



Blueprint for Resilience: A Transformative Development Model for Sri Lanka's Dry Zone

Tank Cascade Water Management

BOOK

1



Blueprint for Resilience: A Transformative Development Model for Sri Lanka's Dry Zone

Presenting CRIWMP's Development Model



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The Climate Resilient Integrated Water Management Project (CRIWMP) is a groundbreaking initiative designed to address the growing challenges of climate change and water scarcity in Sri Lanka's Dry Zone. Funded by the Green Climate Fund (GCF) and implemented by the Government of Sri Lanka with the Technical Support from the United Nations Development Programme (UNDP)

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MESSAGE FROM **HON. MINISTER**

The Green Climate Fund financed Climate Resilient Integrated Water Management Project (CRIWMP) implemented by the Government of Sri Lanka and the United Nations Development Programme (UNDP), offers Sri Lanka a definitive model for resilience, and in particular, modernizing agriculture in climate-vulnerable regions. I recognize CRIWMP's unparalleled success in harmonizing ancient wisdom with cutting-edge practices.

This is no longer just a pilot—it is our chosen path forward. The Ministry of Agriculture, Livestock, Land & Irrigation fully endorses this holistic approach that packages integrated water management, climate-smart agriculture, climate-adaptive livelihoods, and agro-meteorological advisories & climate information as a resilience-building tool as the national standard for rural development. The results speak for themselves: empowered farmers, revitalized ecosystems, and measurable economic gains.

To all valued partners in development: The time for scaling is now. Let us institutionalize these proven methods across all Dry Zone districts, with the urgency our farmers and nation deserve. This blueprint lights the way.

Hon. K. D. Lalkantha

Ministry of Agriculture, Livestock, Land and Irrigation

MESSAGE FROM **THE SECRETARY**

As the Secretary of the Ministry of Agriculture, Livestock, Land, and Irrigation, it is both an honor and a responsibility to introduce *Blueprint for Resilience: A Transformative Development Model for Sri Lanka's Dry Zone*. This publication captures the profound impact of the Green Climate Fund financed, Climate Resilient Integrated Water Management Project (CRIWMP) implemented by the Government of Sri Lanka and the United Nations Development Programme (UNDP), a groundbreaking initiative that has not only addressed critical challenges in the Dry Zone but has also set a new standard for sustainable development in Sri Lanka.

Launched in 2017, CRIWMP has been a lifeline for the rural communities of the Dry Zone, where water scarcity, climate change, and livelihood challenges have long posed significant threats. By harnessing the potential of tank cascades, the project has unlocked a paradigm shift in how we approach resilience-building, climate adaptation, and sustainable development. It has demonstrated that integrated water management, when executed with vision and precision, can transform lives, ecosystems, and economies.

This book outlines the conceptual model, implementation strategies, and lessons learned from CRIWMP, offering a roadmap for future interventions. It emphasizes the importance of a holistic approach—combining climate-smart agriculture, sustainable land and water management, and robust institutional mechanisms—to ensure long-term resilience. The project's success underscores the need for clear government leadership, consolidated economic benefits, and the integration of cascade management plans into broader development strategies.

The lessons from CRIWMP are not just technical; they are transformative. They remind us that development is not merely about infrastructure but about empowering communities, preserving ecosystems, and fostering governance that is inclusive and forward-thinking. As we reflect on these achievements, the Ministry of Agriculture, Livestock, Land, and Irrigation reaffirms its commitment to scaling up these efforts and embedding these principles into national policies and strategies.

To my fellow policymakers, I urge you to take the blueprint offered by CRIWMP as a call to action. Let us use these insights to design and implement policies that prioritize resilience, sustainability, and equity. Let us recognize the interconnectedness of water, land, and livelihoods, and work together to ensure that the Dry Zone—and indeed all of Sri Lanka—can thrive in the face of climate change and other challenges.

This book is a testament to what is possible when innovation, collaboration, and determination converge. Let us carry these lessons forward, not just as a model for the Dry Zone, but as a blueprint for a more resilient and sustainable future for all Sri Lankans.

D. P. Wickramasinghe

Secretary to the Ministry of Agriculture, Livestock, Land and Irrigation

MESSAGE FROM **UNDP**

In a world increasingly defined by uncertainty and interconnected crises, the need for transformative, resilient, and inclusive development models has never been more urgent. Evident from the stories I have heard myself from the communities and local leaders, the Climate Resilient Integrated Water Management Project (CRIWMP) stands as a beacon of hope and innovation, demonstrating how holistic, locally-conceived, community-driven interventions can unlock the potential of vulnerable regions and create pathways for sustainable development.

Sri Lanka's Dry Zone has been long plagued by water scarcity, climate variability, and socioeconomic challenges. It has been a testing ground for resilience-building at its most profound. CRIWMP, launched in 2017 with financing from the Green Climate Fund (GCF) and implemented by the Government of Sri Lanka and the United Nations Development Programme (UNDP), has not only addressed these challenges, but also catalyzed a paradigm shift in how we approach rural development. By revitalizing ancient tank cascade systems, integrating climate-smart agricultural practices, and fostering community ownership, the project has transformed lives, ecosystems, and livelihoods for many. It has shown that resilience is not just about surviving shocks, it is about thriving in the face of adversity.

This book, *Blueprint for Resilience: A Transformative Development Model for Sri Lanka's Dry Zone*, captures the essence of CRIWMP's journey. It underscores the importance of integrated water management, sustainable land use, and inclusive governance in creating lasting impacts. More importantly, it highlights the critical role of community engagement and institutional collaboration in scaling up these efforts to achieve national and global development goals.

The transformative impact of CRIWMP extends far beyond the Dry Zone. It offers a replicable model for rural development, particularly in regions grappling with climate change, resource scarcity, and socioeconomic vulnerabilities. In a time of global polycrises—from economic instability to climate emergencies—the lessons from CRIWMP are a clarion call for holistic, evidence-based interventions that prioritize the needs of the most vulnerable.

As we look to the future, it is my sincere hope that the successes of CRIWMP will be embedded into national development strategies as a top priority for the country that aspires to uplift rural communities. This is not just a pathway for rural development; it is a blueprint for building a more resilient, equitable, and sustainable Sri Lanka. The time to act is now.

I extend my deepest gratitude to all those who contributed to this remarkable initiative—the communities, government partners, development actors, and the dedicated teams who turned vision into reality. Let this book inspire policymakers, stakeholders, and development practitioners to embrace the lessons of CRIWMP and champion transformative interventions that leave no one behind.

Together, we can build a future where resilience is not just a goal but a way of life.

Azusa Kubota

Resident Representative, UNDP in Sri Lanka

EXPERT OPINION

Tank cascade systems have helped sustain people's lives and livelihoods in the Dry Zone of Sri Lanka for several centuries. They evolved with traditional technology as ecosystems that provide multiple services to the community. The United Nations has recognized them as a globally important agricultural heritage system.

However, recent social, economic, and political developments are challenging the function of these systems. While successive governments have made several interventions to improve them, their long-term sustainability is questionable. Considering some of these interventions were foreign-funded, any discontinuation of the benefit stream adversely affects the national economy.

Sri Lanka is moving towards economic stability after several years of crisis. As such, the tank cascade systems have to function efficiently to serve their economic and social services, while conserving their traditional identity. Similar to other interventions in economic and political arenas, the current situation demands a systemic change or a paradigm shift in the approach to tank cascade development and management.

This document describes a recent intervention in tank cascade systems that attempted such a paradigm shift. It describes the strategies employed, challenges faced, and lessons learned while implementing a project titled "Climate Resilient Integrated Water Management Project" (Wev Gam Pubuduwa). Drawing from the lessons learned, it submits several recommendations that can be considered for future strategies to develop and manage cascade systems. We hope its content is useful for policymakers, decision-makers, and donors involved with tank cascade systems.

Prof. L.M. Abeywickrama

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MESSAGE FROM

NATIONAL PROJECT DIRECTOR - CRIWMP

As societies shifted to agriculture, they adapted to changing weather patterns. Over time, they developed ways to cope with climate variability. Today, climate change poses a major threat, severely affecting agriculture-based communities. In Sri Lanka, rising temperatures, prolonged droughts, floods, and erratic rainfall have disrupted lives—especially in the dry zone.

Once sustained by traditional water systems and biodiversity, the dry zone now faces degraded ecosystems due to deforestation, overuse of land, and poor practices. These issues have weakened water cycles, soil health, and local resilience.

The Climate Resilient Integrated Water Management Project (CRIWMP), is funded by the Green Climate Fund and takes an ecosystem-based approach. In its eighth year, CRIWMP supports smallholder farmers—especially women—in managing climate risks and promoting sustainable agriculture.

So far, 325 village irrigation systems have been restored, revitalizing over 15,000 hectares. More than 125,000 people now have safe drinking water, and over 500,000 benefit from climate services and early warnings. The project has improved incomes, health, and adaptive capacity.

To guide future action, the project developed “Blueprint for Resilience,” a strategic model for Sri Lanka’s dry zone. It highlights integrated planning, wetland management, and strong leadership as critical for long-term sustainability. We are proud to support this transformative journey toward a climate-resilient future.

Eng. Chandana Edirisooriya

National Project Director

Climate Resilient Integrated Water Management Project (CRIWMP)

Ministry of Agriculture, Livestock, Land and Irrigation



Blueprint for Resilience:

A Transformative Development Model for Sri Lanka's Dry Zone



ACRONYMS

AWD	Alternate Wetting and Drying
CBO	Community-based Organizations
CI	Cropping Intensity
CKDu	Chronic Kidney Disease of Unknown Etiology
CMC	Cascade Management Committee
CRIWMP	Climate Resilient Integrated Water Management Project
CSA	Climate Smart Agriculture
CWRD&MP	Cascade Water Resources Development & Management Plan
CWS	Community-managed Water Supply Schemes
DAD	Department of Agrarian Development
DAS	Department of Agrarian Services
DNCWS	Department of National Community Water Supply
DOA	Department of Agriculture
DS	Divisional Secretary
EP	Eastern Province
FAO	Food and Agriculture Organization
FO	Farmers Organizations
GAs	Government Agents
GCF	Green Climate Fund
GEF	Global Environmental Facility
GN	Grama Niladhari
GRC	Grievances Redress Committee
GRM	Grievance Redress Mechanism
HFL	High Flood Level
HSBC	Hong Kong and Shanghai Banking Corporation Limited
ID	Irrigation Department
IRBM	Integrated River Basin Management
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute

IWRM	Integrated Water Resources Management
MMDE	Ministry of Mahaweli Development and Environment
MP	Management Plan
MWSIP	Mahaweli Water Security Investment Programme
NCP	North Central Province
NCPCP	North Central Province Canal Project
NDC	Nationally Determined Contributions
NP	Northern Province
NWP	North Western Province
NWSDB	National Water Supply and Drainage Board
O&M	Operation and Maintenance
OFC	Other Field Crops
PCR	Participatory Climate Risk
PDOA	Provincial Department of Agriculture
PID	Provincial Irrigation Department
PIR	Preliminary Investigation Report
PMU	Project Management Unit
PRA	Participatory Rural Appraisal
RWS	Rural Water Supply
SAPSRI	South Asia Partnership Sri Lanka
SCCF	Special Climate Change Fund
SECU	Social and Environmental Compliance Unit
SRM	Stakeholder Response Mechanism
TCEO	Territorial Civil Engineering Organization
TWG	Technical Working Group
VCA	Vulnerability and Capacity Assessment
VIS	Village Irrigation System
WEAP	Water Evaluation and Planning
WUO	Water Users Organization



EXECUTIVE SUMMARY

Village irrigation systems in Sri Lanka have evolved over millennia, intricately interwoven with the landscape and the ecosystem. These systems, often hydrologically linked, forming tank cascades, are vital to the rural fabric of life. However, their survival under current social, economic, and climatic pressures is increasingly threatened. Recent development interventions have struggled to achieve lasting impacts, casting doubts on their sustainability.

An in-depth analysis of the tank cascades revealed its complex interplay of social, environmental, and technical elements. It was further noted that a river basin approach is needed to address emerging issues such as climate change. However, the sustainability of the interventions in village irrigation was doubtful due to the absence of a formal institutional mechanism at the cascade level. Integrating traditional management practices with modern technologies could improve the effectiveness of the interventions. Based on the above findings, the analysis highlighted the need for a paradigm shift in the actions to enhance the resilience of cascade-based communities.

The Climate Resilient Integrated Water Management Project (CRIWMP), launched in 2017, sought to address these issues and unlock the potential of tank cascades in transforming the dry zone's resilience—adapting to climate change, creating sustainable livelihoods, and delivering sustainable development to the rural communities in the Dry Zone. The project is on track to achieve the planned benefits within the expected time frame. This report outlines CRIWMP's conceptual model, implementation strategies, challenges encountered, and the lessons learned. Drawing from this experience, the following recommendations to consider in future development projects concerning tank cascades are made:

- The responsibilities of the government institutions to lead the required paradigm shift should be clearly defined.

- The economic benefits derived from the whole cascade should be consolidated and a mechanism to ensure beneficiaries' contribution to the cascade system's management should be formulated.
- The cascade management plans should fit into a river basin management plan, with due regard to the river basin's sub-watersheds in water resources development plans

Subject to the above recommendations, a model for future interventions in tank cascades is proposed. The major elements in the model include a holistic approach to developing agriculture in a climate-smart manner, integrated management of surface water and groundwater resources using improved weather information and soil-water properties, sustainable land use and management practices, and an appropriate institutional mechanism to ensure good governance. The recognition of cascade development and management in national policies and inclusion in national strategies are highlighted as major requirements to sustain the envisaged paradigm shift.



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Dried-up tank - Kalawelapothana Tank, Divulwewa Cascade, Anuradhapura

1.1 Climate Resilient Integrated Water Management Project (CRIWMP)

In recent times, the northern part of Sri Lanka's Dry Zone has faced significant challenges, exacerbated by the combined impacts of the prolonged 30-year civil war and climate change. These factors have contributed to the persistent suffering of its communities. Recognizing the urgency to uplift lives and livelihoods and improve climate resilience, the Government of Sri Lanka, following the conclusion of the civil conflict in 2009, prioritized the interventions in the region.

In 2015, the Ministry of Mahaweli Development and Environment (MMDE), with technical support from the United Nations Development Programme (UNDP), conducted a comprehensive study titled "Strengthening the Resilience of Smallholder Farmers in the Dry Zone to Climate Variability and Extreme Events through an Integrated Approach to Water Management". This study, enriched by contributions from national and international institutions specializing in irrigation, agriculture, disaster management, water supply, and meteorology, produced several findings and key recommendations:

- **Impact on Village Irrigation Systems (VISs):** VISs are particularly vulnerable to climate change, with communities primarily struggling with low agricultural productivity and inadequate access to quality drinking water from surface or groundwater sources.
- **Other Contributing Constraints:** Deteriorating irrigation infrastructure, degraded watersheds, insufficient adoption of climate-smart agriculture (CSA) technologies, and limited access to actionable weather and climate information pose significant barriers to effective adaptation and disaster preparedness.

- **Integrated Approach:** Given the intricate interconnections between watersheds, irrigation systems, water quality, and climate dynamics, the study advocated an integrated approach. It identified tank cascade systems, physically integrated through hydrological linkages, as the optimal spatial unit for implementing targeted interventions.

Building on these insights, a project proposal was developed and submitted to the Green Climate Fund (GCF). In June 2016, the proposal secured approval, resulting in a grant of USD 38.084 million, complemented by co-financing of USD 14 million from the Government of Sri Lanka. These funds enabled the launch of the Climate Resilient Integrated Water Management Project (CRIWMP) in 2017, with an implementation timeline extending to 2024.

As the project approaches its planned conclusion in 2025, it seeks to document the lessons learned and experiences gained since its inception. This report, the first in a planned series, captures the rationale behind CRIWMP's design, its innovative approaches, challenges encountered in its implementation, and the achievements realized. By focusing on the integrated model introduced by the project, this publication aims to provide actionable insights for future initiatives targeting similar challenges.

Notably, village irrigation systems (VISs) in Sri Lanka have sustained agricultural livelihoods for over 2,000 years, forming a cornerstone of the nation's ancient hydraulic civilization. This report delves into their historical evolution, highlighting relevant lessons for advancing sustainable development in Sri Lanka's Dry Zone.

1.2 Water Resources and the Dry Zone of Sri Lanka

Sri Lanka's annual water resources, defined as the amount of water produced sustainably by all the water sources, are estimated to be between 45 -50 cubic kilometers (km³). Surface water accounts for nearly 85% of this volume. The spatial distribution of rainfall defines the three climatic zones:

- **Wet Zone:** Areas receiving over 2,500 millimeters (mm) of annual rainfall.

- Intermediate Zone: where annual rainfall ranges between 1,750 mm and 2,500 mm.
- Dry Zone: Areas receiving less than 1,750 mm of annual rainfall (Punyawardena, 2020).

Out of 103 distinct river basins in Sri Lanka, 83 rivers are in the Dry Zone and carry nearly 50% of surface runoff (Arumugam, 1969). The Dry Zone extends over about 70% of the area predominantly in the northern, eastern, and south-eastern parts of Sri Lanka.

The Dry Zone is highly vulnerable to climate change. The factors contributing to this situation include increasing rainfall variability, decreased rainfall volume in the primary rain season (North-East monsoon), increasing temperatures, and heavy dependence on agriculture, (Samarasinhe et al., 2020). The persistence of rural poverty, high levels of indebtedness, and water-related health problems are other contributors to the vulnerability in the Dry Zone.

Historically, the Dry Zone's water resource management has relied on an intricate network of small and large reservoirs and water diversions, enabling the communities to store water during short rainy periods and utilize it during dry spells. Among this infrastructure, small-scale reservoirs (Village Tanks) and diversions (Village Anicuts) have been pivotal in ensuring the water security of the rural population. Current estimates indicate the existence of approximately 16,600 Village Tanks and a similar number of Anicuts exist (Witharana, 2020).

Significantly, about 70% of village tanks and 74% of anicuts are situated within hydrologically connected clusters, referred to as Tank Cascades. These cascades exemplify an integrated water management approach, reflecting the historical ingenuity of Sri Lanka's ancient hydraulic civilization.

Village Irrigation Systems (VIS) is used to collectively describe these tanks and anicuts in this document, given their critical importance in water resource management and climate adaptation strategies.



1.3 The Evolution of Village Irrigation and Tank Cascades

Village irrigation systems in Sri Lanka have a history deeply interwoven with the country's ancient hydraulic civilization, evolving over centuries and potentially predating the advent of written records. Tank cascades, recognized as an ingenious advancement in irrigation technology, represent the cumulative knowledge and experiences of the generations. According to a summary of some expert opinions, the chronological order of this process constituted:

- Rainwater tanks
- Small village tanks
- Large reservoirs each submerging several small tanks
- Augmentation of large reservoirs from rivers (Imbulana et al., 2010)

Mendis (2001) presented a slightly different theory, outlining the process as:

- Rain-fed agriculture
- Seasonal or temporary river diversions and inundation irrigation
- Permanent river diversions and channel irrigation
- Development of weirs and spillways on irrigation channels
- The invention of the sluice with its access tower
- Construction of storage reservoirs
- Damming a perennial river

Further elaboration of this evolution is made by Panabokke (2009), who analysed previous literature and emphasized the need for some degree of reliability in the water supply during the harsh dry seasons necessitated water storage. This need, coupled with the inadequacy of groundwater storage in shallow aquifers in the hard rock basement regions, drove the innovation of surface water storage in "small rudimentary ponds". Tennekoon (2001) posits that early villagers may have initially blocked trickling watercourses to pool water, leading to building anicuts, which likely preceded the tanks. Evidence of this gradual evolution remains visible today in structures, as this evolution has continued till

recent times, explained by names such as “Palugaha Amuna Wewa” in Anguruwella cascade, Kurunegala district, and “Kapugama Pahala Wewa” in Anuradhapura district (Figure 1).



Figure 1: Kapugama Pahala Wewa – Palugaswewa Cascade, Anuradhapura

The literature further notes that improved iron tools were available around 400 B.C., marking a pivotal moment in the evolution of agriculture in Sri Lanka. These tools significantly expanded agricultural capabilities, enabling the transition from small rudimentary ponds to more sophisticated small village tanks. These tanks facilitated the development of settlements near reliable water sources. The experience gained from constructing the initial-stage ponds allowed early inhabitants to locate these water storages more scientifically along small inland valleys in the gently undulating landscape, using the ground contours. When the landscape characteristics were conducive, this water infrastructure supported the evolution of small tank settlements and more advanced agricultural practices. With further technological advancements, building larger reservoirs became possible, ushering in an era of irrigated rice cultivation. This transition from subsistence-level rainfed farming (chena) to a more stable and prosperous agricultural

system—a state described as “subsistence affluence” (Panabokke, 2009)—underscored the transformative impact of VISs.

As multiple theories converge, it is evident that the VISs represent one of the oldest and most enduring forms of irrigation in Sri Lanka. They served as the foundation of the country’s ancient hydraulic civilization and remain integral to its agricultural heritage (see Figure 2).

Historical records lend further credence to the scale of this innovation. Siriweera (2000) states that, by 300 A.D., more than 150 tanks had been constructed. By 1300 A.D., this number had expanded to an estimated 15,000 tanks, many of which were either fully or partially functional, demonstrating the extensive legacy and inventiveness of Sri Lanka’s water management systems. This historical ingenuity underscores the pivotal role of village tanks as a sustainable water management solution that continues to support communities in Sri Lanka’s Dry Zone, offering a wealth of lessons for contemporary climate-resilient development efforts.

1.4 Dry Zone Landscape and Relevance to Village Irrigation

The Dry Zone landscape is characterized by unique vegetation and topography that shape its agroecological and hydrological systems. Fernando et al. (2015) describe the vegetation in this region as semi-deciduous. Flood plains and river valleys consist of riverine dry forests. The Zone is also home to distinct dry monsoon rainforests, with



Figure 2: Remnants of ancient irrigation management structures
a. Water depth measurement b. An ancient sluice structure c. Water flow measurement

mangrove dry forests in sheltered coastlines including estuaries and lagoons. Additional vegetation types include shrubland, grasslands, tropical thorn forests, degraded forests, and savanna (Perera, 2012).

Topographically, Sri Lanka is divided into three elevation ranges: low-country, mid-country, and upcountry. The land area lower than 300 m above mean sea level is defined as the low country, lands between 300 m to 900 m as the mid-country, and those above 900 m as the upcountry. The Dry Zone is located in the low country where the landform varies from flat to undulating terrain (Dassanayake et al., 2020).

These landforms have two types of influence on village irrigation. First, it defines soil drainage which varies from well-drained to very poorly drained (Dassanayake et al., 2020), influencing the type of crops and irrigation methods. Panabokke et al. (2002) note that the land surface, which varies from gently undulating to undulating, results in a large number of small inland valleys. Such topography combined with underlain impervious basement rock provides a good environment for building village tanks. It further influences the natural drainage pattern and the location of cascades. Therefore, VISs are not randomly located but are scientifically positioned in small watersheds defined by the landscape.

Panabokke et al. (2002) describe 70 river basins, fully or partially located in the Dry Zone, where small tanks are present. Furthermore, it is noted that about 90% of the tank cascade systems are concentrated in “main cascade zones” located in 27 river basins (Dharmasena, 2019). The density of tanks and the prevalence of cascades tend to decrease in the lower reaches of river basins, and the cascades are generally less prominent in river basins outside the main cascade zones. Therefore, not all small tanks belong to cascades.

1.5 Hydrology of Tank Cascades

The ancient builders of Sri Lanka’s irrigation systems demonstrated a sophisticated understanding of hydrology, applying the tools and knowledge available at that time. This expertise is evident in the strategic placement of tanks within cascades, with their sizes typically increasing downstream. The largest tank in the cascade is usually positioned at the lowest point, where it collects and stores drainage and spill water from

the upstream tanks. Each cascade drains into a common reference point of natural drainage course in a third or fourth-order stream (Sakthivadivel et al., 1997). Therefore, a cascade has a definite hydrological or watershed boundary. A cluster of cascades forms a sub-basin of a river (Sakthivadivel et al., 1996) or a sub-watershed (Panabokke et al., 2009). Several sub-watersheds form a river basin (see Figure 3).

