PERFORMANCE EVALUATION OF TANK IRRIGATION PROJECTS IN DIFFERENT RAINFALL ZONES OF SRI LANKA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

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IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled "***PERFORMANCE EVALUATION OF TANK IRRIGATION PROJECTS IN DIFFERENT RAINFALL ZONES OF SRI LANKA***" in partial fulfillment of the requirement for the award of degree of MASTER OF TECHNOLOGY in Irrigation Water Management and submitted in the Department of Water Resources Development and management of Indian Institute of Technology Roorkee is record of my work carried out during a period from July 2009 to June 2010 under the supervision of Professor S.K. Tripathi in Department of Water Resource Development and Management, Indian Institute of Technology Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Dated: 02/06/2010

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This is to certify that the above mentioned statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Performance Evaluation is a process to know the efficiency with which resources are being utilized for improving the level of service or operation and maintenance of irrigation schemes and it is important to ensure that indicators that are selected to quantify the performance of a system describe it in respect to the objectives established for that system. A meaningful indicator can be used in two distinct ways. It tells managers in all levels, what is the current performance of the system and, in conjunction with other indicators, may help them to identify the correct course of action to improve performance within that system. In this sense the use of the same indicator over time is important because it assists in identifying trends that may help before the remedial measures become too expensive or too complex. The ultimate purpose of performance evaluation is to achieve efficient, productive and effective irrigation and drainage systems by providing relevant feedback to the management at all levels. As such, it may assist management or policy makers in determining whether performance is satisfactory and, if not, which corrective actions need to be taken to improve the situation.

This dissertation discusses indicators that can be used for evaluating long term performance, including physical sustainability. The primary focus is on the management of canal systems for agricultural production which is more important for food security of the country. Agriculture sector in Sri Lanka contributes about 18 % to the Gross Domestic Product (GDP) and provides 34 % of the total employment. About 85 % of population resides in rural areas, where agriculture is the main economic activity. Dry Zone is the granary of the country and produces 2.1 million tons/year of paddy. The 80% of the national production is from the economic activity of small farm holders in the rural areas. Paddy production heavily depends on irrigation, which enables stable production in

the wet season and extended cropped area in the Dry season. Due to government efforts, irrigation development is accelerated since 1970 until self sufficiency level of paddy from 42 % in 1970 to 95 % in 1995 is achieved. Sometimes it fluctuates between 75 % and 99 %. Under this situation, the role of paddy production is viewed from macro-economic view point.

In this study, Nuwarwewa, Tissawewa and Abhayawewa are taken from dry zone and Bathalagoda, Kimbulwanaoya and Hakwatunaoya are taken from Intermediate zone for evaluation. Nuwarawewa irrigation scheme also characterized as the present farm holder are descendant of relatively old settlements of a 1930s, located near the large town of Anuradapura, and fluctuating irrigated area in dry seasons. More than 50 % of farm land is cultivated under tenant and or lease, with crop diversification towards vegetables. Bathalagoda, Kimbulwanaoya and Hakwatunaoya irrigation schemes are characterized as relatively new settlement in 1960s located 40 - 50 Km from Kurunegala, relatively stable irrigation area in dry season, land fragmentation and small owner ships, crop diversification, in a small part, towards mainly Banana, Papaya and vegetable. Tissawewa and Abhayawewa irrigation schemes are characterized as farm household originated from old traditional villages, farmers dependent on paddy cultivation without crop diversification. However these six schemes can be considered to have been playing a significant role in all activities in the farming sector.

Finding from the study

1. ETo given by Modified Penman method is most suitable for Sri Lanka
2. DPR decrease from head reach to tail reach tanks along the river.
3. DPR decrease from head reach to tail reach along the canal.
4. WDP during Maha season less than Yala season
5. OPE increase from head reach to tail reach tanks along the river.
6. Sustainability of irrigation area is greater than 1for all six tanks.

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CE	conveyance efficiency
DPR	delivery performance ratio
e_a	the vapour pressure in the air at about 2 m above the water surface
e_d	the actual vapour pressure
e_s	the saturation vapour pressure
$f(e_d)$	water vapour function
f(n/N)	function of sunshine duration ratio
f(T)	temperature function
f(u)	wind related function
G	the soil heat flux
Kc	crop coefficient
Kc,ini	crop coefficient for initial stage
Kc,mid	crop coefficient for development and mid-season stage
Kc,end	crop coefficient for late-season stage
Kp	pan coefficient
n	actual measured bright sunshine hours
N	maximum possible sunshine hours
OPE	overall project efficiency
P_e	effective rainfall in the basic year
R_a	radiation received at the top of the atmoshphere
R_n	the net radiation
R_{nl}	net long-wave radiation
R_{ns}	net short-wave radiation
R_s	solar radiation
RH	relative humidity
T_m	mean monthly temperature
T_{max}	daily maximum air temperature
T_{mean}	mean air temperature
T_{min}	daily minimum air temperature
U_2	wind speed at 2 m height
w	weighting factor
W	temperature related weighting factor

WDP	water delivery performance
Δ	rate of change of saturation vapor pressure with temperature
α	crop reflection coefficient
γ	psychometric constant
λ	latent heat of vaporization
λET	latent heat flux

CHAPTER 1

CHAPTER 1

INTRODUCTION

1.1 General Information of Sri Lanka

Official Name	Democratic Socialist Republic of Sri Lanka
Capital	Colombo
	note - Sri Jayewardenepura Kotte is legislative capital
Area	total : 65,610 sq km
	Water : 870 sq km
	land : 64,740 sq km
Climate	Tropical monsoon; northeast monsoon (December to March)
	southwest monsoon (June to October)
Location	Southern Asia, island in the Indian Ocean, south of India.
Coordinates	7 00 N, 81 00 E
Coast Line	1340 km
Terrain	Mostly low, flat to rolling plain; mountains in south- central interior
Elevation	Lowest point: Indian Ocean 0 m
	Highest point: Pidurutalagala 2,524 m

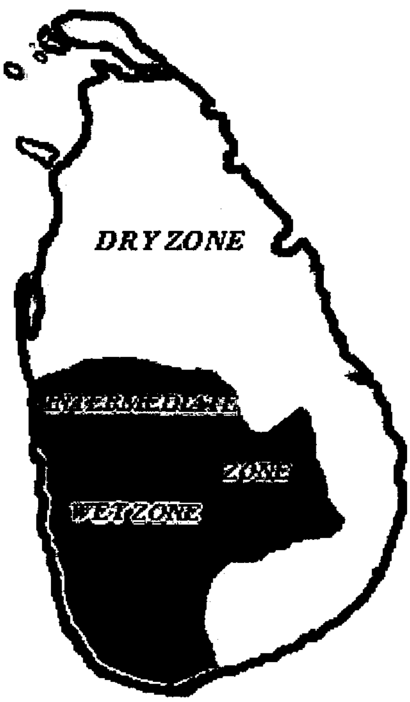
The irrigation area in Sri Lanka is 600,000 ha, 73% of which is occupied by major and medium schemes with more than 80 ha, and 27% of which are categorized into minor irrigation schemes having less than 80 ha. Since independence, the government institutions managed the major and medium irrigation schemes, while the community managed minor schemes. By early 1980s management expenses of irrigation facilities including operation & maintenance become a heavy burden to the government. On the advice of international organizations, the handing over of operation and maintenance of distributory - canals to Farmer Organizations commenced in the early 1990s under the participatory irrigation management policy.

The irrigation lands in Sri Lanka are double cropped. The main cultivation seasons are Maha season (October to March) and Yala season (April to September). The seasonal cropping calendar is prepared by consensus at the "Kanna Meeting" held before commencement of each cultivation seasons. However in major and medium irrigation schemes the cropping period and the extent of irrigable area are decided based on the availability of water in the reservoir.

The rainfall is not uniform in space and time. In Sri Lanka most of the precipitation occurs during the monsoon season and a very large portion of it flows down to the sea. With the increasing demand for different uses it has become imperative to store the precious rain water in tanks, or reservoirs for use in non-monsoon season. There are three climatic zones in Sri Lanka according to the rain fall which are

- **Dry zone**
  Rainfall < 1250 mm annually
- **Intermediate zone**
  Rainfall 1250 mm to 3000 mm annually
- **Wet zone**
  Rainfall > 3000 mm annually

Fig 1.1 Rainfall Zones of Sri Lanka



Most of the irrigation schemes are located in the dry zone where expected water demand is much greater than what is received from the monsoon rain. The lower part of the catchment receives an annual rainfall less than 900mm. During the wet season most of the rain falls in a few but very intense storms, which results in partial storage of irrigation reservoirs. But water availability is a critical issue in the dry zone of Sri Lanka.

There are two type of irrigation schemes in Sri Lanka, namely storage reservoir schemes and diversion schemes. In case of significant areas, additional reservoirs are constructed within the irrigation system for additional water storage. In a river basin most of the irrigation schemes located on the downstream of the others form cascade, reusing drainage water from the upstream schemes.

1.2 Necessity of Evaluation of Tank Irrigation Commands

The main purpose of any irrigation system is to enhance the economic welfare of people at large and command areas in particular. The economic welfare is manifested in higher income, better standard of living and capacity of investment for further development. Irrigation systems play a vital role in development since 70% of the population depends on agriculture. Performance evaluation of an irrigation system is a stock taking exercise to assess achievements of the system in which large investments of money and human efforts have been made. This evaluation process will highlight the deficiencies in project planning and implementation. It helps to improve techniques of project formulation and implementation to ensure optimum performance. Considering the present level of performance of irrigation and drainage in command areas, we expect considerable room for improvement so that the contribution of irrigated agriculture to world food production can also increase. However there are four major constraints (land, water, fund and skill) in the agriculture sector:

1.4 Objective of study

The principal objective of evaluating surface irrigation systems is to identify management practices and system configurations that can be feasibly and effectively implemented to improve the irrigation efficiency. Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. The surface irrigation system is a complex and dynamic hydrologic system and, thus, the evaluation processes are important to optimize the use of water resources in this system. The study entitled "Performance Evaluation of Tank Irrigation Projects in Different Rainfall Zones of Sri Lanka" was undertaken with the under mentioned objectives:

1 To collect of weather data, Cropping pattern data, Water delivery data, Cultivation data from different rainfall zones of tank irrigation in Sri Lanka.

2 To calculate reference evapotranspiration (ETo) using different methods for different rainfall zones of Sri Lanka.

3 To calculate irrigation water requirement of rice grown in different agro climatic zones of Sri Lanka.

4 To select possible performance indicators and use them to evaluate tank irrigation system located in different rainfall zones of Sri Lanka.

1.4 Scope of work

This study based on analysis existing performance conditions of selected irrigation tanks in dry and intermediate zones of Sri Lanka using the performance indicators employing constraints of sustainable operation and maintenance irrigation facilities, efficient water management, and increase of farmer income.. Three tanks were selected from each zone. Study area, issues and problems in water delivery sectors are identified and analyzed during the study. The scope of the work is presented in the form of chapters as follows:

Chapter 1

Introduction of performance evaluation, presents the objective and scope of work.

Chapter 2

Literature Review of the terminology used in performance evaluation and selection of performance indicators.

Chapter 3

Describe study area, soil, climate and selection of tanks for evaluation.

Chapter 4

Methodology adopted for ETo calculation and assessment of performance indicators

Chapter 5

Presents the results and their discussion

Chapter 6

Presents the Summary and Conclusion.

CHAPTER 2

CHAPTER 2

LITERATURE REVIEW

This chapter presents the terminology used in the forthcoming text and then a review of literature on performance evaluation of irrigation commands.

2.1 Performance Evaluation Terminologies

2.1.a Actual value

It is the actual value of a parameter that can be measured or determined, such as measured flow rate, crop yield, irrigation fee, ground water depth, etc.

2.1.b Critical value

The critical value of a key parameter quantifies the physical process whereby the limits of that value if passed, it will affect the other parameters. For example, the salinity of irrigation water has a critical value that reduces crop yield and on the other side, if excess drainage passed beyond critical value, creates flood.

2.1.c Target value

The target value reflects the objectives of managers at different levels. A system manager is most likely to base targets on the outcome of the annual or seasonal planning process

2.1.d Adequacy

A fundamental concern of water delivery system is to deliver the amount of water required to adequately irrigate crops. The required amount is determined as that needed to achieve the given agricultural policy,

2.1.e Efficiency

Resource conservation plays an important role in water delivery because water saved reduces expenditure on infrastructure and is able to irrigate more land. Conveyance efficiency indicates the relative amount of water lost in a reach due to canal seepage and overflow. But the overuse or downstream losses of water is not directly reflected in the concept of conveyance efficiency. A water delivery system that delivers greater than adequate supply does not conserve water resources. Sometime excess water deliveries to farmers create the condition of water logging and salinity. Water delivery efficiency incorporates the concept of conveyance efficiency, since water requirement at a point of delivery includes the expected downstream losses.

2.1.f Equity

Equity can be defined as the delivery of fair share of water to users throughout the system. A share of water represents the right to use the specified amount. The fair share of water may be based on a legal right for water as in a prior appropriation system or may be set as a fixed proportion of a water supply as is done in many rotational delivery schemes. Measuring of equity is a difficult task because there are many other factors that determine the meaning of a fair share. Sometimes it represents subjectively. However it is important to define measures relating to equity. Then systems can be designed or rehabilitated to deliver water to users served by the system in and impartial manner. Therefore equity is defined as spatial uniformity of the ratio of the delivered to required or scheduled amount.

2.1.g Sustainability of Irrigated Area

Sustainability of Irrigated Area is the current irrigated area, divided by the initial irrigated area when the system was first fully developed (Bos, 1997). A trend toward reduced area generally indicates that the system is not sustainable (for water supply, environmental, or economic reasons).If area has increased significantly from the designed area, it may indicate that the water supply is now distributed over too much land, or delivery capacities are being exceeded. The "current irrigated area" must be updated periodically to reflect the actual situation on the land. Bos used "irrigable" area instead of "irrigated" area, but irrigated area can be more precisely determined and can be easily updated from aerial photos. If irrigable land is not being irrigated, that can also indicate a problem, such as water supply leads to deep percolation or runoff. For a heterogeneous irrigation scheme with rotational water supply it is difficult, though not impossible, to produce allocation plans which will not cause any return flow or percolation deep into the groundwater. However it should be noted that the return flow is desirable when the salt accumulated in the crop root zone needs to be leached away. The experience on these schemes shows that deep percolation over the years will cause the groundwater table to rise into the root zone of crop if adequate drainage systems are not adopted.

