RESEARCH REPORT

IT IS NOT JUST WATER THAT FLOWS DOWNSTREAM

Water Management in the Eastern Slopes of the Central Highlands

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Hector Kobbekaduwa Agrarian Research and Training Institute

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Research Report No: 245 October 2021

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First Published: 2021
ISBN: 978-624-5973-07-1

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FOREWORD

Environmental degradation, especially in a context of adverse effects of climate change, can cause a myriad of issues that impact one and all, from household to farm to nation and the world. One of the most critical outcomes of the confluence of such processes is the serious impact on water availability and quality. The scarcities thus generated, moreover, tend to divide communities and cause conflict. While there is a vast literature on the broader implications of ill-conceived and even irresponsible human activity, it is as important to focus on what happens at the relatively micro level. Often the implications go beyond the boundaries of such landscapes. This study is a case in point. The eastern slopes of the central highland region are recognized as a sensitive and vulnerable landscape that holds multiple environmental and economic importance. Compared to other parts of the island, the variations in bio-physical and climatic factors along the elevation of this land mass have created a higher diversity in crops adopted and farming practices followed by large scale tea planters and small-scale agricultural practitioners. Apart from the threats posed by the impact of a changing climate, the anthropogenic activities in the region have put the ecological balance of this environmentally fragile area at considerable risk.

The expansion of agricultural activities in an indiscriminate manner in higher elevations have had serious repercussions for the livelihoods of down-stream farming communities in the watersheds located on the eastern slopes of the central highland region. Agricultural activity in the lower-stream areas has also been compromised by temporal and spatial water shortages induced by activities in the upper-stream areas of the same watersheds. Water quality deterioration in streams and other natural sources is also caused by agriculture and related human activities in upper-streams. The absence of proper institutional arrangements and the eschewing of widely-accepted mechanisms for water management in the region have caused water conflicts between different water users. However, there is a felt need to consider this situation taking into cognizance all relevant factors so that policy design and amendment could be informed by the outcome of scientific investigations. It is this lacuna that this study has sought to correct and it is indeed creditable that the authors have shed light on the magnitude of water management issues in this particular area.

The report contends that the changes in land use and land cover over the past several decades have decisively contributed to environmental degradation and have also helped create the existing issues in water use and management in this region. More importantly, the report offers guidelines for the development of a water management mechanism for averting water conflicts between different water users. I wish to congratulate the authors of this report for undertaking this valuable and timely study and for providing useful insights for policymakers and relevant authorities when it comes to taking on issues pertaining to water management in the sensitive areas of the central highland region.

Malinda Seneviratne
Director/CEO

ACKNOWLEDGEMENTS

We are thankful to former Directors of the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), 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 Director of HARTI Mr. R.L.N. Jayatissa, the present Additional Director Dr. W.A.R. Wickramasinghe for their support and guidance.

We appreciate the support given in various ways by the respondent farmers, divisional and field level officers attached to various government institutes in Walapane area by allocating their valuable time, which was instrumental for the successful completion of the study.

We are thankful to the external reviewers who critically reviewed and made useful comments and suggestions, which immensely helped us in improving this report.

We also wish to thank Mr. A. Rathnasiri, Statistical Officer, Mr. W.P. Kumarasiri, Statistical Assistant of Environmental and Water Resources Management (EWRM) Division and the graduates who served as Investigators for the study, Mr. A.N. Ranasinghe, Mr. S.J. Basnayake, Miss C. Vidanapathirana, Miss I. Lakmali, Miss D. Ganellagodage and Miss. K.D. Karunadasa for all the assistance given during the field data collection.

We also appreciate Ms. Niluka Priyadarshani de Silva, Acting Office Secretary, Ms. Uthpala Jinadari, Management Assistant and the rest of the staff of EWRM Division for the support given throughout this study. We are thankful to Ms. Sharmini Kusum Kumara, former Research Associate of HARTI for her excellent work in language editing of this report. Finally, our appreciation goes to Mr. S.A.C.U. Senanayake, Senior Information and Publication Officer of HARTI for proofreading the final report and to Dr. N.P.G. Samantha, Head/Communication Division for making arrangements to print and publish the report. We appreciate the cheerful assistance extended by the printing staff of HARTI as well.

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EXECUTIVE SUMMARY

Sri Lanka receives an annual rainfall between 750 mm and 6000 mm totaling approximately 130 billion cubic meters of water yield with a large temporal and spatial variation. The agricultural sector is the single largest activity that utilizes the greatest quantity of available water resources of the country. Industrialization, population pressure and urbanization have resulted in a rising demand for water in the country. This has led to Sri Lanka experiencing water stress situations and issues in water allocation between different water-use sectors over the last few decades.

Apart from serving as the upper watershed of the majority of rivers, the central highland area accommodates key crop production systems, contributes to hydropower generation and irrigation supply/flood regulation through major reservoirs. As the eastern slopes of the central highland region receive significantly lower rainfall compared to the south-western slopes, the eastern slopes area has been identified as one of the highly vulnerable areas to the adverse impacts of climate change. A large collection of research studies on the situation of water scarcity, water allocation and management issues in the dry zone of Sri Lanka could be found in scientific literature whereas the studies on the same issues in the central highland region are lacking. Given this background, this study was conducted with the primary objective of studying water management issues and to investigate the existing mechanisms for water allocation among different water user groups in the eastern slopes of the central highland region.

The study was carried out in *Kurunduoya* and *Beliuloya* river basins in Walapane Divisional Secretariat division. The primary data and information were collected by administering a questionnaire survey of 370 farmer households representing one major irrigation scheme and two minor irrigation systems in the study area. Focus group discussions and key informant interviews were also conducted with farmer leaders and state officials to gather data and information. The geographic information system and remote sensing data and analytical tools were used in analyzing land use changes in the study area.

The land use and land cover in the watershed area has significantly changed over the past several decades largely owing to the expansion of cash crop and vegetable cultivation in encroached stream reservations and scrub lands. New types of water uses have emerged and the scale of water use types have changed, particularly in the upstream, causing detrimental impacts on the other water use types and respective water users in the down-stream areas. Specially, illegal water tapping from the irrigation canals have caused severe changes in cropping patterns resulting in food security and livelihood issues in the lower stream farming communities. The resistance by water users in up-stream areas has led to the deterioration of minor irrigation structures (located in plantations) and diminished performance of such schemes that are detrimental to optimum irrigation in agricultural fields in down-stream areas. This situation has led to water conflicts between two communities. The cooperation and

mediation by plantation management towards water conflict resolution between two groups is lacking.

Individually-initiated pipe-borne water supply from streams/canals and water fountains for each housing unit in both estate and rural sectors is found to be a very uneconomical method of water supply, as the water is not regulated at any point so which leads to a continuous water flow from the system around the clock. The dilapidated condition of minor irrigation structures also causes severe water loss especially in the water conveyance process.

There is a lack of prioritization of water allocation/use among different water users depending on the spatial and temporal variation of water requirements nor is there an institutional set up to formalize water use and allocation. In this situation, the water user groups in lower streams are greatly disadvantaged as they have no voice nor entitlement to water and instead have become mere recipients.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	-	Assistant Commissioner
ADA	-	Assistant Director of Agriculture
AER	-	Agro-Ecological Region
AI	-	Agriculture Instructor
AWM	-	Agricultural Water Management
AR&PA	-	Agricultural Research and Production Assistant
ASC	-	Agrarian Services Center
CBO	-	Community-Based Organization
CEO	-	Chief Executive Officer
CWSP	-	Community Water Supply Project
DAD	-	Department of Agrarian Development
DC	-	Distributary Canal
DOA	-	Department of Agriculture
DS	-	Divisional Secretariat
DSC	-	Department of Census and Statistics
DZ	-	Dry Zone
EWRMD	-	Environmental and Water Resources Management Division
FAO	-	Food and Agriculture Organization of the United Nations
FC	-	Field Canal
FGD	-	Focus Group Discussion
FO	-	Farmer Organization
GIS	-	Geographical Information System
GND	-	*Grama Niladhari* Division
GWh	-	GigaWatt hour
HARTI	-	Hector Kobbekaduwa Agrarian Research and Training Institute
IAEA	-	International Atomic Energy Agency
I&D	-	Irrigation and Drainage
ID	-	Irrigation Department

IE	-	Irrigation Engineer
IL	-	Low-country Intermediate Region
IM	-	Mid-Country Intermediate Region
IPS	-	Institute of Policy Studies
IU	-	Upcountry Intermediate Zone
IUCN	-	International Union for Conservation of Nature
IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resource Management
IZ	-	Intermediate Zone
KHP	-	Kurunduoya Hydro-Power Project
KII	-	Key Informant Interviews
LULC	-	Land use and land cover
LUPPD	-	Land Use Policy Planning Division
MASL	-	Mahaweli Authority of Sri Lanka
MCM	-	Million Cubic Meters
MMHP	-	Manelwala Mini-Hydropower Project
MW	-	Mega Watt
NEM	-	North-East Monsoon
NOAA	-	National Oceanic and Atmospheric Administration
NRMC	-	Natural Resources Management Center
NTFP	-	Non Timber Forest Products
NWSDB	-	National Water Supply and Drainage Board
OFC	-	Other Field Crops
RBL	-	Reddish-Brown Latosolic /Lateritic
RS	-	Remote Sensing
RYP	-	Red-Yellow Podzolic
SLCARP	-	Sri Lanka Council for Agricultural Research Policy
SWM	-	South-West Monsoon
TO	-	Technical Officer
UCIZ	-	Upcounty Intermediate Zone
UMCA	-	Upper Mahaweli Catchment Area

UNCTAD	-	United Nations Conference on Trade and Development
UNDP	-	United Nations Development Program
USAID	-	United States Agency for International Development
USDA	-	United State Department of Agriculture
WU	-	Upcountry Wet Region
WUA	-	Water User Association
WZ	-	Wet Zone

CHAPTER ONE

Introduction

1.1 Background

Sri Lanka receives an annual rainfall between 750 mm and 6000 mm totaling approximately 130 billion cubic meters of water yield with a large temporal and spatial variation. The agricultural sector is the single large activity that consumes the largest portion of available water resources of the country (IPS, 2016). Industrialization, population pressure and urbanization have resulted in a rising demand for water in the country (IWMI, 2010). Adverse impacts of changing climate have also aggravated the situation placing increasing pressure on limited water resources from different sectors. In such a context, the demand for water from different sectors and different water users/groups from the same sector creates competition for water. Sri Lanka has been experiencing water stress situations and issues in water allocation between different water-use sectors over the last few decades (Aheeyar, Padmajani and Bandara, 2012; Sivakumar, 2015; Saumyarathne, Gunawardena and Dayawansa, 2016).

Apart from serving as the upper watershed or the catchment for the majority of rivers originating from and flowing to and in different directions of the island, the central highland area accommodates key crop production systems. The contribution made by the important land mass to the hydropower generation and irrigation supply/flood regulation through major reservoirs is invaluable for the national economy. The eastern slopes of the central highland region receive significantly lower rainfall (less than 3500 mm mainly from north-east monsoon rains) compared to the south-western slopes receiving over 5000 mm annual rainfall (Punyawardena, 2008), the eastern slopes area has been identified as a highly vulnerable area due to the adverse impacts of climate change (Hewage *et al.,* 2017)

The variations exist in the elevation, topography, climatic features and other bio-physical characteristics in the eastern slopes, largely shaping the crop production systems in this environmentally sensitive area. The aforementioned variations have generated a vast range of agro-ecological regions (AERs) varying from IL (low country intermediate regions) to WU (upcountry wet regions) allowing farmers and other agricultural practitioners to grow different types of food and non-food crop varieties suitable for tropical as well as temperate climates.

The expansion of vegetable and cash crop (potato) cultivation in the upper elevations (Amarasekara *et al.,* 2010; Amarasekara, 2011) of the eastern slopes of the central highland region has increased the water withdrawal from natural streams and other tributaries as well as man-made diversions (anicuts) and canals (Hewage *et al.,* 2017). The year round intensive crop cultivation pattern is a key characteristic of the seasonal crop production systems in the region, so that the demand for irrigation water is required throughout the year. Unauthorized and illegal water tapping from natural and man-made waterways has been the most common source of irrigation water for highly intensive crop cultivations in upstream areas. With these recent developments, the subsistence farming communities living in downstream lower elevations who have been relying on water flowing in streams and canals for agriculture (largely for subsistence paddy farming and vegetable cultivation) and domestic purposes are disadvantaged and victimized (ibid). This situation has remarkably affected the livelihood and household food security of such downstream farmers, resulting in water conflicts between two farming communities living in up and down streams.

Though the environmental issues, specially the land degradation caused by accelerated soil erosion by water largely due to agricultural activities without applying soil and water conservation measures in the central highland area have widely been discussed (Hewawasam, 2010; Hewage *et al.,* 2017; Jayasekara, Kadupitiya and Vitharana, 2018), the attention paid to water management issues in this environmentally fragile landscape is minimal.

1.2 Research Problem and Justification

Over the past decades, new types of water use have emerged and the scale of water use types have changed, particularly in the upstream, causing detrimental impacts on the other water use types and respective water users. In turn, the livelihoods and food security of the water users downstream have been threatened. In the absence of a proper institutional set up and acceptable mechanism to manage and fairly allocate water resources among different water uses, the need and demand for the limited resource has led to water conflicts between different water users. As a result of changes in the rainfall patterns, rainfall quantity and distribution due to the impacts of climate change, have posed further challenges for most of the water users in terms of availability and accessibility escalating the water related issues of domestic and economic activities. Impacts of changes in land use and water management upstream on stakeholders downstream is a major problem that has not been adequately studied in Sri Lanka.

Absence of an institutional set up to regulate water allocation among different users and an established mechanism to resolve water disputes and conflicts could be identified as the major reason for water disputes to escalate in the eastern slopes of the central highland region. With the findings based on a study of three water schemes in dry zone, Aheeyar, Nanayakkara and Bandara (2008) have also highlighted the requirement of the institutional arrangements for water conflict resolution while establishing a mechanism for fair allocation of water among different users. Further to that, Aheeyar and Smith, (1999), Aheeyar (2006), Nanayakkara (2010) and Saumyarathna, Gunawardena and Dayawansa (2016) have also pointed out the importance of application of participatory irrigation/water management concepts and practices. Further, strengthening of existing water allocation/management system/s (if any) and formulating sustainable mechanisms that are acceptable for different stakeholders is timely and important.

A large collection of research studies on the situation of water scarcity, water allocation and management issues in the dry zone of Sri Lanka could be found in scientific literature whereas the studies on the same issues in the central highland region are lacking.

1.3 Significance of the Study

The policy document of the present government; *Vistas* of *Prosperity and Splendor* reads, under Chapter 07 - New Approach in National Spatial System, '*ensure water resources are free from pollution and manage it in an efficient manner for drinking and agriculture purposes',* as one of the key strategies in the Sectoral Policy *'ensuring water for all'.* It also includes '*ensuring food security'* as one of the macro-economic policy framework in achieving the overall objective of *People-Centric Economy* (Ministry of Finance, 2020). Among the special priority areas of the Ministry of Agriculture, achieving maximum economic benefits of water consumption through efficient water management to meet farmer requirements has been given utmost importance (GOSL, 2020). The Sri Lanka Council for Agricultural Research Policy (2017) has identified 'changes in land use pattern' as a research issue to be investigated as 'lack of information on environmental impacts of different land use patterns' is a serious research gap in the agriculture sector of Sri Lanka. Hence, studying the changes in land use patterns along the banks of water streams and their effects on the environment including the water resource in climate vulnerable landscapes in the central highland region is timely and pertinent.

1.4 Research Objective

In this background, this research was conducted with the primary objective of studying the water management issues in the climate vulnerable eastern slopes of the central highland region and to investigate the existing mechanism/s for allocation of water among different user groups.
The specific objectives of the study are;

- to identify the different water user groups in the study area with different interests and investigate existing water management systems
- to assess the changes in land use especially in the expansion/decline of land extent under different crop production systems over the last few decades and
- to examine the impact of water shortage on livelihood and household food security of disadvantageous water user group/s in down-stream areas

1.5 Limitations of the Study

Lack of cooperation by the farming communities carrying out vegetable and high value cash crop cultivation without concerning the environmental impacts of such practices was an impediment in collection of primary data from the said communities. Therefore, the analysis of land use changes was mainly based on geographic information system (GIS) and remote sensing (RS) data. The erratic weather condition which prevailed in the final quarter of the year 2019 that induced a series of landslides in the study area was also detrimental to conduct field work.

1.6 Organization of the Report

This report consists of 5 chapters dedicated to elaborate land use and land cover changes and different aspects of water management issues in the study locations. The Chapter One presents the general introduction to the water conflicts and management issues in the eastern slopes of the central highland region. The significance of the study and research objectives have also been presented in the same chapter. In the final section of Chapter One, the limitations of the study are also mentioned. Chapter Two is dedicated to provide a thorough perusal of scientific literature on the thrust area of the study. The materials and methods applied in the study are detailed in Chapter Three. The Chapter Four discusses the results of the study derived from different analysis tools and techniques. Achieving research objectives through the findings of the study has been carried out in this chapter. The last chapter, Chapter Five summarizes the research findings to draw the conclusions and recommendations. The References and Annexures have been placed, at the very end of the report, as additional sections.

CHAPTER TWO

Literature Review

2.1 Water in Agriculture

Approximately 70 percent of global freshwater consumption is used in the agricultural sector, yet water use efficiency in many countries is below 50 percent (IAEA, 2020). Water is a critical input for agricultural production and plays an important role in food security. Irrigated agriculture represents 20 percent of the total cultivated land and contributes 40 percent of the total food produced worldwide. Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification.

Due to population growth, urbanization, and climate change, competition for water resources is expected to increase, with a particular impact on agriculture. Population is expected to increase to over 10 billion by 2050, and whether urban or rural, this population will need food and fiber to meet its basic needs. Combined with the increased consumption of calories and more complex foods, which accompanies income growth in the developing world, it is estimated that agricultural production will need to expand by approximately 70 percent by 2050. However, future demand on water by all sectors will require as much as 25 to 40 percent of water to be reallocated from lower to higher productivity and employment activities, particularly in water stressed regions. In most cases, such reallocation is expected to come from agriculture due to its high share of water use.

The movement of water will need to be both physical and virtual. Physical movement of water can occur through changes in initial allocations of surface and groundwater resources mainly from the agricultural to urban, environmental, and industrial users. Water can also move virtually as the production of water intensive food, goods, and services is concentrated in water abundant localities and is traded to water scarce localities.

Inter-sectoral water re-allocations and significant shifts of water away from agriculture will also need to be accompanied by improvements in water use efficiency and improvements in water delivery systems. Improving the efficiency of water use in agriculture will also depend on matching the improvement of the main system (off-farm) with appropriate incentives for on-farm investments aiming to improve soil and water management. Resolving the challenges of the future requires a thorough reconsideration of how water is managed in the agricultural sector, and how it can be repositioned in the broader context of overall water resources management and water security. Moreover, irrigation and drainage schemes, whether large or small, represent prominent spatially dispersed public works in the rural spaces. Thereby, they represent a logical vehicle for mobilizing employment opportunities for communities (World Bank, 2020).

2.2 Practical Challenges for Water in Agriculture

The ability to improve water management in agriculture is typically constrained by inadequate policies, major institutional under-performance, and financing limitations. Critical public and private institutions (encompassing agricultural and water ministries, basin authorities, irrigation agencies, water users' and farmer organizations) generally lack the enabling environment and necessary capacities to effectively carry out their functions.

For example, basin authorities often have limited ability to enforce water allocations and to convene stakeholders. Institutions charged with developing irrigation often limit themselves to capital-intensive larger scale schemes and tend to rely on public sector-based approaches rather than developing opportunities for small-scale private financing and irrigation management. Farmers and their organizations also often respond to highly distorted incentive frameworks in terms of water pricing and agricultural support policies, which further hinder positive developments in the sector.

Moreover, most governments and water users fail to invest adequately in the maintenance of irrigation and drainage (I&D) systems. While inadequate management and operation may play a part in the poor performance of I&D systems, it is especially the failure to sufficiently maintain systems that results in their declining performance and the subsequent need for rehabilitation. This failure to provide adequate funds for maintenance of I&D systems has resulted in the "build-neglect-rehabilitate-neglect" cycle commonly observed in the sector.

Given the existing constraints as mentioned above, the agricultural water management sector is currently in the process of repositioning itself towards modern and sustainable service provision. It proposes a singular water approach on building resilient water services and sustaining water resources, while also managing risks related to broader social and economic water-related impacts. This includes transforming governance and service provision as well as supporting watershed management and greening the sector which can be achieved by providing improved incentives for innovation, reforms, and accountability (World Bank, 2020).

The relationship between environmental degradation and poverty is complicated. It suggests that poverty can drive rural populations to extend their agricultural frontier, causing deforestation and setting off soil erosion especially in hilly environments. On the other hand, in the context of greater market integration, farmers may exploit natural resources more intensively with a view to accumulate profits by relying on the increased use of inorganic inputs, excessive groundwater exploitation and harvesting of timber and Non-Timber Forest Products (NTFPs). The deterioration of the natural environment that emerges from such a pattern of resource use may exacerbate poverty in the long-term through food insecurity arising from the declining productivity of agricultural lands and stagnating farm incomes that can potentially curb food purchases, especially in situations where non-farm incomes are limited (Kurian, 2004).

2.3 Climate Change and Water Use in Agriculture

It is important that water sources are protected both for human uses and ecosystem health. In many areas, water supplies are being depleted because of population growth, pollution, and development. These stresses have been made worse by climate variations and changes that affect the hydrologic cycle. Water influences the intensity of climate variability and change. It is the key part of extreme events such as drought and floods. Its abundance and timely delivery are critical for meeting the needs of society and ecosystems. Climate change affects where, when, and how much water is available. Extreme weather events such as droughts and heavy precipitation, which are expected to increase as climate changes, can impact water resources. A lack of adequate water supplies, flooding, or degraded water quality impacts civilization — now and throughout history. These challenges can affect the economy, energy production and use, human health, transportation, agriculture, national security, natural ecosystems, and recreation (NOAA, 2017).

Climate change now poses a major threat to human development. Much of this threat will be transmitted through more frequent extreme events (e.g. floods and droughts) and temporal and spatial shifts in rainfall patterns. The overall effect will be to exacerbate risk and vulnerability, threatening the livelihoods, health and security of millions of people. Climate modelling exercises point to a complex range of possible outcomes. Beyond the complexity, there are two recurrent themes. The first is that dry areas will get drier and wet areas wetter, with important consequences for patterns and levels of agricultural production. The second is that there will be an increase in the unpredictability of water flows, linked to more frequent and extreme weather events (UNDP, 2006).

The impact of climate change on water and agriculture requires the use of simulation models to predict the distribution and extent of change in key variables that govern crop growth (temperature and evaporative demand) and water availability (rainfall, evaporation, stream flow and groundwater recharge).

The anticipated impacts of climate change pose an additional stress on food production systems under pressure to satisfy the food needs of a rapidly growing and progressively wealthier world. As agriculture develops and becomes more intensive in its use of land and water resources, its impact on natural ecosystems becomes more and more apparent. Damaging the integrity of these ecosystems undermines the food-producing systems that they support. The assessment of viable and effective adaptations to the impacts of climate change on water and agriculture will require a sound understanding and integration of agronomic science with water management and hydrology. Due regard for the resulting environmental interactions and trade-offs will be essential (FAO, 2011).

Interactions between climate change, water and agriculture are numerous, complex and region-specific. Climate change can affect water resources through several dimensions: changes in the amount and patterns of precipitation; impact on water quality through changes in runoff, river flows, retention and thus loading of nutrients; and through extreme events such as floods and droughts. These changes in the water cycle can in turn deeply affect agricultural production in practically all regions of the world and have destabilizing impacts for agricultural markets, food security and non-agricultural water uses. There is thus a strong case for considering agricultural water management and policy in the context of climate change.

A sound policy analysis should build on the state of knowledge of the main linkages between climate change, water and agriculture, and to identify the knowledge gaps and uncertainties. An important knowledge gap is related to seasonal impacts, extremes and variability of water availability since many current studies focus on annual timescales.

Identifying and prioritizing adaptation strategies for agricultural water management in the context of climate change are not easy tasks because of the strong uncertainties related to the impact of climate change and the potential of current agricultural systems to cope with these impacts. Moreover, the resilience of agricultural systems to climate change is not solely an issue of water management, although this dimension may dominate in practice. Beyond water efficiency in agriculture, the challenge also resides in building agricultural systems that are less dependent on water resources on the whole. But whatever the relative importance of water in the challenge of adaptation, the fact nevertheless remains that considering agricultural water management without taking into account climate change is not a realistic option (OECD, 2014).

