Cascade Systems
and
Sustainable Land Management

Ministry of Environment &
Healthy Landscapes Project

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CASCADE SYSTEMS AND SUSTAINABLE LAND MANAGEMENT

Healthy Landscape Project

Ministry of Environment

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1. INTRODUCTION

It is reported that there are approximately 14,200 small tanks in Sri Lanka. Most of these are located in dry and intermediate zones. Currently, maintenance of these tanks and related cultivation activities are done through the farmers' organizations established for these tanks under the guidance of the Department of Agrarian Development. Most of these tanks are located not as isolated tanks, but as interconnected system or tank clusters. A system of small tanks like this is called a tank cascade. Considering this type of system, there are many crucial components can be seen that help to ensure its environmental conservation as well as sustainable productivity. At present, due to various reasons, some of these elements are also seen to be destroyed or extinct. Also, it seems that the paddy fields, highlands, grasslands and forest areas used in the vicinity of these tanks are not being used sustainably as before due to the rising socio-economic and other issues.

These small tank cascade systems play an important role in mitigating various environmental issues including climate change, land degradation, soil erosion, and loss of biodiversity, happening both globally and locally. However, there are various effects on the existing socio-economic environment. Especially the lands around these small tanks, when they are using for various purposes, the sustainable management of those lands is knowingly or unknowingly lost.

Therefore, an attempt was taken in order to aware all stakeholders including relevant government officials and land users by this booklet, since it is very important to manage the lands in cascade systems in sustainable manner. Although the information given here are prepared with special reference to cascade systems, they can be used for other landscapes in the country to manage the lands sustainably.

A Dry Zone tank eco-system[1]

[1] Photo credit: Dr. Sevvandi Jayakody

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2. DISTRIBUTION OF CASCADE SYSTEMS IN SRI LANKA

When we consider the dry and intermediate zones of Sri Lanka, comparatively fertile lands suitable for cultivation spread over a large area are available with a flat or slightly sloping terrain. Nevertheless, in order to successfully use the land for cultivation, appropriate strategies must be used to overcome water scarcity, which is a major limiting factor. In the past, the rulers and the people well understood this situation, so in order to successfully carry out the cultivation, especially in the dry and intermediate zones, many structures such as large tanks, small tanks, canals and water diversions were built to collect rainwater and use it during the dry season.

When constructing small tanks it was based on the tributary or canal and taking into account the topography of the land, so that the rainwater received in that small watershed can be properly stored and reused thereby it was able use water efficiently. As mentioned in the introduction, such a system of tanks or a cluster of tanks arranged by connecting several waterways is called a tank cascade.

These types of tank systems have been in use for decades, and as such, they are closely linked to the natural environment over time. These systems have helped to improve biodiversity as well as agro-biodiversity while creating a favorable micro-environment.

An examination of a printed one inch to one mile map or a 1:50,000 metric scale map of the dry zone, will clearly show the prevalence of such tank clusters (Figure 1). It is also seen that some of the tanks in these cluster of tanks have been left unutilized for various reasons, and some of the tanks are within the protected

areas of wildlife or forest. As observed in a study[2] conducted at the agrarian service region level in Vavunia district, 90 small tanks with 13 cascade systems were identified in Cheddikulam agrarian service region, out of which 43 tanks were abandoned at the time of study.

According to a study[3] based on the North, North-Central, North-Western and Southern provinces, Table 1 shows the number of tank cascades located in the small watersheds of the river basins in those provinces. Accordingly, it is well understood that a significant number of cascade systems are located in these provinces. These clusters of tanks are mostly spread in districts like Anuradhapura, Polonnaruwa, Vavunia, Monaragala, Hambantota, and Kurunegala.

[2] A. Nanthakumaran, H. K. Kadupitiya, S. Devaisya and W. E. P. Athukoralea. 2022. Exploring the village tank cascade systems (VTCSs) in Vavuniya district, Sri Lanka. Journal of Water and Climate Change Vol 00 No 0, 1 doi: 10.2166/wcc.2021.412.

[3] Sujith S. Rathnayaka et.al. Challenges 2021, 12, 24. https://doi.org/10.3390/challe12020024 https://www.mdpi.com/journal/challenges