2.2 Tank Irrigation Project Operation

Irrigation can be defined as human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways or aquifers and to manipulate all or part of this water for the production of agricultural crops. This definition emphasizes the importance of the actions of people in modifying a natural distribution of water. It also restricts the types of action under consideration to those tapping and utilizing water that has been concentrated naturally before being exploited. The definition of irrigation thus encompasses large pump and conventional gravity schemes as well as a variety of types of traditional small-scale schemes where water is raised from wells or diverted from streams, or where receding flood waters are captured in bonded fields. It excludes the water from micro-catchments.

The capacity of available water resources and technologies that can be used to satisfy the demands of the growing population for food and other agricultural commodities remains uncertain. Considering the role of water as a god in social, economic fields it should be reflected in demand management mechanisms. SOme time it can be visualized through resource assessment, water conservation and water reuse. The challenge for irrigated agriculture today is to contribute to the world's food production and to improve food security. However within a river basin water is used by numerous users, upstream, nature, storage, irrigated agriculture, industries, and downstream wetlands. The major objectives of water management are to deliver water in sufficient quantities, according to a time schedule that matches the requirement for healthy plant growth, and with fair distribution among many users.

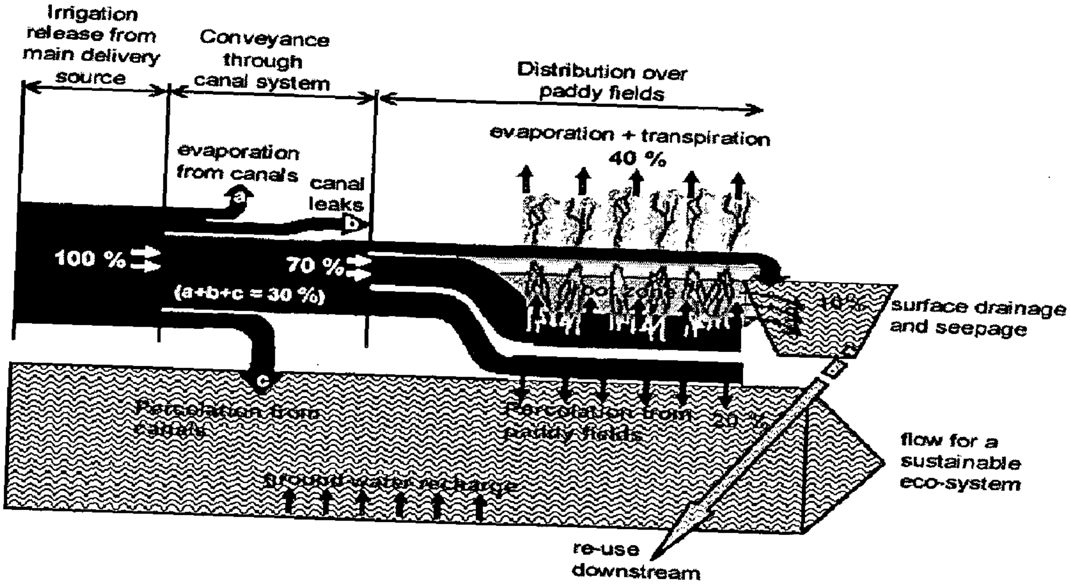


Fig 2.1 Irrigation water supply for paddy crop (Bandara 2006,Irrigation Department Sri Lanka)

Performance assessment can be defined as the systematic observation, documentation, and interpretation of the management of a project with the objective of ensuring that the input of resources, water delivery schedules, intended outputs and required actions proceed as planned. The ultimate purpose of performance assessment is to achieve an efficient and effective project performance by providing relevant feedback to the management at all levels such as operational level and strategic level. It may assist the management to determine whether the performance is satisfactory and, if not, which and where corrective actions need to be taken in order to remedy the situation (Murray-Rust & Snellen 1994).The performance can be assessed in terms of operational, strategic, water supply, agricultural, economic, social, environmental performance as follows.

2.2.a Operational performance is concerned with the routine implementation of the agreed (or pre-set) level of service. It specifically measures the extent to which intentions are being met at any moment in time, at every considered level of the scheme, and thus, requires the actual inputs of resources and the related outputs measured.

2.2.b Water supply performance. This is categorized into capture, allocation and conveyance of water from available source to field by management of irrigation facilities, which is the basic task of irrigation managers. Performance indicators address several aspects of this task. They cover the volumetric component that is primarily concerned with matching supplies to crop demand, as well as the rather more subjective concept of reliability that may affect the users' capacity to manage water efficiently, and the socially oriented aspects of equity. Efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity.

2.2.c Agricultural performance. This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility. Agricultural performance is a 'direct outcome' of water delivery performance in Small & Svendsen's(1990) terms. Assessment of agricultural performance is important because it links the within season indicators of hydraulic or conveyance performance with the wider agricultural economic and rural economic systems as discussed by Small & Svendsen (1990).

2.2.d Economic, social and environmental performance. This deals with the impact of both operational and agricultural inputs on the viability and sustainability of irrigated agriculture. These impacts include both physical and socio-economic sustainability of irrigated agriculture. as well as in time and space.

2.3 Performance Measures for Evaluation of Irrigation Water Delivery Systems. (Modern and Gates - 1990)

Performance measures play major role in analysis of irrigation water delivery systems and are described in terms of adequacy, efficiency, dependability and quality of water delivery. These measures provide a quantitative assessments of overall system performance, suggesting quantitatively the contribution of structural and management components of the system. Spatial and temporal distributions of required, scheduled, deliverable and delivered water are used to calculate the performance measures. These variables may be estimated by combinations of field measurement and simulation techniques.

2.3.a Allocative type performance measure

The allocative type performance measures are those which need to be attended primarily during the allocation of the resource at the planning stage. Allocation of the resource influences production, area to be irrigated, net return, distribution of the resource to the users based on certain considerations, or combinations of these. Hence we classify the performance measures as Productivity, Equity.

2.3.b Scheduling type performance measures

The irrigation schedule (consisting of temporal or seasonal distribution of the resource to different users) needs to be prepared for the allocation plans developed according to the objectives of the scheme. Depending on these objectives, the schedule should be such that water deliveries are adequate both in planning and operation, reliable when in operation considering all the complexities in the irrigation scheme, flexible and sustainable. Depending on the objectives of the scheme following five scheduling type performance measures are defined as adequacy, reliability, flexibility, efficiency, sustainability. All these terms are defined earlier.

The above two allocate and five scheduling type performance measures could also be grouped as follows:

1. Economic - Productivity.
2. Social - Equity
3. Environmental - Sustainability
4. Management - Reliability, adequacy, efficiency and flexibility

All the performance indicators available in literature are described below.

2.4 Performance Indicators

2.4.a General features of performance indicators.

A good indicator can be used in two distinct ways. It tells a manager what is the current performance of the system, and, in conjunction with other indicators, it may help him to identify the correct course of action to improve performance within that system. In this sense the use of the same indicator over time is important because it assists in identifying trends that may need to be reversed before the remedial measures become too expensive to afford or too complex to evaluate meaningfully.

It is important to ensure that the indicators selected for a system will describe its performance in respect of the objectives established for that system. It is this process that links the use of indicators to the overall performance assessment framework. Failure to take this into account may lead to managers to assess in terms of activities that were not included in their initial brief. Moreover, the same indicator can be used by planners and policy makers to make comparisons in performance between systems. The importance of this is two-fold. It helps determine who is a better manager so that appropriate rewards or incentives can be given. It enables future investment decisions to be made in areas most likely to produce the greatest benefit. From the perspective of operational performance, performance indicators are comparatively easy to define. They will normally be simple ratios of actual to target conditions, and the result of the performance assessment process will be to either change operational inputs so as to better achieve the target, or modify the target itself because it proved to be unrealistic or impossible.

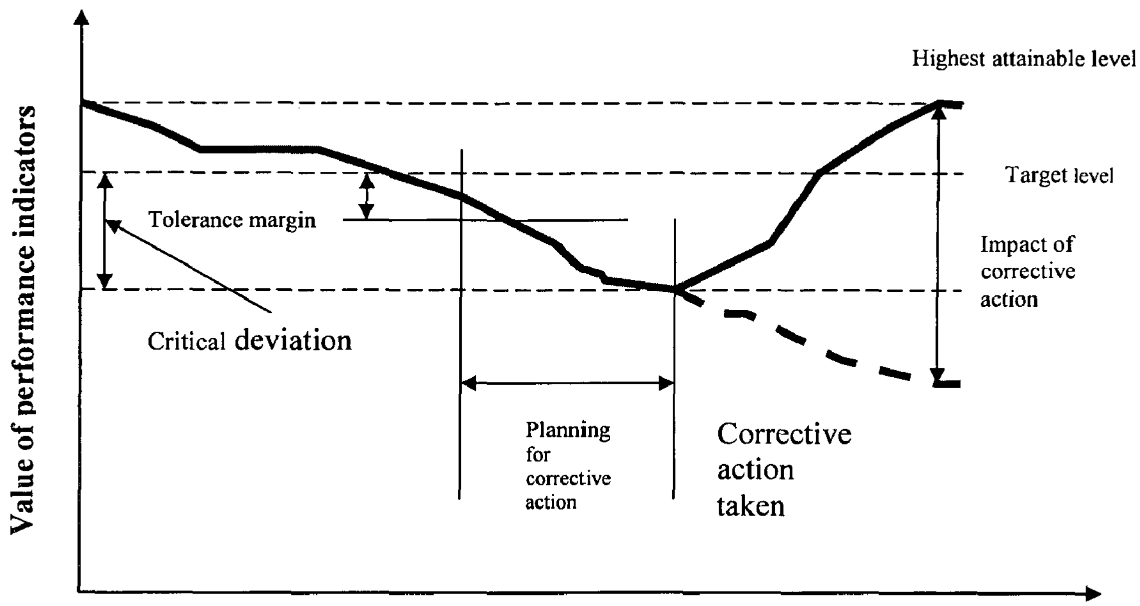


Fig 2.2 Assessing Performance as a Function of time

2.4.a1 Scientific basis

The indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. Discrepancies between the empirical and theoretical basis of the indicator must be explicit, i.e., it must not be hidden by the format of the indicator. To facilitate comparison of performance assessment studies carried out elsewhere, indicators should be formatted identically or analogously as much as possible (Bos & Nugteren 1990, ICID 1978, Wolters 1992}.

2.4.a2 The indicator must be quantifiable

The data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible.

2.4.a3 Reference to a target value

This is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator. These target values (and their margin of deviation) should be related to the level of technology and management (Bos et al. 1991).

2.4.a4 Provide information without bias

Ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain subjective values (Small, 1992).

2.4.a5 Provide information on reversible and manageable processes

This requirement for a performance indicator is particularly sensible from the irrigation manager's view point. Some irreversible and unmanageable processes may provide useful indicators, although their predictive meaning may only be indirect. For example, the frequency and depth of rainfall is not manageable, but information from a long time series of data may be useful in planning to avoid water shortage, and information on specific rainfall events may allow the manager to change water delivery plans.

2.4.a6 Nature of the indicator

An important factor influencing the selection of an indicator has to deal with its nature: the indicator may describe one specific activity or may describe the aggregate or transformation of a group of underlying activities. Indicators ideally provide information on an actual activity relative to a certain target value. The possibility of combining such dimensionless ratios into aggregate indicators should be studied, in the same way as many indicators used for national economic performance are amalgamated.

2.4.a7 Ease of use and cost-effectiveness

Particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the management resources.

2.4.b Available indicators

The performance indicators available in literature are defined as follows:

1 Delivery Performance Ratio $= \dfrac{Actual\ Discharge}{Target\ Discharge}$

2 Water Delivery Performance $= \dfrac{Actual\ Volume}{Target\ Volume}$

3 Overall Project Efficiency $= \dfrac{\text{Crop Irrigation Water Requirement}}{Total\ Inflow\ into\ Canal\ System}$

4 Conveyance Efficiency $= \dfrac{\text{Total Water Supplied by the Conveyance System}}{Total\ Inflow\ into\ the\ Conveyance\ System}$

5 Distribution Efficiency $= \dfrac{Total\ Water\ Delivery\ to\ the\ Field}{Total\ Inflow\ into\ the\ Delivery\ System}$

6 Field Application Efficiency $= \dfrac{\text{Crop Irrigation Water Requirement}}{Water\ Delivery\ to\ Field}$

7 Effectiveness of Infrastructure $= \frac{Number\ of\ Functining\ Structure}{Total\ Number\ of\ Structure}$

8 Equipment Effectiveness $= \frac{Actually\ Functining\ Equipment}{Total\ Equipment\ Provided}8$

9 Relative Water Supply $= \frac{Irrigation+Effective\ Rainfall}{Evapotranspiration+Seepage+Percolation}$

10 Dependability of Supply $= \frac{Actual\ Duration\ of\ Water\ Supply}{Planned\ Duration\ of\ Water\ Supply}$

11 Regularity of Deliveries $\frac{Actual\ Interval\ of\ Water\ Delivery}{Planned\ Interval\ of\ Water\ Delivery} =$

12 Modified Inter Quartile Ratio $= \frac{Average\ DPR\ of\ Best\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Worst\ 25\%\ of\ the\ System}$

13 Head to Tail Equity Ratio $= \frac{Average\ DPR\ of\ Upper\ 25\%\ of\ the\ System}{Average\ DPR\ of\ Tail\ 25\%\ of\ the\ System}$

14 Irrigation Area Performance $= \frac{Actual\ Area}{Target\ Area}$

15 Cropping Intensity Performance $= \frac{Actual\ Cropping\ Intensity}{Target\ Cropping\ Intensity}$

16 Production Performance $= \frac{Total\ Production}{Target\ Production}$

17 Yield Performance $= \frac{Actual\ Yield}{Target\ Yield}$

18 Water Productivity Performance $= \frac{Actual\ Water\ Productivity}{Target\ Water\ Productivity}$

19 Total Financial Viability $= \frac{Actual\ O\&M\ Allocation}{Toal\ O\&M\ Requirement}$

20 Fee Collection Performance $= \frac{Irrigation\ Fee\ Collection}{Irrigation\ Fee\ Due}$

21 Area Based Profitability $= \frac{Incremental\ Benifit\ unit\ Area}{Total\ Irrigation\ Expences\ Unit\ Area}$

22 Water Based Profitability $= \frac{Incremental\ Benifit\ unit\ Water}{Total\ Irrigation\ Expences\ Unit\ Water}$

23 Irrigation Employment Generation $= \frac{Annual\ Person\ Days\ 1\ ha\ Labour\ in\ Scheme}{Annual\ Number\ of\ Official\ Working\ Days}$

