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CONTRIBUTORS OF ARTICLES

Chandana Jayawardana
BSc Eng (Hons) (Moratuwa), MTech (OUSL), MA (BPU), MIET, MIE (SL), CEng.

Ven. Dr. Medagampitiye Wijithadhamma
BA(Hon) Peradeniya, MA (Kelaniya), PhD (Peradeniya), Rajakeeya Panditha

Dhanesh Wisumperuma
BSc (Colombo), PG Dip in Archaeology (Kelaniya), MA (Kelaniya)

Dammika Hewage
BA

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CONTENTS

Irrigation Practices and Norms in Sri Lanka by the 5th Century CE: A Survey based on the *Samantapāsādikā*

by

Chandana Jayawardana and Ven. Medagampitiye Wijithadhamma

Abstract

One of the key elements of water heritage in Sri Lanka is the ancient water related infrastructure, generally referred to as the 'ancient irrigation system'. The present studies on this system began in the colonial era, especially during the Dutch and later British times. That encounter was not limited to reviewing the existing situation, but attempted to restore it to the original function of the ancient system. In the absence of clear evidence, to identify the original function, colonial designers began to conceptualise a new system with inputs for their own "colonial" knowledge. This paper attempts to resurrect the norms and practices of the ancient system, not based on the colonial interpretations but based on the 5th century Buddhist commentarial work, the Samantapāsādikā. Its validity as a source in this endeavour will be discussed in the study. As the Samantapāsādikā was based on previous Sinhala commentaries (Sīhalaṭṭhakathā), the contents of which may cover a period, at least

from the 3rd century BCE to the 5th century CE. The irrigation related contents as depicted there, are discussed under four key elements, (1) Physical (hydraulic infrastructure, water sources, flows, applications), (2) Agro-productive (soils, crops, technology, capitol, labour, knowledge, skills), (3) Organizational (human organization to govern, operate and sustain the system) and (4) Normative (rules and rights, and obligation related to access).

Beginning from the basic Buddhist injunction that "all the creatures depend on food" (*sabbe sattā āhāraṭṭhitikā*)[1], augmenting the food supply is a basic endeavor in all societies. To achieve this, the focus is on the potential of water availability at appropriate times in appropriate amounts. The natural climatic condition in the Rajarata area of Sri Lanka does not ensure this kind of water availability naturally, which prompted Ievers to write: "It may broadly be stated that without artificial irrigation and storage of water, human existence in North-Central Province would be impossible"[2] and in much recent times, Tennakoon to write: "Because of the rainfall vagaries, rain-fed agriculture in the Dry Zone undoubtedly remains a gamble with a high risk of frequent crop losses. Our then farmers in their attempt to minimize losses because of rainfall uncertainties developed irrigation systems over a long period of time"[3]. Several chronicle and epigraphical records imply the conditions in ancient times. Siriweera[4] summarizing the chronicle records notes that some famines occurred

during the reigns of Dutthagamini (161-137 BCE), Vattagamini (89-77 BCE), Kuncanaga (187-189 CE), Sanghabodhi (247-249 CE), Upatissa I (365-406 CE), Kitsirimegha (551-569 CE), Silameghavanna (619-628 CE), Udaya II (887-898 CE), Parakramabahu II (1236-70 CE) and Buvanekabahu (1278-84 CE). The following inscriptional notes highlight the measures adopted to address this natural phenomenon and augment the water availability.

> ... *ket-kam sulab-koṭ siri-Lak ḷondurvay sā-biya nivay* (by attending facilities for the cultivation of fields by means of tanks, he dispelled the fear of famine in prosperous Lanka), Kashyapa V, 929-939 CE[5]

> ... *gaňg-kaḍ band-vay ... (pä)vät-vū diyen Heḷ-divä dubik* [*nivay*] (he repaired the dilapidated tanks and ponds and by means of the water thus supplied, he put an end to scarcity of food in the Island of Ceylon), Mahinda IV, 1026-1042 CE[6]

> *Bäňdä nī gaňga vävu Siri Lakä da ket karavā siyal diya raňdavā* (having dammed streams and rivers (and constructed) reservoirs, and also having caused fields to be made in Sri Lanka, Parakramabahu I, 1153-1186 CE[7]

> ... *boho äḷa avuṇu vävu bandavā durbbhikśa bhaya duru- koṭä* (he dispelled also the famine by the construction of many canals, embankments and tanks) Nissankamalla, 1187-1196 CE[8]

As above records highlight, the timely availability of water for cultivation was considered as a prime responsibility of rulers, thus paving the way to an irrigation system developed through the centuries.

The present form of studies on this ancient system evolved since the colonial era, especially from the Dutch period. During this period, efforts were made to 'repair and restore' ancient reservoirs like Giants' tank (in Northern province), Mulleriyawa reservoir (in Western province), Kondawatuwana, Kantale, Vendrason, Ampara and Irrakkam reservoirs (all in Eastern province), Bandagiriya reservoir (in Southern province) while works like Kudu villu, Amban villu, (both in Eastern province) and Urubokka (in Southern province) were newly started. During the earlier part of the British period, some isolated attempts, like 'restoration' of Giants' tank and initiating Kirama scheme (in Southern province), were made. It was not until mid 19th century, the irrigation activities acquired some recognition through legal and institutional reforms. In 1856, "Paddy Lands Irrigation Ordinance" was passed, followed by "an ordinance to promote the maintenance and extension of paddy cultivation in this island" in 1861. In 1860 irrigation section of Public Works Department was established. Years 1884 and 1887 marked the formation of Central Irrigation Board and Provincial Irrigation Boards respectively. Officers attached to these institutions as well as the provincial administrative officers recorded their first- hand observations on the ancient system in diary notes,

inspection notes, sessional papers and administrative reports.

The later part of the 19th century marked a new phase of technical documentation, started with the view of 'repairing and restoring' the ancient system back to functionality. In 1896, it was decided to assign the responsibility of the execution of irrigation works to the Director of Public Works. For this purpose, a special irrigation assistant (Henry W Parker) and several junior engineers were added to the Public Works Department. Due to the extended scope and diversified functions, a dedicated institution for irrigation activities, Irrigation Department, was established in 1900. Planning and implementation of major irrigation works were exempted from Government Agents' scope and assigned to technically competent personnel working under the Director of Irrigation. Mere observatory remarks were replaced by technically based material including detailed drawings, surveyor reports, cost-benefit financial analysis, irrigation manuals and hydraulic engineering interpretations. These formed the basis of 'restoring' ancient works as well as interfacing them to the newly designed schemes. However, scarcity of information on the original system would have adversely affected this expedition. Kamaladasa correctly notes:

> When the colonial rulers started exploring this complicated and comprehensive process of resuscitating the irrigation infrastructure in mid 19th century in order to review the system, there was neither written documents for them to refer nor a locally accepted or developed directions or guidance for them to follow. Except the scattered physical

> evidences at the field there was no record available at least giving the basic location data let alone the complicated engineering information.[9]

This narration presents two immediate questions. First, in the absence of written documents, locally accepted or developed directions or guidance, how the colonial designers understood the function of the ancient 'scattered physical evidences'. Second, were such information really absent or merely their presence was not known to those colonial designers, in their attempt to 'to review the system'. For the first question, a possible answer is that the modern irrigation and hydraulic engineering knowledge to which those colonial designers were exposed to, was used to understand the original function of the ancient system. Superlatives and achievements of the ancient system were measured by comparing to what extent it complied with the modern principles. Notions like 'Invention of European type valve pit tower 2100 years ago'[10], Jaya-ganga having 'gradient of 6 inches per mile for the first 17 miles'[11] and finding 'old work and the new are never more than a few feet from one another'[12] emerged as totems of ancient irrigation knowledge and skills, inferring that modern hydraulic principles are the standards according to which the local ancient system should be evaluated.