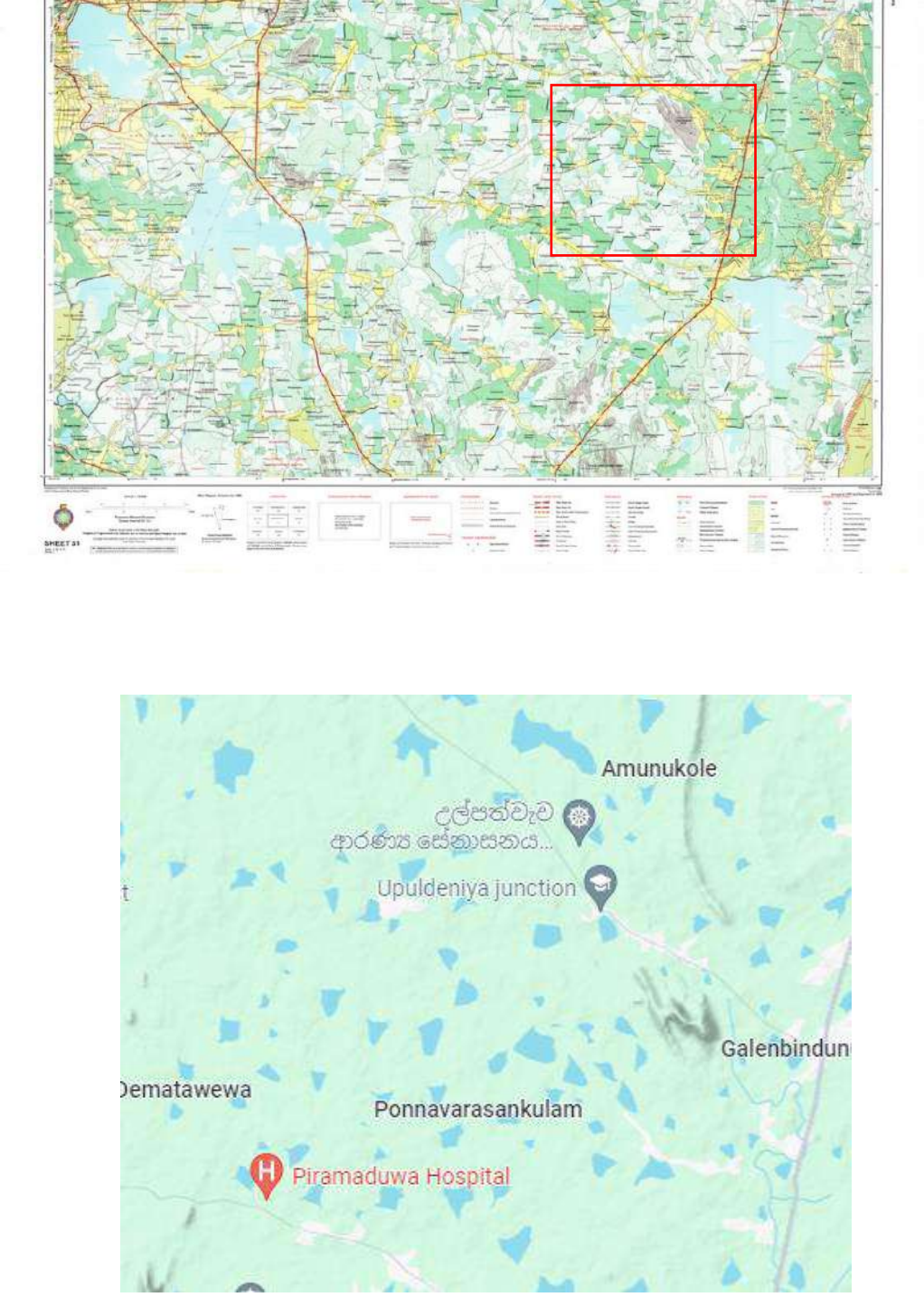

Fig.1. Map No. 31 Anuradhapura (scale 1:50,000) published by the Survey Department. Light blue colour polygons show the distribution of large and small tanks in the area. An enlarged part of this map are also shown.

Some of these cascade systems do not exist in their original form due to various reasons, so it is difficult to identify them as a system at present. Therefore, it is not an easy task to restore some of the cascade systems back to their previous state. The integrity of the systems has also been lost due to the declaration of protected areas in which some of the small tanks of these systems were included.

However, the sustainable management of these cascade systems and their associated lands, economically, ecologically, socially and culturally are very important. Thereby improve the livelihoods of the people in these areas, is a strong challenge that we are facing today.

Cascade systems also play a unique role in conserving biodiversity (Photo credit: Dr. Sevvandi Jayakody).

Table 1. Number of tank cascades located along major river basins in Sri Lanka (Source: Sujith S. Rathnayaka et.al., 2021).

Province /Region	Major river basin	Number of cascades
North and North-Central	Malwathu Oya	189
	Kala Oya	91
	Yan Oya	80
	Ma Oya	45
	Modaragam Aru	45
	Parangi Aru	36
	Mahaweli river	28
	Kanakarayan Aru	23
	Pali Aru	18
	Pe Aru	17
	Pankulam Aru	12
	Panna Oya	09
	Kunchikumban Aru	09
	Manal Aru	08
	Ne Aru	07
North-Western	Daduru Oya	164
	Mee Oya	67
	Rthabala Oya	24
South and South-East	Walawe river	49
	Manik river	36
	Kiridi Oya	32
	Malala Oya	18
	Karada Oya	12
	Kubukkan Oya	09
	Kiram Oya	07
	Uru Bokka Oya	07
	Maduru Oya	07

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3. TYPICAL LAND USE AND LAND COVER OF CASCADE SYSTEMS AND ITS CHANGES WITH TIME

Some of these cascade systems we are talking about are not seen in their original form. Important elements of these systems are lost due to multiple factors such as competing demands for land, shift to commercial agriculture and due to various development activities. Nevertheless, some of the original cascade systems are still found, especially in the Rajarata and the Southern Province.

