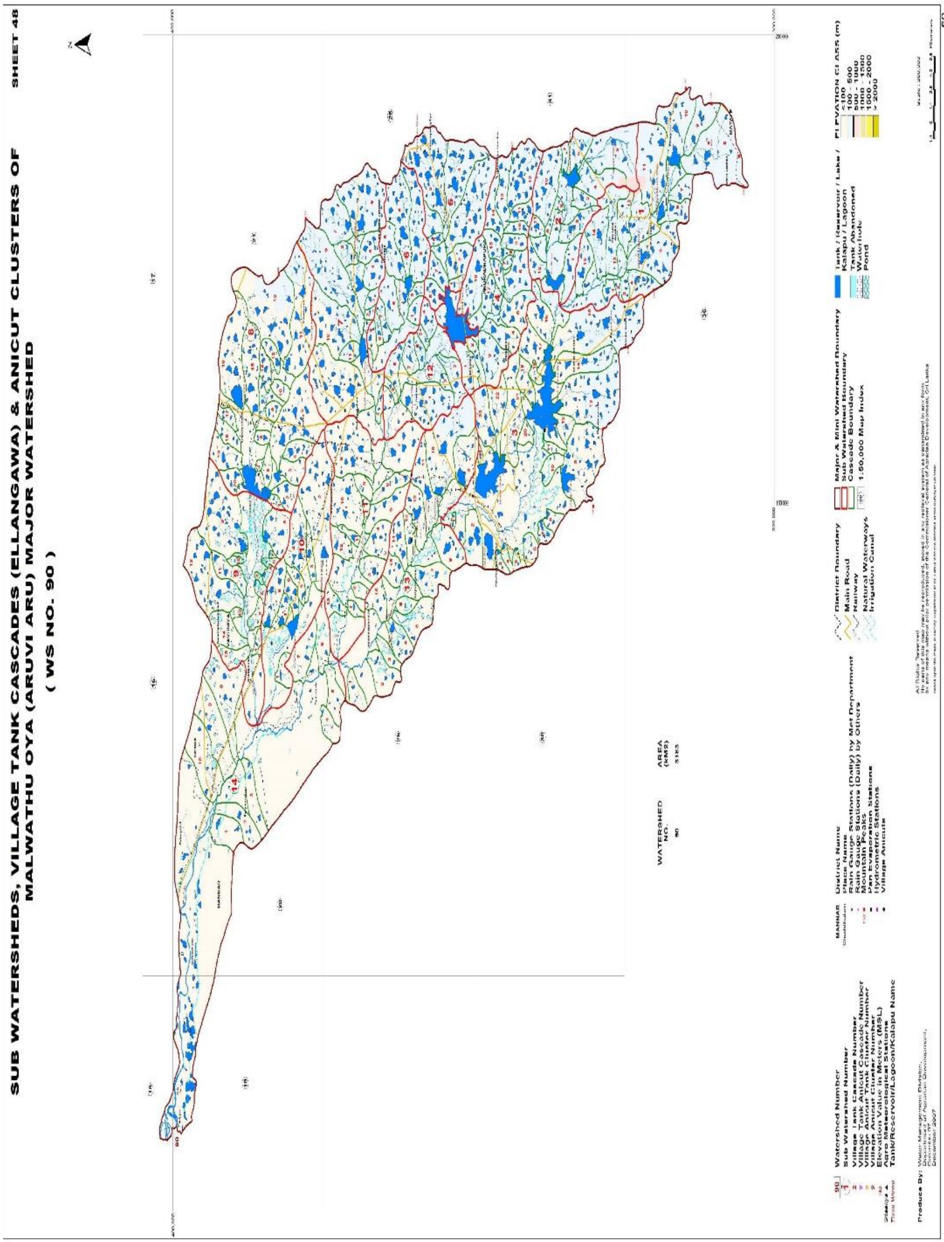


Source: Department of Agrarian Development (2007)

Figure 1.3: Mi-Oya River Basin

1.5.1.2 Malwathu Oya River Basin

The Malwathu Oya river basin is the country's second largest river basin holding 3,246 square kilometers extending from Central province through NC province to Northern province. The main river of the basin runs about 164 km before it reaches the ocean from the NW coast. It is one of the major agricultural areas in the country. Rice production is the main source of livelihood, along with other food crops such as maize, legumes and fruits and vegetables. There are seven major tanks in the Malwathu Oya river basin catchment area – Nachchaduwa, Nuwarawewa, Tissawewa, Mahakandarawa, Pawatkulam, Giant Tank and Akithamurappu. The irrigation systems of the Malwathu Oya river are a legacy of the Sri Lankan ancient hydraulic revolution. Even today, the basin has thousands of small inter-connected rainwater storage tank cascade systems, and larger reservoirs. The number of sub-watersheds and CVTSs in Malwathu Oya river basin are 15 and 179 respectively (Panabokke, 1999). There are over 1450 small tanks along this river basin. Some of the large irrigation tanks in this river basin provide multiple services such as water for irrigation and livestock, water for municipalities, households, industries and aquaculture and fulfil the water requirement of the natural ecosystems and sanctuaries.



Source: Department of Agrarian Development (2007)

Figure 1.4: Malwathu Oya River Basin

The Mahameruwa cascade located in Ehetuwewa Agrarian Service Center (ASC) area in Mi-oya river basin in the Kurunegala district and the Maha Kumbukwewa cascade located in Medawachchiya ASC area in Malwathu-Oya river basin in the Anuradhapura district were selected as study sites in consultation of the officials attached to the Department of Agrarian Development (DAD) in respective districts (Fig. 1.5 and Fig. 1.6). The drastic land use changes occurred in the tank catchment areas as well as the expansion of the command area of the tanks due to the anthropogenic activities are reported and thereby the livelihoods of the communities living in the cascade systems have also been affected.

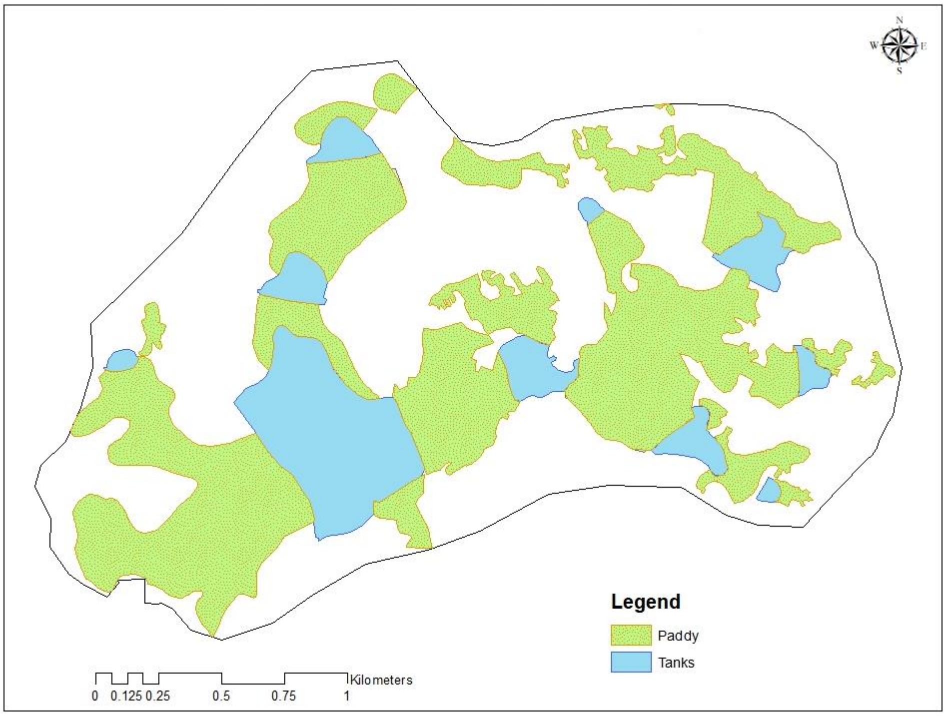
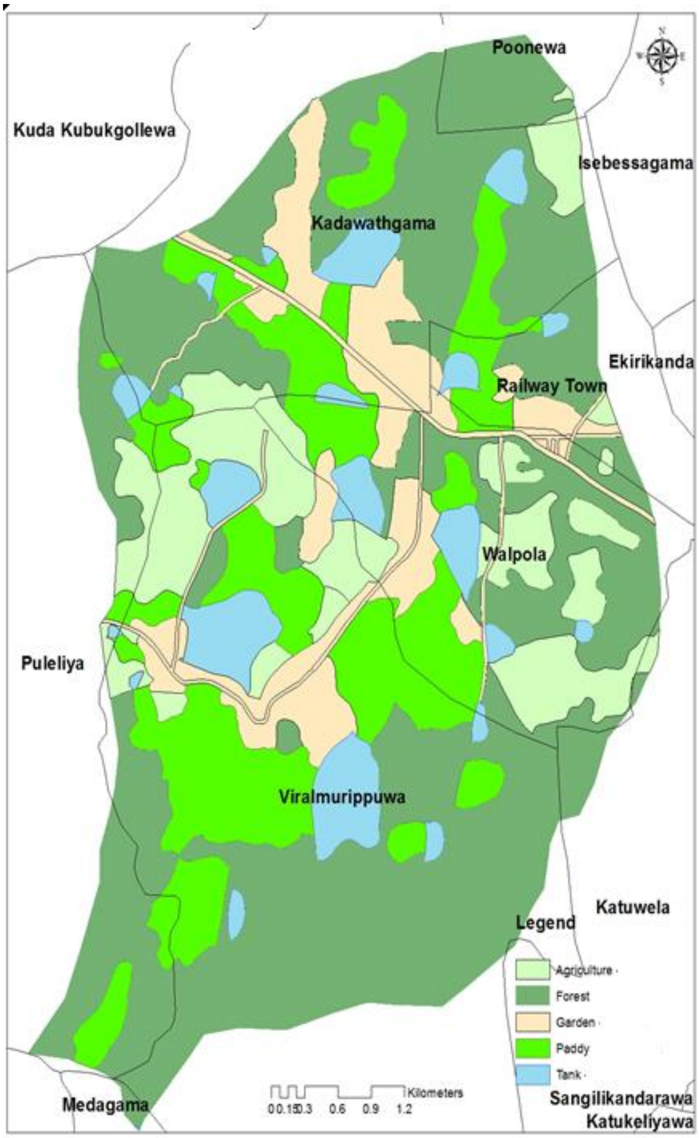


Figure 1.5: Mahameruwa Cascade Area



Source: Adopted from Ministry of Mahaweli Development and Environment, 2018

Figure 1.6: Maha Kumbukwewa Cascade Area

1.5.2 Data Collection and Analysis

In this study, data and information was collected from both primary and secondary sources.

a) Primary data collection

   Data and information on the current agricultural practices was collected through a farmer household survey. The key informant interviews, focus group discussions (FGDs) were also held with farmers, divisional and field level extension officers in the study locations.

b) Secondary data collection

   Documents containing data and information available at respective regional offices of the Irrigation Department (ID), DAD, and the Department of Agriculture (DoA) were studied to extract tank cascade related agronomic and agrarian data and information. The past records and information on village tank rehabilitation and operation and maintenance activities and procedures were also collected from the secondary sources including the farmer organizations (FOs).

1.5.2.1 Sample Distribution

The entire farmer households (312 households) practicing paddy cultivation and whose fields fed by tanks in two village cascades were interviewed. It comprised 179 households from the Mahameruwa cascade and 133 households from the Maha Kumbukwewa cascade. Hence, this questionnaire based survey was a census that covered the entire farming community in the cascades selected. The distribution of farm households in two locations (by Grama Niladhari Division) is presented in Table 1.1. The information on their socio-economic conditions, agricultural and other livelihood activities was collected using a structured questionnaire.

Table 1.1: Distribution of the Study Sample

Province	District	Divisional Secretariat	GN Division	Agrarian Service Centre	
				Ehatu-wewa	Medawach-chiya
North-Western	Kurunegala	Ehatuwewa	Nabadawewa-126	74	-
			Thimbiriyawa-127	48	-
			Hunugalwewa-128	48	-
			Ihala Ebogama	1	-
			Walaththewa-125	6	-
			Kaduruwewa-122	1	-
			Maha Ebogama-123	1	-
			Total	**179**	
North-Central	Anuradha-pura	Medawach-chiya	Thulana-65		106
			Thulana-60		23
			Medawachchiya		1
			Thulana-61		3
			Total		**133**
Total					**312**

1.5.3 Data Processing and Analysis

For data entry and data analysis MS Excel and SPSS statistical packages were used. Simple descriptive statistical tools were employed to derive information relating to the current crop production practices of the study locations. The results were presented in tables and graphs. For the analysis of land use and land cover changes in the catchment area and agricultural land use ArcGIS software was also used.

1.5.4 Limitations of the Study

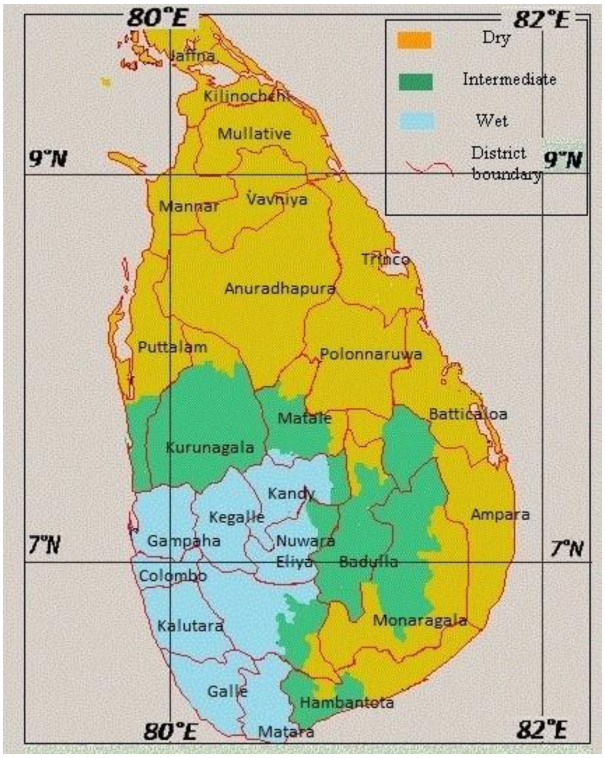
The original design of the study included an engineering survey and a soil survey of the selected village tanks in the two cascades, to ascertain the level of sedimentation of tanks and its effect on crop production activities in respective communities. However, owing to the financial and procedural constraints the research team was compelled to alter the research objectives and methodologies and revise the analytical part of the study. Thus, the engineering and soil surveys were not carried out limiting the achievements of the research objectives.

CHAPTER TWO

Literature Review

2.1 Rainfall Distribution in Sri Lanka

Although Sri Lanka is blessed with an abundant rainfall, it is characteristic of high temporal and spatial variability. Considering the spatial variability, the country is divided into three zones; wet zone, dry zone and intermediate zone. Average rainfall received in the wet zone is 5500mm-2500mm. Other than the short dry spell in January and February, the wet zone receives an ample rainfall in the rest of the year. In the dry zone, which includes the North, East and the Southeast parts, there are marked wet and dry seasons (Burt and Weerasinghe, 2014). The dry zone receives an average rainfall of about 1750mm-900mm. During its two main rainy seasons and the surface runoff is collected and stored in reservoirs which are also called tanks.



