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Resilience thinking and strategies to reclaim sustainable rural livelihoods: Cascade Tank-Village System (CTVS) in Sri Lanka

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Abstract: Cascading Tank Village Systems (CTVSs) of Sri Lanka historically provided a resilient community-based social-ecological water management system in the rural dryzone of Sri Lanka [1]. The CTVS has been described as the 'lifeblood' of communities in the rural dry zone [2] and as a globally important Agricultural Heritage System by the UN Food and Agriculture Association (FAO) [3]. After being abandoned for many centuries, their restoration is now being pursued by different national and international actors as a key to climate change mitigation and sustainable livelihoods for communities [4]. Rural livelihoods in the dry zone are at risk due to multiple factors, poor access and management of water, economic and health pressures, as well as resource limitations and degradation [5]. Despite recent efforts to restore CTVS systems, no social-ecological approach (SES) nor sustainable livelihoods framework (SLF) focused approach to ensuring resilient and sustainable livelihood outcomes has been taken [6]. As part of an on-going PhD project, this paper analyses the background, current challenges and potential for an SES focused resilience thinking approach to CTVS for future sustainable livelihood opportunities and outcomes. The study finds CTVS exhibit all the properties of a complex adaptive SES and that a resilience thinking approach centered on achieving sustainable livelihood outcomes for communities suggests deep institutional changes. CTVS are at a crossroads between restoring the past (system adaptability) or transforming for the future, and a combination of legacy and future market orientation seems the best solution.

Keywords: cascading tank village system; sustainable livelihoods; resilience thinking; Sri Lanka; rural dry zone; community rural development

1. Introduction

Those who cannot remember the past are condemned to repeat it. (George Santayana)

The Casacading Tank Village Systems (CTVS) in Sri Lanka constitute one example of many indigenous approaches globally to ensuring water storage and livelihood options for communities [7]. Bandara [8], pioneered definition of the CTVS system as a connected series of tanks organized within a micro-catchment (meso-catchment) of the dry zone landscape (see figure 2 below), this traditional irrigation cascade system has become widely known and increasingly studied since the 1980s. Panabokke et.al. [2], notes that CTVS started as a small village settlement around small tanks, and eventually stretched over larger areas, as urbanization and the *Rajakariya* (see below) governance system and related investments developed. The previous networked governance system (*Rajakariya*) developed from a village collective use, monitoring and sanctioning system through to a more hierarchical system linking king, (buddhist) temples and, community governance. With abandonment of CTVs there was a return to village subsistence farming and abandonment in the rural dryzone. While restoration efforts cannot reproduce a historical past, current efforts should consider the past to learn what was successful. The current networked tank infrastructure around the dendritic pattern of this particular example of catchment landscape urbanism developed from an

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earlier phase of isolated tanks [9], 'some of which had nothing to do with irrigation per se but all of which had a critical role to play in the practice of irrigation agriculture' [10].

According to the latest statistics, there are currently about 30,000 CTVS built in a land area of 40,000 km2 in the rural dry zone. Specific CTV networks are embedded in and managed by a variety of ecological, socio-economic, and administrative subsystems. Bandara [10] categorised the key subsystems as, a) the ecological system with catchment forests, aquatic habitats, and the commons, b) land-use zoning systems, c) crop combination systems, d) water management systems including, sluices, spills, water control weirs (*Karahankota*) with rotational water distribution systems, and e) management systems, such as the *Velvidane* (Irrigation Headman) system that dates back to pre-colonial times. The multiple small and large reservoirs constituting flows through the overall stock of CTVS are interconnected and 'cascade' to one another to create an interconnected social-ecological management of rainfall, landscape and community livelihoods (see figure 1).