The answer to the second question is not that straight forward, as even after more than a century from colonial encounter, 'written documents' exclusively dedicated to the ancient irrigation technicalities could not be located. However, the absence of the dedicated literature may not readily imply the absence of relevant

technical information. Although technical literature could not be traced, a large volume of literature that was developed at least from the time of introducing Buddhism in 3rd century BCE is still available. Many religious and historical contents were included in the Sinhala commentaries (*Sīhalaṭṭhakathā*), which were subsequently rendered into Pāli, Later, a series of sub commentaries (*ṭīkā*) were composed either to elucidate the points in the commentaries or to give additional information regarding the discussions in the commentaries. Despite the fact that the core themes of these works cover Buddhism and its practice and history, it is possible to locate an enormous body of information related to technical subjects like engineering, architecture, medicine, etc., embodied therein. Commenting on this possibility, Chintamani and Subbaryappa note:

> A cursory study of some of the Buddhist sources like the *Jātakas* and their commentaries known as *Aṭṭakathas* indicates that they contain not a few scientific idea as well as technological practices which, if critically studied, might throw ample light on the general level of science and technology during that period.[13]

It is in this background, that some extracts of the *Samantapāsādikā* will be discussed in this paper to re-examine the irrigation practices and norms in ancient Sri Lanka. Attempts would be made to address the 'locally accepted or developed directions or guidance' related to irrigation matters which were not available to colonial designers due to the lack of 'dedicated written documents' on the subject. According to Beccar *et al*[14],

conceptualization of any irrigation system should be based on four key elements, (1) Physical (hydraulic infrastructure, water sources, flows, applications), (2) Agro-productive (soils, crops, technology, capitol, labour, knowledge, skills), (3) Organizational (human organization to govern, operate and sustain system) and (4) Normative (rules and rights, and obligation related to access). *Samantapāsādikā* contents on irrigation will also be analyzed under these subtitles as it provides a proper integrated format to cover a system with diversified fields.

Locating the *Samantapāsādikā*

The *Samantapāsādikā* is one of the numerous works of Ācariya Buddhaghosa, the renowned commentator who rendered the then existing Sinhalese commentaries (*Sīhalaṭṭhakathā*) into Pāli in the 5th century CE. The mere fact that some non-religious material available in Sinhalese commentaries does not imply that such material is applicable to Sri Lanka. At least three possibilities could be presented in this regard. Firstly, as the commentaries were considered to be introduced to Sri Lanka by the Arahat Mahinda himself, the non-religious material should be of Indian origin. Secondly, as the commentaries were translated into Sinhala at the time of Arahat Mahinda (3rd century BCE) and handed down in the same language till the 5th century CE, there were ample opportunities of accumulating Sri Lankan information into the commentaries. Describing the methodology adopted in rendering Sinhala commentaries

into Pāli, Ācariya Buddhaghosa says in the introductory verses of the *Samantapāsādikā*:

> "And in commencing the exposition, I shall practically base it on the *Mahā-aṭṭhakathā* as well as the *Mahāpaccariya* without discarding the relevant statements and the rulings given in the recognized commentaries such as the *Kurundi* and thenceforth I shall proceed with the correct exposition of the Tradition of the Elders embodied therein"[15].

If that was the case, the Sri Lankan information should also be available in commentaries as we see today. This is the background in which recent studies by Adikaram[16], Rahula[17], Ellawala[18] and Gunawardana[19] exclusively used commentarial contents in their efforts to reconstruct the religious and social history of Sri Lanka. Thirdly, considering the extensive foreign relations that existed among the Asian societies prior to the 5th century CE, and the possibilities of knowledge transmissions thereon, the non-religious material in commentaries may not be able to restrict to any particular locality but a representation of secular knowledge in the region.

These possibilities compel us to observe due care when considering irrigation related information in the *Samantapāsādikā* in the Sri Lankan context. Another limitation in this respect would be the core theme of the work. Being a commentary on the disciplinary code of Theravada tradition and composed with the monastic readership in mind, the contents may only cover the irrigation practices under monastic control and not

present a general scenario. One obvious measure to address these aspects is to subject the *Samantapāsādikā* contents for further scrutiny under the findings of ephigraphical, archaeological, literary material and other historiographical studies. These would provide the necessary corroborative evidence to generalize findings from the *Samantapāsādikā* to the Sri Lankan scenario and broader irrigation norms of the time. The sub commentaries mark a valuable contribution in this expedition.

There are three sub-commentaries written on the *Samantapāsādikā*: (i) *Vajirabuddhi tīkā,* which is considered to be written by Ven. Vajirabuddhi in the late 11th or early 12th century, (ii) *Sāratthadīpanī*, work of Ven. Sāriputta, of the fraternity of Dimbulāgala Mahākāśyapa, composed soon after the convocation held in 1165 under the patronage of Parākramabāhu I (1153-1186 CE) and (iii) *Vimati-vinodhinī* which was authored by Ven. Kassapa, whom the *Sāsana-vamsa-dīpa* calls a poet of the Coḷa country, but regarded in Burma as a native of Ceylon.

In this paper, the irrigation related matters will be discussed under four topics, physical, agro-productive, organizational and normative, the categorization proposed by Beccar *et al* as discussed above. Other chronicle, ephigrapical and literary material will also be addressed parallel to the *Samantapāsādikā* contents, so that its historical validity could be further established. Modern irrigation practices and socio-technological aspects in large will also be considered where necessary,

to highlight the similarities and deviations in the past and present.

Contemporary Irrigation Scenario

As the study is based on 5th century CE work, it would be appropriate to consider the contemporary status of irrigation at least briefly. Studies by Nicholas[20], Brohier[21] and Gunawardena[22], summarized the irrigation works that were in existence by that time based on the chronicle and ephigraphical records. Accordingly, apart from the minor works and storage, they occupied the Anuradhapura city complex (Abhaya väva, Tisā väva and Nuwara väva), there is no sufficient evidence available to conclude that there were major irrigation works before the 1st century CE. However, records on larger scale works begin to appear by the 1st century CE which include damming of perennial rivers (Amban Gaṅga diversion at Äḷahära) and larger reservoirs like Mahavilacciya, Mānakäṭṭiya, Noccipotana, Hirivaḍunna and Nāccadūwa.

During the 3rd century CE, Äḷahära canal was augmented to feed the newly constructed Minnēriya väva. The Kavudulla väva, Vāhalkaḍa väva and Hurulu väva were constructed by damming the Kavuḍulu Oya, Yān Oya and Tavalam Halmillava Oya respectively. Inter-reservoir canal was built connecting the Minnēriya väva and the Kavuḍulla väva. In addition to the Mahaväli-Amban Gaṅga complex, Mahaväli waters were further tapped downstream via Pabbatanta äla, feeding the Dimbulagala area. The Kaṇadarāva väva, fed from

Kaṇadarāva Oya, and some tanks, utilizing the tributaries of the Däduru Oya at north-western plains were also constructed during this period. During the 5th century CE, major works at Kalā Oya basin took shape by combining the Kalā väva and the Balalu väva to form the composite water storage. The inter-basin canal, Jaya Gaṅga was constructed connecting the Kala väva and the Tisa väva at Anuradhapura which also fed an intricate network of small canals in between. The Malvatu Oya was further tapped to feed the Yoda väva and the Akattimurippu tank in the Mannar district. Further to works mentioned above, some small, medium and large scale works are mentioned in the chronicle and ephigraphical records.

This array of irrigation works should represent only the discovered and the listed lot. As such, this does not serve much purpose in locating the irrigation scenario by 5th century CE, other than highlighting the broader view of technical capabilities at the time. The irrigation enterprise had developed to divert perennial rivers which included the Mahaväli – Amban Gaṅga and Däduru Oya basins and damming several other non-perennial rivers like Malvatu Oya, Kalā Oya and Yān Oya. Apart from the diversions, inter–basin canal systems were also in operation augmenting the major storage facilities and feeding network of small tanks. It could be safely assumed that by the 5th century CE, the irrigation scenario in Sri Lanka possessed the basic potential of developing into an advanced state of an interconnected system. Therefore, any snapshot view of that scenario would reveal valuable information

regarding the irrigation system in Sri Lanka, the task attempted in sections to follow.

Physical Structures

- Water storage

Before going into details, it should be clearly demarcated the scope of irrigation as illustrated in the *Samantapāsādikā*. Both normative and physical exposure shed some light in this direction. Being a text dedicated to the discipline of the Saṅgha, the *Samantapāsādikā* should basically cover the irrigation works related to monasteries. As concluded by Siriweera[23], these should be only minor scale irrigation works and not major infrastructure of which the operation and maintenance would have been under the state control. The technical and economic exposure as evident in the *Samantapāsādikā* would only be limited to the field level water users and their immediate suppliers. If the storage is small tanks, then the other irrigation works should not be extended to the structures like large reservoirs, trans-basin canals and their associated hydraulic structures. Therefore, the following sections only illustrate the context of minor irrigation works, i.e. field level utilities and their immediate supply storages.

The rainfall in the area, generally referred to as dry zone of the island is confined to about four months. Except the Däduru Oya, Mahaväli Gaṅga and the Valavē Gaṅga, other rivers flowing across the region do not receive a continuous flow of water throughout the year.

