ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/282330754

Hypothesis of Cultivating Productive Water from Lagoons of Northern Sri Lanka

Article *in* International Journal of Advanced Research · January 2015

CITATIONS
13

READS
298

2 authors, including:

Saravanamuttu Subramaniam Sivakumar
University of Jaffna

187 PUBLICATIONS 909 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Water Management and Governance View project

Cultivating fresh water from salt water Elephantpass lagoon View project

All content following this page was uploaded by Saravanamuttu Subramaniam Sivakumar on 30 September 2015.

The user has requested enhancement of the downloaded file.

ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Hypothesis of Cultivating Productive Water from Lagoons of Northern Sri Lanka

Kuganesan, S. [1], **Sivakumar, S.S.** [2]

1. Hydropower Engineer (Civil), Norconsult AS, Norway

2. Head, Department of Civil Engineering, Faculty of Engineering, University of Jaffna, Sri Lanka

Manuscript Info

Manuscript History:

Received: 18 July 2015
Final Accepted: 22 August 2015
Published Online: September 2015

Key words:

Simulation model, Reservoir operation simulation, Permeability, Irrigation reservoir, Productivity

Corresponding Author

Kuganesan, S

.

Abstract

Jaffna is a peninsula which is 1000 km^2 of land (out of which, Vadamarachchi Lagoon, Upparu Lagoon, Valukaiaru and Elephant pass Lagoon are covered with 75, 25, 15 and 100 km^2 of surface area and 287, 212, 104 and 907 km^2 of catchments area, respectively) covered by Indian Ocean by 160 km of coastline and no location is more than 10 km away from the coast. Hence it is very much susceptible to the salt water intrusion in to the land area. The water resource mainly the underground water in Jaffna Peninsula is totally polluted due to prolonged negligence and improper management of existing barrages at Thondamanaru, Ariyali and Ariyali and the salt water intrusion was taken place due to the none- maintenance of SWE bunds[16]. In addition to these garbage and soakage pit pollution and increased usage of fertilizer chemicals also affected the ground water. As a result, people are facing problem in getting good quality water in their wells. Due to the salt water intrusion, hundreds of acres of lands, hundreds of wells are in abandon stage [14].

A simplified reservoir simulation model was developed to study the water balance of the lagoon Downstream of the reservoirs of the four regulated river basins considered as local catchment to the Elephant Pass lagoon. Total inflow to the lake (lagoon) is the summation of monthly runoff yield from local catchment, direct rainfall on the lake and spill from upstream reservoirs. Outflow from the lake includes evaporation loss, percolation, demand and spillage. Evaporation loss from the lake was a function of water surface area and it was estimated from the monthly average Pan Evaporation values for the study area. Due to the absence of permeability measurements for the lagoon bed, monthly seepage loss was assumed as 2.0% (0.05% for irrigation reservoirs)[14] of the volume of water stored in the lake. Monthly Rainfall data from the representative meteorological station and monthly spill volume from the upstream reservoirs were used as time series of input data. Low regulated water level (LRWL) was set at 0.0 m MSL with the proposed spill crest level of 1,2m MSL. Reservoir operation simulation was done with the constant release per month throughout the year. The results of the monthly simulation of lake showed that even after high evaporation loss, nearly 2MCM/month was available for release without upstream spill and 4MCM/month was available with upstream spill. Flushing out of lagoon bed in order to reduce the salinity can be carried out during the rainy season with excess water. It was found that nearly 70% of the total inflow evaporates directly from the lake and it is an unproductive loss. Reservoir optimization is required to increase the productivity. This study can be basis for future detail hydrological model study and planning of Elephant Pass Lake for best use of water with minimum negative environmental impact.

Copy Right, IJAR, 2015,. All rights reserved

INTRODUCTION

1.1 Backgrounds

The Jaffna lagoon is a shallow coastal water body in the Jaffna peninsula, northern part of Sri Lanka. It is located between 79° 54'E and80° 20'E longitudes and09° 30' N and 09° 50'Nlatitudes.Jaffna lagoon consists of two internal lagoons in the Jaffna peninsula, Vadamarachchi (Thondamanaru) and Upparu and the external lagoon, Elephant pass, which separates the peninsula from the main land. Vadamarachchi and Upparu lagoons comprise an area of 77.6km^2 and 25.9km^2. Catchment area of 298km^{2}and 220km^2 drains respectively to these internal lagoons. The external lagoon with 78km^2 area get discharge from 940km^2 regulated catchment. All of three lagoons have exits to the sea and the fresh rain water inflow to these lagoons drains finally to the sea.

