Indigenous Skills & Practices of Disaster Resistant Construction in Sri Lanka

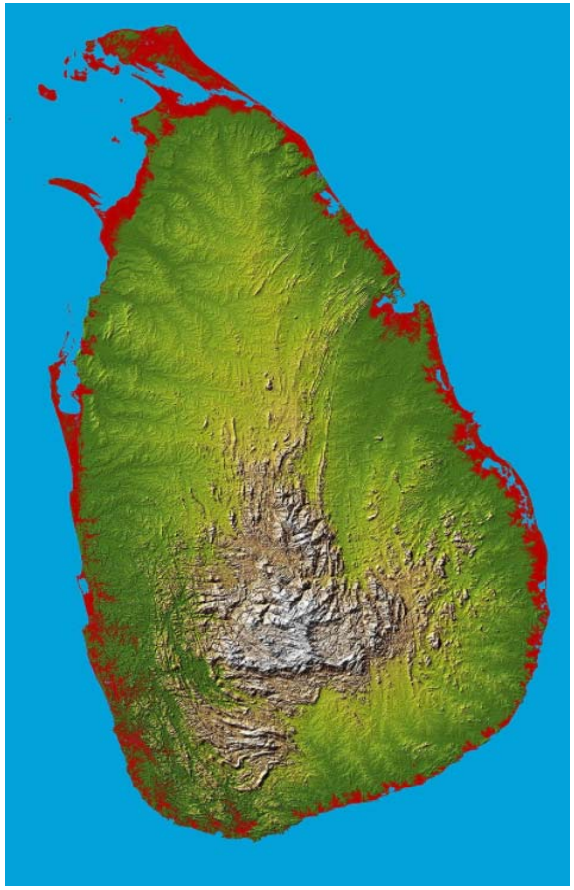
Anoja Seneviratne
Director (MR&D)
Disaster Management Centre
Vidya Mawatha, Colombo 07 ,Sri Lanka
seneviratne.anoja@gmail.com

Content

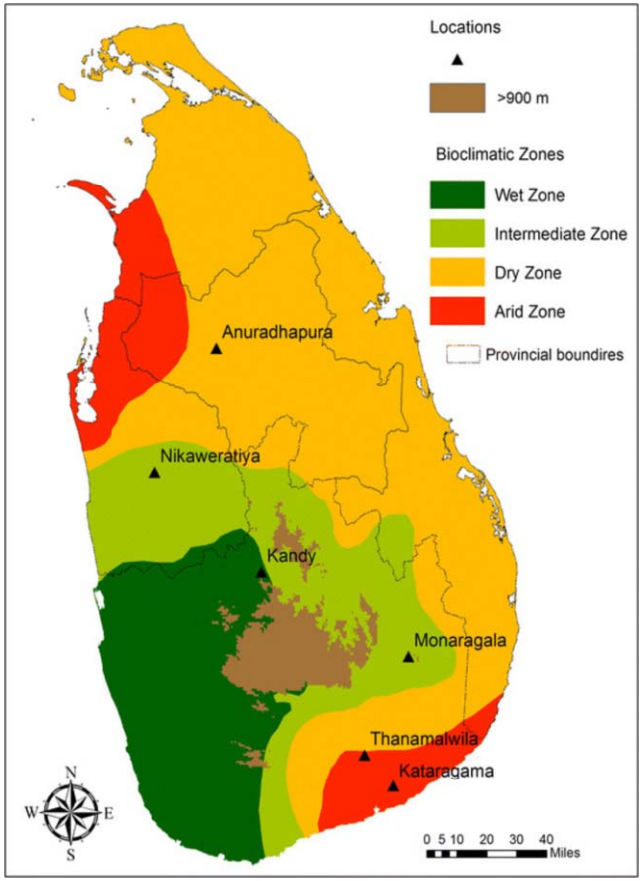
- Brief Description of Sri Lanka
- Disaster Profile of Sri Lanka
- Historical Disaster Event of Sri Lanka
- Importance of Indigenous Knowledge
- Indigenous Knowledge on Disaster Management Strategies
- Disaster Resistant Construction
  - Dam, Reservoir & Canal
  - Water Management
  - Housing
  - Sanitation