Here, an attempt has been made to get an idea of how the lands has been generally used and existing land cover of a typical tank cascade. Furthermore, the major changes in land use associated with these tank cascades are also briefly explained under the background of the current social and economic environment.

The tank and the paddy lands are major components of the cascade system and they are socially, culturally and environmentally also important. However, several other important zones/features/structures can also be identified when considering small tanks and their associated area in a cascade system. That is the tank, its components such as the sluice, the spill of the tank, tank bund, the irrigation canal, tank catchment, dense forest behind the tank (Fig. 2). In terms of land use and land cover, we mainly consider paddy fields, the high land area where crops are cultivated or the area where shifting cultivation was practiced before, the homesteads or

Gangoda, tank catchment and the forest and scrub areas. A brief description of each of these uses is provided below.

Paddy

Paddy fields are located under each small tank in the system. Depending on the amount of water available in the tank, it will be decided whether to cultivate rice in both seasons, or to cultivate rice in the main season (*Maha*) and use it for other crops in the minor season (*Yala*). Depending on the amount of water available, perhaps only a part of the entire paddy field is used for cultivation which is called the *"Betma"* method.

Area where highland crops are grown (formerly used term as *Chena*)

This is mainly done in the scrub area. Clearing of the dense forest over the tank was not often done, and areas of scrub or secondary forest were used for *chena* cultivation. Nowadays chena cultivation is not done as previously, continuous cultivation using agricultural inputs is practiced. These lands today often appear as farmland rather than scrubland. Sometimes ground water (from agricultural wells) is also used for these crops.

The areas where highland crops are grown (known as chena lands) are called by different terms by the farmers according to the period they were used, the nature and the productivity of the lands. A brief explanation of that is presented in Table No. 2.

Table 2. Types of chena lands and their productivity

Type	**Land Productivity/status of the land**	**Generally grown crops/ suitable crops**
Nava dali chena (New land prepared after burning the forest)	Highly productive. Soil is highly fertile.	Vegetables, Mustard, Black gram, Maize etc.
Athdadu Chena (Lands prepared after clearing of secondary forest)	Productive and fertile land	Black gram, Green gram, Vegetables and coarse grains
Landa/Hiri landa (Lands prepared after clearing of scrub/Lands cultivated for 2-3 seasons)	Moderately productive and moderately fertile	Coarse grains and Sesame
Kanathu/Piti (Abandoned lands due to low fertility)	Low productive and less fertile lands	Sesame, Millet
Goda chena (Lands located above the tank or paddy field)	Low line areas with imperfectly drained soil	Paddy, Vegetables

Source: Adapted from Darmasena, P.B. 2010. Essential Components of Traditional Village Tank Systems. Paper presented at the Seminar on Cascade Irrigation Systems for Rural Sustainability. SLFI, Colombo, Sri Lanka.

Forest

Such dense forests are not found near some tanks nowadays. Due to various human activities, these forests have gradually been destroyed and they have turned into scrub areas. But some of these dense forests can exist in the vicinity of some tanks.

Scrub jungle

The scrub area is used to obtain logs, firewood etc. for various needs of the farmers. The scrub forest area was with a dense forest cover, but later it was cleared due to various human activities and became a secondary forest. Sometimes these forests are further destroyed due to various human activities.

Gangoda (Village hamlet)

The area where the residential houses are located on a slightly elevated piece of land near the tank is called the village or Gangoda. In the past, houses were built here as a cluster. But nowadays the new generations are leaving the Gangoda for various reasons and settling near the roads where more facilities are available. For this reason, it is sometimes difficult to identify the Gangoda in its original form.

Tank catchment

The land area where the rain water collected to the tank is called the tank catchment. This area is located over the tank (Fig. 2). The extent of this area is determined by the topography. In a more flat area, the catchment spreads over a large area. If the area is sloping, the catchment may be quite small. Tank catchments also being misused in some tanks. For example, activities such as cultivation of seasonal crops in the catchment and making bricks using clay from the tank catchment. Due to such activities, the soil is eroded and siltation of tank take place.

The entire tanks system spans a sub watershed. The size of the watershed can range from approximately 13 to 26 square kilometers and the average size is about 20 square kilometers[4].

Temporal changes in land use associated with small Tanks

Due to the growth of the population in these villages, the demand for various needs on the land, and the implementation of various development projects including the development of infrastructure, the previous land use and land cover have changed in many cascade systems. A major change seen today is especially the clearing of forest and scrub areas for cultivation or settlement. Also, due to the distribution of lands at different times, the command area has increased beyond the capacity of the tank. The original paddy lands under each tank called as Purana Wela (Old field) and subsequent areas alienate under provisions of Land Development Ordinance called Akkara Wela. Also, the residential areas are not limited to the old village and are spread to the areas close to the roads. Along with infrastructure development, new roads have been created which did not exist before and some roads have also lost the integrity of the cascade systems

[4] Nalaka Geekiyanage and Pushpakumara D.K.N.G. 2013. Ecology of ancient Tank Cascade Systems in island Sri Lanka. Marine and Island Cultures (J). 2, 93-101.