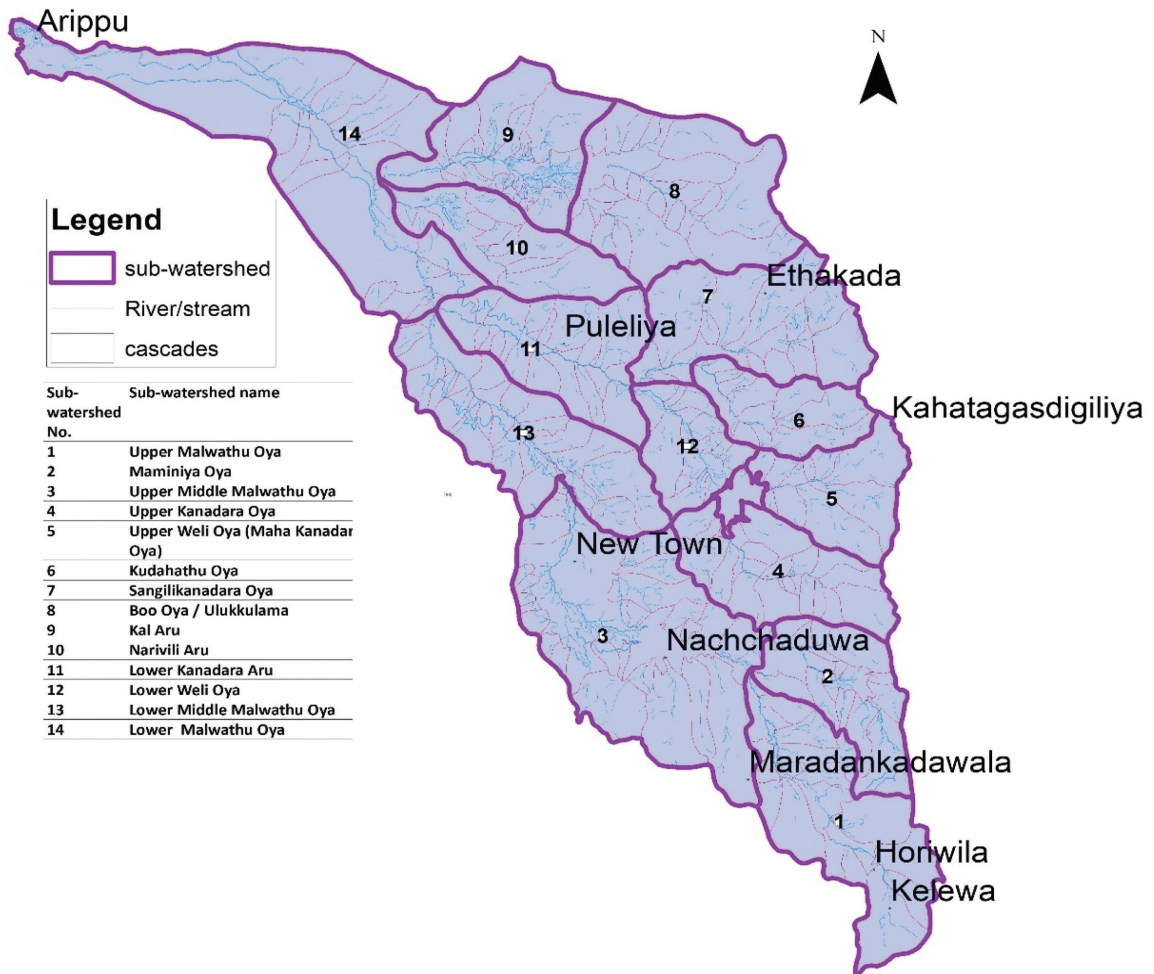


Figure 3: Cascades and sub-watersheds in Malwathu Oya river basin

Sources of data: Department of Agrarian Development (DAD) and Panabokke, 2000

Modern definitions of tank cascades emphasize their hydrological characteristics. Madduma Bandara (1985) describes the cascade as “a connected series of village irrigation tanks organized within a micro-

catchment of the Dry Zone landscape, storing, conveying and utilizing water from an ephemeral rivulet". Subsequent refinements to this definition have introduced key terminological adjustments proposed by various researchers. For instance, the term "meso catchments" has been proposed to describe the total watershed area of a tank cascade, while "micro-catchment" more accurately refers to the immediate catchment of a village tank. It was further recommended to replace the term 'ephemeral rivulet' with 'second-order inland valley or first-order ephemeral stream' (Sakthivadivel et al., 1996). Panabokke et al. (2002) note that first-order ephemeral streams are active only during the Northeast Monsoon (November to January) and briefly in March-April.

Following the decline of Sri Lanka's ancient hydraulic civilization, major state intervention in village irrigation systems recommenced during the British colonial period. However, limited attention was paid to hydrology concerning village irrigation. The collection of scientific data on village irrigation and applying scientific principles in the interventions were absent, hindering their sustainable improvement. To address these shortcomings, Kennedy (1993) outlined four criteria for selecting VISs for improvement. One of these was to estimate hydrological and meteorological data including an accurate estimate of the amount of water available in a normal year for irrigation and the maximum flood runoff that will be generated. It was noted that judgment based on training is necessary to set up this criterion because of the shortage of accurate data. Especially, the catchment area demarcation requires the experience and judgment of the technical person coupled with local inquiry because of the flat terrain. Concepts such as effective rainfall, catchment yield, a modified version of Dicken's formula for flood runoff, flood detention capacity, depth-area-capacity relationships, etc., which are relevant to hydrological calculations were introduced to guide irrigation improvements.

Hydrological analysis of VISs extended to include anicuts, with previous technical guidelines consolidated by Arumugam (1957). In subsequent years, Ponrajah (1984) presented a comprehensive guideline for analyzing "small catchments"—areas smaller than 50 square kilometers. This guideline remains an essential tool for hydrological assessments of village irrigation systems.





Despite these advancements, the development of village irrigation systems largely focused on individual tanks until the 1990s. A shift of focus toward tank cascades has been observed since the mid-1980s (Sakthivadivel et al., 1996). The initial attempts to analyze cascade water balance using hydrological tools included the pioneering research of Itakura and Abernethy (1993) and Itakura (1995). Their studies included a detailed water balance analysis of the Thirappane cascade in the Anuradhapura District, comprising six tanks. These studies incorporated the hydrological connectivity and socioeconomic relationships of the cascade's populations into their analysis—factors often overlooked in earlier assessments.

Building on this, Jayatilaka et al. (2001) developed a water balance model to predict water availability in tanks within a cascade to improve the productive use of water resources. Thirappane tank cascade was selected for this study, as well. The model incorporated variables such as catchment runoff, rainfall on the tank water surface, evaporation of tank water, tank seepage and percolation, irrigation water releases, spillway discharges, and return flow from upstream tanks, as water balance components. Simulations were conducted daily, using an Antecedent Precipitation Index to account for the catchment wetness and address the nonlinear dynamics of the runoff generation process. Tank water depth-related functions were derived to calculate tank seepage and percolation. Apart from providing a useful tool to determine the water availability for seasonal planning, the study derived equations for expressing seepage from the tank as a function of the relative water depth.

Another hydrological analysis of cascades hypothesized that the tanks in a cascade are “water storages formed with a series of bunds in shallow valleys of a small catchment” and it was a “regulating technique developed over time from the experience of peak flows with available technologies” (Perera et al., 2020). In this case, the definition focuses more on the cascade's flood mitigation capability. This analysis was conducted using hydrological software. The results show that a series of bunds in a shallow valley attenuate the peak inflows into the tanks. It allows tanks to withstand flood flows of a higher return period without breaching or overtopping the tank bund.

Further advancing this understanding, Imbulana and Manoharan (2020) conducted a detailed study of the Ranorawa cascade in the Anuradhapura District. Using the Water Evaluation and Planning (WEAP) software developed by the Stockholm Environment Institute, the study assessed the water balance under varying climate scenarios. The findings facilitate designing an optimum mix of solutions to address the vulnerability of smallholder agriculture.

Building on these insights, the CRIWMP identified the need to analyze more complex cascade systems, optimize their hydrological water balances, and improve surface water productivity. The project invested in developing a comprehensive cascade water balance model using the Vensim simulation environment to address this need. Based on the principles of System Dynamics, this model allows for a holistic understanding of water flows and interactions within cascade systems.

Currently, CRIWMP is developing surface water management plans for five cascades. When these plans are combined with the findings from groundwater studies the full potential of these cascades as climate-resilient systems can be assessed. Additionally, the project has distributed the cascade water balance model and a User Manual to relevant institutions, ensuring capacity building and broader application of these tools in sustainable water resource management.

1.6 Water and land use in a cascade system

1.6.1 Key Functions of Village Tanks

The construction of tanks within cascades enabled human life to continue during the dry periods of the year. Tennekoon (2001) identifies several key functions of these tanks and their associated land use (Figure 4), which collectively illustrate their multifaceted role in community life:

- Storing water at different locations of a cascade so that land use is maximized.
- Regulating flood flow during the rainy season and minimizing the risk of breaching downstream tanks during floods
- Providing irrigation for the crops
- Water supply for domestic uses and livestock

- Catering for the nutritional needs of the community through fisheries
- Groundwater recharge thus maintaining the quantity and quality of water in wells for domestic use
- Facilitating the growth of roots, nuts, vegetables, etc. during the dry period
- Providing grazing land for cattle in the upper tank bed during the dry period
- Providing water for wild animals
- Improving the micro-climate near the tank to sustain vegetation during dry periods.
- Enabling the growth of income-generating vegetation through wetland characteristics



Figure 4: Major functions of village irrigation systems

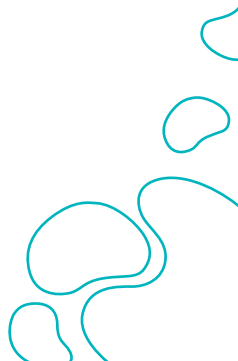
1.6.2 Diversity in Functions Performed by Tanks

While tanks serve multiple functions, an individual tank typically fulfills only a subset of these roles. Madduma Bandara (2007) highlights specialized types of tanks, such as those for wildlife, erosion control, and irrigation. Tennekoon (2001) elaborates further:

- Silt-trapping tanks (Kuluwewa): Located upstream of main village tanks, these small tanks trap silt, ensuring that spill water flowing into the village tank is relatively sediment-free. These tanks often dry out after the rainy season.
- Olagam tanks: Positioned on side slopes of the valley, these tanks lack nearby settlements and primarily support upland cultivation, livestock, and limited paddy cultivation during favorable seasons. They also serve as grazing lands during the cultivation season and act as a reserve water source for domestic use during droughts.
- Temple tanks (Pinwewa): Dedicated to meeting the needs of temple residents and visiting devotees.
- Water holes (Godawala): Shallow depressions upstream of Olagam tanks, providing water for wildlife, cattle, and groundwater recharge.

This intricate system of tanks reflects a carefully managed balance between water and land use, which Dharmasena (2019) describes as “an ecosystem where water and land resources are organized within the micro-catchments of the dry zone landscape, providing basic needs to human, floral, and faunal communities through water, soil, air, and vegetation with human intervention on sustainable basis.”

Priority of water use: Traditionally, the services of the village tank included domestic purposes and the needs of livestock, apart from irrigating the crops. The priority of water use is described as domestic water, water for the livestock, and irrigation, in that order (Panabokke, 2009). The literature further notes that the villagers decided to forego irrigation of the command area during water deficit periods and use the tank’s water for domestic uses. Thus, the social value of water use may have superseded economic values (Panabokke et al., 2001).



1.7 Governance, Management, and Institutions

1.7.1 Governance and Management

The foregoing discussion, which explained the community engagement in tank construction, variation of the functions between the tanks, flood and drought management capability, sustaining the large number of functions served by the tanks and Tank Cascades, and agreed priorities for water use, suggests the existence of a well-established management system and governance arrangements supporting it.

Even after the collapse of ancient hydraulic civilization in the 13th century (Panabokke 2009) the village tanks survived up to now (Panabokke et al., 2002). Ancient inscriptions describe some laws enacted by the king or regional rulers related to the operation and maintenance of village tanks, which were transformed into customs and traditions that survived the political upheavals of the kingdom. One such tradition was the “Rajakariya” system that provided compulsory labor for tank maintenance. The decentralized ancient administration system included a village council or “Gamsbhawa” as the lowest tier of the government. It was comprised of village elders and carried out local administrative matters including the construction and maintenance of irrigation works (Nanayakkara, 2017). It is also suggested that the caste system played a role in the management considering that the caste of villagers differed from the head end to the tail end of a cascade and the institutional mechanism must have addressed the complications arising from this, as well. Panabokke (2009) states that the villagers carried out the construction, operation, and maintenance of tanks considering the tanks as common property resources.

The Rajakariya system functioned during the Kandy period (1469-1815) as well. However, by this time, the system had evolved into a community-driven system, which may have been administered by the local nobles, focusing on village irrigation. During the British period, the “Rajakariya” system was abolished in 1832 (Abeywardana et al., 2018). One of the reasons for this action was the misuse of authority by local officials and the assumption that such abolition would help to motivate people for more intensive cultivation (Mills, 1933). This was followed by

the Colebrook reforms (1829-1832), which weakened the “Gansabhawa” system and pruned down its judiciary powers.

The ancient system of governance provided the peasantry with an organization for agriculture-based economic activities and interference by the state, as described above, resulted in an administrative vacuum. In addition, the traditional land tenure system was also reformed and the control of Buddhist monasteries over irrigation systems was reduced. All uncultivated lands including the forest lands within village boundaries were brought under the Crown (Abeywardana et al., 2018).

These changes were introduced without an adequate alternative governance arrangement. They resulted in the deterioration of irrigation systems and holistic management of tank, paddy, and forest areas including pasture lands. Eventually, the net result of these actions was the neglect of the peasantry by the State, and severe impacts on the rural economy and society. According to reports of Civil Servants of that time such as Skinner and Bailey, the peasants of Nuwarakalawiya were rapidly dying out through drought and disease. Those who survived were “sickly, apathetic, and too listless even to repair a small irrigation work” (Perera, 1955).

Several social and economic impacts at the national level were also noted. During the early periods of British rule, the government had to import “60,000 bags of rice” annually to meet the local demand. Furthermore, the rebellion of 1848 also highlighted the neglect of the peasants.

In parallel, the government adopted measures to resurrect the components of the ancient governance system. The “Gansabhawa Ordinance” was enacted in 1856 (Perera, 1955). Subsequently, the British introduced a village headman system to administer the village irrigation system. Later this title was converted to the “Vel Vidane” (a headman) in 1857 within a Village Committee system with more authority. This officer was sponisible for equitable water distribution among the VIS’s beneficiaries.

Accordingly, a substantial part of the tank-level management system had been resurrected since the middle of the 19th century. Therefore, literature on the management of the tank and its irrigation infrastructure is available. However, how water and other resources within the cascade

were managed is not well known. Madduma Bandara (2007) notes that “The early management systems buried in the historical past still remain poorly understood” and acknowledges that a tank-focused management system, compared to the management of a cascade, is easier to understand.

1.7.2 Institutional Development in the Post-Hydraulic Civilization Period

Institutional changes at the village level during the post-hydraulic civilization period were supported by significant legal and administrative enactments. The Paddy Lands Irrigation Ordinance of 1856 marked a turning point, followed by the forming of the irrigation section within the Public Works Department in 1860 (Jayawardana, 2015). Subsequently, the Central Irrigation Board was formed in 1884, with Provincial Irrigation Boards established in 1887 (Jayawardana, 2015), entrusting substantial responsibility for both major and minor irrigation works to the Government Agents (GAs), as well. Despite these efforts, only a portion of the long-standing neglect and deterioration of village irrigation systems in the Dry Zone could be addressed (Panabokke et al., 2002).

In 1900, the Irrigation Department (ID) was established, replacing the Irrigation Boards and assuming comprehensive responsibility for irrigation management. However, the Government Agent continued to play a significant role in managing minor irrigation works. The agriculture policy of 1932 further expanded the ID's role to include village irrigation. Following Sri Lanka's independence in 1948, the government shifted the department's focus toward major irrigation projects, such as the Galoya Development Project, to boost food production. The responsibility for village irrigation was transferred to the Ministry of Agriculture (Panabokke et al., 2001; 2002).

The Paddy Lands Act of 1958 assigned the newly formed Department of Agrarian Services (DAS) the responsibility for investigating, constructing, and maintaining village irrigation systems. However, the DAS's emphasis on implementing the Paddy Lands Act led to insufficient attention to the maintenance of minor village irrigation works (Panabokke et al., 2002).

The Agriculture Productivity Law enacted in 1972 transferred the

responsibility of village irrigation works to the newly formed Territorial Civil Engineering Organization (TCEO) (Panabokke et al., 2002). Although the TCEO had the technical capacity for this purpose and was decentralized, it is doubtful the expected benefits to the village irrigation sub-sector were delivered. This organization was abolished after five years, after a government change. Following this, the village irrigation works were briefly taken over by the ID in 1979 and again back to the DAS (Panabokke et al., 2002). The Agrarian Services Act No. 59 of 1979 redefined the latter's duties concerning VIS. The same Act specified minor irrigation works as those serving an irrigation command of 200 acres (80 ha) or less. From time to time, the government's responsibilities towards village irrigation continued to change in this manner.

The 13th Amendment to the Constitution of Sri Lanka further decentralized water-related responsibilities by transferring specific functions to Provincial Councils. These functions include:

- Managing irrigation systems not dependent on inter-provincial rivers.
- Rehabilitating and maintaining minor (village) irrigation systems.
- Overseeing agriculture, land use, land improvement, and settlement.
- Protecting the environment

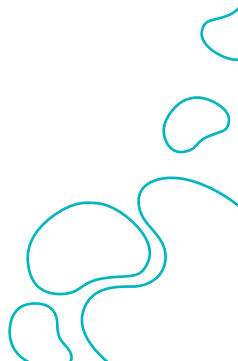
within limits set by Parliament.

However, implementing these functions requires that Provincial Council statutes receive Presidential endorsement (Imbulana et al., 2010). Consequently, the extent of village irrigation-related functions varies across provinces, while the central government retains a role in managing tank cascades associated with inter-provincial rivers.

1.7.3 Farmer Institutions

The preceding sections have highlighted the impact of state intervention on the management of village irrigation systems and farmer institutions. Legal enactments in recent decades have influenced these institutions both positively and negatively.

Amendments to the Irrigation Ordinance in 1951 and 1956 introduced





rules and procedures to ensure the safety of irrigation structures. However, these enactments provided limited recognition of farmers' roles in irrigation management and did little to promote the autonomy and self-reliance of farmer institutions.

The Paddy Lands Act of 1958 marked a shift by establishing the Department of Agrarian Services (DAS), which sought to enhance farmer engagement in managing village irrigation systems. Cultivation committees were formed under this Act, but their effectiveness was constrained by insufficient legal authority, limiting their role as robust farmer institutions (Panabokke et al., 2001).

The Agricultural Productivity Committees were introduced in 1971 (Wijekoon et al., 2016). However, these committees were heavily dominated by government officers, reducing farmers' active involvement and limiting the capacity of these institutions to serve the needs of farming communities effectively.

The Agrarian Services Act No. 59 of 1991 represented a more significant step forward by enabling the establishment of Farmers' Organizations (FOs) and granting them legal authority to undertake irrigation contracts. While this development strengthened farmer participation, forming Farmer Organizations (FO) based on village boundaries posed challenges for managing certain irrigation functions. These limitations were later addressed through subsequent reforms to some extent (Panabokke et al., 2001).

Despite these advances, the evolving role of farmer institutions underscores the need for policies and legal frameworks that empower farmers as active partners in irrigation management. Building the capacity and autonomy of farmer organizations remains crucial for ensuring sustainable and equitable management of village irrigation systems, particularly in the context of climate-resilient agricultural practices.



Figure 5A: A meeting of a Farmer Organization, Kadawala Cascade, Puttalam



Figure 5B: Field visit by DAD officers and CRIWMP team, Palugaswewa Cascade





*After rehabilitation
Kalawelapothana Tank, Divulwewa Cascade, Anuradhapura*

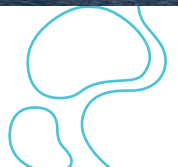
PROMINENT COMPONENTS OF TANK CASCADES

2.1 Cascade Ecosystem

Dharmasena (2010) lists important ecological components of the village tank system as tank bund, downstream reservation, upstream side ridges (soil ridges), high flood area including the tree belt and filter, upstream sediment trap, downstream drainage canal, village hamlet



Figure 6: Ecological services of a tank
Machichawa Tank, Aluthhalmillawa Cascade, Anuradhapura





and its buffer strip, shrub land, paddy fields, and paddy border zones. A more extensive list of such components is given in Geekiyanage and Pushpakumara (2013). These ecological components perform several essential services for the water management of the cascade.

Ratnayake, et al. (2021) discuss ecologically important micro-land uses of a cascade system and their ecological services. Some of the commonly listed and observed ecological services are listed below:

- The catchment upstream of the tree belt and above the High Flood Level of the tank, comprised of bushes and trees around the upstream, enables groundwater recharge and gradually releases water through subsurface flow when the tank water level goes down. It also helps to trap sediment and pollutants.
- The tree belt and undergrowth meadow. The strip of trees called the tree belt is located at the shoreline of the tank and functions as a wind barrier and reduces temperature and evaporation of the water body. The roots create a favorable environment for fish breeding. The meadow, consisting of grasslike plants and shrubs, functions as a water filter and traps the suspended silt from upland cultivations. This area also provides a habitat for birds and small wild animals.
- Upstream shallow tank bed performs functions similar to upstream catchment. It reduces the toxicity of water and creates a habitat for birds.
- Upstream water holes and forest tanks trap sediment and provide water to wild animals and domestic cattle during dry periods. Accordingly, it reduces the conflicts with wild animals. They also support groundwater recharge.
- Soil ridges upstream of the tank are useful to retard the velocity of surface water from the catchment, trap sediment, and reduce soil erosion.
- The dead storage of a tank retains some water after the irrigation season and helps to maintain the water level of nearby wells.
- Downstream reservation or Interceptor functions as a “natural bio-filter” and absorbs harmful pollutants and salts seeping from the tank bund to the paddy fields. It creates a habitat for salt-tolerant vegetation that sometimes has an economic value.

- The drainage canal facilitates agricultural drainage from the paddy fields removes salts and ferric ions and prevents water logging and salinization. They also improve the reuse of water through diversion structures and canals.



Figure 7: The vital role of the ecosystem in sustaining tank cascades

2.2 The Social System

2.2.1 Community Practices

The importance of the social system of cascades is well recognized. Its socio-ecological, socio-cultural, and socio-economic functions impact the livelihoods of the community associated with the system (Ratnayake, et al., 2021). Climate change, increased population, economic factors, and changes in social norms have affected the cascade's functions and sustainability. Some of these aspects relevant to the management of physical systems were included in the preceding discussion of the evolution of village irrigation.

There are some cultivation practices which constitute a part of the social system. They include “bethma”, which enables the redistribution of land plots in the command area temporarily among the landowners during water scarcity. “Kekulama” is the dry sowing of paddy seeds in the fields using early seasonal rains, and that practice allows water to fill the tank and make sufficient water available for the cultivation season (Dharmasena, 2020).

Old paddy fields are titled “Puranawela” and they are located close to the tank bund. It is noted that in the past only these land owners had the right to use tank water for cultivation. “Akkarawela” are new paddy fields developed after Puranawela. They are normally located downstream of Puranawela or on their slopes. Some of these lands originally did not have the right to use tank water (Takaya and Jayawardena, 1984).