Sri Lanka

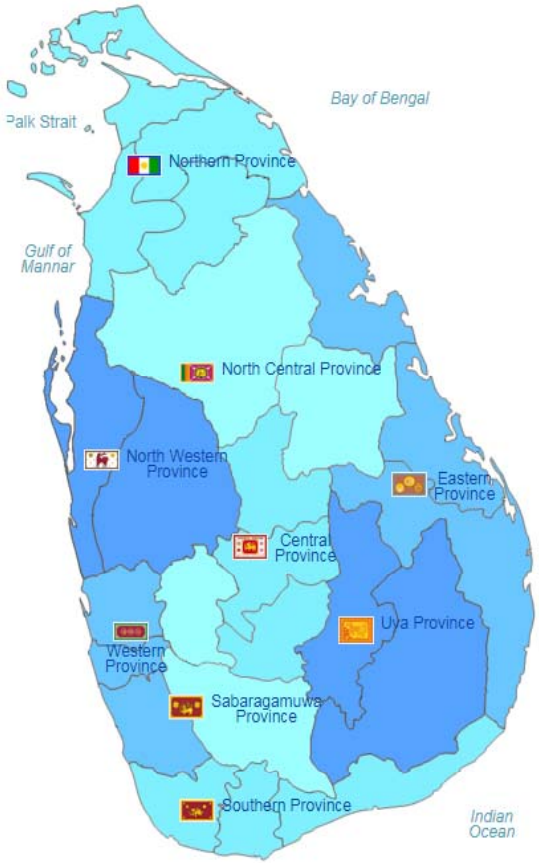
Geography



Climatic Zones



Administration Boundaries



Disaster Profile of Sri Lanka

Historical Disaster Events

- **Floods**
  - B. C. 89-77 Flood inundation King Panduvasudeva and King Devanarnpiyatissa Period
  - Constant shifting of river beds - evident in Anuradapura and polonnaruwa period as well as.

- **Coastal Erosion**
  - Island was much greater in size two thousand years ago than at present (Charles Pridham and Sir W. Jones)
- **Cyclone**
  - 1925 and 1944 forty eight cyclones have been observed
- **Drought**
  - B. C. 161-137 This famine was called akkhakhiiyika famine which literally means the famine during which nuts called akkha
  - 187-189 A.D. Ekandlika famine
  - 247-49 A.D King Sri SangaBodhi Period
  - 365-406 King Upathissa Period
  - 551-569 King Kittisirimegha

Importance of Indigenous Knowledge

- Holistic Comprehensive Approach
- Part and Partial with environment
- Greed Mitigated
- Happiness is the most important wealth
- Equity of Ownership
- Attitude towards nature
- Less selfish holistic community based approach to optimized the eco system

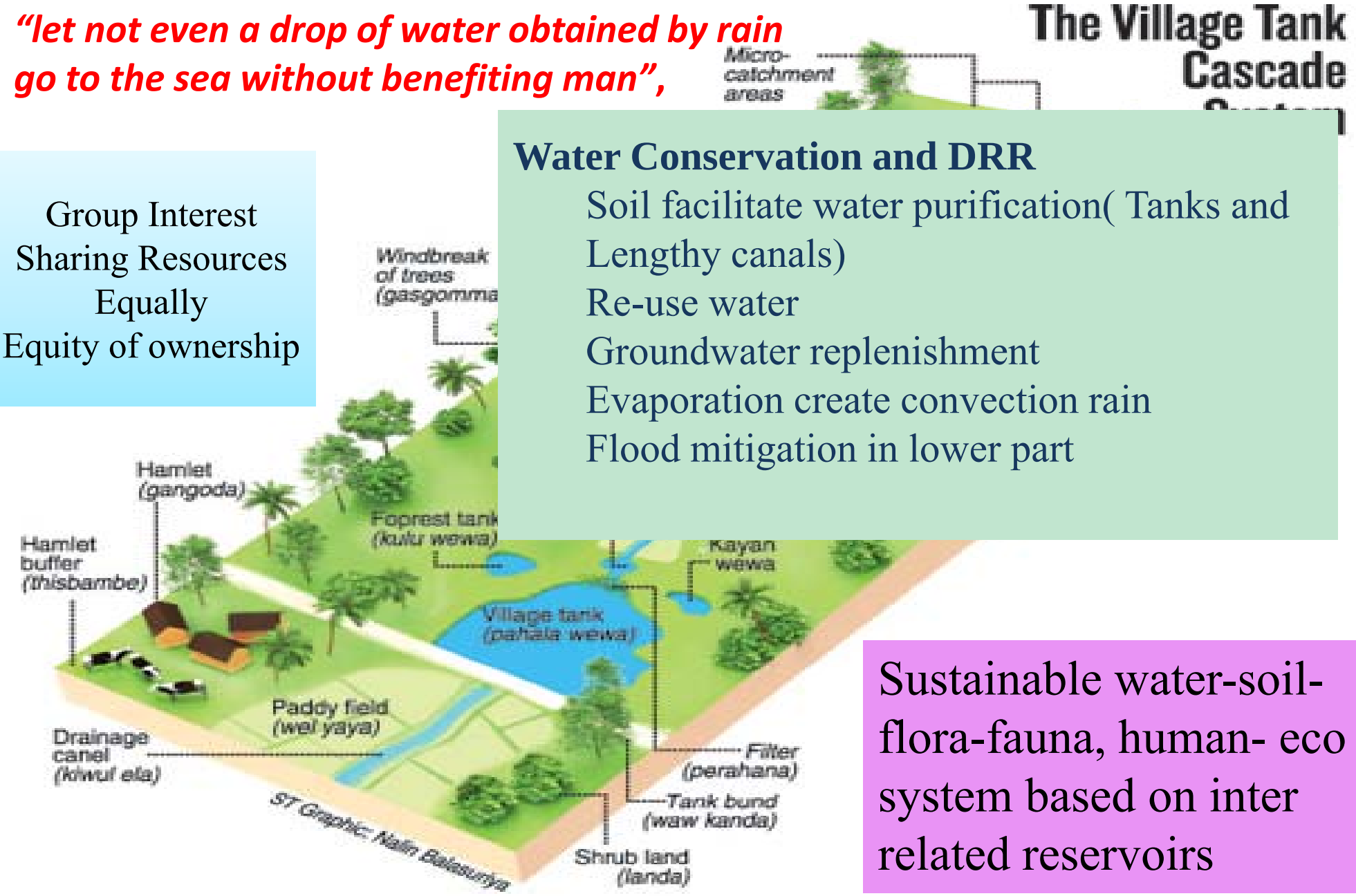
Indigenous Disaster Management Strategies