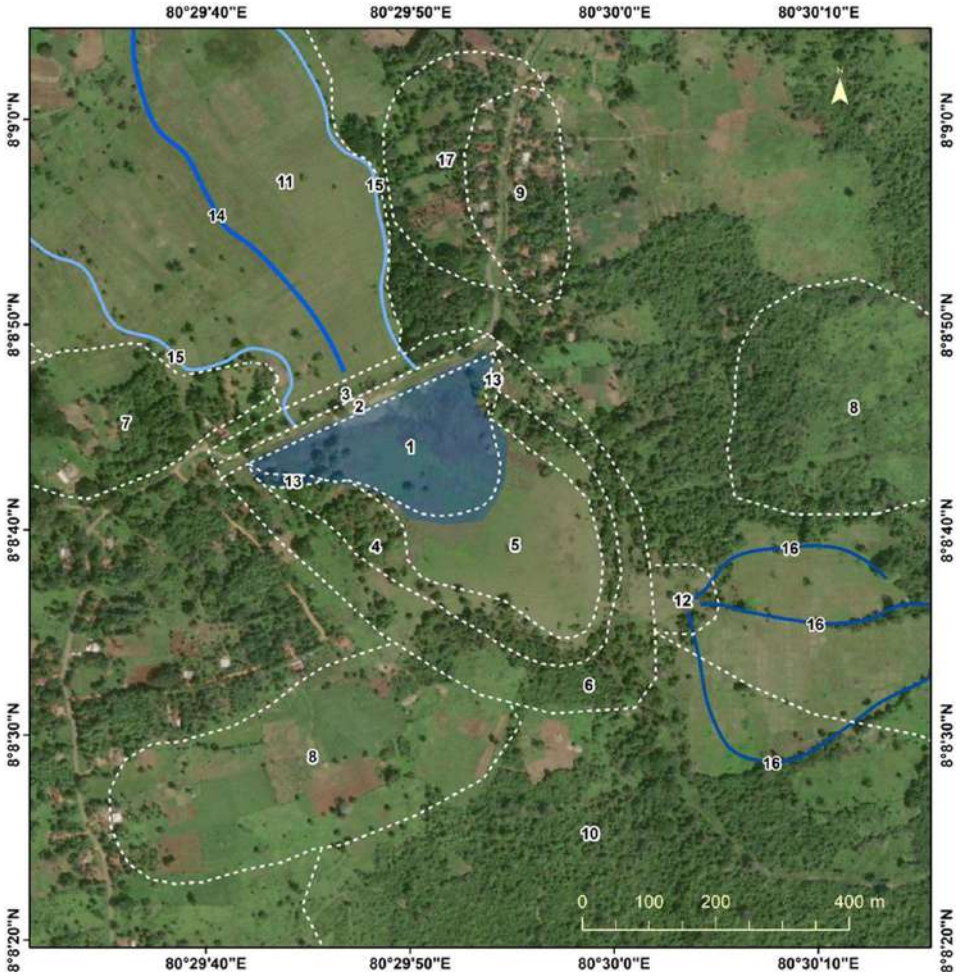

Fig. 2. Tank and the various components (Mahakanumilla cascade and associated micro catchment (Source[5]: Sujith S. Ratnayake et.al.(2021)).

(1)Tank bed, (2)Tank Bund, (3)Kattakaduwa (downstream reservation), (4)Gasgommana (Tree belt), (5)Tank catchment, (6) Upper stream immediate catchment, (7)Scrub, (8)Chena, (9)Hamlet, (10)Forest, (11)Paddy lands, (12)Water hole, (13)Isvatiya (soil ridges), (14)Drain canal (Kivul Ela) , (15)Irrigation canal, (16)Natural stream, (17)This bambe (backyard reservation around hamlet)

[5] Sujith S. Ratnayake, Lalit Kumar, Punchi B. Dharmasena, Harsha K. Kadupitiya, Champika S. Kariyawasam and Danny Hunter (2021). Sustainability of Village Tank Cascade Systems of Sri Lanka:Exploring Cascade Anatomy and Socio-Ecological Nexus for Ecological Restoration Planning. Challenges (J).

4. UNIQUE FEATURES ASSOCIATED WITH CASCADE SYSTEMS AND THE ENVIRONMENTAL SERVICES OF THEM

It has been explained in the third paragraph that in the cascade system, it consists of several small tanks and under them paddy fields, associated gardens and other crop lands. In addition, there are several other important features associated with these tanks and the surrounding area, they provide very important environmental services. In this section, a brief explanation of those elements and the various environmental services they provide is presented. Some of the elements are also described in the third paragraph, but here they are again summarized based on their environmental service. For easy understanding the features and their environmental services are tabulated and shown in the Table 3. The locations of these elements is roughly shown in Figure 2.

Table 3. Components and their role in a small small tank cascade system.

