Potentials of Reservoir Cascade Ecosystem in Adaptation to Climate Change

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1. Introduction

Global climate is changing. Since 1850, eleven of the warmest twelve years are recorded during the twelve year period from 1995 to 2006. Linear warming trend during last 50 years is twice that for the last 100 years. Precipitation has been significantly increased in mid and high latitudes and reduced in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Severe and long droughts have been recorded in the tropics and sub tropics since 1970. Occurrence of extreme weather events, such as, extreme temperatures, intense tropical cyclones and floods are observed during the last 50 years (IPCC, 2007). Warming will be well above the global average in South Asia during the 21st century and summer precipitation will be increased in South Asia during the same period. Intense precipitation and tropical cyclone events are very likely to increase in South Asia (Christensen, 2007). The facts prove that any practices for environmental management should consider the effects of climate change.

Climate of Sri Lanka is also changing. Decrease of annual rainfall and increase of air temperature in Sri Lanka is well recorded. During the instrumental period both monsoon rainfall have been decreased and both intermonsoon rainfall have slightly been increased (Jayasundara, 2004). Variability of monsoon rainfall has been increased. Water, agriculture, health and coasts are found to be most vulnerable to climate change in Sri Lanka.

Dry zone rural agriculture is the most effected sector by climate change in Sri Lanka. High percentage of paddy production in Sri Lanka comes from the Dry Zone and rice cultivation requires highest amount of water compared to all other major crops. Consequently, rice cultivation will mostly affect as a result of water scarcity. Furthermore, reduction of high rainfall at the beginning of the Maha season and increase of rainfall during the harvesting period extend the deterioration of agro-climatic conditions required for rice cultivation. As a result, agriculture sector will be further weakened.

It is need to find out low-cost sustainable methods and technologies to adapt to the climate change. Poor small-holder farmers are engaged in the agriculture sector in Sri Lanka, especially, in the Dry Zone rice production, and therefore, there is no alternative solution other than low-cost technologies. It is also need to conserve water to be used in required periods maintaining their health conditions. Water scarcity is reducing not only the agricultural potential of the Dry Zone but also the living standards of its inhabitants.

Learning from the history of Sri Lanka, it is found evidence of sustaining severe droughts and famines by Dry Zone dwellers with better management of natural resources, particularly, water. Collection of rain water in a cascade of small to large reservoirs was the major strategy in this ancient technology. Development based on such a system has not only resolved the major problem but also improved the environmental conditions by making available water to the whole ecosystem. Therefore, there is a need to investigate the potential of the system consisting cascade of Wewa and Wewa ecosystems for meeting future requirements modified by climate in the Dry Zone of Sri Lanka.

General objective of this study is to assess the multifunctional roles of the reservoir cascade and ecosystems of Dry Zone of Sri Lanka which were supported flourishing of the civilization for centuries, in order to find potentials for adapting in meeting the challenges imposed by recent climate change.

Specific objectives are to:

To investigate the nature of cascade system of water storage and distribution components of the selected river basin;

