# Evaluation of Irrigation Water Issue Practice for Better Water Management at Rajangana Reservoir, Sri Lanka

**H. Chemjong and N.T.S. Wijesekera**

**ABSTRACT**

In most parts of Sri Lanka, water is the critical factor for cultivation. Using the appropriate amount of water is the key factor and therefore efficient water management is very important to increase food production. Common practice of Irrigation water distribution is with the help of Irrigation Department Guidelines. Present work is a study of irrigation water issue practice in Rajangana Irrigation Scheme situated at Anuradhapura which is a district the North Central Province of Sri Lanka. The present study using field data from 2008-2013, computed the theoretical irrigation water requirements as recommended by the Guideline using 75% probable rainfall values and this was named as " Recommended Irrigation Plan", Then this plan was modified with the consideration of actual rainfall that had been experienced during operations. This modification represented the actual water issues that need to be anticipated during operation and hence was named as "Anticipated water use". At the Rajangana Irrigation scheme there is also the actual plan developed for each year along with the water issue at the sluice gate corresponding to the 2008-2013 period. The present research compared the case of Left Bank gravity fed irrigation area which covers an approximate 2500 Ha area with 39 Km tertiary canal network. This area is cultivated mainly with paddy for two main rainy seasons namely "Maha" and "Yala". Water issue model for the study was developed at a weekly time resolution. Comparison of actual water use with the quantities are computed by following Irrigation Department Guidelines disclosed a significant over issue in Maha and Yala seasons amounting to 63% and 52% respectively. In the case of making adjustment to the plan with the receipt of actual rainfall, then a further reduction of water issue by 35% and 8% in Maha and Yala respectively could have been possible. Evaluation revealed the need of gauge network, a spatially distributed performance monitoring system and a critical evaluation on the base of present Guideline in order to suitably manage the water utilization in the Rajangana Left bank irrigation scheme.

*KEYWORDS: Efficient Water Management, Irrigation Water Distribution, Water Issue Practice, Irrigation Water Requirement, Probable Rainfall, Recommended Irrigation Plan, Anticipated Water Use, Water Issue Model, Gauge Network*

## 1. Introduction

Sri Lankan farmers are growing paddy which is reaching 3876000 MT per annum (DCS, 2008) and it fulfils 90% of national demand which was only 40% in 1950 (WRMS, 2010). Sri Lanka has 0.7% approximate rate of population increment which has been increasing the rice consumption about 1.4 MT per year and its effect for increasing rice demand 1.1% per year (DAG, 2014b). Case Study of Walawe basin (2009) has included the rice yield 4.2 MT/Ha and 4.0 MT/Ha in Yala and Maha season respectively and WRMS, (2010) has indicated that average rice yield 4.5 MT/Ha. But here is potentiality of yield is 7-12 MT/Ha. In the review of De Oliveira, about 850 million people of world are food insecure and 60% of these populations are of South Asia and Sub Saharan Africa. This clears the critical scenario of food insecurity in South Asia.

Sri Lanka has three zones which are dry zone, intermediate zone and wet zone where annual rainfall are less than 1750mm, 1750-2500mm and 2500mm respectively (DAG, 2014a). In case study of Walawe Basin (2009), there is approximately 43000 MCM surface water availability but there is only 28% water is in use of irrigation and 65% water is being evaporated, percolated and flowed out to sea.

Only 7% is in industrial and domestic use. This indicates that here is possibility to use more surface water by either reducing losses or adapting the alternative ways. Here, climate change effects have reduced 7% of total runoff (Wijesekera, 2011). A rise of temperature is increasing the evapotranspiration thereby causing the stress for irrigation management and these effects are creating significant challenges for irrigation system.

Water management plays important role for better use of water to support not only for more area but also for keeping farmer secure. Average duty in Sri Lanka are 1300 mm and 1750 mm in Maha and Yala respectively (Imbulana & Merrey, 1995). This mentions that about 19% area per unit volume decrement and increment of irrigation duty in Maha and Yala are 22% and 29% respectively. Additionally, this mentions that irrigation water productivity has decreases 20% within 1984-1993.This hints to think for other alternatives for better irrigation water management and efficient scheduling of water issue practices.

Sri Lanka has been preparing the water scheduling and planning by using the Irrigation Department Guideline (Ponrajah, 1988). In each season, water schedule is being prepared and there is discussion with farmers for the consensus. Especially, Minor and Medium Systems are being managed by Irrigation Department of Sri Lanka with consultation of farmer leaders. Generally, water issue practices depends on the crop types, actual rain, starting time of cropping, time to reach to maturity phase and efficiency of channel therefore this can be vary from plan. Hence, it is very important to compare both plan and actual practices of water issue to manage the water efficiently. In spite of very limited study of irrigation method and practices in Sri Lanka, Wijesekera (2010) has reviewed 16 nos. of irrigation reservoir, 3nos. of water use and 12 are regarding climate change effect in irrigation sector. De Alwis and Wijesekera (2011) has argued to incorporate indicator to capture total water use by plant in review of performance assessment indicator for evaluation of irrigation schemes.