24 Irrigation Wage Generation $= \frac{Annual\ Average\ Rural\ Income}{Annual\ Natinal\ Average\ Income}$

25 Relative Prosperity $= \frac{Percent\ Population\ Above\ Poverty\ line\ in\ Scheme}{Percent\ Population\ Above\ Poverty\ line\ in\ Nationally}$

26 Technical Knowledge of Staff = $\frac{Number\ of\ Staff\ with\ Knowledge\ Required\ to\ Fukkfill\ Job}{Total\ Number\ of\ Staff}$

27 User's Stake in Irrigation System = $\frac{Number\ of\ Active\ Water\ Users\ Organizations}{Toata\ Number\ of\ Water\ Users\ Organizations}$

28 Sustainability of Irrigated Area = $\frac{Current\ Irrigable\ Area}{Initial\ Irrigable\ Area}$

29 Rate of Change Ground Water Depth = $\frac{New\ Depth - Old\ Depth}{Old\ Depth}$

30 Impact of Flooding = $\frac{Area\ Subjected\ to\ Flooding}{Total\ Irrigable\ Area}$

31 Salt Over Crop Yield Ratio = $\frac{Salt\ Yield}{Crop\ Yield}$

32 Relative Change of Water Level = $\frac{Change\ of\ Water\ Level}{Initial\ Water\ Level}$

33 Relative Soil Wetness = $\frac{Actual\ Water\ Content\ in\ Root\ Zone}{Soil\ Water\ Content\ in\ Field\ Capacity}$

34 Biomass Yield Over Irrigation Supply = $\frac{Biomass\ Productionl}{Volume\ of\ Irrigation\ Supply}$

2.5 Selection of Performance Indicators

A series of indicators, as described above, are utilized to assess the performance of irrigation and drainage. This assessment can be viewed from the institutions and from the 'technical / professional' perspective of the water manager, water user, environmentalist, economist, sociologist, etc. Combining these institutions and disciplines into a matrix yields many fields from which the performance of irrigation and drainage can be viewed. This complexity resulted to long-list of about 34 indicators that can be used to quantify the system performance. The level of detail with which performance is assessed depends on the purpose of the assessment **(Figure 2.3).** Researchers tend to assess performance in full detail. Depending on the disciplines involved, the entire long-list of indicators may be used. The cost of collection and handling of all related data, however, is not justified for day-to-day operational management of the system. In this study, 11 indicators were employed for performance evaluation of Nuwarawewa, Tissawewa and Abhayawewa irrigation system and these are described in greater detail in the forthcoming chapter.

Fig 2.3 Recommended number of performance indicators

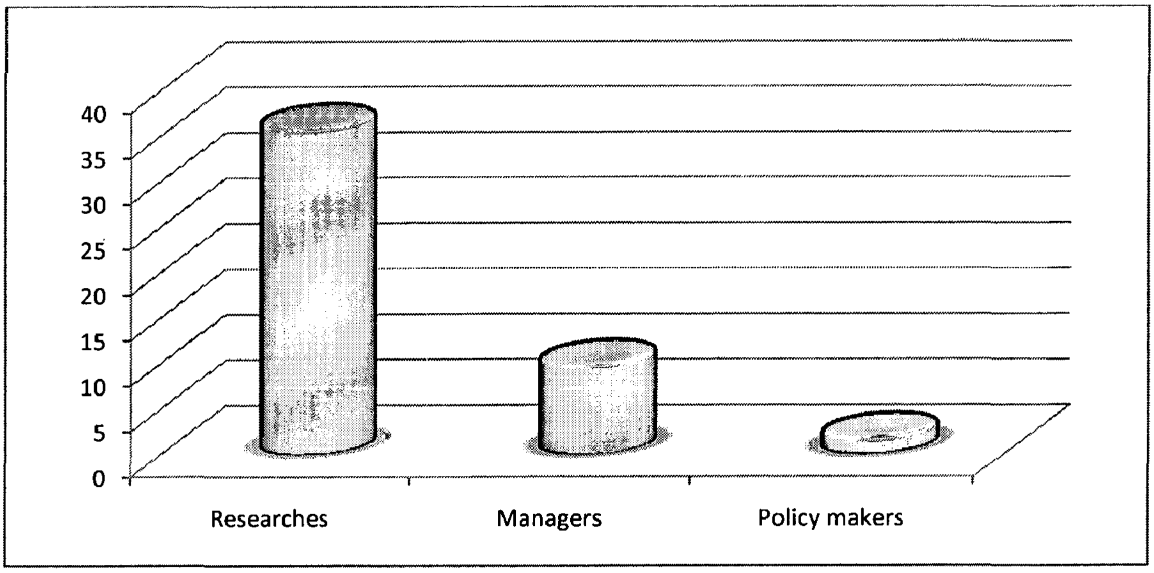
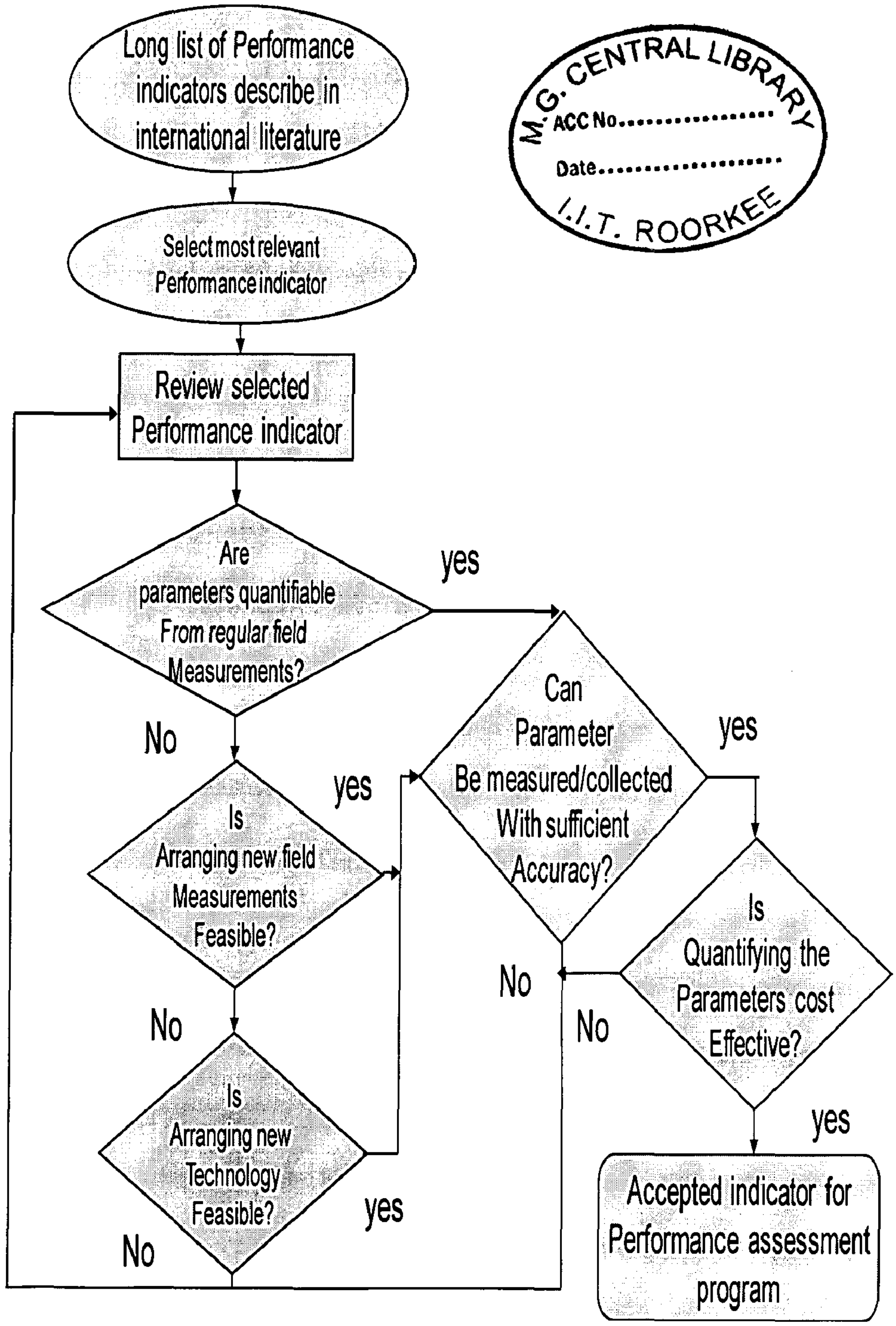


Fig 2.4 Flow Chart For Selection of Performance Indicators



CHAPTER 3

CHAPTER 3

DESCRIPTION OF STUDY AREA

3.1 Climatic Condition.

Despite its relatively small aerial extent, Sri Lanka exemplifies a variety of climatic conditions depending on the geographical settings of respective locations. The average annual rainfall of the island varies from about 500 mm to over 5,500 mm Being located in the low latitudes between 6° and 10° N and surrounded by the Indian Ocean Temperature conditions in Sri Lanka are also characterized by a significant temperature decrease in the central highlands. Sri Lanka has three climatic zones in terms of "Wet Zone" in the southwestern region including central hill country, and "Dry Zone" covering predominantly, northern and eastern part of the country, being separated by an "Intermediate zone," skirting the central hills except in the south and the west In differentiating aforesaid three climatic zones, rainfall, contribution of southwest monsoon rains, soils, land use and vegetation have been widely used. The Wet zone receives relatively high mean annual rainfall over 3000 mm without pronounced dry periods. The Dry zone receives a mean annual rainfall of less than 1,250 mm with a distinct dry season from May to September. The Intermediate zone receives a mean annual rainfall between 1,250mm to 3000 mm with a short and less prominent dry season.

As low temperature is an important climatic factor affecting plant growth in the Wet and Intermediate zones of Sri Lanka, a sub-division based on the altitude takes into account the temperature limitations in these two climatic regions. In this delineation, the Low-country is demarcated as the land below 300 m in elevation and the Mid-country with elevation between 300 - 900 m while the Up-country is the land above 900 m elevation Both Wet and Intermediate zones spread across all three categories of elevation while the Dry zone is confined to the Low-country resulting seven agro-climatic zones covering the entire island These seven agro-climatic zones have further sub-divided into Agro-Ecological Regions

(AER) with a total of 24 AERs covering the entire island. The delineation of AER boundaries of Sri Lanka has been based on the rainfall regime, terrain characteristics, predominant soil type, land use and vegetation so that each AER represents an uniform agro-climate, soils and terrain conditions and as such would support a particular farming system where certain range of crops and farming practices find their best expression. Detailed studies on climatology of Sri Lanka has identified that "climatic year" or "hydrological year" of the island begins in March and not in January so that seasonal weather rhythm or more specifically the rainfall seasons ranges from March to February. It is generally accepted that there are four rainfall seasons in Sri Lanka:

March – April -- First Inter Monsoon (FIM) rains

May – September -- South West Monsoon (SWM) rains

October – November -- Second Inter Monsoon (SIM) rains

November- February -- North East Monsoon (NEM) rains

These rainfall seasons do not bring homogeneous rainfall regimes over the whole island and it is the main cause to exhibit such a high agro-ecological diversity of the country despite its relatively small aerial extent. Out of these four rainfall seasons, two consecutive rainy seasons make up the major growing seasons of Sri Lanka, namely *Yala* and *Maha* seasons. Generally *Yala* season is the combination of FIM and SWM rains. However, since SWM rains are not effective over the Dry zone it is only the FIM rains that fall during the *Yala* season in the Dry zone from mid March to early May. Being effective only for two months, the *Yala* season is considered as the minor growing season of the Dry zone. The major growing season of the whole country, Maha begins with arrival of SIM rains in Mid September/October and continues up to late January/February with the NEM rains. Rice is grown under more diverse environmental conditions than any other major food crop in the world and the situation remains as the same in Sri Lanka too. Except in almost all AERs in the Up country Wet and Intermediate zones where minimum temperature at night time is limiting, paddy is the most common land use in valley bottoms in the all other AERs of the country. Solar radiation is not a limiting factor for rice growth in almost all rice growing regions of Sri Lanka. However, when all other conditions such as water, nutrients and temperature are non-limiting, the intensity of sunlight may determine the yield level depending on the location and season. For example, in the Wet zone, solar radiation may limit the rice yield during *Yala* season due to high cloud cover arising from the southwest monsoonal circulation whereas a similar situation could expect in the Dry zone during Maha season due to overcast conditions that may result due to "weather systems" formed in the Bay of Bengal and northeast monsoonal circulation.

Table 3.1: Agro-Climatic Zones of Sri Lanka.

Zones	Abbreviation
Up Country Wet Zone	WU
Mid Country Wet Zone	WM
Low Country Wet Zone	WL
Up Country Intermediate Zone	IU
Mid Country Intermediate Zone	IM
Low Country Intermediate Zone	IL
Low Country Dry Zone	DL

3.2 Agro-Climatic Region

An agro-ecological region represents a particular combination of the natural characteristics of climate, soil and relief. When an agro-climatic map, which can be considered as areas where the integrated effect of climate is uniform throughout the area for crop production, is superimposed on soil and terrain the resulting map identifies agro-ecological regions. Rainfall distribution in Sri Lanka has traditionally been generalized in to three climatic zones; "Wet Zone" in the southwestern region including central hill country, "Dry Zone" covering predominantly northern and eastern parts of the country and "Intermediate Zone" running between the other two zones. In differentiating aforesaid three climatic zones land use, forestry, rainfall and soils have been widely used. The Wet Zone covers the area, which receives relatively high mean annual rainfall over 3000 mm without pronounced dry periods. The Dry Zone is the area, which receives a mean annual rainfall of less than 1250 mm with a distinct dry season from May to September. The Intermediate Zone demarcates the area, which receives a mean annual rainfall between 1250mm to 3000 mm with a short and less prominent dry season. As low temperature is an important climatic factor affecting plant growth in the Wet and Intermediate Zones of Sri Lanka, a sub-division based on the altitude takes into account the temperature limitations in these two climatic regions. In this delineation, the Low-country is demarcated as the land below 300 m in elevation and the Mid-country with elevation between 300 - 900 m while the Up-country is the land above 900 m elevation. Both Wet and Intermediate Zones spread across all three categories of elevation while the Dry Zone is confined to the Low-country resulting seven agro-climatic zones covering the entire island Based on many decades of work, these seven agro climatic zones have further been divided in to 24 agro-ecological regions in 1979. The differentiation of the Wet Zone into its distinctive agro-ecological regions was governed primarily by differences in rainfall distribution. In the Dry Zone, on the other hand, it was the nature of the soil that primarily determines the identity of individual agro-ecological region. In the Intermediate Zone, it was observed that rainfall distribution and soil play an equally important role. According to this there are 10 agro-ecological regions in the Wet Zone, 9 in the Intermediate Zone and 5 in the Dry Zone.