2.4 Water Management and Water Management Issues

In recent decades the percentage increase in water use on a global scale has exceeded twice that of population growth. This has led to more, and larger, regions in the world being subject to water stress where the current restricted rates of water use and consumption, let alone the desired rates, are unsustainable. Water demands and supplies are changing. What they will be in the future is uncertain, but it is certain that they will change. Demands are driven in part by population growth and higher per capita water consumption in growing urban, domestic, and industrial water sectors. Energy production, water, food security, and climate change are all connected through interactions and feedback. For example, the growing, transportation, processing, and trading of food products require large amounts of water and energy.

Therefore, management of water comes into play to assure rational and sustainable use of water among different sectors while conserving the resource for future generations (Cosgrove and Loucks, 2015).

Water management is the control and movement of water resources to minimize damage to life and property and to maximize efficient beneficial use (USDA, 2013). It is also defined as the activity of planning, developing, distributing and managing the optimum use of water resources. It is a subset of water cycle management (Singh, 2019). The water cycle, through evaporation and precipitation, maintains hydrological systems which form rivers and lakes and support a variety of aquatic ecosystems.

2.5 Agricultural Water Management

The sustainability of agricultural water use is under increasing scrutiny. In recent decades, attempts to solve the growing water issues have focused on management issues without considering the governance dimension, and mostly on a sectoral basis. While successful in many ways, this approach seems to have reached its limits. The issues of optimal allocation of scarce water resources, increasing productivity of water, modalities of control, access, use and management of water by different stakeholders are closely related, and there is a need to consider how the issues of control over, competition for, and access to water resources should be dealt with, together with the issues of efficient and effective management. Over recent years, efforts to support more effective water governance have intensified, with several initiatives promoted by international organizations. These initiatives are helping advance knowledge and promote more effective governance. However, they do not fully integrate the dimension of the critical linkage between water, land, agriculture and food security (FAO, 2014).

Agricultural water management (AWM) seeks to use water in a way that provides crops and animals the amount of water they need, enhances productivity, and conserves natural resources for the benefit of downstream users and ecosystem services. Although AWM includes irrigation, it is not simply about supplying water. It includes soil, land, and ecosystem conservation practices, such as drainage and watershed management; fisheries management; and technologies for lifting, storing, and conveying water. Traditional AWM was concerned with improving the efficiency of water use in large-scale irrigation schemes in which the objective was to control, not manage, water. As larger numbers of farmers are investing in small-scale irrigation systems, and regulation is either absent or uncoordinated, there is a need for improved practices. AWM has the potential to improve incomes and food security for poor farmers in priority countries (USAID, 2020).

2.6 Integrated Water Resources Management in Sri Lanka

Sri Lanka is prosperous in water resources with 103 rivers, more than 20 major wetlands, exceptionally designed minor and major irrigation systems and significant groundwater resources (ME&NR, 2008). Rainfall as the main form of precipitation brings an average rainfall of 1450 mm and 2400 mm to the dry (80% of land area) and wet zones (20% of land area) of Sri Lanka respectively. The annual total volume of surface and ground water availability has been assessed at 44000 million cubic meters (MCM) and 7800 MCM respectively (Imbulana, Wijesekera, and Neupane*,* 2006). The per capita water availability would be about 2500 m^3 with the population to peak at about 22 million by 2025. Therefore, Sri Lanka can be considered as a country with sufficient amounts of available water. However, there will be spatial and temporal variability and the strategies for water resources management should, therefore, focus on reducing this variability (Gunawardena, 2013).

The concept of integrated water resource management (IWRM) was integral to practices in the use of water and natural resources in Sri Lanka as part of its hydraulic civilization dating back from 6th century BC. Water was treated with respect and strong social, cultural and religious links were intertwined in its use with strong relationships established between the temple, tank and community. The source areas and catchments were safeguarded carefully and the use of water for irrigation and livelihoods, the operation and maintenance of water courses and related infrastructure were regulated through edicts issued by the king. There was recognition of customary rights and obligations of the community and penalties were imposed for noncompliance. The complex system of weirs, reservoirs and cascades of reservoirs helped maximize water utilization including from return flows within a watershed or sub basin which were the mainstay of an agricultural society whose main occupation was rice cultivation. Cultivation of crops and related cultural practices followed strict land use norms (SLNWP, 2000; Ratnayake, 2015).

While hilly land and slopes have been developed for irrigated rice production proper terracing and land use practices were followed to ensure that soil was not lost due to erosion. Sri Lanka then was indeed then the “Granary of the East”. The Colonial era, especially under the British saw the state usurp much of the traditional community land under the Waste Land Ordinance of 1840 which appropriated to the state, all lands where title could not be proven. Many communities thus lost much of their community and even inherited lands. The opening of the hill country to development added another dimension to the issue of water resources conservation when much of the central highlands from which most of the water resources originated were opened up for plantation agriculture under state support and sponsorship. This was further compounded by the revenue collection administrative, governance and management institutions that were established without much concern for natural resources management or hydrological parameters (Ratnayake, 2015).

Impact of soil erosion on water resources as a result of poor land management has been a problem since the last century. However, its intensity has been increased due to encroachments of stream and reservoir reservations and illegal gem mining. Nutrients enriched sediments derived from soil erosion transported with the runoff leads to eutrophication of water bodies. Siltation of reservoirs affecting its hydro power generation and storage capacities are some of the long term impacts of the soil erosion (Amarasiri, 2008).

With average per capita water availability (of internal renewable freshwater resources) in Sri Lanka of 2500 m^3 yr-1, there is no great water inadequacy in the country at present . However, the total available water resources at district levels are a cause for concern in the coming years. In the districts of Colombo, Puttalam, and Jaffna, the average drops below 1000 m^3, which is significantly below the recommended levels for human health and quality of life. A figure of 50 litres/day/person (globally) has been suggested as a basic requirement for domestic needs. With the projected levels of population increase by 2025, the national average will drop to ~1900 m^3 and way below 1000 m^3 in 6 districts (Gampaha, Kandy and Kurunegala). The per capita water availability in Sri Lanka is highly variable at district level, with effective steps needed for water conservation and management if severe scarcities are to be avoided in many parts of the country. A per capita availability of 1750 m^3 yr^{-1} is the water-stress threshold for a country. Levels below this are indicative of regular or seasonal water-stress conditions. If so, the 6 districts above will soon be under permanent water-stress conditions (Chandrasekara, *et al.,* 2021).

The impacts on agriculture have been discussed, implying the linkage between water and food security in Sri Lanka. The lack of an IWRM-hydrological model has a bearing on costs and prices of commodities. Water, energy and food security are interlinked through the prices paid for these commodities. If the high costs are due to poor management, then a time will soon come when a price will have to be levied for extracting a natural resource, especially if the water resources required for domestic, agricultural and industrial use are depleted due to population growth, rising living standards and envisaged future climate change (Gunathilake, 2008). It is highlighted that improved management of irrigation and water is essential for maintenance of food security (Barker and Samad, 1998)

Virtual water flows are an essential requirement for water security and economic wellbeing in Sri Lanka and across the world. It could also be an effective concept in IWRM. However, over dependence on food imports is a cause for concern and food security. The virtual water savings by Sri Lanka have not been utilized to improve water quality or security in the country. Generally, water scientists are unaware of what kind of information is required by the policy makers. Like in most developed countries, water data in Sri Lanka should be on open file and easily accessible to scientists. It is clear that there should be improved cross-communication between scientists and policy makers to ensure that new developments, findings and expertise in the hydrological sciences are translated into concrete actions that address water security issues (Gunathilake, 2008).

2.6.1 Water Allocation and Related Issues

There is an increased demand for water in the sectors of agriculture, power generation, industry and urban water supply. As water resources in the rural river basins are exploited to their limits, issues of water pollution and resource degradation arise. To mitigate the damages to water resources and their environment additional limits are imposed on water abstraction. As demands exceed the limited supply, the objectives of water resources development and the water allocation criteria are brought in to focus.

In most developing countries the high capital investments required for water resources development have been borne by the state sector. The tendency to identify the state as the custodian of water resources, the ability of state to formulate and enforce legislation regarding use of water, the obligation of state to control certain aspects of water activities, have all resulted in the government sector playing a key role in administration of water allocation (Dinar *et al.,* 1997).

The problem of water allocation among the sectors has emerged as a growing problem in Sri Lanka, warranting immediate policy interventions for the sustainable and most feasible utilization of the tapped water resources. The water allocation problem (surface and groundwater) in the past were addressed via both ad-hoc and systematic procedures by the relevant stakeholders. However, it has been reported that allocation mechanisms have resulted in many problems of coordination and conflicts.

Lack of a comprehensive water resources management policy and the non-existence of an implementing authority to ensure the equitable access to water to fulfil the basic needs of all stakeholders are being identified as one of the major drawbacks in addressing the problem of growing competition for water between different sectors. It is vital to set up an apex body for inter-sectoral coordination and decision making in the water sector. Lack of integrated and multi-objective planning of available water resources seriously affects the fair and equitable access to water for different users and leads to crisis and conflicts in the allocation of water. Reallocation of existing water shares is socially, culturally, economically and politically very sensitive. Therefore, transparency in project implementation is vital in order to avoid public distrust about the project. Lack of integrated and multi-objective planning of available water resources seriously affects fair and equitable access to water by different users and leads to conflicts and other side-effects of the allocation of water.

The water scarcity is expected to worsen in irrigated agriculture, because of the abstraction of water for drinking purposes. It has been substantially reduced in the past by the improvement of irrigation infrastructure, adoption of water saving management practices such as rotational water issues and implementing cropping calendars and the change of the attitudes of farmers from habitual water usage. Provision of safe water has significantly improved the social and economic wellbeing of the beneficiary community.

The first water allocation priority during water scarce dry periods is provision of portable water followed by sanitary requirements in all case study areas. However, conflicts are experienced in many places in drinking water supply projects when the extracted water is made available to the areas outside the original source of water overlooking the users in the area covered by the resource (Aheeyar, Nanayakkara and Bandara, 2008).

In many cases the temporal and spatial variation of natural water availability does not match the demands in Sri Lanka. The water resources development projects are undertaken to build the physical and institutional infrastructure that address this mismatch. However, the management of basin water resources is complicated by the growing demand from traditional and new water users. There are many examples from river basins in the developing world, where water resources management has failed to cope with this situation, causing economic loss and degradation of water resources. It is therefore important to identify the possibilities of improvement to current water resources management practices (Weragala, 2010).

The IWRM is adopted as a cornerstone of natural resource management strategies to mitigate effects of poverty and environmental degradation. IWRM has been attempted through the integrated management of multiple land uses - forested catchments, agriculture or riverine lands in a watershed context. In the water resources sector, it is assumed that the integrated management of multiple end uses of water - municipal, irrigation, environmental or domestic could enhance the accountability and transparency of policy procedures. When issues of access for upstream and downstream communities in watersheds or of head-end and tail-end farmers within an irrigation system are integrated in management plans, service provision may be enhanced, conflicts minimized and the effects of poverty alleviated (Kurian, 2004).

Aggregate statistics suggest that, overall, Sri Lanka, currently, has no water scarcity. However, the per capita water availability will be inadequate to cater for the country's estimated peak population resulting in water scarcity in terms of either physical or economic by 2025 (Samad *et al.,* 2016). The frequent variability of spatial and temporal water availability due to the bimodal pattern of the annual rainfall and extreme weather events caused by climate change have built a location specific uneven water availability (i.e. deficits and excess) and water scarcity. Further, it is estimated that by 2025, most of the districts in the dry zone will face severe seasonal or year-round absolute water scarcity at the current level of irrigation efficiency (Ibid). Therefore, effective and efficient water management is most important in today's context, and regular review and amendment of policies, laws, and regulations are crucial to mitigate water scarcity and related issues. Although a few attempts were initiated, none of them succeeded (Chandrasekara *et al.,* 2021).

The irrigation sector uses 85 percent of water, and 70 percent is used for paddy production, with the remaining 15 percent used for drinking, domestic water use, industrial, and ecosystem management. The staple food of Sri Lanka is rice, and about 90 percent of irrigated lands are cultivated with paddy. One hundred per cent paddy cultivation is practiced in *Maha* season (primary cultivation season from September to March) and during the *Yala* season (minor or second cultivation season from May to August) when rice cultivation is coupled with other field crops (OFC) based on the availability of water. *Laxapana* is the first hydropower plant that started in Sri Lanka in 1950 and since then the largest contribution to the electricity generation has come from hydro-development projects until the mid-1990s. Thereafter, the dominant electricity generation source changed to the mixed hydrothermal system and, currently, it is from oil (Chandrasekara *et al.,* 2021).

The results of a study conducted in *Hakwatuna Oya* watershed in *Deduru Oya* river basin show that water conflicts exist within the irrigation command as well as in the catchment. Conflicts between head-end and tail-end farmers, farmers and officers, farmers of irrigation command and in the catchment, farmers of irrigation command and fishermen and farmers within irrigation command and outside of the command area were observed during the study. Water scarcity is the main reason which leads to water conflicts. Poor attitudes of farmers, weakness of existing land and water rights, non-implementation of existing law primarily due to political interference, encroachments, inadequate institutional arrangement of water resource management are also considered as factors contributing to water conflicts. The socio-economic and cultural factors, such as gender and religion also played different roles in existing water conflicts. In a given watershed, different users and use cannot be isolated from each other since all of them share a single resource, i.e. water. If interventions are not taken to introduce basic principles of integrated water resources management with the involvement of different stakeholders the existing conflicts would further escalate in the future. Establishment of land and water rights, proper institutional arrangements for water allocation and monitoring, communication between and among sectors, quick and efficient conflict resolution mechanism with improved governance, needs to be in place to avoid conflicts (Saumyaratne, Gunawardena and Dayawansa, 2016).

CHAPTER THREE

Conceptual Framework and Research Methods

3.1 Conceptual Framework

The ground level imperfection in different aspects related to water management; lack of participation by and interconnection between different water users/stakeholders, lack of information sharing network (on crop extent to be cultivated in different cropping systems and their water requirement in the cropping season/s, water requirement for water supply services like National Water Supply and Drainage Board (NWSDB) and etc. within and between different water user groups, lack of intervention and strategies by authorized agencies like Department of Agrarian Development (DAD), estate plantation management, Divisional Secretariat (DS), Forest Department, Department of Agriculture in resource (soil, water and forest) utilization and management, absence of system/s to regulate and management of water allocation among different water user groups has lead the different water user groups and authorities (with minimal intervention) to find ad-hoc and ex-post (reactive) response in case of water scarcity situations.

The water insecurity caused by water scarcity increases the vulnerability of the different water user groups at different levels. It further affects the livelihood of less powerful water user groups and the household food security of such groups. Health and sanitation issues on disadvantageous recipient water user groups is another adverse impact of water insecurity. Apart from apparent physical phenomena such as depletion of groundwater levels, crop damage, environmental degradation in water insecurity situations, activities like water allocations favoring certain groups over the others and unregulated and illegal water tapping by powerful groups have resulted in competition for water and finally water conflicts to occur and continue.

It is assumed in this study that the establishment of a sustainable mechanism for water allocation while meeting the requirements of different water uses would facilitate to minimize or avert water conflicts in the study area. Instead of an ex-post response for water scarcity, it is understood that there should be an ex-ante program to avoid water conflicts among different stakeholders.

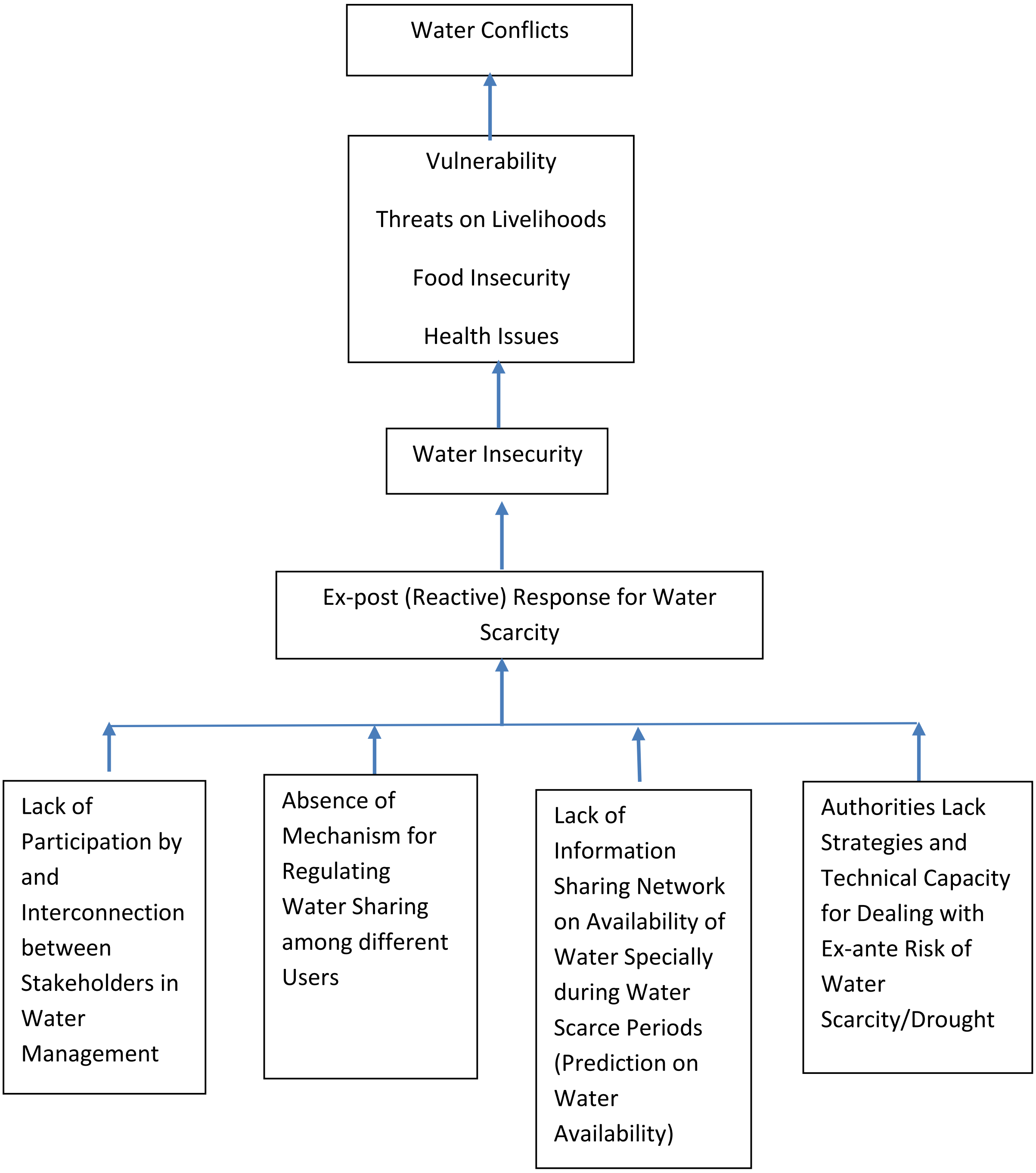
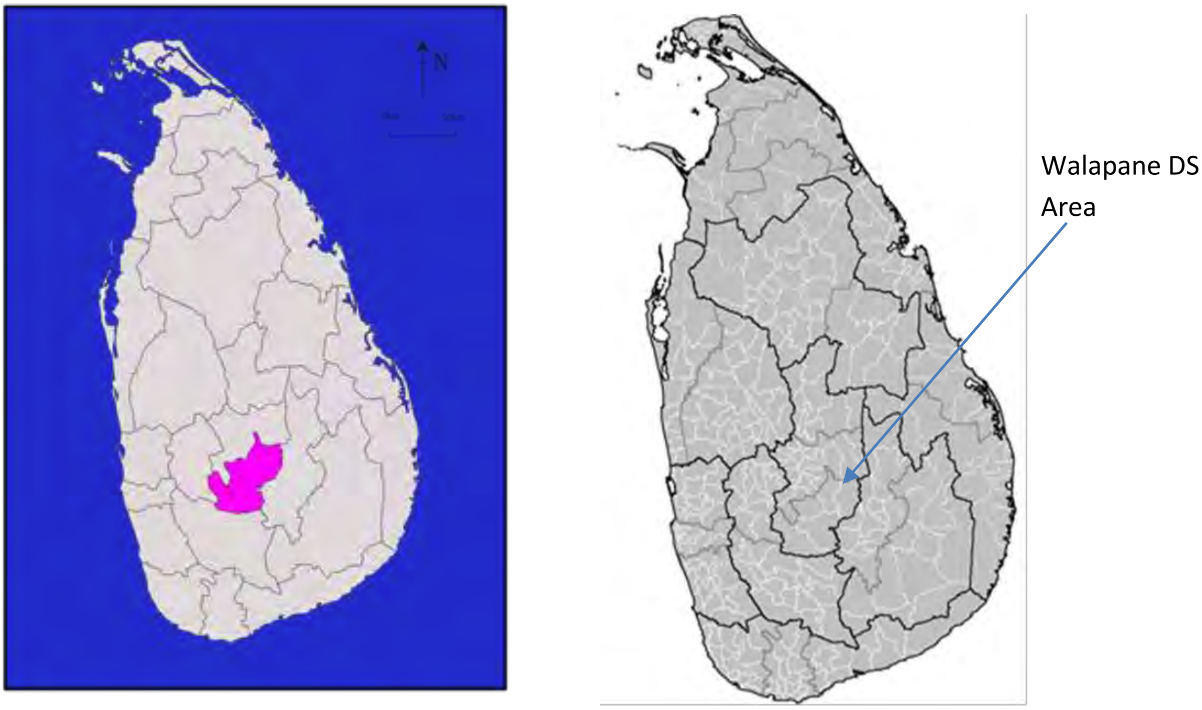


Figure 3.1: Conceptual Framework Adopted in the Study

3.2 Study Location

Walapane Divisional Secretariat (DS) area of Nuwara-Eliya district was selected as the study location. With the total land area of 302 km^2, Walapane DS consists of five Agrarian Services Center (ASC) areas named, Ragala, Ruupaha, Theripehe, Nildandahinna, Walapane and Munwatta extending over 125 *Grama Niladhari* (GN) divisions. The total population in the area in 2017 was reported as 128,036 people representing 35,148 families. The largest proportion (50.5%) of the population is made up of the rural sector and the urban sector population in the study area is limited to about 1 percent. The estate sector accounts for about 48 percent of the population in the Walapane DS area.



Adopted From https://en.wikipedia.org/wiki/Divisional_Secretariats_of_Sri_Lanka

Figure 3.2: Location of the Study Area (Walapane DS) in Nuwaraeliya District

The *Kurunduoya* river basin located in the eastern slopes of the central highland region and associated tributaries were selected to examine the land use changes over the past decades, with special reference to the expansion of market gardens where the vegetable and cash crop cultivation are extensively being undertaken. The *Beliuloya* river basin adjacent to the *Kurunduoya* basin was also selected for this study as the farming communities in some of the villages situated in *Beliuloya* river basin use water diverted from the *Kurunduoya* and conveyed to these villages. The Walapane DS area consists of 5 major irrigation schemes with a cumulative command area of 1894 ac (Table 3.1 and Figure 3.3) and a total of approximately 470 units of minor irrigation structures (small tanks, anicuts and canals) to provide irrigation water mainly for lowland paddy fields. The majority of minor irrigation schemes are characterized with anicuts and associated canal systems while the small tanks in the area are limited to 44 in number (Walapane DS, 2018).

