Way Forwards to Revitalize Village Tank Cascade Systems in Sri Lanka

A Compendium of Policy Briefs

May 2024





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Edited and compiled by
Prof. Mohamed Esham
Dr. Chandana Jayathilake
Prof. Keminda Herath

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Introduction

Sri Lanka’s Village Tank Cascade Systems (VTCS) have enabled multiple generations of cascade landscape communities to prosper. Today, however, there are multiple threats to the sustainability of these ancient water management systems and the ecosystems and biodiversity that support them. The Healthy Landscapes Project (HLP) aims to address these threats. The HLP promotes agrobiodiversity and sustainable practices in areas with severe land and health issues, aiming to improve cascade landscape management and address health challenges. Strong policy initiatives were urgently needed, and HLP recruited experts to draft 18 policy briefs. These briefs guide sustainable VTCS management and engage policymakers.

The overall objectives of developing these policy briefs were to investigate the practices of Village Tank Cascade Systems and find the policy gaps in the existing system; institutions, policies, and practices that affect the harmonious integration of people, ecosystems, and livelihoods.

The policy briefs are categorized under resource inputs, agricultural production, tank restoration and water management, distribution and marketing, supporting services, and local food security.

Resource Inputs

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Biochar: An Alternative Soil Management Technology for Farmers in Village Tank Cascade System in Sri Lanka

Key messages

To improve soil quality and ensure the sustainability of paddy cultivation in VTCS, the following actions need to be taken.

- Encourage paddy farmers to apply organic amendments to enhance soil fertility, reducing reliance on synthetic fertilizers and protecting the environment.
- Support entrepreneurs in establishing high-quality biochar production units, utilizing waste rice husk to improve soil fertility and generate bioenergy.
- Empower farmer societies in VTCS to produce biochar from paddy husk waste through training and incentives.
- Promote the use of biochar as a practical alternative to repeated application of conventional organic amendments, enhancing soil fertility sustainably.
- Provide subsidies for biochar applications to mitigate soil degradation and increase the sustainability of paddy cultivation in Sri Lanka.
- Invest in further research to determine biochar's capacity in paddy soils and develop smart technologies, such as slow-release nitrogen fertilizers, to reduce synthetic fertiliser.

Challenges and Issues to be Addressed

Soil is life. Degradation of soil fertility through years of cultivation has demanded the application of synthetic fertilizers, mainly nitrogen, phosphorus, and potassium, to achieve higher productivity in paddy cultivations in VTCS. However, due to poor fertility conditions, about 70 to 90% of added fertilizers are wasted. This can be rectified, at least in part, through increasing organic matter contents in these soils. However, a large quantity of conventional organic amendments must be applied repeatedly to increase the soil organic matter content. Apart from that, lack of availability and high cost have also discouraged farmers from using organic amendments in paddy fields. As a result, less than 8% of the paddy farmers in the country have used any organic amendment (Kadupitiya et al., 2022). Therefore, alternative technologies must

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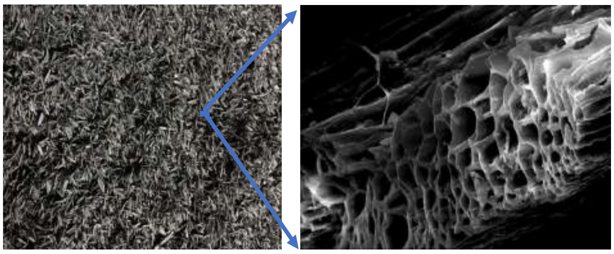
be introduced to improve the soil quality and assure the sustainability of the paddy cultivation in VTCS of Sri Lanka.

Biochar: A Game-changer in Sustainable Agriculture for VTCS Paddy Farming

The average paddy yield in VTCS is 4.1 t/ha while the potential yields are about 8 – 9 t/ha. This productivity gap is partly due to the poor fertility of soils. The soil organic matter content in these soils is very low, about 1.5 % and over 30% less than forest soils in the vicinity (Kulasinghe and Dharmakeerthi, 2022), probably due to repeated cultivation of these lands as a monocrop. Moreover, they also found that the contents of micronutrients such as Zn and Cu are also less than the critical levels. Therefore, the fertilizer distributed under various subsidy schemes has not given the expected benefits and the loss of valuable fertilizers is also high. The efficiency of urea fertilizers applied to paddy fields is often less than 30% (Sirisena and Suriyagoda, 2018). Building up organic matter contents in soil can increase fertilizer retention in soil and the availability of nutrients for rice plants.

Application of organic amendments to paddy lands will not provide the expected benefit without the right rate. Not only do a small fraction of farmers apply organic amendments, but the quantity they apply is far less than the DOA recommended rates (10 t/ha) for integrated plant nutrient management systems. Unlike the previous practice of burning paddy straw, part of the organic matter needed is now being automatically returned to the same field with the introduction of combined harvesters. However, being a tropical country, even the limited applications of organic amendments decompose fast, requiring their repeated application. Recently, a more environmentally friendly and sustainable soil management technology is gaining popularity; application of biochar aka “Black Gold.” Biochar is a solid char produced by heating organic materials under limited or no oxygen situation to temperatures higher than 350 °C, (a process called pyrolysis). Once applied to soil, more than 75% of biochar remains undecomposed for centuries, if not for millennia. Biochar has unique properties (See plate above) such as being highly porous, high specific surface area, high nutrient retention ability, adsorb toxic heavy metals and provide a good habitat for soil microorganisms (Leahman and Joseph, 2015).



A meta-data analysis conducted by Liu and co-researchers in 2022 concluded that the application of over 20 t/ha of biochar made at pyrolytic temperatures between 500 – 600 °C together with 150 to 250 kg/ha of nitrogen fertilizers would increase rice yields by 11% and the efficiency of N fertilizers by 12% due to improvements in soil fertility. After reviewing the available literature, Application of biochar is also very effective in reducing the bioavailability of potentially toxic trace elements such as Cd and Pb in paddy growing soils and emission of greenhouse gasses. An efficiency enhanced fertilizer has also been developed using urea and biochar (WOCAT, 2022). An ongoing long-term field experiment established at the Rice Research Station, Ambalantota revealed that a single application of 40 t/ha of rice husk biochar provided yields comparable to the application of 10 t/ha of compost per ha every season (i.e., 50 t/ha for just five seasons). Application of these organic amendments together with NPK fertilizer has increased paddy yields by 22-28% (Figure 2). Repeated application of compost 10 t/ha is not only costly but also labor intensive. Labour is a scarce resource in most of the VTCS due to the high demand for off-farm labor among the younger generation (Melles and Perera, 2020).

Figure 1. Effect of continuous application of compost or single application of rice husk biochar on average paddy yield over five seasons at Ambalantota, Sri Lanka. (Source: S.T Munasinghe, Department of Agriculture, Personal Communication)

Double Chamber Down Draft

Modified *Kunthaniya*

Farmers can convert paddy husk into biochar and apply them to paddy fields and low-cost technologies to produce high quality rice husk biochar is now available in the country (See the plate). The *Kunthaniya* technology has been modified to increase the quality of rice husk biochar produced at domestic levels. The *Kunthaniya* technology produces biochar batch-wise. A continuous rice husk biochar production technology has also been developed using the down draft double chamber (DDDc) technology. This DDDc pyrolizer could be modified to provide bioenergy to rice mills. In a single season with an average paddy harvest of 5 t/ha, about 500-600 kg of rice husk biochar could be produced while generating bioenergy, if properly planned. Recycling of this biochar within the same field will gradually increase the much-needed organic matter content in soil to improve soil fertility, reduce bio-availability of toxic pollutants and reduce greenhouse gas emissions.

Current & Proposed Policies

During the journey for achieving self-sufficiency in rice production in Sri Lanka, more emphasis was placed on supplying synthetic fertilizers - urea, triple super phosphate, and muriate of potash - to farmers at a subsidized price. Such policy decisions discouraged farmers from using important organic amendments that are essential to arrest the degradation of soil fertility in their paddy cultivating lands. Recently, an opposite policy decision was implemented by the Government by banning the use of synthetic agro-chemicals and providing subsidies only for organic sources of agricultural inputs. Due to the low availability of organic fertilizers and their poor quality, organic only agriculture policy also failed disastrously. Therefore, a balance should be struck between the two extremes, to increase the productivity and sustainability of paddy cultivation in Sri Lanka. Traditional organic amendments have their drawbacks such as rapid decomposition, inadequate supply, poor quality as well as the need for repeated application of large quantities. Promotion of the production and application of high-quality biochar, produced from paddy husk or any other organic waste, will provide multiple benefits not only to the paddy farmers in the VTCS but also to the quality of the environment.

Policy Recommendations

Accordingly, the following recommendations are proposed.

- Government should encourage paddy farmers to apply organic amendments to their paddy fields to improve soil fertility. That will reduce the wastage of synthetic fertilizers and protect the environment.
- Government should support entrepreneurs who are willing to start up small-scale or large-scale high-quality biochar production units. These production units could be established at small-scale or large-scale rice mills utilizing waste rice husk. An added advantage of this encouragement is that rice mills could be supplied with part of their energy requirement from bioenergy generated during the pyrolysis process while producing biochar.
- Farmer societies in VTCS should be encouraged to produce biochar from their paddy husk wastes by providing necessary training and incentives.
- Since the repeated application of large quantities of conventional organic amendments is impractical to be adopted by farmers, they should be encouraged to apply biochar in whatever quantities available as they will accumulate in the soil without being readily decomposed and improve soil fertility.
- Subsidies could be provided for biochar applications rather than only for synthetic fertilizers. Such a policy will help to arrest further degradation of paddy growing soils and increase the sustainability of the paddy cultivations in Sri Lanka.

- Further research should be encouraged by providing the necessary funds to determine the carrying capacity of biochar in paddy growing soils and to develop biochar based smart technologies to reduce synthetic fertilizer requirements. One such technology would be to develop Enhance Efficiency Fertilizers utilizing biochar.

References

Kulasinghe, T.N., & Dharmakeerthi, R.S. (2022). Effects of land use type and tank components on soil properties and sustainability of tank cascade system in the Dry Zone of north central Sri Lanka. Agricultural Systems, 201, 103474.

Lehmann, J., & Joseph, S. (Eds.). (2015). Biochar for environmental management: science, technology, and implementation. Routledge.

Liu, Y., Li, H., Hu, T., Mahmoud, A., Li, J., Zhu, R., Jiao, X., & Jing, P. (2022). A quantitative review of the effects of biochar application on rice yield and nitrogen use efficiency in paddy fields: A meta-analysis. Science of the Total Environment, 830, 154792.

Melles, G., & Perera, E.D. (2020). Resilience thinking and strategies to reclaim sustainable rural livelihoods: Cascade Tank-Village System (CTVS) in Sri Lanka. Challenges, 11(2), 27.

Sirisena, D., & Suriyagoda, L.D. (2018). Toward sustainable phosphorus management in Sri Lankan rice and vegetable-based cropping systems: A review. Agriculture and Natural Resources, 52(1), 9-15.

WOCAT. (2022). Recycling rice husks in Sri Lanka as a biochar-based slow-release urea fertilizer. Retrieved from https://qcat.wocat.net/en/wocat/technologies/view/technologies_6184/

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HLP POLICY BRIEF

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Use of Right Trees for Right Component of Village Tank Cascade Systems

Key messages

The following recommendations aim to advance sustainable water management, biodiversity conservation, and community livelihoods through thoughtful planning and community engagement to adopt the "Right Trees for Right Component" strategy.

- Capacity building: Conduct training programs and workshops for farmers, community members, and local authorities to highlight the importance of planting the right trees and agroforestry practices.
- Incentives and support: Provide incentives and technical support to promote widespread adoption of agroforestry. Establish community-driven tree nurseries and collaborate with local organizations and NGOs for sustained tree-planting initiatives.
- Policy integration: Integrate the "Right Trees for Right Component" concept into water management and agricultural policies within the cascade management to promote sustainable practices and ensure long-term ecological balance.
- Monitoring and evaluation: Establish a robust monitoring and evaluation framework to assess the impact of policies on water resources, biodiversity, and livelihoods, allowing for continuous improvement and refinement.

Optimizing Tree Selection for Ecosystem and Community Resilience of VTCS

Village Tank Cascade Systems (VTCS) play a crucial role in water management, enhancing agricultural productivity, and supporting ecosystem services in Sri Lanka's dry zones. These systems rely on adjacent forests, trees, and woody climbers to regulate water availability, foster biodiversity, and maintain ecosystem health. However, recent deforestation and degradation within VTCS components pose significant threats, with some components vanishing entirely from the VTCS landscape. Despite various tree-planting initiatives to combat these problems, improper species selection has led to negative outcomes such as invasive species proliferation and ecosystem service mismatch. Thus, careful selection of tree and woody climber species for various components

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of VTCS is essential to preserve VTCS functionality and sustainability. Emphasizing endemic and native species can enhance water security, soil stability, biodiversity, and socio-economic growth while preserving cultural heritage. This holistic approach underscores the importance of ecological understanding and community involvement in environmental stewardship. Strategic planting of selected tree species is crucial for safeguarding the cascade system, as recommended in this policy brief, drawing on insights from diverse projects and literature to enhance sustainability and community resilience. Table 1 provides species recommendations for VTCS components.

Community-driven TTree Selection and Placement for Sustainable VTCS Development

- ***Select Right Trees Wisely for Specific Components of VTCS:*** Carefully select tree and woody climber species for VTCS components, considering their roles in water regulation and biodiversity support. Refer to Table 1 for suitable species choices.

- ***Consider Strategic Tree Placement**:* Plan tree placement thoughtfully, placing deep-rooted species near water sources and shallow-rooted ones in peripheral areas to optimize water conservation and minimize interference with agricultural water use.

- ***Prioritize Endemic and Native Tree/Shrub/Woody Climber Species:*** Give preference to endemic and native tree/shrub/woody climber species within VTCS. These species are well-suited to local conditions, promoting longevity, biodiversity, and ecological balance.

- ***Implement Agroforestry Techniques:*** Integrate agroforestry techniques into VTCS, combining tree cultivation with traditional farming to enhance productivity, soil health, and produce diversity. This approach supports sustainable land management amid expanding settlements.

- ***Engage Local Communities:*** Involve local communities in tree-planting decisions to foster ownership, stewardship, and long-term success. Encourage community-run nurseries to sustainably supply suitable species and promote economic opportunities.

Policy Recommendations

To implement this policy brief, the following actions are recommended:

- Capacity Building: Conduct training programs and workshops to educate farmers, community members, and local authorities about the importance of planting the right trees and the benefits of agroforestry.

- Incentives and Support: Provide incentives and technical support to encourage the adoption of agroforestry practices and establish community-driven tree nurseries within the cascade system. Collaborate with local organizations and NGOs to facilitate tree-planting initiatives as long-term connected programs.

- Policy Integration: Integrate the "Right Trees for Right Component" concept into water management and agricultural policies within the cascade management to promote sustainable practices and ensure long-term ecological balance.

- Monitoring and Evaluation: Establish a monitoring and evaluation framework to assess the impact of the policy on water resources, biodiversity, and livelihoods. Use the findings to refine and improve the policy's effectiveness over time.

Table 1: Suitability of different tree species for different components of village tank cascade systems

Plant Species		Suitable Component of the Village Tank Cascade System						
Common name	**Scientific name**	**Tank bund (*Wek-anda*)**	**Tree belt (*Gas-gommana*)**	**Paddy field (*Wela*)**	**Home Garden**	**Interceptor (*Katta- kaduwa*)**	**Hamlet buffer (*This- bambe*)**	**Forest**
Beli	*Aegle marmelos* (L.) Corrêa [I]				√			
Rukaththana	*Alstonia scholaris* (L.) R.Br. [N]	√						
Cashew	*Anacardium occidentale* L.[I]				√			
Veli anoda	*Annona squamosal* L. [I]				√			
Arecanut	*Areca catechu* L. [I]			√	√			
Breadfruit	*Artocarpus incisus* L.f. [I]				√			
Biling	Averrhoa bilimbi L. [I]				√			
Kohomba	*Azadirachta indica* A.Juss. [I]	√			√	√		√
Bamboo	*Bambusa vulgaris* Schrad. ex J.C.Wendl. [I]					√		
Maila	*Bauhinia racemosa* Lam. [N]							√
Pethan (Kaha)	*Bauhinia tomentosa* L. [N]		√					√
Halmilla	*Berrya cordifolia* (Willd.) Burret [N]				√			
Palmyra	*Borassus flabellifer* L. [N]	√				√		
Kaila	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch. [N]		√					√
Katakela	*Bridelia retusa* (L.) A.Juss. [N]	√					√	√
Rattan	*Calamus* spp. [N, W]					√		√
Kithul	*Caryota urens* L. [N]				√	√		
Ehala	*Cassia fistula* L. [N]	√			√	√		√
Wa	*Cassia roxburghii* DC [N]							√
Hulan hik	*Chukrasia tabularis* A.Juss. [N]				√			√
Burutha	*Chloroxylon swietenia* DC. [N]		√			√		√
Kotta	*Ceiba pentandra* (L.) Gaertn. [I]					√		
Orange	*Citrus sinensis* (L.) Osbeck [I]				√			
Lime	*Citrus X aurantifolia* (Christm.) Swingle [I]				√			
Coconut	*Cocos nucifera* L. [I]				√		√	
Lolu	*Cordia dichotoma* Forst. f. [N]							√
Keppetiya	*Croton aromaticus* L. [N]						√	√
Bokalawel	*Derris scandens* (Roxb.) Benth [N]		√			√		√
Kalawel	*Derris parviflora* Benth [E]		√			√		√
Velvet tamarind	*Dialium ovoideum* Thwaites [E]				√		√	√
Mora	*Dimocarpus longan* Lour. [N]				√		√	√
Thibiri	*Diospyros malabarica* (Desr.) Kostel. [N]					√		√
Kaluwara	*Diospyros ebenum* J.Koenig [N]					√		√
Kalumediriya	*Diospyros quaesita* Thwaites [E]					√		√
Kunumella	*Diospyros ovalifolia* Wight [N]							√
Weera	*Drypetes sepiaria* (Wight & Arn.) Pax & K.Hoffm. [N]				√			√
Wood apple	*Feronia limonia* L. [N]					√		√

Common name	Scientific name	Tank bund (*Wek- anda*)	Tree belt (*Gas-gommana*)	Paddy field (*Wela*)	Home Garden	Interceptor (*Katta- kaduwa*)	Hamlet buffer (*This- bambe*)	Forest
Attikka	*Ficus racemosa* L. [N]	√				√		√
Maha nuga	*Ficus benghalensis* L. [N]	√				√		√
Kotadimbula	*Ficus hispida* L.f. [N]							√
Pihimbiya	*Filicium decipiens* (Wight & Arn.) Thwaites [N]	√						√
Gliricidia	*Gliricidia sepium* (Jacq.) Walp [I]			√	√			
Athdemata	*Gmelina arborea* Roxb. ex Sm. [N]							√
Damunu	*Grewia tiliifolia* Vahl [N]					√		√
Wel keliya	*Grewia orientalis* L. [N]							√
Kolon	*Haldina cordifolia* (Roxb.) Ridsd [N]							√
Belipatta	*Hibiscus tiliaceus* L. [N]					√		√
Bu getiya	*Hugonia mystax* L. [N]							√
Kiri wel	*Ichnocarpus frutescens* (L.) W.T.Aiton [N, W]							√
Rathmal	*Ixora coccinea* L. [N]		√			√		√
Pavatta	*Justicia adhathoda* L. [N]			√	√			
Mee	*Madhuca longifolia* (L.) J.F.Macbr. [N]			√		√	√	√
Mango	*Mangifera indica* L. [I]				√	√	√	√
Atamba	*Mangifera zeylanica* (Blume) Hook.f. [E]				√	√	√	√
Palu	*Manilkara hexandra* (Roxb.) Dubard [N]		√					√
Lunumidellea	*Melia azedarach* L. [N]				√			
Korakaha	*Memecylon umbellatum* Burm.f. [N]					√		√
Munamal	*Mimusops elengi* L. [N]				√			√
Helamba	*Mitragyna parvifolia* (Roxb.) Korth. [N]		√	√		√		√
Murunga	*Moringa oleifera* Lam. [I]				√			
Ahu	*Morinda citrifolia* L. [N]						√	√
Karapincha	*Murraya koenigii* L. [N]				√	√	√	√
Bakme	*Nauclea orientalis* (L.) L. [N]	√						√
Thotila	*Oroxylum indicum* (L.) Kurz [N]					√		√
Vetakeya	*Pandanus kaida* Kurz [N]					√		
Indi	*Phoenix pusilla* Gaertn. [N]					√		√
Nelli	*Phyllanthus emblica* L. [N]	√			√	√		√
Kayla	*Phyllanthus reticulatus* Poir. [N]							√
Karanda	*Pongamia pinnata* (L.) Pierre [N]	√				√		√
Guava	*Psidium guajava* L. [I]				√			
Welan	*Pterospermum suberifolium* (L.) Raeusch. [N]							√
Pomegranate	*Punica granatum* L. [I]				√			
Kothalahimbutu	*Salacia reticulata* Wight [N]		√			√		√
Pare Mara	*Samanea saman* (Jacq.) Merr. [I]	√						
Kon	*Schleichera oleosa* (Lour.) Oken [N]					√		√
Kattamberiya	*Scutia myrtina* (Burm.f.) Kurz [N]							√
Kathurumurung	*Sesbania grandiflora* (L.) Pers.				√			
Thelabu	*Sterculia foetida* L. [N]							√
Nithul	*Streblus asper* Lour. [N]		√				√	√

Common name	Scientific name	Tank bund (*Wek- anda*)	Tree belt (*Gas-gommana*)	Paddy field (*Wela*)	Home Garden	Interceptor (*Katta- kaduwa*)	Hamlet buffer (*This- bambe*)	Forest
Goda kaduru	*Strychnos nux-vomica* L. [N]					√		√
Ingini	*Strychnos potatorum* L.f. [N]				√	√		√
Damba	*Syzygium assimile* Thwaites [E]					√		√
Madan	*Syzygium cumini* (L.) Skeels [N]							√
Tamarind	*Tamarindus indica* L. [I]	√			√	√		√
Teak	*Tectona grandis* L.f. [I]				√			
Kumbuk	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. [N]	√	√			√		√
Bulu	*Terminalia bellirica* (Gaertn.) Roxb. [N]	√				√		√
Kottan	*Terminalia catappa* L. [I]	√				√		
Aralu	*Terminalia chebula* Retz. [N]	√				√		√
Nabada	*Vitex leucoxylon* L.f. [N]		√					√
Milla	*Vitex altissima* L.f. [N]							√
Nika	*Vitex negundo* L. [N]			√	√			
Anguna	*Wattakaka volubilis* (L.f.) Stapf [N]				√	√		√
Kudumirissa	*Zanthoxylum asiaticum* (L.) Appelhans, Groppo & J.Wen [N,W], (Syn:*Toddalia asiática* (L.) Lam.)							√
Masan	*Ziziphus mauritiana* Lam. [N, W]				√	√		√
Heen eraminiya	*Ziziphus oenopolia* (L.) Mill [N, W]							√

E=Endemic Species; N=Native Species; I= Introduces Species; W=Woody Climber

References

Dharmasena, P. B., Weerahewa, J., Pushpakumara, G., & Kadupitiya, H. (2018). Past glory and present status of tank, people, and environs in the Bellankadawala village tank cascade system. A report compiled by the University of Peradeniya in collaboration with the Gammedda Movement.

Ministry of Agriculture and Food and Agriculture Organization of the United Nations (2017). A proposal for declaration as a GIAHS the cascaded tank-village system (CTVS) in the dry zone of Sri Lanka. Sri Lanka.

Geekiyanage, N., & Pushpakumara, D. K. N. G. (2013). Ecology of ancient tank cascade system in island Sri Lanka. *Journal of Marine and Island Cultures, 2*(2), 93-101.

Weerahewa, J., Timsina, J., Wickramasinghe, C., Mimasha, S., Dayananda, D., & Puspakumara, G. (2023). Ancient irrigation systems in Asia and Africa: Typologies, degradation, and ecosystem services. *Agricultural Systems, 205*, 103580. https://doi.org/10.1016/j.agsy.2022.103580

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POLICY BRIEF

Potential of Collective Labor-intensive Farming to Improve Smallholder Crop Production Systems in the Traditional Tank Villages:

Insights from a Time-tested Evolved Reciprocal Labor Institution

Key messages

- Reciprocal labor offers a viable labor source for small farmers, but its decline due to agricultural commercialization and socio-cultural changes is evident. However, an evolved reciprocal labor institution continues to endure in a traditional tank village (Mawathawewa) in the dry zone, challenging conventional perspectives on the sustainability of reciprocity in labor exchange within commercial farming contexts. From field observations, it became evident that this institution has led to crop intensification, increased land productivity, and reduced farmers' reliance on forest encroachment in the village.
- A number of prominent characteristics could be observed supporting the Mawathawewa reciprocal labor institution to thrive in a commercial farming context, delivering benefits to both the farmers and the environment.
- This policy brief, with reference to Mawathawewa, offers insights into harnessing the potential of collective labor-intensive farming to enhance smallholder crop production systems in traditional tank villages.

Apparently, the most prominent approach to mobilize labor within a capital-scarce context would be for farmers to rely on reciprocal labor if an institution structuring labor-exchange is in place. However, informal institutions structuring labor exchange around the globe, for the most part, have not been able to survive the test of time as societies became more complex and dynamic. Following the same global trend, farming in tank village systems has also evolved into enterprises largely depending on labor procured through economic transactions. However, it is evident from historical narratives that farming in traditional tank village systems was built on the principles of collective/cluster farming, where reciprocal labor was the most pervasive source used to procure labor for many crop production activities up until the mid-20th Century.

J.M.P.N. Anuradha, University of Peradeniya, Sri Lanka

Are there Tank Villages where Reciprocal Labor still Remains Prominent?

Standing on the assumption that an institution structuring reciprocal labor could still adapt to remain economically viable, I wondered whether a reciprocal labor institution adapted to survive in commercial farming could be traced within any pocket of the dry zone. In the quest to explore for such an exchange-labor mechanism within the dry zone, I could observe an evolved and time-tested reciprocal labor institution that has enabled a small tank village community to overcome the limiting factor of labor in cash-cropping of chili. Labor intensive chili production has enabled the farm households in Mawathawewa to earn a higher income far above the average income a rural Sri Lankan household can earn (Anuradha et al, 2018). Conversely, Mawathawewa farmers have been able to sustain their household incomes with significantly smaller land extents compared to farmers in surrounding villages. Mawathawewa reciprocal labor institution operates in a commercial context of smallholder farming under which many traditional reciprocal labor institutions around the globe could not survive (Anuradha et al, 2018). This policy brief provides insights into how Mawathawewa evolved reciprocal labor institution could adapt and continue to survive in a commercial context of smallholder farming, delivering a comparative advantage to the farm households in Mawathawewa[1].

How does the Evolved Mawathawewa Reciprocal Labor Institution Work and differ from the Eroded Traditional Exchange-labor Institutions?

Although reciprocal labor was substituted by wage labor in many parts of the country, an evolved form of reciprocal labor continues to exist in Mawathawewa as the dominant labor mobilization strategy in the village. This challenges the notion that reciprocal labor doesn`t flourish in areas where commercial agriculture has been promoted (Mitchell, 1991; Ponte, 2000). Mawathawewa farmers acknowledge that the evolved reciprocal labor system in Mawathawewa (hereafter referred to as MA) has its root in the traditional *attam* system (hereafter, referred to as TA) which had been practicing in the village before the late-1980s. The MA operates more like an informal virtual labor bank, functioning without any form or degree of centralized administration. Unlike in the TA, Mawathawewa farmers do not affiliate themselves with fixed labor-sharing groups; rather each farmer negotiates and forms informal contracts with a set of individual farmers. A contract, which is a verbal agreement to exchange labor, is formed between two farmers. The number of contracts formed by an individual farmer is dependent upon his/her external labor requirement. In Mawathawewa, as a general practice, males (husbands) and females (wives) work together and share an equal content of work in the field. As a result, in the MA, the contracts are often formed between two couples (representing two households). In such a contract, a male (husband) and a female (wife) member of one household agrees to work a specific duration of time in another couple`s field and expects the respective couple to work in their field in return over a similar duration of time. Usually, the duration of the work is measured in four-hour units.

A four-hour unit is termed "*waru*" (half-day). There are three choices of work time: half waru (2.5 hours), *waru* (4 hours) and day *waru* (8 hours). Based on the work time of the day, *waru* is divided again as morning waru (from 8.00 am to 12.00 noon) and evening *waru* (from 1.00 pm to 5.00 pm). The work times and durations specified above are cardinal rules of the MA system. When a contract is formed, the two parties must agree upon the duration of exchange labor (in waru units), number of people (either an individual farmer or a couple) and the dates.

As a norm and due to the complexity of contracts, Mawathawewa farm households maintain a

[1] Mawathawewa, which is a traditional tank village located in the Thirappane DS Division, represents a community of 467 people living in 151 house units.

reciprocal labor record book which is similar to a savings account book. These books are kept by each household to maintain records on labor hour units worked (similar to savings), received in return (withdrawal) and lent (credit) from others. The contract, normatively, in adherence to the shared cardinal rules under the consent of both parties, allows transacting parties to practice reciprocal labor as per their convenience.

How could the Mawathawewa Reciprocal Labor Institution Survive while other Exchange Labor Institutions Perished?

In Mawathawewa, a labor transaction between two agents (households) establishes some kind of balance with each other, and hence can be termed "balanced reciprocity" (Sahlins, 1974). In "balanced reciprocity" transactions tend to be equivalent and driven by both motives and norms (Kolm, 2008). It is apparent that the motives or the reasons for the Mawathawewa dwellers to involve in reciprocity in chili farming are attached to tangible economic benefits; significantly reduced cost of labor, improved access to labor in times of need and high net return per unit land etc. Apart from the motives, how far the norms of reciprocity fit into the contemporary values and demands of a community can matter in its survival as a pervasive institution.

Autonomy left with farmers in a closed system: The MA reciprocal labor institution in Mawathawewa differs from the TA by granting individual farmers greater autonomy in determining the number and nature of labor contracts they wish to enter into. This acknowledges the wider heterogeneity in preferences, demographics, and resource endowment within the agrarian society. Unlike the TA, the MA allows contracts to be formed between farmers with different land holdings. Even a relatively large farmer can form a number of contracts with small farmers (the number of contracts depend on the capacity of the large farmer to commit time to work in the farms of the contracting parties) and supplement reciprocal labor with hired labor as necessary. Another reflection of autonomy is the flexibility left with the labor transacting parties in settling reciprocal labor contracts. The MA, as described earlier, has left room for adjustment in work situation contingencies and individual needs with a range of pre-defined choices of conduct. For instance, if an individual farmer fails to attend to work in a field of a contractee (named A) on an agreed date, he may either hire someone to work or borrow *waru* from another fellow contractee and have that person work in A's field in his absence. This flexibility apparently extends to the nature of work and contract terms, enabling farmers to enter into exchange labor contracts to match with their respective labor needs and preferences.