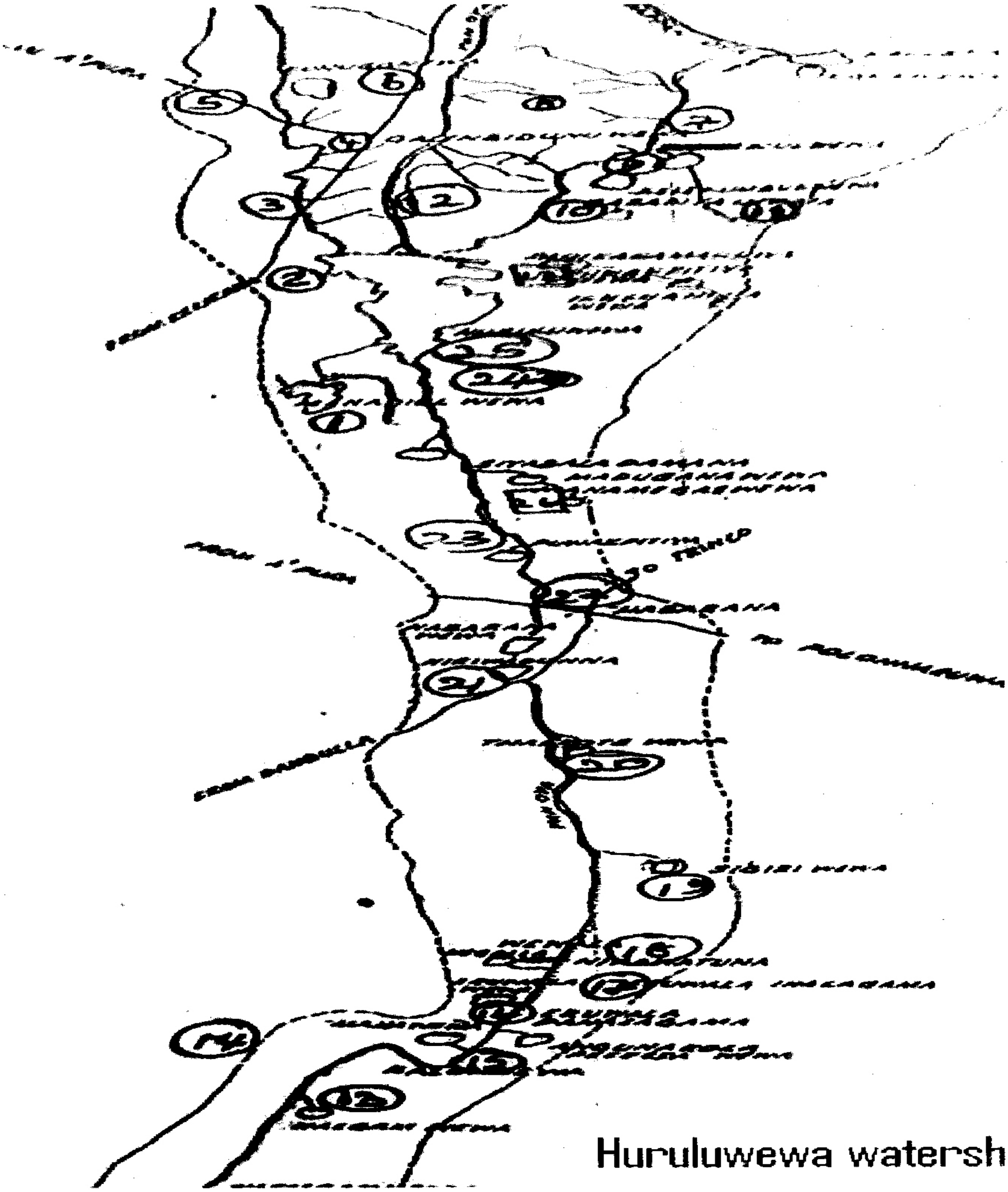
To tabulate and comprehend socio-economic and environmental functions of reservoir ecosystem by combination of primary and secondary data, and

To find out advantages of above system in adaptation to climate change.

2. Material and Methodos

Field investigations, Map reading and literature survey are the methods applied in this research for data collection. Huruluwewa watershed including feeder canal from Lenadora to Seegirimulla, Yan Oya from Sigirimulla to Huruluwewa, its catchment area, the reservoir, command area and the drainage area were mapped and identified 'micro-watersheds' and ancient canals by field observations. Intensive data collection on components and functions of ecosystems was conducted. Identification of the functions of the eco-system further was strengthened by recent publications on the matter.

Identification of water storage and distribution system was conducted by reading 1:50,000 map and field clarification, particularly, ancient canal and small reservoirs were found in the river basin those were not shown in 1:50,000 map. The list of ecosystem components was prepared by making references to literature. The socio-economic and ecological functions of each component were established by analyzing data collected from 17 key informants to represent each micro-watershed and. Further, some of the functions were added to the table from literature survey. Standard text reading methodology was employed in analyzing data collected through interview.