Source: Karunaweera *et al*., (2014)

Figure 2.1: Climatic Zones of Sri Lanka

The average rainfall received by the intermediate zone generally varies between 2500mm-1750mm. Sri Lanka is influenced by tropical cyclones, depressions and thunderstorms associated with migration of the inter-tropical convergence zone (ITCZ).

The country experiences four distinct rainfall seasons: South-West monsoon during May to September, North-East monsoon during December to February; March to April is First inter monsoon and Second inter monsoon from October to November (Imbulana et al., 2010).

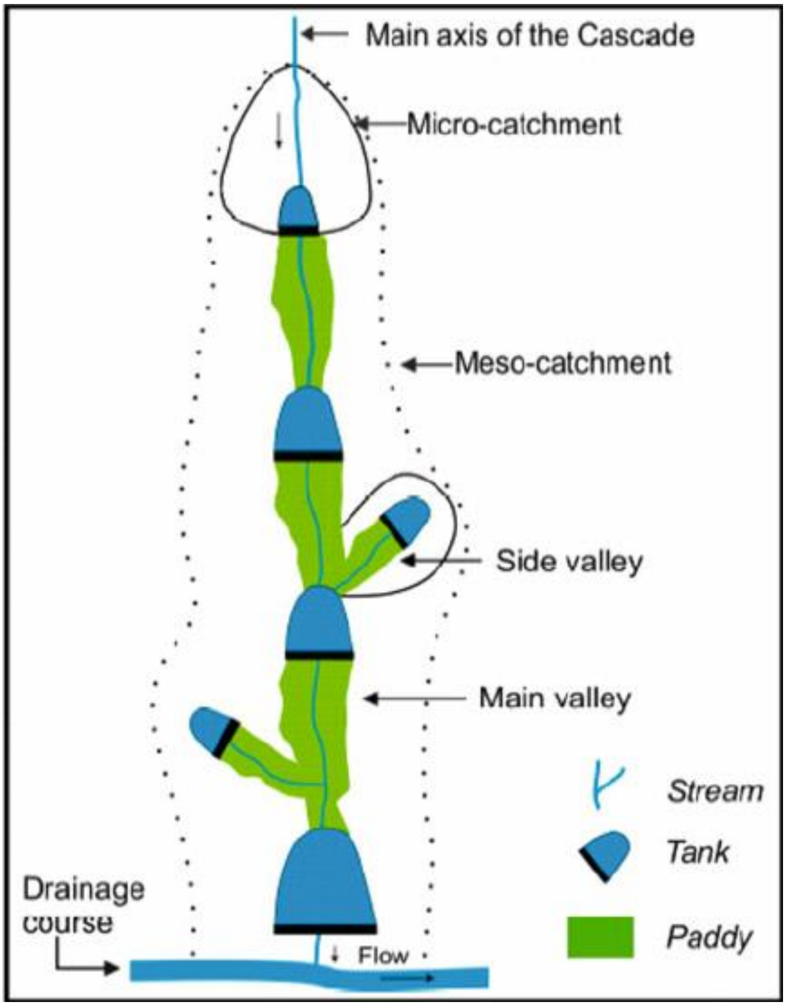
2.2 Village Tank Cascade Systems of Sri Lanka

The history of constructing village tank systems dates back to 3th Century B.C. or before (Witharana, 2004; Tennakoon, 2017). As knowledge of storage and distribution of water for irrigation purposes was necessary to obtain a bountiful harvest to feed the growing population, construction of these irrigations structures was an important pre - condition for the development of early urban societies in the NC areas of Sri Lanka. A cascade is defined as a connected series of small irrigation tanks organized within a meso-catchment of the dry zone landscape; storing, conveying and utilizing water from an ephemeral rivulet. It is usually made up of four to ten individual small tanks, with each tank having its own micro-catchment. The advantage of such a system is that excess water used from one tank in its command area is captured by the next downstream tank, by which this water is put to use again in the next command rea. Accordingly, such water becomes continuously recycled or reused up to end of the cascade. This system helps to surmount irregularly distributed rainfall, non-availability of large catchment areas and the difficulty of constructing large reservoirs (Gunaratne and Kumari, 2014). Tank cascades are found at the elevation range of 100–500 m above mean sea level. The three main cascade zones are found in Sri Lanka (Table 2.1), are north and north-central, north-western and south and south-eastern (Dharmasena, 2017a).

Table 2.1: Tank Cascade Zones in Sri Lanka

Cascade Zone	River Basins	No of Cascades
North and North-Central	Malwathu Oya, Mahaweli Ganga, Panna Oya, Pankulam Aru, Kunchikumban Aru, Yan Oya, Ma Oya, Mannal Aru, Per Aru, Kanakarayan Aru, Pali Aru, Paranki Aru, Nay Aru, Modaragan Aru, Kala Oya	617
North-Western	Mi Oya, Rathambala Oya, Deduru Oya	255
South and South-Eastern	Kirama Oya, Urubokka Oya, Walawe Ganga, Malala Oya, Kirindi Oya, Menik Ganga, Kumbukkan Oya, Karanda Oya, Maduru Oya	177
Total		**1049**

Source: Adopted from Dharmasena (2017a).



Source: Panabokke (1999).

Figure 2.2: A Graphical Representation of a Small Tank Cascade System

In Sri Lanka, four types of village tank cascades have been identified by Tennakoon (2017). They are of *linear, crescent, dendritic* and *fan-formation.* The difference between linear and crescent like cascades may be taken as slight but on the whole, the difference between any two of these can be considered very important. Whatever the shape differences are, it is important to keep in mind that the drainage pattern, starting form a summit of a cascade and moving down in its axis stream with the collection of water from the supplementary slide-slope water paths.

The tank cascade systems exist with their unique environment. The cascade determines its surface water movement based on the sizes and positions of tanks and paddy fields. Further, the tank cascade system, once established, determines the various other aspects in addition to the surface water movement. For example, it manipulates the groundwater behaviour, availability and its spatial and temporal variations. Both these two aspects with human intervention determine the floral and faunal composition and dynamics (Dharmasena, 2020).

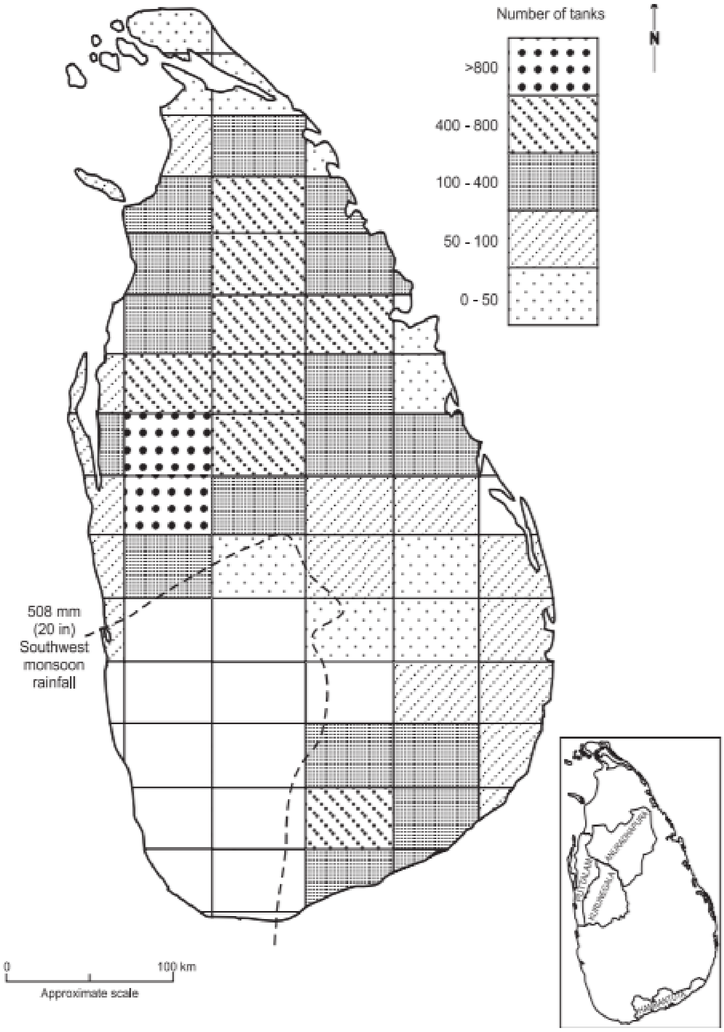
The whole ecology of the tank cascade system is governed by the determinants of cascade formation especially rainfall, landscape and soil. Tank cascades are found (1) in the Provinces of northern, north-central, north-western, Uva and southern; (2) in the Districts of Mullaitivu, Vavuniya, Anuradhapura, Trincomalee, Puttalam, Kurunegala, Hambantota and Monaragala; (3) at the elevation range of 100–500 m amsl; (4) mainly in the agro-ecological regions of the low-country dry zone, where the isohyets of annual rainfall are between 800 and 2000 mm; (5) in the geologically in Wanni and Vijayan complexes and (6) mainly in reddish-brown earth and low humic gley soil associations (Dharmasena, 2020).

About 16,000 small tanks, both operational and abandoned are found distributed in these cascade systems across the dry and intermediate zones of Sri Lanka. Nearly 40 percent of them are located within the NC province and 26 percent in the NW Province. Southern and Northern provinces account for approximately 10 percent of the small tanks respectively while the remaining tanks located in other provinces (Madduma Bandara, 2004). The Figure 2.3 depicts the density and distribution of small village tanks in the dry and intermediate zones.

Table 2.2: State of Village Tanks in the Country

Province	Operational	Abandoned	Total
Northern	608	816	1424
North Central	2095	1922	4017
North Western	4200	2273	6473
Southern	653	757	1410
Uva	16	543	559
Eastern	48	1442	1490
Total	7260	7753	15373

Source: Adopted from Madduma Bandara, (2004).



Adopted from Panabokke, Shakthivadivel & Weerasinghe (2002)

Figure 2.3: The density and distribution of small village tanks in the Dry and Intermediate Zones

More than half of the village tanks in the dry and intermediate zones have been abandoned due to various reasons (Madduma Bandara, 2004). In another studies by Panabokke (2001) and Panabokke, Shakthivadivel and Weerasinghe (2002) have observed the similar situation with regard to the state of village small tanks. Accordingly, nearly 48 percent of village tanks are in abandoned state owing to sedimentation, damaged structures such as tank spill, dam of the tank and etc.

Table 2.3: The State of Operation of Small Tanks in Major Dry Zone Provinces

Province	Total number of small tanks	Percentage of functioning tanks	Procentage of abandoned tanks
Northern (NP) - Wanni	1424	43	57
North Central (NCP) - Rajarata	4017	52	48
North Western (NWP) - Wayamba	6463	65	35
Southern (SP) - Ruhuna	1410	46	54

Adopted from: Panabokke (2001); Panabokke, Sakthivadivel, & Weerasinghe (2002).

The higher percentage of abandoned tanks occur in the NP and the SP, where over 50 percent of the approximately 1,400 small tanks in each province are in an abandoned state. It should be noted that the mean annual rainfall as well as the *Maha* season (major cultivation season) rainfall is lower in the SP and the NP than in the NCP and NWP. In the case of the NCP, out of the approximately 4,000 small tanks, around 48 percent are abandoned, while in the NWP out of the approximately 6,500 small tanks, around 35 percent are abandoned. It should be noted that the M*aha* season rainfall in the NWP is significantly higher than in the NCP, and that there is a higher proportion of gravelly soils and rocky lands (rock knob plains) in the NCP compared to the NWP, which accounts for the higher proportion of abandoned small tanks in the NCP (Panabokke, Sakthivadivel, & Weerasinghe, 2002).

Abeysinghe (1982) reasoned out of several thousand abandoned tanks in the dry zone as lack of adequate catchment area, lack of suitable agricultural soils for viable settlements, non-viability of tanks in economical and engineering perspectives, lack of approach roads, or are located far away from human habitation, or they are situated in forest reserves and nature reserves or wild life sanctuaries.

Because of the lower regional rainfall and the higher annual evaporation in the semiarid climate of some parts of the SP, a larger catchment area is needed to capture adequate runoff to fill the tanks. This is also reflected in the lower tank density in the southeastern segment of the province. The primary reason for the preponderance of abandoned small tanks in this semi-arid environment is the occurrence of the readily dispersible sodic soils in the narrow inland valley bottoms across which these small tanks have been constructed. Tank bunds made from such soil material are unstable during the rainy period and can cause breaching of embankments and ultimately the abandonment of tanks (Panabokke, Sakthivadivel, & Weerasinghe, 2002).

2.2.1 Issues of Cascaded Village-Tank Systems

Though the CVTS of Sri Lanka is a time tested culturally bounded system thriving over two millennia, the sustainability of this globally recognized agricultural heritage system has become a matter of concern. Panabokke, Tennakoon & Ariyabandu, (2001) has explained well of the issues relating to the present day CVTSs owing to the pressures posed by various anthropogenic activities over the time. In the distant past, based on rain-fed *chena* farmers, lowland rice cultivation, homestead mixed garden farming, cattle grazing and herding, tank fishing and food gathering game and tree harvesting, there was a traditionally self-sufficient and inward looking contended life style in equilibrium in tank associated village settlements. This equilibrium having been subjected to external influences has gradually brought about a great disequilibrium, demanding a changed but sustainable production threshold, though the resource base remains limited. Due to *chena* lands being converted to settled rainfed settlements a high degree of land degradation, soil erosion, tank siltation has taken place. The earlier equilibrium that existed in relation to the tank capacity irrigated area and tree covered catchment area too have been severely altered, thus resulting in severe stress and conflicts both in respect of irrigated rice cultivation and upland rainfed *chena* cultivation. Furthermore, production systems too have become different in that they have to be responsive to the prevailing challenges of the open market forces in operation. This also makes it difficult to ascertain realistic production thresholds of both rainfed and irrigated farming systems in the small tank cascade systems.

Dharmasena (2020) also have identified four major issues (low cropping intensity, tank sedimentation, high tank water losses and low resource productivity) relating to the present day CVTSs. In a study carried out by Dharmasena (2005) for the entire Anuradhapura District using rice cultivation statistics recorded from 1970 to 2003, it has been observed that the cropping intensity never exceeded one and fluctuated according to the rainfall received during the *Maha* season. The area cultivable from the water in small tanks decreases gradually due to tank sedimentation and the subsequent high tank water losses. Dharmasena (1992) reported that three small tanks, namely Paindikulama, Siwalagala and Marikaragama, in the Nachchaduwa major watershed have been silted up by 35%, 30% and 23%, respectively, of their initial capacity. Siltation of tanks not only reduces storage capacity, but it also leads to alteration of the tank bed geometry. Thus, subsequent rehabilitation work, where the capacity has been improved by raising the spill and the tank bund, has created shallow water bodies spreading over a larger surface area. This creates additional problems, including flooding of upstream paddy lands, increased water losses, upper areas becoming more saline and disappearance of the *Gasgommana*, as well as the grass cover (*Perahana*) underneath. Some indigenous fish species, which need deeper water to breed and live, also disappear.