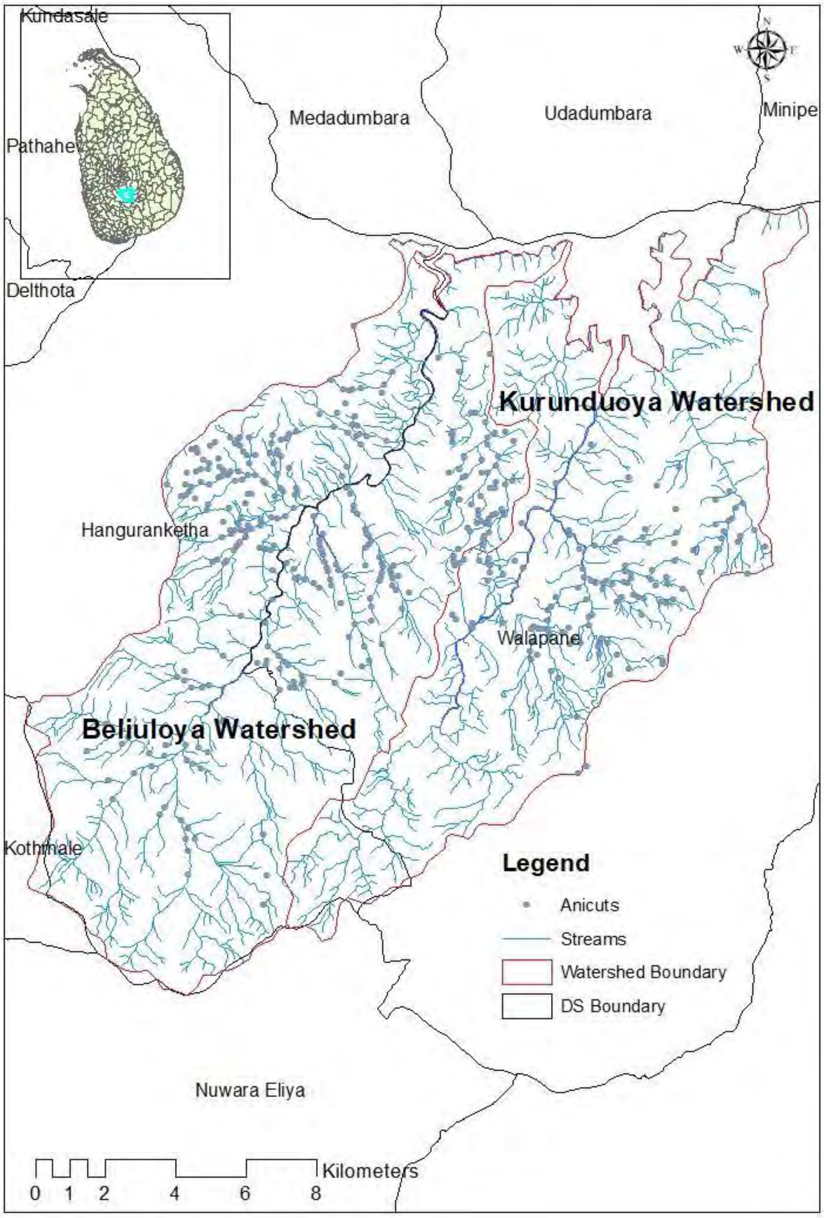
Table 3.1: Major Irrigation Schemes in Walapane DS Area

Irrigation Scheme	Command Area
Paragaha-Araawa Scheme	480 ac
Keenawala Scheme	251 ac
Mulhal-Ela Scheme	327 ac
Bolagandawela Scheme	356 ac
Waduwa-Wela Scheme	480 ac

Source: Walapane Divisional Secretariat (2018)

The major irrigation schemes are administered by the Irrigation Department (ID) while the Department of Agrarian Development (DAD) is responsible for operation and maintenance of minor irrigation structures.

The study area belongs to six agro-ecological regions (AERs); IM_{1a}, IM_{1c}, IM_{3c}, IU_2, WU_{2a} and WU_3. The largest portion of the study area is represented by the Intermediate Zone (IZ) while the upper parts of the two watersheds belong to the AERs in the Wet Zone (WZ) (Figure 3.4). The mean annual rainfall in the area ranges from 1300 mm (mostly in the IM_{1c} region in the lower part of the watershed) to 3500 mm (in upper parts of the watershed). The rainfall distribution is concentrated towards the wet period from October–January. The dry period from May-September receives very limited rainfall. Since this catchment sits within the rain shadow of the South-West monsoon (SWM), the dry period is affected by strong dry winds that restrict crop cultivation in some parts of the area. The mean annual maximum and minimum temperatures are 29°C and 18°C respectively, with the lowest temperatures observed in the latter part of the wet season, and the highest temperatures in the early part of the dry season (Punyawardena, 2008).



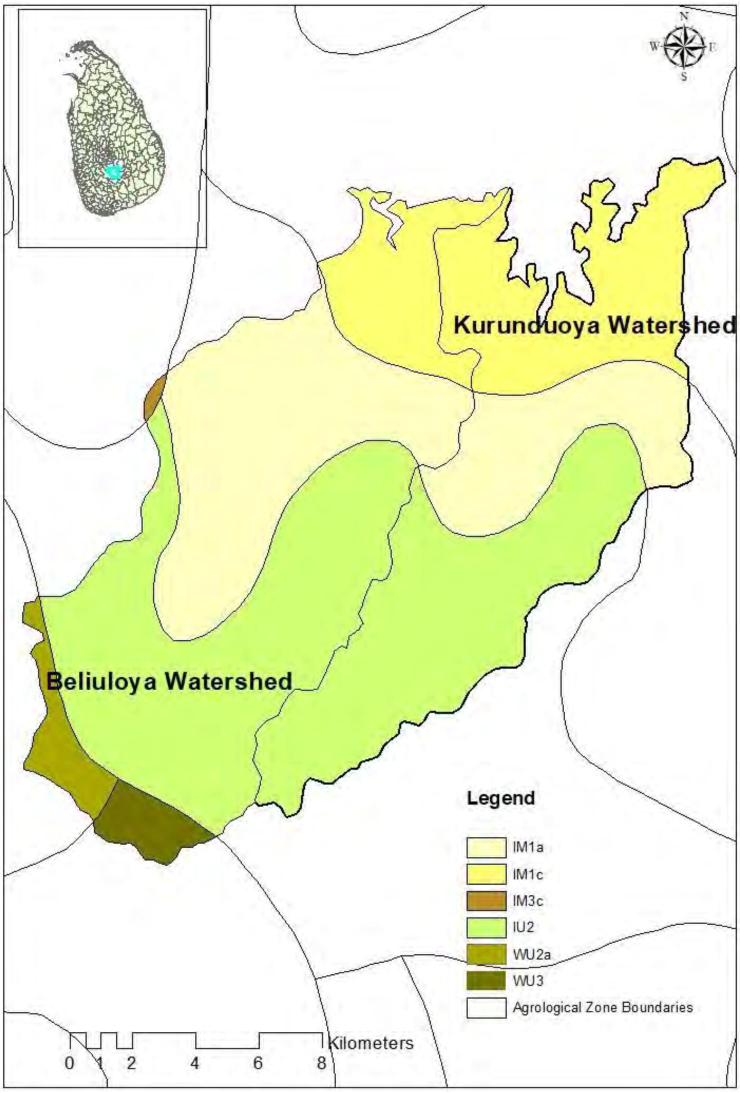
Source: Authors' Work, 2020

Figure 3.3: Streams, Tributaries and Anicuts in the *Kurunduoya* and *Beliuloya* River Basins

The IM_{1a} represents 29 percent (9096 ha) of the total land extent of Walapane DS area (31 803 ha). As the mean annual rainfall is over 2000 mm, which is mainly received from the North-East monsoon (NEM) in October-January period, the *Maha* season is relatively long in this AER. Since the rainfall during the May – August period is very low, the crop cultivation under rainfed conditions in the *Yala* season is not favorable. The prominent land use types in this AER are tea plantations, vegetable cultivation, mixed home gardening, paddy cultivation in lowlands and forests. The rains from the first intermonsoon and SWM do not reach or scarcely reach the IM_{1c}, which covers 27 percent of the total land mass. The IM_{1c} where the expected annual rainfall exceeds 1300 mm, receives the largest portion of the rainfall from the NEM during October – January period. Also during April, this area receives a significant rainfall due to the convective process, followed by a very dry period from May to September, reflecting some similar characteristics to the Dry Zone (DZ) areas. Irregular vegetable cultivation in steep uplands and paddy growing in lowland areas are the prominent crop cultivation patterns in this AER.

The most prominent AER in the Walapane DS area is IU_2. This area receives rainfall mostly from NEM while receiving a small fraction of the rainfall from the SWM as well. However, when the SWM rains are weak this AER does not receive rains, instead, a dry windy weather prevails. The expected mean annual rainfall in this area exceeds 2100 mm. The key land use types are tea and vegetable cultivation. Forest plantations with exotic varieties and natural forests can also be found in this AER.

Though the Walapane DS area is not represented by WU_{2a} and WU_3 AERs the *Beliuloya* and *Kurunduoya* rivers originate in these AERs. The WU_{2a} receives, on average, annual rainfall over 2400 mm while the mean annual rainfall for WU_3 is relatively low (over 1800 mm). The relatively low rainfall in WU_3 is largely attributed to the less effectiveness of SWM above 1100 m in elevation. The WU_3 receives rainfall mainly from the second inter-monsoon rains during October-November period (Punyawardena, 2008). The elevation of the study area varies between 233 m at Randenigala to 2097 m at Mahakudugala.

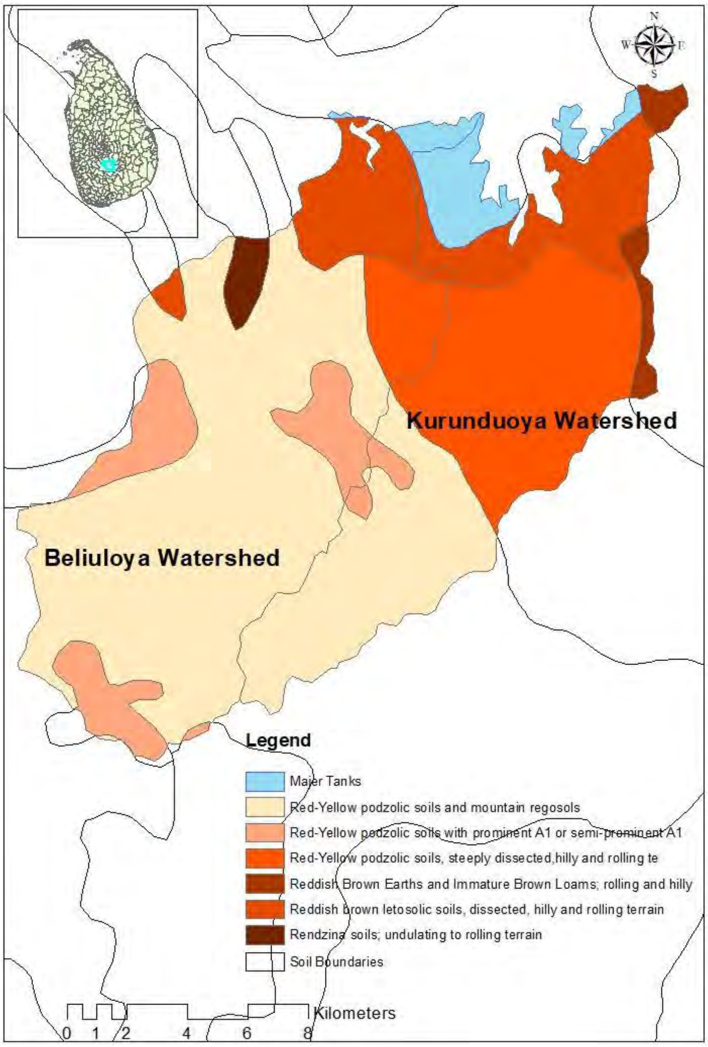


Source: Authors' Work, 2020

Figure 3.4: Agro-Ecological Regions in the *Kurunduoya* and *Beliuloya* River Basins

Of four different soil groups found in two river basins, the red-yellow podzolic (RYP) and reddish-brown latosolic/lateritic (RBL) soils are the prominent soil groups in the area. The RBL soils are mainly concentrated in the lower part of the watersheds whereas RYP soils are dominant in upper and middle parts (Figure 3.5). RYP is the second most prevalent great soil group which belongs to *Tropudults* of the Ultisols order of Soil Taxonomy (De Alwis and Panabokke, 1972), found in the Wet and Intermediate agro-ecological zones of Sri Lanka (Moorman and Panabokke, 1961). The RYP soils are clayey in texture with low pH (FAO, 2002; Wickramasinghe, 2005), possessing a moderate cation exchange capacity, and are highly erodible and prone to erosion under poor management and high rainfall intensities (Tolisano *et al.,* 1993; Panabokke, 1996). According to Joshua (1977), RYP soils are considered to be highly erodible soils having 0.22 erodibility factor value.

The RBL soils are prominent on the Eastern and South Eastern lower slopes of the central highlands. The pH values of these soils are usually between 5.5 and 6 with slightly higher values for the surface horizon. The cation exchange capacity of the B2t horizon is quite variable, ranging from 25 to 40 m.e. per 100 g of clay. The excellent drainage of these soils, coupled with their relatively high structural stability, readily lend them to intensive agricultural use (Moorman and Panabokke, 1961).



Source: Authors' Work, 2020

Figure 3.5: Soil Groups Found in the *Kurunduoya* and *Beliuloya* River Basins

3.3 Data Collection

The data and information for the study was collected mainly from the primary sources. The farmer organizations (FOs), farming communities, persons undertaking water management in FOs (*Jalapalaka*), divisional and field level agricultural officers like Assistant Director of Agriculture (ADA), Assistant Commissioner (AC), Assistant Director (AD), Irrigation Engineer (IE), Technical Officers (TOs) and Divisional Development Officers of DAD, Agriculture Instructors (AIs), Agricultural Research and

Production Assistants (AR&PAs), village level administrative officers (*Grama Niladhari),* officers attached to other stakeholder institutions/organizations like National Water Supply and Drainage Board (NWSDB), Land Use Policy Planning Division (LUPPD) were the key primary data sources.

3.3.1 Sampling Procedure

In order to collect primary data and information at field level, a sample of farmer households representing varied crop production systems at different elevations in the study site was drawn. Farmers in the upper and the upper-middle parts of the watershed have opted to undertake year-round crop cultivation of upcountry vegetables and high value cash crops like potato whereas in lower-middle and lower elevations, the crop cultivation shows great diversity. The vegetable and potato cultivation in the upper and upper-middle elevations are intensive and largely market-oriented. In lower middle and lower elevation areas paddy growing, particularly in the *Maha* seasons is mostly for own household consumption, and vegetable and other field crop (OFC) cultivation in dry *Yala* seasons target both the household food security and the markets . Therefore, in the sample selection, villages from different elevations in the study site were selected to gather information specially on land use, water management and agricultural activities.

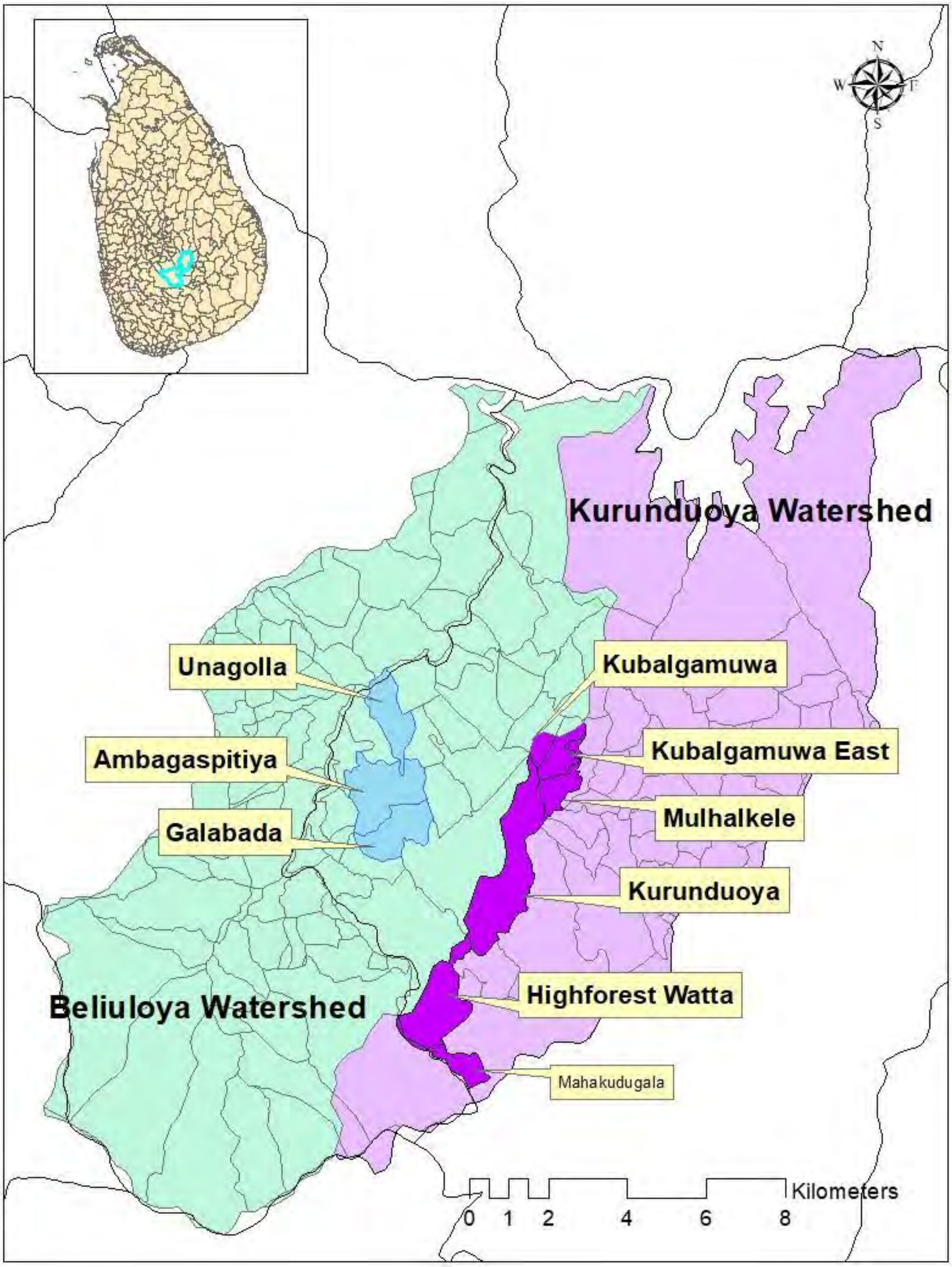
The stratified sampling procedure was applied in this study (Table 3.2). Of six ASC areas located in Walapane DS area, three ASCs named Walapane, Munwatte and Ragala situated in *Kurunduoya* and *Beliuloya* river basins were selected in the first stratum of the sampling procedure. Taking the factors; elevation and the institutional arrangements available for water management, 6 villages were selected from respective ASC areas. Under the institutional arrangements for water management for agricultural purposes, the involvement of ID and DAD could be seen in the study area at different scales/ levels. However, there is no involvement of these institutions in water management related to agricultural activities in the upper elevations. The map elaborating the villages selected for primary data collection is given in Figure 3.6.

Table 3.2: Distribution of Strata in the Sampling Procedure

Elevation	ASC Area	Water Management Institution	Irrigation Scheme	GN Division
High Elevation	Ragala	NA	NA	Mahakudugala
				Highforest Watte
				Kurunduoya
Mid and Low Elevation	Walapane	Irrigation Department	Mulhal-Ela Scheme	Kumbalgamuwa East
				Kumbalgamuwa
				Mulhalkele
	Munwatte	Department of Agrarian Development	Thiriwanamadittha Wewa	Galabada
			Kurundu-ela Canal	Ambagaspitiya
				Unagolla

Table 3.3: Sample Size Distribution in the Questionnaire Survey

GN Division	Name of the Farmer Organization	No. of Households Selected
Kumbalgamuwa East	Ekamuthu	50
Kumbalgamuwa	Keerthi	50
Mulhalkele	Parakrama	50
Galabada	Galabada	60
Ambagaspitiya	Ambagaspitiya	80
Unagolla	Perakum	80
Total		370



Source: Authors' Work, 2020

Figure 3.6: Villages Selected for the Primary Data Collection

The land extent under each GN division selected is given in the Table 3.4 below.

Table 3.4: The Land Extent of GN Divisions Studied

GN Division	Land Extent (ac)
High-Forest Watte	670
Mahakudugala	765
Kurunduoya	724
Kumbalgamuwa East	239
Kumbalgamuwa	512
Mulhalkele	286
Galabada	224
Ambagaspitiya	365
Unagolla	248

Source: Walapane DS (2018)

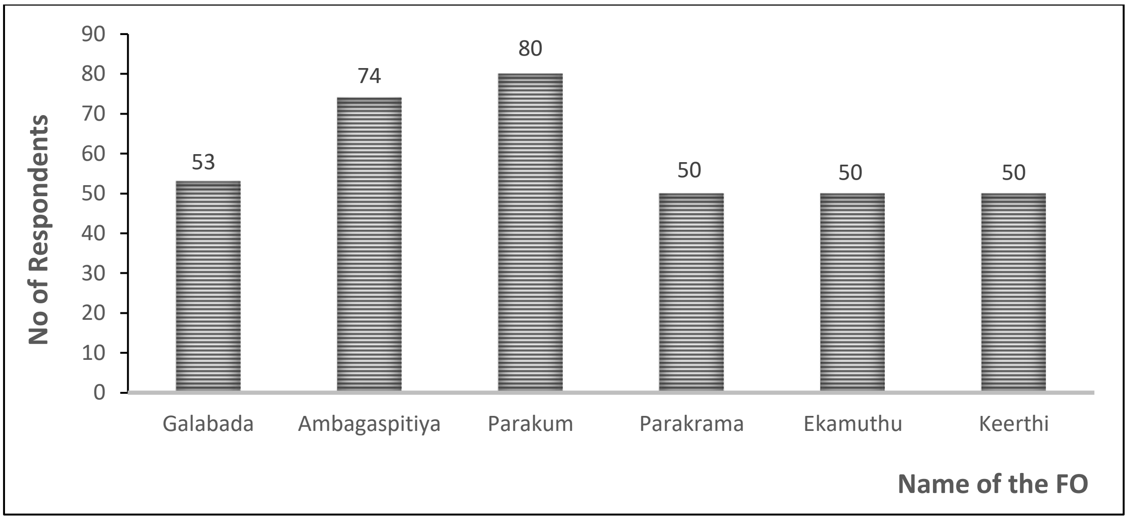
The demographic and socio-economic data and information at household level and the biophysical data at farm level; family size, level of education, farming experience, other sources of income, affiliation to community based organization (CBO), sources of agricultural extension, land types and land size/s, cropping patterns, crop production systems, different agronomic practices, sources of irrigation water, climate adaptation, issues on water availability were collected from the household questionnaire survey.

The key informant interviews (KIIs) and informal discussions were conducted in data collection from the officers of respective government institutions and office bearers of the FOs. Focus group discussions (FGDs) were held with office bearers and knowledgeable and informative groups of farmers in each FO representing the villages where the questionnaire survey was conducted. The secondary data related to agriculture and water management available with different government institutions were also collected in the study.

The field work of the study on data collection was carried out by a group of Field Enumerators attached to the Environmental and Water Resources Management Division (EWRMD) of HARTI during August – December 2019. The field work was supervised by the statistical staff while the KIIs, FGDs and informal discussions and field observation were carried out by the research team of the study.

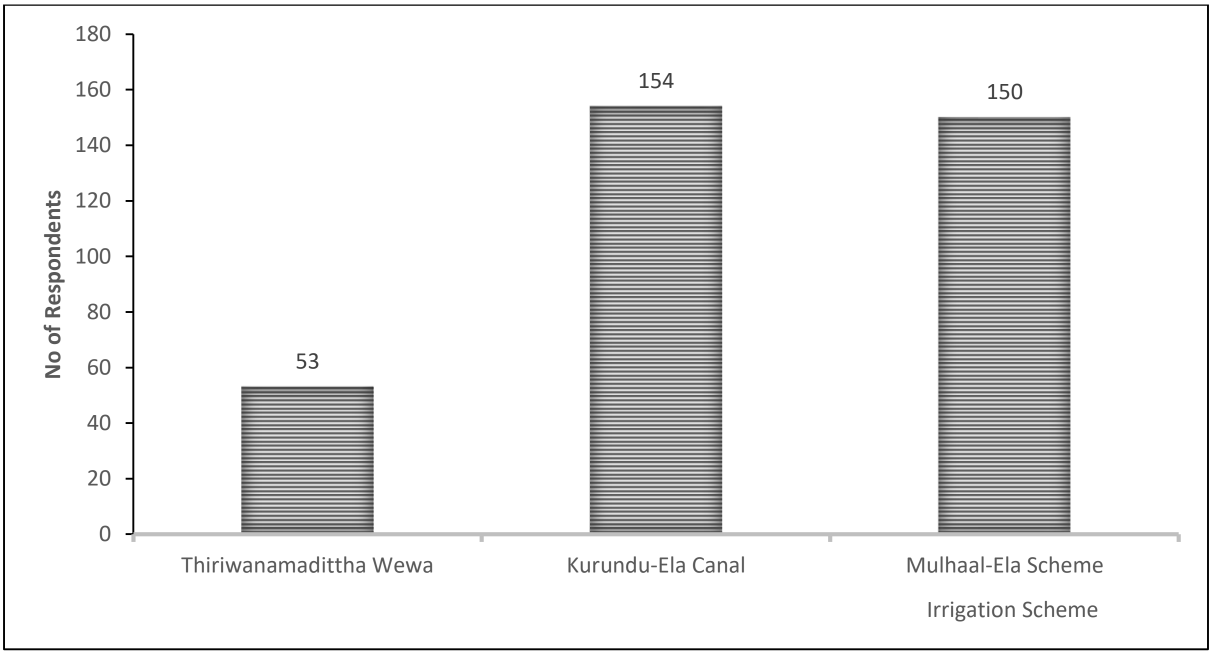
3.4 Data Analysis

Coding and entering of data collected through the questionnaire survey was carried out by the Field Enumerators under the supervision of the statistical staff. A number of incomplete questionnaires owing to farmer's reluctance in providing data and the issues with the accuracy and the reliability of the data provided by farmers were discarded at the stage of data coding and entering. Thus, six and seven incomplete questionnaires from Galabada village and Unagolla village respectively were discarded, bringing the effective sample size to 357 farm households. The effective sample size distribution with respect to representation of FOs and irrigation schemes is depicted in Figure 3.7 and Figure 3.8 respectively.