Due to the nature of the Jaffna peninsula, Ground water is the only available source of water supply in this region and there are no alternative fresh water sources in this area. The extremely permeable high yielding limestone aquifer has been used extensively for all of the water needs of the Jaffna peninsula. In addition to the domestic use, ground water is pumped increasingly for agricultural and industrial activities. As Jaffna peninsula is surrounded by sea on all four sides and no place in it is more than 16 km from the sea, it is susceptible to sea water intrusion from all directions. Increasing extraction from the shallow aquifer has resulted in substantial fresh water level decline and subsequent encroachment of seawater into the aquifer.

The Recharge to the fresh ground water aquifer is entirely from percolation of rainfall in the local catchment, only a limited quantity is available. The rainy season recharge the ground water aquifer annually. The total annual average rainfall in this area is 1300 mm and 70% of it falls within three months from October to December. Most of the water drains to the sea through the intermittent rivers and through lagoons. Recharging the ground water reservoir and protecting it from salt water intrusion are great importance to the existence of Jaffna Peninsula.

It has been proposed since as back as 1879[17] to convert the Jaffna salt water lagoons to fresh water lakes in order to improve the water resources in the Jaffna peninsula. The concept is to isolate the lagoons from the sea by constructing barrages and flush out the salinity of the lagoons repeatedly over a period of years with fresh water run-off. By this process of reducing the salinity of the brackish water in the lagoons, it is anticipated that the uncultivable lands fringing the lagoons would become suitable for cultivation and also the brackishness of water in many of the wells in the peninsula would be reduced gradually. It is also envisaged that lagoons as surface water storage increase the detention of rainwater for percolation and hence increased recharge of groundwater aquifer.

Based on the proposals and then studies by the Irrigation Department, The Thondamannaru barrage in the sea mouth of Vadamrachchi lagoon was completed in the year 1953 and the Ariyalai barrage, which seals the entry of sea water into the Upparru lagoon, was completed in the year 1955[17].

When the works to convert Jaffna peninsula internal lagoons into fresh water lakes was nearing completion, it was recognized that a plentiful supply of rain would be required over the years to leach out the salt encrusted lagoon bed. The leaching action of the two internal salt water lagoons would be naturally slow process on account of the limited catchment area draining into these lagoons. Attention was therefore directed towards converting the Elephant Pass lagoon into a fresh water lake and discharging the excess water into Jaffna lagoon to expedite the process of leaching. [17]

Elephant Pass lagoon is fed by the larger catchment in the main land and receives much more supply of water.4 km long channel called Mulliyan channel, linking Vadamarachchi lagoon with Elephant Pass lagoon was proposed with the hope of accelerating the leaching out process and augment the storage of internal lagoons.

The construction of Elephant Pass lagoon scheme commenced in the year 1962 with the construction of a bund cum spill across the east at Chundikulam and another bund in the west at A9 highway to seal the entry of sea water into the lagoon. Approximately 3,5km out of 4,0km link canal was also completed incorporating the above mentioned proposal of transferring the water to the Vadamarachchi lagoon.

Due to the various difficulties the progress of Elephant Pass scheme was rather slow, when it was eventually completed; it received two major setbacks [17]. It was noted that salt water was seeping considerable quantity through the western bund into the lagoon. Prevention measures were subsequently taken to seal the seepage. The second set back was the damage to the Eastern closure bund. Due probably to the settlement of the sub soil below the bund, the bund has settled and has been overtopped and breached during one of the floods that occurred subsequently. [14]

After a long lapse of time, feasibility study was carried out with fresh field investigations in 1976 by Irrigation Department. However, due to the prolonged conflict in this region, the Elephant Pass lagoon scheme has been abandoned last 30 years without further detail study and implementation. Elephant Pass lagoon scheme is revived again in the recent days after drought conditions in Jaffna peninsula in the period from 2011 to 2013.The current expectation is the possible water supply to part of the Jaffna peninsula from Elephant pass lagoon as a fresh water lake in addition to the other envisaged benefits.

A simplified water balance computation of Elephant pass lagoon can be the first step to make a quantitative evaluation of available water and using it possibly for different purposes.