2.2.2 Engagement of the Government Institutions

Numerous government institutions are engaged in the governance and management of VISs. The Provincial Irrigation Department (PIDs) and the DAD are the main institutions dealing with village irrigation. When a cascade system is benefitted from an inter-provincial river and the command area of a tank is larger than 80 ha, the ID is generally in charge of the tank. Similarly, some irrigation systems augmented by major feeder canals and diversion systems are managed by the ID. DAD provides several services to the farmer community and the FOs are registered under the Agrarian Development Act. Agricultural extension services are provided by the Provincial Department of Agriculture.

Cultivation (Kanna) meetings are officially chaired by the Divisional Secretary (DS), although in practice, this is often delegated to a representative. Other institutions providing different services to the farmer community include the Department of Wildlife Conservation, the Forest Department, the institutions handling inland fisheries and the environment, etc. The Circular No. 06/2023 of the DAD identified more than 20 government institutions that are relevant to the management of cascade systems.

2.2.3 Irrigation System and Physical Infrastructure

The irrigation system forms a part of the cascade ecosystem, as well. Generally, tank rehabilitation addresses the tank bund, sluices, and spillways. Some items occasionally overlooked are as follows:

- Link canals that link different tanks can be very effective in water sharing among the tanks.
- Drainage canals that serve several ecological services and help in water reuse.
- Access roads to key structures such as the sluice and spillway that need to be well-maintained for system operation and emergency response.
- Approach and tail canals to a spillway are important to maintain the designed flood flows to be conveyed efficiently.
- Diversion structures or anicuts, including small structures, that have a useful role in water management and contribute to water reuse.





*After rehabilitation
Aluthgama Tank, Rathmale Cascade, Anuradhapura*

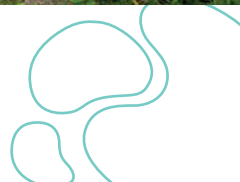
3.1 The Current Situation of Village Irrigation and Associated Rural Communities

VISs are one of the most vulnerable subsystems in the water sector to climate change. The VISs depend on local rains except in a few cases when augmented by stream diversions. This is a major reason for this vulnerability.

Past studies note that the cropping intensities of VISs are very low compared to major irrigation and the cultivation is generally confined to one (Maha) season (Dharmasena, 2019; Wickramasekara, 1984). Various reasons are cited to explain this situation. They include dependence on local rainfall, increased cultivated areas without a corresponding increase in water resources, inadequate rehabilitation strategies, deteriorated irrigation infrastructure (Figure 8), and prolonged droughts.



Figure 8: Deteriorated state of VISs



The deterioration of village cohesiveness and traditional organizations has made some components of the social system dysfunctional (Dharmasena, 2020). As a result, it is often found both Puranawela and Akkarawela (see Section 2.2.1) lands are being irrigated with equal priority, contributing to low cropping intensities and occasional conflicts when there is water scarcity.

Silting in tank beds is another major problem in village irrigation. A study in a selected sample of tanks showed storage capacity reductions ranging from 23% to 35%. Siltation contributes to increased water losses, changed tank bed geometry, and decreased cultivable area (Dharmasena, 2019). Another major problem with the decreased storage capacity of the tanks is the loss of flood and drought mitigation capacity.

Surveys showed that village irrigation infrastructure was substantially deteriorated and some village tanks were abandoned (World Bank, 1981). Panabokke (2009) notes that the percentage of abandoned tanks is very high with percentages of 35 (North Western Province), 48 (North Central Province), 54 (Southern Province), and 57 (Northern Province). Surveys conducted for the CRIWMP in 2016 found that almost all the VISs in the cascades selected for the project had physical infrastructure improvement needs (see Figure 8). Many reasons are attributed to this situation, including the lack of a proper maintenance strategy.

The same surveys found that the ecosystem described in Section 2.1 was also in a very deteriorated condition, thus preventing it from providing the necessary ecological services. There was no institution with a clear mandate to maintain and conserve the ecosystem. This situation has affected the sustainability of VISs as well.

By 2016, at the beginning of CRIWMP, the Department of Agriculture had published recommendations for crop selection on an agroecological region basis and a set of climate-smart agricultural (CSA) practices. Substantial research and development concerning drought-resilient, flood-resilient, and salinity-tolerant crops has been carried out. The need for new technology in the uplands to stabilize rainfed farming has been identified as well. However, the infusion of modern technology into VISs was insufficient, and the CRIWMP identified this as a key constraint to improving the productivity and incomes of farmers who benefit from village irrigation.

High incidence and spreading of Chronic Kidney Disease of unknown etiology (CKDu) in the Dry Zone affects the resilience to climate change impacts. This was first detected in the 1990s in Sri Lanka's North Central Province. However, considering limited economic resources and access to health services in the affected areas, there is a possibility of this disease being present before the first detection (Almaguer et al., 2014). Information obtained from the Provincial Renal Disease Prevention and Research Unit (North Central Province) in 2015 indicated that CKDu has affected 81 divisions in 11 Dry Zone districts and high prevalence was observed in Polonnaruwa and Anuradhapura districts.

While the root cause for CKDu has not been clearly identified, some degree of correlation between the disease, unsafe agricultural practices, and polluted water has been identified. Based on the research carried out in several countries, access to safe drinking water and environmental safeguards to prevent the pollution of water were identified as key interventions leading to the initiation of multi-sectoral collaboration to mitigate CKDu hazard in Sri Lanka (Jayatilake et al., 2013)

While there is a possibility of the population being exposed to these contaminants through food and drinking water, water hardness could have been a reason for getting affected by CKDu role (Almaguer et al., 2014)). The relevance of climatic factors has also been studied. Research shows that a combination of several factors contributes to the disease. The factors include: high ionicity of groundwater, higher daytime temperatures associated with climate change, inadequate drinking of good quality water while working under hot, sunny, and stressful work conditions, and alcohol consumption (Gunatilake, 2014).

These health problems have prevented farmers from productively engaging in livelihood activities, substantially increasing family medical expenses, and weakening the rural economy and farmers' ability to withstand losses from livelihood activities.

Before the impacts of climate change were felt, the farmers depended on their traditional wisdom to forecast dry periods and make water allocation decisions. However, in recent times, erratic rainfall and decreased predictability in rainfall seasons adversely affected their decision-making capability. It was observed that the dissemination of forecasted seasonal weather information to the irrigation system level

needs to be strengthened with technical capacity enhancement of the officials and FOs and better spatial coverage. Similarly, the accuracy of the forecasts had to be improved to ensure acceptance and timely action at the village level.

This situation results in a vicious cycle that can be summarized in Figure 9 in the following manner:

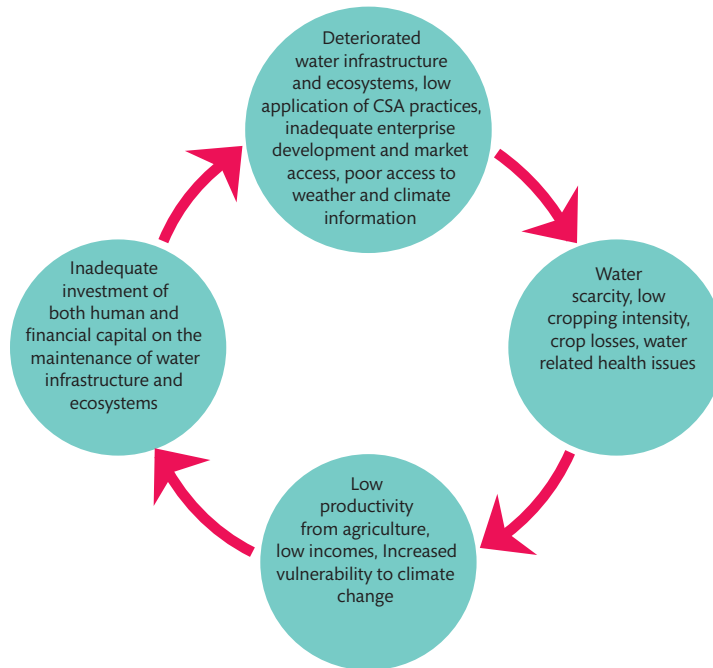


Figure 9: The vicious cycle of low productivity and climate vulnerability in village irrigation

This vicious cycle results in economic hardships, poor health and well-being, and climate vulnerability in the communities. On the other hand, it increases the State's burden of catering to community welfare burden, in terms of expenditure on rehabilitation, operation, and maintenance of irrigation systems, disaster recovery, and other subsidies. This situation needs to be rectified by improving the climate resilience of village irrigation-dependent communities.

3.2 Effectiveness of Past Interventions for Irrigation System Rehabilitation

After a long period of neglect, the state intervention in restoring VISs was initiated mainly in the British period. This effort was continued after the independence. A shift of focus to rehabilitation can be observed since the 1980s. Numerous interventions to restore, rehabilitate, and manage VISs have been implemented since then. Undoubtedly, these interventions have benefitted the village communities in obtaining continued water services from the VISs. However, literature has highlighted the need for improvement in the past attempts to improve climate resilience and sustainability of VISs and tank cascades.

Siriweera (2001) describes two important aspects that have been overlooked in village irrigation restoration in the 20th century. One was the interconnection of these village tanks with large reservoirs, canals, and subsidiary canals. The other was a mechanism for maintaining the small tanks and controlling siltation in the tank bed. It is noted that overlooking these aspects contributed to water shortages and associated hardships.

Panabokke et al. (2009) recommend that it is essential to give due attention to the use of direct rain or the 'green water' which is more efficiently utilized by rain-fed upland cultivation because the run-off collected and stored in these small tanks or 'blue water' is less efficiently utilized in paddy cultivation. It is noted that achieving a balanced use of both direct rainfall and the surface of small tanks stored in small tanks is the key to sustainable food production within a cascade. However, it can be seen that the objective of many rehabilitation projects was on the irrigated command and not on the entire cascade as a production unit.

The inadequacies of the development approach have been reflected in the performance of VIS rehabilitation and restoration projects. Dharmasena (2019) points out that renovation and rehabilitation efforts in Anuradhapura District have not significantly improved cropping intensity. Therefore, it is argued that the strategies employed to rehabilitate tanks and improve the water storage efficiency of tanks should be re-examined.

Inadequate post-rehabilitation maintenance (World Bank, 1981) affects the sustainability of investments in rehabilitation. Inadequate sense of community ownership of the rehabilitated irrigation infrastructure is cited as one reason for poor maintenance (Abeyratne, 1990). World Bank (1999) raised concerns about the sustainability of the rehabilitation benefits unless financial support for operation and maintenance (O&M) is increased.



Figure 10: Poor maintenance of VISs: a major constraint to their sustainability

Adopting a river basin approach for resolving the water-related issues in the Dry Zone has been promoted in literature for a long time. Arumugam (1969) stated, "For optimum utilization of water resources, the country's watersheds have to be well managed". Sakthivadivel et al. (1997) noted that irrigation system planning and modernization should be implemented within the context of the whole river basin. However, meaningful actions to incorporate village irrigation cascade systems into river basin planning are yet to be taken.

Other experts have noted the importance of studying and understanding the cascade hydrology and hydrological linkages among the tanks as essential to make the optimum use of water resources and to implement any modifications to the irrigation system (Sakthivadivel et al., 1996; Panabokke et al. 2002). Changing the hydrology of the cascade by increasing the storage capacity of selected tanks, expanding the irrigated command area, or diverting water elsewhere from the

cascade, the entire hydrology of the cascade is affected. The effect may not be very significant if the cascade is hydrologically well-endowed. However, if limited water resources in the cascade constrain meeting water demand, the downstream water users will be adversely affected. Therefore, the researchers recommend giving due consideration to the hydrological linkages in a cascade before any interventions are planned in an individual tank (Panabokke et al., 2002).

Panabokke (2009) notes the prominence of uplands in traditional cultivation patterns. A substantial part of the food requirements of the village was met by seasonal, rain-fed upland cultivation, and this mode of cultivation served as a buffer against the extremes of rainfall. It was an insurance against paddy crop failure during a water shortage, as well (Panabokke et al., 2001). However, individual tank and command area-focused interventions rarely incorporate uplands or home gardens in the intervention package.

Many rural development projects serve different sectors such as irrigation agriculture, roads, drinking water etc. However, agricultural practices and ecosystem management impact the quality and quantity of drinking water from local resources in a cascade. Moreover, it is noted that the Integrated Water Resources Management (IWRM) principles are engrained in the traditional management of cascade systems (Section 4.2.2). However, most sector-focused interventions do not incorporate such aspects that increase the effectiveness of interventions. The understanding of the inadequacy of such interventions in providing effective solutions to cascade systems resulted in several small-scale interventions focused on tank cascades.

3.3 Cascade-Focused Interventions and Lessons Learned

Plan Sri Lanka implemented the Cascade-based small tanks rehabilitation project in the Anuradhapura district in 2004-2010. The project was conducted in five small tank cascades in Mahawilachchiya, Nuwaragam Palatha Central, and Medawachchiya Divisional Secretariat (DS) Divisions. A Participatory Rural Appraisal (PRA) was conducted at the beginning of project implementation to identify the existing problems in the village and the irrigation system. The construction contracts were given to local FOs. The project had a component for watershed

management and provided training and awareness on watershed management, home garden development, and land improvement at the community and school levels.

Following this, the Hong Kong and Shanghai Banking Corporation Limited (HSBC) partnered with the International Union for Conservation of Nature (IUCN), to implement a project titled “Restoring Traditional Cascading Tank Systems for Enhanced Rural Livelihoods and Environmental Services in Sri Lanka”. The project targeted the Kapiirikgama cascade, covering 21 village irrigation systems spread over 2,391 ha, and developed a sustainable management mechanism with the participation of local communities and regulatory bodies. The project improved irrigation infrastructure and restored watersheds in several of the village irrigation systems with community mobilization.

A Global Environmental Facility (GEF) funded a small grant project in Anuradhapura District, focusing on rehabilitating the ecosystem around VIS. Implemented by South Asia Partnership (SAPSRI), activities include restoration of the immediate upper watershed and the downstream watershed, establishment of natural silt traps, improvement of home gardens (soil conservation measures, especially), inland fisheries, beekeeping, and market facilities for farm produce including active involvement of the community in all the activities. An external review found successful community engagement and mobilization in upstream catchment protection.

The Special Climate Change Fund (SCCF) funded a project titled “Strengthening the Resilience of Post-conflict Recovery and Development to Climate Change Risks in Sri Lanka”, which included measures to improve climate resilience through enhanced water storage and rational use, conservation of soil, improved crop choice, and infrastructural solutions such as roads, irrigation systems, and water supply. The main components include developing climate risk profiles, building the technical capacity of public officials to identify and integrate climate risk considerations in development projects, and adaptation actions in selected villages.

SCCF resources were used in the Maha Nanneriya cascade of the Mi Oya basin in Kurunegala District. The project also incorporated some design innovations to enhance climate resilience. Accordingly, a bottom-level

sluice (mud sluice) and the vegetative interceptor to draw out salinity and minerals from irrigation water were incorporated into the designs. The mud sluice is manually operated to let out the silt-containing bottom water layer just before the monsoon rains begin, to prevent long-term silt deposits.

Lately, the emphasis on environmental aspects and disaster management has gained prominence due to the increasing and visibly intensified cycle of floods and droughts. Accordingly, the NCP Canal Project (NCPCP), superseded by the Mahaweli Water Security Investment Programme (MWSIP), planned to augment around 1,100 village tanks, mainly in cascades, through a trans-basin diversion. This project focuses on Mi Oya-Hakwatuna Oya, Malwathu Oya, Pali Aru, Parangi Aru, Kanakarayan Aru, Ma Oya, and Yan Oya, and is expected to improve water security in those areas while minimizing adverse environmental and social impacts.

When the cascade-focused development interventions are studied, several positive aspects can be observed. In addition to rehabilitating irrigation infrastructure, upstream and downstream watershed and downstream watershed restoration and management, home garden development, soil conservation measures, inland fisheries, beekeeping, and market facilities for farm produce have been given attention. However, effective and sustainable institutional arrangements to continue with the cascade management were not observed. Considering the integrated nature of the cascade ecosystem, burning issues such as the inadequacy of good quality drinking water should have been addressed within a cascade framework. Most of the interventions focused on a single cascade, and observing a river basin-level impact was difficult. The large-scale cascade-level interventions envisaged under the MWSIP are still to be implemented.

3.4 The Need for Gender Mainstreaming

An assessment conducted for the CRIWMP found that women form the majority among the unemployed and the working poor, including landless workers, small-scale farmers, plantation workers, small and cottage industry workers, casual workers, construction workers, small traders, and domestic workers. Women are more vulnerable than men to enjoying a satisfactory quality of life in their old age as they are unlikely

to have accumulated adequate resources while their life expectancy is higher. In the age group over 15 years, female participation in the labor market was 34.7 percent compared to 74.6 for men (GCF, undated).

In rural communities, women traditionally manage household water, home gardens, and livestock. They also take care of children, the disabled, and the elderly. Their traditional role makes them more vulnerable to climate change and disasters, due to impacts on domestic water quality and availability, the health of family members, and the safety of domestic assets such as livestock. The 30-year-old civil war that ended in 2009 and still prevailing diseases such as CKDu had resulted in a high ratio of widows and female-headed households. Some women have chosen to be employed overseas, as domestic migrant labourers.



Figure 11: The traditional role of women in water management

Their vulnerability is exacerbated during extreme climate events and post-disaster situations. Post-disaster needs assessments following flood and landslide events in 2016 and 2017 showed that women were disproportionately vulnerable to negative post-disaster consequences. Flooding impacts women's livelihoods more than men's, and less effort was made to restore the former's livelihood activities after disasters. They sometimes have to travel long distances to find domestic water for drinking, sanitation, and hygiene, especially during droughts (Kolundzija,

et.al.2020). As their home gardens are usually not supported by irrigation, domestic food security is also affected during drought periods.

Women's participation in community work is very high, but only a few women take part in the decision-making process. It is rare to find a FO led by a woman. However, Community-Based Organizations (CBO) formed for drinking water supply schemes are becoming increasingly women-led. Comparatively non-restrictive social norms and low disparity of literacy levels between men and women in Sri Lanka provide a potential to increase their participation in water resources management.

3.5 Climate Change and the Need for Adaptation

The impacts of climate change have aggravated the problems and issues faced by Dry Zone communities. Increasing temperatures, increasing unpredictability of rainfall, prolonged droughts, and flash floods resulting from high-intensity rainfall decrease their climate resilience. As most VISs depend solely on local rain in the immediate watershed as the primary water source, the associated communities have become one of the most vulnerable groups.

As noted in the preceding sections, VISs were built to mitigate droughts and local floods. However, the preliminary surveys carried out for CRIWMP showed the vulnerability of VISs to flash floods attributed to high-intensity rains induced by climate change. High-intensity rains increase soil erosion and siltation of tanks, reducing the flood retention capacity of the cascade system. Degraded ecosystems in the upstream catchments and poor agricultural practices provide an enabling environment for soil erosion. The hydrological connectivity of tanks sometimes induces a chain reaction when an upstream tank is breached due to flooding. As a result, 1,950 VISs were breached due to the floods of 2012 and 2014 (MMDE, 2016).

The impact of damaged irrigation infrastructure extends beyond physical losses and restoration costs. Due to the multi-functionality of village irrigation systems, the village community is deprived of water for domestic purposes, livestock, fish production, and other related livelihood activities. Anecdotal evidence showed that families become destitute after a dam breach and there were no plans for survival till the tank was repaired and filled with water after the next rains. Due to the

dependence of groundwater on the surface water in the tank, a shortage of water for domestic use also occurs. This had to be addressed by government-supported water bowzers or private vendors. Sometimes the villagers had to sell their properties such as cattle and there was out-migration, especially the males for employment outside the village, which affected their family life (MMDE, 2016). Another serious issue is the degradation of cultivated land after a dam breach (See Figure 12). As such, there are long-term social and economic impacts from damage to the irrigation infrastructure.



Figure 12: A breached tank due to floods and its effect on agricultural lands

3.6 The need for a paradigm Shift in the Approach to Improving Climate Resilience

The vicious cycle of low productivity and climate vulnerability in village irrigation due to the current situation shows that cascade systems are not sustainable in the long-term. Considering substantial foreign investments are made to improve them, the negative impacts will affect the national economy, if the investments continue under the 'business-as-usual' scenario. Therefore, the situation calls for immediate action by the relevant institutions and stakeholders.

The literature discussed in the preceding sections demonstrates that the cascades have been an efficient water reuse system in the past.

Furthermore, the cascade systems of Sri Lanka were recognized by the Food and Agriculture Organisation of the United Nations as a “Globally Important Agricultural Heritage System” (Vidanage et al., 2022) in 2018. This recognition results from the cascade’s potential contribution to food security and sustainable development in the context of climate change (FAO, 2018). Therefore, their potential to improve climate resilience through better management is well established.

The preceding discussion shows cascades are hydrologically, socially, and environmentally linked. Therefore, as the experiences of past interventions demonstrate, sectoral approaches to improve village irrigation and tank-based interventions are less effective. This highlights the need for an integrated approach to the interventions. Furthermore, improving the coordination among numerous institutions involved in providing various services to the community is vital for the sustainability of interventions.

The need to address emerging issues such as climate change with a river basin approach in an integrated manner, the need for gender mainstreaming, and the doubts about the sustainability of the interventions in village irrigation due to the absence of formal institutional mechanisms at the cascade level, highlight the need for a paradigm shift in the actions to improve the resilience of cascade-based communities.

3.7 Key Barriers and Constraints

The main barriers to the needed paradigm shift for improving the climate resilience of the communities under village irrigation were identified as:

- a. Lack of an integrated approach to irrigated agriculture-based rural livelihoods that combines modern and traditional engineering techniques, climate-smart agro-technology, and farmer-friendly warnings and advisories that can be used for agricultural planning. It was noted that water resources development and planning of a cascade should be based on a management plan formulated at the cascade level

b. Inadequate funds for the following:

- improve and maintain rural water infrastructure and the ecosystems,
- to provide initial investments in Climate Smart Agriculture (CSA),
- to provide better drinking water facilities, and
- to improve the coverage of weather and hydrological monitoring stations.

It was noted that improving seed availability and market access is needed to enhance the use of CSA techniques. Investments were required for training, development of CSA packages, and knowledge management. As home gardens promote the role of women as income providers, such investments are cost-effective.

- c. Institutional weaknesses, including inadequacies in training and capacity to use the improved technologies for climate resilient agriculture, weather information, support for enterprise development, marketing support for farmers and producer groups, wildlife issues, and coordination between responsible institutions (MMDE, 2016). The absence of an institutional mechanism to bring together the water users and responsible institutions was identified as a constraint**





After rehabilitation
Gallewa Tank, Medderambawewa Cascade, Puttalam

OBJECTIVES AND STRATEGIES

4.1 CRIWMP's Goals and Objectives

The CRIWMP implemented with the funding support of the Green Climate Fund (GCF) can be considered a pioneering effort to use cascade-based village irrigation systems as a planning, development, and water management unit within a river basin to improve the climate resilience of the communities. The project design attempted to address the issues described above, such as changing cultivation patterns, deteriorated irrigation infrastructure and ecosystems, climate change impacts, and the need for an integrated management model at the cascade level. The project focuses on improving the climate resilience of smallholder farmers in the Dry Zone. The objective is to strengthen the resilience of smallholder farmers, particularly women, in the Dry Zone through improved water management to enhance lives and livelihoods (GCF, 2016).

The project is implemented in three river basins in the Dry Zone, Malwathu Oya, Yan Oya, and Mi Oya, which are more vulnerable to climate change. The studies leading to project formulation identified poverty, the incidence of Chronic Kidney Disease of Unknown Etiology (CKDU), and floods and droughts, as the main issues affecting the resilience of Dry Zone farmers. Accordingly, those factors were considered for cascade selection and defining the outputs.

The Ministry of Mahaweli Development and Environment initiated the project in 2017, with technical support from UNDP.