Map 1 Huruluwewa watershed

3. Results

3.1. Nature of climate change in Sri Lanka and its impact

Major impact of climate change in Sri Lanka is related with reduction of annual rainfall. Rainfall of both monsoons has been reduced during the period from 1860 – 1999 and however; there is a slight increase of rainfall in both inter-monsoon periods (Jayasundara, 2004). Consequently, if the same trend is expected in near future, usual *Maha* agricultural season will be disturbed: There will be less rain at the beginning of Maha season particularly in December and slight increase of rainfall in March and April. Both these changes are unfavorable for rice cultivation as rice usually requires more water at the beginning of the growth period and dry spell at the later part of the season.

Increase of temperature during all four seasons as suggested by Jayasundara (2004) aggravates the above problem of scarcity of water at the beginning of the season. Increased evaporation, wind speed, rainfall intensity, and droughts, as projected in the climate change scenarios (IPCC, 2007); will contribute further in to the deterioration of conditions of both agricultural seasons. These changes may also result loss of yields due to bad weather conditions at the harvesting season.

Adaptation measures should be carefully implemented to face above changes. Many of the measures suggested are high cost, high tech or address singular events. For example, increase irrigation potential will not solve problems related with total land quality degradation, particularly resulted from the increase of rainfall intensity. Furthermore, agricultural lands need to be considered as agro-ecosystems rather than irrigation systems. Therefore, there should be an integrated approach in selecting measures for adaptation to climate change.

3.2. Cascade system of *Wewa* in the ancient hydraulic civilization

Huruluwewa watershed was defined as the region from which Yan Oya drains to a point at the end of the command area. Accordingly, 1) feeder canal from Lenadora to Yan Oya and its higher elevation area from which water drain to the canal, 2) Yan Oya from its start at Seegirimulla to Huruluwewa, and 3) highland in both sides of the reservoir and command area consisted the watershed.

Eighteen micro-watersheds identified and selected within Huruluwewa watershed as follows: Walgamwewa, Angunawelpelessa, Puwakpitiya, Mahameegaswea, Kokawewa, Ulpathgama, Maradankalla, Nayakumbura, Kalundewa, Eraula, Polattewa, Veheragala, Madawala, Kudarambewa, Telambugaswewa, Kelenikawewa and Olugollagama. The micro-watersheds are divided into three types based on the location and in relation to the cascade components (Table1).

Table 1. Types of micro-watersheds

Type	Names
Water drains to the feeder canal	Walgamwewa Angunawelpelessa Nayakumbura, Kalundewa,
Water drains to Yan Oya	Eraula, Polattewa, Veheragala, Puwakpitiya, Mahameegaswewa, Madawala, Kudarambewa, Telambugaswewa,
Water drains to the reservoir and command area	Kokawewa, Ulpathgama, Maradankalla, Kelenikawewa and Olugollagama

Ecosystems of almost all micro-watersheds demonstrated high degree of anthropogenic influence, while the degree of influence varies among micro-watersheds and some ecosystem components have been more affected than the others. The most effected component in almost all micro-watersheds is Kattakaduwa (wetland below the dam). The Kattakaduwa has been encroached extending the command up to the reservoir bund (dam).

Environmental management system in the ancient hydraulic civilization mainly consisted of a technology that assures most critical resource of water available in critical periods of droughts. This technology constitute water-conveying system consists of a series of tanks that are interconnected by canals, with surplus water coming from the upstream reservoirs and return flow from the upstream service area to the next downstream reservoir. This system of interconnected reservoirs and canals has been identified as a 'tank cascade system' (TCS). A TCS is defined as 'a connected series of tanks organized within a micro-catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet' and is considered as 'one of the traditional land water management systems which has obviously been developed on the basis of catchment ecosystems' (Madduma Bandara, 1985). Sakthivadivel et al. (1996) stated that reservoir cascade system is the most effective water management practice developed in the world to match the capricious nature of rainfall with the geo-morphological attributes of the landscape.

This cascade system comprises small reservoirs call "*Kulu Wewa*", medium sized reservoirs and large reservoirs, and system of canals running within the same river basin and trans-basin canals. The smallest reservoirs had no sluice, no paddy tracts and store water reducing flood flows and maintaining ground water table high during a longer period to support ecosystem with richer flora and fauna. Some kind of cultivation was possible below the dam using the high ground water table.