3.2.1 Intermediate Zone

3.2.1.1 Low Country Intermediate Zone

This agro-climatic region has been sub-divided in to three agro-ecological regions **(table 3.2)** where rice is the predominant land use in valley bottoms and terraced upland slopes in some areas. The expected annual rainfall at the 75% probability level in this region ranges from 1,100 to 1,600 mm depending on the agro-ecological region. Its average maximum temperature ranges from 29 to 35 ^{0}C. The highest values are being recorded during the period of late February to early May. The average minimum temperature is ranged from 20 to 26 ^{0}C where the lowest values are generally observed during the period of December to February, a common phenomenon for the entire Island. The day time relative humidity is generally ranged from 55 to 75 percent where as nighttime values may reach even up to 90 per cent especially during winter months of the year.

Table 3.2: Agro-ecological regions of Low Country (<300 m MSL) Intermediate Zone.

Agro-ecological Region	Annual Rainfall (mm)	Major Crops
IL1	> 1,400	Coconut, MHG, EAC, Paddy, Rubber
IL2	> 1,600	MHG, Paddy, RUC, Scrub, Sugarcane, Citrus
IL3	> 1,100	Coconut, Paddy, MHG,

MHG: Mixed Home Gardens, RUC: Rainfed Upland Crops, EAC: Export Agricultural Crops

3.2.2 Dry Zone

3.2.2.1 Low Country Dry Zone

This agro-climatic region is the country's driest part and it has been sub-divided in to five agro-ecological regions Even though water is a limiting factor in this part of the country for year round crop production, trans-basin diversion of some rivers of Wet and Intermediate zones and large number of tanks that were built during ancient times have made it possible to cultivate lowlands in to rice or rice based cropping systems. Out of five agro-ecological regions in this region, rice is the predominant agricultural land use in four agro-ecological regions except in DL3 agro-ecological regions **(Table 3.3)**, the Oxisol belt which spreads from northwestern coastal region to northern peninsular. The expected annual rainfall at the

75% probability level in this region ranges from 500mm to 1,250 mm depending on the agro-ecological region. In some agro-ecological regions monthly rainfall distribution depicts a bi-modal pattern where as agro-ecological regions found in the northeastern and eastern parts of the Dry zone shows a uni-modal monthly rainfall distribution. Hence, unless irrigation water is supplied, cultivation of rice in lowland in those regions is possible only during the major rainy season (Maha season).

When the Wet zone of Sri Lanka experiences Southwest monsoon rains, the same monsoonal wind blows over the Dry zone as a warm and dry wind, This wind locally known as Yal hulang, Wesak hulang or Kachchan. Hence, crop water requirement during this period, May to September (Yala season) is very much higher than that of the other times of the year (Maha season). The general wind speed of the Dry zone is 3 – 5 km/hr. However, during said period, it may reach even 12 – 15 km/hr. The average maximum temperature in the Dry zone ranges from 29 to 38 ^{0}C depending on the agro-ecological regions The highest values are being recorded during the period of late February to late September irrespective of the location. Thus, high temperature injuries are being experienced in rice grown during Yala season in the Dry zone, commonly known as the Ehela Pussa. Continuous weather observations have shown that it is becoming a more and more common feature in rice cultivation during recent times and it could be a repercussion of global warming. The average minimum temperature is ranged from 20 to 26 ^{0}C where the lowest values are generally observed during the period of December to February, a common phenomenon for the entire island. However, further low night time temperatures are experienced during winter months in the northern peninsular of the Island due to the influence of the huge land mass of the Indian sub-continent making it possible to grow potato. However, rice is hardly grown in this region due to some other geographic limitations. The day time relative humidity in the Dry zone is generally ranged from 50 to 75 percent where as nighttime values may reach even up to 90 per cent, especially during winter months of the year.

Table 3.3: Agro-ecological regions of Low Country (<300m MSL) Dry Zone.

Agro-ecological Region	Annual Rainfall-(mm)	Major Crops
DL1	> 1,100	MHG, Paddy, Forest plantations, Scrub, Natural forests,
DL2	> 1,300	RUC, Paddy, Natural forests, Sugarcane, Scrub
DL3	> 800	Cashew, Coconut, Condiments, Scrub, Natural forests
DL4	> 750	Scrub, Paddy, RUC
DL5	> 500	Scrub, Natural forests, RUC, Paddy

MHG: Mixed Home Gardens, RUC: Rain fed Upland Crops

3.3 Soils of Sri Lanka

The soils of Sri Lanka have been classified at Great Group level for the whole country and Series level for some parts. However, mapping has been done mainly at Great Group level and the generalized soil map of Sri Lanka is given **in fig 3.1.** Accordingly there are fourteen Great Soil Groups and their extents in the country are given in **Table 3.4**

Table 3.4: Distribution of Great Soil Groups of Sri Lanka.

Great Soil Group	Area ('000 ha)
Reddish Brown	1610
Low Humic Gley	950
Non Calcic Brown	163
Red Yellow Latasols	280
Calcic Red Yellow Latosols	40
Immature Brown Loams	205
Solodized Solonetz	210
Grumusols	15
Red Yellow Podsolic	1490
Reddish Brown Latosolic	60
Alluvials	450

Regosols	190
Bog and Half Bog	60
Lithosols	210

Data Source - Department of Agriculture Sri Lanka

The chemical and physical properties of these soils have been discussed by De Alwis and Panabokke (1972). The physical properties (except for water holding properties) of major Soil Groups such as Reddish Brown Earths, Red Yellow Podzolic, Red Yellow Latosols and Reddish Brown Latosolic are favorable for plant growth. The chemical fertility of Wet Zone soils is poor because these soils have been extensively leached due to high rainfall. The CEC values of most of the soils are low. This requires the use organic manure and special fertilizer management practices on these soils. The base saturation of the Dry Zone soils remains at a higher range. Solodized Solonetz, Bog and Half Bog soils are the major problem soils found in the country. The agricultural potential of soils of Sri Lanka has been discussed by De Alwis and Panabokke (1972). In general, soils of Sri Lanka do not pose major problem for crop production.The placement of major Soil Groups of Sri Lanka within the Orders of soil taxonomy is shown in **Table 3.5.**

Out of the rice growing areas (about 50%) are situated in this zone. Five different agro ecological regions (DL1, DL2, DL3, DL4 and DL5) have been identified in this zone depending on the amount of rainfall each region receives and its distribution pattern.

3.3.1 Low Country Dry Zone 1

Annual rainfall is about 800 mm. Mean temperature is about 30oC . The main great soil groups are RBE and LHG. Drainage classes well drained to poorly drained. Slope range from 0-2%. Rice is mainly grown in moderately to poorly drained soils. During Maha season, all the rice lands are used for rice, but during Yala season imperfectly to poorly drained soils only can used for paddy cultivation under rainfed condition and moderately drain RBE soil needs fair amount of water as supplementary irrigation for a good rice crop. Therefore, these moderately drained lands are suited for other field crops during Yala season. Under good management conditions, 6-8 t/ha paddy yield can be expected during both Maha and Yala seasons. The land form pattern of this region is mainly undulating and the slope varies from 2-8% . Landform ,Rice growing LHG soils are confined to the valley bottoms of the undulating terrain where the slope ranges from 0 - 2%.

3.4 Population of Sri Lanka

Population 20,912,100 (2006 est) Population growth rate 0.8% (2010) Population density (per sq km) 319 (2010 est) Urban population (% of total) 21 (2005 est) Age distribution (% of total population) 0 - 14 24%, 15 - 59 65%, 60+ 11% (2005 est) Ethnic groups 74% Sinhalese, about 18% Tamil, and 7% Moors or Muslims (concentrated in east); the Tamil community is divided between the long-settled Sri Lankan Tamils (11% of the population), who reside in northern and eastern coastal areas, and the more recent immigrant Indian Tamils (7%), who settled in the Kandyan highlands during the 19th and 20th centuries.

3.5 Irrigation Tanks

several different types of tank were built - some of which had nothing to do with irrigation per se but all of which had a critical role to play in the practice of irrigation agriculture. It was, for example, traditional to build a forest tank in the jungle above the village. That tank, however, was not used to irrigate land: on the contrary, its express purpose was to provide water to wild animals and, hence, to reduce the likelihood that they would descend into the paddy fields and destroy the crops in the search for water. Other tanks included:

Table 3.5: Placement of Great Soil Groups within Seven of the Ten Orders of Soil Taxonomy.

USDA Taxonomic Order	Sub Order	Great Group	Equivalent Great Soil Group
Entisols (Recently formed soils)	Aquents Fluvents Psamments	Tropaquents Tropofluvents Quartxipsammenta	Alluvials Sandy Regosols Soils on old alluvium
Vertisols (Shriniking & swelling)	Usterts	Pellusterta	Grumusols
Inceptisols (Embryonic soils with a few diagnostic features)	Tropepts	Ustropepts	Immature Brown Loams Immature Brown Loams in Wet Zone
Alfisols (High Base status forest carrying soils)	Aqualfs	Tropaqualfs Natraqualfs	Low Humic Gley Solodized Solonetz
	Ustalfs	Rhodustalfs Haplustalfs	Reddish Brown Earths Non-calcic brown soils
	Udalfs	Rhodudalfs	Reddish Brown Earths of Intermediate Zone
Ultisols (Low base status forest soils)	Udults	Tropudults Rhodudults Tropudults Plinthudults	Reddish Brown Latosolic Red Yellow Podzolic Red Yellow Podzolic Red Yellow Podzolic with soft laterite
	Humults Ustults	Tropohumults Rhodustults	Red Yellow Podzolic soils with prominent A-1 horizon Red Yellow Podzolic of the semi-dry Intermediate Zone
Oxisols (Sequioxide rich highly weathered soils of the tropical regions)	Ustox	Haplustox Eutrustox	Red Yellow Latosols Calcic Red Yellow Latosols

References: De Alwis KA and CR Panabokke (1972) Handbook of the soils of Sri Lanka. J. Soil Sci. Soc. Ceylon 2, 1-98

- **The mountain tank**, which was built to provide water for 'chena' or slash-and-burn agriculture - a vernacular form of farming now frowned upon (if not actually discouraged) by the authorities.

- **The erosion control tank**, or *'pota wetiye'*, which was so designed that any silt was deposited in it before entering the main water storage tanks. Several erosion control tanks were associated with each village irrigation system. All were built in such a way that they could easily be de-silted.
- **The storage tank**, of which, traditionally, there were two. One being used whilst the other was being repaired. For that reason, such tanks were known as 'twin tanks'.
- **The Irrigation Tank**, of which there was one for each village that depended upon a particular irrigation system.
- The amount of water remains from rainfall after evaporation and infiltration losses are considered as available surface water. Sri Lanka's total annual runoff appears to be roughly 5.0 million ha m. It is estimated that nearly 65% of annual rainfall escapes to the sea as runoff by rivers of 103 river basins and by 94 coastal basins, thus there exists a great potential for irrigation development Schemes for the purpose of storage and / or regulation of runoff water for mainly irrigation have been in existence mainly in the Dry Zone of Sri Lanka from the ancient time. These schemes have been constructed as a series of small reservoirs or a chain of tanks at successive locations down one single watercourse forming a cascade of tank system. These systems are interconnected storage and regulating reservoirs, which serve multiple functions of resource management including irrigation, domestic supply, water for livestock, and subsurface water for perennial cropping. Some of these tanks have very long histories dating back to over thousand years and were once the backbone of an ancient hydraulic civilization, which flourished in the north central part of the country.
- However there have been large tanks, which were meant for meeting water deficiencies with trans-basin diversions.

The ancient irrigation schemes such as Kalawewa, Nuwarawewa and Kantalewewa are examples for these.

Table 3.6: Characterization of irrigation tanks.

Item	Nuwara wewa	Tissa wewa	Abhaya wewa	Batalagoda wewa	Kimbulwana oya	Hakwatuna oya
Condition of Head Works						
Tank Bund	Good	Good	Good	Good	Good	Good
Spill	Good	Good	Good	Good	Good	Good
Sluices	Good	Good	Good	Good	Good	Good
Canals length and Density						
Main canal & Brach canal (km)	17.05	2.92	1.35	33.88	10.5	28.24
D & F canals (km)	53.42	20.06	9.05	77.92	23.53	73.42
Command area (ha)	1040	361	154	3053	800	2550
Canal density of D & F canals (km/ha))	0.051	0.056	0.059	0.026	0.029	0.029
Condition of Distributaries & Field Canals						
Full functioning	70%	70%	70%	60%	70%	60%
Partly functioning	30%	30%	30%	40%	30%	40%
Completely not functioning	0%	0%	0%	0%	0%	0%
Conditioning of structures at Distributaries & Field Canals						
Full functioning	70%	70%	70%	60%	70%	60%
Partly functioning	30%	30%	30%	40%	30%	40%
Completely not functioning	0%	0%	0%	0%	0%	0%
Outlets						
Concrete	85%	85%	85%	75%	85%	75%
PVC pipe	0%	0%	0%	0%	0%	0%
No structure	15%	15%	15%	25%	15%	25%
Water Supply						
Rotation	10 days interval	10 days interval	10 days interval	10 days interval	10 days interval	10 days interval
Operation and Maintenance						
Head Works	Irrigation Department	Farmer organization	Farmer organization	Irrigation Department	Irrigation Department	Irrigation Department
Main canal & Branch canal	Irrigation Department	Farmer organization	Farmer organization	Irrigation Department	Irrigation Department	Irrigation Department
D & F canals	Farmer organization	Farmer organization	Farmer organization	Farmer organization	Farmer organization	Farmer organization

D= Distributory canal, F= Field canal

Other than ancient irrigation schemes there are recent irrigation as well as other schemes existing in Sri Lanka. Altogether there are 521 schemes of which 307 are storage irrigation schemes, 104 are diversion irrigation schemes while 110 are drainage, flood control or salt-water exclusion schemes. Moreover, there are 12 schemes in operation with lift irrigation facilities. All schemes, which provide irrigation water for over 80 ha, are considered as major schemes and such schemes are maintained by the Department of Irrigation. Total irrigable extent under these schemes is nearly 340,000 ha. In addition there are about 25,000 minor schemes, which are maintained by the Department of Agrarian Development each serving less than 80 ha. Minor irrigation schemes provide irrigation facilities for 162,000 ha approximately. These irrigation schemes provide water mainly for the cultivation of paddy while cash earning short age crops are also grown quite frequently.