A special feature of the Project is a bottom-up approach involving farmers from the planning stage. The development approach can also be described as a good mix of traditional knowledge and modern technology. The interventions restore the traditional components such as the upstream tree belt, sediment filters, and downstream “interceptor” described in the preceding sections. On the other hand, the Project invested in improving the quality of weather predictions, converting weather advisories into improved agricultural advisories, and simulating complicated water balance in cascade systems with computer models.



4.2 Strategies Employed by the Project

4.2.1 Landscape Approach

The Food and Agriculture Organization (FAO, 2012) defines a landscape approach as one that “deals with large-scale processes in an integrated and multidisciplinary manner, combining natural resources management with environmental and livelihood considerations”.

Recognizing the intricate connections between the cascade ecosystem, human activities, and community and government institutions, the CRIWMP adopted this approach as the guiding principle. CRIWMP’s development model integrates natural resource management within cascades, emphasizing:

- Irrigated command, rain-fed lands, and home gardens are components of the overall production system.
- Surface water, groundwater, and ecosystems need to be conserved and developed recognizing their interdependencies.
- Demarcation of conservation areas for the sustainable management of the catchments, while ensuring the benefits from those areas to the community are unhindered.
- Livelihood improvement through agriculture, fisheries, livestock, and related industries.

This model brings together institutions across disciplines such as agriculture, irrigation engineering, environmental management, fisheries, and local economic activities into a cohesive form of engagement, fostering collaborative and interdisciplinary solutions

4.2.2 Integrated Water Resources Management

There are several definitions and their interpretations of IWRM. One of the frequently quoted definitions put forward by the Global Water Partnership is as follows: “IWRM is a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems”. (GWP, 2000)

The ancient traditional water resources management practices in cascade systems described in Chapter 1 closely conform to the above definition, although the traditional system slightly varies from some of the principles of IWRM introduced in the latter part of the 20th century. However, the lessons learned from the experiences of implementing IWRM during the past two decades show that such variations do not conflict with the broader concept of IWRM. For example, Merrey et al. (2004) pointed out that IWRM could be counter-productive if improving livelihoods and natural resources are not meaningfully included in the integrated approach. Similarly, GWP (2009) cautioned against treating IWRM as a “one-size-fits-all prescription” and emphasized that pragmatic, context-specific, and sensibly sequenced approaches are more likely to succeed. Implementing IWRM at a sub-basin scale, rather than at the broader river basin level, has been identified as a more practical and impactful strategy.

The integrated approach proposed by the CRIWMP is built on the traditional principles of integrated water resources management and lessons learned in implementing modern versions of IWRM. The design of project interventions considered the complex, but strategically important nexus between village irrigation systems, domestic food security, livelihoods, ecosystems, and safe and adequate drinking water availability, and the role of this nexus in improving resilience to climate change. It also recognized that the sectoral approaches to drinking water and irrigated agriculture are inefficient in providing comprehensive climate resilience in the cascades. Therefore, the cascade, which is physically integrated within hydrological boundaries, is well suited to implementing the interventions with an IWRM focus.

4.2.3 Targeting Criteria: River Basins

The project proposal was developed by a Technical Working Group (TWG) established under the leadership of the Ministry of Mahaweli Development and Environment (MMDE), based on a study titled “Strengthening the Resilience of Smallholder Farmers in the Dry Zone to climate variability and extreme events”. The UNDP provided technical support for this study.

During deliberations, the TWG emphasized a river basin approach is needed, with the tank cascade as the planning and development unit. It

was recognized that rehabilitation alone would not address the persistent issues in village irrigation systems. Therefore, the systems needed to be upgraded to enhance climate resilience.

The criteria used in the selection of river basins assigned priority to:

- The districts of high and medium vulnerability to climate change.
- Areas with high and moderate CKDu risk.
- The river basins with a high presence of village irrigation and cascade systems.

Accordingly, the TWG selected Yan Oya, Malwathu Oya, and Mi Oya river basins for the interventions. The administrative districts intersecting these river basins, namely Anuradhapura, Polonnaruwa, Kurunegala, Puttalam, Vavuniya, Mannar, and Trincomalee districts were targeted for extending the benefits where applicable. As a result, the project area encompassed parts of the North Central Province (NCP), Northwestern Province (NWP), Eastern Province (EP), and Northern Province (NP). The relationship between the selected river basins, CKDu risk, and climate vulnerability is illustrated in Figure 13.

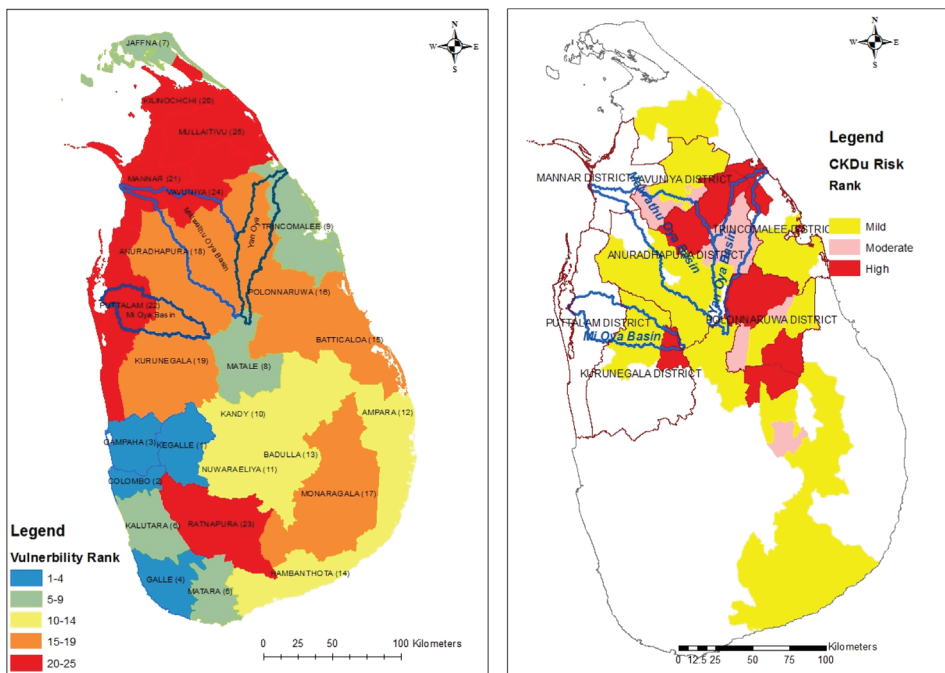


Figure 13: Selected river basins, climate vulnerability, and the incidence of CKDu
Source: MMDE (2016)

As noted above, the high percentage of VISs located in cascades was a criterion for the selection of river basins. The percentage of tanks located in cascades in these three river basins ranges from 83% to 92%. The percentage of tanks located in cascades in each river basin is shown in Table 1.

Watershed Name	Area Km ²	No. of Village Irrigation Tanks			No. of cascades
		Located in a Cascade	Isolated	Total	
Malwathu Oya	3183	1491 (86%)	240	1731	
Mi Oya	1561	1146 (92%)	96	1242	
Yan Oya	1529	618 (83%)	128	746	

Table 1: Percentage of tanks in cascades in selected river basins

The project design also noted that certain vulnerable groups, especially women, should be targeted in the development process. Surveys showed that the involvement of women and youth in water resources management is low and this was specifically addressed in the institutional developments. A major part of the targeted area was affected by the ethnic conflict, which influenced the vulnerabilities. Therefore, the interventions paid special attention to reducing the vulnerabilities of households that are:

- women-headed,
- disability-affected,
- resettled after the end of the conflict, or
- affected with chronic illnesses such as kidney disease.

4.2.4 Cascade Selection Criteria

Given the extensive number of cascades across the three river basins and the limited project budget, cascade selection for the CRIWMP was undertaken on a priority basis. For this purpose, the methodologies adopted by previous projects and research recommendations were scrutinized to explore the possibility of incorporation.

Perera et al. (2021) identified key criteria adopted by village irrigation rehabilitation and development projects between 1981 and 1997, which included:

- Command area: Projects often set lower and upper limits.
- Number of farmer families: Minimum thresholds were specified.

- Tank capacity: Minimum capacity thresholds were applied.
- Hydrological endowment.
- Proximity to settlements.
- Economic Internal Rate of Return (EIRR) and investment efficiency.

However, the CRIWMP was designed mainly to enhance the climate vulnerability of Dry Zone communities. Therefore, it was necessary to select the most vulnerable cascades. Hydrological endowment and better infrastructure facilities reduce the vulnerability and by selecting such a criterion, most vulnerable people would be left behind. Non-agricultural uses of village irrigation systems' water and their contribution to flood and drought management have been highlighted in the preceding sections, and they also had to be considered in the selection. Furthermore, it was necessary to relate the selection to the envisaged intervention areas; irrigation and agriculture, drinking water, and disaster risk mitigation.

Accordingly, the cascade selection process involved the following steps:

1. Primary Indicators for Vulnerability:

Indicators related to the project's three main intervention areas—irrigation and agriculture, drinking water, and disaster risk mitigation—were identified. These included:

- Poverty alleviation: Measured using the Poverty Head Count Index to prioritize interventions that improve livelihoods through better-functioning irrigation systems.
- CKDu prevalence: The percentage of the population affected by Chronic Kidney Disease of Unknown Etiology (CKDu).
- Flood impact: The percentage of the population affected by floods.

2. GIS-Based Analysis and Indexing:

These indicators, available at the Divisional Secretariat Division (DSD) level, were interpolated to the cascade level using Geographic Information Systems (GIS). The indicators were then normalized to create an index ranging from 0 to 3, enabling prioritization.

3. Initial Cascade Prioritization

A preliminary list of prioritized cascades was identified. Cascades with fewer than five Village Irrigation Systems (VISs) were excluded due to their limited significance in achieving a cascade-level impact.

4. Additional Ranking for Mi Oya Basin

The DAD ranking system developed for Mi Oya river basin was incorporated into the selection process.

5. Stakeholder Consultation

The preliminary cascade list was discussed with the district offices of key government partners. Adjustments were made based on their recommendations. For example, Palugaswewa (Horiwila), Sivalakulama (Malwathu Oya basin), and Medde Rambewa Wewa (Mi Oya basin) Cascades were added at the request of senior district officers. Initial consultations with community organizations were conducted at selected locations to identify the needed interventions.

6. Field-Level Validation

A rapid reconnaissance survey was conducted in the selected cascades to identify the most vulnerable and climate-sensitive areas. Adjustments were made based on inputs from the community and field-level government officers, finalizing the list of VISs.

7. Approval from District Agricultural Committees

The selected cascades (Figure 14) and their proposed annual programs were presented to the District Agricultural Committee, DAD, ID, and the PID. Final consent was obtained, ensuring alignment with local government officials and FO representatives.



Figure 14: Cascades selected for the CRIWMP



*After rehabilitation
Kelesiyambalawa Anicut, Thuduwakkakulam Cascade, Vavuniya*

KEY INTERVENTIONS AND INNOVATIVE APPROACHES

5.1 Key Interventions

The CRIWMP classified its interventions into four major focus areas to facilitate implementation through government and non-government partners:

- Improvement and upgrading of village irrigation systems (VISs).
- Climate resilient agricultural practices and expanding market alternatives.
- Enhanced access to and quality of drinking water in selected vulnerable areas.
- Improving the quality of weather and seasonal forecasting, early-warning systems, and strengthening dissemination and communication mechanisms for effective drought and flood mitigation.

The spatial extent of these interventions varied:

- The VIS upgrading was limited to the selected cascades.
 - Agricultural interventions extended beyond the cascades, within the financial constraints, to maximize impact.
 - Drinking water interventions extended beyond the river basin boundaries to the seven project districts, recognizing that groundwater aquifer boundaries often transcend river basin boundaries.
 - Weather and seasonal forecasting improvements were carried out on a river basin scale.
- 

To streamline project implementation, these four areas of intervention were grouped under three main outputs:

1. Upgrading village irrigation systems, including their watersheds, and scaling up climate-smart agricultural practices.
2. Enhancing safe drinking water supply and management.
3. Strengthening early warning, forecasting, and water management systems to enhance the adaptive capacity of smallholder farmers to droughts and floods (MMDE, 2016).

Despite the segregation of activities and outputs, the project proposal emphasized that the components and outputs should be considered elements of an integrated sub-basin/watershed-level water resource management plan.

The Project was implemented through a Project Management Unit (PMU) established under the then Ministry of Mahaweli Development and Environment (MMDE) and continued with succeeding Ministries, with technical support and quality assurance from UNDP. Details of this management structure and sector-specific information on the key interventions are described in other publications in this series.

5.2 Innovative approaches

5.2.1 Envisioned Key Paradigm Shift

The project proposal explains “The key paradigm shift of these recommendations derives from the approach at the VIS level, and at cascade level to address food security, watershed, and water supply management in an integrated manner”.

This paradigm shift reflects insights from professionals with extensive experience in village irrigation systems, emphasizing the need for integrated, multi-purpose interventions.

The interventions were designed based on the multiple services of cascade systems in the Dry Zone (discussed in Chapter 2), and their hydrological linkages. These services include:

- Economic benefits: Irrigating command areas and recharging groundwater to support agriculture.

- Social services: Supplying water for domestic use (drinking, bathing, and washing) and meeting livestock needs.
- Nutritional benefits: Providing supplementary food sources such as roots and fish.
- Environmental contributions: Cooling harsh climates and enabling groundwater recharge.
- Cultural functions: Supporting festivals and community rituals.
- Resource provision: Yielding fruit, fodder, firewood, and other materials essential for local livelihoods (MMDE, 2016).

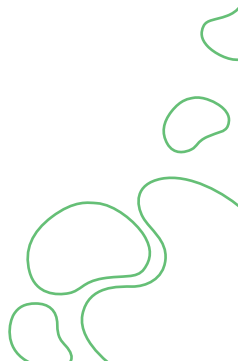
To leverage these multiple services sustainably and productively, the project framed the Cascade Water Resource Development and Management Plan (CWRD&MP), which integrates economic, social, environmental, and cultural services.

The cascade systems, comprising tanks, canals, catchments, and other components, are naturally integrated into the broader ecosystem. The hydrological linkages among Village Irrigation Systems (VISs) allow for efficient reuse of water, including:

- Drainage water from cultivated lands.
- Spill water from upstream tanks.
- Seepage and percolation water flowing downstream.

Therefore, a cascade is a system in balance, which can be adversely affected by any isolated intervention. For example, farmers often expand tank command areas to maximize irrigation potential. However, the linkages in the ecosystem result in upstream tanks' command areas serving as part of downstream tanks' catchments. An institutional mechanism at the cascade level could have contributed to controlling such encroachments. Therefore, an institutional mechanism was required to ensure the system balance resulting from the integrated physical system and its sustainable management.

This need led to the establishment of Cascade Management Committees, ensuring that governance structures mirrored the physical and functional interconnections of cascade systems, enabling the successful implementation of the CWRD&MP.



5.2.2 Main Elements of the CWRD&MP

The CWRD&MP was divided into seven subject areas to ensure effective implementation, each addressing specific aspects of village irrigation systems (VISs) and related components. These elements were designed to integrate seamlessly with the broader objectives of the CRIWMP.

1. Village irrigation system upgrading including hydrological studies incorporating updated climate science knowledge, specifications for water measuring structures, survey specifications, spatial information leading to demarcation of tank catchment boundaries, catchment characteristics, details of drainage canals, link canals, etc., construction standards and quality control guidelines, de-silting and disposal guidelines (including principles such as partial de-silting), and the recommendations for work to be undertaken by future projects. O&M of the system is planned based on the details of irrigation infrastructure obtained from VIS upgrading. Design guidelines or criteria addressing the project's objectives were prepared and included. In case all the farmer's expectations cannot be met, the additional requests beyond the project scope will be documented here for the reference of decision-makers and future projects.
2. The disaster response, operation, and maintenance sub-plan includes guidelines for recording and using village tank water level and rainfall information leading to rainwater conservation and optimum use, depth-area-capacity curves, seasonal cultivation planning using scientific data, operation and maintenance responsibilities of the Farmer Organization and Cascade Management Committee (including irrigation system and ecosystem) with relevant timelines, responding to extreme events, drainage management and re-use. This plan obtains information from VIS upgrading plans and links with agriculture development through seasonal water availability estimates. Responding to extreme events and O&M of VISs are included in the same plan because the same group of farmers conducts routine water management and attends extreme events.

The O&M section of this plan builds on the current O&M arrangements prepared by custodian government institutions and advanced hydro-meteorological information systems developed by the Project such as depth-area-capacity curves.

Reservoir operation guidelines presented in the O&M section enable the FO to make use of the area capacity curve developed under the VIS upgrading Plan. The plans for responding to extreme events will be based on the disaster-response guidelines and specifications prepared by the Ministry of Disaster Management/ Disaster Management Centre, and the plan shall be designed so that the information directly flows to the community and the relevant government organizations.

3. The agricultural development plan contains soil data, CSA advisories, suitable cropping patterns based on soil classification, modes of communication for climate and agricultural advisories, linking with the markets, etc., recommendations for new irrigation application technologies and suitable locations, recommendations and plans for value addition to agricultural production, rain-water conservation technologies for rain-fed land, guidance for fertilizer and agro-chemical application instructions and aquaculture/ livestock development. The cropping patterns and soil classification provided by this component are an input to the operation of the irrigated, rain-fed, and home garden cultivations. Moreover, on-farm water management techniques contained here, combined with improved operation of the irrigation system, form the surface water management strategy of the cascade.

Improved on-farm water management is an important component of the agriculture development plan. The strategy for improving on-farm water management includes plot consolidation and alternate wetting and drying (AWD) methods, the details of which are discussed in the sections below. The data required for the plan were obtained from market surveys and soil and land use surveys. Based on these, cropping patterns corresponding to the average, dry, and wet climatic conditions were planned to be developed. The plan outlines the modes of communication, responsibilities for receiving and disseminating agriculture and weather information, responsibilities for linking with the markets, etc. In addition, the plan amalgamates with Provincial and District Agriculture Plans.

The project proposal noted the need for a market-responsive cropping pattern. Reciprocally, responsive markets encourage adopting CSA techniques. Therefore, agricultural planning was

carried out at a larger spatial scale than a village to influence the markets.

4. Environmental management and catchment conservation strategies aimed to utilize the ecological services of a cascade for its sustainability. They used the spatial information obtained from VIS upgrading such as demarcated conservation areas and other conservation measures. These strategies include incentives for catchment conservation concerning the ecosystem goods and services, specifications for types of trees, micro-catchment management responsibilities of FO and Cascade Management Committee (CMC), measures to manage agricultural and domestic wastewater and improve reuse, and measures to manage wildlife issues. Structural measures include silt traps and erosion control measures. These activities help to control the sedimentation of the reservoir and improve groundwater recharge. It will link with the cascade's maintenance activities where the maintenance of environmentally sensitive components is specified. They also conform to the specifications laid down for groundwater management and drinking water source protection.

This plan was expected to be later linked to a river basin-level catchment conservation and management plan.

5. Drinking water management measures will identify the water sources, their potential to cater to community needs, water supply solutions with due consideration to long-term sustainability, community acceptance of the solutions, community willingness to undertake their construction and O&M, contribution to capital investment, and the preferred institutional arrangement for O&M and source protection. It also contains an institutional setup for the establishment and O&M of new water supply facilities, financial management procedures, and climate-resilient water safety and security plans. Through water source protection, this component is linked with environmental management and catchment conservation.

Building on a baseline survey, the measures provide a framework to establish and maintain water supply facilities in the cascade. The measures shall have adequate provisions for gender inclusion and the actions to be taken during a disaster, including flooding and drought.

6. **Groundwater management:** As the regolith aquifer in the Dry Zone is intricately linked with surface water, groundwater extraction, and recharging have to be scientifically planned to ensure the current surface water uses and the aquifer itself is not adversely affected. Groundwater management plan provides the basic information required for identifying the groundwater potential, recharge rates, safe extraction rates and well densities, and groundwater recharging measures where appropriate (see Box 1). It also contains aquifer information, groundwater elevation/storage variation, monitoring (quality and quantity), quality management, pollution prevention, advice for sharing between domestic water and irrigation, and operational rules. Thereby, this plan links up with drinking water management, agriculture development, and O&M of irrigation systems.

Box 1. Incorporating groundwater into cascade management

One of the innovative approaches of the CRIWMP was incorporating groundwater as a key item in cascade management. For this purpose, the status of groundwater in terms of the degree of deterioration of water quality and quantity was assessed as the first step. This assessment enabled deciding whether good management of the resources itself is sufficient or whether improvements to the groundwater condition are necessary. In the first case, a monitoring strategy was introduced to sustainably protect and maintain the groundwater quality and quantity with the involvement of the CMC and other stakeholders. In the second case, a groundwater improvement strategy based on hydrological and hydrogeological conditions of the cascade and appropriate cost-effective methods was proposed to the community.

Groundwater recharging

Groundwater recharging was implemented in cascades where improving the groundwater conditions was necessary. Different approaches and methods based on the sub-surface conditions were used to collect the rainwater and enable it to infiltrate into the ground.

Roof water and overland rainwater collection in agricultural lands and recharging the aquifers through contour drains, ponds, and infiltration pits are reliable and low-cost methods for village-level groundwater recharging. By introducing groundwater recharging in new community water supply schemes, both the quantity and quality of water sources were considerably improved.



Runoff tank – Mathavailthakulam Cascade, Vavuniya



Runoff tank (Pathas) – Anguruwella Cascade, Kurunegala

The project interventions including awareness programs and exposure visits related to groundwater management enabled to inculcate the community of a groundwater recharge culture in selected cascades. The observations of groundwater levels proved that improving the tank ecosystem including desilting improves groundwater recharging allowing conjunctive water use, thus demonstrating the wisdom of the ancient integrated water management system.

7. An institutional framework at the cascade level: The project proposed an institutional framework for cascade management to facilitate the implementation of management interventions in an integrated and sustainable manner and to ensure holistic water management. This framework was conceptualized as a Cascade Water Users Organization (WUO), which would serve as the primary entity for coordinating and executing cascade-level management activities. The need for an institutional framework at the cascade level is heightened by the absence of an institution with clearly assigned responsibility for planning and managing the cascade's groundwater resources and inadequate gender inclusion at the local level.

To ensure the continuation of this institutional setup after the project, it was envisaged that this institutional setup would:

- Be linked to an appropriate government organization.
- Obtain legal recognition to formalize its operations and enhance its authority.

The evolution and the progress of this institutional framework during the project implementation are elaborated on in Section 5.2.3. Furthermore, the linkages among different components of a cascade management plan, which are crucial to the cascade's integrated management, are further discussed in Section 5.4.

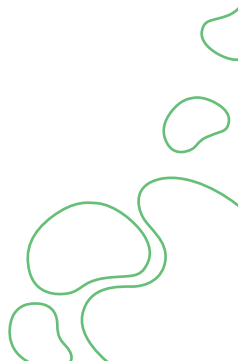
5.2.3 Cascade Management Committee (CMC)

A Technical Working Committee (TWC) was established during the project implementation to guide the cascade-level interventions. The TWC renamed the proposed institutional setup at the cascade level as the "Cascade Management Committee" (CMC).

The CMC was conceptualized as an institutional mechanism to implement CWRD&MP and integrate sectoral activities within cascades. The CMC incorporated existing FOs established under the Agrarian Development Act and other water-related CBOs operating at the village level.

The framework was structured to:

- Facilitate FOs and CBOs to operate within their mandates.
- Address productivity constraints, such as market access, agricultural planning, and climate advisory responses.



- Ensure coordination among water and land users across tanks within the cascade.
- Enhance emergency response mechanisms and minimize conflicts among stakeholders.

Incorporating Lessons from Previous Initiatives: The strengths and weaknesses of cascade-level institutional arrangements trialed in prior projects were carefully reviewed during the framework's development.

- Initially, several CMCs were informally established in selected cascades to raise community awareness about cascade management.
- A detailed institutional framework for the CMC was drafted in 2020, providing a model for other development projects of a similar nature.

The framework outlined:

- Responsibilities of the CMC and its office bearers.
- Links with FOs and other CBOs.
- Arrangements for the CMC to operate as a legally recognized entity.
- Financial management guidelines applicable to FOs, CBOs, and CMCs.