Water losses from small tanks are very high. Within 2–3 months of the cessation of the seasonal rains, most of the tanks appear as marshy lands infested with aquatic weeds. Previous studies conducted on hydrology of minor tanks indicated clearly that the total tank water loss through evaporation and percolation varies from 35 to 90 percent depending on the geometry of the water body (Dharmasena 2005). Water losses are higher from tanks with shallower water bodies, than those with deep water. Therefore, it is clear that the geometry of the tank bed is critical for the water storage efficiency of a tank. It follows that if the tank bed geometry is altered suitably, water loss can be reduced drastically. The failure of tank rehabilitation projects and programs to increase productivity could be attributed to a lack of focus on restoration of the tank bed and its surrounding ecosystem; confinement of programmes to tank and command area development, without addressing the problems of rainfed and homestead farming in the tank catchment; external interactions and socio-economic conditions; a poor social mobilization process and the lack of a local institutional mechanism to continue activities, once the project ceases.

2.2.2 Significance of Restoring the Cascade System

Because of the importance of irrigation in Sri Lanka. Improving irrigation facilities has long been a popular means of rural development (Shakthivadivel, Fernando & Brewer, 1997). Many of over 15,000 small ancient village tanks are in good shape, supporting over 200,000 hectares, accounting for around 37 percent of the total irrigable area of the country (DCS, 2020). Restoring the ancient cascade irrigation system is significant due to varied reasons. With adverse impacts of global climate change looming large improvement of cascade systems may prove beneficial for its time-tested buffering capacity to withstand extreme weather events such as floods and droughts (Madduma Bandara, 2009). In addition to irrigation, the stored water is used for domestic purposes. Further, dried tank beds serve as a pasture land for the cattle and deposited sediments are used as raw material for brick making. Therefore, the tanks have been the symbol of the cultural landscape of North-central Sri Lanka for a period of 2000 years. It has become an essential component of the village culture (FAO, 2017).

There is a wealth of indigenous knowledge established over centuries with regard to operation and maintenance of these tank systems and strategies to keep up with changing climatic conditions. This water-harvesting system in Sri Lanka is therefore, considered as a sustainable water supply method to support local communities in adapting to long-term climate changing conditions. Calculations of eco-system based services also underline the present-day significance of the tank cascade system for local communities (Bebermeier *et al.*, 2017). A tank's catchment, storage and command area are determined hydrologically and socially. The amount of runoff that could be collected within small tanks on depend the extent of a total catchment area of a cascade. The tanks have been the symbol of the cultural landscape of North-central Sri Lanka for a period of 2000 years. It has become an essential component of the village culture as well.

As described these small village tanks were not only meant for supporting agriculture or farming activities but also have many other functions. They have been very vital in capturing, storing and providing water for adjoining crop lands, fulfill needs of human and wildlife and maintain microclimatic environment for natural vegetation. This is reflected in the classification of ancient irrigation structures, which includes many other types of tanks apart from those meant for irrigation of agricultural lands, specially lowland paddy fields. ***Forest tanks***, are located in the forests or the mini-watersheds above the village, fall into a class of tanks of which the function is not to provide irrigation but to provide water for wild animals, hence, prevent instances of them tress passing on paddy and other cultivated fields while in search of water. ***Mountain tanks*** are another class of tanks, primarily built to provide water for '*chena*' or slash-and-burn agriculture activities in uplands. The ***erosion control tanks***, or ***'pota wetiye'***, **"Silt-trap tanks"** or **Kuluwewa** is another a class located above the main tank/s (for irrigation) and designed in a way that any silt is deposited before the entering water to the main water storage tanks. **Olagam tanks** or **associated tanks** or **satellite tanks** of the main village tank are constructed on the side slopes of a cascade away from the main tank. Having situated, or near the forest, those would mostly act as service tank for *chena* cultivators, livestock feeding and provision of village water needs when main tanks are emptied for maintenance purposes. **Pin wewa** or **temple tank was** constructed to provide water to meet personal needs of the devotees who visit the temple and other pilgrims and residents of the temple. Those tanks were certainly for religeo-cultural purposes and not for direct economic purposes.

Besides the main role in rice production, the tanks provide material such as fish, lotus (flowers and roots) and other flora that are beneficial for rural communities for diversified household income. The seepage from tanks ensures the availability and the water quality in dug-wells, the main source of drinking water. Tanks also provide fodder and drinking water for livestock.

The benefits of the tank eco system can be broadly categorized in to three types agricultural benefits, social benefits and environmental benefits.

Agricultural benefits, mainly include cultivation benefits and benefits from livestock (water and grazing land) and fish;

Social benefits, mainly include the supplying of water for domestic purposes, a basket of food (lotus flower, roots and other edible aquatic flora). Water and material supply for other rural income avenues (water-based industries such as brick making and reed industry).

Environmental benefits, mainly includes water for living creatures, acting as a wetland during the dry season and as a regulatory water body in high rainfall events that cause flash floods. It also maintains ground water level in the adjacent lands, the micro-climate and provide recreational function while sustaining bio-diversity.

Therefore, the enormous service provided by tanks to the active functionality of the whole eco system is invaluable. The tank itself is considered as an eco-system by scientists. The studying of tank/s in eco-system perspective and developing concepts and models related to handling and management of functions of tanks is gaining increased popularity in many parts of the world. Such research activities not only facilitate the understanding of structure and functioning of tanks but also help ensuring the wholesome benefits to the society and the environment.

Further, recent dialogues have emphasized the importance of small tanks system for increased ecosystem resilience in the face of changing climate, by acting as a storage and a regulatory water body that provides water for different sectors such as farming, livestock, domestic purposes and wildlife and other livelihoods and industries. More importantly its role is critical for sustenance of the bio diversity during drought incidence. Further, it increases the capacity of the ecosystem to retain excess water during rainy seasons and reduce the threat of floods to the adjoining eco systems including the rural communities and their livelihoods. Therefore, the role of small tanks in the village setup has been upheld with the mounting impacts of climate change. Being an island with high vulnerability to climate change, Sri Lanka can essentially exploit the fullest benefits of tank eco system for increased resilience and adaptive capacity of the rural agricultural communities (Jayasuriya & Shantha, 2019).

2.2.3 Village Tank Restoration and Rehabilitation Processes

Village tank systems are man-made ecological constructions, which served the rural peasant community to produce their own food and look after their social welfare with little outside interference since ancient times. As per the Irrigation Ordinance of 1946, the schemes constructed by proprietors without state (government) support and maintained by the proprietors were considered as village tanks or minor irrigation schemes. The latest definition of minor irrigation schemes as stipulated in the Agrarian Services Act of 1979 is that, irrigation systems with command area less than 80 ha (200 ac). The tank rehabilitation and restoration has been implemented in the past through different approaches and strategies to ensure continuous sustenance of these systems (Aheeyar, 2013).

According to Weerawardena (1986), in the ancient time, farmers had to adhere to certain laws laid down by the king or regional chieftains/nobles in relation to the repair, maintenance and management of small irrigation systems. The adherence to these laws over many generations resulted in the birth of customs and traditions, which gave the management of these irrigation systems a discipline that continued up to British times (Panabokke, Shakthivadivel & Weerasinghe, 2002).

During the pre-colonial era, under the '*Rajakariya*' system (ancient custom of compulsory labor), the minor irrigations were operated and managed by the community themselves. The *Rajakariya* system of maintenance required a compulsory personal labor obligation that helped guarantee the maintenance of these small irrigation systems over a period of several centuries. The responsibility of management was vested with the "*Gamarala*" under the "*Gamsabhawa*" system. On the grounds that it was a form of slavery, with the abolition of the *'Rajakariya'* system by the British administration in 1832 all customary regulations and traditions began to collapse. Without any substitute for *Rajakariya*, maintenance was no longer enforced and many minor irrigation works fell into neglect and general decay (Panabokke, Tennakoon & Ariyabandu, 2001; Panabokke, Shakthivadivel & Weerasinghe, 2002). *The Nuwarakalaviya Gazette in 1873,* mentions that there were 2877 tanks identified, of which 1bout 1500 tanks remained abandoned and most of them have gone under jungle (Tennakoon, 2017).

Despite small tank irrigation systems are generally called as farmer-managed irrigation systems (Groenfeldt, Alwis & Perera, 1987) observed that the state intervention in restoration of village tanks have been there at least from the mid-18th century. Even the British administration was in the view that restoration of village tanks would serve peasant community to produce their own food and look after their social welfare with little outside interference (Aheeyar, 2013).

In the recent history, the first systematic steps to renovate the ancient village irrigation tanks were taken by the Public Works Department (PWD) established in the 1830s (Tennakoon, 2017). Considering the priority given for renovation of major irrigation schemes in the dry zone, however, (Panabokke, Shakthivadivel & Weerasinghe, 2002) argued that until 1887 (from the abolition of *Rajakariya* in 1832), nobody was officially responsible for maintaining village irrigation works and this led to a degradation and decline of many minor irrigation systems, especially in the more remote parts of the dry zone. Provincial Irrigation Boards were established, and Government Agents (GAs) were entrusted with the responsibility of executing both major and minor irrigation works in their administration areas. These Provincial Irrigation Boards were subsequently abolished in 1900 with the creation of a separate central Irrigation Department, which was held responsible for the maintenance of all irrigation schemes through the GAs. These arrangements helped only to partially arrest the 50-year period of neglect and deterioration that many thousand small irrigation systems distributed throughout the dry zone suffered. Thus, during the 19th century, under British administration, the restoration of some of the major ancient irrigation works was carried out. Alongside this some attention was also given to the rehabilitation and improvement of indigenous small village tank irrigation systems.

The irrigation rehabilitation activities in the 20th century were mainly promoted by the need for producing adequate staple food within the country in order to avoid the heavy expenditure incurred on food imports (Panabokke, Shakthivadivel & Weerasinghe, 2002; Tennakoon, 2017). A revival in the repair, rehabilitation and improvement of the numerous small village tank irrigation systems was introduced immediately after World War I. This gave a significant impetus to the improvement and stabilization of the small tank irrigated agriculture, especially in the NCP and NWP.

The period after 1948 is generally regarded as the modern era of tank irrigation development (Tennakoon, 2017). Following the independence in 1948, the responsibility for maintaining minor irrigation schemes was taken over by the Ministry of Agriculture (MoA), and with the introduction of the *Paddy Lands Act* *of 1958*, the Department of Agrarian Development was entrusted with the responsibility for maintaining all village irrigation schemes in addition to investigation and construction as well as the maintenance of minor village tanks. The efforts of the DAD were, however, mainly diverted to the implementation of the Paddy Lands Act, and less to maintenance of minor village works (Panabokke, Shakthivadivel & Weerasinghe, 2002). There was the *Vel Vidane (Field Instructor)* system in which an individual proposed by the villagers in a particular settlement and his name was sent to the government's endorsement of the appointment.

The abolition of the *Vel Vidane* (traditional irrigation headman) system under the Paddy Lands Act of 1958 also resulted in the degradation of the leadership, discipline and maintenance of minor irrigation schemes. The Paddy Lands Act of 1958 eliminated the traditional institution of the *Vel Vidane* and substituted in its place the "Cultivation Committee" or CC. The CC was set up mainly to implement the provisions of the Paddy Lands Act and, in particular, the treasury regulations of this act. The CC had to face many problems, both legal and otherwise. This resulted in a further breakdown in the rural irrigation sector. (Panabokke, Shakthivadivel & Weerasinghe, 2002; Tennakoon, 2017)

With the *Agricultural Productivity Law No. 2 of 1972*, responsibility for executing all minor irrigation works was handed over to the *Territorial Civil Engineering Organization (TCEO)* that was considered to be a decentralized system with a high degree of engineering orientation. The TCEO was in operation for little over 5 years and neither this organization nor the minor irrigation works could adjust comfortably to benefit each other. With the dismantling of the TCEO, the minor works were transferred to the Irrigation Department in 1979 and in the same year they were retransferred to the DAD. *The Agrarian Services Act No. 59 of 1979* revived the DAD, and once again the maintenance of minor irrigation works was vested with the DAD, because the maintenance of minor irrigation works was neglected by the Irrigation Department due to its preoccupation with major irrigation schemes. The Agrarian Services Act No. 59 of 1979 empowered the DAD with the maintenance of all minor irrigation works with a command area of up to 80 ha and it also ensured provisions for water administration and management, which covered the following main functions: a. holding of *Kanna* meetings (pre-seasonal meetings of farmers) on time. b. efficient maintenance of irrigation systems. c. enforcement of such established customs affecting wastage and proper timing of agricultural operations. d. proper timing of paddy cultivation. e. joint measures for conservation of soil (Panabokke, Shakthivadivel & Weerasinghe, 2002).

Apart from the key interventions and regulating approach by the DAD in village irrigation system rehabilitation and maintenance, the other government and non-governmental organizations (NGOs) have also been involved in these tasks through different projects and programs. Such projects and programs have been implemented since 1970s by different government agencies and NGOs. These projects have been either direct small irrigation restoration and rehabilitation projects, special donor funded projects, components of integrated rural development projects and etc. Village irrigation Rehabilitation Project (VIRP), The Anuradhapura Dry Zone Agricultural Project (ADZAP), World Food Program (WFP) funded Minor Irrigation Rehabilitation Project, Small Tank Rehabilitation Project of the Freedom from Hunger Campaign (FFHC), Minor Irrigation Rehabilitation under the Dry Zone Agricultural Development Project of Care International. Samll Tank Cascade Development Program by Kala Oya basin Management Organization, *Kethata Aruna – Nil Diyawara* Tank Rehabilitation Program, *Wevu Gam Pubuduwa* Program, Climate Smart Irrigation Agriculture Project and etc. can be named as a few of such projects and programs implemented and being implemented by different parties in the state and non-governmental sectors.

However, the restoration and rehabilitation of village tanks in solitary basis and the approaches taken in such restorations have been subject to criticisms in different quarts of the related sectors in recent time. Also, the capacity enhancement or increase water availability of village tanks by raising spill and tank bands or extending the tank bunds is not the most preferable mean of tank rehabilitation Instead, the partial desiltation is mostly promoted though it is much costlier than either bund raising or expanding the tank bund or both. Panabokke, Tennakoon & Ariyabandu (2001) argued that, the water spread area of a tank is a function of the geometry of that tank changed through the siltation process over time as well as the changed condition of the tank embankment, its sluices and spill(s). The ways and means of partial desiltation enabling the return to original tank geometry has been demonstrated and thereby how the negative consequences of present tank geometry could be minimized. It is difficult to comprehend why desilting is avoided and raising tank embankment and raising spill levels preferred. Seeing the importance of not only increasing the tank capacity, but also improving the conditions of tank eco-system which is dangerously deteriorating and small tanks turning to mere grassy swamps it has been reported that if present method of bund raising continued, scientists, planners and engineers cannot escape from the challenge of disappearing of minor tanks from the Dry Zone landscape during the next few decades.