Neutrality in a diverse community: In the MA reciprocal labor system, labor exchange is standardized in *waru* units, with a notable gender neutrality in labor valuation, promoting household participation over individual farmer involvement. Both spouses typically engage in labor exchange activities, with labor hours equally valued regardless of gender, indirectly encouraging women's participation with the intent of maintaining a large labor pool. Additionally, the MA allows farmers to select contractees outside the socio-culturally structured differences. However, this freedom is limited within the boundaries of the locality, which forms a closed community separating it from the rest of the society. This allows the MA to provide individual farmers with much choice of selection while also protecting the system from inconsistencies and forces outside the community.

Uniformity across the community in cropping pattern: Reciprocity between unequal partners can lead to contract failure due to demand imbalances. However, the success of the MA system relies on homogeneity among farm households, reflected in similar cropping patterns and operational practices. In Mawathawewa, all households mono-crop chili in Yala (minor) season and cultivate chili, corn, rice, and vegetables in Maha (major) season, leading to synchronized labor demands and supplies. Uniformity in farming practices, such as plot arrangements[2] and harvesting methods, reduces

[2] As a cardinal rule, a plot (liyadda) size should be 6 feet wide and 6 feet long. Within one plot, there should be four lines of the crop. In harvesting, as a norm, 4 people need to be employed in one plot for duration of a waru. One person is responsible to harvest a line of crop which

uncertainties and provides clear guidelines for reciprocal labor mobilization. This uniformity encourages households to maintain yields at an optimal standard, ensuring mutual benefit in labor exchange. The MA system promotes balanced, and mutually beneficial acts, reinforcing emotional bonds and social relationships while suppressing opportunistic behavior.

Latent functions of the institution: Besides the manifest function of the institution, the reciprocal labor institution performs several strong latent functions. On one hand, these latent functions play a significant role in shaping the identity of this community as a cohesive collective of commercial farmers serving the domestic chili market. On the other hand, these latent functions contribute to sustaining the pervasive presence of the reciprocal labor institution itself. As I observed, economic stability and social integrity sustained by reciprocal labor has resulted in less out-migration of the youth in the locality. Maintaining a sufficient active population within the community at all times is important for the smooth continuation of the reciprocal labor institution itself. Another indirect effect of the institution is the encouragement of farm households to maintain their yields at an optimum standard. As the Mawathawewa farmers believe, for theMA system to be economically beneficial, they have to maintain their yields above or on a par with the standards of others with whom they exchange labor. This belief strongly argues the stance that reciprocal labor cannot exist in a commercial agrarian setting that nurtures competitiveness or profit maximization.

References

Anuradha, J.M.P.N., Fujimura, M., Inaoka, T., Sakai, N. (2018). Collective labor-intensive farming towards sustainable farm livelihoods: the experience of labor exchange practice in Mawathawewa, Sri Lanka. *Journal of Environmental Sociology*, Vol. 24.

Kolm, S. C. (2008). *Reciprocity: An economics of social relations*. Cambridge University Press. Mariyono, J., & Sumarno, S. (2015). Chilli production and adoption of chilli-based agribusiness in Indonesia. *Journal of Agribusiness in Developing and Emerging Economies*, *5*(1), 57-75.

Mitchell, W. P. (1991). Some are more equal than others: labor supply, reciprocity, and redistribution in the Andes, *Journal of Agribusiness in Developing and Emerging Econies*, *5*(1)

Ponte, S. (2000). From social negotiation to contract: shifting strategies of farm labor recruitment in Tanzania under market liberalization. *World Development*, *28*(6), 1017-1030.

Sahlins,M. (1974). On the Sociology of Primitive Exchange, M. Sahlins, ed., Stone age Economics, London: Tavistock.

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usually takes four hours of continuous work inclusive of a 15-minute tea break.

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POLICY BRIEF

Natural Grasslands in Tank Cascade Systems of Sri Lanka: Grazing Grounds for Ruminants

Key messages

The following recommendations aim to enhance the understanding, management, and sustainable utilization of grasslands within tank cascade systems.

- Map the grasslands within tank cascade systems.
- Study the dynamics of grasslands as grazing grounds in different seasons to optimize their utilization and sustainability.
- Implement regular monitoring of grassland productivity to identify the various factors contributing to the deterioration of grasslands in tank cascade systems.
- Conduct research to understand the causes that affect the productivity of grasslands in tank cascade systems in order to propose locally appropriate solutions using a systematic approach.
- Educate farmers on basic grassland management practices to promote sustainable use and maintenance of communal pasture lands.
- Establish a communal management system for grasslands within tank cascade systems, integrating economic, socio-economic, land use, and wildlife management with the support of extension services, the State, and local authorities to ensure the sustainable use of these pasture lands.
- Provide suitable planting materials of improved forage species to enhance grassland productivity.

Natural Grasslands in the VTCS

Natural grasslands are plant communities dominated by grass species growing together with other plants such as herbs and weeds. Ecologically, natural grasslands differ from each other due to variations in climate conditions, soil types, topography, natural courses such as fire, and various anthropogenic activities. The types of natural grasslands available in Sri Lanka are described in Table 1. Grasslands in tank cascade systems are one of the natural grassland types available in Sri Lanka and the current policy brief outlook their characteristics and contribution to ruminant animal production in the dry zone of Sri Lanka.

The potential of using some of the above natural grasslands as grazing grounds for ruminant animals has been discussed

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Table 1. Types of natural grasslands in Sri Lanka

Main type	Main-sub type	Sub-type
Montane	Dry	Humid zone dry patana
		Summer zone dry patana
	Intermediate	Intermediate patana
	Wet	Lower wet patana
		Upper wet patana
Savanna		Upland savanna
		Lowland savanna
Lowland	Wet zone pastures	Inland grasslands
		Maritime grasslands
	Dry zone pastures	Damana
		Thalava
		Villu
		Tank bed grasslands
	Intermediate zone pastures	Coconut grazing grounds
	Arid zone pastures	Dry, humid and mixed pastures

Source: Extracted and arranged from Pemadasa (1983).

previously by Premarathne et al., (2003). However, the potential use of the grasslands in tank cascade systems as grazing grounds for ruminant animals has not been identified. A characterization of the botanical and nutritional composition of grasslands in tank cascade systems is necessary to identify potential uses as grazing grounds for ruminants and then to make appropriate suggestions to ensure their sustainable development.

Botanical and Nutritional Composition of Grasslands in Tank Cascade Systems in Dry Zone of Sri Lanka

The botanical composition of grasslands in tank cascade systems was estimated by conducting a scientific study in the Mahakanumulla cascade system located in Northwestern province in Sri Lanka where majority of the cascade systems are established. The botanical composition of grasslands in the Mahakanumulla tank cascade system is shown in Figure 1. The main grasses and herb species observed were *Panicum repence, Panicum maximum, Paspalidum* spp., *Cynadon dactyon, Leptochloa chinensis, Cyperus* spp., *Phyla nodiflora and hygrophila schulli*. In general, a greater accumulation of dead matter (40%) and lower grass percentage (50%) of grasslands in tank cascade systems can be apparent compared to cultivated grasslands for livestock animals (Rodríguez; 2020), suggesting the performance of livestock animals grazing on them can be poor. Therefore, if grasslands in tank cascade systems are to be utilized for feeding ruminant animals for improved production, further attention is required in managing the botanical composition adopting proper grazing management practices.

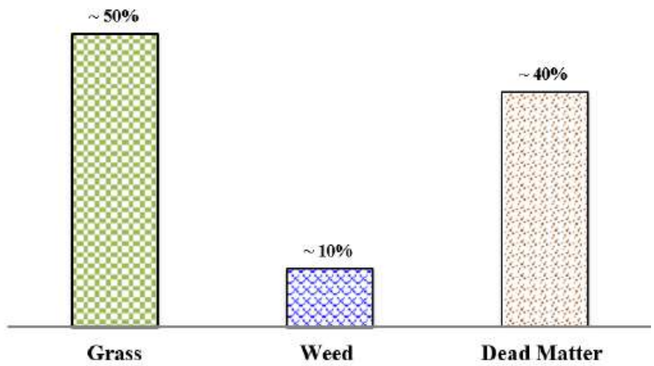

Figure 1. Botanical composition of grasslands in tank cascade systems in dry zone of Sri Lanka

The nutritional composition of grasslands in the Mahakanumulla tank cascade systems is presented in Table 2. The highest dry matter availability can be observed when grasslands in the tank cascade

Table 2. Dry matter availability (DM, kg/ha), dry matter content (DM%), crude protein (CP%), crude fiber (CF%), ash (Ash%), and gross energy content (MJ/kg) of grasslands in Mahakanumulla tank cascade system

Tank name	DM (kg//ha)	DM%	CP %	CF %	Ash %	Gross energy (MJ/kg)
Sembukulama	7250	97.0	7.4	30.8	7.0	16247
Mahakanumulla	1800	94.8	9.1	29.2	9.3	15647
Pahalawewa	5867	95.8	10.1	34.2	8.4	16007
Punchikulama	3441	94.9	6.98	29.9	9.9	15706

system were dominated by *Panicum repence* mainly due to its higher dry matter accumulation. Crude protein of naturally grown pastures in grasslands of tank cascade system varied from 6.9% to 10.2%. In comparison to the reported crude protein of cultivated pastures, these pastures may have a limited amount of protein required for dairy cattle (14-18%), thus, supplementation of protein to dairy cattle, which graze on these pastures, is recommended.

Cattle and Buffalo Production in Tank Cascade Systems of Sri Lanka

Three main tank cascade zones are found in Sri Lanka namely North & North Central, North Western & South, and South Eastern cascade zones. Grasslands in these tank cascade zones provide grazing grounds for ruminant animals. The approximate milk production of cattle and buffalos in these cascade systems is summarized in Table 3.

The total milk production of cattle and buffalo in these cascade zones should be less than that presented in Table 3 because not all the animals are being fed using grasslands in these cascade zones. Naturally growing pastures often become the single source of nutrients for animals regardless of their poor nutritional quality primarily due to limited resources available for farmers to cultivate pastures. These numbers therefore can provide insights into the significance of grasslands in tank cascade systems as important pasture resources for milk production in Sri Lanka.

Table 3. Approximate milk production in Northern & North Central, North Western & Southern and Eastern cascade zones

Cascade zones	Cow milk (L), % of total production in Sri Lanka	Buffalo milk (L), % of total production in SL
North & North Central	91,631,634 (28%)	14,288,848 (26%)
North Western & South	72,134,060 (22%)	18,617,088 (34%)
South Eastern	22,506,606 (7%)	7,642,338 (14%)
Total	**186,272,300 (57 %)**	**40,548,274 (74%)**

Source: Statistical Bulletin of Department of Animal Production and Health for Livestock in Sri Lanka (2022).

Grazing ruminants solely on natural grasslands for improved production can be challenging owing to low productivity and poor nutritional quality of grasslands in tank cascade systems. Supplementary feeding of those ruminants using locally available feed materials can be a viable alternative to increase productivity and profitability. In addition, improved grazing management by clustering the natural grasslands into smaller areas using temporal fences can also benefit farmers allowing them to practice rotational grazing. This can further provide farmers an opportunity to incorporate improved pastures into the natural pastures, even though it can be difficult due to given legal boundaries and economic limitations for the farmers. Further, the following suggestions may be helpful to ensure the sustainable development of grasslands in tank cascade systems as grazing grounds for ruminant animals.

Suggestions to ensure a Sustainable Development of Grasslands in Tank Cascade Systems as Grazing Grounds

- Mapping of the grasslands in tank cascade systems in Sri Lanka.
- Identify the dynamics of grasslands in tank cascade systems as grazing grounds in different seasons of the year.
- Monitoring of various aspects related to the deterioration of the productivity of grasslands in tank cascade systems.
- Research must be carried out to understand the variable causes that affect the productivity of grasslands in tank cascade systems to suggest locally appropriate solutions using a systematic approach.
- Educating farmers to use these communal pasture lands with basic grassland management practices.
- Establishment of a communal management system of grasslands in tank cascade systems addressing economic, socio-economic, land use and wildlife management aspects with the support of extension services, state & local authorities to ensure the sustainable use of these pasture lands.

References

Rodríguez, R., Balocchi, O., Alomar, D., Morales, R. (2020). Comparison of a Plantain- Chicory Mixture with a Grass Permanent Sward on the Live Weight Gain and Meat Quality of Lambs. Animals (Basel). 2020 Dec 2;10(12):2275. doi: 10.3390/ani10122275. PMID: 33276554; PMCID: PMC7761527.

Pemadasa, M.A. (1983) Grasslands. In: Fernando CH (ed.) Ecology and Biogeography in Sri Lanka. Junk Publishers. 99-131.

Premaratne, S., Premalal, G.G.C., and Jayawardene, V.P. (2003). Sustainable management of grassland for ruminant livestock production in Sri Lanka. Tropical Agricultural Research and Extension. 6: 74-79.

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Dairy entrepreneurs in Sri Lanka

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POLICY BRIEF

Developing Climate-Resilient Dairy Farming in Village Tank Cascade Systems

Key messages

Dairy farming in Village Tank Cascade Systems faces increasing vulnerability to climate shocks, impacting milk yield, pastures, and reproduction. Key policy recommendations to enhance resilience and sustainability of dairy farming within VTCs include:

- Offer financial support for climate-related initiatives and empower the community to utilize resources effectively.
- Develop and manage community pasture and fodder areas in upper inundation zones to optimize land use and implement comprehensive training programs for farmers to advance their skills in optimizing pasture utilization through effective silage production techniques.
- Expand livestock extension services and involve grassroots organizations, NGOs, and milk collectors to reduce the knowledge gap of farmers.
- Address credit market inefficiencies and promote microfinance for equitable and accessible financial support for farmers.
- Reduce gender-related barriers to adopting climate-smart adaptation techniques and ensure equitable access to resources and support.
- Develop responsive regulatory frameworks that facilitate farmers' adaptation to climate change challenges.

Small-scale dairy farmers in village tank cascade systems (VTCS) are grappling with numerous challenges brought about by climate change. The increasing temperatures and unpredictable weather patterns are causing a drop in milk production, a surge in pests and diseases, and a decline in the reproductive performance of cows. Despite their efforts to implement cost-effective strategies, these challenges undermine farmers' ability to sustain their livelihoods year-round. The compounded effect of limited access to crucial resources, such as robust social networks and financial capital, coupled with a lack of knowledge on effective adaptation strategies, further impedes farmers' ability to adopt proactive measures to mitigate the impacts of climate change. A comprehensive approach must

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be implemented to address these existing gaps in resilience. This involves breaking down social barriers that hinder adaptation, strengthening the Enabling environment for better capacity development of farmers, offering financial support for climate-related initiatives, and empowering the community to use community resources for dairy farming effectively.

Climate-induced Challenges in Dairy Farming in the Village Tank Cascade Systems

Village Tank Cascade Systems (VTCS) in Sri Lanka are ancient and essential irrigation systems that have supported the livelihoods of surrounding villages for generations. These communities heavily depend on the natural resources provided by the VTCS, such as water and grasslands. While crop farming is the mainstay, dairy farming has emerged as a crucial supplementary or even primary source of income for VTCS farmers. Unfortunately, the sustainability of dairy farming in VTCS is threatened by climate-induced stressors and shocks. Over the past 80 years, Sri Lanka has experienced a general rise in average temperatures and a decrease in average rainfall[3]. Additionally, the country has also witnessed a rise in the intensity and frequency of extreme events like droughts and floods in recent years (Punyawardena and Premalal, 2013, as well as Rathnayake and Herath, 2005).

Climate shocks and stressors exert a profound impact on various facets of animal agriculture within VTCS. Recent research conducted in the communities of Thirappane and Siwalakulama sheds light on the substantial challenges faced by dairy farmers in these regions (Ranasinghe et al., 2023). Dairy farmers in these regions have experienced a shortage in pasture and fodder and a change in animal physiology, resulting in a discernible decline in milk production and reproductive performance. Of the myriad climate impacts observed, the most pronounced among dairy farmers is the dwindling pasture and fodder resources, exacerbated by recurrent droughts and floods that have escalated in frequency and severity over time. The scarcity of nutritious forage and heat stress have significantly contributed to diminished milk production (Figure 1).

Furthermore, a subset of farmers has encountered specific challenges related to reproductive performance. This includes delays in the age at which cattle initially calve, decreased fertility rates, and a higher incidence of abortions. These reproductive issues can be attributed to the physiological stress imposed by climate-related factors and the reduced availability of quality forage, affecting dairy cattle's overall health and reproductive capacity.

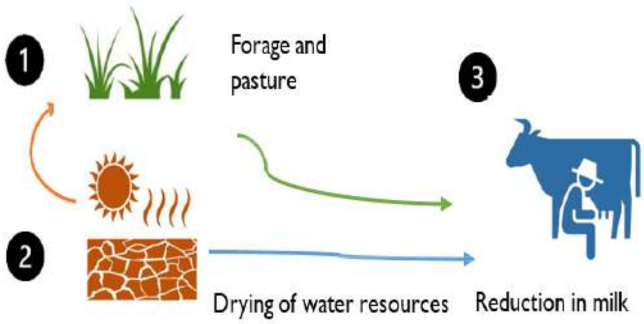

Figure 1: Top three perceived impacts of climate change[4]
Source: Ranasinghe et al., 2023

The effect of increased temperatures on animal physiology and reproduction is believed to be less on the animal breeds they have (Silva et al., 2021). In VTCS, many farmers opted to rear Indigenous, Indian, or crossbred cattle, along with buffaloes, due to their inherent ability to tolerate elevated temperatures. Consequently, farmers have experienced less effect of climate stressors on animal physiology and reproduction. From the perspective of climate adaptation, this attribute holds significant value.

However, the merit of breeds is partially offset by the feeding practices followed by farmers Only a small fraction of farmers employs the cut-and-feed method, and even among those who do, the origin of the pasture and fodder remains natural grasslands (referred to as upper inundation areas of the tanks). Despite the region's agricultural nature,

[3] *There are exceptions to this trend., Jeewanthi et al. (2021).*

[4] *Images were taken from the Noun project.*

the utilization of crop residues in animal feeding is infrequent.

Though extensive farming systems guaranteed adequate feed availability in the past, as time has passed, land sizes have diminished, and the availability of communal grazing land has declined, making it difficult for farming systems to guarantee adequate feed availability. Although farming practices need to be modified to align with these socio-economic changes, the adoption of intensive farming practices in these areas has yet to gain traction.

How do VTCS Farmers Adapt to Climate Change?

Climate adaptive measures taken by dairy farmers in VTCS are dominated mainly by strategies that address heat stress, such as providing shelter and adequate water supply that require lesser financial resources and knowledge. A lesser percentage of farmers modify housing arrangements to reduce the impact of heat stress or adopt new feed management practices to cope with the feed shortage, even though everyone has observed pasture shortage.

An in-depth analysis of the barriers to implementing climate adaptation strategies that effectively address their problems revealed that the adaptive capacity of the majority of farmers remains low in these cascades. More specifically, knowledge, social, physical, and financial capital gaps have prevented them from adopting more effective adaptive measures (Figure 2). However, their access to natural and physical capital is comparatively robust.

While many farmers in VTCS possess land suitable for growing fodder, the size of these plots often proves insufficient to sustain large herds. Despite this limitation, most dairy farmers in the region benefit from relatively good access to natural resources, including grasslands and privately-owned lands of adequate size for fodder cultivation, provided the herd size remains manageable. Moreover, there exists a significant opportunity for

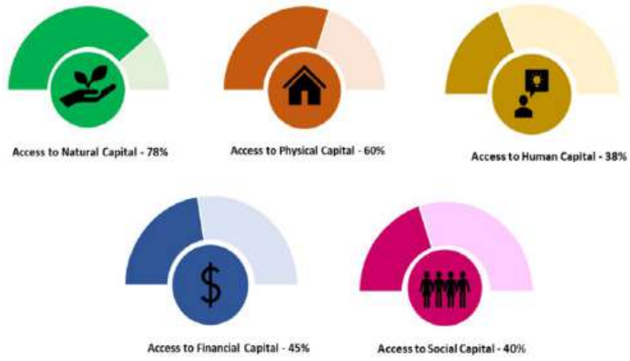

Figure 2: Access to critical resources needed to adapt to climate change by dairy farmers in selected VTCS

improvement in feed management practices. For instance, cultivating drought-resistant fodder and implementing techniques to preserve pastures could greatly enhance feed availability, particularly during periods of scarcity. However, these strategies remain vastly underutilized among dairy farmers in VTCS.

This is due to a lack of knowledge of pasture and fodder cultivation and preservation techniques, such as silage preparation. Farming is often a family livelihood passed down through generations in these rural settings. Although better networking with fellow farmers and institutions helps fill the gap in knowledge and skills in climate adaptation, new technologies do not reach the area due to the absence of effective extension services. As revealed by the study, the limited number of extension workers compared to the size of the area they have to serve has hampered the implementation of effective extension programs in these areas.

Farmers' perceptions of climate change's potential impacts on dairy farming are pivotal in shaping their adaptation decisions. While farmers across similar environmental contexts may face comparable exposures to climate change, their responses diverge based on their levels of awareness, beliefs, and expectations. Indeed, the interpretation of climate change effects varies widely among different farmers, resulting in a spectrum of adaptive responses. Among those who perceive a heightened negative impact from climate stressors and shocks, there exists a greater propensity to adopt adaptive measures.

The conflict between the area's crop and dairy farmers over the natural resources also impeded better collaborations in farming. Finally, financial capital, which encompasses financial resources such as off-farm income and access to formal and informal credit, is also lacking in these areas. Consequently, fewer farmers have been able to modify their housing and complement fodder with concentrated feed during the fodder shortage period.

Additionally, even though downsizing the herd during drought periods to alleviate the strain on available resources is a widely employed approach in other nations, regulatory constraints in Sri Lanka—specifically the Animals Act of 1958—and the underdeveloped state of the beef industry have acted as barriers, preventing farmers from culling productive animals as part of their climate adaptation strategy.

There are also social and cultural barriers to adaptation. Male farmers, especially those with fewer dependents, are generally more effective at adapting to climate change. Female farmers, on the other hand, tend to adopt fewer adaptation strategies, primarily due to social obstacles. Women often spend a significant amount of time on household chores, which limits their time for farming activities. Women also tend to have fewer social connections with other farmers and extension officers, restricting their access to vital information about climate change adaptation. This lack of engagement also hinders them from taking advantage of opportunities provided by community organizations that offer financial support for dairy farming (Ranasinghe et al., 2023).

Alternative Policy Recommendations

- Develop fodder and pasture areas and develop effective communication systems to disseminate information to farmers: The upper inundation area of the tank is one of the most valuable resources available to farmers. This natural pastureland becomes even more fertile after the rainy season. Farmers must be educated to use excess pasture available in rainy seasons to make silage to be utilized in the dry season.
- Explore opportunities to develop community grasslands in this area to benefit the community.
- Bridge the knowledge gap: Expand and strengthen the livestock extension services. Work with grassroots organizations, non-government organizations, and milk-collecting agents to get their involvement in reducing the knowledge gap.
- Address inefficiencies in the credit market while improving the availability and effectiveness of microfinance institutions. By doing so, a more equitable and accessible financial system that better serves all individuals and communities can be created.
- Empower and support female dairy farmers: Reduce the gender-related barriers to adaptation of climate-smart adaptation techniques.

- Develop a more dynamic and responsive regulatory network to address farmers need to adapt to climate change.

Conclusions

Dairy in VTCS is increasingly vulnerable to climate shocks and stresses. Milk yield has been reduced, pastures are in short supply, and reproduction performances have suffered. Actions to prepare stakeholders for the effects of climate change are imperative to maintain and improve the industry's health. Towards this, developing a multi-sectoral approach that addresses legislative issues related to animal culling, the shortage of livestock officers, and gender-related social issues in rural settings is essential. By doing so, the resilience of our farming communities can be enhanced, and the sustainable future of the dairy industry can be assured.

References

Abbas, Q., Han, J., Bakhsh, K., Ullah, R., Kousar, R., Adeel, A., & Akhtar, A. (2022). Adaptation to climate change risks among dairy farmers in Punjab, Pakistan. Land Use Policy, 119, 106184.

Punyawardena, B. V. R., & Premalal, K. H. M. S. (2013). Do trends in extreme positive rainfall anomalies in the central highlands of Sri Lanka exist? Annals of the Sri Lanka Department of Agriculture, 15, 1–12.

Ranasinghe, R. D. A. K., Korale-Gedara, P. M., & Weerasooriya, S. A. (2023). Climate change adaptation and adaptive capacities of dairy farmers: Evidence from village tank cascade systems in Sri Lanka. Agricultural Systems, 206, 103609.

Ratnayake, U., & Herath, G. (2005). Changes in the water cycle: Effect on natural disasters and ecosystems. In N. T. S. Wijesekera, K. A. U. S. Imbulana, & N. B. Paris (Eds.), Sri Lanka National Water Development Report. World Water Assessment Program. Paris.

Silva, G. L. L. P., Punyawardena, B. V. R., Hettiarachchi, A. K., Hulugalla, W. M. M. P., & Lokuge, G. M. S. (2021). Assessing thermal neutral zones in Sri Lanka for ten different dairy cattle breeds and crosses: An approach using temperature humidity index (THI). International Journal of Livestock Production, 12(2), 112-121.

Acknowledgements

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Citation

Korale-Gedara, P., Weerasooriya, S., & Ranasinghe, A. (2024). Climate change adaptation and adaptive capacities of dairy farmers: Evidence from village tank cascade systems in Sri Lanka. Healthy Landscape Project.

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POLICY BRIEF

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Productivity Implications of Upstream and Downstream Variations within a VTCS

Key messages

The following policy recommendations aim to address production inefficiencies and challenges within the Village Tank Cascade Systems.

- Adjust the crop calendar and planning practices to improve efficiency, especially during the Yala season. Implement measures to overcome issues with cascade flow and ensure sufficient support for cultivation during dry periods.
- Address biases in water to minimize efficiency loss in VTCS. Develop policies that ensure fair and equitable water distribution regardless of land tenure seniority, particularly for non-full-time farmers.
- Farmer organization support is a significant factor that contributes to efficiency. Policy interventions are needed to strengthen the capacities of these institutions to enhance coordination and effectiveness in agricultural production.
- Align planning and policy directions to achieve economies of scale in paddy production within VTCS contexts.

Description of the Problem

Production efficiency is a key concern in dry zone agriculture. Figure 1 displays that water use and output is not varying across cascade and across season in a predictive manner that implies efficiency. Among various types of efficiency measures, the most widely accepted type of efficiency measure relevant to cross sectional data is the 'technical efficiency.' Without sufficient information on factors contributing to production efficiency and/or the determinants of inefficiency, it is difficult to develop management measures for vulnerable production ecosystems such as those in VTCS.

D. V. P. Prasada, University of Peradeniya, Sri Lanka

Modelling the Efficiency of Agricultural Production in a VTCS

Agricultural production efficiency can be modelled using a production function approach. Within such a framework, technical efficiency can be considered as an indicator of the productive efficiency of an agricultural system as it gives a measure of input to output conversion. This can be used to analyze the efficiency of a tank cascade as a rice production system. Also, with the identification of the determinants of technical inefficiency, appropriate actions can be taken to control these factors to increase the efficiency in paddy cultivation and achieve optimal functionality of the cascade.

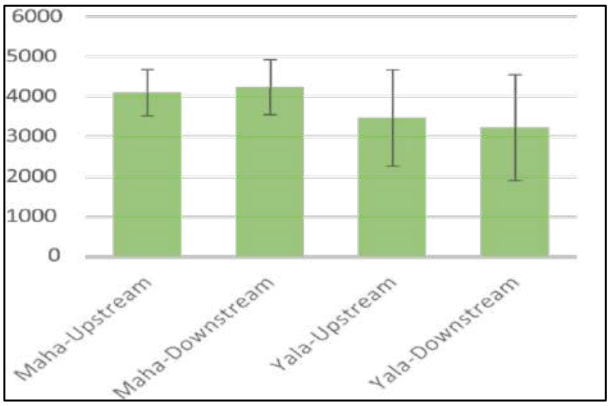

Figure 1A: Yield(kg/ha)

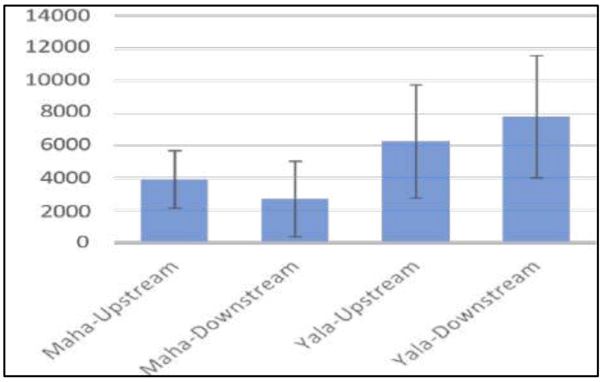

Figure 1B: Water Input (m^3/ha)

Methodology

Site selection

The site selected for the study is the *Mahakanumulla* tank cascade system located in Thirappane and Kekirawa Divisional Secretariats, Sri Lanka. *Mahakanumulla* cascade is a completely rainfed cascade comprising 27 tanks. Mahakanumulla cascade is classified as a branched cascade type with a form index (ratio of length to width) of 2.8. Within the cascade, five tanks are located along the main valley and the rest are located along the side or branch valleys. Mahakanumulla tank is the largest storage tank in the cascade. The tank cascade finally connects to the Nachchaduwa major tank along with the adjacent Thirappane and Ulagalla cascades. In the current study, 17 tanks in the cascade were studied in Maha season of 2019 and the Yala season of 2020.

Data collection

A preliminary field survey was conducted in the Mahakanumulla cascade to collect both primary and secondary data on the socio-economic and ecological environment of the cascade. In the preliminary field visit, the tanks for the study were identified depending on the function and ease of access. Secondary data were collected from the Divisional Secretariat office of Thirappane and the Agrarian Service Centre of Thirappane. A household survey was conducted in 25% of the farmer households in Mahakanumulla cascade with a systematic random sampling method using a household survey questionnaire from December 2019 to January 2020.

Technical efficiency analysis

A production function is an equation connecting the output to inputs and other relevant covariates. This study used the stochastic frontier production function model for cross-sectional data collected from the above household survey and the field measurements of the cascade infrastructure relevant to each farmer field. The frontier production function is defined as the maximum feasible or potential output that can be produced by a production unit such as a farm, given the level of inputs and technology. If the production unit is inefficient, its actual output is less than the potential output. Therefore, the ratio of the actual output and the potential output is posed as a measure of the technical efficiency of the production unit. Further estimations of factors driving inefficiency are possible as an addendum to the production function based technical efficiency analysis discussed above.