Sustainability and Legal Authority: To ensure the long-term sustainability of CMCs, the DAD issued Circular No. 06/2023 on 23rd August 2023, titled "Cascade Management Committee (CMC) Establishment and Continuity." The circular provides legal backing under the Irrigation Ordinance and the Agrarian Development Act.

Key features of the Circular include:

- An integrated approach to managing water and associated resources within a cascade.
- Duties and responsibilities of the CMC
- Defining the composition of the CMC including:
 - The Divisional Secretary as the CMC chairperson.

- Membership comprising FO representatives including women FO representatives, representatives from other relevant community organizations, and representatives of all relevant government agencies.

Establishing CMCs, together with CWRD&MP (section 5.2.2) represents a transformational approach to integrated water resource management at the cascade level. It lays a foundation for ensuring all stakeholders, especially marginalized groups, have a voice in decisions impacting their resources and livelihoods.

5.2.4 Stakeholder Engagement, Social Mobilization, and Civil Society Engagement

The project employed a multi-stakeholder approach to ensure inclusive, coordinated, and effective implementation. Core stakeholders included:

- The Ministry of Irrigation as the Executing Entity and the Implementing Partner.
- UNDP for implementation support including technical support and oversight.
- Relevant government ministries and provincial councils for implementation support.
- Civil Society Organizations (CSOs) for community mobilization.
- Private firms for infrastructure design and development and other required services.
- District-level coordination committees for localized project alignment.

This collaborative framework ensured the engagement of all relevant actors at different stages, fostering a responsive and integrated project execution. The other publications in this series comprehensively describe the project's management structure and its role in stakeholder engagement.

Stakeholder engagement was conducted across three main levels:

- National level – Guiding alignment with national priorities and strategies.
- Sub-national level – Engaging Provincial, District, and Divisional decision-makers.

- Community level – Facilitating grassroots-level engagement, primarily through CSOs.

The PMU under the Ministry of Irrigation, played a pivotal role in managing stakeholder relationships at all levels, with technical support from UNDP.

Community Engagement in Project Activities: Community engagement was a cornerstone of the project, with several participatory interventions designed to build local capacity and ownership. Some activities that promoted community engagement are as follows:

- **Participatory Climate Risk Vulnerability and Capacity Assessment (PCR-VCA):** This assessment enabled communities to analyze vulnerabilities and capacities while developing shared perspectives on natural resource management, agriculture, and disaster preparedness. The process provided the foundation for participatory planning and action at the cascade level.
- **Consultation Processes in Irrigation:** Through the Preliminary Investigation Report (PIR), communities participated in identifying infrastructure upgrading needs and priorities via walk-through surveys and facilitated meetings led by CSOs.
- **Participatory Monitoring Committees:** These committees were established to oversee:
 - Irrigation development activities.
 - Community-Managed Water Supply Schemes (CWSS).
 - Advanced purification systems and existing Rural Water Supply (RWS) schemes.
 - Monitoring progress, addressing site-specific issues, handling grievances, and accommodating community requests.

Community Participation in Project Quality Assurance: Community mobilization extended beyond awareness creation to serve as a mechanism for quality assurance throughout the project lifecycle:

- During VIS upgrading, Preliminary Investigation Report (PIR) meetings enabled the community to articulate their needs to designers.



Figure 15: Community engagement in planning development activities
Mamunugama Cascade, Kurunegala

- Ratification meetings ensured that proposed solutions were aligned with community needs and adhered to project standards.
- Participatory monitoring activities during the construction phase allowed the community to observe and ensure the quality of upgrading works, with necessary rectifications made collaboratively.

This continuous community involvement ensured a seamless handover of completed irrigation infrastructure and maintained the required quality standards.

Capacity Building and Technical Training: Capacity-building efforts included technical training for managing small and advanced water filtration installations. Target groups included:

1. Monitoring committee members.
2. FO staff and potential CBO personnel in new CWSSs.
3. Schoolteachers, students, and surrounding communities.
4. Staff of hospitals and health centers.

The government's contribution to community capacity building was notable, with inputs from:

- Department of Agrarian Development (DAD).
- Provincial Irrigation Department (PID).
- Provincial Department of Agriculture (PDOA).
- Department of Agriculture (DOA).
- National Water Supply and Drainage Board (NWSDB).
- Department of National Community Water Supply (DNCWS).
- Irrigation Department.

Community Mobilization and Civil Society Engagement: Community mobilization and civil society engagement were pivotal to the project's success. CSOs were instrumental in driving community-level engagement, fostering local ownership, and ensuring inclusivity.

Techniques for Community Mobilization: The project employed a range of culturally sensitive and innovative mobilization techniques, including:

- Awareness creation discussions to introduce the concepts of climate resilience and adaptation.
- Focus group discussions with selected community members to address specific needs.
- Street dramas and community discussions leveraging local cultural practices and events to convey key messages.
- Traditional ceremonies and other locally relevant activities to ensure broad participation and understanding of the community

To amplify these efforts, the project also organized provincial-level exhibitions highlighting the critical role of cascade systems in climate change adaptation. These exhibitions fostered a deeper appreciation of cascades among local populations and reinforced the importance of protecting these systems to enhance climate resilience.

Role of Civil Society Organizations (CSOs): Four Civil Society Organizations (CSOs) were selected to lead social mobilization efforts based on their evaluated capabilities. These CSOs served as critical

intermediaries between the project team and end beneficiaries, addressing local contexts and specific needs, effectively. The proactive role adopted by CSOs in addressing community needs ensured that the project effectively combined climate resilience objectives with economic sustainability. Their efforts contributed to a more inclusive and impactful implementation process, fostering strong community ownership and long-term sustainability.

Key contributions of the CSOs included:

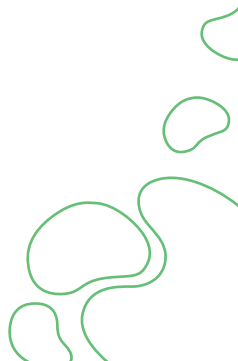
- Educating communities about climate change, adaptation strategies, and potential risks.
- Facilitating connections with potential buyers and markets to promote economic sustainability for agricultural products.
- Gender mainstreaming, ensuring equitable participation and benefits for women.
- Engaging government and non-governmental organizations at divisional and village levels.
- Overseeing the project's grievance redress mechanism up to the divisional level (see Section 5.3.2).

Flexibility and Tailored Strategies: Recognizing the limited initial knowledge about the specific requirements of cascade development, the mobilization budget was kept flexible. This adaptability allowed the CSOs to design and implement tailored engagement strategies incorporating location-specific unique cultural and geographical dynamics.

5.2.5 Gender Mainstreaming

Recognizing the critical role of gender in sustainable water resource management and climate resilience, CRIWMP developed a Gender Management Plan, with the following key elements:

- Strengthening women and women-led organizations to actively participate in Farmer Organization activities, including technical aspects such as water allocation and sharing, irrigation system upgrading, reducing chemical inputs, improving water use efficiency, selecting climate resilient crops, and implementing sustainable land management practices.



- Empowering women through education and engagement to address technical aspects such as planning, implementing, and monitoring water quality issues, protecting watersheds, monitoring rainfall and stream/reservoir levels, maintaining hydrological and meteorological equipment, agro-met information, and advisories.
- Engaging women in planning financing mechanisms, financial management, construction supervision, participatory rural appraisal, agricultural advisories, agriculture extension services, and water supply source protection.
- Supporting women and women-led CBOs on value addition, enhancing food security, and ensuring access to safe drinking water, particularly among their family units.
- Facilitating the capacity development of women's organizations to enable their transformation into water supply societies or enterprises.
- Providing rainwater harvesting systems at the household level for vulnerable groups, particularly women-headed households, elderly individuals, disabled people, and families affected by CKDu.
- Engaging women in disseminating flood warnings and water-related information, assessing flood risk, and developing disaster preparedness and response mechanisms for flood-prone communities.

Women's Role in IWRM: The project emphasized four key aspects of IWRM—environmental sustainability, economic efficiency, social equity, and water governance.

1. **Environmental Sustainability:** Women actively contributed to environmental conservation through training in soil conservation, water conservation, and ecosystem restoration activities.
2. **Economic Efficiency:** This was enhanced by equipping women with knowledge of agricultural technologies, including soil and water conservation, agronomic practices, and food processing. Women were also trained in:
 - Climate-smart agricultural (CSA) practices.
 - Water management and agriculture value chains.
 - Marketing, entrepreneurship, and business development.

3. **Social Equity:** Capacity-building and technical training for CBO staff enabled trained women to serve as resource persons in field-level training programs.
4. **Water Governance:** Women's decision-making capacity in water management was strengthened through targeted training on:
 - Technical aspects of water management.
 - Catchment restoration.
 - O&M of irrigation and community water supply schemes (CWSS).
 - VIS upgrading and cascade management.

The project developed a Gender Action Plan for mainstreaming gender and ensuring the project's gender responsiveness. This aimed to create an enabling environment for women to play a more significant role in water management and decision-making processes.



Figure 16: Capacity building of women for gender mainstreaming – Vavuniya

5.2.6 Private Sector Engagement

The project actively engaged the private sector to leverage its resources, expertise, and networks, ensuring a more sustainable and impactful implementation. This collaboration spanned multiple facets, from agricultural development to ecosystem restoration, demonstrating the value of public-private partnerships in achieving climate resilience goals.

Support for Farmers During the Pandemic: During the COVID-19 pandemic, the project launched a fundraising campaign to assist destitute farmers severely affected by the crisis. The private sector contributed significantly by providing:

- Cash grants.
- Agricultural inputs.
- Seeds of other field crops (OFC).

This timely support alleviated immediate hardships and enabled farmers to sustain their livelihoods during the challenging period.

Promoting Commercial Agriculture and Forward Sales Agreements:

The project facilitated commercial-scale fruit cultivation and established forward sales agreements in collaboration with agribusiness partners. These initiatives:

- Enhanced the participation of private sector agro-technology companies and private seed producers in training programs.
- Strengthened the capacity of farmers to adopt climate-resilient agricultural practices and improve knowledge management.

Private sector sponsorships provided resources for scaling up commercial agriculture development, fostering long-term economic sustainability for farmers.

Ecosystem Restoration and Biodiversity Conservation: The private sector also contributed to ecosystem restoration efforts within cascade systems. Key activities included:

- Providing forest plants for catchment restoration.
- Reintroducing keystone species to maintain ecological balance.
- Planting fruit-bearing forest plants in catchment areas to enhance food availability for wild animals, thereby minimizing wildlife damage to agricultural lands over time.

These contributions supported biodiversity conservation and environmental sustainability in the benefitted area.

Engagement in VIS Upgrading: During the initial phases of the project, the private sector was actively involved in irrigation infrastructure designs

to expedite project activities and avoid delays. Once the implementation mechanisms were fully operational, the responsibility for infrastructure design transitioned to government institutions.

Additionally, the private sector played a critical role in the construction activities under various project components, ensuring the timely and efficient delivery of infrastructure improvements.

Private sector engagement in the project enhanced resource mobilization and brought in technical expertise, innovation, and a results-driven approach. These contributions significantly amplified the project's capacity to address the implementation challenges in agriculture, water management, and ecosystem restoration. They reinforced the importance of collaborative efforts in fostering climate resilience.

5.2.7 Improving On-farm Water Management

On-farm water management is a critical intervention to enhance water use efficiency, improve water productivity, and strengthen climate resilience (see Box 2). The project implemented plot consolidation and the Alternate Wetting and Drying (AWD) method as key strategies to achieve these objectives. Given the complexities related to land titles and ownership in Sri Lanka, the project focused on consolidating the small bundled units (Liyadda) within individual farms rather than the entire command area in plot consolidation. Advanced machinery and laser levelling were utilized to minimize variations in land elevation, ensuring an optimal foundation for the interventions.

The efficacy of these strategies has been demonstrated both in Sri Lanka and internationally. Proper land leveling facilitates the implementation of AWD, as uneven terrain requires multiple water level measurements to ensure adequate irrigation. To monitor soil water levels, 30 cm perforated PVC pipes were installed in paddy fields, allowing irrigation to commence only when the water level fell to 15 cm below the surface.

Innovative Technical Solutions: The project introduced several technical innovations to enhance the impact of on-farm water management:

1. **Sensor-Light System:** Powered by a solar panel, this system emits a red light signal when the water level drops below 15 cm and remains active until irrigation reaches the desired level.



2. **Floating Indicator with Arrow Marker:** This device allows farmers to easily monitor water levels and take timely actions to prevent water deficits.

These innovations enabled farmers to make data-driven decisions regarding irrigation, improving the overall efficiency and effectiveness of water use in agriculture.

The strategies employed demonstrated the potential to:

- Increase crop yields and improve soil properties.
- Facilitate diversified cropping while reducing irrigation water use.
- Mitigate health risks by controlling mosquito breeding.
- Reduce soil erosion and improve land quality.
- Lower methane emissions by up to 55%, contributing to climate change mitigation (Anapalli et al., 2023).

Studies from various Asian countries have shown that when the AWD method is implemented scientifically, it can reduce irrigation water use by up to 38% without compromising yields. Furthermore, these strategies have increased farmers' income by 17% to 38%, depending on the irrigation techniques employed (Lampayan et al., 2014).

By combining proven methodologies with innovative technologies, the project has set a benchmark for sustainable water management and climate-smart agriculture, demonstrating its potential to transform rural livelihoods and contribute significantly to climate adaptation and mitigation goals.

Box 2:

Cascade water management: different strategies and innovations
Cascade water management methods employed by the CRIWMP cut across all three major project outputs. The activities included obtaining improved weather advisories from the Department of Meteorology, disseminating improved agriculture advisories to the community, improving off-farm water management, and introducing advanced techniques of on-farm water management.



An agro-met station established by CRIWMP

Improved seasonal weather advisories: A seasonal weather advisory issued by the Department of Meteorology was co-developed by the district officials to be more location-specific. This advisory was disseminated to the farmers at the cultivation meeting.

10-day weather forecast: This forecast was used to plan farm operations such as land preparation, agricultural inputs application, harvesting, and tank water operations.

Off-farm water management: The techniques included improved seasonal cultivation planning using tank water storage and seasonal weather forecasts, scheduling tank operations responding to short-term weather forecasts, and tank level manually-read rain gauge readings. The project also developed a technical tool to simulate complex cascade water management and applied in two cascades.



Manual rain gauge for irrigation management

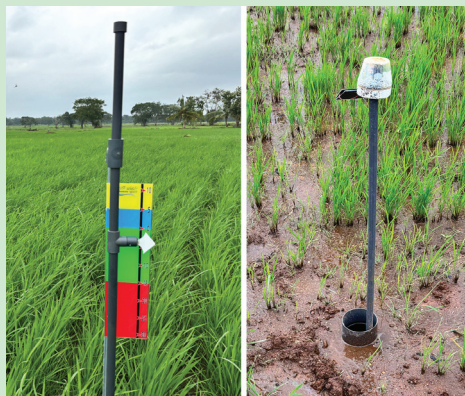


A farmer reading tank water depth

This intervention enables scaling up tank-level water management to the cascade level.

On-farm water management techniques: Alternate Wetting and Drying (AWD) and plot consolidation are the main technologies adopted by the CRIWMP to improve water use efficiency and the productivity of paddy cultivation. The project introduced several innovations to implement these techniques that could be useful for future projects. The innovations included:

- a. A sensor-light system with a solar panel as the power source, which emits a signal (red light) when water falls below a desired water level
- b. A floating indicator with an arrow marker to enable the farmer to keep track of the water level before reaching critical levels



Floating indicator (left) and Sensor lighting system (right)

5.2.8 Improving Off-Farm Water Management:

Scaling Up Tank-level Water Management to the Cascade Level: At present, water management in VISs is carried out mainly at the tank level. Recognizing the need for a more integrated and holistic approach, the project proposal emphasized the importance of scaling up water management to the cascade level. Upon implementation, the hydrological connectivity among tanks revealed the complexity of cascade-level water dynamics.

For instance, in the Thudduwakaikulam cascade in Vavuniya District, 33 tanks and 5 anicuts were interconnected through agricultural drainage and spill water flows. In some areas, the same water source was reused up to six times. This intricate system underscored the necessity of developing a water balance model that incorporated the unique hydrological linkages within each cascade, building on the achievements in this field

outlined in Section 1.5. This innovation enabled the formulation of cascade-specific water management and operation plans.

The improved off-farm surface water management introduced by the project was implemented in two distinct stages:

1. Seasonal Planning at the Tank Level:

- Using long-term meteorological data and assumptions for drainage inflows, a spreadsheet model was used for daily computations of tank storage and water deliveries (Warnakulasooriya et al., 2024).
- In the absence of flow measurement gauges due to delays in canal system upgrades, tank-level water balances were calculated using daily storage data. This approach allowed for the estimation of irrigation duties for each tank, which was subsequently used for seasonal cultivation planning and guiding farmers on irrigation efficiency.

2. Simulation Model Development:

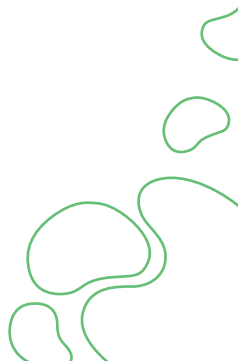
A Vensim Simulation Environment model was developed, applying system dynamics principles to study the behavior of dynamic systems (Gunasekara et al., 2022; Nandalal and Imbulana, 2022).

This model has been applied to two cascades, providing valuable insights into cascade-level water balances. It demonstrated potential for optimizing the use of limited water resources, enhancing agricultural productivity, planning VIS upgrades, mitigating floods, and devising cultivation season plans.

Current Applications and Future Potential: The simulation model is currently being applied to five cascades to prepare comprehensive surface water management plans. The insights derived from these models are invaluable for:

- Enhancing the efficiency of water use at the cascade level.
- Developing strategies for flood and drought mitigation.
- Improving agricultural productivity by optimizing irrigation practices.

By adopting a cascade-level approach, the project has moved beyond traditional tank-level interventions, setting a precedent



for integrated water management that balances hydrological, agricultural, and community needs in the Dry Zone. This innovative strategy fosters sustainable development and climate resilience in water-scarce regions.

5.2.9 Water sharing

The interconnected nature of cascades creates opportunities for transferring water to downstream tanks or anicuts when adequate water is available. However, village communities' strong sense of ownership regarding individual tanks often makes such transfers challenging. Although traditional customs exist for sharing water among uses such as domestic needs, livestock, fisheries, and agriculture, these practices lack formalized guidelines. To address this, the project developed a Water-Sharing Guideline as a part of the CWRD&MP.

Key Elements of the Water-Sharing Guideline are as follows:

1. Sharing Water Among Uses

While drinking water has traditionally been prioritized, the pipe-borne water systems built in certain areas (due to CKDu concerns) have shifted some of the demand. Similarly, livestock water needs vary based on location, adding complexity to water-sharing decisions.

- **Community Consultation:** Water-sharing strategies were developed through participatory consultations, ensuring they reflected local needs.
- **Inland Fisheries:** To sustain fish populations, a minimum water depth must be maintained in tanks. In the absence of locally established guidelines, international standards and technical tools such as simulation models were recommended to guide seasonal water allocation.
- **Options During Water Shortages:** The guidelines suggested strategies such as:
 - Land redistribution and sharing (bethma).
 - Modifying cropping patterns.
 - Ceasing irrigation to save fish populations or selling fish before water levels became critical.

2. Sharing Water Among Different Tanks and Anicuts

While limited literature addresses this issue, the project observed the critical role of link canals in water management within cascades. Specific recommendations for inter-tank water sharing included:

- Diverting water from upstream tanks to downstream tanks when:
 - The upstream tank's water level is at least two-thirds of its full supply depth.
 - Weather forecasts predict heavy rains within 24 hours.
 - The downstream tank's storage is less than 50% of its capacity.

The water-sharing arrangements were not fully implemented due to time constraints. The practical difficulties likely to be encountered in this arrangement are as follows:

- Any water-sharing arrangement should have the full consent of the farmer community, but there could be occasions where the opinions do not converge. The management's role should be to facilitate and guide the community.
- Most spillways do not have a gating arrangement, so releasing water at a depth less than FSL could be a problem. This difficulty occurs when the link canal is joined to the spill tail canal. If the link canal is connected to the irrigation canal or drainage canal, this situation does not arise.

3. Sharing Groundwater Among Different Uses

The groundwater management plan and disaster response plan collectively determine the priority uses of groundwater. Sharing groundwater among different uses depends on the water quality status, under normal conditions. However, the disaster response plan is also relevant to assigning priority during a drought or a flood. Therefore, these two plans have to be formulated together to avoid contradictions.



5.3 Quality Assurance, Safeguards, and Handling the Grievances

5.3.1 Quality Assurance and Safeguards

Information Sharing and Engagement to Ensure Transparency:

Providing accurate and detailed information about the project at all stages including planning, design, construction, and immediate post-construction stages was expected to prevent misconceptions and misunderstandings that could arise during the project implementation. It was noted that such information sharing would build trust between the stakeholders and the project, enhance transparency, and help incorporate local knowledge to make more informed decisions. Therefore, arrangements were made for a consultation process enabling information sharing, learning from feedback, and engaging the beneficiaries in the decision-making and implementation processes. This included a detailed list of works to be executed, provided to the beneficiaries in local languages after the designs are finalized.

Environmental and Social Safeguards: The PMU issued detailed instructions to the staff regarding environmental and social considerations during the construction period, quality control of earthwork and concrete work, health and safety at the work site, and considerations in diversions and dewatering. These instructions were designed to ensure social and environmental safeguards were uniformly implemented in the project area. Necessary gender considerations such as gender-sensitive sanitary facilities were also included in the instructions.

Technical Quality Control: Good quality and sustainability of infrastructure was maintained by providing detailed instructions for the following aspects:

- **Design of structures:** Following the guidelines of government intuitions such as the ID, DAD, NWSDB, etc.
- **Earthwork and Concrete Work:** Standards to maintain structural integrity and durability.
- **Diversion and Dewatering Activities:** Ensuring minimal disruption to ecosystems and surrounding communities during these activities

- **Monitoring:** Periodic monitoring was carried out with the custodian government institutions and the community

The role of government institutions in quality assurance is elaborated in other publications of this series.

5.3.2 Handling Grievances

The Grievance Redress Mechanism (GRM) was a critical component of the CRIWMP, ensuring that stakeholder concerns were effectively addressed while supporting the project's commitment to quality assurance. Potential areas for grievances were proactively identified and mitigated through strategic planning, community engagement, and effective communication. The key areas of potential grievances and the strategies employed to address them are detailed below:

Land-Related Issues: To minimize land-related disputes, the project strictly adhered to upgrading existing infrastructure without planning for new irrigation infrastructure or cultivating additional lands. Despite this, certain community activities had the potential to result in conflicts, including:

- **Cultivation in Tank Beds and Reservations:** Issues arose in areas below the High Flood Level (HFL).
- **Encroachment on Spill Tail Canals:** Unauthorized use or obstruction of spill tail canals created conflicts.
- **Unauthorized Construction:** Construction affecting the operation of irrigation structures was a potential source of disputes.
- **Access to Sites and Structures:** Community concerns about accessibility during and after construction were also noted.

These issues were mitigated through community awareness campaigns that educated stakeholders about project activities and their anticipated impacts, ensuring transparency and collaboration.

Disturbances from Construction Activities: Construction-related disruptions could pose challenges for local communities, including:

- **Labor Camps and Temporary Structures:** These could interfere with community activities.
- **Dust and Noise Pollution:** Generated during construction, this was a concern for nearby residents.

- **Transport and Safety Issues:** Temporary disruptions to transport routes and safety risks from machinery and equipment were highlighted.

Mitigation measures included developing detailed guidelines for contractors to minimize disruptions, maintaining clear communication with affected communities, and ensuring rapid response to any concerns.