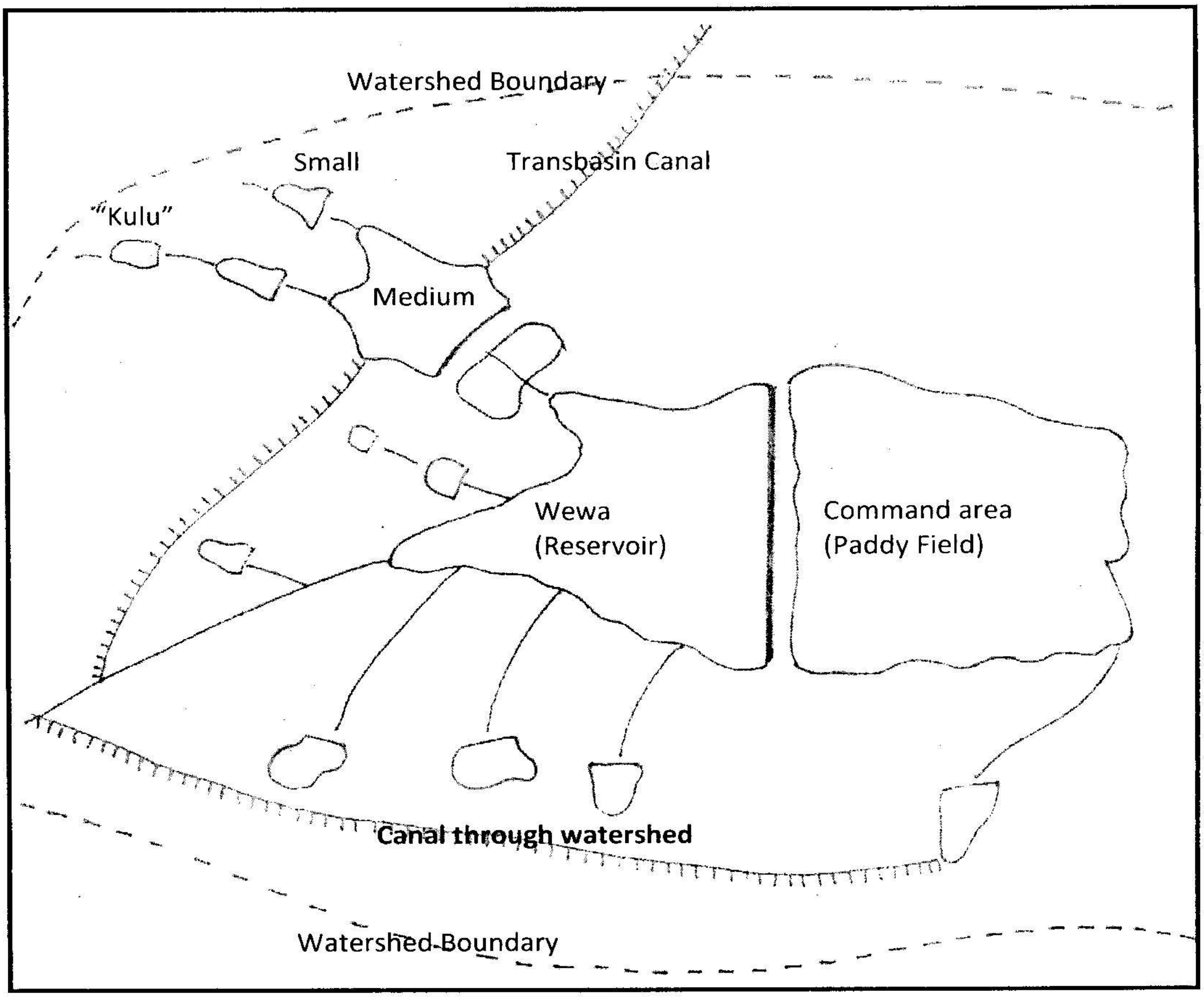


Figure 1 schematic representation of the components of reservoir cascade system

Medium size reservoirs had one or two sluices in the right and left ends of the dam and canals run irrigating below fields. These reservoirs at present call small tanks and include all components of *Wewa* ecosystem discussed below. The sluices constructed of wood and reducing the water level of the *Wewa* a wooden pole is removed in order to issue water. The local term such wooden sluice is "*karahan Kota*".

