SMALL TANK SYSTEMS IN SRI LANKA: ISSUES AND CONSIDERATIONS

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Physical and Hydrological Aspects

Different scholars have made different estimates of the number of small tanks in Sri Lanka ranging from 12,000 to 16,000. About half the existing number of small tanks seem to remain either dilapidated or abandoned. This being an approximation a more realistic inventory of small tanks in operation and in abandonment needs to be prepared.

As per origin of tanks, gaps in knowledge are very many. When did people really start constructing tanks? Was it with the advent of Vijaya and his companions or even before? Did they first practice a highland form of agriculture around natural water pools (villus or wilas) and on the banks of the streams or created artificial pools by blocking of the streams near their upland farms for personal use and gradually improved those pools (wilas) and stream blockades to commence settled irrigated agriculture? Along a cascades main axis stream where did settlers constructed tanks first; in upstream areas moving downstream or *vice versa* or at a mid-point moving upstream first and then moving downstream? Answer thus far advocated to meet these questions are in their embryonic form. Hence, more investigations are necessary to answer them fully.

Small tanks are heavily concentrated in the Dry Zone. Recent studies on the major river basins, sub watersheds and small tank cascades in the Rajarata with due reference to topography soil, rainfall probability and hydrological characteristics, have contributed significantly to expand the understanding the setting, distribution patterns and hydrography of the small cascade systems in the Dry zone. It has been also shown that consideration of a meso-catchment or cascade of interlinked small tanks (STCS) provided a reliable base for further analysis and interpretation of the hydrological basis of small tank systems. This has been clearly demonstrated in a study of 230 STCs of the Rajarata which reveals that 197 of these cascades have an adequate catchment area, but that at the same time 190 of the cascades also have an excess of command area that cannot be serviced by the present tank capacity within the cascade.

Triggering off from the foregoing macro-and meso-morphological studies what is further needed is to try and understand those micro-morphological characteristics (e.g. heennas and mudunnas) which have had a profound influence on the distribution, density, alignment, size, shape and use of small tanks within cascades. When such studies are advanced, they would enable us to acquire a greater 'sense and substance of each tank. Tanks are not isolated entities. Though they may physically differ from one another, they are within certain patterns that are hydrologically and socially determined. They remain economically and socially beneficial and eco-friendly 'pools' of water which have become acclimatized to the extent that they have become an integral parts of the dry zone

environment, with some general resemblance to those in south India, but virtually unparalleled to any other system in the world.

A catchment, storage and command area of a tank are determined hydrologically and socially. The extent of a total catchment area of a cascade determines the amount of run-off that could be collected within the small tanks. The run-off in a catchment area varies depending on gradient, soil characteristics, landuse (e.g in chena lands 30-50%, scrub jungle less than 20 percent, in teak forests 16%), density of drainage and the number of ephemeral streams blocked by the upstream tanks. The water spread area of a tank is a function of the geometry of that tank changed through the siltation process over time as well as the changed condition of the tank embankment, its sluices and spill(s). The ways and means of partial desiltation enabling the return to original tank geometry has been demonstrated and thereby how the negative consequences of present tank geometry could be minimized. It is difficult to comprehend why desilting is avoided and raising tank embankment and raising spill levels preferred. Seeing the importance of not only increasing the tank capacity, but also improving the conditions of tank eco-system which is dangerously deteriorating and small tanks turning to mere grassy swamps it has been reported that if present method of bund raising continued, scientists, planners and engineers cannot escape from the challenge of disappearing of minor tanks from the Dry Zone landscape during the next few decades.

It is argued that cost of desilting a tank is considerably high in terms of the value of paddy that can be generated in the short run by that extra amount of water retained in a tank after desiltaiton. It is difficult to accept because the tank water is not meant for the sole purpose of irrigating a few hectares in its command area. A tank which is multi-functional in terms of receiving, storing regulating and distributing water is truly multi-purpose in character. Economically (for irrigation) socially (for domestic use), religious culturally (for temple goers and its residents use) and environmentally it is indeed multi-purpose in usage.

It is even argued that non-economic purposes for which tank water is used are more important than for economic uses. This finds support from villagers' decision at times, to forego irritated cultivations (in seasons of deficit rainfall) in favour of the use of tank water to meet social needs-drinking, bathing and washing. Though the importance of non-economic functions to which tank water is put into are often inventorized and stressed by many scholars, quantified values of those functions have not yet been scientifically ascertained and demonstrated.

The relations between small tanks and ground water availability in proximity of these tanks is well known. How the shallow regolith acquifers are recharged by tank water, where those acquifers are best found and appropriate spacing and optimal densities of agro-wells in different tank surroundings have been recently studied and documented. It has been found that in respect of fifty cascades in the Anuradhapura districts, the number of agro-wells should not exceed 3,600.

The former equilibrium maintained between a tank, available storage and its command area opened for irrigated cultivation is now in great inbalance. While siltation has reduced tank storage over time, the expansion of 'akkara welas over the past 75 to 100 years both legally and illegally exceeding the tanks' supply capacity has resulted in a high hydrological inbalance causing a perpetual scrambling of too many land-holders in command areas for too little water in these tanks. The demand for water through agro-wells is also placing a stress on the overall hydrological balance. This shortage of irrigation water coupled with land sub-division and prevailing tenurial complexity has aggravated difficulties in the economic use of limited available water.

In the distant past based on rain-fed chena farmers, lowland rice cultivation, homestead mixed garden farming, cattle grazing and herding, tank fishing and food gathering game and tree harvesting, there was a traditionally self-sufficient and inward looking contended life style in equilibrium in tank associated village settlements. This equilibrium having been subjected to external influences has gradually brought about a great disequilibrium, demanding a changed but sustainable production threshold, though the resource base remains limited. Due to chena lands being converted to settled rainfed settlements a high degree of land degradation, soil erosion, tank siltation has taken place. The earlier equilibrium that existed in relation to the tank capacity irrigated area and tree covered catchment area too have been severely altered, thus resulting in severe stress and conflicts both in respect of irrigated rice cultivation and upland rainfed chena cultivation. Further more, production systems too have become different in that they have to be responsive to the prevailing challenges of the open market forces in operation. This also makes it difficult to ascertain realistic production thresholds of both rainfed and irrigated farming systems in the small tank cascade systems.

Institutional Change and Development of Minor Irrigation

One of the main constraints to the development of minor irrigations in Sri Lanka is the continuing change that has occurred over the years, and continues to occur without any regard to it's beneficiaries. Minor irrigations thrive on unique customary water laws and traditions that have sustained a certain level of rural livelihood.

During the pre-colonial era, under the 'Rajakariya' system minor irrigations were operated and managed by the community themselves. The responsibility of management was vested with the "Gamarala" under the "Gamsabawa" system. With abolition of the 'Rajakariya' system in 1932 all customary regulations and traditions began to collapse.

This led to a vacuum in the responsibility of managing minor irrigations which resulted in the degradation of these systems, thus warranting the import of rice to feed the population. Realizing the mistake of abolishing the 'Rajakariya' system, the British implemented the Paddy Lands Irrigation Ordinance – No. 9 of 1856, with the intention of mustering the community organizations to re-establish traditional customs in irrigated paddy cultivation. In 1857, this ordinance was enacted with more state power and recognition give to "Vel Vidane" instead of the "Gamarala". The former was given the responsibility of distribution water equitably to all beneficiaries in a system and attending

to all cultivation activities impartially. The Paddy Lands Irrigation Ordinance was effective till end of the last century. With the tun of the new century, the Irrigation Department was established (1990) and all the irrigation management activities were centralized with the Irrigation Department with the Government Agent taking on the responsibility of minor irrigations with the help of communal labour for maintenance. During this period the handling of water disputes became the responsibility of the civil courts, though the "Gamsabawa" too existed as the main rural institution. In 1932, a new irrigation policy introduced by the Ministry of Agriculture and Lands gave the responsibility of construction and management of minor irrigations to the Irrigation Department. This situation remained until independence in 1948.

Since independence, the responsibility of minor tank management was transferred again to the Ministry of Agriculture due to the heavy involvement of the Irrigation Department with the Gal-oya development project. Subsequently in 1951 and 1956 the Irrigation Ordinance was amended to de-emphasize the role of farmer involvement through enforcement of rigid rules and procedures. These changes destabilized the otherwise self reliant and autonomous farmer institutions that have been in existence since independence. However, with the passing for the Paddy Lands Act of 1958, the Department of Agrarian Services was established in order to encourage farmer participation in minor irrigation development. Under this Act Cultivation Committees were established but lack of legal authority given to these committees malfunctioned their role as an effective village institutions.

In 1972 the responsibility of minor irrigation development was transferred back to the Irrigation Department with the passing of the Agriculture Productivity Law. Under this law, Agricultural Productivity Committees (APC's) were established for the development of irrigated agriculture. However, the composition of membership in these committees were weighted more in favour of officers than farmers. Thus, there was a skewed representation of farmer interests. In 1991, the Agrarian Services Act No. 59 was amended to established farmers organizations (FO's) and to given legal authority to FO's to undertake irrigation contracts. Though this represented the best alternative for farmers, the formation of FO's on village boundaries complicated the independent functioning of FO's. However, in subsequent irrigation development projects this drawback was remedied with FO's being formed on hydrological basis.

While these changes have established the position of minor irrigation with respect to it's construction and management, the latest development under special gazette notification of year 2000 has reverted the responsibility of minor irrigations back to the Irrigation Department. Hence, it is unfortunate that the responsibility has been changing between these departments without the scantiest regard to the large peasant livelihood under village irrigation systems.

Importance of Socio-Economic Considerations

The dry zone farmer had a typical farming system that characterized the crop cultivation under water stress conditions. The "gangoda" (home garden) chena (shifting cultivation)

and "Welyaya" (lowland) were the components of successful farming system that sustained the livelihood of dry zone peasantry. The lowland was mostly cultivated with minor irrigations. However, most of these farmers gave priority to chena cultivation over the other two systems mainly because it was the most stable cultivation practice and also provided most of the family sustenance. Besides, it also provided an assurance against paddy crop failure due to lack of water. Usually the size of the chena depended on the family size, with 2-3 acres as an average. However, due to population increase and pressure on land the size of chena has declined with almost no fallow period between two cultivation periods. These changes have reduced the unit land productivity and total household income.

However, the synergy that exists between chena and lowland cultivation allows prolong chena cultivation to impound more water in small tanks before the commencement of maha cultivation. This incidentally gives the farmer the opportunity of decision making with respect to cultivation. However, one of the main problems of village tank cultivation is the fragmentation of land and complex land tenure patterns. Both these factors contribute to small size of land holdings, which are often economically not viable to cultivate. It has been shown that land sizes vary from 0.25 ac to 1.0 ac under minor tanks in Hambantota. Small size of lands, seasonal cultivation and uncertain income have all contributed to low level of investment on minor irrigation. This is evident in a study where 20 minor tanks were evaluated for its performance after rehabilitation. On an average a family receives Rs. 1000 per month from cultivating paddy under minor irrigation. Twenty five years of data also pointed out that the yield difference between minor and major irrigation to be approximately one ton per hectare.

As a measure of improving productivity under small tanks, various water management practices have been adopted. Some of these practices are traditional while others are more recently introduced. The traditional "bethma" and "Kakulun" have been in existence with minor irrigation since time immemorial. However, increase in "akkarawela" due to legal and illegal settlements have disturbed the water balance in small tanks, thus creating deficiencies in water during yala season even to cultivate a "Bethma". The deteriorating village cohesiveness and traditional organizations have been attributed as reasons for the failure to implement a " bethma". The "bethma" has been emphasized as a result of strong village customs and traditions. More recently, under minor tank rehabilitation programmes, crop diversification has been introduced as a measure of water management. However, in most attempts this has not been very successful due to storage, marketing, and labour problems associated with minor tank agriculture. Location of minor tanks and pre-occupation in chena cultivation have been deterrent factors to adopt more crop diversification.

The recently concluded minor irrigation rehabilitation under NIRP and WFP, suggests that small tank development should be taken as a continuum which is governed by contributory factors and resultant beneficial factors. Hydrological and management factors are the two main components of the contributory factors and it's interrelationship is the input to development of minor tanks. The result of this input is the beneficial factors, which has a direct bearing on livelihood of farmers and their surrounding

environment. The author is of the view that due to the inability of assessing the hydrological factors accurately, number of unsuitable tanks have been selected for rehabilitation, thus resulting in deserving tanks being ignored. Hence, it is suggested that more acceptable criteria and factors should be considered and that all small tanks in the country should be categorized.

Evidently there is a serious policy gap with respect to village irrigation in Sri Lanka. A national policy on minor irrigation should fill the vacuum created by the loss of ancient tradtions and customs. There is a gap between the demand and the real need of the village society, which can only be filled by the bureaucracy. However, the bureaucracy has failed in this endeavor, due mainly to lack of reliable and enhance database on natural resource management. To redress this situation, the department of Agrarian Services is now in possession of a database on village irrigation systems. This data base which consists of 76 main attributes is capable of linking village irrigation systems as well as meso catchment with the help of geographical information system mapping. Hence, it is now believed that the state bureaucracy will be in a better position to meet the gap between the demand and the real need of the village tank communities.

In the light of all the foregoing considerations one questions the scope or the opportunities that would become available for a transformation or a modernization of the various agricultural production systems within tank cascade systems. However, since small tanks constitute a very important part of the rural landscape and it's eco-system, there is a strong rationale for ensuring the sustainability of these settlements for economic, social and environmental reasons.

HISTORICAL PERSPECTIVES ON SMALL TANKS AND FOOD SECURITY

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In the initial of stage formation in Sri Lanka, small village tanks laid the foundation for an agrarian society based on a 'one tank – one village' ecological pattern. Topographical surveyors of the latter part of the nineteenth century have observed that there was one small village reservoir in each square mile in the south-eastern part of the island[1]. The situation in the rest of the Dry Zone was not different. The inscriptions of the first three centuries of the Christian era alone refer to more than 150 such small tanks. Along with medium scale reservoirs such as Abhayawewa, Nuwarawewa and Tisawewa at Anuradhapura; and large reservoirs such as Minneriya, Padaviya and Parakramasamudra; these small village tanks functioned effectively until the middle of the thirteenth century. The most important aspect of these large, medium and small village reservoirs was the interconnection of many of the reservoirs through an intricate network of canals.

This chain of interconnected irrigation complexes provided food security to a large population in the Dry Zone, in the form of provision of water for domestic as well as for agricultural purposes. It also provided most of the protein requirements as inland fisheries was an important economic activity[2]. Inland fishing in fact was much more prevalent than most people perceive. It was so important that there were carefully drafted rules and regulations related to fishing. For example the fifth century Pali text *Samantapasadika* while discussing 'ownership' states that, when someone was fishing. if a fish jumped into the air and if another caught it in the air with hands, the ownership of such fish rested not on the fisherman but on the person who caught it in the air. It was not considered a theft[3].

A question that poses itself as relevant for our theme is whether, agriculture, fishing and such other economic activity related to state owned large and medium reservoirs and small village tanks resulted in hundred percent food security in all eras of history? Although there was food security during most periods of the Dry Zone civilization, there also have been sporadic famines, not less than a dozen in number, recorded in the chronicles such as *Mahavamsa* and *Chulavamsa*[4]. Some of these famines have been local ones and difficulty in transporting grain to affected areas was the cause of hardships. In this context 1998 Noble prize winner for Economics – Amatya Sen's 'Theory of Entitlement' profounded in relation to famines in Bengal in the nineteenth century[5] may be applicable with modifications to some famines in the Sri Lankan Dry Zone as well. But there were also a few serious famines affecting the whole country which resulted even in the human movements from place to place. For

example, the famine called the '*Baminitiya Saya*' which occurred in the reign of Vattagamani (89-77 B.C.) was so serious that a considerable number of monks died while some 24,000 monks left the island to seek refuge in India. The famine continued for several years and the monasteries in Anuradhapura were abandoned. Towards the later stages the famine had grown so accute that some people were forced to live on human flesh[6]. This major famine and other not so serious famines took place approximately over a period of fifteen centuries and considering this length of time they may not give a true picture of food production and food security in pre-modern Sri Lanka.

Yet, irrespective of the development of an intricate irrigation system in the Dry Zone, there had always been uncertainty of food production due to many factors, of which the fluctuation of weather conditions was an important one. The fifth century Pali commentary *Sammohavinodini* refers to the storage of grain in the monasteries at Tissamaharama and Chittalapabbata or Situlpawuva sufficient to sustain twenty-four thousand monks for three months[7]. This indicates two things. First, such storage of grain indicates that there was a surplus of food during certain seasons and secondly it implies that monasteries stored grain because there was an uncertainty of food supplies in certain years. Inscriptions of the fourth century A.D. indicate that grain deposited in mercantile guilds earned an annual interest as high as fifty per cent for rice and twenty-five per cent for other cereals[8]. This again indicates that there was a market demand for grain at various times depending on the vagaries of the weather.

On the other hand, with the extensive network of reservoirs and canals in the Dry Zone, agricultural production was sufficient to sustain the population during most of the eras of the Dry Zone civilization. The large scale construction of dagobas and monastic complexes, as well as other magnificent monuments with exquisite sculptures, and the building of an imposing and intricate irrigation system would not have been possible if there had not been an appreciable quantity of surplus food to feed a substantial workforce. The Pali Literary work *Sahassavatthupakarana* datable to the late Anuradhapura period (9th and 10th centuries), refers to three year old scented rice (*tivassikagandhasali*) which was processed by storing in granaries for three years on various layers of aromatic drugs[9]. If such scented rice was ever consumed in Sri Lanka, it was by members of politically and socially dominant groups namely the royalty, nobility and the priesthood. It was among them that the bulk of the fiscal resource of the country which consisted mainly of the land revenue, was distributed. The average peasant lived at low subsistence level. His plight is lucidly described in the thirteenth century Sinhala classic *Pujavali* which states that after one harvest obtained by labouring hard, day and night, what was left to the cultivator of the soil and his family was barely sufficient for him to subsist on until the next harvest[10].

The popular belief that rice was exported from Sri Lanka also needs to be examined in this context. There is only one solitary reference in the South Indian *Sangam* Text, *Pattinapalai*, one of the ten idylls of the *Pattupattu*, written in the second century A.D. which indicates that foodstuffs were exported to South India from Sri Lanka

(*Illattunavu*)[11]. Perhaps food stuffs referred to here included rice and during times of scarcity, South India may have imported rice from Sri Lanka. But such references do not indicate the general prosperity of one country as compared with the other. The ninth century Muslim traveller, Ibn Khurdadbeh refers to the import of rice to Sri Lanka from South India. Another Muslim writer AI-Idrisi stated in the eleventh century, that Jirbatam was a port in South India which exported rice to Sri Lanka (12).In these instances too, it is unwise to conclude that rice was frequently imported to Sri Lanka from South India during the days of Rajarata civilization. It may be reasonable to conclude from such sporadic and divergent references that during times of crop failures and demand in either country, trade in rice was carried on between India and Sri Lanka.

An important point regarding self-sufficiency of the ancient village needs to be raised here. The ideas of some of the early British administrator scholars on Asia inspired Marx's views on the *Asiatic Mode of Production* characterized by the self-sufficient village economy. The patriotic or nationalist bias of Asian writers too have resulted in an exaggerated and out of proportion account of the self-sufficiency of the Asian village. But it is important to note that although grain supplies were available, some of the essential commodities such as salt, metal and metal implements were not produced in all Asian villages. In Sri Lanka, frequently metals and metal products had to be brought into many of the villages from the few producing and manufacturing areas and salt had to be transported to the interior from the coastal centres. Some of the other needs of the village community which could not be procured locally, too had to be supplied by outsiders which necessitated money exchange or barter. Medieval literature refers to villagers paying currency (*kahavanu*) to purchase ghee, venison and lime. The pedlar or hawker who constantly moved about between the regions played an important role in supplying lightweight commodities such as clothes, rings, necklaces and bracelets to the villagers [13].

By the middle of the thirteenth century, the great cities of Anuradhapura and Polonnaruwa had almost been abandoned, the Rajarata civilization had collapsed and the efficiency of the major and thousands of small tanks had declined. The patches of water retained in tanks provided some from of food security to settlers remaining in the Dry Zone. But the neglect of irrigation system and concommitant spread of diseases resulted in rapid thinning of population. By the end of the fifteenth century only the ruins of the old cities and the silted reservoirs remained as stark reminders of the once flourishing Dry Zone civilization. The bulk of the Sinhala population had drifted to the South-Western part of the Island while most of the Tamils had drifted to the North and East. The earliest map available of the Portuguese connection with Sri Lanka drawn by the Spaniard Cypriano Sanchez sometime around 1606 A.D. contains two notes which suggest that the Yala region and some of the north-central areas of the island had become a 'desert through sickness' (*Deserto per doenea*) [14].

The topographers of the Portuguese, Dutch and early British periods found only occasional densely populated spots in the Dry Zone outside the Jaffna and Baticaloa regions and these too were in the coastal tracts of Kottiyar, Trincomalee, Mannar and

Puttalam. Until about 1931 the interior of the Dry Zone was empty and desolate. The British writer John Davy who published an account of the interior of Ceylon in 1821, found only a solitary paddy field beneath the grate reservoir of Kantale and an almost deserted region[15]. According to the census of 1871, Nuvarakalaviya (present Anuradhapura District) had only 21 persons per square mile while Tamankaduwa (Minneri, Giritale, Parakramasamudra area) had only 4 persons per square mile. The situation in the Ruhuna region beyond Hambantota was not very different. The settlers in all these regions who were grouped in villages around small irrigation tanks eked out a living by paddy and chena cultivation and other economic pursuits such as fishing but whether they had food security throughout the year is doubtful. Life in a village in the Ruhuna region in the early part of the twentieth century is amply demonstrated in the celebrated novel '*Village in the Jungle*' or '*Baddegama*' by Leonard Wolf and it paints a picture of decay and desolation.

The increase in the overall population of the Island, particularly the increase in Indian immigrants for plantations, the rise in the average annual rice import and the alarming situation of food supply in the country or food insecurity led the British colonial administrators to embark on a policy of restoration of irrigation works from the middle of the nineteenth century [16]. Emphasis was laid on the restoration of small village tanks and a few of the major tanks such as the Tissamaharama Tank (1877) and the Minneriya Tank (1903). The major tanks needed links with local streams to replenish their stock to full capacity and also to redirect excess water during times of flood. As far as village tanks were concerned, they had not been linked as yet to a major irrigation work and were dependent on rainfall for their water supply. Hence their restoration did not provide absolute food security and guarantee against crop failures. In the context of late nineteenth century and early twentieth century restoration of irrigation works, it shold be noted that there was no comprehensive plan for a viable colonization scheme and an administrative machinery to look after and maintain the tanks and channels.

However, particularly after 1931, Dry Zone colonization and the development of agriculture and improving of irrigation and water management systems became accepted as essential for the economic growth of the island. After 1931, many major and minor irrigation works were restored, the pace of colonization of the Dry Zone was increased and food security was attempted but as far as small tanks were concerned two aspects have been overlooked. One was the interconnection of these tanks with large tanks, canals and subsidiary canals. The other was the mechanism for maintenance of the small tanks and the control of siltation. The neglect of these aspects still continue to be defects in the system and as a result even after heavy rains during a particular year, if the rains fail in the following year the Dry Zone farmers experience drought and hardships. During the period of the Rajarata civilization, it was not so and the water management was more efficient.

In conclusion, I would like to pause two questions of relevance. Supposing major and small tanks function smoothly and cultivation flourishes will that ensure food security and improve the conditions of the farmers? Only three weeks back, in mid-August,

the farmers at Polonnaruwa staged a protest and Satyagraha at Hingurakgoda with twenty nine demands one of which was a demand for the increase of the purchase price of paddy. With emphasis on 'globalization', 'global village', 'Technology advancement', 'internationalization of trade', 'Open Economy' can the Sri Lankan farmers improve their lot and lead a relatively comfortable life even if there is an excess of paddy and other grains?. These are questions related to developmental strategies and problems, economically – complicated and politically intriguing.

NOTES

(1) R.L.Brohier, Ancient Irrigation Works in Ceylon, Colombo, 1934, p.18

(2) For details see: W.I.Siriweera, The Inland Fisheries in Sri Lanka: A Historical Perspective, ARTI Occasional Publication No. 33, Colombo 1916

(3) Samanthapasadika, Buddhagosha's Commentary on the Vinayapitaka, Vol. II, ed. J. Takakasu and M.Nagai, Pali Text Society, London, 1927, pp. 330-332

(4) W.I.Siriweera, 'Floods Droughts and Famines in Pre-Colonial Sri Lanka', Modern Ceylon Studies, Special Issue, K.W. Goonawardena Felicitation Volume, 1987, pp. 79-85

(5) Amataya Sen, Poverty and Famine: An Essay on Entitlement and Deprivation, Oxford, 1981

(6) Sammohavinodini – Abhidhammapitaka Vibhangattkatha , ed. A.P. Buddadatta, P.T.S.London, 1923, p.445-451

(7) Ibid. p.445

(8) Epigraphia Zeylanica, Vol. II, pp. 178-180; University of Ceylon: History of Ceylon, Colombo, 1959, pp.363

(9) Sahassavattupakarana, ed. A.P. Buddadatta, Colombo, 1959, pp. XVII – XIX, p.26, p.80

(10) Pujavali, ed. Bentota Saddhatissa, Panadura, 1930, pp.355-357

(11) Pattinapalai, ed. With Commentary by Svami Vedachalam, Pallavaram, T.M. Press, 1919, line 191

(12) S.M.H.Nainar, Arab Geographers' Knowledge of South India, Madras, 942, pp.25-26; H.M.Elliot, The History of India as Told by its own Historians, Vol. I. London, 1867, p.90

(13) W.I.Siriweera, A Study of the Economic History of Pre-Modern Sri Lanka, Vikas Publishing House, Delhi, 1994, p. 119

(14) E.Reimers, Constantine De Sa's Maps and Plans of Ceylon, Colombo, 1929, pp. IV, V

(15) John Davy, An Account of the Interior of Ceylon and of its Inhabitants, London, 1821, pp.389-392

(16) A.C.M.Amir Ali, 'Rice and Irrigation in Nineteenth Century Sri Lanka', Ceylon Historical Journal, XXV, 1978, pp. 258-260; Micheal Roberts, 'Irrigation Policy in British Ceylon during the Nineteenth Century' South Asia, Journal of South Asian Studies, No.2, 1972, pp. 56-58

EVOLUTION AND ROLE OF SMALL TANK CASCADE (ELLANGAWA) SYSTEMS IN RELATION TO THE TRADITIONAL SETTLEMENT OF THE RAJARATA

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INTRODUCTION

There is a fifth century B. C. Chinese saying that "it is only after you have properly understood the essential nature of things you have seen that you will be able to perceive their true form and order" (Panabokke 1999). A systematic understanding of the nature of the physical (environmental) elements of the Rajarata is necessary to clearly perceive the evolution and role of small tank cascade (Ellangawa) systems in the Rajarata.

Over the past three decades various aspects of the tank cascade (ellangawa) systems have drawn the attention of several scholars – Tennakoon (1974, 1980, 1994), Madduma Bandara (1985), Somasiri (1979, 1992), Ithakura and Abernethy (1993), Handawela (1994), Nawaratne (1998), Dharmasena (1992), Ulwisiheva (1995), Senaratne (1996), Sakthivadivel *et al* (1996), Perera (1997), and Panabokke (1999). They all have studied many aspects of tank cascade systems from the standpoints of their disciplinary interests. In that process, they have made significant contributions towards expanding our horizons of knowledge about small tank cascade systems.

However, Panabokke's recent study (1999) is the most cohesive bench mark study undertaken, which will no doubt provide a sound launching-pad for the other scholars of the subject to further expand their study horizons. It is a study well substantiated with maps, including a Master Map where all the boundaries of main watersheds (river basins), sub-watersheds and cascades are demarcated. Looking through many windows that Panabokke has opened in his study; new thinking, new visions and re-discoveries in cascade-based development would be necessary. This paper attempts to take-off from his bench mark study, and further the contemporary local knowledge of the evolution and role of small tank cascade systems in the Rajarata. To the extent possible, an attempt is made here to make this paper a complementary reading to Panabokke's recent study – **The Small Tank Cascade Systems of the Rajarata: Their Setting, Distribution Patterns, and Hydrography (1999);** and to facilitate the unifying framework that Panabokke considered so essential in his landmark address on the small tank cascade systems in January 1995 under the auspices of the Sri Lanka Association for the Advancement of Science (SLAAS) and Institute of Fundamental Studies (IFS).

This paper is organized in two parts. ***Part I*** *is devoted to setting out in detail of the physical elements responsible for the evolution of cascades and tanks within them. It is in* ***Part II*** *that the role of these tanks in relation to traditional settlement patterns in the Rajarata is discussed.*

The physical elements that facilitated the evolution of small tank cascades (STC) in the Rajarata include: its morphology, soils with underlying lithology, probability of receiving expected rainfall seasonally and annually and hydrology (Panabokke 1999)

The Evolution of Small Tank Cascade Systems

Morphological features of the Rajarata

The Mataie foot-hill ranges of the Central Highlands extend over the southern extremity of the Rajarata, starting with Kahalla – Pallekele ranges among others, and run northwest, north and northeast towards the coastal plains of the Rajarata and to the Vanni district to the north of it. In the south and in the northeast these ridges are more distinctly continuous than elsewhere, high in elevation and broad-based (e.g. Pallekela Range). The continuity of these ranges is broken only with saddle type gaps such as the Potuwila gap in the Pallekele Range and the Pahala Dampalessa gap near Marasinghe Hammillewa in the Gommunewa – Kahalla Range. In the central and northern regions of the Rajarata, the ridges remain progressively reduced in continuity and elevation and they are generally narrow-based. They remain more frequently dissected than those closer to the southern border of the Rajarata. The dissected parts of the ranges with their summits of erosional remnants stand distinctly apart particularly more towards the northern limit, not so much as parts of ranges, but as isolated hills such as Mihintalekanda, Katupotakanda, Morakanda, Tammannekanda, Veheragala and Vaddakanda. Indeed, the villagers' perception of **Kanda** is nothing more than, an isolated hillock. Ritigala, meaning "long rock" or "long mountain" is the only clearly visible part of a mountain range *per se*. In the western and northern parts, the trend of the ridges remain much the same as elsewhere in the fan-wise expansion of them over the Rajarata. But to the west of Anuradhapura – Medawachchiya – Vavuniya axis, these ridges almost suddenly diminish in their stature, giving way to low earth mounds like earth over a grave-yard. There are only a few low erosional remnants on these mounds such as Vessagiriya and Tantirimale. The overall fan-like spread of mountain ranges followed by these mounds with their dissected remains (in isolation), has facilitated the evolution of an undulating topography in the Rajarata with some regional variations as follows:

- In the south and in the east, the undulation is characterized by a prominent ridge-and-valley topography, where there is a marked gradient between the crest of a ridge and the keel of a valley. The Yan Oya basin and those watersheds in its right bank display these characteristics, than anywhere else.
- Valleys are narrow in the south. A case in point is the valley between Kahalla and Pallekele ranges commencing near Paravahagama and running up to the Maha Siyambalangamuwa reservoir.
- In the central and northern parts of the Rajarata where the low ridges give way to many of the earth mounds, the valleys in between them have become very broad and shallow with almost imperceptible gradients between the surrounding crests of ridges/mounds and the keels of the valleys, making the land truly undulating.

- In the west and in the northwest, land has become increasingly flat keeping only a faint undulation where the earth mounds which separate the valleys are no more than a few feet in height.

The nine major river basins (main watersheds) in the Rajarata – Kala Oya, Modaragam Ara, Malwatu Oya, Parangi Ara, Ma Oya, Mee Oya, Yan Oya, Koddikkaddi Ara and Pankulam Ara separated from each other by the main ridges spanning from the south to the northeast, north, northwest and west and their continuing earth mounds. However, a few upper streams (tributaries) of the main rivers in these basins such as Yan Oya, Malwatu Oya and Kala Oya have cut across in gaps here and there changing their courses to join the main streams/rivers (Figure 1).

The outward expanding ridges, referred to above, branch off at many points into a series of "duck-foot" type wide spreading "finger-ranges" of local significance with out-stretching grooves in between them (Figure 2). While the "centre-fingers" of these "duck-foot" formations remain long, dominantly high, wide at the bases with their dissected erosional remnants apart, the side fingers of the "duck-foot" formations remain relatively short, low in elevation, narrow at the bases with their dissected erosional remnants rather placed far apart. It is in the grooves in between these "finger – ranges" that the majority of sub-watersheds (50 of them) identified by Panabokke (1999) are found. Some of the tributaries in these sub-watersheds are of the third order of magnitude of streams

Our understanding of these general morphological characteristics, lend us only a limited support to expand our local knowledge about the evolution of cascades and the manner in which they function. It will be further possible to expand it, if we probe more into the details of the morphological anatomy of this part of the country, going beyond our reference to major ridges separating the main and sub-watersheds.

A sub-watershed is not simply an earth pan. It has its own morphological characteristics, with inside low ridges or mounds running roughly parallel to the higher ranges which separate a sub-watershed from another. These inside low ridges or mounds are the **heennas** or elongated low mounds, which are the branch extension of the "duck-foot" finger ridges referred to earlier. These elongated low mounds are often the boundaries of cascades. Like the prominent erosional remnants of the high ranges, these mounds have summits popularly known to the villagers as **mudunnas**.

It is to be noted that **mudunnas** (summits) have not gained any reference in the topographical map sheets while **heennas** have gained reference rarely. There were no settlements in association with the **heennas** in the past and as such the surveyors were unable to capture the names of all or most of them in the topographical maps that they prepared during the twentieth century. Only those road-side settlements on or near the **heennas** or the places of significant road crossings of them or those with some archaeological significance have been identified, marked and named in those maps such as Budugeheenna (on the Galewela – Kalawewa Road), Kasagasheenna (near Dewahuwa), Karuwalagasheenna (on the Mihintale – Kahatagasdigiliya Road), Malamiriyagama heenna (on the Anuradhapura- Medawachchiya Road) and

Kirivalheenna (near the Eppawela phospate deposit). But it must be remembered that there are myriads of them known to the local residents although not shown in the One Inch Topographical Sheets.

In any traditional settlement the residents know several nearby **heennas** which are very significant as "local watersheds". **Mudunnas**, to them, are the points of origin of water flows to their tanks when it rains. These water flows soon disappear with the cessation of rain. In essence, the morphology of **heennas** and **mudunnas** among others have played dominant roles in tank evolution. Without a clear understanding of these two micro-morphological aspects, the **heennas** and the **mudunnas** found within sub-watersheds, the nature and form of small tank cascades, numbering over 450, and the role that they have played in relation to traditional human settlement may not be well understood.

Going from the known macro-morphology to relatively less known micro-morphology of the Rajarata, it is indeed necessary to descend a further step down and look at a main tank in a cascade (ellangawa) with its satellite or feeder tanks around as has been done by Tennakoon first in 1974. This is necessary because as Panabokke (1999) revealed that a small cascade forms a distinct small watershed 5 to 10 sq miles (with a modal value of 8 sq. miles), within which, there are several small tank clusters each with a main village tank and two or three minor tanks (Figure 3).

Usually, it is between two **heennas** and at the tail end of the valley bounded by those **heennas** that the largest tank in the cascade is located. Upstream of this tank in the cascade there are several medium size tanks, but they are generally smaller than the tail-end tank. The side slope water courses leading to these tanks are dammed across to form the other minor tanks in that cascade. Those extents from the **mudunnas** (summits) of the **heennas** (low ranges) to the small tanks on the side slopes of the valley are the catchments of those small tanks.

Soil characteristics

The shape and form of the morphology alone do not fully explain the distribution and the varying density of tanks across the Rajarata. Among other determinants of them, is the nature of dominant soils with their underlying geology, specially the lithology of the underlying substratum (Panabokke 1999). Different soils have different capabilities and capacities to absorb and retain gravity-guided or directly received rain water. As shown in Fig. 4, the western coastal belt of the Rajarata is a **latosol** soil region. These **latosols** are very deep and facilitate high water infiltration but it is extremely poor in holding surface water in tanks because its substratum is highly porous. This is principally the reason for the general absence of tanks in the western coast.

To the east of this latosol soil region, there is a belt of rocky, gravelly and highly eroded land where it is possible to hold up water but it is said that the soil quality is "poor for productive agriculture", except in the narrow alluvial tracts. Hence, there is only a thin spread of tanks of which most remain abandoned.

The tank country proper – **Wew Bendi Rajje**, is the heart of the Rajarata which lies to the east of the rocky, gravelly and eroded soil belt referred to above. This reddish-brown earth (RBE) and the low humic-gley earth (LHG) soil group is capable of holding up water in the form of tanks and notably in LHG soils, productive agriculture under irrigation is possible. This is the soil group (RBE and LHG) that is hydrologically most stable, which explains, to a great extent, the high density of tanks in this region.

Rainfall effects

Thus far it is presumed that, the discussion on macro – and micro-morphology and the soil characteristics have helped the reader to gain at least a partial understanding of evolution, distribution and density of tanks in the Rajarata. Still for a more comprehensive understanding of them, it is essential to understand the effects of rainfall and the general hydrology in the region.

Tanks were constructed to store the rain water that was received mostly during the northeast monsoon (October – December) and augment the storages where possible with the Yala rains (April – May) and provide regulated supplies of water to the cultivated fields during the rainless periods. This is a "**man versus nature game**", in which man attempts to win by minimising the negative effect of nature's variable and highly seasonal rainfall on crop raising. A computation made by Panabokke (1999) in respect of the 75% probability values of Maha (northeast monsoon) rainfall for 12 stations has shown that there is a lower probability in those stations in the western segment (Nochchiyagama, Tambuttegama, Nachchaduwa and Anuradhapura) and a higher probability in the eastern segment (Kalawewa, Maha Iluppallama, Maradankadawala, Kahatagasdigiliya, Padaviya, Horowpothana, and Kebitigollawa) in the Rajarata. This computation, as well as the normal rainfall records maintained show that rainfall increases from west to east.

The rainfall characteristics of this land of varying macro – and micro-morphological features in association with the soil structure and formation set out above, have determined the hydrology with marked differences in stream location, direction, volume of flow and inactivity/activity over time. In the western segment of the Rajarata tanks are very few and dry-up quickly where as in the eastern segment tanks are very many and at least the main ones hold water throughout the year except in years of very severe drought. This is particularly so in the sub-watersheds of the Malwatu Oya main watershed such as Maminiya Oya , Upper Kandara Oya, Ranpatwila Oya, Kadahatu Oya and eastern half of the Sangili Kanadara Oya basin.

Origin of tanks

Life would not have been possible in the past without water for personal and community uses. It is logical to realize that even in the remote past, people would have learned through common sense how to block natural water flows and arrest some water in **pools** for use when necessary. If beavers as animals had the instinct to dam the water courses, there was nothing to prevent that **homo sapiens** and their descendants did it better.

Hence, it is futile to search for the first man or the year in which he began to block water flows and built pools to store water. Of course, where there were natural pools around, the people would not have cared to create pools anew; but got accustomed to make use of water in them. This may have been the practice during the pre-Vijayan period. We have no authentic evidence to say that when the people in Sri Lanka really started building tanks during that remote past.

This does not mean that pre-Vijayan people did not grow crops to meet their food requirements. Archaeological findings have confirmed that more than a thousand years before the advent of Vijaya the people living in this country collected and stored grains (Deraniyagala, 1991). Vijaya, on his arrival in Sri Lanka had met Kuveni spinning cotton yarns. If this is true and not a yarn spun by the author of Mahavansa, who recorded this event eight centuries later, then, the pre-Vijayan settlers should be considered as those who knew the art of cultivating crops. What is not certain is whether that mode of cultivation was rain-fed or otherwise and whether paddy was a cultivated crop. However, the above evidences of cultivation, the absence of any reference to paddy and tanks prompt us to conclude that the grains referred to by Deranayagala (1991) were dry grains raised under rain-fed conditions in a form of cultivation similar to the present day slash-and-burn (**chena**) cultivation.

If **chena** cultivation was the mode of agriculture that prevailed at that time, it still cannot be argued that there was no practice of making water **pools** at least for human use, because survival in the dry zone during the rainless periods of five to seven months could not have been possible without water. During the dry seasons, the people may have had the habit of blocking the trickling-down water courses in streams to pool water. By this process, they may have first learned to build anicuts and then pool water permanently in stream beds during the dry seasons, the art which may have been later applied to arrest water in pools on the land surface during the rainy seasons, closer to their highland farms (**chenas?**) to facilitate at least the human needs of water during cultivation seasons. By nature, **chena**, could have been a shifting form of agriculture for want of suitable forest patches for new farmland clearing. With this shift from an old **chena** site to a new one, new pools too have been constructed. However, as long as they had sufficient forest extents closer to perennial streams and **villus** in the natural depressions, the people may not have pursued the creation of new pools. Even in the western segment of the Rajarata where rainfall is low, land is flat or only faintly undulating and the latosol soils are very deep, course-textured with highly porous substratum, there were and still are the **villus** or the grassland swamps, which are natural flat pools or sink-holes of the underlying miocene limestone formations. Examples are Vanathavillu and Kalavillu in the Vilpattu region.

The practice of constructing water pools may not have been confined only to the dry-arid western segment of the Rajarata. It may have been even in a wider practice in the tank country proper (Wew Bendi Rajje) even during the pre-Vijayan era. Like the term **Villu** used for natural water-holes in the west, there was the term **wila** used to identify natural water pools in the "tank country" in the eastern segment of the Rajarata (**villu** may be the Tamil version of Sinhala **wila**). Even to day there are many village names which have

been named after those **wilas**. What is significant here is that almost all of them are located within the Malwatu Oya main watershed. The pre-Aryan or the pre-Vijayan settlers may have first had their settlements in association with these natural water bodies, the **wilas**. These place names include Horiwila (upper Malwatu Oya), Turuwila, Kahapathvilagama, (mid-Malwatu Oya, Kaluwila (Nachchaduwa sub-watershed), Rampatiwila (Rampatvila Oya), Thamarawila – present Kapiriggama, Ratmalwila now Bandara Ratmale, and Upulwila – now Kallanchiya in the Kadahatu Oya sub-watershed in the Malwatu Oya basin. They are just a few examples of the **wilas**. It may be noted here that many of the present village names are not the original names of them. A long search in recorded history and archaeological records including inscriptions would facilitate the identification of many such **wila**-associated original place names.

In this eastern segment of the Rajarata, because of the very nature of its morphology, soil characteristics and relatively higher rainfall than in the west, stream flows are active for a longer period of the year and even during the relatively short dry periods of the year they have some trickling of water, and in many of the deep spots in them, there are water storages which never run dry even in years of severe drought. In common parlance of the villagers these are termed **ebe**. In this part of the country they have been so significant water sources that many places have been named after **ebes** such as **Kok-ebe**, **Kalu-ebe**, and **Nil-ebe**.

There are yet other indirect evidences of the prevalence of permanent water bodies in the eastern segment of the Rajarata. First, is the place names denoting the presence of water-loving birds in some locations permanently such as Kok-maduwa, Kokunnewa, Kokawiddawewa and Kok-eliya. Second is that in the present topographical sheets there is a very high presence of names associated with water-loving or water-front trees such as Kumbuk (*Terminalia arjuna*) and mee (*Maesa perrottetiana*) trees in the eastern segment of the Rajarata. the place names – Kumbukwewa, Kumbukgollawa, Kumbukkadawala, Meegassewa, Meemalwewa etc. in topographical sheets covering this part of the country . Finally, there are so many villages with the names Ulpatgama and Ulpathwewa or the names associated with Ulpathas or springs such as Kalvedi Ulpotha, GarendiUlpotha, Bandara Ulpotha, and Kalunel Ulpotha mostly in the eastern segment of the Rajarata.. Thus the presence of wilas , ebes, water-loving bird haunts and water loving trees as well as springs denote that the "Wev Bendi Rajje" in the east-central segment of the Rajarata, covering Maminiya Oya, Upper Kandara Oya, Rampatvila Oya, Kadahatu Oya together with eastern potion of the Saingili Kanadara Oya sub-watershed from time immemorial, point us to conclude that this part of the country had remained and still remains as the hydrologically most stable part of the Rajarata (Figure 5)

It is very likely that the pre-Aryan settlers and even the Aryan settlers after a century or so of the advent of Vijaya, practised the old form of chena cultivation in proximity to those natural water holes – **ebes**, **wilas** and **springs** and as they had to move away from them for want of suitable forest for chena clearing that they have attempted to develop water pools closer to their new chena plots. This may have been a **group effort**, because in the past, to ensure easy crop-watching, people may have cultivated individual plots adjacent to one another in a kind of continuous stretch (**Yaya**). A common water pool

would have been sufficient to meet their water needs. **Yaya chenas** and **wheel chenas** (mulketa hen) in practice even during the early twentieth century could have been the last remnants of this form of highland farming. It cannot be said that this system of farming is a recent introduction to the Rajarata with the recent return of those descendants of the people who left the Rajarata to the Central Highlands with the shift of the capital from Anuradhapura and Polonnaruwa. Because some recalcitrant original settlers (now called **Vanniye minissu**) remained stead-fast to their motherland without moving out. In 1899, Ievers in his **Manual of the North Central Province** referred to at least 25 villages of **vanniye minussu**. They were the real custodians of chena cultivation, which preserved it for us over the centuries. Two thousand five hundred or more years in practice, chena cultivation may have gone through changes and transformations.

The point attempted to emphasise here is that, creation of water pools to meet the human needs is very old. Some of these temporary water pools may have become permanent features and they subsequently came to be known as tanks during the period between the advent of Vijaya and Buddhism. The first recorded evidence of tank construction, as Mahavansa records it, is during the time of King Devanampiyatissa in the 3rd century BC. However, as explained earlier it is difficult to believe that tank construction by ordinary people was not there before, though the author of Mahavansa has not mentioned so. As the ties between clergy and royalty remained always strong, he may have deliberately chosen to give the credit of earliest tank construction to that king during whose time of Buddhism was introduced to Sri Lanka.

Layout and construction sequence of tanks

Briefly stated, in a cascade (ellangava) of 5 to 10 sq. miles (with modal value of 8 sq miles), there are about 2 to 4 medium size tanks. They were constructed by throwing earth bunds across the main axis stream of a cascade, which is usually an ephemeral stream. As a general rule, the last tank at the tail-end of a cascade (ellangawa) is the largest tank in the system, which finally empties into a third or fourth order stream, usually an **Oya**. This large tank also could be at the confluence of two or three cascades. For instance Kallanchiya (in the Medawachchiya Topographical sheet) the largest tank in the Kadahalu Oya sub-watershed of the Malwatu Oya main watershed, is situated at the confluence of three cascades – (a) Kendewa – Siyambalagaswewa Cascade, (b) Kumbukwewa – Kapiriggama Cascade and (c) Hettikattiya – Bandara Ratmale – Timbiriwewa Cascade; receiving spilled-over waters of 65 tanks. If any more tank construction downstream of Kallanchiya in the Kadahatu **Oya** was contemplated, then, it could have been still a large tank that is capable of holding spilled-over waters from three other cascades – (a) Gonewa cascade (b) Talakolawewa cascade and (c) Talgahawewa cascade (Figure 6). Even a large reservoir was constructed encompassing all these 6 cascades, like the Mahakandarawa tank, it should have a very large extent of command area for irrigation, before it empties finally to an **Oya**. Such an area did not and does not exist between the Kallanchiya tank and the main Kadahathu Oya downstream. Furthermore, even if such a reservoir was constructed, when there were already too many tanks in upstream cascades, in a year of drought or inadequate rainfall, there would not have been that much of excess water to cascade down many tanks and finally to provide

adequate water to a massive tail-end tank. This is confirmed by the fact that in years of drought the present day major village tanks towards the tail-ends of cascades do not have adequate water to spill over. The important thing here is that, given the extent of catchment area of a cascade and mainly the **Maha** season's rainfall that it receives, **there is an optimum number of tanks that could be profitably constructed on the main axis stream of that cascade**. As a matter of fact there are evidences of some in-between excess tanks forced to be abandoned. A case in point is the abandonment of Henketukadawala wewa in between Kapiriggawa and Kallanchiya tanks in the Kumbuk wewa – Kapirigawa – Kallanchiya (4/MAL6) cascade identified by Panabokke in 1999. This kind of possible adjustment made in the past remains a grey area which needs in-depth research to ascertain the maximum number of tanks and the volume of water that each tank was allowed to hold during the **Maha** rainy season. To sum up, this part of the argument, it could be said that (a) morphology of the land; (b) soil characteristics; (c) volume of rain received during the **Maha** season (d) nature of hydrology; (e) volume of water discharged by the upstream tanks; (f) size of the catchment area; and (g) the extent of land available downstream of tanks particularly more in LHG than in RBE soils have contributed to locate a requisite number of tanks in a cascade.

A question that remains to be answered is, "What sequence that the ancient tank builders followed in tank construction in a cascade?" Did they start constructing tanks from the top end of a cascade and continue construction of them downstream one after another, or did they follow the reverse process (from downstream towards upstream)? There is no conclusive evidence to support either. This too is clearly an area to be studied and understood fully. In the following an attempt is made to shed some light on the same.

The few small/medium tanks which have gained reference in inscriptions, notably during the times of king Valagambahu (88 B.C.), Bhatikabhaya (20 B.C. – 9 A.D.) and Vasabha (66 – 110 A.D.) are all those located at mid-points of cascades. Furthermore, the **wilas** mentioned earlier which later improved to be tanks are approximately at mid-points of the cascades. Following are some of the examples.

- Horiwila in the Palugaswewa cascade in the Maminiya sub-watershed
- Turuwila in the Kongaswewa cascade in the mid-Maluwatu Oya sub-watershed
- Thamarawila (now Kapiriggama) in the Kumbukwewa – Kapiriggama cascade in the Kadahatu Oya sub-watershed.
- Rampatvila in the Moragahawela (Moragahawila?) cascade in the Kadahatu Oya sub-watershed
- Ratmalwila (now Bandara Ratmale) in the Hettikattiya - Bandara Ratmale - Timbiriwewa cascade in the Kadahatu Oya sub-watershed.

There could have been many more **wila-**associated village names to which new names have been given as "Kapiriggama" to Thamarawila and Bandara Ratmale to Ratmalwila, when they were restored in the 19th century after centuries in abandonment. Some village names, which were changed in the 19th and 20th centuries, still have the names of "**wila**" components in their names. Thus, the former name of the present Kahapatvilagama could

have been Kahaptiwala. If we take the name Ratmale as a derivative of Ratmalwila, there would have been many **wilas** by that name, because there are at least a score or two of Ratmales in the present day Rajarata.

As all of them are at mid-points of cascades, most probably the tank construction may have started at a mid-point of a cascade. This is also a plausible argument because at a mid-point, water supply is not too much to control and manage, and not very deficient in volume of water expected to be held up, at least in a year of normal rainfall, given the level of ordinary irrigation capability of the village settlers.

Once a mid-point tank was constructed the users of that tank may have been able to gauge whether there was a potential to construct a number of tanks upstream to (a) regulate inflows of water to their main tank; (b) increase the prospects of opening new land for irrigated farming, which in any case would have been a necessity with the increase of population; (c) reduce siltation in the main tank and (d) accommodate service-bound castes separately from the main village who performed certain specified services to the village chieftains who have received land grants **(gam wara)** for the services that they rendered to the state. In most situations the village settlements in the upstream of a cascade are those occupied by the service castes.

From the mid-points downstream of cascades tank construction would have been a late effort successfully made with increased knowledge and experience of water management and irrigation engineering in respect of lager village reservoirs (tanks). It could have been also a necessity to bring more land under irrigation with increasing population and state's desire to develop an agricultural economy.

The side slopes of the ranges or mounds that separate cascade from one another too have tanks constructed by blocking highly seasonal water courses mostly active while it is raining, which eventually join the main axes streams of cascades. The interesting thing is that some of these small tanks are as old as the main tanks or older than them. For instance, Panikewa tank which belongs to the residents of Kapiriggama appears to have been as old as the main tank of Kapiriggama. Panikawa tank is just a mile and a half away from the Kapiriggama settlement centre (Figure 3). It was there as an abandoned tank to be restored by those who re-occupied Kapiriggama village during the 1840s. Could it be that Panikewa had been even the tank constructed earlier than Kapiriggama tank, in that very distant past for the benefit of the chena cultivators moving away from perennial source of water to some distance in the forest?

Role of Tanks in Relation to Traditional Settlements

Tanks by Purpose in Ancient Times

Already a reference has been made to chena cultivation with nearby water pools temporarily created. Then, in the 4th Century and there after we hear of man- made tanks for urban water supply and city beautification. For instance, Tissa wewa in Anuradhapura

was constructed to meet the water needs of the city of Anuradhapura. One main use of water was augmentation of city ponds along with the watering of the royal gardens such as Maha mega "which at a later date may have given the river its name Malwatu Oya instead of the ancient name Kadamba says, Ievers (1899). But there after irrigated cultivation under tanks gained momentum and according to Ievers (1899) –

> *"Agriculture has the first place in the minds of the kings. The creation and repair of irrigation works, on which the food of the people depended, is most carefully recorded and lauded by the chronicles. The internal economy and regulation of village life and of agriculture was systematic and arranged in accordance with what is known as the "Aryan Village System"*

The above was the status by about 3rd century B.C. even during the reigns of Sura Tissa (circa 240 BC) and his successor Elara, the South Indian Invader-kings. It is the prosperity of the country reached by the development of agriculture which induced them to invade and conquer the island. Thereafter, commencing with King Dutugamunu's reign (circa 160 BC), through the reigning periods of Walagambahu (circa 88 BC), Bhatikabhaya (circa 20 BC to 9 A.D), and through Vasabha's (60 – 110 A.D) period down to king Dhatusena (479 AD) was the golden age of small tank construction notably in the above mentioned **Wew bendi Rajje**, the hydrologically stable area of the Rajarata. King Bhatikabhaya and Vasabha were two great rulers who concentrated more on small tank irrigation than the other rulers. After Dhatusena, royal concentration was more on construction of large tanks such as those in the present Polonnaruwa District. Thamankaduwa is more adapted to large tanks. In fact, to the north-west of Minneriya and to the west of Kaudulla tanks disappears as shown by Brohier (Figure 7).

Ancient chronicles also have references to tanks which were constructed by kings to meet very special **religeo – cultural needs**. For instance, King Bhatikabaya who according to Mahawansa improved and raised the bund of Tissa wewa to hold more water in it, is also said to have constructed or improved **Wilas** into tanks to increase the supply of flowers to deck Ruwanweli Dagaba with flowers, during the Buddhist festive seasons. Thamarawila (now Kapiriggama), Ratmalwila (now Bandara Ratmale) and Upulwila (Kallanchiya) all in the present Rambewa Divisional Secretariat Division, in the Anuradhapura District were constructed to supply lotus, "ratmal" and "upul" flowers respectively from those tanks. It could have been possible that the villagers were made obligatory to supply certain quantities of these flowers at fixed times, and, in return to this service, they may have been allowed to have access to water of those tanks to irrigate crops downstream of them.

Particularly during and after king Dhatusena's reign, construction of large tanks as storage tanks had become increasingly popular. Thus water stored in Kalawewa channelled through Yoda Ela benefited many small tanks for their augmentation until it reached Anuradhapura. Such networks began to be increasingly established in the Polonnaruwa kingdom.

Tank by purpose in recent times

Rajarata was in wilderness from the time of the shift of capital from Polonnaruwa to the Hill Country. The kings of Kandy had only remote control of Rajarata through the Dissawes appointed, many of whom did not go beyond the southern Korales of Rajarata , but depended on the **Vanni Unnehes** in Nuwara Wewa for internal administration (Iever 1899 pp. 48 – 50). Until the late 19th century, other than Robert Knox's description of a few tanks, there was virtually no authentic record referring to tanks. However, RW Ievers as Assistant Government Agent prepared **the Manual of the North Central Province in 1899**, that was 26 years after the separation of the North Central Province from the Northern Province with Jafna as the administrative head quarters. As could be seen in this manual, Dickson, the first Government Agent of the North Central province and Ievers have collected an array of reliable information on the status of the tanks in the North Central Province.

According to Ievers (1899 P. 138) in 1873, the total number of tanks located was 2877, of which, 225 were "Crown tanks", 1519 uninhabited/abandoned tanks and 1133 inhabited villages near village tanks. This is a much improved identification than that or Flanderka the Assistant Government Agent of the Northern Province in 1855 according to whom there were 2000 tanks. Note that even today there is no agreement about the number of tanks in the Rajarata. Perera (1997) gives a figure of 5,447 tanks of all sizes for the Rajarata, Panabokke (1999) has arrived at a figure of 3,085 for the Anuradhapura district alone and Tennakoon (1974) estimated this number to be 3,045 for the same district. It remains a difficult task because of the difficulty in (a) distinguishing **godawalas** from side slope tanks of cascades and (b) over the centuries, some of the bunds of these side slope tanks have got so defaced or destroyed, "determination errors" could be high.

Whatever, the error margin of identification of tanks made by Rhys David in 1871, Dickson in 1875 and Ievers in 1899, it is evident from the Manual of the North Central Province, that during the second half of the 19th century there was the British folly, that tanks were always meant for irrigated paddy cultivation, and attempts were made to renovate some of the tanks (a) harnessing free labour of the villages to construct earth bunds; and (b) providing sluices at government expense, (c) getting services of semi-skilled Tamil tank construction workers such as **Oddars** or **Ottayars** and **kulunkatties** from South India or Jaffna. The **Kulankatties** were later came to be called **Vew Lakamas**.

From the time of British interest demonstrated their folly, namely the tanks are for paddy cultivation, it continues obsessively even to the present day. This British perception got further heightened during the two World wars, notably during the World War II with the "grow more food" campaign in Sri Lanka which was made to be believed as "cultivation of more paddy". The argument advocated here is, that, tanks were not meant for the purpose of irrigated paddy cultivation only. Some tanks were multipurpose inclusive of paddy cultivation, no doubt. Yet, there were and there are other tanks, which had and

have one or a very_limited range of specific purposes outside irrigated paddy cultivation, as amplified hereunder.

The multipurpose tanks are the main tanks constructed by the main access streams of cascades and their uses include:

- Regular storage of water in several places of the cascade, so that water is available to maximise the land use in an around many settlements, taking water guided by gravity to the upper contours of the side slopes of the cascade parts, downstream of those tanks.

- Regulated storage of water in upstream tanks in a cascade, reducing the risk of breaching the bunds of those downstream or tail-end tanks, during the seasons of above average rainfall.

- Regulated storage and regulated release of only excess water, through the sluices where by flood damages downstream are avoided or minimised.

- Through the storage process, avoid water scarcity during the dry seasons by having a regulated supply even during those dry seasons. This is a man versus nature game. In it, the nature makes a move from **"raining" to not_raining"** and to effectively meet the latter, man collects and keep water in tanks when the nature rains. Similarly, when it rains, man's invention that is tank, keeps necessary amount of water in the tank, making the excess to spill over.

- Cultivation of irrigated field crops.

- Meeting all domestic water needs such as drinking, bathing and washing

- Meeting the drinking needs of neat cattle, buffaloes and even wild animals and meeting the wallowing and some food needs of the buffaloes.

- Meeting some grazing needs of cattle in upper tank bed, notably on the margins of gradually receding upper show line providing green pasture during the dry periods in particular

- Meeting fish consumption requirements of the villagers.

- Meeting some items of the "basket of food" of the villagers such as roots, nuts, stems and water-front leafy wild vegetable needs during the dry seasons in particular.

- Keeping the ground water levels high to provide water in wells for domestic uses when quality of water in tanks deteriorates with decreasing quantity of water.

- Improving the micro-climate in the immediate tank environment which bring relief to the tree crops in adjacent gardens during the dry seasons.

- Being a wetland during the dry seasons facilitating growing of reeds (**pan vatu**) for mat and bag weaving and even a few vegetables with manual lifting of water using **Yotu**_(grooved wooden swindles) on limited scales. (Incidentally in Panabokke's Moragahawels – Bandara Ratmale – Timbiriwewa – Kallanchiya cascade No 3/KAL6, Timbiriwewa is now known as Labuwewa because in the 1930^{s} and 1940^{s} villagers grew **Labu** (gourd) in the tank bed during the dry seasons.)

The single or limited purpose tanks are the ones constructed by bunding the highly seasonal tributaries originating from the **mudunnas** (summits) of the **heennas** (high mounds or low ridges) on either side of a cascade and emptying into the main axis stream in that cascade. They are located in the slopes of **heennas** upstream of a particular main axis tank or downstream slopes of that tank. Purpose-wise they can be grouped as follows:

- "Silt-trap tanks" or Kuluwew constructed upstream of a main axis tank. It is almost at the edge of the upper shoreline of the main axis tank when it is full. It is constructed by blocking those fast flowing water courses to ensure that loads of silt brought down in solution, suspension and dragging by those water course are blocked, making the silt to deposit in the **Kuluvewa** and only the filtered water to spill over it to the main tank downstream. They are so small in capacity, that a few weeks after the cessation of the Maha season's rainfall, they too run dry. Welituduwa and Kayanwewa are the two **Kuluvew** of the Kapiriggama (formerly Thambaravila) tank (Figure 3). There are no paddy fields downstream of such a **Kuluvewa** and hardly there are open spaces in the upper tank beds. Tank beds are partially hidden under forest.

- **Olagam** or tanks under which no permanent dwellings established, played an important role in supporting the traditional settlements in the Rajarata. This aspect has not received adequate attention of research scholars and developers. A medium size village with a main tank has at least two or three **Olagam** tanks associated with it. These tanks are the "associated tanks" or "satellite tanks" of the main village tank and they are constructed on the side slopes of a cascade at some distance from the main tank (Figure 3). For instance, in Panabokke's Kapirigama cascade (4/MAL6), Kapiriggama village owns four other **Olagam** tanks at side slope elevations below the location of the Kapirigamma main village tank. They are Penikewa, Andarawewa, Pinwewa and the abandoned Ulpathwewa. Other than a few acres of paddy developed under Penikewa and Andarawewa in the 1950s and 1960s, there is no conclusive evidence to say that they were meant mainly for irrigated paddy cultivation. The term Penikewa denote that area was in forest or near forest which was a good source of bee-honey. By virtue of its being in, or near the forest, it could have been mostly a service tank for chena cultivators. More

importantly, Penikewa and other associated tanks, had other important purposes in addition to the irrigation of an extremely limited extent of paddy fields **only during the Maha season**. In the past, cattle breading as a source of food (milk and curd and not meat), draught power for bullock carts, ploughs and mud-levellers (**poruwas**) and as an insurance against drought and famine, remained an integral part of the agricultural way of life in the Rajarata. Hence, the villagers had to protect both crop and cattle. Farmers owning herds of cattle in the past had been economically stable. The Final Village Reports which accompany the Final Village Plans (FVPs) have maintained a standard format in which information on cattle was a must. This was found so in an examination of 30 randomly selected villages mapped between 1929 in its Village Report states, "There are 169 head of black cattle and 172 buffaloes" totalling 341 owned by 34 families with a total population of 120. That means, a family, on an average owned 10 heads of cattle. In the more distant past (late 19th century). Ievers in his **Manual of the North Central Province** (1899) gives vivid descriptions of the importance that the settlers have attached to cattle breeding . He records how the chief **gamaralas** of the villages at the **Muttinamum Mangalle** plead god **Ayyanayaka** who presides over tanks which are supposed to be under his special protection, to protect the tank crops and cattle in the village (Ievers 1899 p. 109). In offering the vow made at the said **Mangalle**, the **ammetirala** (the master of ceremony) thanked the gods for protecting "the tank, the village with inhabitants, both man and beast ..." says Ievers (1899 p. 110). This shows that villagers attached equal importance to protect both crop and cattle. **Cattle were also important to them as curd and Kurakkan constituted a major part of their diet.** The strategy adopted to safeguard this dual interest was a unique one. Conventionally the cultivators were required to protect their crops more closely than the cattle owners were required to watch their cattle, grazing communally in the uncultivated land in the village. This arrangement was necessary because it was the same owners of crops who owned cattle too. It this situation, the age-old communal arrangement was to make the village cattle move out of the paddy lands and chena plots under cultivation to other places where water and grazing grounds are available. These include the **olagama** tanks for drinking water and the tank catchment areas including the surrounding brush-woods formed after abandoning chena sites for grazing. For this kind of shifting cattle for grazing seasonally like in the Swiss Alps (trans humans), the **olgam** tank environment was a necessity in the Rajarata.

- At times the larger **olagamas** become reserve tanks to meet the domestic water needs of village residents when the main tank is emptied to meet the irrigation needs of its command area. Thus, in certain years people of Kapiriggama use water in the Penikewa tank to meet their domestic needs (Tennakoon, 1974)

- It is a misconception that the **pinwewas** (temple tanks) have been constructed to irrigate paddy. The main function of a temple tank is provision of water to meet the personal needs of the devotees who visit the temple regularly on Poya days to observe "sil" and, other pilgrims and the residents of the temple. Those tanks were certainly for religeo-cultural purposes and not for direct economic purposes.

- Finally, the **godawalas** at the top ends of the side slope streams blocked to form **olagama** tanks. These were meant to be the water holes for (a) wild animals and village cattle to quench their thirst, (b) improvement of vegetation and microclimate around them and (c) to arrest free flow of water inducing some rain water percolation to improve ground water levels. They are never made to be deep water holes as the porous substratum does not lend any support to hold water and **godawalas** are shallow depressions which can be expanded to hold water only by blocking their outlets with low earth bunds. If their bottoms are dredged even the available water disappears to porous deep soils.