The nature of the dry season in this area is expressed by Nicholas[24],

> "During the annual drought the temperature rises, the grass turns to stubble and the vegetation becomes parched, the smaller tanks shrink to muddy pools, the streams and watercourses run dry, and the larger rivers, except the Mahaväli Gaṅga and the Valavē Gaṅga, are reduced to trickles or break up into disconnected pools."

It is not certain whether the same climatic conditions prevailed in the 5th century CE, but the *Samantapāsādikā*'s following passage indicates some resemblance. There, watercourse which amounts to a 'river' is defined as:

> During the reign of righteous rulers, it would rain once a half month or ten days or five days. When it rains in this manner with preferred amounts, if the flow in a stream ceases as soon as the rain stops, that could not be treated as a river (*nadī*). If the water flow in a stream prevails during the four months of rainy season (*vassānassa cātumāse*), wetting two inches of a *bhikkhuni*'s attire, covering *timaṇḍala*, then that stream could be treated as a river.[25]

A part of the water received from rain enters into natural flows. According to the *Samantapāsādikā,* only continuous flows for more than four months could be categorized as a river (*nadi*). The streams with flows less than four months would have been non-perennial, which quickly carry off heavy fall of rain and then become dry afterwards.

Water thus received either directly from rain or stream flows need to be captured, stored, maintained and

distributed in an appropriate manner to assure a reliable supply of water for human requirements, specially for cultivation. The starting point of this flow is *talāka*, (hereafter 'tank'), the immediate storage before field level. Some topographical observations would have been prerequisite when locating suitable sites for tanks. The *Samantapāsādikā* indicates to this effect:

> Even without a ridge (*pāḷi*), a large tank (*mahato taḷāka*) retains a certain amount of water. When a ridge is constructed, the water which was not retained due to the unavailability of a ridge also retains.[26]

Apart from such topographical surveys, adherence to some geophysical investigations is also noted:

> In the region of Hatthikucchi, a basket full of soil (*paṭhavi*) was taken and washed in a trough and observed it was consisting large amount of stones (*sakkharā*). *Bhikkūs* themselves excavated a pond (*pokkharaṇiaṁ*) there.[27]

Recent observations emphasise the *Samantapāsādikā*'s above concerns on the geophysical settings. Parker[28] and Blair[29] observed that the natural rock formations were selected to form the foundations of the embankments of large reservoirs like Mahāgalla and Kavuduluväva. Pattiarachchi[30] commenting on the foundation profiles of some ancient tanks, both large and small, notes that they follow the geological strike of the country rocks. Citing several reservoirs, Giritalē, Minnēriya, Sorabora, Galgamuwa, Maha Usväva, Karangahavela, Tungiriya and Mayalanvela, Pattiarachchi concludes that the ancients assured the continuity of rock types for the foundations of the tank bunds. Although the reference in

the *Samantapāsādikā* was for a pond (*pokkharani*), dam construction of any water retention body would have been after a rational and systematic study, rather than primitive trial and error methods.

- **Spillways**

Water releasing either to canals or to natural streams from the tanks are made through spillways or sluice works. Spillways provide the capability to release high flow rates during floods without damage to the embankment and appurtenant structures. The *Samantapāsādikā*'s notion to this effect:

> If any person closes (*pidahati*) the spill (*udakanibbahana),* the place where the embankment (*mariyāda*) is weakened in order to protect the tank (*taḷāka*),... and that leads to breach the embankment, then the damage ... is considered to be incurred by that person himself[31].

And,

> If any person closes (*pidahati*) the spill (*udakanibbahana)* of a dried up tank (*sukkhataḷāka*) where the embankment is weakened ... and water flows during the rainy season and breaches the embankment (*mariyādaṁ*) ... that person has committed the offence of *bhaṇḍadeyya*[32].

Accordingly, it appears that a control structure combined with a breaching mechanism was used as spillway. A particular section of the embankment would have been constructed in such a way that the excessive pressure due to the water, breached that section, and

water was released safely. However, elaborating on this passage in the *Samantapāsādikā*, *Vimati-vinodhinī* notes:

> *nibbahana udaka* means the excess water (*adhika jalaṁ*) that is discharged at a lower elevation of the tank (*taḷākassa ēkēna uttanēna passena*)[33].

And to the same effect, the *Sārattha-dipanī* notes:

> *nibbahana udaka* means the water discharged through a side, in order to protect the tank (*taḷāka*) by keeping the embankment un-damaged (*mariyādaṁ achinḍi*), when floods (mahodakaṁ) follows in[34].

Most probably, a dedicated structure would have been provided by the time of the *Vimati-vinodhinī* and *Sārattha-dipanī* for spilling water, contrary to the *Samantapāsādikā* notion of weakening embankment. This may indicate a change in spillway technology in Sri Lanka from the 5th century CE to 11th century CE.

- **Outlets**

Another important notion in the *Samantapāsādikā* regarding the water releasing from the tanks is its reference to sluice mechanism:

> An openly accessible (*sabbasādhāraṇa*) main canal (*udakavāhaka*) ... is fed from a *tumba* type sluice (*niddhamanatumba)* of an openly accessible main tank (*mahātalāka)*[35].

And,

> If any person ... closes (*pidahati*) the *tumba* type sluice (*niddhamanatumba)* ... and the flow thus created breaches the embankment (*mariyādaṁ*), then the damage ... is considered to be incurred by that person himself[36].

The *Vimati-vinodhinī* sheds some light on understanding the construction features and function of *udakaniddamanatumba*. Accordingly:

> ***niddamanatumba*** means the pipe (*paṇāli*) made out of materials like bricks (*iṭṭhakādīhi*) through which water is released for cultivation (*sassādīnaṁ*)[37].

Several literary works subsequent to the *Samantapāsādikā* elaborate the meaning of Pāli words *udakatumba*[38] and *niddhamana*[39]. Amalgamating those references to form a generalized interpretation, *udakatumba* and *niddhamana* could be considered as 'a vessel with openings at both top and bottom' and 'path of water flow through a sluice' respectively. As such, *niddhamanatumba* should mean a sluice consisting of series of water vessels. The control of water flow would have been achieved by a plugging devise inserted into the upper most unit. Unlike the sluice type generally known as *bisōkotuwa* sluice, the water released through this type of sluice is from the surface of the live storage. The importance of this methodology is recently noted by Madduma Bandara *et al.*[40]. Accordingly, the top water surface of the tank is least affected by the salinity and drawing such water to field will not degrade the field soil condition. This may be one contributing factor for the sustainability of those ancient lands for several centuries.

On the contrary, the most modern mechanical sluices have been designed to convey bottom saline water from tanks, thus salinity accumulates in the fields degrading the soil condition.

Another type of water release mechanism mentioned in the *Samantapāsādikā* is the *udakaniddhamanapanali*:

> If any person ... closes (*pidahati*) the *tumba* type sluice (*niddhamanatumba*)... and the flow thus created breaches the embankment (*mariyādaṁ*), then the damage... is considered to be incurred by that person himself ... The same applies to a person who opens the *panāli* type sluice (*niddhamanapanālim*)[41].

Further elaboration on this sluice arrangement could not be found in the sub commentaries making room for only a conjectured opinion. As the term *panāli* means a tube, this might be a horizontal outlet devise again closed by a plug from the tank side. Alternatively, *niddamanatumba* and *niddhamanpanli* might have formed the horizontal and vertical segments of a composite discharge structure, where both could be opened or closed from the tank side. When the water level is high, water is discharged through the *niddamanatumba* (the vertical segment) and as water level decreases and reaches the minimum tank level, *niddhamanapanali* (the horizontal segment) would have started to discharge water.

- **Water distribution**

From tanks, water is released to main canals and from there to secondary canals:

> An openly accessible (*sabbasādhāraṇa*) main canal (*udakavāhaka*), is excavated passing through different provinces (*janapada*). This canal is fed from... an openly accessible main tank (*mahātalāka*). From this main canal, secondary canals (*khuddaakamātikā*) are drawn out and at the end of those secondary canals, water holes (*āvāṭa*) are excavated for the use by individuals.[42]

Considering the two main types of canal layouts, bifurcating and hierarchical system, it is evident that the above notion closely resembles the latter. An interesting feature of this layout is the existence of water holes (*āvāṭa*), owned by individuals at the tail end of secondary canals.