	Component	Location	Main environmental service/role
01.	Tank	It is located at the most suitable place to collect water according to the topography of the land above the paddy fields.	The main function of the tank is to store rainwater and release that water for cultivation purposes. In addition to this, it provides many ecological services such as providing water for various needs including drinking water requirements, provide water for domestic and wild animals, maintaining groundwater levels at an optimum level, providing relief to dry environmental conditions, and make a habitat for freshwater fish.
02.	Immediate catchment	Area with scattered trees and shrubs above the tree belt	Keeping the groundwater level high by allowing rainwater to seep into the soil gradually and releasing water into the lake by underflow. Filtration of silt and absorption of toxic materials by some plants.
03.	Tank catchment	Upper part of the lake. Shrubs and trees are found here	Increases biodiversity by creating a favorable environment for bird species, controlling the flow of water into the tank, filtering silt, and absorbing toxins.
04.	Sluice	A controllable opening located in the tank bund through which the water is discharged. Based on the location there may be two sluices named “Goda sorowwa”(at the shallow place) and Mada Sorowwa (at the deep place).	The release of water from the tank for cultivation purposes is done through the Goda Sorowwa. While today's sluices are designed with hinged lids, but in the past, small tanks often used Kata sorowwa. The mud sluice is used when the water in the tank is low or to empty the tank.
05.	Outer spill	When the water in a tank overflows, the outer spill is the place where the excess water is allowed to flow out. In most cases, the spill was arranged at one end of the tank bund by laying the stone slabs or concrete down to the level of the bund.	During the high rainy period, the excess water draining away from this by preventing the damage to the tank bund.
06.	Drain canal	A canal to discharge the drained water from paddy fields	Helps to remove salt and iron rust from paddy fields. (reduce iron toxicity in paddy lands)
07.	Scrub and Chena	Non irrigable highlands over the tank where the chena cultivation/highland cropping are done	Cultivation of necessary vegetables and grains is done in these plots. An agricultural ecosystem. Nowadays, its diversity has decreased.
08.	Irrigation canal	The canal that carries water from sluice to paddy fields.	Use to supply water for paddy farming.
09.	Kurulu Paluwa (unharvested area reserved for birds)	An unharvested plot of land for birds.	This provides food for other animals including birds. Birds also control insects in the field.
10.	Water hole	Pits for water collection located slightly into the forest over the tank.	Control of siltation of the tank. Keeping ground water level high, providing water to wild animals.
11.	Hamlet	The highland where people settled	Due to the location near the tank, the ground water level is high. A piece of land with various trees and crops. Contributes to biodiversity conservation.
12	Tis babe	Reserved land area behind the hamlet	This land is used to keep buffalos which prevents mosquitoes coming into the village.
13.	Kattakaduva (Interceptor)	A strip of land located between the tank bund and paddy fields. Various shrubs can be seen in this land strip.	Filtering the salts, iron and other toxins. A biodiversity favorable micro climate is available.
14.	Isvatiya (soil ridges)	Soil ridges close to the tank bund located at the both side of the tank	It prevents the soil from being washed away from the sloping land into the tank.
15.	Tree belt and filter	The tree line at the end of the tank and the surrounding undergrowth	The tree belt acts as a windbreak and reduces water evaporation. Creates a cool environment. The roots of large trees create a suitable environment for fish to breed. The “filter” filters out the silt. Creates an environment suitable for small creatures.

5. WHAT IS SUSTAINABLE LAND MANAGEMENT?

In general, land management can be defined as the proper use of land to obtain a product or service. So what is "sustainable land management"? There are many definitions for this, and they often convey fairly similar meanings. According to the United Nations definition, sustainable land management is;

"The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions".

Accordingly, soil, water, animals and plants should all be taken into account in sustainable land management. Mainly aiming at the production of goods or materials for human needs, the long-term productivity of land-related resources and related environmental actions should also be maintained in a proper manner. In order to achieve this goal, it is essential to use different strategies and activities in land use, and a comprehensive explanation of this is presented in the seventh paragraph.

According to WOCAT[6] information, sustainable land management has the potential to increase crop yields by 30%-170%, it increases water use efficiency by up to 100%, and also possible to increase carbon content by 1% in degraded soils and 2-3% in non-degraded soils.

[6] WOCAT. 2007. Where the land is greener: case studies and analysis of soil and water conservation worldwide, edited by H.P. Liniger & W. Critchley. World Overview of Conservation Approaches and Technologies (WOCAT).

6. PRESENT ISSUES ON LAND USE AND MANAGEMENT

Various issues have been raised regarding the current land use and management of dry zone cascade systems. Non-sustainable land management has also significantly contributed to many of these issues. The problems[7] associated with these systems can be described under four main areas. They can be classified as (1) land-related issues, (2) water-related issues, (3) environment-related issues and (4) other issues.

(1) Land-related issues

Major issues under this are;

- Soil erosion
- Land degradation
- Soil compaction
- Water scarcity (Inadequate soil moisture for crop cultivation)
- Decrease in soil fertility and weed infestation in cultivated land
- Decreasing cropping area extent and land fragmentation

(2) Water-related issues

- Pollution of surface and underground water due to various reasons
- Inadequate water for cultivation
- Waste of water due to poor maintenance of irrigation structures and destruction of them.
- Increase the salinity of water.
- Lowering of ground water table and reduction of water recharge.