"let not even a drop of water obtained by rain go to the sea without benefiting man",

Group Interest
Sharing Resources
Equally
Equity of ownership

Water Conservation and DRR

- Soil facilitate water purification(Tanks and Lengthy canals)
- Re-use water
- Groundwater replenishment
- Evaporation create convection rain
- Flood mitigation in lower part



Sustainable water-soil-flora-fauna, human- eco system based on inter related reservoirs

Indigenous System

~~crop water requirement for root zone~~

water requirement for entire eco system

Major River → **Major Tank/Small Tank/ Field**

Eg- Elahera/ Prakrama Samudraya

Spilling out small tank → **Store in Major Tank**

Re use of water/ Earth Bunds used as silt traps and flow controller for flood mitigation

Eg- Kala Wewa/Jaya Ganga

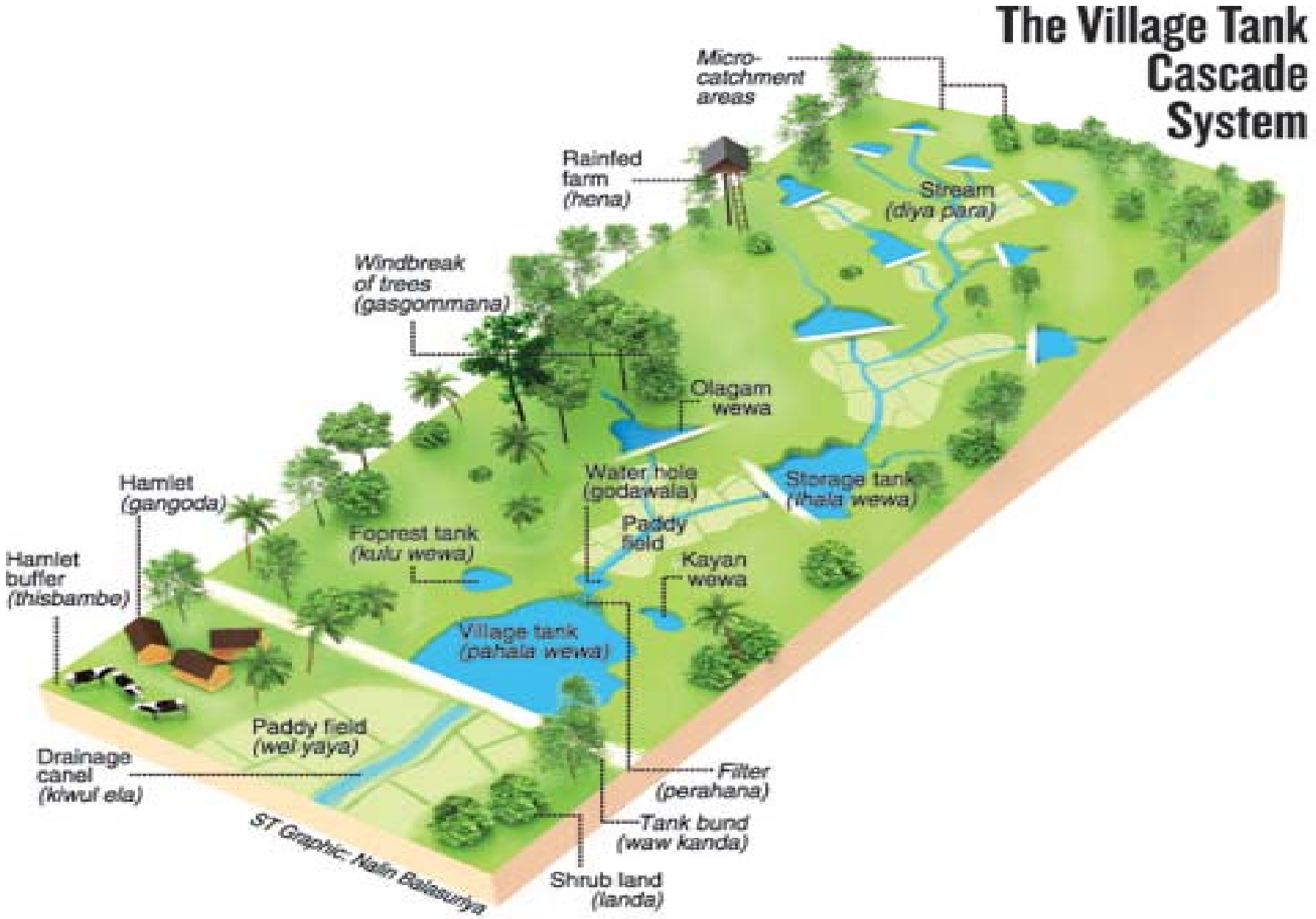
Rainwater Trapping Structure

Vetiya- Very low intensity rainfall

Small Tank -Higher intensity rainfall

Major Tank – Much Higher intensity rainfall

Indigenous Disaster Management Strategies



Cascade System in Sri Lanka

- A tank system in a cascade has a small reservation catchment, the reservoir, a strip of trees downstream of the reservoir that act as a wind breaking barrier, paddy fields, and the village.

- The reservation of the next tank of the cascade starts immediately below the paddy fields of the upper tank.

- The system of tanks, paddy fields and canals are so much integrated and inter woven with the natural environment, it is difficult to identify tank systems as man made structures.

- The primary service provided by the tanks was the storage of rainfall that comes in 3 months to enable year long rice growing with two seasonal crops

- In addition to irrigation water, the tanks provided a number of other services. They made the microclimate pleasant and cool, enabled bio and agro diversity. The tanks also served as the common bathing place for the village and the meeting point for the village.

- Most importantly the independence provided the ancient tanks through to each village has paved the way for a unique decentralized social system in Sri Lanka, where farmers had the highest social rank.