Head works, main canals and Branch canals of major irrigation scheme, (command area greater than 400 ha) are manage by Irrigation Department and Distributory and field canals are manage by farmer organization of the respective area since 1985. Medium irrigation schemes (command area 80 to 400 ha) mange by farmer organization under supervision of Irrigation Department.

3.6 Infrastructure

3.6.1 Roads

The rural road network in Sri Lanka is generally good and most rural communities have good access to these roads. On some of the resettlement programmes the villages situated furthest from the service centers have problems because of lack of maintenance funds for the village roads. In these places seasonal inaccessibility can be a problem particularly with regard to the curtailment of bus services and traders unable to conduct their business.

3.6.2 Marketing

The marketing structure in the study area are dominated by the private sector. The role of the government sector is limited to providing the necessary advice and facilitation of marketing channels except the intervention in the national paddy purchasing programe. Marketing aspects consider price fluctuations of paddy and other governing pricing factors. For agricultural marketing, Government policies usually consider export and import of agricultural products, supply / demand , pricing and price formula, marketing facilities ,etc now a days. Government is promoting crop diversification of paddy and higher productivity of paddy cultivation. In the study area an increasing trend of diversification to vegetables and fruit crops is observed. On the other hand , import amount of Maize, Green gram and Chilies is regularly high in Sri Lanka. The domestic demand for those importing items can be full filled by immediate local supply if countermeasures are taken effectively.

Many farmers borrow cultivation funds in advance from middleman or shop-owners in a village. For settlement of such loans, farmers normally rush to sell their paddy for cash soon after harvest despite the selling prices being at the lowest level. The quality of paddy is not much consideration in transactions, leading to poor quality control by farmers. In the study area, paddy is harvested during Feb - Mar for wet season (Maha) and August for dry (Yala) season. The selling prices normally drop in Mar-Apr and rise during May-June. Most commercial rice millers and paddy collectors stock paddy after harvest season for use in Wet season, and paddy prices do not drop sharply during Sep - Oct after the harvest in Dry season. In Dry zone Schemes, there are a number of commercial rice mills in actively operation But in Intermediate zone Scheme, there are only 2 small commercial rice mills in operation but huge no. of village mills are working. Most farmers in Dry zone sell paddy directly to the commercial mills but farmers in Intermediate zone can only sell to collectors / middlemen. Local brokers play a mediator role in paddy marketing, as buyers and sellers.

There is no wholesale market for paddy/rice in the study area unlike other field crops, such as vegetables, fruits which are everyday commodities to be taken by wholesalers / collectors and producers (farmers) to the economic centers (wholesale market).

During harvesting Government also purchase paddy at higher price to stable the market price. But Government purchase only 10% of the total production the rest of the paddy production purchase by private party.

3.6.3 Banking

With the growning economy, banking facilities in Sri Lanka have also enhanced. The country is in the increasing need of sophisticated banking to meet the needs of the growing business community. Banks of Sri Lanka have been constantly updating their banking philosophy to fulfill the expectations of their customers. They are coming up with new products to meet the aspirations of the changing times. Their working hours have also become more flexible. Some banks also offer night banking facilities. The banks are closed in weekends, public holidays and special bank holidays on June 30 and December 31 Banks in Sri Lanka do all activities which are usually done in banks. One can get an account open, deposit or withdraw money, get drafts, traveler's cheques or pay orders made. However credit cards are now becoming common in Sri Lanka. People still believe in good old tradition of saving money and spending as less as possible. Sri Lanka is a growing economy and banks are continuously expanding. Branches have been opened in remote places where, few years before, there was no existence of anything like banking.

One can take loans from the banks. However, basic requirements would have to be completed. Documents usually needed are address proof and identity proof. Few foreign banks operate in Sri Lanka and one has to be careful while using credit cards there. Capital Colombo and other cities can have ATMs but it would be difficult to find them in remote places

3.6.4 Education

Education in Sri Lanka has a history of over 2300 year, it is believed that the Sanskrit language was brought to the island from North India as a result of the establishment of the Buddhism in the reign of King Devanampiyatissa from the Buddhist monks sent by Emperor Asoka of India. The present educational system of Sri Lanka derives from the British educational system, which was introduced by the British colonial masters in the 19th century. The British colonial government established colleges for boys and girls separately. These colleges consisted of Primary Schools, Lower Secondary and Higher Secondary Schools

In 1938 the education in Government schools made free of charge as consequence of the Universal Franchise granted in 1931.Subsequently many government schools called Maha Vidyalayas and were started in all parts of the country. The medium of education of Maha Vidyalaya's was either Sinhala or Tamil.

Today primary education lasts six years, after which the pupils sit a scholarship examination. Those who passed scholarship examination are qualify themselves to be admitted to popular schools and are granted monthly financial support until they pass out from the university

.After primary education there is Junior Secondary education which lasts for five years, after which pupils have to sit government examination namely G.C.E. ordinary level to qualify for Senior Secondary education which last another two years. Then comes the competitive university entrance examination which is called G.C.E. Advanced level examination.

Those who are not admitted to the universities can either enter vocational technical schools or be employed in companies or in government departments as apprentice or trainees. They can also pursue higher education as external students of traditional universities or at the Open university of Sri Lanka. The open university of Sri Lanka was established in early 1980's with the idea of conferring degrees and diplomas to the working population who can do part-time studies by paying tuition fees

.Medium of study in schools today is either Sinhala or Tamil depending on the native language and from grade six English medium education also available from few Government schools.. The first language and the mathematics are compulsory subjects. all primary junior secondary pupils get their schools uniforms and text books free of charge from the government.

In the universities the medium of study of the Medical and engineering faculties are in English and, in other faculties it can be Sinhala, Tamil or English depending on the University. Some Universities do have post graduate institute that confer second degrees, for example Post Graduate Institute of Medicine attached to the University of Colombo In addition these system lots of private international schools are being introduced to the present day education. Apart from these, the Ministry of Education has launched a non-formal vocational education program which allows school left-outs and adults who did not complete their school education, to earn a living, through self-employment. Most of these courses are held at community centers and they cover a wide range of fields such as dressmaking, beauty culture, hairdressing, stitching, carpentry, plumbing, painting and so on.

3.6.5 Health

3.6.5.1 Physical infrastructure

There is a comprehensive network of health centers, hospitals and other medical institutions located countrywide, Large workforce engaged in curative and public health activities.

3.6.5.4 Extension Services to Farmers

Many institution in the public and private sector are involved in providing extension service to the farmer community with the government organization continuing major role. Service provided by Department of Agriculture, both central and provincial are most extensive as far as the food sector is concerned.

Role of agricultural extension in agricultural development encompasses three dimensions, namely educational, communicational and problem solving. Agricultural extension is an on-going process of communicating useful information to farmers and assisting them to acquire the necessary knowledge, skills and attitudes to effectively utilize the information or technology to improve their farming methods and techniques, to increase production and income with a view to changing their behavior and attitudes for betterment of their livelihood and lifting the social and educational levels of the farming community.

Agricultural Extension services has traditionally been the responsibility of the government even prior to independence. The importance of the agricultural sector in the over all development of the economy and the fact that a large segment of the population was directly involved in farming may have necessitated the need for direct government intervention in agricultural extension. Agriculture extenuation to farmers is the prime responsibility of the Department of Agriculture. Other institutions involved at various levels are the Department of Export Agriculture, Agricultural Development Authority, Agrarian Services Department, Hector Kobbekaduwa Agrarian Research & Training and more recently the Institute and Post Harvest Technology Institute.

3.7 Present Status of the Irrigation Systems

In 1988, following a decade of field experiments, the Government of Sri Lanka formally adopted a policy of transferring full responsibility for the operation and maintenance (O&M) of minor irrigation schemes to farmer organizations (FOs) In the medium and major schemes, farmers and agency personnel were made jointly responsible for the management of the systems: FOs taking charge of O&M of irrigation facilities below the distributary channel head, and the irrigation agency retaining its control of the head works and the main canal system. This program labeled as "Participatory Irrigation System Management" was implemented in a number of major and medium schemes under three government-sponsored programs: Integrated Management of Irrigation Schemes (INMAS), Management of Irrigation Systems (MANIS) program, and in the systems under the Mahaweli Development Project.3 The objectives of the program are to • relieve the government of the financial burden of funding recurrent expenditures for irrigation • improve the maintenance of irrigation facilities and the irrigation service • enhance the productivity of irrigated land and Water • promote a spirit of self-reliance among farmers in irrigation schemes (Abeywickrema 1986; Brewer 1994)

Farmer organizations are fundamental to participatory irrigation system management. Their main function is to deal with irrigation matters, but statutory provisions permit them the right to formulate and implement agricultural programs for their area, market farm produce, and distribute production inputs (GOSL 1991). Owner cultivators and occupiers of land in the designated area are eligible for membership in FOs. Only one person per plot of land is conferred membership. In most localities, cultivating a plot of land irrigated by a

particular distributary channel, regardless of the tenure pattern, is a sufficient qualification for membership. FOs can become legal if they register with the Department of Agrarian Services and the Commissioner approves the registration. Once they are registered, FOs get authority under the Irrigation Ordinance to formulate rules on maintenance, conservation, and management of irrigation infrastructure under their jurisdiction, to devise procedures for distributing water within the area under their command, and to impose and

Levy fees to recover the costs of O&M (IIMI/ HKARTI 1997).

Government policy on irrigation management transfer. The next section outlines the methodology. We then present the results of the analysis. The final section reviews the methodology and concludes with some observations on the irrigation management transfer program in Sri Lanka. Transfer of responsibilities from the government to the FOs can take place informally or formally. Informal transfer is a verbal agreement between the agency and the FOs. Once FOs are established and considered capable of handling responsibilities, the irrigation agency formally "hands over" the O&M of distributary channels to FOs (IIMI/HKARTI 1997). An agreement is signed between the FOs and the agency stipulating the responsibilities of each party. Table 1 summarizes

management responsibilities assigned to various entities before and after the introduction of participatory management.

In Sri Lanka, most of the irrigation systems at present including small to large reservoirs, diversion canals and distribution systems, are the ancient hydraulic civilization flourished the island for centuries before the foreign invasions Sri Lanka has more than 18,000 minor irrigation systems centered on rain-fed tanks. The irrigation tanks are mainly found in the dry zone of Sri Lanka, where the annual rainfall is less than 1,120 mm with a high seasonal variation, and they are the key hydraulic structures that facilitate the management of water for the paddy cultivations in the dry zone for two seasons per year. The annual extents of dry zone paddy cultivations are very much influenced by the seasonal storages of the irrigation tanks and the storages carried over by the tanks from wet season to dry season. Therefore, the loss of the storage capacity of the irrigation tanks due to continuous sedimentation has a serious negative impact on the rice production of

the country and on the life of farmers. Estimation of the sedimentation volume in the irrigation tanks is important in the planning the cultivation season.

Quantitative evaluations of the sedimentation rate in the tanks are needed for policy makers, farmer organizations and environmental groups to plan appropriate management strategies, and projecting the impact of the sedimentation on the agricultural sector and the socio-economic standard of the farming community. Though many soil erosion models of different complexities are being used today for project evaluation and planning, or as research tools to study the hydrological processes and erosion systems have been carried out on their applications for the estimation of sedimentation in irrigation tanks fed by seasonal rains.

3.8 Selection of Tanks

There are three climatic zones according to rainfall which are

- Dry zone - Annual Rainfall < 1250 mm
- Intermediate zone - 1250 mm <Annual rainfall < 3000 mm
- Wet zone - Annual rainfall > 3000mm

There are no irrigation tanks in wet zone due to high amount of rainfall. Hence six tanks have been selected from Dry zone and Intermediate zone such that three from each zone. Five agro ecological zones in Dry zone and eleven agro ecological zones in Intermediate zone are as follows.

DL1 Agro-ecological zone is one of the high rice yielding zones of Sri Lanka. Under good management conditions, 6-8 tons/ha paddy yield can be expected during both Maha and Yala seasons and according to accessible of data three tanks were selected from Dry zone in DL1 agro-ecological zone. Which are

1. Nuwarawewa
2. Tissawewa
3. Abhayawewa

Other three tanks were selected from Intermediate zone in IL1 and IL3 agro-ecological zones namely

1. Batalagodawewa
2. Kimbulwanaoyawewa
3. Hakwatunaoyawewa

CHAPTER 4

CHAPTER 4

METHODOLOGY

4.1 Data

4.1.1 Weather and Crop Data

Weather and Crop data have been collected from Agricultural Department, Mahailuppallama weather station, Rice Research and Development Institute Bathalagoda and Irrigation Department Sri Lanka.**(Annexure -A).**

4.1.2 Water Delivery and Cultivation Data

Water Delivery and Cultivation Data have been collected from Irrigation Engineer's Office Hiriyala, Irrigation Engineer's Office Anuradhapura and Irrigation Department Head office Colombo Sri Lanka **(Annexure B).**

4.2 Methods of ETo Calculation

4.2.1 Modified Penman method

Using climatic data and Modified Penman method, reference crop evapotranspiration can be calculated. For areas where measured data on temperature, humidity, wind and sunshine duration or radiation are available, an adaptation of the Penman method is suggested, compared to the other methods presented it is to provide the most satisfactory results. The original Penman equation predicted evaporation losses from an open water surface (ETo).