Key Findings of the Analysis

In this policy brief, the findings of relative technical efficiency by each farmer obtained in the analysis are averaged by tank to obtain measures of TE for representative paddy farmers under each tank within the cascade. We do so in order to convert farmer level findings to representative measures by the tanks which constitute the cascade. Where data is available the above calculation is performed for both cultivating seasons. Technical efficiency values are represented on a scale of 0 to 1 for each of the tanks by cultivating season in figure 2.

Findings (part 1: figure 2): Comparative illustration of performance of Mahakanumulla Upstream

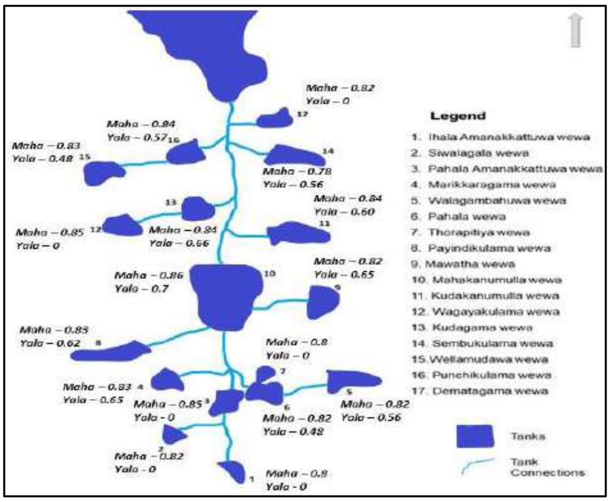

Figure 2: Efficiency values by tank for Yala and Maha seasons (Source: Author)

The production efficiency in the Maha season is uniformly distributed from upstream to downstream. The findings reveal that paddy production efficiency, as measured by stochastic frontier approach, suffers significantly in the Yala season compared to the Maha season. With respect to the location of the cascade architecture, the technical efficiency values are higher in the mid-stream but lower in both upstream end and downstream end, indicating that cultivation is supported efficiently only by the midstream storage tanks. This is indicative of a failure of the VTCS to enable sufficient runoff-based feeding along the cascade axis. Another potential negative implication is the tendency of users to deepen tanks without paying attention to cascade hydrology whenever water becomes scarce. This type of response can worsen the situation further and make the cascade more dysfunctional.

Findings (part 2: table 1): Determinants of Inefficiency

A useful byproduct of TE analysis is the possibility to correlate technical inefficiency to varying drivers, mostly social economic and demographic through a supplementary inefficiency model. Table 1 lists the findings of the inefficiency model and reports the relative magnitude partial regression coefficients for a host of socio-demographic variables.

The important drivers of inefficiency, according to the estimated model, are the lack of scale of production, lack of fulltime effort, division of water in the dry season biased towards residents, lack of government support and the lack of farmer organization support. In the Maha season, the above drivers are more pronounced in the upstream while the inefficiency factors are dominant in the downstream during the Yala season. All of the above findings carry important policy implications to productivity implications in VTCS.

Policy Recommendations

- Study findings reveal poor efficiency in the Yala season both in upstream and downstream ends. This is evidence of a failure in cascade flow and the inability of the VTCS to provide adequate support to cultivation in the dry season. The crop calendar and planning practices need to adapt to such realities in VTCS.

- Water division biased towards seniority of land claims creates efficiency loss in VTCS. This issue needs to be addressed if the original residents are not full-time farmers.

- Farmer organization support is a significant factor in efficiency according to the estimated model. Policy interventions are needed to support farmer institutions that deliver efficiency benefits to cultivators in the VTCS setting.

- Economies of scale are evidently problematic in VTCS settings and planning, and policy directions should be aligned towards creating economies of scale in paddy production in the VTCS context.

Table 1. Inefficiency estimates for Mahakanumulla tank cascade Yala 2020 and Maha 2019/2020

	Maha		*Yala*	
	Upstream	**Downstream**	**Upstream**	**Downstream**
Variable	Coefficient	Coefficient	Coefficient	Coefficient
Farmer age (Years)	0.004	-0.032	0.015	-0.014
Dummy for gender (Male=1, Female=0)	0.303	-0.471	-0.085	-0.362
Farmer education (Years)	-0.072	0.072	0.200	0.220
Cultivation area (ha)	**-0.026****	**-0.031****	**-0.111****	**-0.015***
Fulltime Farming (Yes =1, No =0)	**-1.129****	**-1.192****	**-0.156***	**-1.575***
Dummy for Original Residency (Residents=1, Migrants=0)	-1.157	0.582	**-0.056****	**-0.091***
Dummy for Government subsidies (Yes=1, No=0)	**-1.077****	**-0.325***	**-0.197****	**-0.507***
Index for support by farmer organization	**-0.092***	**-0.305****	**-0.026****	**-0.154***

** Significant at 95% confidence level * Significant at 90% confidence level

References

Sirimanna, S., & Prasada, D. V. P. (2021). Water productivity in tank cascade systems: A case study in Mahakanumulla tank cascade, Sri Lanka. Tropical Agricultural Research, 32(3), 298-306.

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POLICY BRIEF

Community Management in Village Tank Cascade Systems for Sustainability

Key messages

To transition from unsustainable to economically and environmentally viable fishery management practices within VTCS communities, it is essential to implement the following key recommendations.

- Assist in restructuring fishery management towards a more sustainable approach, potentially led by an aquaculture committee.
- Regulate fishing activities, stocking practices, and fishing seasons to enhance community support and ensure sustainability.
- Empower community organizations with enhanced decision-making abilities regarding fishery management.
- Engage fishers in decision-making processes to foster active community support for sustainable management practices.
- Conduct educational campaigns to demonstrate the benefits of sustainable management approaches to non-supporters.
- Highlight the advantages of adopting these practices for long-term resource availability and community well-being.
- Invest in the production of indigenous fish species to address fingerling shortages and preserve native biodiversity.
- Mitigate the risk of native species extinction caused by the introduction of exotic species through stocking practices.

Challenges in village tank cascade systems for sustainable Inland fisheries

Inland fishery through village tank cascade systems (VTCS) provides food and livelihood for a substantial percentage of the population living in the semi-arid north-central section of Sri Lanka. Apart from the production ecosystem services (i.e. crop cultivation, livestock farming, inland fishing, lotus harvesting and water consumption for household usage), VTCS are integral to the delivery of many effective freshwater ecosystem services such as habitat for native fish and aquatic plant species, drought and flood regulation, recreation and ecotourism, educational and scientific opportunities. However, the sustainable delivery of all these ecosystem services is determined by how these human evolved tank systems are managed in alignment with nature. Also, any changes to these ecosystem

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services are crucial to food and livelihood security in turn. In the Dry Zone of Sri Lanka, most of the tanks are managed by farmer organizations (FO) where fishers need to pay an agreed amount of payment to FO for harvesting. Despite several attempts made by the authorities, the establishment of an aquaculture management committee (AMC) has failed, due to the reluctance of fishers to be identified as commercial fishers and to adhere to the net size restriction imposed by the National Aquaculture Development Authority (NAQDA). Fishing activities in some tanks are not monitored by the FO and hence tangos nets with a net size of less than 85mm are frequently used. There are tanks that are managed by the AMC and the fishing of some other tanks is rented to private parties for a certain period (e.g. 1 or 3 years).

Stocking frequency is crucial for sustainability. The study finds that some tanks stock fingerlings annually, while others do it only once or not at all due to concerns about breeding exotic fish. Harvesting time and quantity of harvesting is connected with the fish population and ecosystem diversity. In some tanks, harvesting is limited to the Yala[5] season due to the fishing gear used by poor fishers and the belief that fishing during the Maha season could disrupt water flow to croplands. Therefore, they discourage fishing during the main cultivation season (Maha). Therefore, the study finds that different management approaches have consequences for resource utilization and the fishery ecosystem. Freshwater systems have a synergy across several Sustainable Development Goals. It has clear integration with No Poverty (SDG 1), Zero Hunger (SDG2), Clean Water and Sanitation (SDG 6), Responsible Consumption and Production (SDG 12) and Life on Land (SDG 15). Inland fishery services have a strong positive association between SDG 2, SDG 6, SDG 12 and SDG 15. Hence to achieve global aspirations, management of fishery needs policymakers' attention on different aspects of a fishery ecosystem given the weight SDGs have in policy designing.

Fishing in VTCS was traditionally done for household needs (Murray, 2004). Lack of refrigeration and underdeveloped marketing led to consumption of fish within a range of 30-40 km from production areas (Murray et al., 2022). Despite the demonstrable importance of the freshwater ecosystem, it has often been neglected, and policymakers, planners and water resource developers' attention are crucial for the expansion of the inland fishery industry with a sustainability focus.

Fisheries management approaches in VTCS differ in structure, stocking frequency, and fishing restrictions. A sustainable approach must incentivize users for responsible usage and compensate non-users. Understanding user preferences is crucial for community support (Kulathilake et al., 2010).

Table 1. Management aspect and associated characteristics

Management aspect	Characteristics
Management structure and community involvement	i. Aquaculture management committee (AMC) regulating community fishing ii. Farmer organization (FO) regulating community fishing iii. Renting of village tank to an individual
The frequency of stocking	i. One-time stocking ii. Regular stocking iii. Natural breeding
Restrictions on fishing extract	i. Restrictions on fishing time ii. Restrictions on the quantity of harvesting iii. No restrictions on fishing

[1] Maha Season falls during the "Northeast monsoon" from September to March of the following year. Yala season is effective during the period from May to the end of August.

Fishers' preferences over different management aspects related to the use of fishery

The study found that the fisheries management approaches in VTCS differ in management structure, frequency of stocking, and restrictions on fishing extraction. These are identified as management aspects. Fishers choose the combination of management aspects that yield the highest benefits for them. Sustainable management approaches ensure efficient use of fishery preventing overfishing and use of illegal fishing gears allowing the ecosystem adequate time for replenishment. This study identified several characteristics for each management aspect that fishers of different tanks may adopt various combinations of these characteristics. Table 1 shows the characteristics attached to each management aspect.

We studied the community's preferences for the different management approaches. Community fishing under AMC was found to be preferred over community fishing under FO. Moreover, the fishers prefer regular stocking over one-time stocking and natural breeding. Similarly, farmers showed the preferences for restrictions on fishing time and restrictions on quantity of harvesting compared to no restrictions on fishing.

The effect of socioeconomic characteristics on fisher's preferences

The study found that fishers who are confident about the decision-making ability of community organizations, including office bearers, prefer a management approach that allows community fishing under the management of farmer organization or aquaculture management committee. Moreover, with increased income from fishing, fishers' preference for stocking fingerlings also gets stronger. Net income from fishing does not influence the preference for fishing restrictions.

The relative importance of different aspects related to fishery management

As can be seen in the Figure 1, management structure and community involvement are the most

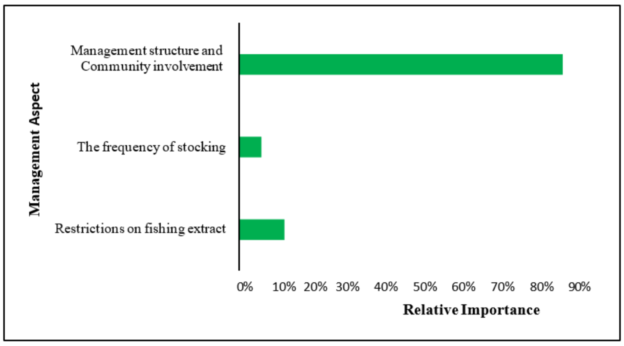

Figure 1: Relative importance of each aspect related to fishery management.

important management aspect for the fishers (83%). The second most important aspect is the restrictions on fishing extract (11%). The frequency of stocking is the third important aspect (6%).

Benefits perceived by fishers (willingness to pay) for adopting different management approaches

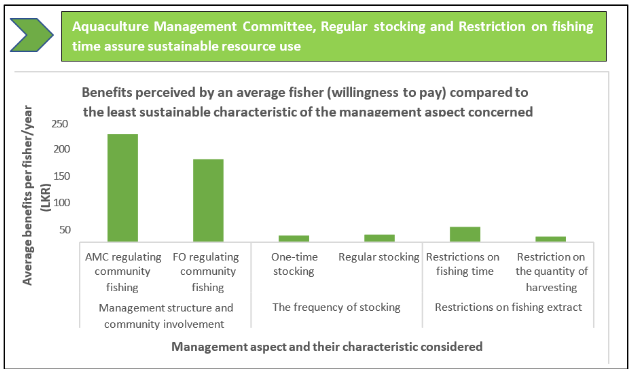

Figure 2 summarizes the average benefits perceived by a typical fisher for different management aspects and their characteristics. On average, fishers perceive the highest benefit (willingness to pay) if community fishing is allowed under the governance of aquaculture management committee compared to renting to outsiders.

Note: The values seem very small; however, concerning the monthly membership payment of 100 LKR per month, these are relatively higher benefit values.

Table 2 shows the average annual benefits they perceived or willing to pay for the selected six management approaches if these hypothetical management approaches were implemented. The results show that Approach A has the highest benefit for the fishers (275 LKR), followed by Approach B (255 LKR). Approach A might be preferred over other management approaches as it derives higher financial returns and minimizes the negative effect of fishing on the environment. The order of preferences indicates that fishers prefer to be engaged in community fishing. Effective imposition of harvest restrictions on community fishing allows fishers to ensure the sustainability of the resource and equal access to the resource (here we refer to the tank or fishery). As revealed by the small difference in benefits (willingness to pay) for approaches D and E, fishers do not perceive a significant additional gain from regular stocking over one-time stocking. Approach C is the least preferred approach (48 LKR). The exclusion of the community receiving fishing benefits and the higher possibility of overexploitation of fishing could explain the least preference for this approach.

Table 2. Average annual benefits fishers perceived (willing to pay) for the selected six management approaches if these hypothetical management approaches are in operation

Management approaches	**Average annual benefit (LKR)**
Approach A – AMC regulating community fishing, Regular stocking, Restrictions on fishing time	275
Approach B – AMC regulating community fishing, Regular stocking, Restrictions on quantity of harvesting	255
Approach C- FO renting the tanks to individuals, Regular stocking, Restrictions on fishing time	48
Approach D – FO regulating community fishing, One-time stocking, Restrictions on fishing time	220
Approach E – FO regulating community fishing, Regular stocking, Restrictions on fishing time	222
Approach F – FO regulating community fishing, Regular stocking, Restrictions on quantity of harvesting	202

Note: AMC = Aquaculture Management Committee, FO= Farmer Organization

The study extended with cost and benefit calculation of these management structures and found that aquaculture management committee the highest net return per fisher is also recorded by fishers who are governed under the AMC.

Alternative policy recommendations

- Authorities should assist in restructuring management if it's unsustainable. The best approach is fishery, managed by the aquaculture committee, regulating fishing, and stocking, and limiting fishing time for increased community support and sustainability.
- To obtain active community support, the decision-making ability of the community organizations also needs to be strengthened. The fishers rely more on a management entity that can make impactful decisions regarding the fishery.
- Non-supporters of these sustainable management approaches should be educated by demonstrating the benefits of adopting them.
- Investing in producing indigenous species also helps to reduce the shortage of fingerlings and to remove the fear of extinction of indigenous species due to stocking of exotic species.
- To utilize the resources available in the VTCS optimally and to enhance the livelihood of the community, future research could be conducted to understand the sociocultural and institutional drivers determining the fisheries management approaches in VTCS.

References

Gunasekara, U., Korale-Gedara, P., & Gunathilaka, D. (2023). Preferences of inland fishers for different management attributes in village tank cascade systems in Sri Lanka. Agricultural Systems, 208, 103644.

Kulatilake, M., Liyanage, H. S. W. A., Fernando, W. M. J. R., Chandrasoma, J., & Van der Knaap, M. (2010). Development of co-management in the Inland Fisheries in Sri Lanka: Case studies of Senenayake Samudra and Mahavilachchiya Reservoirs. Aquatic Ecosystem Health & Management, 13(3), 294-300. https://doi.org/10.1080/14634988.2010. 503554 .

Murray, F. J., & Little, D. C. (2022). Rural consumer preferences for inland fish and their substitutes in the dry-zone of Sri Lanka and implications for aquaculture development. Frontiers in Sustainable Food Systems, 6, Article 867701. https://doi.org/10.3389/fsufs.2022.867701.

Silva, G. L. L. P., Punyawardena, B. V. R., Hettiarachchi, A. K., Hulugalla, W. M. M. P., & Lokuge, G. M. S. (2021). Assessing thermal neutral zones in Sri Lanka for ten different dairy cattle breeds and crosses: An approach using temperature humidity index (THI). International Journal of Livestock Production, 12(2), 112-121.

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POLICY BRIEF

Development of Inland Fisheries in Village Tank Cascade Systems in Sri Lanka

Key messages

The following policy recommendations aim to empower local communities, enhance fishery productivity sustainably, and promote the value of small indigenous species in securing food and nutrition security while conserving biodiversity within VTCS.

- Establish fisheries management societies comprising members of farmer organizations (FOs) from the members of the farmer organizations (FO's) of the commanding area of each village tank for responsible management and sustainable use of fisheries resources in VTCS.
- Introduce a subsidiary gillnet fishery under existing legal provisions to responsibly exploit Small Indigenous Species (SIS) for food and nutritional security.
- Introduce Culture-Based Fisheries (CBF) to enhance fish production in each village tank.
- Establish a national-level fisheries management coordinating committee to oversee VTCS, resolve multi-sectoral conflicts, and ensure coordinated management at the national level.
- Enhance the marketing infrastructure to promote both fresh and dried fish produced from VTCS to improve economic opportunities for local communities.
- Recognize the importance of SIS as a protein source

What is a Village Tank Cascade System (VTCS)?

The small village reservoirs (tanks) have been constructed in the past in the undulating landscape having well-defined micro-catchments, to collect rainwater (Panabokke et al. 2001). They often form a connected series within a micro- or meso- catchment of the dry zone landscape for storing, conveying, and utilizing water from seasonal rivulets, which are known as village tank cascade systems (VTCS). Dharmasena (2020), considering its socio-ecological significance, a VTCS is defined as an ecosystem having human intervention where water and land resources are organized within the micro-catchments of the dry zone landscape, providing basic needs to human, floral and

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faunal communities on a sustainable basis. At present, 1162 functional village tank irrigation systems are reported to occur in different parts of dry zone of the country (Sirimanna and Prasada 2021).

The efficiency, effectiveness, and resource footprint of VTCS

In 2018, VTCS in the Dry Zone of Sri Lanka was designated as a "Globally Important Agricultural Heritage System" (FAO 2018), due to the attributes of national and global importance such as their role in the country's agricultural production, supporting agro-and wild-biodiversity, constituting a unique buffer against natural disasters and climate change. The VTCS also contributes to efficient water management with flowing water from one tank to another, through a network of tanks and streams.

These systems are managed and maintained by local villagers and are virtually unparalleled to any other irrigation system in the world (Panabokke et al. 2001). The VTCS provide many environmental services from their plant and animal biodiversity. In the recent past, under the Agrarian Development Act No. 46 of 2000 and the Amended Act No. 46 of 2011, legal provisions are vested to manage village tanks by both the government and farmer organizations.

In many VTCS, some traditional cultivation systems that have been evolved as adaptations to droughts, are found even present day. For example, an experienced village leader defines the cultivable area of paddy during the drought using a traditional measuring scale called 'diyaketa pahana'. This farming system is known as 'Bethma' farming, which helps conserve the available irrigation water. This system also helps to minimize conveyance losses to the fields far away from irrigation channels, and to reduce the vulnerability of the crop from water scarcity (Geekiyanage and Pushpakumara 2013).

The importance of VTCS in ichthyofaunal diversity

In Sri Lanka, there are 97 freshwater fish species of which 61 are endemic species. Of these, 12 'point endemic' species were listed as Critically Endangered (CR); 24 range-restricted species were Endangered (EN); and nine species were Vulnerable (VU). In addition, five species were Near Threatened (NT); two were listed as Data Deficient (DD); and the remaining were listed as Least Concern (LC) (see Appendix I). This means that 74% i.e., approximately three quarters of the freshwater fish endemic to Sri Lanka, were found to be threatened with extinction. There are over 30 exotic fish species in Sri Lankan freshwater. They were introduced both intentionally (mainly to enhance inland fisheries) and accidentally (by the aquarium industry). Some of them have become invasive in many natural and human-made habitats, making a direct impact on native freshwater fish either by competing with them for resources or directly through predation.

Small indigenous fish species (SIS) and other native fish species in reservoirs.

The native freshwater fish species, depending on the exploitation through subsistence fisheries, can be arbitrary categorized into two groups: large indigenous species (LIS) and small indigenous species (SIS). The major species under these two categories are given in Appendix II.

Indigenous fish species found in the dry zone reservoirs of Sri Lanka are those which are categorized as 'least concern' in the IUCN red data list (Goonatilake et al. 2020). Only a handful of species (e.g., *Clarias brachysoma*, *Ompok lakdiva*, *Dawkinsia singhala*) are endemic but they are also under 'least concern' category as they are common having a wide distribution (Goonatilake et al. 2020; see Appendices I and III).

There is a clear-cut segregation of the occurrence of freshwater fish species in tanks and reservoirs (lentic habitats) and rivers and streams (lotic habitats) as shown in Appendix IV. Consequently, there is no adverse impact on the ichthyofaunal diversity in inland freshwaters through the exploitation of native fish species present in village tanks.

Fish and fisheries in VTCS for supporting food, nutritional and livelihood security.

Exploitation of SIS

In Sri Lanka, inland management strategies implemented by fisheries authorities have been directed towards gillnet fisheries targeting exotic cichlid species, which prevented the exploitation of small indigenous species (SIS). Previous work has demonstrated that the introduction of a subsidiary fishery using 15 to 52 mm stretched mesh gillnets for SIS would be useful to provide a supplementary income for fishing communities and provide an additional source of food fish from Sri Lankan inland waters (Amarasinghe et al. 2016). This would not have any adverse impact on the existing fishery of the larger sized fish species such as tilapia and exotic carps.

This untapped fishery potential is not realized in the inland fishery of Sri Lanka mainly due to the regulatory constraints. According to the Inland Fisheries Management Regulations of 1996 Gazette Extraordinary No. 948/25 and dated 1996.11.07, minimum permissible mesh size of gillnet is 85 mm.

The SIS, which are often eaten whole are important sources of minerals, in particular calcium and iron, and have high vitamin A content. It was estimated that through the exploitation of SIS, an additional 4,500 tons of food fish could be obtained from reservoir fisheries.

The abundant SIS occurring in VTCS are *Amblypharyngodon grandisquamis*, *Dawkinsia singhala*, *Laubuka lankensis*, *Puntius chola*, *Rasbora microcephalus*. There are legal provisions to issue licenses to identifiable group of fishermen under the Fisheries and Aquatic Resources (Amendment) Act No. 35 of 2013.

Culture-based fisheries development in VTCS

Culture-based fisheries (CBF) strategies rely on stocking of adequate number of hatchery-reared fish fingerlings of desirable species which are capable of optimally utilizing natural food available in natural or quasi-natural water bodies for subsequent capture. Small village reservoirs, including VTCS are biologically productive water bodies and can be utilized for the development of CBF. A reasonable success has been achieved in Sri Lanka in the development of CBF in these water bodies (Amarasinghe and Nguyen 2010).

Description of the problem that policymakers should address

In village irrigation systems having command area (i.e., irrigable area) of less than 80 ha, including VTCS, which fall under the jurisdiction of the Department of Agrarian Development, legal provisions are available in the Agrarian Development Act No. 46 of 2000 and the amended Act No. 46 of 2011 for incorporating the fisheries and aquaculture in the village reservoir management. In village reservoirs, including those in the VTCS, the residents of the village who are involved in agriculture or agriculture-related activities are entitled to membership in the farmers' organizations (FOs) that are constituted under the Act. However, the lack of commitment from the Agrarian authorities prevents utilization of the potential contribution of this sector to the food and nutritional security of rural communities. Also, as CBF is recognized as a type of aquaculture, there is a risk of identifying CBF income as taxable income, and as such, there should be tax relief for levies collected by reservoir FOs.

Current and proposed policies

Sri Lanka government placed high priority for the development of aquaculture and culture-based fisheries. To facilitate CBF development, a new Parliamentary Act, named as 'Aquaculture and Culture-based Fisheries Act' is proposed, under which there are several provisions for multi-sectoral coordination. Under Part XI of the proposed act, "Management of Culture-based Fisheries", Section 63 states that there shall be a culture-based fisheries management coordinating committee.

The conservation priorities of fauna and flora including freshwater fish are endorsed, mainly based on IUCN criteria, by the biodiversity secretariat of the Ministry of Environment, and declare conservation zones. The VTCS however are not included under the conservation zones.

References

Amarasinghe, U.S. & T.T.T. Nguyen (2010). Enhancing rural farmer income through fish production: Secondary use of water resources in Sri Lanka and elsewhere. In: S.S. De Silva and F.B. Davy (eds) Success Stories in Asian Aquaculture. pp. 103-130. Springer Science, Netherlands. ISBN 978-90-481-3085-6 (Print) ISBN 978-90-481-3087-0 (Online) http://library.enaca.org/emerging_issues/success_stories/success-stories-asian-aquaculture.pdf

Amarasinghe, U.S., P.A.D. Ajith Kumara & S.S De Silva. 2016. A rationale for introducing a subsidiary fishery in tropical reservoirs and lakes to augment inland fish production: case study from Sri Lanka supplemented with evidence from elsewhere. Food Security 8: 769-781. DOI: 10.1007/s12571- 016-0596-4

Dharmasena, P.B. (2020). Cascaded tank-village system: present status and prospects. pp. 63–75. In: Agricultural Research for Sustainable Food Systems in Sri Lanka, Springer: Singapore.

FAO (2018). Sri Lanka among Globally Important Agricultural Heritage Systems. https://www.fao.org/srilanka/news/detail-events/en/c/1118377/ (accessed 23/08/2023)

Goonatilake, S. De A., M. Fernando, O. Kotagama, N. Perera, S. Vidanage, D. Weerakoon, A.G. Daniels & L. Máiz-Tomé (2020). The National Red List of Sri Lanka: Assessment of the Threat Status of the Freshwater Fishes of Sri Lanka 2020. Colombo: IUCN, International Union for Conservation of Nature, Sri Lanka and the Biodiversity Secretariat, Ministry of Environment and Wildlife Resources. xv + 106 pp.

Sirimanna, S. & D.V.P. Prasada (2021). Water productivity in tank cascade systems: A case study in Mahakanumulla tank cascade, Sri Lanka. Tropical Agricultural Research 32(3): 298-306. http://doi.org/10.4038/tar.v32i3.8493

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Appendix I. *Freshwater fish species in Sri Lanka, their species status and threat status. CR: Critically endangered; EN: Endangered; VU: Vulnerable; NT: Near threatened; LC: Least concern; DD: Data deficient*

Family	Scientific name	Common English name	Species status	Threat status
Adrianichthyidae	*Oryzias carnaticus*	Deep-bodied ricefish	Native	DD
Adrianichthyidae	*Oryzias dancena*	Spotted ricefish	Native	DD
Anabantidae	*Anabas testudineus*	Climbing perch	Native	LC
Anguillidae	*Anguilla bengalensis*	Long-finned eel	Native	NT
Anguillidae	*Anguilla bicolor*	Level-finned eel	Native	NT
Aplocheilidae	*Aplocheilus dayi*	Day's killifish	Endemic	EN
Aplocheilidae	*Aplocheilus werneri*	Werner's killifish	Endemic	EN
Aplocheilidae	*Aplocheilus parvus*	Dwarf panchax	Native	LC
Bagridae	*Mystus ankutta*	Yellow dwarf catfish	Endemic	EN
Bagridae	*Mystus nanus*	Striped dwarf catfish	Endemic	LC
Bagridae	*Mystus zeylanicus*	Sri Lanka mystus	Endemic	LC
Bagridae	*Mystus gulio*	Long-whiskered catfish	Native	LC
Belonidae	*Xenentodon cancila*	Freshwater garfish	Native	VU
Channidae	*Channa ara*	Giant snakehead	Endemic	VU
Channidae	*Channa kelaartii*	Brown snakehead	Endemic	NT
Channidae	*Channa orientalis*	Smooth-breasted snakehead	Endemic	VU
Channidae	*Channa punctata*	Spotted snakehead	Native	NT
Channidae	*Channa striata*	Murrel	Native	LC
Cichlidae	*Etroplus suratensis*	Green chromide	Native	LC
Cichlidae	*Pseudetroplus maculatus*	Orange chromide	Native	LC
Clariidae	*Clarias brachysoma*	Walking catfish	Endemic	NT
Cobitidae	*Lepidocephalichthys jonklaasi*	Jonklaas's loach	Endemic	EN
Cobitidae	*Lepidocephalichthys thermalis*	Common spiny loach	Native	LC
Cyprinidae	*Amblypharyngodon grandisquammis*	Large silver carplet	Endemic	LC
Cyprinidae	*Dawkinsia singhala*	Filamented barb	Endemic	LC
Cyprinidae	*Dawkinsia srilankensis*	Blotched filamented barb	Endemic	EN
Cyprinidae	*Devario annnataliae*	Natali’s danio	Endemic	CR
Cyprinidae	*Devario micronema*	Kitulgala danio	Endemic	EN
Cyprinidae	*Devario monticola*	Agra danio	Endemic	CR
Cyprinidae	*Devario pathirana*	Barred danio	Endemic	EN
Cyprinidae	*Devario malabaricus*	Giant danio	Native	LC
Cyprinidae	*Esomus thermoicos*	Flying barb	Native	LC
Cyprinidae	*Garra ceylonensis*	Stone sucker	Endemic	NT
Cyprinidae	*Garra phillipsi*	Phillips' garra	Endemic	CR
Cyprinidae	*Horadandia atukorali*	Hora dandia	Endemic	VU
Cyprinidae	*Labeo fisheri*	Mountain labeo	Endemic	EN
Cyprinidae	*Labeo heladiva*	Sri Lanka labeo	Endemic	LC
Cyprinidae	*Labeo lankae*	Orange-fin labeo	Endemic	EN
Cyprinidae	*Laubuka insularis*	Knuckles labuca	Endemic	EN
Cyprinidae	*Laubuka lankensis*	Lanka labuca	Endemic	NT
Cyprinidae	*Laubuka ruhuna*	Southern laubuca	Endemic	EN
Cyprinidae	*Laubuka varuna*	Western laubuca	Endemic	EN
Cyprinidae	*Pethia bandula*	Bandula barb	Endemic	CR
Cyprinidae	*Pethia cumingii*	Cuming's barb	Endemic	EN
Cyprinidae	*Pethia melanomaculata*	Tic-tac-toe barb	Endemic	LC
Cyprinidae	*Pethia nigrofasciata*	Black ruby barb	Endemic	VU
Cyprinidae	*Pethia reval*	Red-fin two-banded carplet	Endemic	EN
Cyprinidae	*Puntius bimaculatus*	Redside barb	Native	LC
Cyprinidae	*Puntius dorsalis*	Long-snouted barb	Native	LC
Cyprinidae	*Puntius kamalika*	Kamalika’s barb	Endemic	EN
Cyprinidae	*Puntius kelumi*	Kalum’s Long-snouted barb	Endemic	EN
Cyprinidae	*Puntius layardi*	Layard’s barb	Endemic	DD
Cyprinidae	*Puntius tetraspilus*	Long-snouted barb	Endemic	DD
Cyprinidae	*Puntius thermalis*	Swamp barb	Endemic	LC
Cyprinidae	*Puntius titteya*	Cherry barb	Endemic	VU

Cyprinidae	*Puntius vittatus*	Silver barb	Native	LC
Cyprinidae	*Rasbora armitagei*	Armitage's rasbora	Endemic	CR
Cyprinidae	*Rasbora dandia*	Striped rasbora	Native	LC
Cyprinidae	*Rasbora microcephalus*	Common rasbora	Native	LC
Cyprinidae	*Rasbora naggsi*	Naggsi’s rasbora	Endemic	EN
Cyprinidae	*Rasbora wilpita*	Wilpita rasbora	Endemic	VU
Cyprinidae	*Rasboroides pallidus*	Pallaides rasbora	Endemic	EN
Cyprinidae	*Rasboroides vaterifloris*	Vateria flower rasbora	Endemic	EN
Cyprinidae	*Systomus pleurotaenia*	Black-lined barb	Endemic	VU
Cyprinidae	*Systomus asoka*	Asoka barb	Endemic	CR
Cyprinidae	*Systomus martenstyni*	Martenstyn's barb	Endemic	EN
Cyprinidae	*Systomus "Richmondi"*	Redfin olive barb	Endemic	EN
Cyprinidae	*Systomus spilurus*	Olive barb	Endemic	LC
Cyprinidae	*Systomus timbiri*	Thimbiri barb	Endemic	CR
Cyprinidae	*Tor khudree*	Mahseer	Native	NT
Eleotridae	*Eleotris fusca*	Brown gudgeon	Native	LC
Gobiidae	*Sicyopus jonklaasi*	Lipstick goby	Endemic	EN
Gobiidae	*Stiphodon martenstyni*	Martenstyn's goby	Endemic	CR
Gobiidae	*Awaous melanocephalus*	Scribbled goby	Native	LC
Gobiidae	*Glossogobius giuris*	Bar-eyed goby/ Tank goby	Native	LC
Gobiidae	*Oligolepis acutipennis*	Sharptail goby	Native	DD
Gobiidae	*Redigobius balteatus*	Rhino-horn goby	Native	DD
Gobiidae	*Redigobius bikolanus*	Speckled goby	Native	DD
Gobiidae	*Schismatogobius deraniyagalai*	Redneck goby	Native	EN
Gobiidae	*Sicyopterus griseus*	Stone goby	Native	EN
Gobiidae	*Sicyopterus lagocephalus*	Red-tailed goby	Native	EN
Heteropneustidae	*Heteropneustes fossilis*	Stinging catfish	Native	LC
Mastacembelidae	*Macrognathus pentophthalmos*	Sri Lankan spiny eel	Endemic	CR
Mastacembelidae	*Mastacembelus armatus*	Marbled spiny eel	Native	LC
Nemacheilidae	*Paracanthocobitis urophthalma*	Tiger loach	Endemic	EN
Nemacheilidae	*Schistura madhavai*	Rakwana mountain loach	Endemic	CR
Nemacheilidae	*Schistura notostigma*	Banded mountain loach	Endemic	NT
Nemacheilidae	*Schistura scripta*	Scriptic mountain loach	Endemic	CR
Osphronemidae	*Belontia signata*	Combtail	Endemic	VU
Osphronemidae	*Malpulutta kretseri*	Ornate paradise fish	Endemic	EN
Osphronemidae	*Pseudosphromenus cupanus*	Spike-tailed paradise fish	Native	LC
Siluridae	*Ompok argestes*	Wet zone butter catfish	Endemic	VU
Siluridae	*Ompok ceylonensis*	Dry zone butter catfish	Endemic	LC
Siluridae	*Wallago attu*	Shark catfish	Native	NT
Synbranchidae	*Ophichthys desilvai*	De Silva's blind eel	Endemic	CR
Synbranchidae	*Ophisternon bengalense*	Swamp eel	Native	EN
Syngnathidae	*Microphis ocellatus*	Ocellated pipefish	Native	EN

Source: Goonatilake et al. 2020.