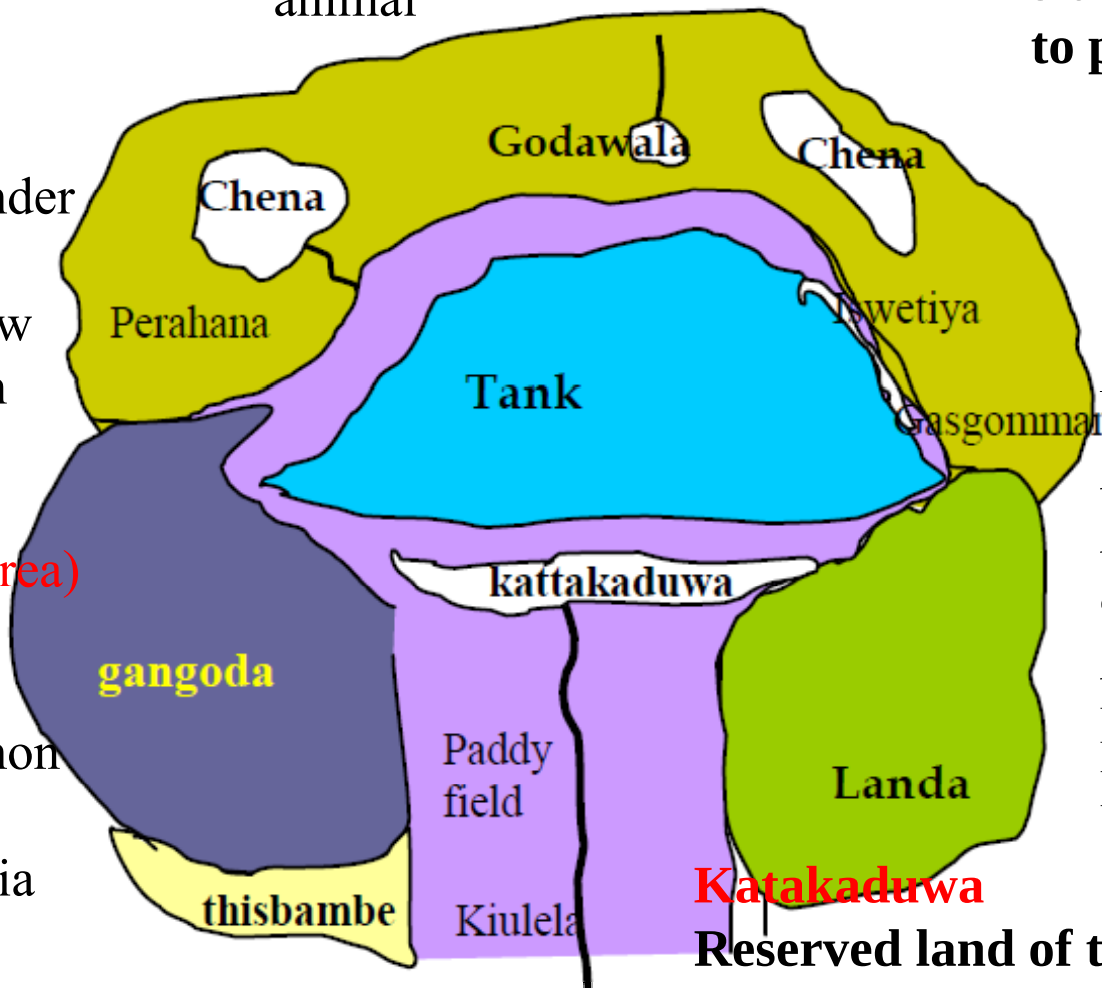
Disaster Risk Reduction in Tank System

Kulu Wewa
Trap Sediments and provide water for catteles/animals

Godawala
Water hole to trap sediment Provide water for animal

Iswetiya/Potawetiya
Soil ridge in upstream side of the tank bunds to prevent erosion

Perehana
Meadow developed under gasgommana
Filter the sediment flow coming from upstream



GasGommana
Upstream land strip(Above tank bed)
Accumulate water only when tank spill
Act as wind barriers
Reduce ET and Lower T

Gangoda(Settlment Area)

Tisbambe
Fertile land area common
Protection wild animal and Maleria

Kiwul Ela
Specific trees
Remove salt and iron improve condition of water

Katakaduwa
Reserved land of tank bundMicro climate Environment Water hole, wet land and dry upland diversity is high

Techniques and Technology in Resilient Water Diversion

- **Angamedilla type Diversion**
  - Build where large quantity of water collected
  - Water collected at the dam circulates below the main canal and run through a sub canal and that water again collected to the water in the main canal
  - Safety of dam bund in case of sudden pressure of water. Environment friendly system
- **Redebendilla type Diversion**
  - Constructing dam either on the left or right (sometimes both side) river bank across the stream or river
  - Water blocked by the dam is easily diverted to the canal
  - Construction is easy but possibility to damage during high pressure causing damage to downstream
  - Not use in large scale water sources.