Source: HARTI Survey Data, 2019.

Figure 3.7: The Effective Sample Distribution of the Study (FO Representation)



Source: HARTI Survey Data, 2019.

Figure 3.8: The Effective Sample Distribution (irrigation Scheme Representation)

The data analysis was carried out using Microsoft Excel and SPSS statistical software. The descriptive and inferential statistical techniques were employed in data analysis. Frequency tables, trend lines, charts and graphs were used in presentation of analyzed data.

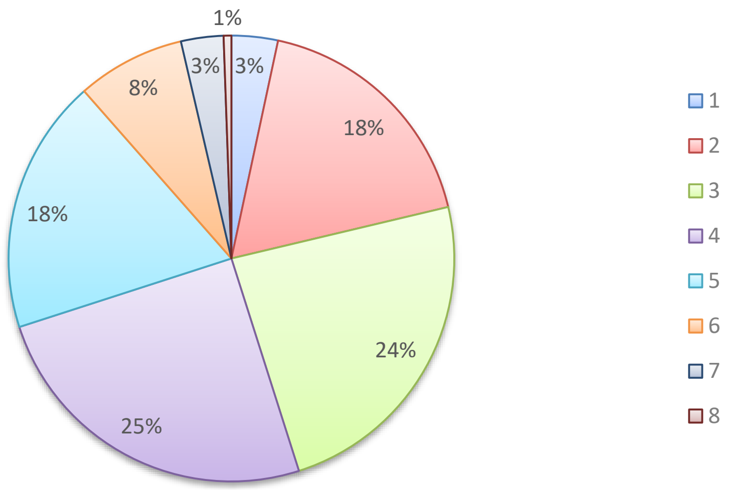
In order to analyze the land use changes over the last few decades, the remote sensing (RS) and geographical information system (GIS) tools were also used. The upper and middle sections of the *Kurunduoya* river basin were considered in detecting land use and land cover changes. The land use maps of the particular river basin for 1983 and 2020 were analyzed using ArcGIS 10.6 software. The remote sensed data on different land uses were verified with the field observations.

CHAPTER FOUR

Results and Discussion

4.1 Demographic Characteristics of the Sample

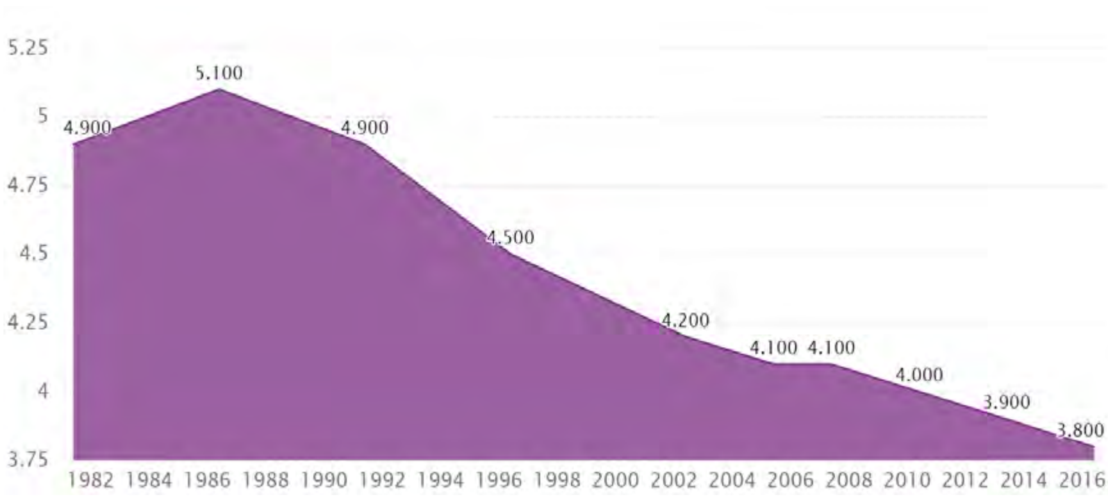
The demography of the study area with special reference to the farm households is discussed in this section. The family size, age and income sources of the head of the household, who is primarily involved in crop production activities are examined. The type of farming by respondent farmer; whether a full time farmer or a part-time farmer has also been included under the demographic characteristics. The information on dependency ratio at household level is also provided in this section. The poverty status of the households was determined with the information on receiving financial assistance from the *Samurdhi* Development Program.



Source: HARTI Survey Data, 2019.

Figure 4.1 The Family Size Distribution

The total population reported in the respondent households is 1342 people while the average family size was reported as 3.76 in the study location. The family size ranges from one member families to households with a maximum of 8 members. Farm households with 3 or more members account for 79 percent of the sample. Twenty-five percent of the sample is represented by households with 4 members followed by 3-member families (24%) and 2 and 5-member families (18% each). Households with one member and 7 members account for 3 percent each. This figure is similar to the national average value of the family size, 3.8, as reported by the Department of Census and Statistics (DCS) in 2018 (Figure 4.2).



Source: Household Income and Expenditure Survey Series, Department of Census and Statistics

Figure 4.2: National Average Household Size in Sri Lanka (1982 – 2016)

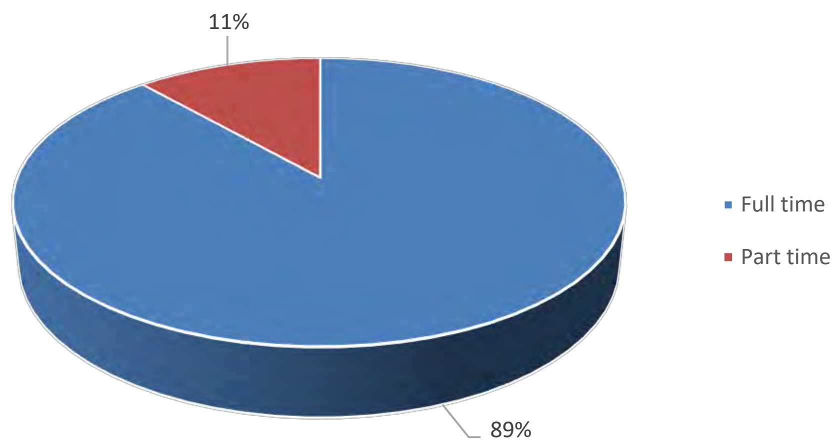
The majority of the respondent farmers (58%) belong to the age group over 55 years of which over 8 percent of the farmers are above 70 years. It is a reflection of the situation in which the overwhelming majority of the population involved in the agriculture sector in Sri Lanka is from the older group of people. The accounting for over 90 percent of the respondent farmers by this age group above 40 years further implies the poor level of youth involvement in agriculture.

Table 4.1: Age Distribution of Respondent Farmers

Age Group (Years)	No.	Percentage (%)
<25	1	0.28
25 – 40	32	8.96
41 – 55	115	32.21
56 – 70	179	50.14
>70	30	8.40
Total	357	100.00

Source: HARTI Survey Data, 2019.

The importance of crop production activities in the study area is highlighted by the majority of the respondent farmers (89%) involved in agriculture on a full-time basis (Figure 4.3). Thus, agriculture has been the main livelihood of the communities living in the area.



Source: HARTI Survey Data, 2019.

Figure 4.3: Type of Farming by Respondents

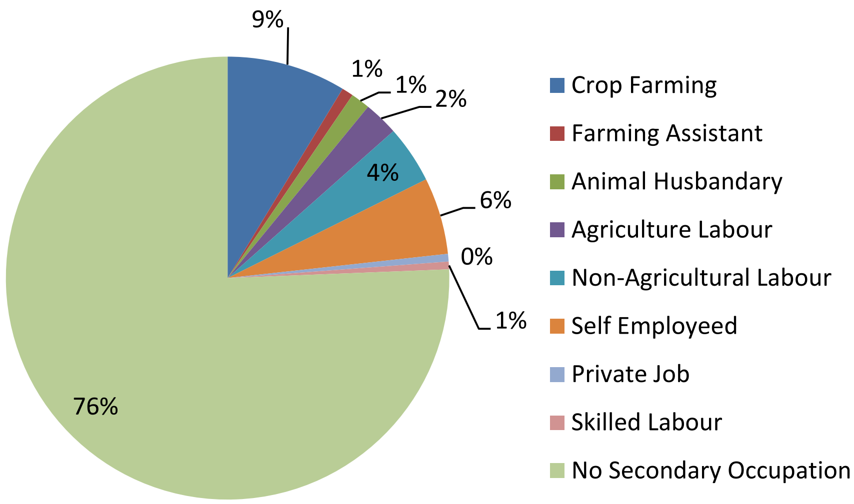
Being the primary occupation of 84 percent of the respondents in the study location, crop cultivation further marks the importance as the main source of income for the majority (Table 4.2). Nine percent of the respondent farmers are involved in crop production activities while engaging in government jobs as their primary occupation. Skilled labour such as carpentry, masonry, iron welding, electrician have also been reported as the primary source of income for 3 percent of respondent farmers.

Table 4.2: Primary Occupation of the Respondent Farmers

Primary Occupation	No.	Percentage (%)
Crop Farming	295	82.63
Farming Assistant	6	1.68
Self Employed	7	1.96
Government Job	32	8.96
Private Sector Job	6	1.68
Skilled Labour	11	3.08
Total	357	100.00

Source: HARTI Survey Data, 2019.

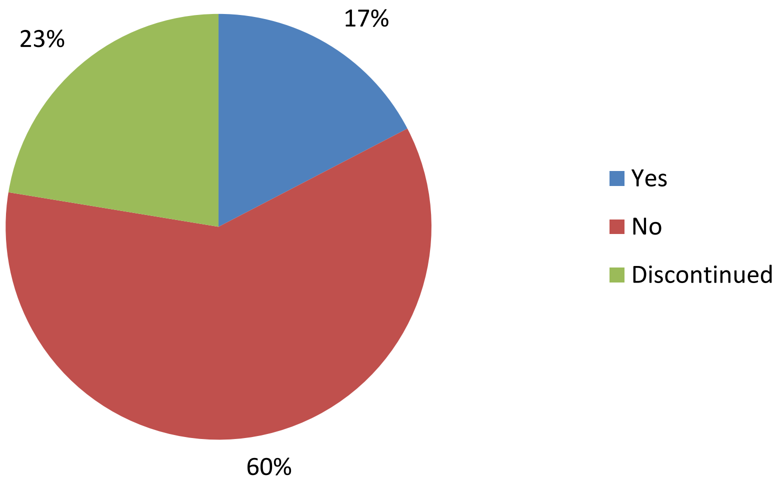
Less than one fourth of the respondent farmers are engaged in any kind of employment as a secondary source of income. It further emphasizes the importance of agriculture as the key income source in the study area. Of the respondents involved in any secondary occupation, the overwhelming majority is still engaged in agriculture and related on-farm income earning activities such as farming assistance, animal husbandry and agricultural labour which accounts for 55 percent. Respondents involved in self-employment and as non-agricultural labourers account for 23 percent and 17 percent respectively (Figure 4.4).



Source: HARTI Survey Data, 2019.

Figure 4.4: Secondary Source of Income for Respondent Farmers

Though animal husbandry, particularly cattle rearing has traditionally been a widespread and popular economic activity having multiple benefits such as source of farm power and manure (cow dung) and cow milk, the proportion of households that has been involved in any kind of livestock related activity is limited to 17 percent (Figure 4.5). Of the respondents who are not practicing any kind of animal husbandry, 27 percent (23% from the total sample) have discontinued animal husbandry during the last 5-year period largely owing to the lack of grazing lands and fodder during the non-rainy period.

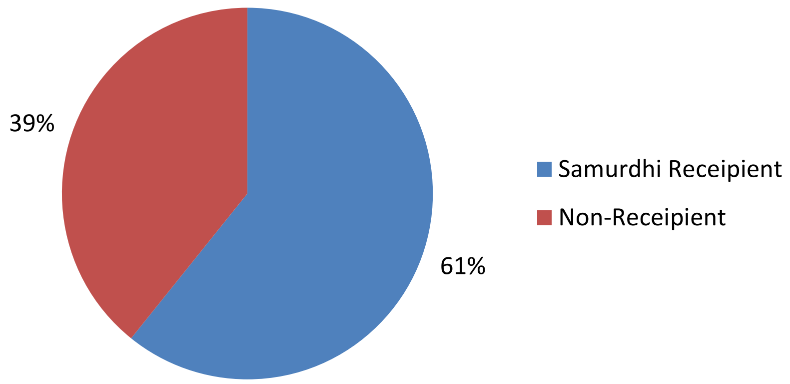


Source: HARTI Survey Data, 2019.

Figure 4.5: Involvement in Livestock Activities by Respondent Households

Considering the poverty level in the study location, nearly two third of the respondent households are receiving the government assistance through *Samurdhi* Development

Program. The uncertainty associated with crop production and marketing and lack of alternative and stable income sources for the majority of the community have allowed many farm households to receive the *Samurdhi* assistance.

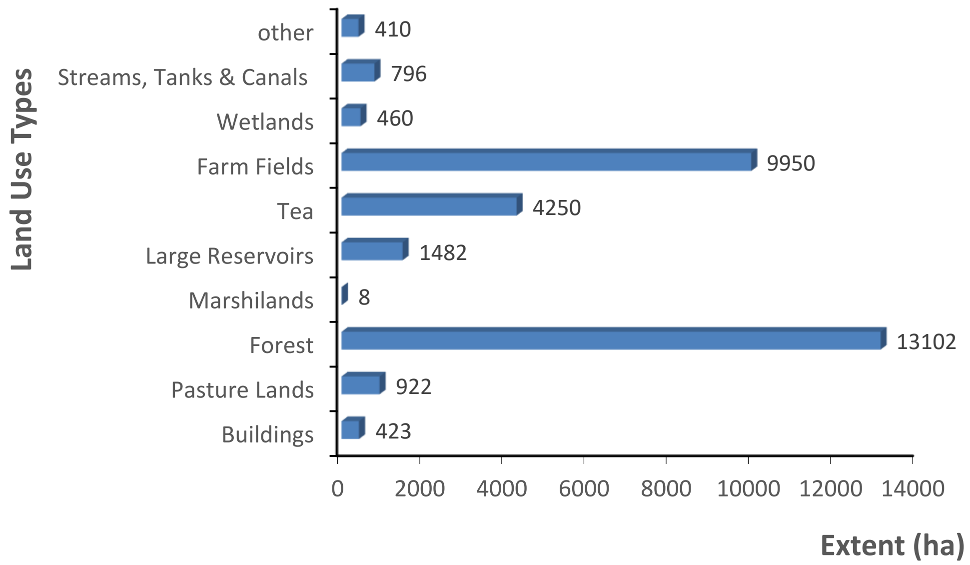


Source: HARTI Survey Data, 2019.

Figure 4.6: Status of Respondent Households with regard to *Samurdhi* Benefits

4.2 Land Use in the Study Area

The total land area of the Walapane DS area is 390 km^2, consisting of different land use types. The crop cultivation (agriculture) comprising tea plantations and other agricultural fields is the most prominent land use in the area accounting for 47 percent followed by a forest area of 41 percent .



Source: Walapane Divisional Secretariat (2018)

Figure 4.7: Land Use Types in Walapane DS Area

Of the agricultural lands, tea plantations and paddy lands account for 30 percent and 29 percent respectively. Though *chena* cultivation has been restricted legally due to its adverse impacts on the environment, this type of crop production is practiced at a very minimum level (4%), especially in the lower elevation areas of the study location. The vegetable and cash crop (mainly potato and tobacco) cultivations are mainly undertaken in market gardens accounting for one fifth of the total agricultural lands. The home gardens and other forms of uplands such as semi-permanent croplands are cultivated only in rainy *Maha* seasons and account for 16 percent of the total agricultural lands in the Walapane DS area.

Table 4.3: Different Land Use Types in Agricultural Lands in Walapane DS Area

Land Use Type	Extent (ha)	Percentage (%)
Chena	597	4
Market Gardens	2845	20
Paddy Fields	4186	29
Tea	4250	30
Other	2322	16
Total	14200	100

Source: Walapane Divisional Secretariat (2018)

As per the field observations, the expansion of market gardens, particularly in the upper parts of the *Kurunduoya* river basin has led to severe repercussions on the environment and the agricultural and other types of water use in the middle and lower parts of the same watershed. Also, livelihoods and food security of the farming communities living in some villages in neighboring watersheds (in *Beliuloya* river basin) where the water diverted from *Kurunduoya* is used for agriculture and other domestic purposes, are under the threat due to the excessive water consumption in market gardens in the upper-stream of the watershed.

In addition to the field observations made relating to the current land use in the upper and middle areas in the *Kurunduoya* river basin, the changes in land use and land cover (LULC) over the past 4 decades were investigated using GIS and RS techniques. Accordingly, the LULC changes in the upper and middle sections of the river basin (area above B 332 highway - from Padiyapelellla to Walapane and the B 413 highway - from Walapane to Ragala) were identified and categorized for year 1985 and year 2020. The details of the LULC in 1985 are elaborated in Table 4.4 and Figure 4.8.

Of the total area concerned (9182 ha), the vegetation represented by forest area (both natural and commercial forest plantations for timber) and scrub lands make up nearly two third of the extent. The main agricultural crop, tea, covers 28 percent while vegetable cultivation is limited only to 4 percent. The land use category ‘settlement’ represents both built area (roads, houses and tea factories) and home gardens and it accounts for 6 percent of the total land area above B 332 and B 413 highways in the *Kurunduoya* river basin. Thus, crop cultivation undertaken in home gardens is also included in the land use category ‘settlements’. The vegetable cultivation used to be indiscriminately carried out in the eastern parts of the Piduruthalagala Conservation

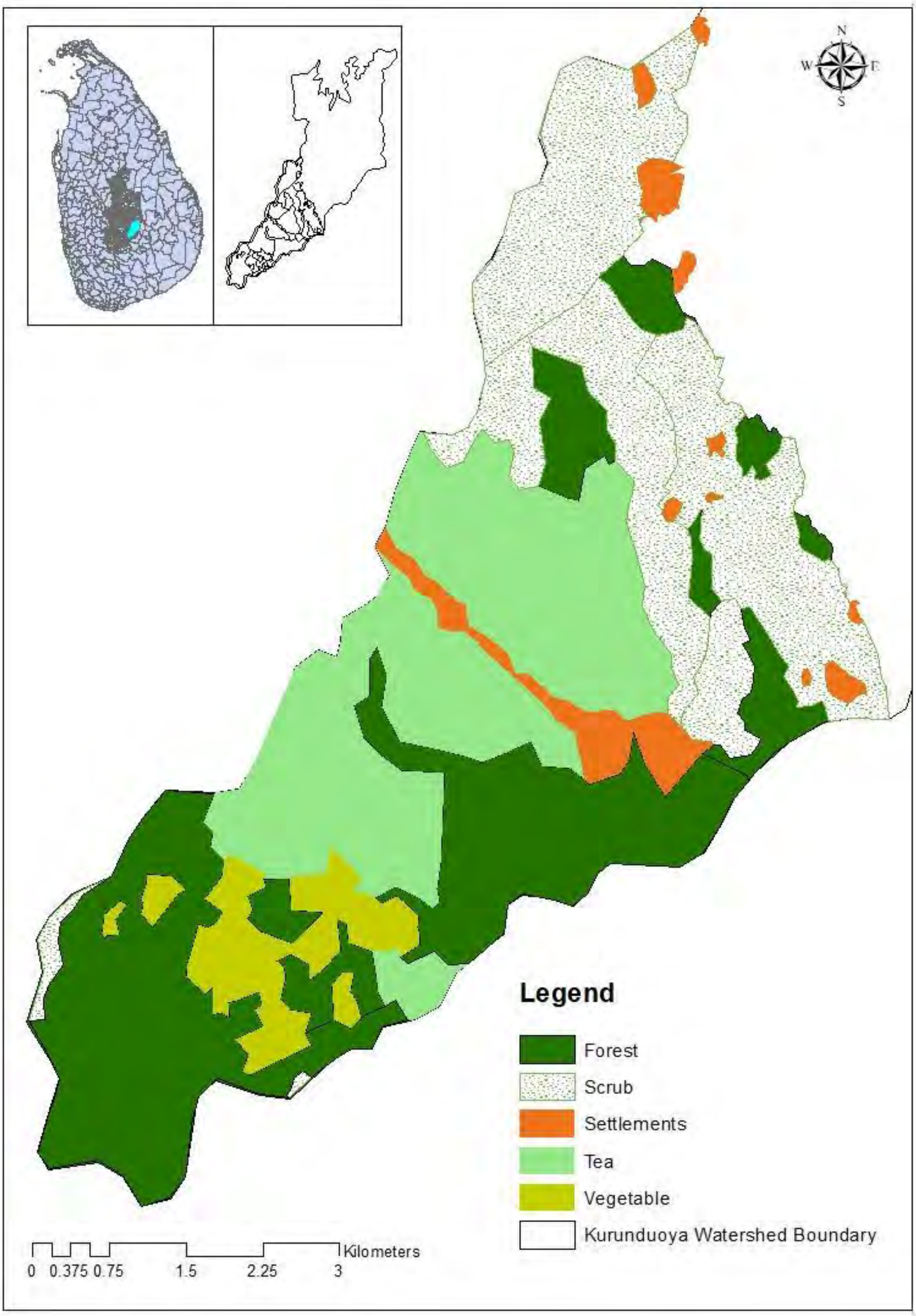
Forest area which is widely known as the *Cloud Forest* area. The *Kurunduoya* river originates in the *Cloud Forest* from where the *Beliuloya* river also commences.

Table 4.4: Land Use and Land Cover Types in Upper *Kurunduoya* Basin in 1985

Land Use Type	Extent (ha)	Percentage (%)
Forest	3086	34
Scrub Lands	2642	29
Settlements	380	4
Tea	2532	28
Market Gardens	542	6
Total	9182	100

Source: Authors' Work, 2020.

The intensive vegetable cultivation area includes the land area about 80 ha (200 ac) that had been allocated for poor farmers to solely grow apples in early 1970 by the government in power at that time. With the failure of this initiative to achieve envisaged results with regard to local apple production, the project was abandoned in 1980 and the 200 ac land mass was to be regained by the government for the expansion of forest cover in the upper watershed area. However, the said land area, currently known as '*Apple Farm*', had been gradually and unlawfully converted into vegetable farms. By 1985, the land extent under vegetable and cash crop cultivation in the *Apple Farm* and the nearby encroached area was approximately 139 ha (348 ac). During the 15-year period starting from 1970, the encroached land area is 74 percent of the originally and legally allocated extent for the project (200 ac). Though the Department of Forest has been able to acquire some land plots by evicting illegal cultivators from the said *Apple Farm* and has converted the regained lands into forest area by replanting with local tree varieties, the rest of the disputed area has further been expanded for vegetable and cash crop cultivation by encroaching the forest reserve.



Source: Authors' Work, 2020.

Figure 4.8: Land Use and land Cover in 1985

In the past three and half decades , the LULC of the area has significantly changed. Table 4.5 shows the respective land extents and the relative extent for different land use categories in 2020. The natural vegetation cover has recorded an 8 percent decrease (from 63% in 1985 to 55% in 2020). The total forest cover has increased by 2 percent (73 ha) due to the regaining of encroached forest lands in the controversial *Apple Farm* area. The land extent converted from the *Apple Farm* to forest area in the *Cloud Forest* during the time period is approximately 38 ha. Thus, the land area still under vegetable and cash crop cultivations in *Apple Farm* is 253 ac (101 ha). The intensive vegetable and cash crop cultivation within the thick forest area is seen in Figure 4.8. The commercial forest plantations have also significantly accounted for increased forest cover in the *Kurunduoya* river basin.