Appendix II. *Examples of LIS and SIS in Sri Lankan freshwaters.*

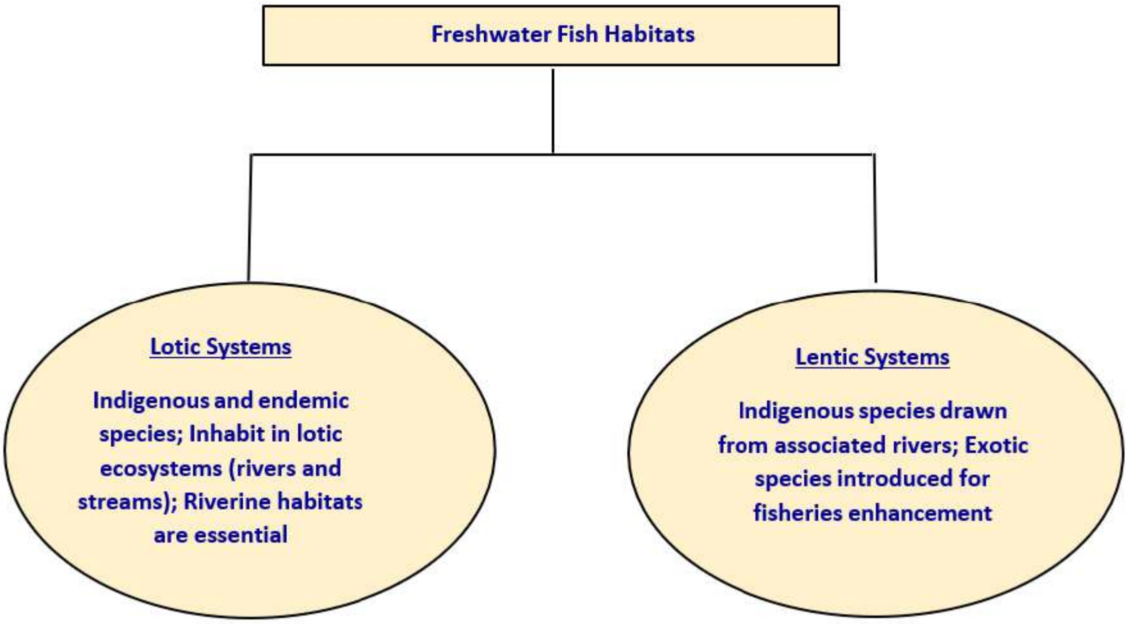
Large (>25 cm) indigenous fish species (LIS)	Small (<25 cm) indigenous fish species (SIS)
Channa striatus	*Dawkinsia singhala*
Anguilla bicolor	*Mystus nanus*
Ompok bimaculatus (=Ompok ceylonensis)	*Amblypharyngodon grandisquamis*
Wallago attu	*Devario malabaricus*
Glossogobius giuris	*Puntius dorsalis*
Labeo dussumieri (=Labeo heladiva)	*Esomus thermoicos*
Systomus sarana (=Systomus spilurus)	*Rasbora microcephalus*
Channa ara	*Puntius vittatus*
Clarias brachysoma	*Heteropneustes fossilis*
Tor kuhdree	*Anabas testudineus*
Mastacembelus armatus	*Puntius chola*
Labeo lankea	

Appendix III. *Examples of some habitats of freshwater fish, and species found in them*

Habitat	Examples of species found in these habitats
Fast flowing rivers/Streams	*Garra ceylonensis, Dawkinsia singhala, Dawkinsia srilankensis, Laubuka insularis, Rasbora naggsi, Systomus asoka, Sicyopus jonklaasi*
Moderately flowing rivers/Streams	*Laubuka ruhuna, Pethia reval, Puntius kamalika, Puntius kelumi, Puntius thermalis*
Slow flowing river/Streams	*Aplocheilus werneri, Paracanthocobitis urophthalma, Belontia signata, Malpulutta kretseri, Lepidocephalichthys jonklaasi, Dawkinsia singhala, Pethia bandula, Puntius titteya, Rasboroides pallidus*
Stagnant/Still water	*Mystus ankutta, Clarias brachysoma, Dawkinsia singhala, Pethia reval*
Paddy fields	*Aplocheilus werneri, Horadandia atukorali, Pethia reval, Macrognathus pentophthalmos*
Irrigation canals	*Laubuka lankensis, Mystus zeylanicus, Systomus spilurus, Dawkinsia singhala*
Deep pools/Pools of large rivers	*Tor kuhdree, Walago attu, Channa ara*
Tanks	*Amblypharyngodon grandisquamis, Rasbora microcephalus, Systomus spilurus*
Marshes	*Amblypharyngodon grandisquamis, Horadandia atukorali, Ophichthys desilvai, Aplocheilus dayi*

Sources: Murray et al. 2001; de Silva et al. 2015.

***Appendix IV**. Clear habitat segregations between native freshwater fish species (riverine) and exotic cichlids (lacustrine)*



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Tank Restoration and Water Management

HLP

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POLICY BRIEF

Dying Echoes, Thriving Ripples: Rescuing Village Tank Cascade Systems from Degradation

Key messages

To effectively address the multifaceted challenge of Village Tank Cascade System (VTCS) degradation, a nuanced and comprehensive strategy is indispensable. This involves implementing a combination of short-term, medium-term, and long-term solutions, each tailored to address specific facets of the degradation process.

- Short-term Solutions: Swift action is needed to prevent channel obstruction and desiltation, ensuring effective water distribution for agriculture. Soil fertility conservation and minimizing water pollution are vital for optimizing water quality and quantity. Conservation efforts for tank beds, catchment areas, and forests are crucial for ecological balance and water retention.
- Medium-term Solutions: Proper maintenance of infrastructure, erosion control, and establishment of Water Users' Associations are essential for sustained water management. Repairing channels serves to enhance water distribution efficiency. Promoting sustainable agricultural practices serves to uphold ecological equilibrium. Responsible land use planning safeguards vital catchment areas and forested lands.
- Long-term Solutions: Climate change adaptation, securing donor funds, and evidence-based policy formulation are critical for the enduring sustainability of VTCSs. Stakeholder coordination and raising awareness of property rights foster effective management and community engagement in conservation efforts.

Challenges and Sustainability Issues

Village tank cascade systems (VTCSs) consist of interconnected small tanks that store rainwater to irrigate dry lowland plains for paddy farming during major cultivation seasons.

Goods and services provided by these ecosystems, which include provisioning, regulating, cultural, and supporting services (Figure 1), have supported the lives of many generations of communities. However, over the past century, some areas in the region have witnessed significant changes in land use and hydrological patterns that can have negative effects Wickramasinghe et al. (2023).

- Paddy fields have expanded from 1.6% to 20.2%.
- Homestead areas have increased from 1.6% to 11.5%.

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Figure 1. Ecosystem Services of VTCSs

- Surge in the runoff coefficient, rising from 0.2 to 0.45, causing increased water outflow during rains and reduced water retention.

As a result of these changes, sadly, these communities have been facing several challenges related to water management at present. The system has faced an ecological imbalance and decreased resilience, mainly due to the rapid reduction in forest area within the VTCS. The diffusion of essential components in VTCSs, including homestead areas, is no longer confined to specific locations but has proliferated across various areas. Consequently, significant elements like *Kattakaduwa* (the downstream reservation) have experienced a size reduction.

Worsening the above problem, some of the previously connected tanks are no longer connected and have fallen into disrepair or disuse with deteriorated distribution channels, culverts, and sluice gates. This has caused the siltation of waterways and increased salinity in both the irrigation water and the surrounding fields. The siltation is exacerbated by the extreme rainfall patterns and the breakdown of cohesive organizations that maintained these vital systems in the past.

Many dairy farmers in these areas have increasingly recognized the detrimental impacts of climate change on their operations. The shortage of pastures, a reduction in milk yield, and stunted growth in their animals are now widely perceived as the consequences of a changing climate.

Sirimanna et al. (2022) also have reported a clear deterioration in the Mahakanumulla and Ulagalla cascades. The ratio between catchment forest, water surface, and command area, which was originally 5:1:1, has changed to 1:2:1 over a period of 100 years.

Consequently, water scarcity in dry periods has escalated due to limited storage and recharge capacities. Furthermore, the shift from shifting cultivation to permanent cropping over the past century has proven unsustainable, complicating these challenges.

Additionally, Kulasinghe and Dharmakeerthi (2022) provided a comprehensive account of the decline in soil physical and chemical properties, revealing the unsustainable nature of local farming systems.

Nitrate transport into tanks further complicates environmental concerns. Persisting with current land and tank management practices may exacerbate soil fertility degradation and pose a threat to the sustainability of VTCSs.

Revealing the Culprits: Causes of Degradation

The sustainability of VTCSs is under threat due to a multitude of interconnected causes. These causes can be categorized into three layers: immediate, underlying, and root causes (figure 10), each contributing to the gradual degradation of these vital systems.

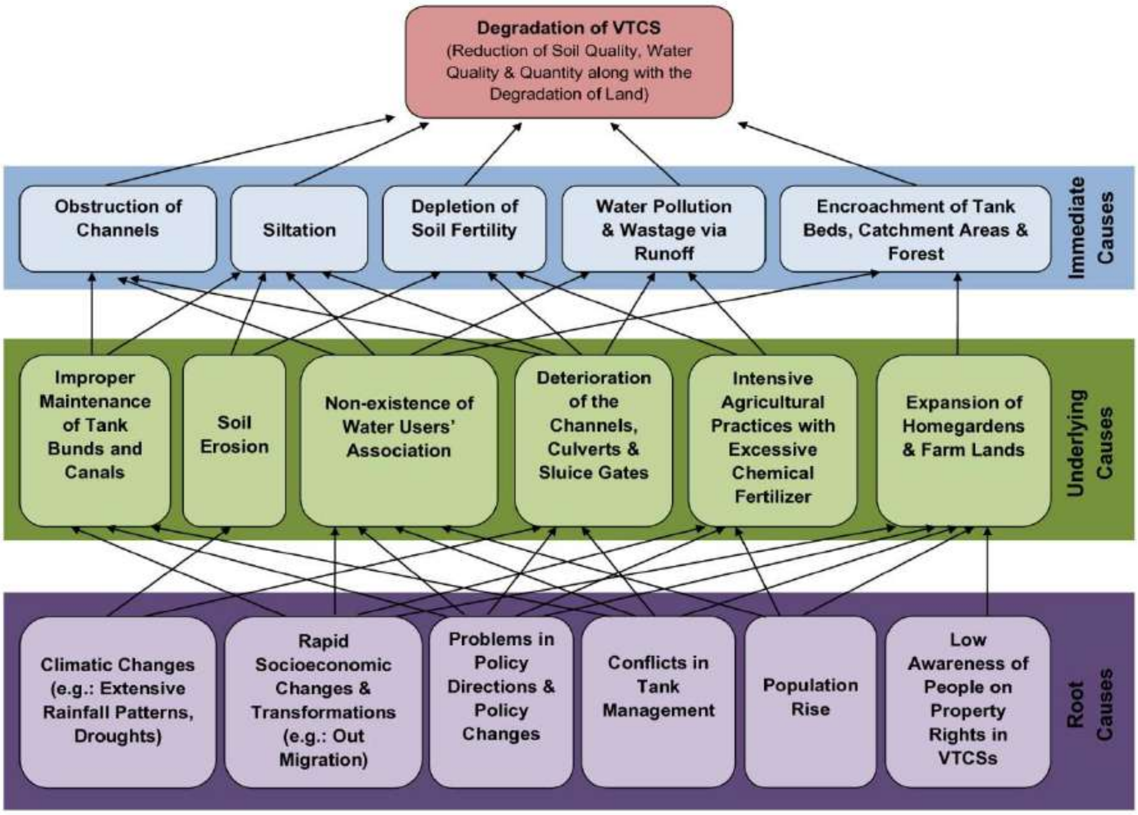

Figure 2. Problem Tree

Immediate Causes:

Obstruction of channels disrupts the flow of water, leading to inefficiencies and reduced water availability for irrigation. Siltation, the accumulation of sediments in the tanks and channels, reduces their capacity, hindering water storage and distribution. Unsustainable farming practices without proper soil management deplete the soil's nutrients and affect crop yields. The contamination of water sources and excessive runoff contribute to the deterioration of water quality and quantity. Additionally, the encroachment of human settlements and agricultural activities on crucial areas such as tank beds, catchment areas, and forests disrupts the ecological balance and affects the catchment's ability to retain water.

Underlying Causes:

Neglect of maintenance leads to the deterioration of infrastructure, exacerbating siltation and channel blockages. Soil erosion due to poor land management practices further exacerbates siltation and sediment buildup. The absence of organized community groups for water management, like Water Users' Associations, can lead to uncoordinated and unsustainable water use. Ageing infrastructure, such as deteriorating channels, culverts, and sluice gates, hampers efficient water distribution. The overuse of chemical fertilizers harms the environment, affecting soil and water quality. Encroachment and expansion of agriculture into VTCS catchment areas disrupt the natural balance by reducing the important regulating components such as *Kattakaduwa*.

Root Causes:

Variability in rainfall patterns, including extensive rainfall and droughts, impacts water availability and water quality. Outmigration from rural areas and changing lifestyles affect the community's ability to maintain traditional VTCSs. Inadequate policies and their inconsistent implementation contribute to the mismanagement of VTCSs. Conflicts within the community regarding tank management can hinder effective conservation efforts. The increasing population places additional demands on VTCSs leading to land fragmentation, further straining these systems. Lack of awareness regarding property rights, lack of consideration of landscape connectivity and responsibilities regarding VTCSs can hinder community-driven conservation initiatives.

In comprehending the intricate factors contributing to the degradation of VTCSs, a thorough exploration of their multifaceted causes becomes imperative. To truly secure the sustainability of these invaluable ecosystems, interventions must adopt a holistic approach, addressing not only the overt manifestations but also delving into the very roots, underlying intricacies, and immediate triggers of deterioration. Furthermore, a comprehensive strategy necessitates active engagement with the local community and policymakers, fostering a collaborative synergy that intertwines efforts for restoration and preservation. By intricately dissecting and understanding the myriad aspects influencing VTCS health, we pave the way for a more effective and lasting conservation framework.

Reviving Vitality: Solutions for Ecosystem Rehabilitation

The challenges confronting VTCSs call for a multi-faceted approach to restore and sustain these vital systems. Solutions can be categorized into short- term, medium-term, and long-term strategies (figure 3), each addressing specific aspects of VTCS degradation.

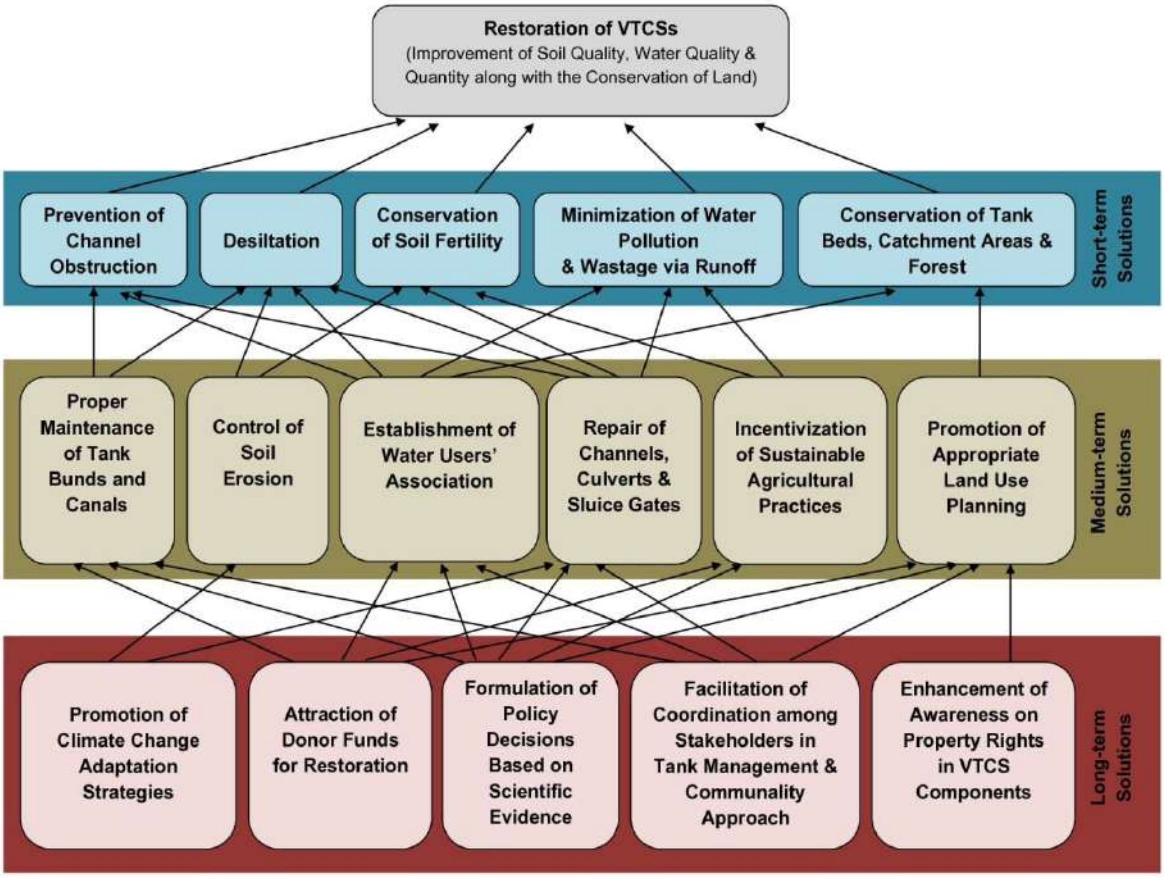

Figure 3. Solution Tree

Short-term Solutions:

- **Prevention of channel obstruction:**
  Swift and decisive action is imperative to avert blockages in the channels, which can disrupt the smooth flow of water. The timely clearance of obstructions is essential to guarantee the effective and unhindered distribution of water to agricultural lands, promoting optimal irrigation.

- **Desiltation:**
  Regular desiltation activities are necessary to remove accumulated sediments from the tanks and channels. This restores their capacity and enhances water retention.

- **Conservation of soil fertility:**
  Implementing comprehensive measures aimed at conserving and rejuvenating soil fertility, by embracing organic farming practices and employing appropriate fertilizer strategies, is imperative for significantly augmenting crop yields.

- **Minimization of water pollution and wastage via runoff:**
  Implementing comprehensive and proactive

initiatives aimed at reducing water pollution and minimizing runoff wastage is paramount for effectively preserving and optimizing both the qualitative and quantitative aspects of water within VTCSs.

- **Conservation of tank beds, catchment areas and forest:**
  Protecting and conserving the tank beds, catchment areas, and forests while establishing appropriate tree species in all landscape levels ensures the ecological balance and the catchment's ability to retain water. This will ensure that all units provide necessary regulating services while also keeping the available regulatory components intact.

Medium-term Solutions:

- **Proper maintenance of tank bunds and canals:**
  The consistent and thorough maintenance and repair of crucial components such as tank bunds, canals, and sluice gates play an indispensable role in averting the gradual deterioration of the infrastructure, thereby ensuring its sustained functionality and resilience over time.

- **Control of soil erosion:**
  The implementation of effective soil erosion control measures, exemplified by the strategic integration of practices like terracing and contour farming, serves as a proactive approach aimed at mitigating the adverse impact of sedimentation within the VTCSs. These conscientious efforts contribute significantly to preserving the ecological integrity and functionality of the landscape, fostering sustainable water management practices within the community.

- **Establishment of Water Users' Associations:**
  Establishing well-organized community groups, such as Water Users' Associations, serves as a pivotal strategy to cultivate a sense of cohesion in water management endeavours. This approach not only promotes the coordination of water resources but also plays a vital role in guaranteeing fair and equitable distribution, alongside encouraging responsible and sustainable utilization practices within the community.

- **Repair of channels, culverts, and sluice gates:**
  The timely implementation of comprehensive repairing and upgrading measures for channels, culverts, and sluice gates, coupled with a concerted effort towards the revitalization of landscape connectivity, serves to significantly enhance the overall efficiency of water distribution within the system.

- **Incentivization of sustainable agricultural practices:**
  Promoting the adoption of sustainable agricultural practices among farmers, such as embracing organic farming techniques and minimizing the utilization of chemical fertilizers, serves to cultivate and uphold a harmonious ecological equilibrium within VTCSs.

- **Promotion of appropriate land use planning:**
  Encouraging responsible land use planning emerges as a pivotal strategy in forestalling unwarranted encroachment on the vital catchment areas of VTCS and the expanses of forested lands, thereby safeguarding the delicate ecological balance inherent in these regions.

Long-term Solutions:

- **Promotion of climate change adaptation strategies:**
  The implementation of adaptive strategies, specifically tailored to respond effectively to evolving climate patterns, holds paramount importance for ensuring the enduring sustainability of VTCSs. Among these strategies, the incorporation of drought-resistant crop varieties emerges as a pivotal component, contributing significantly to the resilience and prolonged viability of VTCS in the face of

dynamic environmental challenges.

- **Attraction of donor funds for restoration:** Securing vital financial support from generous donors and reputable development agencies plays a pivotal role in facilitating comprehensive restoration and enhancement endeavours of VTCSs. The infusion of funds not only catalyses the progress of these projects but also contributes substantially to the overarching goal of sustaining and revitalizing VTCSs, ensuring their long-term effectiveness and resilience.

- **Formulation of policy decisions based on scientific evidence:** Ensuring a harmonious alignment of policy decisions with robust scientific evidence stands as a crucial imperative, fostering the bedrock of sustainable VTCS management and judicious resource allocation. This strategic synergy not only fortifies the foundation of informed governance but also cultivates an ecosystem where the delicate balance between societal needs and environmental preservation is conscientiously upheld.

- **Facilitation of coordination among stakeholders in tank management and communality approach:** Improving the synergy and collaborative efforts among diverse stakeholders, encompassing the community, governmental bodies, and non-governmental organizations, plays a pivotal role in cultivating an environment conducive to the effective management of VTCSs.

- **Raising awareness on property rights in VTCS components:** Enhancing community engagement in conservation endeavours is achieved through the elevation of awareness surrounding property rights and responsibilities pertaining to the various components of VTCSs. This heightened understanding empowers community members to actively participate in and contribute to the preservation and sustainable management of VTCS.

References

Kulasinghe, T. N., & Dharmakeerthi, R. S. (2022). Effects of land use type and tank components on soil properties and sustainability of tank cascade system in the Dry Zone of north central Sri Lanka. *Agricultural Systems*, *201*, 103474.

Sirimanna, S., Kahathuduwa, K. K. P. N., & Prasada, D. V. P. (2022). Are cascade reservoir systems sustainable agroecosystems? A comparative assessment of efficiency, effectiveness, and resource footprint in a Sri Lankan micro-cascade. *Agricultural Systems*, *203*, 103493.Wickramasinghe, M.R.C.P., Dayawansa, N. D. K., Jayasiri, M. M. J. G. C. N., & De Silva, R. P. (2023). A study on external pressures of an ancient irrigation cascade system in Sri Lanka. *Agricultural Systems*, *205*, 103593.

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POLICY BRIEF

Understanding the Hydrology of Village Tank Cascades

Key messages

Village Tank Cascade Systems in Sri Lanka's Dry Zone faces diverse challenges. Understanding cascade hydrology is crucial for effective irrigation management. Recommendations for system sustainability include:

- Physical Rehabilitation: Prioritize the rehabilitation of tank bunds, spillways, main channels, sluices, and control structures. Ensure proper delivery and control of irrigation water.
- Understanding the Cascade System: Recognize the interconnectedness of small tanks within the cascade system. Address water scarcity and ecosystem health issues effectively.
- Water-Saving Agricultural Practices: Encourage water availability tracking, season planning, early land preparation, crop diversification, and promoting short-duration paddy varieties.
- Capacity Building for Farmer Organizations: Strengthen farmer organizations through financial management, leadership skills, and irrigation structure management. Enhance water management and record-keeping.
- Institutional Improvements: Reinforce relevant institutions for effective catchment management. Provide financial and human resource support. Emphasize the ecological importance of small tank cascade systems.

Village tank cascade systems – Village level irrigation systems in the dry zone landscape

In the north-central dry zone of Sri Lanka, rainfall and surface runoff have been stored in human-made reservoirs since ancient times. They continue to provide water for irrigation. About 12000 – 16000 small tanks are present in the dry and intermediate zones of Sri Lanka (Panabokke *et al.*, 2001) and 90% of them are in cascades (Madduma Bandara, 1985). Village tank cascade system is simply a hydrologically interconnected series of small tanks made in ancient times and is still functional to provide irrigation water and ecosystem services to the communities. Today, 35% of the irrigated rice production is supported by these tank cascades (FAO, 2011). The main elements that make up

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a cascade are the watershed boundary of the meso-catchment, the individual micro-catchment boundaries of the small tanks, and the main valley and side valleys (Madduma Bandara, 1985). A total of 457 cascades are identified in the North Central Province of Sri Lanka (Panabokke *et al.*, 2002). However, out of the total annual cultivated extent under minor irrigation tanks, 50-70 percent is cultivated during the Maha season, highlighting the issue of water scarcity in the Yala season. In fact, the system is facing high water scarcity, due to various causes.