Construction Methodologies and Structure Locations: Stakeholders could raise concerns about:

- **Construction Methods:** Preferences for specific methodologies (e.g., gabion walls versus retaining walls) and the usability of installed devices such as measuring tools.
- **Structure Locations:** Concerns about structures potentially inundating lands or affecting livelihoods.
- **Quality of Construction:** Concerns about construction quality (e.g., concrete mixes, foundation stability, and compaction standards) were foreseen.
- **Delayed Payments for Services:** Previous experiences showed service providers occasionally expressed grievances about delayed payments despite fulfilling contractual obligations.

To address these issues, participatory decision-making was emphasized, enabling communities to provide input during the planning and design phases. Adjustments were made wherever feasible to align with stakeholder expectations. Rigorous monitoring and quality control mechanisms were implemented. Community members and stakeholder institutions were involved in periodic participatory monitoring to ensure that project standards were met. To address likely grievances from service providers, the project ensured:

- Clear Contractual Guidelines providing transparency about payment schedules and conditions.
- Streamlined Payment Processes reducing delays through improved administrative systems.
- Offering formal avenues for service providers to raise and resolve payment-related concerns.

The project designed and implemented a three-tier Grievance Redress Mechanism (GRM) to address community concerns and ensure effective project implementation. The details of the GRM are outlined below:

Tier 1: Village Level

At the village level, the GRM was structured as follows:

- **Chairperson:** Grama Niladari (GN)
- **Secretariat:** A representative from the Project Management Unit (PMU), typically the Safeguard Specialist or Field Coordinator from the respective district
- **Other Members:** Economic Development Officer (EDO), Agrarian Research and Production Assistant (ARPA), and representatives from civil society organizations (CSOs), the contractor, and the consultant responsible for construction supervision
- **Community Representatives:** Farmers' organizations and local community members (with gender-balanced selection by the community during the Grievance Redress Committee (GRC) formation meeting. In the case of water supply schemes, the Village Coordination Committee (VCC) or the Executive Committee of the relevant CBO functioned as the first-tier GRC.

Tier 2: Divisional Secretary Division Level

At the divisional level, the GRM included:

- **Chairperson:** Divisional Secretary or representative
- **Secretariat:** Safeguard Specialist and/or Field Coordinator from PMU
- **Other Members:** Agrarian Development Officer, Agriculture Instructor(s), Divisional Officer or representative from the DNCWS, representatives of NGOs or CSOs active in the area, Grama Niladharis, and representatives from FOs and CBOs, as well as the contractor (site in charge) and consultant Religious leaders or clergy, the chairman/representative of the local mediation board, and representatives from the Forest Department and Department of Wildlife Conservation were included as needed, based on the nature of the grievance.

Tier 3: National Level

The third tier of the GRM included the following:

- **Oversight Bodies:** Social and Environmental Compliance Unit (SECU) and Stakeholder Response Mechanism (SRM) of UNDP
- **Independent Mechanisms:** The Independent Redress Mechanism of the GCF and formal legal processes within Sri Lanka

During the implementation of the GRM, the following categories of grievances were identified related to civil works:

- Quality of civil works
- Delays in rehabilitation and construction activities
- Communication gaps, including deficiencies in public consultations and the disclosure of meeting information
- Requests for additional works
- Damages or disturbances to public property
- Damages or disturbances to private property
- Delays, underpayment, and defaulted payments for goods and services
- Gaps in coordination, management, and administrative roles of stakeholders
- Disputes related to eligibility and entitlement to project benefits

This comprehensive approach to grievance redress aims to ensure transparency, accountability, and community engagement, fostering a collaborative environment for the successful implementation of the CRIWMP. By providing multiple avenues for addressing grievances, the project demonstrated a commitment to addressing community concerns in a timely and effective manner, thereby enhancing its overall impact on climate resilience and water management.

5.3.3 UNDP's Role in Quality Assurance

As a key technical partner, UNDP played a pivotal role in ensuring the quality and integrity of the project. According to the Funding Proposal (GCF, 2016), UNDP's quality assurance responsibilities included:

- **Compliance with Guidelines:** Ensuring adherence to the National Implementation Modality (NIM) guidelines and compliance with GCF and UNDP policies and procedures including the SRM and the standards of UNDP's SECU.
- **Monitoring and Oversight:** Conducting regular monitoring missions and participating in administrative forums to ensure the project met its quality and governance objectives. Details of these administrative forums and their outcomes are documented in complementary publications within this series.

5.4 The Model Adopted by the CRIWMP

5.4.1 Main Elements in the Model

The CRIWMP combined the key interventions and innovative approaches described in Sections 5.1 and 5.2 into a quality-assured implementation model. The main elements of the model are as follows:

- The conceptual model consisting of a cascade management plan and a cascade management committee described in Sections 5.2.2 and 5.2.3
- The implementation model consisting the engagement of stakeholders, civil society, and the private sector, and community mobilization for effective implementation of designed interventions Sections 5.2.4 to 5.2.8
- Strategies and measures to ensure the quality of work and social and environmental safeguards discussed in Section 5.3

The integration of various activities included in the conceptual model is illustrated in Figure 17 below:



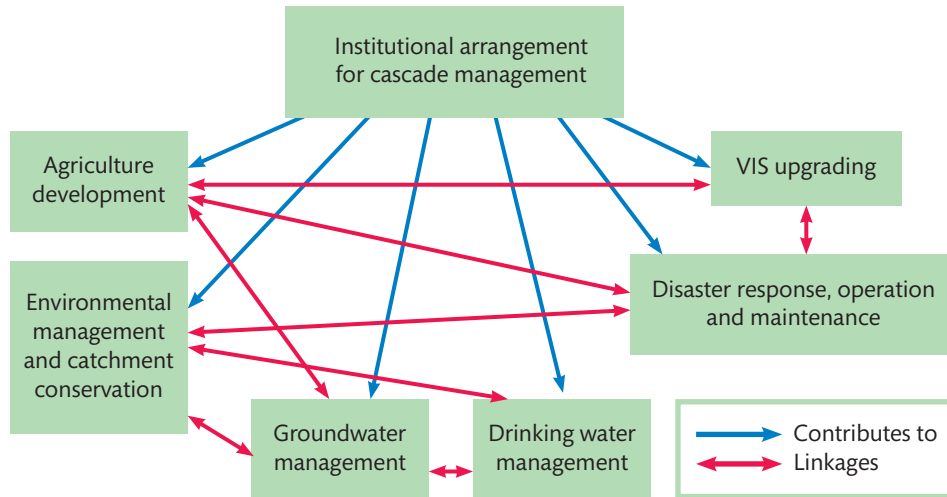


Figure 17: Linkages among different components of a cascade management

Figure 18 below illustrates the generalized stakeholder engagement model employed by the CRIWMP. It highlights the participatory mechanisms used to mobilize communities and engage stakeholders across key stages of implementation.

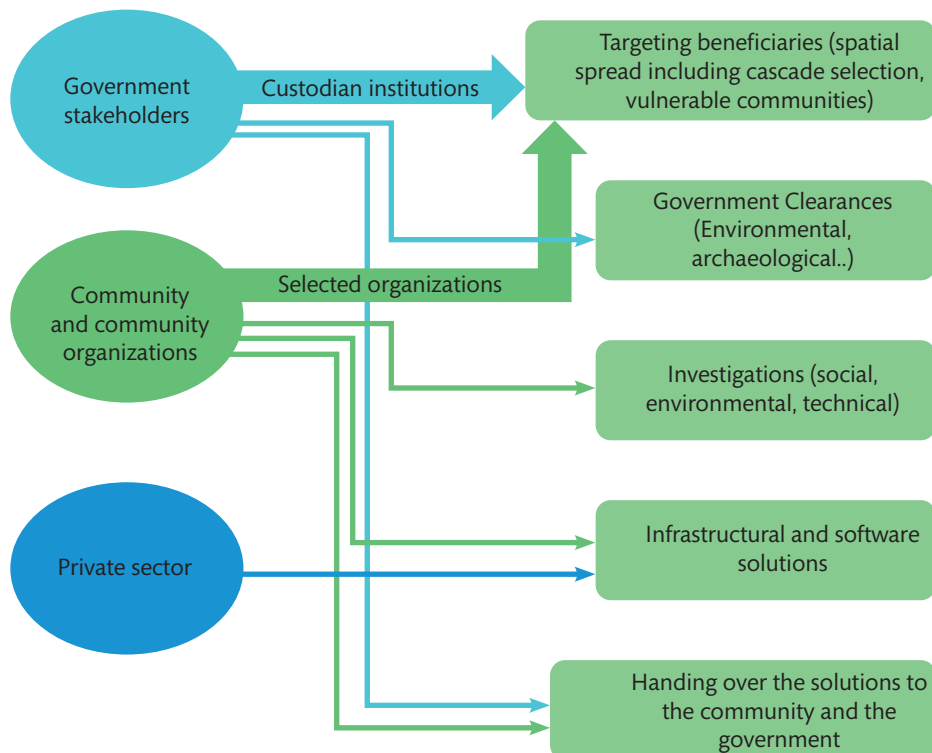


Figure 18: Implementation of stakeholder engagement

5.4.2 The CRIWMP model as a Mix of Traditional Knowledge and Modern Technology

The feasibility study conducted for the CRIWMP identified the barriers and interlinked causes impacting effective water and agricultural management. The degradation of the traditional upstream ecosystem surrounding village tanks, including the tree belt and sediment-trapping arrangements (see Section 2.1), has resulted in the siltation of tank beds, higher evaporation, and uncontrolled pollution ingress. Furthermore, pollution of the water bodies is exacerbated by inadequate ecological agricultural practices. The CRIWMP restored these traditional ecosystem components to the extent possible.

While the virtues of the traditional water management system and the ancient hydraulic civilization are well documented and acknowledged, the current social, economic, political, and climatic realities necessitate adaptation through modernization and technological advancement. Below, the challenges associated with this transformation and the solutions implemented through CRIWMP are outlined:

Transitioning from Subsistence Agriculture to Climate-Smart Practices: Traditional subsistence agriculture struggles to remain viable in today's competitive economic environment. To address this, the CRIWMP promoted climate-smart agriculture (CSA). However, the implementation of CSA faced limitations due to insufficient climate advisories, and the CRIWMP improved this situation. The increased unpredictability of monsoonal rainfall and shifting patterns necessitated providing enhanced climate forecasting and early warning systems. To improve productivity, especially outside the irrigated command areas, micro-irrigation techniques were introduced.

Enhanced Tools for Flood Management: Increased rainfall intensity has led to more frequent and severe flooding. The project developed advanced hydrological and hydraulic tools for integrated flood management to mitigate such impacts. A pioneering flood and water management simulation model was created, integrating a hydrological model, a hydraulics model, and a reservoir simulation model on a unified platform. This model, completed for the Mi Oya basin, represents a significant advancement in combining water management and reservoir simulation for river basin planning in Sri Lanka. The ID and the staff of University of Peradeniya played a major role in developing this model.



Cascade-Specific Hydrological Solutions: The intricate hydrological linkages unique to each cascade necessitated tailored solutions to optimize surface water use. A cascade water balance simulation model was developed and implemented, as detailed in Section 5.2.8. This approach ensured more efficient water resource management across the cascade systems.

Improving Access to Good Quality Drinking Water: Access to clean drinking water remains a critical constraint for enhancing agricultural productivity and climate resilience. To address this, the project introduced modern technologies such as pipe-borne water systems and advanced water filtration methods, improving community access to safe drinking water.

The CRIWMP's approach demonstrates the effectiveness of blending traditional knowledge with modern technological innovations to strengthen the resilience of communities in Village Irrigation Systems (VISs). Further details on these interventions are elaborated in the preceding and subsequent sections.





Catchment encroachment
Kolongaswewa Tank, Siwalakulama Cascade, Anuradhapura

6.1 Legal and Administrative Challenges

Several regulations and legal enactments are relevant to development activities in the cascade. They include:

- Forest Ordinance No. 17 (1907) and subsequent amendments necessitate any removal of trees to be sanctioned or cleared by the authorities at the district or national level depending on the extent of such removal. The clearance had to be obtained for the excessive forest growth on the tank bunds and other structures, for providing access roads, etc., especially when restoring abandoned tanks.
- The Fauna and Flora Protection Ordinance Act (1993) provides for the protection, conservation, and preservation of fauna and flora. Interventions similar to those listed above are required to obtain clearance.
- Antiquities Ordinance, No. 09 of 1940, Antiquities Act, No. of 1955, and subsequent amendments require development works to be cleared by the authorities of the Department of Archaeology.
- National Environment Act No. 47 of 1980, subsequent amendments and regulations specify the conditions to follow in development works to prevent adverse impacts on the environment.
- Pradeshiya Saba (Local Authorities) Act, No. 15 of 1987, subsequent amendments and regulations, Provincial Road Development Authorities of Wayamba, North Central and Northern Provinces, National Thoroughfare Act, No. 40 of 2008, and Road Development Authority Act, No. 73 of 1981 are relevant to the development activities in the cascades.
- Factories Ordinance, No. 45 of 1942, subsequent amendments, and relevant regulations specify the conditions of the employment of labor.

- Explosives Act no. 21 of 1956 and regulations under the act control the supply, purchase, use, and transport of explosives. This is applicable when a development activity requires the establishment of new quarries.
- Right to Information Act, No. 12 of 2016 specifies the rights of the citizen to project information.

These regulations enabled environment-friendly, safe, and transparent implementation of the project. The requirements of environmental and labour employment conditions were incorporated into the project documents including tender documents.

However, the large number of approvals and clearances and the time required for such clearances were a barrier to completing some of the development activities on time. Quite often the time taken for the clearances was out of the project's control and depended on the resources available with the agency providing the clearance. The boundary of archaeological zones is vague and some of the archaeological remains were found only during surveys. Some of the tank bunds being used as public roads was a challenge, as well. Providing the road width and pavement conditions required for public roads resulted in unanticipated cost increases on VIS upgrading. Moreover, there is no procedure for the cascade community to be compensated for providing a public service outside the cascade area.

6.2 Challenges in Community Mobilization

There is a limited availability of experienced mobilization experts dealing with this subject. As such, the social mobilization strategy of a development project should be designed as a flexible and adaptive process, incorporating learning-by-doing as a foundational approach.

Other challenges in community mobilization included the following:

- Aging of the population engaged in agriculture and inadequate youth engagement
- Conflicts with wildlife, especially human-elephant conflicts, which led to out-migration by the community
- Racial and caste differences within the Cascade community

- Inadequate technical capacity of social mobilizers
- Language differences
- Inability of the project to provide comprehensive solutions to community problems outside the scope of the project. Some examples were the poor quality of public roads and other essential services.
- The current status of incomes from agriculture does not exert enough “pull” to keep the private sector and youth attracted

Some of these issues are elaborated in Box 3.

Box 3. Challenges in Social Mobilization

Socio-economic issues prevalent in some cascades posed several challenges to community mobilization. Some specific issues are discussed below:

The majority (80%) of the farmers in Bandara Kumbukwewa cascade were 65 years or older. As such, the participation in meetings was low. Furthermore, their interest and enthusiasm in technical matters such as water management and climate-smart agriculture, which are essential to ensure climate resilience, was low. Moreover, the land-to-farmer ratio in paddy lands in this cascade was about 15 acres to one. It implies that an average farmer has a large land holding (in terms of village irrigation) and therefore, the farmer is heavily occupied in agricultural work.

There were several reasons for this situation. During the civil war, this cascade was located close to the war zone. Attacks by the rebel groups forced some farmer families to leave the village temporarily, and some of those who settled in safer locations did not return. Another main reason for out-migration is human-elephant conflict which result in loss of life and property.

Racial and caste differences in some cascades were a constraint to bringing the community together in a cascade management plan. Although the caste system is not recognized legally, it was found that such considerations are a part of social life in some rural areas. Although the caste system could have contributed positively

to water resources management in the past, it is a deterrent for the same purpose now. Such issues were observed in Sivalakulama, Mathavuvaithakulam, Ratmale, and Medde Rambewa cascades.

Inadequate technical knowledge among social mobilizers was another challenge. Some cascades consisted of farmers speaking different languages and that also posed constraints to effective communication.

Several lessons were learned from these experiences. Socio-economic screening of the cascade should precede the implementation of solutions. Such studies should capture the willingness of the community to change and adapt. When a project is heavily technology-driven sufficient training should be provided to the social mobilizers in advance. Another major lesson is that human-wildlife conflict has to be addressed through a national strategy.

Despite these issues and constraints, it is heartening to note improved water management and climate-smart agricultural practices being adopted in cascades such as Sivalakulama and Madde Rambewa, showcasing the success of community mobilization efforts.



6.3 Challenges imposed by the inadequacy of technical data

- **Weather Forecasting:** Existing weather forecasts typically provide qualitative information, such as patterns described as “normal,” “above normal,” or “below normal.” Farmers, however, require actionable insights, such as the extent of cultivable areas based on forecasted weather patterns. Therefore, the lack of a reasonably accurate range of rainfall values linked with the weather forecasts was a challenge to meet farmers’ expectations.
- **Establishing Cascade Boundaries:** Defining cascade boundaries posed significant challenges due to minimal elevation differences and the influence of human interventions. Topographical maps alone were insufficient, and advanced technologies like drone surveys were prohibitively expensive. Furthermore, minor topographical changes, such as rural roads, culverts, and built-up areas, can change the catchment boundaries. Therefore, cascade boundaries were eventually established using both topographical data and physical observations.
- **Hydrological Linkages and Cascade Development:** Despite the DAD demarcating cascade boundaries in major river basins, local interventions such as link canals altered hydrological linkages, often increasing the number of VISs in a cascade. As the budget was linked to the number of VISs, this complicated the process of pre-establishing the number of cascades for development.

6.4 Challenges in Gender Mainstreaming

While the CRIWMP actively encouraged women’s participation in its training programs and activities, several challenges were encountered:

- **Low Representation of Women Officers:** The limited number of women in relevant officer categories and institutions resulted in fewer women participating in capacity-building programs.
- **Domestic Responsibilities:** Women’s attendance in project activities, including water resource management initiatives, was hindered by their preference for or prioritization of domestic responsibilities.

6.5 Risks and Their Management

The CRIWMP proactively identified key risks during the project planning phase, enabling the design of effective mitigation strategies. These risks included:

- Limited capacity among stakeholders to implement integrated solutions.
- Inadequate O&M and financing for the O&M of community-managed interventions.
- Limited coordination among stakeholders.
- Delays in infrastructure completion due to changes in seasonal rainfall and construction material shortages.
- Climate shocks affecting project investments.
- Risks from sediment movement, waste production, and grievances.

Mitigation Measures

- **Capacity Building:** Tailored programs enhanced stakeholder capacity for integrated water management, ensuring long-term project sustainability.
- **Operations and Maintenance:** O&M plans were developed through participatory processes, with duties assigned to individual farmers. These plans were supported by capacity building, training, and the provision of essential O&M equipment. Financing mechanisms for O&M were integrated into the CWRD&MP.
- **Coordination Mechanisms:** National, subnational, and community-level committees, alongside regular stakeholder meetings, strengthened coordination. CMCs played a vital role in sustaining collaboration post-project.
- **Climate Shock Responses:** Enhanced weather forecasts and the development of standard operating procedures (SOPs) for tank management reduced the impacts of climate variability. Scientific disaster response measures were integrated into O&M plans to bolster resilience.
- **Environmental and Social Safeguards:** Sediment movement, waste production, and other environmental risks were mitigated

through robust safeguards. A grievance redress mechanism (detailed in Section 5.3.2) ensured transparency in addressing community and stakeholder concerns.

Unanticipated Risks

Unforeseen challenges such as the COVID-19 pandemic in 2021 and the subsequent energy and economic crises in 2022 and 2023 posed additional risks. These external factors impacted project timelines and resource availability. Specific risks related to the implementing modality and various project components are detailed in other publications in this series.

Despite these challenges, the CRIWMP demonstrated resilience through adaptive planning and implementation, contributing valuable lessons for future climate-resilient water management projects.

6.6 Wildlife-Human Conflicts

One of the most pressing challenges to sustaining agriculture in Sri Lanka's Dry Zone is the escalating wildlife-human conflict, particularly the human-elephant conflict. This issue was acutely felt in nearly all project cascades, with notable prevalence in parts of Kurunegala, Puttalam, Anuradhapura, and Vavuniya Districts. Crop damage caused by elephants severely hindered community mobilization and investment in agricultural innovations, undermining the project's efforts to foster resilient livelihoods.

Damage to critical water measurement structures was another significant concern. Frequent destruction of these structures by wild animals strained farmers and authorities, who lacked adequate financial resources to undertake recurring repairs.

Recent research highlights that traditional subsistence characteristics of village-irrigation-based agricultural systems have undergone significant transformations. The commercialization of rainfed cultivation has led to the continuous, intensive production of a narrow range of high-demand crops, replacing the traditional "periodic cultivation of diverse crop mixes for household subsistence" (Fernando et al., 2015). This shift has exacerbated wildlife-human conflicts, as traditional practices, such as shifting cultivation (chena), periodically left fallow lands available



for wildlife feeding. The decline in such practices, combined with an increase in the elephant population, has intensified crop damage and escalated tensions between human and wildlife needs.

The project invested in restoring forest tanks to provide water for wildlife, believing it would keep the wild animals in forests, reducing the crop damage by wild animals. However, evidence is insufficient to confirm the efficacy of forest tanks in reducing elephant incursions into agricultural areas. Similarly, increasing the cropping intensity and conversion to perennial crops are recommended for climate resilience. But those interventions could also contribute to the intensification of conflicts with wildlife. The combined effort of the authorities and the researchers is needed to resolve the issue because otherwise, many interventions for climate resilience in agriculture are unsustainable.





*Experience sharing with farmers, stakeholders, and project team
Palugaswewa Cascade, Anuradhapura*

LESSONS LEARNED

7.1 Need for a Baseline

A set of baseline information is useful to evaluate the project's performance. The baseline should comprise social, economic, environmental, and technical information. As noted in the concept paper prepared for CWRD&MP, its first step is collecting baseline information. This would include water quality data, groundwater resources, surface water sources, drinking water sources, drinking water issues, cropping intensities, productivity information, basic marketing information, and other disaggregated socio-economic information, which were expected to be gathered during the Project's Baseline survey. Water quality data may include those from existing databases of NWSDB and WRB and may have to be supplemented with sample surveys when the former is inadequate.

Different components of the project such as VIS upgrading, CSA, drinking water, and disaster mitigation collected a major part of originally conceived baseline information. However, supplementing such data with a comprehensive baseline survey, to cover subject areas such as groundwater, is needed. One of the major reasons for the project's emphasis on ecosystem restoration including upstream reservation, dead storage, etc., and restoration of abandoned tanks, was to improve groundwater recharge, among other reasons. Although groundwater management plans are currently being prepared for each cascade based on the present field data and data from stakeholders, the lack of spatial and temporal distribution of groundwater before the project interventions constrained the assessment of the benefits of ecosystem restoration.

Therefore, the baseline survey should be planned to assess the achievement of the expected benefits and key performance indicators.

7.2 Prominence Assigned to Software Components

Post-evaluations of several projects (please see Chapter 3) have noted the inadequate emphasis on software components of projects such as institutional development and water management. In such situations, projects run out of financial resources and time to implement them, adversely affecting the sustainability of the benefits of such projects. One of the lessons learned from previous rehabilitation works is that physical improvements should be preceded by institutional and agricultural policy reforms (World Bank, 1981).

The CRIWMP experience underscores the importance of initiating institutional development—such as forming community organizations—concurrently with physical interventions. Particularly, interventions such as converting paddy areas to OFCs, plot and land consolidation, and the AWD method, influence the design of irrigation canal structures. Therefore, drafting agriculture plans and water management strategies before the irrigation canal system designs is important. An example of this kind of project planning is the USAID-funded Irrigation System Management Project conducted in the late 1980s, which conducted a “diagnostic analysis study” to investigate the deficiencies of the irrigation system before the structural designs and physical improvements.