Larger reservoirs below collect water from outflow of many medium reservoirs and command of larger area of paddy fields. Some canals run along the catchment feeding medium reservoirs starting from a point above in the stream allowing larger area to feed. This technique reduces the speed of water movement to the larger reservoirs as water should flow through whole the catchment and large reservoir may feed from ground water. An example is provided in Huruluwewa catchment where an ancient canal starts at a point above Siyambaladamana and runs through the catchment on its right side of the stream.

Trans-basin canals take water out to another catchment which may need more water. Such a canal runs from the left bank of Yanoya through medium reservoir at Mahadiulwewa to Malwathuoya basin entering to Manankattiya wewa.

3.3. Components and functions of Wewa ecosystem

Construction of small, medium and large reservoirs for collection of water during the *Maha* rainy season in order to use for irrigation, domestic use, maintaining livestock and eco-systems was characteristic to resource management in the Dry Zone of Sri Lanka starting from 500 BC. Diversion schemes of perennial streams to areas of water shortage were also found (Manamperi, 1973). Natural resource management in the anciant civilization supposd to be a sustainable system. The civilization of the Dry Zone based on this hydraulic technology existed for 17 centuries and collapsed due to various reasons. Among the suggested courses of falling down of the civilization are malaria and other epidemics, climate change, salinization of the soil, deterioration of the ruling, conflicts, invasions and war.

Modern rehabilitation of ancient reservoirs has not paid due attention on the multi-functional role of the former reservoir based ecosystems. They were implemented as settlement schemes rather than ecosystems. As a result, at least expected major function of irrigation was not succeeded up to the expatiations. Furthermore, the ecosystems were deteriorated by accelerated soil erosion, changes in the soil formation dynamics and increased evaporation.

The components and functions of the improved ecosystems existed within constructed cascade of reservoirs were documented making field observations, mapping and collecting data from key informants. Many of the systems were destructed by various development activities. Supporting field data with relevant literature following components were identified: 1.forest, 2.highland farming *(Chena)*, 3. Home garden, 4. filtration area, *(Taulla or Perahana)*, 5. reservoir *(Wewa of Kulam)*, 6. breakwater, *(Relapanawa)*, 7. wetland *(Kattakaduwa)* and 8. command (paddy fields)(Table 2).

The forest consists of many timber species and medicinal plants and provides habitat for many types of animals including animals for hunting. These forests were maintained by strict rules and regulations. They helped sustenance of springs. The other uses of forest are recreation, hunting, and collection of honey, fuel wood and fruits. Timber species consist of both introduces and endemic verities, both fast growing and slow growing and super grade, grade one and low grade varieties. Identified natural forest in this ecological region is savanna grassland with sparsely located trees. Improved wewa ecosystem maintains richer flora with more trees and wetland plant species and aquatic ecosystem which keep wetland conditions throughout the year. The distribution of plant species within the system has also a pattern agreed with the locations of wewa ecosystem components. The ecological and socio-economic functions of the forest are listed in the table 2.

Highland farming *(chena)* has been conducted shifting from location to location after two to three years of continuous cultivation. This is considered as a sustainable farming system with its original characteristics of land preparation, soil conservation measures, crop variety selection and shifting to other locations. Land preparation starts with cutting branches of large trees, cutting of small trees at eye level and then cleaning shrubs and making control fire. The control fire found to be the easiest method of getting rid of weeds and pests. This complex system of land preparation completes with zero tillage seeding after control of erosion by blocking sheet and gullies with remnants of fired wood. This system of complex land preparation methods facilitate to grow valuable trees better and control weeds. Fallow period after cultivation of two to three years last for another twenty years: the soil has been reformed, the forest has been recovered.

Selection of seeds with different growth rates, with different agro-meteorological requirements and different uses assures control of soil erosion as plants cover the ground just after the first rain and make multi-story crop cover later. Selection of crops with different agro-ecological requirements provides assurance of harvesting at least some of the crops which suit with prevailing weather conditions and their by preventing from total lost of yield. Such multi-cropping system comforts year around harvesting.