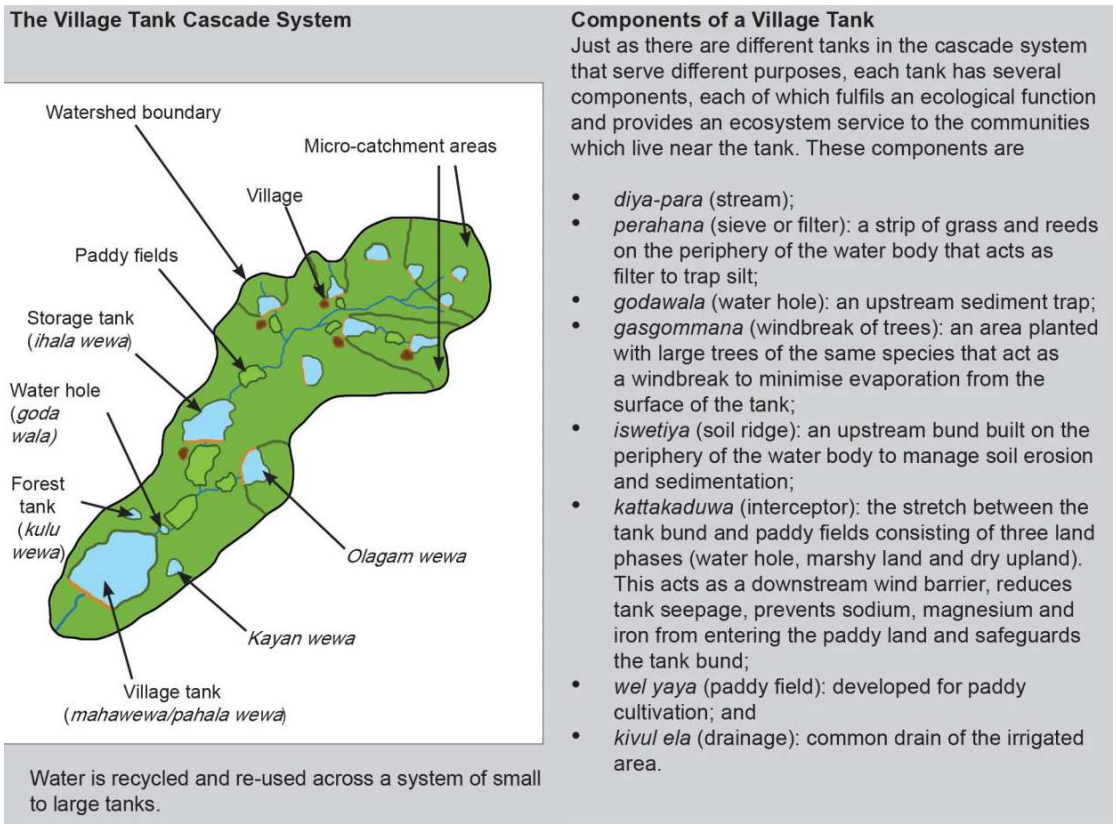

Figure 1. Components of a Village Tank; Source [4], p.3.

As can be seen by the diagram (Figure 2) the system is a modular integrated water storage and management system capable of sustaining resilient sustainable livelihoods during seasonal changes in precipitation and with capacity for livelihood diversification. It integrates multiple individual elements around the tank to achieve social and ecological balance.

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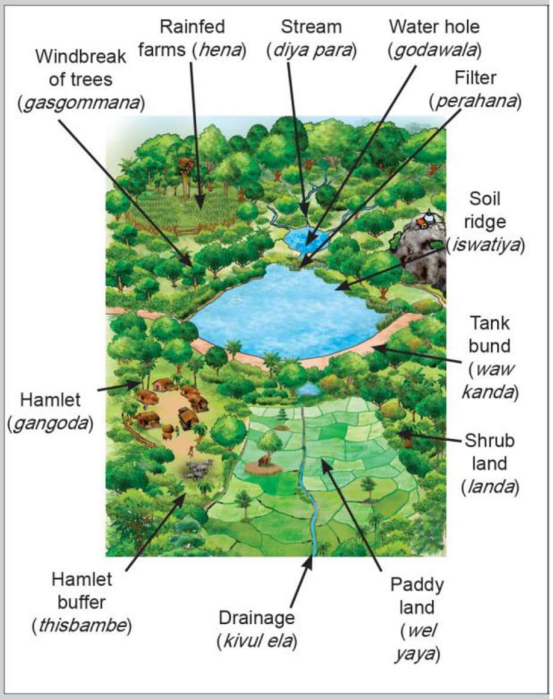
Traditionally, there is one village tank for the use of each village. In addition, there are also a number of other tanks with different purposes associated with village tanks:

- *kulu wewa** (forest tank), created in the upper catchment of the village tank in order to provide water for wild animals, filter debris and silt, and capture the rainwater that will enter into the village tank through seepage. By providing water for wild animals, these forest tanks reduce the likelihood of these animals damaging crops while searching for water near the village;
- *kayan wewa*, built where the upper catchment has been cleared or degraded. It is used to trap sediment and control salinity;
- *olagam wewa*, which lies close to the village, but is not associated with a permanent settlement or cultivation. It is used a source of water for seasonal cultivation;
- *goda wala* (water hole): constructed for the trapping and deposition of silt, to avoid siltation and sedimentation of the main village tank;
- *ihala wewa* (storage tank): constructed for the storage of water, and associated with paddy cultivation and other community activities; and
- *maha wewa/pahala wewa* (village tank): the main component of the cascade system. Water from all other tanks in the system drain into this tank, which is used for agriculture.



* There are no known Tamil names.

Figure 2. Tank-village: Source [4] .

These integrated social-ecological complexes provide environments for multiple rural livelihood opportunities. Dharmasena [11] identified seven rural livelihood opportunities found in the tank-village system: 1) rainfed upland farming; 2) agro-based forestry; 3) livestock development; 4) command area cultivation; 5) homestead farming; 6) agro-based industries, and 7) fishery [12]. However, to date there has been limited recognition of this integrated social-ecological complex as a basis for CTVS based sustainable livelihood strategies and outcomes.

2. History and development

Inscriptions evidence that the CTVS water management was introduced in the 3rd century BCE (Before Common Era) and had uninterrupted expansion and development, as evidenced by local oral village tradition until the 13th Century CE (Common Era) [6]. Once fully developed the CTVS were governed by a hierarchical but durable governance system, under which the King, community and leaders had different responsibilities, and fees and sanctions were levied for water use.

Shannon & Manawadu [9] note that the expansion of CTVS during the monarchy period built around urban centres, e.g. Anhuradhapura, and were thus a consequence of and response to indigenous landscape urbanism. In their careful stratigraphic study, Gilliland et al [13] identify two likely disturbances – one political and the other climatic - around 1000 AD – overthrow of Anhuradhapura and severe drought, as precipitating the abandonment and disuse of the tanks. This then led to a focus on subsistence farming, out migration to the Wet Zone, and large-scale abandonment of the CTVS. Consistent with the complex adaptive system (CAS) approach of resilience thinking and SLF, such natural and social shocks are often the cause of system breakdowns as socio-political and environmental thresholds are exceeded.