It seems that, the present day minor irrigation tank development is geared towards crop irrigation only. The desire of the irrigation engineers is that the entire water storage of a tank should be releasable for crop irrigation. They are not in favour of having a "dead storage" in a tank, It is unfortunate that what is not releasable by a tank sluice has come to be known as "dead storage". In fact it is a "live storage" of water in a village in the Rajarata. It helps to keep the ground water table high during the dry seasons, save fish in tanks, provide drinking water for animals wild and domesticated, supply domestic water needs, support at least some green pasture in its water front during the dry seasons and contribute some wild vegetable to the villagers' food basket. Siltation of tanks over the years has denied these "live storages" of water, to the villagers during the dry seasons.

In the Anuradhapura district of the Rajarata alone, covering 2,809 square miles, there are over 3,000 tanks both big and small (Tennakoon, 1974; Panabokke, 1999). Roughly, there is one tank for every square mile. When all the tanks in a cascade is viewed as a whole, there are major tanks with village settlements in the keel of the valley and small tanks around these major tanks, all in the side slopes of the cascading valley, some upstream of the major tanks with settlements and the others downstream of them. In other words, there are tank clusters in a cascade with major village tanks with their individual small satellite tanks around them. there were different purposes of constructing these tanks. It seems that this small tank cascade system was so evolved over a period of time not only to have maximum possible surface storage of water for human uses including agriculture, but also for the purposes of retaining maximum possible amounts of rain water percolated into sub soils and maintaining ground water level artificially high to keep surrounding vegetation lush and improve micro-climate as well. If there had been no such effort, there would not have been so many springs (**ulpothas**) and tanks fed by them (**ulpathgamas** and **Ulpatwewas** in the Rajarata. The evolution, location and the pattern of small tank distribution (in clusters along the site slopes of cascading valleys) clearly shows that ancient tank builders have attempted to

improve the overall physical environment and hydrology of the Rajarata taking minor watersheds (cascades) as cohesive development entities with maximum possible retention of surface and ground storage of water received from seasonal rainfall. Here, we need to give a new interpretation to the all too frequently quoted wish of king Parakramabahu the Great, that is "let not a single drop of water flows freely to the ocean". The fitting interpretation may be that let surface run-off be arrested to store water not only in tanks but also to induce remaining water to percolate into the sub soil to keep ground water level artificially high as well. This could have been the avowed policy followed in the development of small tank cascade systems in the Rajarata in that distant past.

Temples would have been the focal points of socio-economic upliftment in the rural Rajarata. An examination of 457 cascades identified by Panabokke (1999) has brought an interesting point to light. That is, the presence of a single temple site (marked on Topographical sheets) in a cascade as a general rule, and exceptions to this are extremely rare. Could it be that all economic, and social functions in addition to the religio-cultural activities were directed and monitored from the temple premises? All monks did not live in seclusion being away from the village society. They even had the right to own land and receive their due shares of fish in the tank! In any case a small village even like today, could not have been a viable economic entity. But a cluster of villages as a society or broad community encompassing a whole cascade, would have been a vibrant economic entity enabling the efficient use of labour and exchanging services and skills for development, that would resist economic exploitation of villages by outsides.

The modern myths and mistakes

By the mid twentieth century it has been often said that "a tank means a village and a village means a tank" which is a modern myth (Arumugam 1957 p. 9). A "village means a tank" is no doubt (unless portable water is available) but **a tank does not necessarily mean a village**. Under the majority of satellite small tanks there never have been human settlements. Some of them were meant for purposes other than to directly support settlement establishment. This needs to be well understood and all tanks should not be renovated solely to encourage human settlement beside them.

Renovation of individual tanks in isolation should not be attempted, though it had been the practice over the past several decades. It has created more human, physical and environmental problems. The villagers' petitions to the Government Agents (District Secretaries) lying in the Kachcheries (District Secretariats) during the past several decades deals with the following:

- Submergence of some fields of a village due to the upstream march of the upper shore-line of the immediate downstream tank in which the storage capacity has been increased by raising bund and spill levels.
- Inadequate water inflows to a downstream tank as the bunds and spill levels of tanks upstream raised to retain more water in them.

- Illegal downstream expansion of field stretches from the tail-end of a village field, to the bed of a tank below and to avoid submergence of those fields, owners on their own or in connivance with some residents of the village to which the downstream tank belongs, leaving open the sluice gates of that tank on the sly (often at night) and making the upper shoreline water of it to recede, clearing those submerged fields of the upstream village.
- Sudden release of sluice gates and temporary lowering of spill levels releasing excessively impounded volumes of water in those upstream tanks to a downstream tank, notably during the rainy seasons threatening to breach the bund of that downstream tank.
- Refusal of the upstream tank owning villagers to release even a reasonable quantity of water to a downstream tank which is water-starved and desperately in need of some water to it so as to meet domestic water requirements and/or to save a crop which requires only the last wetting before crop ripening
- Delay in some water accumulation in a village tank particularly during the early part of the Maha rainy season due to upstream tank blockades caused by tank bund and spill levels raising which discourage the farmers (depending on the downstream tank) to start their cultivation activities early in the season which remains a perpetual grievance.

All the above bones of contention are easily avoidable if the improvement and maintenance of an entire small tank cascade system is viewed as a whole. Its water requirements for agriculture need to be assessed (under each tank) making adjustments in individual tank storage needs. Regulating the flow from one main tank to another main tank within the cascade in accordance with a community-based consultative approach, guided by a cascade-based local management body is desirable. This system needs to leave certain responsibilities with individual village groups for operational convenience.

Observations and recommendations

- During the latter half of the twentieth century the swing of the development pendulum was towards construction of large reservoirs, irrigation system construction and maintenance of them. In fact the latter is becoming an increasing headache to irrigation bureaucrats and the state.

- Theses large irrigation works will survive so long as state can manage them. When the state operation failed they too have failed in the past. The gigantic irrigation works attempted after the sixth century AD by the Kings all collapsed or deteriorated when the rulers failed to patronise continuous maintenance. But a larger number of small tank irrigation systems withstood all challenge for nearly thirteen century after the 6th century AD in the Rajarata for Rhys David to identify 1574 tank-based village settlements in 1871 and Ievers in 1899 to record a similar number of tank-based villages in operation (in the North Central Province alone). This was because these systems were manageable by the

ordinary villagers within their own command and that they had a sense of ownership.

- Whatever, the merits of globalisation and market oriented economy that we long for, it is absolutely necessary to have a spatially and temporally well distributed food security for our own safety. Dispersed but cascade based tank settlements have distinct advantages in this regard. Even the establishment of cascade-based grain storages is well worth special consideration. Neglect of small tanks provides no solution at all where food security has to be ensured.

- Small cascade-based tank system had been a classic example of man's ability to maintain a long lasting symbiotic relationship of man with available water, vegetation, climate, soil characteristics, animals domesticated and wild, being a partner of a well renowned hydraulic civilisation. Its revival is therefore, urgently called for.

- The cost/benefit theory cannot be successfully applied to measure the manifold economic and social benefits tanks to the individuals, communities and the nation. Yet an approximation can be made by intuiting values to the manifold social benefits. Then it will be found that those benefits far exceed the costs de-silting tanks to improve their water storage capacity which gives cumulative benefits indefinitely. If the small tanks were successfully used for two thousand years or even more, it is the benefits which they accrued to people over cost which induced them to continue it to the present day remaining stead fast to the use of tanks as a source of productive input – that is water. The need for cascade-based small tank development cannot, therefore, be ignored.

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THE NATURE AND PROPERTIES OF SMALL TANK SYSTEMS OF THE DRY ZONE AND THEIR SUSTAINABLE PRODUCTION THRESHOLDS

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Nature and Properties of Small Tank Systems

Past Scientific Investigations

I have discussed the past scientific studies made by several researchers since 1950 in my recent publications on this subject (Panabokke 1996 and 1999). I wish to however draw your attention to a pioneer and classical contribution made as far back as in 1936 on the Evolution of Scientific Development of Village Irrigation Works, by a very distinguished former Director of Irrigation J. S. Kennedy (1936) in his Presidential address to the Institute of Engineers and published in the Transactions of the Institution. Two very important statements stand out in his address which are as follows:

> *"Science is systematic and formulated knowledge, and when the knowledge that has been systematically accumulated on a subject, by trained observation and experiment, is fully organized, the subject becomes amenable to quantitative treatment."*
>
> *"Every village irrigation work has an individuality of its own, and when located on the topo map, the engineer has next to acquire the* ***sense and substance*** *of that individuality."*

The main aim of my past and recent studies on small tank systems has been the systematic formulation of knowledge by observation and experiment, with a view to subjecting this knowledge to quantitative treatment; and also to search for that elusive **sense and substance** of the individuality of the range of small tank systems in the dry zone landscape.

Essential Nature of Small Tank Cascade Systems

It is now clearly recognized that the large number (more than 15,000) of small tanks that are distributed across the undulating landscape of the dry zone are not randomly located and distributed as commonly perceived; rather they are found to occur in the form of distinct cascades that are positioned within well defined small watersheds or meso-catchment basins. A cascade of tanks is made up of 4 to 10 individual small tanks, with each tank having its own micro-catchment, but where all of the tanks are situated within a single meso-catchment basin. These meso-catchment basins could vary in extent from 6 to 10 sq. miles, with a modal value of 8 sq. miles in the North Central Province region.

A schematic representation of a typical **small tank cascade system** at a scale of 1:50,000 is shown in Figure 1. The main elements that make up a cascade, namely (a) the watershed boundary of the meso-catchment, (b) the individual micro-catchment boundaries of the small tanks, (c) the main central valley, (d) side valleys, (e) axis of the main valley, and (f) the component small tanks as well as the irrigated rice lands are shown in the same figure. These small tanks form a series of successive water bodies along small water courses and are called a **"cascading system"**. The advantage of such a system is that excess water from a reservoir along with the water used in its command area is captured by the next downstream reservoir, and is thus put to use again in the command area of the second reservoir. This water is thus continuously recycled. This system helps to surmount irregularly distributed rainfall, non-availability of large catchment areas and the difficulty of constructing large reservoirs.

Three small tank cascades close to Anuradhapura that lie adjacent to each other and are easily observed on the Maradankadawala-Tirappane road with the aid of the 1 inch to 1 mile topo sheet of Anuradhapura are depicted in Figure 2. The kilometer sign posts shown in this map-figure will help the reader to locate himself when travelling on this road, and thus enable him to easily locate the tank cascade systems on the ground.

Distribution Patterns

The setting and distribution pattern of small tank cascades across the Rajarata landscape has been described by Panabokke (1999). Altogether a total of 457 small tank cascades have been identified and demarcated over 50 sub-watersheds that make up the nine river basins of the Rajarata. A summary statement of the total number of sub-watersheds present within each main watershed, together with the total number of cascades present within each sub-watershed is given in Table 1.

Table 1. Summary Statement of the Distribution Pattern

Main Watershed Basins	Number of Sub-watersheds	Number of Cascades
MAL – Malwathu Oya	15	179
K – Kala Oya	12	68
Y – Yan Oya	7	74
MA – Ma Oya	4	40
MO – Modaragam Ara	3	42
PAR – Parangi Aru	4	34
PAN – Pankulam Ara	3	11
KO – Koddikkaddi Ara	1	8
ME – Mee Oya	1	1
Total	**50**	**457**

It should be noted that there are a small percentage of small tanks that do not occur within a cascade, but as individual tanks with their own independent micro-catchment. A

SCHEMATIC REPRESENTATION OF A SMALL TANK CASCADE

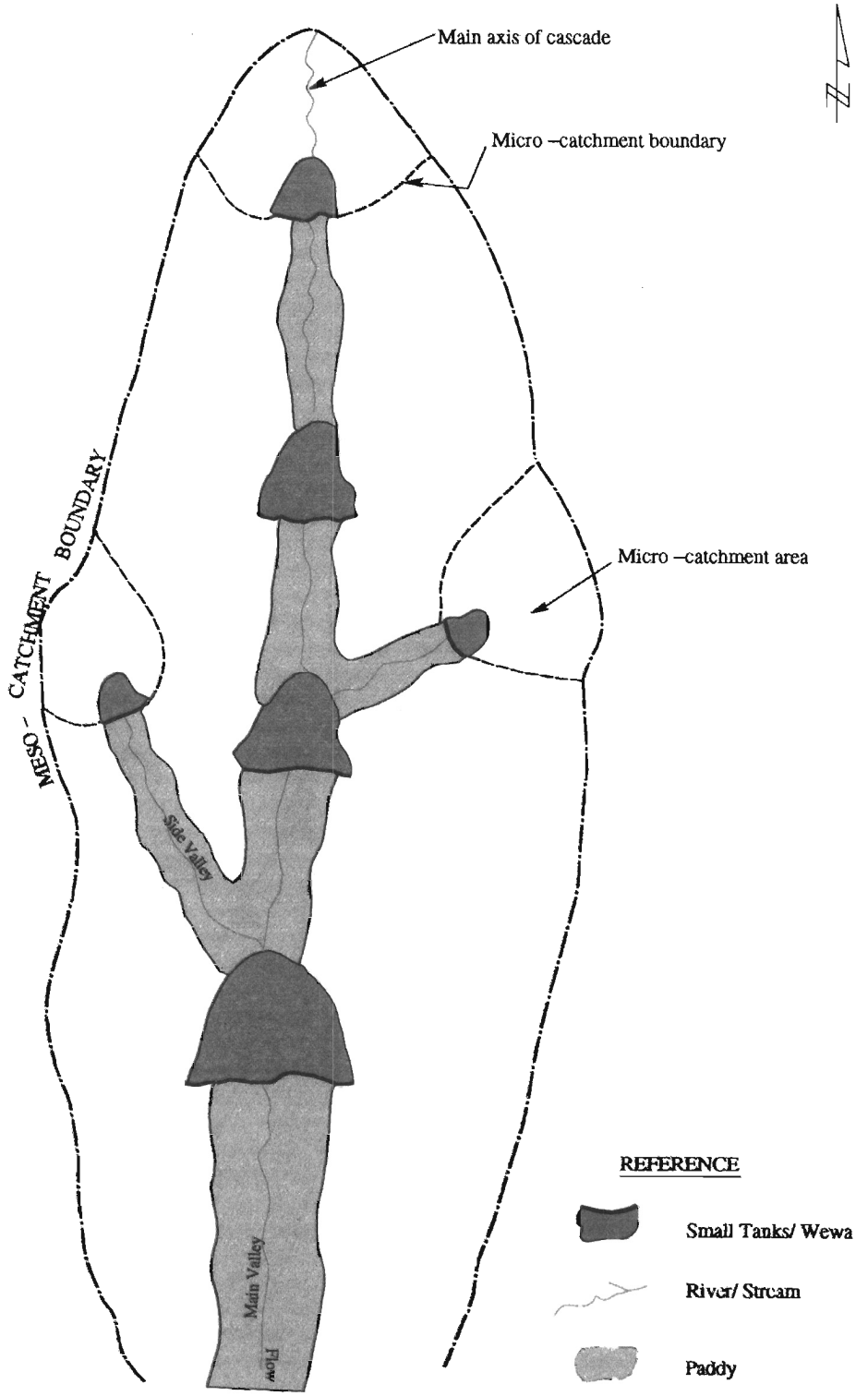


Figure 1

Prepared by Environment & Forest Conservation Division, Mahaweli Authority of Sri Lanka, Polgolla.

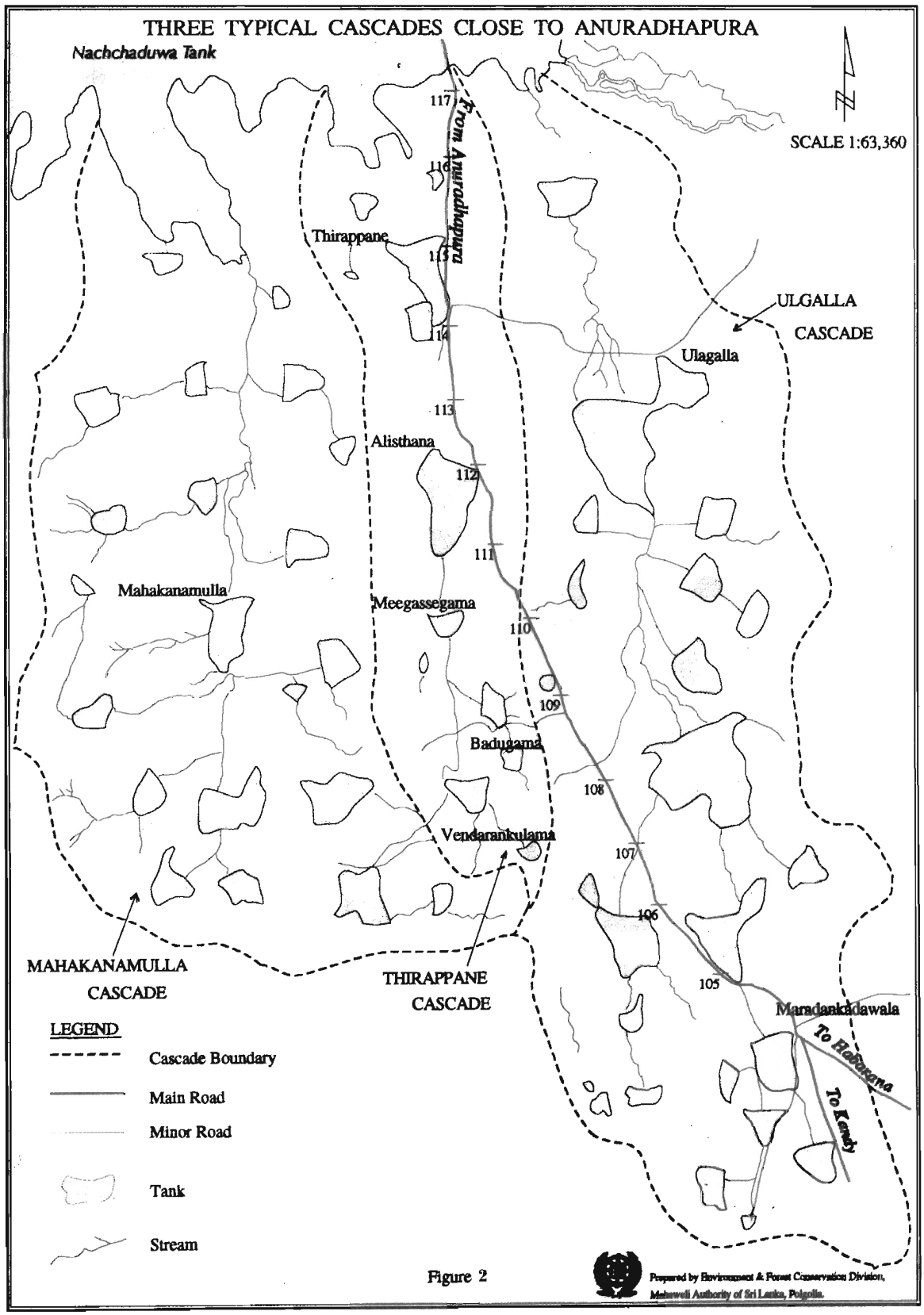

THREE TYPICAL CASCADES CLOSE TO ANURADHAPURA
Nachchaduwa Tank
From Anuradhapura
SCALE 1:63,360
Thirappane
ULGALLA
CASCADE
Ulagalla
Alisthana
Mahakanamulla
Meegassegama
Badugama
Vendarankulama
MAHAKANAMULLA
CASCADE
THIRAPPANE
CASCADE
Maradankadawala
To Habarana
To Kandy
LEGEND
Cascade Boundary
Main Road
Minor Road
Tank
Stream
Prepared by Environment & Forest Conservation Division,
Mahaweli Authority of Sri Lanka, Polgolla.

Figure 2

well known example being that of the Pul Eliya village tank close to Medawachchiya studied by Leach in 1956, and often cited by social science researchers.

As shown in the master map titled "The Hydrography of the Rajarata" (Panabokke 1999) a high density of small tanks occurs in the upper watershed regions of the main river basins such as the Malwathu Oya, Kala Oya and Yan Oya, as well as the major tributaries such as the Maminiya Oya, Kanadara Oya and Kadahatu Oya. This conforms to the normal process of landscape evolution where a higher drainage density occurs in the upper aspects of a watershed, thus resulting in a higher tank density in its upper reaches. By contrast a lower density of small tank cascades occurs across all the lower reaches of the sub-watersheds of the Malwathu Oya, Kala Oya, Yan Oya and Moderagam Ara.

The natural drainage system and the small tank distribution pattern of the Anuradhapura district is depicted in Figure 3. It could be observed from this figure that the highest small tank density occurs around the Kanadara, Kadahatu and Rampathvila Oyas which are located on the main watershed divide that separates the western flowing and eastern flowing main river systems. This region, accordingly, constitutes the heart of the Rajarata tank civilization or the "Wew Bendi Rajje" described by Tennakoon (1999).

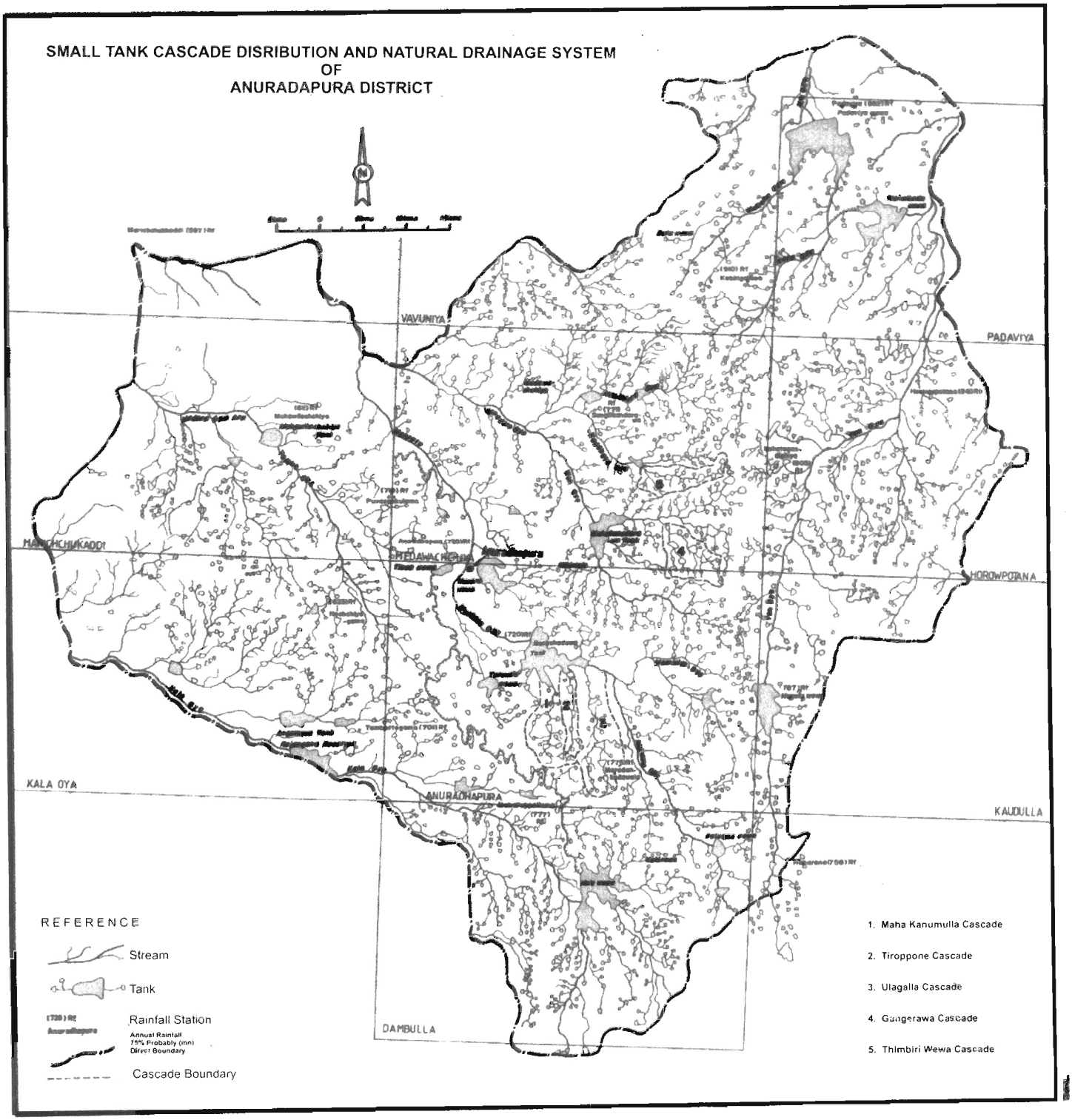
A further important feature of this particular region is the virtual absence of abandoned tanks. There is also an oral tradition in this region that it was never totally abandoned during the dark period between the thirteenth and nineteenth centuries, and it is said to have had an unbroken history of continuous settlement over the last 2000 years. It is also claimed that during the heyday of the Anuradhapura civilization this region had a very close symbiotic association with the main capital city, and it was also its main source of food sustenance.

Range in Size, Shape, Form – Typologies

As stated earlier by Kennedy (1936), "when the knowledge is fully organized, the subject becomes amenable to quantitative analysis". We have now reached a stage whereby the cascades can be characterized in terms of their size, shape and form, thus leading to various forms of quantitative analysis and development of typologies. It should be noted that cascades lend themselves better to quantitative analysis than the individual small tanks because a cascade is closer to a natural system than an individual small tank.

In terms of **size** the following **size classes** of cascades are recognized. The size class denotes the total area of the meso-catchment of the cascade.

Small	< 2,500 acres
Medium	2,500 - 5,000 acres
Large	5,000 - 7,500 acres
Very Large	> 7,500 acres


SMALL TANK CASCADE DISRIBUTION AND NATURAL DRAINAGE SYSTEM
OF
ANURADAPURA DISTRICT
VAVUNIYA
PADAVIYA
MANNCHCHUKADDI
MEDAWACHCHIYA
HOROWPOTANA
KALA OYA
ANURADHAPURA
KAUDULLA
DAMBULLA
REFERENCE
Stream
Tank
Rainfall Station
Annual Rainfall
75% Probably (mm)
Direct Boundary
Cascade Boundary
1. Maha Kanumulla Cascade
2. Tiroppone Cascade
3. Ulagalla Cascade
4. Gangerawa Cascade
5. Thimbiri Wewa Cascade

In respect of **shape and form**, the form index of a cascade could be expressed as the ratio of the overall area of the cascade to its overall length. This value could range from 1.15 to 2.55 and it gives a measure of its general shape which could then be linked with its general geometry that could be linear, branched or angular. Examples of cascades of different size, shape and form are shown in Figure 4.

Panabokke (1998, unpublished) has measured a total of 50 cascades for their (a) area, (b) form index, (c) cropping intensity, (d) ratio of tank catchment area to tank command area; and he observes a strong correlation between the area of the cascade and its form index; and a weak quantitative but noticeable qualitative relationship between the drainage density and cropping intensity, and also between the drainage density and the ratio of cascade area to tank area.

Merits of Considering Tank Cascade Systems over Individual Tanks

As seen in Figure 1, the hydrology of the whole meso-catchment within which the individual small tanks are located has a specific significance in as far as it relates to the hydrology of the individual tanks themselves. For example, while the small tank located in the uppermost aspect of either the main valley or the side valley receives its runoff exclusively from its own micro-catchment, the other tanks located mid-way or at the lower aspect of the main valley will receive their runoff from a larger catchment together with the drainage flow from the tank immediately above it. Thus the hydrology of the lowermost tank within the cascade will be determined by the runoff generated by the whole meso-basin together with the drainage flows from all the tanks and paddy fields located above it.

As shown by Panabokke (1998), the shallow regolith groundwater is located in the lowland, which generally lies adjacent to and athwart the lowermost member of the soil catena. The groundwater regime is therefore confined to a specific topographical location within the cascade, and not at random across the landscape as commonly envisioned. Panabokke (1998) has also shown that the safely exploitable groundwater in the dry season is mainly confined to the areas immediately adjacent to the main axis of the cascade. Senaratne (1996) has developed a methodology to estimate the carrying capacity of agrowells within a cascade.

Quantitative Criteria and Hydrological Endowment

Two quantitative parameters that have a close bearing on the hydrological characteristics of a cascade are:

(a) the ratio of the total catchment area of cascade (CAA) to the total water spread area of all tanks located within the cascade (WA), and
(b) the ratio of the total command area under all the small tanks (COA) to the total water spread area (WA).

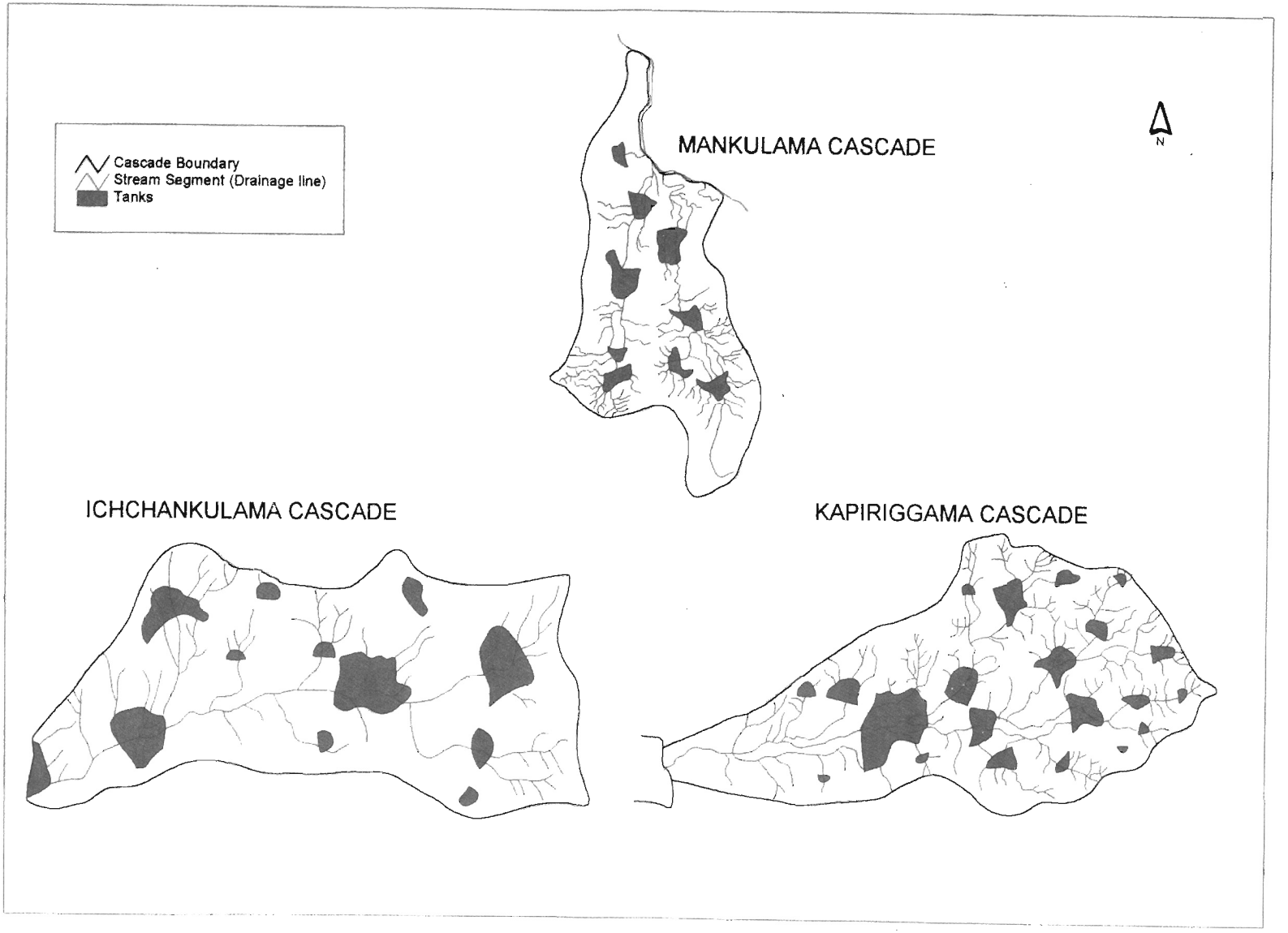

Cascade Boundary
Stream Segment (Drainage line)
Tanks
MANKULAMA CASCADE
N
ICHCHANKULAMA CASCADE
KAPIRIGGAMA CASCADE

Figure 4a

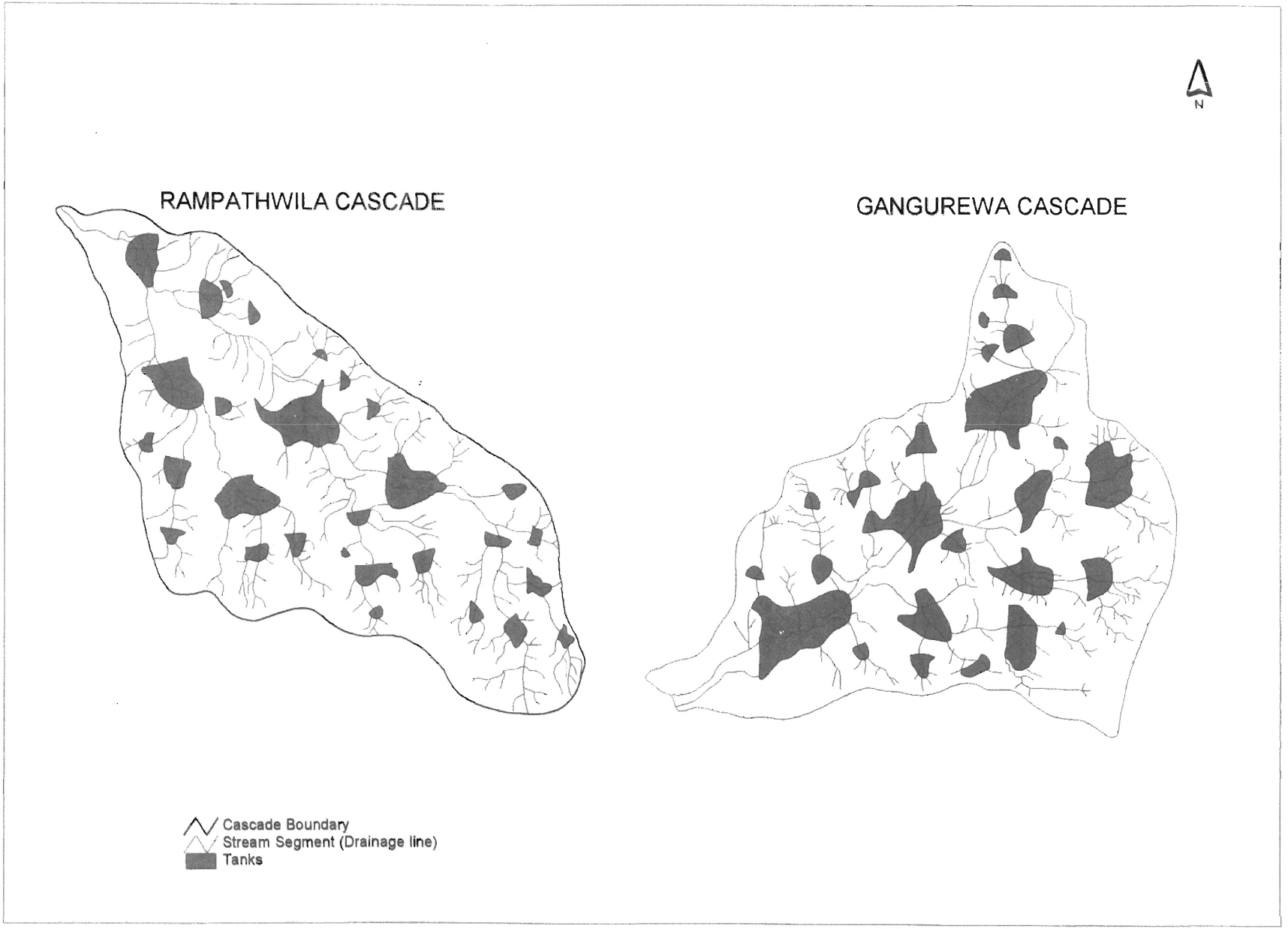

N
RAMPATHWILA CASCADE
GANGUREWA CASCADE
Cascade Boundary
Stream Segment (Drainage line)
Tanks

Figure 4b

It has been earlier established from quantitative studies that cascades which have a CAA/WA ratio higher than 8.0; and a COA/WA ratio less than 1.0, have the necessary hydrological potential for assured wet season rice cultivation.

A study of 230 cascades in 16 Divisional Secretariats in the Anuradhapura district shows the following results:

Number of Cascades with CAA/WA > 8.0	197
Number of Cascades with CAA/WA < 8.0	33

Number of Cascades with COA/WA < 1.0	40
Number of Cascades with COA/WA > 1.0	190

It could be seen from the above results that a high proportion of the 230 cascades of this district have an adequate catchment area where the CAA/WA ratio is higher than 8.0. On the other hand, it is quite clear from the above data that the command area of a very high proportion of these cascades is very much in excess of the tank water spread area, and these imposes a severe stress on the overall hydrological balance of the cascade. Because of the unrestricted expansion of the "akkarawela" extents that have taken place over the last 75 to 100 years, the tank water supply is not able to meet the normal irrigation requirements of the present command area. In the search for a reliable and easily measurable index for characterizing the **hydrological endowment** of a cascade, it was found that the **Cropping Intensity (CI)** of the small tanks located within the cascade, averaged over five consecutive maha seasons, provides a reliable and easily measurable integrated value of its hydrological endowment.

The range of values of Cropping Intensity (CI) in respect of 50 cascades in the Anuradhapura district is shown below in Table 2.

Table 2. Cropping Intensity of 50 Cascades in Anuradhapura District

Cropping Intensity*	No. of Cascades
> 9.0	5
8.0 - 9.0	8
7.0 - 8.0	12
6.0 - 7.0	13
5.0 - 6.0	8
< 5.0	4

* 9.0 denotes 90 percent
5.0 denotes 50 percent

As seen in the above Table, fifty percent of the cascades of the Anuradhapura district have a maha season cropping intensity of between 60 to 70 percent, while a further 25 percent have a maha season cropping intensity of less than 60 percent. This indicates the great variation in the hydrological endowment of cascades across this district. It is generally observed that the cascades in the western segment of this district have a lower CI than those in the eastern segment; and this is closely related to the amount of rainfall received during the usual maha seasons in these two segments. This has been well illustrated in Figure 3 of Panabokke's (1999) publication.

The Abandoned Tanks of the Rajarata, Ruhuna, Wayamba and Wanni

A total of six river basins that make up the Rajarata, and eight river basins that make up the dry zone part of the Ruhuna have been studied in detail. A further ten river basins of the Wayamba or North Western Province (NWP), and ten river basins of the Wanni or Northern Province (NP) were also studied in a more general manner for purposes of comparison. The percentage of functioning and abandoned tanks in each of the foregoing regions is shown below.

Region	Total No. of Small Tanks	Percentage Functioning Tanks	Percentage Abandoned Tanks
Rajarata (NCP)	4,017	52	48
Ruhuna (SP)	1,410	46	54
Wayamba (NWP)	6,463	65	35
Wanni (NP)	1,424	43	57

Adopting a heuristic approach, it could be demonstrated that there are different sets of reasons for the abandonment of small tanks in the different regions of the dry zone, especially in the Rajarata and the Ruhuna.

In the western aspects of the **Rajarata** the abandonment is primarily due to the poor soil and land quality, combined with a low hydrological endowment. In the eastern aspect it is primarily due to the sharper relief of the meso-land forms, and less to the land quality and nature of the hydrological endowment. The more stable small tank cascade systems are characterized by almost a total absence of abandoned tanks. These are found in the upper aspects of the sub-watersheds and have been discussed in a preceding section of this paper.

In the **Ruhuna**, the primary reason for the occurrence and preponderance of abandoned small tanks in the semi-arid environments is the sodic soil (solodized solonetz), in combination with a very low hydrological endowment. By contrast, the primary reason for the occurrence and preponderance of abandoned small tanks in the quasi-cascades of the Timbolketiya topo sheet, which is situated in a semi-humid environment, is the very

high runoff generated from the shallow and rocky land surfaces of the small tank catchment areas.

Differences in the macro- and meso-drainage patterns between the Rajarata and Ruhuna landscapes also have a close bearing on the nature and distribution patterns of small tank cascade systems in the two respective environments.

From any point of view, it could be argued that there had been adequate justification for the restoration of the abandoned ancient **major** irrigation reservoirs in the dry zone. The same rationale cannot however be extended to the restoration of the many abandoned **minor** small tanks in the same region. Selective criteria are now available for determining which of those types of abandoned small minor tanks would be worth restoring. These criteria have been discussed in Sakthivadivel *et al.* (1996).

In the final analysis, there is little or no rationale for restoring a greater majority of these abandoned small tanks; rather priority attention should be given to ensuring the productivity and sustainability of the presently functioning small tanks. By making use of the recently developed criteria it should be possible to rank the large number of presently abandoned small tanks according to their suitability for restoration, or else for restoration as water bodies exclusively for enhancing the groundwater regimes of these regions.

Sustainable Production Thresholds of Small Tank Systems

The Diversity of Production Systems within a Meso-catchment Basin and their Implications

Both traditionally, and even up to modern times, a diversity of production systems could be identified within a meso-catchment cascade basin. In order of importance these are (a) rainfed upland or "chena" cultivation, (b) lowland rice cultivation under small tank irrigation, (c) homestead mixed gardens, (d) cattle grazing and herding, and (e) food gathering from tank bed and similar sources and game harvesting from adjacent forest.

Traditionally it was a closed system within a tank village or a cascade, with the settlers living a frugal and contended life with very little external inputs. This situation has undergone radical change over the last 150 years, and the main production systems are now linked in many ways to external supplies and market forces. As a result, the earlier self sufficient subsistence equilibrium no longer prevails, and many imbalances are now recognized.

One of the major problems facing the transformation or the modernization of the traditional farming systems within a cascade is that of bringing about a balanced utilization of the present resource base in terms of the productivity of the different production systems in relation to the external market forces that now operate in the contemporary environment. This needs a careful analysis of the various factors of

production of the diverse agriculture and livestock production systems, and also a careful examination of how these interact with market forces outside the cascade area. It is only when these studies have progressed to some degree that it will be possible to pilot test the relevant interventions that have to be carried out with a view to modernizing the traditional farming systems.

Multiple Uses of Water within a Cascade

It is now becoming increasingly evident that the surface waters that have been captured and stored in these small village tanks had served a multitude of functions apart from irrigation supply for paddy during the wet maha season. It had been recognized by Ievers (1899), and Abeyratne (1956), that because of the highly variable nature of the rainfall coupled with the high evaporation rates for a greater part of the year and the paucity of readily accessible and adequate groundwater supplies in this hard rock region, it was these small tank surface storage systems that provided the lifeblood for human existence in this environment.

It is also now being increasingly recognized that the uses of water for several other essential purposes such as inland fisheries, livestock needs during the dry season, replenishment of groundwater conditions, domestic bathing needs and environmental amelioration during the enhanced dry moths from July-September, should all collectively be assigned an economic and social value.

It is also considered essential to partition the efficient use of the direct rain or the **green** water which is more efficiently utilized by rainfed "chena" cultivation, in contrast with the runoff collected and stored **blue** water in these small tanks which is less efficiently utilized in paddy cultivation as shown by Navaratne (1998).

Balancing and harmonizing the utilization of this green water and blue water components should undoubtedly be a major research and management thrust in the future research mandate of the Department of Agriculture. Sustainable food production within a cascade or meso-basin would, in the long run, be strongly governed by our ability to achieve a balanced use of both direct rainfall and surface stored supply of small tanks.

Balancing Production Thresholds with the Hydrological Endowment of Cascades

In the preceding section of this paper, the wide range in variation of the hydrological endowment of cascades was recognized. This was clearly reflected in the values of Cropping Intensity (CI) of irrigated rice across cascades which was observed to range from below 50 percent to more than 75 percent. It was also noted that the extent of the total catchment area of a cascade determined the amount of runoff that could be collected within the small tanks situated in the cascade; and that much of this catchment area was also subject to "chena" or rainfed agriculture during the maha season. Hence the total agricultural production thresholds, both rainfed and irrigated, of the small tank cascade system should be subject to a high order of variation dependent on several known factors.

Furthermore, the reliance on food security from both highland rainfed crops and lowland irrigated paddy will also be highly variable between cascades.

There is also the need to recognize the existence of different rainfall probability regimes across the western segment and the eastern segment of the Rajarata, and this too would impose variable threshold potential for food production across this region. Based on an empirical body of data now available, it is possible to broadly quantify the contribution made to rainfed food crops and irrigated paddy across the range of hydrological endowments of the cascades that are distributed across this landscape. This would, in the final analysis, help to characterize the production thresholds of the various cascades; and this in turn would then have to be evaluated against the economic benefits that would accrue to the varying income levels of families now living within these cascade regions.

Newly Emerging Dimensions of Agrowell Development

One of the very significant developments that has taken place at a very rapid pace in recent times has been the construction of agrowells under numerous small tank command areas. Each of these agrowells can irrigate between 0.5 to 1.0 acre of land by lift irrigation, and the growing of high value crops during the dry season has helped to raise farmer income.

It must, however, be clearly borne in mind that this shallow groundwater table that is being presently exploited by these agrowells is very limited in its quantity, and it is also of a very ephemeral nature. If it is over-exploited it could lead to very disastrous consequences both environmentally and economically. This shallow groundwater which is now termed the **regolith aquifer** is restricted to a definite landscape position within a cascade of small tanks, and is not ubiquitous as commonly perceived. The small tanks within the cascade also help to recharge and augment this shallow groundwater table during the rainy season, which in turn can be exploited during the dry yala season.

There are now well proven and reliable methods and guidelines available for estimating the location, spacing and density of agrowells in this regolith aquifer of the hard metamorphic rock basement region. These guidelines should be strictly enforced and adhered to in order to prevent serious ecological and environmental degradation taking place in this small tank cascade environment.

A recent study conducted on 50 cascades within the Anuradhapura district (Senaratne, 1996) has shown that the optimum number of agrowells that could be safely accommodated within these 50 cascades is not more than 3,600; and that already within five of these 50 cascades, the number of agrowells had already exceeded the upper critical limit. The red signal has therefore been already flashed, and time is now appropriate to take timely action to prevent any further expansion of agrowell construction in these stressed areas.

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STRATEGIES FOR OPTIMIZING FOOD SECURITY UNDER SMALL TANK SYSTEM IN RELATION TO THE HIGH VARIABILITY OF THE RESOURCE BASE

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INTRODUCTION

To begin with what is meant by the term **small tank** needs to be clarified. The small tank system in Sri Lanka is synonymous with the **village tank system**. According to the categorization of tanks by the Agrarian Services Department, the small tanks or the village tanks are those tanks, which command not more than 80 ha. Nevertheless, under small irrigation works the extent asweddumized is about 192,085 ha of which nearly 70% are in the dry and semi-dry intermediate zones (Assessed from implementation programme of the Ministry of Agricultural Research and Development 1993/94). This extent of land area is nearly 26% of the total land area having irrigation facilities in the country and that area is available for staple food grain production. Therefore, small tank system is capable of making a fair contribution to the food grain production, at national level.

It is a historical fact that these small tanks sustained the life in the remote villages of the dry zone. They stabilized the village settlements; provided irrigation facilities to produce rice the staple; and it also the domestic water supply directly as well as indirectly, without which life in the dry zone would have been impossible during the protracted dry period experienced annually. It also provided water requirements of the village livestock Thus, small tanks have served as a multifunctional resource, and while it's important functions had been the production of food and provision of domestic water for the village people. However, at present the role of the small tanks in food security issues of the village communities is uncertain.

Simply the statement as "Production of enough food grain locally to meet the basic food requirements of the population can be defined as food security. This is more valid at the national level. However, if the village tank settlement sector is considered as a separate entity the concept of food security needs to be somewhat modified. Food security in this situation should mean that while producing the optimum quantities of food grains strengthen the financial capability of the people through crop diversification to purchase the required quantum of food from other parts of the country where surplus food grain is available. In the absence of opportunities to earn adequate cash income from non-agricultural production enterprises in small tank villages, it is necessary to produce high value crops optimizing the use of physical resources available in the minor tank-village settlement sector. It is to be noted that in the major irrigation settlement sector, available resources permit the production of surplus food grain locally. On the other hand in the small tank sector food grain production is much below the potential due to many reasons, which would be examined in latter sections of this paper. New approaches are required to

increase food grain production and cash incomes to achieve food security in the small tank – settlements.

Objectives

The objective of this paper is to identify strategies to optimize food grain production and enhance cash incomes of the farmers using this highly variable resource base. The irritation potential of small tank system is highly variable and unstable in its performance due to a number of inherent factors (Somasiri, 1976). These would be examined in the following sections. What strategies are available to transform the out puts of this unreliable and unstable system to relatively more stable levels than at present.

A complete understanding of the nature of the resource base and problems associated with their utilization by a community having limited financial and material resources should form the basis for any strategy to use such resources in a secure manner. From the viewpoint of utilizing the resources of the small tank environment, it is essential to characterize all the resource components of that environment.

Characteristics of the Tank-Village Settlement

In Sri Lanka, it is estimated that there are about 22,000 inland water bodies. This includes large reservoirs as well as water bodies not meant for irrigation. Freedom from Hunger Campaign estimates 18,000 minor tanks, and that there could be another 12,000 tanks in an abandoned state. However, it is unlikely that all these small tanks were simultaneously operational during any period of the history. According to Agrarian Services Department estimates there are about 8,500 small tanks in working condition and I would consider this figure to be the presently operational number of the small tanks. A great majority of these tanks are in the dry zone districts.

In the dry and semi-dry intermediate zones village settlements are always associated with small tanks, no village did exist without a tank to provide the basic food grains and water. Therefore, it is very important to remember that small tank system encompasses several interrelated resource components requiring a holistic approach to the efficient utilization of them.

The main components of the tank-village settlement complex are: (a) small tank (village tank), (b) Gangoda- the housing area, (c) Chena or upland that is the rainfed cropland, (d) tank command area – commonly called the welyaya, identified in two parts Puranawela and Akkarawela, and (e) the tank catchment. Usually, chena is located within the tank catchment. All these components are independent variables, therefore a great diversity exists within the system.

Characteristics of Small Tanks

Size distribution

A vast majority of these small tanks occur in cascades, usually with several tanks in a second order valley, one tank located at a lower elevation than the one upstream so that overflow of the upper is collected by the tank at the lower elevation. These tanks vary in terms of the surface area at full supply level, shape, depth and the volume of water stored or the capacity at full supply level. Thus, a range of sizes, shapes and storage capacities characterize the village tanks. Analysis of the size distribution in a sample of 2006 tanks show that the size of tanks in terms of the surface area at full supply range from 2 ha to 600 ha. 88.6% of these tanks have the surface areas below 60 ha (Somasiri, 1980). The surface area of 72 % of the tanks is below 20 ha Table 1. The number of tanks larger than 60 ha are less than 12% of the sample. The height from sill level to spill level of the smaller tanks generally increase with the increase of the tank size. Thus, as much as the surface areas of small tanks have a wide range, the storage capacities of these tanks at full supply level also have a very wide range.

Table 1. Classification of Small Tanks Based on the Surface Area at Full Supply

Surface area at FSL (Size)	Class	Number of tanks in each class	Percentage
2 – 20	1	749	37.3
21 – 40	2	703	35.0
41– 60	3	320	15.9
61 – 80	4	82	4.1
81 – 240	5	86	4.3
241 – 600	6	66	3.3

Small tank hydrology

The hydrology of the small tanks had been a neglected area of investigation up to 1976 (Somasiri, 1976); therefore, there had been a serious dearth of quantitative data on the hydrology of small tanks. This field of investigation has received very little attention, even now the small tank designs are based on the hydrology of major watersheds and the development criteria proposed by Arumugam (Arumugam, 1957). In spite of the lack of scientific study of tank hydrology necessary for management purposes of small tank systems for agricultural development in the dry zone, there is broad realization that the small tank system should form an essential and an integral part of the settled land use patterns in the dry zone.

Sources of tank water supply

The primary source of tank water supply is the locally occurring rainfall. Direct rainfall on the tank surface and the rainfall runoff from its own catchment are the main sources of water supply to the storage (Somasiri,1976), while in a cascade the water from a tank at a higher elevation may contribute to a tank at lower elevation. Rainfall being the primary sources of small tanks water supply the dependence of the small tank system on the regional climate needs no elaboration. The seasonal pattern of the rainfall; it's erratic behaviour and uncertainty in terms of quantity and duration are well documented (Alles,1971; Kannangara, 1988; Kannangara and Panabokke, 1991; and Panabokke and Walgama, 1974). The small tank water supply arising from the direct rainfall on the tank surface is independent of all factors except for the rainfall quantity; that is the total annual rainfall alone determines that component of the tank water supply. On the other hand contribution to the tank storage from the catchment yield is dependant on a number of factors, namely catchment shape and size; catchment surface cover, soils, land use, rainfall intensity- duration relationship, drainage density and the rainfall season. In a given catchment water yield varies from year to year. It also varies between seasons that is from Maha to Yala, from Maha season to Maha season and from Yala season to Yala season (Somasiri, 1979). The catchment yield in the Maha season is always more than the yield of the Yala season (Somasiri, 1980). Such variation in catchment runoff results on one hand in a high variability of the use potential of small tanks and on the other hand the usable storage can not be assessed until a major part of the rainy season is passed. Therefore, preparation of advance agricultural implementation programmes under small tanks becomes meaningless.

Tank density and tank water supply

The tank density in an area is another factor that influences the water supply to the small tanks, because at higher tank densities the catchments are smaller. With the increase of tank density, the water supply becomes unstable due to limitations in the catchment size. The above discussion illustrates the very high dependance of the small tank water supply on a number of independently variable factors. Thus, small tank is a highly variable resource base with an unstable water supply.

Catchment land use and water yield

The catchment cover has a major influence on catchment runoff as shown in Table 2 (Somasiri, 1995). In chena land (cleared land) generated 36 to 55 % of the rainfall received in the maha season as runoff, whereas scrub and forest land produced less than 2%. In the dry zone micro-catchments, land use plays a dominant role in determining catchment runoff, because land use varies from year to year, where as other factors remain constant. (Sumanaratne and Somasiri, 1990). Comparison of runoff as a percentage of the rainfall of maha, yala and full year for three catchments, which had three different land use compositions showed distinct differences in the runoff percentage of the seasonal rainfall (Bandara and Somasiri, 1992) The catchment with a dominance

of chena land (79%) generated the highest runoff (39%), one with dominance of teak (73%) generated the second highest (16%), while the runoff of the catchment with about 89% of primary and secondary forest generated the least that is about 6% of the rainfall.

Table 2. Rainfall Runoff Under Three Different Land Covers Patterns in Nachchaduwa Catchment

Parameters	Cleared land		Scrubland		Forest	
	Maha	Yala	Maha	Yala	Maha	Yala
1987/88						
Rainfall, mm	802	382	558	275	727	413
Runoff, mm	292	73	7	4	8	0
Runoff %	36.4	19.1	1.3	1.5	1.1	0
1988/89						
Rainfall, mm	342	165	587	338	323	243
Runoff, mm	188	27	2	1	3	0.3
Runoff %	54.9	16.4	0.5	0.3	0.7	0.1

Source : Somasiri, 1995

Drainage density and runoff

The studies conducted during the Maha 1993/94 shows that surface runoff from plots with higher drainage density is several fold high as the surface runoff from plots of similar characteristics (Somasiri, 1995). Clearly this appears to be a good method for improving the water supply to small tanks in the dry zone. Enhancement of runoff generation from forested catchments would be possible by improving the drainage density in such manner that increase drainage will not increase soil erosion.

Catchment size and tank storage

The relationship of the size of small tank catchments and tank capacity at full supply level appears to determine the frequency of filling and also spilling. A detailed study of 19 small tanks in the Anuradhapura district showed that the tanks whose ratio of catchment area to full capacity was less than 9 ha/ha.m did not reach full supply level except on rare occasions (Somasiri, 1995). Further, those tanks, which had the above ratio less than 9 ha/ha.m never, reached even the 50% of full capacity during the period 1987 to 1992. The tanks with higher ratios of catchment area to full capacity showed a higher frequency of filling. Such tanks filled over the 75% capacity level, in more than 66 % of the maha seasons, in the study period. Greater success could be expected from tanks with high ratios of catchment to storage. Under these tanks planning the implementation programme of agricultural activities in advance of the tank filling is possible, while taking lesser risks than for tanks with lower ratios of catchment to storage.

Activities affecting catchment yield

Presently some activities such as construction of ponds for water harvesting are promoted in the small tank catchments. Agro-wells are constructed in catchments. These activities no doubt will reduce the catchment water yield, the most important water supply of the small tanks, causing further variability and instability of the system.

Production potential of small tanks

The irrigation potential of a small tank is related to the total available storage and the size of the command area. The cropping intensity in the command area and the agricultural production to a large measure depend on the water availability for irrigation. At present, the size of command area of most small tanks is much more than what the tank could support at the designed duty of about 1 hectare meter or 3 ac.ft (Arumugam, 1957). Under the circumstances cropping intensities realized are far below the optimum for any given season. The following tables give data for five districts illustrating the low irrigation potential of the small tank system in terms of the cropping intensity achieved.

Table 3. Cropped Area in the Maha Season under Minor Tank Irrigation as a % of the Asweddumized Command Area. Ten Year Period of 1980- 1989

District	80	81	82	83	84	85	86	87	88	89	Average
Anuradhapura	82	40	42	74	53	53	31	54	5	39	52
Vavuniya	89	86	88	87	71	56	31	44	23	20	59.5
Hambantota	72	54	71	72	57	67	48	64	57	41	60.3
Moneragala	93	81	94	87	92	92	68	80	70	63	82.0
Kurunegala	96	73	69	69	91	93	57	80	68	77	78.4

Source : Somasiri, 1991

Table 4. Cropped Area in the Yala Season under Minor Tank Irrigation as a % of the Asweddumized Command Area. Ten Year Period of 1980-1989

District	80	81	82	83	84	85	86	87	88	89	Average
Anuradhapura	02	1.5	1.5	1.4	28	5.8	9.3	1.2	6.4	0.4	6.1
Vavuniya	0.6	0.7	0.7	0.4	21	0.4	5.7	0.3	1.7	-	3.5
Hambantota	32	36	41	23	50	32	40	19	23	21	13.9
Moneragala	09	10	12	08	20	15	18	08	30	09	13.9
Kurunegala	37	34	42	26	83	44	54	27	57	17	41.3

Source: (Somasiri,1991)

In general, the cropping intensities have been very low: assuming that there is potential for double cropping the normal way of assessing the cropping intensities that gives a maximum value of 200%, the actual cropping intensities realized are as follows:

Anuradhapura	district	29%
Vavuniya	district	31%
Hambantota	district	45%
Moneragala	district	48%
Kurunegala	district	60%

However, under the particular rainfall regime experienced in the dry zone, the small tanks are probably not designed for double cropping, but only to provide supplementary irrigation for a rice crop in Maha season. Therefore, it is more reasonable to assume maximum cropping intensities at 100% per year, in which case the above values should be doubled.

Village Settlement

The traditional village settlement used to be located by the side of the tank at very close proximity. The tank served as the only source of water for domestic use and for animal husbandry in addition to its use for agriculture. Therefore the settlement had to be close to the tank. However, in the recent past the settlement pattern had changed in a very distinct manner. On one hand with the increase of the village population the traditional clustered settlement could not be accommodated within the gangoda. On the other hand the road access acquired much more importance than the distance to the tank. Thus settlements in clusters expanded into the catchment areas and also the ribbon shaped settlements appeared along the access roads to the village and the tank. The people began to live further and further away from the traditional focal point, the tank and began to give less importance to the small tank irrigation sector for food grain production.

Chena – Rainfed Upland Agricultural Sector

With the population expansion in the village, chena cultivation acquired greater importance in the village economy. This is partly because of adequate land availability for chena cultivation compared to the limited access to irrigated lands. Furthermore, though chena cultivation has been described as a wasteful system of agriculture, in terms of a farmer minimizing his risks and optimizing his labour input, chena has been a very rewarding, particularly in areas with land availability. However, now it is long pass the time to transform the chena into a stable system of rainfed agriculture, because land is no longer a plentiful resource. Traditionally, chena ensured the production of coarse grains, which served as a major component of the diet of the tank-village population. At present the place of coarse grains in their diet has been taken over by the imported wheat flour.
Welyaya or the Command Area of the Small Tank

The two distinct components of the small tank command area is the Purana wela and Akkara wela. Purana wela was the traditional irrigated component of the village agricultural system. However, with the population expansion new areas were added to the command of the small tank and are called akkara wela. Usually akkara wela is irrigated with a high level sluice, provided adequate water is available above that sluice level. Further expansion of asweddumized area adjacent to the purana wela has taken place due encroachments. The end result of all these latter day additions to irrigable area under the small tank is the expansion of the command area by several folds of the initially irrigable area without corresponding increments of the tank water supply. Under these circumstances command area is cropped only when the tank storage is considered adequate to irrigate the whole area under command. Water adequacy is assessed on the basis of the past experience from the maximum tank level attained in the maha season. It is observed that tank water is not utilized when the above condition is not met. Further, the land fragmentation in the command area is a severe problem. An average size of holding is less than half to one third of a hectare. An individual holding may consist of a number of widely scattered parcels, as the degree of land fragmentation is quite high. An individual holding may consist of anything from one to seven scattered parcels with an average of about 3 parcels per individual holding. Presently, land fragmentation could be seen even in the akkara wela. The small size of holdings and the scatter of parcels in the holding discourage the farmer to invest on labour and inputs, therefore, both land and water remain unutilized or under utilized. Thus, the whole system appears to have lost its place as a provider of the staple food grain for the viliage people. It is quite evident that the command area to tank storage relationship is an important factor that determines the irrigation potential of small tanks.

Constraints to Optimization of Water Use in the Small Tank System

Climate

There are a number of constraints affecting the production of food grains in the small tank environment. They include physical, biological and economic constraints, some of which are beyond elimination while there are others for which solutions could be found. These constraints limit the use of land and scarce water resources for food grain production. The climate experienced in the small tank environment is well documented, therefore it is not necessary to delve any further. The bimodal rainfall distribution is such that the length of the main rainy season just matches the growth duration of most climatically adopted food grain crops, provided they are planted with the initial rains; only few pulse crops are available for planting in the mid season. The length of the minor rainy season is inadequate for maturing any food grain. During the protracted dry period that follow the minor rainy season cultivation of any annual crop is impossible and even the establishment of perennials are extremely difficult.

At the beginning of the Maha rains that is at the close of the long dry period, water storage in small tanks is below the sill level or more often than not the tank would be dry. There is no water for land preparation to establish crops to enable the use of rainfall for crop growth. On the other hand tank water supply is very unstable and the irrigation

potential seems very low. However, tanks having larger catchment area, that is more than 9 ha of catchment area per hectare meter of tank storage, are found to have more stable water supply. For those small tanks whose water supply is unstable, early cultivation is involves high risks, which the farmer is keen to minimize.

Adverse soil properties

The extreme hard consistency of the dominant soil groups Reddish Brown Earths and Low Humic Gley soils when dry do not permit tillage when of the soil is dry. The tillage of the wet soil is made difficult due stickiness and plasticity of wet soil, however puddling using plenty of water is the only practical alternative for seed bed preparation, which is only suitable for paddy growing.

Unreliable tank water supply

According to the small tank characteristics discussed in the earlier sections, small tank water storage is unreliable for any advance planning of agricultural activities. Any efforts to optimize the use of the maha season's rainfall and supplement with tank irrigation involves high risks of crop failure, this is against the farmer attitude on risk management. The farmer invests labour and inputs only when and where risks are at a minimum.

Land fragmentation

As mentioned in an earlier section land fragmentation is a serious issue for optimizing the use of land and water. The size of holding in scattered parcels in the command area is economically not attractive to invest on cultivation of food grain, in this case paddy. Cultivation of cash crops and coarse grains in the rainfed chena is economically much more attractive. Therefore, cultivation of the tank command area is given low priority.

Rainfed upland cultivation against irrigated agriculture – Labour competition

Under the climatic and soil conditions encountered in the small tank environment, it is profitable to invest on rainfed upland agriculture or chena cultivation than on tank irrigated cropping due to some inherent factors associated with the command area as discussed above. At the beginning of the maha rainy season, labour required for planting on rainfed uplands is very high. There are a number of operations in the chena that can not be set aside at the beginning of the season for the sake of planting in the tank command area. By necessity rainfed upland cultivation is given the highest priority. Any attempt to cultivate the command area of the small tank is when idle labour is available.

Weed problems

Weed infestation in the rainfed uplands as well as in the tank command is a major problem encountered in the dry zone. Weed control in rainfed upland area is a high

priority. All the available labour is utilized in the uplands during the initial phases of the upland crops development, without which all upland crops may be smothered by pernicious weeds. At the time when the farmer is ready to work the command area a heavy weed growth in the command area can be expected. At that stage to kill the weeds and prepare a weed free seedbed submergence of fields is resorted to, a process that draws heavily on the tank storage.

Lack of capital for investment

The farmers dependent on small tank irrigation and chena cultivation are constrained by lack of capital. More often than not they are not credit worthy. There is no crop insurance for the small tank based agriculture because of the inherent high risks involved. These farmers are resource poor; at most they own hand tools only, that is also the all-purpose mammoty; while they rarely own tractor power.