Home garden in the *Wewa e*cosystem had also specific nature. The settlement was located in a secured one place close to the *Wewa* and was not scattered around the system. The settlement had one compound surrounded by houses with one container of grains *(Bissa)*. There was no individual home garden for each family as it is in the modern context. The garden consisted with timber and crop varieties which require more attention. All were common property of the community.

Gas Gommana mainly consisted with trees that require more water and surrounds the Wewa. These tree species are multi-functional, with medicinal, food and other values. This tree belt around the *Wewa* breaks the dry wind and reduces evaporation from the water surface. Some of the trees have also biological function of cleaning water.
A belt around the *Wewa* with grasses and aquatic plants is called filter for its function of filtering of water entered in to *Wewa. Taulla* and *Perahana* are some of the local terms for this type of section. This section is reach with aquatic plants and grasses and stretched along the streams and also named as a constructed wetland efficiently removes pollutants in order to sustain the system (Mahatantila, 2008). Water moves through this wetland before entering to the Wewa and many hazardous elements are absorbed by the land and tree species and clean water moves down to Wewa. One example of such effective species is **Terminalia Arjuna** (*Kumbuk*). *Kumbuk* seeds move from upstream floating and lands along the flood level of the wava during the rainy season and start growing. This species is tolerant to flooding, many days can survive under water and adult trees may grow permanently keeping all the roots under water. *Kumbuk* tree absorbs salinity in water and store it in the bark. As much area of the dry zone soil consist high proportion of calcium carbonate, the bark of *Kumbuk* is also consists of much calcium carbonate. The bark of *Kumbuk* is removed and burned and ash with high content of calcium carbonate was used in making paintings. Removal of the bark not make harm to the tree as it can recover itself. The ecological and socio-economic functions of *Thaulla* are presented in the Table 2.

Wewa is the main component of the ecosystem as it plays central role in keeping ecosystem and providing most needed source of water in the most part of the year. *Wewa* provide habitats for many aquatic flora and fauna species including fish for catching. Many species of reptiles and birds live around *Wewa.* Most of these species survive due to availability of water collected in *Wewa.* Furthermore, the keeping of the ground water table high by *Wewa* water levels throughout the year supports many other species to survive.

Breakwater (*Relapanawa)* constructed in comparatively larger *Wewa* using stones which is another component of the system protecting Wewa itself from breaking the dam and keeps water clear. Clean water for bathing is assured at some selected places along the breakwater.

A real wetland that keeps wet during whole year is available below *Wewa* dam. Water leaking through the dam enters in to this strip of land below the dam. Leaking water contains a lot of minerals and, specially, iron oxides and may contaminate below paddy fields if directly entered. A small ridge out of mud has been constructed preventing water movement below. Hence, above the ridge water is available all the time and usually water does not move to paddy fields. During heavy rains water collected in this strip flushes down without giving an opportunity to absorb by paddy fields. In this wet land many tree and other species that require wet conditions and high mineral contents grow well and absorb salinity.

The paddy fields below *Wewa* are the targeted main beneficiary of collected water and grow rice- the most water required staple food in the world. The fields consist of low humic glay soils, with a hard pan below retaining water on soil longer without leaking down and making water logged conditions. Moreover, the field tracts with ridges closely constructed help retaining erosive material during heavy rains.