[7] These issues were compiled based on farmer discussions and literature.

- Crop damage due to Iron toxicity

(3) Environment related issues

- Deforestation
- Damage to biodiversity
- Distribution of invasive plants
- Unexpected weather changes (The occurrence of flash floods and prolonged periods of drought)
- Health related issues of the people (E.g.: kidney disease)
-

(4) Other issues

- Wildlife threats
- Inadequate lands due to population growth and increased state land encroachments.
- Marketing issues
- Issues regarding inputs (High price and unavailability etc.)
- Tendency of new generation leaving agriculture and related labor problems

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7. SUSTAINABLE LAND MANAGEMENT STRATEGIES AND ACTIVITIES

Sustainable land management strategies and the activities are explained in this section, and those strategies and activities can be applied to the lands associated with the cascade systems as well as to the lands that are under different uses in other landscapes of Sri Lanka. Furthermore, according to the definition of sustainable land management, this includes the sustainable use of all natural resources including soil, water, plants and animals.

Sustainable Land Management Strategies

(1) Minimize the soil erosion and conservation of soil moisture through the maintenance of land cove appropriately.
(2) Increase the absorption of excess water into the soil by properly controlling the runoff on the surface.
(3) Soil nutrient recycling
(4) Integrated Pest Management
(5) Nutrient management
(6) Integration of crop cultivation and animal husbandry
(7) Selection of crops according to the land suitability
(8) Surface and ground water conservation
(9) Protection of suitable habitats for various species.
(10) Biodiversity conservation
(11) Reduce the pressure on lands

Major sustainable land management activities that can be adopted in the field

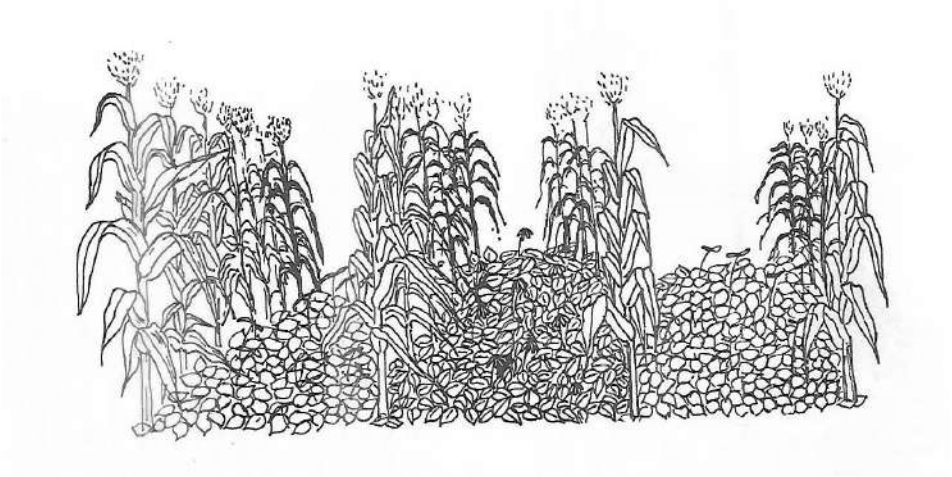
	Strategies	Main Activities
01.	Minimize soil erosion and conserve soil moisture through proper maintenance of land cover	▪ Mixed cropping ▪ Live/Dead/Organic mulching ▪ Use of fertilizer appropriately
02.	Increase the infiltration by properly controlling the runoff	▪ Implementation of agro-forestry ▪ Use of Agronomic/Mechanical/Biological soil conservation measures ▪ Mulching
03.	Recycling of soil nutrients	▪ Use of organic fertilizer ▪ Implementation of agro-forestry ▪ Use of live mulches ▪ Planting of shade trees ▪ Soil conservation
04.	Integrated Pest Management	▪ Apply pesticides only when necessary ▪ Use of herbal pesticides ▪ Creating a suitable environment for the promotion of predators ▪ Use of traditional methods for pest control
05.	Management of crop nutrient (fertilizer) use	▪ Application of mixture of chemical fertilizers and organic fertilizers ▪ Use of chemical fertilizers as per prescribed recommendations ▪ Use fertilizer based on soil tests ▪ Application of fertilizers at the right time of crop growth and when soil moisture is available so as not to waste ▪ Reducing wastage through the use of slow releasing fertilizers
06.	Integrating crop production and animal husbandry	▪ Combine animal husbandry with crop cultivation whenever possible ▪ Combine Agro-forestry and animal husbandry (Silvo-pastoralis)
07.	Selection of crops according to land suitability	▪ Determination of land capability and land suitability and selection of crops accordingly ▪ Cultivation of crops according to a land use plan prepared at the farm level
08.	Conservation of surface and ground water	▪ Repair and proper maintenance of irrigation structures ▪ Control of silt inflow to tanks ▪ Proper maintenance of reservations required for waterways/sources ▪ Preventing adding of agrochemicals and animal wastes to water ▪ introduce practices to increase water infiltration into the soil ▪ Appropriate maintenance of components such as water hole, kulu wewa etc.
09.	Protecting suitable habitats for various organisms	▪ Conservation of forests and scrub ▪ Conservation of features found in the tank like Kattakaduwa, Gas Gommana ▪ Optimum/minimum use of pesticides
10.	Biodiversity conservation	▪ Conservation of forests, scrub and other vegetation ▪ Conservation of features found in the tank like Kattakaduwa, Gas Gommana