Marketing problems

Their products rarely compete with crops produced under assured irrigation in major systems. Proper markets are not available, therefore income from agriculture is very low and there are no surpluses for re-investments in agriculture.

Poor water management

Lack of properly planned, designed and constructed delivery system with adequate controls is a distinct feature of the small tank system. In some small tanks the modern sluice gates are not installed, therefore water releases can not be controlled. Under the circumstances it is not possible to manage the tank water as desired. Much water is wasted in a given command area due to poor water management practices of the farmer. However, at least part of that lost water from one command area flows into the adjacent down stream tank in the cascade. This reuse helps to increase the overall water use efficiency.

Strategies for food security

Is it not a historical fact that the small tank-village settlements persisted without out side help for a very long time during and prior to the foreign domination of this country. Is there any evidence to show that the village settlements declined due to food shortages? It is well established that dry zone villages declined due to Malaria rather than a food shortage. Traditionally the dry zone farmers in small tank-villages lived a very frugal life, contended and happy. He expected crop failures and lived accordingly. His crops, farming practices, storage facilities, food habits and his way of life was fashioned on the basis of uncertainty and vagaries of weather which affects his only occupation. However, in the present context there is a serious problem. Since independence from the Colonial rule, the politicians and public officials have considered the tank village farmer as " poor miserable human being living in misery". All attempts to help him have been on this

basis (Medagama, 1976). This attitude of the politicians and the public officials has been responsible for the present state of actual misery that the tank-village farmers experience. These villagers have changed their food habits and way of life. Now we have a new situation. Re-establishment of food security in the villages under the present context is essential. Following discussion is on the possible alternative strategies to achieve food security in the small tank settlements.

Any strategy to increase food grain production and enhance farmer income in the small tank environment must consider better yielding crops and optimizing the use of land, water, labour and other resources in that given environment. Adoption of better yielding food grain crops and high value other field crops are considered common to all approaches or all strategies for optimizing the use of land, water and labour. Out of the possible alternatives for optimizing the use of land, water and labour one must pay attention to the most limiting resource for it would be the controlling factor. In this respect water appears to be the most limiting resource in the small tank environment. Thus one must optimize the use of rainfall and the runoff that is conserved in small tanks where land and labour is not limiting. Where water is not limiting but land is limiting the approach is to optimize the use of land. Both these situations require the optimization of labour in order to make agriculture a more attractive and economic enterprise. The other aspect that needs attention is approaches that minimize risks because risks are not acceptable to the farmers in small tank systems. There are no risk absorption mechanisms in the small tank agricultural sector.

Strategies available are:

1 Optimizing the Use of Rainfall and Land

a) Stabilize rainfed agriculture and adept high value crops

Traditional chena cultivation or shifting cultivation is no longer a suitable practice in the small tanks-village sector. There are no forestlands for clearing and cultivation; whatever, forests that are there in the dry zone are found only in the forest and wildlife reserves and national parks. At present, the farmers are compelled to clear scrubland, which had no time to regenerate fertility or smother the pernicious weeds and grasses. Now the areas used for chena have reached a semi-stabilized condition. Therefore, there is no alternative but to the use of new technology to farm these uplands. There are two possible approaches to stabilized rainfed farming; one to simulate forest fallow condition with a certain quantum of new technology and the other is to use new technologies in full.

It has been adequately demonstrated at Maha Iluppallama research station that avenue planting of rapidly growing leguminous trees are able to simulate forest fallow conditions for rainfed farming. However, some new

technologies are required, namely new high yielding crop varieties, good seeds, some fertilizer, micro-nutrients, and pest and weed control.

The other approach to rainfed upland agriculture in the small tank village environment, mainly in the dry zone, is to use new technologies for the farming activities. These new technologies include the use of tractor power for tillage and seed bed preparation, high yielding crop varieties, quality seeds, fertilizer, micro-nutrients, pest and disease control and weed management. However, there are a number of drawbacks to this approach, The new technologies are capital consuming, that is high investments are needed. What the small tank village farmers lack most is capital for investment, particularly at the end of the protracted dry period he may not have any reserves even for an emergency. Furthermore, he may be indebted to the local money lenders. The other problem is that farmers who practice rainfed agriculture have been used to ways of minimizing risk. Therefore there is no justification to force him to invest on rainfed agriculture that is inherently high risk, unless a system is developed to absorb the risks, say in the form of crop insurance or government assistance. Shortage of mechanical power at the beginning of the cropping season is a major problem for land preparation so that planting is made possible with the initial rains. The soil conditions are such that even when the tractor power is available, land can not be tilled until after the first rains to moisten the soil and give a suitable consistence. This means for timely preparation of land a surge of mechanical power is required for a very short duration. A low risk high technology is what is wanted.

b) Integration of upland agriculture with animal husbandry

Integration of animal husbandry, particularly dairy cows with the rainfed agriculture component discussed above, will eliminate some of the drawbacks that accompany the adoption of new technologies. In the first place a regular income may be assured and some cash reserve for investment on maha cultivation may be possible. It also helps to cut down on the fertilizer use due to the availability of farmyard manure. Some degree of weed control can be achieved by grazing or cut and feed.

ii Optimizing the Use of Tank Water and the Command Area

a) Land consolidation in the command area and operation of purana wela as one production unit

As discussed under constraints above, the reasons for under utilization of tank water and land in the command area of small tanks are: land fragmentation, size of holdings, scattered parcels in a holding, size of the present command area which do not match the tank storage. The other

important factor contributing to low cropping intensity in the tank command area is the unreliable nature of tank water supply. Command area is not cultivated early in maha season making use of maha rainfall mainly due to this state of uncertainty. Further due to over expansion of the command area it had been a problem to provide adequate water for paddy unless when the tank is at full supply level or near it. There is an urgent need to undertake land consolidation to eliminate the problems related to scatter of parcels in a holding, small size of holdings and land tenure problems. Approaches are needed to utilize tank water even when the tank is half or one third it's full capacity. The whole command area should be treated as one unit for operational purposes. Establishment of a cooperative farm could achieve this or a collective farm or farm operated by one or two individuals on a lease arrangement to pay the landowners with a share of the produce.

Let us treat akkarawela and puranawela together with new lands down stream of puranawela as two separate entities. Under any one arrangement which allows the use of purana wela and any new lands down stream of purana wela as one unit of operation will facilitate planning and development of a more suitable water delivery system, with better controls for better water management. Also it would be possible to divide puranawela and adjacent new areas to it into two or three land segments. The segment nearest to the source of water could be cultivated initially when the tank is partly filled. As the storage increase with the advancing of the season progressively next segments may be added to cultivation. Age classes of paddy may be selected for all sections to mature at the same time. The particular approach will ensure the use of tank water the most limiting resource to produce much needed grain crop for food security.

Akkarawela may be unutilized for other field crops under rainfed condition commencing in early maha. A meda season of other field crops is possible provided tank water level at the end of maha season is high enough to irrigate the akkarawela. Depending on the tank water balance, a short duration crop is possible in the yala season. This kind of approach is the only opportunity to optimize the use of tank water under normal or below normal storage. To lift water from the supply channels and adoption of micro-irrigation to cultivate high value crops in the better drained soils of Akkarawela is another approach to optimize the tank water use.

iii Use of Ground Water for High Value Crop Production

The use of ground water commonly identified as agriculture under agro-wells has been given much publicity and already has made large investments by various programmes of assistance. It is a good strategy to enhance the farmer income,

which in turn helps to attain food security of the particular farmers. However, the ground water extraction is not without problems. Ground water extraction will adversely affect the small tank storage. This is case of few benefiting at the cost of a lager section of the society. High density of agro-wells lead to a situation of over extraction of limited ground water, ultimately resulting in the over depletion of the aquifer. At a stage when the agro-well density increases beyond the carrying capacity, none-of the wells will be able to supply the required duty of water. This situation has already arisen in Paluwa, where many wells are not in use because the well recharge is not adequate to irrigate such an area of land as an economic enterprise. There are a large number of wells remaining unused. Further, over extraction of ground water may lower the ground water level to affect the vegetation and cause irreversible environmental damage.

Over extraction of ground water is likely to affect tank storage. The lowering of the ground water level leads to the enhancement of tank water loss occurring due to deep percolation through the tank bed. Few farmers who operate the agro-wells in the command area indirectly use the tank water, while a larger number of the village population may be deprived of the legitimate right to tank water. The social and economic consequences of this on the village population should be considered with greater seriousness. A system of ground water extraction, use and management if developed to spread the benefits to many of those who have the right to tank water is nothing but fair.

The use of ground water will remain a good strategy as long as the extraction is less than the average annual recharge of the ground water aquifer. It is advisable to use well water on less water demanding crops; it is ideal for orchards where limited water supplies are needed.

iv Supportive Policy Strategies

Many attempts have been made to increase the cropping intensities in the command areas of the small tanks and stabilize rainfed upland-farming (Unpublished Annual reports of Maha Iluppallama Reseach Centre), however, without the expected successes. This is mainly due to the high risks involved in dry zone agriculture. The lack of policy strategies appears to be an important factor for the non-acceptance of the departmental initiatives by the farmers in small tank based areas. Also the overwhelming extension emphasis placed on major irrigation sector and the low priority given to small tank based agriculture by the extension services could be another factor for the lack of achievement in improving the small tank based agriculture.

The inability of the farmers in small tank based systems to take risks, as pointed out earlier, in undertaking agricultural activities particularly in early part of the season under uncertain rainfall conditions and unreliable tank water supply is an important factor that limits the optimum use of water resources. Perhaps introduction of risk absorption mechanisms such as crop insurance may be a good

policy strategy to encourage investments on rainfed upland agriculture and early cultivation of the tank command areas to optimize the use of both rainfall and runoff water.

The establishment of farm-gate prices for the agricultural products should be another strategy to ensure reasonable incomes for the purchase of food grain from outside the system.

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SOCIO-ECONOMIC AND INSTITUTIONAL ASPECTS OF SMALL TANK SYSTEMS IN RELATION TO FOOD SECURITY

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INTRODUCTION

The village tank is a small reservoir to impound surface relief of water of a small watershed for irrigation and domestic purposes. Some are of the opinion that our ancient prosperity was centred around these tanks. In the dry zone, it has been said that a tank mean a village and village mean a tank. The village irrigation system has social, cultural and economic values. It is an integral part of the entire eco-system. There is a belief that such social conditions prevailed in ancient times helped in achieving self-sufficiency in food, which was attained by establishment of balance between demand and supply of food.

To a great extent, the work our ancestors accomplished in the construction of village irrigation systems remains an asset for modern development. Village tanks are also refereed to as the minor irrigation system. Minor irrigation is defined in the present context as the irrigation system, which have a command area of less than 80 ha. One-estimate places that the total number of these minor tanks in use and in abandoned condition at about 30,000. (Medagama, 1982; FFHC, 1979). It is estimated that over 50 percent of these schemes are in working condition. According to the Department of Agrarian Services, there are about 8,500 operational minor tanks in the Dry Zone alone (Dayaratne, 1990).

The highest concentration of these minor tanks is located under 'Deduru-Oya' basin in Kurunegala district Spatial distribution of minor tanks had been primarily dictated by social factors such as human habitation and size of population. The irrigation capacity was governed by the size relationship of the catchment, tank and command area (Somasiri, 1979). Village tanks provided all the water needs of the village community and governed by the customs, norms and values associated with traditional village life.

Importance of Minor Tanks in Paddy Production

Minor irrigation systems accounts for about 250,000 ha. which is 45% of total lands under irrigation. It supports the livelihood of over 400,000 farm families. According to the Department of Census and Statistics (1998), production of paddy from the land irrigated by minor tanks accounted for about 21 percent of total paddy extent cultivated during the period of 1995 - 1998 (Table 1). According to the table, Maha production share from minor tanks is about 23 percent and Yala season production share is about 18 percentage of total paddy extent cultivated.

Table 1. Paddy Extent Cultivated by Type of Water Source, 1995-1998

Season	Type of Water Source						Total (000'Ac)
	Major Irrigation Extent (Ac)	%	Minor Irrigation Extent (Ac)	%	Rainfed Extent (Ac)	%	
Maha	251190	47	126915	23	159833	29	538698
Yala	180586	61	51914	18	63096	21	295596
Total	432537	52	178829	21	222929	26	834294

Source: Department of Census and Statistics, 1988

Institutional Aspects in Minor Tanks Development and Management

Historical evolution of irrigation institutions in village tank systems

Irrigation development played a central part in Sri Lanka's distinguished cultural heritage, and much has been written about the advanced nature of the ancient irrigation infrastructure and hydrologic civilization that lead to a relatively self sufficient and self reliant economy (Brohier, 1934, Seneviratne, 1989). Sri Lanka's water laws, customs and traditions are among the oldest in human civilization. These customary laws have been evolved over the years for water harvesting, water conservation, water distribution and collective operation and maintenance.

Historical definition of minor tank was based on its community management aspects. According to the irrigation ordinance of 1946, minor irrigation systems are one constructed by the proprietors without government support or with the help of masonry works and sluices supplied free of charge by the government and maintained by farmers. Therefore, village irrigation systems are generally known as "farmer-managed systems". Most of these systems originated, designed, constructed and maintained by the villagers using collective efforts. The initial water and land right was determined by this collective effort. However, state intervention in village irrigation systems is evident from time to time since 1850s.

Irrigation Institutions during Pre-Colonial Era

The village temple was one of the primary institutions associated with the tank based irrigation systems. The village agricultural activities and Buddhist temple had a strong linkage where Buddhist monk gave the leadership and provided auspicious time for all agricultural activities. The most important thing was the collective decision making arrangement prevailed in the each village. The decisions were made at *Kanna* meetings held in temple. The major decisions made at this meetings were date of first issue of water, last date of water issue, method of water issue, cleaning of channels, bunds and sluices, date of harvesting and threshing of paddy at communal '*Kamath*'. The water issues were made beginning from tail end and gradually towards top end. When tank water was not sufficient, they decided on method of cultivation, type of crop and type of

variety. There were also different rules for management of cattle and draught animals and they were never allowed to roam about destroying channels, bunds or crops. There were separate entry paths across the channels to move cattle.

The people performed the specific irrigation development and management tasks in ancient time through the feudal system of '*Rajakariya*' (literally work performed by the people to the king). Since all the land and other resources were owned by the king, the construction, repair and maintenance of common property resources by beneficiaries were socially, morally and legally decreed requirements of a given agricultural community. There were numerous rules, customary regulations and sanctions as regards to irrigation to punish the rule breakers or individualistic mined predator As water was a scarce resource, there were more tenurial concerns towards water than land. All decisions pertaining to irrigation and cropping were made based on the concept of equitable right to water, which were implemented through '*Gamsabawa*' (Village Council) headed by '*Gamarala*' (Village Headmen). (Leach, 1980). The main functions of '*Gamarala*' were implementation of 'Gamsabawa' decisions, regulate the main sluice and to ensure equitable distribution of irrigation water. The '*Gamarala*' was paid in kind by the village farmers for his services.

Irrigation Institutions during the Colonial Era

The well-established and prosperous tank-village socio-economic and cultural system began to collapse gradually with the invasion of colonial rulers to Sri Lanka. The degradation of peasant agriculture started firstly with the arrival of Portuguese (1505-1650), whose agricultural interest in Sri Lanka was limited only to cinnamon. The influx of the Dutch in 1656, unlike the Portuguese, much attention was given to domestic agriculture. However, the invasion of British rulers to the country in 1815, started the degradation of irrigation networks once again.

In 1832 British colonial rulers abolished the feudal "*Rajakariya*" system in order to give more effort to develop monetised plantation agriculture and to avoid the development of a potential opposition forum against colonial rule. The function of '*Gamsabawa*' and '*Gamarala*' became inactive and customary rules and regulations malfunctioned. In short, everybody's business became nobody's' business and ultimately led to deterioration of irrigation systems (Robert, 1980; Silva and Vidanapathirana, 1984). Silva and Vidanapathirana (1984) reviewed the Sir John Keane irrigation sessional paper (SLV, 1905) and pointed out that the Cole Brooke Commission made a serious mistake in recommending the abolition of '*Rajakariya*'. There was a vacuum in the responsibility of maintaining irrigation systems between 1832-1887, which led to degradation of village irrigation works. Once prosperous country had to import large quantities of rice to feed the its entire population.

The British, however, in the later part of their administration, tried to improve the domestic non-monetised peasant agriculture (Farmer, 1957). There were attempts to re-establish irrigation discipline and improvement of the effectiveness of local community organizations through the implementation of various ordinances. The first such effort

was the introduction of Paddy Lands Irrigation Ordinance - No. 9 of 1856 to enforce the ancient customs regarding irrigation and cultivation of paddy lands. Under this act the local representative of '*Gamarala*' was replaced by '*Vel vidane*' (Irrigation headman) in 1857 with more state power and recognition. The main functions of '*Vel vidane*' were, securely keeping the items such as sluices, spills etc. in good order, passing information from government officials to farmers, under taking earth works and other such activities involving farmers correctly and properly, preparation of share holder lists and observe all instructions with regard to cultivation (Economic Review, 1995). '*Gamsabawa*' received the sole authority to handle water disputes. This paddy land ordinance was enacted until the end of the century

The establishment of the Irrigation Department (ID) in year 1900 is the other turning point which shifted the trend of irrigation system management towards centralization and bureaucracy once again (Moore, 1982). Irrigation management became the dual responsibility of farmers and the state. Under the new institutional setup, Irrigation Department and the Government Agents were responsible for the maintenance of minor irrigation schemes in their areas with the help of communal labours. Although '*Gamsabawa*' has remained as the central rural institution, handling of water disputes became the responsibility of civil courts. A new irrigation policy was introduced in 1932 by the Ministry of Agriculture and Lands, in which construction, improvement and maintenance of irrigation schemes were the responsibility of the Irrigation Department from 1932-1948.

Irrigation Institutions during the Post Independence Period

Soon after the independence in 1948, the responsibility of maintaining minor irrigation was handed over to the Ministry of Agriculture due to the heavy involvement of the Irrigation Department on Major Irrigation Development (Gal-oya Project). At the same time the Irrigation Ordinance of 1951 and 1956 de-emphasized the farmer involvement through enforcement of rigid rules and procedures. As correctly pointed out by Silva (1977) regarding the status of village council during this period, "*...the village councils have to perform these functions within a framework of administrative and financial controls which seriously undermine the sense of autonomy and self reliance while these institutions may otherwise have developed. On the administrative side, village councils were part of the machinery of government...*"

However, the government of Sri Lanka encouraged farmer participation through various institutions after 1958. Department of Agrarian Services (DAS) was established with the passing of the Paddy Land Act of 1958 and responsibility of executing all minor irrigation schemes were entrusted to the new department. Further, Cultivation Committees (CCs) were formed under this act in order to resume again to provide incentives and recognition for farmer participation in improving paddy cultivation. Although the act had the provision for forming irrigation rules by CCs, no legal effect was given to this provision. The committee framed only draft rules. As the CCs could not implement sanctions against rule breakers for their failure to contribute communal labour for maintenance, tanks, bunds and distributory systems fell into disrepair. Finally

an amendment was made to the irrigation ordinance in 1967, which provided the legal powers to CCs.

In 1972 the responsibility of minor tanks was transferred again to Irrigation Department with the passing of Agricultural Productivity Laws. Agricultural Productivity Committees (APCs) were established in each village council under Agricultural Productivity Law. The Minister of Agriculture selected the farmer representatives for these committees, rather, farmers did not elect them themselves. This was the major limitation with this act, which reduced the real farmer representation, thus APCs were less accountable to farmers. *"Agricultural productivity law had certain consequences for village level agricultural planning and development and to some extent for the linkup of village with the national economy through a process of politicization."* (Abeyratne *et al*, 1986).

The passing of Agrarian Services Act No. 59 of 1978 transferred the responsibility of minor irrigation schemes to the DAS and abolished APCs and established Agrarian Services Committees (ASCs). These committees were comprised of elected farmer representatives and state officials. Sometime state officials outnumbered the farmer representative, because number of farmer representatives was limited to ten. Therefore ASCs couldn't function independently and these committees were not felt by farmers as their own institutions.

The Agrarian Services Act No. 59 of 1978 was amended in 1991. Under this amendment farmer, organizations established by DAS were legally registered under the department. The main purpose of the amendment was to give the legal recognition and to provide maintenance contracts to FOs. In addition an institutional strengthening programme was conduced by DAS. The programme consisted of series of components including ownership awareness through involvement and contribution of farmers in all steps of rehabilitation, training and awareness creation on social and technical aspects of rehabilitation, training on O&M and finally the strengthening of FOs through a social mobilization programme.

However, establishment of FOs based on administrative boundaries (village basis) acted as a major hindrance in farmer participation, which were otherwise centered around a hydrological boundary. Under this circumstances some schemes have to be maintained by different FOs. Meanwhile some *'Grama Niladhari'* (GN) divisions were bisected by several irrigation schemes. Therefore, creation of FOs based on administrative boundaries has caused problems in sharing of water, O&M and implementation of effective sanction against defaulting farmers.

Selected Socio-economic Issues Associated with Minor Irrigation Systems

Farming systems under minor tanks

Typically village tank systems in the dry zone of Sri Lanka consists of three fold farming systems. They are namely *'gangoda'* (homegarden), *chena* (shifting cultivation) and

'*Welyaya*' (lowland paddy cultivation). Farming systems under minor tanks are relatively homogeneous in the dry zone which has evolved through the years on the basis of the farmers' knowledge and experience on utilization of natural resources (land and water) and human resources (labour). The farming system prevailed under the village tank system in the dry zone of Sri Lanka was considered to be most stable settlement system. This farming system is an outcome of risk aversion attitude from vagaries of weather and subsistence nature of production.

(a) Homegarden (Gangoda)

Homegarden in the dry zone village as an important component of their village eco-complex. It provides a pleasant and environmentally sustainable system consisting of variety of multi-layered perennial tree species. Although well managed homegarden can play an important role in the village tank community, dry zone farmers have mostly neglected the homegarden due to very high involvement in low land crop cultivation or the chena cultivation.

(b) Chena cultivation

Available research findings indicates that, unlike in major irrigation systems farmers in the dry zone village tank systems gives priority for chena cultivation than irrigated lowland paddy cultivation as it is the most stable and important component of the income. Therefore, they are reluctant to do anything that would interfere with the success of shifting agriculture, (Vithanage, 1982 Marambe *et al,* 1999). Chena crops on the other hand act as a crop insurance against crop failure in paddy, provider of substantial household income and important source of family diet. Most of the food grains produced in chena lands are reserved in households until the next years' harvest due to uncertainty of rain. The chena cultivation system allows some distributional effect of income within the village, since, the resources available under village tank is minimum and limited only to a segment of village inhabitants.

Domestic food security, less water requirement, storability and low cost of production are the main criteria's used by farmers in selecting crops for chena cultivation. Traditionally farmers cultivate 2-3 acres of land under chena for two years and then abandoned for 10-15 years. The number of adult labours available in the household determined the size of the chena land. However, with increasing population pressure, the size of chena land and fallow period has been reduced tremendously. In some places, there are virtually no fallow periods. These changes have caused to reduced unit land productivity and total household income. Generally farmers begin chena cultivation with the onset of initial *Maha* rain which in fact forced them to postpone lowland cultivation. However, delay in starting paddy cultivation permitted the village tank to get filled, which provided an opportunity to make correct decisions on the extent of paddy cultivation and method of water management.

(c) Lowland paddy cultivation

Low land paddy cultivation under minor tanks is mainly for domestic consumption and seldom comes to the market. Begum (1987) reported that 86 percent of sample farmers under minor tanks used new improved varieties. However, Wickramarachchi *et al.* (2000) found that, 100 percent of farmers in three sample minor tanks used new improved varieties, but which have not been periodically replaced for many years. Hence, seeds are poor in quality and yield potentials are very low. Broadcasting is the major method of planting due to the following reasons.

1. Since paddy cultivation starts just after the chena cultivation, farmers do not have sufficient time for paddy nursery preparation and transplanting.
2. Transplanting demands high labour, therefore, farmers have difficulties in finding sufficient labourers.
3. Second priority given to paddy cultivation is a disincentive to make an additional investment on transplanting.

Land Fragmentation

The process of land fragmentation with increasing population pressure is inevitable. Although these small parcels of paddy land plots are economically non-viable, the prestige associated with owning of some land in village paddy tract forced them to maintain these small lots of land. In fact, fragmentation of land holdings curtailed the production process due to the problem of economic of scales and shift of economic priority to other areas, for example chena cultivation.

Further to the problems of land fragmentation, traditionally farmers have inherited land from different tracts of the *Puranwela* land. In most occasions, these plots as well have been divided into more than one plot. Begum (1987) found that, average size of low land in *Puranawela* is 1.2 acres. Abeyratna *et al.* (1986) noted that, 70% of paddy holdings under six sample tanks was less than one acre each. Sivayoganathan *et al.* (1991) explained that, most farms in most districts where the tanks were rehabilitated under VIRP had less than 0.5 hectare. They also noted that, the existing uneconomical size of land holdings would remain as a constraint in the improvement of farmers' well being even in the rehabilitated irrigation schemes. Table 2 shows the average operational land size in sample minor tanks.

Complex Land Tenure Systems

The complex land tenure systems existing in the small village tank command areas further complicated the problems of poverty, low level of income and household food security. In addition, many of the traditional cultivators do not have freehold right to the lands they customary cultivate. The type of land tenure under minor tanks are diverse such as share tenancy (*Kuli ande* and *otuande*), mortgage, leased out, *Thattumaru* and *Kattimaru*.

Under the *Kuli ande* system (labour tenancy), land owner provides all inputs required for paddy cultivation except labour and management. At the end of harvest, the net yield is equally divided between owner and tenant. Under the *Otu ande* system, the land-lord provides only the land and tenant supplies all the inputs including labour and management. The land-lord receives 25% of the harvest as a land rent. Under the mortgage system, land lord give up the land use right to a cultivator for one or more season for a fixed amount. *'Thattumaru'* is system of rotation of land plots in different tracts between two or more farmers. *'Kattimaru'* is a system of rotation of land plot between two or more farmers between two or more seasons. (Abeyratne *et al*, 1986).

All these arrangements act as obstacles in achieving potential income from particular land plot to the farmer. This is an added burden to farmers where their income is already limited by small size of land holdings, seasonality and low productivity. The insecure form of land right is one of the main constraints in improving agricultural productivity and resource management.

Seasonal and Uncertain Income

Majorities of minor tanks are filled by run off water from their own catchment. Rainfall intensity, rainfall duration, soil physical properties determine the catchment water yield. Failures to receive adequate amount of rainfall lead to abandonment of lowland paddy cultivation or crop failure or reduced yield. Table 2 shows the number of seasons cultivated during the period of 1992-1996 in some selected minor tanks. According to these figures in majority of villages in the dry zone, Maha season is the most probable cultivation and Yala cultivation using tank water is rarely practiced. The table also indicates the level of crop damage experienced in 1996/97 Maha due to scarcity of water.

Therefore, it is very clear that, crop production under village tank system is seasonal and very uncertain. Especially uncertainty of the rainfall adversely affects the amount and stability of the paddy production and paddy yield. In other words, farmers have to face greater difficulty in terms of food security and cash income especially in years following 2-3 years of no harvest or greatly reduced harvest. It should be noted that as discussed above the given situation gets further complicated with small land holdings and complexities of land tenure.

Low Productivity

High risk and uncertainty involved in the village tank cultivation prevent farmers to perform a commercialized high input cultivation. The socio-economic issues discussed above have a contribution to the low investment and minimal attention given for cultivation under village tanks. The outcome of the process is low productivity and low income.

Scarcity of water in combination with low input use results in very low paddy yield from village tanks averaging 46 bushels per acre compared to about 68 bushels per acre in

major schemes over period of 1976-1980 (World Bank, 1981). According to the last 25 years national data, yield advantage is about one metric ton higher under major irrigation compared to minor irrigation. (Figure 1). The average yield under irrigated condition is 3.5 mt/ha. Average paddy yields in two sample minor tank areas are given in Table 3.

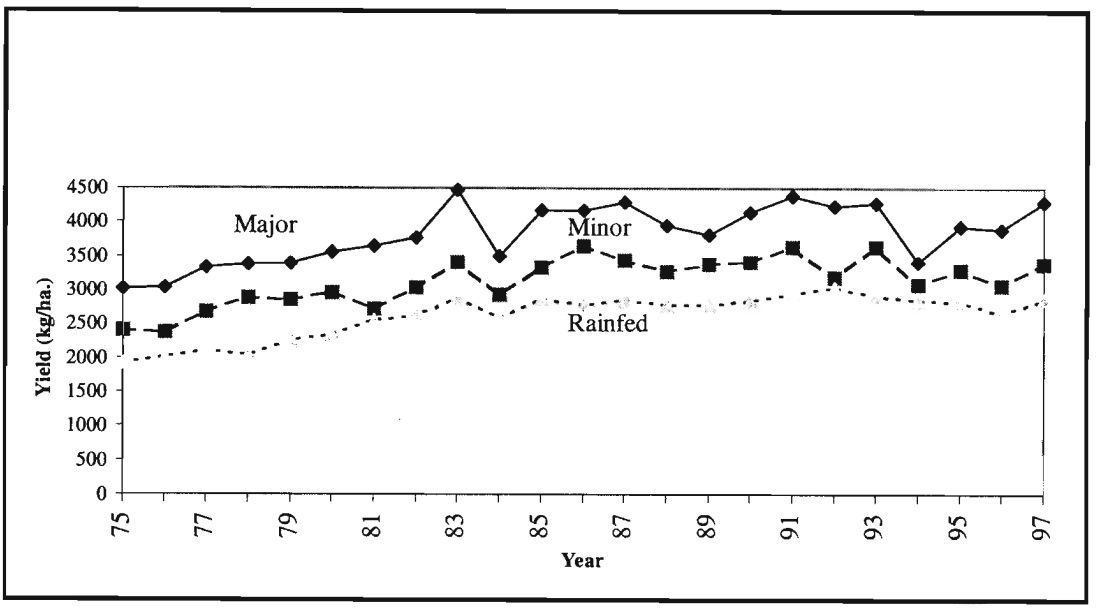

Figure 1. Average Paddy Yield under Different Modes of Irrigation (Maha Season)

Water Management Packages Practiced in Minor Tank Systems

Since water is major limiting factor for crop production in minor tank systems, there were several customary water management packages implemented by the village community depending on the level of water available in the tank in a particular season. This decision was made collectively at the *Kanna* meeting. The major water management packages practiced in minor tank systems are discussed below.

(a) Dry sowing (*Kekulam System*)

Dry sowing is one of the methods of planting of paddy during the Maha season in the dry zone. Under this method farmers plough the land with the onset of the Maha rains and broadcast the seed paddy instead of waiting for the tank to fill. This practice helps to save large quantity of tank water from land preparation. The crop can thus mature with direct rainfall, requiring only limited supplementary irrigation from the tank. This water management strategy helps farmers to save considerable amount of water, which can be utilized to cultivate a meda crop (catch crop), or early Yala or regular Yala season. However, the factors such as rainfall pattern, expectations about rainfall patterns, and farmers

attitude towards risk plays a major role in making of decision on dry sowing method.

(b) Crop diversification

The concept of crop diversification under minor tanks was promoted in the past to conserve tank water and to utilize the available water in an efficient manner. Since non-paddy crops require significantly less amount of water than paddy crop, farmers can go for *Yala* cultivation with less amount of tank water. However, crop diversification experiences shows that farmer's preference in growing paddy crop is very high due to various reasons. The main reasons behind this argument are, firstly, rice is the stable food which can hardly be substituted by non paddy crops, secondly, non paddy crops require high investment and consequent risk associated is very high, thirdly, marketing problems linked with non-paddy crops grown in remote minor tank villages and fourthly, requirement of high labour throughout the season which effect the other components of the village tank farming system (specially chena cultivation). However, successful stories of crop diversification under minor tanks have been reported (Ariyabandu and Wickremasinghe 1998).

(c) Bethma cultivation

'Bethma' is a water management technique, in which cultivation is practiced, only in upper reach of the system sharing the land with lower reach farmers, when available water in the village tank is insufficient to cultivate entire command area. The extent of cultivation under 'Bethma' system is decided collectively by landowners depending on the availability of tank water. This was a regular event in the past in the traditional village community system. However, with the breakdown of traditional village community of farmers due to various social, economic and political reasons there were difficulties in implementing 'bethma' system in some places. Further to this breakdown of village organizational set up and social cohesiveness, the increase in area under irrigation in *Maha* season, which reduced the water availability in *Yala* season and consequently reduced the feasibility of Bethma in *Yala*.

Designed and Actual Command Area Under Minor Tanks

The village tank was a complex eco-system designed by our ancestors to harvest rain water, conserve the water and utilize the water efficiently for all aspects of human needs. Command area of minor tanks was designed, based on the water relief pattern of the area. In addition, the eco-system had several important components including 10-20 acres of reservation land to protect the bund and to supply soil for earthwork of the bund, green catchment area, wind belt (Gasgommana)) and salt trap (Katta Kaduwa).

However, with the increasing population pressure and improper government intervention, the command areas have been increased without considering hydrological dimensions of the catchment system and cascade relationships. In the past, the government has distributed land haphazardly under minor tanks through land rights, 99 year permits, and year permits. In addition, farmers themselves have encroached reservation lands in the different component of the eco-system. The combination of all these factors have lead to increase in actual command area significantly compared to the designed command area. Table 2 clearly illustrates the difference between actual and design command areas in a sample of minor tanks. The overall increase in command area has serious implications in terms of reduced probability of cultivation and problems associated with traditional water management practices.

Begum (1987) found that, out of 20 tanks studied, Bethma cultivation was practiced only in two of them. The reason identified was tank water availability was often limited to support even a Bethma cultivation, which is due to the recent expansion of command area under these small tanks.

Table 2. Some Features of Sample Village Tanks in Hambantota and Anuradhapura

Tank name[1]	Design command area (Ac)	Actual command area (Ac)	Average paddy land holding size (Ac)	No of seasons cultivated during last 5 years		% of crop damage due to water shortage in last Maha[2] (1996/97)
				Maha	Yala	
1. Padawgama wewa	12	40	01	04	-	60
2. Halagala wewa	7	49	0.7	05	01	50
3. Illukmulla wewa	30	30	01	05	01	10-15
4. Handunkakuwa wewa	15	26	0.75	04	02	50
5. Palankada wewa	20	40	1.5	02	01	0
6. Padukkulama wewa	35	80	0.25	04	-	50
7.Kadurugaspitiya wewa	75	150	0.50	05	01	50
8. Weerasole wewa	20	80	0.25	01	-	100
9. Kottalbadda wewa	80	160	0.50	05	02	15

Source: HARTI survey data - 1996/97 Maha

Note: [1] Tank No 1-5 are located in Hamabantota district and 6-9 are in Anuradhapura district

[2] Damages are farmers' eye estimate.

Table 3. Average Paddy Yield Under Village Tanks in Two Climatic Zones (as a % of land lots)

Average yield mt/Ac	Hambantota (DZ) Maththala Tank		Uva-Paranagama (IZ) Yalagamuwa tank	
	Maha	Yala	Maha	Yala
	N=16	N=0	N=15	N=4
<1	0.6	-	27	-
1-5	37.5	-	40	1.00
1.5-2	37.5	-	7	-
2-3	19	-	26	-
>3	-	-	-	-

Source: Survey Data, HARTI

CONCLUSIONS

Minor irrigation plays a significant role in domestic agriculture, especially in the production of staple diet paddy. In socio-economic point of view, considering small land holdings and the lower productivity under minor tanks, the dependents on minor tanks are much larger than their contribution to national production. Therefore, improvement of minor tanks is more valuable in social welfare terms.

Village tank eco-systems in the past were socially, economically and culturally feasible and created a prosperous and self-reliant economy. However, degradation of minor tanks and its sustainability began with the commencement of decline in traditional management practices in village irrigation systems. The deceleration of traditional management practices in minor irrigation schemes is the result of following factors

- Influx of colonial rulers to the country and the abolition of '*Rajakariya*' system and of customary laws of irrigation management.
- The increased intervention by government and NGO's in institutional set up and refurbishment of minor tanks.
- Creation of dependency among farmers for outside support.
- Top down approach adopted in minor tank improvement without considering perspectives of existing water users and hydrological aspects.
- State intervention on redefining hydrological boundaries and land right radically disturbed the traditional village social structure and its value system.

Since independence in 1947, agrarian laws pertaining to the operation and maintenance of minor irrigation have been changed at least four times and consequently, responsibility of minor irrigation also changed from one institution to others. As a result large number of tanks have been abandoned and tanks in working condition also operated at varing levels of efficiency. With these government interventions, farmers believed that the government owns the irrigation system and were responsible for ensuring operation and

maintenance. However, various new strategies have been used since late, to solicit farmer participation and to re-introduce traditional water management practices.

The one of the major weaknesses in the current institutional strengthening programme is the establishment of FOs based on village boundaries (Administrative Grama Niladhari boundaries), rather than hydrological boundaries. The situation makes it difficult to address the FOs as an organization that should take the responsibility over the schemes. On the other hand, the problem of lack of co-ordination in water management among villages in the cascade systems is continuing as ever before.

Underlying socio- economics situation in village tank community emphasises the vital requirement of tenurial reforms to make the cultivation economically viable. The ability to integrate minor tank paddy cultivation with chena provided a protection and insurance for paddy cultivation and also viability of the small holder subsistence paddy economy. However, the increasing population and village expansion programmes have curtailed the paddy-chena interrelationship and substantially changed the village economy. Therefore, the government must create opportunities for off farm income to ensure household food security. Further, institutional factors such as credit, inputs, seed paddy and extension, basic rural infrastructure, and crop productivity improvement prgrammes are necessary to support the livelihood. Unplanned top down approaches adopted for minor tank developments have serious implications on their sustainability and its livelihood.

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CONTRIBUTION OF SMALL TANKS TO UPKEEP THE VILLAGE COMMUNITY

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Mahaweli Restructuring and Rehabilitation Project

INTRODUCTION

Irrigation can be defined as the process of artificially supplying water to soil for growing crops. In Sri Lanka, the surface irrigation systems are broadly categorized into two types; the Tanks (reservoirs) and the Anicuts (weirs). Tanks are mostly located in the dry zone to store water during the rainy period and distribution during dry period. From the anicuts the water level of a stream is elevated and diverted to the irrigated area, as such they are mainly located in wet zones. For convenience of control and management, irrigation systems are grouped into three categories based on the extent of irrigated area; Major schemes (irrigated area is above 600 ha), Medium schemes (80 to 600 ha) and Minor schemes (below 80 ha). In all there are about 24,000 minor irrigation schemes in the country with an irrigation potential of over 250,000 ha.

The Small Tanks

The term village based minor tanks (wewa) has been used to refer to an artificial lake or pond for storing water on the surface of the ground which has been constructed by local people at geographically suitable locations with their indigenous skills mostly during ancient times. Hence, the location of the tanks and its size had been determined on social as well as hydrological factors. There are about 12,500 such minor (small) tanks scattered throughout the country with an irrigation potential of over 100,000 ha.

Most of these tanks are shallow mini reservoirs with an average depth of 2.5 to 3.5 meters with micro-catchments of less than 20 km^2. The feeding streams are non-perennial and water flow is available for relatively short periods following monsoon rains. The irrigable area also depends on storage capacity and land availability. Rehabilitation of Small Scale Irrigation Schemes (SSIS) is one of the foremost development activities launched by the government from 1970's mainly because;

(i) the cost of rehabilitating SSIS is relatively less compared to major schemes but the benefits are much greater.
(ii) the transfer of operation and maintenance activities after rehabilitation to the beneficiary farmers reduces the expenditure for maintenance, and
(iii) these are not only used for irrigation, but also as water source for domestic needs, livestock and source of high protein food supply such as tank fish.

Various studies have revealed that the utilization of irrigation and land resources under SSIS remains much below the projected potential. Contributory factors are; inefficient management and inadequate maintenance of irrigation structures leading to the deterioration of the whole system. Up to 1970 s the beneficiaries, by law and convention were compelled to repair and maintain their systems. But thereafter, due to more government intervention and disregard to farmers' participation and contribution, the farmers are accustomed to depend on government support for even small repairs and maintenance. The change in the SSIS definition from the Irrigation Ordinance (No. 32 – 1946) - " **a scheme constructed and managed by the farmers with a little government assistance limited only for masonry structures** to the Agrarian Services Act (No 58 – 1979) - **" a scheme in which the command area is less than 80 ha (200 acres)"** has also influenced their attitude. But from 1990 s, various strategies have been adopted to inculcate into the former responsibilities and create a sense of owner-ship among the farming community.

Performance of Small Tanks

Contributory factors and beneficial factors

The contributory factors which directly affect the performance of small tanks can be mainly categorized into two namely; Hydrological factors and Management factors (Figure 1). Hydrological factors are governed by natural resources such as rainfall, catchment characteristics and tank characteristics. So, there are limitations in improving hydrological factors to achieve high performances. But the management factors are controlled and managed by humans and hence there are always possibilities and potentials for improvements. The beneficial factors can be categorized into mainly three groups namely; Agricultural benefits, Social benefits and Environmental benefits. The characteristics of contributory factors and beneficial factors can be used for small tank categorization. Currently, no such categorization system is being adopted and all the tanks are considered equally.

During the feasibility study stage (before tank rehabilitation) also, some hydrological factors are considered to compute the possible cultivation extent and based on that and the pro-rata cost the rehabilitation cost is determined. Since, most of the hydrological factors cannot be assessed accurately, possibilities of selecting unsuitable tanks are high. Resultantly, more investments are made on non-suitable tanks and the chances of improving deserving tanks may be reduced. Hence, more broader criteria and factors should be considered and all the tanks in the country should be categorized.

function independently due to developments in individual schemes (e.g. raising the bund and spill to increase the water holding capacity) disregarding the hydrological inter-relationship within the cascade system. As a result, the tanks with less catchment area get less inflow and face water deficit.

(b) The rainfall (onset, intensity & duration) and catchment characteristics (size, surface texture, topography & vegetative cover) are the governing factors of the tank water inflow. Of the above, the vegetative cover is the only factor, which man can easily change but most influentially affect the runoff of the system. The degradation in the vegetative cover causes soil erosion and the silt gets deposited in tank beds and thereby reduces the water holding capacity. In anicuts, this react in a different way. Due to soil erosion the hard surface is exposed and resultantly the water infiltration rate is reduced. Consequently, high surface runoff occurs with the onset of rains but ceases after that, due to non-availability of sub surface flow. This adversely affects the wet zone farmers who cultivate under anicuts without water storage.

Physical characteristics of the schemes

Studies have revealed that the water inflow from the catchment varies between 20% - 30% during Maha (wet) season. Since these tanks are shallow and have a high water spreading area the tendency for water losses is very high. On an average 30% of the seasonal water inflow is lost due to evaporation, seepage and percolation. Therefore from the total rainfall, only 16% is available for irrigation at the tank outlet. Considering conveyance efficiency as 80% and water available for the crop is about 13%. Hence, due to low inflow and high losses the irrigation potential in small tanks is marginal. Only timely cultivation and effective system management could ensure optimum utilization of scarce water resources.

Characteristics of hydrological factors

i. Rainfall of the area – Rainfall is the governing factor affecting the performance of small tanks. The tanks located in high rainfall prone areas have high performance than the lower rainfall prone areas.

ii. Catchment water yield - Since most of the small tanks have very limited catchment area its' characteristics such as size. shape slope vegetation. soil cover etc. are affect the water inflow to the tank..

iii. Tank Characteristics – Tank characteristics such as water depth, shape, water spread area, location of the tank, tank bund condition etc. affect for water storage and conservation mainly to minimize the water losses.

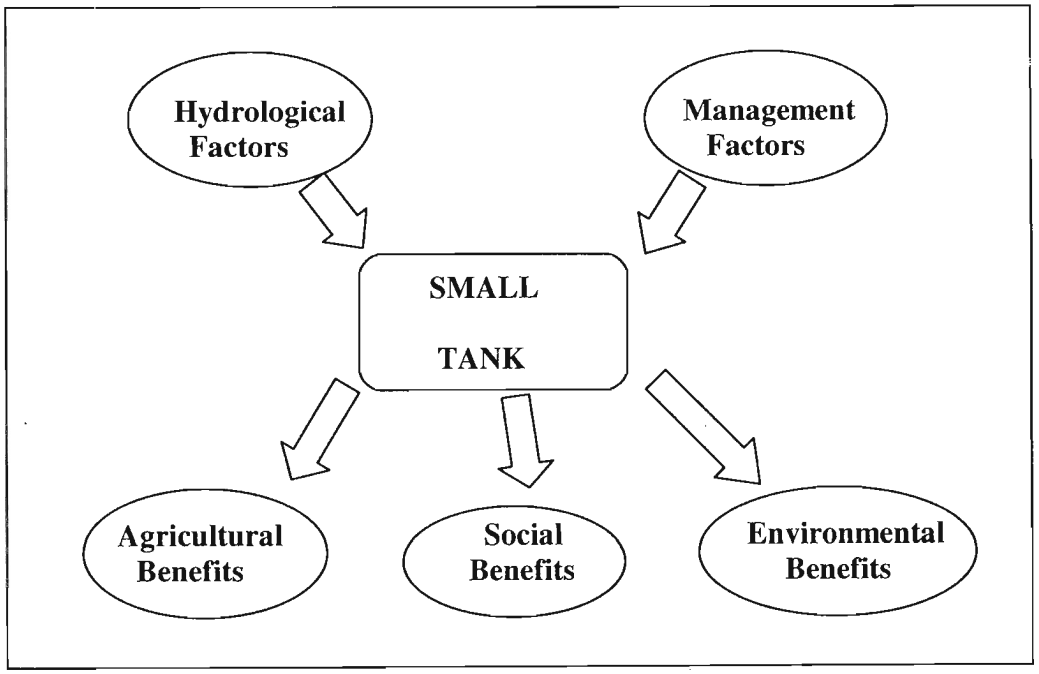

Figure 1. Contributory Factors and Beneficial Factors

Furthermore, some of the small tanks constructed in ancient times had not been used for irrigation. For an example, some small tanks located upstream of major tanks were to deposit the silt coming from slope catchments. Those tanks were called "Kulu wewas" which means tanks in jungles and the purpose of these tanks was to avoid siltation of major tanks. These also helped to increase ground water level in upstream area, which helped to increase water springs and grow healthy forest cover. Gradually, with the population growth, people started settling-down in these areas and under various development programs the command areas were developed Resultantly, the runoff for major tanks as well as for some village tanks have been drastically reduced. Hence small tank categorization based on their performances is absolutely necessary.

Characteristics of contributory factors - hydrological factors

The catchment or the watershed is the most crucial component of a small tank. Following are the two major setbacks in the tank water inflow experienced during the recent past due to changes in the catchment.

(a) Many dry zone tanks had been built in a cascade (series) along the valley during ancient period aiming at optimum water utilization. But today many tanks

Management Factors

Management factors consist mainly of water management and maintenance activities. To facilitate effective management functions, most of the tanks have been rehabilitated or improved during recent past. In addition, during last decade or so, more innovative actions have been taken to improve rehabilitation programme and thereby enhance system management activities to improve the system performances.

Cost effectiveness and low-cost technologies in rehabilitation

The average rehabilitation cost for minor schemes is Rs 40,000 per ha (based on National Irrigation Rehabilitation Project rates) which is more than double for major schemes. The other advantage in small schemes is that the pace of development is simple and rapid which require less planning and designs and more farmers and local labour can be engaged during construction period. Also, simple and low-cost technologies can be adopted in designs and construction of small scale irrigation systems.

Planning and implementation can be carried out in close collaboration with the beneficiaries and their proposals based on experiences can be easily incorporated in rehabilitation activities. Their active participation is expected at least to recover part of investment cost (10-25%) in labour.

The Farmer Organizations (FO) are encouraged to take either part or full contract mainly because it (a) creates awareness on quality and standards which facilitates system management (b) reduce conflicts and complaints and develop sense of ownership (c) helps to develop FO's fund. Instead of awarding the full contract to FO, each can be divided into packages and awarded to small farmer groups (5 to 10 members) within the FO. The benefits of this system are (i) all members actively participate in construction. (ii) quality upgraded due to self monitoring (iii) speedy construction with less capital (iv) team work, cohesiveness and leadership are developed (v) 5% deposit from each group's payments build-up the FOs' fund. Some difficulties/constraints experienced are (i) skilled labour shortage due to parallel construction (ii) need for continuous supervision from officers' (iii) payments at short intervals.

Farmer participation and empowerment in system management

The success of any irrigation development depends on the degree of beneficiary participation. The attitude of " construction is officers responsibility and maintenance is farmers responsibility" has changed now. Arrangements have been made to get more and more farmer involvement for planning and construction that leads for successful management after constructions. In order to ensure farmer participation, assist and to ensure continuous rapport between farmers and officers, a series of training programmes and meetings have been formulated during Pre-construction, Construction and Post-construction stages.

The operation and maintenance of small schemes are the responsibility of beneficiaries from the past. Due to more and more government involvement in rehabilitation, farmers are accustomed to neglect the maintenance activities. Negligence of customary rules such as timely cultivation and erosion of leading authority and inability to take legal action against defaulters have contributed to the deterioration of the performance of the system. To overcome this situation a Maintenance Fund has been proposed under small schemes.

Maintenance Fund

Building-up maintenance fund at scheme level is a long felt need. Farmers naturally tend to attend to the labour-intensive maintenance works (clearing, earthwork etc.) but not minor repairs or works that need money (replace or repair the gates etc.). As a result, the whole system is bound to deteriorate and lead to another rehabilitation. to avoid such situations a programme has been launched to establish a maintenance fund in most of the nirp schemes. The target at the first phase is to collect an average of rs.500 per acre to raise rs.25, 000 – rs.50, 000 per scheme depending on the cultivated extent. The FO deposits this money in a bank for a period of 10 years. Before commencement of the cultivation season (once in 6 months) the interest proceeds of the deposit (about rs.2500) can be spent on repairs on the decision of the cultivation meeting.

Characteristics of the management factors

i. **Water distribution** – Timely and rotational water distribution, performance of water distributor (Jala Palaka) and his seasonal payment.

ii. **System maintenance** – Seasonal maintenance, mode of maintenance,(share system or sharamadana) and maintenance fund

iii. **System protection** – timely attendance to minor repairs, legal action against defaulters who break the gates for taking water illicitly, cultivation in reservations, cattle damage to bunds and canal system etc.

Beneficial Factors

Management of beneficial factors

Cultivation decisions – It can be observed at some of the cultivation meetings farmers decide not to do cultivation during that season mainly to conserve water for domestic purposes. Especially, when water level by end of Maha season is low, they give priority to social and environmental factors rather than agricultural factors. Resultantly, the cropping intensity gets reduced but social benefits accrue to villagers. Hence, the current practice of estimating cropping intensity alone is not a suitable determinant to decide the performance of a small tank.

Dead storage or live storage – In general, the sluice (outlet) sill level is constructed about 0.75 m (2ft) above the tank bed level. The residual storage is mainly for domestic purposes, animals and fish. Since this water quantity is not used for irrigation, it is called "**dead storage**" in irrigation terms. But in considering farmers and animal lives this should be called as "**live storage**". In some recently rehabilitated tanks, the sluice sill levels have been lowered, closer to tank bed levels and this dead or live storage has not been left out. In fact this leads to immense problems not only to the villagers but also to the flora and fauna in the area.

Independent decisions – When compared with major schemes, a lot of advantages could be observed in small schemes. They can get independent decisions by looking at the water level or by forecasting weather patterns from past experience. At the beginning or mid of the season they can control water issues after considering water availability. This paves the way for discreet water management.

Characteristics of beneficial factors

Agricultural benefits – The agricultural benefits can be mainly categorized into two;

(i) **Cultivation benefits** – crop type, cropping intensity, yield, market value etc.
(ii) **Benefits from livestock and fish**

Social benefits also can be categorized into mainly two;

(i) **Domestic water use** – water used for drinking, bathing, washing etc.
(ii) **Water for other rural income avenues** – Other income generating activities implemented by using tank water are;

- Cadajan weaving – for own house and for selling
- Brick making
- Selling of Lotus flowers and use of yam and seeds for consumption.

Environmental benefits

Environmental benefits also can be categorized into two;

i. Water for living creatures – drinking water for wild animals, birds, aquatic plants and small living creatures in and vicinity of water

ii. To maintain ground water level – This helps to maintain upland plants and soil moisture.

To What Extent the Above Factors have Contributed Towards the Performances of Small Tanks Satisfactorily?

Area selected for the study

The Maho Agrarian Services Center (ASC) area in Kurunegala district was selected to assess the performance. Brief description of the small tanks characteristics in the area is given below;

Total number of small tanks (working) in the area		= 263
No of abandoned tanks		= 6
Total extent of the working tanks		= 1750 ha
Tanks grouping according to extent		
Less than 4 ha (10 acres)	= 141	
Between 4 ~ 10 ha (10 ~ 25 acres)	= 81	
Between 10 ~ 20 ha (25 ~ 50 acres)	= 33	
Above 20 ha (50 acres)	= 8	

This shows that most of the tanks in the area are very small compared to Anuradhapura district (average size of small tank is 20 ha). The average land holding size is 0.4 ha (1 acre) per family.

There are about 35 villages in the area. Every village has a comparatively big tank which is called "Maha Wewa" and some small tanks. The name of the village is pre-fixed to identify the tank e.g. Kakunawa Maha Wewa, Uduweriya Maha Wewa etc. The other four to six small tanks in the village are identified by various names mainly using the names of trees e.g.Palu Wewa, Kubuk Wewa etc.

Tanks selected for the study

Twenty village tanks (Maha Wewas) were selected for a rapid analysis. The applicability and suitability of the contribution factors and the beneficial factors were assessed. Out of twenty, fourteen tanks have been rehabilitated during last ten years. The World Food Program or the food for work is a highly satisfactory program in the area.

Contributory Factors

Hydrological factors

(i) Rainfall – The monthly rainfall figures for the last 10 years (1990 to 1999) was obtained from Maho ASC. The monthly average rainfall and 75 % probability rainfall which is used for irrigation design purposes were compared. The agro-ecological region is IL-3

Maha Season –Rainfall (mm)

Month	October	November	December	January	February	March	Total
Average Rainfall	304.5	225.2	130.7	85.3	43	62.3	851
75% Pro Rainfall	191	165	89	51	38	51	585
No.of years less Pro*	1	3	3	6	7	6	

Yala Season –Rainfall (mm)

Month	April	May	June	July	August	September	Total
Average Rainfall	176.5	179.7	36.9	58	26.9	93.3	571.2
75% Rainfall	102	51	38	25	13	38	267
No.of years less Pro*	1	2	8	2	5	3	

* Number of years in which the monthly rainfall is less than the probability values during last ten years

The above results show that in both Maha and Yala seasons the average rainfall is higher than the expected (probability) rainfall. In Maha seasons in eight out of ten years the average rainfall is higher than the expected rainfall. In Yala season, in all ten years seasonal averages are higher than the expected values.

The results indicate that the Maha ASC area in general has received expected rainfall. Hence it is a suitable area for small tanks development and maintenance.

In considering the monthly rainfall, for January, February and March in Maha season and June, July and August in Yala season, during more than five years (50%) the expected rainfall has not been received.

This is why farmers are continuously requesting to deepen their tanks (desilting) to store more water from October, November and December rains to compensate the following dry months

(ii) **Water yield (runoff)**

In most of the tanks the catchment area is less than 2.5 sq km (one sq mile). Especially, the main tank (village tank) has comparatively large catchment and located at the bottom of the cascade (a series of tanks in one stream). Out of twenty tanks studied, 14 have spilled more than seven years out of ten and balance tanks spilled over only four years. But most of the farmers complained that the upper tanks development without proper investigations would cause a reduction in the inflow to their tanks.

Hence, under the forthcoming rehabilitation programmes, proper studies should be carried out on runoff and cascade characteristics before making proposals to increase capacities by raising spills to cater to additional command area.

(iii) **Tank characteristics**

In nine out of twenty tanks studied, in nine tanks the water depth is more than three meters. In twelve tanks 50% of water is saved for Yala season. This really is a good characteristic of a small tank with high performance.

Management Factors

(i) **Water distribution** – In almost all the twenty village tanks studied water management practices are being implemented satisfactorily. In 14 tanks Jala palakas (water controllers) control the gates and in other schemes the former vel-vidane system (village leader) prevails. The average irrigation duty in most of the schemes is 2.5 ac ft/ac. Only in five tanks, the farmers pay a contribution (half a bushel of paddy per acre) to Jala palaka for his service. In other schemes this method is not being practiced, Resultantly, some water controllers show lethargic attitude in water management practices.

The department of Agrarian Services should intervene, convince and persuade the farmers to pay the contribution (salaris) to Jala palaka for his service. Free service or service for public acceptance cannot be expected now due to economical difficulties, as in the past.

(ii) **System Maintenance** – In almost all the schemes, seasonal maintenance is done on share (pangu) basis. It really is a satisfactory outcome compared to major schemes in which the maintenance is done with state funds. Only in five schemes contribution to the Maintenance fund has been collected. During the field visit discussions most of the farmers agreed that they need such a fund for minor repairs and maintenance activities.

The Department of Agrarian Services with the assistance of Govi Sevana Niyamaks should take the initiative to build up the Maintenance Fund.

(iii) **System protection** - Complaints on taking water illegally has not been reported mainly because the defaulters can be easily identified. It is a good sign of small schemes compared to major schemes where water tapping illegally is a common practice. In two occasions the Divisional officer has taken legal action against cattle damages. Newly recruited Govi Sevana Niyamakas, in general perform their duties as cultivation officers satisfactorily.

The Divisional Officer in Agrarian Services Department, should inquire into minor conflicts, conduct a good rapport with farmer leaders and take legal action against defaulters. This will pave the way for maintaining law and order and thereby maintain the sustainability of the irrigation systems.

Beneficial Factors

Agricultural benefits

In all the twenty village tanks studied, full command area has been cultivated during last ten years. Bethma system is practiced satisfactorily during Yala season in most of the schemes. In some schemes they grow vegetables and other cash crops to a limited extent. The Maha average paddy yield is 80 bushels per acre. In average, 50 % of their paddy harvest is sold and balance is kept for consumption. The farmers complained that the income from agriculture is not adequate to run a seven-member family. For an example they emphasized that the selling of Maha harvest brings an income of Rs 10000 (Rs 250 * 40 bushels) from which 50% goes as production cost and balance about Rs 1000 per month is hardly sufficient for their subsistence.

Farming one acre alone will not be adequate to live. Hence, youngsters tend to leave from agricultural pursuits and seek other employment, mainly males in the security forces and females in free trade zones or as housemaids in middle-east countries. Growing high value crops and developing the tendency to more off-farm activities would relieve these problems.

Benefits from livestock and fish

Both these trades are not performing satisfactorily. On an average, 50 to 75 cattle belonging to two or three owners are reared under each tank but not practiced systematically. The milking cows are very limited and the reason attributed is the low milk price. They rear the cattle mainly for flesh and one of their main complaints is the inadequacy of grass lands to maintain large herds. The fishing industry, though is a lucrative trade specially in countries like Thailand, Philippines etc. has not gathered full swing. In most of the tanks, they auction the tank for the right to catch fish annually for about Rs 5000. But the buyer, usually an outsider from the village sells the harvest for about Rs 20,000. The farmers are reluctant to getting into the fishing industry mainly because of religious bias and consider it as a low level trade.

The government should intervene, to promote the fishing industry in small tanks. Private companies should be brought into this business and systematic marketing arrangement should be made.

Social Benefits

Domestic water use

Most of the villagers come to the tank for drinking water and bathing. In the tanks studied, farmers from far distances come for bathing since most of the small tanks in their areas are dry during Yala season. But, in all Maha Wewas generally about two to three feet depth of water is available for domestic purposes. This as per villagers' views is an invaluable advantage from small tanks. In some seasons they decide to forgo the cultivation to conserve water for domestic purposes.

Other rural income avenues

Under most of the tanks, brick manufacturing industry or cadjan weaving is implemented but on a very small scale. Brick making is a lucrative trade and under one tank they said that their earning is about Rs 5000 per month, which is five times than the income from crops. But still the tendency of such activities is limited. Also, in some tanks, thousands of beautiful lotus flowers could be seen. The outsiders come and pluck the flowers for selling but villagers are not interested. The villagers think that selling of flowers is not a correct thing since those are used for religious activities. But, in contrast, one flower-seller at Awkana said that his daily income is about Rs 600 and on poya days it exceeds Rs 1500.

Environmental Benefits

Water for living creatures

In most of the village tanks, since they don't get dried the small birds like wild ducks, wild pigeons and various other birds live in the water. Burrowing animals and thousands of small insects live in the water. Also, wild elephants, wild boars and other animals in the jungles too come for water to the tank. Further, water in the tank gives a cooling environment and lovely atmosphere.

Developed countries, for example Australia has taken the initiatives to develop small tanks or ponds, not for irrigation but to maintain a better environment. These water bodies are for flora and fauna in the system and to maintain the ecological sustainability. It gives pleasant scenery and cooling atmosphere. Similarly, our small tank system also should be well maintained for environmental benefits.

Ground water for uplands

The water level in small tanks helps to maintain the ground water level. This helps to maintain the upland cultivation, water level in the wells in the village and soil moisture content of the area. This really is an indirect benefit from the village tank.

CONCLUSIONS

Small tanks are highly relevant and attractive development programmes in considering the agricultural, social and environmental benefits. The performance of theses tanks depends on contributory factors. Conservation measures to improve catchment inflow, management arrangement for effective O & M are the key driving inputs to make the system more functional. As such, the small tanks in the country should be categorized based on the hydrological and management contributory factors. Based on the above categorization, future development programmes should be undertaken.

In spite of the fact, that the advantages of small tanks are often said, however, their benefits have not been properly understood. However, it has been revealed that there is a greater potential for improvements. Hence, the officers in Technical, Institutional and Agricultural sectors should implement an integrated programme to enhance the performances of the small tanks.

The sustainability of the village depends on the tank and vice versa. These tanks functioned and served the community for more than thousand years and will continue to do so in the future. Tank has a life. It serves the community without asking any return. Hence, it is our duty and responsibility to preserve and conserve this valuable life-giving resource. In the midst of the current large scale irrigation and agricultural development projects, the small tanks still render a massive contribution to maintain the village farmer and to upkeep the agricultural economy of the country.

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DIAGNOSTIC TOOLS TO ASSESS UNDER-PERFORMANCE OF IRRIGATION SCHEMES

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INTRODUCTION

In Sri Lanka today, the total irrigated area amounts to about 536,000 ha, under 98 major (irrigating over 400 ha), 282 medium (irrigating between 80 and 400 ha) and about 22,500 minor (irrigating less than 80 ha) irrigation schemes. The large investments made in the irrigation sub-sector has contributed tremendously to increase in food production and employment generation. However, there is a general concern nowadays that the performance of irrigation schemes is well below optimal levels.

The concerns were first raised in early 1970's and resulted in the implementation of several major irrigation projects, mostly donor assisted, commencing from 1975. The most recent and the largest so far, was the World Bank/EU financed National Irrigation Rehabilitation Project (NIRP). The completion reports of these projects show mixed results. In some of the projects, the rehabilitation requirements have not been properly assessed. During the implementation of NIRP, a collaborative research project was carried out together with H.R. Wallingford, U.K. to develop a procedure for planning rehabilitation of irrigation schemes. This paper outlines the diagnostic tools identified during the study and describes one procedure in detail.

Assessment of Performance of Irrigation Schemes

There are many factors that determine the performance of an irrigation scheme. Complex linkages can exist between these factors as illustrated in figure 1. As an example, poor operational control could lead to excess water in the drains, encouraging weed growth and reduction in drain capacity. This may result in flooding of cropped lands at times of intense rainfall, discouraging farmers from investing in inputs, reduce yield, worsen problems of water control in the system, and lead to further waste of water.

External causes such as falling commodity prices could reduce returns to farming so that farmers leave the land or do not invest in inputs. The result is that crop output falls, water demand falls, channels run part fall, sedimentation and weed growth proliferate, water supply becomes erratic and crop yield falls further.