Further, Shakthivadivel, Fernando & Brewer (1997) and Aheeyar (2013) emphasized the need of irrigation system rehabilitation planning and implementation within the cascade context rather than employing individual tank restoration approach. Therefore, planning rehabilitation or improvements of any tank system requires assessing and understanding the entire hydrology of the cascade before any intervention to any tank in the cascade is contemplated, especially when water is becoming scarce. Thus, failure to consider cascade hydrology had been detrimental to small tank rehabilitation projects and they have been criticized for poor benefit-cost ratios and other flaws. Despite efforts made to renovate small tanks under various tank rehabilitation projects implemented, there has not been any significant improvement in cropping intensity. This calls into question the strategies currently being used to rehabilitate tanks, as well as their effect on the water storage efficiency of tanks (Dharmasena, 2020). Aheeyar (2013) noted that participatory development approach is vital to address the real needs of the rural people and make the beneficiaries and line agencies strong partners in the project implementation and to create a sense of responsibility, ownership and accountability and ensure involvement in the post project sustainable operation and maintenance (O&M).

CHAPTER THREE

Results and Discussion

3.1 Introduction

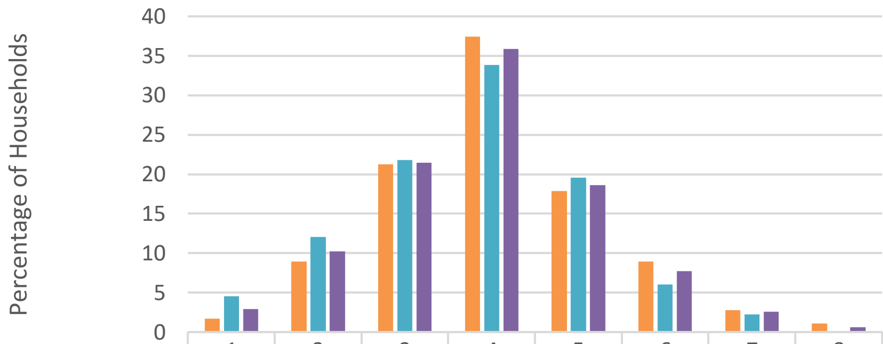
The situation of current crop production patterns in upland fields including *chena* cultivation, lowland paddy cultivation and the home gardening and the socio-economic conditions of the farm households are discussed in this chapter. Particularly, the family size, age and gender distribution of farmers, type of lands and land distribution of farm households, income generating activities will be discussed in the initial part of the Chapter 3. Changes occurred in land use and land cover in the last four decades were analyzed using GIS and remote sensed data. The results of these analysis are also presented and discussed in this chapter.

3.2 Demographic Information of the Farmer Households

The total number of households surveyed in the study was 312. It comprises 179 households from Mi Oya River basin in the Kurunegala district and 133 households from Malwathu Oya River basin in the Anuradhapura district. In the sample 95 % and 80% of the respondent farmers in Mi Oya river basin and Malwathu River Oya basin are respectively males, reflecting the gender bias in holding and playing different roles as the head of the household (HH) in the study location, the typical tank villages in the agrarian communities in the dry zone Sri Lanka.

3.2.1 Family Size

Almost all the households surveyed in the two districts consisted of only a single family. As illustrated in Figure 3.1, in both districts the highest number of households (above 30%) have four members in the family. Percentage households with three members were about 20 percent and that number is also more or less equal in Kurunegala and Anuradhapura districts. Further, about 20 percent of households in the two districts are five member families.



	1	2	3	4	5	6	7	8
Kurunegala	2	9	21	37	18	9	3	1
Anuradhapura	5	12	22	34	20	6	2	0
Total	3	10	21	36	19	8	3	1

Number of Family Members in Household

Source: HARTI Survey Data, 2016

Figure 3.1: Number of Family Members in the Study Area

3.2.2 Gender Ratio

The total population in the respondent households in the sample was 1240 persons consisting of 59 percent males and 41 percent females. The total number of persons of farm households in Mahawmeruwa cascade area is 733 while the same statistics for the Maha Kumbukwewa cascade area in Anuradhapura district is 507 persons. As shown in Table 3.1, gender ratio of the population, which is the number of males per 100 females is 99.

Table 3.1: Gender Distribution of the Sample

District	Male	Female	Gender Ratio
Kurunegala	373	360	1.04
Anuradhapura	244	263	0.93
Total	**617**	**623**	**0.99**

Source: HARTI Survey Data, 2016

3.2.3 Age Distribution of Sample Farmers

In both districts, the age of the majority of the farmers are above 50 years. As shown in Table 3.2, 24 percent of the sample in Mi Oya river basin and 23 percent in Malwathu Oya river basin were between 41 years and 50 years. Non-surprisingly, more than half of the respondent farmers are above 50 years of age, reflecting the general picture of the subsistence farming which is largely constituted by the middle-aged and aged farmers due to lesser involvement by the members of young generations in Sri Lankan agricultural sector. However, there is a fair involvement of young people (age 21 – 40 years) in farming accounting for 24 percent each. Farmers above 60 years account for a quarter in each cascade system.

Table 3.2: Age Distribution of Sample Farmers

Age group	District		Total
	Kurunegala	Anuradhapura	
21-30	7 (4%)	5 (4%)	12 (4%)
31-40	36 (20%)	26 (20%)	62 (20%)
41-50	43 (24%)	30 (23%)	73 (23%)
51-60	48 (27%)	40 (30%)	88 (28%)
Above 60	45 (25%)	32 (24%)	77 (25%)
Total	**179 (100%)**	**133 (100%)**	**312 (100%)**

Source: HARTI Survey Data, 2016

3.2.4 Level of Education of Respondent Farmers

As far as the formal education level of the respondent farmers is concerned, it is revealed that nearly one fourth of farmers are confined to primary education. The overwhelming majority has not continued formal education beyond the General Certificate of Education (GCE) Ordinary Level examination. Accordingly, 58 percent of farmers' education is limited to the grade 10 at which the GCE (O/L) examination is held. Thus, nearly 80 percent of respondent farmers are below the GCE (O/L) qualifications. Those who have passed the GCE Advanced Level examination account for only around 2 percent while the percentage of farmers having tertiary education including degree and diploma is limited to 1.

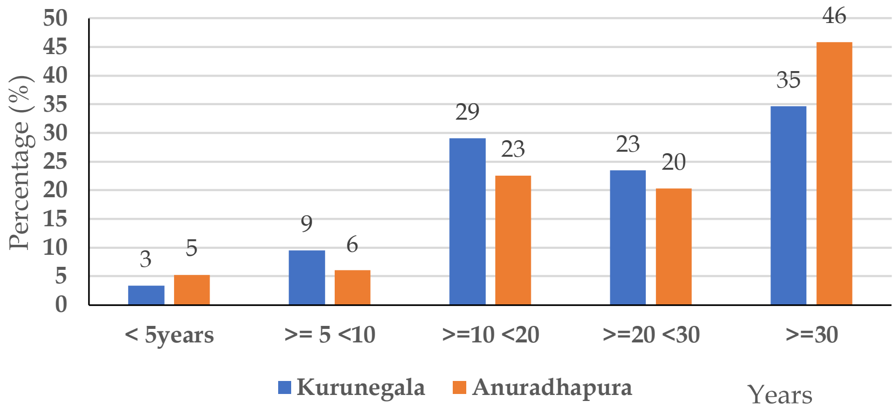
Table 3.3: Education Level of Sample Farmers

Education Level		Kurunegala	Anuradhapura	Total
Not Attended	No	3	1	4
	%	1.68	0.75	1.28
Primary (1-5)	No	54	15	69
	%	30.17	11.28	22.12
Secondary (6-11)	No	92	88	180
	%	51.40	66.17	57.69
Passed GCE O/L	No	14	17	31
	%	7.82	12.78	9.94
Upto GCE A/L	No	10	8	18
	%	5.59	6.02	5.77
Passed GCE A/L	No	5	2	7
	%	2.79	1.50	2.24
Graduate	No		1	1
	%	0.00	0.75	0.32
Diploma	No	1	1	2
	%	0.56	0.75	0.64
Total		**179**	**133**	**312**

Source: HARTI Survey Data, 2016

3.2.5 Farming Experience

The farmers' experience in crop production is one of the key factors that affect farmers' decision making process in relation to production as well as marketing aspects of the crops grown. Adoption by farmers to the situations caused by repercussions of natural phenomena and anthropogenic activities also have direct impacts from the farmers' experience. The Figure 3.2 shows that over 60 percent of respondent farmers are having farming experience for more than 20 years. The majority of the farmers are of over 30-year experience in crop production. This situation reflects that the aged and middle aged farmers are vastly involved in farming in the study locations.



Source: HARTI Survey Data, 2016

Figure 3.2: Farming Experience of the Respondent Farmers

3.2.6 Occupation

In this study a primary occupation broadly refers to the kind of work a person does for pay/earn most of the time. More specifically, this term is used to describe the occupation corresponding with a respondent farmer's primary job. Accordingly, little over 3 percent of the head of the households are not engaged in any kind of income earning source as they are reported to be elderly persons. The majority of the respondents are involved in farming as the primary source of income and it accounts for over two third of the total sample in both districts. The contribution to the agriculture related other activities (farm assistant, livestock, agricultural labour and etc.) have been limited to less than 3 percent of the total sample. The second most important primary occupation for the respondent farmers is employments in the government sector followed by skilled labour activities and self-employments. This information emphasizes that the importance of farming and other agricultural activities as the primary occupation of the overwhelming majority of the respondent farmers.

Table 3.4: The Primary Occupation of Respondent Farmers

Occupation	Kurunegala		Anuradhapura		Total	
	No	%	No	%	No	%
House wife	1	0.56	1	0.75	2	0.64
No Occupation (Elderly Respondents)	8	4.47	2	1.50	10	3.21
Farming	129	72.07	87	65.41	216	69.23
Farming assistant	2	1.12	1	0.75	3	0.96
Livestock	4	2.23		0.00	4	1.28
Nonagricultural Labor	1	0.56		0.00	1	0.32
Skilled Labor	8	4.47	5	3.76	13	4.17
Government Sector	9	5.03	27	20.30	36	11.54
Private job	3	1.68	7	5.26	10	3.21
Self-Employment	12	6.70		0.00	12	3.85
Foreign Employment	2	1.12	3	2.26	5	1.60
Total	**179**	**100.00**	**133**	**100.00**	**312**	**100.00**

Source: HARTI Survey Data, 2016

The secondary occupation allows one to be involved in tasks and activities in addition to the primary occupation so that he/she can earns extra income as well. In case of farming, owing to the risks and uncertainties associated with this particular livelihood, farmers tend to seek other source of income to support the household economy.

Table 3.5: The Secondary Occupation of Respondent Farmers

Occupation	Kurunegala		Anuradhapura		Total	
	No	%	No	%	No	%
Farming	33	18.44	33	24.81	66	21.15
Livestock	6	3.35		0.00	6	1.92
Agricultural Labour	7	3.91		0.00	7	2.24
Nonagricultural Labour	6	3.35	7	5.26	13	4.17
Skilled Labour	12	6.70	4	3.01	16	5.13
Government Sector	1	0.56	3	2.26	4	1.28
Private Sector	1	0.56	2	1.50	3	0.96
Self-Employment	47	26.26	8	6.02	55	17.63
No Secondary Occupation	66	36.87	76	57.14	142	45.51
Total	**179**	**100.00**	**133**	**100.00**	**312**	**100.00**

Source: HARTI Survey Data, 2016

The majority of farmers (45 percent) have no any secondary source of income and they are totally engaged in farming as their sole economic activity. Farming is the prominent secondary occupation of the respondents those who are involved in non-agricultural activities as the primary occupation. Farmers involved in agriculture-related other activities such as livestock and farm labour accounts for only about 4 percent of the sample. Self-employment activities like brick making, sawing, mobile-business and etc. are playing a key role being prominent secondary occupations for nearly one fifth of respondents.

In the ancient village tank-based production systems, livestock used to be an integral component. At present, the livestock farming in the system is not a major activity either as a primary or secondary source of income as compared to the old days. There are some limitations. Shortage of grazing lands has been the main reason. Some farmers in the system keep a few cows of cattle/buffalo for milk production. These animals are managed in extensive manner, feeding on communal grazing ground during daytime, brought back home in the evening, and kept in paddocks. The usual grazing lands are paddy fields after harvest, catchment areas of the village tanks, tank bed during dry period, tank bund, shrub jungle and other open areas.

3.2.7 Type of Engagement in Farming

As shown in Table 3.6, about nine percent of the respondent farmers in the Kurunegala district are not engaged in farming. They have given their farm lands (in the form of either leased out or rented out) to a second party for crop cultivation mostly due to non-availability or inadequacy of family labour to carryout agronomic activities. Nearly two third of the respondents are involved in farming activities in full time basis. The part-time farmers are less in the Kurunegala district (25 percent) compared to that of in Anuradhapura district (41 percent).

Table 3.6: Type of Farming Practiced by the Sample Farmers

Level of farming	District		Total
	Kurunegala	Anuradhapura	
Not actively taking part	17 (9%)	0 (0%)	17 (5%)
Full time	118 (66%)	79 (59%)	197 (63%)
Part time	44 (25%)	54 (41%)	98 (31%)
Total	**179 (100%)**	**133 (100%)**	**312 (100%)**

Source: HARTI Survey Data, 2016

3.3 Crop Production Systems

Traditionally, three forms of crop production activities; lowland paddy cultivation, home gardening and *chena* cultivation in village tank systems prevailed. Though, over the time these systems have drastically changed due to various reasons and factors, still some basic components of those production systems can be identified. Home gardening and upland (including *chena*) cultivation are mostly limited to rainy *Maha* seasons. The lowland paddy growing and upland farming (including home gardens and other uplands) are practiced in the land lots with assured irrigation facilities in the dry *Yala* seasons as well.

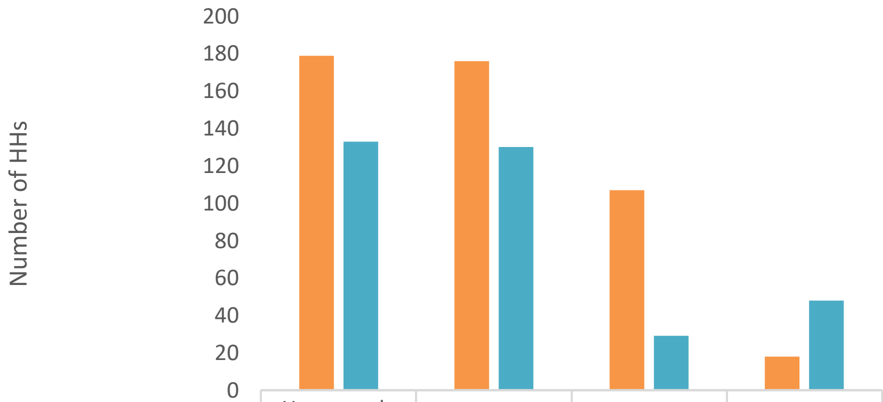
3.3.1 Type of Lands Cultivated

Home gardening either for own household consumption or for marketing or the both and lowland cultivation, mostly with paddy in the rainy *Maha* seasons and either paddy or other field crops (OFCs) in dry *Yala* seasons are the common cultivation pattern identified in the study locations. Cultivation of home gardens and low lands has been a common practice in both river basins. However, the proportion of farmers involved in regular upland cultivation and shifting cultivation (*Chena*) is relatively low in both locations. The Table 3.7 and the Figure 3.3 illustrate the different land types used for crop cultivation in two study locations.