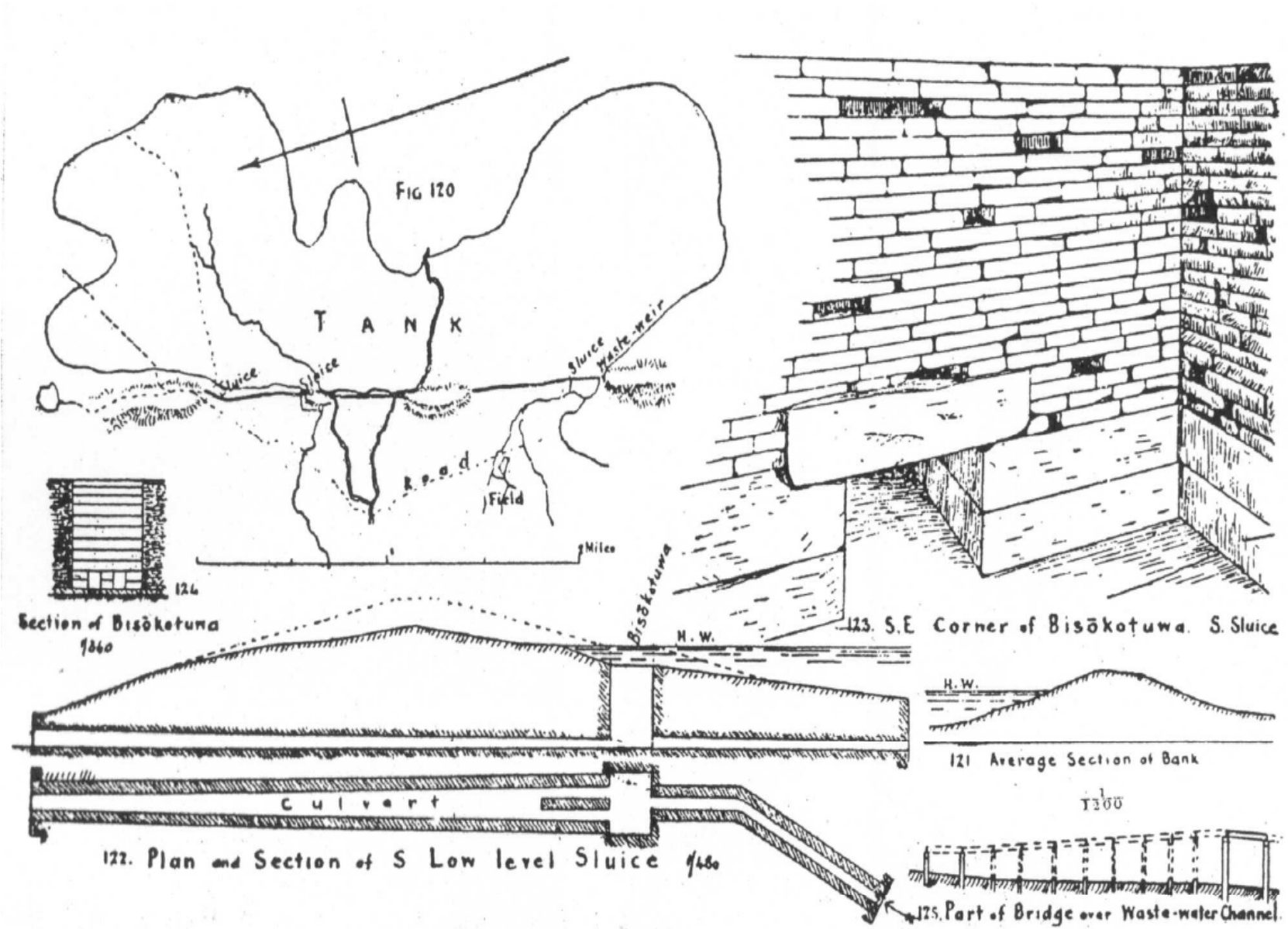
Disaster Resilient Construction

Biso Kotuwa

- Issue of water from the large reservoir, which will have water depths in excess of 10-15 meters was a difficult task.
- This problem was overcome by ancient Sri Lankans with an ingenious creation called the Bisokotuwa, built near the point where the water level meets the inner slope of the dam bund.
- It is an open well with rectangular section having faces lined with stonework and timber flanks, and an inlet culvert and an outlet culvert placed at its bottom.
- Sluice gates regulated the water inflow and outflow.
- Bisokotuwa also served as a place where de-silting can be done.

- " whatever form the design took, it was a triumph of the ingenuity of the ancient Sinhalese engineers. It was this invention alone, which permitted them to proceed boldly with the construction of reservoirs that still rank among the finest and greatest works of this kind in the world". Thus the ancient Sri Lankans were the inventors of the valve-pit more than 2000 years before it was used in the West in the 19th century. .*(Parker, 1909)*"

Bisokotuwa



Figs. 120–125. Pāvaṭ-kulam.

Disaster Resilient Construction

Karahana

- Water distributing devices
- Water supply to the field in holistic manner drainage from upper field are used in lower fields (Re-Use)
- Based on group interest

Disaster Resilient Construction

Diverting water from River