Indicators of Under-Performance

Outward indications of under performance, termed as **'perceived defects'** in rehabilitation terminology are:

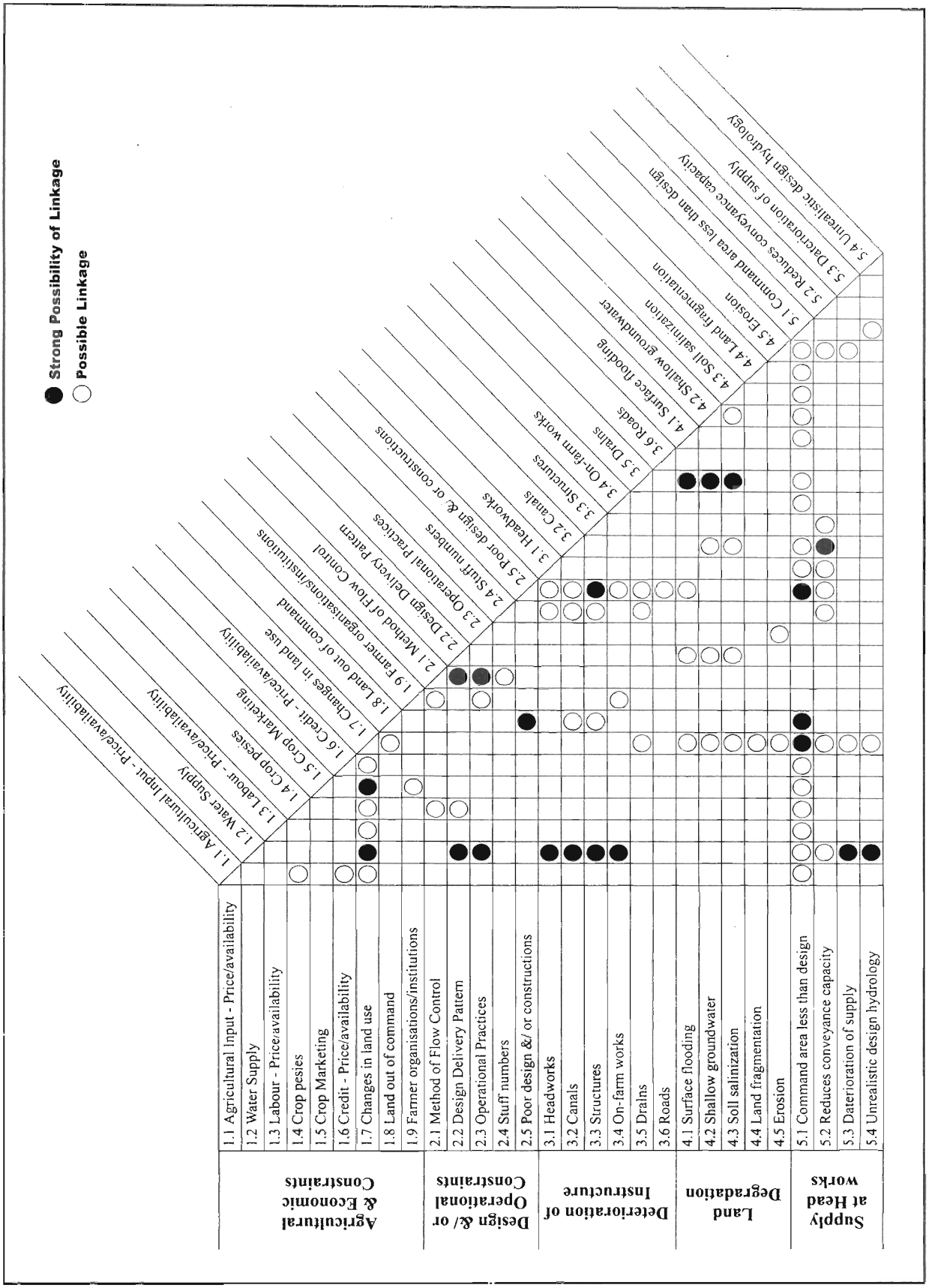

Figure 1. Links Between Causes and Effects

- reduced crop area;
- water shortage; and
- falling crop yields

Primary causes for the perceived defects can be grouped into following broad categories:

- agricultural/economic
- design and operation
- system deterioration
- land degradation and
- headworks supply

Primary causes arise due to a large number of possible alternative, or complimentary, **underlying causes** as illustrated in Figure 2. Diagnostic tools to identify the underlying causes are also indicated in Figure 2.

Diagnostic Tools

The diagnostic tools developed to assess under performance of an irrigation scheme are :

(a) Farmer Questionnaire to indicate relative importance of agricultural and economic constraints.
(b) Checklist to indicate relative importance of system design and operation constraints.
(c) Condition assessment survey to determine the status of infrastructure and prioritise rehabilitation needs.
(d) Checklist to quantify land degradation problems and diagnose causes.
(e) Standard procedures to assess hydrological and hydraulic problems.

Only the diagnostic tool to assess the condition of infrastructure is discussed in this paper.

Diagnostic tool for assessing the condition of Infrastructure

Assets of an Irrigation Scheme

Surface irrigation schemes typically include a large number of relatively low cost assets, of several different types and functions, spread over a large area. These assets fall into following categories:

- Head works
- Cross Regulators
- Turnouts
- Drops
- Cross drainage structures
- Aquaducts

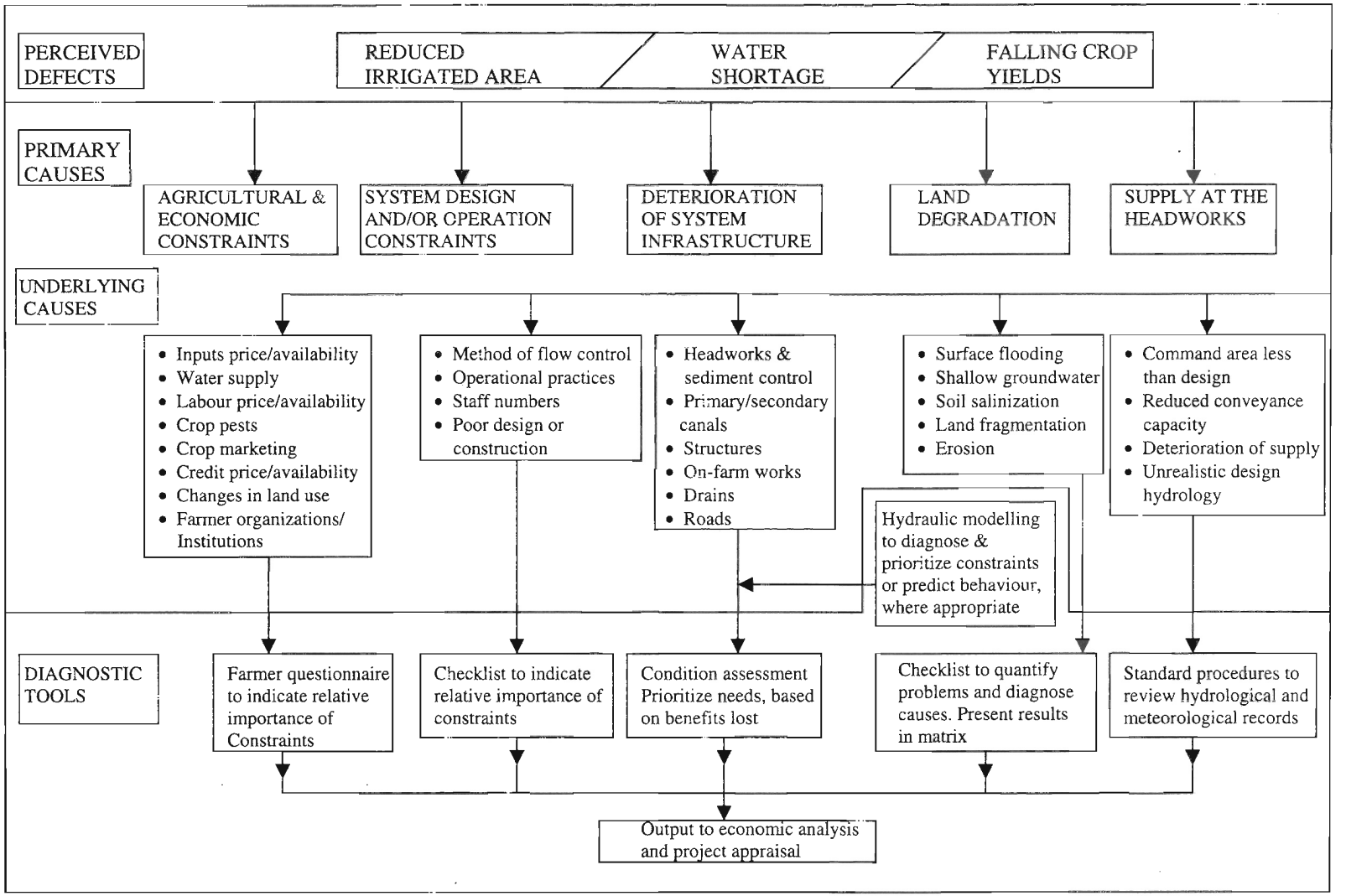

Figure 2.Determinants of Performance and Diagonostic Method

- Syphons
- Measurement Structures
- Canal reaches
- Drains
- O& M roads
- Canal & Spills

Fitness of Assets :

The diagnostic tool involves the assessment of fitness of an asset to perform it's function by means of a walk-through survey. An asset may fail to perform it's intended hydraulic functions whilst still structurally sound. It may also fail structurally, with some associated hazard. A scoring system was developed to reflect the fitness of the asset for it's function.

Assessment of Irrigation Engineer/Technical Offices

The assessment scores for Irrigation engineer/Technical Officer's inspection were developed as set out in the box below:

Derivation of Scores:

- The key function, hydraulic or/and structural, of each type of asset was identified – in most cases a single function predominates.

- The principal elements of each type of asset were defined.

- Questions relating to the expected modes of deterioration of each element were formulated.

- The effect of deterioration of each element on overall effectiveness was judged. The allotted score represents remaining percentage effectiveness.

The standardized questions for one type of asset is given in Table 1 with guidance notes. Table 2 contains the scores assigned to each question, representing the element's hydraulic functioning or structural integrity.

Table 1. Structure Type : Gates Cross Regulator

		Yes	No	Un-assessed
1.	Are any of the gates missing?			
2.	Is it difficult to fully open or close any gate?			
3.	Is any gate seriously corroded or rotting?			
4.	Are there serious cracks or movement in any part of the structure?			
5.	Is leaking occurring around the structure?			
6.	Is the d/s apron seriously damaged or undercut?			

7. Is it difficult to read the u/s or d/s gauge boards?
8. Does the overall condition concern you?

Guidance Notes :

1. Missing Gate

Only answer YES if a gate has been removed from the structure Where a gate is broken but still present, answer No to this question and YES to question 2.

2. Gate Operation

Answer YES when the condition of the lift mechanism, missing components or other factors make it impossible to effectively operate a gate. If a gate is missing, answer YES to question 1 and No to this question.

3. Gate Condition

Answer YES where corrosion or rotting has reduced the strength or water tightness of any gate. Disregard minor patches of surface corrosion or minor deterioration of any gate.

4. Cracks/damage and Movement

Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotation movement may be visible Disregard shallow, surface cracks or minor damage that does not affect function.

5. Leakage

Answer YES if you can see washout of fine soil particles, very wet areas or other evidence of water flowing around the structure.

6. D/S Apron

Answer YES where the apron, or other bed protection. is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure.

7. Gauge Boards

Answer NO when gauge boards have not been installed.

8. **Overall Condition**

Answer YES, if:

- There is a serious fault or deterioration or failure to function that is not covered by any other question.

  OR

- Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

Table 2. Condition Assessment Scores

Structure Type : Gated Cross Regulator

A yes answer to the questions carries the scores indicated. A No answer carries a score of 100%. Answer unassessed when you cannot judge the condition. In this care, an inspection by a seminar Officer is necessary.

	Hydraulic	Structural	Class	% Effective
1. Are any of the gates missing?	1		V.Poor	45
2. Is it difficult to fully open or close any gate?	1		V.Poor	45
3. Is any gate seriously corroded or rotting?		1	Poor	70
4. Are there serious cracks or movement in part of the structure?		1	Poor	60
5. Is leaking occurring around the structure?		1	Poor	60
6. Is the d/s apron seriously damaged or undercut?		1	V.Poor	40
7. Is it difficult to read the u/s or d/s gauge boards?		1	Good	90

The box below shows how the values for Condition Index (CI) correspond to broad descriptions of condition.

A general question 'Does the overall condition concern you?' is included on all assessment forms. It is intended to allow a Technical Officer to highlight a concern, which may not be explicitly covered in the YES/NO question format. It allows for the following situations:

'Overall Concern'

- Where the standard assessment questions do not adequately describe deterioration.

- Where an asset is apparently in good condition but it is failing to function as required.

- Where it is apparent that deterioration is in initial stages but may progress rapidly to failure.

The response to the question is not scored.

Condition Index (CI)	Status
100-81	Good-A YES response retumed for a question (s) related to a minor fault. No significant structural deterioration or loss of hydraulic function.
70-80	Fair- indicates partial loss of function and/or some risk to the integrity of the structure. Action not immediately urgent.
51-69	Poor-A serious loss of function and/or potentially serious threat to structural integrity. Action needs to be taken to prevent progressive failure.
< 50	Very poor- Effective failure.

Senior Irrigation Engineer's Inspection

A Senior Irrigation Engineer's inspection should be undertaken if the irrigation Engineer/ Technical Officer responds positively to the question 'Does the overall condition concern you?' or where the answer to a question as unassessed.

The inspection should result in an overall classification based on the condition of the worst element. Standard reporting forms for canal reaches and hydraulic structures, with guidance notes, are available.

Selecting Priorities

Once an inventory of asset condition is prepared, the priority of works is based on the benefit actually, or potentially, foregone. The Priority Index takes account of:

Parameters included in the Index:

- Asset condition, as calculated from the Irrigation Engineer/ Technical Officers report.
- A measure of the area served by the asset relative to the total area.
- An indicator reflecting the strategic importance of the asset.

Each asset type is given a strategic importance on a scale 1 to 4, see table below. The score is intended to reflect the importance of its function, hazard in the event of failure, and relative cost of rebuilding.

Score =1	Score = 2	Score = 3	Score = 4
Measurement Structure	Canal reach Drain Head regulator/ Gated off take Cross regulator Drop/chute Inspection road Escape Bridge	Cross drainage Culvert Aqueduct Syphon	Diversion weir Embankment Dam Barrage Intake works

The Priority Index is calculated from the following formula:

Priority Index = (100-CI) x$\sqrt{}$ (a/A)x Is - equation (I) (3)

Where:

CI	=	Condition Index
a	=	The area served by, or dependent on, the asset*
A	=	Command area of the scheme
Is	=	Importance score

* Note : Structures such as bridges, inspection roads, escapes, etc are assigned a service area equal to that of the canal reach on which they occur.

Calculation of the Priority Index to produce a ranking of works according to need is most easily done on a customized spreadsheet or an asset management program such as MARLIN (Maintenance and Rehabilitation of Irrigation Networks), currently being developed at H.R. Wallingford, U.K.

An example showing how the priority index system applies to a number of assets is shown in Table 3 below.

Table 3. Example of Priority Ranking

Scheme are = 1500 ha				
Asset	**Area Served (ha)**	**Importance (1)**	**Condition Score (2)**	**Priority Index (3)**
Main canal 2+500-3+420	1500	2	75(fair)	50
Sec. Canal 1. 3+000-4+000	380	2	40(v. poor)	60
Sec. Canal 2. 0+000-0+850	435	2	55 (poor)	48
MC drain culvert 8+430	1220	3	60 (poor)	108
DC drop 2+690	185	2	75 (poor)	17

(1) Importance : See Section. 5.5
(2) Condition Score: Determined by most serious defect recorded by Irrigation Engineer/Technical Officer.
See scores in Table 2
(3) Priority Index : In calculated as indicated in equation (i) of section 5.5

Assets ranked according to priority Index			**Priority Index**
1.	MC drain culvert	8+430	108
2.	Sec. Canal 1.	3+000-4+000	60
3.	Main canal	2+500-3+420	50
4.	Sec. Canal 2.	0+000-0+850	48
5.	DC drop	2+690	17

CONCLUSION

This methodology has been so far tested in few schemes in Sri Lanka, Indonesia and Mexico. In Indonesia, it is currently being adopted to prioritize maintenance works. The author is of the view that this procedure is a versatile tool for rehabilitation planners. Of course, the marking system may have to be modified with the application of the procedure to more schemes.

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TOWARDS EFFICIENT UTILIZATION OF SURFACE AND GROUNDWATER RESOURCES IN FOOD PRODUCTION UNDER SMALL TANK SYSTEMS

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INTRODUCTION

Main sources of water for irrigation in most of the dry zone areas in Sri Lanka are river diversions and reservoirs in varying sizes. There are about 12,000 small tanks and anicuts found in Sri Lanka, feeding an extent of about 185,000 ha. This is 35 percent of the total irrigable area in the country, and small irrigation schemes produce 191,000 mt annually accounting for 20 percent of the national irrigated rice production (Agricultural Implementation Programme, 1994/95). Even though the rice yields of small irrigation systems are relatively low, their production capacity should not be overlooked from the national economic point of view.

The Agrarian Services Act No. 58 of 1979 defines small irrigation works as an irrigation work serving up to 80 ha. of irrigable land. There are about 2000 small tanks in the Anuradhapura district and 70 percent of them bear the capacity of irrigating less than 40 ha of land. The command area is as small as less than 20 ha in 50 percent of the total number of tanks in the Anuradhapura district. Highest number of small tanks is found in Kurunegala district and it is more than 4200.

Tank density is high in Anuradhapura and Vavunia districts. Existence of large number of tanks in an area depends on favourable climate, soil and topographical factors. It can be observed that the optimum density of tanks is found around the iso-hyet of 1500 mm of annual rainfall, and a decreasing trend is observed either side of this iso-hyet (Figure 1). Low density of tanks is found in certain dry zone areas where Red Yellow Latasols and Regosols are found. Percolation rates are relatively high in these soils; therefore, water-storing ability is low in these areas.

Tank cascade systems

Small tanks do not exist as individuals. Natural drainage system in a watershed is blocked by earth bunds in appropriate locations to store water forming a series of tanks along the drainage. The drainage pattern formed in the undulating topographic formation in the dry zone landscape can be classified as dendritic drainage pattern. This ramifying nature of the drainage system has led to form clusters of small tanks found in series, which are connected to form a system known as 'tank cascades' (Madduma Bandara, 1985).

Existence of small tanks in a cascade pattern is an advantageous feature in many ways. Surface water bodies spread over an area can maintain the groundwater level closer to the land surface at least in lower portions of the minor basins. It can be stipulated that absence of such a branched system of tanks could lead to rapid depletion of groundwater due to natural gradient of the drainage system. Therefore, in the absence of tank cascade systems natural vegetation seeing now would have not been in the same composition with deep-rooted large tree species found in the various positions along the catenary slope.

Upper tanks in a tank cascade system act as buffer reservoirs to absorb flood-generating rainfall, which would otherwise bring the risk of breaching lower tanks. Similarly, these upper tanks are buffer reservoirs to supply water to the lower tanks when they are in short of water to save the crop.

Present status of small tank farming

In a comparison made on rice yield data between small and major irrigation schemes in both Anuradhapura and Polonnaruwa Districts during the period from 1981 to 1990, it was observed that the rice yields are always lower in small irrigation schemes (Figure 2). This situation has emerged due to several reasons. Most important factors are low level of crop and water management, lack of proper weed, pest and diseases management, poor tillage operations and lack of proper drainage.

Cropping intensity is very low in small tank systems. In a study carried out for Anuradhapura District using rice cultivation statistics recorded from 1970 to 1990, it was observed that the cropping intensity had never exceeded one, and it fluctuated according to the rainfall received during maha season (Figure 3). With all efforts made to renovate small tanks under various tank rehabilitation projects implemented during this period in Anuradhapura District, no significant improvement in cropping intensity could be achieved. This would drive us to make serious thoughts on present tank rehabilitation methodology and its impact on water storage efficiency of tanks.

Cultivable extent from small tanks decreases gradually due to tank siltation and high tank water losses. A study carried out in 1990 showed that three small tanks; Paindikulama, Siwalagala and Marikaragama in the Nachchaduwa major watershed have been silted up by 35, 30 and 23 percent respectively of their initial capacity (Dharmasena, 1992). Siltation of tanks not only causes reduction of storage capacity but also leads to alter the tank bed geometry. Subsequent rehabilitation works, where the capacity has been by raising the spill and the tank bund would create a shallow water body spreading over a larger surface area. This makes the situation more complicated creating several other problems. They are: a) inundation of upstream paddy lands; b) development of salinity conditions in the upper area; c) increase of tank water losses; d) disappearance of the tree strips in the high flood region (*Gasgommana*) and the grass cover (*Perahana)* underneath; and e) disappearance of some indigenous fish species, which cannot survive in shallow waters or do not find a favourable breeding environment.

Water losses from small tanks are very high. Within a period of 2 – 3 months since the seasonal rains cease, most of the tanks appear as somewhat marshy lands infested with aquatic weeds. A tank water balance study (Dharmasena, 1998a) carried out in selected tanks in the Siwalakulama tank cascade shows that contribution of direct rainfall to the storage varies from 25 to 40 percent (Table 1). Relatively higher contribution from direct rainfall was recorded in tanks with smaller catchment areas. Total tank water loss through evaporation and percolation varies from 35 to 90 percent depending upon geometry of the water body. Water losses are higher from tanks with shallower water bodies than those with deep water. Therefore, it is clear that tank bed geometry determines more the water storing efficiency of a tank than other factors do. These results indicate that about half the storage stored in a tank would not remain to irrigate the downstream command area. Figure 4 shows the relationship between percent annual tank water loss and the tank geometry. It indicates that if the tank geometry could be altered to form a high capacity: area ratio, water loss would be reduced to a very satisfactory level.

Table 1. Annual Tank Water Loss and Direct Rainfall in Selected Tanks in the Siwalakulama Cascade (1996/97)

Tank name	Catchment (ha)	Capacity (ham)	Tank bed Area (ha)	Cap./ area (m)	Direct Rainfall (%)	Total Loss (%)
Puliyankulama	226	44.0	35.0	1.26	24	37
Borawewa	33	12.2	14.0	0.87	30	79
Puswellagama	121	14.0	17.3	0.81	39	90
Pahala Aliyawetunawewa	169	18.0	17.0	1.06	26	49
Kolongaswewa	129	21.5	24.8	0.87	36	63
Vembuwewa	174	19.0	17.0	1.12	25	52
Thamarakulama	369	47.4	36.3	1.31	28	40
Siwalakulama	207	65.6	47.5	1.38	28	49

Source: Dharmasena, 1998a

Concept of partial desiltation

In tank rehabilitation programmes at present, the tank bund is strengthened, structures repaired or replaced, and the capacity lost due to deposition of sediment is regained by raising the spill and the tank bund. This has come out with the common belief that the desiltation of minor tanks would result in very low economic returns. However, scientists, planners and engineers cannot escape from the challenge of disappearing of minor tanks from the dry zone landscape during next few decades.

Desiltation of small tanks should aim not only at increasing storage potential and reducing tank water loss but also at protecting the tank eco-system. As desiltation is an

expensive task as well as a must to undertake, it is important to develop a technological concept, which generates a low cost and effective desiltation process. The partial desiltation concept was introduced (Dharmasena, 1994) with this background on the basis of findings from hydrological research studies conducted by the Field Crops Research and Development Institute, Maha Illuppallama.

The process of desiltation in this concept is not essentially aimed at expanding the present capacity of tank. The main objective of the concept is to reduce tank water losses by manipulating tank bed geometry through desiltation. It is clear that the said objective cannot be successfully achieved by a complete desiltation, which would not much alter the area: height ratio of the tank storage.

Sedimentation studies (Dharmasena, 1992) indicate that half of the sediment deposited in small tanks is found within one third of the tank bed area closer to bund. Thus, the same capacity can be maintained by removing sediment in this area and heap up in the upstream area. These soil heaps must be formed at safe gradient and stabilized with trees and grasses to prevent washing down to the tank. These mounds would appear as micro-islands, where productive plant species could be grown. These soil mounds must not block the natural drainage, which supply water to the tank. An illustration of the desilting technique is given in Figure 5. Further, protection for there is a need to construct a soil bund along the periphery of the desilted area except in places where natural streams enter into the tank.

Methodology for partial desiltation

Partial desiltation technique consists of preliminary field surveys, preparation of plans, designs and estimates, removal of sediments, making soil mounds, establishment of upstream reservation (*Gasgommana*) with soil mounds and natural streams, renovation of tank bunds and sluices, establishment of downstream reservations (*Kattakaduwa*) and main drainage of the command area (*Kiul-ela*). The technique should consist of all these activities without which the impact of partial desiltation would not be much effective. However, before commencement of technical planning a Participatory Rapid Appraisal or a similar exercise must be carried out to obtain farmers' views on tank rehabilitation, and to consider their suggestions for incorporating in the subsequent planning and implementation programme.

A tank bed engineering survey has to be carried out to understand the present tank bed geometry, storage capacity and area-capacity-elevation relationship. A sediment depth survey is also to be carried out to prepare original (prior to sedimentation) contour map and area-capacity-elevation curves, which would later be super-imposed to the existing tank bed perspectives. The depth to original tank bed can be determined by field experience. It is identified as the depth at which the sand/(silt+clay) ratio shows a sudden contrasting higher value (Dharmasena, 1992). An illustration of the partial desiltation design is given in Figure 6.

Excavation of soil needs the support of machinery. However, the associated farming community can do shaping up of soil mounds and upstream bund. Most important components in this programme are stabilization of bunds with vegetative cover, establishment of *Gasgommana* (upstream vegetation) and *Kattakaduwa* (downstream reservation) area. Farmers must be aware right at the inception of the programme of how they are supposed to contribute to this activity. Total work should be undertaken by farmer organizations.

Benefits of partial desiltation

Partial desiltation of a tank would provide various benefits to the community some of which cannot be assessed by an economic analysis. It is quite obvious that the return to investment from desiltation is not economical if the purpose of desiltation is to increase the storage. The concept of partial desiltation is not meant merely to increase the storage unless there is a demand from the community or an additional storage potential in the system. The economic analysis should therefore, be based on consideration of following benefits in order to determine the return to investment of partial desiltation.

Even though the asweddumized lands are available in plenty for cultivation in most of the command areas, availability of water in the tank limits the cultivable extent. Reduction of tank water losses from partial desiltation would lead to improve the water availability in minor tanks providing more opportunities for cultivating relatively a larger extent.

Partial desiltation reduces the water-spread area. More than half the land inundated with tank water would be free of surface water after a successful desiltation. Water body would be confined to the portion closer to tank bund. The land area freed from water spread can be covered with perennial vegetation. This soil is fertile with nutrients and high level of organic matter (5 - 8 %) and also has an easy access to groundwater. In a cottage industry improvement programme, this land may best be utilized to grow Bamboo (*Bambusa* spp.), Rattan (*Calamus* spp.), Mat grass (*Cyperus pangorei*), Vetakeya (*Pandanus* spp.), Patabeli (*Hibiscus tiliaceus*), Palmaira (*Borassus flabellifer*), Kithul (*Caryota urens*) etc. all of which provide various raw materials for cottage industries.

Water storing efficiency of the tank would be increased with improvements on tank geometry by partial desiltation as shown in Figure 4. Any water remaining in the tank after `maha' cultivation can be kept without much losses for yala cultivation. Further, this tank storage can raise the groundwater in the command area and yala cultivation can be supplemented by well water with a great assurance. Both these reasons could lead to increase the cropping intensity of the command area.

Minor tanks are seasonal reservoirs. These can be utilized for raising fish species of short duration or harvesting half matured fish stock. An adequate dead storage of a tank with favourable geometry can improve this situation for rearing long duration fish species. The other advantage of having a good dead storage during dry periods in that these tanks can be utilized for raising fingerlings in protected areas.

Groundwater resource in small tank systems

Exploitation of available water resources for agricultural production in the dry zone of Sri Lanka has reached its safe maximum or perhaps is exceeding the tolerable limits of eco-sphere. Despites all efforts aimed at intensifying irrigated agriculture derived on surface water, some agricultural communities resort to farming with alternative water sources indicating the state of water crisis. Shallow groundwater gathering in low-lying valleys, alluvial deposits and areas under influence of surface reservoirs, canals and tributaries has been approached during recent past for cultivation with lift irrigation. This art of agriculture emerged in 1980s especially in the central part of the dry zone known as agro-well farming is now spreading with the blessing of development agencies and the over enthusiasm of farmers.

The increasing trend of using shallow groundwater for cultivation leads to rise two major issues, which should be given due consideration. They are: a) what potential it has for increasing the agricultural production in the dry and intermediate zones; and b) how best it could be integrated and managed to achieve the optimum efficiency and productivity.

Potential of the shallow groundwater reserves and their limitation need to be fully realized in order to prepare a properly integrated water resource plan and for its implementation in a watershed. As agro-well farming is a new situation, farmers have no experience, and as usual go on experimenting through their trial and error approach. Several research works were undertaken during last few years to investigate the potential and make recommendations on use of shallow groundwater for agriculture.

Efficient utilization of surface and groundwater

Recommendations emerged from the studies conducted by the Department of agriculture (Dharmasena, 1998a and 1998b) are summarized below to understand the fact that surface and groundwater resources should be managed in an integrated manner to achieve most possible productivity from small tank farming systems.

Both groundwater and surface water resources should be planned on watershed basis. For such planning it is essential to prepare inventories of tanks, tank cascades, aquifers, cultivable lands, locations of groundwater abstraction etc. in a watershed.

A water resource-monitoring unit has to be established in each province to monitor quantity and quality of water, advice and coordinate the rehabilitation of tanks, construction of agro-wells and protection of natural waterways.

In tank cascade systems upper areas of tank catchments must be covered with forest or conserved with suitable measures for absorption of high proportion of rainfall. Most potential areas for abstraction of groundwater are lower parts of a watershed and the main drainage of the tank cascade; therefore, use of groundwater must be promoted in lower parts of the cascade while trapping more rainwater in upper tanks.

Tanks must be rehabilitated in a manner of reducing water-spread area to minimize evaporation and percolation losses. This can be successfully achieved by adopting partial desiltation concept. Traditional tank eco-system must be restored as it provides protection to water resources and various benefits to villagers.

Water wastage in surface irrigation must be minimized to relief the pressure on use of groundwater. Lift irrigation and micro-irrigation systems can be adopted in place of surface irrigation by pressurising the tank water. Gravity irrigation is a wasteful method of irrigation in areas where, water is a critical factor for farming. Conjunctive use of ground and surface water must be encouraged to make the maximum assurance to the agricultural production in the area.

Crop diversification is an appropriate option to optimise the income level of farmers and increase the land and water productivity. Field crops, perennials, and vegetables can be introduced according to the land suitability for different crops.

As regolith aquifers are limited groundwater reserves, and their depletion would cause environmental hazards, only 25 percent of the potential groundwater storage in an aquifer is recommended for abstraction. In selecting location of abstraction it is recommended that imperfectly drained area is the most suitable area for construction of agro-wells.

Weathered rock zones are less permeable, therefore, well should be dug down to the bedrock for exposing the fractured or shattered zones. Construction of an observation well of small diameter is recommended for testing of water quality and conducting a pumping test for estimating the recovery rate.

Construction of an agro-well is recommended only when the water quality is good for irrigating crops and minimum water depth is at least 2 m during dry period and 5 m during wet period. If agro-wells are constructed without expecting any other water sources, well density should not exceed 6 – 7 per 100 ha of watershed. Wells should not be constructed at very close spacing. Under any unavoidable circumstances wells should not be spaced closer than 100 m.

Well diameter can be decided on the results of a pumping test. The procedure for a pumping test is outlined below.

A well is pumped and allowed to recover a half the depth of water pumped out. If the diameter of the observation well is D (m) and the time taken to recover a half is $T_{1/2}$ (hrs), then the well specific capacity (K) is:

$$K = \frac{0.54\, D^2}{T_{1/2}}$$

Well diameter is decided according to the following Table.

Water depth in July (m)	Well diameter (m) for		
	K > 3	K = 1.5 - 3.0	K < 1.5
2	5.5	7.0	9.5
3	4.5	6.5	8.0
4	4.0	5.5	7.0
5	3.5	5.0	6.0

Under agro-wells crop combinations are more effective than a single crop in terms of water saving, risk of pest and disease and market failures. Planting times should be arranged to prevent build up of high peak water demands which most frequently lead to water shortages and consequent crop losses. Cultivation schedules are prepared aiming at receiving high prices for the produce.

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INNOVATIVE APPROACHES IN VILLAGE IRRIGATION SYSTEM MANAGEMENT

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INTRODUCTION

The topic "Innovative Approaches in Village Irrigation System Management" looks very challenging because it exposes ideas and materials that might lead to address the pressing need of the day.

This presentation is based on the assumption that the real managers of village irrigation systems are the village beneficiaries of those systems and also this is a process of natural resource management in this country. As Mr. L. R. Brohier stated, that "methods of land surveying" is the best example for this type of phenomenon. History becomes the backsight of surveying and future will become the foresight. No angle can be measured unless the foresight is followed by the backsight.

Now, we look into the history of the irrigation science pertaining to the village systems.

Recent History

Village Irrigation System has three main components namely, the Watershed (micro catchment), Reservoir or Weir and Farmland and these three components should be treated as" one way street system."

Watershed

Two main facts that can be stated as far as the micro level watersheds are concerned are the rapid changes in land use and outside interventions.

People were freely allowed to use them, if the lands were available and did not know that those lands were reserved and meant for specific purposes (Tables 1 and 2).

Following data depicts the present condition of micro catchments.

Table 1. Present Condition of Microcatchments

No	River Basin	NF%	WB area In Acs	MC area sq.mls		No.of Feeder Canals
				Total	Average	
90	Malwatuoya (n=1108)	35.4	42052	667	0.60	108
99	Deduru oya (n=3485)	9.0	34647	990.8	0.28	196
	District					
	Monaragala n=811	25.5	-	502	0.62	41
	Trincomalee n=450	41.4	9754	398	0.88	22

NF- Natural Forest Cover
WB- Water Bodies
MC- Micro Catchment

Table 2. Present Landuse Details of a Typical Village Tank Cascade in Rajarata

	Net Catchment Area in sq.km	WSA %	Paddy %	Chena %	Homestead	Forest %	Bare %
Average	1.94	10.2	6.1	8.6	4.3	48.2	22.6
Minimum	0.26	5.31	3.4	0	0	38	0
Maximum	3.70	14.65	11.0	22	12	68	35

WSA – Water Spread Area

The above situation is moderate in Rajarata when compared to the other areas.

Reservoirs

There is sufficient evidence to suggest that all the village tanks were not irrigation tanks and some were reserved for environmental and other purposes, which were identified as crown tanks during the colonial period. Ruins of large number of abandoned tanks both in Anuradhapura and Monaragala districts reveal that number of village tanks were reduced while augmenting the individual tank capacities, without considering the hydrological interconnection among these tanks.

Attempt of duplicating some techniques already experimented in major tanks, for village systems have resulted in producing adverse effects. Nearly 20%(average) of very high seepage and percolation loss indicates the adverse result of incremental tank water

heights and frequent failures of masonry sluice structures in those systems have become a serious drawback. Incorrect interpretation given for "Mada Sorowwa" (Silt ejecter in ancient times) as a "low level sluice" has led to tank bed siltatian and hence reduced the dead storages. Following figures will illustrate the present condition of village tanks (Tables 3 and 4).

Table 3. Present Condition of Village Tanks in two Main River basins

No	River Basin	Silted >1m Nos	Av.WH in ft	VT Sluice Nos	Av.Net catchment Sq.mls	Av.Com Area Acs	No. of Olagon
90	Malwatu oya n=1108	671	7.1	258	0.60	50.4	386
99	Deduru Oya n=3485	1059	5.8	-	0.30	10.0	-

Table 4. Present Condition of Village Tanks in two Districts

District	Silted >1m -Nos	Av.WH Ft	VT Sluice Nos	AV.NET CATCHMENT Sq.mls	Av.Com Area Acs	No.of Olagam
Monaragala n=811	98	5	61	0.62	25.2	35
Trincomalee n=450	42	5.2	104	0.88	56	243

Silted > 1m- Tank beds silted more than 1m depth.
Av WH- Average water height in ft.
VT - Vertical type
AV Com-area - Average command area
Olagam- Remotely operating tanks, farmers are not living closely.

Farmlands- "the most critical area"

New lands were alienated as crown-grants, long term lease lands, year permits. Some encroachments have also taken place in addition to the first priority area called "purana wela" that was prepared at the very beginning of the scheme. Most of these alienations were done without considering the underlying agrarian structure and water rights.

Ancient land allocation system was mainly based on equity and compensative measures that have been adopted, to maintain the water rights. This Water Right was an inbuilt part of the Land Right in the ancient system.

Figure 1 illustrates the ancient mechanism of village irrigation resource management.

Entire mechanism was driven by the force of equity that led for efficient beneficiary participation as well as the sustainability of the system and individual as well as community rights were established in very rational and scientific manner, followed by well connected individual and group activities.

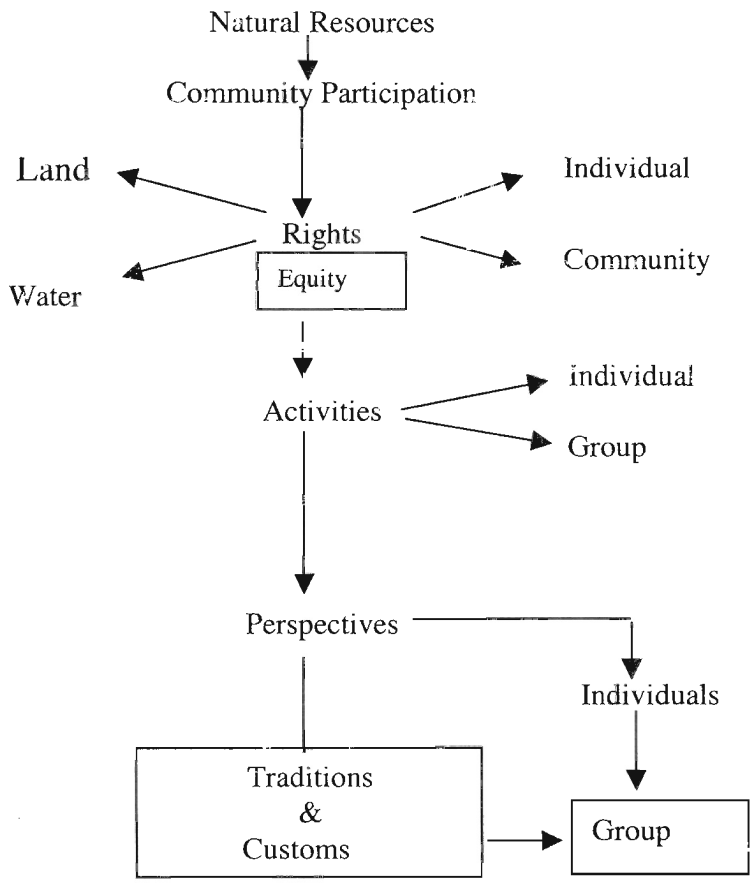

Figure 1. Ancient Mechanism for Village Irrigation Resource Management

The best solution identified by the society to establish and regulate individual as well as group activities were ***customs*** and ***traditions***. ***Bethma*** is a very good example for this phenominon and even an equivalent system with the same degree of efficient resource management anywhere in the world including communist countries was not heard of.

No proper weightage has been given for ancient irrigation technology such as traditional flow measuring devices that are still existing in some part of the country.

Principles that governed the ancient mechanism of irrigation system management were broken down especially during the last century and the science behind those customs and traditions become null and void and remaining today as folktales. But rudiments of ancient concepts and techniques adopted for village irrigation system management are still visible in the country, especially in some parts of North Central & Southern areas.

The major mistake attributed to our present approaches is the belief that the above ancient mechanism is still alive but infact, it is really dead now.

Role of the State

What should be the role of the state in the natural resource management process? Dominant role should be the formulation and implementation of national policy.

Policy should be the formal way of accepting principals and norms of the society and should not only a statement written on the paper but also a series of activities to direct the society towards a particular goal.

During the colonial period, different policies were formulated to suit their own agenda and not for the real benefit of the farming community in this country. Even after the independence, we did not have a sufficient national policy pertaining to village irrigation, to meet the demands that are based on the real needs of the society.

Idea of having a national policy in village irrigation is to fill the vacuum created due to the loss of momentum of ancient customs and traditions, which are inherited to those systems.

Role of the Bureaucracy

Why did the above mentioned situation arose and how? When we try to analyze the situation, it has become a usual practice to nominate two defendants and they are "the state" and "the society". Sri Lankans were allowed to entertain the privileges of the democracy after independence and the state was theoretically identified as a government "of the people, by the people and for the people" but in reality,it fell short of it. The best way of analyzing the situation is the "**Gandian model**" developed in India. **Samaj** or the society reacts on real community needs or the principles and the **Raj** or the state reacts on the demand and always there is a gap between the society and the state.

Now let us find out, who is the interface or the go between these two?
Answer is the "modern bureaucracy", as illustrated in the Figure 2.
Now it is clear that the existence of the policy gap was not the direct fault of either the state or the society.

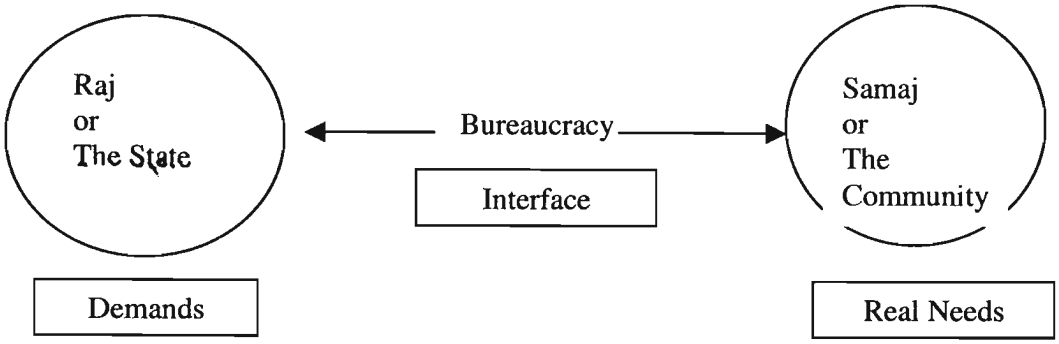

Figure 2. Role of the Bureaucracy in Village Irrigation System Management

It is very necessary to understand the reasons for the failure of the bureaucracy to contribute successfully, to fill the policy gap in village irrigation sector. That is mainly due to a lack of reliable and enhanced data base laid on "natural resource management base" and this mechanism is schematically shown in Figure 3.

Database on Village irrigation

Database laid on natural resource management base has been prepared by the Department of Agrarian Services (DAS) in 2000 and this has been computerized in **"dbase 4"** database management software. This attribute database consists of seventy-six (76) main attributes that should be linked into individual village irrigation systems as well as Meso-catchment areas (cascade) with the help of geographical information system (GIS) mapping (Annex I).

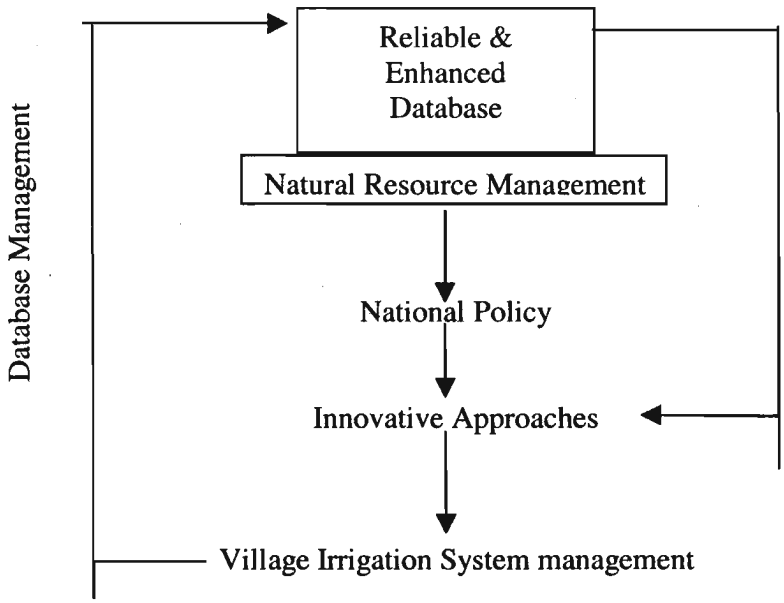

Figure 3. Proposed Mechanism for Village Irrigation System Management

Analysis done of this particular database in Annex 1 shows the type of analysis that this database could do. Data processing and verification process adopted by the DAS is shown in Figure 4.

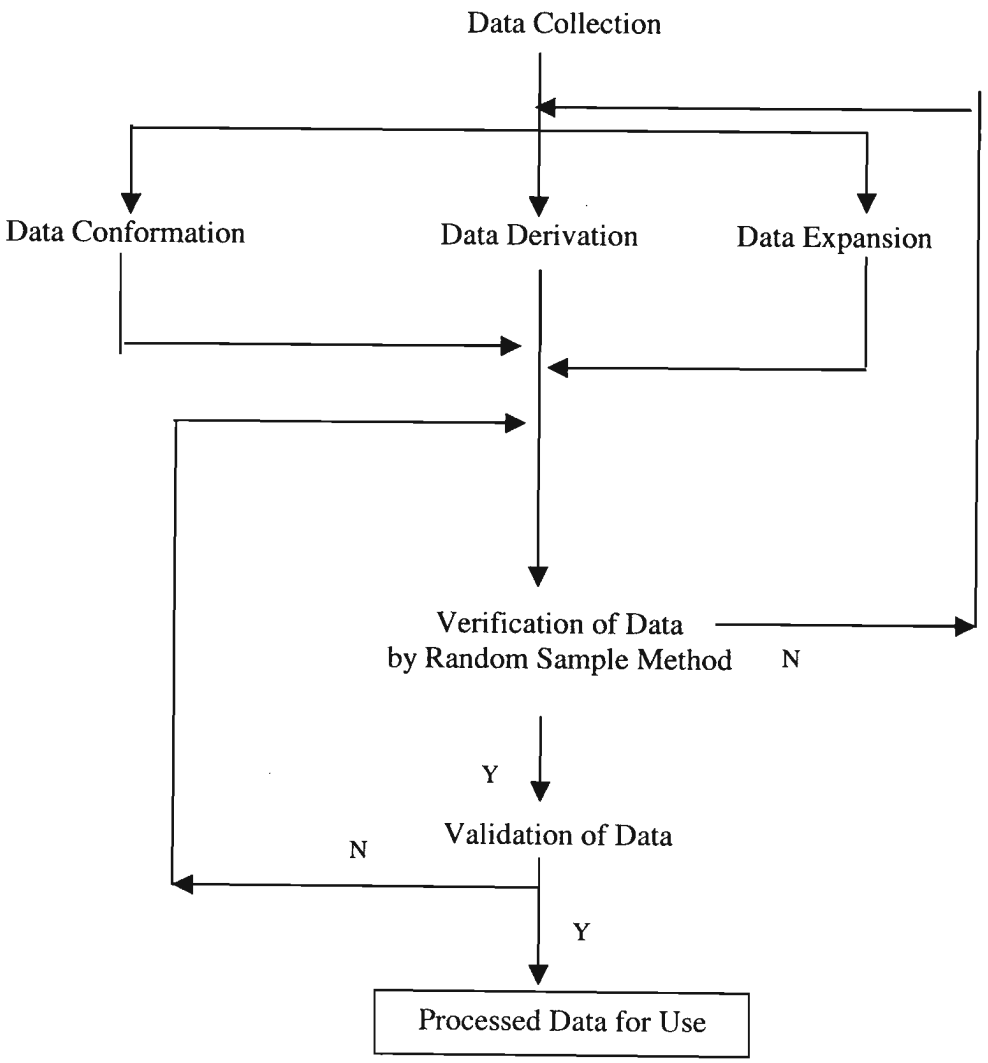

Figure 4. Data Processing Flow Chart adopted by the DAS

Management Potentials

It is understood that the wayside benefits of these village irrigation systems are more valuable than its direct benefits, as far as the entire ecosystem is concerned.

Those hydrologically interconnected and eco-frendly village irrigation systems have become acclimatized to the extent that they have almost become a part and parallel of the nature.

They are so conspicuous that no equivalent can be found anywhere in the world accept in south India which has some resemblance of this nature. Therefore, the concepts and techniques brought from other parts of the world cannot be superimposed without desorting the systems and this had already been proved in many practical cases.

It has been identified and proved that the potentials realized to upgrade these village systems by infrastructure development is so limited in many cases but still there is enough room to improve the performance by introducing an appropriate management techniques.

These facts will lead to certain conclusions. When this situation is examined, it will be clear that innovative approaches based on the national policy that originates with the help of reliable and enhanced database, will result in a remedial measures which are rationally conclusive.

"We all are made wise not by the recollection of our past, but by the responsibility of our future"

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Annex 1

Data base file structure

File Name :- MIDB.dbf

Number of fields :- 76

Number	Field Name	Type	Description
1	Flag	C	
2	SE-NO	N	District serial no.
3	DIS-NO	N	Id number given to district.
4	ASC-NO	N	Id number given to GK.
5	Nature	C	T-Tank A-Anicut.
6	Status	C	W-Working , A-Abandened
7	Sub-No	N	GK Serial No.
8	Name-Scheme	C	Name of scheme.
9	D-S. Area	C	Divisional Secretary area.
10	G-N. Area	C	Grama Niladari area.
11	Com-Area	N	Command area in Acs
12	A- bays	N	Number of bays in Anicut
13	A-L Gates	N	No. of lifting gates in anicut
14	WA-HT	N	Water height of anicut in Ft.
15	A-NAT	N	1-Concrete Structure 2.Temporary Structure
16	T-NAT	N	1-Main Tank 2-Olagama (Remote tank) 3.Other
17	DAM-L	N	Dam length in ft.
18	MAX-HT	N	Maximum bund height in ft.
19	SEEP	N	Bund seepage 1-high 2-low 3-nil
20	T COAD	N	Condition of Tank bund 1-Very good 2- Good 3-Bad
21	NO-SLU	N	Number of sluices
22	VT-SLU	N	Number of vertical sluices
23	MWH	N	Maximum tank water height in Ft.

24	SILT	N	Tank bed siltation 1-Less than 1Ft 2-1 to 3 Ft 3-More than 3 Ft
25	TB-Cul	L	Tank bed cultivation- Y-yes , N-no
26	F-CAN	L	Feeder canal system – Y-yes , N-no
27	IR-CA	L	Irrigation canal system y –available N – Not available
28	CAN-LENGTH	N	Total length of irrigation canals in Ft.
29	FTO-PO	L	Farm Ternout/Pipe outlets Y-available N-not available
30	T-FMD	L	Traditional Flow Measuring Devices. Y –available N –not available
31	DR-CAN	L	Drainage canal, Y- available N- not available
32	DC-CON	N	Conditions of drainage canal 1- Clear 2- Blocked
33	KATTA	L	Kattakaduwa in command area Y –available N – not available
34	SALINITY	L	Soil salinity in command area Y – available N – not available
35	ALKALINE	L	Soil Alkaline in command area Y – available N – not available
36	AGRO-WELL	L	Agrowells in command area Y –available N – not available
37	AW-NO	N	Number of agrowells in command area
38	AVG-CUL	N	Average cultivated area in Acs in last 10 years.
39	AVG-HAR-AR	N	Average harvested area in Acs in last 10 years.
40	AVG-HHRVES	N	Average harvest in BU/Ac in last 10 years.

41	MOL	N	Minimum operating level in Ft.
42	NO-Farmers	N	Number of farmers.
43	NO-OWN-CUL	N	Number of owner cultivators.
44	NO-TEN-CUL	N	Number of tenant cultivators.
45	TM-EXTENT	N	Extent of thattumaru lands.
46	KM-EXTENT	N	Extent of Kattimaru lands.
47	FRAGMENT	L	Land fragmentation in command area. Y –available N –not available
48	BETHMA	L	Bethma cultivation. Y –still practice N – no
49	UPLAND	L	Upland cultivation. Y –Practice N –no
50	WA-MASTER	N	Water Master 1 – Traditional 2 – New
51	FO-AREA	N	Jurisdiction of Farmer organization (F.O.) 1 – Irrigation scheme 2 – GN Division 3 – Number of Irri-schemes 4 – other
52	TOT-MEMBERS	N	Total number of members in F.O.
53	RE-MEMBERS	N	Total number of registered members in F.O.
54	AG-ROAD	L	Weather farmers request for Agriculture Roads, Y – yes N – no
55	MAINTENANCE	N	Method of Irrigation maintenance, 1 – Share list 2 – Up and down 3 – Voluntary 4 – Other
56	REPAIR-10Y	L	Weather this scheme was repaired during last 10 years. Y-yes , N-no
57	CO-ORD	C	Irrigation co-ordinates.
58	AE-REGION	C	Agro Ecological Region.

59	HY-ZONE	N	Hydrological Zone number.
60	RV-BASIN	N	River Basin number.
61	CASCADE	L	Weather this scheme is located in a cascade? Y – yes , N – no
62	CAS-NO	C	Cascade number.
63	EVA-STATION	N	Evaporation Station number.
64	RG-STATION	C	Name of closest Reaingauge Station.
65	WSA	N	Water spread area in Acs.
66	EF TWH	N	Effective tank water height in Ft.
67	G-CATCH	N	Gross catchment area in Sq.Mls.
68	N- CATCH	N	Net catchment area in Sq.Mls.
69	CAT-SHAPE	N	Shape of catchment. 1 – Fan shape 2 – Fern leaf
70	AV-GRADIENT	N	Average gradient of Access Valley.
71	NF-PERCENT	N	Percentage of Natural Forest cover in the catchment.
72	SY-MAHA	N	Specific yield in Maha Ac.Ft/Sq.Ml
73	SY-YALA	N	Specific yield in yala Ac.Ft/Sq.Ml
74	SOIL	N	Identification number of dominant Soil type.
75	G-T-CAPA	N	Gross Tank capacity in Ac.Ft.
76	N-T-CAPA	N	Net tank capacity in Ac.Ft.

C –Character
N- Numeric
L - Logic

SMALL TANK SYSTEM FOR CONTINUED FOOD PRODUCTION WITH REFERENCE TO NORTH CENTRAL AND NORTH WESTERN PROVINCES

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The small tank system operational in the North Central and North Western Provinces has positively contributed to reduce the risk associated with the poor and variable water availability to crops, and to increase and sustain agricultural production (Table 1).

The operational efficiency of the system is dependent on the functional efficiency of each of the four key land use components; the tank (reservoir), the settlement (village), the command down stream and the catchment (the upper aspect of the water shed located at an elevation above these reservoir), integrating to form the small tank system.

A steady growth of population in the provinces since independence is observed resulting from natural increase and migration (Table 2).

Consistent with the increase in population, the incidence of encroachment of village and crown lands has also increased. In the process, the village forest, largely comprising of the catchment of the small tank system, came to be occupied by the villagers, and encroachments by migrating population were concentrated on the state lands (Abeysinghe, 1983). In the process of encroachment, the natural forest was destroyed, and what is presently witnessed is, mostly regenerated secondary vegetation.

The population increase since early 1970's created a high demand for land and encroachments of 2 – 6 acres in extent appeared in the village and the state forest areas. Most of these encroachments were situated within the catchments of the small tank system. With the regularization and land alienation in mid 1970's, specially in the NCP, ownership rights for highland blocks were generally fixed. Even then, the land remained in undeveloped and poorly managed state. Thus the encroached land remained highly susceptible to surface soil loss, resulting from high intensity of storms that occur for durations exceeding 15 to 30 minutes.

Catchment affected by alternative land uses

In developing the encroached / regularized / alienated block to a homestead cum agricultural production unit, any systems approach was hardly used by the occupants. The benefits of available technologies synthesized with research and extension backing from integrated farming systems appropriate for specific farming situations did not go to them. Consequently, large majority of the encroachments, mostly on the catchment of the small tank system, encountered soil and land problems. Deterioration, of soil structure, soil erosion, poor soil-water retentivity, soil compaction, poor soil water infiltration and

resultant rapid and excessive run-off charged with high concentration of sediment load.

Table 1. Area of Paddy cultivated Under Different Irrigation Systems and Rainfed Conditions in NCP and NWP, in Maha 1997 /98 and Yala 1999

Location	Extent Cultivated, ha					
	Maha 1997 / 98			Yala 1999		
North Central Province (NCP)	**Major Irrigati**	**Minor irrigation**	rainfed	Major irrigation		rainfed
1. Anuradhapura District		**36479**	2172	13349	**6110**	11
2. Polonnaruwa District		**2177**	979	44334	**1799**	11
3. Total in the NCP	**Ation** 29680 45032	**38656**	3151	57683	**7909**	22
North Western Province (NWP)						
1. Kurunegala District	12344	**33289**	28220	9236	**17678**	18373
2. Puttlam District	5294	**7143**	1448	4219	**1930**	207
3. Total in the NWP		**40432**	29688	13455	**18608**	18580

Source : Division of Statistics, Ministry of Agriculture & Lands, 1999

Table 2. The Growth of Population in the North Central and North Western Provinces Since Independence

Location	Land area km^2	Density /km^2			
		1953	1971	1981	1988
North Central Province	10532.9	22	52	81	94
Anuradhapura District	7129.2	22	55	82	96
Polonnaruwa District.	3403.7	-	48	77	90
North Western Province	7749.7	110	181	220	251
Kurunegala District	4772.8	133	215	254	288
Puttlam District	2971.9	75	127	165	192

Sources - Abeysinghe, 1983 and NARESA, 1991

contributing to tank siltation, adversely affected the production capacity of the catchment area and storage capacity of the tank. As a result, productivity of the command area is low (Tennakoon, 1986; Somasiri, 1992).

The observations made with respect to an individual tank system, within reasonable limits, could be extrapolated to the tanks forming a cascade system.
(Panabokke, 1999; Shakthivadivel *et.al*, 1996).

Regardless of the variation in soil fertility featured by a high content of Non Calcic Brown Loams, the system of land use and agricultural production under small tank system found in the Kurunegala District (in Agro-ecological Zone IL_3) is broadly

similar to that found in the Anuradhapura District (Agro-ecological zone – DL1). Therefore, the experience with land use and agricultural production available to date and innovations expected in the near future in Anuradhapura (NCP) would be also useful to develop an alternative system of farming in the IL3 region of the Kurunegala district (NWP).

NCP–PRDP Role in the Small tank – Catchment Area Development

North Central Province Participatory Rural Development Project, supported by IFAD is assisting the socio-economic development in the Anuradhapura District. Sectoral development activity is undertaken by the relevant government organizations committed to the provincial programmes. In this upland / highland development is an important sub component. The target group assisted under this sub component consists of the socially mobilised low income poor farmers / interest groups, interested in the development of their highland units, to achieve sustainable productivity gains. Most of the highland blocks (village blocks) selected for development under this programme, were in the upper slopes of the micro-watersheds of small tank system or part of a meso – watershed of a cascade system, and generally, these highland lots were therein early stage of degradation. Cultivation being practiced on these highlands is non-innovative; and hardly any system approach is used in the production process. The present subsistent farming practices are generally destructive (Dharmasena, 1991).

Field visits made to sites/villages undertaken for development confirmed that most farm units owned by individual interest group members were failing to achieve the anticipated project objectives; viz: increasing the cropping intensity within the farm units by about 5-15% in Yala and by 10 – 30% in Maha; and achieving a mid and long term sustainability of agricultural production, while increasing productivity.

An Alternative Strategy

It is recognized that highland development – stabilization is essential for conservation and utilization of land in rainfed areas. The erratic rainfall patterns, heavy evapo-transpiration losses, erosion, poor water holding capacity of soils and poor fertility of affected soils are major factors that limit agricultural production. Some of these limitations are tied up with the nature of resources themselves, others are caused by agricultural practices. Since the project activity is spread over a very large area covering 15 DS divisions in the district, the pilot programme is confined to five DS divisions. The selection of sites was conditioned by the availability / limitations of resources, physical and human.

Air photo (1:10000) interpretation supported with topographical sheet (1:63000) was adequate to detect distinct differences of the farming situations. Six farming situations were identified as suitable for intervention. They are (1) Ellapattuwa village in Meda Nuwaragam Palatha (2) Ullukkulama village in Maha-Wilachchiya, (3) Wannanmaduwa village in Tirappane, (4) Nochchikulama and (5) Kele Tirappane in Mihintale and (6) Weragala in Rambewa.

Table 3. Crop Suitability Recommendations as Determined by The Key Resource Limitations /Potentials in the NCP and NWP

Crop Recommendation / Resource/ Resource Potential Limitation Characterizing the Farming situation	No limitations for growing recommended vegetables OFC and other crop	Marginal for leafy vegetables and Tomato good for Brinjals, "Tibbotu" and selected field crops & Hardy and Psedo-perennials under rainfed	Rainfed cropping with soil moisture conservation techniques.*	Good to Moderade for all crops with priority for mechanization good managemernt or less labour intensive agro-forestry /forestry and pasture (grasses)	Marginal for Agricultural crops/suitable for conservation forestry
Soil_- Deep (Gravelly Layer located at a depth > 50 cm)	+ _	+ _	+ _	+ + _ _	_ _
- **Shallow (Gravelly layer located at a** depth < 50 cm & a deep soil profile.)	_ +	_ +	_ +	_ _ + +	_ +
- Soil depth < 50 cm					+
Water supply - Adequate (Rain + Agrowell, >50 m^3 Recharge/day)	+ +	_ _	_ _	+ _ + +	_ _
- Medium (Rain + Agrowell/ drinking water well 50 -25 m^3 recharge/day)	_ _	+ +	_	_ + _ _	_ _
- Rainfalls only	_ _	_ _	+ +	_ _ _ _	_ _
Labour supply					
- No limitation.	+ +	+ +	+ +	_ _ _ _	_ _
- Seasonal.	_ _	_ _	+ +	_ _ _ _	_ _
- Inadequate.	_ _	_ _	_ _	+ + + +	_ +

+ Conditions relevant to the identification of the 'Farming Situation"

- Not relevant

NB : No. limitation of sunlight, wind and temperature anticipated

- Technology – Soil and water conservation
- Conservation bunds/ditches, Strengthen with suitable plant combinations
- Vegetable hedges/mulches
- Stone gravel and sand mulches
- Vegetative strips/dead and controlled growth
- Grassed water ways/Drains
- Organic amendments/ and plant residue management

Land classification criteria of relevance to agricultural production constraints/limitations were developed and matched with the basic growth requirements of the crops to be introduced (Table 3), with improved mangement systems. In that the technology currently available, as appropriate, would be continued with / modifications.

Main consideration in the selection of crop varieties was the varietal protential available for improvement, (yield and quality) and survival under water stress. Aspects underlining soil, water and crop management would be: soil and water conservation techniques (residue management and use of organic manure); control of soil erosion (construction and strengthening of contour bunds, and drains with the establishment of farm income generating crops such as pineapple); water harvesting and weed control.

This strategy was developed with the recognition that the homested unit (front and backyard of the dwelling house) should be developed to enable effective use of resources available within it. For example, those farmers who had relatively easy access to drinking water wells and who preferred to establish perennials and pseudo perennials on their highland blocks during the yala season, were encouraged to established the seedlings in well prepared planting holes by providing minimum irrigation water required. Those farmers who had no access to such a water source were made to establish plants in relatively large polythene containers filled with a suitable growth medium, again, providing minimum water required. Thus, in the latter case, a system for water saving until field planting with the onset of seasonal rains was introduced. This provided a method to use minimum quantity of water, at fairly long intervals, to protect plants grown under dry conditions. While allowing their uninterrupted growth during the dry spell, during June through to September. The new innovations available from research and leader farmer experiences for accommodating the major constraint of water stress through risk management and whole farm planning / management will gradually be introduced to the small farm units.

Innovations to Enhance Cropping Strategy

The land on the upper aspects of catena, where highland dwellings are located on the RBE soils, is mostly marginal for agricultural production. This is a result of loss of both physical and chemical fertility. It is well seen that the poor fertility, is due to inadequate attention given by the farmers to conservation of the soil. Soil erosion has led to degradation of its productivity. Loss of organic matter has contributed to soil dispersion and promoted soil compaction, making it unfavourable for use in agricultural production. Consequently, farmers prefer to cultivate any available state owned scrub land during the Maha season, which is relatively fertile and easy to cultivate; and situated a few kilometers away from their dwellings. The tradition, in many of those villages in the less populated parts of Anuradhapura District (eg. DS division of Maha Wilachchiya, Medawachchiya, Mihintale) is to encroach and continue to cultivate state owned land most of which is scrub land, adopting traditional " chena " practices. The advantages of chena type of cultivation practices compared with the more stabilized system of cultivation are a few; It enables cultivating a relatively large extent of land during the rainy season. Cultivating this land receives high priority of farmers in the district. The

second priority during the rainy season is cultivating the land owned by them and situated around the dwelling. Its cultivation depends on the certainity of the expected rainfall, and therefore not regular or systamatic. This practice is bound to change with the strategy being followed.

Those dweller farmers who can not claim accessibility (ownership) to any state owned scrub lands to cultivate " Chena " give priority to cultivating land situated around the dwelling houses. In these, they are not aware of the need to adopt land use practices for improvement of soil fertility, and management, and sustainability of resources. The attention given to arrest the trend towards degradation of the environment and loss of productivity of the lands is very low and so, the productivity declines. This is a key area which calls for intervention of the project. Such farmers need to be motivated to adopt the correct land use practices.

A scheme has been defined under the pilot programme to encourage farmers to practice methods to improve the physical environment for higher productivity. The initial step in the implementation of the strategy for productivity enhancement and working towards sustainability suggested is the adoption of appropriate soil and water conservation practices (i.e. construction of soil & water, conservation bunds and other suitable mechanical and vegetative means and the use of suitable structures/ system for water harvesting, and where necessary, for storage of rain water).

The introduction of appropriate drought tolerant cultivars and suitable cultural practices to intensify cropping in the area around farmer dwellings. This land mostly is poorly managed and much of it is left fallow even during the rainy season. Here, attention could be given to the cultivation of certain crops which has a high user demand within the region. Many tropical crops, including coarse grain cereals could be cultivated with economic gain on these lands; drought resistant cereals such as Kurakkan could find its suitable place on this land. The interest of farmers is there to cultivate cereals and grain legumes and other subsidiary crops both during Maha and Yala seasons. What is necessary is to provide them with improved crop varieties and technical know-how to do profitable cultivation on small farms.