Table 3.7: Types of Lands Cultivated by Respondent Households

Location	Type of land	Households	
		No	%
Kurunegala	Home Garden	179	100
	Low Lands	176	98
	Uplands	107	60
	Chena	18	10
Anuradhapura	Home Garden	133	100
	Low Lands	130	98
	Uplands	29	22
	Chena	48	36

Source: HARTI Survey Data, 2016



	Homegardens	Lowlands	Highlands	Chena
Kurunegala district	179	176	107	18
Anuradhapura district	133	130	29	48

Kurunegala district Anuradhapura district

Source: HARTI Survey Data, 2016

Figure 3.3: Types of Lands Cultivated by Respondent Households

Home gardening is practiced in all the respondent households where as the upland/highlands and *chena* cultivations have been limited to some lesser number of households in both locations. However, the *chena* cultivation is practiced by 36 percent of households in Anuradhapura while it is limited to a 10 percent of households in Kurunegala. The upland cultivation is a prominent type of crop production activity in the villages in Anuradhapura (involved by about 60 percent of households), however, it is limited to only 22 percent of households in Kurunegala.

3.3.2 Crop Cultivation in Home Gardens

Home gardening considered in tank village systems to be a vital source of nutritious and fresh food of households and a source of income as well. However, in most of the instances, owing to absence of regular supplementary irrigation facilities, the home gardening in dry zone areas has been limited to rainy *Maha* season. When a source of irrigation is assured, farmers tend to grow crops in home gardens in *Yala* seasons too. Table 3.8 Presents the supplementary irrigation facilities available for home gardening.

Table 3.8: Source of Water for Home Gardening

District		Kurunegala	Anuradhapura	Total
Rainfed	No	133	80	99
	%	74	60	69
Agro-well	No	16	32	48
	%	9	24	15
Domestic well	No	21	18	39
	%	12	14	12
Pipe-Born Water from Community Water Supply Scheme	No	9	3	12
	%	5	2	4
Total Respondent (N)		**179**	**133**	**312**

Source: HARTI Survey Data, 2016

Accordingly, about 69 percent of home gardens are rain dependent and only less than one third of home gardens are cultivated with any supplementary water sources such as agro-wells, domestic wells and pipe-born water from community water supply schemes. The priority for vegetable and OFC cultivation can be seen in both locations. Upland paddy cultivation in home gardens is practiced by only 3 percent of households, which is limited to rainy *Maha* seasons.

3.3.3 Crop Cultivation in Lowlands

The number of land parcels (plots) possessed by individual households, in village tank systems, used to be an indicator of the wealth of the given household. In both locations the lowland land category showed a higher land holding distribution ranging from 1 – 8 land parcels (Table 3.9). The total number of land plots possessed by the sample households (306) was 677. However, the number of lowland plots currently being used for lowland cultivations by the sample HHs was reported to be 673 in the study locations as other fields have been leased-out or rent-out to different parties.

The proportion of farm households possessing 4 or more lowland plots is limited to around 10 percent. The majority of farm households is reported to possess only one lowland plot (36 percent) followed by 2 plots (30 percent). Farm households having 3 lowland plots account for one fifth of the sample.

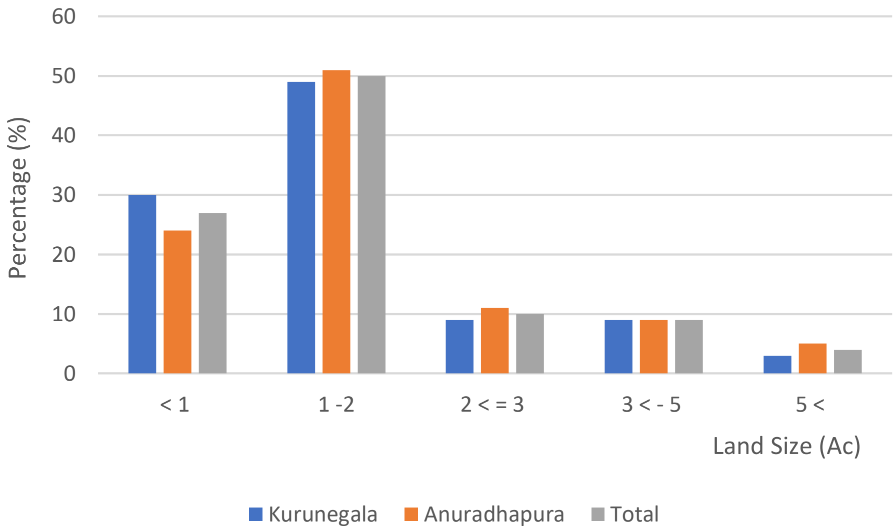
Table 3.9: Number of Lowland Parcels Owned by Households

No of Land Parcels		District		Total Households
		Kurunegala	Anuradhapura	
1 Plot	No	58	51	109
	%	33	39	36
2 Plots	No	56	35	91
	%	32	27	30
3 Plots	No	34	36	70
	%	19	28	23
4 Plots	No	14	6	20
	%	9	5	7
5 Plots	No	5	2	7
	%	3	1	2
6 Plots	No	2	-	2
	%	1	-	1
7 Plots	No	3	-	3
	%	2	-	1
8 Plots	No	3	-	3
	%	2	-	1
Total HH		**176**	**130**	**306**

Source: HARTI Survey Data, 2016

As described in Figure 3.4, majority of the total extent of lowland plots owned by respondent HHs were within an acre to 2-acre category. Land parcels that are less than an acre in Mi Oya river basin and Malwathu Oya basin were 30 and 24 percent respectively. Land plots with more than five acres were very less in both river basins.

The cultivation patterns of the lowland fields are totally depended on the water availability, particularly in the dry seasons. Thus, a diversity in the cropping patterns and the crops cultivated in lowlands can be seen in both locations. Given the importance of food security paddy is the sole crop grown during rainy *Maha* seasons.



Source: HARTI Survey Data, 2016

Figure 3.4: Distribution of Lowlands by Extent

On the other hand, the wet and muddy conditions of the fields in rainy period are more appropriate for paddy rather than other crops such as vegetables and OFCs.

Table 3.10: Cultivation Patterns in Lowland Plots

District	Paddy in Both Seasons		Paddy in *Maha* & OFCs/Vegetables in *Yala*		Only *Maha* (Paddy)		Total No of Lowland Plots
	No	%	No	%	No	%	
Kurunegala	111	27	18	4	281	69	410
Anuradhapura	142	54	2	1	119	45	263
Total	**253**	**38**	**20**	**3**	**400**	**59**	**673**

Source: HARTI Survey Data, 2016

Nearly 60 percent of the lowland plots are cultivated only in *Maha* season due to the water scarcity in the dry season. Even in dry *Yala* seasons, the majority of farmers are preferring to grow rice when the irrigation is assured. The proportion of farmers growing OFCs and/or vegetables in the *Yala* seasons is limited to 3 percent. This situation reflects the farmers' priority on food security status of the HHs rather investing on high value cash crops or vegetables.

Though the lowlands under the respective village tanks are provided with irrigation, all the land plots under the entire command area do not have the same opportunity to access to irrigation, largely owing to the location of the land plots. In this situation, specially the tale-enders are mostly disadvantageous and always at the receiving end.

In many instances, villagers tend to convert uplands located close to the paddy field into lowlands. However, it takes long time for such newly converted lowlands to get irrigation facilities through a proper field canal network. Therefore, some land plots have to be provided with supplementary irrigation when the irrigation supply from the tank is not adequate. Table 3.11 shows the different source of irrigation used by respondent farmers.

Table 3.11: Source of Water/Irrigation for Lowlands

Water Source		Kurunegala	Anuradhapura	Total
Village Tank	**No**	401	258	659
	%	98	98	98
Rainfed	**No**	16	10	26
	%	4	4	4
Agro well	**No**	5		5
	%	1		1
River	**No**	15		15
	%	4		3
Total	**N**	**410**	**263**	**673**

Source: HARTI Survey Data, 2016

Accordingly, lowlands in the cascade in Anuradhapura district are completely dependent on irrigation facilities from the village tanks and the rainfall. Four percent of farm plots have no irrigation facilities from the village tanks, hence, such fields are considered to be rainfed lowlands. However, in case of lowlands in Mahameruwa cascade nearly one tenth of the fields are having supplementary irrigation sources like agro-wells and river/stream. In the critical stages of the crop and during the latter part of the dry *Yala* season, the tale-enders opt to pump water from agro-wells and the nearby river/stream (the Mi Oya river) to protect the crop.

There have been unique systems of sharing resources in the community of village tank systems. One important aspect is the sharing of the paddy tract during seasons of water shortage (*Bethma*). Paddy lands are individually owned. But during the seasons of water shortage, as cultivation of the full extent under the tank in not possible, one portion of the command area (paddy fields) is left out while the other portion is distributed among all the farmers under the tank equally. This system is known as —*Bethma* cultivation. The decision is taken during a meeting attended by farmers and officials collectively. This arrangement was only for that season (FAO, 2017). However, this system is not being practiced in the villages studied so that the majority of farmer HHs (about 60 percent) are able to cultivate paddy only in the rainy *Maha* seasons.

3.3.4 Upland Cultivation

In this study, the uplands located in the common forested area in the village tank catchment is considered as the *chena* plots while the other forms of uplands except home gardens used for crop cultivation are defined as the regular uplands.

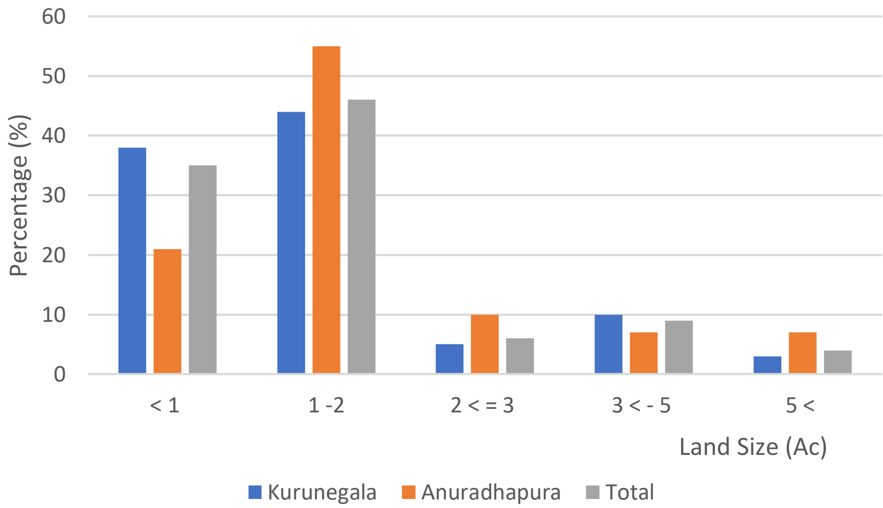
The Table 3. presents the distribution of upland plots used for crop cultivation in the study locations. In Anuradhapura, the number of HHs involved in upland crop production activities and the number of upland plots possessed by those HHs are significantly lesser than those in the cascade in the Kurunegala district. When the proportion of HHs having upland cultivation plots in Kurunegala was reported to be 60 percent it was mere 22 percent in Anuradhapura.

Table 3.12: Distribution of Upland Plots among Sample Households

	Kurunegala		Anuradhapura		Total HH	
	No	**%**	**No**	**%**	**No**	**%**
Households	107	60	29	22	136	44
Total HH (N)	179		133		312	

Source: HARTI Survey Data, 2016

Of the total extent of uplands owned by respondent HHs, the majority comes under the category of less than an acre. The percentage of HHs possessing uplands less than 1 ac in Mi Oya river basin and Malwathu Oya river basin was about 38 and 21 respectively (Figure 3.5). In the 1 ≥ 2 category 44 percent were in the Mi Oya basin and it was 55 percent in the Malwathu Oya river basin. Land plots over five acres were very less and it was about three percent in Mi Oya river basin and seven percent in the Malwathu Oya basin.



Source: HARTI Survey Data, 2016

Figure 3.5: Distribution of Uplands by Land Size

According to the Table 3.13, the total number of upland plots in the study locations in the Kurunegala and Anuradhapura districts are 148 and 33 respectively. The majority of HHs (74 percent) are holding only one upland plots. In Anuradhapura along, 86 percent of HHs are reported to be holding only 1 upland parcel. The proportion of HHs possessing 2 upland plots are one fifth of the sub-sample (of 136 HHs).

Table 3.13: Number of Upland Parcels Owned by Sample Households

No of Land Parcels		District		Total HH
		Kurunegala	Anuradhapura	
1 Plot	**No**	76	25	101
	%	71	86	74
2 Plots	**No**	23	4	27
	%	22	14	20
3 Plots	**No**	7	-	7
	%	6	-	5
5 Plots	**No**	1	-	1
	%	1	-	1
Total HH (N)		**107**	**29**	**136**

Source: HARTI Survey Data, 2016

Although the uplands in two cascade areas are used for crop growing as semi-permanent or permanent cultivation plots, over three fourth of the uplands can be identified as solely rain dependent plots (Table 3.14). The other main water source for upland farming is agro-wells accounting for about 13 percent. Domestic well, pipe-born water from the community water supply schemes and runoff water harvesting tanks (*Pathaha*)are the other water sources for upland crop cultivations.

Table 3.14: Distribution of Water Source in Uplands

Water Source		Kurunegala	Anuradhapura	Total
Village Tank	No	4	2	6
	%	3	6	3
Rainfed	No	110	26	136
	%	75	79	75
Agro-well	No	19	4	23
	%	14	12	13
Domestic well	No	5	1	6
	%	3	3	4
Pipe-Born Water from Community Water Supply Scheme	No	5		5
	%	3		3
Pathaha	No	3		3
	%	2		2
Total		**148**	**33**	**181**

Source: HARTI Survey Data, 2016

Table 3.15: Cropping Patterns in Uplands

Cropping Pattern	Kurunegala	Anuradhapura	Total
Paddy in *Maha* and OFC/vegetables in *Yala*	3(2%)	1(3%)	4 (3%)
Paddy in *Maha* and not cultivating in *Yala*	21(17%)	8(28%)	29 (22%)
Cultivating mixed crops	71(58%)	17(59%)	88 (65%)
Maha OFC and not cultivating in *Yala*	2(2%)	0	2 (1%)
Perennial crops	10(8%)	3(10%)	13 (9%)
Total	**107 (100%)**	**29 (100%)**	**136 (100%)**

Source: HARTI Survey Data,2016

In Mi Oya and Malwathu Oya River basins 17 percent and 28 percent of the farmers respectively undertake upland cultivation only for paddy crop in *Maha* seasons. In both river basins majority of the HHs cultivate mixed crops and perennial crops in uplands.