- **Never silenced the river** (McCully,1996); Natural river flow has not been stopped totally and part of water has been diverted **no serious affect to down stream and no large reservoir** (constructing oblique dam or weirs
- oblique dam would have greater stability; and the blow of a log would have much **less tendency to displace a stone of an oblique dam"** than a square one built perpendicular to the current.
- To convey the diverted water from the river to the reservoir and from one reservoir to another, **canals were** used, some of them **very long and ingeniously located**. Jaya Ganga, the right bank canal of the Kalawewa reservoir conveying water to Tissa Wewa reservoir, **is 91 km long and 12 m wide**. The canal **feeds a number of small tanks** on the way, and over its **first 30 km, the canal has a gradient of 1 in 10,000 (6 inches to a mile),** an accuracy hard to achieve even today

Sanitation in Ancient Sri Lanka

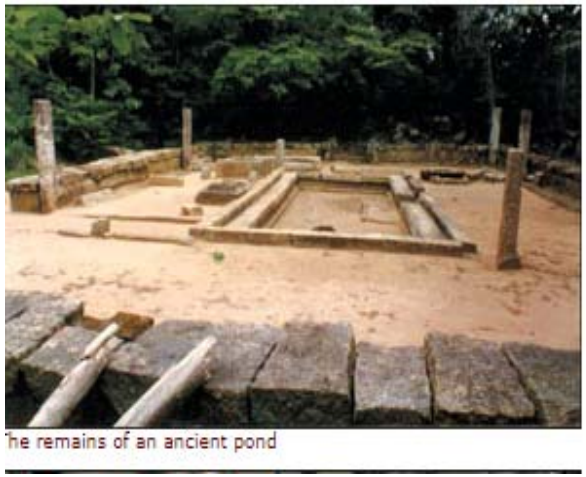
- Ancient Sri Lankan dual-tiered system in the urban potable water and wastewater context:
    - Cohesiveness of local communities.
    - Public health considerations.
- Accordingly, dumping garbage, allowing garbage to pile up, leaving room for water to gather in one place, defecation in public places, disposing of dead bodies of such pets as cats in streets were strictly prohibited.

- Water and urine have been diverted from the toilets of Baddhasima Pasada at Polonnaruwa through terracotta pipes into a separate septic pit while excreta was diverted to another septic pit.