The availability of lands to some farmer families, exceeding the capacity of family labour is a matter of concern. Shortage of labour impedes better landuse and cultivation pratices. A way out of this situation is to introduce farm machinery and implements suitable for small scale farms. Another alternative may be to promote cultivation of short-aged improved varieties on a large area, benefitting from favourable climatic conditions, thereby reducing the high risks / losses, thus matching the land suitability with crop demands. A less labour demanding cropping system such as agro-forestry and forestry could be introduced. The allocation of land to conservation farming is another possibility.

Selection of crops for cultivation that are agronomically suitable and economically gainful; matching the cropping system with the land suitability; adjusting the production calendar to suit the market demands are being well recognized, particularly in planning

under agrowells. Adjustment of cropping area to suit the availability of labour is being given consideration.

The measures recommended in this paper to improve agricultural production/productivity under small tank system, if adopted, would provide a favourable and sustainable physical foundation for the small farmers to continue to farm in the North Central and North Western Provinces, while improving the resource potential of the small tank system.

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SMALL TANK SYSTEMS IN SRI LANKA: ISSUES AND CONSIDERATIONS

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Physical and Hydrological Aspects

Different scholars have made different estimates of the number of small tanks in Sri Lanka ranging from 12,000 to 16,000. About half the existing number of small tanks seem to remain either dilapidated or abandoned. This being an approximation a more realistic inventory of small tanks in operation and in abandonment needs to be prepared.

As per origin of tanks, gaps in knowledge are very many. When did people really start constructing tanks? Was it with the advent of Vijaya and his companions or even before? Did they first practice a highland form of agriculture around natural water pools (villus or wilas) and on the banks of the streams or created artificial pools by blocking of the streams near their upland farms for personal use and gradually improved those pools (wilas) and stream blockades to commence settled irrigated agriculture? Along a cascades main axis stream where did settlers constructed tanks first; in upstream areas moving downstream or *vice versa* or at a mid-point moving upstream first and then moving downstream? Answer thus far advocated to meet these questions are in their embryonic form. Hence, more investigations are necessary to answer them fully.

Small tanks are heavily concentrated in the Dry Zone. Recent studies on the major river basins, sub watersheds and small tank cascades in the Rajarata with due reference to topography soil, rainfall probability and hydrological characteristics, have contributed significantly to expand the understanding the setting, distribution patterns and hydrography of the small cascade systems in the Dry zone. It has been also shown that consideration of a meso-catchment or cascade of interlinked small tanks (STCS) provided a reliable base for further analysis and interpretation of the hydrological basis of small tank systems. This has been clearly demonstrated in a study of 230 STCs of the Rajarata which reveals that 197 of these cascades have an adequate catchment area, but that at the same time 190 of the cascades also have an excess of command area that cannot be serviced by the present tank capacity within the cascade.

Triggering off from the foregoing macro-and meso-morphological studies what is further needed is to try and understand those micro-morphological characteristics (e.g. heennas and mudunnas) which have had a profound influence on the distribution, density, alignment, size, shape and use of small tanks within cascades. When such studies are advanced, they would enable us to acquire a greater 'sense and substance of each tank. Tanks are not isolated entities. Though they may physically differ from one another, they are within certain patterns that are hydrologically and socially determined. They remain economically and socially beneficial and eco-friendly 'pools' of water which have become acclimatized to the extent that they have become an integral parts of the dry zone

environment, with some general resemblance to those in south India, but virtually unparalleled to any other system in the world.

A catchment, storage and command area of a tank are determined hydrologically and socially. The extent of a total catchment area of a cascade determines the amount of run-off that could be collected within the small tanks. The run-off in a catchment area varies depending on gradient, soil characteristics, landuse (e.g in chena lands 30-50%, scrub jungle less than 20 percent, in teak forests 16%), density of drainage and the number of ephemeral streams blocked by the upstream tanks. The water spread area of a tank is a function of the geometry of that tank changed through the siltation process over time as well as the changed condition of the tank embankment, its sluices and spill(s). The ways and means of partial desiltation enabling the return to original tank geometry has been demonstrated and thereby how the negative consequences of present tank geometry could be minimized. It is difficult to comprehend why desilting is avoided and raising tank embankment and raising spill levels preferred. Seeing the importance of not only increasing the tank capacity, but also improving the conditions of tank eco-system which is dangerously deteriorating and small tanks turning to mere grassy swamps it has been reported that if present method of bund raising continued, scientists, planners and engineers cannot escape from the challenge of disappearing of minor tanks from the Dry Zone landscape during the next few decades.

It is argued that cost of desilting a tank is considerably high in terms of the value of paddy that can be generated in the short run by that extra amount of water retained in a tank after desiltaiton. It is difficult to accept because the tank water is not meant for the sole purpose of irrigating a few hectares in its command area. A tank which is multi-functional in terms of receiving, storing regulating and distributing water is truly multi-purpose in character. Economically (for irrigation) socially (for domestic use), religious culturally (for temple goers and its residents use) and environmentally it is indeed multi-purpose in usage.

It is even argued that non-economic purposes for which tank water is used are more important than for economic uses. This finds support from villagers' decision at times, to forego irritated cultivations (in seasons of deficit rainfall) in favour of the use of tank water to meet social needs-drinking, bathing and washing. Though the importance of non-economic functions to which tank water is put into are often inventorized and stressed by many scholars, quantified values of those functions have not yet been scientifically ascertained and demonstrated.

The relations between small tanks and ground water availability in proximity of these tanks is well known. How the shallow regolith acquifers are recharged by tank water, where those acquifers are best found and appropriate spacing and optimal densities of agro-wells in different tank surroundings have been recently studied and documented. It has been found that in respect of fifty cascades in the Anuradhapura districts, the number of agro-wells should not exceed 3,600.

The former equilibrium maintained between a tank, available storage and its command area opened for irrigated cultivation is now in great inbalance. While siltation has reduced tank storage over time, the expansion of 'akkara welas over the past 75 to 100 years both legally and illegally exceeding the tanks' supply capacity has resulted in a high hydrological inbalance causing a perpetual scrambling of too many land-holders in command areas for too little water in these tanks. The demand for water through agro-wells is also placing a stress on the overall hydrological balance. This shortage of irrigation water coupled with land sub-division and prevailing tenurial complexity has aggravated difficulties in the economic use of limited available water.

In the distant past based on rain-fed chena farmers, lowland rice cultivation, homestead mixed garden farming, cattle grazing and herding, tank fishing and food gathering game and tree harvesting, there was a traditionally self-sufficient and inward looking contended life style in equilibrium in tank associated village settlements. This equilibrium having been subjected to external influences has gradually brought about a great disequilibrium, demanding a changed but sustainable production threshold, though the resource base remains limited. Due to chena lands being converted to settled rainfed settlements a high degree of land degradation, soil erosion, tank siltation has taken place. The earlier equilibrium that existed in relation to the tank capacity irrigated area and tree covered catchment area too have been severely altered, thus resulting in severe stress and conflicts both in respect of irrigated rice cultivation and upland rainfed chena cultivation. Further more, production systems too have become different in that they have to be responsive to the prevailing challenges of the open market forces in operation. This also makes it difficult to ascertain realistic production thresholds of both rainfed and irrigated farming systems in the small tank cascade systems.

Institutional Change and Development of Minor Irrigation

One of the main constraints to the development of minor irrigations in Sri Lanka is the continuing change that has occurred over the years, and continues to occur without any regard to it's beneficiaries. Minor irrigations thrive on unique customary water laws and traditions that have sustained a certain level of rural livelihood.

During the pre-colonial era, under the 'Rajakariya' system minor irrigations were operated and managed by the community themselves. The responsibility of management was vested with the "Gamarala" under the "Gamsabawa" system. With abolition of the 'Rajakariya' system in 1932 all customary regulations and traditions began to collapse.

This led to a vacuum in the responsibility of managing minor irrigations which resulted in the degradation of these systems, thus warranting the import of rice to feed the population. Realizing the mistake of abolishing the 'Rajakariya' system, the British implemented the Paddy Lands Irrigation Ordinance – No. 9 of 1856, with the intention of mustering the community organizations to re-establish traditional customs in irrigated paddy cultivation. In 1857, this ordinance was enacted with more state power and recognition give to "Vel Vidane" instead of the "Gamarala". The former was given the responsibility of distribution water equitably to all beneficiaries in a system and attending

to all cultivation activities impartially. The Paddy Lands Irrigation Ordinance was effective till end of the last century. With the tun of the new century, the Irrigation Department was established (1990) and all the irrigation management activities were centralized with the Irrigation Department with the Government Agent taking on the responsibility of minor irrigations with the help of communal labour for maintenance. During this period the handling of water disputes became the responsibility of the civil courts, though the "Gamsabawa" too existed as the main rural institution. In 1932, a new irrigation policy introduced by the Ministry of Agriculture and Lands gave the responsibility of construction and management of minor irrigations to the Irrigation Department. This situation remained until independence in 1948.

Since independence, the responsibility of minor tank management was transferred again to the Ministry of Agriculture due to the heavy involvement of the Irrigation Department with the Gal-oya development project. Subsequently in 1951 and 1956 the Irrigation Ordinance was amended to de-emphasize the role of farmer involvement through enforcement of rigid rules and procedures. These changes destabilized the otherwise self reliant and autonomous farmer institutions that have been in existence since independence. However, with the passing for the Paddy Lands Act of 1958, the Department of Agrarian Services was established in order to encourage farmer participation in minor irrigation development. Under this Act Cultivation Committees were established but lack of legal authority given to these committees malfunctioned their role as an effective village institutions.

In 1972 the responsibility of minor irrigation development was transferred back to the Irrigation Department with the passing of the Agriculture Productivity Law. Under this law, Agricultural Productivity Committees (APC's) were established for the development of irrigated agriculture. However, the composition of membership in these committees were weighted more in favour of officers than farmers. Thus, there was a skewed representation of farmer interests. In 1991, the Agrarian Services Act No. 59 was amended to established farmers organizations (FO's) and to given legal authority to FO's to undertake irrigation contracts. Though this represented the best alternative for farmers, the formation of FO's on village boundaries complicated the independent functioning of FO's. However, in subsequent irrigation development projects this drawback was remedied with FO's being formed on hydrological basis.

While these changes have established the position of minor irrigation with respect to it's construction and management, the latest development under special gazette notification of year 2000 has reverted the responsibility of minor irrigations back to the Irrigation Department. Hence, it is unfortunate that the responsibility has been changing between these departments without the scantiest regard to the large peasant livelihood under village irrigation systems.

Importance of Socio-Economic Considerations

The dry zone farmer had a typical farming system that characterized the crop cultivation under water stress conditions. The "gangoda" (home garden) chena (shifting cultivation)

and "Welyaya" (lowland) were the components of successful farming system that sustained the livelihood of dry zone peasantry. The lowland was mostly cultivated with minor irrigations. However, most of these farmers gave priority to chena cultivation over the other two systems mainly because it was the most stable cultivation practice and also provided most of the family sustenance. Besides, it also provided an assurance against paddy crop failure due to lack of water. Usually the size of the chena depended on the family size, with 2-3 acres as an average. However, due to population increase and pressure on land the size of chena has declined with almost no fallow period between two cultivation periods. These changes have reduced the unit land productivity and total household income.

However, the synergy that exists between chena and lowland cultivation allows prolong chena cultivation to impound more water in small tanks before the commencement of maha cultivation. This incidentally gives the farmer the opportunity of decision making with respect to cultivation. However, one of the main problems of village tank cultivation is the fragmentation of land and complex land tenure patterns. Both these factors contribute to small size of land holdings, which are often economically not viable to cultivate. It has been shown that land sizes vary from 0.25 ac to 1.0 ac under minor tanks in Hambantota. Small size of lands, seasonal cultivation and uncertain income have all contributed to low level of investment on minor irrigation. This is evident in a study where 20 minor tanks were evaluated for its performance after rehabilitation. On an average a family receives Rs. 1000 per month from cultivating paddy under minor irrigation. Twenty five years of data also pointed out that the yield difference between minor and major irrigation to be approximately one ton per hectare.

As a measure of improving productivity under small tanks, various water management practices have been adopted. Some of these practices are traditional while others are more recently introduced. The traditional "bethma" and "Kakulun" have been in existence with minor irrigation since time immemorial. However, increase in "akkarawela" due to legal and illegal settlements have disturbed the water balance in small tanks, thus creating deficiencies in water during yala season even to cultivate a "Bethma". The deteriorating village cohesiveness and traditional organizations have been attributed as reasons for the failure to implement a " bethma". The "bethma" has been emphasized as a result of strong village customs and traditions. More recently, under minor tank rehabilitation programmes, crop diversification has been introduced as a measure of water management. However, in most attempts this has not been very successful due to storage, marketing, and labour problems associated with minor tank agriculture. Location of minor tanks and pre-occupation in chena cultivation have been deterrent factors to adopt more crop diversification.

The recently concluded minor irrigation rehabilitation under NIRP and WFP, suggests that small tank development should be taken as a continuum which is governed by contributory factors and resultant beneficial factors. Hydrological and management factors are the two main components of the contributory factors and it's interrelationship is the input to development of minor tanks. The result of this input is the beneficial factors, which has a direct bearing on livelihood of farmers and their surrounding

environment. The author is of the view that due to the inability of assessing the hydrological factors accurately, number of unsuitable tanks have been selected for rehabilitation, thus resulting in deserving tanks being ignored. Hence, it is suggested that more acceptable criteria and factors should be considered and that all small tanks in the country should be categorized.

Evidently there is a serious policy gap with respect to village irrigation in Sri Lanka. A national policy on minor irrigation should fill the vacuum created by the loss of ancient tradtions and customs. There is a gap between the demand and the real need of the village society, which can only be filled by the bureaucracy. However, the bureaucracy has failed in this endeavor, due mainly to lack of reliable and enhance database on natural resource management. To redress this situation, the department of Agrarian Services is now in possession of a database on village irrigation systems. This data base which consists of 76 main attributes is capable of linking village irrigation systems as well as meso catchment with the help of geographical information system mapping. Hence, it is now believed that the state bureaucracy will be in a better position to meet the gap between the demand and the real need of the village tank communities.

In the light of all the foregoing considerations one questions the scope or the opportunities that would become available for a transformation or a modernization of the various agricultural production systems within tank cascade systems. However, since small tanks constitute a very important part of the rural landscape and it's eco-system, there is a strong rationale for ensuring the sustainability of these settlements for economic, social and environmental reasons.

HISTORICAL PERSPECTIVES ON SMALL TANKS AND FOOD SECURITY

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In the initial of stage formation in Sri Lanka, small village tanks laid the foundation for an agrarian society based on a 'one tank – one village' ecological pattern. Topographical surveyors of the latter part of the nineteenth century have observed that there was one small village reservoir in each square mile in the south-eastern part of the island[1]. The situation in the rest of the Dry Zone was not different. The inscriptions of the first three centuries of the Christian era alone refer to more than 150 such small tanks. Along with medium scale reservoirs such as Abhayawewa, Nuwarawewa and Tisawewa at Anuradhapura; and large reservoirs such as Minneriya, Padaviya and Parakramasamudra; these small village tanks functioned effectively until the middle of the thirteenth century. The most important aspect of these large, medium and small village reservoirs was the interconnection of many of the reservoirs through an intricate network of canals.

This chain of interconnected irrigation complexes provided food security to a large population in the Dry Zone, in the form of provision of water for domestic as well as for agricultural purposes. It also provided most of the protein requirements as inland fisheries was an important economic activity[2]. Inland fishing in fact was much more prevalent than most people perceive. It was so important that there were carefully drafted rules and regulations related to fishing. For example the fifth century Pali text *Samantapasadika* while discussing 'ownership' states that, when someone was fishing. if a fish jumped into the air and if another caught it in the air with hands, the ownership of such fish rested not on the fisherman but on the person who caught it in the air. It was not considered a theft[3].

A question that poses itself as relevant for our theme is whether, agriculture, fishing and such other economic activity related to state owned large and medium reservoirs and small village tanks resulted in hundred percent food security in all eras of history? Although there was food security during most periods of the Dry Zone civilization, there also have been sporadic famines, not less than a dozen in number, recorded in the chronicles such as *Mahavamsa* and *Chulavamsa*[4]. Some of these famines have been local ones and difficulty in transporting grain to affected areas was the cause of hardships. In this context 1998 Noble prize winner for Economics – Amatya Sen's 'Theory of Entitlement' profounded in relation to famines in Bengal in the nineteenth century[5] may be applicable with modifications to some famines in the Sri Lankan Dry Zone as well. But there were also a few serious famines affecting the whole country which resulted even in the human movements from place to place. For

example, the famine called the '*Baminitiya Saya*' which occurred in the reign of Vattagamani (89-77 B.C.) was so serious that a considerable number of monks died while some 24,000 monks left the island to seek refuge in India. The famine continued for several years and the monasteries in Anuradhapura were abandoned. Towards the later stages the famine had grown so accute that some people were forced to live on human flesh[6]. This major famine and other not so serious famines took place approximately over a period of fifteen centuries and considering this length of time they may not give a true picture of food production and food security in pre-modern Sri Lanka.

Yet, irrespective of the development of an intricate irrigation system in the Dry Zone, there had always been uncertainty of food production due to many factors, of which the fluctuation of weather conditions was an important one. The fifth century Pali commentary *Sammohavinodini* refers to the storage of grain in the monasteries at Tissamaharama and Chittalapabbata or Situlpawuva sufficient to sustain twenty-four thousand monks for three months[7]. This indicates two things. First, such storage of grain indicates that there was a surplus of food during certain seasons and secondly it implies that monasteries stored grain because there was an uncertainty of food supplies in certain years. Inscriptions of the fourth century A.D. indicate that grain deposited in mercantile guilds earned an annual interest as high as fifty per cent for rice and twenty-five per cent for other cereals[8]. This again indicates that there was a market demand for grain at various times depending on the vagaries of the weather.

On the other hand, with the extensive network of reservoirs and canals in the Dry Zone, agricultural production was sufficient to sustain the population during most of the eras of the Dry Zone civilization. The large scale construction of dagobas and monastic complexes, as well as other magnificent monuments with exquisite sculptures, and the building of an imposing and intricate irrigation system would not have been possible if there had not been an appreciable quantity of surplus food to feed a substantial workforce. The Pali Literary work *Sahassavatthupakarana* datable to the late Anuradhapura period (9th and 10th centuries), refers to three year old scented rice (*tivassikagandhasali*) which was processed by storing in granaries for three years on various layers of aromatic drugs[9]. If such scented rice was ever consumed in Sri Lanka, it was by members of politically and socially dominant groups namely the royalty, nobility and the priesthood. It was among them that the bulk of the fiscal resource of the country which consisted mainly of the land revenue, was distributed. The average peasant lived at low subsistence level. His plight is lucidly described in the thirteenth century Sinhala classic *Pujavali* which states that after one harvest obtained by labouring hard, day and night, what was left to the cultivator of the soil and his family was barely sufficient for him to subsist on until the next harvest[10].

The popular belief that rice was exported from Sri Lanka also needs to be examined in this context. There is only one solitary reference in the South Indian *Sangam* Text, *Pattinapalai*, one of the ten idylls of the *Pattupattu*, written in the second century A.D. which indicates that foodstuffs were exported to South India from Sri Lanka

(*Illattunavu*)[11]. Perhaps food stuffs referred to here included rice and during times of scarcity, South India may have imported rice from Sri Lanka. But such references do not indicate the general prosperity of one country as compared with the other. The ninth century Muslim traveller, Ibn Khurdadbeh refers to the import of rice to Sri Lanka from South India. Another Muslim writer AI-Idrisi stated in the eleventh century, that Jirbatam was a port in South India which exported rice to Sri Lanka (12).In these instances too, it is unwise to conclude that rice was frequently imported to Sri Lanka from South India during the days of Rajarata civilization. It may be reasonable to conclude from such sporadic and divergent references that during times of crop failures and demand in either country, trade in rice was carried on between India and Sri Lanka.

An important point regarding self-sufficiency of the ancient village needs to be raised here. The ideas of some of the early British administrator scholars on Asia inspired Marx's views on the *Asiatic Mode of Production* characterized by the self-sufficient village economy. The patriotic or nationalist bias of Asian writers too have resulted in an exaggerated and out of proportion account of the self-sufficiency of the Asian village. But it is important to note that although grain supplies were available, some of the essential commodities such as salt, metal and metal implements were not produced in all Asian villages. In Sri Lanka, frequently metals and metal products had to be brought into many of the villages from the few producing and manufacturing areas and salt had to be transported to the interior from the coastal centres. Some of the other needs of the village community which could not be procured locally, too had to be supplied by outsiders which necessitated money exchange or barter. Medieval literature refers to villagers paying currency (*kahavanu*) to purchase ghee, venison and lime. The pedlar or hawker who constantly moved about between the regions played an important role in supplying lightweight commodities such as clothes, rings, necklaces and bracelets to the villagers [13].

By the middle of the thirteenth century, the great cities of Anuradhapura and Polonnaruwa had almost been abandoned, the Rajarata civilization had collapsed and the efficiency of the major and thousands of small tanks had declined. The patches of water retained in tanks provided some from of food security to settlers remaining in the Dry Zone. But the neglect of irrigation system and concommitant spread of diseases resulted in rapid thinning of population. By the end of the fifteenth century only the ruins of the old cities and the silted reservoirs remained as stark reminders of the once flourishing Dry Zone civilization. The bulk of the Sinhala population had drifted to the South-Western part of the Island while most of the Tamils had drifted to the North and East. The earliest map available of the Portuguese connection with Sri Lanka drawn by the Spaniard Cypriano Sanchez sometime around 1606 A.D. contains two notes which suggest that the Yala region and some of the north-central areas of the island had become a 'desert through sickness' (*Deserto per doenea*) [14].

The topographers of the Portuguese, Dutch and early British periods found only occasional densely populated spots in the Dry Zone outside the Jaffna and Baticaloa regions and these too were in the coastal tracts of Kottiyar, Trincomalee, Mannar and

Puttalam. Until about 1931 the interior of the Dry Zone was empty and desolate. The British writer John Davy who published an account of the interior of Ceylon in 1821, found only a solitary paddy field beneath the grate reservoir of Kantale and an almost deserted region[15]. According to the census of 1871, Nuvarakalaviya (present Anuradhapura District) had only 21 persons per square mile while Tamankaduwa (Minneri, Giritale, Parakramasamudra area) had only 4 persons per square mile. The situation in the Ruhuna region beyond Hambantota was not very different. The settlers in all these regions who were grouped in villages around small irrigation tanks eked out a living by paddy and chena cultivation and other economic pursuits such as fishing but whether they had food security throughout the year is doubtful. Life in a village in the Ruhuna region in the early part of the twentieth century is amply demonstrated in the celebrated novel '*Village in the Jungle*' or '*Baddegama*' by Leonard Wolf and it paints a picture of decay and desolation.

The increase in the overall population of the Island, particularly the increase in Indian immigrants for plantations, the rise in the average annual rice import and the alarming situation of food supply in the country or food insecurity led the British colonial administrators to embark on a policy of restoration of irrigation works from the middle of the nineteenth century [16]. Emphasis was laid on the restoration of small village tanks and a few of the major tanks such as the Tissamaharama Tank (1877) and the Minneriya Tank (1903). The major tanks needed links with local streams to replenish their stock to full capacity and also to redirect excess water during times of flood. As far as village tanks were concerned, they had not been linked as yet to a major irrigation work and were dependent on rainfall for their water supply. Hence their restoration did not provide absolute food security and guarantee against crop failures. In the context of late nineteenth century and early twentieth century restoration of irrigation works, it shold be noted that there was no comprehensive plan for a viable colonization scheme and an administrative machinery to look after and maintain the tanks and channels.

However, particularly after 1931, Dry Zone colonization and the development of agriculture and improving of irrigation and water management systems became accepted as essential for the economic growth of the island. After 1931, many major and minor irrigation works were restored, the pace of colonization of the Dry Zone was increased and food security was attempted but as far as small tanks were concerned two aspects have been overlooked. One was the interconnection of these tanks with large tanks, canals and subsidiary canals. The other was the mechanism for maintenance of the small tanks and the control of siltation. The neglect of these aspects still continue to be defects in the system and as a result even after heavy rains during a particular year, if the rains fail in the following year the Dry Zone farmers experience drought and hardships. During the period of the Rajarata civilization, it was not so and the water management was more efficient.

In conclusion, I would like to pause two questions of relevance. Supposing major and small tanks function smoothly and cultivation flourishes will that ensure food security and improve the conditions of the farmers? Only three weeks back, in mid-August,

the farmers at Polonnaruwa staged a protest and Satyagraha at Hingurakgoda with twenty nine demands one of which was a demand for the increase of the purchase price of paddy. With emphasis on 'globalization', 'global village', 'Technology advancement', 'internationalization of trade', 'Open Economy' can the Sri Lankan farmers improve their lot and lead a relatively comfortable life even if there is an excess of paddy and other grains?. These are questions related to developmental strategies and problems, economically – complicated and politically intriguing.

NOTES

(1) R.L.Brohier, Ancient Irrigation Works in Ceylon, Colombo, 1934, p.18

(2) For details see: W.I.Siriweera, The Inland Fisheries in Sri Lanka: A Historical Perspective, ARTI Occasional Publication No. 33, Colombo 1916

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(7) Ibid. p.445

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(9) Sahassavattupakarana, ed. A.P. Buddadatta, Colombo, 1959, pp. XVII – XIX, p.26, p.80

(10) Pujavali, ed. Bentota Saddhatissa, Panadura, 1930, pp.355-357

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EVOLUTION AND ROLE OF SMALL TANK CASCADE (ELLANGAWA) SYSTEMS IN RELATION TO THE TRADITIONAL SETTLEMENT OF THE RAJARATA

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INTRODUCTION

There is a fifth century B. C. Chinese saying that "it is only after you have properly understood the essential nature of things you have seen that you will be able to perceive their true form and order" (Panabokke 1999). A systematic understanding of the nature of the physical (environmental) elements of the Rajarata is necessary to clearly perceive the evolution and role of small tank cascade (Ellangawa) systems in the Rajarata.

Over the past three decades various aspects of the tank cascade (ellangawa) systems have drawn the attention of several scholars – Tennakoon (1974, 1980, 1994), Madduma Bandara (1985), Somasiri (1979, 1992), Ithakura and Abernethy (1993), Handawela (1994), Nawaratne (1998), Dharmasena (1992), Ulwisiheva (1995), Senaratne (1996), Sakthivadivel *et al* (1996), Perera (1997), and Panabokke (1999). They all have studied many aspects of tank cascade systems from the standpoints of their disciplinary interests. In that process, they have made significant contributions towards expanding our horizons of knowledge about small tank cascade systems.

However, Panabokke's recent study (1999) is the most cohesive bench mark study undertaken, which will no doubt provide a sound launching-pad for the other scholars of the subject to further expand their study horizons. It is a study well substantiated with maps, including a Master Map where all the boundaries of main watersheds (river basins), sub-watersheds and cascades are demarcated. Looking through many windows that Panabokke has opened in his study; new thinking, new visions and re-discoveries in cascade-based development would be necessary. This paper attempts to take-off from his bench mark study, and further the contemporary local knowledge of the evolution and role of small tank cascade systems in the Rajarata. To the extent possible, an attempt is made here to make this paper a complementary reading to Panabokke's recent study – **The Small Tank Cascade Systems of the Rajarata: Their Setting, Distribution Patterns, and Hydrography (1999);** and to facilitate the unifying framework that Panabokke considered so essential in his landmark address on the small tank cascade systems in January 1995 under the auspices of the Sri Lanka Association for the Advancement of Science (SLAAS) and Institute of Fundamental Studies (IFS).

This paper is organized in two parts. ***Part I*** *is devoted to setting out in detail of the physical elements responsible for the evolution of cascades and tanks within them. It is in* ***Part II*** *that the role of these tanks in relation to traditional settlement patterns in the Rajarata is discussed.*

The physical elements that facilitated the evolution of small tank cascades (STC) in the Rajarata include: its morphology, soils with underlying lithology, probability of receiving expected rainfall seasonally and annually and hydrology (Panabokke 1999)

The Evolution of Small Tank Cascade Systems

Morphological features of the Rajarata

The Mataie foot-hill ranges of the Central Highlands extend over the southern extremity of the Rajarata, starting with Kahalla – Pallekele ranges among others, and run northwest, north and northeast towards the coastal plains of the Rajarata and to the Vanni district to the north of it. In the south and in the northeast these ridges are more distinctly continuous than elsewhere, high in elevation and broad-based (e.g. Pallekela Range). The continuity of these ranges is broken only with saddle type gaps such as the Potuwila gap in the Pallekele Range and the Pahala Dampalessa gap near Marasinghe Hammillewa in the Gommunewa – Kahalla Range. In the central and northern regions of the Rajarata, the ridges remain progressively reduced in continuity and elevation and they are generally narrow-based. They remain more frequently dissected than those closer to the southern border of the Rajarata. The dissected parts of the ranges with their summits of erosional remnants stand distinctly apart particularly more towards the northern limit, not so much as parts of ranges, but as isolated hills such as Mihintalekanda, Katupotakanda, Morakanda, Tammannekanda, Veheragala and Vaddakanda. Indeed, the villagers' perception of **Kanda** is nothing more than, an isolated hillock. Ritigala, meaning "long rock" or "long mountain" is the only clearly visible part of a mountain range *per se*. In the western and northern parts, the trend of the ridges remain much the same as elsewhere in the fan-wise expansion of them over the Rajarata. But to the west of Anuradhapura – Medawachchiya – Vavuniya axis, these ridges almost suddenly diminish in their stature, giving way to low earth mounds like earth over a grave-yard. There are only a few low erosional remnants on these mounds such as Vessagiriya and Tantirimale. The overall fan-like spread of mountain ranges followed by these mounds with their dissected remains (in isolation), has facilitated the evolution of an undulating topography in the Rajarata with some regional variations as follows:

- In the south and in the east, the undulation is characterized by a prominent ridge-and-valley topography, where there is a marked gradient between the crest of a ridge and the keel of a valley. The Yan Oya basin and those watersheds in its right bank display these characteristics, than anywhere else.
- Valleys are narrow in the south. A case in point is the valley between Kahalla and Pallekele ranges commencing near Paravahagama and running up to the Maha Siyambalangamuwa reservoir.
- In the central and northern parts of the Rajarata where the low ridges give way to many of the earth mounds, the valleys in between them have become very broad and shallow with almost imperceptible gradients between the surrounding crests of ridges/mounds and the keels of the valleys, making the land truly undulating.

- In the west and in the northwest, land has become increasingly flat keeping only a faint undulation where the earth mounds which separate the valleys are no more than a few feet in height.

The nine major river basins (main watersheds) in the Rajarata – Kala Oya, Modaragam Ara, Malwatu Oya, Parangi Ara, Ma Oya, Mee Oya, Yan Oya, Koddikkaddi Ara and Pankulam Ara separated from each other by the main ridges spanning from the south to the northeast, north, northwest and west and their continuing earth mounds. However, a few upper streams (tributaries) of the main rivers in these basins such as Yan Oya, Malwatu Oya and Kala Oya have cut across in gaps here and there changing their courses to join the main streams/rivers (Figure 1).

The outward expanding ridges, referred to above, branch off at many points into a series of "duck-foot" type wide spreading "finger-ranges" of local significance with out-stretching grooves in between them (Figure 2). While the "centre-fingers" of these "duck-foot" formations remain long, dominantly high, wide at the bases with their dissected erosional remnants apart, the side fingers of the "duck-foot" formations remain relatively short, low in elevation, narrow at the bases with their dissected erosional remnants rather placed far apart. It is in the grooves in between these "finger – ranges" that the majority of sub-watersheds (50 of them) identified by Panabokke (1999) are found. Some of the tributaries in these sub-watersheds are of the third order of magnitude of streams

Our understanding of these general morphological characteristics, lend us only a limited support to expand our local knowledge about the evolution of cascades and the manner in which they function. It will be further possible to expand it, if we probe more into the details of the morphological anatomy of this part of the country, going beyond our reference to major ridges separating the main and sub-watersheds.

A sub-watershed is not simply an earth pan. It has its own morphological characteristics, with inside low ridges or mounds running roughly parallel to the higher ranges which separate a sub-watershed from another. These inside low ridges or mounds are the **heennas** or elongated low mounds, which are the branch extension of the "duck-foot" finger ridges referred to earlier. These elongated low mounds are often the boundaries of cascades. Like the prominent erosional remnants of the high ranges, these mounds have summits popularly known to the villagers as **mudunnas**.

It is to be noted that **mudunnas** (summits) have not gained any reference in the topographical map sheets while **heennas** have gained reference rarely. There were no settlements in association with the **heennas** in the past and as such the surveyors were unable to capture the names of all or most of them in the topographical maps that they prepared during the twentieth century. Only those road-side settlements on or near the **heennas** or the places of significant road crossings of them or those with some archaeological significance have been identified, marked and named in those maps such as Budugeheenna (on the Galewela – Kalawewa Road), Kasagasheenna (near Dewahuwa), Karuwalagasheenna (on the Mihintale – Kahatagasdigiliya Road), Malamiriyagama heenna (on the Anuradhapura- Medawachchiya Road) and

Kirivalheenna (near the Eppawela phospate deposit). But it must be remembered that there are myriads of them known to the local residents although not shown in the One Inch Topographical Sheets.

In any traditional settlement the residents know several nearby **heennas** which are very significant as "local watersheds". **Mudunnas**, to them, are the points of origin of water flows to their tanks when it rains. These water flows soon disappear with the cessation of rain. In essence, the morphology of **heennas** and **mudunnas** among others have played dominant roles in tank evolution. Without a clear understanding of these two micro-morphological aspects, the **heennas** and the **mudunnas** found within sub-watersheds, the nature and form of small tank cascades, numbering over 450, and the role that they have played in relation to traditional human settlement may not be well understood.

Going from the known macro-morphology to relatively less known micro-morphology of the Rajarata, it is indeed necessary to descend a further step down and look at a main tank in a cascade (ellangawa) with its satellite or feeder tanks around as has been done by Tennakoon first in 1974. This is necessary because as Panabokke (1999) revealed that a small cascade forms a distinct small watershed 5 to 10 sq miles (with a modal value of 8 sq. miles), within which, there are several small tank clusters each with a main village tank and two or three minor tanks (Figure 3).

Usually, it is between two **heennas** and at the tail end of the valley bounded by those **heennas** that the largest tank in the cascade is located. Upstream of this tank in the cascade there are several medium size tanks, but they are generally smaller than the tail-end tank. The side slope water courses leading to these tanks are dammed across to form the other minor tanks in that cascade. Those extents from the **mudunnas** (summits) of the **heennas** (low ranges) to the small tanks on the side slopes of the valley are the catchments of those small tanks.

Soil characteristics

The shape and form of the morphology alone do not fully explain the distribution and the varying density of tanks across the Rajarata. Among other determinants of them, is the nature of dominant soils with their underlying geology, specially the lithology of the underlying substratum (Panabokke 1999). Different soils have different capabilities and capacities to absorb and retain gravity-guided or directly received rain water. As shown in Fig. 4, the western coastal belt of the Rajarata is a **latosol** soil region. These **latosols** are very deep and facilitate high water infiltration but it is extremely poor in holding surface water in tanks because its substratum is highly porous. This is principally the reason for the general absence of tanks in the western coast.

To the east of this latosol soil region, there is a belt of rocky, gravelly and highly eroded land where it is possible to hold up water but it is said that the soil quality is "poor for productive agriculture", except in the narrow alluvial tracts. Hence, there is only a thin spread of tanks of which most remain abandoned.

The tank country proper – **Wew Bendi Rajje**, is the heart of the Rajarata which lies to the east of the rocky, gravelly and eroded soil belt referred to above. This reddish-brown earth (RBE) and the low humic-gley earth (LHG) soil group is capable of holding up water in the form of tanks and notably in LHG soils, productive agriculture under irrigation is possible. This is the soil group (RBE and LHG) that is hydrologically most stable, which explains, to a great extent, the high density of tanks in this region.

Rainfall effects

Thus far it is presumed that, the discussion on macro – and micro-morphology and the soil characteristics have helped the reader to gain at least a partial understanding of evolution, distribution and density of tanks in the Rajarata. Still for a more comprehensive understanding of them, it is essential to understand the effects of rainfall and the general hydrology in the region.

Tanks were constructed to store the rain water that was received mostly during the northeast monsoon (October – December) and augment the storages where possible with the Yala rains (April – May) and provide regulated supplies of water to the cultivated fields during the rainless periods. This is a "**man versus nature game**", in which man attempts to win by minimising the negative effect of nature's variable and highly seasonal rainfall on crop raising. A computation made by Panabokke (1999) in respect of the 75% probability values of Maha (northeast monsoon) rainfall for 12 stations has shown that there is a lower probability in those stations in the western segment (Nochchiyagama, Tambuttegama, Nachchaduwa and Anuradhapura) and a higher probability in the eastern segment (Kalawewa, Maha Iluppallama, Maradankadawala, Kahatagasdigiliya, Padaviya, Horowpothana, and Kebitigollawa) in the Rajarata. This computation, as well as the normal rainfall records maintained show that rainfall increases from west to east.

The rainfall characteristics of this land of varying macro – and micro-morphological features in association with the soil structure and formation set out above, have determined the hydrology with marked differences in stream location, direction, volume of flow and inactivity/activity over time. In the western segment of the Rajarata tanks are very few and dry-up quickly where as in the eastern segment tanks are very many and at least the main ones hold water throughout the year except in years of very severe drought. This is particularly so in the sub-watersheds of the Malwatu Oya main watershed such as Maminiya Oya , Upper Kandara Oya, Ranpatwila Oya, Kadahatu Oya and eastern half of the Sangili Kanadara Oya basin.

Origin of tanks

Life would not have been possible in the past without water for personal and community uses. It is logical to realize that even in the remote past, people would have learned through common sense how to block natural water flows and arrest some water in **pools** for use when necessary. If beavers as animals had the instinct to dam the water courses, there was nothing to prevent that **homo sapiens** and their descendants did it better.

Hence, it is futile to search for the first man or the year in which he began to block water flows and built pools to store water. Of course, where there were natural pools around, the people would not have cared to create pools anew; but got accustomed to make use of water in them. This may have been the practice during the pre-Vijayan period. We have no authentic evidence to say that when the people in Sri Lanka really started building tanks during that remote past.

This does not mean that pre-Vijayan people did not grow crops to meet their food requirements. Archaeological findings have confirmed that more than a thousand years before the advent of Vijaya the people living in this country collected and stored grains (Deraniyagala, 1991). Vijaya, on his arrival in Sri Lanka had met Kuveni spinning cotton yarns. If this is true and not a yarn spun by the author of Mahavansa, who recorded this event eight centuries later, then, the pre-Vijayan settlers should be considered as those who knew the art of cultivating crops. What is not certain is whether that mode of cultivation was rain-fed or otherwise and whether paddy was a cultivated crop. However, the above evidences of cultivation, the absence of any reference to paddy and tanks prompt us to conclude that the grains referred to by Deranayagala (1991) were dry grains raised under rain-fed conditions in a form of cultivation similar to the present day slash-and-burn (**chena**) cultivation.

If **chena** cultivation was the mode of agriculture that prevailed at that time, it still cannot be argued that there was no practice of making water **pools** at least for human use, because survival in the dry zone during the rainless periods of five to seven months could not have been possible without water. During the dry seasons, the people may have had the habit of blocking the trickling-down water courses in streams to pool water. By this process, they may have first learned to build anicuts and then pool water permanently in stream beds during the dry seasons, the art which may have been later applied to arrest water in pools on the land surface during the rainy seasons, closer to their highland farms (**chenas?**) to facilitate at least the human needs of water during cultivation seasons. By nature, **chena**, could have been a shifting form of agriculture for want of suitable forest patches for new farmland clearing. With this shift from an old **chena** site to a new one, new pools too have been constructed. However, as long as they had sufficient forest extents closer to perennial streams and **villus** in the natural depressions, the people may not have pursued the creation of new pools. Even in the western segment of the Rajarata where rainfall is low, land is flat or only faintly undulating and the latosol soils are very deep, course-textured with highly porous substratum, there were and still are the **villus** or the grassland swamps, which are natural flat pools or sink-holes of the underlying miocene limestone formations. Examples are Vanathavillu and Kalavillu in the Vilpattu region.

The practice of constructing water pools may not have been confined only to the dry-arid western segment of the Rajarata. It may have been even in a wider practice in the tank country proper (Wew Bendi Rajje) even during the pre-Vijayan era. Like the term **Villu** used for natural water-holes in the west, there was the term **wila** used to identify natural water pools in the "tank country" in the eastern segment of the Rajarata (**villu** may be the Tamil version of Sinhala **wila**). Even to day there are many village names which have

been named after those **wilas**. What is significant here is that almost all of them are located within the Malwatu Oya main watershed. The pre-Aryan or the pre-Vijayan settlers may have first had their settlements in association with these natural water bodies, the **wilas**. These place names include Horiwila (upper Malwatu Oya), Turuwila, Kahapathvilagama, (mid-Malwatu Oya, Kaluwila (Nachchaduwa sub-watershed), Rampatiwila (Rampatvila Oya), Thamarawila – present Kapiriggama, Ratmalwila now Bandara Ratmale, and Upulwila – now Kallanchiya in the Kadahatu Oya sub-watershed in the Malwatu Oya basin. They are just a few examples of the **wilas**. It may be noted here that many of the present village names are not the original names of them. A long search in recorded history and archaeological records including inscriptions would facilitate the identification of many such **wila**-associated original place names.

In this eastern segment of the Rajarata, because of the very nature of its morphology, soil characteristics and relatively higher rainfall than in the west, stream flows are active for a longer period of the year and even during the relatively short dry periods of the year they have some trickling of water, and in many of the deep spots in them, there are water storages which never run dry even in years of severe drought. In common parlance of the villagers these are termed **ebe**. In this part of the country they have been so significant water sources that many places have been named after **ebes** such as **Kok-ebe**, **Kalu-ebe**, and **Nil-ebe**.

There are yet other indirect evidences of the prevalence of permanent water bodies in the eastern segment of the Rajarata. First, is the place names denoting the presence of water-loving birds in some locations permanently such as Kok-maduwa, Kokunnewa, Kokawiddawewa and Kok-eliya. Second is that in the present topographical sheets there is a very high presence of names associated with water-loving or water-front trees such as Kumbuk (*Terminalia arjuna*) and mee (*Maesa perrottetiana*) trees in the eastern segment of the Rajarata. the place names – Kumbukwewa, Kumbukgollawa, Kumbukkadawala, Meegassewa, Meemalwewa etc. in topographical sheets covering this part of the country . Finally, there are so many villages with the names Ulpatgama and Ulpathwewa or the names associated with Ulpathas or springs such as Kalvedi Ulpotha, GarendiUlpotha, Bandara Ulpotha, and Kalunel Ulpotha mostly in the eastern segment of the Rajarata.. Thus the presence of wilas , ebes, water-loving bird haunts and water loving trees as well as springs denote that the "Wev Bendi Rajje" in the east-central segment of the Rajarata, covering Maminiya Oya, Upper Kandara Oya, Rampatvila Oya, Kadahatu Oya together with eastern potion of the Saingili Kanadara Oya sub-watershed from time immemorial, point us to conclude that this part of the country had remained and still remains as the hydrologically most stable part of the Rajarata (Figure 5)

It is very likely that the pre-Aryan settlers and even the Aryan settlers after a century or so of the advent of Vijaya, practised the old form of chena cultivation in proximity to those natural water holes – **ebes**, **wilas** and **springs** and as they had to move away from them for want of suitable forest for chena clearing that they have attempted to develop water pools closer to their new chena plots. This may have been a **group effort**, because in the past, to ensure easy crop-watching, people may have cultivated individual plots adjacent to one another in a kind of continuous stretch (**Yaya**). A common water pool

would have been sufficient to meet their water needs. **Yaya chenas** and **wheel chenas** (mulketa hen) in practice even during the early twentieth century could have been the last remnants of this form of highland farming. It cannot be said that this system of farming is a recent introduction to the Rajarata with the recent return of those descendants of the people who left the Rajarata to the Central Highlands with the shift of the capital from Anuradhapura and Polonnaruwa. Because some recalcitrant original settlers (now called **Vanniye minissu**) remained stead-fast to their motherland without moving out. In 1899, Ievers in his **Manual of the North Central Province** referred to at least 25 villages of **vanniye minussu**. They were the real custodians of chena cultivation, which preserved it for us over the centuries. Two thousand five hundred or more years in practice, chena cultivation may have gone through changes and transformations.

The point attempted to emphasise here is that, creation of water pools to meet the human needs is very old. Some of these temporary water pools may have become permanent features and they subsequently came to be known as tanks during the period between the advent of Vijaya and Buddhism. The first recorded evidence of tank construction, as Mahavansa records it, is during the time of King Devanampiyatissa in the 3rd century BC. However, as explained earlier it is difficult to believe that tank construction by ordinary people was not there before, though the author of Mahavansa has not mentioned so. As the ties between clergy and royalty remained always strong, he may have deliberately chosen to give the credit of earliest tank construction to that king during whose time of Buddhism was introduced to Sri Lanka.

Layout and construction sequence of tanks

Briefly stated, in a cascade (ellangava) of 5 to 10 sq. miles (with modal value of 8 sq miles), there are about 2 to 4 medium size tanks. They were constructed by throwing earth bunds across the main axis stream of a cascade, which is usually an ephemeral stream. As a general rule, the last tank at the tail-end of a cascade (ellangawa) is the largest tank in the system, which finally empties into a third or fourth order stream, usually an **Oya**. This large tank also could be at the confluence of two or three cascades. For instance Kallanchiya (in the Medawachchiya Topographical sheet) the largest tank in the Kadahalu Oya sub-watershed of the Malwatu Oya main watershed, is situated at the confluence of three cascades – (a) Kendewa – Siyambalagaswewa Cascade, (b) Kumbukwewa – Kapiriggama Cascade and (c) Hettikattiya – Bandara Ratmale – Timbiriwewa Cascade; receiving spilled-over waters of 65 tanks. If any more tank construction downstream of Kallanchiya in the Kadahatu **Oya** was contemplated, then, it could have been still a large tank that is capable of holding spilled-over waters from three other cascades – (a) Gonewa cascade (b) Talakolawewa cascade and (c) Talgahawewa cascade (Figure 6). Even a large reservoir was constructed encompassing all these 6 cascades, like the Mahakandarawa tank, it should have a very large extent of command area for irrigation, before it empties finally to an **Oya**. Such an area did not and does not exist between the Kallanchiya tank and the main Kadahathu Oya downstream. Furthermore, even if such a reservoir was constructed, when there were already too many tanks in upstream cascades, in a year of drought or inadequate rainfall, there would not have been that much of excess water to cascade down many tanks and finally to provide

adequate water to a massive tail-end tank. This is confirmed by the fact that in years of drought the present day major village tanks towards the tail-ends of cascades do not have adequate water to spill over. The important thing here is that, given the extent of catchment area of a cascade and mainly the **Maha** season's rainfall that it receives, **there is an optimum number of tanks that could be profitably constructed on the main axis stream of that cascade**. As a matter of fact there are evidences of some in-between excess tanks forced to be abandoned. A case in point is the abandonment of Henketukadawala wewa in between Kapiriggawa and Kallanchiya tanks in the Kumbuk wewa – Kapirigawa – Kallanchiya (4/MAL6) cascade identified by Panabokke in 1999. This kind of possible adjustment made in the past remains a grey area which needs in-depth research to ascertain the maximum number of tanks and the volume of water that each tank was allowed to hold during the **Maha** rainy season. To sum up, this part of the argument, it could be said that (a) morphology of the land; (b) soil characteristics; (c) volume of rain received during the **Maha** season (d) nature of hydrology; (e) volume of water discharged by the upstream tanks; (f) size of the catchment area; and (g) the extent of land available downstream of tanks particularly more in LHG than in RBE soils have contributed to locate a requisite number of tanks in a cascade.

A question that remains to be answered is, "What sequence that the ancient tank builders followed in tank construction in a cascade?" Did they start constructing tanks from the top end of a cascade and continue construction of them downstream one after another, or did they follow the reverse process (from downstream towards upstream)? There is no conclusive evidence to support either. This too is clearly an area to be studied and understood fully. In the following an attempt is made to shed some light on the same.

The few small/medium tanks which have gained reference in inscriptions, notably during the times of king Valagambahu (88 B.C.), Bhatikabhaya (20 B.C. – 9 A.D.) and Vasabha (66 – 110 A.D.) are all those located at mid-points of cascades. Furthermore, the **wilas** mentioned earlier which later improved to be tanks are approximately at mid-points of the cascades. Following are some of the examples.

- Horiwila in the Palugaswewa cascade in the Maminiya sub-watershed
- Turuwila in the Kongaswewa cascade in the mid-Maluwatu Oya sub-watershed
- Thamarawila (now Kapiriggama) in the Kumbukwewa – Kapiriggama cascade in the Kadahatu Oya sub-watershed.
- Rampatvila in the Moragahawela (Moragahawila?) cascade in the Kadahatu Oya sub-watershed
- Ratmalwila (now Bandara Ratmale) in the Hettikattiya - Bandara Ratmale - Timbiriwewa cascade in the Kadahatu Oya sub-watershed.

There could have been many more **wila-**associated village names to which new names have been given as "Kapiriggama" to Thamarawila and Bandara Ratmale to Ratmalwila, when they were restored in the 19th century after centuries in abandonment. Some village names, which were changed in the 19th and 20th centuries, still have the names of "**wila**" components in their names. Thus, the former name of the present Kahapatvilagama could

have been Kahaptiwala. If we take the name Ratmale as a derivative of Ratmalwila, there would have been many **wilas** by that name, because there are at least a score or two of Ratmales in the present day Rajarata.

As all of them are at mid-points of cascades, most probably the tank construction may have started at a mid-point of a cascade. This is also a plausible argument because at a mid-point, water supply is not too much to control and manage, and not very deficient in volume of water expected to be held up, at least in a year of normal rainfall, given the level of ordinary irrigation capability of the village settlers.

Once a mid-point tank was constructed the users of that tank may have been able to gauge whether there was a potential to construct a number of tanks upstream to (a) regulate inflows of water to their main tank; (b) increase the prospects of opening new land for irrigated farming, which in any case would have been a necessity with the increase of population; (c) reduce siltation in the main tank and (d) accommodate service-bound castes separately from the main village who performed certain specified services to the village chieftains who have received land grants **(gam wara)** for the services that they rendered to the state. In most situations the village settlements in the upstream of a cascade are those occupied by the service castes.

From the mid-points downstream of cascades tank construction would have been a late effort successfully made with increased knowledge and experience of water management and irrigation engineering in respect of lager village reservoirs (tanks). It could have been also a necessity to bring more land under irrigation with increasing population and state's desire to develop an agricultural economy.

The side slopes of the ranges or mounds that separate cascade from one another too have tanks constructed by blocking highly seasonal water courses mostly active while it is raining, which eventually join the main axes streams of cascades. The interesting thing is that some of these small tanks are as old as the main tanks or older than them. For instance, Panikewa tank which belongs to the residents of Kapiriggama appears to have been as old as the main tank of Kapiriggama. Panikawa tank is just a mile and a half away from the Kapiriggama settlement centre (Figure 3). It was there as an abandoned tank to be restored by those who re-occupied Kapiriggama village during the 1840s. Could it be that Panikewa had been even the tank constructed earlier than Kapiriggama tank, in that very distant past for the benefit of the chena cultivators moving away from perennial source of water to some distance in the forest?

Role of Tanks in Relation to Traditional Settlements

Tanks by Purpose in Ancient Times

Already a reference has been made to chena cultivation with nearby water pools temporarily created. Then, in the 4th Century and there after we hear of man- made tanks for urban water supply and city beautification. For instance, Tissa wewa in Anuradhapura

was constructed to meet the water needs of the city of Anuradhapura. One main use of water was augmentation of city ponds along with the watering of the royal gardens such as Maha mega "which at a later date may have given the river its name Malwatu Oya instead of the ancient name Kadamba says, Ievers (1899). But there after irrigated cultivation under tanks gained momentum and according to Ievers (1899) –

> *"Agriculture has the first place in the minds of the kings. The creation and repair of irrigation works, on which the food of the people depended, is most carefully recorded and lauded by the chronicles. The internal economy and regulation of village life and of agriculture was systematic and arranged in accordance with what is known as the "Aryan Village System"*

The above was the status by about 3rd century B.C. even during the reigns of Sura Tissa (circa 240 BC) and his successor Elara, the South Indian Invader-kings. It is the prosperity of the country reached by the development of agriculture which induced them to invade and conquer the island. Thereafter, commencing with King Dutugamunu's reign (circa 160 BC), through the reigning periods of Walagambahu (circa 88 BC), Bhatikabhaya (circa 20 BC to 9 A.D), and through Vasabha's (60 – 110 A.D) period down to king Dhatusena (479 AD) was the golden age of small tank construction notably in the above mentioned **Wew bendi Rajje**, the hydrologically stable area of the Rajarata. King Bhatikabhaya and Vasabha were two great rulers who concentrated more on small tank irrigation than the other rulers. After Dhatusena, royal concentration was more on construction of large tanks such as those in the present Polonnaruwa District. Thamankaduwa is more adapted to large tanks. In fact, to the north-west of Minneriya and to the west of Kaudulla tanks disappears as shown by Brohier (Figure 7).

Ancient chronicles also have references to tanks which were constructed by kings to meet very special **religeo – cultural needs**. For instance, King Bhatikabaya who according to Mahawansa improved and raised the bund of Tissa wewa to hold more water in it, is also said to have constructed or improved **Wilas** into tanks to increase the supply of flowers to deck Ruwanweli Dagaba with flowers, during the Buddhist festive seasons. Thamarawila (now Kapiriggama), Ratmalwila (now Bandara Ratmale) and Upulwila (Kallanchiya) all in the present Rambewa Divisional Secretariat Division, in the Anuradhapura District were constructed to supply lotus, "ratmal" and "upul" flowers respectively from those tanks. It could have been possible that the villagers were made obligatory to supply certain quantities of these flowers at fixed times, and, in return to this service, they may have been allowed to have access to water of those tanks to irrigate crops downstream of them.

Particularly during and after king Dhatusena's reign, construction of large tanks as storage tanks had become increasingly popular. Thus water stored in Kalawewa channelled through Yoda Ela benefited many small tanks for their augmentation until it reached Anuradhapura. Such networks began to be increasingly established in the Polonnaruwa kingdom.

Tank by purpose in recent times

Rajarata was in wilderness from the time of the shift of capital from Polonnaruwa to the Hill Country. The kings of Kandy had only remote control of Rajarata through the Dissawes appointed, many of whom did not go beyond the southern Korales of Rajarata , but depended on the **Vanni Unnehes** in Nuwara Wewa for internal administration (Iever 1899 pp. 48 – 50). Until the late 19th century, other than Robert Knox's description of a few tanks, there was virtually no authentic record referring to tanks. However, RW Ievers as Assistant Government Agent prepared **the Manual of the North Central Province in 1899**, that was 26 years after the separation of the North Central Province from the Northern Province with Jafna as the administrative head quarters. As could be seen in this manual, Dickson, the first Government Agent of the North Central province and Ievers have collected an array of reliable information on the status of the tanks in the North Central Province.

According to Ievers (1899 P. 138) in 1873, the total number of tanks located was 2877, of which, 225 were "Crown tanks", 1519 uninhabited/abandoned tanks and 1133 inhabited villages near village tanks. This is a much improved identification than that or Flanderka the Assistant Government Agent of the Northern Province in 1855 according to whom there were 2000 tanks. Note that even today there is no agreement about the number of tanks in the Rajarata. Perera (1997) gives a figure of 5,447 tanks of all sizes for the Rajarata, Panabokke (1999) has arrived at a figure of 3,085 for the Anuradhapura district alone and Tennakoon (1974) estimated this number to be 3,045 for the same district. It remains a difficult task because of the difficulty in (a) distinguishing **godawalas** from side slope tanks of cascades and (b) over the centuries, some of the bunds of these side slope tanks have got so defaced or destroyed, "determination errors" could be high.

Whatever, the error margin of identification of tanks made by Rhys David in 1871, Dickson in 1875 and Ievers in 1899, it is evident from the Manual of the North Central Province, that during the second half of the 19th century there was the British folly, that tanks were always meant for irrigated paddy cultivation, and attempts were made to renovate some of the tanks (a) harnessing free labour of the villages to construct earth bunds; and (b) providing sluices at government expense, (c) getting services of semi-skilled Tamil tank construction workers such as **Oddars** or **Ottayars** and **kulunkatties** from South India or Jaffna. The **Kulankatties** were later came to be called **Vew Lakamas**.

From the time of British interest demonstrated their folly, namely the tanks are for paddy cultivation, it continues obsessively even to the present day. This British perception got further heightened during the two World wars, notably during the World War II with the "grow more food" campaign in Sri Lanka which was made to be believed as "cultivation of more paddy". The argument advocated here is, that, tanks were not meant for the purpose of irrigated paddy cultivation only. Some tanks were multipurpose inclusive of paddy cultivation, no doubt. Yet, there were and there are other tanks, which had and

have one or a very_limited range of specific purposes outside irrigated paddy cultivation, as amplified hereunder.

The multipurpose tanks are the main tanks constructed by the main access streams of cascades and their uses include:

- Regular storage of water in several places of the cascade, so that water is available to maximise the land use in an around many settlements, taking water guided by gravity to the upper contours of the side slopes of the cascade parts, downstream of those tanks.

- Regulated storage of water in upstream tanks in a cascade, reducing the risk of breaching the bunds of those downstream or tail-end tanks, during the seasons of above average rainfall.

- Regulated storage and regulated release of only excess water, through the sluices where by flood damages downstream are avoided or minimised.

- Through the storage process, avoid water scarcity during the dry seasons by having a regulated supply even during those dry seasons. This is a man versus nature game. In it, the nature makes a move from **"raining" to not_raining"** and to effectively meet the latter, man collects and keep water in tanks when the nature rains. Similarly, when it rains, man's invention that is tank, keeps necessary amount of water in the tank, making the excess to spill over.

- Cultivation of irrigated field crops.

- Meeting all domestic water needs such as drinking, bathing and washing

- Meeting the drinking needs of neat cattle, buffaloes and even wild animals and meeting the wallowing and some food needs of the buffaloes.

- Meeting some grazing needs of cattle in upper tank bed, notably on the margins of gradually receding upper show line providing green pasture during the dry periods in particular

- Meeting fish consumption requirements of the villagers.

- Meeting some items of the "basket of food" of the villagers such as roots, nuts, stems and water-front leafy wild vegetable needs during the dry seasons in particular.

- Keeping the ground water levels high to provide water in wells for domestic uses when quality of water in tanks deteriorates with decreasing quantity of water.

- Improving the micro-climate in the immediate tank environment which bring relief to the tree crops in adjacent gardens during the dry seasons.

- Being a wetland during the dry seasons facilitating growing of reeds (**pan vatu**) for mat and bag weaving and even a few vegetables with manual lifting of water using **Yotu**_(grooved wooden swindles) on limited scales. (Incidentally in Panabokke's Moragahawels – Bandara Ratmale – Timbiriwewa – Kallanchiya cascade No 3/KAL6, Timbiriwewa is now known as Labuwewa because in the 1930^{s} and 1940^{s} villagers grew **Labu** (gourd) in the tank bed during the dry seasons.)

The single or limited purpose tanks are the ones constructed by bunding the highly seasonal tributaries originating from the **mudunnas** (summits) of the **heennas** (high mounds or low ridges) on either side of a cascade and emptying into the main axis stream in that cascade. They are located in the slopes of **heennas** upstream of a particular main axis tank or downstream slopes of that tank. Purpose-wise they can be grouped as follows:

- "Silt-trap tanks" or Kuluwew constructed upstream of a main axis tank. It is almost at the edge of the upper shoreline of the main axis tank when it is full. It is constructed by blocking those fast flowing water courses to ensure that loads of silt brought down in solution, suspension and dragging by those water course are blocked, making the silt to deposit in the **Kuluvewa** and only the filtered water to spill over it to the main tank downstream. They are so small in capacity, that a few weeks after the cessation of the Maha season's rainfall, they too run dry. Welituduwa and Kayanwewa are the two **Kuluvew** of the Kapiriggama (formerly Thambaravila) tank (Figure 3). There are no paddy fields downstream of such a **Kuluvewa** and hardly there are open spaces in the upper tank beds. Tank beds are partially hidden under forest.

- **Olagam** or tanks under which no permanent dwellings established, played an important role in supporting the traditional settlements in the Rajarata. This aspect has not received adequate attention of research scholars and developers. A medium size village with a main tank has at least two or three **Olagam** tanks associated with it. These tanks are the "associated tanks" or "satellite tanks" of the main village tank and they are constructed on the side slopes of a cascade at some distance from the main tank (Figure 3). For instance, in Panabokke's Kapirigama cascade (4/MAL6), Kapiriggama village owns four other **Olagam** tanks at side slope elevations below the location of the Kapirigamma main village tank. They are Penikewa, Andarawewa, Pinwewa and the abandoned Ulpathwewa. Other than a few acres of paddy developed under Penikewa and Andarawewa in the 1950s and 1960s, there is no conclusive evidence to say that they were meant mainly for irrigated paddy cultivation. The term Penikewa denote that area was in forest or near forest which was a good source of bee-honey. By virtue of its being in, or near the forest, it could have been mostly a service tank for chena cultivators. More

importantly, Penikewa and other associated tanks, had other important purposes in addition to the irrigation of an extremely limited extent of paddy fields **only during the Maha season**. In the past, cattle breading as a source of food (milk and curd and not meat), draught power for bullock carts, ploughs and mud-levellers (**poruwas**) and as an insurance against drought and famine, remained an integral part of the agricultural way of life in the Rajarata. Hence, the villagers had to protect both crop and cattle. Farmers owning herds of cattle in the past had been economically stable. The Final Village Reports which accompany the Final Village Plans (FVPs) have maintained a standard format in which information on cattle was a must. This was found so in an examination of 30 randomly selected villages mapped between 1929 in its Village Report states, "There are 169 head of black cattle and 172 buffaloes" totalling 341 owned by 34 families with a total population of 120. That means, a family, on an average owned 10 heads of cattle. In the more distant past (late 19th century). Ievers in his **Manual of the North Central Province** (1899) gives vivid descriptions of the importance that the settlers have attached to cattle breeding . He records how the chief **gamaralas** of the villages at the **Muttinamum Mangalle** plead god **Ayyanayaka** who presides over tanks which are supposed to be under his special protection, to protect the tank crops and cattle in the village (Ievers 1899 p. 109). In offering the vow made at the said **Mangalle**, the **ammetirala** (the master of ceremony) thanked the gods for protecting "the tank, the village with inhabitants, both man and beast ..." says Ievers (1899 p. 110). This shows that villagers attached equal importance to protect both crop and cattle. **Cattle were also important to them as curd and Kurakkan constituted a major part of their diet.** The strategy adopted to safeguard this dual interest was a unique one. Conventionally the cultivators were required to protect their crops more closely than the cattle owners were required to watch their cattle, grazing communally in the uncultivated land in the village. This arrangement was necessary because it was the same owners of crops who owned cattle too. It this situation, the age-old communal arrangement was to make the village cattle move out of the paddy lands and chena plots under cultivation to other places where water and grazing grounds are available. These include the **olagama** tanks for drinking water and the tank catchment areas including the surrounding brush-woods formed after abandoning chena sites for grazing. For this kind of shifting cattle for grazing seasonally like in the Swiss Alps (trans humans), the **olgam** tank environment was a necessity in the Rajarata.

- At times the larger **olagamas** become reserve tanks to meet the domestic water needs of village residents when the main tank is emptied to meet the irrigation needs of its command area. Thus, in certain years people of Kapiriggama use water in the Penikewa tank to meet their domestic needs (Tennakoon, 1974)

- It is a misconception that the **pinwewas** (temple tanks) have been constructed to irrigate paddy. The main function of a temple tank is provision of water to meet the personal needs of the devotees who visit the temple regularly on Poya days to observe "sil" and, other pilgrims and the residents of the temple. Those tanks were certainly for religeo-cultural purposes and not for direct economic purposes.

- Finally, the **godawalas** at the top ends of the side slope streams blocked to form **olagama** tanks. These were meant to be the water holes for (a) wild animals and village cattle to quench their thirst, (b) improvement of vegetation and microclimate around them and (c) to arrest free flow of water inducing some rain water percolation to improve ground water levels. They are never made to be deep water holes as the porous substratum does not lend any support to hold water and **godawalas** are shallow depressions which can be expanded to hold water only by blocking their outlets with low earth bunds. If their bottoms are dredged even the available water disappears to porous deep soils.

It seems that, the present day minor irrigation tank development is geared towards crop irrigation only. The desire of the irrigation engineers is that the entire water storage of a tank should be releasable for crop irrigation. They are not in favour of having a "dead storage" in a tank, It is unfortunate that what is not releasable by a tank sluice has come to be known as "dead storage". In fact it is a "live storage" of water in a village in the Rajarata. It helps to keep the ground water table high during the dry seasons, save fish in tanks, provide drinking water for animals wild and domesticated, supply domestic water needs, support at least some green pasture in its water front during the dry seasons and contribute some wild vegetable to the villagers' food basket. Siltation of tanks over the years has denied these "live storages" of water, to the villagers during the dry seasons.