From the 13th to 17th Century CE – the so-called dark age of traditional irrigation in Sri Lanka, evidence is limited. In this era, the traditional system declined mainly due to foreign invasions, malaria, some depletion of soil fertility, and even to a combination of "pull and push" mechanisms, i.e. mechanisms attracting emigration ("pull") or immigration ("push") that attracted the people to

the wet zone and the hill country. Under colonial British rule (18th to 20th Century CE), there were many changes to the socio-economic structure in the rural agriculture community, and the *Rajakariya* system particularly at village level was abolished [14] and first replaced by a mixed crown property and common property system leading to further decline of the CTVS overall [15]. According to Abeywardana et al [6], the initial intention of the British regime was not to reactivate the traditional system but to adopt a community-based traditional governance and ecological elements in the later stages of their administration. Subsequent history also saw multiple and somewhat chaotic administrative changes, and a focus on large scale agriculture.

Replacement of the '*Gamarala* or Village headman responsible system for the earlier *Rajakariya* system' (described above) was the key milestone policy change in the British regime. In addition, the establishment of the Department of Agrarian Services in 1858, the Irrigation Department in 1900 resulted in the conversion of the community-owned and community-driven local system to a centralised bureaucratic system. Similarly, alterations in the Agrarian Services Act in 1979, the influence of 'Green Revolution Technology' in the 1960s to 1990s, and the effects of open-economic policy in the 1980s have resulted in abuse of the traditional system's core values. Consequently, these internal and external factors reinforced the centralised bureaucratic setup in water administration and management of Sri Lanka [16]. Wijekoon et al [14] recently concluded that the multiple overlapping and uncoordinated governance systems not only exclude active community participation but now require a complete institutional review.

Community management of irrigation systems in traditional agriculture was a prominent feature at the village level social setup. Traditional water governance is connected to political, institutional, social, economic, and administrative systems in water resource management and delivering water services to the community. Originally, political and institutional set ups operated between rulers and villagers in the traditional social setup. The (bhuddist) monastic institutions and the village level officers were empowered to control and monitor the policy framework. The officers roles varied and were more formalized post 1856 - *Welvidane* (Officer in-charge of paddy fields), *Wevvidane* (Officer in- charge of irrigation), *Gamarala* (nobleman of the village), *Mohottala* (sheriff), *Vedarala* (physician), *Anumethirala* (approving officer) and *Denumethirala* (wiseman of the village).

According to Dharmasena [11], the '*Sathwida Anavidhana*', (ten commandments) were the special rules and regulations used in this framework. The package included ten principles, which as we show below overlap with recent resilience thinking principles [17], including (1) Keep control over limited water available during extremely dry seasons, (2) adopt risk evading farming, (3) Utilize the environment ensuring its sustainability, (4) Live with minimum needs and in the simplest way, (5) Harvest rainwater and store for future use, (6) Work as a team, (7) Store excess grains for future use, (8) Be independent of external interventions, (9) Protect the knowledge for a future generation, and (10) Continue to practice cultural activities.

Thus, there is a tradition of integrated management of CTVS, which might provide some guidelines for governance in the present. Although alluded to in recent proposals for restoration history and its lessons for the present, however, are not considered [3].

3. Methodology: combining sustainable livelihoods and resilience thinking

While there are occasional allusions to social-ecological systems and livelihoods in discussions of CTVS there is no systematic accounting for these in discussions about current restoration. Elinor Ostrom's work on collective solutions to the so-called common's problem is well known and relevant here, and she dedicates some discussion in her leading book to collective action potentials for irrigated farming in Sri Lanka [18]. Her work on the self-organising capacity of SES [19] identifies seven socio-economic setting dimensions and variables, system elements and interactions and outcomes (see figure 1 below) critical to understanding such systems [and see 20]. Fully understanding the current challenge requires attention to the variables below and our broader study intends to address these. Here we indicate how the resource system (CTVS), governance system and users interact and with other resource systems also. With respect to rural livelihoods, which are often alluded to but seldom defined in resilience projects [21], we use the sustainable livelihoods

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framework (SLF) for relevant outcome measures in development contexts [22]. The framework below identifies the relevant variables for SES based analysis of livelihood opportunities in specific political, social and economic settings. Our future engagement with on-site communities aims to map these variables to the present and future.

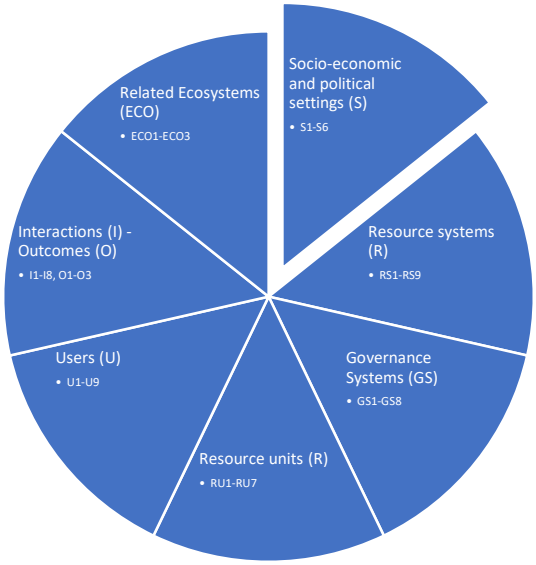

Figure 3. Source adapted from [19].