1.2 Objectives of the Study

The overall objective is to study the water balance of the Elephant Pass lagoon. The main tasks which are oriented towards the objective of the study can be summarized as follows

- Study the hydrology and meteorology of sub-catchments draining the water to the Elephant Pass lagoon.
- Data collection for the study.
- Establish a rainfall-runoff relationship to the catchment to estimate the inflow to the lagoon.
- Use the operation simulation to determine available water for release and spill from the lagoon for the proposed lowest and highest regulated water level.
- Provide recommendations for future works.

2. DESCRIPTION OF THE STUDY AREA

2.1 Catchment Description

Four intermittent river basins, such as Kanakarayan aru, Nethali aru, Pramanthal aru and Theruvil aru drain into the Elephant Pass lagoon. Medium and small size reservoirs in the river basins detain the rain water for irrigation.

2.2 Climate and Hydrology

Due to the location of Sri Lanka, close to the equator, the climate of the island could be characterized as tropical. Monsoonal and convectional rain accounts for a major share of the annual rainfall of Sri Lanka. The catchment area gets rainfall mainly from Northeast monsoon and depression in the Bay of Bengal and hence cyclones brings strong winds with intense rain, sometimes it leads to floods also.

Figure 2.2 shows the monthly average precipitation and temperature variation recorded during the period 1961 – 1990. The average annual rainfall during is around 1300 mm/year and daily maximum and minimum temperatures are 32.7 and 23.5 respectively. As shown in the above figure 2.2, peak rain fall occurs during the months of October to December and rest of the months get a little scattered rainfall.

2.3 Topography

Topography of the Jaffna peninsula is relatively flat and the highest elevation is 3.2MSL. Jaffna lagoon elevation varies from -1.0 m MSL to + 2.5 m MSL.

2.4 Geology

Jaffna lagoon is geologically underlain with alluvial and lagoon deposits, silt and clay. Miocene limestone (from Vedditalativu Lagoon to Chundikkulam Lagoon) and graniticgneiss and undifferentiated charnockite and proterrozoic gneissic rocks are found (mainly between the north and north-north east coastal sector of Sri Lanka) as the basement rock.

3. DATA COLLECTION

This section describes collecting relevant data for the study and its suitability for use in this study. Data includes topographical data, hydrological and meteorological data and data about existing water regulating structures and reservoirs. The available data relevant for the study is summarized. Data needed for this water balance study were collected from main hydro-meteorological data sources in Sri Lanka and from global organizations, monitoring the global climate and water resources.

3.1 Data Sources

3.1.1 Sri Lankan Institutions

- Department of Irrigation
- Department of Meteorology
- Survey Department

3.1.2 Global organizations

- World Meteorological Organization (WMO)
- International Steering Committee for Global Mapping

In Sri Lanka, local offices of the irrigation department (Irrigation Engineer's office) administrate and maintain the irrigation reservoirs, cultivation area and the watershed within their range. These local offices also record the daily rainfall, river flow and water level of the reservoirs, release and spillage from the reservoirs. However, there are no river flow measurements available during the last thirty years in this study area.

3.2 Data collected for the Study

- Topographical maps and details
- Meteorological data
- Evaporation data

3.2.1 Topographical Maps

Topographical maps with 1:50 000 scale prepared by department of survey, Sri Lanka is available for the study area. However, topographical information used in the irrigation department studies was used in this study. Area, Elevation-Storage curve for the Elephant Pass lagoon is derived from the 1976 survey data from department of irrigation as documented [6].

GIS (Geographical Information system) data for the study area obtained from Global Map data for Sri Lanka (International Steering Committee for Global Mapping).

3.2.2 Iso-Yield Maps

Iso-Yield maps of Sri Lanka which shows the iso-yield curves for the two seasons, Maha and Yala. Maha (Perumpogam) season, rainy season in the catchment, is from October to March and Yala (Sirupogam) Season is from April to September. Iso-Yield (Contours of average yield) maps are widely used for design of irrigation head works for small catchments in Sri Lanka.

3.2.3 Rainfall Data

Daily recorded values from Iranamadu (operated by Dept. Irrigation) and Thirunelveli (operated by Dept. of Meteorology) meteorological stations collected for this study.

Monthly average rainfall values based on monthly averages for the observed rainfall records available from 1939 to 2014 at Iranamadu meteorological station is used for monthly operation study.