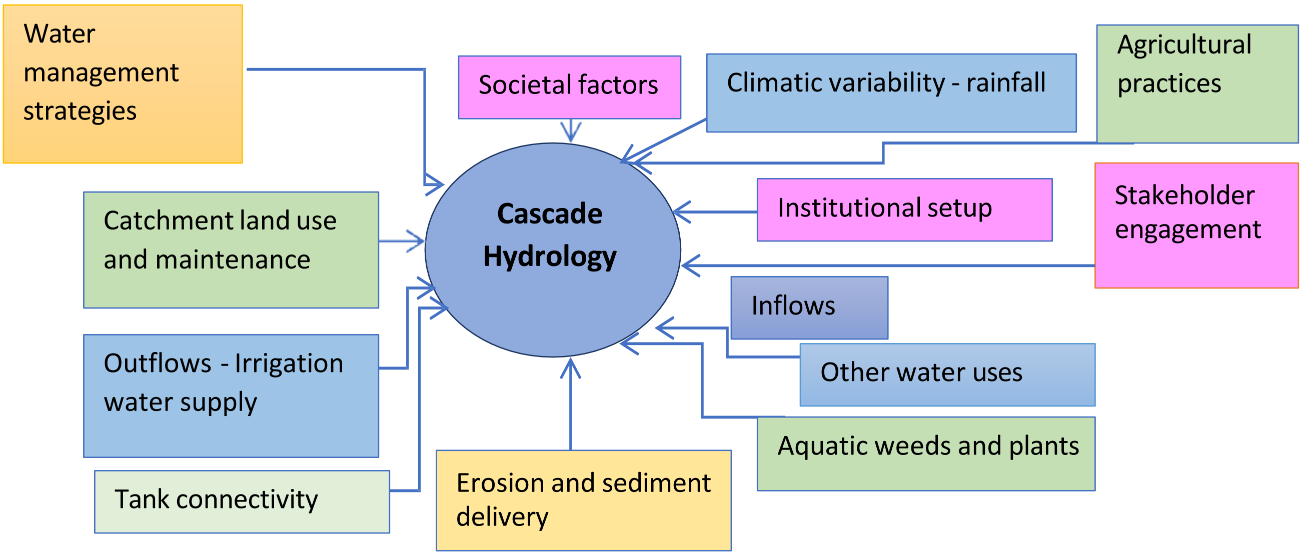

Figure 1: Complexity and interconnectivity of components of cascade hydrology

The basic objectives of the construction of village tanks are to store water during the rainy season in the dry zone and to support the prolonged drought of about 9 months. With time, these tanks have been incorporated into the natural environment and continue to provide numerous benefits including;

- Water for irrigation, domestic supply, livestock, and environment
- Distribute available water to the irrigation command areas through the interconnected canal network
- Re-use of water
- Flow regulation, avoiding a sudden influx of large volumes of water in order to minimize the risks of tank bund breaching
- Recharge groundwater and groundwater table stabilization
- Support wildlife habitats and biodiversity
- Recreation

Cascade systems consist of an interconnected series of small tanks. This connection primarily occurred through the stream network. Cascade systems provide the hydrological connectivity between the tanks, canals and even groundwater. Especially, the tanks and canals recharge the groundwater in the regolith aquifer present in the dry zone of Sri Lanka. This regolith aquifer needs recharged water from the cascades to sustain. Since these tanks are well-interconnected within a cascade, they act as an ecosystem. An alteration of one section in this ecosystem will definitely have impacts on other components since they are constantly interacting with each other. Hydrology of the cascade systems plays a pivotal role in this interconnection. In many instances, the hydrology of these systems is studied and evaluated considering a single tank or a few tanks in a single cascade system. This has led to a poor understanding of the hydrology of the whole system which is essential for decision making in irrigation and other water uses. Even in cascade restoration work, hydrological understanding will provide a favourable platform for planning and implementation. Figure 1 presents the contributory factors for cascade hydrology highlighting the complexity of these systems.

Hydrological and other challenges

The cascade hydrology is challenged by a number of causes;

- Land use changes – Over the centuries, the land uses have changed considerably. In many places, forest cover has been cleared for human settlements. This has led to alteration of hydrology and less runoff collection to small tanks and hence less water availability for use. This issue is severe during the dry periods since there is no capacity for the cascade watershed to hold an adequate amount of water.
- Encroachment of cascade components – The small tanks comprise of several components which also can be identified as land uses (Gasgommana, Thawulla, Thisbambe). These components play very specific roles in the sustainability of these systems. These components are encroached for either human settlements or agriculture leading to less runoff to the small tank, and more sediment generation.
- Sedimentation – Some of the small tank components are used to trap sediments flowing into the tank. Since these components are ignored and not maintained over the years, their functions are also disrupted. Therefore, small tanks are sedimented heavily reducing their live storage capacity.
- Growth of aquatic weeds – aquatic weed growth is a serious problem in some small tanks. This leads to reducing the tank capacity while enhancing sediment trapping and subsequently deteriorating water quality.
- Agro well development – Agro wells are large diameter shallow wells constructed to supplement water for irrigation in these areas. The proliferation of agro wells within an area leads to over abstraction of shallow groundwater. This has also become a serious issue with respect to hydrology in some locations in the dry zone. Agro-well development directly affects groundwater stability which is interlinked with cascade hydrology.
- Climate variability – Studies have identified a considerable variability in the rainfall pattern in Sri Lanka. These rainfall pattern changes also have a direct impact on cascade hydrology. Unexpected, prolonged droughts can completely disturb the hydrology and other functions of the cascades.
- Population growth – Population growth demands more food from cascade systems. Overexploitation of land resources is the ultimate result to cater to this demand. Intensive agricultural practices can lead to high demand for water and water quality deterioration due to over use of agrochemicals and fertilizer.
- Human elephant conflict – Human elephant conflict is a serious problem in cascade dominated agricultural landscape in the dry zone. In some locations, elephant menace keeps human settlements and agriculture away from the tanks which leads to poor use and less maintenance of the ranks.
- Poor maintenance – Farmers and farmer organizations are generally responsible for tank maintenance at the ground level. However, due to shifting of livelihood from agriculture and lack of participatory approaches, some tanks are in unacceptable conditions which lead to alteration of the hydrology and functions of the whole cascade system.
- Socio-political power dynamics – Power dynamics of social and political systems negatively influencing on these cascade systems. This can lead to encroachment of important components of the tanks, unplanned water releases, unregulated development of agro-wells within the watershed areas and many more. They are directly affecting the hydrology of the cascade systems.
- National policy and funding challenges for maintenance/rehabilitation – In many cases,

financial mobilization for rehabilitation and relevant policy support is lacking as per the requirement. Lack of proper studies on these systems also lead to unplanned restoration activities which can ultimately impact on the hydrology of these systems.

With these challenges, water availability, water structures and system rehabilitation, water quality and water flow pathways are impacted. For the system sustainability, one should understand the challenges faced by cascades and the overall system hydrology to introduce appropriate site-specific management strategies.

Research overview

A study conducted in the Mahakanumulla village tank cascade system in Anuradhapura revealed that the system has undergone considerable changes with respect to land use, population growth and agricultural intensification over the centuries.

- *Changes over the last century:*

Increase of paddy land extent from 6.3% to 20.2% Increase of homestead extent from 1.6% to 11.5%. Conversion of 24% of forest and chena lands to agriculture and settlements Population increased at village level by 2-27 times. The runoff coefficient of the catchment area increased from 0.29 to 0.45 indicating a high outflow of water during rains and limiting water retention within the system. This is an indication of increasing water scarcity in dry periods due to limited recharge capacity.

- *Over application of inorganic fertilizers: 43% (Urea), 57% (TSP), 51% (MoP) of farmers.*

- *Spatial and temporal variability of water quality over the main axis of the cascade. Accumulation of agro-chemicals towards the downstream of the cascade is the result of this increase. This is an indication of external pressure inserted into the system.*

(Wickramasinghe *et al.*, 2023)

Hemachandra *et al.* (2022) conducted a study to develop an index to assess the village tank cascade system sustainability. Since the sustainability of the cascade systems should achieve the equilibrium of its ecological, hydrological, agricultural, and social subsystems and cultural norms, they have emphasized the importance to incorporate all these factors in the sustainability assessment.

Accordingly, a number of hydrological parameters have been incorporated under the physical-environmental factors.

Policy recommendations

For the system sustainability and hydrological viability, the following recommendations can be made.

- Physical rehabilitation of the tanks and irrigation structures, maintenance of records:

  The physical rehabilitation includes tank bund, spillways, and main channels. In addition, it is important to maintain the sluices, drainage system, control structures, turnouts etc. for proper delivery and control of irrigation water issues. With a well-maintained irrigation structure, it is easier to maintain records of irrigation water issues and water availability in the tanks during the cultivation season. Lack of records is one of the serious drawbacks in proper management of irrigation and other water uses in these systems. Studies and research on these systems are also affected due to the unavailability of required data.

- Understanding the cascade system as a unit:

  Even though, the majority of the small tanks in the dry zone landscape are hydrologically interconnected, use and maintenance of these tanks are occurred as single units. Water scarcity and poor ecosystem health are consequences of the lack of this understanding.

Enhancement of systems thinking is paramount in the sustainable use of these systems.

- Agricultural practices for water saving: Maintenance of records on water availability, planning of the cultivation season ahead, starting of the cultivation with the onset of rains, early land preparation for the next season, growing of other field crops during Yala season to save water and promotion of short duration paddy varieties in both seasons are some of the interventions suitable for water saving.

- Capacity building of farmer organizations and improve their organizational behavior: Strengthening of the farmer organizational activities through promoting book-keeping and financial management, enhancing leadership skills and knowledge, provision of basic construction and repairing skills for irrigation structure management, proper delivery of irrigation water and maintaining records, etc. are important.

- Institutional improvements: In addition to farmer organizations, other relevant institutions should be reinforced for effective catchment management with financial, knowledge and human resources.

- Establish more effective operation and maintenance mechanism.

- Identify the ecological importance of small tank cascade systems.

- Incorporate local knowledge and experience in management plans.

Catchment management and encroachment prevention – A participatory approach should be established with the farmer organizations to promote the maintenance of surface and groundwater resources, soil conservation, and proper maintenance /re-establishment of key tank components such as Kattakaduwa and Gasgommana.

Conclusions

Village Tank Cascade Systems as important irrigation systems in the Dry Zone of Sri Lanka face a number of challenges due to natural and anthropogenic pressures. These pressures are spatially diverse and impact differently on different cascades. A proper understanding of cascade hydrology will help to overcome many obstacles related to irrigation. However, hydrological knowledge as a system rather than individual tanks is still lacking. Insufficient or lack of hydrological measurements and associated knowledge base is essential for the smooth functioning of the tank cascades.

References

FAO. (2011). Irrigation in Southern and Eastern Asia in Figures: AQUASTAT Survey-2011. Retrieved from https://www.fao.org/3/i2809e/i2809e.pdf

Hemachandra, E. M. G. P., Dayawansa, N. D. K., & Ranjith Premalal De Silva. (2022). A Sustainability Index for Assessing Village Tank Cascade Systems (VTCs) in Sri Lanka. In G. M. Tarekul Islam, Shampa Shampa, & Ahmed Ishtiaque Amin Chowdhury (Eds.), Water Management: A View from Multidisciplinary Perspectives, 8th International Conference on Water and Flood Management. Springer International Publishing.

Madduma Bandara, C. M. (1995). Tank cascade systems in Sri Lanka: Some thoughts on their development implications. In K. A. Haq, C. M. Wijayaratne, & B. M. S. Samarasekera (Eds.), Summaries of papers presented at Irrigation Research Management Unit seminar series during 1994. IWMI.Colombo, Sri Lanka.

Panabokke, C. R., Sakthivadivel, R., & Weerasinghe, A. D. (2002). Small tanks in Sri Lanka: Evolution, present status and issues. International Water Management Institute.

Panabokke, C. R., Tennakoon, M. U. A., Ariyabandu, R. De S. (2001). Small tank systems in Sri Lanka: Issues and considerations. In H. P. M. Gunasena (Ed.), Food security and small tank systems in Sri Lanka: Proceedings of the workshop organized by the Working Committee on Agricultural Science and Forestry, 9 September 2000. National Science Foundation (NSF).

Wickramasinghe, M. R. C. P., Dayawansa, N. D. K., Jayasiri, M. M. J. G. C. N., & De Silva, R. P. (2023). A study on external pressures of an ancient irrigation cascade system in Sri Lanka. Agricultural Systems, 205. https://doi.org/10.1016/j.agsy.2022.103593.

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POLICY BRIEF

Unlocking Value: The Economic Viability of Silt Removal from Tanks

Key messages

Desiltation, which improves tank water holding capacity and delivers both financial and ecosystem benefits, underscores the need for the following recommendations.

- Prioritize desiltation to enhance tank water holding capacity. Invest in 25% partial desiltation, which is financially viable with positive ecosystem benefits. Introduce buyback systems to optimize profitability and incentivize desiltation investments.
- Allocate financing for desilting and restoration based on assessed benefits per beneficiary segment to ensure fairness and prevent undue burden on the local community.
- Emphasize strategic utilization and optimization of domestic funding to support and advance agricultural development initiatives.
- Allocate renovation funding for cascade systems with 85% from domestic sources and 15% from global sources to ensure inclusive support and maximize the broader benefits of these systems.

Sustaining Sri Lanka's Small Tanks through Desiltation

Sri Lanka has been grappling with a severe economic crisis since late 2021, which continues to affect the nation. Therefore, the government must prioritize the allocation of public funds to different sectors with great care. The agricultural sector holds a significant position in the Sri Lankan economy, encompassing various aspects that require prudent budget management. Agriculture and irrigation management related budgetary allocations are such allocations that come under the purview of the country, as the public funds must be allocated carefully for the given sectors during this difficult time in the country.

In Sri Lanka, there are approximately 16,500

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small tanks and 14,500 anicuts, collectively covering around 246,000 hectares of land. This constitutes 39% of the country's total irrigable area and contributes substantially to the national rice production, accounting for 20% of the overall output, with an annual yield of 191,000 metric tons (Department of Agrarian Development, 2023).

Given the pivotal role these small tanks play in the agricultural sector, the Sri Lankan government allocates a substantial portion of its national budget to the enhancement and progress of agricultural development initiatives. A significant share of this allocation is directed toward the rehabilitation, restoration, and desiltation of small reservoirs, underlining their paramount importance in sustaining the nation's agricultural productivity. Figure 1 illustrates the budget allocations for restoration, rehabilitation and desilting of small tanks and the line graph shows the same budget allocation as a percentage of total budget allocation for agriculture development programmes.

Whether the renovation of minor tanks in the dry and intermediate zones of Sri Lanka e generates sufficient economic returns through rice production is questionable. as changes in the geometry of these tanks, primarily due to sedimentation, are causing them to become shallower over time.

Previous rehabilitation efforts aimed at increasing capacity inadvertently led to greater water losses through evaporation and percolation accelerated by these shallow water bodies, resulting in unwarranted drought periods during the dry season.

Consequently, this situation has led to a notable reduction in the availability of water for agricultural cultivation, negatively impacting the primary occupation of farmers and subsequently, the primary source of income for farming households. As a result, the food security of the farming community is jeopardized by this issue.

Historically, rehabilitation programs focused on strengthening tank bunds, repairing, or replacing structures, and restoring lost capacity due to the deposition of sediments by raising spillways and tank bunds. Nevertheless, the expansion of water spread areas and the creation of shallow water bodies resulting from the current rehabilitation methods not only diminish water use efficiency but also give rise to several environmental challenges within the tank ecosystem. These issues include:

- The disappearance of the tree strip (Gasgommana) along the early water spread area's periphery contributed to increased water evaporation due to advection effects.
- The development of salinity in the upstream area around the Full Supply Level (F.S.L.) is particularly evident if the tank is second or third in a series.
- Inundation of upstream rice fields due to an

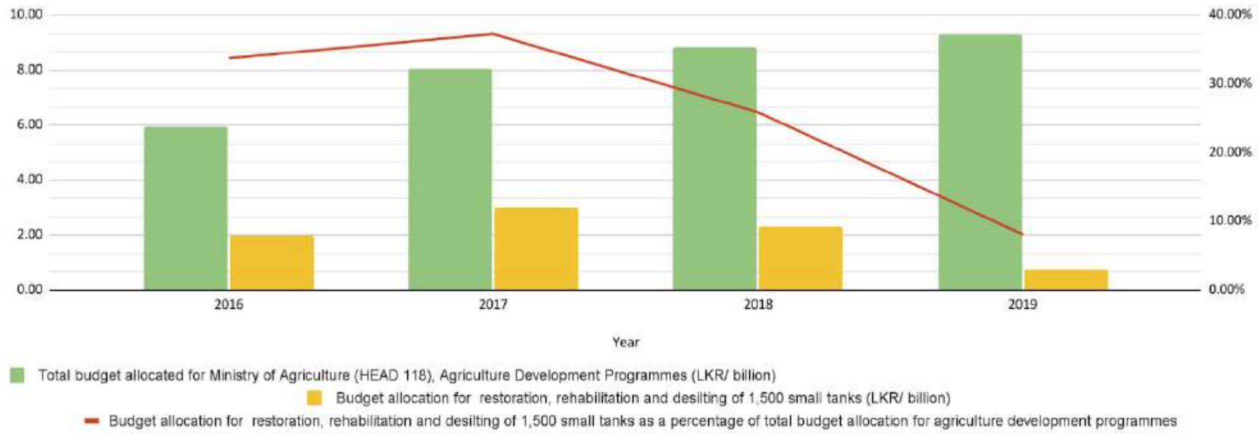

Figure 1: Budget allocations for the agricultural development programmes such as restoration, rehabilitation and desilting of small tanks and its percentage

increase in spill height for capacity improvement, leading to conflicts between village communities residing in the upper and lower tanks.

- The disappearance of certain fish species unable to thrive in shallow waters. (Dharmasena, 2023)

Hence, a solution that does not change the tank's geometry was needed, and as a result, desiltation - removal of silt - has been identified as the most suitable solution, aiming not only to increase storage capacity and reduce water loss but also to preserve the tank ecosystem (Dayananda et al., 2021).

However, it should be noted that desiltation is an expensive undertaking, albeit a necessary one, which is the main concern of policymakers as they reconsider the allocation of public expenditure that this will require compared to the economic returns this investment will provide.

These initiatives often yielded limited economic benefits in paddy cultivation, and this is the main concern of most policymakers, which led them to conclude that desiltation is an expensive expenditure to make under the given circumstances. Since the desiltation process represents both a necessary and costly undertaking, it becomes imperative to formulate a technological concept that facilitates a desiltation process characterized by both cost-effectiveness and efficiency to prevent the gradual disappearance of these minor tanks from Sri Lanka's dry zone landscape in the coming decades (Dharmasena, 2023). As a technological solution for this particular issue, the process of partial desiltation emerged.

Why Partial Desiltation?

The concept of partial desiltation has been introduced against the backdrop of extensive hydrological research studies conducted by the Department of Agriculture, as documented in the research conducted by Dharmasena in 1994, and this method is identified as an economical solution for the above-mentioned issue, which is the high cost coupled with complete desiltation.

The concept of desiltation outlined here primarily aims to manage the tank bed geometry rather than significantly increase the tank's current capacity.

Its primary goal is to mitigate water losses in the tank by altering the tank bed geometry through desiltation.

An examination of sedimentation patterns reveals that minor tanks accumulate sediment in the range of 20% to 35%, with about half of the sediment located within one-third of the tank bed area, closer to the bund (Dharmasena, 1992).

Therefore, it is possible to maintain the same storage capacity by removing sediment from this specific area and depositing it in the upstream tank bed. Such partial desilting efforts would significantly increase the capacity-to-water-spread area ratio while keeping over 50% of the tank bed free of water. To prevent sediment from returning to the desilted area, it is essential to stabilize the soil mounds with vegetative cover.

Financial Returns of Partial Desiltation

In the evaluation of the desiltation process, with a keen focus on the cost-benefit analysis, key concerns have been expressed by policy analysts who contend that the execution of this desiltation procedure may not be justifiable. According to the market rates in Sri Lanka, the desiltation cost per square meter stands at 1.21 USD (Provincial Irrigation Department, 2019).

Drawing from a case study conducted by Dayananda et al. in 2021, which centers on the Mahakanumulla area – a representative dry zone cascade village engaged in rainfed farming the total expenses associated with a 25% desiltation effort and the corresponding financial returns are as follows.

Table 1: Total expenditure associated with a 25% desiltation effort and the corresponding financial returns

Cost of 25% desiltation	Increased benefit of 25% desiltation for farmers
251,743 USD	120,000 USD

Upon completion of the desiltation process, there is a notable increase in water availability during the *Yala* season. This increase plays a pivotal role in boosting overall profitability, primarily by expanding the extent of cultivation during this season. This observation aligns with the findings of Dharmasena (2023), who also indicated that post-desiltation, the tanks effectively store surplus water for utilization in the *Maha* season, facilitating *Yala* cultivation. Consequently, such an investment leads to the efficient utilization of land, water, and labor resources, thereby enhancing private profitability (Dayananda et al., 2021).

What are the Benefits for the Ecosystem?

The primary objective of partial desiltation is not merely to expand storage unless there is either a specific demand from the community or a technical potential within the system to justify such an expansion.

Moreover, the tank systems yield a variety of additional ecosystem services, extending beyond their primary function of supporting agricultural water needs. These services encompass the facilitation of fisheries and livestock management, as documented by Renwick in 2001. Furthermore, these systems contribute to flood prevention, soil erosion mitigation, enhancement of water quality, and water storage for dry season usage, as reported by Schütt and colleagues in 2013.

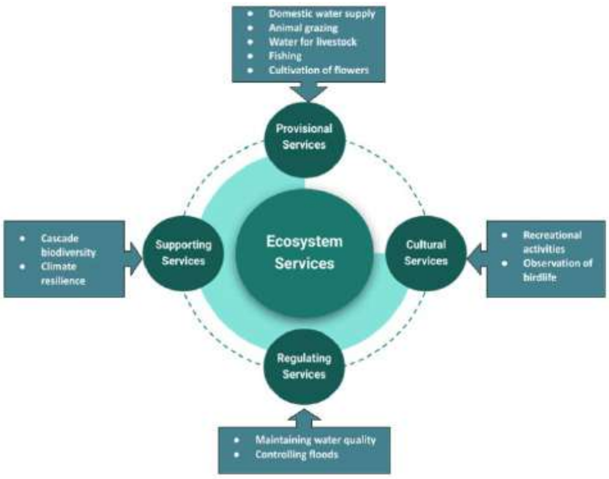

Figure 2: Ecosystem services provided by cascade systems

Additionally, these tank systems play a pivotal role in supporting climatic resilience in the face of changing climate patterns and safeguarding human well-being, as highlighted by Senanayake et al. in 2010.

Partial desiltation of a tank offers several advantages to the community, some of which may not be quantifiable through economic analysis, such as provisional services including domestic water supply, animal grazing, water for livestock, fishing and the cultivation of flowers sourced from the tank. Additionally, there are services related to regulation, such as maintaining water quality and controlling floods. Supporting services are also present in the form of biodiversity within the cascade ecosystem. Lastly, cultural services encompass recreational activities and the observation of birdlife.

In recent years, as our understanding of these complex cascade systems has expanded, there has been a rising national and global interest in comprehending the cascade tank system more thoroughly. This heightened interest encompasses endeavors to restore these tanks to their original state and to investigate their potential for climate adaptation. Furthermore, it is noteworthy that the rehabilitation of deteriorated cascades has been recognized as a pivotal climate change adaptation strategy within the National Adaptation Plan for Sri Lanka, as articulated by the Ministry of Mahaweli Development and Environment (MMDE) in 2016.

Valuation of Ecosystem Benefits of Partial Desiltation

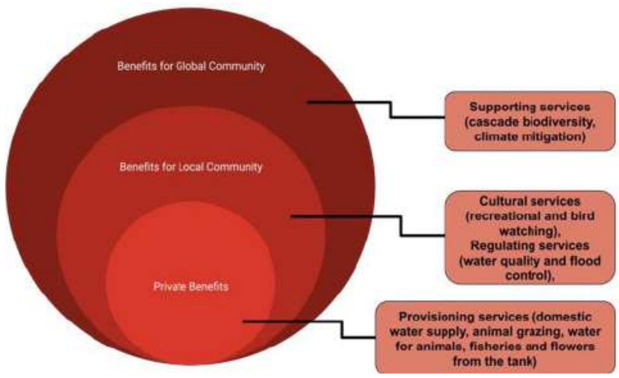

Figure 3: Graphical illustration of the ecosystem services provided by the Mahakanumulla cascade to various segments

The studies conducted over the past few years highlighted the value of these services. As an example, the figures of these ecosystem services can be illustrated using the previously mentioned case study, which centers on the Mahakanumulla tank village. The value of provisioning, regulatory, supporting, and cultural services of Mahakanumulla was reported as 169,800 USD/ha, 246,300 USD/ha, 82800 USD/ha and 140 USD/ha, respectively. The aggregate value of the ecosystem services under consideration was 424,520 USD/ha (Dayananda et al, 2021).

These ecosystem services may further be categorized into three distinct segments, delineating their various impacts and beneficiaries.

- Private Benefits (Provisional Services) - This category comprises services that primarily cater to the immediate and specific needs of local stakeholders.
- Benefits for the Citizens of Sri Lanka (Local Tourism- Cultural, and Regulatory Services): Within this realm, services directly enhance the well-being and experiences of Sri Lankan citizens, encompassing elements such as local tourism, cultural enrichment, and essential regulatory functions that directly impact the populace.
- Benefits for the Global Community (Biodiversity Advantages, Existence Values, and Climate Mitigation - Global Public Goods): These services transcend national boundaries and provide advantages to the broader global population. They include the preservation of biodiversity, the intrinsic worth of existence, and climate mitigation, collectively representing global public goods.

Hence, it becomes evident that the financial burden of desiltation is a shared responsibility, extending beyond the cascade village residents. This duty is not confined solely to the local community but is also a global endeavor, aimed at aiding in the restoration and rehabilitation of small tanks to bring them to their original status. This collective effort is essential in addressing global challenges while facilitating solutions for national-level initiatives.

According to Dayananda et al. (2021), under 25% partial desiltation, the ecosystem benefits would increase by 5%-10% over a period of five years.

Table 2: Value assessments of ecosystem services across beneficiary segments

Beneficial Segment	Ecosystem Service	Value for each segment (USD/ha)	Percentage of value occupied by each segment
Private	Provisional Services	169,800.00	34.02%
Local	Regulating Services	246,300.00	49.38%
	Cultural Services	140.00	
Global	Supporting Services	82,800.00	16.6%

Table 3: Incremental benefits of ecosystem services by 25% desiltation

Scenario		Provisioning services (USD)	Regulatory, Supporting and Cultural services (USD)
25% desiltation	Ecosystem benefits increase by 5%	24,523	36,789
	Ecosystem benefits increase by 10%	50,939	76,418

Source: Dayananda et al., 2021

Analyzing Comprehensive Economic Impacts: Extended Cost-Benefit Analysis

It is evident that a 25% desilting effort yields greater returns when integrated with an analysis of ecosystem benefits. It becomes apparent that the direct costs associated with desilting village tanks in the study area are high in comparison to the advantages derived from irrigation. However, when ecosystem services are factored into the analysis, the scenarios result in higher returns on desilting.

Table 4: Economic returns from 25% tank desiltation

Scenario	Without eco-system services			With 5% increment in eco-system services			With 10% increment in eco-system services		
	NPV (USD)	BCR	IRR	NPV (USD)	BCR	IRR	NPV (USD)	BCR	IRR
25% desiltation	-157,127	0.38	-21%	-108,544	0.55	-12%	-61,400	0.76	-2%

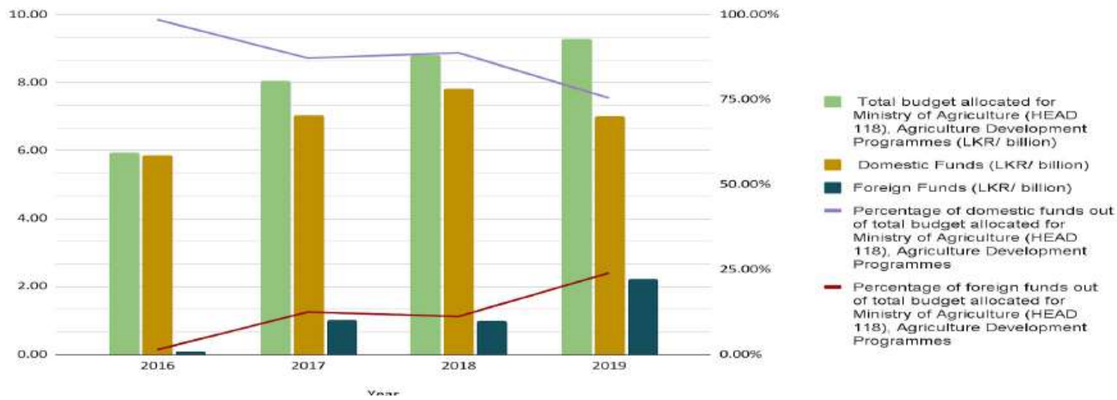

Figure 4: The domestic and foreign funding patterns for the agricultural development programmes

Recommendations

- Desiltation is required to enhance the water holding capacity of tanks. According to the study done by Dayananda et al. (2021), 25% partial desiltation is more profitable when the financial returns of investments are coupled with ecosystem benefits. The profitability of 25% desiltation can be further improved with market interventions such as buyback systems, making this investment more worthwhile.

- The financing of desilting and restoration processes should prioritize the assessed value of benefits received by each beneficiary segment. It is crucial to align funding allocation with the specified percentages outlined above, rather than solely burdening the village community residing in proximity with both financial and responsibility obligations.

- In the context of budget allocations for agricultural development programs, the majority of funds originate from domestic sources, with a relatively small portion coming from foreign sources.

- It is evident from the preceding observations that the benefits of these cascade systems extend not only to the village community but also to the local and global communities. This underscores the importance of including their contributions in this context. Therefore, the recommendation presented here advocates for financing renovations in accordance with the mentioned percentages, which would translate to approximately 83.5% from domestic sources and 16.6% from global sources.

References

Dayananda, D., Dilhari, W. A. D. S., & Weerahewa, J. (2021). An assessment of economic and environmental benefits of desilting village tanks in Sri Lanka: an application of linear programming. In MODSIM2021, 24th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2021 (pp. 561-567).

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POLICY BRIEF

Performance Parameters of VTCS in Mahakanumulla System

Key messages

The following recommendations are crucial to optimize the effectiveness and sustainability of the Mahakanumulla Village Tank Cascade Systems, fostering improved water management outcomes for agricultural production and ecosystem resilience.

- Develop evidence-based policies that reflect the Village Tank Cascade System's (VTCS) role in cultivation, flood control, and landscape management, while ensuring adequate provisions for ecological and environmental amenities in the upstream areas.
- Focus on resolving water feed to storage, especially in downstream regions like Wellamudawa, Kudagama, and Puncikulama tanks.
- Promote the establishment of new cross-linkages within the Mahakanumulla VTCS.
- Tank rehabilitation practices and crop planning activities should consider tank performance indicators to avoid water-related crises in this mainly rainfed landscape.

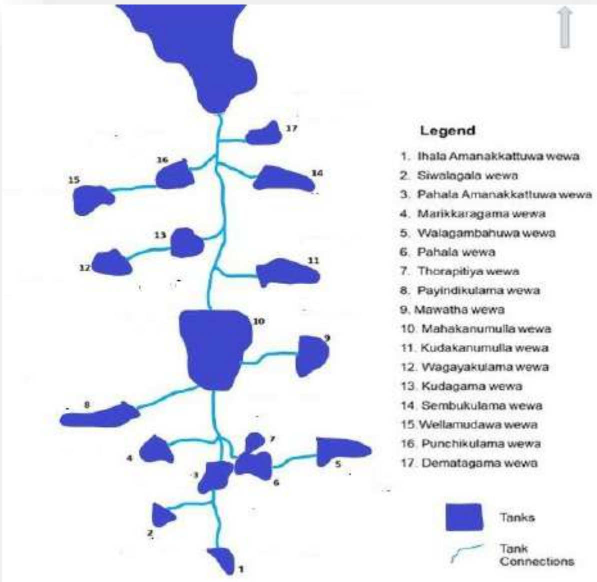

Figure 1: Mahakanumulla VTCS (Sirimanna and Prasada, 2021)

Description of the Problem

Water use efficiency is a key concern in dry zone agriculture. For a cascade to function efficiently, it is important that the recharge and storage of the tanks are of adequate effectiveness. Conveyance efficiency between tanks and across command areas is also important in this context. In this study, we look at the performance metrics of tanks within the Mahakanumulla cascade to diagnose possible gaps in the efficiency of each tank of the VTCS using a quantitative approach.