This study utilises the sustainable livelihoods framework (SLF), where 'a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base' [23]. As shown in the figure below (figure 2), SLF focuses on typical SES phenomena although it does not use the terminology, such as vulnerability, shocks, institutions and governance, and interventions to enhance rural livelihoods in many ways [24]. Hence, it is not surprising that both SLF and SES have been linked in recent development literature and studies [25]. From an SLF perspective resilience is achieved through enhancing household and community assets enabling resilience to vulnerability and livelihood strategies that allow for multiple outcomes towards stability and growth [26].

To date there has been limited discussion of resilience thinking to the restoration of Sri Lankan CTVS for promoting sustainable livelihoods. Resilience thinking, which is about the capacity of systems to respond to disturbances but maintain their function and overall identity, is a useful analytic framework and practical strategy for intervening in SES [7]. For this project report – we analyse the history and current challenges of the CTV system from an SES and resilience perspective, including key concepts, such as adaptive cycles, thresholds, panarchy, resilience and other core concepts for such water catchment-based systems [27]. The paper then proposes a series of strategies to restore the systems according to resilience principles to ensure sustainable livelihoods for the population.

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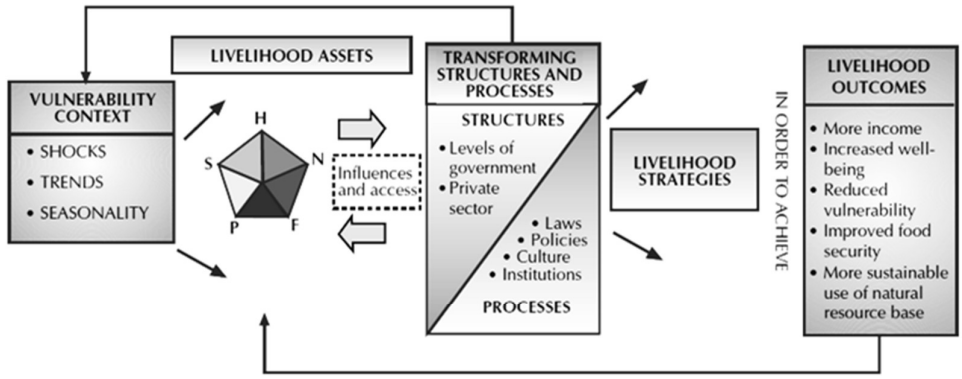

H represents **human capital**: the skills, knowledge, ability to labour and good health important to the ability to pursue different livelihood strategies;
P represents **physical capital**: the basic infrastructure (transport, shelter, water, energy and communications) and the production equipment and means that enable people to pursue livelihoods;
S represents **social capital**: the social resources (networks, membership of groups, relationships of trust, access to wider institutions of society) upon which people draw in pursuit of livelihoods;
F represents **financial capital**: the financial resources which are available to people (whether savings, supplies of credit or regular remittances or pensions) and which provide them with different livelihood options; and
N represents **natural capital**: the natural resource stocks from which resource flows useful for livelihoods are derived (e.g. land, water, wildlife, biodiversity, environmental resources).

Figure 4. Sustainable Livelihoods Framework. Source [29], Creative Commons license (CC BY 3.0).

The model also signals important feedbacks such as current livelihood outcomes, institutions and processes and the vulnerability context influencing assets. Albeit not framed originally in system and resilience terms – the translation to CAS and SES perspectives is an obvious and fruitful one.

4. Applying SLF to Sri Lanka CTVS context

The significant problems we face cannot be solved at the same level of thinking we were at when we created them. (Albert Einstein)

In the process of investigating resilience opportunities and outcomes for the CTV livelihoods in Sri Lanka, the application of SLF as an analytical framework to understand the livelihood status and future possibilities for sustainable livelihoods is important [1]. The SLF as an analytical structure enables a broader and systematic understanding of the status of the CTVS and overlaps with the concerns of resilience thinking in several areas. Previous studies, including the qualitative case study of Marzano [30] show how at the village level the multiple capitals involved in determining poverty, livelihoods, access and other SLF elements and the problem with current approaches to aid. SLF in general has a long history of use as analytic framework for current and future possibilities [31]. This is another intersection with resilience thinking, which often focuses on participatory scenario planning [32].

4.1. SLF Vulnerabilities

The SLF identifies vulnerabilities as shocks, trends, and seasonality in livelihood contexts. The vulnerability context for CTVS communities impacts on and interacts with households-capitals' and is influenced by the inclusive or exclusive nature of institutions and processes. In the literature, the outcome of these interactions on the CTVS community is alluded to albeit not from an SLF perspective and includes: frequent and extreme natural calamities; increasing temperature and humid levels; exposure to economic pressures. The effect of these vulnerabilities and risks on assets

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and capitals as a product of the current inadequate nature of institutions [33], including primary health care, village and community governance processes includes: relative poverty; suffering from non-communicable diseases such as chronic kidney disease, cancer, and diabetics; high rate of out-migration; declining trends of the diversity and quantity of biodiversity, soil fertility, natural resources, and other issues [16].