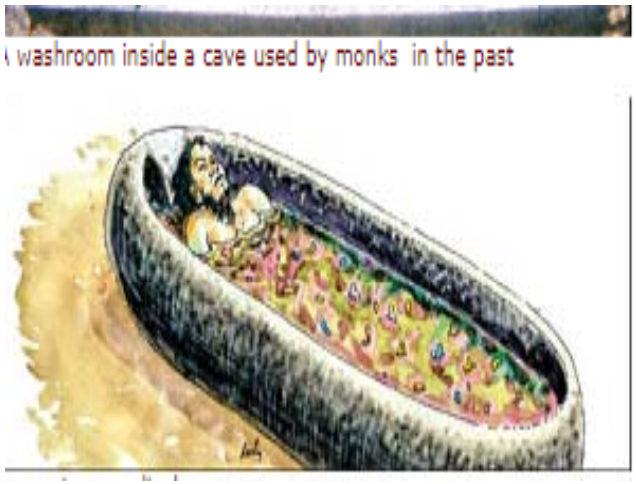
Toilets and Baths

- Distance from the residences
- Liquid passing through urinals was diverted into pits along terracotta pipes
- large bottomless clay pots of decreasing size have been placed one above the other. These pots contained sand, lime and charcoal through which urine filtered down to the earth in a somewhat purified form. There had been seven pots in certain pits but the number had been fewer in some others. The pots had been vertically fixed together with a mixture of cement and clay. These urine pits point to the attention paid by construction engineers to the details of sanitary care and environmental protection.

washroom inside a cave used by monks in the past



The remains of an ancient pond



washroom inside a cave used by monks in the past

Resilient Building Construction

- Old buildings have thicker wall and special walling and roofing materials. Control temperature and humidity measurements of the building in day time
- Low energy consuming buildings with thick brick wall (450mm) earth wall
- Use white color
- Wood windows
- Place windows only in east and west directions so that indoor thermal and visual comfort achieved

Ventilation- Energy Conservation

Ground Level has been raised

Air Inlet at the Ground Level

Sound Proof wall

Construction Materials

- Materials used for construction were indigenous and consist mainly of earth, stone, brick and timber.
- Ruwanweli Stupa has a height of 103 m and a base diameter of 91.4 m.
- The Jetavana Stupa built by King Mahasen (276-303 AD) attained a height of 122 m making it, at that time, the tallest brick structure in the world, and the third tallest structure in the world (surpassed only by the two pyramids in Giza). With a total volume of bricks in excess of 300,000 m3 it, arguably, is still the largest brick structure in the world.

Building Construction

- Ancient Sri Lankans showed many skills in constructing these mega structures.

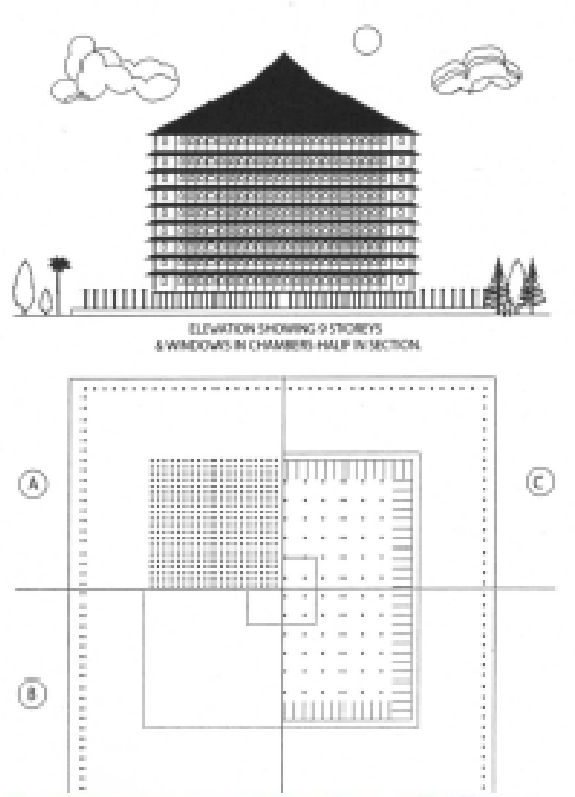
- The bricks used were of very high quality, much stronger than the modern day bricks,
- the mortar used was a very thin slurry (butter clay), which did not weaken the brickwork.
- The structure was water proofed by a thick plaster giving good weather protection .
- Much care was taken in selecting the site and preparing the foundations.
  - Ruwanveli Stupa foundation was constructed with layers having crushed stones, clay, cement, brick, metal, and impregnated with chemicals. Hence it is essentially a reinforced concrete foundation with damp and insect proofing. Many Stupas were located on bedrock and the brickwork started from the foundation level. Setting out and raising the structure was done very precisely. For the domes of mega Stupas, paddy-heap shape (ellipsoidal or paraboloidal), which produces no tension under self weight, was used.