Wickramaarachchi, Wijesekera and Gamage (2000) has mentioned that lack of the concern about sensitivity of paddy to water stress is a major concern with regards to water scheduling and its results low yield. Shantha et.al. (2012) has carried out the study of minor tank in Trincomalee and this study has recommended to improve the efficiency of water resource uses. De Costa (2010) has mentioned the need of good policy framework and commitment of research area in water sector. Hadad and Bakr (2013) has studied in four climatic zone of Iraq and mentioned that rainfall, irrigation scheduling methods, climatic factors, soil factors and plant types affect the water issue in irrigation. Hamlyin (2004) has also supported its conclusion. Faulkner et.al. (2008); Bauman and Tuong (2001); De Olivera et.al. (2009); Wridt et.al. (2009) mention the need of evaluating seasonal variation of precipitation and soil water content to study which helps to select the suitable agriculture patterns, technologies and varieties. Bauman and Tuong (2001) has mentioned that reduction of the ponded depth can save 23% water with reduction of only 6% paddy production. It shows that the water volume based taxes has better results than conventional area based taxes. Prasthasarathi et.al. (2012) mentioned that aerobic rice production-environment friendly method which can reduce the significant volume of water i.e. 50% can have crop yield 4-6 MT/Ha. De- Olivera et.al. (2009) has also found out the same findings in Latin America. Rama Rao (2011) has studied about the System of Rice Intensification and found out 20.15% increment of productivity and reducing the input about 10.85% coverage.

According to Irrigation Department Guideline, water issue are planned and implemented which open the way to carryout comparative study to evaluate the degree of adequacy for efficient water uses.

Rajangana reservoir in North Central Province of Sri Lanka has capacity of 100.66 MCM and considered as water abundant. WMS (1982) states that there was no requirement of water management in 1968 because of high availability but it was managed and maintained poorly. De Alwis (2008) has accepted about the poor management of water with water abundance. Considering the importance of water management, comparative evaluation of planned and actual water release in Gravity fed System of Left Bank Canal System is important. Objective of this study is comparative evaluation of Irrigation Demand and Actual Water Use in gravity flow system of Irrigation scheme to identify suitable management options, crop types, scheduling and implementation.

### 1.1. Study Area

Rajangana Irrigation System is located in Anuradhapura district of North Central Province. For the study, Left bank irrigation system was selected for the comparative study where 37 turnouts in gravity flow system. Total coverage area is 2559.44Ha where is established 18 pump stations and these stations are providing water for 334 Ha of upland area.

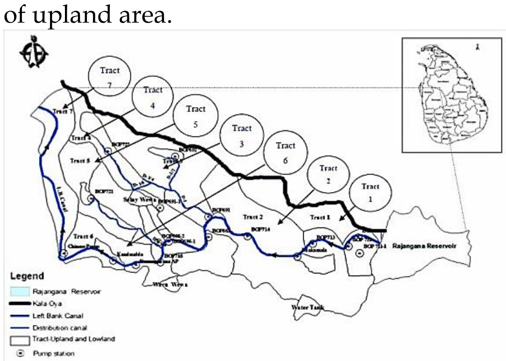


Figure 1: Rajangana LB Canal System

## 2. Methodology

Institutional visit and field visits were undertaken to the project area for data collection of 10 years data. Especially, 5 Years (2008/09-2012/13) was selected for study. For example, cropping data, L.B. sluice water issued data, pumping hour data, crop yield and fertilizer data were collected where October-September is the period of water year. All data were prepared as weekly resolution and followed by data checking and incorporating suitable assumptions for computation. In this Rajangana Irrigation System, one canal has fed both gravity flow and lift irrigation but in study, only gravity flow system was taken for computation which was on the base of Irrigation Department Guideline. Prior to the computations a detailed literature review was carried out to understand the available guidelines, practices and relate research in Sri Lanka, Rajangana scheme and elsewhere. Detailed field surveys were undertaken for both data collection and gap filling of institutional data. A critical evaluation of the results are then discussed and concluded for appropriate water management recommendations.

## 3. Analysis and Result

### 3.1. Irrigation Water Requirement

One objective of Study is the comparison between actual water use and water demand on the base of Irrigation Department Guideline. 75% probability and pan evaporation data was considered from the table of Irrigation Department Guideline Ponrajah (1988). Cropping pattern, its types and extent with crop season commencement date was taken in actual base of the field. Effective rainfall was computed according to the relation in Irrigation Guideline Ponrajah (1988). Collected field data collection and interaction with officials reveal that there is always full extent in both Maha (October-March) and Yala season (April- September).