Natural stresses are affecting rural agricultural communities in the world. Although, in Sri Lanka the rural agricultural population have shown they can understand the natural changes and develop resilience adaptive measures [4], social-political and economic stresses override the adaptability of natural shocks and create a more complex vulnerable environment in the CTV livelihoods. CTVS as a complex SES, such vulnerabilities are interconnected and results in multiple effects of system transformation.

4.2. SLF Capitals Analysis

The five capitals as depicted in the original SLF model have been sometimes supplemented in more recent formulations with additional political and cultural capitals. Moser and Anis [34] suggest that SLF is the best analytical framework to incorporate livelihood assets, capabilities, and powers in forms of material and non-material: natural, human, social, cultural, financial, and political capitals. As understood in SLF, understanding assets is not simply about what and its distribution, it is important to know how they are interconnected with which vulnerabilities and strategies [35]. Current CTVS studies tend to relate the capitals of CTVS with water management and irrigation system perspective. This study will extend the current knowledge to understand the complex interactions of material and non-material-capitals for the social-wellbeing of the CTV community. As evidence in the literature to date (and discussed above), some of the main assets and capabilities, and current levels of access to households in CTVS are summarised in table 1.

Table 1. Developing capitals framework in SLF thinking, in a form of a qualitative summary of literature survey.

	CAPITALS	LEVEL OF ACCESS
Human [36][37]	Traditional agriculture skills and knowledge; Modern agriculture skills and knowledge; Indigenous knowledge in; medicine, art, industry, water management, food, and livelihood raw materials management Main labour from the older population including females	Traditional knowledge has not been transferred to youth labour/immediate generation due to various social, economic, and political reasons. Youth labour limited to rural employment opportunities.
Social	Buddhist values and practices (*Dharma*) Farmer Organisation networks Funeral aid society *Samurdihi* (financial aid) society Rural development societies Food, labour, and other resource sharing practice	Buddhist values and practices decrease through. Social networking and common interest of gathering become non-functional, due to spending more time on multiple employment jobs as the economic pressures.
Natural	High biodiversity - ecosystems such as wetlands, seasonally wet and drylands, paddy fields, uplands, forests, scrublands, tank beds, home gardens, rocky lands, and water streams Land for livelihoods Natural multiple water sources Natural food sources, cottage materials, medicine, fuel, fertilizer, timber, water All year daylight and energy Livelihood animals (cow, water-buffalo)	Most of the common natural capitals are controlled and regulated by government authorities. Thus, the governance system creates access restrictions to use as well as in conservation. There are financial, knowledge, and infrastructure deficiencies in access and improvement of natural capitals in village livelihoods.
Physical	Major irrigation infrastructure The mix of restored and abandoned, high-density small tanks and water ponds distribution Traditional tools and equipment, and modern agricultural and related machinery Traditional small tank irrigation landscape	Water management and irrigation infrastructure management is active in most of the areas in the dry zone Sri Lanka, but technical aspects and their sustainability have been criticised by many scholars as it is leading to multiple issues in linked systems.

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		While the farmer communities limited to traditional equipment received from the past generation, few of the elite or business community access to the majority of modern machinery.
Financial	Government subsidies, remittance programmes Government bank loan and credit schemes *Samurdi* programme (poverty alleviation financial scheme)	The common criticism is the inefficiency and gap of not meeting the needs of village communities relates to available financial capitals and poor coordination among institutions.

The CTVS household capitals are spread thinly and most of them are highly vulnerable to external factors. Multi-benefiting assets available such as natural assets in the household level ecosystem have not been effectively integrated into their livelihoods. The main argument of SLF and SES is to restore and enhance the natural capital of the CTVS while re-organising the governance system for sustainable water management, which will lead to a sustainable livelihood. In contrast, understanding deep-rooted complex relationships on prevailing capitals, structures, and processes gives a holistic picture of the current status of the community. Further, it revealed how significantly important each livelihood assets of the CTV system enhance and maintain its resiliency for a long period.

4.3. SLF Institutions & Processes

As Scoones [38] observes, SLF in development contexts is increasingly attentive to the politics and political ecology of community development. This has direct relevance to the Sri Lankan case. As an example, political pressures create an environment of promoting overuse of chemical inputs, pesticides [39], and intensive agriculture methods, displacing a nascent organic agriculture movement and other agricultural adaptations with market and sustainability potential [40]. This is rooted in the representation of Farmer Organisations (FOs) leaders who are nominated on caste, class, and political power, and do not have capacity in traditional local knowledge and the real context in farming and irrigation [41]. Awsadahami [42] meanwhile sees a continuation of European colonialization and forced dependency on foreign technology displacing local knowledge and skills. Therefore, understanding the deep-rooted vulnerabilities, and cause and effects through SLF demands to study CTV community assets and capabilities.

Politics, power, and institutions are the key variables of transforming structures and processes in livelihoods [23]. The SLF argues that the policy framework and institutions should mediate the role of equitable access to livelihood resources rather than a resource abundance, which is a common criticism in the CTVS discourse. Therefore, policies and institutional interactions with livelihoods have analysed through; how different policy forms and expertise are deployed, how different scales and agencies are networked and resiliently functioning, and how the power of politics and its interests affect livelihoods through policy outcomes.