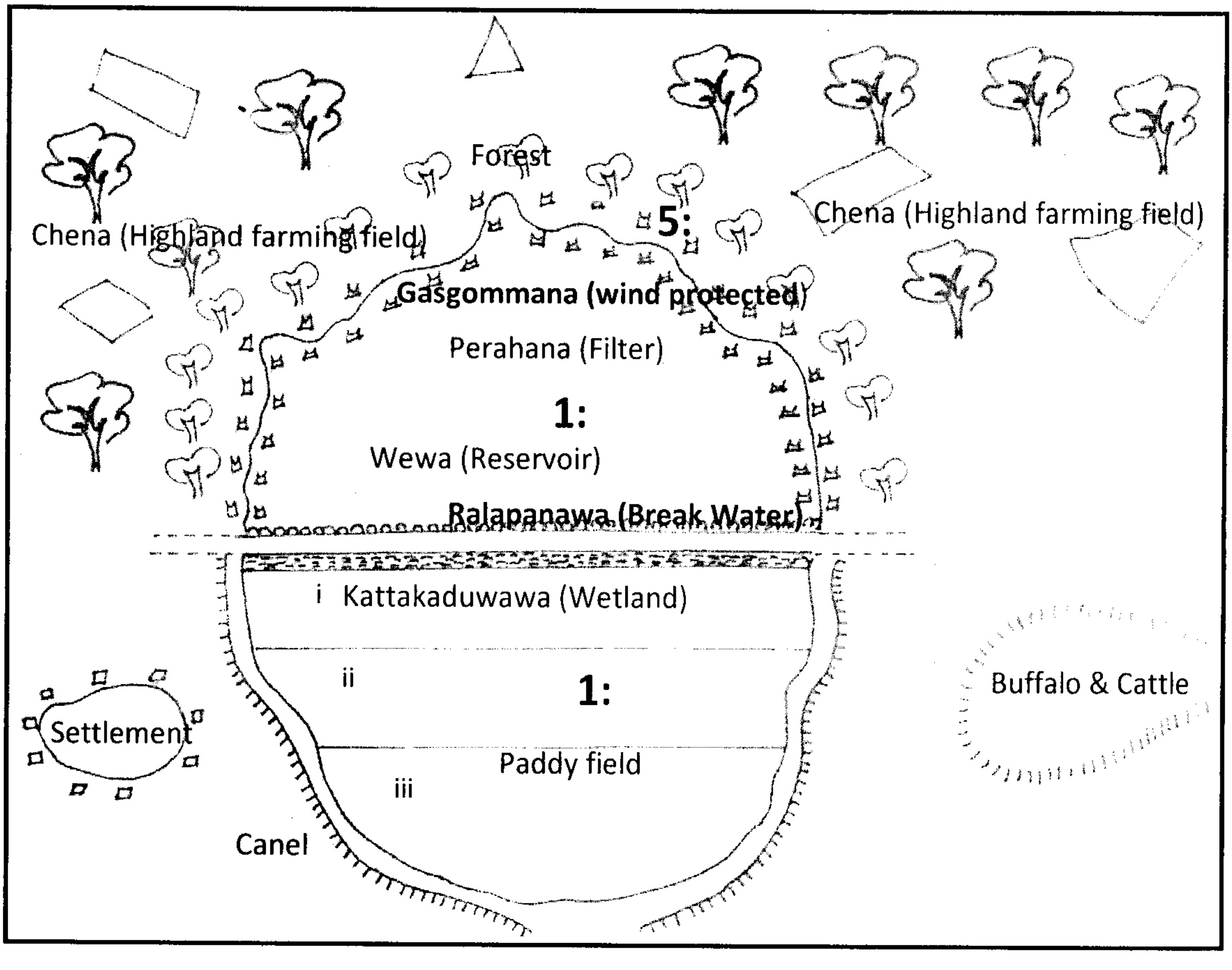


Figure 2. Schematic representation of Wewa ecosystem components

Proportions of catchment, reservoir and command area is 5: 1: 1. The catchment is five times larger than the reservoir and the command area is same size as the reservoir. A sketch showing the spatial distribution of component is shown in Figure 2.

Table 2 Ecosystem components and functions

Component	Ecological function	Socioeconomic function
Forest	Maintain biodiversity, keep comfortable environment, soil formation, reduce soil erosion, reduce surface flow, keep up springs	Supply timber, medicines, honey, food, fuel wood, animals for hunting, recreation
Chena (highland farming)	Control forest, modifications to the food chain, modifications to the biogeochemical cycles, modifications to the biomass production, acceleration of soil erosion	Production of almost all food crops except rice, crops for other nees
Home garden	Keep up vegetation cover almost analogue to the natural forest with a mix of forest and non-forest species	Growing of essential medicines, fruits, trees for timber, comfortable environment, fodder
Gasgommana (wind belt)	Reduce wind speed, reduce evaporation, reduce erosion,	Shelter and comfortable environment for domestic animals and people, growing specific species of medicines, fodder
Taulla or *Perahana* (filter)	Reduce wewa siltation, habitat of birds, protect from pollutants, control storm flow ,water quality amelioration	Pasture, plants used in production of mat and other household items, clay for pottery and bricks
Wewa (reservior)	Maintain aquatic ecosystem, water purification	water for irrigation, bathing, drinking, washing, food (fish and plant products), flowers
Ralapanawa (break water)	Break waves, protect wewa from breaking the dam, keep water clear	Protect the dam, bathing places
Kattakaduwa (wetland)	Absorb salinity of leaking water, maintain specific wetland ecosystem	Grow wetland species of medicines and food crops,
Paddy fields	Arrest erosive material	Produce major staple food