The Penman equation consists of two terms: the energy (radiation) term and the aerodynamic (wind and humidity) term. The relative important of each term varies with climatic conditions. Under clam weather conditions the aerodynamic term is usually less important than the energy term. It is under windy conditions and particularly in the more arid regions that the aerodynamic term becomes relatively more important. A slightly modified Penman equation is suggested to determine ETo, involving a revised wind function term. The procedure to calculate ETo may seen rather complicated. This is due to the fact that the formula contains components which need to derived from measured relate climatic data where no direct measurements of needed variable. For instance, for places where in direct measurements of net radiation are available, these can be obtained from measured solar radiation, sunshine duration or cloudiness observations, together with measured humidity and temperature. This method uses mean daily climatic data, with an adjustment for day and night time weather conditions. The modified equation is

$$ET_o = C\,[W^* R_n + (1 - W)^* f(u)^* (e_a - e_d)]$$

where

ET_o	=	reference crop evapotranspiration in mm/day
W	=	temperature related weighting factor
R_n	=	net radiation in equivalent evaporation in mm/day
f(u)	=	wind related function
(e_a-e_d)	=	difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air in mbar
C	=	adjustment factor to compensate for the effect of day and night weather conditions

The suggested wind function applies to conditions found during summer, with moderate winds, RHmax of about 70%, and day-night wind ratios of 1.5 to 2.0; no adjustment is required for these conditions.

Vapour pressure (e_a- e_d)

Air humidity affects ETo. Humidity is pressed here as saturation vapour pressure deficit (ea-ed): the difference between the mean saturation water vapour pressure (ea) and the mean actual water vapour pressure(ed). Air humidity data are reported as relative humidity (RHmax and RHmin) in percentage and then RHmean is obtained. Mean saturation water vapor pressure (ea) is depended on mean air temperature and is given in **Annexure C-5.** Mean actual water vapour pressure (ed) is gained from (ea) multiplies with RH mean.

Wind function f (u)

The effect of wind on ETo for different climatic results with a function and is defined as wind function. Wind function f (u) is

f(u) = 0.27(1 + U2/100)

where

U2 = wind speed in km/day at 2 m height

Annexure C-6 can be used for values of f (u) for wind speed at 2 m height. Where wind data are not collected at 2 m height, the appropriate correction for wind measurements taken at different heights are given in **Table 4.1** Correction Factor for Wind Measurement

Table 4.1: Correction Factors for Wind Measurement.

Measurement height (m)	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0
Correction factor	1.35	1.15	1.06	1.00	0.93	0.88	0.85	0.83

Source: Irrigation and Drainage Paper 24 (1992)

Weighting factor (1-W)

(1-W) is a weighting factor for the effect of wind and humidity on ETo. These values as related to mean temperature and altitude are given in **Annexure C-4** shown in Appendix A. W is the weighting factor for the effect of radiation on ETo. Values of Was related to temperature and altitude are given in **Annexure C-7.**

Net radiation (Rn)

Net radiation (Rn) is the difference between all incoming and outing radiation. It can be measured, but such data are seldom available. Rn can be calculated from solar radiation or sun-shine hours, temperature and humidity data. The amount of radiation received at the top of the atmosphere (Ra) is dependent on latitude and the time of the year. Part of (Ra) is absorbed and scattered when passing through the atmosphere. The remainder, including some that is scattered but the earth's surface, is identified as solar radiation (Rs). Rs is dependent on Ra and the transmission through the atmosphere, which is largely dependent on cloud cover. Part of Rs is reflected back directly by the soil and crop and is lost to the atmosphere. Reflection (α) depends on the nature of the surface cover. Total net radiation (Rn) is equal to the difference between Rns and Rnl. Rn is calculated from the following steps.

$Rs = (.25+.5xn/N)Ra$

Where

Rs	=	solar radiation
Ra	=	radiation received at the top of the atmosphere. (given in **Annexure C-2)**
n	=	actual measured bright sunshine hours
N	=	maximum possible sunshine hours that depends on latitude and time of year (given in **Annexure C-3)**
Rns	=	$(1-\alpha)Rs$

Where

Rns	=	net short-wave radiation
α	=	crop reflection coefficient (most crop α =0.25)
Rnl	=	f(T)xf(ed)xf(n/N)

Where

Rnl	=	net long-wave radiation
f (T)	=	temperature function (given in **Annexure C-10)**
f(ed)	=	water vapor function (given in **Annexure C-11)**
f(n/N)	=	function of sunshine duration ratio (given in **Annexure C-12)**

Rn can be determined by

Rn = Rns -Rnl

Adjustment factor (C)

The Penman equation assumes the most common condition where radiation is medium to high, maximum relative humidity is medium to high and moderate daytime wind about double the nighttime wind. However, these conditions are not met. For instance, coastal areas with pronounced sea breezes and calm nights generally have day/ night ratios of 3 to 5; part of the middle East have dry wind during the day and calm wind conditions during the night with maximum relative humidity approaching 100 percent. For such conditions, corrections to Penman equation are required. Therefore, adjustment factor (c) is needed and is given in **Annexure C-13**) for different condition of RH max, Rs, Uday and Uday/Unight.

Calculation of ETo for Dry and Intermediate zones are given in **Table 4.2** and **Table 4.3** respectively.

4.2.2 Radiation Method

The radiation method is essentially an adaptation of the Makkink formula (1957). This method is suggested for areas where available climatic data include measured air temperature and sunshine, cloudiness or radiation, but not measured wind and humidity. Knowledge of general levels of humidity and wind is required and these are to be estimated using published weather descriptions, extrapolation from nearly areas or from local sources.

The radiation method should be more reliable than the presented Blaney- Criddle method. In fact, in equatorial zones, on small islands, or at high altitudes the radiation method may be more reliable even if measured sunshine or cloudiness data are not available; in this case solar radiation maps prepared for most locations in the world should provide the necessary solar radiation data. Relationship is given between the presented radiation formula and reference crop evapotranspiration, taking into account general levels of mean humidity and daytime wind. The equation is expressed as

$$\mathbf{ETo = c\,(w \times Rs)\ \ mm/day}$$

where

ETo	=	reference crop evapotranspiration
C	=	adjustment factor which depends on mean humidity and daytime wind condition
Rs	=	solar radiation in equivalent evaporation in mm/day
w	=	weighting factor which depends on temperature and latitude

Table 4.2: ETo by Modified Penman Method in Dry Zone.

Data	**Jan**	**Feb**	**Mar**	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (^{O}C)	25.25	26.5	28.35	29.20	28.85	28.80	28.75	28.80	28.60	27.65	26.40	25.50
Mean relative humidity (%)	88	85	83	83.00	77.00	73.00	70.00	71.00	72.00	84.00	88.00	89.00
Sunshine hours (n)	6.1	7.7	8.4	8.70	7.90	8.10	7.40	7.80	7.60	6.60	5.40	4.80
Maximum possible sunshine hours (N)	11.68	11.84	12	12.26	12.48	12.58	12.48	12.36	12.10	11.88	11.72	11.62
Wind speed at 2m height (km/day)	49	56	76	125	135	156	310	181	168	146	65	52
P [Annexure C-1]	0.264	0.27	0.27	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ea (mbar) [Annexure C-5]	32.18	34.65	38.61	40.16	39.84	39.64	39.53	39.64	39.18	37.07	34.44	32.65
ed = ea*RHmeav/100 (mbar)	28.32	29.45	32.04	33.33	30.68	28.94	27.67	28.14	28.21	31.14	30.31	29.06
ea-ed (mbar)	3.862	5.198	6.563	6.83	9.16	10.70	11.86	11.50	10.97	5.93	4.13	3.59
f(u) [Annexure C-6]	0.407	0.422	0.407	0.61	0.64	0.69	1.11	0.76	0.70	0.66	0.45	0.41
(1-w) [Annexure C-7]	0.251	0.239	0.22	0.22	0.21	0.21	0.21	0.21	0.22	0.21	0.24	0.24
(1-w)*f(u)*(ea-ed)	0.395	0.524	0.588	0.92	1.22	1.55	2.76	1.84	1.70	0.82	0.45	0.36
Ra (mm/day) [Annexure C-2]	13.6	14.5	15.3	15.60	15.30	15.00	15.10	15.40	15.30	14.80	13.90	13.30
Rs =(0.25+0.5n/N)Ra (mm/day)	6.951	8.34	9.18	9.44	8.67	8.58	8.25	8.71	8.63	7.81	6.68	6.07
Rns =(1-α)(0.25+0.5n/N)Ra (mm/day)	5.214	6.255	6.885	7.08	6.50	6.43	6.19	6.53	6.47	5.86	5.01	4.55
Rnl = f(t)*f(ed)*f(n/N) [Annexure C-10,11,12]	0.862	1.029	1.029	1.01	1.05	1.20	1.12	1.19	1.16	0.86	0.70	0.66
Rn = Rns-Rnl	4.352	5.226	5.856	6.07	5.45	5.23	5.07	5.34	5.31	4.99	4.31	3.90
W [Annexure C-8]	0.749	0.761	0.773	0.77	0.77	0.77	0.76	0.77	0.77	0.76	0.76	0.75
W.Rn	3.259	3.979	4.527	4.70	4.21	4.02	3.88	4.09	4.07	3.80	3.26	2.92
Uncorrected ETo	3.654	4.502	5.114	5.62	5.43	5.56	6.65	5.93	5.77	4.63	3.71	3.28
Adjustment Factor C [Annexure C-13]	1.07	1.1	1.1	1.10	1.10	1.10	1.00	1.10	1.05	1.04	1.00	1.03
ETo (mm/day)	**3.91**	**4.95**	**5.63**	**6.18**	**5.97**	**6.12**	**6.65**	**6.53**	**6.05**	**4.81**	**3.71**	**3.38**

Average ETo = 5.32 mm/day

Table 4.3: ETo by Modified Penman Method in Intermediate Zone.

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (^{O}C)	25.75	27.00	28.35	28.55	28.30	27.60	27.36	27.45	27.50	27.05	26.50	25.90
Mean relative humidity (%)	88.10	87.70	86.90	86.20	80.60	81.90	82.40	81.10	80.10	85.50	88.60	87.10
Sunshine hours (n)	6.30	7.10	7.50	6.60	6.70	7.10	8.20	8.70	7.10	4.70	6.00	7.40
Maximum possible sunshine hours (N)	11.72	11.86	12.00	12.24	12.42	12.52	12.42	12.34	12.10	11.92	11.78	11.68
Wind speed at 2m height (km/day)	13.75	14.65	15.35	15.50	15.20	14.85	15.00	15.30	15.30	14.90	14.05	13.50
P [Annexure C-1]	49.00	56.00	49.00	125.0	135.0	156.0	310.0	181.0	168.0	146.0	65.00	52.00
ea (mbar) [Annexure C-5]	0.266	0.270	0.270	0.280	0.280	0.284	0.284	0.280	0.280	0.270	0.266	0.266
ed = ea*RHmeav/100 (mbar)	33.13	35.70	38.61	39.1	38.49	36.96	36.46	36.65	36.75	35.81	34.7	33.4
ea-ed (mbar)	29.19	31.31	33.55	33.67	31.02	30.27	30.04	29.72	29.44	30.61	30.70	29.10
f(u) [Annexure C-6]	3.94	4.39	5.06	5.39	7.47	6.69	6.42	6.93	7.31	5.19	3.95	4.31
(1-w) [Annexure C-7]	0.41	0.42	0.41	0.61	0.64	0.69	1.11	0.76	0.70	0.66	0.45	0.41
(1-w)*f(u)*(ea-ed)	0.25	0.24	0.23	0.22	0.23	0.23	0.24	0.23	0.23	0.24	0.24	0.25
Ra (mm/day) [Annexure C-2]	0.40	0.44	0.46	0.73	1.07	1.07	1.67	1.24	1.20	0.82	0.43	0.45
Rs =(0.25+0.5n/N)Ra (mm/day)	7.13	8.05	8.63	8.05	7.90	7.92	8.70	9.22	8.31	6.66	7.09	7.65
Rns =(1-α)(0.25+0.5n/N)Ra (mm/day)	5.31	6.01	6.45	6.00	5.95	5.97	6.61	6.95	6.31	5.04	5.27	5.73
Rnl = f(t)*f(ed)*f(n/N) [Annexure C-10,11,12]	0.97	1.01	0.98	0.84	1.67	1.17	1.34	1.39	1.16	0.71	0.85	1.08
Rn = Rns-Rnl	4.33	4.99	5.47	5.16	4.28	4.81	5.27	5.55	5.15	4.33	4.42	4.66
W [Annexure C-8]	0.75	0.76	0.77	0.77	0.77	0.77	0.76	0.77	0.77	0.76	0.76	0.75
W.Rn	3.25	3.80	4.23	3.99	3.31	3.69	4.03	4.25	3.94	3.30	3.34	3.49
Uncorrected ETo	3.65	4.24	4.69	4.72	4.38	4.76	5.71	5.49	5.14	4.11	3.77	3.94
Adjustment Factor C [Annexure C-13]	1.07	1.1	1.1	1.10	1.10	1.10	1.00	1.10	1.05	1.04	1.00	1.03
ETo (mm/day)	**3.90**	**4.67**	**5.16**	**5.19**	**4.82**	**5.24**	**5.71**	**6.04**	**5.40**	**4.28**	**3.77**	**4.06**

Average ETo = 4.85 mm/day

Solar radiation (Rs)

The amount of radiation received at the top of the atmosphere (Ra) is dependent on latitude and the time of year only. Part of Ra is obtained and scattered when passing through the atmosphere. The remainder, including some that is scattered but reached the earth's surface, is defined as solar radiation (Rs). Rs is dependent on Ra and the transmission through the atmosphere, which is largely dependent on cloud cover. Rs can be measured directly but is frequently not available for the area of investigation. Rs can also be obtained from measured sunshine duration or cloudiness data.

$Rs = (0.25 + 0.5xn/N)Ra$

where

Rs = solar radiation

Ra = radiation received at the top of the atmosphere

n = actual measured bright sunshine hours

N = maximum possible sunshine hours that depends on latitude and time of year

If sunshine duration is recorded with cloudiness, conversion to n/N is required. Cloudiness is expressed in okats (0 to 8) and sometimes in tenths (0 to 10) Conversion is obtained from the following

Table 4.4: Conversion for Cloudiness (Okats) to Sunshine Duration Ratio.