Timber as Construction Material

- As timber is hygroscopic, its moisture content affects almost every property, which are important in structural terms; **strength, stiffness, durability, dimensional changes (shrinkage and swelling), shape stability**,
- Apart from these internal conditions, the external conditions like **wind loads, settlements, thermal effects** would also contribute to the structure‟ s behavior. All these internal and external conditions might induced formations of structural members, which in turn produce internal forces and moments.

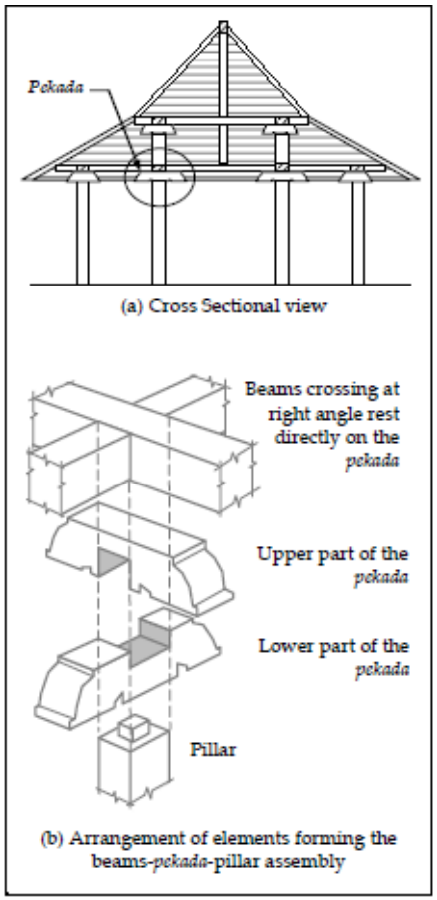
Timber has been used in the construction of the buildings, bridges, machinery, boats

Timber made buildings since this early period. Lovamahapaya in Anuradhapura (1st c. B.C), of which the super structure is supposed to be of timber.



it was a 9 storey building built with stone and timber with a copper tile roof. Each floor had 100 chambers, and it could accommodate 9000 monks. With a height of around 49 m, it would have been one of the earliest high-rises in the ancient world

- ***Pekada*: Pillar – Beam Interface**
  - Eg: Audience Hall at Kandy as a typical example.
- Certain amount of flexibility would be beneficial in timber joinery. This would be possible by keeping beams on the pillar top in free standing manner connecting beams and pillars through mortice



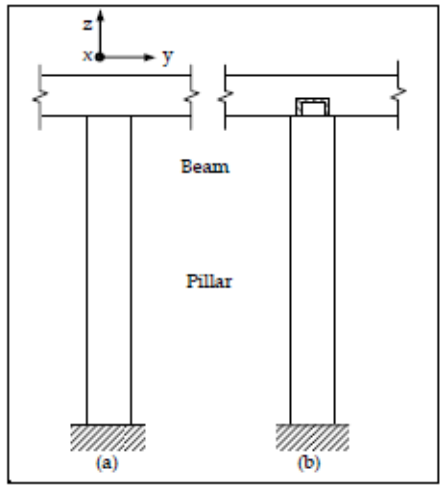


Figure 4 – Pillar and Beam structures

arrangement at Assembly Hall, Kandy

Figure 3 – *Pekada* at Assembly Hall, Kandy.

- Sri Lanka's ancient monastic architecture displays a rich variety of architectural forms and styles.
- Monasteries were designed using guidelines given in manuscripts, which outline the layout of various components such as shrines, image houses, assembly halls, etc.
- They blend well with the environment causing minimum intervention. Efficient and environmental friendly systems were used for water supply and drainage, sanitary requirements, waste disposal etc.
- Some monasteries were very large accommodating thousands of monks. According to the Chinese monk Fa-Hsien, who visited Anuradhapura in the 5th century AD, there were 5000 monks residing at the Abayagiri monastery and 3000 at Mahavihara.

Indigenous Landscape Structure

- The rock fortress Sigiriya (5th century AD) is a meticulously planned royal complex with palaces, water gardens, ponds, and supporting infrastructure. The rock rises 183 m and the palace complex is located on its summit.
- The water garden in the ground is served with water, conveyed entirely under gravity, using underground conduits made of clay.
- Its exceptionally engineered hydraulic inflow and outflow conveyance system is a marvel even by today's standards. Sigiriya is one of the oldest landscaped gardens in the world.

Sigiriya

Lightening Protection

(Mahawamsa)a device called Vajrachumbata, fixed at the top of the Stupa, to prevent damage to the pinnacle by lightening. *(This is fifteen centuries before Benjamin Franklin studied lightening in the West.)*

- Our ancients were much more responsible and wise in dealing with the environment.

- Respected and protected the environment and achieved sustainable development.
- In searching for sustainable solutions for development, we should not forget the wealth of knowledge and wisdom of our ancients, all over the world.
- While practicing sustainable development, ancient Sri Lankans produced significant innovations in irrigation and water management, architectural and structural engineering.

Thank You