In contrast with other infrastructure systems, modern irrigation is characterized by the strong dependency of the users on the supply authorities. Users of most infrastructures such as drainage, roads, domestic water supply, electricity systems, etc., can make use of the system deliveries at their discretion or at least, the system is designed in a manner which facilitate such usage. However in most cases, the user of irrigated water is dependent on the supply authorities with regard to frequency, period and quantity of water release. Horst notes this dependency occurs at two levels[43]. Firstly, at group level where the individual farmer is dependent on the group members and secondly, the group as a whole depends on the operation of the major system mostly

governed by the authorities. From the *Samantapāsādikā* contents alone, it could not be concluded the social relationships between these parties existed in the 5th century CE. However, from a technical point of view, the existence of individually owned water holes, and hence buffer water stocks would have made the users more independent from the co-farmers as well as from the major systems in their water utilization patterns.

As the water flows through the irrigation canals (or natural streams to that matter) under the force of gravity, the elevation at the head end of the canal must be higher than the command area. In some instances, the level of the stream from where the canals get water may be below the canal bed level. In such instances, weirs (or barrages) are constructed across the stream to raise the water level so that the water can be diverted to the canal. The *Samantapāsādikā* provides evidences of this type of water diversion:

> If the river (*nadi*) or a canal (*mātikā*) starting from the river, is dammed (*āvaraṇaṁ karonti*) using wood and if the water still flows through it, then at such locations, the *kamma* could be performed. If the water flow is fully ceased either by a dam (*āvaraṇa*) or by constructing an enclosure (*koṭṭaka*), then at those locations where the water is not flowing, the *kamma* should not be performed[44].

Another method of diversion from streams to canal is by the construction of a dam across a stream and impounding the water. The *Samantapāsādikā* mentions this type of diversions also:

> If a tank (*taḷāka*) is constructed by ceasing the river flow or a ridge (*pāli*) is constructed at the downstream and if the incoming water fills the tank, *kamma* should not be performed there[45].

- **Water lifting mechanisms**

Machinery for raising water from one level to another was an operation of immense importance in any civilization based on irrigated water supply. The *Samantapāsādikā* indicates the existence of at least three implements used in this encounter:

> *tulan* is the balance used for lifting water, similar to the one used by the people who are weighing leaves. *karakaṭaka* is the implement, in which a long rope is pulled either by cattle or by hands. *cakkavaṭṭaka* is the *arahaṭaghaṭiyanta*. *cammakhaṇḍaṃ* is the leather container which is applied in the balance or in *karakaṭaka*[46].

The balance mentioned in the first type should not be an equal arm type, but a different arm balance, indicating the existence of well-sweep type (counterbalanced bailing bucket) water lifting mechanism. A long pole is suspended or supported at or near its center, and while one end is weighted with a stone, the other carries the bucket at the end of a rope. This forms one of the oldest and simplest mechanisms which lightened the human labour of dipping, carrying and emptying buckets.

The second reference in the *Samantapāsādikā* indicating the water lifting mechanisms is *karakaṭaka*, in which a long rope with a leather container is used, pulled by either human or animal power. This should be a rope

and bucket arrangement where rotary motion came in with the pulley or drum set at the opening of the well. This may possibly related to the water lifting methods known as *nasba* in Iraq or *mote* in India. It is a modification of the well-bucket used in irrigating on river-banks, in which an animal pulls up a leather container, so arranged that when the desired height is reached it discharges through an open limb. That is being kept suspended (and therefore closed), when at lower levels, by a subsidiary rope.

Third type is *cakkavaṭṭaka,* for which the *Samantapāsādikā* narrative is very limited, only describing as *arahaṭaghaṭiyantaṃ.* However, the *Vimativinodhini* further explains the meaning of *arahaṭaghaṭiyanta* as:

> *arahaṭaghaṭiyanta* means a mechanism (*yantaṁ*) having wheel (*cakkasanṭhānaṁ*) with many spokes (*anekāraṁ are are*) to which small pots are attached (*ghatīkāni banditvā*), rotated by single or double means (*ēkēhi dvīhi vā paribbhamīya*).[47]

This should be the peripheral pot wheel water lifting powered by men or animals through rotary motion. The phase 'single or double means' may suggest the centre drum of the wheel was fixed either with one or two cranks to facilitate the motion power. The origin of peripheral pot wheel (*noria*) was assigned to various localities in various studies, Laufer[48] to Sogdiana (Central Asian Persia) and Pagliaro[49] and Forbes[50] to

Greek. Needham[51] referring to early Buddhist literature conjectures *noria* to Indian origins. The above contents in the *Samantapāsādikā* strongly support this conjunction and prompt us to conclude that the power driven rotary motion would have been a common phenomenon in Sri Lanka also by the 5th century CE, at least in the context of water lifting.

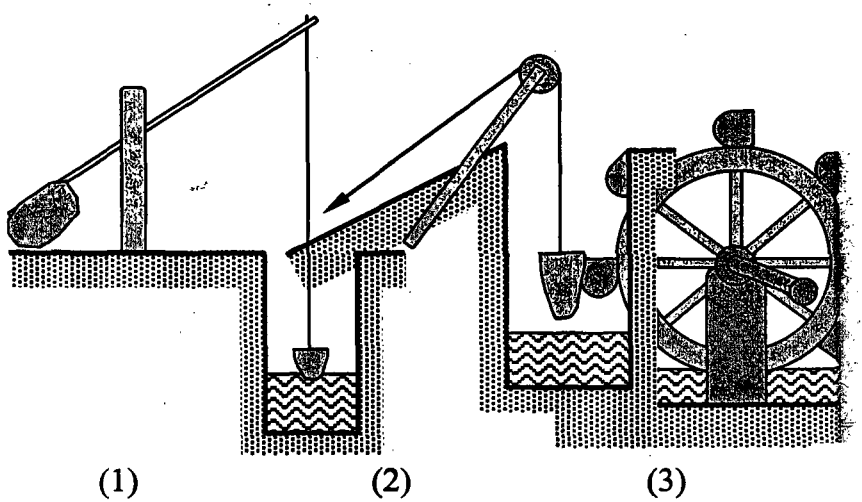

Figure 1: Water lifting mechanism as detailed in *Samantapāsādikā*
(1) *tulan*: well-sweep (2) *karakaṭaka*: rope and bucket arrangement and
(3) *cakkavaṭṭaka*: peripheral pot wheel

These revealings point to two important areas in studying history of technology in Sri Lanka: ground water utilization and power driven machinery. Archeological remains as observed by Brohier[52] at

Kudiramali, a head-land situated on the north-western coast between Puttlam and Manaar supplements the evidence for ground water harnessing in early times. There, some remains of a well (*urā-lin*) made out of clay cylinders were found. These cylinders, perfectly round in shape, about 18 inches in height and 1 ¾ inches in thickness, have been baked to a cast-iron hardness. The upper end rounds off at the rim and of 3 feet in diameter; the lower edge finishes off in a flat rim and is about 3 feet 3 inches in diameter. Consequently, when each cylinder was fitted on to the one below it, the well maintained an average diameter of three feet throughout in construction. Although Deraniyagala[53] dated these remains to the 11th century CE, much later than the time covered by the *Samantapāsādikā*, these remains would represent a tradition continuing from ancient times.

Pacey[54] notes that there are no reports of machines with gears, pulleys, cams or cranks before 1200 CE available at India or at Southern Asia. Therefore, despite the presence of some water-raising wheels and simple mechanical devices for lifting water, the South Asia was noted as a machine prone region in ancient times. Such suppositions should now be reviewed in the light of the *Samantapāsādikā*s comments noted above, according to which, the utilization of wheels, pulleys and possibly cranks in Indian and Sri Lanka societies should go back to 5th century CE and most probably, much earlier than that.

Ago-Productive Elements

Agriculture would have been the first encounter that required man-soil interfacing. Since then, physical properties of soils became a matter of interest and frequent attempts were made to classify the soil types according to their characteristics, in order to solve the practical problems. According to Brady[55], early soil classifications were limited to 'good' and 'bad' for agricultural purposes or based on the textural features. The Chinese, Egyptian, Greek and Roman societies acknowledged differences in soil as media for plant growth, a practice which is still continuing as 'cotton', 'soybean', 'wheat' or 'rice' soils. The modern era of soil sciences started in the late 19th century, spearheaded by the Russian school under the guidance of soil scientist V.V Dokuchaev. Their findings were then transmitted and promoted in the United States also under the leadership of C.F Marbut of the US Department of Agriculture in the late 1920's and since then subjected to many developments.