7.3 Cascade Selection and VIS Selection

The experience during the project implementation showed that the cascade selection methodology adopted by CRIWMP was justified because some VISs in selected cascades were not rehabilitated or upgraded for a very long time. However, it is also accepted that different development projects have different objectives such as climate resilience, food security, rural development, etc. The literature and experience showed that the selection criteria are specific to the project objective, and therefore, a “one-size-fits-all” type of selection criteria cannot be designed. If cascades are to be selected for a particular development project, the selection criteria must be drafted based on scientific reasoning, documented, and well-understood by the project management at the implementation stage.

A critical takeaway is the importance of upgrading all tanks within a cascade to meet the needs of communities, flora, and fauna. Enhancing

the infrastructure of each tank ensures a more equitable distribution of water resources and supports biodiversity conservation. The upgrading strategy should consider the recent intervention implemented at the VIS level and address the essential improvement needs. Despite differences in intensity structural improvements, the upgrading package should select all the VISs for improvement. If structural improvements are unnecessary, the VISs should be included in the CSA, ecosystem improvement, and water management programs. A holistic approach to upgrading the VISs in a cascade ensures that the entire ecosystem within a cascade is resilient to climate impacts.

The project selected approximately 10% of the VISs in the three river basins for upgrading. Sometimes, this resulted in questions regarding non-inclusion among the stakeholders. Documenting the cascade selection criteria adopted by the project helped to explain and justify the cascade selection.

Although hydrological endowment was not a direct selection criterion, it can serve as an indicator for tailoring interventions. For cascades with low hydrological endowment, recommended strategies include crop diversification and augmenting tanks through small- to large-scale diversions.

While the cascade-level approach to resource management offers substantial benefits, a key drawback is the exclusion of isolated tanks and anicuts. These systems, critical to the climate resilience of dependent communities, must also be incorporated into future development models to ensure inclusivity.

7.4 Technology and the Capacity to Improve Productivity

The innovative approaches adopted in CSA-related interventions highlighted the significant potential to improve farmer incomes and reduce the cost of production (see Section 8.1). Improved land use, crop diversification, improved on-farm water management, and agriculture technology packages applied to command areas, uplands, and home gardens demonstrated the potential for increasing land and water productivity.

Simulation models developed under CRIWMP (refer to Sections 5.2.8 and 5.4.2) provided valuable insights into scaling cascade-level



development to the river basin level. These technical tools revealed untapped productivity potential within cascades, underscoring the importance of evidence-based planning.

However, the technical capacity among the field-level officers and farmer leaders is insufficient to use these tools at present. Addressing this gap requires targeted capacity-building programs and the establishment of dedicated water management units within relevant institutions. Additionally, exploring the involvement of private-sector stakeholders could further enhance technical and operational capacities for sustainable water resource management.

7.5 Optimum use of the production systems in the cascade and polycentric governance

Panabokke (2001) notes that the cascade supports a diverse production system which could be identified in the ancient traditional system, some of which continued to its current version. They are listed as:

- Rainfed upland cultivation (chena),
- Lowland paddy cultivation in the tank's command area
- Mixed gardens in the homestead
- Livestock raising including grazing and herding
- Food collected from the tank and associated sources and game harvested from the adjacent forest

Some of these production systems are shown in Figure 19.

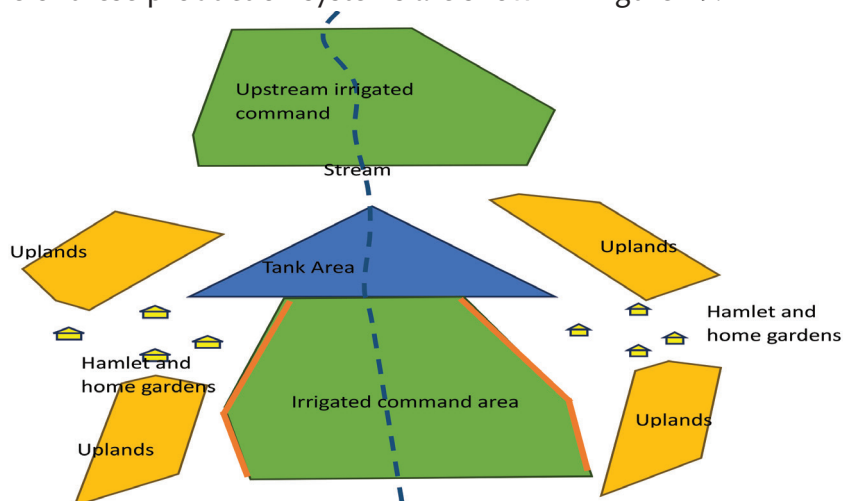


Figure 19: Land sources contributing to cascade productivity

One of the critical lessons derived from studying the evolution of village irrigation is the pivotal role of good governance in ensuring sustainability. Historical experiences, particularly those from the 19th Century (Section 1.7), demonstrate disruptions to governance systems often led to the deterioration of physical infrastructure.

Traditionally, village irrigation systems operated as closed systems within villages or cascades, requiring minimal external inputs for sustainability. However, the increasing intervention from the late 19th century onward has made these systems more reliant on government support. Today, central and provincial government institutions play a significant role in establishing and managing community organizations, irrigation systems, natural resource management, and essential services such as drinking water, healthcare, and protection from wildlife. Additionally, the private sector contributes significantly by providing services such as water, healthcare, agricultural inputs, and market access. To access these services, communities must participate in market-driven activities, often selling a portion of their produce.

Therefore, a new cascade-level governance system should contain important elements of the traditional system but should be compatible with the current social economic, and political realities. A lesson learned during the project implementation was that meeting these criteria required an integrated approach to cascade management based on polycentric governance principles. The CMC is established using such principles. However, to make it sustainable, several improvements are needed.

- **Reconfiguring Participation and Structure:** The current CMC reliance on the active participation of numerous government institutions poses challenges for long-term engagement. Introducing a dual-tier structure, with a core team meeting frequently and a broader group convening at longer intervals, could enhance efficiency and ensure sustained participation.
- **Clarifying Institutional Linkages:** The CMC's connections to existing mechanisms such as District and Divisional Agricultural Committees should be clearly defined to optimize collaboration and resource sharing.



- **Empowering Communities:** The extent to which the CMC empowers communities should be critically assessed. Ideally, the CMC should evolve into a community-led management body, with government institutions continuing to provide governance and technical support.

Business models and community empowerment: Further studies are required to identify and implement suitable cooperative business models to promote community empowerment. Potential models include producer groups, cooperatives, and farmer companies. Transforming sectoral organizations, such as FOs, into these business models is a possibility that could enhance their functionality and resilience. This business model should be guided by a robust business plan for cascade management, which encourages inclusivity of women and youth. Such a plan should integrate modern agricultural practices, market linkages, and innovative solutions to ensure economic viability.

Promoting Inclusivity: Building stronger partnerships with the private sector is a promising avenue. Creating attractive economic and leadership opportunities for youth is imperative to encourage their involvement in sustainable water and resource management. Greater opportunities must be provided for women to actively participate in water and associated resources management at both village and cascade levels.

Policy Implications: Strengthening governance structures, fostering community empowerment, and integrating private-sector partnerships are essential for creating resilient and sustainable tank cascade systems. Addressing multifaceted challenges in these interventions requires a concerted effort by the government and the community, supported by robust policy frameworks.

7.6 The Relevance of an Integrated Approach to Problem-solving

Improved understanding of the cascade system through CRIWMP experience has led to identifying the cascade as a unit comprising social, ecological, and technical domains (Imbulana and Aheeyar, forthcoming). The social domain includes the laws, regulations, customs, and institutions associated with the management. The ecological domain includes the

cascade ecosystem, and the technical domain includes the standards for the technical functions. Finding solutions without considering the integrated nature of these domains leads to unsustainable resource development.

The experience from the Sivalakulama cascade, where two tanks were artificially linked to capture the spilled water in the upstream tank (before the project), demonstrates the importance of the connectivity of the three domains. On the surface, this intervention is an efficient water management strategy. However, the linking system did not include a water-regulating mechanism or operating rules. Therefore, the flood risk of the downstream tank was increased and conflicts between community groups resulted. Box 4 presents a detailed discussion on the subject.

On the positive side, this experience shows that there is an untapped in-basin water resource development potential. Artificially linking cascades were observed at several locations in the project area. They include Thudduvakaikulam cascade in Vavuniya and Anuradhapura Districts (linking four cascades), Sinnakunchukkulam cascade in Mannar District (linking three cascades) Divulwewa/Minihettigama complex in Anuradhapura District (linking two cascades).

Box 4. Sivalakulama cascade: the need for considering the whole picture

The Sivalakulama cascade is located in the Galenbindunuwewa Divisional Secretary Division of Anuradhapura District. At present, it contains 20 tanks. However, investigations of the hydrological linkages before the CRIWMP designs revealed that there had been two cascades initially: the upstream one ending at Muriyakadawala tank and the downstream one ending at Sivalakulama tank. An artificial linkage had been created by a diversion canal from the spill tail canal of Muriyakadawala to augment Thambarakulama tank downstream, as shown by the red circle in the map below.

This is a good intervention leading to improved water use efficiency at the cascade level. However, the discussions with farmers revealed that the flood risk in Thambarakulama tank has increased due to



the diversion. The diversion structure had been built without any regulating mechanism, and therefore, the downstream farmers were unable to stop the flood inflow when the downstream tank is full. Moreover, the spill tail canal of the

upstream tank had been encroached upon by a group of farmers after the diversion, making it difficult to use it during a flood.

This example demonstrates the need to consider a cascade as a unit consisting of three domains; social (laws, regulations, customs etc.), ecological (ecosystem), and technical (standards for technical functions). In this case, the diversion should have been preceded by operational rules specifying when the diversions stop and the agreements within farmer groups to conserve the original spill tail canal of the upstream tank. Secondly, regulating structures with control gates have to be built and the responsibilities assigned to who and when they are operated. The spill tail canal and drainage canals are a part of the cascade ecosystem and they should be preserved during any intervention. Although the diversion demonstrated the water resources development potential in the cascades, a holistic analysis of the system is needed for sustainable solutions.



7.7 Conceptual Approach to Cropping Intensity and Land Productivity

Cropping Intensity (CI) is widely recognized as an agronomic indicator for evaluating the performance of irrigation schemes. The FAO recommends comparing current CI values with reference benchmarks to assess irrigation performance (Savva and Franken, 2002). In Sri Lanka, the popularly used definition of CI is:

$$\text{Cropping Intensity} = (\text{Area sown with paddy} / \text{Area asweddumized}) \times 100$$

Asweddumized area refers to the maximum land area prepared for paddy cultivation in a given year, encompassing land bunded and ridged at the start of the annual cropping cycle (Wickramasekara, 2002).

The CRIWMP adopted Cropping Intensity (CI) as a project-level performance indicator of the climate resilience of the community, mainly resulting from VIS upgrading. Several inherent characteristics of CI need to be considered when this indicator is applied to future projects of a similar nature.

One of them is its relationship to rainfall. Dharmasena, (2004) explained the relationship of rainfall with CI and showed that the latter is essentially a function of rainfall. To accommodate any errors that arise from this dependency, CI needs to be measured and used as an indicator by averaging for a specific period of years after the intervention.

Contributing Factors to Improvement: While rehabilitated irrigation infrastructure improves CI, other factors significantly contribute, including cropping patterns and water use efficiency at both on-farm and off-farm levels. As emphasized in the project proposal, increases in CI result from a holistic package of interventions. These include restoring tank cascade functionality and implementing a suite of modern, improved, and time-tested technologies at the farm level.

Limitations in Measuring the Productivity at Cascade Level: CI primarily focuses on the irrigated command area. However, CRIWMP interventions aim to enhance productivity across the entire cascade, including uplands, home gardens, inland fisheries, and livestock systems. Effective water-sharing decisions made by the community, especially during a drought or water scarcity, contribute to broader productivity

gains at the cascade level, though CI could decrease sometimes. Thus, CI only partially captures the full impact of interventions and should be complemented by other indicators.

7.8 Gender Mainstreaming

The challenges involved in gender mainstreaming were discussed in Section 6.4. Addressing these challenges requires systemic changes to promote gender equity in professional roles and social structures.

One of the measures proposed by the project to improve women's participation in decision-making was their inclusion in the CMC. This was substantially effective and the discussions with the community revealed that women were provided a forum, perhaps for the first time, to voice women-specific water-related problems. However, the same discussions revealed that women tend to assign a high value to their household responsibilities, and if there is a conflict with time allocation, women are likely to select to meet those responsibilities. Therefore, gender mainstreaming measures should be realistic with existing social norms. Furthermore, to ensure their voice is heard, there has to be an attitude change, especially among their male counterparts.

7.9 Paradigm Shifting: Policy Support and Evolution Over Time

The concept of cascade-based development implemented by the CRIWMP marked a novel approach in Sri Lanka, and such development had not been previously implemented on a large scale. The project introduced several innovations leading to a paradigm shift in VIS upgrading and cascade management, which were discussed in the preceding sections. However, the project experiences showed that attitude changes and structural design improvements are necessary for a smooth paradigm change. Some challenges were beyond the project scope and required to be addressed by improvements in national strategies and policies. Key Lessons learned from the paradigm-shifting effort are as follows:

Integration of Multidisciplinary Expertise: Effective cascade-based development requires a multidisciplinary approach, bringing together diverse expertise. However, professional silos and biases can impede

collaboration Appointing a multi-disciplinary team is important for this type of integrated intervention. Project management plays a critical role in integrating the inputs of different disciplines and ensuring synergy among team members.

Farmer Engagement and Attitudinal Changes: Farmers demonstrated an encouraging capacity to grasp key principles of cascade management. However, enthusiasm varied, with some farmers hesitant to adopt innovations until tangible benefits were evident. Demonstrating increased incomes and productivity through practical examples is pivotal. Strengthening business development models to complement agricultural income gains can further incentivize adoption.

Water Sharing and Resource Optimization: Sharing water among tanks and anicuts within cascades can enhance water-use efficiency and reduce production losses. However, this requires infrastructure such as link canals and regulated outlets, alongside greater awareness and trust among farmers. Unpredictable rainfall patterns often exacerbate reluctance to share water, underscoring the need for robust capacity-building initiatives and adaptive water management strategies.

Challenges Beyond Project Scope: Solutions for certain challenges, such as human-wildlife conflict and limited land and water resources, fell outside the project scope. Addressing these issues requires a holistic rural development strategy that links cascade management into broader socio-economic and environmental frameworks.

Therefore, the recognition by national policies and enabling legal support are essential for an effective paradigm shift. It should be followed up with a national strategy for village irrigation development and management. The envisaged paradigm shift will evolve with time, and it is essential to convert the key interventions from project mode to program mode.





Women empowered by climate-smart agriculture
Bandarakumbukwewa Cascade, Anuradhapura

NOTABLE ACHIEVEMENTS

8.1 Improving the economic status of the rural poor

The assessments of project interventions carried out in Polonnaruwa District showed that the agriculture technology package provided by the project has the potential to reduce the production cost in the irrigated command by 25%. In the Maha season, these interventions increased the farmers' income by more than 30%. Considering VIS upgrading was not carried out in Polonnaruwa, this development shows that improved off-farm water management could further increase farmers' income.

The technological package introduced by the "Yaya" program for the paddy lands implemented by the project constituted the following activities, which are discussed in detail in Box 5:

- a. Consolidation of paddy land plots and land levelling
- b. Implementing Alternative Wet and Dry (AWD) techniques
- c. Promoting vegetable cultivation in paddy lands
- d. Improving fertilizer use and nutrient management
- e. Evaluating different cultivation techniques and selecting the most productive cultivation method
- f. Developing a comprehensive database of paddy land parcels to establish land ownership and optimize resource allocation

Box 5. Productivity enhancement by the Yaya Program

The purpose of the Yaya program implemented by the CRIWMP was to introduce advanced technologies and improved agricultural practices in the paddy field to increase productivity and farmer incomes. It has been carried out in several cascades including Sivalakulama, Thudduwakaikulam, Kadawala, Medde Rambewa, and Kumbuk Wewa cascades in the 2024-25 Maha season. The

main activities included in the program include the following:

- a. Consolidated fragmented paddy land plots of 61 ha of paddy lands in 5 cascades (1,275 plots reduced to 360 plots after intervention)
- b. Remove unnecessary field bunds during plot consolidation and create a large bund in the paddy field and canals to enable vegetable cultivation
- c. Implement Alternative Wet and Dry (AWD) techniques (151 farmers under 05 tanks)
- d. Improve fertilizer use and nutrient management using techniques such as spilled-fertilizer application and deep ploughing using disc ploughs for better nutrient absorption (57 ha in 05 tanks)
- e. Evaluating different cultivation techniques such as parachute, row seeding, transplanting, and broadcasting and selecting the most productive cultivation method (61 ha)
- f. Develop geospatial maps and a comprehensive database of paddy land parcels to establish land ownership and optimize resource allocation



Laser leveling – Pahala Aliyawetuna Tank, Siwalakulama Cascade, Anuradhapura

Plot consolidation

The fragmented small land plots in paddy fields hinder good on-farm water management and employment of farm machinery. This technique rearranges the land holding by removing unnecessary bunds and forms a larger bunded plot. This was carried out within the legal boundaries of the farmer's paddy field. The equipment used included laser levelers, dozers, and four-wheel tractors.

Improved cultivation techniques

Broadcasting is widely used by farmers due to its cost-effectiveness and time-saving. However, it has disadvantages such as uneven distribution, wastage of seeds, and poor plant spacing. Seed depth can affect seed germination and crop establishment. The project introduced techniques for ensuring the even distribution of seeds across the field.

Another technique was seeding with Seeders, which enables planting seeds at the desired depth and spacing for better germination and establishment of crops. However, it is noted that costs and maintenance requirements need to be considered when adopting such methods.

The parachute method involves tossing rice seedlings containing a soil ball as a projectile into the puddled field. The advantages of this method include uniform seed distribution leading to better germination, reduced seed wastage, and time and labor-saving. However, the equipment cost, skill requirement, suitable field and weather conditions, and seed compatibility should be considered when selecting this method.

Transplanting with a mechanical Transplanter was another technique employed by the project. It minimizes weed problems and labor usage while ensuring a uniform plant population. Transplanted rice plants enable better nutrient utilization and potentially higher yields under optimal growing conditions. It facilitates AWD techniques and therefore more water-efficient. It is, however, labor intensive, and more expensive than direct seeding. The risks include the possibility of transplant shock, and vulnerability to pests and disease, and the success depends on the seedling quality.

Additionally, project interventions have notably reduced the time women and girls spend fetching water—saving an average of 1.3 hours per day per individual. This has enabled them to engage in productive activities, income generation, social roles, or education-related pursuits, contributing to gender empowerment and household well-being. This achievement is elaborated in Box 6.

Box 6. Benefits of Rooftop Rainwater Harvesting Systems

The CRIWMP provided 4,000 households and 49 schools in the project area with rainwater harvesting systems intending to narrow the gap between the demand and supply of safe drinking water in the project area. The project provided 5000-liter polyethylene (PE) storage tanks with PE filter, gutters, down pipes, and the first flush arrangements. The household's contribution includes the basement for the rainwater tank. This intervention specifically targeted households with women-headed Families, elderly, differently-abled, CKDu Patients, and Social Welfare Recipients (Samurdhi/Aswesuma programs).

Several measures were undertaken to ensure the post-project sustainability of the intervention. A comprehensive series of O&M training was conducted and a user handbook was provided to the beneficiaries. The water quality of the collected rainwater was tested and a post-user perception survey was carried out. The project and the Department of National Community Water Supply (DNCWS) signed a triparty agreement with the household to provide backup support and technical guidance.

The project team estimated that a family in the project area spent an average of 1-1.3 hours per day to fetch water before the intervention. As such, providing RH tanks saved 135,600 labour hours with a value of USD 57,000.



36 years old Shiranthi and her sister, both disabled, had to travel 200 m to fetch water or had to pay mobile vendors for drinking water before they were provided with a RWH tank

8.2 Endorsement in Research and Development Outputs

The CRIWMP's approach has been validated by leading research studies, highlighting its contributions to transformative adaptation and sustainable water management practices.

Endorsement of the Integrated Approach for Cascade System Sustainability: A study by Ratnayake et al. (2021) emphasized the need for deeper research into the interactions between critical subsystems within cascade systems. Findings revealed that land use changes, land cover alterations, and increasing climate variability, adversely affect socio-economic and ecological productivity. Droughts, for instance, reduce upland soil moisture and farming system productivity. These challenges, identified during the CRIWMP's design phase and addressed in the implementation phase, underscore the project's alignment with emerging research insights.

Recognition of Institutional and Adaptive Approaches: Research conducted by the International Water Management Institute (IWMI) recognized the CMCs and Climate-Smart Agriculture (CSA) activities introduced by the CRIWMP as exemplary transformative adaptation measures. CMCs were noted for their polycentric governance model, demonstrating the potential to enhance adaptive capacity. IWMI studies (Imbulana et al., 2023; Amarasinghe et al., forthcoming) advocate integrating CMCs within detailed river basin plans to maximize the impact of high-value crop diversification. It is noted that such efforts must be supported by comprehensive land use and water availability plans to ensure sustainability.

Recognition of the Benefits Imparted to the Community: Ariyawanshe et al. (2023) highlighted the effectiveness of CRIWMP interventions in the Medde Rambewa cascade. The study noted that farmers benefited from timely access to weather information, facilitating better decision-making in agricultural practices. It underscored the importance of leveraging existing institutions as focal points for cascade governance and emphasized that addressing critical community challenges is vital to sustaining community engagement in cascade management.

Justification of the Targeting Criteria: The Updated Nationally Determined Contributions (NDCs) of 2021 reinforced the importance

of CRIWMP-selected river basins. Of the 15 river basins prioritized for integrated river basin management, the three CRIWMP river basins were the only ones from the Dry Zone. Furthermore, these basins were among the five prioritized for IRBM plan completion by 2025. As such, recent government strategies have endorsed the selection of river basins for the CRIWMP, and its development concepts could play an important role in river basin planning.

8.3 Aligning with GCF Investment Criteria

8.3.1 Impact Potential

By the end of 2024, with one year of activities remaining, the CRIWMP reached 790,743 beneficiaries cumulatively, achieving 100% of its target for direct beneficiaries. The output-wise (main outputs are described in Section 5.1) achievements are as follows:

- **Output 1:** A total of 556,678 beneficiaries were reached. Cropping intensity on 10,488 ha of land increased from a baseline of 1.0 to 1.67. Upgrades to VIS headworks achieved 94% of the target, with the remaining upgrades planned for 2025.
- **Output 2:** A cumulative 127,837 beneficiaries were supported through pipeline extension programs, household and rainwater harvesting systems, and rural water supply schemes, improving access to safe water.
- **Output 3:** A total of 556,578 beneficiaries gained access to improved agro-met advisory dissemination systems, enhanced disaster preparedness capacity, and related guidelines, strengthening climate resilience at the community level.

8.3.2 Paradigm Shift Potential

During its initial implementation, the project concentrated on refining the strategies to implement the conceptual model of paradigm shift presented in the project proposal. Toward the end of the project, the focus shifted to sustaining the paradigm shift in the long term through scaling up, replication, and adopting measures. Some outcomes of this effort are described below.

Scaling up and replication: In 2022, the National Food Security Committee endorsed CSA practices for scaling up to address the food security crisis. Subsequently, the practices were implemented at the provincial level across the North Central Province (NCP), North Western Province (NWP), Eastern Province (EP), and Northern Province (NP), aligning with the project's operational areas. These practices are now included in the National Agriculture Policy as a policy action.

Examples of replication include:

- Adoption of the project's O&M plans format for cascade systems in Vavuniya and Mannar Districts.
- DAD initiatives to establish water depth gauges in tanks outside project areas to replicate water management methodologies.
- Recognition of CMCs as a critical institutional model by ongoing projects.
- Expansion of roof rainwater groundwater recharge systems, first demonstrated in Kurunegala.