### 3.2. Crop Evapotranspiration

Evapotranspiration (ET0) is taken of A class pan of Maha-Illupallama station and crop coefficient (KC) values from the table of Irrigation Guideline as well as corn for FAO No 24 Report. In Yala season, paddy variety is longer i.e. 3.5 month period and in Maha season, paddy is cultivated of 3 month period type. Water availability also guides the selection of paddy variety. In Yala season, evapotranspiration is 3.36mm/day with assuming 3-4 days watering intervals for corn (Ranaweera et.al, 2002) and Kc is 0.69 for initial growth stage. Generally, Indian types are cultivated therefore we assumed the same type and FAO no. 24 has mentioned 20/35/40/30 day distribution for this corn (Doorenbos & Pruitt, 1977). This literature has mentioned about Kc values 1.05 and 0.55 for mid-season and harvesting. Here is average temperature is 29° to 34° and in coldest season- January, it is within the range of 14° to 17°. After interpolating, its value was found out as Kc, 0.69, 0.87, 1.05, 0.80 and days are 20, 35, 40 and 30 for initial, development, maturity and late stages respectively.

### 3.3. Selection of Stagger

Staggering practices are generally in canal irrigation for optimizing the canal capacities and management of equipment power for farming. For management of the overloading condition of the canal and to manage of machines and draft power, stagger is recommended for equal or unequal stagger of total extent of cultivation (Ponrajah, 1988). However the Rajangana Irrigation System does not incorporate the staggering system therefore it is avoided in computation.

### 3.4. Land Preparation Water Requirement

In Sri Lanka, information of land preparation work is generally used for the irrigation system planning and design. In Rajangana, reddish brown earth (RBE) soils are found in upland and low humic gleys (LHG) are prevalent in the low land area (WMS, 1982). Based on Irrigation Department Guidelines (Ponrajah 1981), 7 inch water depth for land preparation and duration of 15 days were adopted for weekly water requirement computations in the case of lowland paddy.

Rainfall is a major factor for land preparation work in Yala season during which OFC crops are also cultivated. The staff of Rajangana ID indicated that the field practices demonstrated a usual land preparation time of one week and a cultivation pattern similar to upland. In case of upland farming, soil saturation is not practiced.

The Irrigation Guideline is only focused on paddy cultivation. Information available on OFC does not enable a reasonable comparison with paddy. In the case of OFC, grown in upland area a 1.5 inch (38 mm) water depth has been recommended for land preparation to be issued within 15 day duration. According to Irrigation Department (ID) guidelines, upland cultivation requires water only for tillage and the indicated period is 4.27 days. A land preparation water quantity of 38 mm in one week was taken as the recommended amount for OFC cultivation in uplands.

### 3.5. Farm Loss

In case of farm loss, ID Guideline (Ponrajah, 1988) has recommended quantities of 4 inches and 6 inches for Maha and Yala respectively. Guidelines do not provide direct information to determine the farm loss in case of OFC crops. Values corresponding to farm loss for OFC could not be found for work done elsewhere in the world.

In the present work, Farm loss for OFC crops were based on several assumptions. In Sri Lanka, basin irrigation is used for paddy cultivation. In the Basin irrigation practice, farm loss generally occurs due to the deep percolation and runoff losses. Paddy fields of Hsueh Chia Experimental Station of Taiwan had recorded deep percolation values of 295mm and 273 mm for first and second rice crop cultivations respectively (Kuo, Ho & Liu. 2005). Naderi et al. (2013) found that a wheat farm had an average deep percolation and runoff loss amounting to 52.9% and 6.7% of the total applied in Iran respectively. These evidences show that the surface irrigation has a high deep percolation loss. Surface Irrigation has a 40%-60% application efficiency in basin irrigation while, field and drip irrigation demonstrate a higher application efficiency 80% to 95 % (Irmak et al., 2011). In practice, low flow rate methods such as micro Irrigation techniques, small pipe irrigation and small ditch irrigation etc., are used for OFC cultivation. During the Yala OFC cultivation, when the water is scarce, it can be safely assumed that the runoff losses are very low as compared with Paddy. Reported values mention that the losses in case of micro irrigation are in the range of 5%-20% while, in the case of basin irrigation the same would be around 40%-60%. As such average farm loss in micro irrigation is approximately 25% of basin irrigation. Therefore, a value of 38mm which is 25% of 152 mm was considered as the farm loss for OFC.

### 3.6. Effective Rainfall

Effective rainfall computations were carried out using the ID guideline recommended empirical equations. To compare the water plans of the Rajangana ID Office and the Guideline Recommendations, computations were carried out with the use of 75% probable rainfall of the DL1 agro ecological region given in the ID guideline. Effective rainfall values of each year with using 75% probable values of ID guideline are shown in weekly temporal resolution (Figure 2). Accordingly the ID guideline recommended monthly empirical equation was proportionately converted to compute weekly effective rainfall values. To compare actual water issue with the guideline recommendation, effective rainfall values for each year were computed using actual values of rainfall recorded at Rajangana for the period 2002 - 2013.