According to the contents in the *Samantapāsādikā*, it is evident that some form of soil classification techniques were in practice before the 5th century CE in Sri Lanka:

> *appapāsāṇā* means less stones. Here the stones are those with a size larger than a fist (*muṭṭhippamāna*). The stones having the size of a fist are named *sakkharā*. *kaṭhalā* means the debris. *marumbā* means gravel. *vālikā* means sand. *yebhuyyena paṁsū* is the composition having two thirds of soil (*pāṁsu*) and one third of stones (*pāsāṇa*)[56].

And,

> *ye buyyena sakkharā* means the ground with large amount of stones with the size of a fist[57].

Relevant, but a slightly different classification could be noted in the *Sikha vaḷaṅda hā sikha vaḷaṅda vinisa*, 10th century CE Sinhalese literary work:

> Here the earth is threefold, [first] the earth containing white soil (*sudu pas*) and white clay (*sudu māṭi*); [second] the earth containing less sand (*mada väli*), gravel (*hakuru*), rocks (*pahaṇa*), stone debris (*kaḷasakalā käbiliti*), more soil (*boho pas*) and clay (*māṭi*); [third] the earth containing more clay (*māti räs*) and more soil (*pas räs*) [which retains water for] four months after raining for one day. All these three types of earth should not be excavated. The earth having two thirds of sand and one third of clay could be excavated[58].

The fact that soil classification details appearing in the above texts, supplemented by the remains of ancient irrigation and mega construction works where the soil characteristic of the site should have played a prominent role, prompts us to investigate the possible soil taxonomical knowledge that existed in those times. The *Sikha vaḷaṅda hā sikha vinisa* and *Jātaka aṭuvā gāṭapadaya*, another Sinhalese literary work in the 12th century CE, demonstrate a knowledge field named *vatthu vijjā* in following terms:

> *vatthu vijjā* means the science (*vijjā*) of knowing excavation sites for wells (*liṅdu*), ponds (*pokunu*) and home-gardens (*gevatu*).[59]

> *Vatthu vijjā* means the science (*vidyā*) of knowing soil characteristic (*bim lakuṇu*)[60].

The *Jātaka aṭuvā gāṭapadaya* further demonstrates the scope of the professional, *vatthu vijjācariya*, the Pāli equivalent of Sinhala term *vāstuvidyācārya* as:

> *vāstuvidyācāryayo* means the masters (*āduru*) who are engaged in *gruhavastu* and *ārāmavastu* and also exploring the soil characteristics (*bhūmi lakśaṇa*) like the colour of clay (*māṭiyehi pähä*) and knowing the soil characteristics up to the depth of six cubits (*sariyanekhi*) at the least and eighty cubits (*asūriyanekhi*) at the most[61].

Therefore, it is obvious that the knowledge field *vāstu* transcended the architectural element of building constructions, as the term is translated today, but covered the knowledge of soil investigation as well. Although the above narrations confirm its existence in the medieval times, they would have been developed since early times stamping its mark on the *Samantapāsādikā*.

Operation and Maintenance

- Tank de-siltation

The siltation of any reservoir not only causes reduction of storage capacity, but also alters the tank bed geometry. One method adopted to improve the capacity is by raising the spill and the reservoir embankment, which creates a shallow water-body spreading over a larger surface area. Some of the implications of this strategy in Sri Lankan setup 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 regions and the grass cover underneath; and (e) disappearance of some indigenous fish species, which cannot survive in shallow waters or not finding a favorable breeding environment[62]. An alternative would be the de-siltation of the reservoir bed and remove the silt accumulated there periodically. However, due care should be exercised as otherwise this may result in some further complications. Fresh silt deposits on the entirety of the tank bed, at all levels over a period of time. The seepage of water tends to drag the finer particles of the silt into the spaces between the existing soil particles, and consequently reduce the porosity of the soil. This incoming silt continues to form a thicker water-penetration-resistant membrane, the effectiveness of which increases with time and thereby helping to conserve water. Removing this silt in order to increase the capacity of the reservoir would destroy this very valuable low permeability membrane. Therefore, it is important to distinguish the portion of accumulated silt to be removed and the portion which should be left untouched. It appears that the same problem was addressed by our forefathers and the procedure adopted there is noted in the *Samantapāsādikā*:

> The watery mud (*tanukakaddama*) which could be removed using the pots, should be removed by the people who clean the pond (*pokkharaṇiaṁ*). The dried mud (*sukkhakaddama*) should not be removed. Dried mud ruptures. Mud which is not connected with the underneath ground (*heṭṭhā paṭhviā asambandho*), could be removed. Silt (*udakapappaṭaka*) deposits where the water flows. It is shaken by the wind. It should be removed[63].

- **Irrigation maintenance**

Apart from silt accumulation in tank beds, the buildup of silt and debris would choke the canals and prevent the water flow to fields. This calls for periodic cleaning and the methodology adopted according to the *Samantapāsādikā*:

> When the water is not required by the users, water holes (*āvāṭa*), secondary canals (*khuddaakamātikā*) and the main canal (*udakavāhaka*) are cleaned and then *tumba* type sluice (*niddhamanatumba*) is opened[64].

These notions highlight the rationality adopted in the ancient irrigation maintenance strategies which are not known in modern practices.

The dissipation of kinetic energy in the flowing water and the prevention of erosion and damage to the irrigation structures is a challenge frequently encountered by the designers. In general, kinetic energy, i.e. energy due to the velocity of the flow, is dissipated either in the vertical or the horizontal direction or both by incorporating structures, specially designed for the purpose. But in ancient practice, it appears this was addressed by increasing the horizontal movement of water and thereby minimizing the slope and the increased surface roughness. If the canal path is straightened, this effect could not be realized hence prohibited:

> If the canal (*mātikā*) was straightened with the intention of breaching or spilling the embankment (*velaṁ*), then the

offence of *pārājika* is committed. If the dried up canal (*sukkhamātikā*) was straightened and the embankment breached or spilled due to the water flowed subsequently, then the offence of *bhaṇḍadeyya* is committed.[65]

Apart from the above, several other actions have also been prohibited which may cause damage to embankment if performed:

If any person summons cattle weakening the embankment (*mariyāda*) or promotes the village children to do so, if those cattle damage the embankment by hoof, ... or promotes the village children to do so or instruct the village children to play in the water or scares the ones who are thus playing or cut down a tree inside the water or make someone else to do so, if the waves formed by those means damage the embankment, ... If any person closes spill (*udakanibbahana),* ... or closes the *tumba* type sluice (*niddhamanatumba)* or makes another water course to enter or constructs a ridge (*pāli*) to that effect or straightens the canal (*mātikā*) or breaches the tank belonging to himself at the upstream and the flow thus created breaches the embankment, ... the damage by all these means is considered to be incurred by that person himself. In all such cases, action has to be taken by considering the amount of water thus drained. The same applies to a person who opens the *panali* type sluice (*niddhamanapanālim)*[66].

If any person obstructs the spill (*udakanibbahana)* of a dried up tank (*sukkhataḷāka*) where the embankment is weakened or obstructs the *tumba* type sluice (*niddhamanatumba)* or constructs a ridge (*pāli*) across another course or straightens the dried up canal (*sukkhamātikā*), then the water flows during rainy season and breaches the embankment, in all such cases, that person has committed the offence of *bhaṇḍadeyya*[67].

> If any person demolishes the embankment (*mariyāda*) of a dried up tank (*sukkhavāpi)* up to the base and if the water flows in during rainy season drains out, that person has committed the offence of *bhaṇḍadeyya*[68].

The implications of some of these actions were well noted in recent times when Parker[69] records the possible cause of Panda *väva* embankment breach in the early years of the 19th century:

> The final breach in the embankment was made in the early years of the last century, and its history is instructive as showing how many other great reservoirs in Ceylon may have burst. According to the information which I received, a track made by cattle that crossed the embankment had become worn down into a deep hollow which was left unfilled. The natural consequence of such neglect followed. A sudden and extremely high rise of the water, following a very heavy rainfall, caused its level to mount up during the darkness of a rainy night until it overtopped the low place; and when the daylight broke the embankment was found to be completely breached at the spot, and the reservoir was empty.

Various efforts were undertaken during the colonial period to avoid recurrences as found in the archival documents:

> The cattle nuisance and damage on Nachchaduwa Tank bund and the high level channel bund persists. Cattle seizures and prosecutions have previously led to violence and it was decided some time ago not to resort to these methods to preserve the Irrigation works from damage. Specific cases of any considerable damage should always be reported immediately to the Government Agent with a request for action on his part whereby the expense and

> repeated waste of money in repairing damages could be avoided[70].