In the Anuradhapura district of the Rajarata alone, covering 2,809 square miles, there are over 3,000 tanks both big and small (Tennakoon, 1974; Panabokke, 1999). Roughly, there is one tank for every square mile. When all the tanks in a cascade is viewed as a whole, there are major tanks with village settlements in the keel of the valley and small tanks around these major tanks, all in the side slopes of the cascading valley, some upstream of the major tanks with settlements and the others downstream of them. In other words, there are tank clusters in a cascade with major village tanks with their individual small satellite tanks around them. there were different purposes of constructing these tanks. It seems that this small tank cascade system was so evolved over a period of time not only to have maximum possible surface storage of water for human uses including agriculture, but also for the purposes of retaining maximum possible amounts of rain water percolated into sub soils and maintaining ground water level artificially high to keep surrounding vegetation lush and improve micro-climate as well. If there had been no such effort, there would not have been so many springs (**ulpothas**) and tanks fed by them (**ulpathgamas** and **Ulpatwewas** in the Rajarata. The evolution, location and the pattern of small tank distribution (in clusters along the site slopes of cascading valleys) clearly shows that ancient tank builders have attempted to

improve the overall physical environment and hydrology of the Rajarata taking minor watersheds (cascades) as cohesive development entities with maximum possible retention of surface and ground storage of water received from seasonal rainfall. Here, we need to give a new interpretation to the all too frequently quoted wish of king Parakramabahu the Great, that is "let not a single drop of water flows freely to the ocean". The fitting interpretation may be that let surface run-off be arrested to store water not only in tanks but also to induce remaining water to percolate into the sub soil to keep ground water level artificially high as well. This could have been the avowed policy followed in the development of small tank cascade systems in the Rajarata in that distant past.

Temples would have been the focal points of socio-economic upliftment in the rural Rajarata. An examination of 457 cascades identified by Panabokke (1999) has brought an interesting point to light. That is, the presence of a single temple site (marked on Topographical sheets) in a cascade as a general rule, and exceptions to this are extremely rare. Could it be that all economic, and social functions in addition to the religio-cultural activities were directed and monitored from the temple premises? All monks did not live in seclusion being away from the village society. They even had the right to own land and receive their due shares of fish in the tank! In any case a small village even like today, could not have been a viable economic entity. But a cluster of villages as a society or broad community encompassing a whole cascade, would have been a vibrant economic entity enabling the efficient use of labour and exchanging services and skills for development, that would resist economic exploitation of villages by outsides.

The modern myths and mistakes

By the mid twentieth century it has been often said that "a tank means a village and a village means a tank" which is a modern myth (Arumugam 1957 p. 9). A "village means a tank" is no doubt (unless portable water is available) but **a tank does not necessarily mean a village**. Under the majority of satellite small tanks there never have been human settlements. Some of them were meant for purposes other than to directly support settlement establishment. This needs to be well understood and all tanks should not be renovated solely to encourage human settlement beside them.

Renovation of individual tanks in isolation should not be attempted, though it had been the practice over the past several decades. It has created more human, physical and environmental problems. The villagers' petitions to the Government Agents (District Secretaries) lying in the Kachcheries (District Secretariats) during the past several decades deals with the following:

- Submergence of some fields of a village due to the upstream march of the upper shore-line of the immediate downstream tank in which the storage capacity has been increased by raising bund and spill levels.
- Inadequate water inflows to a downstream tank as the bunds and spill levels of tanks upstream raised to retain more water in them.

- Illegal downstream expansion of field stretches from the tail-end of a village field, to the bed of a tank below and to avoid submergence of those fields, owners on their own or in connivance with some residents of the village to which the downstream tank belongs, leaving open the sluice gates of that tank on the sly (often at night) and making the upper shoreline water of it to recede, clearing those submerged fields of the upstream village.
- Sudden release of sluice gates and temporary lowering of spill levels releasing excessively impounded volumes of water in those upstream tanks to a downstream tank, notably during the rainy seasons threatening to breach the bund of that downstream tank.
- Refusal of the upstream tank owning villagers to release even a reasonable quantity of water to a downstream tank which is water-starved and desperately in need of some water to it so as to meet domestic water requirements and/or to save a crop which requires only the last wetting before crop ripening
- Delay in some water accumulation in a village tank particularly during the early part of the Maha rainy season due to upstream tank blockades caused by tank bund and spill levels raising which discourage the farmers (depending on the downstream tank) to start their cultivation activities early in the season which remains a perpetual grievance.

All the above bones of contention are easily avoidable if the improvement and maintenance of an entire small tank cascade system is viewed as a whole. Its water requirements for agriculture need to be assessed (under each tank) making adjustments in individual tank storage needs. Regulating the flow from one main tank to another main tank within the cascade in accordance with a community-based consultative approach, guided by a cascade-based local management body is desirable. This system needs to leave certain responsibilities with individual village groups for operational convenience.

Observations and recommendations

- During the latter half of the twentieth century the swing of the development pendulum was towards construction of large reservoirs, irrigation system construction and maintenance of them. In fact the latter is becoming an increasing headache to irrigation bureaucrats and the state.

- Theses large irrigation works will survive so long as state can manage them. When the state operation failed they too have failed in the past. The gigantic irrigation works attempted after the sixth century AD by the Kings all collapsed or deteriorated when the rulers failed to patronise continuous maintenance. But a larger number of small tank irrigation systems withstood all challenge for nearly thirteen century after the 6th century AD in the Rajarata for Rhys David to identify 1574 tank-based village settlements in 1871 and Ievers in 1899 to record a similar number of tank-based villages in operation (in the North Central Province alone). This was because these systems were manageable by the

ordinary villagers within their own command and that they had a sense of ownership.

- Whatever, the merits of globalisation and market oriented economy that we long for, it is absolutely necessary to have a spatially and temporally well distributed food security for our own safety. Dispersed but cascade based tank settlements have distinct advantages in this regard. Even the establishment of cascade-based grain storages is well worth special consideration. Neglect of small tanks provides no solution at all where food security has to be ensured.

- Small cascade-based tank system had been a classic example of man's ability to maintain a long lasting symbiotic relationship of man with available water, vegetation, climate, soil characteristics, animals domesticated and wild, being a partner of a well renowned hydraulic civilisation. Its revival is therefore, urgently called for.

- The cost/benefit theory cannot be successfully applied to measure the manifold economic and social benefits tanks to the individuals, communities and the nation. Yet an approximation can be made by intuiting values to the manifold social benefits. Then it will be found that those benefits far exceed the costs de-silting tanks to improve their water storage capacity which gives cumulative benefits indefinitely. If the small tanks were successfully used for two thousand years or even more, it is the benefits which they accrued to people over cost which induced them to continue it to the present day remaining stead fast to the use of tanks as a source of productive input – that is water. The need for cascade-based small tank development cannot, therefore, be ignored.

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THE NATURE AND PROPERTIES OF SMALL TANK SYSTEMS OF THE DRY ZONE AND THEIR SUSTAINABLE PRODUCTION THRESHOLDS

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Nature and Properties of Small Tank Systems

Past Scientific Investigations

I have discussed the past scientific studies made by several researchers since 1950 in my recent publications on this subject (Panabokke 1996 and 1999). I wish to however draw your attention to a pioneer and classical contribution made as far back as in 1936 on the Evolution of Scientific Development of Village Irrigation Works, by a very distinguished former Director of Irrigation J. S. Kennedy (1936) in his Presidential address to the Institute of Engineers and published in the Transactions of the Institution. Two very important statements stand out in his address which are as follows:

> *"Science is systematic and formulated knowledge, and when the knowledge that has been systematically accumulated on a subject, by trained observation and experiment, is fully organized, the subject becomes amenable to quantitative treatment."*
>
> *"Every village irrigation work has an individuality of its own, and when located on the topo map, the engineer has next to acquire the* ***sense and substance*** *of that individuality."*

The main aim of my past and recent studies on small tank systems has been the systematic formulation of knowledge by observation and experiment, with a view to subjecting this knowledge to quantitative treatment; and also to search for that elusive **sense and substance** of the individuality of the range of small tank systems in the dry zone landscape.

Essential Nature of Small Tank Cascade Systems

It is now clearly recognized that the large number (more than 15,000) of small tanks that are distributed across the undulating landscape of the dry zone are not randomly located and distributed as commonly perceived; rather they are found to occur in the form of distinct cascades that are positioned within well defined small watersheds or meso-catchment basins. A cascade of tanks is made up of 4 to 10 individual small tanks, with each tank having its own micro-catchment, but where all of the tanks are situated within a single meso-catchment basin. These meso-catchment basins could vary in extent from 6 to 10 sq. miles, with a modal value of 8 sq. miles in the North Central Province region.

A schematic representation of a typical **small tank cascade system** at a scale of 1:50,000 is shown in Figure 1. The main elements that make up a cascade, namely (a) the watershed boundary of the meso-catchment, (b) the individual micro-catchment boundaries of the small tanks, (c) the main central valley, (d) side valleys, (e) axis of the main valley, and (f) the component small tanks as well as the irrigated rice lands are shown in the same figure. These small tanks form a series of successive water bodies along small water courses and are called a **"cascading system"**. The advantage of such a system is that excess water from a reservoir along with the water used in its command area is captured by the next downstream reservoir, and is thus put to use again in the command area of the second reservoir. This water is thus continuously recycled. This system helps to surmount irregularly distributed rainfall, non-availability of large catchment areas and the difficulty of constructing large reservoirs.

Three small tank cascades close to Anuradhapura that lie adjacent to each other and are easily observed on the Maradankadawala-Tirappane road with the aid of the 1 inch to 1 mile topo sheet of Anuradhapura are depicted in Figure 2. The kilometer sign posts shown in this map-figure will help the reader to locate himself when travelling on this road, and thus enable him to easily locate the tank cascade systems on the ground.

Distribution Patterns

The setting and distribution pattern of small tank cascades across the Rajarata landscape has been described by Panabokke (1999). Altogether a total of 457 small tank cascades have been identified and demarcated over 50 sub-watersheds that make up the nine river basins of the Rajarata. A summary statement of the total number of sub-watersheds present within each main watershed, together with the total number of cascades present within each sub-watershed is given in Table 1.

Table 1. Summary Statement of the Distribution Pattern

Main Watershed Basins	Number of Sub-watersheds	Number of Cascades
MAL – Malwathu Oya	15	179
K – Kala Oya	12	68
Y – Yan Oya	7	74
MA – Ma Oya	4	40
MO – Modaragam Ara	3	42
PAR – Parangi Aru	4	34
PAN – Pankulam Ara	3	11
KO – Koddikkaddi Ara	1	8
ME – Mee Oya	1	1
Total	**50**	**457**

It should be noted that there are a small percentage of small tanks that do not occur within a cascade, but as individual tanks with their own independent micro-catchment. A

SCHEMATIC REPRESENTATION OF A SMALL TANK CASCADE

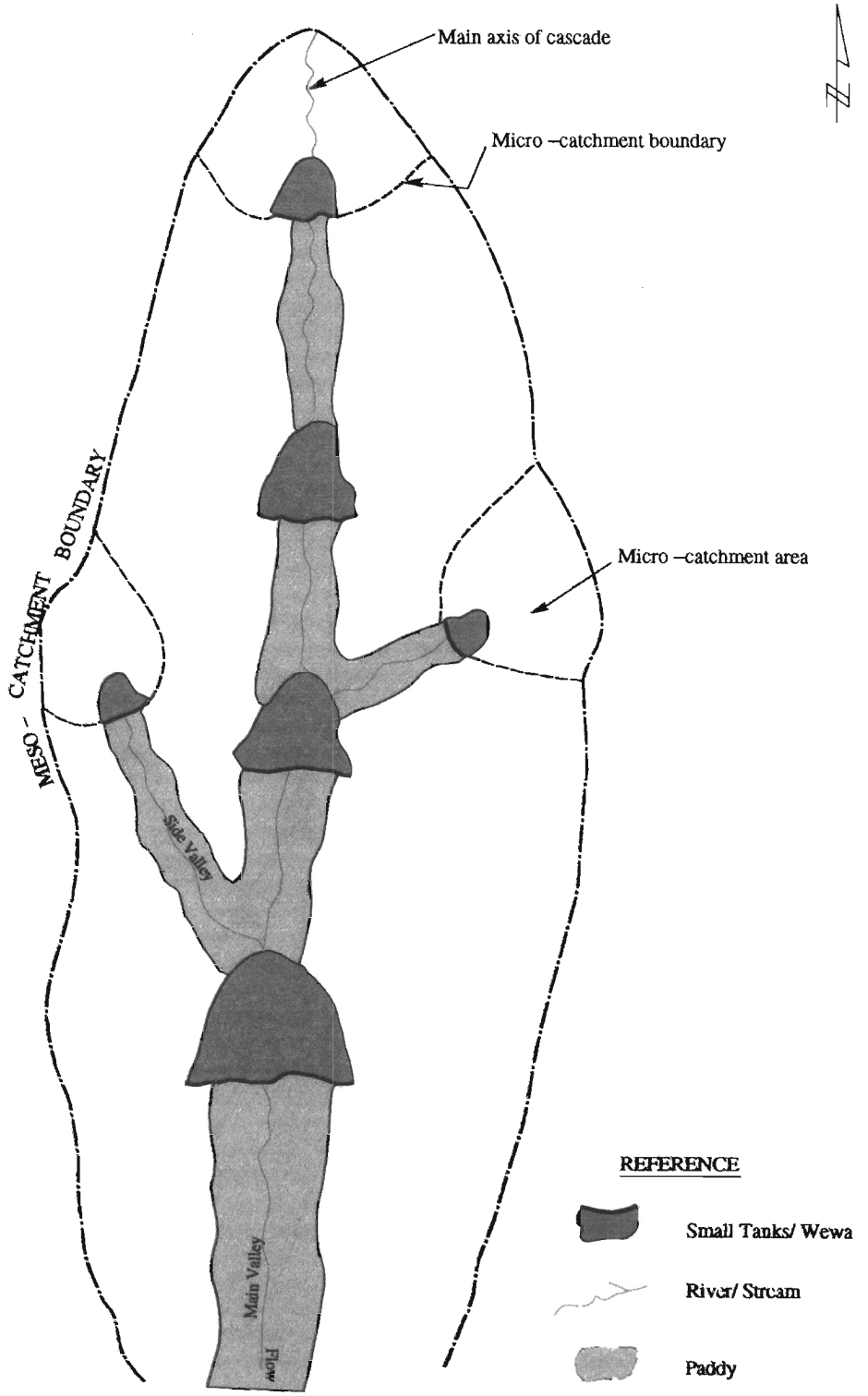


Figure 1

Prepared by Environment & Forest Conservation Division, Mahaweli Authority of Sri Lanka, Polgolla.

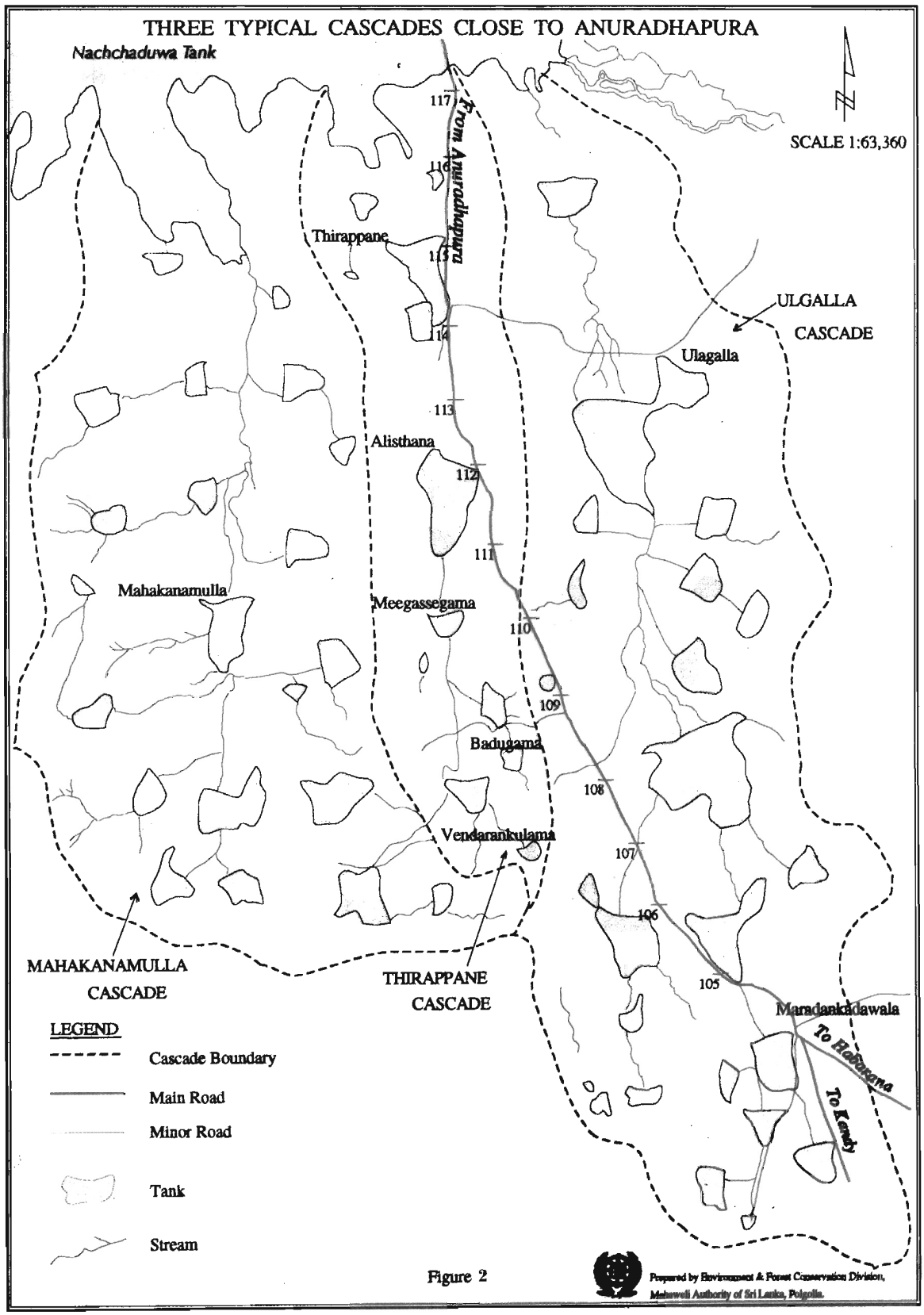

THREE TYPICAL CASCADES CLOSE TO ANURADHAPURA
Nachchaduwa Tank
From Anuradhapura
SCALE 1:63,360
Thirappane
ULGALLA
CASCADE
Ulagalla
Alisthana
Mahakanamulla
Meegassegama
Badugama
Vendarankulama
MAHAKANAMULLA
CASCADE
THIRAPPANE
CASCADE
Maradankadawala
To Habarana
To Kandy
LEGEND
Cascade Boundary
Main Road
Minor Road
Tank
Stream
Prepared by Environment & Forest Conservation Division,
Mahaweli Authority of Sri Lanka, Polgolla.

Figure 2

well known example being that of the Pul Eliya village tank close to Medawachchiya studied by Leach in 1956, and often cited by social science researchers.

As shown in the master map titled "The Hydrography of the Rajarata" (Panabokke 1999) a high density of small tanks occurs in the upper watershed regions of the main river basins such as the Malwathu Oya, Kala Oya and Yan Oya, as well as the major tributaries such as the Maminiya Oya, Kanadara Oya and Kadahatu Oya. This conforms to the normal process of landscape evolution where a higher drainage density occurs in the upper aspects of a watershed, thus resulting in a higher tank density in its upper reaches. By contrast a lower density of small tank cascades occurs across all the lower reaches of the sub-watersheds of the Malwathu Oya, Kala Oya, Yan Oya and Moderagam Ara.

The natural drainage system and the small tank distribution pattern of the Anuradhapura district is depicted in Figure 3. It could be observed from this figure that the highest small tank density occurs around the Kanadara, Kadahatu and Rampathvila Oyas which are located on the main watershed divide that separates the western flowing and eastern flowing main river systems. This region, accordingly, constitutes the heart of the Rajarata tank civilization or the "Wew Bendi Rajje" described by Tennakoon (1999).

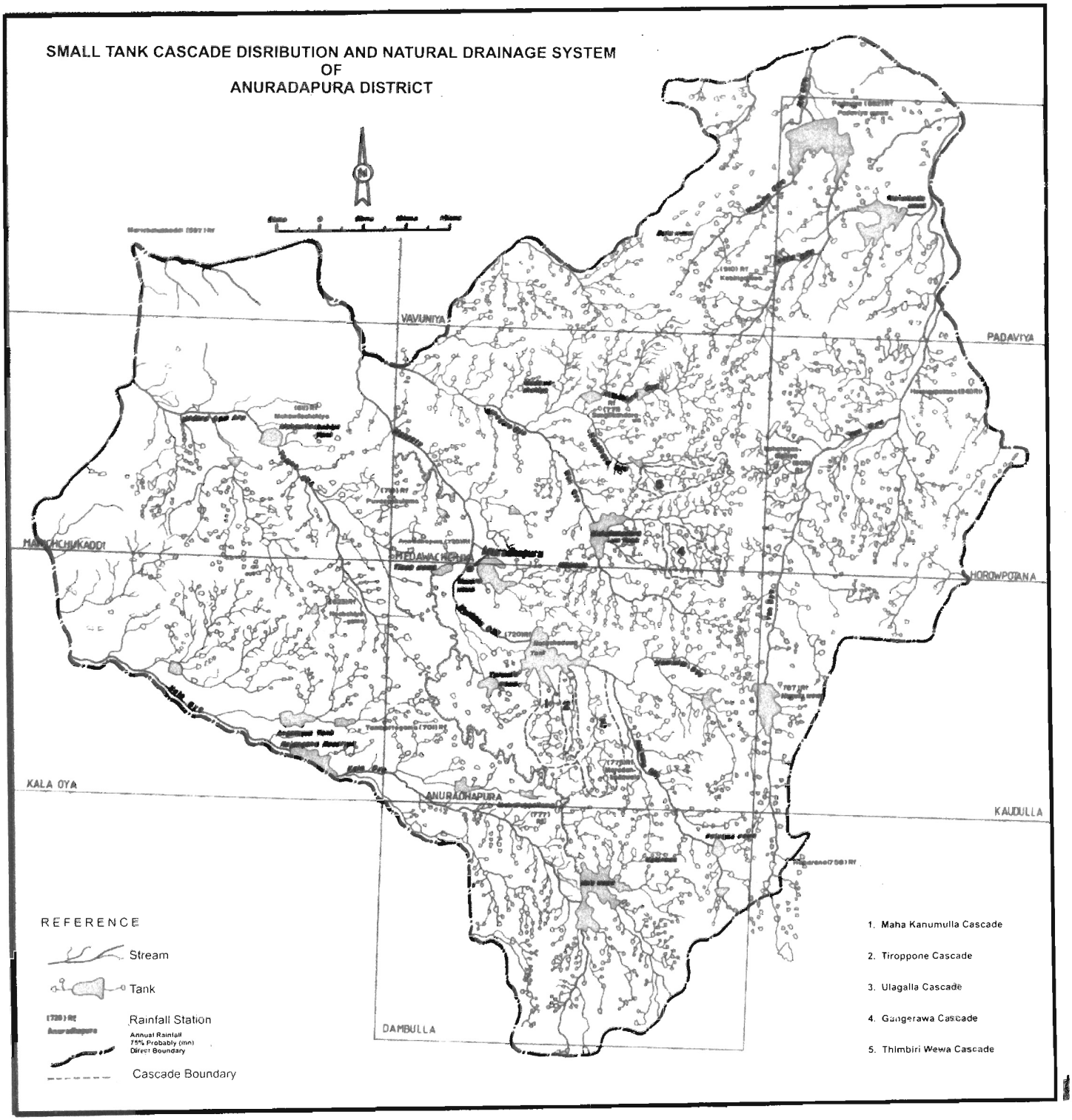
A further important feature of this particular region is the virtual absence of abandoned tanks. There is also an oral tradition in this region that it was never totally abandoned during the dark period between the thirteenth and nineteenth centuries, and it is said to have had an unbroken history of continuous settlement over the last 2000 years. It is also claimed that during the heyday of the Anuradhapura civilization this region had a very close symbiotic association with the main capital city, and it was also its main source of food sustenance.

Range in Size, Shape, Form – Typologies

As stated earlier by Kennedy (1936), "when the knowledge is fully organized, the subject becomes amenable to quantitative analysis". We have now reached a stage whereby the cascades can be characterized in terms of their size, shape and form, thus leading to various forms of quantitative analysis and development of typologies. It should be noted that cascades lend themselves better to quantitative analysis than the individual small tanks because a cascade is closer to a natural system than an individual small tank.

In terms of **size** the following **size classes** of cascades are recognized. The size class denotes the total area of the meso-catchment of the cascade.

Small	< 2,500 acres
Medium	2,500 - 5,000 acres
Large	5,000 - 7,500 acres
Very Large	> 7,500 acres


SMALL TANK CASCADE DISRIBUTION AND NATURAL DRAINAGE SYSTEM
OF
ANURADAPURA DISTRICT
VAVUNIYA
PADAVIYA
MANNCHCHUKADDI
MEDAWACHCHIYA
HOROWPOTANA
KALA OYA
ANURADHAPURA
KAUDULLA
DAMBULLA
REFERENCE
Stream
Tank
Rainfall Station
Annual Rainfall
75% Probably (mm)
Direct Boundary
Cascade Boundary
1. Maha Kanumulla Cascade
2. Tiroppone Cascade
3. Ulagalla Cascade
4. Gangerawa Cascade
5. Thimbiri Wewa Cascade

In respect of **shape and form**, the form index of a cascade could be expressed as the ratio of the overall area of the cascade to its overall length. This value could range from 1.15 to 2.55 and it gives a measure of its general shape which could then be linked with its general geometry that could be linear, branched or angular. Examples of cascades of different size, shape and form are shown in Figure 4.

Panabokke (1998, unpublished) has measured a total of 50 cascades for their (a) area, (b) form index, (c) cropping intensity, (d) ratio of tank catchment area to tank command area; and he observes a strong correlation between the area of the cascade and its form index; and a weak quantitative but noticeable qualitative relationship between the drainage density and cropping intensity, and also between the drainage density and the ratio of cascade area to tank area.

Merits of Considering Tank Cascade Systems over Individual Tanks

As seen in Figure 1, the hydrology of the whole meso-catchment within which the individual small tanks are located has a specific significance in as far as it relates to the hydrology of the individual tanks themselves. For example, while the small tank located in the uppermost aspect of either the main valley or the side valley receives its runoff exclusively from its own micro-catchment, the other tanks located mid-way or at the lower aspect of the main valley will receive their runoff from a larger catchment together with the drainage flow from the tank immediately above it. Thus the hydrology of the lowermost tank within the cascade will be determined by the runoff generated by the whole meso-basin together with the drainage flows from all the tanks and paddy fields located above it.

As shown by Panabokke (1998), the shallow regolith groundwater is located in the lowland, which generally lies adjacent to and athwart the lowermost member of the soil catena. The groundwater regime is therefore confined to a specific topographical location within the cascade, and not at random across the landscape as commonly envisioned. Panabokke (1998) has also shown that the safely exploitable groundwater in the dry season is mainly confined to the areas immediately adjacent to the main axis of the cascade. Senaratne (1996) has developed a methodology to estimate the carrying capacity of agrowells within a cascade.

Quantitative Criteria and Hydrological Endowment

Two quantitative parameters that have a close bearing on the hydrological characteristics of a cascade are:

(a) the ratio of the total catchment area of cascade (CAA) to the total water spread area of all tanks located within the cascade (WA), and
(b) the ratio of the total command area under all the small tanks (COA) to the total water spread area (WA).

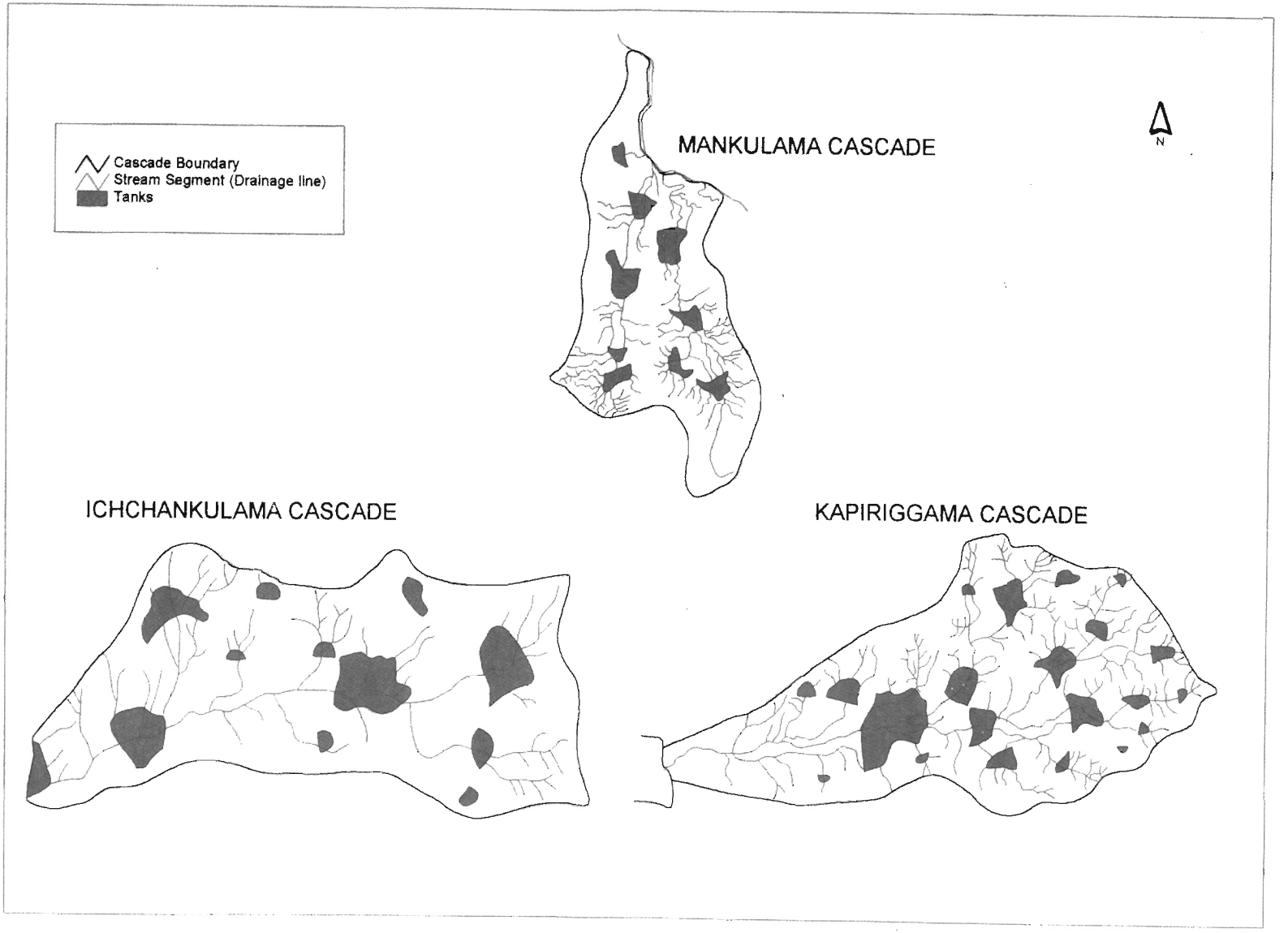

Cascade Boundary
Stream Segment (Drainage line)
Tanks
MANKULAMA CASCADE
N
ICHCHANKULAMA CASCADE
KAPIRIGGAMA CASCADE

Figure 4a

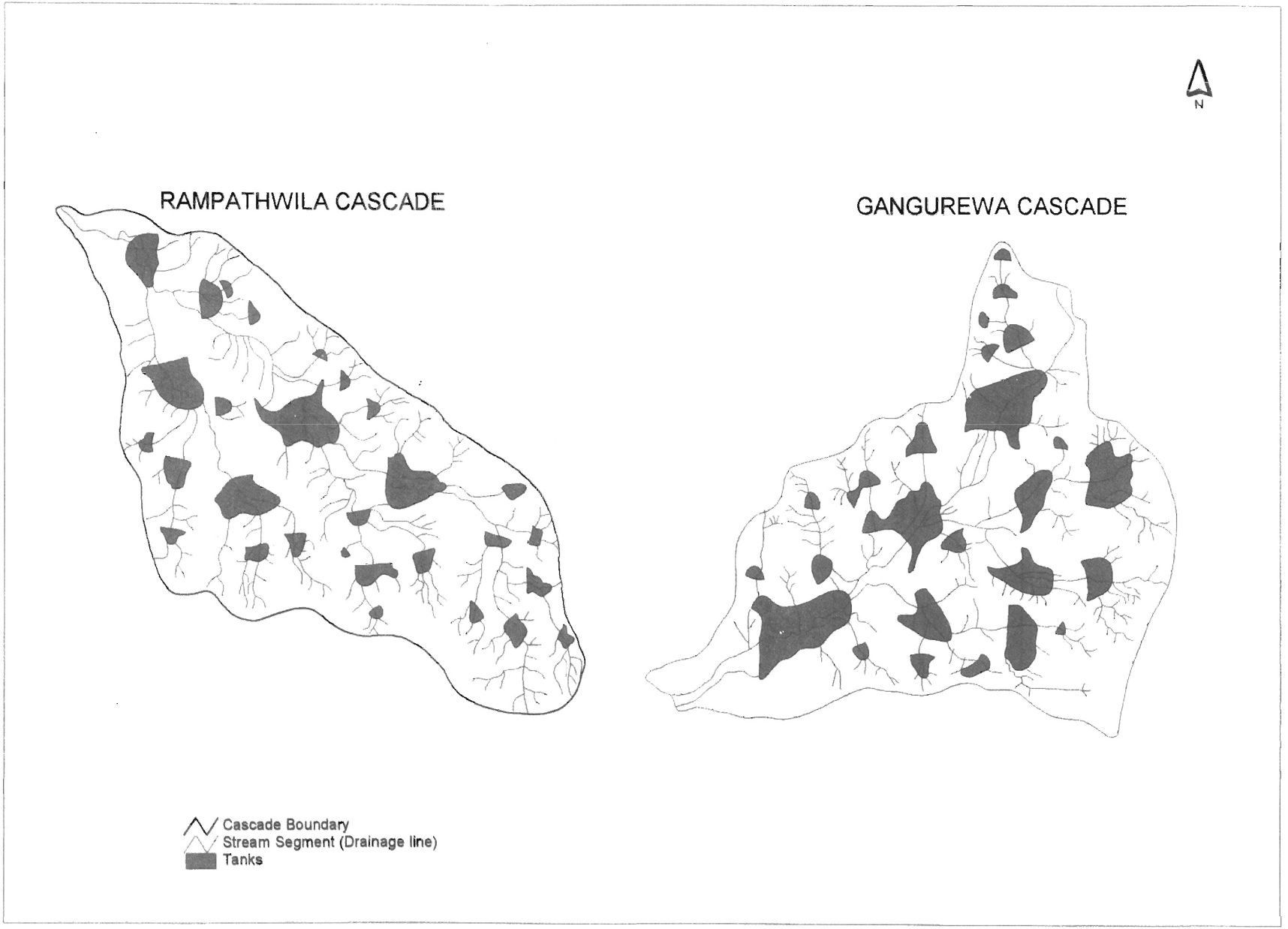

N
RAMPATHWILA CASCADE
GANGUREWA CASCADE
Cascade Boundary
Stream Segment (Drainage line)
Tanks

Figure 4b

It has been earlier established from quantitative studies that cascades which have a CAA/WA ratio higher than 8.0; and a COA/WA ratio less than 1.0, have the necessary hydrological potential for assured wet season rice cultivation.

A study of 230 cascades in 16 Divisional Secretariats in the Anuradhapura district shows the following results:

Number of Cascades with CAA/WA > 8.0	197
Number of Cascades with CAA/WA < 8.0	33

Number of Cascades with COA/WA < 1.0	40
Number of Cascades with COA/WA > 1.0	190

It could be seen from the above results that a high proportion of the 230 cascades of this district have an adequate catchment area where the CAA/WA ratio is higher than 8.0. On the other hand, it is quite clear from the above data that the command area of a very high proportion of these cascades is very much in excess of the tank water spread area, and these imposes a severe stress on the overall hydrological balance of the cascade. Because of the unrestricted expansion of the "akkarawela" extents that have taken place over the last 75 to 100 years, the tank water supply is not able to meet the normal irrigation requirements of the present command area. In the search for a reliable and easily measurable index for characterizing the **hydrological endowment** of a cascade, it was found that the **Cropping Intensity (CI)** of the small tanks located within the cascade, averaged over five consecutive maha seasons, provides a reliable and easily measurable integrated value of its hydrological endowment.

The range of values of Cropping Intensity (CI) in respect of 50 cascades in the Anuradhapura district is shown below in Table 2.

Table 2. Cropping Intensity of 50 Cascades in Anuradhapura District

Cropping Intensity*	No. of Cascades
> 9.0	5
8.0 - 9.0	8
7.0 - 8.0	12
6.0 - 7.0	13
5.0 - 6.0	8
< 5.0	4

* 9.0 denotes 90 percent
5.0 denotes 50 percent

As seen in the above Table, fifty percent of the cascades of the Anuradhapura district have a maha season cropping intensity of between 60 to 70 percent, while a further 25 percent have a maha season cropping intensity of less than 60 percent. This indicates the great variation in the hydrological endowment of cascades across this district. It is generally observed that the cascades in the western segment of this district have a lower CI than those in the eastern segment; and this is closely related to the amount of rainfall received during the usual maha seasons in these two segments. This has been well illustrated in Figure 3 of Panabokke's (1999) publication.

The Abandoned Tanks of the Rajarata, Ruhuna, Wayamba and Wanni

A total of six river basins that make up the Rajarata, and eight river basins that make up the dry zone part of the Ruhuna have been studied in detail. A further ten river basins of the Wayamba or North Western Province (NWP), and ten river basins of the Wanni or Northern Province (NP) were also studied in a more general manner for purposes of comparison. The percentage of functioning and abandoned tanks in each of the foregoing regions is shown below.

Region	Total No. of Small Tanks	Percentage Functioning Tanks	Percentage Abandoned Tanks
Rajarata (NCP)	4,017	52	48
Ruhuna (SP)	1,410	46	54
Wayamba (NWP)	6,463	65	35
Wanni (NP)	1,424	43	57

Adopting a heuristic approach, it could be demonstrated that there are different sets of reasons for the abandonment of small tanks in the different regions of the dry zone, especially in the Rajarata and the Ruhuna.

In the western aspects of the **Rajarata** the abandonment is primarily due to the poor soil and land quality, combined with a low hydrological endowment. In the eastern aspect it is primarily due to the sharper relief of the meso-land forms, and less to the land quality and nature of the hydrological endowment. The more stable small tank cascade systems are characterized by almost a total absence of abandoned tanks. These are found in the upper aspects of the sub-watersheds and have been discussed in a preceding section of this paper.

In the **Ruhuna**, the primary reason for the occurrence and preponderance of abandoned small tanks in the semi-arid environments is the sodic soil (solodized solonetz), in combination with a very low hydrological endowment. By contrast, the primary reason for the occurrence and preponderance of abandoned small tanks in the quasi-cascades of the Timbolketiya topo sheet, which is situated in a semi-humid environment, is the very

high runoff generated from the shallow and rocky land surfaces of the small tank catchment areas.

Differences in the macro- and meso-drainage patterns between the Rajarata and Ruhuna landscapes also have a close bearing on the nature and distribution patterns of small tank cascade systems in the two respective environments.

From any point of view, it could be argued that there had been adequate justification for the restoration of the abandoned ancient **major** irrigation reservoirs in the dry zone. The same rationale cannot however be extended to the restoration of the many abandoned **minor** small tanks in the same region. Selective criteria are now available for determining which of those types of abandoned small minor tanks would be worth restoring. These criteria have been discussed in Sakthivadivel *et al.* (1996).

In the final analysis, there is little or no rationale for restoring a greater majority of these abandoned small tanks; rather priority attention should be given to ensuring the productivity and sustainability of the presently functioning small tanks. By making use of the recently developed criteria it should be possible to rank the large number of presently abandoned small tanks according to their suitability for restoration, or else for restoration as water bodies exclusively for enhancing the groundwater regimes of these regions.

Sustainable Production Thresholds of Small Tank Systems

The Diversity of Production Systems within a Meso-catchment Basin and their Implications

Both traditionally, and even up to modern times, a diversity of production systems could be identified within a meso-catchment cascade basin. In order of importance these are (a) rainfed upland or "chena" cultivation, (b) lowland rice cultivation under small tank irrigation, (c) homestead mixed gardens, (d) cattle grazing and herding, and (e) food gathering from tank bed and similar sources and game harvesting from adjacent forest.

Traditionally it was a closed system within a tank village or a cascade, with the settlers living a frugal and contended life with very little external inputs. This situation has undergone radical change over the last 150 years, and the main production systems are now linked in many ways to external supplies and market forces. As a result, the earlier self sufficient subsistence equilibrium no longer prevails, and many imbalances are now recognized.

One of the major problems facing the transformation or the modernization of the traditional farming systems within a cascade is that of bringing about a balanced utilization of the present resource base in terms of the productivity of the different production systems in relation to the external market forces that now operate in the contemporary environment. This needs a careful analysis of the various factors of

production of the diverse agriculture and livestock production systems, and also a careful examination of how these interact with market forces outside the cascade area. It is only when these studies have progressed to some degree that it will be possible to pilot test the relevant interventions that have to be carried out with a view to modernizing the traditional farming systems.

Multiple Uses of Water within a Cascade

It is now becoming increasingly evident that the surface waters that have been captured and stored in these small village tanks had served a multitude of functions apart from irrigation supply for paddy during the wet maha season. It had been recognized by Ievers (1899), and Abeyratne (1956), that because of the highly variable nature of the rainfall coupled with the high evaporation rates for a greater part of the year and the paucity of readily accessible and adequate groundwater supplies in this hard rock region, it was these small tank surface storage systems that provided the lifeblood for human existence in this environment.

It is also now being increasingly recognized that the uses of water for several other essential purposes such as inland fisheries, livestock needs during the dry season, replenishment of groundwater conditions, domestic bathing needs and environmental amelioration during the enhanced dry moths from July-September, should all collectively be assigned an economic and social value.

It is also considered essential to partition the efficient use of the direct rain or the **green** water which is more efficiently utilized by rainfed "chena" cultivation, in contrast with the runoff collected and stored **blue** water in these small tanks which is less efficiently utilized in paddy cultivation as shown by Navaratne (1998).

Balancing and harmonizing the utilization of this green water and blue water components should undoubtedly be a major research and management thrust in the future research mandate of the Department of Agriculture. Sustainable food production within a cascade or meso-basin would, in the long run, be strongly governed by our ability to achieve a balanced use of both direct rainfall and surface stored supply of small tanks.

Balancing Production Thresholds with the Hydrological Endowment of Cascades

In the preceding section of this paper, the wide range in variation of the hydrological endowment of cascades was recognized. This was clearly reflected in the values of Cropping Intensity (CI) of irrigated rice across cascades which was observed to range from below 50 percent to more than 75 percent. It was also noted that the extent of the total catchment area of a cascade determined the amount of runoff that could be collected within the small tanks situated in the cascade; and that much of this catchment area was also subject to "chena" or rainfed agriculture during the maha season. Hence the total agricultural production thresholds, both rainfed and irrigated, of the small tank cascade system should be subject to a high order of variation dependent on several known factors.

Furthermore, the reliance on food security from both highland rainfed crops and lowland irrigated paddy will also be highly variable between cascades.

There is also the need to recognize the existence of different rainfall probability regimes across the western segment and the eastern segment of the Rajarata, and this too would impose variable threshold potential for food production across this region. Based on an empirical body of data now available, it is possible to broadly quantify the contribution made to rainfed food crops and irrigated paddy across the range of hydrological endowments of the cascades that are distributed across this landscape. This would, in the final analysis, help to characterize the production thresholds of the various cascades; and this in turn would then have to be evaluated against the economic benefits that would accrue to the varying income levels of families now living within these cascade regions.

Newly Emerging Dimensions of Agrowell Development

One of the very significant developments that has taken place at a very rapid pace in recent times has been the construction of agrowells under numerous small tank command areas. Each of these agrowells can irrigate between 0.5 to 1.0 acre of land by lift irrigation, and the growing of high value crops during the dry season has helped to raise farmer income.

It must, however, be clearly borne in mind that this shallow groundwater table that is being presently exploited by these agrowells is very limited in its quantity, and it is also of a very ephemeral nature. If it is over-exploited it could lead to very disastrous consequences both environmentally and economically. This shallow groundwater which is now termed the **regolith aquifer** is restricted to a definite landscape position within a cascade of small tanks, and is not ubiquitous as commonly perceived. The small tanks within the cascade also help to recharge and augment this shallow groundwater table during the rainy season, which in turn can be exploited during the dry yala season.

There are now well proven and reliable methods and guidelines available for estimating the location, spacing and density of agrowells in this regolith aquifer of the hard metamorphic rock basement region. These guidelines should be strictly enforced and adhered to in order to prevent serious ecological and environmental degradation taking place in this small tank cascade environment.

A recent study conducted on 50 cascades within the Anuradhapura district (Senaratne, 1996) has shown that the optimum number of agrowells that could be safely accommodated within these 50 cascades is not more than 3,600; and that already within five of these 50 cascades, the number of agrowells had already exceeded the upper critical limit. The red signal has therefore been already flashed, and time is now appropriate to take timely action to prevent any further expansion of agrowell construction in these stressed areas.

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STRATEGIES FOR OPTIMIZING FOOD SECURITY UNDER SMALL TANK SYSTEM IN RELATION TO THE HIGH VARIABILITY OF THE RESOURCE BASE

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INTRODUCTION

To begin with what is meant by the term **small tank** needs to be clarified. The small tank system in Sri Lanka is synonymous with the **village tank system**. According to the categorization of tanks by the Agrarian Services Department, the small tanks or the village tanks are those tanks, which command not more than 80 ha. Nevertheless, under small irrigation works the extent asweddumized is about 192,085 ha of which nearly 70% are in the dry and semi-dry intermediate zones (Assessed from implementation programme of the Ministry of Agricultural Research and Development 1993/94). This extent of land area is nearly 26% of the total land area having irrigation facilities in the country and that area is available for staple food grain production. Therefore, small tank system is capable of making a fair contribution to the food grain production, at national level.

It is a historical fact that these small tanks sustained the life in the remote villages of the dry zone. They stabilized the village settlements; provided irrigation facilities to produce rice the staple; and it also the domestic water supply directly as well as indirectly, without which life in the dry zone would have been impossible during the protracted dry period experienced annually. It also provided water requirements of the village livestock Thus, small tanks have served as a multifunctional resource, and while it's important functions had been the production of food and provision of domestic water for the village people. However, at present the role of the small tanks in food security issues of the village communities is uncertain.

Simply the statement as "Production of enough food grain locally to meet the basic food requirements of the population can be defined as food security. This is more valid at the national level. However, if the village tank settlement sector is considered as a separate entity the concept of food security needs to be somewhat modified. Food security in this situation should mean that while producing the optimum quantities of food grains strengthen the financial capability of the people through crop diversification to purchase the required quantum of food from other parts of the country where surplus food grain is available. In the absence of opportunities to earn adequate cash income from non-agricultural production enterprises in small tank villages, it is necessary to produce high value crops optimizing the use of physical resources available in the minor tank-village settlement sector. It is to be noted that in the major irrigation settlement sector, available resources permit the production of surplus food grain locally. On the other hand in the small tank sector food grain production is much below the potential due to many reasons, which would be examined in latter sections of this paper. New approaches are required to

increase food grain production and cash incomes to achieve food security in the small tank – settlements.

Objectives

The objective of this paper is to identify strategies to optimize food grain production and enhance cash incomes of the farmers using this highly variable resource base. The irritation potential of small tank system is highly variable and unstable in its performance due to a number of inherent factors (Somasiri, 1976). These would be examined in the following sections. What strategies are available to transform the out puts of this unreliable and unstable system to relatively more stable levels than at present.

A complete understanding of the nature of the resource base and problems associated with their utilization by a community having limited financial and material resources should form the basis for any strategy to use such resources in a secure manner. From the viewpoint of utilizing the resources of the small tank environment, it is essential to characterize all the resource components of that environment.

Characteristics of the Tank-Village Settlement

In Sri Lanka, it is estimated that there are about 22,000 inland water bodies. This includes large reservoirs as well as water bodies not meant for irrigation. Freedom from Hunger Campaign estimates 18,000 minor tanks, and that there could be another 12,000 tanks in an abandoned state. However, it is unlikely that all these small tanks were simultaneously operational during any period of the history. According to Agrarian Services Department estimates there are about 8,500 small tanks in working condition and I would consider this figure to be the presently operational number of the small tanks. A great majority of these tanks are in the dry zone districts.

In the dry and semi-dry intermediate zones village settlements are always associated with small tanks, no village did exist without a tank to provide the basic food grains and water. Therefore, it is very important to remember that small tank system encompasses several interrelated resource components requiring a holistic approach to the efficient utilization of them.

The main components of the tank-village settlement complex are: (a) small tank (village tank), (b) Gangoda- the housing area, (c) Chena or upland that is the rainfed cropland, (d) tank command area – commonly called the welyaya, identified in two parts Puranawela and Akkarawela, and (e) the tank catchment. Usually, chena is located within the tank catchment. All these components are independent variables, therefore a great diversity exists within the system.

Characteristics of Small Tanks

Size distribution

A vast majority of these small tanks occur in cascades, usually with several tanks in a second order valley, one tank located at a lower elevation than the one upstream so that overflow of the upper is collected by the tank at the lower elevation. These tanks vary in terms of the surface area at full supply level, shape, depth and the volume of water stored or the capacity at full supply level. Thus, a range of sizes, shapes and storage capacities characterize the village tanks. Analysis of the size distribution in a sample of 2006 tanks show that the size of tanks in terms of the surface area at full supply range from 2 ha to 600 ha. 88.6% of these tanks have the surface areas below 60 ha (Somasiri, 1980). The surface area of 72 % of the tanks is below 20 ha Table 1. The number of tanks larger than 60 ha are less than 12% of the sample. The height from sill level to spill level of the smaller tanks generally increase with the increase of the tank size. Thus, as much as the surface areas of small tanks have a wide range, the storage capacities of these tanks at full supply level also have a very wide range.

Table 1. Classification of Small Tanks Based on the Surface Area at Full Supply

Surface area at FSL (Size)	Class	Number of tanks in each class	Percentage
2 – 20	1	749	37.3
21 – 40	2	703	35.0
41– 60	3	320	15.9
61 – 80	4	82	4.1
81 – 240	5	86	4.3
241 – 600	6	66	3.3

Small tank hydrology

The hydrology of the small tanks had been a neglected area of investigation up to 1976 (Somasiri, 1976); therefore, there had been a serious dearth of quantitative data on the hydrology of small tanks. This field of investigation has received very little attention, even now the small tank designs are based on the hydrology of major watersheds and the development criteria proposed by Arumugam (Arumugam, 1957). In spite of the lack of scientific study of tank hydrology necessary for management purposes of small tank systems for agricultural development in the dry zone, there is broad realization that the small tank system should form an essential and an integral part of the settled land use patterns in the dry zone.

Sources of tank water supply

The primary source of tank water supply is the locally occurring rainfall. Direct rainfall on the tank surface and the rainfall runoff from its own catchment are the main sources of water supply to the storage (Somasiri,1976), while in a cascade the water from a tank at a higher elevation may contribute to a tank at lower elevation. Rainfall being the primary sources of small tanks water supply the dependence of the small tank system on the regional climate needs no elaboration. The seasonal pattern of the rainfall; it's erratic behaviour and uncertainty in terms of quantity and duration are well documented (Alles,1971; Kannangara, 1988; Kannangara and Panabokke, 1991; and Panabokke and Walgama, 1974). The small tank water supply arising from the direct rainfall on the tank surface is independent of all factors except for the rainfall quantity; that is the total annual rainfall alone determines that component of the tank water supply. On the other hand contribution to the tank storage from the catchment yield is dependant on a number of factors, namely catchment shape and size; catchment surface cover, soils, land use, rainfall intensity- duration relationship, drainage density and the rainfall season. In a given catchment water yield varies from year to year. It also varies between seasons that is from Maha to Yala, from Maha season to Maha season and from Yala season to Yala season (Somasiri, 1979). The catchment yield in the Maha season is always more than the yield of the Yala season (Somasiri, 1980). Such variation in catchment runoff results on one hand in a high variability of the use potential of small tanks and on the other hand the usable storage can not be assessed until a major part of the rainy season is passed. Therefore, preparation of advance agricultural implementation programmes under small tanks becomes meaningless.

Tank density and tank water supply

The tank density in an area is another factor that influences the water supply to the small tanks, because at higher tank densities the catchments are smaller. With the increase of tank density, the water supply becomes unstable due to limitations in the catchment size. The above discussion illustrates the very high dependance of the small tank water supply on a number of independently variable factors. Thus, small tank is a highly variable resource base with an unstable water supply.

Catchment land use and water yield

The catchment cover has a major influence on catchment runoff as shown in Table 2 (Somasiri, 1995). In chena land (cleared land) generated 36 to 55 % of the rainfall received in the maha season as runoff, whereas scrub and forest land produced less than 2%. In the dry zone micro-catchments, land use plays a dominant role in determining catchment runoff, because land use varies from year to year, where as other factors remain constant. (Sumanaratne and Somasiri, 1990). Comparison of runoff as a percentage of the rainfall of maha, yala and full year for three catchments, which had three different land use compositions showed distinct differences in the runoff percentage of the seasonal rainfall (Bandara and Somasiri, 1992) The catchment with a dominance

of chena land (79%) generated the highest runoff (39%), one with dominance of teak (73%) generated the second highest (16%), while the runoff of the catchment with about 89% of primary and secondary forest generated the least that is about 6% of the rainfall.

Table 2. Rainfall Runoff Under Three Different Land Covers Patterns in Nachchaduwa Catchment

Parameters	Cleared land		Scrubland		Forest	
	Maha	Yala	Maha	Yala	Maha	Yala
1987/88						
Rainfall, mm	802	382	558	275	727	413
Runoff, mm	292	73	7	4	8	0
Runoff %	36.4	19.1	1.3	1.5	1.1	0
1988/89						
Rainfall, mm	342	165	587	338	323	243
Runoff, mm	188	27	2	1	3	0.3
Runoff %	54.9	16.4	0.5	0.3	0.7	0.1

Source : Somasiri, 1995

Drainage density and runoff

The studies conducted during the Maha 1993/94 shows that surface runoff from plots with higher drainage density is several fold high as the surface runoff from plots of similar characteristics (Somasiri, 1995). Clearly this appears to be a good method for improving the water supply to small tanks in the dry zone. Enhancement of runoff generation from forested catchments would be possible by improving the drainage density in such manner that increase drainage will not increase soil erosion.

Catchment size and tank storage

The relationship of the size of small tank catchments and tank capacity at full supply level appears to determine the frequency of filling and also spilling. A detailed study of 19 small tanks in the Anuradhapura district showed that the tanks whose ratio of catchment area to full capacity was less than 9 ha/ha.m did not reach full supply level except on rare occasions (Somasiri, 1995). Further, those tanks, which had the above ratio less than 9 ha/ha.m never, reached even the 50% of full capacity during the period 1987 to 1992. The tanks with higher ratios of catchment area to full capacity showed a higher frequency of filling. Such tanks filled over the 75% capacity level, in more than 66 % of the maha seasons, in the study period. Greater success could be expected from tanks with high ratios of catchment to storage. Under these tanks planning the implementation programme of agricultural activities in advance of the tank filling is possible, while taking lesser risks than for tanks with lower ratios of catchment to storage.

Activities affecting catchment yield

Presently some activities such as construction of ponds for water harvesting are promoted in the small tank catchments. Agro-wells are constructed in catchments. These activities no doubt will reduce the catchment water yield, the most important water supply of the small tanks, causing further variability and instability of the system.

Production potential of small tanks

The irrigation potential of a small tank is related to the total available storage and the size of the command area. The cropping intensity in the command area and the agricultural production to a large measure depend on the water availability for irrigation. At present, the size of command area of most small tanks is much more than what the tank could support at the designed duty of about 1 hectare meter or 3 ac.ft (Arumugam, 1957). Under the circumstances cropping intensities realized are far below the optimum for any given season. The following tables give data for five districts illustrating the low irrigation potential of the small tank system in terms of the cropping intensity achieved.

Table 3. Cropped Area in the Maha Season under Minor Tank Irrigation as a % of the Asweddumized Command Area. Ten Year Period of 1980- 1989

District	80	81	82	83	84	85	86	87	88	89	Average
Anuradhapura	82	40	42	74	53	53	31	54	5	39	52
Vavuniya	89	86	88	87	71	56	31	44	23	20	59.5
Hambantota	72	54	71	72	57	67	48	64	57	41	60.3
Moneragala	93	81	94	87	92	92	68	80	70	63	82.0
Kurunegala	96	73	69	69	91	93	57	80	68	77	78.4

Source : Somasiri, 1991

Table 4. Cropped Area in the Yala Season under Minor Tank Irrigation as a % of the Asweddumized Command Area. Ten Year Period of 1980-1989

District	80	81	82	83	84	85	86	87	88	89	Average
Anuradhapura	02	1.5	1.5	1.4	28	5.8	9.3	1.2	6.4	0.4	6.1
Vavuniya	0.6	0.7	0.7	0.4	21	0.4	5.7	0.3	1.7	-	3.5
Hambantota	32	36	41	23	50	32	40	19	23	21	13.9
Moneragala	09	10	12	08	20	15	18	08	30	09	13.9
Kurunegala	37	34	42	26	83	44	54	27	57	17	41.3

Source: (Somasiri,1991)

In general, the cropping intensities have been very low: assuming that there is potential for double cropping the normal way of assessing the cropping intensities that gives a maximum value of 200%, the actual cropping intensities realized are as follows:

Anuradhapura	district	29%
Vavuniya	district	31%
Hambantota	district	45%
Moneragala	district	48%
Kurunegala	district	60%

However, under the particular rainfall regime experienced in the dry zone, the small tanks are probably not designed for double cropping, but only to provide supplementary irrigation for a rice crop in Maha season. Therefore, it is more reasonable to assume maximum cropping intensities at 100% per year, in which case the above values should be doubled.

Village Settlement

The traditional village settlement used to be located by the side of the tank at very close proximity. The tank served as the only source of water for domestic use and for animal husbandry in addition to its use for agriculture. Therefore the settlement had to be close to the tank. However, in the recent past the settlement pattern had changed in a very distinct manner. On one hand with the increase of the village population the traditional clustered settlement could not be accommodated within the gangoda. On the other hand the road access acquired much more importance than the distance to the tank. Thus settlements in clusters expanded into the catchment areas and also the ribbon shaped settlements appeared along the access roads to the village and the tank. The people began to live further and further away from the traditional focal point, the tank and began to give less importance to the small tank irrigation sector for food grain production.

Chena – Rainfed Upland Agricultural Sector

With the population expansion in the village, chena cultivation acquired greater importance in the village economy. This is partly because of adequate land availability for chena cultivation compared to the limited access to irrigated lands. Furthermore, though chena cultivation has been described as a wasteful system of agriculture, in terms of a farmer minimizing his risks and optimizing his labour input, chena has been a very rewarding, particularly in areas with land availability. However, now it is long pass the time to transform the chena into a stable system of rainfed agriculture, because land is no longer a plentiful resource. Traditionally, chena ensured the production of coarse grains, which served as a major component of the diet of the tank-village population. At present the place of coarse grains in their diet has been taken over by the imported wheat flour.
Welyaya or the Command Area of the Small Tank

The two distinct components of the small tank command area is the Purana wela and Akkara wela. Purana wela was the traditional irrigated component of the village agricultural system. However, with the population expansion new areas were added to the command of the small tank and are called akkara wela. Usually akkara wela is irrigated with a high level sluice, provided adequate water is available above that sluice level. Further expansion of asweddumized area adjacent to the purana wela has taken place due encroachments. The end result of all these latter day additions to irrigable area under the small tank is the expansion of the command area by several folds of the initially irrigable area without corresponding increments of the tank water supply. Under these circumstances command area is cropped only when the tank storage is considered adequate to irrigate the whole area under command. Water adequacy is assessed on the basis of the past experience from the maximum tank level attained in the maha season. It is observed that tank water is not utilized when the above condition is not met. Further, the land fragmentation in the command area is a severe problem. An average size of holding is less than half to one third of a hectare. An individual holding may consist of a number of widely scattered parcels, as the degree of land fragmentation is quite high. An individual holding may consist of anything from one to seven scattered parcels with an average of about 3 parcels per individual holding. Presently, land fragmentation could be seen even in the akkara wela. The small size of holdings and the scatter of parcels in the holding discourage the farmer to invest on labour and inputs, therefore, both land and water remain unutilized or under utilized. Thus, the whole system appears to have lost its place as a provider of the staple food grain for the viliage people. It is quite evident that the command area to tank storage relationship is an important factor that determines the irrigation potential of small tanks.

Constraints to Optimization of Water Use in the Small Tank System

Climate

There are a number of constraints affecting the production of food grains in the small tank environment. They include physical, biological and economic constraints, some of which are beyond elimination while there are others for which solutions could be found. These constraints limit the use of land and scarce water resources for food grain production. The climate experienced in the small tank environment is well documented, therefore it is not necessary to delve any further. The bimodal rainfall distribution is such that the length of the main rainy season just matches the growth duration of most climatically adopted food grain crops, provided they are planted with the initial rains; only few pulse crops are available for planting in the mid season. The length of the minor rainy season is inadequate for maturing any food grain. During the protracted dry period that follow the minor rainy season cultivation of any annual crop is impossible and even the establishment of perennials are extremely difficult.

At the beginning of the Maha rains that is at the close of the long dry period, water storage in small tanks is below the sill level or more often than not the tank would be dry. There is no water for land preparation to establish crops to enable the use of rainfall for crop growth. On the other hand tank water supply is very unstable and the irrigation

potential seems very low. However, tanks having larger catchment area, that is more than 9 ha of catchment area per hectare meter of tank storage, are found to have more stable water supply. For those small tanks whose water supply is unstable, early cultivation is involves high risks, which the farmer is keen to minimize.

Adverse soil properties

The extreme hard consistency of the dominant soil groups Reddish Brown Earths and Low Humic Gley soils when dry do not permit tillage when of the soil is dry. The tillage of the wet soil is made difficult due stickiness and plasticity of wet soil, however puddling using plenty of water is the only practical alternative for seed bed preparation, which is only suitable for paddy growing.

Unreliable tank water supply

According to the small tank characteristics discussed in the earlier sections, small tank water storage is unreliable for any advance planning of agricultural activities. Any efforts to optimize the use of the maha season's rainfall and supplement with tank irrigation involves high risks of crop failure, this is against the farmer attitude on risk management. The farmer invests labour and inputs only when and where risks are at a minimum.

Land fragmentation

As mentioned in an earlier section land fragmentation is a serious issue for optimizing the use of land and water. The size of holding in scattered parcels in the command area is economically not attractive to invest on cultivation of food grain, in this case paddy. Cultivation of cash crops and coarse grains in the rainfed chena is economically much more attractive. Therefore, cultivation of the tank command area is given low priority.

Rainfed upland cultivation against irrigated agriculture – Labour competition

Under the climatic and soil conditions encountered in the small tank environment, it is profitable to invest on rainfed upland agriculture or chena cultivation than on tank irrigated cropping due to some inherent factors associated with the command area as discussed above. At the beginning of the maha rainy season, labour required for planting on rainfed uplands is very high. There are a number of operations in the chena that can not be set aside at the beginning of the season for the sake of planting in the tank command area. By necessity rainfed upland cultivation is given the highest priority. Any attempt to cultivate the command area of the small tank is when idle labour is available.

Weed problems

Weed infestation in the rainfed uplands as well as in the tank command is a major problem encountered in the dry zone. Weed control in rainfed upland area is a high

priority. All the available labour is utilized in the uplands during the initial phases of the upland crops development, without which all upland crops may be smothered by pernicious weeds. At the time when the farmer is ready to work the command area a heavy weed growth in the command area can be expected. At that stage to kill the weeds and prepare a weed free seedbed submergence of fields is resorted to, a process that draws heavily on the tank storage.

Lack of capital for investment

The farmers dependent on small tank irrigation and chena cultivation are constrained by lack of capital. More often than not they are not credit worthy. There is no crop insurance for the small tank based agriculture because of the inherent high risks involved. These farmers are resource poor; at most they own hand tools only, that is also the all-purpose mammoty; while they rarely own tractor power.

Marketing problems

Their products rarely compete with crops produced under assured irrigation in major systems. Proper markets are not available, therefore income from agriculture is very low and there are no surpluses for re-investments in agriculture.

Poor water management

Lack of properly planned, designed and constructed delivery system with adequate controls is a distinct feature of the small tank system. In some small tanks the modern sluice gates are not installed, therefore water releases can not be controlled. Under the circumstances it is not possible to manage the tank water as desired. Much water is wasted in a given command area due to poor water management practices of the farmer. However, at least part of that lost water from one command area flows into the adjacent down stream tank in the cascade. This reuse helps to increase the overall water use efficiency.