Table 4.5: Land Use and Land Cover Types in Upper *Kurunduoya* Basin in 2020

Land Use Type	Extent (ha)	Percentage (%)	Change against 1985	
			Extent (ha)	Percentage (%)
Forest	3159	34	73	2
Scrub Lands	1908	21	- 734	- 28
Settlements	886	10	506	133
Tea	2456	27	- 76	- 3
Market Gardens	773	8	231	43
Total	**9182**	100		

Source: Authors' Work, 2020.

The scrub lands have been sacrificed in the conversion process of vegetation cover into other forms of land uses, particularly into market gardens and settlements including home gardens (Figure 4.8). The land cover reduction in scrub land category is 28 percent. Scrub lands are being largely encroached and converted into vegetable and cash crop cultivations, specially in the middle section of the river basin in Highforest Watte and Kurunduoya GN divisions.

The crop yield reduction due to excessive soil erosion by water in tea plantations in steep terrains in the central highland region has been recognized as a serious issue. The yield penalties experienced by tea planters has been attributed to the reduction of soil depth due to accelerated erosion in tea plantations. This situation has led tea plantations to become marginalized (Ananda, Herath and Chisholm, 1996; Ananda, 1998; Ananda and Herath, 2001; Herath, 2001). The inverse relationship between reduction of soil depth due to erosion and crop yield in tea cultivations has been revealed by Coomaraswamy *et al.,* (2001) as well.

Source: Google Earth (2020)

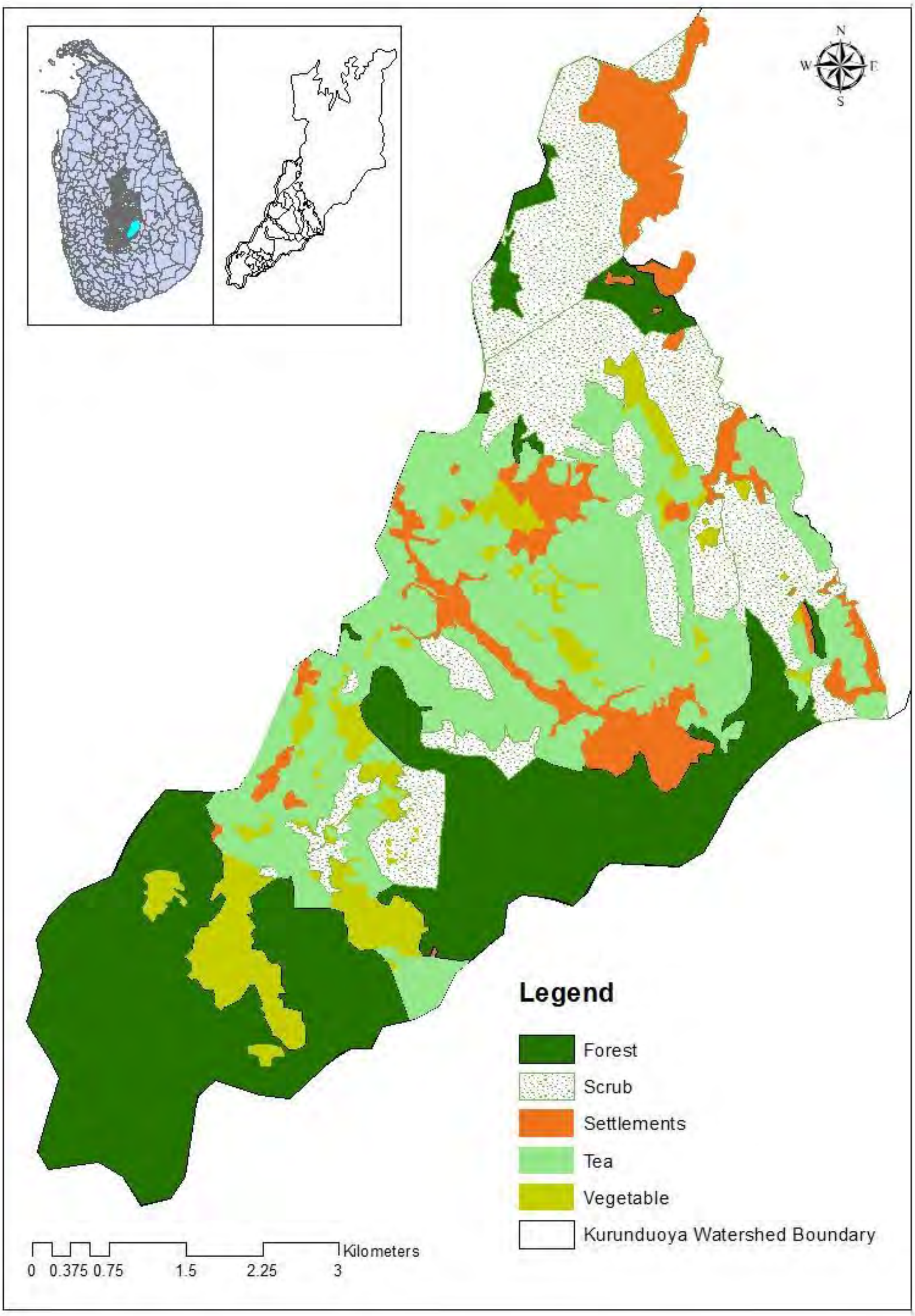
Figure 4.9: Intensive Vegetable and Cash Crop Cultivation in the *Cloud Forest* Area

Marginalization of tea lands possesses a wide range of adverse impacts on the environment and the regional economy. There is a lack of proper maintenance of marginalized tea lands that are directly exposed to the impacts of erosive raindrops. Minimum land cover in marginalized tea lands that promote runoff and inhibits infiltration further induces land degradation in the form of soil erosion causing on-site and off-site effects (ILO, 2019). Krishnarajah (1985) observed that on average the annual sediment loss in tea plantations is over 40 t ha^{-1} yr^{-1}. It is also observed 100 - 200 t ha^{-1} yr^{-1} soil loss in tea plantations in steep lands with less than 40 percent ground cover (Stocking, 1992, as cited by Herath, 2001).

On the other hand, marginalized tea lands are always under the threat of encroachment for vegetable and cash crop cultivations by the communities living in the plantations. Extensive cultivation on marginalized lands always poses threats to the water resources and downstream water bodies in terms of high sedimentation and deteriorated water quality. Therefore, it is always highly recommended to maintain tea plantations with appropriate level of ground cover and not permit using other inappropriate farming practices in sensitive landscapes. Ananda and Herath (2001) found stone terraces and lateral drains in tea lands to be effective in erosion control while ILO (2019) has suggested a series of soil and water conservation measures; contour planting, lock-and-spill drains to trap sediment and convey overland flow out of the farm field, planting live barriers (strips) across the slope. Converting highly erosive and poorly managed seedling tea fields into vegetative propagated tea varieties has also been recommended as an efficient and effective measure to reduce erosion in tea plantations in the central highland region (Dent and Goonewardene, 1993; Weerahewa *et al.,* 2000; Udayakumara *et al.,* 2010; Dharmasena and Bhat, 2011).

The most worrisome fact with regard to the LULC changes during the given period, as observed in the field visits and verified with the land use analysis using RS, is the unprecedented increase in market gardens and settlements by encroaching scrub lands and stream reservations as well as marginalized areas of the tea plantations. By 2020, market gardens have recorded a 43 percent increase while settlements and home gardens showing the highest incremental change, expansion by 133 percent compared to the situation in 1985. It is revealed that, by 2009, nearly 50 percent of the riparian zones in the upper catchment of the *Kurunduoya* stream are encroached to cultivate potato and other exotic vegetables (Amarasekara *et al.,* 2010).

These market gardens and home gardens meant for cash crop (potato) and vegetables are prepared along the stream reservations, in scrub lands and tea plantations with assured water sources . The water source for these unauthorized land use is tapped water from *Kurunduoya* and its tributaries. The cropping intensity of these lands are mostly over 250 percent with higher productivity levels owing to high inputs and favorable climatic conditions. Gamage and Aheeyar (1998) has also reported the higher cropping intensity in extensive vegetable cultivation fields in this region. In general, high value vegetables, mostly leeks, cabbage and carrot are grown in these lands twice per year other than one compulsory crop with potato cultivation reaching to 300 cropping intensity with assured water derived from the streams even in the *Yala* season with less rainfall, during May – September period. In some occasions, short duration crops like radish and knol-khol are grown in between two major crops recording 400 cropping intensity.



Source: HARTI Survey Data, 2019.

Figure 4.10: Land Use and Land Cover in 2020

The total land extent and the land use types of the villages studied vary depending on the location and the elevation of the particular villages.

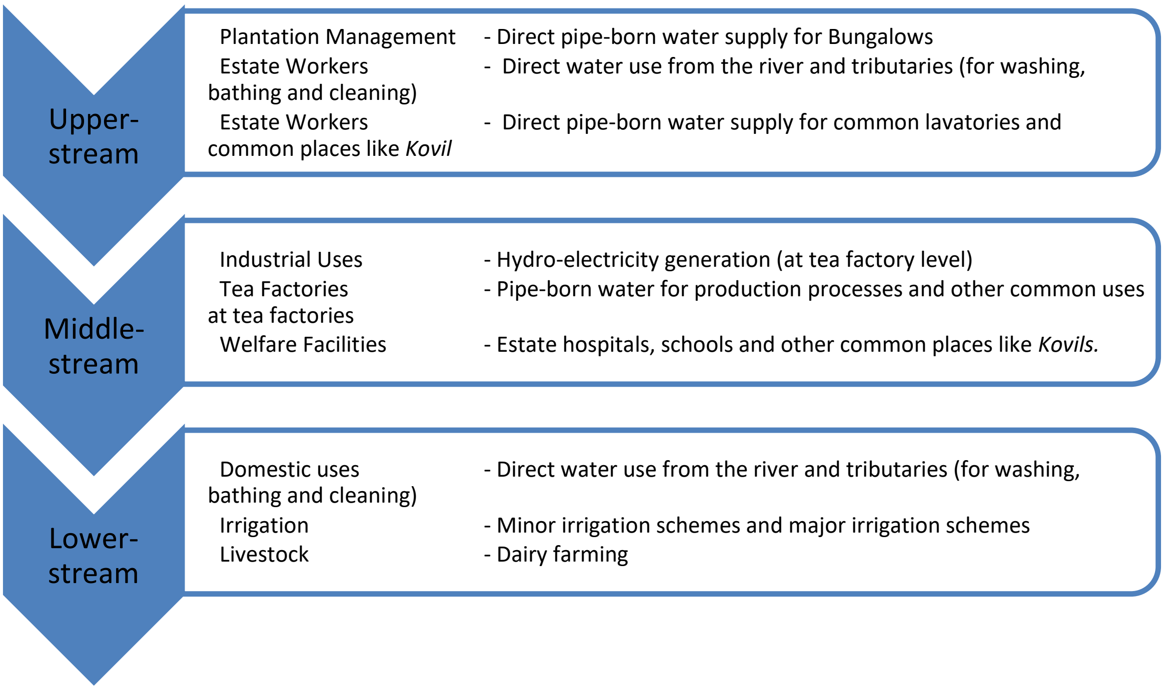
4.3 Water Use Types and Different Water Users in the Study Location

4.3.1 Traditional Types of Water Users and Water Use Types

Traditionally, in the *Kurunduoya* river basin, the types of water use were limited to a very few domestic purposes (drinking, bathing, washing and cleaning etc.), agriculture and industrial use (tea factories) and community services. Among them, agriculture , particularly the paddy-based crop cultivation in lowlands in the lower middle and lower parts of the watershed was reported to be the most prominent sector to which the utmost priority was given. The terraced-lowlands used to be fed with irrigation water, specially in the dry *Yala* seasons in which the rainfall is not sufficient to maintain the crop particularly at the critical stages of the growth. As a result, a large number of structures like anicuts, minor tanks and canals to divert and convey water into the lowland paddy fields have been built over the past centuries largely as the community owned interventions. Of the 470 minor irrigation systems (anicuts and diversions, small tanks and canals), a considerable portion is located within the tea plantations which are currently owned by private companies.

Later on, with the government interventions, through the Irrigation Department, large scale irrigation schemes, with over 80 ha of command area, have also been built and implemented to meet the agricultural water demand from the expanded cultivation lands in lower parts of the watershed. In order to institutionalize the water management and operation and maintenance of the irrigation structures, the DAD is involved in the matters of the minor irrigation schemes in the area. However, the agriculture water requirement from the estate sector (estate employees and the management) was negligible as the crop cultivation in the estate sector was limited to subsistence level to meet the requirement of the estate community and the management. Thus, the vegetable and cash crop cultivation were not undertaken at a commercial level in the estate sector in the early stage.

The communities belonging to the estate sector and the rural sector in the upper and lower parts of the watershed respectively, used water flowing in the river and other tributaries and man-made canals for their domestic purposes. In some cases, dug wells had also been used for domestic water requirements in the lower-middle and the lower parts of the river basin. The water scarcity and seasonal water shortage were not experienced by either community in the past. Pipe-borne water supply was in place only for common lavatories used by estate workers dwelling in line houses while no direct water supply for each house unit. The water usage for electric generation (micro level hydro-electricity generators installed for the use of tea factories) and other requirements of tea factories and related premises (bungalows, estate-run hospitals, estate schools and other common places) were the other traditional types of water uses in the *Kurunduoya* river basin (Figure 4. 11).



Source: HARTI Survey Data, 2019.

Figure 4.11: The Traditional Water Use Types and Water Users along the *Kurunduoya* River Basin

4.3.2 The Present-day Water Use Types and Water Users

The number of water use types and water users have significantly increased over time. Presently, new types of water use such as mini hydro-electricity generation, recreation at waterfalls, regional level drinking water supply by NWSDB, rural drinking water supply schemes, estate sector drinking water supply scheme, individually initiated pipe-borne water supply for the majority of the households in the estate and rural sectors, commercial level vegetable and cash crop cultivation in the estate sector can be identified in the *Kurunduoya* river basin.

There are two mini hydro-electricity power plants established in the middle of the *Kurunduoya* basin. The Manelwala Mini Hydropower Project (MMHP) commissioned in 2008, operates with a capacity of 2.4 MW. The designed flow of the MMHP is 1 $m^3 s^{-1}$ and it generates 7.94 GWh of average annual energy to be supplied to the national grid. The second mini hydro-power plant in the river basin, the Kurunduoya Hydro power Project (KHP) operating with a flow rate of 2 $m^3 s^{-1}$ and the established capacity of 4.65 MW. The channels through which the water is conveyed to the power houses of MMHP and KHP originate immediately above the anicuts of Mulhal-Ela major irrigation scheme and the Manelwala minor irrigation scheme.

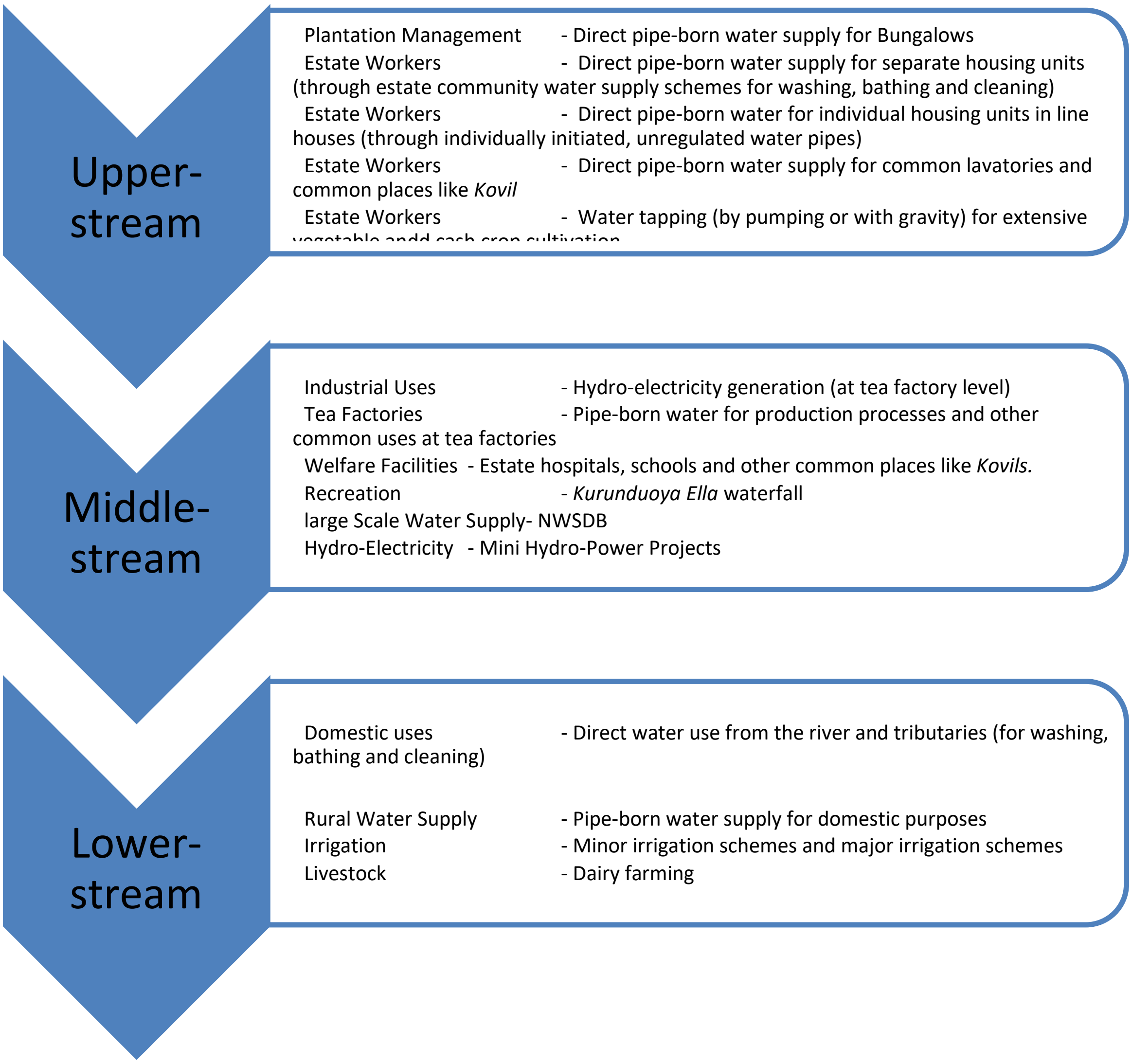
The NWSDB of Walapane region has two divisional centers in Ragala and Walapane, providing drinking water for over 2500 customer base in urban and peri-urban centers like Walapane, Nildandahinna and Ragala, with an average monthly production of

40,000 m^3. For Walapane and Nildandahinna areas, the water intake structures from the *Kurunduoya* river is built in Maha-Uva estate in the middle part of the river basin.

The *Kurunduoya Ella (Mathurata Ella),* the third tallest waterfall (189 m or 620 ft) of Sri Lanka is also located in the middle of the *Kurunduoya* river. Though it is a beautiful two level waterfall, *Kurunduoya Ella* is not visited by many since there is no well-established road; rather there is a trail with a footpath stretching over 3 km. However, the local tourists frequently visit the place to feel the adventurous and recreational features of the waterfall and the surrounding forest patches.

With improvements in the welfare activities towards uplifting the living conditions of the estate workers, the separate housing units with required sanitary facilities have been provided by the estate companies and government institutions in the *Kurunduoya* watershed area. The community level drinking water supply schemes have been an integral part of such activities. The water supply is regulated by a committee comprising of the members from the community and the estate management. However, the number of beneficiary households with separate housing units is very small compared to the total families living in the respective estate villages. Such non-beneficiary families who are still living in estate line houses have also opted to get pipe-borne water for each housing unit by laying lengthy pipes with different diameters from upper streams. However, there is no regulatory mechanism to control the water freely flowing in the pipes to each and every household. It is a very serious issue that the families cannot and do not stop water flow using a valve or tap/s once the household water requirement is fulfilled, because doing so will cause pipes to burst due to high water pressure from the upstream. Therefore, a large volume of water that can be used for other water purposes and by various water users, is wasted and lost to the community as a whole.

The similar situation can be observed in lower parts of the river basin where the overwhelming majority of the community used to directly use water from the river, tributaries and man-made canals for domestic purposes. Presently, a large number of individual households are using separate pipe lines originating from the river and tributaries to get an endless and non-regulated water flow for domestic purposes. This unwarranted and wasteful activity is widely practiced in many villages where community water supply schemes have not been implemented. Absence of any institutional intervention, even at the community level, to do away with this practice and establish a regulatory mechanism/s to provide water for domestic purposes have been detrimental to the optimum use of scarce water resources in the river basin. Communities unable to afford the expenses for laying of pipe, labour and technical services to get direct pipe-borne water have still opted to use water directly from tributaries and/or dug wells. Further, communities living in villages located further away from the streams and man-made canals have not been able to get pipe-borne water facilities with their own initiatives and are still depending on dug wells while some are fetching water from long distances.



Source: HARTI Survey Data, 2019.

Figure 4.12: Present Water Use Types in *Kurunduoya River Basin*

As discussed in length in the land use change section, the unprecedented expansion of market gardens and settlements including home gardens in which extensive vegetable and cash crop cultivations are undertaken has been a matter of discussion on many fronts. The excessive water tapping, through laying pipes originating in the upper streams, directly from *Kurunduoya* river, other tributaries and minor irrigation canals for such crop cultivations has been an issue for many of the water users downstream. Similar to the unregulated domestic water supply for individual estate line housing units and households, there is no mechanism among crop growers to stop the water flow once the water requirement is fulfilled in the lower stream rural sector too. Thus, the unregulated water flow continues around the clock which is detrimental to the other water uses and various water users.

4.4 Water Quality Issues of *Kurunduoya* River

In addition to the water scarcity and seasonal water shortages affecting the majority of water use types and various water users in the middle and lower parts of the *Kurunduoya* river, the deteriorating water quality has also been a serious issue. There are inappropriate agricultural activities undertaken in river banks and reservations from where the sediments enter into the river and tributaries. Over irrigation and intensive rainfall events create large runoff taking sediments out from the farm which have been identified as one of the main causes for water quality problem in the central highland region in which the *Kurunduoya* river basin is located (Gunatilake and Gunawardena, 2000; Hewawasam, 2010; Diyabalanage *et al.,* 2017). In previous studies by Amarasekara, Dayawansa and De Silva (2009) and Samarasinghe and Bandara (2016) have also highlighted the seriousness of the soil erosion occurring in farmlands where the appropriate soil and water conservation measures are not applied. Dharmasena (2016) has observed higher rain erosivity in this area during the northeast monsoon period that coincides with the initial stage of the upland crop cycle. Further, remarkable increase in rainfall in the Nuwaraeliya district, causing rainfall/erosion disasters, has been predicted for decades to come (Dharmasena, 2015).

The high sediment loads carrying silt and sand with suspended clay during the rainy periods have been detrimental in optimum functions of mini hydro-power plants located in middle parts of the stream. Most importantly, the water purification process of the NWSDB encounters hardships due to high sediments in the river water used for drinking water supply. In such instances, the NWSDB is compelled to take great effort and resources to make drinking water available to the consumers. In some occasions, the water intake and purification come to a standstill until the river water settles and there is less suspended sediments and silt which causes high turbidity. The water quality deterioration of the *Kurunduoya* river basin adversely impacts not only on communities living in the watershed and their economic activities but also on the fauna and flora and the ecosystem. Owing to excess suspended sediments and high chemical levels in the river some fauna species have become endangered (Werner, 1986; Karunarathna *et al.,* 2016).

In *Kurunduoya* river basin, poor water quality is not only due to sediments flowing into the water streams, but by excessive plant nutrients and other substances such as agro-chemicals used in vegetable cultivations and tea plantations. It is revealed that intensive farming on steep slopes, coupled with over application of fertilizers and accumulation of nutrients in downstream water bodies due to soil erosion, have contributed to environmental hazards in the Upper Mahaweli Catchment Area (UMCA) including the *Kurunduoya* catchment (Amarasekara *et al.,* 2010). In a study by Hewage *et al.,* (2017) conducted in the entire Walapane DS area except Ragala ASC area, it has also been identified that the deteriorated water quality in the majority of streams due to overuse of fertilizer and other chemicals in crop cultivations is a critical issue encountered by water users in the downstream areas. Particularly, the drinking water supply schemes by NWSDB and rural-level water-user societies as well as water users who use stream water directly for washing, bathing and cleaning are also severely affected.