The institutional and policy framework relates to village livelihoods and agriculture has been transformed into a more complex and chaotic phase. Many institutions and societies in different scales are duplicating their roles and responsibilities mainly in irrigation and agricultural services [19], [20]. Then, these structures and processes promote modern commercial agricultural practices and introducing new technology to farmer communities without sustainable procedures [6]. The study findings reveal that these household-level processes and structures are limited to, poverty elevation and well-fare policies; gender equality and female participation in household income generation; the community forestry model and guidelines in the line with National Forest Policy 2012; and cascade-based small tank livelihoods rehabilitation programmes are prominent processes control by government and private structures such as Farmer Organisations (FOs); local representation of irrigation department, agriculture, agrarian services, forestry, and Mahaweli Authority; and financial welfare and business promotion institutions. As an example, the cultural and social dynamics of the prevailing society influence the FOs' functions through political interferences and the social status of farmers and state officials [18]. This process has resulted in increasing the negative force of challenges to the long-term sustainability of the CTVS.

4.4. SLF Strategies

Influences of existing CTVS structures and processes and capitals contexts shape the current livelihood strategies to cope up with vulnerabilities at the household level. Recent studies have drawn attention to how the diversity of livelihood strategies at the household level been narrowed but others still exist, such as, the traditional water management practices "bethma" and "kakulama" in some villages. Other issues identified include diverse and unsustainable water resource consumption; unsustainable land-use strategies; less diversified agricultural and livelihood practices; market bias towards high-cost inputs strategy for high yield expectation; and institutional spoon-feeding strategy on farmer survival [6], [14], [21]. Beside governance and policy challenges, there is increasing evidence that transformative change in resilience agriculture and livelihood strategies is needed for resilience CTVS [4].

4.5. SLF outcomes

The current livelihood outcomes are not sufficiently analysed systematically in the context of the CTVS. However, as things currently stand, the CTVS present many negative livelihood outcomes . Thus, the region has the poorest households in the poorest regions in Sri Lanka; the community is suffering from non-communicable diseases such as unknown chronic kidney disease, cancer, diabetics, etc. and poor health conditions; the region has the lowest level of access to socio-economic infrastructure; crop yields increase at a slower rate; high cost of production and vulnerable market structure; the increasing rate of young and middle age out-migration; life-threatening livelihood pressure on farmers, e.g. leading to suicides in some cases, for failing to cover even subsistence needs. Limited consideration in the sustainability of the CTVS livelihoods, and the poor co-ordination and chaotic institutional intermediation towards the household level and community livelihood strategies, vulnerabilities, needs a new resilience paradigm shift to a whole system perspective. These and other outcomes are detailed in the much of the literature already referenced [2],[10],[15],[30].

4.6. SLF Overview

Consequently, the study has outlined the current strategies and livelihood outcomes of the CTVS communities relative to the existing literature and studies. We find current institutions and processes creating barriers for meaningful increases in household capitals, and the resilience of communities in general in terms of these capitals as vulnerable to shocks and trends, including declining biodiversity [43] changing political and economic trends, including modernization, market changes, education levels, and inconsistent management decisions [36]. The strength of SLF for this study is the way it addresses causes and consequences of rural development as well as signaling leverage points for change. However, while it offers helpful insights, including relative to politics it does not directly address the cycles of change both historically and contemporaneously that operate in the rural dry zone, nor does it directly suggest strategies for strengthening resilience in communities. Although it implies the need for change in institutions and processes as a central mechanism it does not suggest, except for greater inclusion, how this should be achieved. To answer these questions resilience thinking and the underlying social-ecological (SES) perspective on community development is critical. While these ideas have been alluded to in current approaches to Sri Lankan CTVS restoration, e.g. [44] they have yet to be more systematically applied.

5. Social ecological perspective on change

The strength of the resilience approach to adaptive cycles of change in SES is that the underlying processes scale over time and geography. It introduces time and geography scales to understand he current state of SES systems and identify leverage points. Thus, over a long time scale, overall history highlights four phases of the adaptive cycle of this SES – through rapid growth (r), a conservation phase (K), the release phase (Ω) and a reorganisation phase (α), where the last phase can lead to significant negative transformation. As depicted below (figure 5)– SES treats the initial exploitation phase in systems as building connections into the stability of the conservation phase. Some cycles of

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change, e.g. seasonal, bring with them regular cycles of breakdown and renewal which are not inherently destructive. In other cases, however, such changes may be initiated by ecological or political shocks on a system that is vulnerable to potentially irreversible breakdown.

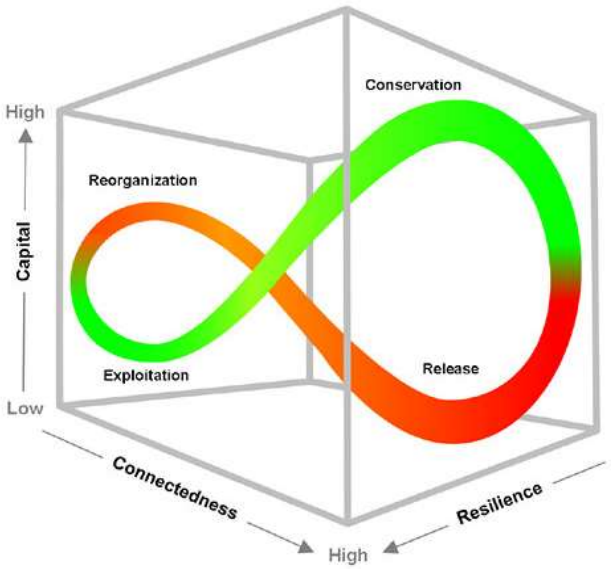

Figure 5. Adaptive Cycle - Source [45] Creative Commons CC BY-NC-SA 2.0.