3.2.4 Evaporation Data

Evaporation in the study area is considerably high and significant in this study. Monthly evaporation values measured by Pan Evaporation at Iranamadu meteorological station used in Irrigation department studies were used in this study also. These monthly evaporation values obtained by averaging over long periods of observation of the Pan Evaporation

$E_L = K\,Ep$

Where

E_L - Evaporation from lake

Ep - Evaporation from the pan

K - Pan coefficient

Monthly Evaporation values adjusting using a Pan Coefficient of 0.8 used in this study and tabulated in the following Table 3.2.

4. WATER BALANCE COMPUTATIONS

The study of the water balance structure of lakes, river basins and ground-water basins forms a basis for the hydrological substantiation of projects for the rational use, control and redistribution of water resources in time and space (e.g. inter-basin transfers, stream flow control, etc.).Knowledge of the water balance assists the prediction of the consequences of artificial changes in the regime of streams, lakes, and ground-water basins. [18]

4.1 Water Balance Equation

The water balance equation for any water body indicates the relative values of inflow, outflow and change in water storage for the volume considered. The simplified water balance equation for the reservoir (lagoon) can be written as follows:

$$\mathbf{S_{t+1} = S_t + I_t - O_t}$$

Where

S_{t+1}-Storage at the end of time step

S_t - Storage at the beginning of time step

I_t - Inflow to the reservoir during time step

O_t - Outflow from the reservoir during time step

4.1.1 Inflow to the Lagoon

- Runoff from the catchment
- Rainfall directly on the lagoon
- Spill/Release from upstream reservoirs.

1. Runoff from the catchment

Downstream of the reservoirs of the four regulated river basins considered as local catchment to the Elephant Pass lagoon. Monthly average runoff yield from the catchment is computed by using iso-yield maps of Sri Lanka plotted for the two seasons, Maha and Yala.

2. Rainfall directly on the Reservoir (lagoon)

As lagoon consists of considerably large surface area, yield from the direct rainfall on the lagoon (reservoir) is significant. When computing the precipitation that falls on the surface of lakes and reservoirs, it is necessary to take into account the fact that, due to the attenuation of ascending air currents above the water surface which aids in the formation of convective local precipitation, the amount of precipitation falling on the water surfaces is less than on the land. It may be 15-25% less than the precipitation recorded from a gauging station on the land [18]. Monthly yield from the lagoon is taken as 80% of the monthly rainfall volume in this study.

3. Spill/Release from Upstream Reservoirs.

Based on the observations and knowledge of this intermittent river basin, spilling from the reservoirs in the upper catchment occurs in general during the months of November, December and January. Monthly average values of spilling from the Iranamadu tank were used in this study.
Computation was done with and without upstream spill/release.

4.1.2 Outflow from the Lagoon

- Evaporation loss
- Percolation
- Demand
- Spillage

1. Evaporation Loss

Evaporation from the reservoir (lagoon) is estimated from Pan Evaporation data. Evaporation loss is computed as a function of water surface area as follows.

$E_t = A_t E_L$

Where

E_t - Evaporation loss in each time step

A_t - Water surface area at the beginning of each time step

E_L - Adjusted pan evaporation

2. Percolation

In the operation studies of irrigation reservoirs, monthly seepage loss is taken as 0.5% of the volume of water stored in the reservoir. Percolation is expected to be high in the lagoon area and rate of Percolation was taken as 2% and 4% of reservoir volume for this study.

3. Demand / Reservoir Release

Minimum operating water level is set at 0.0 m MSL and constant release per month throughout the year considered.

4. Spill

Spill cum causeway with crest level at 1,2m MSL was proposed by the irrigation department studies in 1976. Computation was done with HRWL (Highest Regulated Water Level) of 1.0 m& 1.2 m MSL in this study. Spill loss was computed as rest volume at end of each time step when water level exceeds HRWL.

4.1.2 Lagoon Storage

Water surface area and Water level in the lagoon is given as function of reservoir storage by using the Area, Elevation-Storage curve for the Elephant Pass lagoon.