Strategies for food security

Is it not a historical fact that the small tank-village settlements persisted without out side help for a very long time during and prior to the foreign domination of this country. Is there any evidence to show that the village settlements declined due to food shortages? It is well established that dry zone villages declined due to Malaria rather than a food shortage. Traditionally the dry zone farmers in small tank-villages lived a very frugal life, contended and happy. He expected crop failures and lived accordingly. His crops, farming practices, storage facilities, food habits and his way of life was fashioned on the basis of uncertainty and vagaries of weather which affects his only occupation. However, in the present context there is a serious problem. Since independence from the Colonial rule, the politicians and public officials have considered the tank village farmer as " poor miserable human being living in misery". All attempts to help him have been on this

basis (Medagama, 1976). This attitude of the politicians and the public officials has been responsible for the present state of actual misery that the tank-village farmers experience. These villagers have changed their food habits and way of life. Now we have a new situation. Re-establishment of food security in the villages under the present context is essential. Following discussion is on the possible alternative strategies to achieve food security in the small tank settlements.

Any strategy to increase food grain production and enhance farmer income in the small tank environment must consider better yielding crops and optimizing the use of land, water, labour and other resources in that given environment. Adoption of better yielding food grain crops and high value other field crops are considered common to all approaches or all strategies for optimizing the use of land, water and labour. Out of the possible alternatives for optimizing the use of land, water and labour one must pay attention to the most limiting resource for it would be the controlling factor. In this respect water appears to be the most limiting resource in the small tank environment. Thus one must optimize the use of rainfall and the runoff that is conserved in small tanks where land and labour is not limiting. Where water is not limiting but land is limiting the approach is to optimize the use of land. Both these situations require the optimization of labour in order to make agriculture a more attractive and economic enterprise. The other aspect that needs attention is approaches that minimize risks because risks are not acceptable to the farmers in small tank systems. There are no risk absorption mechanisms in the small tank agricultural sector.

Strategies available are:

1 Optimizing the Use of Rainfall and Land

a) Stabilize rainfed agriculture and adept high value crops

Traditional chena cultivation or shifting cultivation is no longer a suitable practice in the small tanks-village sector. There are no forestlands for clearing and cultivation; whatever, forests that are there in the dry zone are found only in the forest and wildlife reserves and national parks. At present, the farmers are compelled to clear scrubland, which had no time to regenerate fertility or smother the pernicious weeds and grasses. Now the areas used for chena have reached a semi-stabilized condition. Therefore, there is no alternative but to the use of new technology to farm these uplands. There are two possible approaches to stabilized rainfed farming; one to simulate forest fallow condition with a certain quantum of new technology and the other is to use new technologies in full.

It has been adequately demonstrated at Maha Iluppallama research station that avenue planting of rapidly growing leguminous trees are able to simulate forest fallow conditions for rainfed farming. However, some new

technologies are required, namely new high yielding crop varieties, good seeds, some fertilizer, micro-nutrients, and pest and weed control.

The other approach to rainfed upland agriculture in the small tank village environment, mainly in the dry zone, is to use new technologies for the farming activities. These new technologies include the use of tractor power for tillage and seed bed preparation, high yielding crop varieties, quality seeds, fertilizer, micro-nutrients, pest and disease control and weed management. However, there are a number of drawbacks to this approach, The new technologies are capital consuming, that is high investments are needed. What the small tank village farmers lack most is capital for investment, particularly at the end of the protracted dry period he may not have any reserves even for an emergency. Furthermore, he may be indebted to the local money lenders. The other problem is that farmers who practice rainfed agriculture have been used to ways of minimizing risk. Therefore there is no justification to force him to invest on rainfed agriculture that is inherently high risk, unless a system is developed to absorb the risks, say in the form of crop insurance or government assistance. Shortage of mechanical power at the beginning of the cropping season is a major problem for land preparation so that planting is made possible with the initial rains. The soil conditions are such that even when the tractor power is available, land can not be tilled until after the first rains to moisten the soil and give a suitable consistence. This means for timely preparation of land a surge of mechanical power is required for a very short duration. A low risk high technology is what is wanted.

b) Integration of upland agriculture with animal husbandry

Integration of animal husbandry, particularly dairy cows with the rainfed agriculture component discussed above, will eliminate some of the drawbacks that accompany the adoption of new technologies. In the first place a regular income may be assured and some cash reserve for investment on maha cultivation may be possible. It also helps to cut down on the fertilizer use due to the availability of farmyard manure. Some degree of weed control can be achieved by grazing or cut and feed.

ii Optimizing the Use of Tank Water and the Command Area

a) Land consolidation in the command area and operation of purana wela as one production unit

As discussed under constraints above, the reasons for under utilization of tank water and land in the command area of small tanks are: land fragmentation, size of holdings, scattered parcels in a holding, size of the present command area which do not match the tank storage. The other

important factor contributing to low cropping intensity in the tank command area is the unreliable nature of tank water supply. Command area is not cultivated early in maha season making use of maha rainfall mainly due to this state of uncertainty. Further due to over expansion of the command area it had been a problem to provide adequate water for paddy unless when the tank is at full supply level or near it. There is an urgent need to undertake land consolidation to eliminate the problems related to scatter of parcels in a holding, small size of holdings and land tenure problems. Approaches are needed to utilize tank water even when the tank is half or one third it's full capacity. The whole command area should be treated as one unit for operational purposes. Establishment of a cooperative farm could achieve this or a collective farm or farm operated by one or two individuals on a lease arrangement to pay the landowners with a share of the produce.

Let us treat akkarawela and puranawela together with new lands down stream of puranawela as two separate entities. Under any one arrangement which allows the use of purana wela and any new lands down stream of purana wela as one unit of operation will facilitate planning and development of a more suitable water delivery system, with better controls for better water management. Also it would be possible to divide puranawela and adjacent new areas to it into two or three land segments. The segment nearest to the source of water could be cultivated initially when the tank is partly filled. As the storage increase with the advancing of the season progressively next segments may be added to cultivation. Age classes of paddy may be selected for all sections to mature at the same time. The particular approach will ensure the use of tank water the most limiting resource to produce much needed grain crop for food security.

Akkarawela may be unutilized for other field crops under rainfed condition commencing in early maha. A meda season of other field crops is possible provided tank water level at the end of maha season is high enough to irrigate the akkarawela. Depending on the tank water balance, a short duration crop is possible in the yala season. This kind of approach is the only opportunity to optimize the use of tank water under normal or below normal storage. To lift water from the supply channels and adoption of micro-irrigation to cultivate high value crops in the better drained soils of Akkarawela is another approach to optimize the tank water use.

iii Use of Ground Water for High Value Crop Production

The use of ground water commonly identified as agriculture under agro-wells has been given much publicity and already has made large investments by various programmes of assistance. It is a good strategy to enhance the farmer income,

which in turn helps to attain food security of the particular farmers. However, the ground water extraction is not without problems. Ground water extraction will adversely affect the small tank storage. This is case of few benefiting at the cost of a lager section of the society. High density of agro-wells lead to a situation of over extraction of limited ground water, ultimately resulting in the over depletion of the aquifer. At a stage when the agro-well density increases beyond the carrying capacity, none-of the wells will be able to supply the required duty of water. This situation has already arisen in Paluwa, where many wells are not in use because the well recharge is not adequate to irrigate such an area of land as an economic enterprise. There are a large number of wells remaining unused. Further, over extraction of ground water may lower the ground water level to affect the vegetation and cause irreversible environmental damage.

Over extraction of ground water is likely to affect tank storage. The lowering of the ground water level leads to the enhancement of tank water loss occurring due to deep percolation through the tank bed. Few farmers who operate the agro-wells in the command area indirectly use the tank water, while a larger number of the village population may be deprived of the legitimate right to tank water. The social and economic consequences of this on the village population should be considered with greater seriousness. A system of ground water extraction, use and management if developed to spread the benefits to many of those who have the right to tank water is nothing but fair.

The use of ground water will remain a good strategy as long as the extraction is less than the average annual recharge of the ground water aquifer. It is advisable to use well water on less water demanding crops; it is ideal for orchards where limited water supplies are needed.

iv Supportive Policy Strategies

Many attempts have been made to increase the cropping intensities in the command areas of the small tanks and stabilize rainfed upland-farming (Unpublished Annual reports of Maha Iluppallama Reseach Centre), however, without the expected successes. This is mainly due to the high risks involved in dry zone agriculture. The lack of policy strategies appears to be an important factor for the non-acceptance of the departmental initiatives by the farmers in small tank based areas. Also the overwhelming extension emphasis placed on major irrigation sector and the low priority given to small tank based agriculture by the extension services could be another factor for the lack of achievement in improving the small tank based agriculture.

The inability of the farmers in small tank based systems to take risks, as pointed out earlier, in undertaking agricultural activities particularly in early part of the season under uncertain rainfall conditions and unreliable tank water supply is an important factor that limits the optimum use of water resources. Perhaps introduction of risk absorption mechanisms such as crop insurance may be a good

policy strategy to encourage investments on rainfed upland agriculture and early cultivation of the tank command areas to optimize the use of both rainfall and runoff water.

The establishment of farm-gate prices for the agricultural products should be another strategy to ensure reasonable incomes for the purchase of food grain from outside the system.

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SOCIO-ECONOMIC AND INSTITUTIONAL ASPECTS OF SMALL TANK SYSTEMS IN RELATION TO FOOD SECURITY

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INTRODUCTION

The village tank is a small reservoir to impound surface relief of water of a small watershed for irrigation and domestic purposes. Some are of the opinion that our ancient prosperity was centred around these tanks. In the dry zone, it has been said that a tank mean a village and village mean a tank. The village irrigation system has social, cultural and economic values. It is an integral part of the entire eco-system. There is a belief that such social conditions prevailed in ancient times helped in achieving self-sufficiency in food, which was attained by establishment of balance between demand and supply of food.

To a great extent, the work our ancestors accomplished in the construction of village irrigation systems remains an asset for modern development. Village tanks are also refereed to as the minor irrigation system. Minor irrigation is defined in the present context as the irrigation system, which have a command area of less than 80 ha. One-estimate places that the total number of these minor tanks in use and in abandoned condition at about 30,000. (Medagama, 1982; FFHC, 1979). It is estimated that over 50 percent of these schemes are in working condition. According to the Department of Agrarian Services, there are about 8,500 operational minor tanks in the Dry Zone alone (Dayaratne, 1990).

The highest concentration of these minor tanks is located under 'Deduru-Oya' basin in Kurunegala district Spatial distribution of minor tanks had been primarily dictated by social factors such as human habitation and size of population. The irrigation capacity was governed by the size relationship of the catchment, tank and command area (Somasiri, 1979). Village tanks provided all the water needs of the village community and governed by the customs, norms and values associated with traditional village life.

Importance of Minor Tanks in Paddy Production

Minor irrigation systems accounts for about 250,000 ha. which is 45% of total lands under irrigation. It supports the livelihood of over 400,000 farm families. According to the Department of Census and Statistics (1998), production of paddy from the land irrigated by minor tanks accounted for about 21 percent of total paddy extent cultivated during the period of 1995 - 1998 (Table 1). According to the table, Maha production share from minor tanks is about 23 percent and Yala season production share is about 18 percentage of total paddy extent cultivated.

Table 1. Paddy Extent Cultivated by Type of Water Source, 1995-1998

Season	Type of Water Source						Total (000'Ac)
	Major Irrigation Extent (Ac)	%	Minor Irrigation Extent (Ac)	%	Rainfed Extent (Ac)	%	
Maha	251190	47	126915	23	159833	29	538698
Yala	180586	61	51914	18	63096	21	295596
Total	432537	52	178829	21	222929	26	834294

Source: Department of Census and Statistics, 1988

Institutional Aspects in Minor Tanks Development and Management

Historical evolution of irrigation institutions in village tank systems

Irrigation development played a central part in Sri Lanka's distinguished cultural heritage, and much has been written about the advanced nature of the ancient irrigation infrastructure and hydrologic civilization that lead to a relatively self sufficient and self reliant economy (Brohier, 1934, Seneviratne, 1989). Sri Lanka's water laws, customs and traditions are among the oldest in human civilization. These customary laws have been evolved over the years for water harvesting, water conservation, water distribution and collective operation and maintenance.

Historical definition of minor tank was based on its community management aspects. According to the irrigation ordinance of 1946, minor irrigation systems are one constructed by the proprietors without government support or with the help of masonry works and sluices supplied free of charge by the government and maintained by farmers. Therefore, village irrigation systems are generally known as "farmer-managed systems". Most of these systems originated, designed, constructed and maintained by the villagers using collective efforts. The initial water and land right was determined by this collective effort. However, state intervention in village irrigation systems is evident from time to time since 1850s.

Irrigation Institutions during Pre-Colonial Era

The village temple was one of the primary institutions associated with the tank based irrigation systems. The village agricultural activities and Buddhist temple had a strong linkage where Buddhist monk gave the leadership and provided auspicious time for all agricultural activities. The most important thing was the collective decision making arrangement prevailed in the each village. The decisions were made at *Kanna* meetings held in temple. The major decisions made at this meetings were date of first issue of water, last date of water issue, method of water issue, cleaning of channels, bunds and sluices, date of harvesting and threshing of paddy at communal '*Kamath*'. The water issues were made beginning from tail end and gradually towards top end. When tank water was not sufficient, they decided on method of cultivation, type of crop and type of

variety. There were also different rules for management of cattle and draught animals and they were never allowed to roam about destroying channels, bunds or crops. There were separate entry paths across the channels to move cattle.

The people performed the specific irrigation development and management tasks in ancient time through the feudal system of '*Rajakariya*' (literally work performed by the people to the king). Since all the land and other resources were owned by the king, the construction, repair and maintenance of common property resources by beneficiaries were socially, morally and legally decreed requirements of a given agricultural community. There were numerous rules, customary regulations and sanctions as regards to irrigation to punish the rule breakers or individualistic mined predator As water was a scarce resource, there were more tenurial concerns towards water than land. All decisions pertaining to irrigation and cropping were made based on the concept of equitable right to water, which were implemented through '*Gamsabawa*' (Village Council) headed by '*Gamarala*' (Village Headmen). (Leach, 1980). The main functions of '*Gamarala*' were implementation of 'Gamsabawa' decisions, regulate the main sluice and to ensure equitable distribution of irrigation water. The '*Gamarala*' was paid in kind by the village farmers for his services.

Irrigation Institutions during the Colonial Era

The well-established and prosperous tank-village socio-economic and cultural system began to collapse gradually with the invasion of colonial rulers to Sri Lanka. The degradation of peasant agriculture started firstly with the arrival of Portuguese (1505-1650), whose agricultural interest in Sri Lanka was limited only to cinnamon. The influx of the Dutch in 1656, unlike the Portuguese, much attention was given to domestic agriculture. However, the invasion of British rulers to the country in 1815, started the degradation of irrigation networks once again.

In 1832 British colonial rulers abolished the feudal "*Rajakariya*" system in order to give more effort to develop monetised plantation agriculture and to avoid the development of a potential opposition forum against colonial rule. The function of '*Gamsabawa*' and '*Gamarala*' became inactive and customary rules and regulations malfunctioned. In short, everybody's business became nobody's' business and ultimately led to deterioration of irrigation systems (Robert, 1980; Silva and Vidanapathirana, 1984). Silva and Vidanapathirana (1984) reviewed the Sir John Keane irrigation sessional paper (SLV, 1905) and pointed out that the Cole Brooke Commission made a serious mistake in recommending the abolition of '*Rajakariya*'. There was a vacuum in the responsibility of maintaining irrigation systems between 1832-1887, which led to degradation of village irrigation works. Once prosperous country had to import large quantities of rice to feed the its entire population.

The British, however, in the later part of their administration, tried to improve the domestic non-monetised peasant agriculture (Farmer, 1957). There were attempts to re-establish irrigation discipline and improvement of the effectiveness of local community organizations through the implementation of various ordinances. The first such effort

was the introduction of Paddy Lands Irrigation Ordinance - No. 9 of 1856 to enforce the ancient customs regarding irrigation and cultivation of paddy lands. Under this act the local representative of '*Gamarala*' was replaced by '*Vel vidane*' (Irrigation headman) in 1857 with more state power and recognition. The main functions of '*Vel vidane*' were, securely keeping the items such as sluices, spills etc. in good order, passing information from government officials to farmers, under taking earth works and other such activities involving farmers correctly and properly, preparation of share holder lists and observe all instructions with regard to cultivation (Economic Review, 1995). '*Gamsabawa*' received the sole authority to handle water disputes. This paddy land ordinance was enacted until the end of the century

The establishment of the Irrigation Department (ID) in year 1900 is the other turning point which shifted the trend of irrigation system management towards centralization and bureaucracy once again (Moore, 1982). Irrigation management became the dual responsibility of farmers and the state. Under the new institutional setup, Irrigation Department and the Government Agents were responsible for the maintenance of minor irrigation schemes in their areas with the help of communal labours. Although '*Gamsabawa*' has remained as the central rural institution, handling of water disputes became the responsibility of civil courts. A new irrigation policy was introduced in 1932 by the Ministry of Agriculture and Lands, in which construction, improvement and maintenance of irrigation schemes were the responsibility of the Irrigation Department from 1932-1948.

Irrigation Institutions during the Post Independence Period

Soon after the independence in 1948, the responsibility of maintaining minor irrigation was handed over to the Ministry of Agriculture due to the heavy involvement of the Irrigation Department on Major Irrigation Development (Gal-oya Project). At the same time the Irrigation Ordinance of 1951 and 1956 de-emphasized the farmer involvement through enforcement of rigid rules and procedures. As correctly pointed out by Silva (1977) regarding the status of village council during this period, "*...the village councils have to perform these functions within a framework of administrative and financial controls which seriously undermine the sense of autonomy and self reliance while these institutions may otherwise have developed. On the administrative side, village councils were part of the machinery of government...*"

However, the government of Sri Lanka encouraged farmer participation through various institutions after 1958. Department of Agrarian Services (DAS) was established with the passing of the Paddy Land Act of 1958 and responsibility of executing all minor irrigation schemes were entrusted to the new department. Further, Cultivation Committees (CCs) were formed under this act in order to resume again to provide incentives and recognition for farmer participation in improving paddy cultivation. Although the act had the provision for forming irrigation rules by CCs, no legal effect was given to this provision. The committee framed only draft rules. As the CCs could not implement sanctions against rule breakers for their failure to contribute communal labour for maintenance, tanks, bunds and distributory systems fell into disrepair. Finally

an amendment was made to the irrigation ordinance in 1967, which provided the legal powers to CCs.

In 1972 the responsibility of minor tanks was transferred again to Irrigation Department with the passing of Agricultural Productivity Laws. Agricultural Productivity Committees (APCs) were established in each village council under Agricultural Productivity Law. The Minister of Agriculture selected the farmer representatives for these committees, rather, farmers did not elect them themselves. This was the major limitation with this act, which reduced the real farmer representation, thus APCs were less accountable to farmers. *"Agricultural productivity law had certain consequences for village level agricultural planning and development and to some extent for the linkup of village with the national economy through a process of politicization."* (Abeyratne *et al*, 1986).

The passing of Agrarian Services Act No. 59 of 1978 transferred the responsibility of minor irrigation schemes to the DAS and abolished APCs and established Agrarian Services Committees (ASCs). These committees were comprised of elected farmer representatives and state officials. Sometime state officials outnumbered the farmer representative, because number of farmer representatives was limited to ten. Therefore ASCs couldn't function independently and these committees were not felt by farmers as their own institutions.

The Agrarian Services Act No. 59 of 1978 was amended in 1991. Under this amendment farmer, organizations established by DAS were legally registered under the department. The main purpose of the amendment was to give the legal recognition and to provide maintenance contracts to FOs. In addition an institutional strengthening programme was conduced by DAS. The programme consisted of series of components including ownership awareness through involvement and contribution of farmers in all steps of rehabilitation, training and awareness creation on social and technical aspects of rehabilitation, training on O&M and finally the strengthening of FOs through a social mobilization programme.

However, establishment of FOs based on administrative boundaries (village basis) acted as a major hindrance in farmer participation, which were otherwise centered around a hydrological boundary. Under this circumstances some schemes have to be maintained by different FOs. Meanwhile some *'Grama Niladhari'* (GN) divisions were bisected by several irrigation schemes. Therefore, creation of FOs based on administrative boundaries has caused problems in sharing of water, O&M and implementation of effective sanction against defaulting farmers.

Selected Socio-economic Issues Associated with Minor Irrigation Systems

Farming systems under minor tanks

Typically village tank systems in the dry zone of Sri Lanka consists of three fold farming systems. They are namely *'gangoda'* (homegarden), *chena* (shifting cultivation) and

'*Welyaya*' (lowland paddy cultivation). Farming systems under minor tanks are relatively homogeneous in the dry zone which has evolved through the years on the basis of the farmers' knowledge and experience on utilization of natural resources (land and water) and human resources (labour). The farming system prevailed under the village tank system in the dry zone of Sri Lanka was considered to be most stable settlement system. This farming system is an outcome of risk aversion attitude from vagaries of weather and subsistence nature of production.

(a) Homegarden (Gangoda)

Homegarden in the dry zone village as an important component of their village eco-complex. It provides a pleasant and environmentally sustainable system consisting of variety of multi-layered perennial tree species. Although well managed homegarden can play an important role in the village tank community, dry zone farmers have mostly neglected the homegarden due to very high involvement in low land crop cultivation or the chena cultivation.

(b) Chena cultivation

Available research findings indicates that, unlike in major irrigation systems farmers in the dry zone village tank systems gives priority for chena cultivation than irrigated lowland paddy cultivation as it is the most stable and important component of the income. Therefore, they are reluctant to do anything that would interfere with the success of shifting agriculture, (Vithanage, 1982 Marambe *et al,* 1999). Chena crops on the other hand act as a crop insurance against crop failure in paddy, provider of substantial household income and important source of family diet. Most of the food grains produced in chena lands are reserved in households until the next years' harvest due to uncertainty of rain. The chena cultivation system allows some distributional effect of income within the village, since, the resources available under village tank is minimum and limited only to a segment of village inhabitants.

Domestic food security, less water requirement, storability and low cost of production are the main criteria's used by farmers in selecting crops for chena cultivation. Traditionally farmers cultivate 2-3 acres of land under chena for two years and then abandoned for 10-15 years. The number of adult labours available in the household determined the size of the chena land. However, with increasing population pressure, the size of chena land and fallow period has been reduced tremendously. In some places, there are virtually no fallow periods. These changes have caused to reduced unit land productivity and total household income. Generally farmers begin chena cultivation with the onset of initial *Maha* rain which in fact forced them to postpone lowland cultivation. However, delay in starting paddy cultivation permitted the village tank to get filled, which provided an opportunity to make correct decisions on the extent of paddy cultivation and method of water management.

(c) Lowland paddy cultivation

Low land paddy cultivation under minor tanks is mainly for domestic consumption and seldom comes to the market. Begum (1987) reported that 86 percent of sample farmers under minor tanks used new improved varieties. However, Wickramarachchi *et al.* (2000) found that, 100 percent of farmers in three sample minor tanks used new improved varieties, but which have not been periodically replaced for many years. Hence, seeds are poor in quality and yield potentials are very low. Broadcasting is the major method of planting due to the following reasons.

1. Since paddy cultivation starts just after the chena cultivation, farmers do not have sufficient time for paddy nursery preparation and transplanting.
2. Transplanting demands high labour, therefore, farmers have difficulties in finding sufficient labourers.
3. Second priority given to paddy cultivation is a disincentive to make an additional investment on transplanting.

Land Fragmentation

The process of land fragmentation with increasing population pressure is inevitable. Although these small parcels of paddy land plots are economically non-viable, the prestige associated with owning of some land in village paddy tract forced them to maintain these small lots of land. In fact, fragmentation of land holdings curtailed the production process due to the problem of economic of scales and shift of economic priority to other areas, for example chena cultivation.

Further to the problems of land fragmentation, traditionally farmers have inherited land from different tracts of the *Puranwela* land. In most occasions, these plots as well have been divided into more than one plot. Begum (1987) found that, average size of low land in *Puranawela* is 1.2 acres. Abeyratna *et al.* (1986) noted that, 70% of paddy holdings under six sample tanks was less than one acre each. Sivayoganathan *et al.* (1991) explained that, most farms in most districts where the tanks were rehabilitated under VIRP had less than 0.5 hectare. They also noted that, the existing uneconomical size of land holdings would remain as a constraint in the improvement of farmers' well being even in the rehabilitated irrigation schemes. Table 2 shows the average operational land size in sample minor tanks.

Complex Land Tenure Systems

The complex land tenure systems existing in the small village tank command areas further complicated the problems of poverty, low level of income and household food security. In addition, many of the traditional cultivators do not have freehold right to the lands they customary cultivate. The type of land tenure under minor tanks are diverse such as share tenancy (*Kuli ande* and *otuande*), mortgage, leased out, *Thattumaru* and *Kattimaru*.

Under the *Kuli ande* system (labour tenancy), land owner provides all inputs required for paddy cultivation except labour and management. At the end of harvest, the net yield is equally divided between owner and tenant. Under the *Otu ande* system, the land-lord provides only the land and tenant supplies all the inputs including labour and management. The land-lord receives 25% of the harvest as a land rent. Under the mortgage system, land lord give up the land use right to a cultivator for one or more season for a fixed amount. *'Thattumaru'* is system of rotation of land plots in different tracts between two or more farmers. *'Kattimaru'* is a system of rotation of land plot between two or more farmers between two or more seasons. (Abeyratne *et al*, 1986).

All these arrangements act as obstacles in achieving potential income from particular land plot to the farmer. This is an added burden to farmers where their income is already limited by small size of land holdings, seasonality and low productivity. The insecure form of land right is one of the main constraints in improving agricultural productivity and resource management.

Seasonal and Uncertain Income

Majorities of minor tanks are filled by run off water from their own catchment. Rainfall intensity, rainfall duration, soil physical properties determine the catchment water yield. Failures to receive adequate amount of rainfall lead to abandonment of lowland paddy cultivation or crop failure or reduced yield. Table 2 shows the number of seasons cultivated during the period of 1992-1996 in some selected minor tanks. According to these figures in majority of villages in the dry zone, Maha season is the most probable cultivation and Yala cultivation using tank water is rarely practiced. The table also indicates the level of crop damage experienced in 1996/97 Maha due to scarcity of water.

Therefore, it is very clear that, crop production under village tank system is seasonal and very uncertain. Especially uncertainty of the rainfall adversely affects the amount and stability of the paddy production and paddy yield. In other words, farmers have to face greater difficulty in terms of food security and cash income especially in years following 2-3 years of no harvest or greatly reduced harvest. It should be noted that as discussed above the given situation gets further complicated with small land holdings and complexities of land tenure.

Low Productivity

High risk and uncertainty involved in the village tank cultivation prevent farmers to perform a commercialized high input cultivation. The socio-economic issues discussed above have a contribution to the low investment and minimal attention given for cultivation under village tanks. The outcome of the process is low productivity and low income.

Scarcity of water in combination with low input use results in very low paddy yield from village tanks averaging 46 bushels per acre compared to about 68 bushels per acre in

major schemes over period of 1976-1980 (World Bank, 1981). According to the last 25 years national data, yield advantage is about one metric ton higher under major irrigation compared to minor irrigation. (Figure 1). The average yield under irrigated condition is 3.5 mt/ha. Average paddy yields in two sample minor tank areas are given in Table 3.

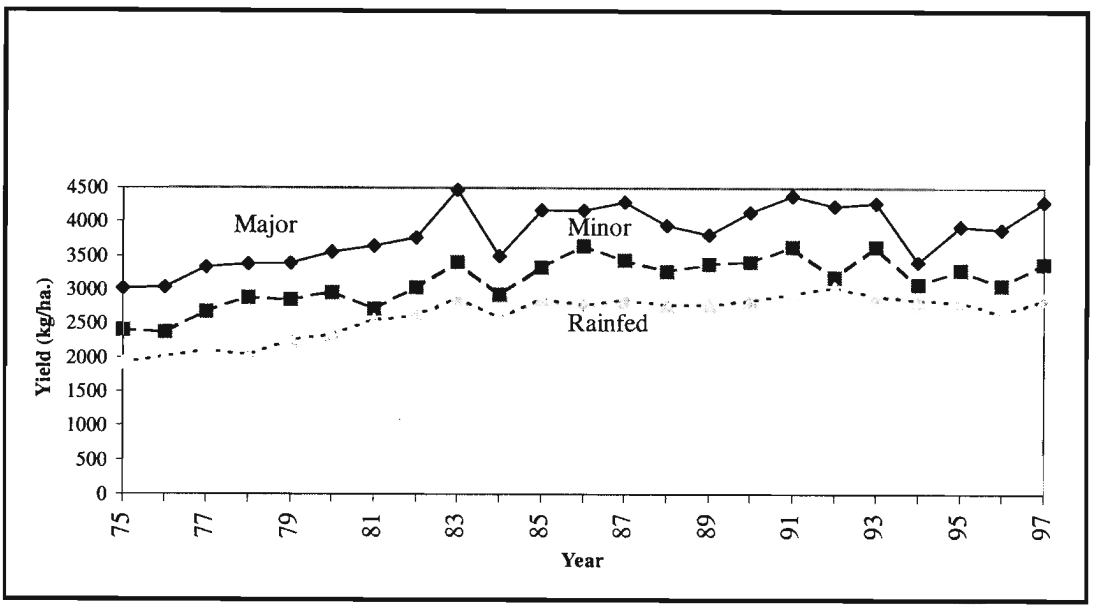

Figure 1. Average Paddy Yield under Different Modes of Irrigation (Maha Season)

Water Management Packages Practiced in Minor Tank Systems

Since water is major limiting factor for crop production in minor tank systems, there were several customary water management packages implemented by the village community depending on the level of water available in the tank in a particular season. This decision was made collectively at the *Kanna* meeting. The major water management packages practiced in minor tank systems are discussed below.

(a) Dry sowing (*Kekulam System*)

Dry sowing is one of the methods of planting of paddy during the Maha season in the dry zone. Under this method farmers plough the land with the onset of the Maha rains and broadcast the seed paddy instead of waiting for the tank to fill. This practice helps to save large quantity of tank water from land preparation. The crop can thus mature with direct rainfall, requiring only limited supplementary irrigation from the tank. This water management strategy helps farmers to save considerable amount of water, which can be utilized to cultivate a meda crop (catch crop), or early Yala or regular Yala season. However, the factors such as rainfall pattern, expectations about rainfall patterns, and farmers

attitude towards risk plays a major role in making of decision on dry sowing method.

(b) Crop diversification

The concept of crop diversification under minor tanks was promoted in the past to conserve tank water and to utilize the available water in an efficient manner. Since non-paddy crops require significantly less amount of water than paddy crop, farmers can go for *Yala* cultivation with less amount of tank water. However, crop diversification experiences shows that farmer's preference in growing paddy crop is very high due to various reasons. The main reasons behind this argument are, firstly, rice is the stable food which can hardly be substituted by non paddy crops, secondly, non paddy crops require high investment and consequent risk associated is very high, thirdly, marketing problems linked with non-paddy crops grown in remote minor tank villages and fourthly, requirement of high labour throughout the season which effect the other components of the village tank farming system (specially chena cultivation). However, successful stories of crop diversification under minor tanks have been reported (Ariyabandu and Wickremasinghe 1998).

(c) Bethma cultivation

'Bethma' is a water management technique, in which cultivation is practiced, only in upper reach of the system sharing the land with lower reach farmers, when available water in the village tank is insufficient to cultivate entire command area. The extent of cultivation under 'Bethma' system is decided collectively by landowners depending on the availability of tank water. This was a regular event in the past in the traditional village community system. However, with the breakdown of traditional village community of farmers due to various social, economic and political reasons there were difficulties in implementing 'bethma' system in some places. Further to this breakdown of village organizational set up and social cohesiveness, the increase in area under irrigation in *Maha* season, which reduced the water availability in *Yala* season and consequently reduced the feasibility of Bethma in *Yala*.

Designed and Actual Command Area Under Minor Tanks

The village tank was a complex eco-system designed by our ancestors to harvest rain water, conserve the water and utilize the water efficiently for all aspects of human needs. Command area of minor tanks was designed, based on the water relief pattern of the area. In addition, the eco-system had several important components including 10-20 acres of reservation land to protect the bund and to supply soil for earthwork of the bund, green catchment area, wind belt (Gasgommana)) and salt trap (Katta Kaduwa).

However, with the increasing population pressure and improper government intervention, the command areas have been increased without considering hydrological dimensions of the catchment system and cascade relationships. In the past, the government has distributed land haphazardly under minor tanks through land rights, 99 year permits, and year permits. In addition, farmers themselves have encroached reservation lands in the different component of the eco-system. The combination of all these factors have lead to increase in actual command area significantly compared to the designed command area. Table 2 clearly illustrates the difference between actual and design command areas in a sample of minor tanks. The overall increase in command area has serious implications in terms of reduced probability of cultivation and problems associated with traditional water management practices.

Begum (1987) found that, out of 20 tanks studied, Bethma cultivation was practiced only in two of them. The reason identified was tank water availability was often limited to support even a Bethma cultivation, which is due to the recent expansion of command area under these small tanks.

Table 2. Some Features of Sample Village Tanks in Hambantota and Anuradhapura

Tank name[1]	Design command area (Ac)	Actual command area (Ac)	Average paddy land holding size (Ac)	No of seasons cultivated during last 5 years		% of crop damage due to water shortage in last Maha[2] (1996/97)
				Maha	Yala	
1. Padawgama wewa	12	40	01	04	-	60
2. Halagala wewa	7	49	0.7	05	01	50
3. Illukmulla wewa	30	30	01	05	01	10-15
4. Handunkakuwa wewa	15	26	0.75	04	02	50
5. Palankada wewa	20	40	1.5	02	01	0
6. Padukkulama wewa	35	80	0.25	04	-	50
7.Kadurugaspitiya wewa	75	150	0.50	05	01	50
8. Weerasole wewa	20	80	0.25	01	-	100
9. Kottalbadda wewa	80	160	0.50	05	02	15

Source: HARTI survey data - 1996/97 Maha

Note: [1] Tank No 1-5 are located in Hamabantota district and 6-9 are in Anuradhapura district

[2] Damages are farmers' eye estimate.

Table 3. Average Paddy Yield Under Village Tanks in Two Climatic Zones (as a % of land lots)

Average yield mt/Ac	Hambantota (DZ) Maththala Tank		Uva-Paranagama (IZ) Yalagamuwa tank	
	Maha	Yala	Maha	Yala
	N=16	N=0	N=15	N=4
<1	0.6	-	27	-
1-5	37.5	-	40	1.00
1.5-2	37.5	-	7	-
2-3	19	-	26	-
>3	-	-	-	-

Source: Survey Data, HARTI

CONCLUSIONS

Minor irrigation plays a significant role in domestic agriculture, especially in the production of staple diet paddy. In socio-economic point of view, considering small land holdings and the lower productivity under minor tanks, the dependents on minor tanks are much larger than their contribution to national production. Therefore, improvement of minor tanks is more valuable in social welfare terms.

Village tank eco-systems in the past were socially, economically and culturally feasible and created a prosperous and self-reliant economy. However, degradation of minor tanks and its sustainability began with the commencement of decline in traditional management practices in village irrigation systems. The deceleration of traditional management practices in minor irrigation schemes is the result of following factors

- Influx of colonial rulers to the country and the abolition of '*Rajakariya*' system and of customary laws of irrigation management.
- The increased intervention by government and NGO's in institutional set up and refurbishment of minor tanks.
- Creation of dependency among farmers for outside support.
- Top down approach adopted in minor tank improvement without considering perspectives of existing water users and hydrological aspects.
- State intervention on redefining hydrological boundaries and land right radically disturbed the traditional village social structure and its value system.

Since independence in 1947, agrarian laws pertaining to the operation and maintenance of minor irrigation have been changed at least four times and consequently, responsibility of minor irrigation also changed from one institution to others. As a result large number of tanks have been abandoned and tanks in working condition also operated at varing levels of efficiency. With these government interventions, farmers believed that the government owns the irrigation system and were responsible for ensuring operation and

maintenance. However, various new strategies have been used since late, to solicit farmer participation and to re-introduce traditional water management practices.

The one of the major weaknesses in the current institutional strengthening programme is the establishment of FOs based on village boundaries (Administrative Grama Niladhari boundaries), rather than hydrological boundaries. The situation makes it difficult to address the FOs as an organization that should take the responsibility over the schemes. On the other hand, the problem of lack of co-ordination in water management among villages in the cascade systems is continuing as ever before.

Underlying socio- economics situation in village tank community emphasises the vital requirement of tenurial reforms to make the cultivation economically viable. The ability to integrate minor tank paddy cultivation with chena provided a protection and insurance for paddy cultivation and also viability of the small holder subsistence paddy economy. However, the increasing population and village expansion programmes have curtailed the paddy-chena interrelationship and substantially changed the village economy. Therefore, the government must create opportunities for off farm income to ensure household food security. Further, institutional factors such as credit, inputs, seed paddy and extension, basic rural infrastructure, and crop productivity improvement prgrammes are necessary to support the livelihood. Unplanned top down approaches adopted for minor tank developments have serious implications on their sustainability and its livelihood.

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CONTRIBUTION OF SMALL TANKS TO UPKEEP THE VILLAGE COMMUNITY

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Mahaweli Restructuring and Rehabilitation Project

INTRODUCTION

Irrigation can be defined as the process of artificially supplying water to soil for growing crops. In Sri Lanka, the surface irrigation systems are broadly categorized into two types; the Tanks (reservoirs) and the Anicuts (weirs). Tanks are mostly located in the dry zone to store water during the rainy period and distribution during dry period. From the anicuts the water level of a stream is elevated and diverted to the irrigated area, as such they are mainly located in wet zones. For convenience of control and management, irrigation systems are grouped into three categories based on the extent of irrigated area; Major schemes (irrigated area is above 600 ha), Medium schemes (80 to 600 ha) and Minor schemes (below 80 ha). In all there are about 24,000 minor irrigation schemes in the country with an irrigation potential of over 250,000 ha.

The Small Tanks

The term village based minor tanks (wewa) has been used to refer to an artificial lake or pond for storing water on the surface of the ground which has been constructed by local people at geographically suitable locations with their indigenous skills mostly during ancient times. Hence, the location of the tanks and its size had been determined on social as well as hydrological factors. There are about 12,500 such minor (small) tanks scattered throughout the country with an irrigation potential of over 100,000 ha.

Most of these tanks are shallow mini reservoirs with an average depth of 2.5 to 3.5 meters with micro-catchments of less than 20 km^2. The feeding streams are non-perennial and water flow is available for relatively short periods following monsoon rains. The irrigable area also depends on storage capacity and land availability. Rehabilitation of Small Scale Irrigation Schemes (SSIS) is one of the foremost development activities launched by the government from 1970's mainly because;

(i) the cost of rehabilitating SSIS is relatively less compared to major schemes but the benefits are much greater.
(ii) the transfer of operation and maintenance activities after rehabilitation to the beneficiary farmers reduces the expenditure for maintenance, and
(iii) these are not only used for irrigation, but also as water source for domestic needs, livestock and source of high protein food supply such as tank fish.

Various studies have revealed that the utilization of irrigation and land resources under SSIS remains much below the projected potential. Contributory factors are; inefficient management and inadequate maintenance of irrigation structures leading to the deterioration of the whole system. Up to 1970 s the beneficiaries, by law and convention were compelled to repair and maintain their systems. But thereafter, due to more government intervention and disregard to farmers' participation and contribution, the farmers are accustomed to depend on government support for even small repairs and maintenance. The change in the SSIS definition from the Irrigation Ordinance (No. 32 – 1946) - " **a scheme constructed and managed by the farmers with a little government assistance limited only for masonry structures** to the Agrarian Services Act (No 58 – 1979) - **" a scheme in which the command area is less than 80 ha (200 acres)"** has also influenced their attitude. But from 1990 s, various strategies have been adopted to inculcate into the former responsibilities and create a sense of owner-ship among the farming community.

Performance of Small Tanks

Contributory factors and beneficial factors

The contributory factors which directly affect the performance of small tanks can be mainly categorized into two namely; Hydrological factors and Management factors (Figure 1). Hydrological factors are governed by natural resources such as rainfall, catchment characteristics and tank characteristics. So, there are limitations in improving hydrological factors to achieve high performances. But the management factors are controlled and managed by humans and hence there are always possibilities and potentials for improvements. The beneficial factors can be categorized into mainly three groups namely; Agricultural benefits, Social benefits and Environmental benefits. The characteristics of contributory factors and beneficial factors can be used for small tank categorization. Currently, no such categorization system is being adopted and all the tanks are considered equally.

During the feasibility study stage (before tank rehabilitation) also, some hydrological factors are considered to compute the possible cultivation extent and based on that and the pro-rata cost the rehabilitation cost is determined. Since, most of the hydrological factors cannot be assessed accurately, possibilities of selecting unsuitable tanks are high. Resultantly, more investments are made on non-suitable tanks and the chances of improving deserving tanks may be reduced. Hence, more broader criteria and factors should be considered and all the tanks in the country should be categorized.

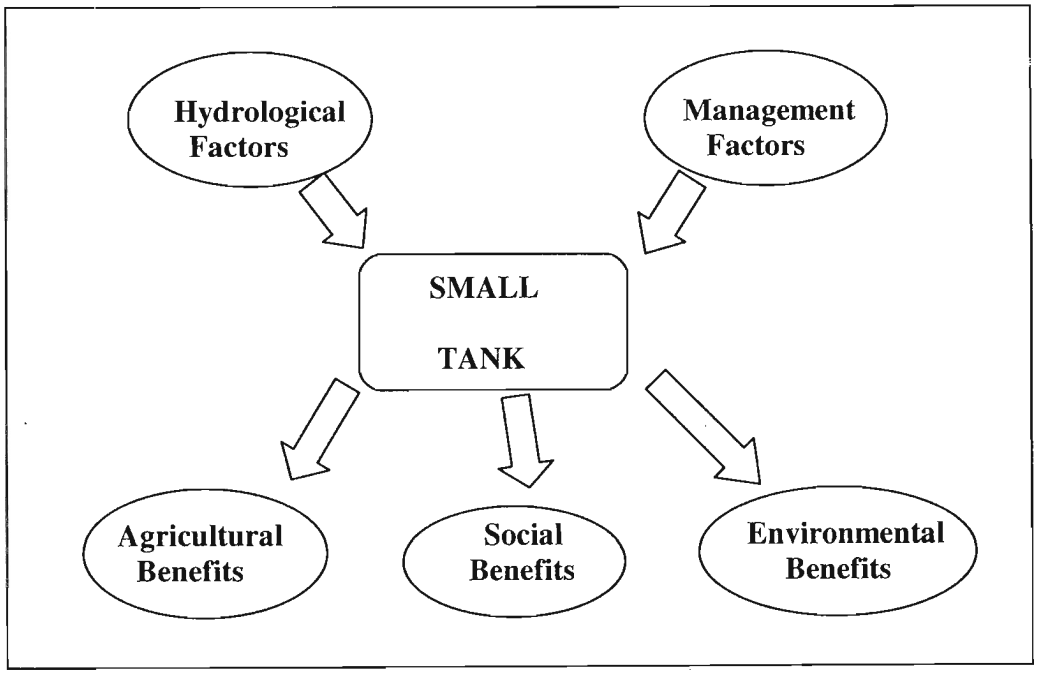

Figure 1. Contributory Factors and Beneficial Factors

Furthermore, some of the small tanks constructed in ancient times had not been used for irrigation. For an example, some small tanks located upstream of major tanks were to deposit the silt coming from slope catchments. Those tanks were called "Kulu wewas" which means tanks in jungles and the purpose of these tanks was to avoid siltation of major tanks. These also helped to increase ground water level in upstream area, which helped to increase water springs and grow healthy forest cover. Gradually, with the population growth, people started settling-down in these areas and under various development programs the command areas were developed Resultantly, the runoff for major tanks as well as for some village tanks have been drastically reduced. Hence small tank categorization based on their performances is absolutely necessary.

Characteristics of contributory factors - hydrological factors

The catchment or the watershed is the most crucial component of a small tank. Following are the two major setbacks in the tank water inflow experienced during the recent past due to changes in the catchment.

(a) Many dry zone tanks had been built in a cascade (series) along the valley during ancient period aiming at optimum water utilization. But today many tanks

function independently due to developments in individual schemes (e.g. raising the bund and spill to increase the water holding capacity) disregarding the hydrological inter-relationship within the cascade system. As a result, the tanks with less catchment area get less inflow and face water deficit.

(b) The rainfall (onset, intensity & duration) and catchment characteristics (size, surface texture, topography & vegetative cover) are the governing factors of the tank water inflow. Of the above, the vegetative cover is the only factor, which man can easily change but most influentially affect the runoff of the system. The degradation in the vegetative cover causes soil erosion and the silt gets deposited in tank beds and thereby reduces the water holding capacity. In anicuts, this react in a different way. Due to soil erosion the hard surface is exposed and resultantly the water infiltration rate is reduced. Consequently, high surface runoff occurs with the onset of rains but ceases after that, due to non-availability of sub surface flow. This adversely affects the wet zone farmers who cultivate under anicuts without water storage.

Physical characteristics of the schemes

Studies have revealed that the water inflow from the catchment varies between 20% - 30% during Maha (wet) season. Since these tanks are shallow and have a high water spreading area the tendency for water losses is very high. On an average 30% of the seasonal water inflow is lost due to evaporation, seepage and percolation. Therefore from the total rainfall, only 16% is available for irrigation at the tank outlet. Considering conveyance efficiency as 80% and water available for the crop is about 13%. Hence, due to low inflow and high losses the irrigation potential in small tanks is marginal. Only timely cultivation and effective system management could ensure optimum utilization of scarce water resources.

Characteristics of hydrological factors

i. Rainfall of the area – Rainfall is the governing factor affecting the performance of small tanks. The tanks located in high rainfall prone areas have high performance than the lower rainfall prone areas.

ii. Catchment water yield - Since most of the small tanks have very limited catchment area its' characteristics such as size. shape slope vegetation. soil cover etc. are affect the water inflow to the tank..

iii. Tank Characteristics – Tank characteristics such as water depth, shape, water spread area, location of the tank, tank bund condition etc. affect for water storage and conservation mainly to minimize the water losses.

Management Factors

Management factors consist mainly of water management and maintenance activities. To facilitate effective management functions, most of the tanks have been rehabilitated or improved during recent past. In addition, during last decade or so, more innovative actions have been taken to improve rehabilitation programme and thereby enhance system management activities to improve the system performances.

Cost effectiveness and low-cost technologies in rehabilitation

The average rehabilitation cost for minor schemes is Rs 40,000 per ha (based on National Irrigation Rehabilitation Project rates) which is more than double for major schemes. The other advantage in small schemes is that the pace of development is simple and rapid which require less planning and designs and more farmers and local labour can be engaged during construction period. Also, simple and low-cost technologies can be adopted in designs and construction of small scale irrigation systems.

Planning and implementation can be carried out in close collaboration with the beneficiaries and their proposals based on experiences can be easily incorporated in rehabilitation activities. Their active participation is expected at least to recover part of investment cost (10-25%) in labour.

The Farmer Organizations (FO) are encouraged to take either part or full contract mainly because it (a) creates awareness on quality and standards which facilitates system management (b) reduce conflicts and complaints and develop sense of ownership (c) helps to develop FO's fund. Instead of awarding the full contract to FO, each can be divided into packages and awarded to small farmer groups (5 to 10 members) within the FO. The benefits of this system are (i) all members actively participate in construction. (ii) quality upgraded due to self monitoring (iii) speedy construction with less capital (iv) team work, cohesiveness and leadership are developed (v) 5% deposit from each group's payments build-up the FOs' fund. Some difficulties/constraints experienced are (i) skilled labour shortage due to parallel construction (ii) need for continuous supervision from officers' (iii) payments at short intervals.

Farmer participation and empowerment in system management

The success of any irrigation development depends on the degree of beneficiary participation. The attitude of " construction is officers responsibility and maintenance is farmers responsibility" has changed now. Arrangements have been made to get more and more farmer involvement for planning and construction that leads for successful management after constructions. In order to ensure farmer participation, assist and to ensure continuous rapport between farmers and officers, a series of training programmes and meetings have been formulated during Pre-construction, Construction and Post-construction stages.

The operation and maintenance of small schemes are the responsibility of beneficiaries from the past. Due to more and more government involvement in rehabilitation, farmers are accustomed to neglect the maintenance activities. Negligence of customary rules such as timely cultivation and erosion of leading authority and inability to take legal action against defaulters have contributed to the deterioration of the performance of the system. To overcome this situation a Maintenance Fund has been proposed under small schemes.

Maintenance Fund

Building-up maintenance fund at scheme level is a long felt need. Farmers naturally tend to attend to the labour-intensive maintenance works (clearing, earthwork etc.) but not minor repairs or works that need money (replace or repair the gates etc.). As a result, the whole system is bound to deteriorate and lead to another rehabilitation. to avoid such situations a programme has been launched to establish a maintenance fund in most of the nirp schemes. The target at the first phase is to collect an average of rs.500 per acre to raise rs.25, 000 – rs.50, 000 per scheme depending on the cultivated extent. The FO deposits this money in a bank for a period of 10 years. Before commencement of the cultivation season (once in 6 months) the interest proceeds of the deposit (about rs.2500) can be spent on repairs on the decision of the cultivation meeting.

Characteristics of the management factors

i. **Water distribution** – Timely and rotational water distribution, performance of water distributor (Jala Palaka) and his seasonal payment.

ii. **System maintenance** – Seasonal maintenance, mode of maintenance,(share system or sharamadana) and maintenance fund

iii. **System protection** – timely attendance to minor repairs, legal action against defaulters who break the gates for taking water illicitly, cultivation in reservations, cattle damage to bunds and canal system etc.

Beneficial Factors

Management of beneficial factors

Cultivation decisions – It can be observed at some of the cultivation meetings farmers decide not to do cultivation during that season mainly to conserve water for domestic purposes. Especially, when water level by end of Maha season is low, they give priority to social and environmental factors rather than agricultural factors. Resultantly, the cropping intensity gets reduced but social benefits accrue to villagers. Hence, the current practice of estimating cropping intensity alone is not a suitable determinant to decide the performance of a small tank.

Dead storage or live storage – In general, the sluice (outlet) sill level is constructed about 0.75 m (2ft) above the tank bed level. The residual storage is mainly for domestic purposes, animals and fish. Since this water quantity is not used for irrigation, it is called "**dead storage**" in irrigation terms. But in considering farmers and animal lives this should be called as "**live storage**". In some recently rehabilitated tanks, the sluice sill levels have been lowered, closer to tank bed levels and this dead or live storage has not been left out. In fact this leads to immense problems not only to the villagers but also to the flora and fauna in the area.

Independent decisions – When compared with major schemes, a lot of advantages could be observed in small schemes. They can get independent decisions by looking at the water level or by forecasting weather patterns from past experience. At the beginning or mid of the season they can control water issues after considering water availability. This paves the way for discreet water management.

Characteristics of beneficial factors

Agricultural benefits – The agricultural benefits can be mainly categorized into two;

(i) **Cultivation benefits** – crop type, cropping intensity, yield, market value etc.
(ii) **Benefits from livestock and fish**

Social benefits also can be categorized into mainly two;

(i) **Domestic water use** – water used for drinking, bathing, washing etc.
(ii) **Water for other rural income avenues** – Other income generating activities implemented by using tank water are;

- Cadajan weaving – for own house and for selling
- Brick making
- Selling of Lotus flowers and use of yam and seeds for consumption.

Environmental benefits

Environmental benefits also can be categorized into two;

i. Water for living creatures – drinking water for wild animals, birds, aquatic plants and small living creatures in and vicinity of water

ii. To maintain ground water level – This helps to maintain upland plants and soil moisture.

To What Extent the Above Factors have Contributed Towards the Performances of Small Tanks Satisfactorily?

Area selected for the study

The Maho Agrarian Services Center (ASC) area in Kurunegala district was selected to assess the performance. Brief description of the small tanks characteristics in the area is given below;

Total number of small tanks (working) in the area		= 263
No of abandoned tanks		= 6
Total extent of the working tanks		= 1750 ha
Tanks grouping according to extent		
Less than 4 ha (10 acres)	= 141	
Between 4 ~ 10 ha (10 ~ 25 acres)	= 81	
Between 10 ~ 20 ha (25 ~ 50 acres)	= 33	
Above 20 ha (50 acres)	= 8	

This shows that most of the tanks in the area are very small compared to Anuradhapura district (average size of small tank is 20 ha). The average land holding size is 0.4 ha (1 acre) per family.

There are about 35 villages in the area. Every village has a comparatively big tank which is called "Maha Wewa" and some small tanks. The name of the village is pre-fixed to identify the tank e.g. Kakunawa Maha Wewa, Uduweriya Maha Wewa etc. The other four to six small tanks in the village are identified by various names mainly using the names of trees e.g.Palu Wewa, Kubuk Wewa etc.

Tanks selected for the study

Twenty village tanks (Maha Wewas) were selected for a rapid analysis. The applicability and suitability of the contribution factors and the beneficial factors were assessed. Out of twenty, fourteen tanks have been rehabilitated during last ten years. The World Food Program or the food for work is a highly satisfactory program in the area.

Contributory Factors

Hydrological factors

(i) Rainfall – The monthly rainfall figures for the last 10 years (1990 to 1999) was obtained from Maho ASC. The monthly average rainfall and 75 % probability rainfall which is used for irrigation design purposes were compared. The agro-ecological region is IL-3

Maha Season –Rainfall (mm)

Month	October	November	December	January	February	March	Total
Average Rainfall	304.5	225.2	130.7	85.3	43	62.3	851
75% Pro Rainfall	191	165	89	51	38	51	585
No.of years less Pro*	1	3	3	6	7	6	

Yala Season –Rainfall (mm)

Month	April	May	June	July	August	September	Total
Average Rainfall	176.5	179.7	36.9	58	26.9	93.3	571.2
75% Rainfall	102	51	38	25	13	38	267
No.of years less Pro*	1	2	8	2	5	3	

* Number of years in which the monthly rainfall is less than the probability values during last ten years

The above results show that in both Maha and Yala seasons the average rainfall is higher than the expected (probability) rainfall. In Maha seasons in eight out of ten years the average rainfall is higher than the expected rainfall. In Yala season, in all ten years seasonal averages are higher than the expected values.

The results indicate that the Maha ASC area in general has received expected rainfall. Hence it is a suitable area for small tanks development and maintenance.

In considering the monthly rainfall, for January, February and March in Maha season and June, July and August in Yala season, during more than five years (50%) the expected rainfall has not been received.

This is why farmers are continuously requesting to deepen their tanks (desilting) to store more water from October, November and December rains to compensate the following dry months

(ii) **Water yield (runoff)**

In most of the tanks the catchment area is less than 2.5 sq km (one sq mile). Especially, the main tank (village tank) has comparatively large catchment and located at the bottom of the cascade (a series of tanks in one stream). Out of twenty tanks studied, 14 have spilled more than seven years out of ten and balance tanks spilled over only four years. But most of the farmers complained that the upper tanks development without proper investigations would cause a reduction in the inflow to their tanks.

Hence, under the forthcoming rehabilitation programmes, proper studies should be carried out on runoff and cascade characteristics before making proposals to increase capacities by raising spills to cater to additional command area.

(iii) **Tank characteristics**

In nine out of twenty tanks studied, in nine tanks the water depth is more than three meters. In twelve tanks 50% of water is saved for Yala season. This really is a good characteristic of a small tank with high performance.

Management Factors

(i) **Water distribution** – In almost all the twenty village tanks studied water management practices are being implemented satisfactorily. In 14 tanks Jala palakas (water controllers) control the gates and in other schemes the former vel-vidane system (village leader) prevails. The average irrigation duty in most of the schemes is 2.5 ac ft/ac. Only in five tanks, the farmers pay a contribution (half a bushel of paddy per acre) to Jala palaka for his service. In other schemes this method is not being practiced, Resultantly, some water controllers show lethargic attitude in water management practices.

The department of Agrarian Services should intervene, convince and persuade the farmers to pay the contribution (salaris) to Jala palaka for his service. Free service or service for public acceptance cannot be expected now due to economical difficulties, as in the past.

(ii) **System Maintenance** – In almost all the schemes, seasonal maintenance is done on share (pangu) basis. It really is a satisfactory outcome compared to major schemes in which the maintenance is done with state funds. Only in five schemes contribution to the Maintenance fund has been collected. During the field visit discussions most of the farmers agreed that they need such a fund for minor repairs and maintenance activities.

The Department of Agrarian Services with the assistance of Govi Sevana Niyamaks should take the initiative to build up the Maintenance Fund.

(iii) **System protection** - Complaints on taking water illegally has not been reported mainly because the defaulters can be easily identified. It is a good sign of small schemes compared to major schemes where water tapping illegally is a common practice. In two occasions the Divisional officer has taken legal action against cattle damages. Newly recruited Govi Sevana Niyamakas, in general perform their duties as cultivation officers satisfactorily.

The Divisional Officer in Agrarian Services Department, should inquire into minor conflicts, conduct a good rapport with farmer leaders and take legal action against defaulters. This will pave the way for maintaining law and order and thereby maintain the sustainability of the irrigation systems.

Beneficial Factors

Agricultural benefits

In all the twenty village tanks studied, full command area has been cultivated during last ten years. Bethma system is practiced satisfactorily during Yala season in most of the schemes. In some schemes they grow vegetables and other cash crops to a limited extent. The Maha average paddy yield is 80 bushels per acre. In average, 50 % of their paddy harvest is sold and balance is kept for consumption. The farmers complained that the income from agriculture is not adequate to run a seven-member family. For an example they emphasized that the selling of Maha harvest brings an income of Rs 10000 (Rs 250 * 40 bushels) from which 50% goes as production cost and balance about Rs 1000 per month is hardly sufficient for their subsistence.

Farming one acre alone will not be adequate to live. Hence, youngsters tend to leave from agricultural pursuits and seek other employment, mainly males in the security forces and females in free trade zones or as housemaids in middle-east countries. Growing high value crops and developing the tendency to more off-farm activities would relieve these problems.

Benefits from livestock and fish

Both these trades are not performing satisfactorily. On an average, 50 to 75 cattle belonging to two or three owners are reared under each tank but not practiced systematically. The milking cows are very limited and the reason attributed is the low milk price. They rear the cattle mainly for flesh and one of their main complaints is the inadequacy of grass lands to maintain large herds. The fishing industry, though is a lucrative trade specially in countries like Thailand, Philippines etc. has not gathered full swing. In most of the tanks, they auction the tank for the right to catch fish annually for about Rs 5000. But the buyer, usually an outsider from the village sells the harvest for about Rs 20,000. The farmers are reluctant to getting into the fishing industry mainly because of religious bias and consider it as a low level trade.

The government should intervene, to promote the fishing industry in small tanks. Private companies should be brought into this business and systematic marketing arrangement should be made.

Social Benefits

Domestic water use

Most of the villagers come to the tank for drinking water and bathing. In the tanks studied, farmers from far distances come for bathing since most of the small tanks in their areas are dry during Yala season. But, in all Maha Wewas generally about two to three feet depth of water is available for domestic purposes. This as per villagers' views is an invaluable advantage from small tanks. In some seasons they decide to forgo the cultivation to conserve water for domestic purposes.

Other rural income avenues

Under most of the tanks, brick manufacturing industry or cadjan weaving is implemented but on a very small scale. Brick making is a lucrative trade and under one tank they said that their earning is about Rs 5000 per month, which is five times than the income from crops. But still the tendency of such activities is limited. Also, in some tanks, thousands of beautiful lotus flowers could be seen. The outsiders come and pluck the flowers for selling but villagers are not interested. The villagers think that selling of flowers is not a correct thing since those are used for religious activities. But, in contrast, one flower-seller at Awkana said that his daily income is about Rs 600 and on poya days it exceeds Rs 1500.

Environmental Benefits

Water for living creatures

In most of the village tanks, since they don't get dried the small birds like wild ducks, wild pigeons and various other birds live in the water. Burrowing animals and thousands of small insects live in the water. Also, wild elephants, wild boars and other animals in the jungles too come for water to the tank. Further, water in the tank gives a cooling environment and lovely atmosphere.

Developed countries, for example Australia has taken the initiatives to develop small tanks or ponds, not for irrigation but to maintain a better environment. These water bodies are for flora and fauna in the system and to maintain the ecological sustainability. It gives pleasant scenery and cooling atmosphere. Similarly, our small tank system also should be well maintained for environmental benefits.

Ground water for uplands

The water level in small tanks helps to maintain the ground water level. This helps to maintain the upland cultivation, water level in the wells in the village and soil moisture content of the area. This really is an indirect benefit from the village tank.

CONCLUSIONS

Small tanks are highly relevant and attractive development programmes in considering the agricultural, social and environmental benefits. The performance of theses tanks depends on contributory factors. Conservation measures to improve catchment inflow, management arrangement for effective O & M are the key driving inputs to make the system more functional. As such, the small tanks in the country should be categorized based on the hydrological and management contributory factors. Based on the above categorization, future development programmes should be undertaken.

In spite of the fact, that the advantages of small tanks are often said, however, their benefits have not been properly understood. However, it has been revealed that there is a greater potential for improvements. Hence, the officers in Technical, Institutional and Agricultural sectors should implement an integrated programme to enhance the performances of the small tanks.

The sustainability of the village depends on the tank and vice versa. These tanks functioned and served the community for more than thousand years and will continue to do so in the future. Tank has a life. It serves the community without asking any return. Hence, it is our duty and responsibility to preserve and conserve this valuable life-giving resource. In the midst of the current large scale irrigation and agricultural development projects, the small tanks still render a massive contribution to maintain the village farmer and to upkeep the agricultural economy of the country.

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DIAGNOSTIC TOOLS TO ASSESS UNDER-PERFORMANCE OF IRRIGATION SCHEMES

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INTRODUCTION

In Sri Lanka today, the total irrigated area amounts to about 536,000 ha, under 98 major (irrigating over 400 ha), 282 medium (irrigating between 80 and 400 ha) and about 22,500 minor (irrigating less than 80 ha) irrigation schemes. The large investments made in the irrigation sub-sector has contributed tremendously to increase in food production and employment generation. However, there is a general concern nowadays that the performance of irrigation schemes is well below optimal levels.

The concerns were first raised in early 1970's and resulted in the implementation of several major irrigation projects, mostly donor assisted, commencing from 1975. The most recent and the largest so far, was the World Bank/EU financed National Irrigation Rehabilitation Project (NIRP). The completion reports of these projects show mixed results. In some of the projects, the rehabilitation requirements have not been properly assessed. During the implementation of NIRP, a collaborative research project was carried out together with H.R. Wallingford, U.K. to develop a procedure for planning rehabilitation of irrigation schemes. This paper outlines the diagnostic tools identified during the study and describes one procedure in detail.

Assessment of Performance of Irrigation Schemes

There are many factors that determine the performance of an irrigation scheme. Complex linkages can exist between these factors as illustrated in figure 1. As an example, poor operational control could lead to excess water in the drains, encouraging weed growth and reduction in drain capacity. This may result in flooding of cropped lands at times of intense rainfall, discouraging farmers from investing in inputs, reduce yield, worsen problems of water control in the system, and lead to further waste of water.

External causes such as falling commodity prices could reduce returns to farming so that farmers leave the land or do not invest in inputs. The result is that crop output falls, water demand falls, channels run part fall, sedimentation and weed growth proliferate, water supply becomes erratic and crop yield falls further.

Indicators of Under-Performance

Outward indications of under performance, termed as **'perceived defects'** in rehabilitation terminology are:

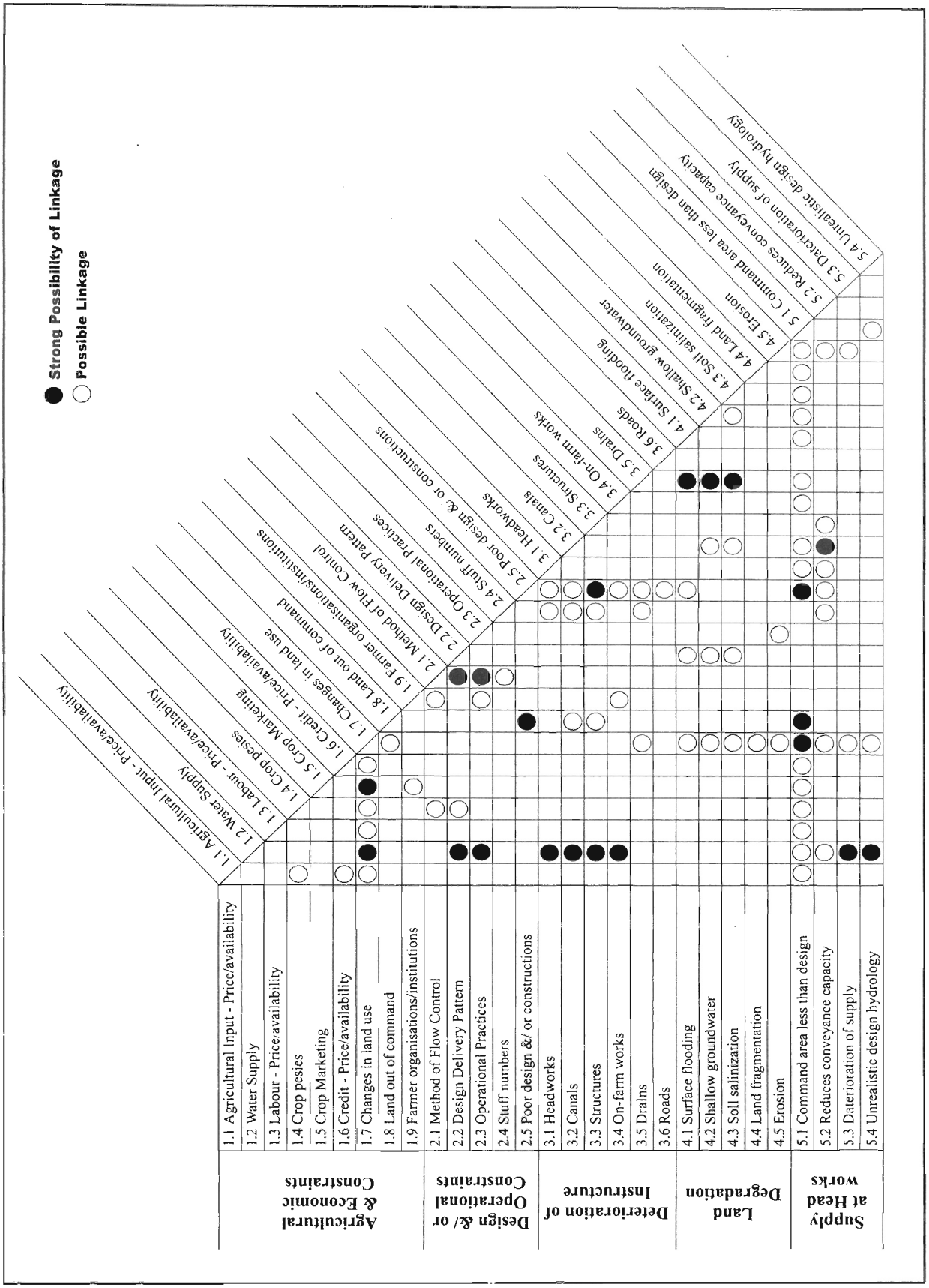

Figure 1. Links Between Causes and Effects

- reduced crop area;
- water shortage; and
- falling crop yields

Primary causes for the perceived defects can be grouped into following broad categories:

- agricultural/economic
- design and operation
- system deterioration
- land degradation and
- headworks supply

Primary causes arise due to a large number of possible alternative, or complimentary, **underlying causes** as illustrated in Figure 2. Diagnostic tools to identify the underlying causes are also indicated in Figure 2.