3.3.5 *Chena* Cultivation

Since the ancient time, the upland crop cultivation, particularly in the form of *chena* cultivation in village tank systems has been the prominent cropping system in many aspects. With the increased population growth and conversion of forest patches into non-agricultural uses and legal constraints on shifting cultivation prompted the village communities to make changes to the traditional forms of upland farming practices. The usual longer fallowing period with several years became shorter and in many instances, the same plot of land is cultivated in every year by the same farmer. Thus. Some of these *chena* plots have become permanent or semi-permanent type uplands where the crop cultivation is undertaken with or without supplementary irrigation facilities. The total respondent HHs involved in *chena* cultivation in both river basins were limited to 66. The proportion of farm HHs engaged in *chena* cultivation in Mi Oya and Malwathu Oya river basins is 10 percent and 36 percent respectively.

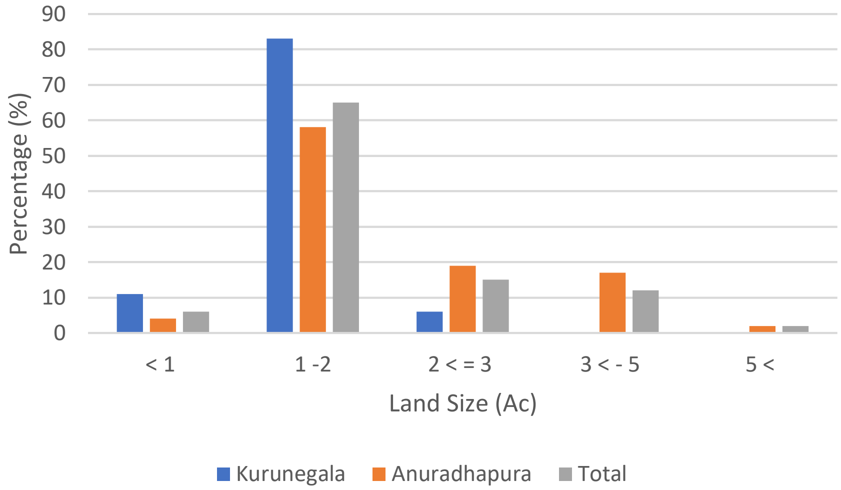
According to the Table 3.16, the total number of upland plots in the study locations in the Kurunegala and Anuradhapura districts are 21 and 49 respectively. Unlike in other types of croplands (lowlands and uplands), the maximum number of *chena* fileds possessed by HH was reported to be 2 in both locations. However, the overwhelming majority of HHs (94 percent) are holding only one *chena* plot. In Anuradhapura along, 98 percent of HHs are reported to be holding only 1 upland parcel. The proportion of HHs possessing 2 upland plots are one limited to mere 6 percent (of 66 HHs).

Table 3.16: Number of *Chena* Land Parcels Owned by Sample Households

No of Land Parcels		**District**		**Total HH**
		Kurunegala	**Anuradhapura**	
	No	15	47	62
1 Plot	**%**	83	98	94
	No	3	1	4
2 Plots	**%**	17	2	6
Total HH (N)		**18 (100%)**	**48 (100%)**	**66 (100%)**

Source: HARTI Survey Data, 2016

Of the total extent of *chena* lands possessed by respondent HHs, majority in the Mi Oya river basin and Malwathu Oya river basin are 1≥2-acre category. As the HHs involved in *chena* cultivation in Mi Oya river basin is at very low level, the land extent owned by HHs is also at a very low level compared to the situation in the Malwathu Oya river basin in Anuradhapura district.



Source: HARTI Survey Data, 2016

Figure 3.6: Distribution of *Chena* Lands by Land Extent

Though farming in *chena* lands have traditionally been a complete rainfed system, in the present context some plots are provided with irrigation facilities.

Table 3.17: Water Source for *Chena* Cultivation

		Kurunegala	Anuradhapura	Total
Village Tank	**No**	0	1	1
	%	**0**	2	1
Rainfed	**No**	18	47	65
	%	86	96	93
Pathaha	**No**	1	0	1
	%	5	0	1
River/Stream	**No**	2	1	3
	%	9	2	5
Total	**No**	**21**	**49**	**70**
	%	**100**	**100**	**100**

Source: HARTI Survey data, 2016

However, *chena* plots having supplementary irrigation facilities are very limited (7 percent). As per Table 3.17, over 93 percent of *chena* plots are cultivated under rainfed condition.

3.4 Land Use Changes in the Study Areas

Anthropogenic disturbances to the tank catchment areas have been identified as the major reason for the accelerated soil erosion resulting in tank sedimentation in the dry zone. By identification of the land use changes over the time in any particular area, specially in a tank catchment, the magnitude of catchment degradation can be assessed. For this purpose, digital maps of the two cascades were analyzed. The land use maps in 1983 and 2018 were analyzed using ArcGIS software.

The changes in land use in the Mahameruwa cascade in Ehetuwewa ASC area over the particular time period is presented in the Figure 3.7 and Figure 3.8. The information of the extent of different land use types is summarized in Table 3.18.

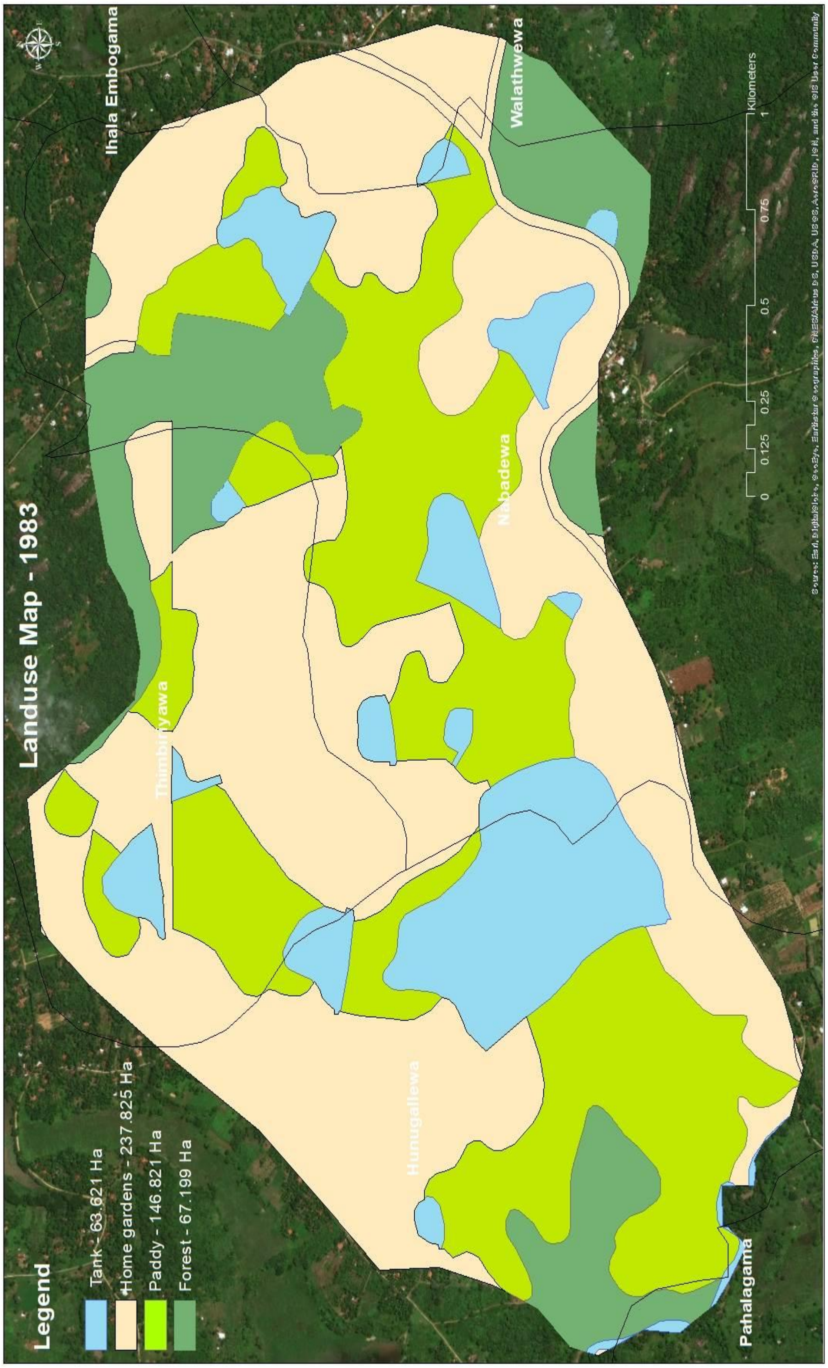


Figure 3.7: Land Use Map of Mahameruwa Cascade in 1983

Figure 3.8: Land Use Map of Mahameruwa Cascade in 2018

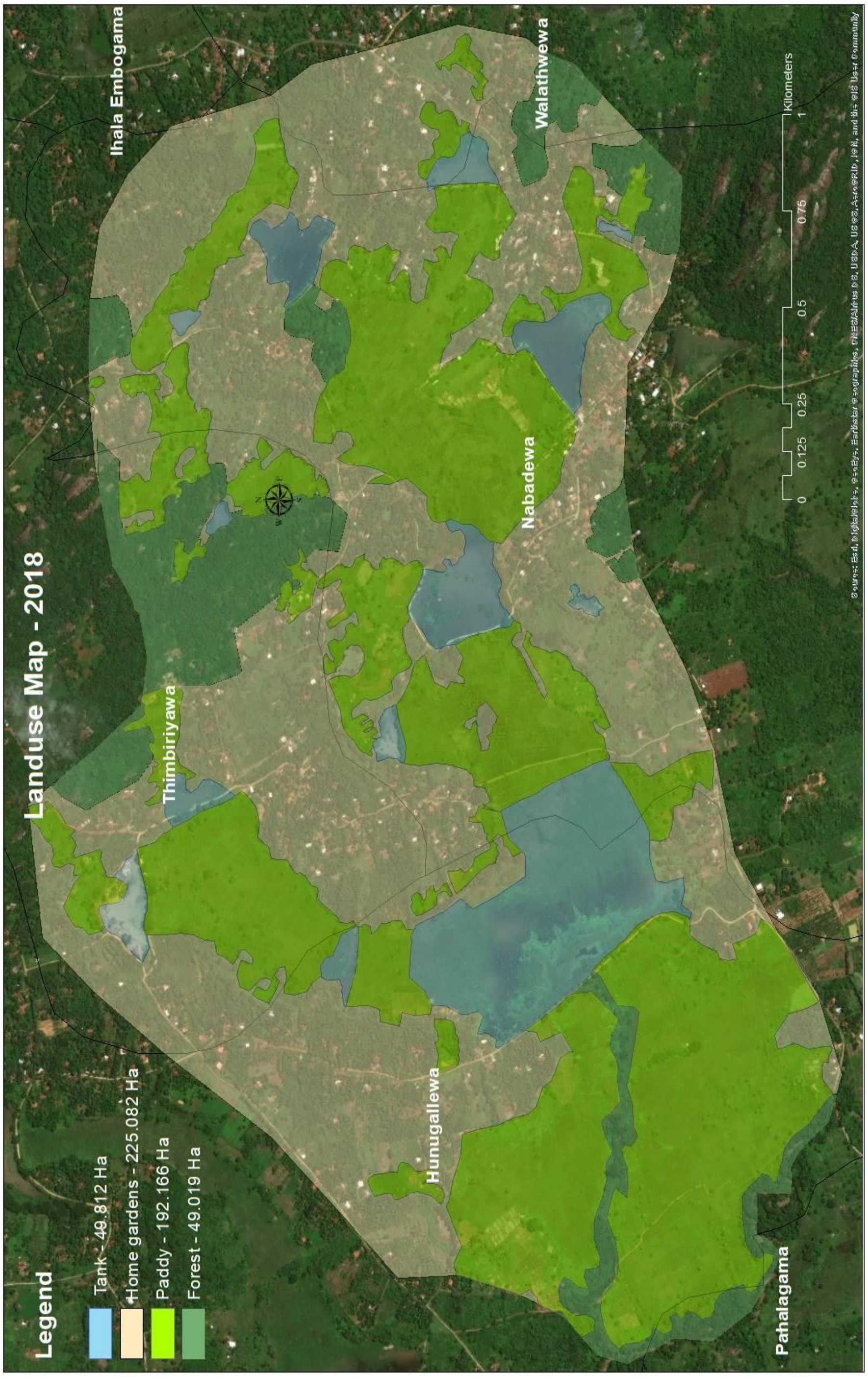


Figure 3.9: Land Use Map of Mahameruwa Cascade in 2018 (Sketch)

Table 3.18: Changes in Land Use Types in Mahameruwa Cascade

Land use Type	Extent in 1983 (ha)	Extent in 2018 (ha)	Change	
			Extent (ha)	Percentage (%)
Village Tank	63.71	49.81	- 13.90	- 21,8
Residential and Home garden	237.82	225.08	- 12.74	- 12.74
Paddy Lands	146.82	192.16	+ 45.34	30.88
Forest/Shrub Area	67.79	49.09	- 18.70	27.58
Total	**516.14**	**516.14**		

It reveals that the total paddy land extent has remarkably increased by 31 percent while all the other land use types have declined including the area under the tanks. The extent of forest patches in catchment areas has decreased by 28 percent. The decline of forested area is mainly attributed to the conversion into paddy lands.

The increase in the paddy land extent and decrease in the tank area clearly provide evidence for water scarcity for cultivations in paddy lands specially in the dry *Yala* seasons. As the tale-ender farmers in the command area of the tank immediately above have converted inundated area of the compelled the *Jalapalaka* (*Water Controller*) to open the sluice gates even before the water level of the tank reaches the spill level. This situation has adversely affected the water storage of some tanks in the two cascades studies. The lands adjacent to the paddy fields are cleared and converted into paddy fields with the increase of population and number of farm household units. It has affected the demand for limited water stored in the village. The practice of efficient water sharing and management in dry spells should be promoted for fair share of water among the member farmers of each farmer organization. Traditional water sharing methods such as *bethma* can be promoted as a viable solution for this situation. Also the crop diversification should be promoted to encourage farmers to grow low water consuming crops specially in the dry seasons.

Changes in land use in the Maha Kumbukwewa cascade in Medawachchiya ASC area over the particular time period can be seen in Figure 3.10 and Figure 3.11. Information on the extent of different land use types is summarized in Table 3.19.