3.4. *The Potentials of Wewa ecosystem in adaptation to climate change*

Wewa ecosystem can be considered as a well planned system for improving environmental conditions in dry lands. Water is considered central in all other natural recourses and the system reduces the flow of water by several means, such as collecting in Wewa, up keeping springs; allow natural regeneration of vegetation in selected locations. The system itself maintains the water quality, by constructions and biological means, for instance, by maintaining a wet land below the dam and above the water body. The system increases biodiversity by providing space and better conditions for species that require more water. Hence, this system processes most needed requirements to adaptation to climate change, particularly in the dry zone of Sri Lanka.

Nevertheless, This Wewa ecosystem has been declined due to implementation of modern irrigation and other infrastructure developments. Many of small Wewa have been converted in to paddy lands by establishing major settlement schemes and Mahaweli project. Furthermore, size of water spread area and the command have been increased by those settlement schemes resulting, water scarcity for larger area of lands. Due to rehabilitation of larger Wewa, without consideration of ancient canal system, water flow speed has been increased. This is a result of adaptation of modern irrigation engineering, which expects speed flow to the reservoir. Construction of road systems also has neglected ecosystem functions due to unawareness of the value of the system. Self interest values of settlers at present has further deteriorated the system by encroaching vulnerable components of the system for growing crops.

Another issue in relation to modern context of adaptation is laid with settlement planning. With higher population requiring secure and comfortable place to live, planning of settlements should consider small town rather than allowing people to settle themselves where the wish. This measure will not only provides protection against adverse effects of climate change but also offers opportunity to present modern utilities effectively such as electricity, water supply, and other urban facilities.

Projected climate change imposes the need for improving environment so that people can live and work productively in the Dry Zone. With the increase of temperature and dryness the Dry Zone is becoming an area where productive agriculture and comfortable life in the modern context is impossible during the next few decades.

Dryness during southwest monsoon period with a potential to turn to droughts, reduced rainfall during the northeast monsoon gradually deteriorates the conditions.

Wewa ecosystem regeneration is one of the best strategies in selecting measures to adapt to climate change in dry lands. Spring regeneration by protecting watersheds, forest plantations with consideration of transpiration levels of tree species in scrublands, *Chena* land stabilization, proper arrangement of the settlement, maintenance of *Perahana*, *Kattakaduwa* and other components are the major elements that should be incorporated into any climate change adaptation strategy in the Dry Zone.

4. Discussion

Secrets of the ancient hydraulic civilization have been studied by many authors of many fields such as geographers, historians, archeologists, sociologists, engineers and many others. Besides, there is still a huge indigenous knowledge among people. However, when development activities are proposed the knowledge is not incorporated in the plans. Climate change advocates again the need for consideration of the ancient technology is a must. It is the role of scientists not only to uncover the secrets but also to make pressure on planners to consider such technologies for the benefit of the nation.

5. Conclution

Climate change is an inevitable condition which needs an integrated approach in adaptation, particularly, in the Dry Zone of Sri Lanka. Ancient civilization continued for around two centuries has successfully faced similar situations by construction of Wewa ecosystem with a systematic cascade of reservoirs and canal systems. There are specific ecological and socio-economic functions performed by each component of the system. This system has been neglected and deteriorated by modern development activities. Still there is a potential of regeneration of the system. Scientific investigations of the components and functions of the system help to understand their potentials. Regeneration of these ecosystems possesses a large potential and economic gain in the long term sustainability of the settlements.