Amarasekara *et al.*, (2009) have observed that over application of fertilizers on vegetable plots was causing nutrient accumulation in the soil and the plots also recorded high levels of phosphorous (P) (above 75 ppm) in the *Kurunduoya* watershed. Further, in the same study, the results of the water quality analysis have shown the higher levels of nitrate, available P and Nitrate Nitrogen (NO_3 -N) levels. In another study by Amarasekara, Dayawansa and De Silva (2014), it has been proved that the nutrient removal with surface runoff is higher in vegetable plots in *Kurunduoya* watershed. A greater fraction of NO_3-N is removed as soluble form from farmlands but in the case of Phosphate Prosperous (PO_4-P) and Ammonium Nitrogen (NH_4-N) removal of particulate fraction is prominent. Particulate losses are approximately 15 times higher than the dissolved losses for NH_4-N and approximately 100 times higher than the dissolved losses for PO_4-P. In the case of NO_3-N soluble fraction is approximately 1.5 times higher than the particulate losses. These results conclude that greater amounts of nutrients and sediments are transported from poorly managed vegetable cultivation lands. In a study by Wijewardena (2000), it is suggested that the possibility of excessive quantities of plant nutrients contribute to high concentration of some chemicals, particularly Calcium and Sodium in drinking water sources in the upcountry intermediate zone (UCIZ) where intensive agriculture is being carried out with excessive use of chemical fertilizers and organic manure.

Contamination of water streams with human waste and solid and liquid waste from estate housing units has also been reported to be a serious issue relating to water quality in the areas of the lower stream. As there is no water quality testing for the water used for rural community water supply schemes, individually initiated pipe-borne water supply for separate housing units and water tapped from open canals and streams for drinking and other domestic purposes, communities in middle and lower streams using such water sources are at a high risk in terms of health and sanitation. The seriousness of this issue in the same river basin, the *Kurunduoya* river has also been highlighted by Hewage *et al.,* (2017).

4.5 Sources of Domestic Water Use

Though traditionally, the domestic water requirement was largely met with the dug wells (both individual and common wells) in lower parts of the *Kurunduoya* and *Beliuloya* watersheds, presently it is highly diversified owing to different factors. The regulated pipe-borne water supply is the prominent source of drinking water in the villages in Walapane and Munwatte ASC areas. It accounts for 44 percent of the households surveyed (Table 4.6). All these pipe-born water supply services are operated under various community-based water supply schemes as the water supply by NWSDB does not cover the rural areas studied.

Table 4.6: Drinking Water Source in the Lower Areas of the Watersheds

Water Source	In Rainy Season		In Dry Season	
	No	Percentage (%)	No	Percentage (%)
Own dug well	24	7	21	6
Common well	10	3	14	4
Pipe-born water (individual pipeline)	134	38	126	35
Pipe-born water (Common water supply scheme)	158	44	153	43
River or water canal	9	3	17	5
Purchased from the water outlet/bowser	6	2	7	2
Harvested rain water	5	1	5	1
Water fountains	11	3	14	4
Total	357	100	357	100

Source: HARTI Survey Data, 2019.

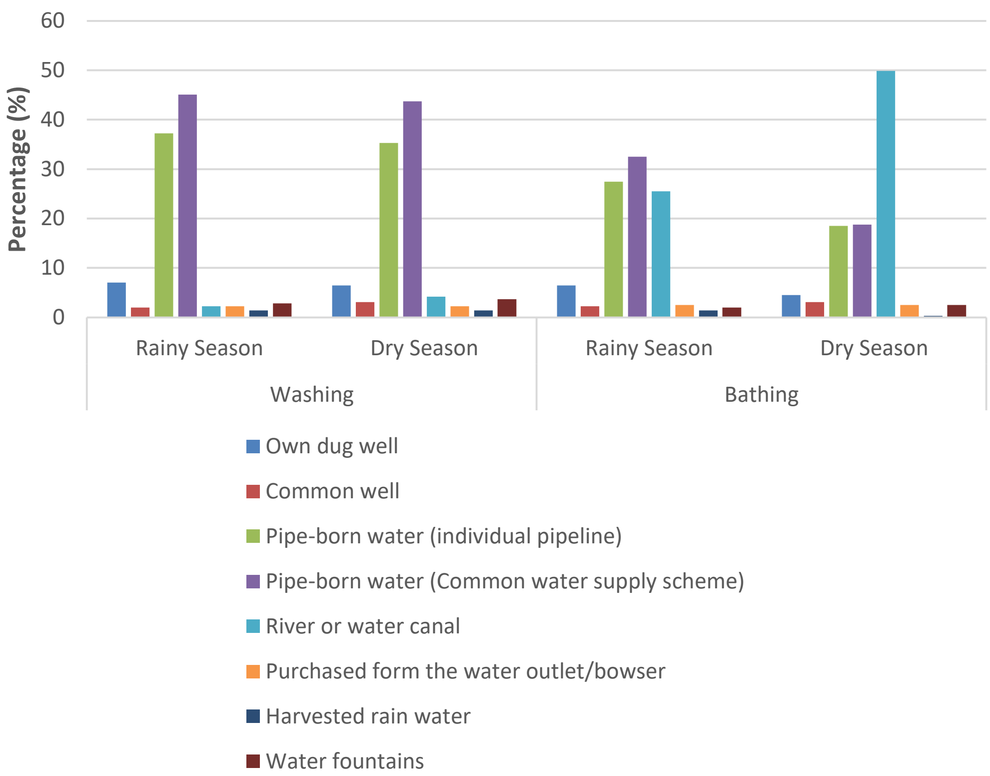
Through individually laid pipelines from streams and canals, over one third (38 and 35 % in rainy and dry seasons respectively) of the households are provided with pipe-borne water. The unregulated nature of this practice causes severe water loss in the waterways which is detrimental to other types of water uses. Ten percent of households are still using dug wells (either individual or common wells) for drinking purposes. There are about 9 percent of households directly using rivers , water canals and natural fountains for drinking water supply. Households purchasing water from water distributors and shops are limited to only 2 percent while the rain water harvesting for drinking purposes accounts for only 1 percent.

Table 4.7: Different Water Sources for Washing and bathing in Rainy and Dry Seasons

Water Source	For Washing				For Bathing			
	Rainy Season		Dry Season		Rainy Season		Dry Season	
	No	Percentage (%)	No	Percentage (%)	No	Percentage (%)	No	Percentage (%)
Own dug well	25	7	23	6	23	6	16	4
Common well	7	2	11	3	8	2	11	3
Pipe-borne water (individual pipeline)	133	37	126	35	98	27	66	18
Pipe-borne water (Common water supply scheme)	161	45	156	44	116	32	67	19
River or water canal	8	2	15	4	91	25	178	50
Purchased from the water outlet/bowser	8	2	8	2	9	3	9	3
Harvested rain water	5	1	5	1	5	1	1	0
Water fountains	10	3	13	4	7	2	9	3
Total	**357**	**100**	**357**	**100**	**357**	**100**	**357**	**100**

Source: HARTI Survey Data, 2019.

As far as the water sources for washing (including preparation of food), cleaning and bathing are concerned, the importance of water streams including rivers and man-made canals can be seen particularly in the dry seasons. In the rainy seasons, for washing at household level, the pipe-borne water sources accounts for over 82 percent while it slightly drops to 79 percent in the dry seasons. The demand for open water sources like streams and fountains for washing purposes increases to 8 percent in the dry seasons against the rainy season (5%).

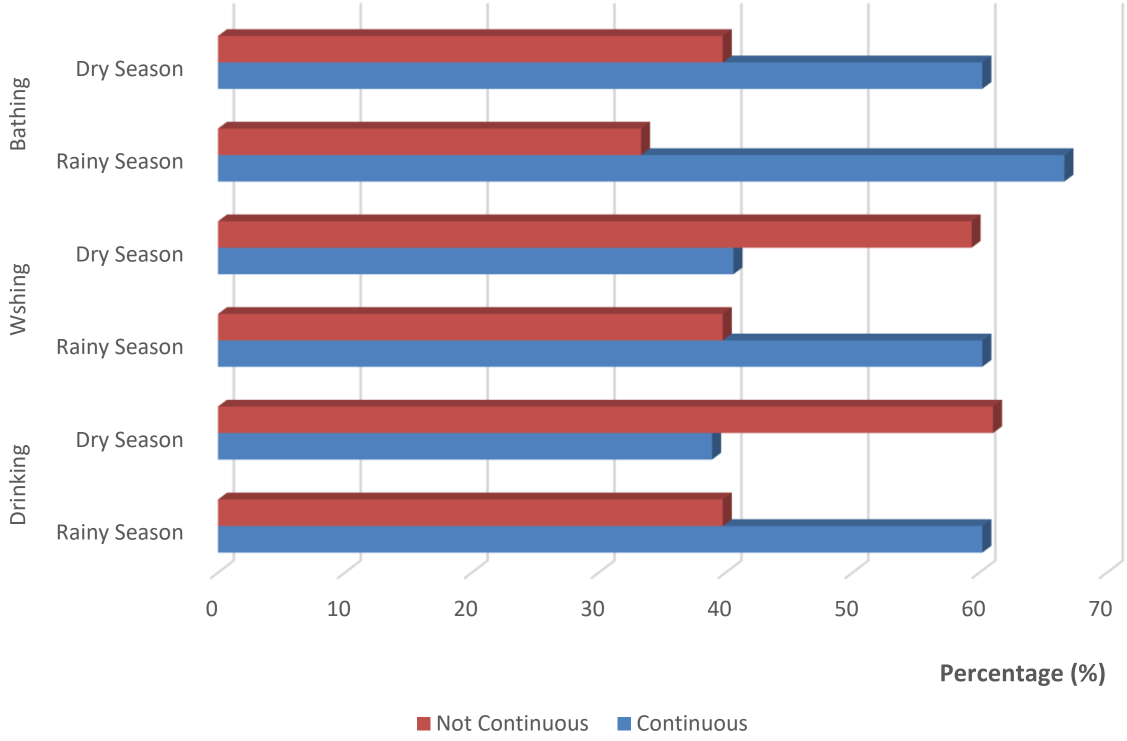


Source: HARTI Survey Data, 2019.

Figure 4.13: Water Sources for Washing and Bathing

The most significant changes in the sources of water between rainy and dry seasons can be observed in water use for bathing. The contribution of open water sources like streams and canals surges by 100 percent from 25 percent in the rainy season to 50 percent in the dry season. The contribution of pipe-borne water sources for bathing drops by 22 percent from 59 percent in the rainy season to 37 percent in the dry season. All together use of streams and fountains accounts for over 53 percent of the households to meet their water requirement for bathing in the dry season.

In general, the majority of the villagers encounter water shortage for all domestic water uses; drinking, washing and cleaning and bathing. The water shortages in the dry season mostly affect the water used for washing and drinking while villagers opt to use streams and water canals for bathing once the other water sources for bathing are not available. Discontinuation of water supply in pipe-borne water sources heavily affect the majority of the households.



Source: HARTI Survey Data, 2019.

Figure 4.14: Status of Continuity of Water Supply for Domestic Uses

4.6 Water Sources for Agricultural Activities

The total irrigable land area in each GN division studied varies from 89 ac in Mulhalkele to 147 ac in Ambagaspitiya. The Mulaha-Ela major irrigation scheme has been designed to provide irrigation facilities for a total command area of 565 ac in 6 GN divisions; 514 Kumbalgamuwa, 514B Kumbalgamuwa East, 514C Mulahalkele, 514D Thennehenwala, 514E Deliwala North and 514F Deliwala South. However, as per the views of farmers in the study area, the actual lowland area cultivated with the irrigation facilities of this scheme is said to be higher than the given value though the official statistics are not available. The lowland area has been expanded by converting adjoining low-lying lands into paddy fields over time. In this study, more than two third of the officially declared command area (494 ac) representing 3 FOs of this irrigation scheme was studied.

The Kurundu-Ela minor irrigation scheme which directly originated from the upper stream of *Kurunduoya* river at Highforest Watte GN division located in a key tea plantation, provides irrigation facilities for over 226 ac farmlands in Ungolla and Ambagaspitiya GN divisions. Kurundu-Ela canal passes over 8 km distance through tea plantations and scrub lands to bring irrigation water to two adjoined GN divisions. The *Thiriwanamadittha wewa* minor irrigation scheme provides irrigation water for 71 ac farm fields in Galabada GN divisions. *Thiriwanamadittha wewa* extending over 4 acres in the midst of a tea plantation which is also located in Highforest Watte GN division.

From *Thiriwanamadittha wewa*, irrigation water flows in a canal running over 5 km to reach Galabada GN division.

Table 4.8: The Irrigable Cropland Extent in GN Divisions Studied

GN Division	Total Land Extent (ac)	Irrigable Land Extent (ac)
514 - Kumbalgamuwa	512	217
514B - Kumbalgamuwa East	239	108
514C - Mulhalkele	286	169
505C - Galabada	224	71
505C - Ambagaspitiya	365	147
506A - Unagolla	248	141

Source: HARTI Survey Data, 2019.

4.6.1 Crop Production Systems and Cropping Patterns in Minor Irrigated Areas

4.6.1.1 Traditional Cropping Systems in the Recent Past

Prior to the emergence of issues relating to water shortage about 15 years back, farming communities in Galabada, Unagolla and Ambagaspitiya areas used to undertake year-round crop cultivation in irrigable lands. The crop cultivation in home gardens and other uplands (seasonal crops) was limited to rainy *Maha* seasons as secured water source was not available in dry *Yala* seasons. In uplands, vegetable and OFCs (finger millet, maize, horse-gram) were the most common crop varieties grown. In uplands, potato was also one of the favorite crops grown due to its high profit. Perennial crops such as fruits and spices are also grown in home gardens. Tobacco also used to be one of the highly profitable cash crops grown in the study area. Among vegetables, green beans and cabbage were dominant crop varieties. Thus, in uplands, the cropping intensity is mostly limited to 100 percent as the cultivation of seasonal crops is carried out only in one season.

In terraced lowlands, paddy farming was prominent and it is mostly for the purpose of meeting household food security. The paddy farming is, usually, initiated in December – January period to avoid heavy rains in October – November and it lasts April – May with harvesting. Farmers prefer to go for long duration paddy varieties (4 – 4 ½ months) to obtain a better crop yield. In *Yala* seasons, under irrigation, vegetable and cash crop cultivation in lowlands used to be the most common cropping pattern in the area. Tomato and green beans have been the most commonly grown vegetable varieties as the favorable conditions which prevail during the dry season. Potato cultivation was carried out in lowlands under irrigation during dry seasons. Green bean seed production is also a very profitable agricultural activity in the area. The favorable agro-ecological conditions prevailing in the area coupled with farmers' knowledge and skills were catalysts for producing local bean seeds at commercial level (Hewage *et al.,* 2017). In a study on investment on soil conservation measures by farming communities, Aheeyar (2000) has also observed a similar cropping pattern in the same watershed areas having upland cultivations with OFCs (including tobacco) and vegetable crops in rainy seasons while lowland is cultivated with paddy and vegetable/cash crops in rainy and dry seasons respectively. Lowland areas with good drainage, used to be cultivated with short duration vegetables such as radish and knol-khol (sometimes cabbage too) to make the cropping intensity about 250 percent in lowlands.

4.6.1.2 Present Cropping Systems in the Study Area

The cropping patterns and crop varieties grown in the area have significantly changed and so has the cropping intensities, largely due to the water shortage caused by changes in the number of different water use types and water users over the time. The impacts of climate changes have also affected the cropping pattern and crops cultivated in the area. Further, socio-economic factors associated with farm households as well as government policies towards cultivation of certain crops have also affected crop production systems in the area. With regard to potato, increased production cost due to higher market prices of imported seed potatoes and high incidence of diseases like early and late blight have caused the cultivation extent of the crop to diminish in the area. The adverse impacts of tobacco cultivation in steep terrain, such as land degradation by soil erosion and subsequent off-site effects on downstream water bodies including reservoir siltation had prompted the government to restrict this cash crop being cultivated in the central highland region. Therefore, presently, tobacco is not cultivated in the study area.

The paddy cultivation has still been the prominent crop being cultivated in lowlands in rainy *Maha* seasons. The time of paddy cultivation has also not changed and thus, crop duration of paddy is from January – May. However, the cultivation extent and the paddy varieties grown have changed due to issues related to water availability at the critical stages. Table 4.9 shows the changes in the paddy land extent cultivated under minor irrigation schemes during the rainy seasons.

Table 4.9: Paddy Cultivation Extents in Minor Irrigated Areas in *Maha* Seasons

GN Division	Total Land Extent (ac)	Irrigable Land Extent (ac)	Cultivation Extent in *Maha* Seasons (ac)	Change (%)
Galabada	224	71	64	10
Ambagaspitiya	365	147	119	19
Unagolla	248	141	108	23

Source: HARTI Survey Data, 2019.

Accordingly, paddy cultivation extent has dropped by 20 percent in the villages irrigated under *Kurundu-Ela* minor irrigation scheme while the reduction in cultivation area in Galabada village is about 10 percent. Lands not cultivated with paddy crop are located further away from the irrigation canal and these lands are cultivated with vegetable crops such as beans, tomato and cabbage. Since farmers frequently encounter water shortages, especially in the latter part of the crop cycle, they are reluctant to go for high yielding long duration paddy varieties. Instead, farmers prefer to cultivate medium duration paddy varieties (like BW 369), whose average yields are not as high as long duration varieties. This situation causes food security issues at village level. To avert food (rice) shortage (due to reduced extent and relatively low yielding paddy varieties) at households and to their extended families, farmers tend to cultivate paddy in the dry *Yala* seasons as well in lowlands closely located to the irrigation canal/s. This has become an income penalty for farmers as they are self-prevented from receiving higher income by growing vegetables. Thus, the water scarcity has caused food security and income vulnerabilities at household level where agriculture and related on-farm activities have been the primary source of income for the overwhelming majority of farmers. The subsistence and uneconomical nature of paddy cultivation in this part of the country has been emphasized in studies by Aheeyar (2000) and Amarasekara (2011) as well.

Table 4.10: Lowland Extents Cultivated in Minor Irrigated Areas in *Yala* Seasons

GN Division	Total Land Extent (ac)	Irrigable Land Extent (ac)	Cultivation Extent in *Yala* Seasons (ac)	Change (%)
Galabada	224	71	47	34
Ambagaspitiya	365	147	86	42
Unagolla	248	141	79	44

Source: HARTI Survey Data, 2019.

In dry *Yala* seasons, the limitations posed by water scarcity leads farmers to abandon lowland fields and this is greater in the *Maha* seasons. Accordingly, two third of the lowlands are left fallow due to lack of irrigation facilities in Galabada area. The lowland fields remaining uncultivated in Ambagaspitiya and Unagolla GN divisions are 42 and 44 percent respectively, of the irrigable lands. This causes cropping intensity to drop below 200 percent. Since, *Yala* season is considered to be economical for farmers, high value vegetable and cash crops are widely grown for the market, however the lesser cultivable land extent prevents farmers from earning higher income. Therefore, in these circumstances the cropping area reduction is over one third of the land extent, it severely affects the income of farm households leading farming communities to be further impoverished.

4.6.2 Crop Production Systems and Cropping Patterns in Major Irrigated Areas

Crop fields under Mulhal-Ela major irrigation system are located at lower elevation compared to the croplands under minor irrigation systems discussed above. Therefore, there are some slight differences in crops cultivated and cropping patterns which could be observed in the two systems. Upland rainfed vegetable/cash crop/OFC cultivation, paddy-based lowland system, irrigated vegetable production in lowlands used to be the main seasonal crop production systems in the area. Very similar to the minor irrigated fields, the entire irrigable land extent under Mulhal-Ela scheme, traditionally, used to be cultivated in both rainy and dry seasons, without experiencing severe water shortage. However, the upland seasonal crop cultivation with vegetables, cereals and coarse grains and other cash crops had been limited to rainy *Maha* seasons. In this area, cucurbits and egg-plants were also widely grown crop varieties in home gardens and other rainfed uplands. Crops like finger millet, maize and horse-gram used to be prominent in the rainfed uplands covered with relatively less fertile and shallow soils. However, bean cultivation for seed production is not popular in this area, perhaps, due to the agro-ecological conditions in the lower elevations that do not suit the cultivation requirements. Tobacco cultivation had been the most profitable cash crop cultivated in the past, which was later abandoned due to government regulations. Potato cultivation, either as an upland rainfed crop in *Maha* seasons or lowland irrigated crop in dry season, in this area, was not as popular as in minor irrigated areas due to relatively lower yields. In most of the uplands, cultivation was limited to one crop, thus, the cropping intensity was reported to be 100 percent except lands located close to streams and cultivated with vegetables at small-scale.

In lowlands, paddy cultivation was carried out in full scale in the *Maha* seasons largely for own consumption at farm households. In dry seasons also, paddy cultivation is necessarily practiced in lowland fields with poor drainage as such lands restrict growing vegetables and OFCs. Vegetable cultivation was the most common crop production system in lowlands during dry seasons as it provided additional income compared to subsistence paddy cultivation. Generally, the majority of farmers establish 3 crop cycles annually to reach 300 percent cropping intensity in irrigated lowlands; paddy cultivation (January – May); vegetable cultivation (May – August) and vegetable cultivation (September – December).

Though farm fields are facilitated from a major irrigation project; Mulhal-Ela scheme, in the face of present-day water shortage, the majority of the farming community are affected and it is threatening the household food security and family's farm income. Table 4.11 shows the lowland areas affected by water scarcity in the rainy seasons. The overall reduction in the paddy cultivation extent is about 3 percent and, thus, the impact of water shortage on the extent of lowland paddy cultivation in *Maha* seasons is not as high as in minor irrigation areas. However, the water shortage experienced in the latter part of the paddy crop has compelled farmers to grow medium duration varieties in place of high yielding long duration varieties that, traditionally, used to be grown. This situation forces farmers to grow paddy in the following cropping season (May – August) as well to ensure household food security, compromising higher farm income from profitable vegetable cultivation. On the other hand, paddy cultivation in the dry season is possible only to farmers whose lands are located close to the main irrigation canal/s and mostly in the head end, with assured water supply throughout the season.

Table 4.11: Paddy Cultivation Extents in Mulhal-Ela Irrigated Areas in *Maha* Seasons

GN Division	Total Land Extent (ac)	Irrigable Land Extent (ac)	Cultivation Extent in *Maha* Seasons (ac)	Change (%)
Kumbalgamuwa	512	217	205	6
Kumbalgamuwa East	239	108	99	8
Mulhalkele	286	169	157	2

Source: HARTI Survey Data, 2019.

The impacts of water scarcity are severe in the dry seasons as the land area left fallow is extensive. Accordingly, on average, 16 percent of lowlands are left without any cultivation in the *Yala* seasons.

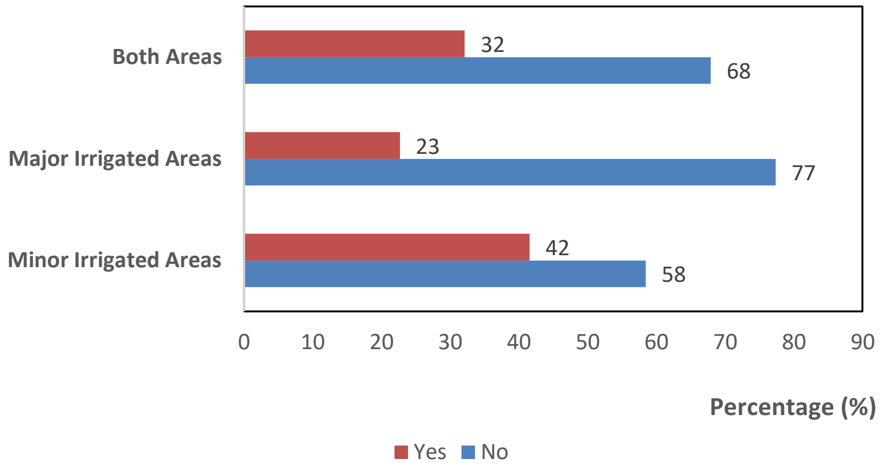
Table 4.12: Cultivated Extents in Mulhal-Ela Irrigated Areas in Dry Seasons

GN Division	Total Land Extent (ac)	Irrigable Land Extent (ac)	Cultivation Extent in *Maha* Seasons (ac)	Change (%)
Kumbalgamuwa	512	217	178	18
Kumbalgamuwa East	239	108	89	24
Mulhalkele	286	169	147	13

Source: HARTI Survey Data, 2019.

4.6.3 Issues relating to Agriculture Water Use

The water shortage in critical stages of the cropping cycles, both in vegetable cultivation in the dry seasons and in paddy cultivation is experienced by a significant portion of farmers irrespective of the irrigation system. The water scarcity issues emerging in the major irrigation scheme is relatively lower than highly affected minor irrigated schemes. As shown in Figure 4.15, on average, one third of the farming communities encounter issues caused by water shortages in agricultural activities.