4.2 Operation Simulation

Operation simulation is a process often employed in hydro-technical developments, e.g. for hydropower plants, water supply works, irrigation projects and flood control projects. The purpose of operation simulation is to estimate the production and economic benefit of the system under varying hydrological conditions [4]

Microsoft Excel based simplified model has been developed for the Elephant pass lagoon operation study based on the water balance equation. Water balance components, as described in this section, are incorporated by logical procedures with the help of Excel functions and operation simulation for the lagoon was run with monthly time step.

5. RESULTS AND DISCUSSION

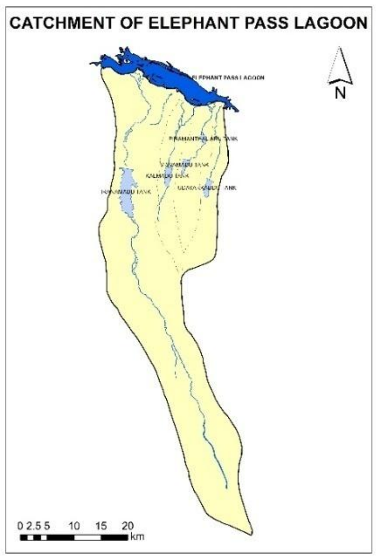

Figure 2.1: Catchment of Elephant Pass lagoon

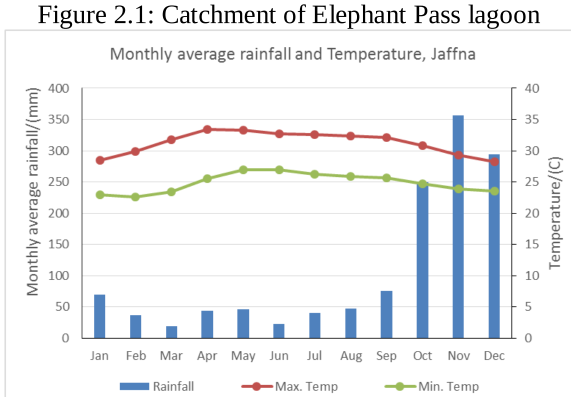

Figure 2.2: Climatological information is based on monthly averages for the 30-year period (1961-1990)[http://www.worldweather.org/]

Table 3.1: Monthly average rainfall values for the study area.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
Monthly average Rainfall/ (mm/month)	69.6	37.2	19.1	43.4	46.3	23.2	40.5	47.8	75.4	249.8	356.1	294.5

Table 3.2: Monthly Evaporation values at Iranamadu meteorological station.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
Monthly Evaporation/ (mm/month)	76.2	82.9	110.6	102.7	117	127.4	126.8	123.4	122.5	97.5	69.2	67.4

The simulation results shows 70% of the total inflow evaporates directly from the reservoir and it is an unproductive loss. Evaporation loss is very high, obviously due to large water surface area. Surface area of Elephant Pass lagoon (9300ha) with the capacity of 106MCM at proposed HRWL is nearly 7 times larger than the surface area of Iranamadu reservoir (1300ha) with the capacity of 131MCM.

Pan Evaporation data measured by a class-A pan on the reservoir's bank usually overestimated the reservoir evaporation. The reason for this difference is presumably the significantly different thermal condition of the pan water as compared to reservoir water. [19]

Pan coefficient of 0.8 is used to adjust the evaporation values. However, thermal condition of coastal water body (lagoon) is totally different from the Iranamadu inland meteorological station. Direct field measurements and model studies are important to verify the actual evaporation.

Increasing the spill crest level from 1.0 m MSL to 1.20 m MSL inundates additional 880ha land area. It is due to the flat topography of the lagoon. Upstream spill occurs same period when local catchment get much rainfall. However, Flushing out of salinity can be carried out during rainy season. Data for tidal heights are required to determine the efficiency of the leaching process.

Even after high evaporation loss, roughly 2MCM available without upstream spill and 4MCM available with upstream spill with the designed crest level of 1.2m MSL.

Seepage loss was assumed in this study as 2% of the initial reservoir volume at each time step. Field measurements are required to verify the assumption.

The use of long time steps, e.g. a month, may lead to systematic under estimation of flood loss in the system and over estimation of water available for use/demand in the system. Figures up to 15-20% have been reported. This error can be reduced or eliminated by using a one day time step [4]. Operation simulation with daily time step can give better result.

6. FUTURE WORKS

Kanagarajan river basin which feeds the Irranamadu tank and Elephant Pass lagoon is important for the livelihood and also for the existence of Northern Province. Reestablish the river gauging station in the Kangarayan river basin and recording the flow measurements is essential for the future studies.