Cloudiness	0	1	2	3	4	5	6	7	8
n/N ratio	0.95	0.85	0.75	0.65	0.55	0.45	0.35	0.15	0.00

Source: Irrigation and Drainage Paper 24 (1992)

Weighting factor (w)

The weighting factor (w) reflects the effects of temperature and latitude on the relationship between Rs and ETo. Value of w is related to temperature and latitude. Temperature reflects the mean air temperature in °C for the period considered.

$$w = \frac{\Delta}{(\Delta+\gamma)}$$

where

w = weighting factor

Δ = rate of change of saturation vapor pressure with temperature

γ = psychrometric constant at 20°C Rate of change of saturation vapor pressure

with temperature is obtained from the slope of vapor curve

$$\Delta = \frac{4098 * 0.6108 e^{\frac{17.27T}{(T+237.3)}}}{(T+237.3)^2}$$

Psychrometric constant (γ) for different altitude (z) is obtained by

$\gamma = 0.665 \times 10^{-3}$ p

where

p = atmospheric pressure at altitude (z) of 20°C (kPa)

Atmospheric pressure at altitude (z) of 20°C is calculated by

$$P = 101.3 (\frac{293+0.0065Z}{293})^2$$

where

z = elevation above sea level (m)

Adjustment factor (C)

The adjustment factor (c) is given by the relationship between the radiation terms (w x Rs) and reference crop evapotranspiration (ETo). It depends greatly on general levels of mean relative humidity (RHmean) and daytime wind (Uday 07:00□19:00 hours) at 2 m height

Table 4.5: ETo by Radiation Method in Dry Zone.

Data	**Jan**	**Feb**	**Mar**	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (^{O}C)	25.25	26.5	28.35	29.20	28.85	28.80	28.75	28.80	28.60	27.65	26.40	25.50
Mean relative humidity (%)	88	85	83	83.00	77.00	73.00	70.00	71.00	72.00	84.00	88.00	89.00
Sunshine hours (n)	6.1	7.7	8.4	8.70	7.90	8.10	7.40	7.80	7.60	6.60	5.40	4.80
Maximum possible sunshine hours (N)	11.68	11.84	12	12.26	12.48	12.58	12.48	12.36	12.10	11.88	11.72	11.62
Wind speed at 2m height (km/day)	49	56	76	125	135	156	310	181	168	146	65	52
P	0.264	0.27	0.27	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Rs	6.951	8.34	9.18	9.44	8.67	8.58	8.25	8.71	8.63	7.81	6.68	6.07
W	0.749	0.761	0.773	0.77	0.77	0.77	0.76	0.77	0.77	0.76	0.76	0.75
W.Rs	5.205	6.349	7.096	7.303	6.698	6.583	6.312	6.67	6.613	5.951	5.05	4.556
Adjustment Factor C	0.775	0.775	0.775	0.775	0.775	0.775	**0.778**	**0.778**	**0.775**	**0.775**	**0.775**	**0.775**
ETo (mm/day)	**4.03**	**4.92**	**5.50**	**5.66**	**5.19**	**5.10**	**4.91**	**5.19**	**5.13**	**4.61**	**3.91**	**3.53**

Average ETo = 4.81 mm/day

Table 4.6: ETo by Radiation Method in Intermediate Zone.

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (OC)	25.75	27.00	28.35	28.55	28.30	27.60	27.36	27.45	27.50	27.05	26.50	25.90
Mean relative humidity (%)	88.10	87.70	86.90	86.20	80.60	81.90	82.40	81.10	80.10	85.50	88.60	87.10
Sunshine hours (n)	6.30	7.10	7.50	6.60	6.70	7.10	8.20	8.70	7.10	4.70	6.00	7.40
Maximum possible sunshine hours (N)	11.72	11.86	12.00	12.24	12.42	12.52	12.42	12.34	12.10	11.92	11.78	11.68
Extra-terrestrial radiation (mm/day)	13.75	14.65	15.35	15.50	15.20	14.85	15.00	15.30	15.30	14.90	14.05	13.50
Wind speed at 2m height (km/day)	49.0	56.0	49.0	125.0	135.0	156.0	310.0	181.0	168.0	146.0	65.0	52.0
P	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27
Rs	7.13	8.05	8.63	8.05	7.90	7.92	8.70	9.22	8.31	6.66	7.09	7.65
W	0.75	0.76	0.77	0.77	0.77	0.77	0.76	0.77	0.77	0.76	0.76	0.75
W.Rs	5.34	6.13	6.67	6.23	6.10	6.08	6.66	7.06	6.37	5.08	5.36	5.74
Adjustment Factor C	0.775	0.775	0.775	0.775	0.775	0.775	**0.778**	**0.778**	**0.775**	**0.775**	**0.775**	**0.775**
ETo (mm/day)	**4.14**	**4.75**	**5.17**	**4.83**	**4.73**	**4.71**	**5.18**	**5.49**	**4.94**	**3.93**	**4.16**	**4.45**

Average ETo = 4.71 mm/day

above the soil surface. RHmean and Uday are estimated data. If Uday is not height for 2 m, it is converted by using equation.

U2day = conversion factor × Uzday

where

z = height of recorded wind speed

$$\text{Conversion factor} = \frac{4.87}{\ln(67.8Z - 5.42)}$$

4.2.3 Penman Monteith Method

The combination formula recommended by the Expert Consultation on FAO Methodologies for crop water requirements (UNFAO) derived by combining the equation of aerodynamic resistance and surface resistance is stated below:

$$\mathbf{ETo} = \frac{0.408\Delta(Rn - G) + \gamma\frac{900}{(T+273)}u2(es - ea)}{\Delta + \gamma(1 + 0.34u2)}$$

where

ET_o - Reference Evapotranspiration (mm/day)

R_n - Net Radiation At The Crop Surface (MJ/ m^2/ day)

G - Soil Heat Flux Density (MJ/ m^2 /day)

T - Mean Daily Air Temperature (°C)

u_2 - Wind Speed At 2 m Height (m /sec)

e_s - Saturation Vapour Pressure (kPa)

e_a - Actual Vapour Pressure (kPa)

e_s - e_a - Saturation Vapour Pressure Deficit (kPa)

Δ - Slope Vapour Pressure Curve (kPa/ °C)

γ - Psychrometric Constant (kPa/ °C).

The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not shortage of water.

No weather-based evapotranspiration equation can be expected to predict evapotranspiration perfectly under every climatic situation due to simplification in formulation and errors in data measurement. It is probable that precision instruments under excellent environmental and biological management conditions will show the FAO Penman-Monteith equation to deviate at times from true measurements of grass ET_o. However, the Expert Consultation agreed to use the hypothetical reference definition of the FAO Penman-Monteith equation as the definition for grass ET_o when deriving and expressing crop coefficients.

It is important, when comparing the FAO Penman-Monteith equation to ET_o measurements, that the full Penman-Monteith equation and associated equations for R_a and R_s be used to enable accounting for variation in ET due to variation in height of the grass measured. Variations in measurement height can significantly change LAI, d and z_{om} and the corresponding ET_o measurement and predicted value. When evaluating results, it should be noted that local environmental and management factors, such as watering frequency, also affect ET_o observations.

The FAO Penman-Monteith equation is a close, simple representation of the physical and physiological factors governing the evapotranspiration process. By using the FAO Penman-Monteith definition for ET_o, one may calculate crop coefficients at research sites by relating the measured crop evapotranspiration (ET_c) with the calculated ET_o, i.e., $K_c = ET_c/ET_o$. In the crop coefficient approach, differences in the crop canopy and aerodynamic resistance relative to the hypothetical reference crop are accounted for within the crop coefficient. The K_c factor serves as an aggregation of the physical and physiological differences between crops and the reference definition.

Table 4.7: ETo by Penman Montieth Method in Dry Zone Using CROPWAT 8.0.

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m?/day	mm/day
January	20.9	29.6	88	49	6.1	16.8	3.26
February	21.3	31.7	85	56	7.7	20.2	4.01
March	22.9	33.8	83	49	8.4	22.3	4.65
April	24.1	34.3	83	125	8.7	22.9	5.06
May	24.8	32.9	77	135	7.9	21.1	4.82
June	24.9	32.7	73	156	8.1	20.9	4.93
July	24.5	33	70	310	7.4	20.1	5.58
August	24.4	33.2	71	181	7.8	21.2	5.19
September	24.1	33.1	72	168	7.6	21	5.06
October	23.3	32	84	146	6.6	18.7	4.13
November	22.5	30.3	88	65	5.4	16	3.3
December	21.9	29.1	89	52	4.8	14.6	2.93
Average	**23.3**	**32.1**	**80**	**124**	**7.2**	**19.7**	**4.41**

Source of data: Agriculture Department, Weather station Mahailuppallama

Table 4.8: ETo by Penman Montieth Method in Intermediate Zone Using CROPWAT 8.0.

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m?/day	mm/day
January	20.7	30.8	88	49	6.3	17.3	3.41
February	20.9	33.1	88	56	7.1	19.5	3.98
March	22.4	34.3	87	49	7.5	21	4.45
April	23.6	33.5	86	125	6.6	19.6	4.35
May	24.4	32.2	81	135	6.7	19.2	4.35
June	24.2	31	82	156	7.1	19.4	4.26
July	23.9	30.8	82	310	8.2	21.1	4.71
August	23.8	31.1	81	181	8.7	22.5	4.82
September	23.5	31.5	80	168	7.1	20.2	4.52
October	22.8	31.3	86	146	4.7	16	3.56
November	22.1	30.9	89	65	6	17	3.48
December	21.7	30.1	87	52	7.4	18.4	3.6
Average	**22.8**	**31.7**	**85**	**124**	**7**	**19.3**	**4.12**

Source of data: Agriculture Department, Weather station Bathalagoda

4.2.4 Blaney-Criddle method

The Blaney-Criddle method was first proposed in 1945 by H.F. Blaney and W.D.Criddle. The method has been revised many times and these are so many variations that when the method is used. This method is suited for mostly estimates of ET (Jensen 1974). Only air temperature and rainfall data are needed to complete the calibration by determining the appropriate monthly crop coefficient. In this equation, it is assumed that the potential evapotranspiration, or the consumptive use, depends only on the mean monthly temperature and the monthly sunshine hours. The monthly sunshine hours are also called the monthly daylight hours. The monthly consumptive use (u) is given by

$$u = kf$$

where

u = the monthly consumptive use

k = an empirical coefficient of the crop

f = the monthly consumptive use factor

$$f = P\frac{(4.6Tm+81.3)}{100}$$

where

Tm = the mean monthly temperature (°C)

p = the monthly daylight hours expressed as a percentage of the total daylight hours of the year

The value of p depends on the latitude of the place. The crop coefficient k depends on the location and type of crop. Values of k are different in different months, depending upon the stage of the growth of crop The Blaney-Criddle equation for reference crop evapotranspiration is expressed as:

Table 4.9: ETo by Blaney Criddle Method in Dry Zone.

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (^{O}C)	25.25	26.5	28.35	29.20	28.85	28.80	28.75	28.80	28.60	27.65	26.40	25.50
Mean relative humidity (%)	88	85	83	83.00	77.00	73.00	70.00	71.00	72.00	84.00	88.00	89.00
Sunshine hours (n)	6.1	7.7	8.4	8.70	7.90	8.10	7.40	7.80	7.60	6.60	5.40	4.80
Maximum possible sunshine hours (N)	11.68	11.84	12	12.26	12.48	12.58	12.48	12.36	12.10	11.88	11.72	11.62
Wind speed at 2m height (km/day)	49	56	76	125	135	156	310	181	168	146	65	52
P	0.264	0.27	0.27	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Uncorercted Eto	5.2	5.5	5.7	6.0	6.0	6.1	6.1	5.9	5.9	5.6	5.3	5.2
Adjustment Factor C	0.541	0.697	0.697	0.697	0.697	0.697	**0.84**	**0.84**	0.697	0.697	**0.58**	**0.58**
ETo Blaney - Criddle Method (mm/day)	**2.80**	**3.80**	**3.96**	**4.18**	**4.15**	**4.24**	**5.10**	**5.00**	**4.13**	**3.90**	**3.10**	**3.02**

Average ETo = 3.95 mm/day

Table 4.10: ETo by Blaney Criddle Method in Intermediate Zone.

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air temperature (OC)	25.75	27.00	28.35	28.55	28.30	27.60	27.36	27.45	27.50	27.05	26.50	25.90
Mean relative humidity (%)	88.10	87.70	86.90	86.20	80.60	81.90	82.40	81.10	80.10	85.50	88.60	87.10
Sunshine hours (n)	6.30	7.10	7.50	6.60	6.70	7.10	8.20	8.70	7.10	4.70	6.00	7.40
Maximum possible sunshine hours (N)	11.72	11.86	12.00	12.24	12.42	12.52	12.42	12.34	12.10	11.92	11.78	11.68
Extra-terrestrial radiation (mm/day)	13.75	14.65	15.35	15.50	15.20	14.85	15.00	15.30	15.30	14.90	14.05	13.50
Wind speed at 2m height (km/day)	49.0	56.0	49.0	125.0	135.0	156.0	310.0	181.0	168.0	146.0	65.0	52.0
P	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27
p(0.46T+8)	5.28	5.51	5.68	5.92	5.89	5.88	5.85	5.78	5.78	5.52	5.37	5.30
Adjustment Factor C	0.54	0.70	0.70	0.70	0.70	0.70	**0.84**	**0.84**	0.70	0.70	**0.58**	**0.58**
ETo (mm/day)	**2.85**	**3.84**	**3.96**	**4.12**	**4.10**	**4.10**	**4.91**	**4.85**	**4.03**	**3.85**	**3.13**	**3.07**

Average ETo = 3.90 mm/day

$ETo = C [P(0.46T + 8)]$

where

ETo = reference crop evapotranspiration in mm/day

T = mean daily temperature (°C)

p = mean daily percentage of total annual daytime hours

c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates

Table 4.11: Summery of ETo Calculated by different methods.

Methods	Average Annual ETo in Dry Zone (mm/day)	Average Annual ETo in Intermediate Zone (mm/day)
Modified Penman Method	5.32	4.85
Radiation Method	4.81	4.71
Penman Montieth Method	4.41	4.12
Blaney Criddle Method	3.95	3.90

The ETo calculated by different method was 5.02 mm/day (Modified Penman) 4.60 mm/day (Radiation method) 3.64 mm/day (Blaney-Criddle Method) 4.27 mm/day (Penman Montieth method). Modified Penman method was adopted for further calculation in view of the fact it appeared to be more realistic and is also recommended by Irrigation Department of Sri Lanka.

Table 4.12: Irrigation Water Requirement of Rice in Dry Zone during Yala Season.