The project's weather and agro-met advisory dissemination system, including a weather portal and mobile app, has been recommended for replication beyond project areas. Tools developed to support scaling up include, among others:

- CSA guidelines,
- A simulation model for cascade water balance and a user's manual, and
- Guidelines for groundwater recharging and Climate Resilient Water Safety and Security Plans (CRWSSP).

Knowledge sharing: The project generated a wealth of knowledge products, including research papers, manuals, videos, advisories, and leaflets, and widely circulated them among stakeholders. Key topics include transformative adaptation, integrated water management, CSA practices, and governance innovations.

Training modules and guidelines developed under the project—such as those for CRWSSP, rooftop rainwater harvesting system maintenance, and integrating climate risks into drinking water solutions— have been effective for knowledge sharing with new capacity-building activities.

Planned knowledge-sharing outputs for 2025 include:

- A publication series documenting lessons learned (including this report).
- A symposium to consolidate and share experiences and insights from project implementation, expected to result in several peer-reviewed research papers.

These initiatives are critical to ensuring the long-term sustainability and replication of the project's innovations while contributing to global dialogues on climate-resilient development.

8.3.3 Sustainable Development Potential

The project's contribution to Sustainable Development Goals is described in Section 8.4. Below, we explore the economic, social, environmental, and gender empowerment co-benefits realized through its interventions.

Economic Co-Benefits

- **Increased Agricultural Income:** By 2023, improved agricultural practices, livelihood support programs, and enhanced water management boosted the income of 21,158 farmer families, amounting to approximately USD 18 million. These gains were achieved through increased cropping intensity and diversification into commercial crops.
- **Time Savings from Safe Drinking Water:** The provision of safe drinking water reduced the time spent for fetching water, allowing for increased economic productivity. This translated to an annual benefit of USD 468,600.
- **Skills Development:** Training initiatives enhanced employment opportunities, equipping beneficiaries with skills for diverse livelihood activities.

Social Co-Benefits

- **Access to Safe Drinking Water:** Rainwater harvesting systems provided year-round access to clean and reliable drinking water for 21,884 people across 4,000 households and 49 schools. These interventions prioritized vulnerable groups, including households with CKDu patients, persons with disabilities, and widows.

- **WASH Programs:** Water, Sanitation, and Hygiene (WASH) programs were conducted in schools equipped with small, advanced water filters, improving awareness and practices.

Enhanced Food Security: By increasing cropping intensity from a baseline of 0.9 to approximately 1.67, the project significantly contributed to food security.

Environmental Co-Benefits

- **Ecosystem Restoration:** The project improved water management practices restored degraded ecosystems, and incorporated catchment conservation into VIS O&M plans. These measures ensure the long-term sustainability of ecosystems.
- **Agroforestry Systems:** Introduced agroforestry systems enhanced biodiversity and ecosystem services in agricultural areas.
- **Groundwater Recharge:** Innovative measures, such as diverting rainwater harvested from rooftops and restoring tank ecosystems, improved groundwater recharge, and supported flora and fauna during dry seasons.
- **Energy Savings:** Using solar energy in four Climate Resilient Water Supply Schemes (CWSS) saved 1,200–1,400 kWh per month, providing a financial benefit of approximately USD 81 per month to CBOs in 2024.

Gender-Sensitive Development

- **Empowering Women Farmers:** Over 280,000 women benefitted from agricultural technology packages by the end of 2024.
 - **Institutional Inclusion:** Women's farmer organizations were integrated into CMCs, an institutional model now accepted by the government.
 - **Reduced Care Burden:** Improved drinking water services eased women's household responsibilities, enabling their economic empowerment. By 2024, 9241 women actively managed new CWSS in the project areas, supported by scheme-specific water tariff systems.
- 

8.3.4 Meeting the Needs of the Recipient

The project was designed with a deep understanding of Sri Lanka's financial, economic, social, and institutional needs. Effective stakeholder engagement during implementation ensured that the needs of the recipient were met, particularly during the economic crisis. Key achievements include:

- **Supporting the government to address food insecurity:** During the economic crisis, the project distributed OFC seeds and other agricultural inputs, directly addressing food insecurity. External support from the Governments of Japan and Thailand, alongside private sector contributions, totaled an estimated USD 2 million.
- **Strengthening Hydrological Networks:** Automated stream gauges, rainfall stations, and agro-met stations were installed to address gaps identified by national agencies in selected river basins.
- **Meeting the Capacity Development Needs:** The project provided O&M equipment to FOs including 42 FOs outside upgraded cascades. IT equipment was also delivered to the DAD, PID in NWP, NCP, and EP, 35 Agrarian Service Centers (ASCs), and the DNCWS. These resources enhanced water management, data sharing, and dissemination of agro-met advisories.
- **Weather Information Systems:** In 2022, a web portal and mobile app for weather information dissemination were launched, addressing a request from the Department of Meteorology. High-end computers were provided to the National Meteorological Centre and the Seasonal Forecasting Division to improve numerical data processing capacity and service delivery chain.

8.3.5 Country Ownership

An indicator of the project's country ownership is its contribution to the Nationally Determined Contributions (NDC). The Updated NDCs of 2021 (MOE, 2021) highlighted several potential areas of investment in Sri Lanka to be considered during the post-Covid recovery period. Some of those relevant to the project included:

- Ensuring domestic food production systems -agriculture and fisheries- are climate-sensitive, and environmentally sustainable
- Promoting efficient water management and irrigation systems.

The contribution of the project to specific NDCs is as follows:

Sector	NDC	Contribution
Agriculture	NDC 1. Climate change considerations mainstreamed into agriculture in Sri Lanka	Contribution to the National Guideline on Climate Smart Agriculture Promoting home gardens, facilitating value addition, and linking the markets to farmers
	NDC 5. Enhance sustainable land and water management practices in areas where anticipated climate vulnerability is severe	Introducing input-efficient farming methods, promoting crop diversification including climate-tolerant varieties, promoting soil conservation measures, and improving the management of tank cascades together with upgrading irrigation infrastructure
	NDC 6. Enhanced early warning and risk management mechanisms introduced to reduce climate change vulnerability	Contributing to improved seasonal climate forecasting, simplified and timely communication of climate information and advisories to farmers and field-level officials, strengthening early warning systems,
Fisheries	NDC 2. Expand aquaculture and culture-based fisheries to address food security issues relating to climate change	Establish fish ladders in spillways
Water (Water sector-wide Integrated River Basin Management (IRBM))	NDC 1. Integrated River Basin Management (IRBM) adopted in 15 prioritized river basins (including Malwathu, Mi, and Yan Oya) in Sri Lanka	Preparing water resource development and management plans for selected cascades, formulating climate change adaptation measures, contributing to similar river basin level plans including IRBM plans, promoting water retention and groundwater recharge in meso and micro catchments through cascade ecosystem restoration, tree planting, ponds, and earth ridges
	NDC 3. Promote climate-resilient water supply schemes	Providing rainwater harvesting facilities for the most vulnerable people with inadequate access to potable water, implementing a tariff system to recover the cost of new WSS, capacity development in communities and CBOs

Water (Irrigation sub-sector)	NDC 8. Introduce or promote alternative water resources as a climate change resilience-building intervention for domestic and supplementary irrigation	Groundwater recharge, groundwater management plans indicating water availability and safe abstraction levels
	NDC10. Assess river floods and mitigation measures and early warning systems for possible flash floods for five priority basins (including Malwathu Oya)	Installing river and reservoir gauges in selected cascades, improving the rainfall data collection through Tank level gauges and agro-met stations, and improving river flow data collection (Malwathu Oya), conducting capacity building programs for newly established early warning systems
Loss and Damage NDCs	NDC 2. Strengthen the existing weather and climate forecasting system	Contributing to improving early warning systems

Table 2: Contribution of the CRIWMP to NDCs

Further to the above, the project has contributed to augmenting the impacts of the following water-sector NDCs, although the NDCs did not target the selected cascades:

Sector	NDC	Contribution
Water	NDC 7. Restore, rehabilitate, and augment 25 major / medium reservoirs, 300 minor irrigation systems, and 200 km length of irrigation canals in Sri Lanka for enhancing climate resilience in the agriculture sector.	Prioritize Tank cascades using a selection criteria, restore abandoned tanks, augment storage capacity, and upgrade VISs
	NDC 9. Enhance water management in 40 irrigation schemes	Increase water use efficiency in irrigation through improved water management, micro-irrigation systems and low water-intensive crops, farmer training and awareness building for efficient water use, improved rotation schedules

Table 3: Indirect contribution of CRIWMP to water-sector NDCs

The project interventions have also contributed to integrating Sustainable Development Goals and Gender into the NDCs.

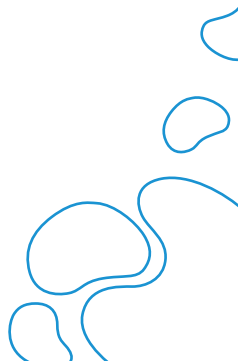
In addition, the following examples demonstrate the country's ownership of the project outputs:

- GCF funds were delayed during the restructuring process. The government provided funds to continue with selected interventions that were to be supported with donor funds
- The project's paradigm shift hinged on the integrated approach. The Circular issued by the DAD in August 2023 titled "Cascade Management Committee (CMC) Establishment and Continuity" (see Section 5.2.3) demonstrated the country's ownership of the project's paradigm shift and supported its sustenance.

8.3.6 Efficiency and Effectiveness

Several interventions within the project significantly enhanced both its efficiency and effectiveness. Key contributions include:

- Fertilizer-efficient farming practices that reduced production costs and ensured food production resilience during the economic crisis.
- Community contributions towards new water supply facilities exceeded initial expectations, demonstrating robust local engagement and ownership.
- Efficient project execution facilitated the mobilization of external resources, including private sector investments, even during periods of crisis.
- The project reached the originally targeted number of beneficiaries with the allocated funds (see Section 8.3.1) despite delays caused by the restructuring process, the COVID-19 pandemic, and the economic crisis. CRIWMP stands out as one of the few development projects that achieved its targets within the planned financial and time constraints.



8.4 Contribution to Achieving Sustainable Development Goals

The CRIWMP's integrated model is closely aligned with several key Sustainable Development Goals (SDGs), including:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- The proportion of the population not covered by essential health services
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 13. Take urgent action to combat climate change and its impacts
- Goal 15. Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Figure 20 graphically demonstrates the project's contribution to SDGs.

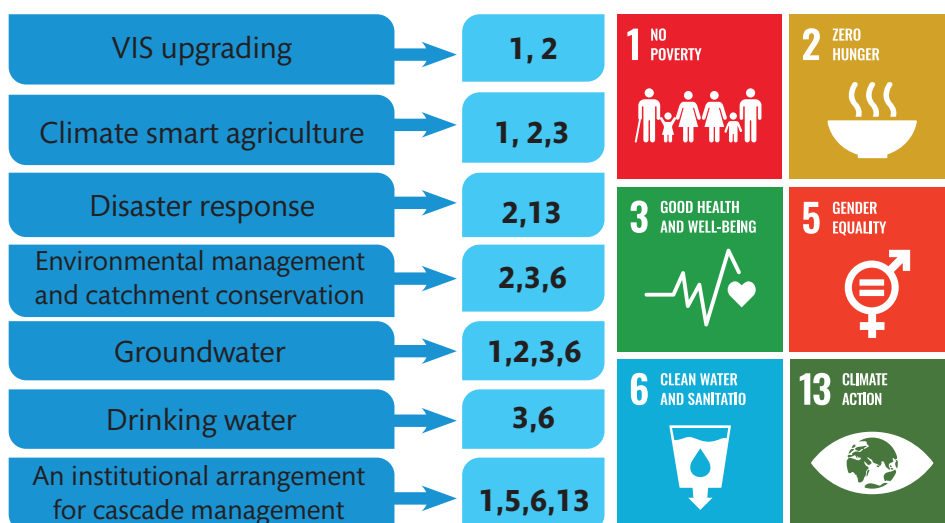


Figure 20: Fitting the CRIWMP model to SDGs

RECOMMENDATIONS AND CONCLUSIONS

9.1 Government's role in the management of cascades

As described in section 1.7.2, the government's responsibility for village irrigation systems has been continuously changing. Furthermore, different institutions could be responsible for different tanks in the same cascade (Section 2.2.2). This has confused the community in village irrigation systems to obtain the required services for livelihoods. Similarly, when development interventions are planned, multiple government institutions are involved in granting the necessary clearances and approvals. In some cases, village irrigation may not be prioritized among their mandates. Additionally, gaps and overlaps in institutional functions further complicate the governance landscape. These are constraints to achieve cascade's potential for improved water and land productivity, because it requires continuous technical and governance inputs from the government.

To address this, it is recommended that a government institution with the necessary capacity be designated to lead and implement the paradigm shift introduced by recent development projects, working in a programmatic modality with other stakeholders. Given the multitude of government institutions with mandates over different aspects of village irrigation, enhanced coordination is critical. It is essential to eliminate overlaps and gaps in institutional responsibilities to ensure a coherent and streamlined approach across the country.

9.2 Consolidating the economic benefits of the community and the sustainability of the cascade system

Further improvements are needed in the institutional setup of the currently established CMC model. As the CMC evolves, it will need robust policy support to thrive. Specific procedures for financial management and business development within the CMC should be

developed and initially implemented under the oversight of government institutions. Additionally, the community must be empowered to take on the management of cascade resources. Their capacity should be strengthened to monitor the quality of surface and groundwater, with potential government compensation for such services.

The strategies to enhance the productivity introduced by the CWRD&MP have to be improved so that the entire productivity system including irrigated, rain-fed, and home gardens contributes to the upkeep of the irrigation infrastructure and the ecosystem ensuring their sustainability. The linking up with the existing administrative arrangements at the District and Provincial level such as Divisional and District Agriculture Committees and Provincial Coordination Committees have to be defined. The representation of CMCs at such higher-level committees has to be arranged.

In light of these considerations, it is strongly recommended that the implementing arrangements for the CMC be revisited and modified as necessary, with the required legal support obtained by amending the Agrarian Development Act and other relevant legislation.

9.3 Integration with River Basin Management Plans

The importance of a river basin approach to address current and emerging water resource challenges is well-documented in the literature (Imbulana, 2021; Imbulana et al., 2023). As the tank cascade is a hydrologically defined watershed within a river basin, it has significant implications for water resources development and management at the river basin level, and vice versa. Dharmasena (2020) highlighted that ancient large reservoirs are typically located in the downstream or lower plains of a river basin, while tank cascades are often situated upstream. This relative placement offers opportunities for integrating flood management strategies at the river basin level.

As outlined in previous sections, formal and informal interventions to harness the water resources of cascade systems by linking cascades suggest a clear potential for integrated water resources development within the river basin. This approach could help reduce the magnitude and cost of inter-basin water diversions while facilitating livelihoods and micro-scale natural resource management that can be scaled up to the river basin level.

9.4 Implementation of Water Resources Development Projects at the Cascade Level

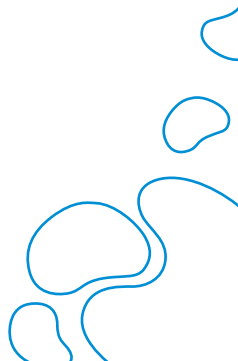
The lessons learned from the CRIWMP (described in Chapter 7) include critical insights into cascade selection, intervention design, baseline preparation, sequencing activities, stakeholder mobilization, and prioritizing software solutions. These learnings offer valuable guidance for formulating a national strategy for tank cascade development and management. Such a strategy can facilitate replicating best practices while avoiding previous challenges.

Recognizing the need to upgrade isolated tanks that are not part of a cascade system, a sub-watershed (refer to Section 1.5) can be used as the spatial planning unit for water resource development. This approach incorporates isolated tanks, link canals, and feeder canals into renovation and upgrading plans. The potential for interlinking cascades to improve water use efficiency also has been noted. However, cascades remain the fundamental water management unit in this context.

The non-economic functions of water within a cascade system are well-documented. For instance, multiple authors, including Ratnayake et al. (2021), have highlighted the ecological services provided by cascades. Nevertheless, some of these functions are not yet fully quantified or demonstrated (Panabokke et al., 2001). Developing methods to measure and assign economic value to these ecological services can enable their inclusion in the economic analysis of development projects, and justifying the investments in cascade development. Research in this subject area such as Vidanage and Perera (2010) and Dissanayake et al. (2021) needs to be consolidated and incorporated into national project evaluation strategies.

9.5 The Recommended Model

Over time, the CMCs must evolve into a self-sustaining entity. To achieve this, all production systems within a cascade must be incorporated into a robust business plan. Revenue generated through implementing this business plan should directly contribute to the operation and maintenance of irrigation systems and the conservation of the broader ecosystem.



The schematic (Figure 21) shows the recommended model built on the originally conceived model of the CRIWMP and the experience gained by implementing the project. The main activities in the model and its suggested order of implementation are summarized below:

- An agriculture development plan encompassing all production systems in a cascade (irrigated command, uplands, home gardens, livestock, and fisheries) CSA practices, improved land use practices, and improved water application techniques is drafted and implemented.
- A water resources development and management plan comprising VIS upgrading and improved water allocation and management is drafted, incorporating the requirements of the agriculture development plan.
- Institutional arrangement at the cascade level is implemented. Initially, the current version of the CMC is established, which will be scaled up to a self-sustaining institution with technical and governance inputs from the government
- The information developed from agricultural planning such as soil drainage classes, soil-water relationships, and the recommended cropping pattern responsive to the weather forecasts will enable the managers to calculate the crop water requirements and irrigation requirements
- The irrigation system is designed for upgrading in a climate-resilient manner. The information generated during this stage and estimated irrigation requirements contribute to the cascade's surface water management plan. Technical information such as depth-area-capacity curves, hydrological linkages, command areas, and cultivated areas are collected and input to the surface water balance assessment. Irrigation requirements and surface water balance are used to calculate the area that can be irrigated with surface water.
- A groundwater development and management plan is prepared. The groundwater potential assessed during this process is used to estimate the potential groundwater extraction for irrigation, and it contributes to deciding the cultivable extent using groundwater.

- Based on weather forecasts and groundwater management plans sustainable home gardens, upland cultivations, and eco-friendly cultivations in micro catchments are implemented.
- The irrigation system is upgraded as per the designs.
- Using the estimates of cultivable extents, sustainable natural resources management strategies, and economic tools, a business plan for the cascade is developed and implemented. The strategies contributing to the business plan shall include sustainable land use practices, improved access to land, water, and other resources, and land consolidation
- Necessary policy and legal support are provided to the community institutions to implement the business plan leading to sustainable cascade systems and empowered communities

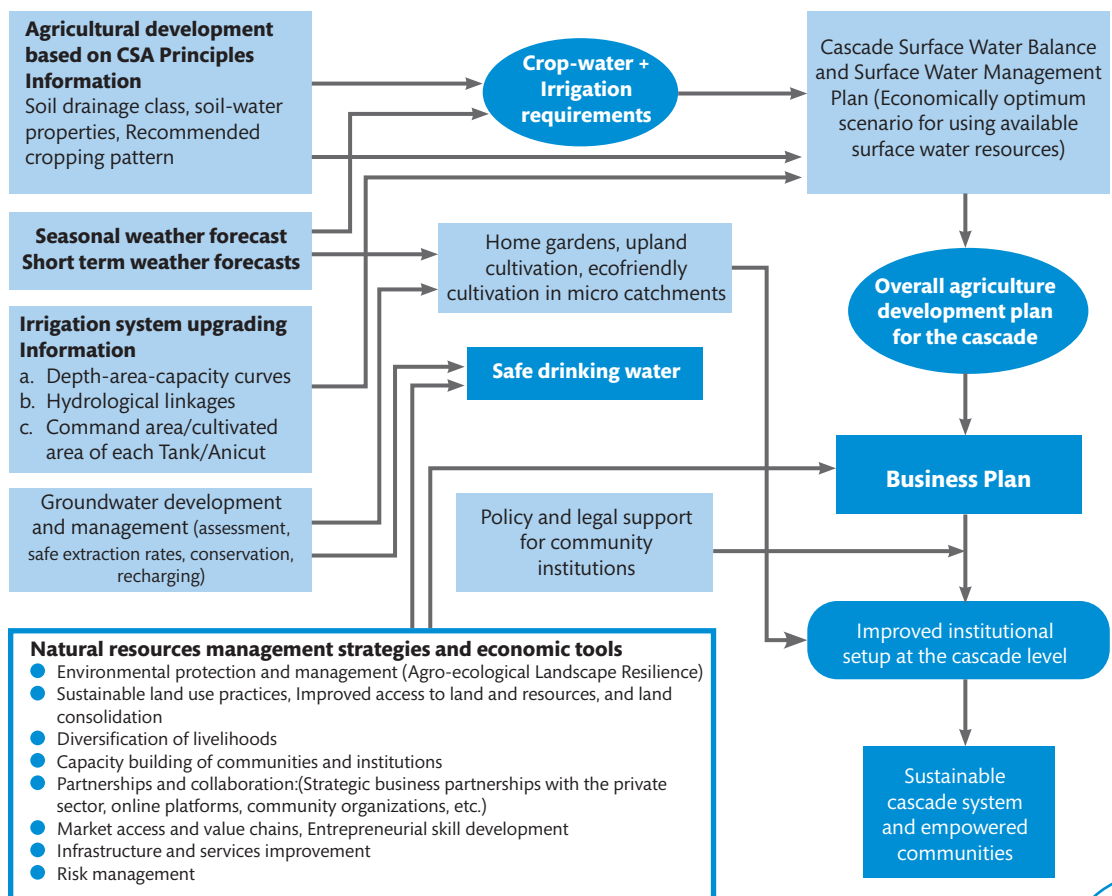


Figure 21: The proposed model for tank cascade development and management

9.6 Conclusions

9.6.1 Achievement of the Expectations of the Project Proposal

All the physical targets of the project are expected to be achieved by the end of the project. Governance and institutional interventions such as cascade management plans and CMCs have been formed. Technical innovations enabling replicability and scaling up have been designed and shared with the relevant institutions.

The expectations of the project proposal hinged on the improved climate resilience of rural communities in the tank cascades of the Dry Zone. Based on findings from multiple research studies and limited impact assessments associated with the project, it can be concluded that these expectations have been substantially achieved. The alignment of project interventions with Sri Lanka's NDCs, national policies, and government circulars provides a strong foundation for the sustainability of these interventions.

The sustainability of tank cascades, an integral part of ancient hydraulic civilization, depends on community engagement in the cascade's management. This engagement can survive in the long term only if it results in economic and social benefits and helps in finding solutions to critical problems faced by the community.

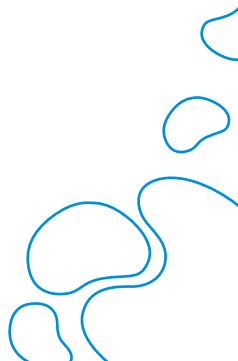
9.6.2 Future Actions

The integrated solutions piloted by the CRIWMP have been implemented across approximately 10% of the selected river basins. To significantly enhance climate resilience in the Dry Zone, the recommended model must be replicated and scaled up, incorporating stakeholder-driven modifications. The following key actions are necessary:

- **Policy Formulation and Alignment:** Develop new national policies or amend existing policies related to agriculture, water resources, and the environment to integrate tank cascades as essential components of river basin management plans, especially in areas where cascades are prevalent.
- **National Strategy for Cascade Systems:** Using lessons from CRIWMP, formulate a national strategy for tank cascade systems development and management. This strategy should align with

river basin management plans and rural development initiatives. Addressing challenges encountered during project implementation will require actions at a broader scale beyond individual cascades. These efforts should be structured within a program mode and be nationally driven.

By adopting these actions, Sri Lanka can leverage the CRIWMP's successes to strengthen its approach to climate-resilient water management, ensuring the sustainable development of vulnerable communities in the Dry Zone.





"Mangala Wap Pen Poojawa"
Gurunirawa Tank, Divulwewa Cascade, Anuradhapura



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MINISTRY OF AGRICULTURE, LIVESTOCK, LANDS & IRRIGATION