		▪ Optimum/minimum use of pesticides ▪ Control spreading of invasive plant and animal species ▪ Not blocking corridors necessary for movement of animals ▪ Protection of Environmental Sensitive Areas ▪ Maintenance of structures like kulu wewa/goda wala (water hole) ▪ Maintenance of diversity in agro-ecosystems.
11.	Reducing pressure on land	▪ Plan the land use according to land suitability ▪ Minimize land fragmentation and see the potential for land consolidation ▪ Introduction of other livelihood activities based on agricultural products ▪ Increase the unit production

A detailed explanation of a selected few of the above mentioned activities is given below to enhance the knowledge of the reader.

1) Mixed cropping

Mixed cropping is the cultivation of more than one crop at the same time on the same plot of land. Here, the selection of crops should be done carefully. Crops should be selected in such a way that they do not compete for sunlight, water and other factors required for crop growth. For example, using a mixture of a tall crop and a short growing crop helps to make optimal use of sunlight. In the dry zone, cultivation of maize and cowpea in the same plot of land simultaneously can be taken as an example. Also, intercropping with crops that provide shelter for pests that can damage one crop should be avoided.



Maize, Cowpea and Soybeans as a mixed crop

Advantages of mixed cropping

- Soil erosion is minimized due to complete ground cover.
- Even if there is a crop loss in one crop, it will be compensated by the other crop.
- By intercropping a leguminous crop, nitrogen is supplied to the soil by fixing atmospheric nitrogen. It also helps in the growth of the other crop.
- Sunlight is optimally utilized for food production.
- Natural weed control as it covers the ground.

2) Mulching

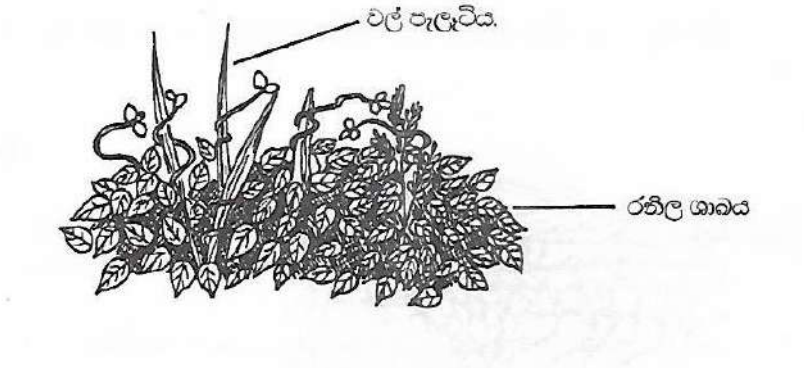
The use of any non-living (dead) or living material (e.g. vines) to cover the space between crops in the ground is called mulching. Here leguminous vines are grown to cover the ground as live mulch. For example, the cultivation of Pueraria as a cover crop in rubber cultivation. Crop residues or paddy straw can be used as dead mulch. Nowadays, the use of polythene film as a mulch is popular.

Mulch can be prepared from materials on the farm (e.g. crop residues) or brought from outside the farm.

Use polythene as a mulch (Source: Internet)

Straw is used as mulch in a chili cultivation

(Photo: Healthy Landscape Project)



Suppress of weeds by leguminous mulch

Advantages of Mulching

- Minimize soil erosion
- Fertilization of the soil due to the addition of organic matter to the soil
- Control of weeds
- Fertilization of soil due to the fixation of atmospheric nitrogen by live mulches.
- Maintaining optimum soil temperature

3) Agro-Forestry

This is the cultivation of perennial plants/scrubs and crops selected according to a certain pattern on the same land at the same time. Here two main features of the cultivated land can be observed. The two elements are perennial plants/shrubs and crops. In this case, the shrubs are periodically pruned and the green manure generated is applied to the crop as a mulch. There are several factors to be considered when choosing shrubs. That is;

- Plants should be of multipurpose qualities such as providing of firewood, green manure, animal fodder and shade.
- Should have deep root system. It helps to bring plant nutrients from deep layers in the soil to the soil surface while minimizing competition for nutrients with the crop.
- Able to fix the atmospheric nitrogen.
- Can be eradicate from the field easily when needed.
- Must be able to withstand frequent pruning
- Must be easily propagated by seeds or cuttings.
- Must be able to withstand long dry periods.
- These shrubs should not be an anchoring place for diseases and pests harmful to crops.