Weekly effective rainfall experienced at Rajangana was computed using observed rainfall values instead of 75% probable rainfall are shown in Figure 3.

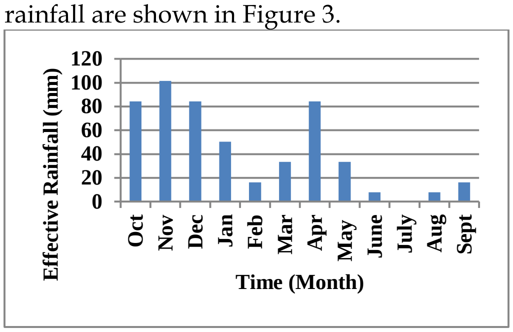


Figure 2: Effective Rainfall According to Irrigation Department Guideline

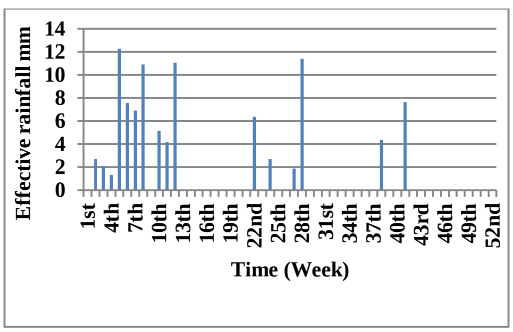


Figure 3: Effective Rainfall on the Base of Rajangana Station

### 3.7. Canal Efficiency

Irrigation demand values at the headwork were computed with the application of canal conveyance efficiency to canals on the field irrigation requirement. In the present work, computations were carried out with an overall canal conveyance efficiency of 70% as recommended by Ponrajah (1980).

### 3.8. Gravity Flow System

Remaining quantity of water in the LB Canal is found after deducting the quantity of water extracted for Lift Irrigation from the gravity irrigation system. In the present study, the behavior of gravity flow system is evaluated. Therefore; the total quantity of gravity flow was computed with the use of water release data and the pumped water quantities of each year. Comparison of pumped water and the total water releases indicate that general pumped water quantity varies from 0.14% - 0.36% per week. In order to present all the values in a comparative graphic the logarithmic plots are used.

Table 1: Net Gravity Flow Water Quantity in Maha Season

| Wat. Year | Water Issue for Gravity Flow System in Maha Season (MCM/Month) | | | | | |
|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar |
| 08/09 | 15.5 | 9.9 | 10.4 | 13.7 | 6.7 | 7.0 |
| 09/10 | 0.01 | 7.1 | 13.5 | 14.2 | 14.0 | 9.3 |
| 10/11 | 0.0 | 12.0 | 9.77 | 10.8 | 10.7 | 5.3 |
| 11/12 | 0.1 | 10.0 | 11.8 | 16.8 | 15.3 | 6.4 |
| 12/13 | 1.1 | 14.4 | 9.2 | 14.2 | 13.7 | 2.4 |

**Table 2: Net Gravity Flow Water Quantity in Yala Season**

| Wat. Year | Water Issue for Gravity Flow System in Yala Season (MCM/Month) | | | | | |
|---|---|---|---|---|---|---|
| | Apr | May | Jun | Jul | Aug | Sept |
| 08/09 | 18.2 | 13.5 | 11.1 | 10.6 | 0.5 | 0.0 |
| 09/10 | 8.0 | 8.3 | 10.5 | 10.2 | 2.9 | 0.0 |
| 10/11 | 11.2 | 18.0 | 13.0 | 14.6 | 7.9 | 0.6 |
| 11/12 | 12.0 | 18.9 | 11.3 | 11.3 | 8.8 | 1.0 |
| 12/13 | 20.4 | 15.5 | 17.5 | 17.1 | 5.3 | 2.7 |

### 3.9. Irrigation Water Requirement

LB main canal of the Rajangana irrigation scheme has both lift and the gravity irrigation system. In the case of lift irrigation system, reliable data of crop types, cultivation periods and cultivation extents could not be found. With the water extraction data for the lift irrigation system, Irrigation water requirements in the gravity fed system were computed. Crop and cultivation data also restricted the comparative evaluation of the present study to the gravity fed irrigation system. Computation of irrigation water requirements were done using spreadsheets prepared in line with the ID guideline. A typical format demonstrates the use of Crop Calendar, Crop Coefficients, Crop Evapotranspiration, Land Preparation, Farm Loss, Effective Rainfall and Canal Efficiencies. The stepwise computational method was used in the study and associated spread sheets. Computations were done for each crop at each tract and then results were summed to capture the variations at the LB canal level. Availability of actual water issues for the gravity fed irrigation system enabled a comparison.