And again,

> In my opinion, the net result of providing cattle crossings over channels and bunds, buffalo wallows, and fending at a few places will practically be nil unless these measures are supplemented by strong action by revenue officers in enforcing their powers of cattle control[71].

This should be the kind of occurrences which were aimed to be avoided by regulations as highlighted above.

- **Irrigation Developments and Social Movements**

Development patterns in ancient irrigation have been discussed in various studies under both technical and social aspects. In technical aspect, Brohier[72] (later referred by Needham[73]) hypothesized a four stage theory where the large reservoirs were presented as a development stage of small village tanks. Accordingly, it was noted that the small village tanks were replaced by the large reservoirs once the hydraulic skills were developed. Mendis[74] refuted Brohier and presented a seven stage theory, noting that the large reservoir stage was a result of the invention of (*sorrowa*) with its access tower (*bisokoṭuwa*). The social element of this development pattern was discussed by Leach:

> Once a village and its tank have been constructed, it is there forever and since the irrigation area must always remain the same size, the population of the village itself can only vary between very narrow limits. Such a situation of enforced *physical immobility* [emphasis mine] lends itself to the development of social arrangements whereby

> the population of neighboring villages stand in fixed socio-economic relations one with another[75].

Gunawardana refutes Leach's above ideas when he says:

These comments may apply to the dry zone after the collapse of the main complexes of irrigation works, but, in the period up to the thirteenth century, the development of irrigation spread over a long time would have *progressively extended* [emphasis mine] the area under cultivation and also contributed to its greater exploitation[76].

Above technical and social aspects of irrigation development would have been based on the present remains of the ancient system and modern social settings, which may not fully mimic the ancient scenario. The following lines of the *Samantapāsādikā* marks a pointer to understand the ancient setup in its undisturbed pure form:

> If any person, seeing the water in excess (*atibaum udakaṁ*) at the tank (*taḷāka*) diverts the canal (*mātikā*) by side or at the upstream or clears the forest and makes fields or takes additional to the normal share (*pakatibhāga*) used to be received from the previous cropping and requests *kahāpana* and receives *kahāpana* from the new crops which were coming from the newly cultivated fields, then all these actions are not acceptable.[77]

Accordingly, the extension of the command area was not allowed even the water was available in excess. For a single tank, several factors would have contributed to

this stand, such as limitations of reservoir hydraulic head, topographical obstacles to the extended open channel distribution, water right issues, problems with increasing channel capacity, etc. But promulgation as a rule suggests a broader perspective not limited to a single tank, but covering irrigation enterprise as a whole. If the population in a village reaches the limits of its sustainable capacity but still the water is available in excess, a new village with a new tank would have been setup, rather than augmenting the existing tank–channel–command area capacities. This may be the driving factor which gave rise to extensive village tank network to occupy the Rajarata plains in cascade form, making the modern irrigation engineers to comment "the small village tanks, like the village cattle are far too numerous for efficiency."[78] This form of development makes Leach's *physical immobility* hypothesis as well as Gunawardana's *progressive extension* hypothesis only partially applicable. While ensuring the social mobility, the web of small tanks would have facilitated the formation of cohesive user groups (villages) capable of managing irrigation facilities in a decentralized manner. Further, this phenomenon negates the product development pattern described by Schumpeter[79], as the 'gale of creative destruction' ('S-curve of technological progress' in recent literature). There new products make old products obsolete and in turn themselves become obsolete as result of the lure of profits. May be Brohier's four stage hypothesis was fueled by this array of thinking, but the above *Samantapāsādikā* notation discards its relevance in Sri Lanka's irrigation development strategy.

Normative Aspects

Treating rain as a human related activity has previously been noted. The idea was that the virtues of the people, especially the ruler of the land, prompt the deity of rain cloud to bestow rain on the lands. The *Samantapāsādikā* notes to this effect:

> During the reign of righteous rulers (*dhammikānaṃ rājūnaṃ kāle*), it would rain once a half month (*anvaḍḍamāsaṃ*) or ten days (*anudasāhaṃ*) or five days (*anupañcāhan*).[80]

Many references are available in this regard in the chronicle literature and also in subsequent works. Sri Sangha Bodhi (300-302 CE) on being confronted by a severe drought, seated in the courtyard of the Mahā Thūpa at Anuradhapura resolving that he would rise only if he would be raised up by the water that the god shall rain down (*Mhv.* 86.76). Upatissa I (368-410 CE) is said to have a recital of Buddhist *sūtras* during the time of a famine, in order to induce gods to make rain (*Cv.* 37.189-98). Vitharana[81] summarizes some of the literature where similar references available, *sulaṅga valā äti devi*, 'the deity in whose position are the winds and the clouds' (*Dhampiyā Aṭuvā Gäṭapadaya*[82]); *väsi valā devi* (*Butsarana*[83]; and *vässa valāhaka dēvatā* (*Pūjāvaliya*[84], *Pansiya panas jātaka pota*[85], *Saddharmālankāraya*[86]. As noted by Tennakoon[87] this line of thinking, i.e., the rain in right time is an act of supernatural powers, is still persistent among the village folk.

With such perceptions on rain, the possibility of assigning private ownership to water is very remote. But that is so as long as human requirements of water only depend on natural precipitation. Once supplemented by the irrigation, that irrigated water ceases to be God given 'everyone's' share and becomes 'someone's' property. Such property rights assigned to irrigated water have to be addressed in efforts to understand the operation of an irrigation system, present or past. However, due care should be exercised here as the modern perceptions of 'ownership' may not have been relevant in the ancient Sri Lankan scenario, as highlighted by Codrington[88]. According to Siriweera[89], studies by Perera[90], Ariyapala[91] and Geiger[92] discussed the terms 'owner', 'ownership' and 'inalienable ownership' in Sri Lankan tenure context, but without providing any definition of those terms. In the *Samantapāsādikā*, there are notions supplementing these studies, specially highlighting the operational realities embedded within the broader context of irrigated water rights.

- Investments, User Rights, Transfers and Risk Mitigation

At present, the largest or in most cases, the sole investor in irrigation infrastructure is the government. The irrigated water is released to users at a subsidized rate or free of charge. But in the 5th century CE, individual investors were actively engaged in irrigation infrastructure projects, and private proprietorship of irrigation works was a common phenomenon. Commenting on this practice based on the early brāhmī

inscriptional records (from 3rd century BCE to the 1st century CE), Paranavitana[93] notes, "In several inscriptions, the phase vapi – or vavi – hamika (proprietor of a tank) is added to the proper name as it was a title." Some of these owners were *parumakas*, some were *upasakas* and the others were referred to by merely the bare names:

> *Anuḷapi–vapi–hamika parumaka–Maha–Vebaliya leṇe śagaśa* (Paranavitana 1970:1130)
> The cave of Maha–Vebali, the proprietor of the tank of Anuḷapi, [is given] to Saṅgha

> *Naka–nakaraka–vapi–hamika upasaka–Dataha leṇe upasaka–Huma ca leṇe śagaśa* (Paranavitana 1970:1129)
> The cave of the lay–devotee Datta, proprietor of the tank of Naka–nakaraka, and the cave also of the lay–devotee Huma, [is given] to the Saṅgha

> *Siddham* [| *] *Yavavavika–vavi–hamika–Cuḷa–Humanala leṇe upasika–Humaya ... sagaya niyate* (Paranavitana 1970:1210)
> Yavavavika tank, (and) of the female lay-devotee Huma, is dedicated to the Saṅgha

Further to the private proprietorship of the tanks, there are several references in these early brāhmī inscriptions to prove that donating such tanks to the Saṅgha was widely in practice.