Storage Area Elevation curve derived from land survey in 1976. Survey should be done to get the present contours of the terrain. Measuring the storage capacity of lagoon by conventional means is labor-intensive, costly, and time-consuming. Remote sensing can be used to estimate the reservoir storage capacity.

References

1. Elizabeth, M.Shaw, 1994, Hydrology in Practice, Stanley Thomas Ltd, Third edition.
2. International Steering Committee for Global Mapping,
3. Joint online weather service from the Norwegian Meteorological Institute (DNMI) and the Norwegian Broadcasting Corporation (NRK):"Weather forecast for Jaffna Lagoon, Northern (Sri Lanka)"
4. Killingtveit, Å & Sælthun, 1995, N.R: Hydrology, Hydropower Development Vol.7, Norwegian Institute of Technology, Division of Hydraulic Engineering.
5. Ponrajah, A.J.P, 1982, Design of Irrigation Headworks for Small Catchments, Irrigation Department, Colombo, Sri Lanka. Research Journal of Science & IT Management Vol.02, 20-27.
6. Shanmugarajah.K, 1993, Water Resources Development Jaffna Peninsula, Fast Books, A division of Wild & Woolley Pty. Ltd Glebe.
7. Sivakumar SS (2014); Application of Electronic Spread Sheet and Water Balance Error Optimization Technique in Ground Water Model Study to Improve the Ground Water System in Restricted Area Int. J. of Adv. Res. **2** (6). 0] (ISSN 2320-5407)
8. Sivakumar, S.S, 2013, Reclamation of Land and Improve Water Productivity of Jaffna Peninsula of Northern Sri Lanka by Improving the Water Quality of the Lagoons Irrigation Department.
9. Sivakumar, S.S., Alternate management options of small scale surface water resource system to develop ground water system for the improvement in food productivity in Dry Zone of Sri Lanka. Proceedings of Workshop on Challenges in Groundwater Management in Sri Lanka. P63-72 (2011)
10. Sivakumar, S.S., Conjunctive Use of Surface and Groundwater to Improve Food Productivity in Restricted Ares. 2008, University of Moratuwa, Sri Lanka.
11. Sivakumar, S.S., Management Policy of Water Table in Dry Zone of Sri Lanka to Subsidise the Pain of Non Rice Crop Cultivators for the Food Productivity Improvement, RJSITM, The International Journal Research Publications, Volume 02, Number 09, pp, July-2013, ISSN:2251-1563
12. Sivakumar, S.S., Policy alternatives of the management of minor and medium irrigation schemes to develop groundwater system in restricted catchments for the improvement in food productivity in the dry zone of Sri Lanka. Proceedings of National Conference on Water, Food Security and Climate Change in Sri Lanka Vol. 3, Page 73-88 (2009) IWMI Publication ISBN 978-92-9090-720-6
13. Sivakumar, S.S., Post Conflict Development Strategies. 2012: Emergency Northern Recovery Project.
14. Sivakumar, S.S., Reclamation of Land and Improve Water Productivity of Jaffna Peninsula of Northern Sri Lanka by Improving the Water Quality of the Lagoons. RJSITM. 2(08): p. 20-27
15. Sivakumar, S.S., Groundwater balance study in a restricted catchments in Vavuniya to find effective recharge location by introducing new operational policy on minor / medium irrigation schemes. Seminar on Irrigation for the Centenary programme of Irrigation Department, P163-174(2001)
16. Sivakumar, S.S., Water Utility and Management Policy for Effective Sharing of Natural Water Resource in the Costal Dry Zone of Sri Lanka in the North East Region. ENGINEER, Journal of Institution of Engineers Sri Lanka, Vol;XLVII, No.01, pp 37-42,January 2014, ISSN 1800-1122
17. Sivakumar.S.S, 2002, Water Resources and Agriculture Development Strategy North East Province 2002/2012, Irrigation Department.
18. Sokolov,A.A, & Chapman,T.G (eds), 1974, Methods for water balance computations, An International guide for research and practice. The UNESCO Press, Paris.
19. Tanny, J. et al. 2008. Evaporation from a small water reservoir: Direct measurements and estimates. Journal of Hydrology, 351, 218-229.
20. World Meteorological Organization, WMO

View publication stats