### 3.10. Water Requirement Computation

Total water demands were evaluated by using two methods. One method is to evaluate the planned water quantities at the beginning of each season. The other method is to evaluate the actual water issue with the anticipated water use during the season when actual evaporation and rainfall are taken into consideration.

### 3.11. Recommended Irrigation Plan

This water manager would prepare prior to a cultivation season. With the availability of Crop type, Cropping Calendar and Extent of Cultivation, a manager would have to estimate the evaporation and rainfall. For these estimates, Guideline quoted values is utilized. In the ID guideline, 75% probable rainfall is given on the basis of agro ecological zones. Rajangana reservoir falls in to the agro ecological zone DL1. Hence this method is termed as "Recommended Irrigation Plan (DL1). This plan also uses the evaporation values of Kalawewa of guidelines which is closest to Rajangana.

### 3.12. Anticipated Water Use

This is a modification of the recommended water issue plan to reflect how the system has performed with actual rainfall and evaporation. In other words, a good and efficient irrigation water manager would make attempts to issue more water when the actual rainfall is less than the 75% probable rainfall and vice versa. This method enables the understanding of whether such changes are significant; therefore the anticipated water use which is calculated with historical data, considers the field reality with the knowledge of actual Crop type, Cropping Calendar, Extent of Cultivation, Rajangana rainfall and Evaporation at Maha Illupallama. Closest location to Rajangana having evaporation data was at Maha-Illupallama.

### 3.13. Comparison of Rajangana ID Plan and Recommended Irrigation Plan (DL1)

Comparative monthly plots of monthly water quantities corresponding to Rajangana ID plan (RID), Recommended Irrigation Plan (RIP) and the monthly effective rainfall were computed using 75% probable rainfall of DL1. Differences between the Rajangana ID Plan and Recommended Irrigation Plan (DL1) were identified. According to seasonal comparison, there is an over estimation in most of the months while in some months especially in Yala season, there is as under estimation when compared with the ID Guideline recommended values. Comparison of the variation of differences over the year, there is a significant deviation in the Yala season i.e. approximately 2 MCM per month. Annual variations show a general increase in the recent year except for 2009/10.

In the water duty comparison for Maha and Yala seasons, average water duty estimations in the Rajangana Irrigation Division Plan were 1.83 m and 2.13 m respectively for Maha and Yala seasons. Same from the Recommended Irrigation Plan, these were 1.34 m and 1.70 m for both seasons respectively.

### 3.14. Comparison of Actual Water Use and Recommended Irrigation Plan (DL1)

Actual weekly water use values of Gravity Irrigation System of L.B. Canal were aggregated as monthly and seasonal data in order to carry out a quantitative evaluation.

Actual water issues showed water releases as an environmental flow after the cultivation seasons. Environmental flow quantities were not separated when seasonal and annual comparisons were done. Rajangana Irrigation Plan, Actual water use and RIP (DL1) weekly values were plotted on the same graph. Monthly Actual Water Use plotted with monthly effective rainfall. Monthly values of Recommended Irrigation Plan with guideline recommended effective rainfall for DL1 and Values and the differences of both plan are considered. The water duty comparison for Maha and Yala seasons for these two cases are found out separately. Comparative evaluation of water issue was computed for each crop growth stage and seasonal and annual variation was found.

### 3.15. Comparison of Actual Water Use and Anticipated Water Use

Anticipated water use (ANWU) was computed considering effective rainfall and it was compared with the actual water released to L.B. Gravity Irrigation System. The detail comparison summarized as monthly and seasonal data which were compared for a quantitative evaluation.

Monthly actual and anticipated water uses are plotted with monthly effective rainfall. Monthly Seasonal and Annual differences could be seen within the study period.

Percentage of seasonal water volume differences between the Actual Water Use (AWU) and ANWU are computed for Maha Season and Yala Season separately. In the Yala Season, the percentage difference is lower than that of Maha Season. In both seasons high differences were noted during the initial period. The average differences in Yala and Maha Seasons were 51% and 117% respectively. In Maha season, the average percentage difference is about 55% in land preparation and it is high in initial stage period which is 372%

Duty of AWU and ANWU and its difference were computed. This water duty difference is 1.16 m (117% of the water duty of AWU) in Maha season and 0.82 m in Yala which is 51% of AWU.

### 3.16. Comparison of Recommended Irrigation Plan (DL1) and Anticipated Water Use

Recommended Irrigation Plan (RIP) was calculated with effective rainfall of DL1 Agro Ecological Region and Evaporation of Kalawewa-ID Guideline. The ANWU was computed with rainfall of Rajangana and actual pan evaporation of Maha Illupallama. These were compared to each other and this monthly and seasonally.

Percentage difference was computed using the following equation.

$$\frac{RIP-ANWU}{ANWU} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(Eq. 1)}$$

During the study period, average differences in the water duty of these plan and uses for Maha and Yala season are 35% and 8% respectively.