Pa[rumaka]–yahapala–puta parumaka Hadane ima vapi Dipigala–viharahi niyate śagaśa (Paranavitana 1970:1225)
The chief Hadana, son of the chief Yasopāla, donated this tank to the Saṅgha in the Dīpigalla–vihāra

Parumaka–Abaya–puta parumaka–Tiśaha vapi Acagirika–Tiśa–pavatahi agata anagata–catu–diśa–śagaśa dine (Paranavitana 1970:1051)
The tank of the chief Tissa, son of the chief Abhaya, was donated to the Saṅgha of the four quarters, present and absent, in the monastery of Acchagirika–Tissa–pabbata

While these early inscriptions bear evidence to the private investments, and hence the proprietorship of the tanks and the practice of donating them to the Saṅgha, they are silent on the circumstances, terms and conditions under which such donations took place. The *Samantapāsādikā*'s passage below enlightens us on that background:

> If any person says 'I have a large tank (*mahātaḷāka*) which produces crops, I will offer that to Saṅgha, and if Saṅgha do accept that, then an offence is committed due to the acceptance as well as utilization. If any monk rejects that tank, no one should complain. ..... If anyone offera a similar tank and get rejected by the monks, and if that is commented 'Saṅgha already possess such and such tanks. How come those cases are valid', then it should be responded that 'they were offered as allowed articles (*kappiyabhaṇḍa*), which are meant for fulfilling four

> requisites.' If it is offered 'Well sir, make this use for fulfilling four requisites', then that is valid.[94]

Regarding the transfer of proprietorship, early inscriptions also highlight the occurrences where irrigation works were inherited from one generation to the next and also the cancellation of donations made by one party, subsequently by others. The Perimiyankulama rock inscription[95] provides us with an example to the first effect:

> .. *Ketavalaka– vaviya dakapati tumaha pita sataka koṭasaha tipatiya nahati maji–binaka satanani me dakapatiya sa–koṭasahi eka koṭasa pati* ... (Paranavitana, 1983:45)
>
> [The Nāga granted] the water–revenue of Ketavalaka tank, and the three categories of revenue of the shares (of this tank) owned by his father, to wit, the share of the fish, (the portion of) this water–revenue that has been inherited, and (the revenue of) one share out of six shares.

And the Vihāragala rock inscription[96] records an instance where a donation was cancelled and then re-donated, the Uppalakoṇika tank was first donated to the Saṅgha of Ekadvāra monastery by King Sabha (59-65 CE) was re–donated by King Gajabāhu (112-134 CE). The reason for re–donation was the annulment of the original donation by the King Vasabha (65-109 CE), the immediate successor of the King Sabha (59-65 CE) and paternal grandfather of King Gajabāhu.

*Sidha [| *] Vahaba–rajaha pute Tisa–raje Tisa–rajaha*

Pute Gamini–aba–raje Saba–rajaha [pa]–dinaka Upala

doṇika–vavi pohatakara[hi] jina–poḍavaya bhikhu–sagaha

ta paḍi dine ni(yataya) Ekadoraya–viharati [bi]khusagaha–aṭaya (Paranavitana, 1983:62)

Success! The son of King Vasabha (was) King Tissa. King Gamaṇi Abhaya, son of King Tissa re–granted the Uppala-doṇika tank, first granted by King Sabha, to the community of the *bhikkhus*, for the purpose of carpets of antelope skins to the community of *bhikkhus* of the Ekadvāra monastery.

The inheritance of irrigation works, being donated to the Saṅgha, subsequent cancellations and re-donations as appearing in the above inscriptions stand for the evidence of real occurrences in the irrigation history of Sri Lanka. However, the *Samantapāsādikā*'s passage below illustrates that these transfers were not done in an arbitrary manner, but governed by some regulations and standard practices:

> After knowing that the title was dismissed by the *bhikkhu* and if the owner, or his children, or heirs of his clan re-offer, then it should be accepted. If his clan ceased to exist and if the one who becomes the guardian of that province *(janapada)* re-offers, then the case would be similar to the small canal (*nihaṭandakavāhakaṁ*) rejected by the *bikkhu* at Cittalapabbate and the royal queen Aḷandanāga.[97]

Apart from the donations, monasteries invested on irrigation projects by utilizing their land for constructing tanks:

> Monks having constructed a tank (*taḷāka*) by employing others' labour and by engaging themselves, people cultivate using that tank and offer allowed articles (*kappiyabhaṇḍa*) then that is valid. Again people excavate a land belonging to the Saṅgha and offers the crops cultivated thereby as an allowed article, that is valid.[98]

Users of such projects were supposed to pay to the investing party, for their user rights. Balance between the water infrastructure facilities (for users) and sources of investments (from investors) would have been a result of identifying the correct combination of risks for both parties. This user-investment configuration would have been prompted to consider local water needs and to try to find local solutions, in the broader context. The earnings could be reinvested in the irrigation infrastructure itself, thus ensuring a continuous fund flow. However, expansion of works would have been limited by the regulations as discussed previously.

The farming would not be merely a subsistence level endeavor depending on subsidies and grants (as the case today), but a means of generating social wealth. The cultivators were assured the availability of irrigated water, thus mitigating the risk of water stress. On the other hand, they were supposed to make payments for the parties who invested in those irrigation projects. Donation of irrigation work to the Saṅgha, as previously discussed would have been transferring such payments

to the benefit of the monasteries. Paranavitana[99], Perera[100] and Codrington[101], after evaluating the inscriptional and ephigraphical material of early Anuradhapura period conclude the term *dakapati*, stands for a payment made by irrigated water users to the facility suppliers. These payments and supplies would have been governed by certain regulations, of which some references were made in the *Samantapāsādikā*:

> During the draught season when water becomes scarce, water is released in intervals (*udakavāre*). If someone does not receive his due share during the interval allocated to him and crops become withered, then another should not receive his share during his allocation. If any monk unduly drives water from a secondary canal (*khuddakamātikā*) or a field belonging to someone else, to a canal or a field belong to him or to someone else, or covers the [catchment] (*aṭ avimukhaṁ*), then he has committed the offence of *avahāra*.[102]

When the users default the payments, the facility owners were entitled to curtail the supply. However, if the users have already invested on their cultivation, their user rights should remain intact, which demonstrate the responsibilities and limitations associated with rights and privileges.

> When people are oppressed by the state taxes (*rājabali*) and refuse to contribute to *bhikkhūs*, the water supply could be curtailed. But such should be during the ploughing season (*kasikammakāle*) and should not be during the cropping season (*sassakāle*). Then, if they comment 'Sirs, didn't others cultivate from these waters', it should be responded that 'they were assisting Saṅgha in various means and provided various allowed articles

> (*kappiyabhaṇḍa*)'. If they then promise 'we also would comply', then it should be considered. If anyone offers or constructs tank (*taḷāka)* in a non-allowable (*akappiya*) manner, that should not be accepted. The allowable articles (*kappiyabhaṇḍa*) are not valid.[103]

There are references to open access regimes also, where the users could withdraw the water without compensating to any party:

> People cultivate crops using the water drawn from an openly accessible tank (*taḷāka*). A main canal (*mahāmātikā*) starts from this tank and leads through the fields feeding the crops. This main canal is also openly accessible and from that, secondary canals (*kuddhakamātikā*) are drawn to individual fields.[104]

These findings do merely touch the normative aspects of ancient irrigation, and only points toward a system in which hydrological, hydraulic and economic elements operated in an integrated manner. However, considering the fact that inscriptional, epigraphical and archaeological evidence do not provide us much detail in this respect, the *Samantapāsādikā*'s above revealing proves their importance in the study of irrigation history of Sri Lanka.

Having discussed the physical, agro-productive, organizational and normative aspects of the ancient Sri Lankan irrigations enterprise as revealed in the *Samantapāsādikā*, one more area needs to be discussed at least briefly; the possible transmissions of this technical knowledge and skills. This is specially so, in

the context of the extensive off shore cultural contacts maintained by Sri Lanka since the early period.

Influences and Transmissions

No society is isolated or self sufficient to claim that it has never obtained some aspects of its technology from outside sources. General cultural contacts are the oldest means of transferring technological knowledge from one society to another. These contacts may be the result of exploration, travel, trade, war or migration. The *Samantapāsādikā* itself mentions the well known practice of naval transport from Mahātittha (present Mannar area) to Tāmralipti (present Tamluk of West Bengal) or to Swarnabhūmi (present Thailand). These travels might have mobilized the local knowledge, ideas and authoritative texts on various subjects among the societies. According to Malalasekara[105], the *Samantapāsādikā* was translated into Chinese by Saṅghabhadra in 489 CE, just after it was originally compiled in Sri Lanka. The *Vimati-vinodhinī* has been held in great esteem in Burma, where it was one of the authorities appealed to when Dhammaceti carried out his reform in the 15th century CE. Under such broader web of cultural contacts, the chances are ample for transferring the techniques, skills and knowledge in and out.