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Measuring the Effectiveness of a Tank within the Mahakanumulla VTCS

A tank (or a reservoir) within a cascade receives water from the respective upstream of the tank and holds and dispenses it to the downstream. It is possible for tanks to have cross-linkages, making the architecture more complicated than a simple linear structure. Nevertheless, a metric of the upstream runoff that is collected to a given tank, and the storage capacity, both as a ratio to the irrigation demand created by the command area of the tank provides us with two measures of effectiveness.

The first parameter (i.e., the effective runoff, $\boldsymbol{R_o}$) can be derived using a calibration methodology adopted in Sakthivadivel *et al*. (1997) with respect to each tank, as follows,

$$\boldsymbol{R_o} = 0.2738T_{ca} - 1.4861$$

Where, R_0- Effective runoff to the tank

T_{ca} - tank catchment area

The second parameter, i.e., Tank storage capacity (St) is derived following Sakthivadivel et al. (1997) and Arumugam (1957) with respect to each tank in the Mahakanumulla VTCS.

$$\boldsymbol{S_t} = 0.4 \times A_{tws} \times d$$

Where, A_{tws} - Tank water spread area

d- Effective tank depth at sluice head

Each of the above parameters as a ratio to Irrigation water demand relevant to each tank generate the diagnostic performance parameter of interest. The following calibration is adopted to derive the irrigation demand on each tank in the VTCS, as in Sakthivadivel et al. (1997).

$$\boldsymbol{I_t} = 5.7947 + 0.7078A_{co}$$

Where, I_t- Irrigation water demand

A_{co}- Command area of the tank

Methodology

We calculate the primary parameters discussed above (and shown in table 1 also) using the field-level data obtained in the Maha season of 2019 and Yala season of 2020. Then, we derive the secondary diagnostic parameters listed in table 2. These performance parameters are measured or derived with respect to all the component tanks of the Mahakanumulla cascade.

Comparing the two performance parameters of each tank provides us with an index of the effectiveness of the respective tank. Large gaps between the two performance parameters are indicative of the ineffectiveness of the tank's intended function and an implication for the inefficiency of the VTCS. In contrast, if the two parameters are closer to each other, the tank's contribution to the cascade can be judged as effective.

These concerns are discussed illustratively and potential policy concerns arising thereof are pointed out in the subsequent sections of this brief, with respect to upstream and downstream for comparative convenience.

Table 1: Primary parameters of tank function

Primary Parameters	Calibration
Irrigation water demand	$\boldsymbol{I_t} = 5.7947 + 0.7078A_{co}$ **(**Sakthivadivel *et al*. (1997).**)** I_t- Irrigation water demand A_{co}- Command area of the tank
Effective runoff to the tank	$\boldsymbol{R_o} = 0.2738T_{ca} - 1.4861$ **(**Sakthivadivel *et al*. (1997).**)** R_0- Effective runoff to the tank T_{ca} - tank catchment area
Tank storage capacity	$\boldsymbol{S_t} = 0.4 \times A_{tws} \times d$ (Sakthivadivel *et al.* (1997) and Arumugam (1957) A_{tws} - Tank water spread area d- Effective tank depth at sluice head (depth from full supply level to the silt level)

Table 2: Performance parameters of the tank

Diagnostic performance Parameter	Method of calculation	Description
supply index adequacy	. $Tank\ water\ supply\ adequacy = \frac{R_0}{I_t}$	Measures the ability of the individual tanks to hydrologically endow its command area. Estimated using the ratio between R_0 and I_t.
Storage index adequacy	$Tank\ water\ storage\ adequacy = \frac{S_t}{I_t}$	This measures whether the tank is capable of storage adequate amount water for irrigation.

Key Findings of the Analysis

In this policy brief, we adopt an approach of displaying the performance parameters illustratively while contrasting the tanks across each other with respect to the selected parameter, using a 'value map diagram' as shown in figures 2 and 3. This approach provides the comparative performance of each tank both within and between the tanks at the same time.

Findings (part 1: figure 2): Comparative illustration of performance of Mahakanumulla Upstream

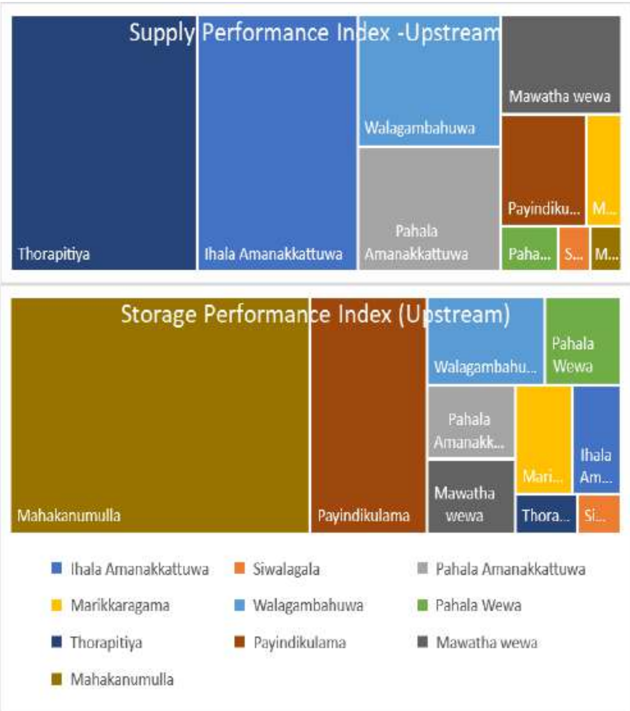

Figure 2: Performance of the tanks of Mahakanumulla Upstream

The supply and storage performance indices should be reasonably close in value to reflect the efficacy of the tank and its efficient contribution to the VTCS. We find that Thorapitiya and Ihala Amanakattuwa tanks are well endowed from the upstream feed but have very poor storage performance leading to large mismatches in their relative contribution to VTCS. A similar scale mismatch of performance is observable in the storage performance with respect to Mahakanumulla and Pyindikulama tanks which display large holding capacity with respect to irrigation demand but poor upstream feed. However, both supply and storage issues are not necessarily critically problematic to the overall integrity of the VTCS as Thorapitiya and Ihala Amanakattuwa are located high up in the stream flow and Mahakanumulla and Payindikulama are located low down in the upstream.

Findings (part 2: figure 3): Comparative illustration of the performance of Mahakanumulla downstream

Wellamudawa tank in the downstream displays high receipt of upstream feed but relatively poor storage capacity. This is a critical concern that may lead to the cultivation water needs of the command area of the tank. The possibility of flooding and potential damage to tank structures are also likely in a setting of this nature. On the other hand, a tank such as Kudagama tank displays a large holding capacity which is not sufficiently matched by the relative water supply performance to the tank. Potential drying of the tank and command area cultivation is likely in this instance. In this case, long-term impacts could amount to the tank's abandonment.

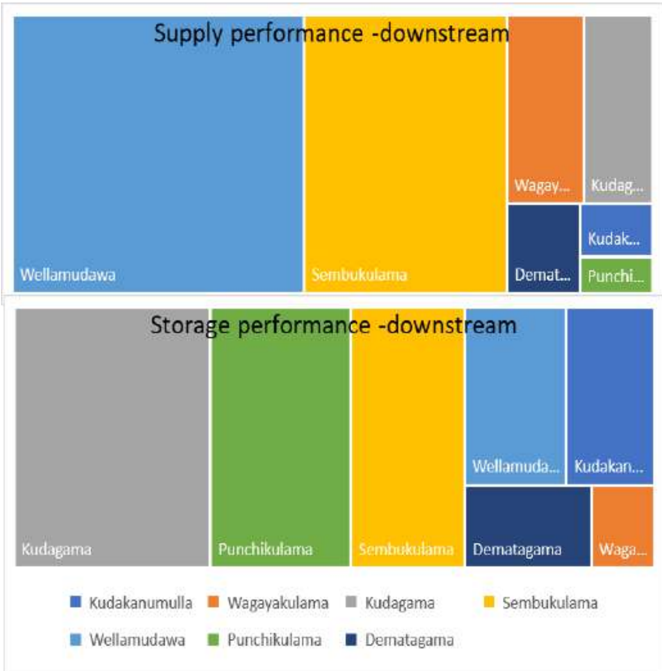

Figure 3: Performance of the tanks of Mahakanumulla downstream

Policy Recommendations

- Policies should reflect the above evidence in mainstream the contribution of the VTCS to cultivation, flood control and landscape management including making adequate provision for ecological and environmental amenities in the upstream.
- Implications of water feed to storage mismatches are most problematic downstream of Mahakanumulla VTCS, with special reference to Wellamudawa, Kudagama and Puncikulama tanks.
- Given the cascade architecture of Mahakanumulla VTCS, new cross linkages from tanks with relatively high-water feed endowment (for instance, Wellamudawa tank) and cross-linkages to tanks with relatively high storage performance (for instance, Kudagama tank) could enable higher efficacy and overall water use efficiency in the VTCS.
- Tank rehabilitation practices and crop planning activities should consider tank performance indicators to avoid water-related crises in mainly rainfed landscapes.

References

Sirimanna, S., & Prasada, D. V. P. (2021). Water productivity in tank cascade systems: A case study in Mahakanumulla tank cascade, Sri Lanka. Tropical Agricultural Research, 32(3), 298-306.

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POLICY BRIEF

Perspectives of Economic Development in Village Tank Cascade Systems in Sri Lanka

Key messages

The wewa-ellangava system, or tank cascade system, is vital for Sri Lanka's rural communities, providing water for agriculture, domestic use, and cultural practices. Despite their historical importance, these systems face challenges like low cropping intensity and inadequate maintenance.

- **Economic Benefits and Challenges**: Village tank cascade systems offer direct economic benefits through water supply and irrigation, as well as indirect benefits like biodiversity conservation and erosion control. However, challenges such as lack of awareness and maintenance hinder their economic potential.
- **Policy Options**: Diversifying agriculture, promoting tourism, supporting water-based livelihoods, and improving infrastructure are key policy options to maximize economic benefits. Sustainable measures are essential to address challenges and unlock economic opportunities.
- **Recommendations**: Strengthening community institutions, implementing market-based solutions to increase profits and fee system for conservation, investing in infrastructure, promoting sustainable agriculture, supporting tourism, improving access to finance, and utilizing technology are recommended to enhance economic development.
- **Conclusion**: By implementing these recommendations, Sri Lanka can harness the economic potential of village tank cascade systems, ensuring sustainable rural development and environmental preservation.

Source: Google Earth Pro, Airbus 2024

Introduction

The wewa-ellangava system, also known as the tank cascade system, is a traditional irrigation system in Sri Lanka. The system consists of a network of tiny tanks that empty into sizable reservoirs that hold surface runoff and rainfall for later use (Geekiyanage and Pushpakumara, 2013; Department of Earth Sciences, 2019). Village Tank Cascade Systems (VTCS) are a cornerstone of the country's ancient hydraulic civilization, providing a resilient agricultural infrastructure that supports the livelihoods of rural communities in the dry zone. These systems are not only crucial for agriculture

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but also for household and environmental purposes. These systems are autonomous agro-ecological systems that have historically mitigated the impacts of droughts and floods, contributing to food security and self-sufficiency in rice production. Despite their historical significance and potential for climate change adaptation, VTCS face challenges such as low cropping intensity, tank sedimentation, and higher water losses. This policy brief examines the economic aspects of VTCS, highlighting the need for sustainable development, modernization, and collective action to enhance their efficiency and resilience.

Economic Benefits and Challenges

Tank cascade systems in Sri Lanka provide various direct and indirect use values, contributing to both economic and ecological sustainability. The primary direct use value of tank cascade systems is supplying water for domestic, agricultural, and industrial purposes. These systems store rainwater during the wet season and release it during the dry season, ensuring consistent water availability for various needs. It is estimated that an average villager normally uses the tank around 228 days per year for bathing and washing clothes Kala Oya basin small irrigation tanks (Perera, et al., 2005). Fishing is another important economic activity carried out in these small tanks. About 25 persons on average are engaged in fishing in some of these tanks (Perera, et al., 2005.

Secondly, the tank cascade systems support irrigation activities, enabling farmers to cultivate crops throughout the year. This directly contributes to agricultural productivity and food security. According to Wijekoon et al. (2016) village tank systems were responsible for 26% of the total paddy cultivation during the 2014/15 Maha season in Sri Lanka, with a cultivated area of 203,836 ha out of a total extent of 772,626 ha. Further, they reported that the minor irrigation systems accounted for 28% of the total Maha season production in 2014/15 and 24% of the total Yala paddy production in 2015. The efficient administration of small-scale irrigation projects can lead to higher rice production. For instance, in Sri Lanka, the average rice yield from small reservoirs was noted as 4235 kg/ha during the main cultivation (Maha) season and 3967 kg/ha during the secondary cultivation season (Yala) (Wijekoon et al., 2016). In addition to paddy, farmers derive economic value from many other crops. Perera, et al (2005) estimates the direct benefits of these crops in Kala Oya basin small irrigation tanks including, Banana, Coconut, Lotus flowers and Lotus roots. when 922 ha of lowlands and 205 ha of uplands were allocated per annum for crop cultivation under normal environmental conditions, the annual profitability of the VTCS was LKR 111 million as estimated by Dayananda et al. (2023) using a Bio-Economic model in the Mahakanumulla VTCS of the Anuradhapura district.

There are many indirect use values, which are not values in these contexts and some are values in certain studies. One important aspect is biodiversity conservation. Tank cascade systems often serve as habitats for various flora and fauna. They support biodiversity by providing breeding grounds for aquatic species and habitats for terrestrial wildlife. Dissanayake (2018) finds that households living in the Pihimbiyagollewa tank cascade system are willing to pay to conserve the for marginal improvements in biodiversity in the system. They placed the highest value on cascade water for paddy followed by cascade water for other uses and cascade biodiversity indicating its importance.

Another important indirect use is erosion control. The reservoirs formed by tank cascade systems help control soil erosion by reducing the velocity of water runoff. This indirectly benefits agricultural productivity by preserving fertile soil. Cooray and Jayawardene (1982) highlighted that the primary source of groundwater recharge stems from the irrigation system itself, specifically through infiltration from tanks and channels. This implies that the water used for irrigation replenishes the groundwater reservoirs, contributing significantly to their sustainability. Paranamanna and Mendis (2007) asserted that when considering an ecosystems perspective, the historical irrigation systems can indeed be acknowledged as effective mechanisms for water and soil conservation. These ancient structures, which include tanks and channels, played a crucial role in maintaining ecological balance and preserving natural resources. Additionally, tank cascade systems can mitigate the impacts of flooding by regulating water flow. During periods of heavy rainfall, these systems can store excess water, reducing the risk of downstream flooding (Schütt et al., 2013).

Further, tank cascade systems hold cultural significance in Sri Lanka, often being associated with traditional practices and rituals. Additionally, they offer recreational opportunities such as fishing, boating, and nature tourism, indirectly contributing to local economies. Overall, tank cascade systems in Sri Lanka provide a range of direct and indirect use values that are essential for sustaining livelihoods, ecosystems, and cultural heritage in the region.

Despite the potential for economic development, village tank cascade systems in Sri Lanka face several challenges that need to be addressed (Jayasuriya et al., 2017):

- Lack of knowledge and awareness regarding the full range of ecosystem services provided by the tanks and tank cascades. This lack of understanding limits the ability of stakeholders to fully utilize and conserve these systems, hindering their economic potential (Nanthakumaran, et al., 2021).
- Inadequate maintenance and rehabilitation of the tanks and associated infrastructure, leading to reduced water storage capacity and inefficient irrigation practices (Wikramanayake and Corea, 2003).
- Inadequate coordination and collaboration among farmer organizations, government authorities, and other relevant stakeholders in the management of tank cascade systems.
- Insufficient access to financial resources and funding for the maintenance and improvement of tank cascade systems, hindered by a lack of sustainable funding mechanisms.
- The unregulated use of agrochemicals and their impact on tank water quality, leading to potential health hazards and environmental degradation.

Evaluation of Policy Options

The economic perspectives of village tank cascade systems in Sri Lanka are multifaceted. On one hand, these systems have the potential to significantly contribute to local economic development by enhancing agricultural productivity and creating employment opportunities for rural communities (Wikramanayake and Corea, 2003). On the other hand, the challenges faced by these systems, such as decreased water capacity and inadequate maintenance, can hinder economic growth and livelihoods (Nanthakumaran et al., 2021). Therefore, it is crucial to implement sustainable and effective measures to address these challenges and maximize the economic potential of village tank cascade systems in Sri Lanka. There are several economic development opportunities:

- Agriculture Diversification: Beyond traditional rice cultivation, village tank cascade systems can support diversified agriculture, including high-value crops such as fruits, vegetables, and spices. By leveraging water availability and micro-climatic conditions, farmers can enhance productivity and income diversification.
- Agro-tourism and Eco-tourism: The scenic beauty and cultural heritage associated with village tank cascade systems present opportunities for agro-tourism and eco-tourism initiatives. Community-based tourism ventures can offer visitors immersive experiences, including farm stays, nature trails, and cultural exchanges, generating additional income for local communities.
- Water-based Livelihoods: Village tank cascade systems support various water-based livelihoods, including fisheries, aquaculture, and cottage industries like traditional crafts and handloom weaving. Sustainable management practices can enhance these livelihood opportunities while ensuring the conservation of water resources and ecosystems.
- Water Supply and Micro-enterprises: Improved water management within village tank cascade systems can facilitate reliable water supply for

domestic use and small-scale enterprises. Access to clean water can spur the growth of micro-enterprises, such as small-scale food processing units, handicraft production, and community-based service providers.

Conclusions and Policy Recommendations

To unlock the economic development potential of village tank cascade systems in Sri Lanka, the following policy recommendations are proposed:

- Strengthen Community Institutions: Enhance the capacity of tank committees and local community organizations to manage and govern village tank cascade systems effectively. This includes providing training on water management, sustainable agriculture practices, and enterprise development.
- Introduce market-based solutions, including buy-back arrangements for crops, to help farmers manage risks associated with climate variability and to stabilize income. Also implementing a fee system to fund the improvement and conservation of village tanks, with contributions from farmers and users.
- Infrastructure Investment: Invest in infrastructure upgrades and maintenance of village tank cascade systems to improve water storage capacity, irrigation efficiency, and flood control mechanisms. Adopt climate-resilient design principles to mitigate the impacts of climate change.
- Promote Sustainable Agriculture: Provide technical assistance, financial incentives, and market linkages to promote diversified and climate-smart agriculture practices within the catchment areas of village tank cascade systems. Facilitate farmer cooperatives and producer groups to access markets and value chains.
- Support Community-based Tourism: Facilitate the development of agro-tourism and eco-tourism initiatives in collaboration with local communities, tourism authorities, and private sector stakeholders. Provide training on hospitality, tourism management, and environmental conservation to community members.
- Access to Finance and Markets: Improve access to credit, grants, and other financial services for rural entrepreneurs and smallholder farmers operating within village tank cascade systems. Foster partnerships with financial institutions and market aggregators to support enterprise development and market linkages.
- Utilize modern technology, such as remote sensing and geographic information systems, to gather accurate data on water availability, usage patterns, and land use in village tank cascade systems.

References

Cooray, A.T. and P. H. Jayawardene (1982): Ground Water Hydrology in the Mahaweli System H

Dayananda, D., Weerahewa, J., & Weerasooriya, S. A. (2023). Resource-use efficiency and environmental sustainability in the village tank cascade systems in the dry zone of Sri Lanka: An assessment using a bio-economic model. Frontiers in Sustainable Food Systems, 7, 1084973.

Department of Earth Sciences (2019) "Tanks in the Dry Zone of Sri Lanka"., Freie Universtät Berlin. 29 October 2019. Archived from the original on 20 October 2022. Retrieved 18 September 2022.

Dissanayake, T. M. (2018). Valuing Restoration of Ancient Irrigation Systems: A choice experiment on small tank cascade restoration in Sri Lanka. bepress.

Geekiyanage, Nalaka; Pushpakumara, D.K.N.G. (2013). "Ecology of ancient Tank Cascade Systems in island Sri Lanka". Journal of Marine and Island Cultures. 2 (2): 93–101. doi:10.1016/j.imic.2013.11.001. ISSN 2212-6821.

Jayasuriya, B., Ranasinghe, D. and Madduma-Bandara, M, C. (2017) Socio-Cultural, Ecological and Managerial Perspectives of a Selected Cascade Tank System in Anuradhapura District, Sri Lanka. Available at: https://doi.org/10.4038/ijms.v4i2.21.

Nanthakumaran, A. et al. (2021) Exploring the village tank cascade systems (VTCSs) in Vavuniya district, Sri Lanka. Available at: https://doi.org/10.2166/wcc.2021.412.

Paranamana, P.A.G., & Mendis, D.L.O, undated, Ecosystem Based Indegenious Water Management. http://thakshana.nsf.ac.lk/slstic/NA-334/NA-334.pdf retrieved 26th Feb 2024

Perera, H. D. B. S., Vidanage, S. P., & Kallesoe, M. F. (2005). Multiple Benefits of Small Irrigation Tanks and Their Economic Value: A Case Study in the Kala Oya Basin, Sri Lanka. IUCN-The World Conservation Union, Sri Lanka Country Office.

Wijekoon, W. M. S. M., Gunawardena, E. R. N., & Aheeyar, M. M. M. (2016). Institutional reforms in minor (village tank) irrigation sector of Sri Lanka towards sustainable development. In Proceedings of the 7th International Conference on Sustainable Built Environment 2016, Kandy.

Wikramanayake, N. and Corea, H, J, E. (2003) Alternative Technology for Urban Wastewater Treatment: Case Studies and Issues of Implementation and Sustainability. Available at: https://doi.org/10.1061/40685(2003)252.

Schütt, B., Bebermeier, W., Meister, J., & Withanachchi, C. R. (2013). Characterisation of the Rota Wewa tank cascade system in the vicinity of Anuradhapura, Sri Lanka. DIE ERDE–Journal of the Geographical Society of Berlin, 144(1), 51-68.

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POLICY BRIEF

Sustainable Value Chain Development in Village Tank Cascade Systems (VTCS)

Key messages

In most value chains, rural producers are the key players. Enhancing their ability to seize market opportunities, secure equitable agreements, and improve the quality of their products not only boosts overall value chain efficiency but also leads to increased rural incomes, employment, and economic growth within rural regions. The following policy options would help create an enabling environment for enhanced collaboration, sustainability, and socio-economic well-being within rural communities in the VTCS.

- An enabling business environment consisting of a clear and straightforward regulatory framework reduces bureaucratic hurdles and encourages the formalization of businesses.
- Fostering public-private partnerships to encourage collaborations between government entities, private sector organizations, and non-governmental organizations.
- Building capacity, and awareness through empowerment to enhance industry best practices, processing techniques, and product quality improvement.
- Digitizing the value chain stream and connecting stakeholders through a common e-platform under the government flagship enhances traceability and promotes credibility and reliability.

Restoring VTCS: Challenges and Pathways

Over the decades, VTCS in Sri Lanka played a crucial role in shaping the livelihood of millions of people of the country. Tank cascades are unique systems, made by humans to sustain their livelihood. VTCS are carriers of cultural heritage, and extensive sources of ecological, economic, and social services, values, and functions. Hence, it is evident that these cascade systems are well managed and governed throughout the years. Over the years, due to many reasons, these systems have been disturbed and diluted in many ways. The existing system exhibits a diminished level of sustainability. The contemporary diversification of income sources among communities residing in the proximity to these cascades offers promising prospects for rural development. Nevertheless, harnessing these opportunities poses substantial

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challenges, jeopardizing the delicate balance between economic and ecological considerations (Abeywardana, *et al.*, 2018). The absence of comprehensive value chain studies hampers the disclosure of these opportunities, fostering the emergence of unethical ventures within these communities.

What is a Value Chain?

"A value chain consists of all value-generating activities required to produce, deliver and dispose of a commodity". *(Schmitz, 2005)*

This includes design, production, marketing, distribution and support services leading up to consumption. As the product passes through the stages of the value chain, its value increases. *Miller and Jones (2010)*

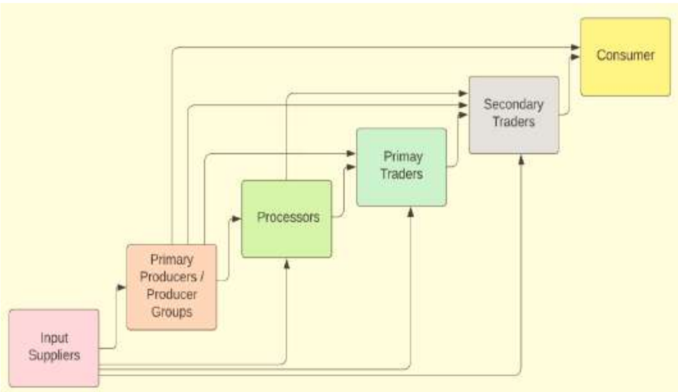

Figure 1: Generic Value Chain Stream Depicting Primary Activities
Source: Authors Compilation

Why is Action Needed?

- *Power struggle:* The dynamics of power within value chains are of paramount significance. Markets wherein a few dominant entities wield considerable influence can adversely affect small-scale producers, leading to a reduction in their earnings from the sale of their goods. This holds true in ecotourism, where only a handful of stakeholders assume key decision- making roles, thereby favoring a restricted number of downstream participants.

- *Information asymmetry:* There is an uneven distribution of information among various actors involved in the value chain, leading to imbalances in decision-making power and outcomes. At the core of this issue is the unequal access to critical information related to market trends, pricing mechanisms, and technological advancements. Larger entities or intermediaries often possess more comprehensive knowledge, leaving smaller producers and rural participants at a disadvantage.

- *Improper regulatory mechanisms:* This results in a deficiency in the overall integrity, quality, and sustainability of these chains. The absence of robust certification standards can compromise the quality of products within rural value chains. A lack of standardized practices may hinder the competitiveness of rural goods in broader markets. In the case of ecotourism, there are no safety precautions for tourists when engaging in the different initiatives. The village-level guides hardly maintain professionalism, which results in dissatisfaction among tourists.

- *Limited market access and less developed infrastructure:* Inadequate connections between rural producers and broader markets can result in missed opportunities for growth and hinder the overall resilience of rural economies. In the case of traditional food production, limited market access hinders the real opportunities and those are limited only for the food exhibitions.

- *Limited collaborations and social cohesion:* Limited collaboration leads to isolated pockets within the value chain, hindering the seamless flow of information and resources. This fragmentation can result in inefficiencies and missed opportunities for collective growth. Lack of collaboration stifles innovation, as there is a limited exchange of ideas, knowledge, and best practices among value chain participants. Weak social cohesion may exacerbate existing disparities within rural communities as it encourages social exclusion. In almost all value chains agricultural and non-agricultural communities showcased conflict of interest on different initiatives, which ultimately leads to social fragmentation.

Policy Options

In addressing the multifaceted challenges hindering the optimal growth of value chains in the VTCS, the formulation of effective policies becomes paramount. This set of policy options aims to enhance collaboration, sustainability, and socio-economic well-being within rural communities. By focusing on strategic interventions, these policies seek to promote inclusive development, foster innovation, and create an enabling environment for resilient and thriving rural value chains. The overarching goal of these policy options is to create an environment conducive to the growth, resilience and inclusivity of rural value chains. By strategically addressing key barriers, the policies aim to unlock the full potential of these chains, fostering economic prosperity, social cohesion, and environmental sustainability within rural communities.

- ***Providing an enabling business environment for rural value chain development:*** This broadly involves a combination of policy measures, infrastructure development, and community empowerment. Simplify regulatory procedures and licensing requirements for rural enterprises. A clear and straightforward regulatory framework reduces bureaucratic hurdles and encourages the formalization of businesses. Introduce incentive programs that reward sustainable practices, innovation, and value addition within rural value chains. Incentives can include tax breaks or grants for businesses adopting environmentally friendly and socially responsible practices.

- ***Fostering Public-Private-Partnerships (PPPs):*** Foster partnerships between government entities, private sector organizations, and non-governmental organizations. PPPs can provide resources, expertise, and support for rural value chain development initiatives. Further, this encourages establishing collaboration platforms such as industry associations, cooperatives, or business clusters. These platforms enable rural enterprises to share knowledge, pool resources and collectively address common challenges. Further, initiatives require promoting the formation and strengthening of producer cooperatives. Collaboration enhances collective bargaining power, facilitates resource pooling, and fosters a sense of community ownership.

- ***Capacity Building, Community Awareness and Empowerment:*** Offer training programs that enhance the technical skills of rural producers, including agricultural practices, processing techniques, and product quality improvement. This contributes to increased productivity and the production of higher-quality goods. For instance, honeybee collectors do not possess the technical expertise to purify honey and thus, trade raw form at lower prices. The intermediaries derive higher margins. Provide education on business management, financial literacy, and entrepreneurship. Conduct workshops on market trends, pricing mechanisms, and market access strategies (United Nations Conference on Trade and Development, 2020). Facilitate training on the adoption of modern technologies, including digital tools, precision agriculture, and efficient production methods. Foster inclusive decision-making processes that involve all community members, ensuring diverse perspectives are considered. Empowering individuals to actively participate in shaping the direction of value chain activities builds a sense of ownership and shared responsibility. Implement policies and programs that address social disparities, ensuring equal opportunities for women, youth, and marginalized groups. Inclusive approaches contribute to social cohesion and equitable distribution of benefits within the community.

- ***Strengthen Value Stream:*** Encourage and facilitate collaboration among stakeholders within the value chain to align with market requirements and adhere to industry standards. Work in conjunction with farmer associations to systematically identify and comprehend commodity value chains, as well as to assess market access opportunities and challenges. Promote active dialogue between value chain actors and their supporters. Investigate existing communication channels among stakeholders and implement improvements to enhance communication efficiency along the entire value chain. This should facilitate material, money and information flows simultaneously.

- ***E-platforms and SMART value chains concept for better connection***s: Establishing and connecting stakeholders into a common e-platform under the government flagship would be ideal to place the credibility and reliability of the value chains. Further, this enhances the traceability of the system, which is considered one of the key ethics in such ventures. E-platforms provide a digital marketplace where rural producers can connect directly with buyers, expanding market reach. Transparent pricing information on e-platforms enables farmers to make informed decisions, ensuring fair compensation for their produce. This also reduces the transaction costs (unethical trading, i.e. price discrimination) associated with traditional value chains.