### 3.17. Water Use, Crop yield and Rainfall

A seasonal comparison Paddy yield, water use and effective rainfall from 2008/09 to 2012/13 are considered. In Maha Season, average effective rainfall at Rajangana is 0.64 m and the same in Yala season is 0.16 m.

Average actual water duty and recommended ID water duty for Maha season are 2.18 m and 1.34 m respectively. The same respective values for Yala season are 2.4 m and 1.7 m. Average paddy yield in Maha season is 6.67 Mt/Ha while almost the same in Yala season is 6.85 MT/Ha.

This study indicates that effective rainfall between seasons is significantly different and that the paddy yield is in sensitive to effective rainfall. This gives an indication that significant quantity of water for crop growth is made available by irrigation. Paddy yield variation reflects a pattern that closely matches with that of actual water use. With the increase of water use, the yield has shown an increase in the Yala season, but it is not so in the Maha season. In the Maha season, paddy yield appears to reach a limit that indicates a necessity to recognize the other reasons for increasing yield in Yala season.

This behavior is prominent where seasonal paddy yields are compared with the excess water utilization (i.e. AWU - RIP).

## 4. Conclusions

Rajangana L. B. gravity fed irrigation system over the five year study period revealed the need of appropriate canal water measurement system and also the need to introduce a spatially distributed performance monitoring system for the identification of critical areas ensuring efficient water management. Evaluations pointed to an over issue of water in the LB gravity fed irrigation system throughout the seasons which could result from many issues such as canal water losses, poor application, lack of a spatially distributed measurement system, availability of water in abundance and a week based data sets for planning. Irrigation Department guidelines should be critically evaluated and updated with the incorporation of structured research programs. Comparison of actual water issues at the LB Sluice disclosed a significant over issues of water throughout the both seasons with showing approximately 63% and 52% higher volume of the water requirements. Comparison of Guideline Based and Actual Water Duty values showed that the actual utilizations are much more than estimated in both seasons. On average, Maha Season - actual water duty was 2.18 m while the guideline based value was 1.34 m. The respective values for Yala season were 2.40 m and 1.70 m. Evaluation of Maha Season water issues during crop growth stages indicated that on average the Initial Crop Growth Stage used a water quantity to 4 times of which is anticipated from ID guidelines. In other Growth Stages, the increment varied between 1.5 -2.4 Times and Evaluation of Yala Season water issues during crop growth stages indicated that on average the Initial Crop Growth Stage used a water quantity nearly twice of the anticipated by following ID guidelines. In other Growth Stages the increase varied between 1.25 -1.57 times. Paddy Yield per unit of water indicates a highest value of 3.62 MT/m with average value of 2.99. A tendency of growing water overuse could be noted in the Yala season while in two Maha seasons overuse of water had not resulted in better yield.

## 5. References


Abideen, Z.U. (2014). Comparison of crop water requirements of maize varieties under irrigated condition of semi-arid environment. *Journal of Environment and Earth Science, vol.4* (6), 1-3.

Adnan, S., Khan, A.H. (2011). Effective rainfall for irrigated agriculture plains of Pakistan. *Pakistan Journal of Meteorology vol.6*, 61-72.

Ajmera, S. & Shrivastava, R.K. (2013).Water distribution schedule under Warabandi system considering seepage losses for an irrigation project. *International Journal of Innovations in Engineering and Technology (IJIET), vol.2,* 178-187.

Ali,O.O.(2013).A computer program for calculating the crop water requirements. Greener journal of agriculture science, vol3 (2), 150-163

Bauman, B.A.M. & Tuong, T.P. (2001).Field water management to save water and increase its productivity in irrigated low land rice. *Agriculture water management* 49, 11-30

Bos, M.G., Burton, M.A. & Molden, D.J. (2005). Irrigation *and drainage performance assessment*. CABI Publishing.

Cabangon R.J & Tong, T.P. (2000).Management of cracked soils for water saving during land preparation for rice cultivation. Soil and tillage research, 56,105-116

Case study in Walawe basin Sri Lanka (2009).Ministry of Agriculture Development & Agrarian Service Sri Lanka P.18

Chowdhary, S., Al-Zahrani, M. & Abbas, A. (2013).Implication of climate change on crop water requirement in arid region: An example of Al-Jouf, Saudi-Arebia. *Journal of King Saud University Engineering and Science*, 1-10.

Citing Wikipedia. (2014, February 10). In Wikipedia, Demographics of Sri Lanka. Retrieved from http://en.wikipedia.org/wiki/Demographics_of_Sri_Lanka

DAG: Department of Agriculture (2014a, March 25).Maize. Government of Sri Lanka.Retrieved from http://www.agridept.gov.lk/index.php/en/crop-recommendations/1026

DAG: Department of Agriculture. (2014b, May 5) Rice. Retrieved from http://www.agridept.gov.lk/index.php/en/crop-recommendations/80816.67.