The possible transfer of Sri Lankan irrigation knowledge was a subject which was discussed since the colonial times. Bailey[106] in his report on irrigation suggests that "it cannot be the India that we must look

for the origin of tanks and canals in Ceylon", and that the knowledge of their construction was derived through "the Arabian and Persian merchants who traded between Egypt and Ceylon." Tenant[107] assigns the origin of Sri Lanka's irrigation knowledge to India or China, "To be convinced of the Tamil origin of the tank system which subsists to the present day in Ceylon, it is only necessary to see the tanks of the southern Dekkan. The innumerable excavated reservoirs or *colams* of Ceylon will be found to correspond with the Mysore; and the vast *crays* formed by drawing a bund to intercept the water flowing between two elevated ridges exhibit the model which has been followed at Pathavie, Kandelai, Menery, and all the huge constructions of Ceylon." If it was not India, "... instead of borrowing a system from Egypt, Singhalese might have imitated the ingenious devices of their own co-religionists in China." At the same time, Tenant acknowledges the independent developments, "But whoever may have been the original instructors of the Singhalese in the formation of the tanks, there seems every reason to believe that their own subsequent experience, and the prodigious extent to which they occupied themselves in the formation of the works of this kind, they attained a facility unsurpassed by the people of any other country." According to Gunawardana[108], the irrigation technology transfer between Sri Lanka and sub continent was a two way process. While the influence of South Indian spread to Sri Lanka in proto-historical times, there was a reverse flow, from Sri Lanka to South India in historical times. However, in the sphere of sluice technolgy, Gunawardana concludes that both countries followed

independent paths of development. '*Piston*' type sluice dominated the South Indian case while in Sri Lanka, 'cistern' sluice [suitability of terminology 'piston' sluice and 'cistern' sluice is still to be confirmed] was clearly the preferred type.

In these circumstances, it would be appropriate to consider the irrigation knowledge transfer possibilities, at least among the Asian region. Mannou-Ike reservoir, firstly constructed in 702 CE is still the largest irrigation tank in Japan. In 821 CE, it was destroyed by a flood and the repair work was commissioned to a Buddhist monk named Kukai (774-53CE) who returned from China after his studies on Buddhism. This repair work was characterized with some special features like (i) arch shaped bund, which was the first of its type in Japanese reservoir tank systems, (ii) newly introduced spillway, (iii) renewal of the sluiceway and (iv) rock bed under the bund (protecting the bund from pressure at the time of discharging water)[109]. Nagata suggests that Kukai adopted these designs due to his off shore exposure[110]. Kukai travelled to China after his ordination and studied under Huiguo (746-805 CE), who was one of the most prominent successors to Amogavajra (704-774 CE). Considering the Amogavajra's possible exposure to Sri Lankan irrigation during his stay here, Mogi speculates that it could be Sri Lankan irrigation knowledge that transmitted to Japan, introducing special features at Mannou-Ike reservoir.[111]

Farmer managed irrigation systems have a long history of adapting indigenous technologies to the

topography, hydrology, water availability, water rights and socio-cultural conditions of local environment. Highlighting the water distribution at farm level in Sri Lanka, Ievers[112] notes the usage of a structure called *karahan*, which used to divert the water flow along main channels into branches. This is a wooden log with gaps or openings of cut in that. Depending on the width of the gap, the proportion of water diverted in the respective branch could be decided. This type of water distribution through wooden proportioning weirs is not limited to Sri Lanka, but used in many Asian countries even today. Amber[113] mentions a long list to this effect, *chaukhat* (in Pakistan), *pantung* (in Uttar Pradesh, India), *thelu* (in Himachal Pradesh and India), *saacho, gahak, gari, panidhara, khat bunda* (in Nepal), *gah* (in Bhutan), *tae wai, tae nam, kiang nam* (in Thailand), *sabang, paraku, takuak, kalimbatang, penaro* (in Sumatra and Indonesia), *cowal* (in Java and Indonesia), *pemaroan, tembuku* (in Bali and Indonesia), *tablon, padila* (in Philippines).

Broad similarities as discussed above are not sufficient to establish a knowledge transfer connection, in the absence of other supplementary evidence. Remarkably, similar products could be innovated in different regions and circumstances, in the same period, without awareness of each other's works. Only if similarities extend to idiosyncrasies or highly specialized features, one may reasonably claim the possibility of links. On the other hand, subsequent to transfers, the products may undergo modifications generated by the social, economic, technological, geographical and cultural factors beyond recognition of its original form.

Therefore, mere similarities or differences between products in different regions neither imply knowledge transfers nor independent inventions. In this background, it is important to evaluate the findings of similar studies in other technology biased knowledge fields so that general trends could be identified.

In an article in *World Archaeology*, Gillian Juleff[114] discussed the emergence of a wind driven steel technology in Sri Lanka in the first millennium and its possible spread further afield to Burma, Cambodia, Sarawak and Japan. Commenting on this speculation, Goonatilake[115] notes that such transmission should not be limited to steel technology, but there were ample opportunities for transmitting trail of sciences and technologies from Sri Lanka to Southeast Asia, China and even as far as Japan. This was based on the already published literature which was mostly on the religious element which hardly touched matters dealing with science and technology. The fact that irrigation related material embodied in the *Samantapāsādikā*, covering topological, geophysical, taxonomical and also the operational and maintenance norms existed in Sri Lanka as early as the 5th century CE, may mark a pointer towards a general tendency of outward technology transmission from Sri Lanka.

Conclusion

The history of science and technology in the Sri Lankan context still remains as a virtually unexplored area. The studies so far conducted remain inadequate in quantity,

unreliable and contentious in quality. One factor contributing to this situation is the sources through which this early knowledge is appraised. Using remains of an ancient system as a source would only serve if their original functions were not distorted in subsequent modifications. Using modern western knowledge in ascertaining these functions may again uproot these ancient systems from their due setup. Studies on our ancient irrigation knowledge and skills have been subjected to both these unfavorable conditions, calling for alternative sources and a knowledge base. This paper tried to focus on this aspect by selecting a 5th century CE Pāli commentarial work, the *Samantapāsādikā*, for studying ancient irrigation knowledge that prevailed in Sri Lanka.

A single source may not give a comprehensive understanding on a subject which prevailed centuries ago. In a multifaceted subject like irrigation, with many ecological, technical, social and economic variables, this is specially so. However, the sources used in this study, the *Samantapāsādikā* and its three sub-commentaries *Vajirabuddhi tīkā, Sāratthadipanī, Vimati-vinodhinī* accompanied by the collaborative evidence from modern writings, illustrate some contemporary irrigation knowledge and skills, which are not revealed elsewhere. This was evident in all four aspects of irrigation this study was concentrating on, (1) physical, (2) agro-productive, (3) organizational and (4) normative. The description on water releasing mechanisms used in small tanks and water lifting mechanisms are unique in nature. The soil categorization and testing methodologies prove

[redacted] form of geo–physical investigations were [redacted] with early irrigation works. Operation and [redacted] aspects, which would have contributed to [redacted] continuity, were also discussed. Discussion [redacted] normative aspect reveals that hydrological, [redacted] and economic elements operated in an [redacted] manner.

By the 5th century CE, Sri Lanka was actively [redacted] with off shore societies through various channels [redacted] travels, conveyance of various Buddhist doctrinal [redacted] etc.). In such circumstances, the transfers of [redacted] knowledge would be imperative and the last [redacted] of the paper was dedicated to a discussion on the [redacted] of some hydraulic structures and [redacted] adopted in Asian countries.

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[redacted] how the water passes through *dabarā*. *Amāvatura* (ed. [redacted], p. 127), *Ummagga Jātaka* (ed. R. Wanaratna, [redacted]) and *Pujāvaliya* (ed. W. Amaramoli, p. 147) give a metaphor that a baby was freely and effortlessly borne like a quantum of water passed through a *dabarā*. *Saddharmaratnāvaliya* notes that juice was freely drained from a stem of sugar cane like water flows out from a *dabarā* (p. 1117). Considering all these notations, it could be concluded that the term *dabarā*, and thereby *udaka tumba*, should mean a vessel with openings at both top and bottom and through which the water flows smoothly and freely

[redacted] *Gāṭapadaya* highlights the term *udaka niddhamana* [redacted] on occasions *udaka niddhamanena* (part I;p.232) and *udaka* [redacted] (part II; p.120) for which the meaning assigned is "water course" and "tunnel through which water is conveyed" respectively. There the term *niddhamana* appears in several other occasions like *niddhamana dvārēna* (part I, p.97) *niddhamana* [redacted] (Part I, p.65) and *niddhamanena* (part. II, p.23) for which the common meaning "water course" is assigned. *Dampiyā Atuwā* [redacted] gives the Sinhala meaning of *niddhamanena* as *molen* [redacted]. *Saddharmaratnāvaliya* (ed. K. Gnanawimala), having the same source as *Dampiyā Atuwā Gāṭapadaya* uses the term [redacted] (p.462) in this particular occasion of which the present meaning is *sorowwa*, the sluice. Considering all these, it could be concluded that *udaka niddhamana* should mean a path of the water flow through a sluice.

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