6. Results: Applied to Sri Lankan CTVS

Contributing to this consolidation in Sri Lanka was the *Rakajariya* system and development of CTVS from isolated village and community tanks to a connected series of tanks driven by landscape urbanism in the dry zone, as previously mentioned [9][46]. Thus, the foreloop of growth and conservation was driven by political and governance changes for the Sinhalese majority, as well as urbanisation. Hydrogeological, political and other disturbances – previously mentioned - lead to an 'unmanaged' release or breakdown. Current restoration looks to the past and future but obviously in a new socio-economic and political environment, e.g. of Sinhalese and Tamil conflict.

Referring to Ostrom's categories, current efforts to restore the former system to inflow-outflow equilibrium and contribute to productivity are aided by relatively clear system boundaries, locations, and storage characteristics. Although the technical work of reconstruction, desilting, etc. of these integrated human-constructions is having success, the relevant resource units (see diagram below) and including crops, e.g. tea, paddy, etc., are under pressure from industrial agriculture, as well as loss of indigenous knowledge of SES and capacity to maintain CTVS-based livelihoods. Although number of users and socio-economic status is broadly known there are uncertainties here. Prior leadership, governance and other patterns no longer obtain and a new 'order' must be established.

Since the 1970s significant government budget and international aid and resourcing from major donors, including UNDP, Asia Development Bank, HSBC Bank, and others has been directed to restoring specific tank systems. Dharmasena [47] suggests that while restoration has helped in general, failure to consider the social and ecological interconnected nature of the tanks and livelihoods, 'the proposed technologies must be compatible with the present prevalent physical, social and economic conditions in these regions rather than confining (sic.) to engineering aspects of rehabilitation' [47]. Based on his evaluation of rehabilitation projects, while recommending restoration efforts, Aheeyar [48] found that overlapping policies, institutional role, and responsibilities, as well as inefficiencies in state-led water management failed to manage the whole system effectively and to deliver expected results for better livelihoods.

In their study Wijekoon et al. [14] conclude that enhanced resilience can be achieved by 'augment(ing) tank storage by removing aquatic weeds and de-silting, introduce water saving measures/technologies, strengthen the FOs (Farmer Organisations), improve governance of MIS

(Minor Irrigation Systems) and develop access to market facilities' [49]. Koepke et al [16] find weak implementation of environmental laws, preference for high use of pesticides by farmers, on-going tensions between local communities and government, and migration of youth to the cities. They conclude also that what looks like a typical tragedy of the commons scenario [50], that is 'the overuse of water as a common pool resource by multiple rational actors, can be more likely be related to structural causes and societal dynamics' [16]. Therefore, overall one might conclude that particular focus on a balance between restoration and transformation is required with a view to sustainable livelihoods.

Clearly the CTVS have a history of development and change punctuated by environmental, socio-political and other changes. In the modern era and given current challenges for development in Sri Lankan rural dryzone [46], the question is what can be restored, i.e. how adaptable is the system, and what must be transformed. Lessons might be learned from other catchment-based challenges [51]. Panabokke et al. [2] noted that ad hoc infrastructure improvements and maintenance issues such as raising dams and spillways and desilting tanks have seriously disrupted the hydrological balance in CTVSs. Outdated policy frameworks, weak and overlapping governance role in water management and improving traditional technologies, and opaque power structures have driven to a whole system operational and management issues in the dry zone, Sri Lanka. Koepke et al [16] have noted recently that the 'social structure of rural life in the areas under research is today characterized by small- scale agriculture (paddy cultivation and *chena*, a form of slash-and-burn vegetable farming) on relatively fragmented plots' [16]; clearly not a basis for sustainable livelihoods.

There is evidence across history and currently that collaborative governance arrangements, including community and other actors, so-called pluri-centric government (see principles below) is essential for sustainable livelihoods, especially for multiple use scenario of CTVS, i.e. supporting paddy culture, local ecosystems, household gardens and many other elements [22]. Potentially a greater role for appropriate market linkages, as a key institution for cross-scale outcomes, may be relevant, including eco-tourism opportunities [52]. Thus Dorward et al [26] conclude that 'in many poorer rural areas, increasing productivity of farm activities will have greater potential for stimulating poverty-reducing growth, whereas increased productivity of non-farm activities will play a more important role in supporting secondary, linkage-dependent poverty-reducing growth, particularly if the activities have low barriers to entry and high labour demands' [28].

The caste-based occupation, which was supported by '*Rajakariya*' system, ranged from farming, blacksmiths work, laundering, dancing, and drumming, goldsmith work. This mechanism succeeded in maintaining the diversity and specialised knowledge to deliver an effective system. Although no longer adequate to current circumstances and with its detractors [53] the idea of polycentric governance integrating multiple actors is still important. Declining farm productivity, resiliency, and profitability of farming, and unsustainable water management and agricultural practices has resulted in economic and health issues in tank-village system communities [16]. On the other hand, lack of access to mainstream markets, inadequate village level health, education, and other services, as well as labour shortage due to high demand in off-farm labour among the younger generation listed as key challenges that are highly vulnerable in the current socio-economic system.