Conclusions

The recommendations and policy implications articulated herein are interconnected, acknowledging the marginalized status of numerous stakeholders within the value chain, even within their local economies. To integrate these groups into the broader economy, it is essential to concurrently implement the recommendations alongside comprehensive programs for market systems and social protection. Realizing the full potential of these recommendations is contingent upon the enactment of complementary enabling policies. This includes measures to facilitate cross-border movements of people and goods, the establishment of conducive business environments to foster investment, the presence of structures facilitating upgrading and increased value addition, ultimately translating into heightened incomes and improved livelihoods, particularly for women and the youth. Further, leveraging e-platforms and incorporating SMART principles may revolutionize the connectivity and efficiency of rural value chains. Ultimately, a well-crafted policy framework, grounded in the principles of inclusivity and sustainability, will not only uplift rural communities but also contribute significantly to the overall economic resilience of the nation. The transformative potential of these initiatives lies in their ability to create a harmonious synergy between technology, agriculture, and community empowerment, paving the way for a more resilient and prosperous rural landscape.

References

Abeywardana, N., Bebermeier, W., & Schütt, B. (2018). Ancient Water Management and Governance in the Dry Zone of Sri Lanka Until Abandonment, and the Influence of Colonial Politics during Reclamation. *Water, 10*(12), 1-29.

Miller, C., & Jones, L. (2010). *Agricultural Value Chain Finance*. Hampshire, United Kingdom: Practical Action Publishing.

Schmitz, H. (2005). *Value chain analysis for policy-makers and practitioners*. Geneva: ILO.

United Nations Conference on Trade and Development. (2020). *Maximizing sustainable agri-food supply chain opportunities to redress COVID-19 in developing countries*. United Nations Conference on Trade and Development.

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Supporting Services

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POLICY BRIEF

Agricultural Land Use, Tenure, Ownership, and Succession for Sustainable Landscapes

Key messages

The following recommendations are crucial for shaping informed policy directions aimed at enhancing agricultural productivity, ensuring equitable land access, and promoting sustainable land use practices in VTCS.

- Develop policies based on socio-economic and institutional factors that influence home garden systems to ensure food security and meet nutrient requirements.
- Implement targeted socio-economic interventions to encourage the adoption of diverse home garden systems.
- Strengthen land ownership by enhancing land registration procedures and digitizing records to ensure clear and secure land titles.
- Conduct awareness campaigns to emphasize the benefits of formalizing land transactions and provide legal aid services and capacity building to ensure fair outcomes in land transactions.
- Introduce policies promoting voluntary land consolidation, such as land pooling, joint farming, and establishing land consolidation funds, among small-scale farmers to enhance agricultural productivity.
- Implement centralized land use planning to ensure sustainable and effective land use.
- Review and refine existing land succession policies to address challenges such as land fragmentation, inequality, barriers to productive land use, and the perpetuation of inequalities.
- Address gender disparities in land ownership and inheritance rights through awareness campaigns and capacity-building initiatives.
- Facilitate joint ownership and registration of land titles in both spouses' names to ensure equal land rights and access for women.
- Promote women's participation in decision-making processes related to agricultural activities and land management.

Land Use and Land Management Dynamics in VTCS

Sri Lanka's VTCS has served as the backbone of the country's agricultural landscape for centuries. These intricate systems comprise a diverse range of land uses, each contributing to the sustainability and productivity of the region's agriculture. The diverse tenure, ownership patterns, and succession in the VTCS play a pivotal role in the land use and management of the system.

Land Use in VTCSs:

Balancing tradition and modernization in land use

At the core of VTCS lies Puranawela, the irrigated land that sustains agriculture

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throughout both the Yala (Dry) and Maha (rainy) seasons. Ownership of Puranawela is not merely a legal right; it carries profound social and cultural significance, granting holders a revered status as the original village inhabitants. Akkarawela, the one-acre parcel often developed for paddy cultivation, serves as the major land use type in VTCS. Chena, another important land use type is referred to as shifting agriculture in upland forest areas. The expansion of Gamgoda, comprising residential sites and home gardens, mirrors the growth of the population. This evolution poses new challenges and opportunities in land management and land tenure.

Importance of home gardens (Gamgoda) as a land use system in VTCS

As the population increases people have given more attention to developing home gardens as a food production system to meet daily food and nutrient requirements, ensure food security, and mitigate food scarcity problems. The global existence of small-scale food production at the household level has a wide range in terms of physical appearance and utilization. There are three fundamental food production systems based on a variety of type-specific general features. Based on some of these features, these three types of home food production systems i.e. household gardens, market gardens, and field gardens can be identified in a VTCS in the dry zone of Sri Lanka.

Land Management in VTCS

Paddy land tenure types and their changes over time

Among the land use patterns in VTCS, paddy cultivation holds a major place. There are many types of paddy land tenures in the VTCS, including share tenancy, mortgage, leasing (*badu*), *thattumaru*, and *kattimaru*. Share tenancy, commonly known as the *anda* system, is a land tenure system in which poor people grow paddy lands with the landlord's help. There are two kinds of share tenancies: *kuli ande* and *otu ande*. The landowner supplies all inputs necessary for paddy production except labor and management under the Kuli *ande* system (labor tenancy). The net produce is split evenly between the owner and the renter after the harvest. The landlord only provides the land in the *otu ande* system, and the tenant gives all inputs, including labor while managing the field. As a land rent, the landlord receives a quarter of the harvest. A mortgage is a method in which a landowner gives up the right to utilize the land to a cultivator for one or more seasons in exchange for a predetermined fee. A leasing system is a contract between the lessor and the lessee. *Thatturmaru* is a method in which two or more farmers rotate land holdings in separate areas. *Kattimaru* refers to a system of rotating land plots between two or more farmers throughout two or more seasons. The *bethma* method is used, in which the lower field is left out during times of water scarcity, but everyone gets a part in the top field that is irrigated. All these tenure systems maintained trustworthiness towards each stakeholder as a result of strong social cohesion. Later, people deviated from traditional tenancy systems which were more specifically based on trustworthiness and social interactions. Instead, they preferred more tenure rights in their cultivation lands.

Evolution of land ownership and succession laws

Ownership and title issues concerning land in Sri Lanka are typically influenced by a complex historical background that dates back to pre-colonial and colonial rule and subsequent land reforms. By the early 20th century, challenges arose with the collapse of the dry zone irrigation system, lack of concern for paddy cultivation, displacement of subsistence farmers, population overcrowding in the wet zone, and food shortages. Consequently, the first Land Commission was established in 1927 to redistribute land to landless peasants and promote agricultural development. A Land Development Ordinance (LDO) No. 19 was enacted in 1935 to retain state lands in trust for all citizens and alienate the lands for peasants' benefit. Under this ordinance, lands were given to farmers as permits and later converted to grants such as *Swarnabhoomi*, *Jayabhoomi*, *Isurubhoomi*, and *Ranabima.* However, these reforms were not without complexities in land ownership, as the land was distributed through various mechanisms. These include state-owned land, permits, land grants, and leasehold tenures imposing certain restrictions on land usage and transfer.

Problem Statements

Optimization of land use: Home gardens, a solution to the food crisis?

With the rising population pressure, it has become important to give attention to the problems such as food scarcity, food security, and nutrient deficiency that can result from recurring crises. The variation in the food production systems adopted in the VTCS serves differently for the community either by allowing them to provide their nutrient requirement or ensure financial security or serve as a system to ensure their food security respectively by three production system types. It is important to understand the determinants of this variation to support the community in the most suitable food production system for their well-being. Socio-economic and institutional variables might have an impact on the household choice of the food production system practiced in their home gardens.

Land ownership and succession issues: Secure tenure rights, and existing informal land market

All the tenure arrangements serve as a means for the farmer to obtain potential revenue from a certain land allotment. Farmers' income is already constrained by small land holdings; seasonality, and low productivity, thus complicated land tenure systems are an additional burden. In a cascade system, insecure land rights are one of the primary obstacles to enhancing agricultural production and resource management (Bugri, 2008). Under the LDO, beneficiaries were allowed to cultivate the lands, but the rights to sell, lease, mortgage, and abandon land were controlled. The LDO served as the government's guide in deciding how to distribute lands to the first generation of settlers. These deeds do not provide complete property rights and do not allow for open market transactions or property subdivisions. As subdivisions of agricultural lands are restricted and allowed only up to a minimum subdivision unit, the second generation who want to engage in agriculture has only a few options: cultivate their father's property or share the land informally among descendants, get a lease, or encroach forest lands for cultivations.

Conclusion and Policy Recommendations

Land use

A study that was done on this aspect has analyzed the socio-economic and institutional factors affecting the choice of food production system practiced in home gardens (Figure 1). The decision to have a household garden is more driven by socio-economic and institutional factors rather than market gardens and field gardens. The effect of these factors on the decision to have a field garden is comparatively less. Each type of food production system plays a different role in fulfilling a household’s essential requirements. The study identified which socio-economic factors are influential in having which type of home garden system. Understanding the socio-economic and institutional drivers behind the existence of diverse food production systems in home gardens not only deepens our comprehension of human and environmental interactions but also provides valuable insights for decision-makers regarding the development of socio-economic determinants aimed at encouraging the adoption of each type of home garden system. Using these results,

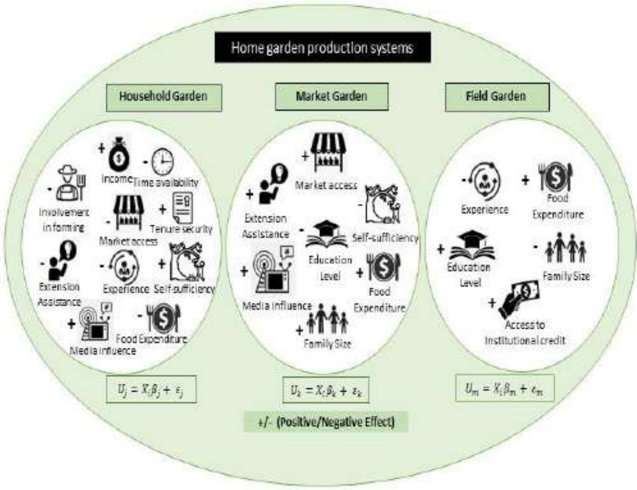

Figure 1: Effect of socio-economic and institutional factors on the choice of food production system practiced in home gardens.

policymakers can predict farm management decisions of households and plan evidence-based strategic government intervention to meet the daily nutrient requirement, ensure food security, and mitigate food scarcity.

Securing tenure rights and initiating a proper land transaction system

a) Addressing ownership and titling issues

To strengthen land ownership and ensure clear titles, the government should improve the land registration system by streamlining procedures, digitizing records, and creating online platforms for easy access to land information. Awareness campaigns should emphasize the benefits of formalizing land transactions, such as enhanced security and access to credit. Mechanisms for regularizing informal transactions and simplified procedures should be developed. Dedicated legal aid services and capacity-building programs should ensure fair outcomes in land transactions. To address issues of fragmented land holdings and enhance agricultural productivity in Sri Lanka, the government should introduce policies and incentives promoting voluntary land consolidation among small-scale farmers, using methods like land pooling, joint farming, and the creation of land consolidation funds. Centralized land use planning is essential to identify suitable agricultural areas, encourage cluster farming, and discourage non-agricultural land use. This planning, incorporating factors like soil quality, water availability, ecology, and market demand, ensures sustainable and effective land use. Effective land use planning optimizes productivity while minimizing environmental harm and further informal fragmentation.

b) Proper land succession planning

In Sri Lanka, where agriculture remains a primary source of livelihood and employment, the inheritance and succession of paddy land significantly influence a family's choice to continue the tradition of heirloom farming. Prevailing land succession policies and the regulatory framework involve specific policies to deal with subdivision units for lands, land fragmentation, land sales, etc. The emphasis is tilted to ensure food security and economic development, but it is also vital to recognize and address any associated costs that arise from these policies. These can arise from various challenges that hinder agricultural land's productive use, perpetuate inequality, and impede sustainable development. Neglecting these issues, including landlessness, gender disparities, and complexities in land ownership resulting from informal land transactions, can have profound and interconnected implications. To better understand the successor characteristics affecting the choice of family farm succession decision of the current operator for paddy lands in Sri Lanka, a study was conducted on the succession of agricultural lands under the LDO.

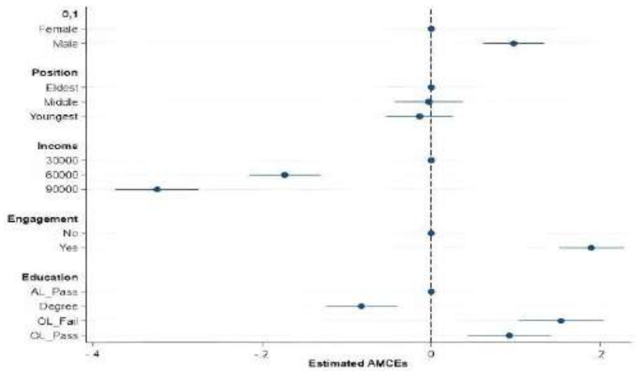

Figure 2: Change of Probabilities for being selected as the successor.

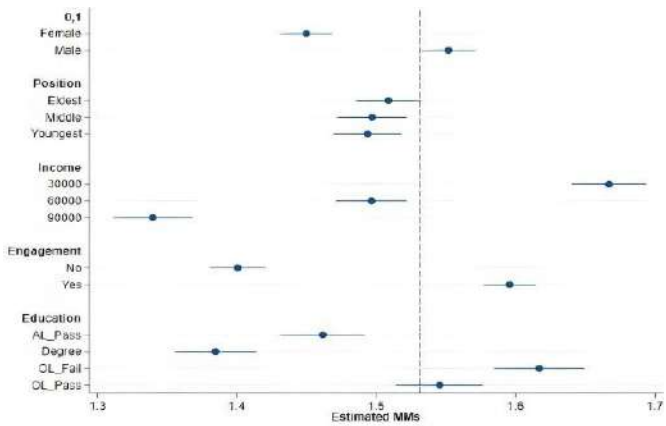

Figure 3: Marginal means

The findings (Figures 2 and 3) suggest that a child's gender, birth order, level of education, income, and involvement in paddy farming influence the decision of the landowner/operator to select a particular child as a successor. Addressing gender disparities in land ownership and inheritance rights is crucial. Awareness campaigns, capacity-building initiatives, and sound policymaking should address cultural and social barriers restricting women's access to land. Women should be educated about their land rights, legal entitlements, grievance redress channels, and options for seeking justice. Encouraging women's participation in decision-making processes through agricultural activities, leadership in farming associations, and representation in land committees is essential. Joint ownership and registration of land titles in both spouses' names should be facilitated to ensure equal rights and land access for women.

References

Bandara, M. (1985). Catchment ecosystems and village tank cascades in the dry zone of Sri Lanka a time- tested system of land and water resource management. In Strategies for river basin management, Springer, Dordrecht. 99-113.

Bugri, J. T. (2008). The dynamics of tenure security, agricultural production, and environmental degradation in Africa: Evidence from stakeholders in North-East Ghana. *Land Use Policy, 25*(2), 271-285.

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POLICY BRIEF

Resilience to Threats: Case of Ulagalla Cascade

Key messages

The following recommendations are key to address challenges faced by the Village Tank Cascade System (VTCS) in relation to natural disasters and wildlife threats.

- Recognize the positive association between the quality of cascade infrastructure and productivity, particularly in the upstream. Invest in improving infrastructure in the upstream areas to enhance productivity and resilience to natural hazards.
- Ensure that safety nets for farmers are equitable across the entire cascade system, regardless of whether the location is upstream or downstream. This includes providing adequate support and assistance to farmers affected by natural hazards.
- Special attention should be focused on the upstream areas of the cascade system due to increased wildlife threats. Develop specific insurance schemes and measures to protect against wildlife damage in these areas.
- Establish and maintain adequate wildlife food buffers in the upstream areas to reduce wildlife threats extending downstream. This can help mitigate conflicts between agriculture and wildlife.

Description of the Problem

Policy interventions always attempt to provide sustainable solutions to natural hazards (wildlife threats). Yet, such policies fail to understand the important trade-offs presented in the case of village tank cascade systems. In the context of Ulagalla VTCS in Anuradhapura district, exposure and resilience to threats have become a priory concern not only on account of cascade ecology but also due to rapid landscape transformation brought about by urbanization around the A-class highway running across the cascade.

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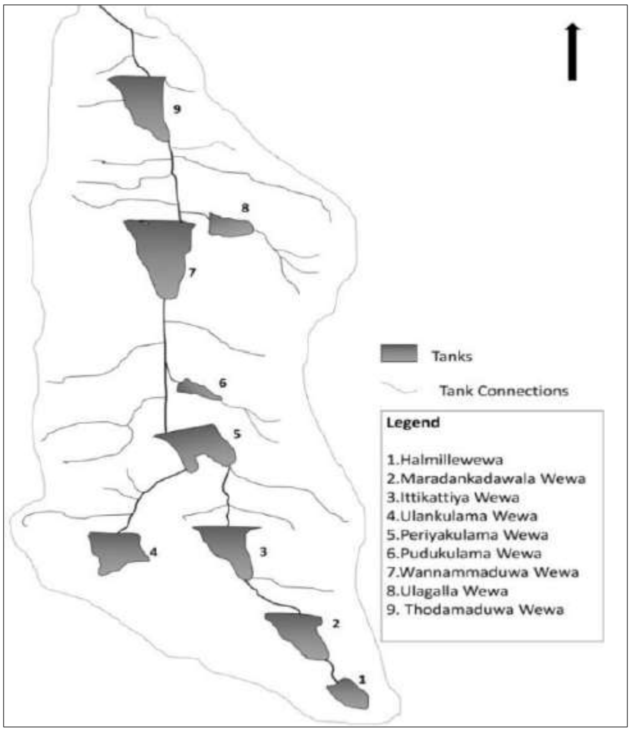

Figure 2: Ulagalla cascade (Recreated based on Sakthivadivel et al., 1994).

Research Approach to Studying the Resilience of Agricultural Production in a VTCS

The study adopts a production function approach, controlling for various possible threats that could have an impact on agricultural output. Potential factors that could moderate such impacts are included in the model to remove biases that could arise from ignoring a detailed institutional setting of production. The production function that conceptualized thus is fitted in a linear model of factors affecting productivity of farmers in the Ulagalla cascade and the partial impact of natural disasters and wildlife threat (mainly elephant encroachment on tanks and command areas) are obtained. The analysis is carried out separately for each season and each section of the cascade (i.e. upstream and downstream).

Methodology

Site selection

The selected site for the study is the Ulagalla tank cascade system located in Thirappane and Kekirawa Divisional Secretariats, Sri Lanka, adjacent to Thirappane and Mahakanumulla tank cascades. Ulagalla tank cascade is categorized as a large, long & straight, broad & wavy, undulating cascade having valleys at head and middle with moderately sloping axis (Sakthivadivel et al., 1994). The cascade covers 19 completely rain-fed tanks. Of these, only nine tanks are functioning as irrigation tanks at the moment.

Data collection

Both primary and secondary data were collected for the study through field surveys and household surveys. Field surveys were conducted to explore the research site. During the field surveys, tanks were identified for the study according to their current function. Then the water spread area, catchment area, command area, and homestead area under each selected tank were estimated. Spatial mapping was conducted to identify and compare the changes in land use patterns in the Ulagalla cascade. The 1:40 000 scaled imagery of water spread area, command area, feeding area and homestead area of each tank were obtained for the sampling plan.

A household survey was carried out from February to March 2020, covering 25% of farmer households that are registered under the Farmer Organizations in Ulagalla cascade. Accordingly, randomly selected 170 individuals were interviewed using a pretested, structured questionnaire. Secondary data such as farmer registration lists, farmer organization registration list, and fertilizer subsidy registration list were collected from Divisional Secretariats, Agrarian Service Centres, and Grama Seva Officers.

Empirical analysis

The upstream and the downstream productivities and determinants were enumerated for Yala 2019, Maha 2019/2020 and Maha 2020/21 seasons. The upstream and downstream tanks were analyzed separately in order to identify the variations of water productivity in paddy between the upstream- downstream and Yala - Maha. The boundary of the upstream and the downstream of the cascade were demarcated at the point where the cumulated water surface areas of the upstream and downstream tanks were approximately equal. The empirical model estimated included the following variables: Field level water productivity in paddy, farm size, fertilizer input, degree of wildlife conflict, previous hazard losses, farmer organization support, adaptation of water conservative methods, availability of agro wells, cascade parameters such as water head and command area, lining in the field canal, length of the field canal. degree of human-wildlife conflicts was enumerated on a scale (1-very low, 2- low, 3- moderate, 4- high, 5-very high). The index for previous hazard losses took into account the frequency of occurrence of the crop losses due to natural disasters and the stated rupee value of the crop losses. The level of farmer organization support included a ranking of the services of the famer organizations such as maintenance of tank parts, distribution of water, distribution of fertilizer subsidy and decision making on the cultivation process on a Likert scale (1-very low, 2- low, - moderate, 4- good, 5- very good).

Table 1: Descriptive analysis of the variables for 2019- Yala and 2019/2020- Maha

Variable	Upstream		Downstream	
	***Yala* season** Mean (Sd)	***Maha* season** Mean (Sd)	***Yala* Season** Mean (Sd)	***Maha* Season** Mean (Sd)
Degree of wildlife threat	2.11 (1.19)	2.58 (1.14)	4.32 (1.33)	3.14 (0.98)
Index for losses due to natural disasters	3.14 (1.21)	4.03 (1.43)	4.51 (2.12)	4.63 (1.98)
Index for farmer organization support	3.38 (1.18)	2.81 (1.02)	2.92 (3.32)	1.94 (1.52)
water conservative methods (1-yes; 0-no)	0.61 (1.22)	0.11 (1.03)	0.43 (0.12)	0.18 (0.14)
Water head (m)	1.91 (0.78)	2.39 (1.89)	1.42 (1.27)	2.19 (3.40)
Command area (ha)	24.42 (17.12)	50.59 (32.18)	14.57 (6.7)	48.52 (34.06)
Index for condition of the field canal	2.08 (2.42)	1.48 (1.28)	2.11 (1.11)	1.67 (2.56)
Length of the field canal (km)	0.41 (0.07)	0.72 (0.21)	0.35 (0.42)	0.81 (1.04)

Key Findings of the Analysis

In this policy brief, we adopt a statistical model to associate the degree of hazard risks and conditions of the cascade infrastructure to the productivity of the cascade. In the first part of the findings, the central tendency and the variability of resilience parameters are benchmarked (Table 1). In the second part of the findings, the study outlines the estimated partial impacts of resilience on productivity (Table 2).

Findings (part 1: Table 1): Parameters of resilience

Wildlife threat is prominent downstream compared to upstream. Seasonal differences exist but not as prominently as the contrast between downstream and upstream. Similarly, natural hazard related losses are more pronounced downstream. Adaptation parameters are not season-specific or location- specific but the variable capturing farmer organizational support shows a slight bias towards upstream (i.e., higher index in upstream context). The exposure is higher in the downstream, but the readiness is not particularly evident in the downstream.

Findings (part 2: table 2): Determinants of resilience

Table 2. Partial impacts of determinants of productivity for upstream and downstream by season

Variable	Upstream		Downstream	
	***Yala* season**	***Maha* season**	***Yala* season**	***Maha* season**
	Coefficient	Coefficient	Coefficient	Coefficient
Degree of human-wildlife conflicts	**-0.013****	**-0.044****	**-0.004****	-0.011
Index for crop losses due to natural disasters	**-0.001****	-0.019	**-0.013****	-0.073*
Index for farmer organization support	**0.018****	0.010**	0.004*	0.004*
Practice of water conservation (1- yes, 0-No)	0.081	0.100	0.103	0.014
Water head (m)	**0.002****	**0.011****	**0.001****	**0.001****
Command area (ha)	**0.004****	**0.005****	0.001**	0.010*
Index for condition of field canal	**0.063****	**0.006****	0.003*	0.007**
Length of the field canal (m)	-0.070*	-0.017*	**-0.007****	-0.006*
R^2	0.633	0.717	0.698	0.499
N	84	84	86	86

** Significant at 95% confidence level * Significant at 90% confidence level

The estimated model clearly outlines a trade-off between the natural disaster threats under focus and the quality of the cascade infrastructure. In particular, the hazard losses and wildlife impact are negatively associated to productivity while the quality of cascade infrastructure and farmer organization support are positively correlated. The partial coefficient points towards almost equal magnitude opposite effects for the two categories of determinants. While both the natural threats are critical in the dry season, the quality of cascade infrastructure and organizational support are invariant to the season in its impact towards productivity. The evidence from the model carries policy implications on the type of support that can potentially help cascade to recover from natural hazards (including wildlife encroachments).

Policy Recommendations

- Natural hazards pose a threat to the VTCS irrespective of whether the location is upstream or downstream and therefore farmer safety nets should equally apply to all parts of the cascade.
- Wildlife threat is more pronounced at the upstream, necessitating special focus on the upstream of the cascade in terms of insurance against wildlife damage.
- Further, maintenance of adequate wildlife food buffers can also minimize future threats extending to the downstream.
- All cascade infrastructure parameters considered display a positive association with productivity, especially in the upstream. Thus, the tradeoff between the quality of the cascade infrastructure and the natural hazards can be harnessed in the upstream through a special policy focus towards upstream.

References

Kahathuduwa, K. K. P. N., & Prasada, D. V. P. (2022). Variation of Water Productivity in Paddy Cultivation Within a Tank Cascade: A Case Study in Ulagalla, Sri Lanka. Tropical Agricultural Research, 33(3).

Sakthivadivel, R., Panabokke, C. R., Fernando, N., & Wijayaratna, C. M. (1994). Guidance package for water development component of small tank cascade systems. CGIAR working paper.

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Local Food Security

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POLICY BRIEF

Sustainable Utilization of Food Environments in VTCS for Local Food Security

Key messages

To effectively utilize VTCS for enhancing community nutrition while ensuring the sustainability of the system, it is important to consider the following recommendations.

- Establish a cascade management system/committee for the entire cascade, including village-level sub-committees and representatives, with assigned responsibilities.
- Formalize the management of different components of the VTCS to facilitate residents' easy access to extract food resources and prevent exploitation.
- Harvest food resources and sell them locally. Extraction of tank-based resources could be associated with fisheries societies. The women from fishing families could be mobilized for this task.
- Mobilize local farmer organizations to supply local produce to nearby retail shops.
- Organize awareness programmes to educate residents about the biodiversity and crop/food diversity in the VTCSs.
- Promote crop diversification and home gardens, and reward well-managed home gardens.

Can VTCS Provide a Solution for Poor Nutrition during Economic Crises?

With rising food prices, malnutrition and undernutrition are becoming a serious concern in Sri Lanka. At the national level, the percentage of underweight children under five years increased to 15.3 per cent in 2022 from 12.2 per cent in 2021. Both stunting and wasting among children under five years increased to 9.2 per cent and 10.1 per cent, respectively, in 2022, from 7.4 per cent and 8.2 per cent, respectively, recorded in 2021 (Family Health Bureau of Ministry of Health, 2022). The food security status of the country remained vulnerable at the end of 2022, with 68.0 per cent of the population adopting food based coping strategies by limiting portion sizes, reducing the

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number of meals, and relying on less preferred food (WFP, 2022).

While income and behavioral factors are important determinants of food choice, the food environment also plays an important role in the choice of food of an individual. The VTCS are not just hydraulic systems, but they are also a part of a food production system, a food landscape, livelihood, and lifestyle of the inhabitants. Therefore, in VTCS, we could identify all the typologies of a food environment in an interconnected system viz. a wild food environment, cultivated food environment and built-in food environment. This diversity adds to the rich diversity of food available within the system if capitalized properly would add to the diet quality and dietary diversity of the residents and hence improve their nutrition at a low cost. However, VTCS are rarely seen with a systemic view with these interconnections considered and hence are underutilized as food production systems. Therefore, it is important to study the food environment for its ability to improve the diets of the residents while ensuring the sustainability of the system.

Research Overview

The cultivated food environment in VTCS mainly comprises of paddy fields, chena and home gardens. The cascade components such as gasgommana, kattakaduwa, wew ismatta, wew thawulla make the wild food environment. Food environment typology identified in a VTCS, and their interconnections are shown in Figure 1.

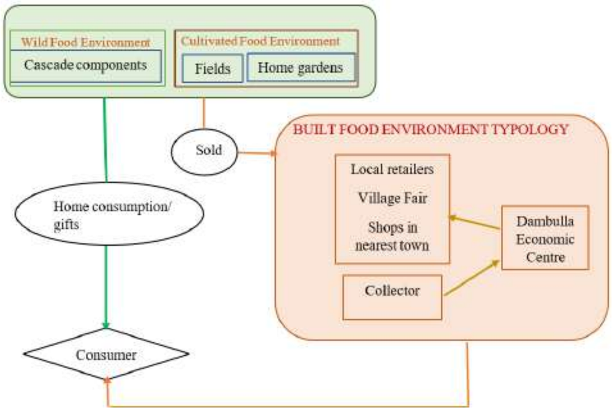

Figure 1: Natural food environment and Built food environment typologies in Mahakanumulla VTCS.

(Source: Adapted from Nayanathara and Hemachandra, 2021)

The food diversity in VTCS is very high. The plant species growing naturally in the VTCS perform important roles for the functioning and sustaining of the VTCS and are good sources of food. However, the residents are not much knowledgeable about the foods naturally available in the wild food environment of VTCS (Nayanathara and Hemachandra, 2021). A majority of the VTCS resident population is engaged in agriculture and almost all of them are engaged in paddy cultivation. There are also farmers engaged in *chena* cultivation in which maize, chili, upland, rice, okra, brinjal, pumpkin, *kekiri* etc. are grown. Mostly, low-country vegetables are cultivated in the area. Paddy, though the most prominent crop cultivated, is mainly for subsistence and Other Field Crops, fruits and vegetables are mostly produced for the market. Relatively fewer farmers are engaged in livestock, animal husbandry and fisheries though the tank system provides them with a suitable environment.

Kattakaduwa and wew thawulla/ wew ismatta provide leafy vegetables such as *kohila, mugunuwenna, thorakola, gotukola* and varieties of mushrooms. *Gasgommana* provides fruits such as woodappple, *palu, weera, kon, damba*, tamarind etc. most of which are underutilized fruit crops high in antioxidants. Home gardens also play a significant role in providing VTCS households with fruits, coconut, jackfruit, breadfruit etc. Among the cascade components, tanks contribute the most as a food source, especially fish. The highest frequency of extraction of food in a week is from the tank and the items obtained the most are fish, *olu-ala*, *olu-dandu* and the green leaves from the tank-bed (Figure 2). *Kattakaduwa*, stream-sides, forest and the neighbourhood lands are used as the sources of green leaves and produce such as cassava are also obtained from the neighbourhood lands. Other than supplying fish, the tanks and other VTCS components are not popular sources of food among the residents. The availability of local produce in the local retail shops is perceived to be low (Nayanathara and Hemachandra, 2021).