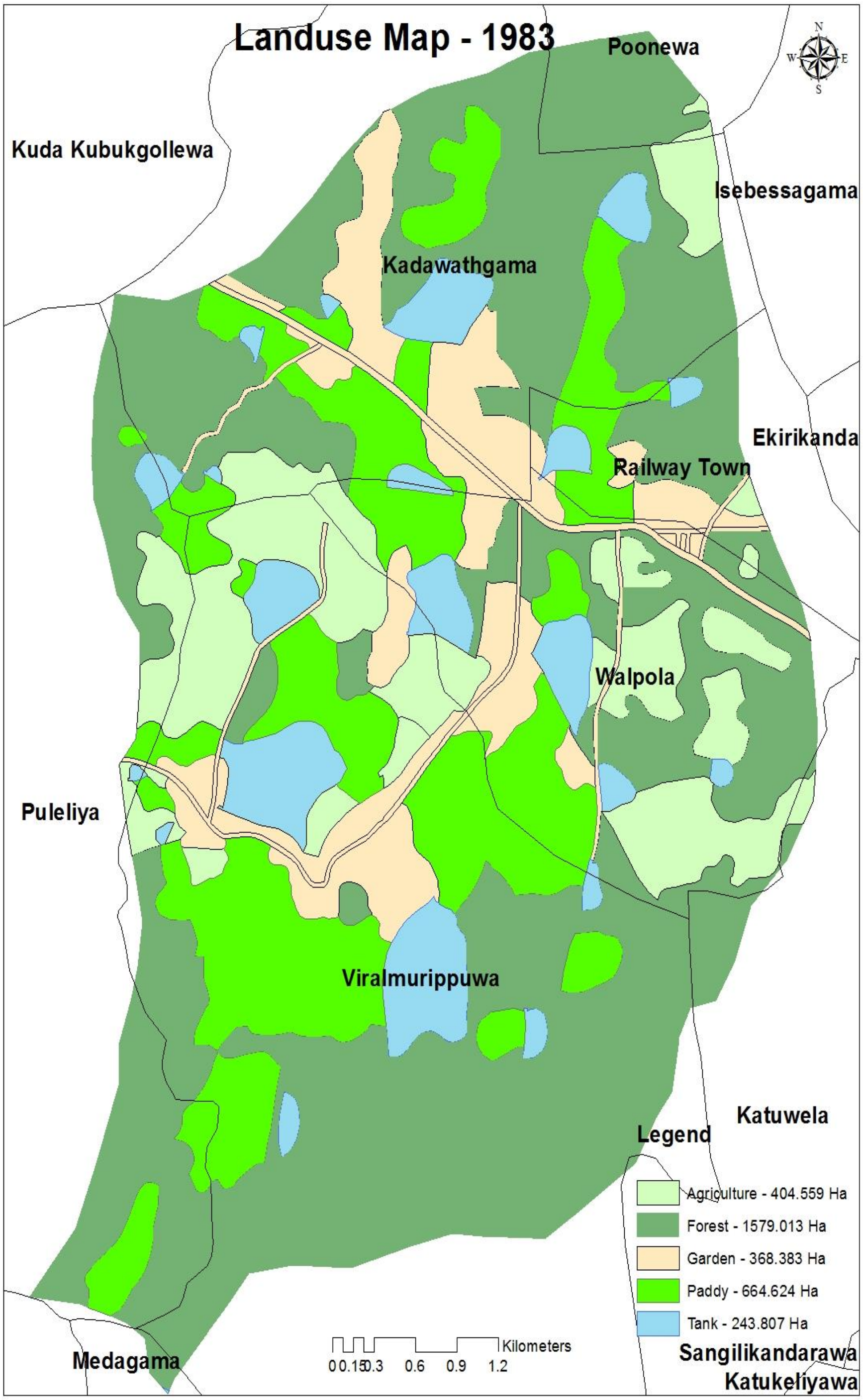


Figure 3.10: Land Use Map of Maha Kumbukwewa Cascade in 1983

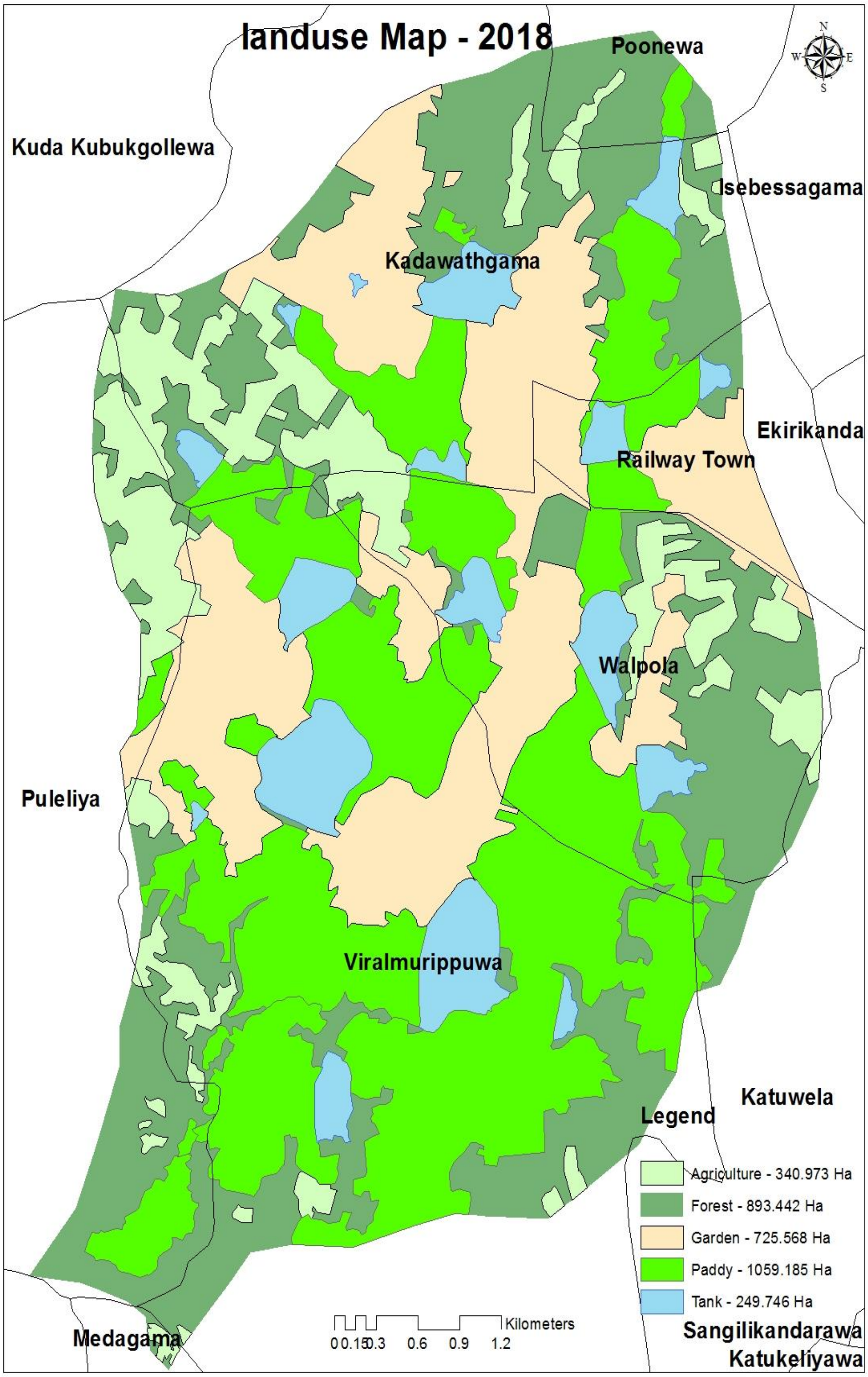


Figure 3.11: Land use Map of Maha Kumbukwewa Cascade in 2018

Table 3.19: Changes in Land Use Types in Maha Kumbukwewa Cascade

Land use Type	Extent in 1983 (ha)	Extent in 2018 (ha)	Change	
			Extent (ha)	Percentage (%)
Village Tank	248.82	249.74	0.92	0.37
Residential and Homegarden	369.58	725.56	355.98	96.32
Paddy Lands	664.62	1059.18	394.56	59.36
Other Agricultural Lands	406.76	340.97	-65.79	-16.17
Forest/Shrub Area	1579.11	893.44	-685.67	-43.42
Total	**3268.89**	**3268.89**		

It reveals that the total paddy land extent has remarkably increased by 59 percent while all the other land use types have diminished except the tank area. The extent under tanks has increased due to increase of the spill level of the Walpola tank during the period (1983 – 2018). The extent of forest patches in catchment areas has decreased by 43 percent. The forest lands have extensively been converted into paddy lands and residential plots over the given period. In this area, the other agricultural lands, specially *chena* and upland crop lands have become either paddy lands or home gardens. Increase in paddy land extent without a considerable increase in the tank areas and their capacities in this location clearly provides evidence for water scarcity for cultivations in paddy lands specially in the dry *Yala* seasons.

3.5 Reasons for Diminished Services of Village Tanks

As discussed in the previous sections the crop cultivation in the majority of lowlands as well as uplands (including home gardens and regular uplands) have been limited to the rainy *Maha* seasons in both study locations. As pointed out by the farming communities and the field level officers, the issues related to availability of water in the tanks have been the major reason for this situation. Siltation of tanks beds leading to lower capacities over the time has been the key factor for lesser water availability, particularly in the dry seasons. Decline of forest and shrub patches in the tank catchment areas due to agricultural and non-agricultural activities escalating soil erosion is considered to be the main reason for rapid sedimentation of tank beds. Apart from using as the source of irrigation for crop cultivation, village tanks in the study locations fulfil various needs of the village communities including domestic purposes (washing, bathing and cleaning) and livestock. Table 3.20 summarizes the reasons for diminished services of village tanks.

Table 3.20: Reasons for Reduced Services from Village Tanks

Human Activities	Kurunegala		Anuradhapura		Total	
	No	%	No	%	No	%
1. Tank sedimentation due to cultivation of catchment area	153	85	111	83	267	88
2. Activities leading to poor water management	38	21	4	4	42	13
4. Due to poor participation in tank cleaning	22	12	18	14	40	12
5. Decreasing capacity of the tank due to deposit of plant debris, garbage & other material.	10	6	9	7	19	6
6. Contamination of tank due to human activities	7	4	6	4	13	4
Total no. of respondents (N)		**179**		**133**		**312**

Source: HARTI Survey Data, 2016

Reduction of tank capacity by siltation due to excessive sediments from the catchment areas (88 percent) and aquatic plants and debris (6 percent) is identified as the key factor contributing to diminish the services of the tanks. Issues relating to the institutional settings in operation and maintenance (O&M)

of village tank systems have also adversely affected the tanks and their services (25 percent).

Lack of timely interventions in regular O&M activities and minor and major rehabilitation works have also been detrimental on the sustenance of the services of village tank systems. In last four decades, only two tanks in study locations have undergone any rehabilitation work relating to increased tank capacity. Two rehabilitation work have been done by raising the spill level and strengthening the tank bunds of two tanks instead of undertaking any partial desiltaion activity. However, the experts' view on capacity improvement of village tanks by increasing the spill level is always negative. Panabokke, Tennakoon & Ariyabandu (2001) noted that the capacity enhancement or increase water availability of village tanks by raising or extending the tank bunds is not the most preferable mean of tank rehabilitation Instead, the partial desiltation is mostly promoted though it is much costlier than either bund raising or expanding the tank bund or both. The ways and means of partial desiltation enabling the return to original tank geometry has been demonstrated and thereby how the negative consequences of present tank geometry could be minimized.

Further, Sengupta, Jacob & Khan (2013) has warned of several negative impacts of increasing tank capacity by raising the spill and tank bund, such as inundation of upstream paddy lands; development of salinity conditions in the upper area; increase of tank water losses; disappearance of the tree strips in the high flood region (*Gasgommana*) and the grass cover (*Perahana*); disappearance of some indigenous fish species, which cannot survive in shallow water or do not find a favorable breeding environment.

It is argued that cost of desilting a tank is considerably high in terms of the value of paddy that can be generated in the short run by that extra amount of water retained in a tank after desiltaiton. However, it is difficult to accept because the tank water is not meant for the sole purpose of irrigating a few hectares in its command area. A tank which is multifunctional in terms of receiving, storing regulating and distributing water is truly multi-purpose in character. Economically (for irrigation) socially (for domestic use), religious culturally (for temple goers and its residents use) and environmentally it is indeed multi-purpose in usage (Panabokke, Tennakoon & Ariyabandu, 2001).

In both instances relating to rehabilitation work of two village tanks, the construction activities have been undertaken by a third party because of the FOs were not capable enough in financial, technical and institutional capacity aspects. The general perception among the farming communities and the respective officials (attached to the DAD) and the actual situation experienced relating to undertaking rehabilitation work by a third party is also negative. There have been always complaints on the quality of the work, sense of ownership of the irrigation systems, issues on payments and settlements and etc. when the third party is carrying out minor irrigation rehabilitations.

On the other hand, the rehabilitation work has been undertaken on isolated tanks rather considering the entire cascade system. Shakthivadivel, Fernando & Brewer (1997), Panabokke, Tennakoon & Ariyabandu (2001) and Aheeyar (2013) emphasized the need of irrigation system rehabilitation planning and implementation within the cascade context rather than employing individual tank restoration approach. Therefore, planning rehabilitation or improvements of any tank system requires assessing and understanding the entire hydrology of the cascade before any intervention to any tank in the cascade and it is contemplated, especially when water is becoming scarce. Thus, failure to consider cascade hydrology had been detrimental to small tank rehabilitation projects and they have been criticized for poor benefit-cost ratios and other flaws.

In addition to the rehabilitation work on raising the spill level and the tank bund carried out in the past, the research team observed, during the field work, an ongoing minor tank rehabilitation work in Mahameruwa cascade in Kurunegala. The said work was on removal of silt from the tank bed. However, due to the lack of technical guidance and monitoring from relevant officials from the DAD, the silt removal activities were confined to the edges of the tank (boundary of the water spread area). The third party contractor undertook silt removal on the edges of the water spread area as digging and uploading silt from the tank bed in the middle of the tank is costlier. Also, removal of silt from the edges of the water spread aerea allows the contractor to dig clay from the edges of the tank and sell to the brick makers. However, such activities pose adverse impacts to the tank. Removal of silt and clay from the edges of the tank allows the water spread area of the tank to expand. Increase in water spread area of the tank causes higher water losses by evaporation, specially in the dry spells. Therefore, the selection, planning and implementation of tank rehabilitation should be carried out in a scientific manner. A continuous supervision by officials with technical expertise should be ensured throughout the process, through which frequently occurring misconduct associated with tank desiltation could be controlled to a satisfactory extent while ensuring the quality of the rehabilitation work and long-term sustainability of the system.

In the regions like Tamil Nadu and Andra-Pradesh in India that having similar climatic conditions to the dry zone areas of Sri Lanka, the silt from tanks are used for productivity increase in upland crop fields. Therefore, there is a huge demand for tank silt from the upland farmers as many research studies have proved that tank silt is useful in release of nutrients such as total nitrogen and beneficial to sandy and alkaline soils. It is a source of manure for crop production. It is also an organic amendment for improving water-use efficiency and productivity. The tank silt contains organic carbon, microbial biomass carbon (Adhinarayanan, 2017; Nandini, 2019). Thus, for FOs and other community organizations, desiltation of village tanks in such regions has become an income earning activity involved with the private sector entities, rather than a costlier task like in the dry zone region of Sri Lanka.