7. Resilience thinking analysis

The Stockholm Resilience Centre has recently formulated seven principles for resilience thinking projects [54]. The seven principles are 1) maintain diversity and redundancy, 2) manage connectivity, 3) manage slow variables and feedbacks, 4) foster complex adaptive systems thinking, 5) encourage learning, 6) broaden participation, and 7) promote polycentric governance systems. As noted above these principles appear to coincide well with indigenous thinking and are a platform for future thinking.

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Figure 6. Seven Resilience Principles: based on [54].

From the discussion above (and within the limitations of this paper), there are several immediate connections. Diversity and redundancy in terms of the full CTVS system needs to be maintained, which includes household gardens, ecosystem health, as well as considering new possibilities and livelihood strategies, e.g. eco-tourism, microfinance-based opportunities [57]. Connectivity at community level needs to be re-established and 'empowered' to manage this commons. This should include appropriate social learning strategies, which must be carefully implemented to include and revive indigenous knowledge and experience [55]. Following restoration, slow variables and feedbacks, e.g. new precipitation patterns, combatting urban drift with regional focus and other strategies can be used. As the example of other catchments shows, e.g. GBCMA in Australia [56], education and workshops can stabilise and enhance existing system knowledge and learning. Both broader participation and polycentric governance could restore a balance to current top down management while encouraging inputs from expertise. These and other suggestions mentioned above could bring real change.

8. Conclusion

History and the present show the potential significance of well-functioning CTVS to livelihoods in the Rural Dry Zone. Learning and applying these lessons to the present requires CAS and SES thinking, as well as application of resilience principles. In particular, we have suggested in section 6 above where the issues lie from a CAS and SES perspective relative to current restoration efforts. Further, in section 7 we have suggested how applying the resilience framework principles might identify the social, economic and governance principles that policy and practice should pursue – examples from other water catchment projects, e.g. in Australia, show how this might be applied.

The detailed discussion on livelihood opportunities in agriculture and irrigation sectors suggests the need to investigate off-farm water-sensitive diverse social-economic opportunities in the context of a sustainable community. To what extent traditional approaches to tanks and agriculture, even if restored and well managed [58], provide adequate livelihoods for the CTVS community, and 'whether the rising aspirations of societies could be satisfied through a tank based economy alone?' are still not been answered holistically [59], [60]. This is a significant challenge to be investigated in the future.

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Considered through a current knowledge of the sustainable livelihood structure and its potentials this study identifies key features that have challenged the restoration and transformation of livelihoods context of the CTVS Sri Lanka. Mainly they are;

- As a restoration effort the technical works including desilting, ecological land-use restoration, dam construction, and restoration, etc. are having technical success, the resource units and users are under pressure from industrial agricultural practices, exclusion of indigenous knowledge in farming production and markets;
- Ad-hoc infrastructure improvements and maintenance issues such as raising dams and spillways and desilting tanks, as well as destabilizing the environment-social sensitivity in the whole system have disrupted the hydrological balance in CTVSs;
- Social structure of rural life in the dry zone CTVs has been reduced to small- scale agricultural community life on fragmented resource units, which makes the more vulnerable to maintain their livelihoods and well-being;
- On the other hand, lack of access to mainstream markets, inadequate village level health, education, loss of environment-social sensitive knowledge system, and other services, as well as labour shortages due to high demand in off-farm labour among the younger generation are key challenges in the current socio-economic system;
- Finally, overlapping policies, institutional roles, and responsibilities, as well as inefficiencies in state-led water management, failed to manage the whole system effectively and to deliver expected results for better livelihoods

Reviewing present understanding, the potential livelihood scenarios and viable strategies are under SLF and SES resilience thinking include:

- The technologies employed must be compatible with the present social-ecological conditions in the CTVS and its resilience, rather than limited to a recovery approach in restoration whole system;
- Collaborative governance arrangements, including community and other actors (polycentric governance), are essential for sustainable livelihoods, especially for fostering a sustainable multiple-use scenario of CTVS and its diversity maintenance;
- Potentially a greater role for appropriate market linkages, as a key institution for cross-scale outcomes, including eco-tourism, natural resource management opportunities, ex: national park management and inclusive development [60].
- Whereas increased productive diversity in non-farm activities with social-ecological conservation and regrowth will play a more important role in supporting secondary, linkage-dependent poverty-reducing growth, particularly in a situation where there are social-ecological-economic barriers to entry and high labour demands;
- Therefore, overall one might conclude that a particular focus on a balance between restoration and transformation is required with a view to sustainable livelihoods

In her classic treatment of collective action approaches to the commons and in particular her discussion of institutional failures and fragilities, Elinor Ostrom [18] dedicates fifteen pages to a case study of the irrigation system in the dry zone and highlights the success of a project which improved collective governance of water with positive livelihood outcomes. Frameworks exist which can drive this process from a technical to a socio-technical approach towards sustainable livelihood outcomes.

Future research for this project is being prepared and will involve a multi-method case study integrating, a multiple case study of three villages, interviews with government and other experts, analysis of current agriculture and rural development policy with respect to CTVS-based livelihood possibilities. Given current COVID restrictions on travel, some of this work will be conducted remotely until field work in Sri Lanka again is possible. Our hope is that through engagement of government, planners and other stakeholders applied development work might be possible, which we could report here.

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