Diagnostic Tools

The diagnostic tools developed to assess under performance of an irrigation scheme are :

(a) Farmer Questionnaire to indicate relative importance of agricultural and economic constraints.
(b) Checklist to indicate relative importance of system design and operation constraints.
(c) Condition assessment survey to determine the status of infrastructure and prioritise rehabilitation needs.
(d) Checklist to quantify land degradation problems and diagnose causes.
(e) Standard procedures to assess hydrological and hydraulic problems.

Only the diagnostic tool to assess the condition of infrastructure is discussed in this paper.

Diagnostic tool for assessing the condition of Infrastructure

Assets of an Irrigation Scheme

Surface irrigation schemes typically include a large number of relatively low cost assets, of several different types and functions, spread over a large area. These assets fall into following categories:

- Head works
- Cross Regulators
- Turnouts
- Drops
- Cross drainage structures
- Aquaducts

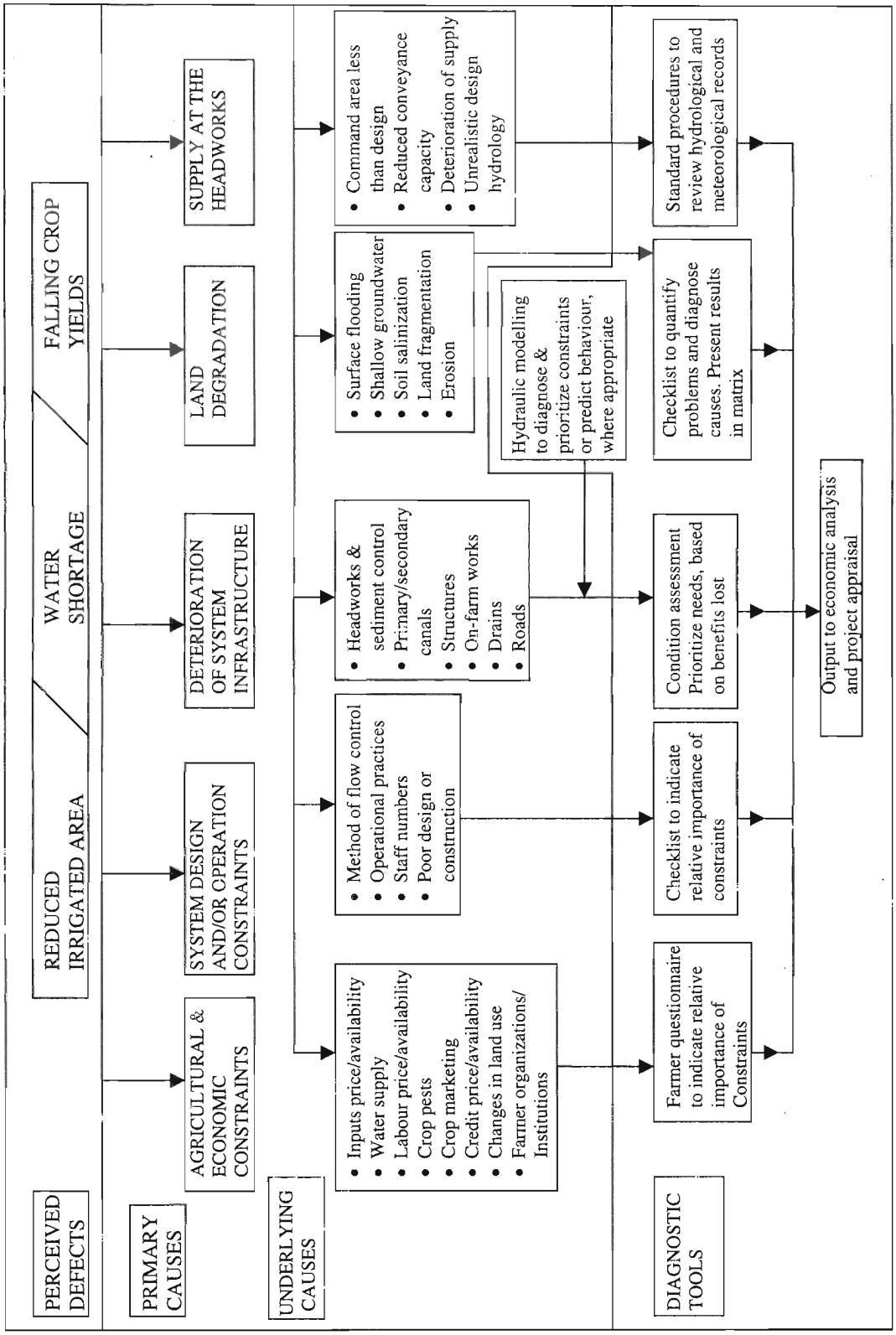

Figure 2.Determinants of Performance and Diagonostic Method

- Syphons
- Measurement Structures
- Canal reaches
- Drains
- O& M roads
- Canal & Spills

Fitness of Assets :

The diagnostic tool involves the assessment of fitness of an asset to perform it's function by means of a walk-through survey. An asset may fail to perform it's intended hydraulic functions whilst still structurally sound. It may also fail structurally, with some associated hazard. A scoring system was developed to reflect the fitness of the asset for it's function.

Assessment of Irrigation Engineer/Technical Offices

The assessment scores for Irrigation engineer/Technical Officer's inspection were developed as set out in the box below:

Derivation of Scores:

- The key function, hydraulic or/and structural, of each type of asset was identified – in most cases a single function predominates.

- The principal elements of each type of asset were defined.

- Questions relating to the expected modes of deterioration of each element were formulated.

- The effect of deterioration of each element on overall effectiveness was judged. The allotted score represents remaining percentage effectiveness.

The standardized questions for one type of asset is given in Table 1 with guidance notes. Table 2 contains the scores assigned to each question, representing the element's hydraulic functioning or structural integrity.

Table 1. Structure Type : Gates Cross Regulator

		Yes	No	Un-assessed
1.	Are any of the gates missing?			
2.	Is it difficult to fully open or close any gate?			
3.	Is any gate seriously corroded or rotting?			
4.	Are there serious cracks or movement in any part of the structure?			
5.	Is leaking occurring around the structure?			
6.	Is the d/s apron seriously damaged or undercut?			

7. Is it difficult to read the u/s or d/s gauge boards?
8. Does the overall condition concern you?

Guidance Notes :

1. Missing Gate

Only answer YES if a gate has been removed from the structure Where a gate is broken but still present, answer No to this question and YES to question 2.

2. Gate Operation

Answer YES when the condition of the lift mechanism, missing components or other factors make it impossible to effectively operate a gate. If a gate is missing, answer YES to question 1 and No to this question.

3. Gate Condition

Answer YES where corrosion or rotting has reduced the strength or water tightness of any gate. Disregard minor patches of surface corrosion or minor deterioration of any gate.

4. Cracks/damage and Movement

Answer YES where cracks appear to be caused by differential movement of the structure or overloading of the structure. Vertical, horizontal or rotation movement may be visible Disregard shallow, surface cracks or minor damage that does not affect function.

5. Leakage

Answer YES if you can see washout of fine soil particles, very wet areas or other evidence of water flowing around the structure.

6. D/S Apron

Answer YES where the apron, or other bed protection. is breaking up or unstable because of serious undercutting. Disregard minor surface abrasion or bed/bank scour if this is now stable and does not threaten the stability of the structure.

7. Gauge Boards

Answer NO when gauge boards have not been installed.

8. **Overall Condition**

Answer YES, if:

- There is a serious fault or deterioration or failure to function that is not covered by any other question.

  OR

- Deterioration has begun and may progress rapidly causing important loss of function or risk of structural failure before next inspection.

Table 2. Condition Assessment Scores

Structure Type : Gated Cross Regulator

A yes answer to the questions carries the scores indicated. A No answer carries a score of 100%. Answer unassessed when you cannot judge the condition. In this care, an inspection by a seminar Officer is necessary.

	Hydraulic	Structural	Class	% Effective
1. Are any of the gates missing?	1		V.Poor	45
2. Is it difficult to fully open or close any gate?	1		V.Poor	45
3. Is any gate seriously corroded or rotting?		1	Poor	70
4. Are there serious cracks or movement in part of the structure?		1	Poor	60
5. Is leaking occurring around the structure?		1	Poor	60
6. Is the d/s apron seriously damaged or undercut?		1	V.Poor	40
7. Is it difficult to read the u/s or d/s gauge boards?		1	Good	90

The box below shows how the values for Condition Index (CI) correspond to broad descriptions of condition.

A general question 'Does the overall condition concern you?' is included on all assessment forms. It is intended to allow a Technical Officer to highlight a concern, which may not be explicitly covered in the YES/NO question format. It allows for the following situations:

'Overall Concern'

- Where the standard assessment questions do not adequately describe deterioration.

- Where an asset is apparently in good condition but it is failing to function as required.

- Where it is apparent that deterioration is in initial stages but may progress rapidly to failure.

The response to the question is not scored.

Condition Index (CI)	Status
100-81	Good-A YES response retumed for a question (s) related to a minor fault. No significant structural deterioration or loss of hydraulic function.
70-80	Fair- indicates partial loss of function and/or some risk to the integrity of the structure. Action not immediately urgent.
51-69	Poor-A serious loss of function and/or potentially serious threat to structural integrity. Action needs to be taken to prevent progressive failure.
< 50	Very poor- Effective failure.

Senior Irrigation Engineer's Inspection

A Senior Irrigation Engineer's inspection should be undertaken if the irrigation Engineer/ Technical Officer responds positively to the question 'Does the overall condition concern you?' or where the answer to a question as unassessed.

The inspection should result in an overall classification based on the condition of the worst element. Standard reporting forms for canal reaches and hydraulic structures, with guidance notes, are available.

Selecting Priorities

Once an inventory of asset condition is prepared, the priority of works is based on the benefit actually, or potentially, foregone. The Priority Index takes account of:

Parameters included in the Index:

- Asset condition, as calculated from the Irrigation Engineer/ Technical Officers report.
- A measure of the area served by the asset relative to the total area.
- An indicator reflecting the strategic importance of the asset.

Each asset type is given a strategic importance on a scale 1 to 4, see table below. The score is intended to reflect the importance of its function, hazard in the event of failure, and relative cost of rebuilding.

Score =1	Score = 2	Score = 3	Score = 4
Measurement Structure	Canal reach Drain Head regulator/ Gated off take Cross regulator Drop/chute Inspection road Escape Bridge	Cross drainage Culvert Aqueduct Syphon	Diversion weir Embankment Dam Barrage Intake works

The Priority Index is calculated from the following formula:

Priority Index = (100-CI) x$\sqrt{}$ (a/A)x Is - equation (I) (3)

Where:

CI	=	Condition Index
a	=	The area served by, or dependent on, the asset*
A	=	Command area of the scheme
Is	=	Importance score

* Note : Structures such as bridges, inspection roads, escapes, etc are assigned a service area equal to that of the canal reach on which they occur.

Calculation of the Priority Index to produce a ranking of works according to need is most easily done on a customized spreadsheet or an asset management program such as MARLIN (Maintenance and Rehabilitation of Irrigation Networks), currently being developed at H.R. Wallingford, U.K.

An example showing how the priority index system applies to a number of assets is shown in Table 3 below.

Table 3. Example of Priority Ranking

Scheme are = 1500 ha				
Asset	**Area Served (ha)**	**Importance (1)**	**Condition Score (2)**	**Priority Index (3)**
Main canal 2+500-3+420	1500	2	75(fair)	50
Sec. Canal 1. 3+000-4+000	380	2	40(v. poor)	60
Sec. Canal 2. 0+000-0+850	435	2	55 (poor)	48
MC drain culvert 8+430	1220	3	60 (poor)	108
DC drop 2+690	185	2	75 (poor)	17

(1) Importance : See Section. 5.5
(2) Condition Score: Determined by most serious defect recorded by Irrigation Engineer/Technical Officer.
See scores in Table 2
(3) Priority Index : In calculated as indicated in equation (i) of section 5.5

Assets ranked according to priority Index			**Priority Index**
1.	MC drain culvert	8+430	108
2.	Sec. Canal 1.	3+000-4+000	60
3.	Main canal	2+500-3+420	50
4.	Sec. Canal 2.	0+000-0+850	48
5.	DC drop	2+690	17

CONCLUSION

This methodology has been so far tested in few schemes in Sri Lanka, Indonesia and Mexico. In Indonesia, it is currently being adopted to prioritize maintenance works. The author is of the view that this procedure is a versatile tool for rehabilitation planners. Of course, the marking system may have to be modified with the application of the procedure to more schemes.

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TOWARDS EFFICIENT UTILIZATION OF SURFACE AND GROUNDWATER RESOURCES IN FOOD PRODUCTION UNDER SMALL TANK SYSTEMS

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Maha Illuppallama

INTRODUCTION

Main sources of water for irrigation in most of the dry zone areas in Sri Lanka are river diversions and reservoirs in varying sizes. There are about 12,000 small tanks and anicuts found in Sri Lanka, feeding an extent of about 185,000 ha. This is 35 percent of the total irrigable area in the country, and small irrigation schemes produce 191,000 mt annually accounting for 20 percent of the national irrigated rice production (Agricultural Implementation Programme, 1994/95). Even though the rice yields of small irrigation systems are relatively low, their production capacity should not be overlooked from the national economic point of view.

The Agrarian Services Act No. 58 of 1979 defines small irrigation works as an irrigation work serving up to 80 ha. of irrigable land. There are about 2000 small tanks in the Anuradhapura district and 70 percent of them bear the capacity of irrigating less than 40 ha of land. The command area is as small as less than 20 ha in 50 percent of the total number of tanks in the Anuradhapura district. Highest number of small tanks is found in Kurunegala district and it is more than 4200.

Tank density is high in Anuradhapura and Vavunia districts. Existence of large number of tanks in an area depends on favourable climate, soil and topographical factors. It can be observed that the optimum density of tanks is found around the iso-hyet of 1500 mm of annual rainfall, and a decreasing trend is observed either side of this iso-hyet (Figure 1). Low density of tanks is found in certain dry zone areas where Red Yellow Latasols and Regosols are found. Percolation rates are relatively high in these soils; therefore, water-storing ability is low in these areas.

Tank cascade systems

Small tanks do not exist as individuals. Natural drainage system in a watershed is blocked by earth bunds in appropriate locations to store water forming a series of tanks along the drainage. The drainage pattern formed in the undulating topographic formation in the dry zone landscape can be classified as dendritic drainage pattern. This ramifying nature of the drainage system has led to form clusters of small tanks found in series, which are connected to form a system known as 'tank cascades' (Madduma Bandara, 1985).

Existence of small tanks in a cascade pattern is an advantageous feature in many ways. Surface water bodies spread over an area can maintain the groundwater level closer to the land surface at least in lower portions of the minor basins. It can be stipulated that absence of such a branched system of tanks could lead to rapid depletion of groundwater due to natural gradient of the drainage system. Therefore, in the absence of tank cascade systems natural vegetation seeing now would have not been in the same composition with deep-rooted large tree species found in the various positions along the catenary slope.

Upper tanks in a tank cascade system act as buffer reservoirs to absorb flood-generating rainfall, which would otherwise bring the risk of breaching lower tanks. Similarly, these upper tanks are buffer reservoirs to supply water to the lower tanks when they are in short of water to save the crop.

Present status of small tank farming

In a comparison made on rice yield data between small and major irrigation schemes in both Anuradhapura and Polonnaruwa Districts during the period from 1981 to 1990, it was observed that the rice yields are always lower in small irrigation schemes (Figure 2). This situation has emerged due to several reasons. Most important factors are low level of crop and water management, lack of proper weed, pest and diseases management, poor tillage operations and lack of proper drainage.

Cropping intensity is very low in small tank systems. In a study carried out for Anuradhapura District using rice cultivation statistics recorded from 1970 to 1990, it was observed that the cropping intensity had never exceeded one, and it fluctuated according to the rainfall received during maha season (Figure 3). With all efforts made to renovate small tanks under various tank rehabilitation projects implemented during this period in Anuradhapura District, no significant improvement in cropping intensity could be achieved. This would drive us to make serious thoughts on present tank rehabilitation methodology and its impact on water storage efficiency of tanks.

Cultivable extent from small tanks decreases gradually due to tank siltation and high tank water losses. A study carried out in 1990 showed that three small tanks; Paindikulama, Siwalagala and Marikaragama in the Nachchaduwa major watershed have been silted up by 35, 30 and 23 percent respectively of their initial capacity (Dharmasena, 1992). Siltation of tanks not only causes reduction of storage capacity but also leads to alter the tank bed geometry. Subsequent rehabilitation works, where the capacity has been by raising the spill and the tank bund would create a shallow water body spreading over a larger surface area. This makes the situation more complicated creating several other problems. They are: a) inundation of upstream paddy lands; b) development of salinity conditions in the upper area; c) increase of tank water losses; d) disappearance of the tree strips in the high flood region (*Gasgommana*) and the grass cover (*Perahana)* underneath; and e) disappearance of some indigenous fish species, which cannot survive in shallow waters or do not find a favourable breeding environment.

Water losses from small tanks are very high. Within a period of 2 – 3 months since the seasonal rains cease, most of the tanks appear as somewhat marshy lands infested with aquatic weeds. A tank water balance study (Dharmasena, 1998a) carried out in selected tanks in the Siwalakulama tank cascade shows that contribution of direct rainfall to the storage varies from 25 to 40 percent (Table 1). Relatively higher contribution from direct rainfall was recorded in tanks with smaller catchment areas. Total tank water loss through evaporation and percolation varies from 35 to 90 percent depending upon geometry of the water body. Water losses are higher from tanks with shallower water bodies than those with deep water. Therefore, it is clear that tank bed geometry determines more the water storing efficiency of a tank than other factors do. These results indicate that about half the storage stored in a tank would not remain to irrigate the downstream command area. Figure 4 shows the relationship between percent annual tank water loss and the tank geometry. It indicates that if the tank geometry could be altered to form a high capacity: area ratio, water loss would be reduced to a very satisfactory level.

Table 1. Annual Tank Water Loss and Direct Rainfall in Selected Tanks in the Siwalakulama Cascade (1996/97)

Tank name	Catchment (ha)	Capacity (ham)	Tank bed Area (ha)	Cap./ area (m)	Direct Rainfall (%)	Total Loss (%)
Puliyankulama	226	44.0	35.0	1.26	24	37
Borawewa	33	12.2	14.0	0.87	30	79
Puswellagama	121	14.0	17.3	0.81	39	90
Pahala Aliyawetunawewa	169	18.0	17.0	1.06	26	49
Kolongaswewa	129	21.5	24.8	0.87	36	63
Vembuwewa	174	19.0	17.0	1.12	25	52
Thamarakulama	369	47.4	36.3	1.31	28	40
Siwalakulama	207	65.6	47.5	1.38	28	49

Source: Dharmasena, 1998a

Concept of partial desiltation

In tank rehabilitation programmes at present, the tank bund is strengthened, structures repaired or replaced, and the capacity lost due to deposition of sediment is regained by raising the spill and the tank bund. This has come out with the common belief that the desiltation of minor tanks would result in very low economic returns. However, scientists, planners and engineers cannot escape from the challenge of disappearing of minor tanks from the dry zone landscape during next few decades.

Desiltation of small tanks should aim not only at increasing storage potential and reducing tank water loss but also at protecting the tank eco-system. As desiltation is an

expensive task as well as a must to undertake, it is important to develop a technological concept, which generates a low cost and effective desiltation process. The partial desiltation concept was introduced (Dharmasena, 1994) with this background on the basis of findings from hydrological research studies conducted by the Field Crops Research and Development Institute, Maha Illuppallama.

The process of desiltation in this concept is not essentially aimed at expanding the present capacity of tank. The main objective of the concept is to reduce tank water losses by manipulating tank bed geometry through desiltation. It is clear that the said objective cannot be successfully achieved by a complete desiltation, which would not much alter the area: height ratio of the tank storage.

Sedimentation studies (Dharmasena, 1992) indicate that half of the sediment deposited in small tanks is found within one third of the tank bed area closer to bund. Thus, the same capacity can be maintained by removing sediment in this area and heap up in the upstream area. These soil heaps must be formed at safe gradient and stabilized with trees and grasses to prevent washing down to the tank. These mounds would appear as micro-islands, where productive plant species could be grown. These soil mounds must not block the natural drainage, which supply water to the tank. An illustration of the desilting technique is given in Figure 5. Further, protection for there is a need to construct a soil bund along the periphery of the desilted area except in places where natural streams enter into the tank.

Methodology for partial desiltation

Partial desiltation technique consists of preliminary field surveys, preparation of plans, designs and estimates, removal of sediments, making soil mounds, establishment of upstream reservation (*Gasgommana*) with soil mounds and natural streams, renovation of tank bunds and sluices, establishment of downstream reservations (*Kattakaduwa*) and main drainage of the command area (*Kiul-ela*). The technique should consist of all these activities without which the impact of partial desiltation would not be much effective. However, before commencement of technical planning a Participatory Rapid Appraisal or a similar exercise must be carried out to obtain farmers' views on tank rehabilitation, and to consider their suggestions for incorporating in the subsequent planning and implementation programme.

A tank bed engineering survey has to be carried out to understand the present tank bed geometry, storage capacity and area-capacity-elevation relationship. A sediment depth survey is also to be carried out to prepare original (prior to sedimentation) contour map and area-capacity-elevation curves, which would later be super-imposed to the existing tank bed perspectives. The depth to original tank bed can be determined by field experience. It is identified as the depth at which the sand/(silt+clay) ratio shows a sudden contrasting higher value (Dharmasena, 1992). An illustration of the partial desiltation design is given in Figure 6.

Excavation of soil needs the support of machinery. However, the associated farming community can do shaping up of soil mounds and upstream bund. Most important components in this programme are stabilization of bunds with vegetative cover, establishment of *Gasgommana* (upstream vegetation) and *Kattakaduwa* (downstream reservation) area. Farmers must be aware right at the inception of the programme of how they are supposed to contribute to this activity. Total work should be undertaken by farmer organizations.

Benefits of partial desiltation

Partial desiltation of a tank would provide various benefits to the community some of which cannot be assessed by an economic analysis. It is quite obvious that the return to investment from desiltation is not economical if the purpose of desiltation is to increase the storage. The concept of partial desiltation is not meant merely to increase the storage unless there is a demand from the community or an additional storage potential in the system. The economic analysis should therefore, be based on consideration of following benefits in order to determine the return to investment of partial desiltation.

Even though the asweddumized lands are available in plenty for cultivation in most of the command areas, availability of water in the tank limits the cultivable extent. Reduction of tank water losses from partial desiltation would lead to improve the water availability in minor tanks providing more opportunities for cultivating relatively a larger extent.

Partial desiltation reduces the water-spread area. More than half the land inundated with tank water would be free of surface water after a successful desiltation. Water body would be confined to the portion closer to tank bund. The land area freed from water spread can be covered with perennial vegetation. This soil is fertile with nutrients and high level of organic matter (5 - 8 %) and also has an easy access to groundwater. In a cottage industry improvement programme, this land may best be utilized to grow Bamboo (*Bambusa* spp.), Rattan (*Calamus* spp.), Mat grass (*Cyperus pangorei*), Vetakeya (*Pandanus* spp.), Patabeli (*Hibiscus tiliaceus*), Palmaira (*Borassus flabellifer*), Kithul (*Caryota urens*) etc. all of which provide various raw materials for cottage industries.

Water storing efficiency of the tank would be increased with improvements on tank geometry by partial desiltation as shown in Figure 4. Any water remaining in the tank after `maha' cultivation can be kept without much losses for yala cultivation. Further, this tank storage can raise the groundwater in the command area and yala cultivation can be supplemented by well water with a great assurance. Both these reasons could lead to increase the cropping intensity of the command area.

Minor tanks are seasonal reservoirs. These can be utilized for raising fish species of short duration or harvesting half matured fish stock. An adequate dead storage of a tank with favourable geometry can improve this situation for rearing long duration fish species. The other advantage of having a good dead storage during dry periods in that these tanks can be utilized for raising fingerlings in protected areas.

Groundwater resource in small tank systems

Exploitation of available water resources for agricultural production in the dry zone of Sri Lanka has reached its safe maximum or perhaps is exceeding the tolerable limits of eco-sphere. Despites all efforts aimed at intensifying irrigated agriculture derived on surface water, some agricultural communities resort to farming with alternative water sources indicating the state of water crisis. Shallow groundwater gathering in low-lying valleys, alluvial deposits and areas under influence of surface reservoirs, canals and tributaries has been approached during recent past for cultivation with lift irrigation. This art of agriculture emerged in 1980s especially in the central part of the dry zone known as agro-well farming is now spreading with the blessing of development agencies and the over enthusiasm of farmers.

The increasing trend of using shallow groundwater for cultivation leads to rise two major issues, which should be given due consideration. They are: a) what potential it has for increasing the agricultural production in the dry and intermediate zones; and b) how best it could be integrated and managed to achieve the optimum efficiency and productivity.

Potential of the shallow groundwater reserves and their limitation need to be fully realized in order to prepare a properly integrated water resource plan and for its implementation in a watershed. As agro-well farming is a new situation, farmers have no experience, and as usual go on experimenting through their trial and error approach. Several research works were undertaken during last few years to investigate the potential and make recommendations on use of shallow groundwater for agriculture.

Efficient utilization of surface and groundwater

Recommendations emerged from the studies conducted by the Department of agriculture (Dharmasena, 1998a and 1998b) are summarized below to understand the fact that surface and groundwater resources should be managed in an integrated manner to achieve most possible productivity from small tank farming systems.

Both groundwater and surface water resources should be planned on watershed basis. For such planning it is essential to prepare inventories of tanks, tank cascades, aquifers, cultivable lands, locations of groundwater abstraction etc. in a watershed.

A water resource-monitoring unit has to be established in each province to monitor quantity and quality of water, advice and coordinate the rehabilitation of tanks, construction of agro-wells and protection of natural waterways.

In tank cascade systems upper areas of tank catchments must be covered with forest or conserved with suitable measures for absorption of high proportion of rainfall. Most potential areas for abstraction of groundwater are lower parts of a watershed and the main drainage of the tank cascade; therefore, use of groundwater must be promoted in lower parts of the cascade while trapping more rainwater in upper tanks.

Tanks must be rehabilitated in a manner of reducing water-spread area to minimize evaporation and percolation losses. This can be successfully achieved by adopting partial desiltation concept. Traditional tank eco-system must be restored as it provides protection to water resources and various benefits to villagers.

Water wastage in surface irrigation must be minimized to relief the pressure on use of groundwater. Lift irrigation and micro-irrigation systems can be adopted in place of surface irrigation by pressurising the tank water. Gravity irrigation is a wasteful method of irrigation in areas where, water is a critical factor for farming. Conjunctive use of ground and surface water must be encouraged to make the maximum assurance to the agricultural production in the area.

Crop diversification is an appropriate option to optimise the income level of farmers and increase the land and water productivity. Field crops, perennials, and vegetables can be introduced according to the land suitability for different crops.

As regolith aquifers are limited groundwater reserves, and their depletion would cause environmental hazards, only 25 percent of the potential groundwater storage in an aquifer is recommended for abstraction. In selecting location of abstraction it is recommended that imperfectly drained area is the most suitable area for construction of agro-wells.

Weathered rock zones are less permeable, therefore, well should be dug down to the bedrock for exposing the fractured or shattered zones. Construction of an observation well of small diameter is recommended for testing of water quality and conducting a pumping test for estimating the recovery rate.

Construction of an agro-well is recommended only when the water quality is good for irrigating crops and minimum water depth is at least 2 m during dry period and 5 m during wet period. If agro-wells are constructed without expecting any other water sources, well density should not exceed 6 – 7 per 100 ha of watershed. Wells should not be constructed at very close spacing. Under any unavoidable circumstances wells should not be spaced closer than 100 m.

Well diameter can be decided on the results of a pumping test. The procedure for a pumping test is outlined below.

A well is pumped and allowed to recover a half the depth of water pumped out. If the diameter of the observation well is D (m) and the time taken to recover a half is $T_{1/2}$ (hrs), then the well specific capacity (K) is:

$$K = \frac{0.54\, D^2}{T_{1/2}}$$

Well diameter is decided according to the following Table.

Water depth in July (m)	Well diameter (m) for		
	K > 3	K = 1.5 - 3.0	K < 1.5
2	5.5	7.0	9.5
3	4.5	6.5	8.0
4	4.0	5.5	7.0
5	3.5	5.0	6.0

Under agro-wells crop combinations are more effective than a single crop in terms of water saving, risk of pest and disease and market failures. Planting times should be arranged to prevent build up of high peak water demands which most frequently lead to water shortages and consequent crop losses. Cultivation schedules are prepared aiming at receiving high prices for the produce.

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INNOVATIVE APPROACHES IN VILLAGE IRRIGATION SYSTEM MANAGEMENT

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INTRODUCTION

The topic "Innovative Approaches in Village Irrigation System Management" looks very challenging because it exposes ideas and materials that might lead to address the pressing need of the day.

This presentation is based on the assumption that the real managers of village irrigation systems are the village beneficiaries of those systems and also this is a process of natural resource management in this country. As Mr. L. R. Brohier stated, that "methods of land surveying" is the best example for this type of phenomenon. History becomes the backsight of surveying and future will become the foresight. No angle can be measured unless the foresight is followed by the backsight.

Now, we look into the history of the irrigation science pertaining to the village systems.

Recent History

Village Irrigation System has three main components namely, the Watershed (micro catchment), Reservoir or Weir and Farmland and these three components should be treated as" one way street system."

Watershed

Two main facts that can be stated as far as the micro level watersheds are concerned are the rapid changes in land use and outside interventions.

People were freely allowed to use them, if the lands were available and did not know that those lands were reserved and meant for specific purposes (Tables 1 and 2).

Following data depicts the present condition of micro catchments.

Table 1. Present Condition of Microcatchments

No	River Basin	NF%	WB area In Acs	MC area sq.mls		No.of Feeder Canals
				Total	Average	
90	Malwatuoya (n=1108)	35.4	42052	667	0.60	108
99	Deduru oya (n=3485)	9.0	34647	990.8	0.28	196
	District					
	Monaragala n=811	25.5	-	502	0.62	41
	Trincomalee n=450	41.4	9754	398	0.88	22

NF- Natural Forest Cover
WB- Water Bodies
MC- Micro Catchment

Table 2. Present Landuse Details of a Typical Village Tank Cascade in Rajarata

	Net Catchment Area in sq.km	WSA %	Paddy %	Chena %	Homestead	Forest %	Bare %
Average	1.94	10.2	6.1	8.6	4.3	48.2	22.6
Minimum	0.26	5.31	3.4	0	0	38	0
Maximum	3.70	14.65	11.0	22	12	68	35

WSA – Water Spread Area

The above situation is moderate in Rajarata when compared to the other areas.

Reservoirs

There is sufficient evidence to suggest that all the village tanks were not irrigation tanks and some were reserved for environmental and other purposes, which were identified as crown tanks during the colonial period. Ruins of large number of abandoned tanks both in Anuradhapura and Monaragala districts reveal that number of village tanks were reduced while augmenting the individual tank capacities, without considering the hydrological interconnection among these tanks.

Attempt of duplicating some techniques already experimented in major tanks, for village systems have resulted in producing adverse effects. Nearly 20%(average) of very high seepage and percolation loss indicates the adverse result of incremental tank water

heights and frequent failures of masonry sluice structures in those systems have become a serious drawback. Incorrect interpretation given for "Mada Sorowwa" (Silt ejecter in ancient times) as a "low level sluice" has led to tank bed siltatian and hence reduced the dead storages. Following figures will illustrate the present condition of village tanks (Tables 3 and 4).

Table 3. Present Condition of Village Tanks in two Main River basins

No	River Basin	Silted >1m Nos	Av.WH in ft	VT Sluice Nos	Av.Net catchment Sq.mls	Av.Com Area Acs	No. of Olagon
90	Malwatu oya n=1108	671	7.1	258	0.60	50.4	386
99	Deduru Oya n=3485	1059	5.8	-	0.30	10.0	-

Table 4. Present Condition of Village Tanks in two Districts

District	Silted >1m -Nos	Av.WH Ft	VT Sluice Nos	AV.NET CATCHMENT Sq.mls	Av.Com Area Acs	No.of Olagam
Monaragala n=811	98	5	61	0.62	25.2	35
Trincomalee n=450	42	5.2	104	0.88	56	243

Silted > 1m- Tank beds silted more than 1m depth.
Av WH- Average water height in ft.
VT - Vertical type
AV Com-area - Average command area
Olagam- Remotely operating tanks, farmers are not living closely.

Farmlands- "the most critical area"

New lands were alienated as crown-grants, long term lease lands, year permits. Some encroachments have also taken place in addition to the first priority area called "purana wela" that was prepared at the very beginning of the scheme. Most of these alienations were done without considering the underlying agrarian structure and water rights.

Ancient land allocation system was mainly based on equity and compensative measures that have been adopted, to maintain the water rights. This Water Right was an inbuilt part of the Land Right in the ancient system.

Figure 1 illustrates the ancient mechanism of village irrigation resource management.

Entire mechanism was driven by the force of equity that led for efficient beneficiary participation as well as the sustainability of the system and individual as well as community rights were established in very rational and scientific manner, followed by well connected individual and group activities.

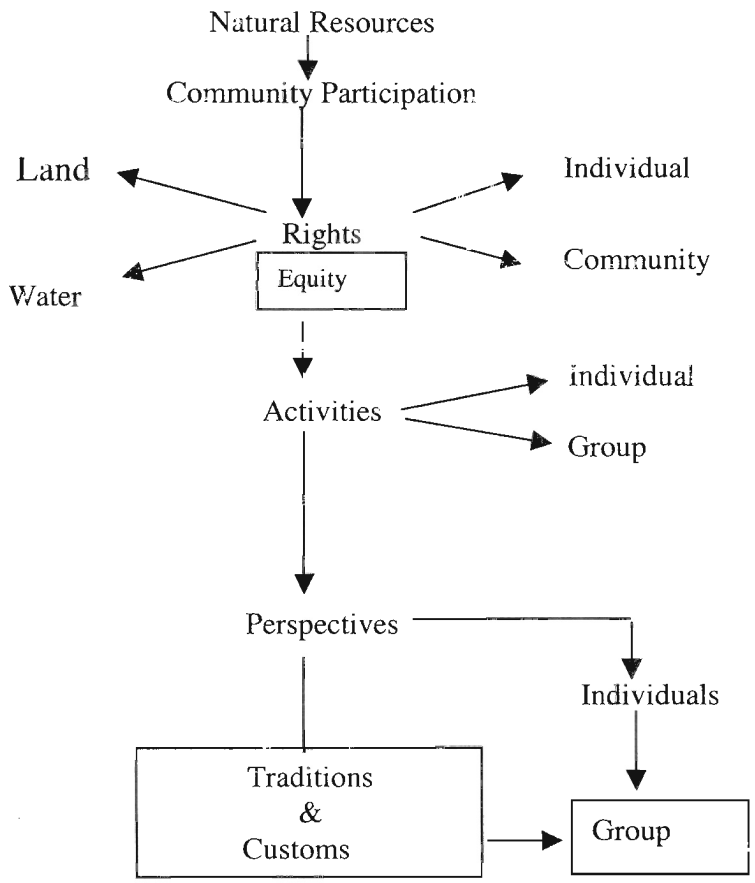

Figure 1. Ancient Mechanism for Village Irrigation Resource Management

The best solution identified by the society to establish and regulate individual as well as group activities were ***customs*** and ***traditions***. ***Bethma*** is a very good example for this phenominon and even an equivalent system with the same degree of efficient resource management anywhere in the world including communist countries was not heard of.

No proper weightage has been given for ancient irrigation technology such as traditional flow measuring devices that are still existing in some part of the country.

Principles that governed the ancient mechanism of irrigation system management were broken down especially during the last century and the science behind those customs and traditions become null and void and remaining today as folktales. But rudiments of ancient concepts and techniques adopted for village irrigation system management are still visible in the country, especially in some parts of North Central & Southern areas.

The major mistake attributed to our present approaches is the belief that the above ancient mechanism is still alive but infact, it is really dead now.

Role of the State

What should be the role of the state in the natural resource management process? Dominant role should be the formulation and implementation of national policy.

Policy should be the formal way of accepting principals and norms of the society and should not only a statement written on the paper but also a series of activities to direct the society towards a particular goal.

During the colonial period, different policies were formulated to suit their own agenda and not for the real benefit of the farming community in this country. Even after the independence, we did not have a sufficient national policy pertaining to village irrigation, to meet the demands that are based on the real needs of the society.

Idea of having a national policy in village irrigation is to fill the vacuum created due to the loss of momentum of ancient customs and traditions, which are inherited to those systems.

Role of the Bureaucracy

Why did the above mentioned situation arose and how? When we try to analyze the situation, it has become a usual practice to nominate two defendants and they are "the state" and "the society". Sri Lankans were allowed to entertain the privileges of the democracy after independence and the state was theoretically identified as a government "of the people, by the people and for the people" but in reality,it fell short of it. The best way of analyzing the situation is the "**Gandian model**" developed in India. **Samaj** or the society reacts on real community needs or the principles and the **Raj** or the state reacts on the demand and always there is a gap between the society and the state.

Now let us find out, who is the interface or the go between these two?
Answer is the "modern bureaucracy", as illustrated in the Figure 2.
Now it is clear that the existence of the policy gap was not the direct fault of either the state or the society.

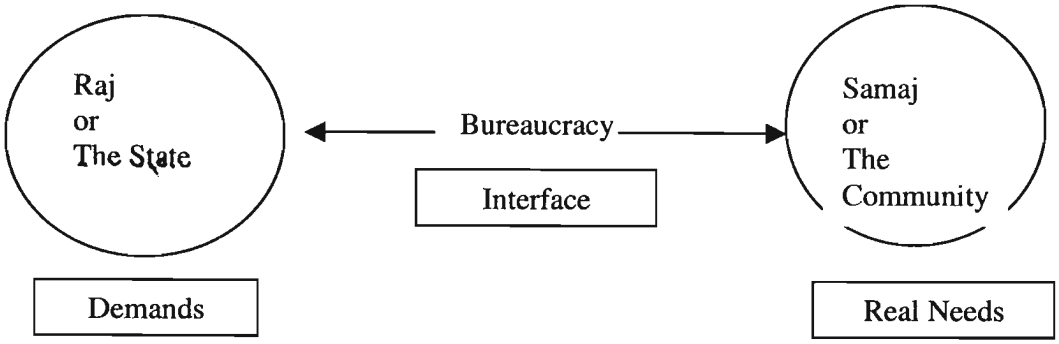

Figure 2. Role of the Bureaucracy in Village Irrigation System Management

It is very necessary to understand the reasons for the failure of the bureaucracy to contribute successfully, to fill the policy gap in village irrigation sector. That is mainly due to a lack of reliable and enhanced data base laid on "natural resource management base" and this mechanism is schematically shown in Figure 3.

Database on Village irrigation

Database laid on natural resource management base has been prepared by the Department of Agrarian Services (DAS) in 2000 and this has been computerized in **"dbase 4"** database management software. This attribute database consists of seventy-six (76) main attributes that should be linked into individual village irrigation systems as well as Meso-catchment areas (cascade) with the help of geographical information system (GIS) mapping (Annex I).

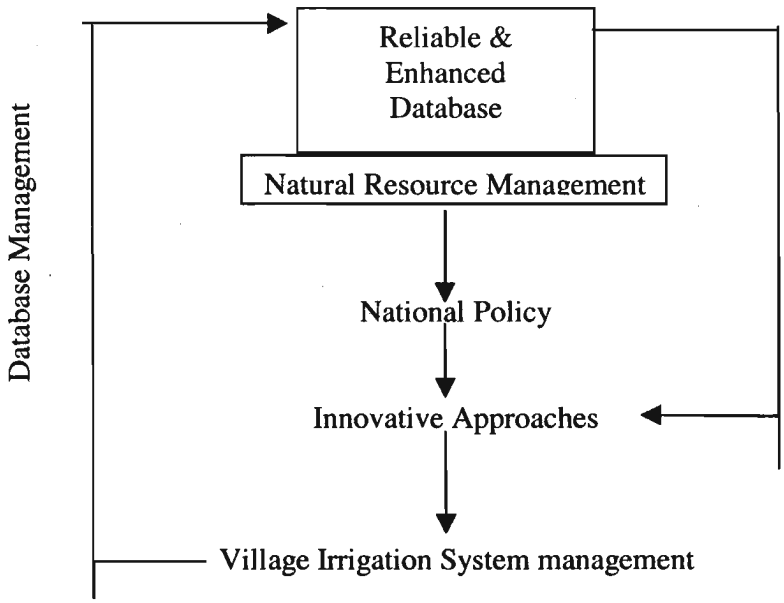

Figure 3. Proposed Mechanism for Village Irrigation System Management

Analysis done of this particular database in Annex 1 shows the type of analysis that this database could do. Data processing and verification process adopted by the DAS is shown in Figure 4.

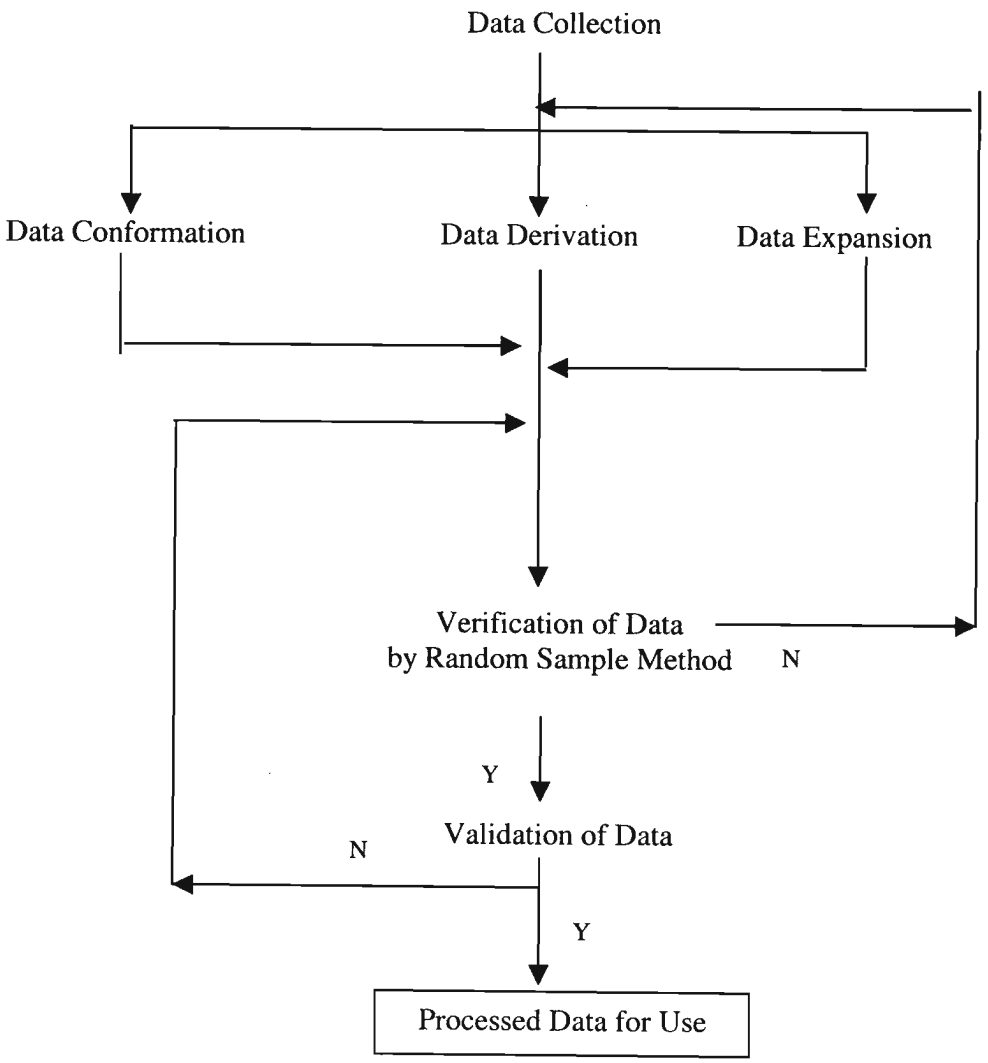

Figure 4. Data Processing Flow Chart adopted by the DAS

Management Potentials

It is understood that the wayside benefits of these village irrigation systems are more valuable than its direct benefits, as far as the entire ecosystem is concerned.

Those hydrologically interconnected and eco-frendly village irrigation systems have become acclimatized to the extent that they have almost become a part and parallel of the nature.

They are so conspicuous that no equivalent can be found anywhere in the world accept in south India which has some resemblance of this nature. Therefore, the concepts and techniques brought from other parts of the world cannot be superimposed without desorting the systems and this had already been proved in many practical cases.

It has been identified and proved that the potentials realized to upgrade these village systems by infrastructure development is so limited in many cases but still there is enough room to improve the performance by introducing an appropriate management techniques.

These facts will lead to certain conclusions. When this situation is examined, it will be clear that innovative approaches based on the national policy that originates with the help of reliable and enhanced database, will result in a remedial measures which are rationally conclusive.

"We all are made wise not by the recollection of our past, but by the responsibility of our future"

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Annex 1

Data base file structure

File Name :- MIDB.dbf

Number of fields :- 76

Number	Field Name	Type	Description
1	Flag	C	
2	SE-NO	N	District serial no.
3	DIS-NO	N	Id number given to district.
4	ASC-NO	N	Id number given to GK.
5	Nature	C	T-Tank A-Anicut.
6	Status	C	W-Working , A-Abandened
7	Sub-No	N	GK Serial No.
8	Name-Scheme	C	Name of scheme.
9	D-S. Area	C	Divisional Secretary area.
10	G-N. Area	C	Grama Niladari area.
11	Com-Area	N	Command area in Acs
12	A- bays	N	Number of bays in Anicut
13	A-L Gates	N	No. of lifting gates in anicut
14	WA-HT	N	Water height of anicut in Ft.
15	A-NAT	N	1-Concrete Structure 2.Temporary Structure
16	T-NAT	N	1-Main Tank 2-Olagama (Remote tank) 3.Other
17	DAM-L	N	Dam length in ft.
18	MAX-HT	N	Maximum bund height in ft.
19	SEEP	N	Bund seepage 1-high 2-low 3-nil
20	T COAD	N	Condition of Tank bund 1-Very good 2- Good 3-Bad
21	NO-SLU	N	Number of sluices
22	VT-SLU	N	Number of vertical sluices
23	MWH	N	Maximum tank water height in Ft.

24	SILT	N	Tank bed siltation 1-Less than 1Ft 2-1 to 3 Ft 3-More than 3 Ft
25	TB-Cul	L	Tank bed cultivation- Y-yes , N-no
26	F-CAN	L	Feeder canal system – Y-yes , N-no
27	IR-CA	L	Irrigation canal system y –available N – Not available
28	CAN-LENGTH	N	Total length of irrigation canals in Ft.
29	FTO-PO	L	Farm Ternout/Pipe outlets Y-available N-not available
30	T-FMD	L	Traditional Flow Measuring Devices. Y –available N –not available
31	DR-CAN	L	Drainage canal, Y- available N- not available
32	DC-CON	N	Conditions of drainage canal 1- Clear 2- Blocked
33	KATTA	L	Kattakaduwa in command area Y –available N – not available
34	SALINITY	L	Soil salinity in command area Y – available N – not available
35	ALKALINE	L	Soil Alkaline in command area Y – available N – not available
36	AGRO-WELL	L	Agrowells in command area Y –available N – not available
37	AW-NO	N	Number of agrowells in command area
38	AVG-CUL	N	Average cultivated area in Acs in last 10 years.
39	AVG-HAR-AR	N	Average harvested area in Acs in last 10 years.
40	AVG-HHRVES	N	Average harvest in BU/Ac in last 10 years.

41	MOL	N	Minimum operating level in Ft.
42	NO-Farmers	N	Number of farmers.
43	NO-OWN-CUL	N	Number of owner cultivators.
44	NO-TEN-CUL	N	Number of tenant cultivators.
45	TM-EXTENT	N	Extent of thattumaru lands.
46	KM-EXTENT	N	Extent of Kattimaru lands.
47	FRAGMENT	L	Land fragmentation in command area. Y –available N –not available
48	BETHMA	L	Bethma cultivation. Y –still practice N – no
49	UPLAND	L	Upland cultivation. Y –Practice N –no
50	WA-MASTER	N	Water Master 1 – Traditional 2 – New
51	FO-AREA	N	Jurisdiction of Farmer organization (F.O.) 1 – Irrigation scheme 2 – GN Division 3 – Number of Irri-schemes 4 – other
52	TOT-MEMBERS	N	Total number of members in F.O.
53	RE-MEMBERS	N	Total number of registered members in F.O.
54	AG-ROAD	L	Weather farmers request for Agriculture Roads, Y – yes N – no
55	MAINTENANCE	N	Method of Irrigation maintenance, 1 – Share list 2 – Up and down 3 – Voluntary 4 – Other
56	REPAIR-10Y	L	Weather this scheme was repaired during last 10 years. Y-yes , N-no
57	CO-ORD	C	Irrigation co-ordinates.
58	AE-REGION	C	Agro Ecological Region.

59	HY-ZONE	N	Hydrological Zone number.
60	RV-BASIN	N	River Basin number.
61	CASCADE	L	Weather this scheme is located in a cascade? Y – yes , N – no
62	CAS-NO	C	Cascade number.
63	EVA-STATION	N	Evaporation Station number.
64	RG-STATION	C	Name of closest Reaingauge Station.
65	WSA	N	Water spread area in Acs.
66	EF TWH	N	Effective tank water height in Ft.
67	G-CATCH	N	Gross catchment area in Sq.Mls.
68	N- CATCH	N	Net catchment area in Sq.Mls.
69	CAT-SHAPE	N	Shape of catchment. 1 – Fan shape 2 – Fern leaf
70	AV-GRADIENT	N	Average gradient of Access Valley.
71	NF-PERCENT	N	Percentage of Natural Forest cover in the catchment.
72	SY-MAHA	N	Specific yield in Maha Ac.Ft/Sq.Ml
73	SY-YALA	N	Specific yield in yala Ac.Ft/Sq.Ml
74	SOIL	N	Identification number of dominant Soil type.
75	G-T-CAPA	N	Gross Tank capacity in Ac.Ft.
76	N-T-CAPA	N	Net tank capacity in Ac.Ft.

C –Character
N- Numeric
L - Logic

SMALL TANK SYSTEM FOR CONTINUED FOOD PRODUCTION WITH REFERENCE TO NORTH CENTRAL AND NORTH WESTERN PROVINCES

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The small tank system operational in the North Central and North Western Provinces has positively contributed to reduce the risk associated with the poor and variable water availability to crops, and to increase and sustain agricultural production (Table 1).

The operational efficiency of the system is dependent on the functional efficiency of each of the four key land use components; the tank (reservoir), the settlement (village), the command down stream and the catchment (the upper aspect of the water shed located at an elevation above these reservoir), integrating to form the small tank system.

A steady growth of population in the provinces since independence is observed resulting from natural increase and migration (Table 2).

Consistent with the increase in population, the incidence of encroachment of village and crown lands has also increased. In the process, the village forest, largely comprising of the catchment of the small tank system, came to be occupied by the villagers, and encroachments by migrating population were concentrated on the state lands (Abeysinghe, 1983). In the process of encroachment, the natural forest was destroyed, and what is presently witnessed is, mostly regenerated secondary vegetation.

The population increase since early 1970's created a high demand for land and encroachments of 2 – 6 acres in extent appeared in the village and the state forest areas. Most of these encroachments were situated within the catchments of the small tank system. With the regularization and land alienation in mid 1970's, specially in the NCP, ownership rights for highland blocks were generally fixed. Even then, the land remained in undeveloped and poorly managed state. Thus the encroached land remained highly susceptible to surface soil loss, resulting from high intensity of storms that occur for durations exceeding 15 to 30 minutes.

Catchment affected by alternative land uses

In developing the encroached / regularized / alienated block to a homestead cum agricultural production unit, any systems approach was hardly used by the occupants. The benefits of available technologies synthesized with research and extension backing from integrated farming systems appropriate for specific farming situations did not go to them. Consequently, large majority of the encroachments, mostly on the catchment of the small tank system, encountered soil and land problems. Deterioration, of soil structure, soil erosion, poor soil-water retentivity, soil compaction, poor soil water infiltration and

resultant rapid and excessive run-off charged with high concentration of sediment load.

Table 1. Area of Paddy cultivated Under Different Irrigation Systems and Rainfed Conditions in NCP and NWP, in Maha 1997 /98 and Yala 1999

Location	Extent Cultivated, ha					
	Maha 1997 / 98			Yala 1999		
North Central Province (NCP)	**Major Irrigati**	**Minor irrigation**	rainfed	Major irrigation		rainfed
1. Anuradhapura District		**36479**	2172	13349	**6110**	11
2. Polonnaruwa District		**2177**	979	44334	**1799**	11
3. Total in the NCP	**Ation** 29680 45032	**38656**	3151	57683	**7909**	22
North Western Province (NWP)						
1. Kurunegala District	12344	**33289**	28220	9236	**17678**	18373
2. Puttlam District	5294	**7143**	1448	4219	**1930**	207
3. Total in the NWP		**40432**	29688	13455	**18608**	18580

Source : Division of Statistics, Ministry of Agriculture & Lands, 1999

Table 2. The Growth of Population in the North Central and North Western Provinces Since Independence

Location	Land area km^2	Density /km^2			
		1953	1971	1981	1988
North Central Province	10532.9	22	52	81	94
Anuradhapura District	7129.2	22	55	82	96
Polonnaruwa District.	3403.7	-	48	77	90
North Western Province	7749.7	110	181	220	251
Kurunegala District	4772.8	133	215	254	288
Puttlam District	2971.9	75	127	165	192

Sources - Abeysinghe, 1983 and NARESA, 1991

contributing to tank siltation, adversely affected the production capacity of the catchment area and storage capacity of the tank. As a result, productivity of the command area is low (Tennakoon, 1986; Somasiri, 1992).

The observations made with respect to an individual tank system, within reasonable limits, could be extrapolated to the tanks forming a cascade system.
(Panabokke, 1999; Shakthivadivel *et.al*, 1996).

Regardless of the variation in soil fertility featured by a high content of Non Calcic Brown Loams, the system of land use and agricultural production under small tank system found in the Kurunegala District (in Agro-ecological Zone IL_3) is broadly

similar to that found in the Anuradhapura District (Agro-ecological zone – DL1). Therefore, the experience with land use and agricultural production available to date and innovations expected in the near future in Anuradhapura (NCP) would be also useful to develop an alternative system of farming in the IL3 region of the Kurunegala district (NWP).

NCP–PRDP Role in the Small tank – Catchment Area Development

North Central Province Participatory Rural Development Project, supported by IFAD is assisting the socio-economic development in the Anuradhapura District. Sectoral development activity is undertaken by the relevant government organizations committed to the provincial programmes. In this upland / highland development is an important sub component. The target group assisted under this sub component consists of the socially mobilised low income poor farmers / interest groups, interested in the development of their highland units, to achieve sustainable productivity gains. Most of the highland blocks (village blocks) selected for development under this programme, were in the upper slopes of the micro-watersheds of small tank system or part of a meso – watershed of a cascade system, and generally, these highland lots were therein early stage of degradation. Cultivation being practiced on these highlands is non-innovative; and hardly any system approach is used in the production process. The present subsistent farming practices are generally destructive (Dharmasena, 1991).

Field visits made to sites/villages undertaken for development confirmed that most farm units owned by individual interest group members were failing to achieve the anticipated project objectives; viz: increasing the cropping intensity within the farm units by about 5-15% in Yala and by 10 – 30% in Maha; and achieving a mid and long term sustainability of agricultural production, while increasing productivity.

An Alternative Strategy

It is recognized that highland development – stabilization is essential for conservation and utilization of land in rainfed areas. The erratic rainfall patterns, heavy evapo-transpiration losses, erosion, poor water holding capacity of soils and poor fertility of affected soils are major factors that limit agricultural production. Some of these limitations are tied up with the nature of resources themselves, others are caused by agricultural practices. Since the project activity is spread over a very large area covering 15 DS divisions in the district, the pilot programme is confined to five DS divisions. The selection of sites was conditioned by the availability / limitations of resources, physical and human.

Air photo (1:10000) interpretation supported with topographical sheet (1:63000) was adequate to detect distinct differences of the farming situations. Six farming situations were identified as suitable for intervention. They are (1) Ellapattuwa village in Meda Nuwaragam Palatha (2) Ullukkulama village in Maha-Wilachchiya, (3) Wannanmaduwa village in Tirappane, (4) Nochchikulama and (5) Kele Tirappane in Mihintale and (6) Weragala in Rambewa.

Table 3. Crop Suitability Recommendations as Determined by The Key Resource Limitations /Potentials in the NCP and NWP

Crop Recommendation / Resource/ Resource Potential Limitation Characterizing the Farming situation	No limitations for growing recommended vegetables OFC and other crop	Marginal for leafy vegetables and Tomato good for Brinjals, "Tibbotu" and selected field crops & Hardy and Psedo-perennials under rainfed	Rainfed cropping with soil moisture conservation techniques.*	Good to Moderade for all crops with priority for mechanization good managemernt or less labour intensive agro-forestry /forestry and pasture (grasses)	Marginal for Agricultural crops/suitable for conservation forestry
Soil_- Deep (Gravelly Layer located at a depth > 50 cm)	+ _	+ _	+ _	+ + _ _	_ _
- **Shallow (Gravelly layer located at a** depth < 50 cm & a deep soil profile.)	_ +	_ +	_ +	_ _ + +	_ +
- Soil depth < 50 cm					+
Water supply - Adequate (Rain + Agrowell, >50 m^3 Recharge/day)	+ +	_ _	_ _	+ _ + +	_ _
- Medium (Rain + Agrowell/ drinking water well 50 -25 m^3 recharge/day)	_ _	+ +	_	_ + _ _	_ _
- Rainfalls only	_ _	_ _	+ +	_ _ _ _	_ _
Labour supply					
- No limitation.	+ +	+ +	+ +	_ _ _ _	_ _
- Seasonal.	_ _	_ _	+ +	_ _ _ _	_ _
- Inadequate.	_ _	_ _	_ _	+ + + +	_ +

+ Conditions relevant to the identification of the 'Farming Situation"

- Not relevant

NB : No. limitation of sunlight, wind and temperature anticipated

- Technology – Soil and water conservation
- Conservation bunds/ditches, Strengthen with suitable plant combinations
- Vegetable hedges/mulches
- Stone gravel and sand mulches
- Vegetative strips/dead and controlled growth
- Grassed water ways/Drains
- Organic amendments/ and plant residue management

Land classification criteria of relevance to agricultural production constraints/limitations were developed and matched with the basic growth requirements of the crops to be introduced (Table 3), with improved mangement systems. In that the technology currently available, as appropriate, would be continued with / modifications.

Main consideration in the selection of crop varieties was the varietal protential available for improvement, (yield and quality) and survival under water stress. Aspects underlining soil, water and crop management would be: soil and water conservation techniques (residue management and use of organic manure); control of soil erosion (construction and strengthening of contour bunds, and drains with the establishment of farm income generating crops such as pineapple); water harvesting and weed control.

This strategy was developed with the recognition that the homested unit (front and backyard of the dwelling house) should be developed to enable effective use of resources available within it. For example, those farmers who had relatively easy access to drinking water wells and who preferred to establish perennials and pseudo perennials on their highland blocks during the yala season, were encouraged to established the seedlings in well prepared planting holes by providing minimum irrigation water required. Those farmers who had no access to such a water source were made to establish plants in relatively large polythene containers filled with a suitable growth medium, again, providing minimum water required. Thus, in the latter case, a system for water saving until field planting with the onset of seasonal rains was introduced. This provided a method to use minimum quantity of water, at fairly long intervals, to protect plants grown under dry conditions. While allowing their uninterrupted growth during the dry spell, during June through to September. The new innovations available from research and leader farmer experiences for accommodating the major constraint of water stress through risk management and whole farm planning / management will gradually be introduced to the small farm units.

Innovations to Enhance Cropping Strategy

The land on the upper aspects of catena, where highland dwellings are located on the RBE soils, is mostly marginal for agricultural production. This is a result of loss of both physical and chemical fertility. It is well seen that the poor fertility, is due to inadequate attention given by the farmers to conservation of the soil. Soil erosion has led to degradation of its productivity. Loss of organic matter has contributed to soil dispersion and promoted soil compaction, making it unfavourable for use in agricultural production. Consequently, farmers prefer to cultivate any available state owned scrub land during the Maha season, which is relatively fertile and easy to cultivate; and situated a few kilometers away from their dwellings. The tradition, in many of those villages in the less populated parts of Anuradhapura District (eg. DS division of Maha Wilachchiya, Medawachchiya, Mihintale) is to encroach and continue to cultivate state owned land most of which is scrub land, adopting traditional " chena " practices. The advantages of chena type of cultivation practices compared with the more stabilized system of cultivation are a few; It enables cultivating a relatively large extent of land during the rainy season. Cultivating this land receives high priority of farmers in the district. The

second priority during the rainy season is cultivating the land owned by them and situated around the dwelling. Its cultivation depends on the certainity of the expected rainfall, and therefore not regular or systamatic. This practice is bound to change with the strategy being followed.

Those dweller farmers who can not claim accessibility (ownership) to any state owned scrub lands to cultivate " Chena " give priority to cultivating land situated around the dwelling houses. In these, they are not aware of the need to adopt land use practices for improvement of soil fertility, and management, and sustainability of resources. The attention given to arrest the trend towards degradation of the environment and loss of productivity of the lands is very low and so, the productivity declines. This is a key area which calls for intervention of the project. Such farmers need to be motivated to adopt the correct land use practices.

A scheme has been defined under the pilot programme to encourage farmers to practice methods to improve the physical environment for higher productivity. The initial step in the implementation of the strategy for productivity enhancement and working towards sustainability suggested is the adoption of appropriate soil and water conservation practices (i.e. construction of soil & water, conservation bunds and other suitable mechanical and vegetative means and the use of suitable structures/ system for water harvesting, and where necessary, for storage of rain water).

The introduction of appropriate drought tolerant cultivars and suitable cultural practices to intensify cropping in the area around farmer dwellings. This land mostly is poorly managed and much of it is left fallow even during the rainy season. Here, attention could be given to the cultivation of certain crops which has a high user demand within the region. Many tropical crops, including coarse grain cereals could be cultivated with economic gain on these lands; drought resistant cereals such as Kurakkan could find its suitable place on this land. The interest of farmers is there to cultivate cereals and grain legumes and other subsidiary crops both during Maha and Yala seasons. What is necessary is to provide them with improved crop varieties and technical know-how to do profitable cultivation on small farms.

The availability of lands to some farmer families, exceeding the capacity of family labour is a matter of concern. Shortage of labour impedes better landuse and cultivation pratices. A way out of this situation is to introduce farm machinery and implements suitable for small scale farms. Another alternative may be to promote cultivation of short-aged improved varieties on a large area, benefitting from favourable climatic conditions, thereby reducing the high risks / losses, thus matching the land suitability with crop demands. A less labour demanding cropping system such as agro-forestry and forestry could be introduced. The allocation of land to conservation farming is another possibility.

Selection of crops for cultivation that are agronomically suitable and economically gainful; matching the cropping system with the land suitability; adjusting the production calendar to suit the market demands are being well recognized, particularly in planning

under agrowells. Adjustment of cropping area to suit the availability of labour is being given consideration.

The measures recommended in this paper to improve agricultural production/productivity under small tank system, if adopted, would provide a favourable and sustainable physical foundation for the small farmers to continue to farm in the North Central and North Western Provinces, while improving the resource potential of the small tank system.

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