DCS: Department of Census and Statistics.(2014, May 5).*Paddy Statistics*. Retrieved from http://www.statistics.gov.lk/agriculture/Paddy%20Statistics/PaddyStats.htm

De Alwis, S.M.D.L.K. (2008) *Evaluation of Operational Performance in Rajangana Major Irrigation Scheme* (Unpublished Master's thesis). University of Moratuwa, Sri Lanka.

De Alwis S.M.D.L.K. & Wijesekera N.T.S. (2011).Comparison of Performance Assessment Indicators for education scheme performances of Sri Lanka. *Engineer Vol* (XXXIV), No 3 pp. 39-50.

De Costa, W.A.J.M. (2010).Adaptation of agricultural crop production to climate change: A policy framework for Sri Lanka.j.*Natn.Sci. Foundation Sri Lanka* 38(2), 79-89.

De Oliveira, A., Trezza, R., Holzapfel, E. A., Lorite, I. & Vital Pedro, S.Paz (2009) Irrigation water management in Latin America. *Chilean Journal of Agriculture Research 69*(Suppl.1), 7-16.

Doorenbos, J. & Pruitt, W.O. (1977).*Guideline for predicting Crop water requirements*. FAO Irrigation and Drainage Paper 24, 1-95.

Faulkner, J.W., Steenhuis, T., De Giesen, N.V., Andreini, M. & Leibe, J.R. (2008) Water use and productivity of two small reservoir irrigation schemes in Ghana's Upper East Region. *Irrigation and Drain, Vol. 57*,151-162

Gersfelt, B. (2007). *Allocating irrigation water in Egypt*. Food policy for developing countries: The role of government in the global food system. International Food Policy Research Institute, 1-14.

Hadad, A.H.A & Bakr, T.S. (2013).Irrigation scheduling effect on water requirements. *Journal of Engineering Vol. 19(1),* 96-145.

Hamlyn, G.J. (2004).Irrigation Scheduling: Advantage and Pitfalls of plant based method. *Journal of experimental borani vol.55*, No.407.Water saving agriculture special issue, pp.2427-2436.

Hundertmark, W. & Facon, T. (2014, April 13).*Option for effective rice water management.FAO Corporate Document Respiratory*. Retrieved from http://www.fao.org/docrep/006/y4751e/y4751e0j.htm

Huppert, W. (2000).Governing irrigation service delivery in water scarce situations.ICID *Journal, vol.49* No.1, 55-60.

Hvidt, M. (1998). *Water, technology, and development: Upgrading Egypt's irrigation system. London*: Tauris Academic Studies.

Imbulana, K.A.U.S. & Merrey, D.J. (1995).*Impact of management interventions on the performance of five irrigation schemes in Sri Lanka* (Working Paper No. 35, 23-24.

Incrocci,L.,Marzialetti,P.,Incrocci,G.,Di,Vita, A.,Balendonck,J.,Bibbiani,C.,Spagnol,S. & Pardossi, A. (2014).Substrate water status and evapotranspiration scheduling in heterogeneous nursery crops. *Agriculture water management* 131, 30-40

Irmark, S., Odhiambo, L.O. & Kranz, W.L. (2011). *Irrigation efficiency and uniformity and crop water use efficiency* (EC732, p.1-8).University Nebraska Lincoln.

Kamaladasa, B. (2007). *Irrigation development in Sri Lanka*. Centenary commemoration publications.Page.179.

Khan, M.A., Islam, M.Z. & Hafeez, M. (2011).Irrigation water demand forecasting-A data preprocessing and data mining approach based on Spatio-temporal data. *Data Mining and Analytics CRPIT vol* 121,184-194

Kuo, S.F., Ho, S.S & Liu, C.W. (2005).Estimation of irrigation water requirements with derived crop coefficients for upland and paddy crop in ChiaNan Irrigation Association, Taiwan. *Agriculture water management* 82,433-451.

Loeve,R.Somaratne,P.G.,Ariyaratne,B.R.,Anputhas,M.&Inapala,K.(2003).Institutional changes to reduce land preparation delay in the North Central Province of Sri Lanka.Working Paper 69.1-67.International Water Management Institute

Majumdar, D.K. (2004).*Irrigation water management: Principle and Practice*, PHI: Prentice Hall of India.

Mattamana, B.A., Varghese, S. & Paul, K. (2013).Irrigation system assessment-Farmer's and Manager's view. *International Journal of Engineering Science and Innovative Technology (IJESIT), vol.2* (2), 148-159.

Mehmood A. Khan, Islam, Md.Zahidul & Hafeez, Mohsin. (2011)Irrigation Water Demand Forecasting-A Data Pre-Processing and Data Mining Approach based on Spatio-Temporal Data. *Conference in Research and Practice in Information Technology (CRPIT), Vol.121*, 183-206.