Research evidence in developing country contexts shows a positive relationship between production diversity and dietary diversity. Research conducted in Mahakanumulla VTCS using 24-hour diet recall in both Yala and Maha seasons provides supporting evidence that farming households with higher production diversity show higher dietary diversity. This applies to irrigation water is managed by farmer organizations under the Agrarian Development Department in small tanks and by the water board under the Department of Irrigation in medium to large tanks. Such an arrangement is far from scientific and will lead to system imbalance. This centralization of governance into a government bureaucracy and irrigation efficiency-based decisions taken mainly by

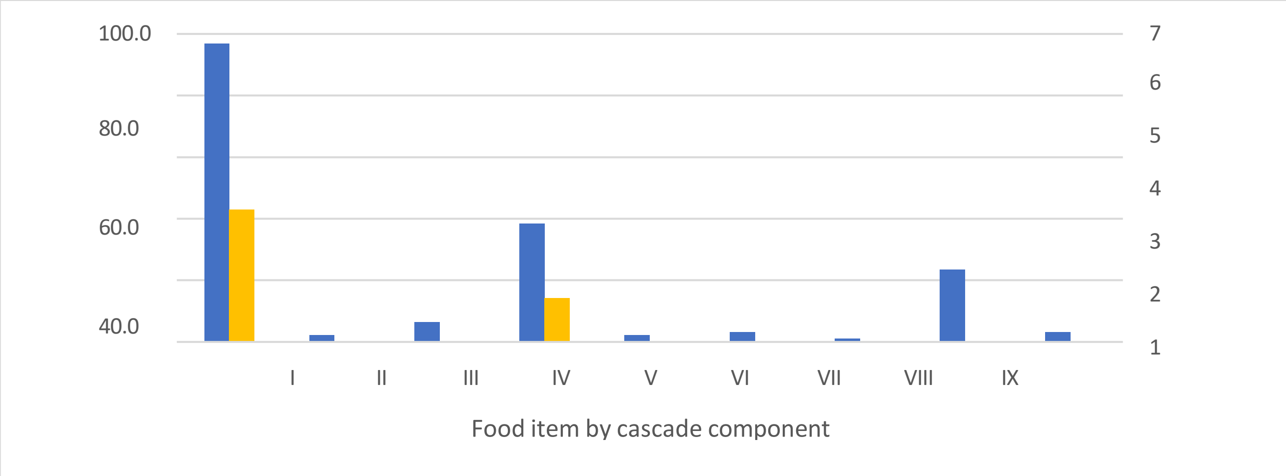

Figure 2: Percentage of households and the mean number of days households extracted food from cascade components in a week.

both field cultivations and home gardens as well. Overall research evidence suggests the possibility of improving the nutritional status of rural households in VTCS via production diversity-induced dietary diversity (Nayanathara and Hemachandra, 2024).

Current & Proposed Policies for Managing Cascades

VTCS are not managed as a system at present. Individual tanks are managed locally by farmer organizations under the authority of the Department of Agrarian Department. Important decisions are taken concerning when and how much tank water will be released for paddy cultivation in each season and required canal cleaning and land preparations before the onset of monsoonal rains i.e. basically to prepare an irrigation calendar. Other system components and interactions between them are overlooked. VCTS is seen mainly as a water storage facility for paddy cultivation. In addition, fishing and lotus flower plucking are monitored by farmer organizations with the authority of the Department of Agrarian Development. Presently, administrative officers rather than local experts limited the system view and thinking essential for managing VTCS sustainably.

There are many studies (research and development projects) carried out in VTCS in Sri Lanka. VTCS are mostly studies with the objective of water resource management or as a climate change adaptation strategy in climate change or ecology literature. Studies are scant on VTCS as an ecological and social economical systems. Therefore, most recommendations of these studies are based on efficient water resource management or ecological conservation and rarely on the management of overall VTCS i.e. not only the tanks and canals but also the other system components. The centralized governance and management of VTCS as irrigation entities rather than social-ecological systems has led to the deterioration and degradation of social, cultural, and environmental norms and values that contributed to the continuation of VTCS over the years.

Sri Lanka's National Climate Adaptation Strategy 2016 recognizes the importance of developing VTCS to minimize future food security risks posed by climate change (Climate Change Secretariat, 2016a). Diets can be improved by increasing the income of the people. Income from farming could be improved if crop specialization is practiced. However, for the sustainability of VTCS, it is essential to have a balance between the economy and the environment. Therefore, input-intensive specialized commercial agriculture is not suitable for VTCS. If to retain the characteristics and benefits of a VTCS while addressing the socio-economic and ecological needs of the residents, the VCTS must be managed using a different model.

Some projects on tank rehabilitation and cascade restoration have recommended a cascade management committee (may with slightly different names) to be formed for sustainable management of the cascade (Kekulandala, et al. 2021). However, they have not been implemented so far. Agrarian Development Act No. 46 also has given legal provision for organization of farmers beyond the village-level farmer organizations to District, Provincial and National level Federations. However, such has not been materialized yet. Further, these Federations are defined based on administrative boundaries. VTCSs are spread over several villages, DS Divisions and sometimes Districts. Therefore, organizing a local management body should not be based on administrative boundaries but rather based on cascade boundaries. Further, crop diversification for VCTS is recommended by many researchers. If production and consumption are non-separable as research evidence suggests, diets could be improved with diversified agricultural activity. A VTCS management committee could audit the system resource availability for improved diets and take decisions to improve and manage those resources for the long-term sustainability of the system.

Policy Recommendations

Malnutrition and undernutrition are looming serious concerns in Sri Lanka during economic crises. VTCSs are multifunctional ecological systems with underutilized resources that could be utilized to enhance the diets of the local people. The common resources in the VTCS are rich sources of diverse food crops. While promoting the utilization of these resources for enhanced diets, care must be taken not to allow overutilization or exhaustion of resources while ensuring a fair allocation. A management committee comprising of local people in each VTCS in Sri Lanka will be able to take an audit of the resources, service flow and replenishing time and therefore provide more benefits to the local community while ensuring the sustainability of the VTCS. The committee should be patronaged by relevant government officers with a systemic view of the cascade or subject experts not solely based on their administrative roles. Management interventions must map, understand, and respond to this complexity through various institutional and governance mechanisms. Further, crop diversification should be the strategy with reduced focus on paddy cultivation. Well diversified and managed home gardens, uplands, and lowlands in *Yala* season and common cascade areas while contributing to the dietary diversity could ensure the sustainability of the VTCS in Sri Lanka.

References

Climate Change Secretariat. (2016a). National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025.

Family Health Bureau of Ministry of Health. (2022).

Kekulandala, B., Jacobs, B., & Cunningham, R. (2021). Management of small irrigation tank cascade systems (STCS) in Sri Lanka: past, present and future. Climate and Development, 13(4), 337–347.

Nayanathara, N. & Hemachandra D. (2024) Production and Dietary Diversities with Seasonality in Rural Agricultural Context in Sri Lanka: A Case of Mahakanumulla Village Tank Cascade System. Tropical Agricultural Research, 34(3), Forthcoming.

Nayanathara, N., & Hemachandra, D. (2021). An Assessment of the Food environment in the Mahakanumulla Village Tank Cascade System. Conference on Cascade Ecology & Management – 2021. Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka, 17th & 18th September 2021, pp. 104-107.

World Food Programme. (2022).

Citation

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POLICY BRIEF

Food and Nutrition Policy for Nutrition-Sensitive Healthy Landscapes

Key messages

Nutrition-sensitive healthy landscapes in Sri Lanka's dry zone play a vital role in community well-being by supporting sustainable food systems and addressing malnutrition. The outlined Food and Nutrition Policy emphasizes the importance of integrating traditional water management systems into efforts to enhance food security and promote sustainable agriculture within these landscapes.

- Advocate policy and lawmakers (Department of Agriculture, Environment, Forestry, etc.) for implementing interventions that promote biodiversity conservation and sustainable use practices.
- Implement policies to transition farming communities from current monocropping to diversified agriculture systems to enhance sustainability and resilience.
- Develop policies focused on the restoration and conservation of the tank and its components giving special emphasis on food resources.
- Establish policies to improve crop yields and assist management decisions using technology sensors and analysis tools.
- Implement policies to develop and strengthen local food supply chains to improve access to fresh, nutritious produce.
- Support policies that promote income-generating activities that contribute to improved nutrition outcomes among farming communities.
- Promote traditional and indigenous knowledge in their food production systems.
- Develop policies that provide financial support and incentives for farmers adopting nutrition-sensitive practices.
- Allocate resources and establish policies to promote investment in research and innovation to develop new technologies and approaches that enhance the nutritional value of food.

The Challenge

Although high numbers for agricultural production have been reported and it is suggested that the state of global nutrition and food security is still fragile. Malnutrition and undernutrition are still major concerns, with overall declines in global crop diversity adding to this predicament. Nutritionally inadequate diets, particularly those lacking in fruits, vegetables (F&V), pulses, and animal-based foods, stand as the primary contributor to malnutrition on a global scale. Dietary factors rank as the fourth leading cause of overall mortality and morbidity in Sri Lanka. Compounded by an economic crisis, evidenced by a staggering 95% food inflation rate in 2022, many Sri Lankans now struggle to afford nutritious meals, resulting in a national food

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ins999ecurity rate of 32% [WFP. 2022]. This scenario has undoubtedly exacerbated the prevailing dietary and nutritional issues in Sri Lanka.

Nutritional Status in Sri Lanka

Sri Lanka grapples with a triple burden of malnutrition, encompassing undernutrition, deficiencies in essential micronutrients (MN), and the rising prevalence of overweight, obesity, and non-communicable diseases (NCDs). Anemia and micronutrient deficiencies present notable health hurdles within the country. Anemia affects a significant proportion of the population, ranging from 8% to 19% across children, adolescents, women, and men, with variations observed based on specific age groups and physiological conditions [Jayatissa et al., 2023].

Deficiencies in essential MN like vitamin D, vitamin B12, and zinc represent notable health concerns in Sri Lanka [Jayatissa et al., 2023]. The prevalence of vitamin D deficiency ranges from 13% to 36% among Sri Lankans, with pregnant women being particularly vulnerable, showing the highest rates of deficiency in both vitamin D and vitamin B12, critical for maternal and fetal well-being. Additionally, over a quarter of adolescents aged 10 to 18 suffer from zinc deficiency, a vital nutrient essential for their growth and overall development.

Moreover, a considerable challenge confronts the adult population, with more than one-third being overweight or obese, a prevalence notably 10 percentage points higher among females than males. In Sri Lanka, approximately one third of children under the age of 5 are affected by malnutrition. Overall, 19.2% were stunted, 11.8% wasted, 21.6% underweight, and 1.7% overweight [DCS, 2017]. Both the prevalence of stunting and overweight/obesity in this age group are lower than the South Asia regional averages of 30.7% and 2.5%, respectively. On the contrary, the prevalence of wasting has risen to 20%, surpassing the regional average of 14.1%.

Non-communicable Diseases (NCDs)

NCDs, including those linked to dietary factors, make up 83% of all fatalities in Sri Lanka. Since 2009, there has been a 29.1% rise in mortality due to diabetes and a 15.6% increase in mortality due to heart disease. Nearly 30% of adults have been diagnosed with high blood pressure, and approximately a quarter are affected by diabetes [Institute for Health Metrics and Evaluation, 2019].

Diets in Sri Lanka

In Sri Lanka, diets predominantly revolve around cereals, primarily rice and wheat, which are commonly accompanied by limited servings of vegetables, meat, or fish cooked in curries. A crucial aspect to note about the Sri Lankan diet is that although certain foods like vegetables or fish may be consumed regularly, individuals often fall short of consuming adequate quantities of these items. For instance, only 27.5% of adults adhere to the World Health Organization's (WHO) recommendation of consuming at least 400 grams per person per day.

Food Supply

Part of the challenge for achieving a more diverse and nutritionally adequate diet in Sri Lanka may be in part due to an insufficient supply of various foods (Figure 1).

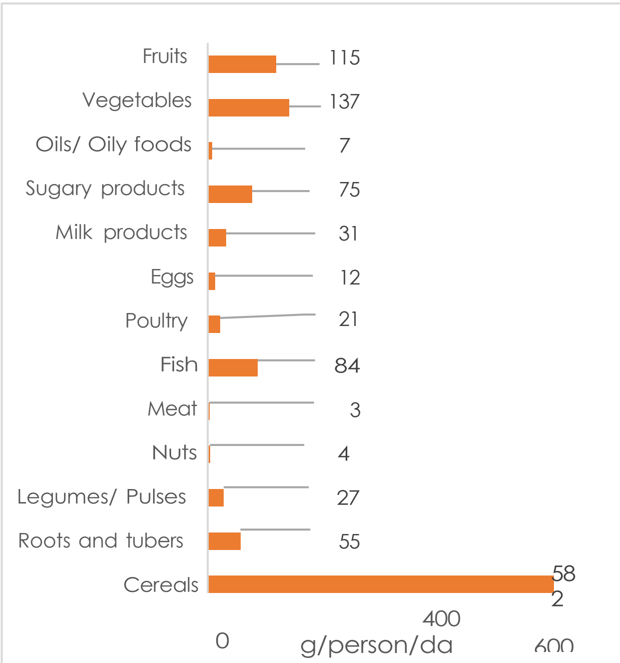

Figure 1: Average per capita supply of foods in Sri Lanka (grams/ person/ day) [Source: ourworldindata.org]

Apart from cereals, there is a glaring inadequacy in the availability of nutrient-rich foods such as meat, poultry, legumes/pulses, nuts, fruits, and vegetables. A clear indication of this deficiency is the total daily supply of fruits and vegetables, which amounts to only 252 grams per person per day, significantly below the WHO's recommendation.

Food and Nutrient Intake

Sri Lankan diet's scarcity of nutrient-rich foods results in notable gaps in nutrient consumption. While caloric deficiency remains a concern, median intakes of proteins and dietary fiber are sufficient. Conversely, median intakes of most vitamins and minerals fall short and vary across age groups, with adolescents and adults facing greater inadequacies compared to children.

Acknowledging the imbalanced nature of the Sri Lankan diet and its significant contribution to the prevalence of diet related NCDs, the country has implemented various national guidelines, programs, and policies. These initiatives aim to redefine dietary patterns and enhance nutritional and health outcomes throughout the life cycle of Sri Lankans.

Food Security

Based on data prior to the Covid-19 pandemic, Sri Lanka was ranked 66th among 113 countries in the Global Food Security Index (GFSI)-2019, which considers the dimensions of food availability, affordability, quality, and safety of foods. An estimated 17 percent of its 22 million population is food-insecure, indicating an improvement from 2022 when 28 percent of households were noted as food-insecure. A quarter of the population is now estimated to live below the poverty line, which compromises their ability to access sufficient, nutritious food.

Sri Lanka's nutrition policy framework is comprehensive, encompassing various policies, strategic plans, program implementations, and operational guidelines. The Food Based Dietary Guidelines (FBDGs) for Sri Lankans have been formulated to offer advice on the components of a healthy diet, aiming to mitigate the incidence of diet related NCDs. The guidelines address the needs of all age groups and across different life stages.

The recently updated National Nutrition Policy (NNP) 2021-2030 for Sri Lanka outlines strategic directions crucial for ensuring food and nutrition security. These

directions include enhancing the availability and accessibility of healthy foods through nutrition-sensitive food value chains, implementing financial strategies to promote healthy food behaviors, and mobilizing communities for dietary diversification. However, despite these advancements, these strategies have not yet been translated into actionable interventions.

The Multi-Sector Action Plan for Nutrition 2018-2025 is a comprehensive strategy developed to address malnutrition and its underlying causes across multiple sectors, including agriculture, health, education, and social welfare. The plan aims to improve nutritional outcomes by integrating nutrition-sensitive approaches into various sectors' policies, programs, and actions.

Cascaded Tank-Village System in the Dry Zone

A Sri Lankan agrarian system, the “ellanga gammana” or Village Tank Cascade System (VTCS) in the Dry Zone, was designated as a Globally Important Agricultural Heritage System (GIAHS) by the Food and Agriculture Organization of the United Nations (FAO). The village tanks host a significant agro-biodiversity and wild biodiversity and constitute a unique buffer against natural disasters and climate change. The VTCS also contributes to efficient water management with water from one tank flowing to another, through a network of tanks and streams. Four distinctive zones identified in a VTCS [18] provide a variety of foods to the community (Figure 1). Each zone had one or several components of ecological significance (Fig. 2). However, the continuation of the VTCS is threatened by the poor income of farmers, rural-urban migration of the youth, deforestation, and the degradation of the tank eco-system.

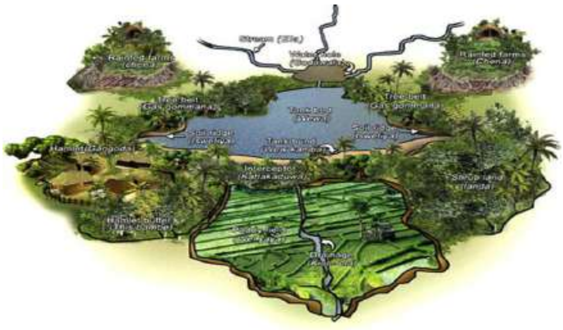

Figure 2. Components and their relative positions in the small tank system in Sri Lanka [Geekiyanage & Pushpakumara, 2013].

Nutrition-sensitive landscapes such as VTCS recognize the interconnectedness of agriculture, environment, and nutrition. Such landscape strategies strengthen food security and nutrition by helping vulnerable communities build socially, ecologically, and economically resilient communities. Although ecological and agricultural importance was investigated, the impact of this system on human nutrition and health as well as food security hasn't been thoroughly evaluated. This policy brief aims to integrate nutrition considerations into VTCS landscape planning and management, promoting the production and consumption of diverse, nutritious foods that enhance the overall health and well-being of communities in Sri Lanka.

Rationale

Case Study

Assessment of nutrition, food security and health in Horiwila and Thirappane Village Tank Cascade System (VTCS) [Silva et al., 2021]

A baseline assessment on nutritional status, food security and health was carried out in Horiwila and Thirappane Village Tank Cascade System (VTCS) under the UNEP-GEF funded 'Healthy Landscapes: Managing Agricultural Landscapes in Socio-Ecologically Sensitive Areas to Promote Food Security, Wellbeing and Ecosystem Health'. The objectives of the study were: (1) to assess human health, food security, nutrition issues, wellbeing, and impacts; (2) to characterize and / healthy foods; (3) to find out information gaps in relation to nutrition and health and constraints to healthy food consumption; (4) to assess the impact of the Covid19 pandemic. Qualitative and quantitative data were collected from 100 participants from villages situated in two cascade complexes in January 2021.

Key findings:

- The participants of the study had an overall nutritionally inadequate diet, especially low in calories and deficient in almost all micronutrients. They consumed relatively low amounts and frequency of fruits and animal sources of foods.
- The variety of foods consumed was not satisfactory. On average, only 6-7 food groups out of 12 food groups and around 9 individual food items were consumed by the participants on a normal day.
- Household food insecurity in the study population was 43%, which shows lesser access to nutritious and desired foods by the households.
- Undernutrition as well as overnutrition, especially central obesity was prominent in the study population. This shows the consequences of an imbalanced diet. Also, we speculate that this population may have some other lifestyle factors or genetic predisposition to obesity, which may have a root in their childhood nutrition.
- High prevalence of non-communicable diseases and psychological distress was found in the study population.
- The participants perceived that they have a food system which has the potential to provide nutritious and healthy foods and food security, but they admitted that the system is not utilized optimally due to socio-economic reasons (low income, lack of food literacy, nutrition transition and issues related to their agricultural practices). Although the food system in the village tank cascade system is highly vulnerable with current socioeconomic and nutrition transition in these rural communities, the food and ecosystem still show potential of building resilience at the farm/household level.

Health and Well-being: Linking food production with nutrition enhances the health outcomes of communities.

The integration of nutrition considerations into VTCS landscape planning and management is imperative for enhancing the health outcomes of communities. By promoting the production and consumption of diverse, nutritious foods, we can address malnutrition and diet related NCDs effectively. Nutrient-rich foods such as fruits, vegetables including green leafy vegetables, roots, cereals and grains, pulses and tank fish are abundant in this system (Table 1). Therefore, embedding nutrition considerations in VTCS landscape planning ensures the availability, accessibility, and affordability of healthy foods, ultimately benefiting the health of the population.

Table 2 Sources of foods from different parts of the VTCS.

Sources	Food items
Below the tank bund	Fruits - *himbutu* Green leafy veg - *Mukunuwenna, gotukola, kankun, kara kola, lee kola*
From the tank	Tank fish – *theppili, lula, hunga, magura* Other foods - *Olu,* lotus stem, *kekatiya*
Paddy field	*Kiri handa kola, thal kola, monara kudumbiya*
Village forest	Green leafy vegetables - *Kowakka, anguna kola* *elabatu*, Bitter gourd, *thumba karawila, gon karapincha, paaliya, damba, wal batu, nelum batu, karamba, palu, weera, eraminiya, kothala himbutu, gal siyambala*, tamarind, Ceylon olives, *Nelli, Kon*, wood apple
Home garden	Fruits - Sweet orange, guava, papaya, jack fruit, *ambarella*, pomegranate, mango, papaya, guava Root vegetables – *kiri ala*, cassava

Sustainability: Promoting sustainable agriculture practices contributes to long-term food security.

Sustainable agriculture practices are essential for long-term food security and environmental conservation. By integrating nutrition considerations into VTCS landscape planning, we can encourage the adoption of practices that enhance soil health, conserve water resources, and minimize the use of agrochemicals. Diverse cropping systems, agroforestry, and integrated pest management not only contribute to improved nutrition by diversifying food production but also promote ecosystem resilience and biodiversity conservation. Thus, incorporating nutrition into VTCS landscape planning ensures that this system is not only productive but also environmentally sustainable, safeguarding food security for future generations.

Economic Development: A healthy population is essential for economic productivity and growth.

Nutrition is intrinsically linked to economic development and productivity. Malnutrition, whether undernutrition or overnutrition, has significant economic consequences, including reduced productivity, increased healthcare costs, and diminished human capital development. By promoting the production and consumption of diverse, nutritious foods through VTCS landscape planning and management, we can mitigate the economic burden of malnutrition. Healthy individuals are more productive, have lower healthcare expenditures, and contribute positively to economic growth. Therefore, integrating nutrition considerations into VTCS landscape planning not only improves the health of communities but also fosters economic development and prosperity at village level as well as in the country as a whole.

Key Policy Recommendations:

1. Integrated Landscape Planning:

Institutional support towards conserving rich farms and off-farm biodiversity has not been provided. Despite the many laws in place, there is a lack of effective enforcement of the laws to protect and sustainably use biodiversity. Therefore, advocacy to the policy and lawmakers (Department of Agriculture, Environment, Forestry etc.) is needed for the biodiversity conservation and sustainable use interventions.

Policy 1: Advocacy to the policy and lawmakers (Department of Agriculture, Environment, Forestry etc.) for the biodiversity conservation and sustainable use interventions.

Strategies:

- ***Multi-Sectoral Collaboration:*** Foster collaboration between agriculture, health, and environment sectors to develop comprehensive plans.
- ***Biodiversity Conservation:*** Encourage farming practices that enhance biodiversity, promoting the production of a variety of nutrient-rich foods.

2. Agricultural Practices:

The communities in VTCS are particularly exposed to climate change impacts on their agricultural production and livelihoods. Maintaining species and genetic diversity in fields provides a low-risk buffer in uncertain weather and the diversity in production landscapes is considered a necessity. Therefore, farmer awareness and provision of necessary technical and infrastructure support will help the farming communities to shift from the current monocropping unsustainable agriculture system to more diverse agriculture production.

The restoration and conservation of the tank and its components are very much essential to promote the benefits of the food system. Dynamic conservation relies on the active participation of all core stakeholder groups, in particular local communities in the traditional agricultural systems. Therefore, programs should be planned to conserve and restore the village tanks with the involvement of multi-stakeholders (including local communities).

Monitoring and evaluation of the progress and the effect of the implementation of the action plan should also be undertaken.

Precision farming is important for VTCSs as farmers spend a huge amount of money on inputs, especially fertilizer. Further, health concerns are also important, as farmers exposed to agrochemicals face high risks of cancer and kidney disorders. The unabated use of antibiotics in livestock rearing is a major cause for concern, although not yet proven to be directly linked to drug resistance. The consumers also have concerns regarding the safety of agricultural production. The environmentally sustainable advances in the productivity and profitability of the precise use of agricultural inputs in the production system and good agricultural practices (GAP) will help to generate both livelihoods and income. Therefore, it is recommended to provide farmers with the necessary awareness and inputs to enhance the popularity of precision farming of locally grown food.

Policy 2: Shifting farming communities from the current monocropping unsustainable agriculture system to more diverse agriculture production.

Policy 3: Restoration and conservation of the tank and its components giving special emphasis on food resources.

Policy 4: Improving crop yields and assisting management decisions using technology sensors and analysis tools.

Strategies:

- ***Diversification:*** Support farmers in diversifying their crops to include a range of fruits, vegetables, and nutrient-rich grains.
- ***Conserve and restore the village tanks*** with the involvement of multi-stakeholders (including local communities).
- ***Sustainable Farming:*** Promote sustainable and regenerative agriculture practices to maintain soil health and reduce environmental impact.

3. Food Systems and Value Chain:

Focusing on local food systems promotes the consumption of locally grown foods, which are often more nutritious and environmentally sustainable than imported or processed foods. Strengthening local food supply chains involves supporting small-scale farmers, improving transportation and distribution networks, establishing farmers' markets, promoting community-supported agriculture (CSA), and implementing policies that incentivize the production and consumption of nutritious foods within communities. This policy contributes to nutrition-sensitive agricultural systems by addressing issues of food access, availability, and quality, ultimately leading to improved dietary diversity and nutrition outcomes.

Policy 5: Develop and strengthen local food supply chains to improve access to fresh, nutritious produce.

Households with higher incomes generally have better access to nutritious foods and healthcare. Therefore, supporting income-generating activities, particularly for vulnerable populations such as smallholder farmers and women is necessary to improve their economic well-being and enable them to afford a diverse and nutritious diet. Income-generating activities may include training in agricultural practices, providing access to credit and financial services, promoting entrepreneurship, and creating employment opportunities in the agricultural sector. By increasing household income, this policy indirectly improves nutrition outcomes by empowering individuals and families to make healthier food choices, invest in healthcare, and access essential services related to nutrition and health. Thus, it contributes to building nutrition-sensitive agricultural systems by addressing the underlying socioeconomic factors that influence dietary patterns and nutritional status.

Policy 6: Support income-generating activities that contribute to improved nutrition.

4. Community Empowerment:

Reintroduction of indigenous food production practices will help restore food sovereignty to rural communities. Traditionally, these farming communities had enough cultivated and wild-sourced food available. However, the forces of globalization, ignorance of traditional farming and outmigration of village youths to urban areas, loss of traditional knowledge, loss of farm and natural diversity due to habitat degradation, urbanization, and climate change, etc., are negatively impacting indigenous food sovereignty efforts. Food sovereignty initiatives will empower traditional farming communities to grow and consume their own healthy food that would contribute to enhanced human health and wellbeing.

The need of a new knowledge base is being strongly felt for transition towards more sustainable agriculture. Farmers greatly value local experiential knowledge as they see it as having practical and local relevance. The potential of farmers' experiential knowledge, however, is not being optimally used and a better strategy to integrate various forms of knowledge is needed. Therefore, it is recommended to plan and implement programs which promote the traditional and indigenous knowledge in their food production systems.

Policy 7: Promote traditional and indigenous knowledge in their food production systems.

Strategies:

- Engage communities in decision-making processes related to agriculture and nutrition.
- Programmes should be carried out to build knowledge and understanding of native agriculture and food systems and help promote native communities' innovative ideas and best practices.
- Nutrition Education: Implement nutrition education programs to raise awareness about the importance of diverse diets and promote healthy eating.

2. Policy Incentives:

Financial incentives involve providing monetary support and rewards to farmers who adopt nutrition-sensitive practices in agriculture. These incentives can take various forms, such as subsidies, grants, tax incentives, or payments for ecosystem services. The aim is to encourage farmers to implement practices that promote the production of diverse, nutrient-rich foods, improve soil health, and enhance overall agricultural sustainability. By offering financial support, governments or organizations seek to offset the costs associated with transitioning to nutrition-sensitive agricultural systems, thereby making it more economically viable for farmers to adopt these practices. Financial incentives play a crucial role in incentivizing behavior change among farmers and promoting the adoption of practices that contribute to improved nutrition outcomes and food security for communities.

Policy 8: Provide financial support and incentives for farmers adopting nutrition-sensitive practices.

The traditional landraces differing in morphological characters have been effectively used by farmers as markers for taste, texture, cooking quality, resistance to biotic/abiotic stresses, etc., besides yield per se. Farmers are the sole custodians of the genetic wealth of the landraces they use. Conservation is especially important in the case of the disappearance of traditionally adapted crop varieties. Therefore, it is recommended to conduct research to mainstream indigenous knowledge in conserving and popularizing the traditional landraces that will result in implementing effective adaptation action on the ground.

Policy 9: Invest in research and innovation to develop new technologies and approaches that enhance the nutritional value of food.

Strategies:

- Provide incentives such as subsidies, grants, tax incentives, or payments for ecosystem services.
- Support research on crop varieties suitable for the dry zone's agro-ecological conditions.
- Encourage the adoption of innovative and sustainable agricultural practices.

Monitoring and Evaluation:

Data Collection: Establish a robust monitoring and evaluation system to track the impact of the policy on nutrition outcomes.

Adaptive Management: Use collected data to adapt and refine policy strategies based on ongoing evaluations.

References

Department of Census and Statistics (DCS)-(2017). Sri Lanka Demographic and Health Survey 2016. Sri Lanka.

Geekiyanage, N., & Pushpakumara, D. K. N. G. (2013). Ecology of ancient Tank Cascade Systems in island Sri Lanka. *Journal of Marine and Island Cultures, 2*(2), 93-101. https://doi.org/10.1016/j.imic.2013.11.001.

Institute for Health Metrics and Evaluation. (2019). Sri Lanka Country Profile. Retrieved from https://www.healthdata.org/research-analysis/health-by-location/profiles/sri-lanka.

Jayatissa, R., Perera, A., & De Alwis, N. (2023). National Nutrition and Micronutrient Survey in Sri Lanka: 2022. Department of Nutrition, Medical Research Institute in partnership with UNICEF and WFP.

Silva, K. D. R. R., Perera, O., Sitisekara, S. M. H. D., Madumali, K. A. C., Ratnayake, R. S. S., Chandrasekara, A., Dharmasena, P. B., & Hunter, D. (2021). Household Food Security, Dietary Intakes and Dietary Diversity of Adults Living in Cascaded Tank-Village System in the Dry Zone of Sri Lanka. *Conference on Cascade Ecology & Management – 2021*. Faculty of Agriculture, University of Peradeniya.

World Food Programme (WFP). (2022). Sri Lanka Food Security Monitoring. Retrieved from https://docs.wfp.org/api/documents/WFP-0000144142/download.

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