Examples of shrubs are Gliricidia and Pavatta.

Thus, perennial plants/shrubs and crops can be established in different patterns. Accordingly, agroforestry systems have different names. These different types of agroforestry have different advantages and some disadvantages, and however, agroforestry plays an important role in sustainable land management. Different types of agroforestry can be categorized[8] as given below for ease of understanding.

1) Agri-silvi culture
    a. Alternatively done
        i. Chena cultivation
        ii. Farming with improved fallow
        iii. Taungya/Participatory forestry[9]
2) Mixed forestry at the same time
        i. Presence of perennial plants in a cultivated land (presence of Mee trees in paddy fields, presence of fertilizing plants around paddy fields, natural grass/herbs around paddy fields, Ovita, tree belt, kattakaduwa, etc.)
        ii. Plantation mixed forestry (coconut under/intercropping, rubber intercropping, shade trees in tea plantations, shade trees in export crop plantations etc.)
    b. Agroforestry in which different zones can be identified at the same time
        i. Avenue/Alley cropping
        ii. Sloping Agricultural Land Technology (SALT)
        iii. Live fences

[8] Weerakoon W.L. 2009. Sustainable Agriculture, Its principles and agro-forestry. C-SARD. MONLAR. Sri Lanka.

[9] Taungya is a system of forest management in which land is cleared and. planted initially to food crops. Seedlings of a desirable timber species are then planted on the same plot of land, either in combination with the food crops, or following several years of cultivation..

iv. Boundary planting
v. Wind brakes

c. Forestry with animal husbandry
    i. Cultivation that can be done at the same time as well as in zones
    ii. Cultivation of grass, herbaceous plants/shrubs and rearing of animals

d. Crops, farm animals and forestry
    i. Home gardens (These three components are available in Kandyan home gardens, low country and dry zone home gardens)

e. Other components
    i. Apiculture with forestry
    ii. Aquaculture with forestry

Cowpea and Maize in an alley cropping with Ipil-Ipil trees

Advantages of Agroforestry

- Soil conservation
- Plant nutrient recycling and soil fertilization (Nutrients from the lower layers of the soil are absorbed by deep rooted shrubs and returned to the soil surface by their leaves).
- Act as windbreaks and reduce evaporation
- Creating a more favorable micro-environment
- Suppress the weeds as a result of the shade created by well grown shrubs in the fallow period.
- Receive firewood and fodder as additional benefit.

4) Soil Conservation

Various methods can be used for soil conservation. All these methods can be classified under three main categories according to their nature. That is;

(a) Mechanical measures

These methods are more suitable for steeper land. These may cost more but are more effective. Also, proper maintenance of these structures is essential, otherwise the damage caused by heavy rains is likely to be greater than without these methods. Some of the commonly used methods are mentioned below.

- Soil bunds (mostly suitable for dry areas).
- Lock and Spill drains (mostly suitable for wet and intermediate zones).
- Stone bunds(This method is suitable if stones are abundant)
- Terraces (suitable for sloppy lands).

- Contour platforms (suitable for steep of moderate slopes and suitable for plantation crops).
- Single platforms (Suitable for steep lands, Suitable for export agricultural crops, plantation crops, fruit crops, and forest plantations).

The use of soil bunds for soil conservation in a maize field
(Photo: Healthy Landscape Project)

Lock and spill drains are used in a cultivated field (Source: SriCAT website).

(b) Biological measures

- Hedgerows (Suitable for Moderate or steep slopes. Improve the soil fertility. Conserve the soil moisture).
- Planting of Vetiver grass (plants along the contours).
- Cover crops (Minimize the soil dispersion. Conserve soil moisture. Can be used for plantation crops).

(c) Agronomic measures

- Mulching (Minimize the soil dispersion. Conserve soil moisture. Maintain the optimum temperature of the soil).
- Contour planting
- Minimum tillage (Only suitable for certain crops).
- Selective weeding
- Use of organic fertilizer
- Forest plantation/Agroforestry/Permanent crop cultivation

Moisture conservation in coconut cultivation as a sustainable land management method (Source: SriCAT website)

5) Maintenance of diversity in agro-ecosystems

It is clear that a natural ecosystem is well-diversified. Natural cycles are found in these ecosystems populated by different flora and fauna. For such systems, no external inputs are applied, and the system itself is self-reliant. When considering the current agricultural ecosystem, it is not self-sustaining. But considering the current agricultural ecosystem, it is not observed that the system is self-sustaining. Thus, for some degree of self-sufficiency to occur, agricultural ecosystems must also be diverse. Ancient agricultural ecosystems in particular were comparatively more diverse, thus preserving their sustainability to some extent.

The diversity of agro-ecosystems can also be improved by integrating multiple elements such as multi story home gardens, mixed cropping, live fences, agroforestry, vegetable cultivation on bunds of the paddy fields, leafy vegetable cultivation on suitable areas of the paddy lands, fish farming with paddy cultivation (not popular in Sri Lanka). This leads to sustainable land management.

"Protect Land Resource by managing the lands sustainably"

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