Source: HARTI Survey Data, 2019.

Figure 4.15: Irrigation Issues in Minor Irrigation Schemes

4.6.3.1 Irrigation Issues in Minor Irrigation Schemes

In case of minor irrigation systems, the proportion of farmers affected by water scarcity (42 %) is almost two times higher than that of major irrigation schemes (23 %). It has been advantageous to farmers whose farm plots are located in the head end and close to the irrigation canals/streams to carry out farming activities in lowlands without encountering any water shortage.

Different water uses in upstream areas have adversely affected water availability for farming activities in downstream farming communities in this study. The water uptake for 2 mini hydro-power plants immediately above the water diversion anicut of Mulhal-Ela scheme has posed a great threat for the continuous irrigation water availability for this major irrigation scheme. Moreover, direct water use by NWSDB for drinking water supply, from the midstream of *Kurunduoya* river has also been affecting water availability for irrigation in downstream schemes. The endless water uptake for market gardens and home gardens prepared in stream reservations and in marginalized tea plantations in upstream and midstream areas has also been identified as a major cause of water scarcity in downstream areas.

The water shortage issues experienced in minor irrigation schemes providing irrigation facilities for villages in Galabada, Ambagaspitiya and Unagolla GN divisions are caused by different factors compared to the major irrigation scheme, the Mulhal-Ela scheme. The catchment and the inundated area of *Thiriwanamadittha wewa* located in a tea plantation area in upper elevation is under continuous encroachment for cash crop and vegetable cultivation by some section of the estate community. Presently, the inundated area of the tank has been limited to about 2 ac against its original extent, 4 ac, so that the capacity of the tank has significantly diminished. Over the past few decades, more than half of the catchment area of this waterbody have been converted into market gardens from which excessive sediment load inflowing into the tank further diminishes the tank capacity. The crop cultivation in encroached catchment area is undertaken using pumped water from the same waterbody, the *Thiriwanamadittha wewa*. Thus, the capacity and functions of the tank are under threat from different fronts, causing irrigation issues in downstream farmlands.

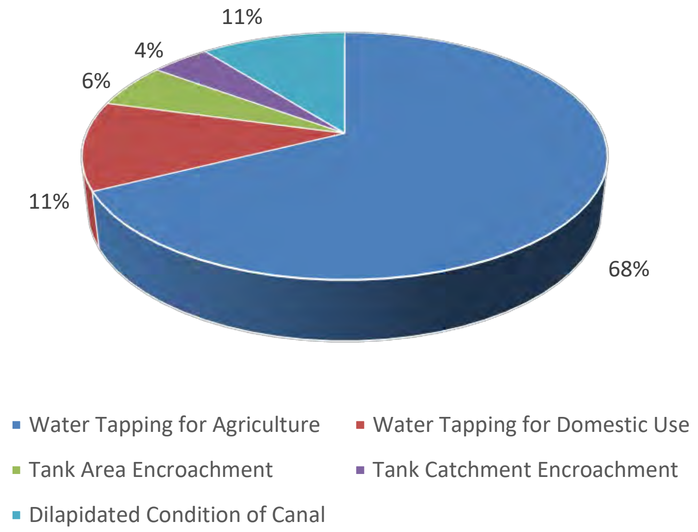
Source: Google Earth (2020)

Figure 4.16: *Thiriwanamadittha Wewa* with Encroached Catchment Area

The water canal conveying irrigation water from *Thiriwanamadittha wewa* to intended farm fields in Galabada GN division runs through tea plantations and scrub lands. A large portion of those scrub lands and marginalized sections of tea plantations, presently, have been made into market gardens by estate workers for intensive year-round cash crop and vegetable cultivation. The water requirement for those market gardens is met through illegal water tapping from the canal running from the *Thiriwanamadittha wewa* to Galabada village. As the pipes used for tapping water from the canal are not regulated using valves or any other devices by growers, there is a water out flow around the clock causing an immense water loss from the irrigation system. Water losses occurring due to seepage and infiltration through non-layered conveyance canals also contribute to water scarcity in this system.

In *Kurundu-Ela* minor irrigation scheme, the water scarcity issue is caused by excessive water tapping for agricultural and domestic purposes by the communities living in the estate sector. The *Kurundu-Ela* canal originating in the upper stream of *Kurunduoya* river is providing irrigation water to villages in Ambagaspitiya and Unagolla GN divisions. It runs through tea plantations, settlements of estate workers and scrub lands over 8 km to reach its destination. As a result of expansion of settlements and agricultural fields in scrub lands and marginalized tea lands by estate workers, along the *Kurundu-Ela*, the water uptake has dramatically increased. Water tapping is done by placing a large number of unregulated pipes leading to individual line housing units and farm plots. The severe water shortage in the lower stream croplands affects the food security and farm income of rural households. Only about one tenth of the *Kurundu-Ela* canal is layered with concrete so that the water loss through infiltration and seepage also contribute to the water shortage in the lower end.

Figure 4.17 presents the information about farmers' perception on the main causative factor for the water shortage issue experienced in minor irrigation systems. Accordingly, the overwhelming majority of farmers are of the view that illegal water tapping for intensive crop production (68 %) is the key factor for the water scarcity experienced by them. Farmers believe that water intake for domestic uses from the minor irrigation canals and dilapidated conditions of those canals that allow natural water losses in the process of water conveyance have equally contributed to reduce the cultivation extents.

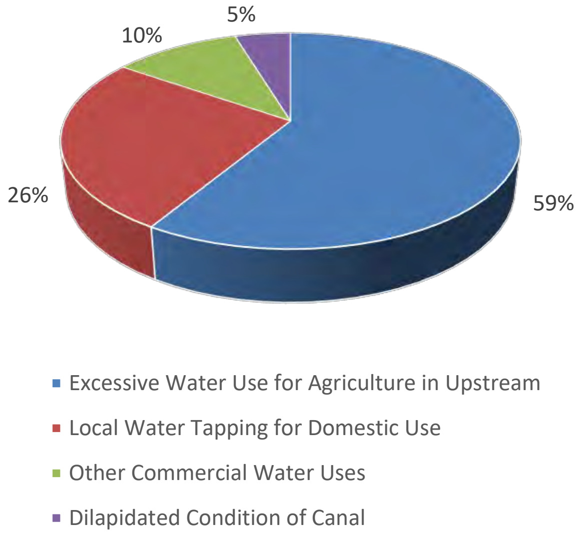


Source: HARTI Survey Data, 2019.

Figure 4.17: Causes for Water Shortage in Minor Irrigation Systems

4.6.3.2 Irrigation Issues in Major Irrigation Schemes

Intensive agricultural activities in the upstream areas has been ranked as the main causative factor for water shortage in major irrigation schemes as well. The illegal water tapping from the major irrigation canals for domestic uses by the local communities is perceived by over one fourth of the farmers, as the major reason for their key irrigation issue (Figure 4.18). The non-conventional water users such as mini hydro-power plants and NWSDB are also perceived to be a main reason by 10 percent of the farming communities in the major irrigation area. The dilapidated status of irrigation canals (5%) is also said to be one of the main reasons for irrigation water issues in the area.



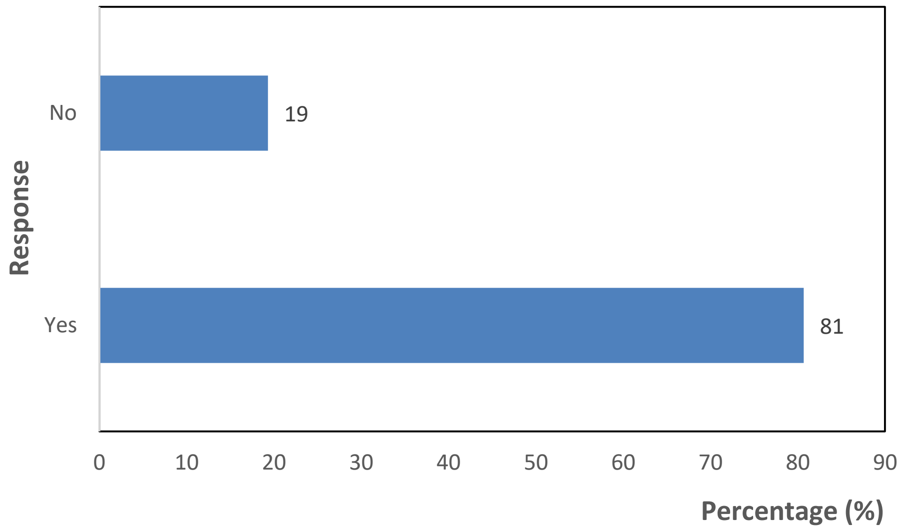
Source: HARTI Survey Data, 2019.

Figure 4.18: Causes for Water Shortage in Major Irrigation Systems

4.7 Conflicts over Water Sharing

Traditionally, different water users, particularly relating to the minor irrigation systems used to harmoniously meet their water needs without inflicting any disadvantages for the other water users. Despite being two communities belonging to two ethnic groups this coexistence in water use and management have been demonstrated by members of the both communities. The cooperation rendered from the management of the plantations in which the significant parts of the minor irrigation systems is located was also at a highly commendable level. These minor irrigation systems used to be operated and maintained by the beneficiary farming communities downstream. The financial and technical assistance were received for major rehabilitations from relevant governmental intuitions through the intervention of local political establishments.

Generally, cleaning and minor repair of irrigation structures including the ones located in areas belonging to tea plantations were carried out twice per cropping season to ensure optimum functions of the irrigation systems. These activities were undertaken by the downstream farmers under the leadership of respective FOs without any hindrance from the communities in the upper-streams. However, presently, the sustainability of those irrigation structures and their functions have come under threat due to the disruptive behavior from some segments in the estate community. Encroaching tank inundated area and catchment for crop cultivation, damaging canal banks to lay pipes for illegal water tapping, obstructing waterways flowing downstream, objecting to downstream farmers (led by FOs) visiting and attending to cleaning and minor repairs of structures located in tea plantations are types of the incidents that are on a rising trend. When the reactions for these obstructions come from communities downstream, this invariably leads to heated arguments between the two parties. In some instances, physical fights between aggressive members of two groups erupt, though such cases are settled among themselves without involving law enforcement and the Police. Figure 4.19 proves that the majority of downstream farmers (81 %) in minor irrigation systems have experienced disputes with the members of the other water use types, particularly the agricultural and domestic water users in the upper-stream areas. This situation has caused less involvement of downstream farmers in maintenance and operation activities of those structures further aggravating the irrigation related issues and consequently resulting in food security and livelihoods of those areas being affected.



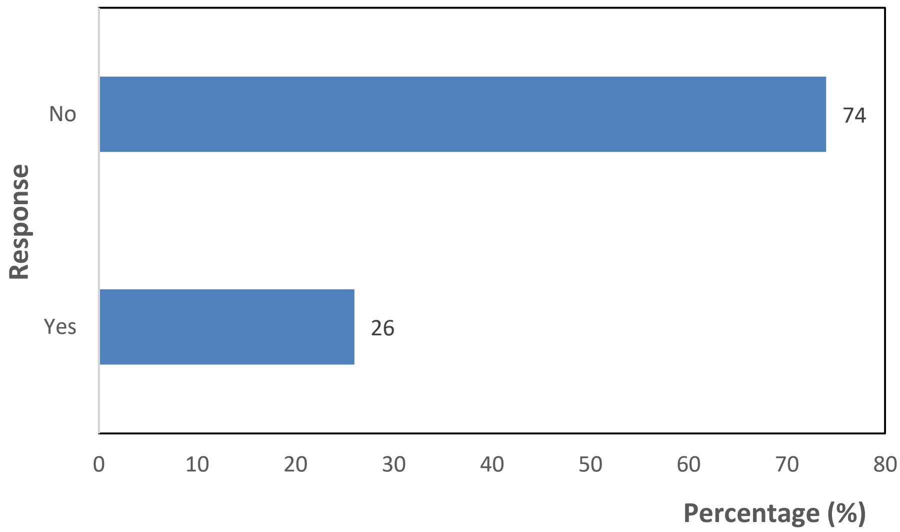
Source: HARTI Survey Data, 2019.

Figure 4.19: Experience in Disputes with other Water Users over Water Use

The responsibility of the operation and maintenance (O&M) of minor irrigation schemes in entirety and the distributary canal (DC) and field canal (FC) of major irrigation schemes have been transferred to the FOs. The interventions of government officials responsible for minor irrigation schemes (DOs and AR&PAs attached to the DAD and GN officers attached to the DS office) in solving these kinds of issues are at negligible level as the plantation management is not cooperative in this regard. Though this matter has been taken to the attention of the Divisional Secretary, the possible actions are restricted due to the limited or lack of power the Divisional Secretary has over the lands belonging to plantation companies. On the other hand, the plantation management is reluctant to take actions that oppose the views of the estate communities due to the possible trade union actions. As none of the state agencies has been able to provide an acceptable solution to this very critical issue, the majority of farmers are dissatisfied over the existing institutional settings. It has also been emphasized that irrigation management transfer to the farming communities alone does not bring about significant improvements in the quality of irrigation management and/or agricultural productivity levels. The substantial increase in investments of both the farmer groups and the government on irrigation maintenance has to take place for the sustainability of the irrigation schemes under participatory management (Samad and Vermillion, 1999a; Samad and Vermillion, 1999b).

In case of major irrigation schemes, the water uptake from the *Kurunduoya* river and water conveyance through main canal and branch canals to the distributary canals are directly operated by the respective institute, the Irrigation Department. The activities and performances of other water users in upstream and middle-stream of the *Kurunduoya* river directly affect the water availability for downstream agricultural water users, the farmers. However, there is no direct interaction between down-stream irrigation water users and the other water users in the upper and middle-streams. Therefore, direct conflicts or disputes over water use between different parties do not occur, as in minor irrigation systems. Moreover, there are no direct claims made by the downstream farmers for their right for water, from the up and middle stream water users and, thus, they have always been at the receiving end. The representatives and members of the FOs in paddy-based lowland crop production systems have been complaining about water scarcity to the responsible institutes, the irrigation Department, however, there has not been a viable solution to the problem .

Though farmers in the major irrigation system (Mulhal-Ela scheme) have not experienced inter-sectoral conflicts over water use, they have encountered disputes with the members of the same community. The office bearers and officials responsible for water management at field level (*Jalapalaka*) are mostly involved in these disputes with the illegal water tappers (for domestic uses). Figure 4.20 reveals that a quarter of respondent farmers in major irrigation schemes have experienced water disputes with the members of other water use types .



Source: HARTI Survey Data, 2019.

Figure 4.20: Experience in Disputes over Water Use and Irrigation Management

4.8 The Need of a Comprehensive Water Management Mechanism

As far as the opportunities with different water users to fulfil their respective water requirements are concerned, it is observed that some sectors enjoy non-restricted access for unlimited water use while certain disadvantageous water user groups are struggling to meet the basic needs for water including drinking and other domestic purposes and primary household livelihoods and food security. Starkloff (1998) found that the composite effect of ecological consequences of the absence of an integrated water centered approach to land use and land users' orientation towards narrow and short-term economic returns are the vulnerability of watersheds in the central highland region. While highlighting the constraints from social factors for implementing a hydrologically sound land use system, it is further emphasized the need of educating officials of the government organizations and public on eco-hydrology and most importantly for regulatory measures to be implemented by an adequately empowered 'watershed management authority'. Endorsing such institutional set up, Wijeratne (1998) noticed that if the state or an autonomous institute takes the major responsibility for the management the performance of such an integrated system may be enhanced and the multiple uses may be optimized (and therefore conflicts may be reduced), and multiple users may be benefited. Even in such cases, FOs and other water user groups may share the responsibility with the agency. It may be argued that in such systems what is more important is to institutionalize a process to ensure productive interactions between the agency and the organized water user groups.

Caldera (1998) also emphasized the requirement of increasing management and institutional interventions to optimum economic benefits from and to ensure equity and other social considerations in access to and conserve natural resources in watersheds. Kamaladasa (2010) argues that mere installation of physical infrastructure and implementation of direct training sessions alone will not fully consolidate the social and economic benefits of the water services unless proper interventions are made to improve the legal, regulatory and institutional environments.

Sustainability of the physical infrastructure depends entirely on the capacity of the institutions, organizations and individuals. Proper social behavior is also needed to complement the improved institutional and organizational capacities. Highlighting the importance of educating farmers and other water users in participatory irrigation management, Sivayoganathan and Mowjood (2003) emphasized the need of strengthening water user groups through training and by providing necessary legal, economic and social support to encourage them to become partners of the system rather than mere recipients. Furthermore, the role of extension workers in farmer education on irrigation and water management has also been emphasized through the success stories relating to agricultural water management strategies. It is of great importance to have better water management at micro-level as well, particularly in agriculture where the intensive use and scarcity issues of water are more acute (Dharmasena, Fleddermann and Weerakoon, 1998).

The role of water user associations (WUA), in the case of this study, particularly for irrigation and domestic water user groups, are paramount for the efficient water allocation and management. WUAs such as FOs and other community-based organizations may have a number of mandated functions related to allocation and conveyance of irrigation and domestic water through canals and other delivery works, including irrigation scheduling, maintenance activities, fee collection and dispute resolution. As a scarce resource, water should be used productively and as a tool to poverty alleviation to achieve food security and it could be realized only through efficient management and governance (Nicol, Ariyabandu and Mtisi, 2006; Clement *et al.,* 2011; UNCTAD, 2011).

The social, economic and political configuration of disadvantageous water users in downstream areas are determined by the functions and the layout of the irrigation structure and water use behavior of the users in the upstream (Paranage, 2018). There is a high political risk associated with institutional reforms in the water sector of Sri Lanka, leading to only gradual and less visible benefits. Further, the political economy factors also play vital roles in the demand for institutional reforms in the water sector Samad (2005). Therefore, the political will is a very decisive factor for the success of any initiative relating to the community, like estate communities, that are overwhelmingly dependent on the local political leadership even for their basic livelihood activities. The communities in the lower stream also seek the political intervention and support for finding solutions for irrigation and water availability issues, despite prompt and proactive responses .

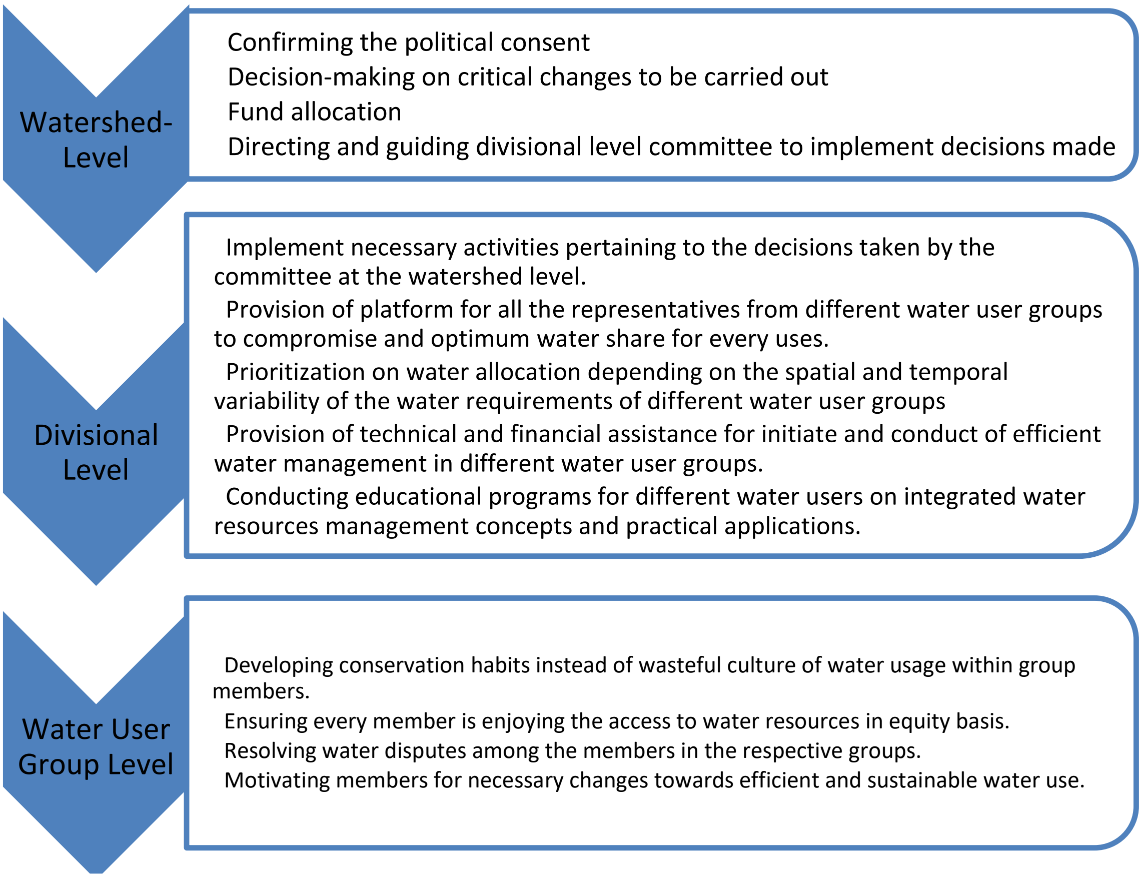
Promoting and strengthening community water supply programs (CWSP) has become a must to do away with the individually initiated pipe-borne water supply for drinking and domestic purposes of each housing unit as it is proved to be a wasteful type of water use practiced by both communities in upper and lower streams. The CWSPs in rural and estate sectors should be implemented in a way such that all the members in the community are equally benefited. In this kind of programs, the inclusion of the poorest segments in the society/community should be ensured. Ariyabandu and Aheeyar (2004) pointed out that although the majority benefited from such projects , there are significant livelihood trade-offs in obtaining access to water. The impacts of trade-offs vary according to the wealth category within the communities: with minimal effect on the rich, the poor have often had to forgo consumption, family possessions and permanent assets to raise the initial cash contributions needed in order to have access to domestic water. The sustainability of such rural and estate CWSPs are dependent on the stability of the CBOs that take care and manage the same, therefore, it is essential to empower the CBOs attitudinally, technologically, and financially to reap the maximum benefits. As proposed by Ranasinghe (1998) the source protection of CWSPs should also be given utmost priority as it is meant to implement measures to assure priority usage of water resources to drinking water and to protect quality and sustainability of the water source (either surface or groundwater).

Gender aspects of domestic water use and household water security should be taken into consideration in planning and implementation of different water supply projects. It is suggested in some overseas studies in similar situations (UNCTAD, 2011; Horbulyk and Balasubramanya, 2018) that increased women participation in WUAs, particularly the CBOs associated with CWSPs should be assured for better results.

In any attempt to avert further encroachments and find alternative lands for those who are already involved in illegal crop cultivations in sensitive areas, the involvement of plantation management is pivotal. Thus, an institutional set up should be formed at watershed level, the representation from the tea plantation management should be assured. The custodians and legal protectors of forests and stream reservations, the Department of Forest Conservation should also be made available for such institutional set up.

At divisional level, the legal authority over the state lands is vested with the Divisional Secretaries, thus, the representation of Divisional Secretary in the institutional set up is also very important. Further, the regional, divisional and village level officials attached to the DAD and DOA and the provincial DOA should also be a part of the institutional set up as the agricultural water use is a pivotal component of the river basin management.

Taking the variety of water uses, water user groups and associated institutes, and potential governing and implementing agencies into consideration an institutional set up is proposed for advanced water management mechanisms ensuring efficiency and equity. The proposed institutional setup contains a number of committees (management or governing bodies) at different strata from watershed level to the local water user group level.



Source: HARTI Survey Data, 2019.