Moormann, F.R. & Panabokke, C.R. (1961).*New approach to the identification and classification of the most important soil group of Ceylon*.2R-2251-150,4-62.

Naderi, N., Ahmadi, M.K.Z. & Fazloula, R. (2013).Evaluation of water management and Irrigation efficiency in wheat farm. *International Journal of Agriculture: Research and Review vol, 3*(4), 751-756.

Pakhale, G., Gupta, P. & Nale, J. (2010).Crop and Irrigation water Requirement estimation by remote sensing and GIS: A Case study of Karnal District of Haryana, India. *International Journal of Engineering and Technology vol. 2*(4), 207-211.

Parthasarathi, T., Vanitha, K., Lakshamanakumar, P. & Kalaiyarasi, D. (2012).Aerobic rice-mitigating water stress for the future climate change. *International journal of Agronomy and Plant Production. Vol, 3*(7), 241-254.

Patanduk, J. (2013).Study of river water quality Pangkajene for irrigation Pangkep Distcit-Indonesia.*International Journal of Engineering and Technology vol. 3*(2), 165-169.

Patwardhan, A.S., Neiber, J.L., Johns, E.L., Member & ASCE. (1990).Effective rainfall estimation methods. Journal of Irrigation and Drainage Engineering vol.116 (2), 182-193.

Paul, S., Panda, S.N., Member, ASCE, Kumar D.N.(2000).Optimum Irrigation Allocation: A multi-level approach. Journal of Irrigation and Drainage Engineering.Vol.126 (3), 149-155.

Ponrajah, A.J.P. (1980).*Technical Guideline No.20*. Irrigation Department.

Ponrajah A.J.P. (1984).*Design of Irrigation Head works for Small Catchments*. Irrigation Department Colombo

Ponrajah, A.J.P. (1988).*Technical Guideline of Irrigation Work*. Irrigation Department, Colombo.

Rahaman, M.M., Islam, M.O. & Hasanuzzaman, M. (2008). Study of effective rainfall for irrigated agriculture in South Eastern part of Bangladesh. *World Journal of Agricultural Sciences Vol. 4*(4), 453-457.

Raju, P.V., Sai, M.V.R.S. & Roy, P.S. (2008). In season time series analysis of Resourcesat-1 AWiFS data for estimating irrigation water requirement.

*International Journal of Applied Earth Observation and Geo information 10*, 220-228.

Rama Rao, I.V.Y. (2011). Estimation of efficiency, sustainability and constraints in SRI (System of Rice Intensification) vis-a-vis Traditional method of Paddy cultivation in north coastal zone of Andra Pradesh. *Agriculture Economics Research Review, vol. (*24), 325-331

Ranaweera, N.F.C., De Silva, G.A.C., Fernando, M.H.J.P. & Hindagala, H.B. (2002).*Maize Production in Sri Lanka* (CGRPT No.16, 1-73).The CGRPT Centre.

Shahzada, A. & Khan, A.H. (2011).Effective rainfall for irrigated agriculture plains of Pakistan. *Pakistan Journal of Meteorology vol.6,* 61-72.

Shantha, A.A., Ali, B.G.H.A.and Bandara, R.A.G. (2012).Efficiency and managerial ability of paddy farming under minor irrigation conditions: A frontier production function approach. *Journal of Agriculture Sciences, Vol7* (3).145-158

Sirgure, P.S. (2013). Research review of Irrigation scheduling and water requirement in Citrus. *Scientific journal of review 2*(4)113-121.

Tsai, S. M., Chen, S. & Wang, H. Y., (2005).A study on the practical model of planned effective rainfall for paddy fields in Taiwan. *Journal of Marine Science and Technology, vol.13, No.2, pp.73*-82

Wickramaarachchi T.N., Wijesekera, N.T.S and Gamage, Nimal P.D. (2000).Water scheduling for better yield in paddy cultivation-A study from Mahaweli system of Sri Lanka.38-44.

Wijesekera N.T.S. (2010) Surface Water Resources and Climate Change.

Wijesekera, N.T.S. (2011) Irrigation Infrastructure management requirements to ensure water scarcity for impoverished rural populations under climate change scenario. *Journal of the Institution of Engineer*, Sri Lanka

WMS: Water Management Synthesis Project (1982). The Rajangana Irrigation Scheme, Sri Lanka: Diagnostic Analysis.

Wriedt, G., Velde, M.V.D, Aloe, A. & Bouraoui, F. (2009).Estimating irrigation water requirements in Europe. *Journal of Hydrology* 373,527-544.

WRMS: Water resources Management Sri Lanka (2010).*Sri Lanka water Development*. Ministry of Irrigation *Report*: P.6-9, 26-31, 45-51, and 58,104-122,128.

WWO: World weather online. (2014, April 5).*Anuradhapura monthly climate average, SriLanka. Retrieved* from http://www.worldweatheronline.com/Anuradhapura-weather-averages/North-Central/LK.aspx