CHAPTER FOUR

Conclusions and Recommendations

4.1 Major Findings, Conclusions and Recommendation

1. The catchment areas of village tank cascades have been gradually diminishing due to anthropogenic activities while the command areas under the tanks have increased to a remarkable level by converting adjacent forest lands and other areas into lowland paddy fields.
2. Long-term negligence and scant attention to village tanks particularly in the aspects of regular O&M and minor and major rehabilitation have led to rapid decline in the irrigation capacities of village tanks.
3. Sedimentation of tank beds due to excessive erosion in the tank catchment area is reported to be the key factor for diminished capacity of the village tanks.
4. Owing to low water retaining capacity of the tanks the irrigable area in the command area has also become limited. This has compelled the farmers to abandon or limit the cultivation in dry *Yala* seasons.
5. Though, the entire command area of respective tanks is cultivated during rainy Maha seasons with paddy, the majority of the lands are not cultivated in Yala seasons. Because the food security is the foremost priority of farm households in the minor irrigation schemes, farmers whose lands are irrigable even in the dry seasons tend to grow paddy. The upland farming including the home gardening are mostly limited to rainy Maha seasons due to unavailability of supplementary irrigation facilities.
6. Tank sedimentation has lowered the ground water level, which in turn has affected the crop production systems undertaken with supplementary irrigation facilities provided by the limited number of agro-wells in the study locations.
7. The past tank rehabilitation works have been focused on restoring solitary tanks rather taking the entire tank cascade system into consideration. Further, tank rehabilitation activities aiming at increased storage/capacity have relied on raising the spill or the tank bund instead of desiltation activities.

Therefore, prior to tank rehabilitation an assessment of the needs should be conducted. The number of beneficiaries, cost effectiveness, potential beneficial sectors i.e. crop production, aquaculture, livestock, domestic usage, and other livelihoods such as brick making should be considered while ensuring the hydrological assessment of the entire cascade.

At least three to four tanks in a cascade (depending on the total number of tanks arranged in a particular cascade) should be rehabilitated or bring into the optimal level of operation, to reap maximum benefit of such rehabilitation.

The ecosystem associated with the tank should be preserved in the rehabilitation process. The tank catchment, sediment control structures (biological), and downstream canals should be taken care of.

8. Due to lack of financial, technical and institutional capacities with the FOs, tank rehabilitation activities are out-sourced to third party contractors, thus, the expected level of work quality and the standards cannot be expected. Therefore, it is recommended to provide training and awareness programs to enhance the capacities of FOs in terms of financial management, basic technical know-how on regular O&M activities and minor rehabilitation works.

9. In the absence of continuous supervision of the relevant officials with the technical expertise, misconduct and malpractices are taking place in tank rehabilitation processes.

   Therefore, continuous supervision by officials with technical expertise should be ensured throughout the process, through which frequently occurring wrongful acts associated with tank desiltation could be controlled to a large extent.

REFERENCES

Abeysinghe, A. 1982. *Minor irrigation in Sri Lanka, Parts 1 & 2*. Economic Review.

Abeywardana, N. Bebermeier, W. and Schütt, B. 2018. Ancient Water Management and Governance in the Dry Zone of Sri Lanka Until Abandonment, and the Influence of Colonial Politics during Reclamation. *Water*, *10*, 1746. https://doi.org/10.3390/w10121746

Adhinarayanan R. 2017. Enhancing Soil Organic Carbon through Tank Silt Application. Proceedings of the Global Symposium on Soil Organic Carbon, 21 – 23 March, 2017, Rome, Italy.

Aheeyar, M.M.M. 2013. Alternative Approaches to Small Tank/Cascade Rehabilitation: Socio-economic and Institutional Perspective, HARTI Research Report No: 162, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Bandaranayake, G.M. and Kumara, S. 2016. Modeling for River Basin Management: Its application to Mi Oya in the Dry Zone of Sri Lanka. Proc. of the The Fifth International Research Conference on Humanities and Social Sciences. 10-11 November 2016, Nugegoda, Sri Lanka.

Bebermeier, W., Meister, J. Withanachchi, C.R. Middelhaufe, I. and Schütt, B. 2017 Tank Cascade Systems as a Sustainable Measure of Watershed Management in South Asia. *Water* 2017, 9, 231; doi:10.3390/w9030231

Burt, T. P. and Weerasinghe, K. D. N. 2014. Rainfall Distributions in Sri Lanka in Time and Space: An Analysis Based on Daily Rainfall Data. Climate 2014, 2, 242-263; doi:10.3390/cli2040242

DCS 2020. Paddy Statistics. Department of Census and Statistics, Colombo, Sri Lanka. Dharmasena P.B. (2020) Cascaded Tank-Village System: Present Status and Prospects. In: Marambe B., Weerahewa J., Dandeniya W. (eds) Agricultural Research for Sustainable Food Systems in Sri Lanka. Springer, Singapore. https://doi.org/10.1007/978-981-15-2152-2_3

De Silva, S.S. 1988. Reservoirs of Sri Lanka and their fisheries. FAO Fisheries Technical Paper, 298:128 p.

Dharmasena, P.B., 1992. Soil Erosion Control Measures for Rainfed Farming in the Dry Zone of Sri Lanka (Unpublished). Ph.D Thesis, University of Peradeniya, Peradeniya, Sri Lanka.

Dharmasena, P.B. and Joseph, K.D.S.M. 1994. Land degradation: A threat to agricultural Production in the Dry Zone. Proc. of the Workshop on 'Soil Quality: Assessment of Degradation and Restoration' organized by Kelaniya - Calgary Academic Link Programme held at Sri Lanka Foundation Institute, Colombo - 7, Sri Lanka on 23 -25 March, 1994. pp 65-69.

Dharmasena, P.B. 2005 Small tank heritage and current problems. In: Aheeyar, M.M.M. (ed). Proc. of the Symposium on Small Tank Settlements in Sri Lanka held on 21st August 2004, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Dharmasena, P.B. 2009. Dry Zone Tank-Village: A System for Reducing the Impact of Drought. Proc. of the Workshop on Role of Community in Adaptation to the Climate Change Crisis. (Eds) Gunaratne, L.H.P., W.A.P. Weearakkody, K.S. Hemachandra and P.Y. Yapa, Swedish Cooperative Centre and Postgraduate Institute of Agriculture, Peradeniya, Sri Lanka. p. 125-136.

Dharmasena, P.B. 2010a. Essential Components of Traditional Village Tank Systems. In: Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability. Central Environmental Authority, Colombo, Sri Lanka.

Dharmasena, P.B. 2010b. Evolution of hydraulic societies in the ancient Anuradhapura Kingdom of Sri Lanka. In: Peter MI, Ward C (eds) Landscape and societies: selected cases. Springer, Dordrecht; New York, pp 341–352.

Dharmasena, P.B. 2017a. Ecosystem and human health issues. Presentation made at the Strategic Expert Consultation workshop: UNEP-GEF Project on Healthy Landscapes, Plant Genetic Resources Center (PGRC), Gannoruwa, Sri Lanka, 8 Sept 2017

Dharmasena, P.B. 2017b. Overview of small tank cascades: evolution, present status and future scenarios. Presentation made at Policy Dialogue on Restoration and Management of Small Tank Cascade Systems, at Bandaranaike Centre for International Studies (BCIS), Colombo, 14 Feb 2017.

Dharmasena, P.B. 2020. Cascaded Tank-Village System: Present Status and Prospects. Marambe, B. et al. (eds.), Agricultural Research for Sustainable Food Systems in Sri Lanka, https://doi.org/10.1007/978-981-15-2152-2_3

FAO, 2017. A Proposal for Declaration as a GIHAS: The Cascaded Tank-Village System (CTVS) in The Dry Zone of Sri Lanka. Ministry of Agriculture and Food and Agriculture Organization of the United Nations, Sri Lanka. Pp 126.

Fernando, A.D.N. 1979. Major ancient irrigation works of Sri Lanka. Journal of Asiatic Societies (Sri Lanka Branch), 22:1–24.

Groenfeldt, D., Alwis, J. and Perera, J. 1987. Strategies for Improving Minor Irrigation Schemes in Sri Lanka. IIMI Working Paper No. 6, International Irrigation Management Institute, Kandy, Sri Lanka.

Gunarathne, M.H.J.P. & Kumari, M.K.N. 2014. Water quality for Agriculture and Aquaculture in Malwathu Oya Cascade - I in Sri Lanka. Rajarata University Journal 2014, 2: 33 – 39

IIMI-SLFO. 1994. Guidance package for water development of small tank cascade systems, International Irrigation Management Institute-Sri Lanka Field Operations. IIM-SLFO, Colombo.

Imbulana, K.A.U.S., Wijesekara, N.T.S., Neupane, B.R., Aheeyar, M.M.M. and Nanayakkara, V.K. 2010. Sri Lanka Water Development Report:2010. Ministry of Irrigation and Water Resources Management, Colombo, Sri Lanka. ISBN:978-955-8395-02-8

Jayanesa, H.A.H. & Selker, J.S. 2004. Thousand Years of Hydraulic Civilization Some Sociotechnical Aspects of Water Management. Understanding the Role of Politics in Water 225-237. https://www.worldwatercouncil.org/sites/default/files/Thematics/proceedings_waterpol_pp.225-262.pdf

Jayasinghe, U. & Rambodagedara, M. 2019. Lessons to be Learnt from Ancient Water Management Techniques of Sri Lanka for the Development of Integrated Water Resources Management Concept. Working Paper No. 13. Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Jayasuriya, H.J.C. and Shantha, W.H.A. 2019. *Reconsidering Eco-System Based Approach (EBA) in Village Tank Rehabilitation for Enhanced Rural Livelihoods and Environmental Services, held on 20th December 2018,* Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka (unpublished).

Madduma Bandara C.M. 1985. Catchment Ecosystems and Village Tank Cascades in the Dry Zone of Sri Lanka: A Time-Tested System of Land and Water Management; in Strategies for River Basin Management. In L. Lundgvist, U. Loham & M. Folkenmark (Eds.), Strategies for Rice Basis Development, Reidel Publishing Company, Linkoping, Sweden, pp 99-113.

Madduma Bandara, C.M. 2004. Small tank cascade systems: their relevance for minor irrigation rehabilitation. Proc. of the Symposium on Small Tank Settlements in Sri Lanka held on 21st August 2004, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Madduma Bandara, C.M. 2009. Village Tank Cascade Systems of Sri Lanka: A Traditional Technology of Water and Drought Management. Proceedings of the third annual workshop on disaster reduction hyperbase - Asian application (DRH-Asia), Tokyo, Japan, 2009.

Marambe, B., Pushpakumara, G. and Silva, P. 2012. Biodiversity and Agrobiodiversity in Sri Lanka: Village Tank Systems. In: Nakano, S.I., Yahara, T., Nakashizuka, T., Yamamoto, S. (Eds.), Biodiversity Observation Network in the Asia-Pacific Region. Springer, Japan, pp. 403–430.

Mogi, A. 2007. A Missing Link: Transfer of Hydraulic Civilizations from Sri Lanka to Japan. Pugwash Regional Workshop Learning from Ancient Hydraulic Civilizations to Combat Climate Change Colombo, Sri Lanka, 22-28 November 2007.

Murray, F.J. and Little, D.C. 2000. *The nature of small-scale farmer managed irrigation systems in North West Province, Sri Lanka and potential for aquaculture.* Institute of Aquaculture, University of Stirling, Stirling, Scotland.http://aquaticcommons.org.id/eprint/2913

Nandini, D.U. 2019. Breeding of Soil with Tank Silt. AGROBIOS NEWSLETTER, 27(10): 61-62.

Panabokke, C.R. 1999. The Small Tank Cascade Systems of the *Rajarata:* Their Setting, Distribution Pattern and Hydrography. Mahaweli Authority of Sri Lanka, Colombo, Sri Lanka.

Panabokke, C.R. 2001. The Nature and Properties of Small Tank Systems of the Dry Zone and Their Sustainable Production Thresholds. In Gunasena, H. P. M. (Ed.). Food Security and Small Tank Systems in Sri Lanka: Proceedings of the workshop organized by the Working Committee on Agricultural Science and Forestry, 9 September 2000. Colombo, Sri Lanka: National Science Foundation (NSF).

Panabokke, C.R. 2009. Small Village Tank Systems in Sri Lanka: Evolutions, Settings, Distribution and Essential Functions. Occasional Publications, Hector Kobbekaduwa Agrarian Research and Training Institute. Colombo, Sri Lanka.

Panabokke, C.R., Sakthivadivel R. and Weerasinghe, A.D. 2002. Evolution, present status and issues concerning small tank systems in Sri Lanka. International Water Management Institute. Colombo, Sri Lanka.

Panabokke, C.R., Tennakoon, M.U.A. & Ariyabandu, R.de. S. 2001. Small Tank Systems in Sri Lanka: Issues and Considerations. In Gunasena, H. P. M. (Ed.). Food Security and Small Tank Systems in Sri Lanka: Proceedings of the workshop organized by the Working Committee on Agricultural Science and Forestry, 9 September 2000. Colombo, Sri Lanka: National Science Foundation (NSF).

Paranavithana, S., 1960. The withdrawal of Sinhalese from the ancient capitals. History of Ceylon, vol 1, University of Ceylon, Peradeniya, PP 713–720

Perera, M.P. 2017. Evolution of Tank Cascade Studies of Sri Lanka. Saudi Journal of Humanities and Social Sciences, 2(7): 597-610. DOI: 10.21276/sjhss-2,7:597-610

Seneviratne, A. 1987. The Hydraulic Civilization of the Ancient Rajarata in Sri Lanka. International irrigation Management Institute. pp 107.

Sengupta, S., Jacob, N. & Khan, H. 2013. Plan for restoration of cascading tank systems in Anuradhapura district, Sri Lanka. Available at https://cdn.cseindia.org/userfiles/anuradhapura_paper.pdf (accessed on 19.07.2018).

Shakthivadivel, R., Fernando, N. & Brewer, J.D. 1997. Rehabilitation Planning for Small Tanks in Cascades: A Methodology Based on Rapid Assessment. Research Report No. 13. International Irrigation Management Institute, Colombo, Sri Lanka.

Shakthivadivel, R., Fernando, N., Panabokke, C.R. & Wijayaratna, C.M.W. 1996. Nature of Small Tank Cascade Systems and a Framework for Rehabilitation of Tanks within Them. IIMI Country Paper No. 13. International Irrigation Management Institute, Colombo, Sri Lanka.

Siriweera, W.I. 2001. Historical Perspectives on Small Tanks and Food Security. In Gunasena, H. P. M. (Ed.). Food Security and Small Tank Systems in Sri Lanka: Proceedings of the workshop organized by the Working Committee on Agricultural Science and Forestry, 9 September 2000. Colombo, Sri Lanka: National Science Foundation (NSF).

Tennakoon, M.U.A. 2017. Cascade Based Tank Renovation for Climate Resilience Improvement. Ministry of Disaster Management, Colombo, Sri Lanka. Pp 137.

UNDP 2017. Climate Resilient Integrated Water Management Project. https://www.lk.undp.org/content/srilanka/en/home/operations/projects/environment_and_energy/Climate-Resilient-Integrated-Water-Management-Project.html

Vidanage, S., S. Perera and M. Kallesoe, 2005 The Value of Traditional Water Schemes: Small Tanks in the Kala Oya Basin, Sri Lanka. IUCN Water, Nature and Economics Technical Paper No. 6, IUCN - The International Union for Conservation of Nature, Ecosystems and Livelihoods Group Asia.

Weerawardana, I. K. 1986. Irrigation laws and the peasant. Economic Review.

Witharana, D.D. 2004. Village Tank Categorization in Small Tank Settlements in Sri Lanka. Proc. of the Symposium on Small Tank Settlements in Sri Lanka held on 21st August 2004, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.