Figure 4.21: Different Tasks and Responsibilities of the Proposed Water Management Mechanism

Members

District Secretary (Nuwaraeliya)
Political leadership (District level)
Deputy Conservator of Forest (Uva-Central Province)
Divisional Irrigation Engineer (Nuwaraeliya) – Irrigation Department
Assistant Commissioner (Nuwaraeliya) – DAD
Deputy Director of Agriculture (Extension) – DOA
Deputy Director of Agriculture (Extension) – Provincial DOA (Central Province)
Superintendent – Plantation Company

Divisional Level

Members

Divisional Secretary – Walapane
Assistant Director of Agriculture (Extension) – DOA
Divisional Development Officers – DAD – Walpane, Munwatte, Ragala ASC Areas
Engineer – NWSDB - Walapane
District Engineer (Nuwaraeliya) – DAD
Range Forest Officer – Mahakudugala

Secretary – Walapane Pradeshiya Sabhawa
Managers – Mini Hydro-Power Plants
Assistant Superintendents – Plantation Company
Representative from the estate community (workers' union)
Two representatives of farmer federations

Water User Groups

1. Estate community water supply schemes (common)
2. Individually initiated pipe-borne water supply for line housing units
3. Water tapping from natural streams for crop cultivation in stream reservation and marginal lands (estate workers)
4. Water tapping from minor irrigation canals for crop cultivation (estate workers)
5. Water uptake for common places (schools, hospitals, *Kovils*) and tea factories
6. Water diversion from streams/minor tanks to paddy-based lowland cultivation
7. Institutionalized large scale drinking water supply (NWSDB)
8. Water uptake for mini hydro-power generation
9. Rural community water supply schemes
10. Irrigation water supply through major irrigation schemes
11. Water tapping from canals in major irrigation schemes for domestic water uses

CHAPTER FIVE

Conclusion and Recommendations

5.1 Conclusions

The number of water uses and water user groups in the study area has dramatically increased over time and they have become highly diversified and complex. There is an apparent competition among different water user groups for the scarce resources. The water quality of the *Kurunduoya* river and its tributaries has deteriorated due to different causes such as sediments flowing in with runoff from the intensive vegetable market gardens and home gardens, inorganic fertilizers and agro-chemicals from crop fields, human waste and other domestic wastes from the estate settlements.

The land use and land cover in the watershed area has significantly changed over the past 4-decade period largely owing to the expansion of cash crop and vegetable cultivation in encroached stream reservations and scrub lands.

Illegal water tapping from the irrigation canals have caused drastic changes in cropping patterns resulting in food security and livelihood issues in the lower stream farming communities.

The obstructions caused by certain segments in the estate community to operation and maintenance of minor irrigation structures located in the tea plantations have posed a severe threat to water availability for cultivation and other domestic water use for the downstream farmer groups. This situation has created disputes/conflicts between two water user groups of different ethnic and cultural backgrounds.

The cooperation and mediation by plantation management towards conflict resolution between two groups is lacking. As a viable solution cannot be found without the involvement of the plantation management, the officials attached to the government institutions are reluctant to intervene in disputes over water.

Continuous encroachment into minor tanks and tank catchment areas by estate communities for unwarranted crop cultivation has caused capacity reduction of such water bodies that is detrimental to water security in the lower stream areas.

Individually-initiated pipe-borne water supply from streams/canals and water fountains for each housing unit in both estate and rural sectors is found to be a very wasteful method of water supply, as the water is not regulated at any point and there is a continuous flow of water in the system.

The irrigation structures, particularly in the minor irrigation systems are in a very dilapidated condition causing water loss and reduced water conveyance efficiency.

There is neither any prioritization on water allocation/use among different water users depending on the spatial and temporal variation of water requirements nor institutional set up to formalize water use and allocation. In this situation, the water user groups in lower streams are heavily disadvantaged as they have no voice or right to water and instead have become mere recipients.

5.2 Recommendations

The intensive crop cultivation in sensitive landscapes such as stream reservations that causes severe water quality issues has to be regulated or halted and those who are already involved should be given alternative lands to continue their livelihood.

The individually-initiated pipe-borne water supply for each housing unit (in both estate and rural sectors) should be halted/discontinued and a common water supply scheme with proper regulatory mechanism for water uptake and distribution should be initiated.

The plantation management should be persuaded to get involved in solving issues between water users in lower and upper stream areas.

The irrigation structures including minor tanks and canal systems should be rehabilitated to make water conveyance and irrigation efficiency high.

The communities should be educated on soil and water conservation as these resources are becoming scarce in the study area.

The agricultural extension system should be strengthened by increasing the mobility of field level extension officers to provide timely information on appropriate crop forecasting based on the climate/weather information pertaining to the forthcoming season.

By enhancing micro-level water management in market gardens and upland farm fields the water use efficiency and productivity can be increased.

REFERENCES

Aheeyar, M.M.M. (2000). Social Linkages of Watershed Management. Proceedings of the 26th WEDC Conference - Water, Sanitation and Hygiene: Challenges of the Millennium, Dhaka, Bangladesh.

Aheeyar, M.M.M. (2006). Sustainability of Participatory Irrigation Management: A Review of Concepts and Perspectives. *Sri Lanka Journal of Agrarian Studies,* 11 (1), pp. 119-133.

Aheeyar, M. M. M., Nanayakkara, V.K. and Bandara, M.A.C.S. (2008). Allocation of Water among Different Water-use Sectors in Sri Lanka: Lessons of Experience. Research Study No: 128, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Aheeyar, M.M.M., Padmajani, M.T. and Bandara, M.A.C.S. (2012). Farmer participation in irrigation system management: Achievements and drawbacks, HARTI Research Report No: 151. Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Aheeyar, M.M.M. and Smith, L.E.D. (1999). The Impact of Farmer Participation on Water Distribution Performance in Two Irrigation Schemes in Sri Lanka. *Sri Lanka Journal of Social Sciences* 22: 27-43.

Amarasekara, M.G.T.S. (2011). Poverty, Soil Erosion and Water Quality: A Case Study in Kurundu Oya Sub Catchment of Upper Mahaweli Catchment, Sri Lanka. *Journal of Social Sciences and Humanities 2: 104-118.*

Amarasekara, M.G.T.S., Dayawansa, N.D.K. and De Silva, W.P.R.P. (2009). Stream Water Quality in Relation to Intensive Vegetable Farming in the Mahakudugala Sub Catchment of Kurundu Oya Catchment. Symposium Proceedings of the Water Professionals' Day, Geo-Informatics Society of Sri Lanka.

Amarasekara, M.G.T.S., Dayawansa N.D.K. and De Silva, R.P. (2014). Soil Erosion and Nutrient Transport from Lands Under Intensive Agriculture in Upper Mahaweli Catchment Area in Sri Lanka, World Science Echo, 1(1), pp. 1-19.

Amarasekara, M. G. T. S., Kumarihamy, R. M. K., Dayawansa, N. D. K. and De Silva, R. P. (2010). The Impact of Inappropriate Soil Management on River Water Quality: A Case Study in the Kurundu Oya Sub-Catchment of the Upper Mahaweli Catchment, Sri Lanka. In. Evans, A.; Jinapala, K. (Eds.), Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka, BMICH, Colombo, Sri Lanka, 9-11 June 2009. Vol. 2: Water quality, environment and climate change. Colombo, Sri Lanka: International Water Management Institute. 186p. doi:10.3910/2010.205

Amarasiri, S. (2008). Caring for Water. Greater Kandy Water Supply Project National Water Supply & Drainage Board Sri Lanka. Worldwide Enterprises (Pvt) Ltd., Kandy, Sri Lanka.

Ananda Coomaraswamy, A., Ekanayake, S.A.B., Ananthacumaraswamy, S., Chishom, A.H. and Jayasuriya, S. (2001). Effect of Land Degradation on Tea Productivity in Sri Lanka. In Ascough J.C. & Flanagan, D.C. (eds.), Proceedings of the International Symposium on Soil Erosion Research for the 21st Century, 3-5 January 2001, Honolulu, HI, USA, pp. 75-78.

Ananda, J. (1998). Soil erosion damage function for smallholder tea in Sri Lanka: an empirical estimation. Paper presented at the 1st World Congress of Environmental and Resource Economics. Venice, Italy, 24-27 June 1998.

Ananda, J. and Herath, G. (2001). Price and Subsidy Policy on Soil Conservation: Application to Smallholder Tea Growers. Economic Analysis & Policy, 3(2), pp. 99-110.

Ananda, J., Herath, G. and Chisholm A. (1996). An economic analysis of the on-site cost of soil erosion in tea smallholdings in Sri Lanka. La Trobe University School of Economics and Commerce, Discussion Paper No A.96.19, Melbourne, Australia.

Ariyabandu, R.D.S. and Aheeyar, M.M.M. (2004). Secure Water through Demand Responsive Approaches: The Sri Lankan Experience. Overseas Development Institute, Water Policy Program, London, UK. pp. 54.

Barker, R. and Samad, M. (1998). Food Security and Irrigation Development in Sri Lanka: Past Achievement and Future Prospects. Proceedings of the National Conference of the Status and Future Directions of Water Research in Sri Lanka, 4 – 6 November, 1998, Colombo, Sri Lanka.

Caldera, R.K.L.P. (1998). Participation of User Groups to Overcome Some Adverse Environmental Impacts on Watershed Management. Available at https://publications.iwmi.org/pdf/H023514.pdf

Chandrasekara, S.S.K., Chandrasekara, S.K., Gamini, P.H.S., Obeysekera, J., Manthrithilake, H., Kwon, H.H. and Vithanage, M. (2021). A review on water governance in Sri Lanka: The Lessons Learnt for Future Water Policy Formulation. *Water Policy,* 23: 255–273.

Clement, F., Haileslassie, A., Ishaq, S., Blümmel, M., Murty, M., Samad, M., Dey, S., Das, H. and Khan, M. (2011). Enhancing Water Productivity for Poverty Alleviation: Role of Capitals and Institutions in The Ganga Basin. *Experimental Agriculture, 47*(S1), pp.133-151. Doi:10.1017/S0014479710000827

Cosgrove, W.J. and Loucks, D.P. (2015). Water management: Current and future challenges and research directions. Water Resources Research. https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014WR016869

DCS (various years). Household and Expenditure survey. Department of Census and Statistics. Colombo, Sri Lanka.

De Alwis, K.A. and Panabokke, C.R. (1972). Handbook of the soils of Sri Lanka. *Journal of Soil Science Society of Ceylon* **2,** pp.1-98.

Dent, D.L. and Goonewardene, L.K.P.A. (1993). Resource Assessment and Land Use Planning in Sri Lanka: A Case Study. Environmental Planning Issues No. 4, The Environmental Planning Group, The International Institute for Environment and Development, London. pp.139.

Dharmasena, P.B. (2015). Concept Note on Strategic Agriculture against Climate Change and Natural Disasters. pp.15.

Dharmasena, P.B. (2016). Conservation of Soil Resources of the Kapiriggama Village Tank Cascade System. IUCN Programme on Restoring Traditional Cascading Tank Systems Technical Note No. 6. IUCN, Sri Lanka Country Office, Colombo, Sri Lanka. pp.55.

Dharmasena, P.B. and Bhat, M.S. (2011). Assessment of Replacement Cost of Soil Erosion in Uva High Lands Tea Plantations of Sri Lanka. *Current World Environment*, 6(2), pp. 241-246.

Dharmasena, P. B., Fleddermann, A. and Weerakoon, W. L. (1998). A stride towards micro-level water management in Sri Lanka: research and applications. Paper 53 of Session 18, Conference Papers h023544, International Water Management Institute.

Dinar, A., Rosegrant, M.W. and Meinzen-Dick, R. (1997). Water Allocation Mechanisms: Principles and Examples. Policy Research Working Paper 1779, Agriculture and Natural Resources Department, World Bank, Washington DC.

Diyabalanage, S., Samarakoon, K.K., Adikari, S.B. and Hewawasam, T. (2017). Impact of soil and water conservation measures on soil erosion rate and sediment yields in a tropical watershed in the Central Highlands of Sri Lanka. *Applied Geography*, 79,pp. 103-114.

FAO (2002). Gateway to land and water information; Sri Lanka. Available at http://www.apipnm.org/swlwpnr/reports/y_sa/z_lk/lk.htm; accessed 1/7/2019.

FAO (2011). Climate change, water and food security. FAO Water Report – 36. Food and Agriculture Organization of the United Nations, Rome, Italy. pp.173.

FAO (2014). Water Governance for Agriculture and Food Security. Committee on Agriculture, Twenty-fourth Session, Food and Agriculture Organization of the United Nations, Rome, 29 September - 3 October2014.

Gamage, D and Aheyaar, M.M.M. (1998). Economic and Social Factors Affecting Land Degradation in the Upper Mahaweli Catchment – Sri Lanka. Ministry of Forestry and Environment and Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

GOSL (2020). The Gazette of the Democratic Socialist Republic of Sri Lanka (Extra Ordinary) no 2187/27 of 2020.09.07. Government of Sri Lanka, Colombo, Sri Lanka.

Gunathilake, A. (2008). Water Security and Related Issues in Sri Lanka: The Need for Integrated Water Resource Management (IWRM). *Journal of National Science Foundation of Sri Lanka 36,pp. 3-13.*

Gunatilake, H.M. and Gunawardena, E.R.N. (2000). An Assessment of On-Site and Off-Site Costs of Soil Erosion in the Upper Mahaweli Watershed. *Sri Lanka J. Agric. Sci.,* 37,pp.103-134.

Gunawardena, E.R.N. (2013). Sustainable Water Resource Management in Sri Lanka: Status at Present and Strategies for Future. https://www.researchgate.net/publication/259255380_Sustainable_Water_Resources_Management_in_SriLanka_Status_at_Present_and_Strategies_for_Future

Herath, G. (2001). Estimating the User Cost of Soil Erosion in Tea Smallholdings in Sri Lanka. *Australasian Journal of Regional Studies*, 7(1), pp. 97-111.

Hewage, S., C. Jayamini, N. Wijesooriya, R. Rambukwella, R. Vidanapathirana, D. Priyadarshana and G. Samarasinha (2017). The Report of the Baseline Survey to the Project on Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin. Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka (unpublished).

Hewawasam, T., (2010). Effect of land use in the upper Mahaweli catchment area on erosion, landslides and siltation in hydropower reservoirs of Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, 38(1), pp.3–14. DOI: http://doi.org/10.4038/jnsfsr.v38i1.1721

Horbulyk, T. and Balasubramanya, S. (2018). Impact of Water Users Associations on Water and Land Productivity, Equity and Food Security in Tajikistan. Final Report: Volume I. Colombo, Sri Lanka: International Water Management Institute (IWMI).

IAEA (2020). Agricultural Water Management. International Atomic Energy Agency. https://www.iaea.org/topics/agricultural-water-management

ILO (2019). Tools and Guidelines for Watershed Management in The South-Western Region of Sri Lanka for Increased Climate Resilience. International Labor Organization Country Office for Sri Lanka and the Maldives, Colombo, Sri Lanka. 56pp.

Imbulana, K.A.U.S, Wijesekera, N.T.S., and Neupane, B.R. (2006). Sri Lanka National Water Development Report. Ministry of Agriculture, Irrigation and Mahaweli Development and Environment. UN-WWAP, UNESCO and University of Moratuwa, Sri Lanka, Paris and New Delhi.

IPS – Institute of Policy Studies, (2016). Better Water, Sustainable Agriculture and Better Lives for Sri Lanka. [Online] http://www.ips.lk/talkingeconomics/2016/03/22/better-water-sustainable-agriculture-and-better-lives-for-sri-lanka/ (browsed on December18, 2018)

IWMI - International Water Management Institute, (2010). Sri Lanka: Issues and Opportunities for Investment. (IWMI Water Issue Brief 7), International Water Management Institute (IWMI), Colombo, Sri Lanka: 4p. doi: 10.5337/2010.220

Jayasekara, M.J.P.T.M., Kadupitiya, H.K. and Vitharana, U.W.A. (2018). Mapping of Soil Erosion Hazard Zones of Sri Lanka. *Tropical Agricultural Research 29 (2): 135 – 146.*

Joshua, W.D. (1977). Soil erosive power of rainfall in the different climatic zones of Sri Lanka. In Erosion and Solid Matter Transport in Inland Waters. Paris: IAHS-AISH, Proceedings of Symposium Publication 122. pp. 51-61.

Kamaladasa, B., (2010). Interventions Necessary in Capacity Building in Existing Water Organizations to Improve Productivity and Access to Water. In. Jinapala, K., de Silva, S. and Aheeyar, M. M. M. (Eds.), Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka, BMICH, Colombo, Sri Lanka, 9-11 June 2009. Vol. 3: Policies, Institutions and Data Needs for Water Management. Colombo, Sri Lanka: International Water Management Institute. 162p. doi:10.3910/2010.203

Karunarathna, S., Henkanaththegedara, S., Gabadage, D., Botejue, M., Madawala, M. and Surasinghe, T.D. (2016). Ecology and Demography of the Critically Endangered Kandian torrent toad *Adenomus kandianus*: a long-lost endemic species of Sri Lanka. *Fauna & Flora International* (2016): 1-8. doi:10.1017/S0030605316000594

Krishnarajah, P. (1985). Soil Erosion Control Measures for Tea Land in Sri Lanka. *Sri Lanka Journal of tea Sciences,* 54 (2): 91 -100, 1985.

Kurian, M. (2004). Institutions for integrated water resources management in upland watersheds of Southeast Asia—A comparative analysis of Thailand and Lao PDR. Colombo, Sri Lanka: IWMI. 20p. (Working Paper 81).

ME&NR (2008). Caring for the Environment 2008- 2012: Towards sustainable development. Ministry of Environment and Natural Resources, Battaramulla, Sri Lanka.

Ministry of Finance (2020). National Policy Framework: Vistas of Splendor and Prosperity. Ministry of Finance, Colombo, Sri Lanka.

Moormann, F.R. and Panabokke, C.R. (1961). Soils of Ceylon – A New Approach to the Identification and Classification of the Most Important Soil Groups of Ceylon. Food and Agriculture Organization of the United Nations and Department of Agriculture, Ceylon, Colombo, Sri Lanka, pp.65.

Nanayakkara, V.K. (2010). Sri Lanka's Water Policy: Themes and Issues. Proceedings of the National Conference on 'Water for Food and Environment', held from June 9 –11, 2009 at the Bandaranaike Memorial International Conference Hall (BMICH), Colombo, Sri Lanka, pp. 113-126.

Nicol, A., Ariyabandu, R. and Mtisi, S. (2006). Water as a Productive Resource: Governance for Equity and Poverty Reduction. Human Development Report - 2006. Human Development Report Office. United Nations Development Program.

NOAA (2017). The water Cycle. National Oceanic and Atmospheric Administration, United States Department of Commerce. https://www.noaa.gov/education/resource-collections/freshwater/water-cycle

OECD (2014), Climate Change, Water and Agriculture: Towards Resilient Systems, OECD Studies on Water, OECD Publishing. http://dx.doi.org/10.1787/9789264209138-en

Panabokke, C.R. (1996). Soils and Agro-Ecological Environments of Sri Lanka. Natural Resources, Energy and Science Authority of Sri Lanka, Colombo, Sri Lanka. pp.220.

Paranage, K. (2018). Understanding the Relationship between Water Infrastructure and Socio-Political Configurations: A Case Study from Sri Lanka. *Water,* 2018, 10, 1402; doi:10.3390/w10101402

Punyawardena, B.V.R. (2008). Rainfall and Agro-Ecological Regions of Sri Lanka. Department of Agriculture, Peradeniya, Sri Lanka.

Ranasinghe, K. S. K. (1998). Source protection for cost effective and sustainable rural water supply. Paper 13 of Session 14, Conference Papers h023528, International Water Management Institute. https://ideas.repec.org/p/iwt/conppr/h023528.html

Ratnayake, R. (2015). Institutions for IWRM in Sri Lanka – A Perspective. https://lankajalani.org/wp-content/uploads/2015/03/Integrated-Water-Resources-Management.pdf

Samad, M. (2005). Water institutional reforms in Sri Lanka. *Water Policy,* 7 (1),pp. 125–140.

Samad, M., Aheeyar, M., Royo-Olid, J. and Arulingam, I. (2016). The Political and Institutional Context of the Water Sector in Sri Lanka. An Overview. International Water Management Institute, Sri Lanka

Samad, M. and Vermillion, D. (1999a). Assessment of Participatory Management of Irrigation Schemes in Sri Lanka: Partial Reforms, Partial Benefits. Research Report 34, International Water Management Institute, Colombo, Sri Lanka.

Samad, M. and Vermillion, D. (1999b). An Assessment of the Impact of Participatory Irrigation Management in Sri Lanka. *International Journal of Water Resources Development, 15(1,2),pp. 219-240.*

Samarasinha, G.G.de L.W. and Bandara, M.A.C.S. (2016). Adoption of Soil and Water Conservation Measures: Case of Upper Watershed Management Project (UWMP). Working Paper No. 09. Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Saumyarathne, N.G.R., Gunawardena, E.R.N. and Dayawansa, N.D.K. (2016). Water Conflicts among Different Water Users and Uses in the Hakwatuna Oya Watershed in the Deduru Oya Basin, Sri Lanka. *Tropical Agricultural Research 28,pp. 38-49.*

Singh, H. (2019). Water Management: Meaning, Statistics and Solutions. https://www.jagranjosh.com/general-knowledge/watermanagement-1440753457-1

Sivakumar, S.S. (2015). Conflict in Water Resource Utilization in Northern Sri Lanka. Proceedings of the Workshop on Water Conflicts Resolution, Treatment & Desalination by WaSo Project of Department of Civil Engineering University of Jaffna, Sri Lanka 18-19th April 2015. DOI: 10.13140/RG.2.1.2195.6644

Sivayoganathan, C. and Mowjood, M.I.M. (2003). Role of Extension in Irrigation Water Management in Sri Lanka. *Tropical Agricultural Research and Extension* 6: 49-55.

SLCARP (2017). National Research Priorities - 2017 – 2021. Sri Lanka Agricultural Research Policy, Colombo, Sri Lanka.

SLNWP (2000). Sri Lanka Water Vision – 2025. Sri Lanka National Water Partnership, pp25.

Starkloff, R. (1998). Social and environmental aspects of *watershed vulnerability* in the Sri Lankan hill country. Conference Paper H023527. International Water Management Institute. https://publications.iwmi.org/pdf/H023527.pdf

Tolisano, J., Abeygunewardene, P., Athukorala, T., Davis, C., Fleming, W., Goonesekera, K., Rusinow, T., Vattala, H.D.V.S. and Weerewardene, I.K. (1993). An Environmental Evaluation of the Accelerated Mahaweli Development Program: Lessons Learned and Donor Opportunities for Improved Assistance. Prepared for the U.S. Agency for International Development, DAI, Woodmont Avenue, Bethesda, Maryland 20814, USA, 120 pp.

Udayakumara, E. P. N., Shrestha, R. P., Samarakoon, L. and Vogt, D.S. (2010). People's perception and socioeconomic determinants of soil erosion: A case study of Samanalawewa watershed, Sri Lanka. *International Journal of Sediment Research*, 25(4), pp. 323–339.

UNCTAD (2011). Water for Food – Innovative Water Management Technologies for Food Security and Poverty Alleviation. UNCTAD Current Study on Science, Technology and Innovation, No. 04. Switzerland. 39p.

UNDP (2006). Beyond Scarcity: Power, Poverty and the Global Water Crisis. UNDP, New York

USAID (2020). Agricultural Water Management. United States Aid for International Development. https://www.globalwaters.org/resources/agricultural-water-management

USDA (2013). Water Management. Natural Resources Conservation Service, United States Department of Agriculture. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/manage/

Walapane, D.S. (2018). Resource Profile of the Walapane Divisional Secretariat. Walapane Divisional Secretariat, Nildandahinna, Walapane.

Weerahewa, J., Gunatilake, H.M., Thrikawala, S. and Kotagama, H.B. (2000). Impact of Potato Trade Liberalisation on Soil Erosion: A Multi Period Market Simulation Model. *Sri Lankan Journal of Agricultural Economics,* 3(1), pp 123 - 141.

Weragala, D.K.N. (2010). Water Allocation Challenges in Rural River Basins: A Case Study from the Walawe River Basin, Sri Lanka. PhD dissertation (unpublished), Utah State University, United Kingdom.

Werner, W. L. (1986). A Comparison between Two Tropical Montane Ecosystems in Asia: Pidurutalagala (Ceylon/Sri Lanka) and Pangrango-Gede (Java). *Mountain Research and Development*, 6(4), pp.335–344

Wickramasinghe, W.M.A.D.B. (2005). Management of intermediate zone soils for rice. In: Soils of the Intermediate Zone of Sri Lanka (eds R.B. Mapa, A.R. Dassanayake & H.B. Nayakekorale), Soil Science Society of Sri Lanka, Colombo, pp. 191-197.

Wijeratne, C.M. (1998). Impacts of the Institutional System on the Participants and on Irrigation Performance: A Note for Discussion. Conference Papers h018378, International Water Management Institute. https://publications.iwmi.org/pdf/H018378.pdf

Wijewardena, J. D. H., (2000). Impact of intensive vegetable cultivation on drinking water quality in the upcountry region of Sri Lanka. Conference Papers h023508, International Water Management Institute.

World bank (2020). Water in Agriculture. Available online at, https://www.worldbank.org/en/topic/water-in-agriculture#1 (accessed on 04.April, 2021).

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ISBN: 978-624-5973-07-1

9 7 8 6 2 4 5 9 7 3 0 7 1

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