Months	Apr		May		Jun		Jul		Aug		Sep	
No of days		15	20	11	19	11	19	10	0			
ET_O (mm/day)	6.18		5.97		6.12		6.65		6.53		6.05	
Growth stages			1	2	2	3	3	4	4			
Kc per gr.st			1.0	1.15	1.15	1.20	1.20	0.90	0.90			
ETcrop (mm/day)			6.0	6.9	7.0	7.3	8.0	6.0	5.9			
ETcrop (mm/month)	0.0		194.9		214.5		211.5		0.0			
SAT (mm)	175.0											
WL (mm)	100.0											
PERC (mm/month)	75.0		155.0		150.0		145.0		0.0			
P (mm/month)	127.0		50.8		12.7		0.0		12.7		25.4	
Pe (mm/month)	76.6		20.5		0.0		0.0		0.0		5.2	
IN (mm/month)	273.4		329.4		364.5		356.5		0.0			
IN (mm/day)	18.2		10.6		12.2		12.3		0.0			

Net Irrigation Requirement 1323.8 mm

Table 4.13: Irrigation Water Requirement of Rice in Dry Zone during Maha Season.

Months	Jan		Feb		Mar		Oct		Nov		Dec	
No of days	9	22	23	5	15				15	15	15	16
ET_O (mm/day)	3.91		4.95		5.63		4.81		3.71		3.38	
Growth stages	2	3	3	4	4				1	1	2	2
Kc per growth stages	1.15	1.20	1.20	0.90	0.90				1.00	1.00	1.15	1.15
ETcrop (mm/day)	4.5	4.7	5.9	4.5	5.1				3.7	3.7	3.9	3.9
ETcrop (mm/month)	143.7		158.9		76.0				111.3		120.5	
SAT (mm)												
WL (mm)												
PERC (mm/month)	155.0		140.0		75.0				150.0		155.0	
P (mm/month)	76.2		25.4		50.8		127.0		152.4		127.0	
Pe (mm/month)	36.0		5.2		20.5		76.6		96.9		76.6	
IN (mm/month)	262.7		293.7		130.5				164.4		198.9	
IN (mm/day)	8.5		10.5		8.7				5.5		6.4	

Net Irrigation Requirement 1050.2 mm

Table 4.14: Irrigation water Requirement of Rice in Intermediate Zone during Yala Season

Months	Apr		May		Jun		Jul		Aug		Sep	
No of days		15	20	11	19	11	19	10				
ET_O (mm/day)	5.19		4.82		5.24		5.71		6.04		5.40	
Growth stages			**1**	**2**	**2**	**3**	**3**	**4**	**4**			
Kc per gr.st			1.00	1.15	1.15	1.20	1.20	0.90	0.90			
ETcrop (mm/day)			4.8	5.5	6.0	6.3	6.9	5.1	5.4			
ETcrop (mm/month)	0.0		157.4		183.7		181.6		0.0			
SAT (mm)	175.0											
WL (mm)	100.0											
PERC (mm/month)	75.0		155.0		150.0		145.0		0.0			
P (mm/month)	101.6		50.8		38.1		25.4		12.7		38.1	
Pe (mm/month)	56.3		15.6		5.5		5.2		0.0		12.9	
IN (mm/month)	293.7		296.7		328.2		321.3		0.0			
IN (mm/day)	19.6		9.6		10.9		11.1		0.0			

Net Irrigation Requirement 1239.9 mm

Table 4.15: Irrigation water Requirement of Rice in Intermediate Zone during Maha Season

Months	Jan		Feb		Mar		Oct		Nov		Dec	
No of days	9	22	23	5	15				15	15	15	16
ET_O (mm/day)	3.90		4.67		5.16		4.28		3.77		4.06	
Growth stages	**2**	**3**	**3**	**4**	**4**				**1**	**1**	**2**	**2**
Kc per gr.st	1.15	1.20	1.20	0.90	0.90				1.00	1.00	1.15	1.15
ETcrop (mm/day)	4.5	4.7	5.6	4.2	4.6				3.8	3.8	4.7	4.7
ETcrop (mm/month)	143.3		149.9		69.7				113.1		144.7	
SAT (mm)												
WL (mm)												
PERC (mm/month)	155.0		140.0		75.0				150.0		155.0	
P (mm/month)	50.8		38.1		50.8		190.5		165.1		88.9	
Pe (mm/month)	20.5		12.9		15.6		127.4		107.1		46.1	
IN (mm/month)	277.8		277.0		129.0				156.0		253.6	
IN (mm/day)	9.0		9.9		8.6				5.2		8.2	

Net Irrigation Requirement 1093.6 mm

4.4 Calculation of Performance Indicators

As discussed in the previous chapters, performance evaluation is imperative for not only assessment of the system of the status of irrigation schemes but also for improved performance. To this end, seven schemes namely Nuwarawewa and Thissawewa Abhayawewa in dry zone and Batalagodawewa Kimbulwanaoya, Hakwatunaoya in intermediate zone were selected for evaluation and performance indicators are computed in this chapter are presents their computation using the data described in annexure-C. Here it is noted that while calculating the performance indicators some assumptions need to be made to initiate computation under different stages and these are mentioned at the required places.

4.4.1 Delivery Performance Ratio

The delivery performance ratio is described as follows;

$$\textit{Delivery Performance Ratio} = \frac{\textbf{\textit{Actual Discharge}}}{\textbf{\textit{Target Discharge}}}$$

It is the most important, operational performance indicator. Since only one system (Tissawewa) has complete data set, from sluice discharge to field application level. Therefore DPR is computed only for this system. The other five systems which are Nuwarawewa Abhayawewa Batalagoda Kimbulwanaoya and Hakwatunaoya did not have such reliable measurements, and therefore omitted in delivery performance ratio computation. In any system the maximum amount of water is delivered during land preparation period. Therefore delivery performance ratio is computed at 5 points of delivering the Tissawewa right bank canal system. The measured daily discharges are given in Annexure b-1

Table 4.16: Delivery Performance Ratio Tissawewa RB Canal System.

Date	Discharge (m3/s)														
	Point A (0 Chainage)			Point B (74 m Down Stream)			Point C (695 m Downstream)			Point D (1565 m Down Stream)			Point E (1565 m Down Stream)		
	Actual	Target	DPR	Actual	Target	DPR	Actual	Target	DPR	Actual	Target	DPR	Actual	Target	DPR
1/6/2008	1.22	1.00	1.22	0.00	--	--	0.00	--	--	0.00	--	--	0.45	0.55	0.82
2/6/2008	1.22	1.00	1.22	0.00	--	--	0.00	--	--	0.41	0.44	0.93	0.00	--	--
3/6/2008	1.22	1.00	1.22	0.00	--	--	0.92	0.87	1.05	0.00	--	--	0.00	--	--
4/6/2008	1.27	1.00	1.27	0.40	0.35	1.16	0.00	--	--	0.00	--	--	0.00	--	--
5/6/2008	1.27	1.00	1.27	0.00	--	--	0.00	--	--	0.00	--	--	0.00	--	--
11/6/2008	1.30	1.00	1.30	0.00	--	--	0.00	--	--	0.00	--	--	0.43	0.55	0.78
12/6/2008	1.23	1.00	1.23	0.00	--	--	0.00	--	--	0.47	0.44	1.07	0.00	--	--
13/6/2008	1.18	1.00	1.18	0.00	--	--	0.95	0.87	1.08	0.00	--	--	0.00	--	--
14/6/2008	1.15	1.00	1.15	0.43	0.35	1.23	0.00	--	--	0.00	--	--	0.00	--	--
15/6/2008	1.19	1.00	1.19	0.00	--	--	0.00	--	--	0.00	--	--	0.00	--	--
21/6/2008	1.22	1.00	1.22	0.00	--	--	0.00	--	--	0.00	--	--	0.50	0.55	0.90
22/6/2008	1.16	1.00	1.16	0.00	--	--	0.00	--	--	0.41	0.44	0.92	0.00	--	--
23/6/2008	1.14	1.00	1.14	0.00	--	--	0.91	0.87	1.04	0.00	--	--	0.00	--	--
24/6/2008	1.22	1.00	1.22	0.44	0.35	1.26	0.00	--	--	0.00	--	--	0.00	--	--
25/6/2008	1.20	1.00	1.20	0.00	--	--	0.00	--	--	0.00	--	--	0.00	--	--
Average	**1.21**	**1.00**	**1.21**	**0.42**	**0.35**	**1.22**	**0.93**	**0.87**	**1.06**	**0.43**	**0.44**	**0.97**	**0.46**	**0.55**	**0.83**

Figure: 4.1 Line diagram of Tissawewa RB system

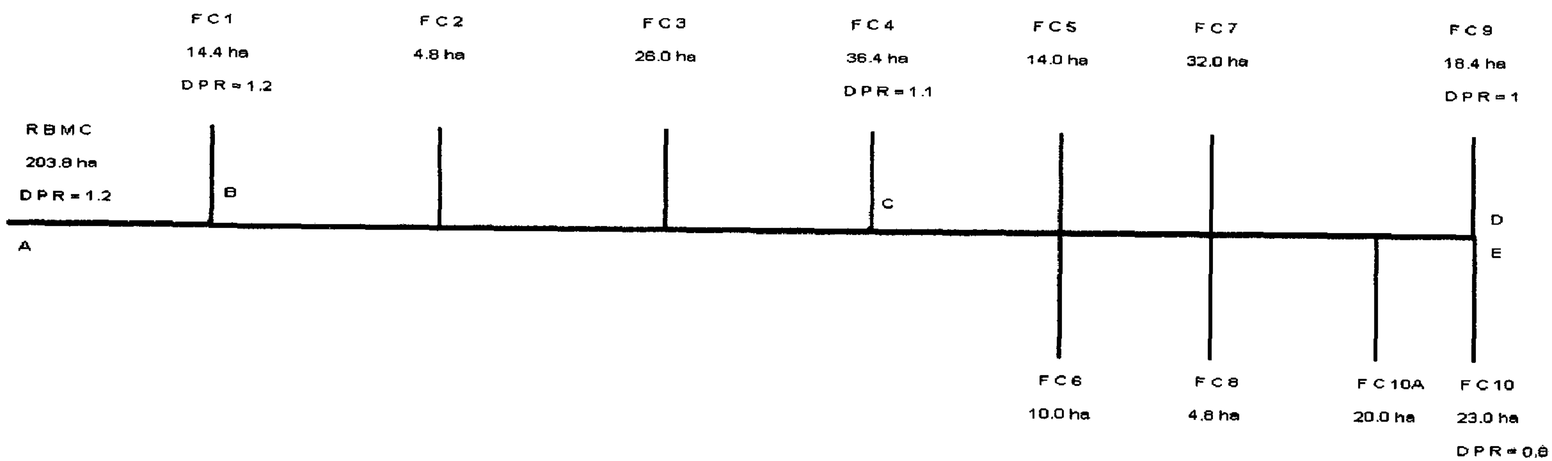
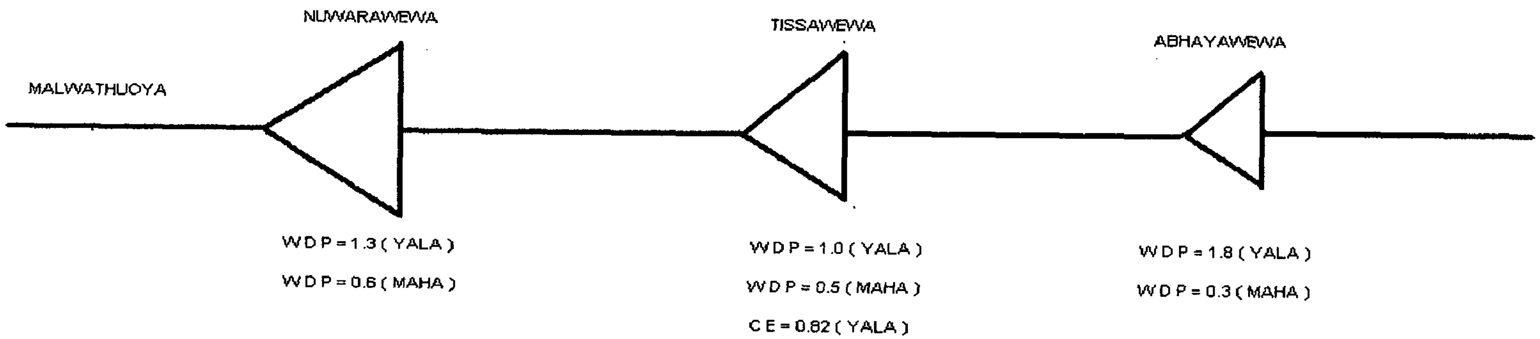


Figure 4.2 Line Diagram of Nuwarawewa, Tissawewa and Abhayawewa in Malwathuoya



WDP is decrease along the river from upper reach to tail reach for both Yala and Maha seasons

4.4.2 Water Delivery Performance

The water delivery performance is defined as follows. It is deviated from delivery performance ratio though it look alike delivery performance ratio is based on discharge and Water Delivery Performance is based on volume.

$$\textit{Water Delivery Performance} = \frac{\textit{Actual Volume}}{\textit{Target Volume}}$$

To calculate target volume intended water supply to the field is according to the crop water requirement. Then field application efficiency is 75 % which is calculated as below. Conveyance efficiencies are 80 % and 90% for main canals and distributory canals respectively. **Then Target volume (ham) = Crop water requirement (m)x Area cultivated (ha)** Sometime the overall system may not receive rainfall uniformly. However some extent of it is reflected in actual discharge volume.

Table 4.17: Water Delivery Performance of Nuwarawewa during Yala Season in Dry zone (April To September).

Year	Rainfall (mm)	Nuwarawewa Tank (River Head Reach)			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994	306.5	1000	1260	1748	1.39
1995	280.9	800	1008	1423	1.41
1996	370.4	NA	NA	NA	NA
1997	273.3	NA	NA	NA	NA
1998	550.0	960	1210	1691	1.40
1999	124.4	1000	1260	2098	1.67
2000	241.5	960	1210	2654	2.19
2001	372.0	1000	1260	1088	0.86
2002	211.0	220	277	214	0.77
2003	256.0	1000	1260	1312	1.04
2004	416.0	NA	NA	NA	NA
2005	159.3	1000	1260	2026	1.61
2006	97.0	1000	1260	1463	1.16
2007	279.0	860	1084	888	0.82
2008	175.6	1040	1310	1231	0.94
2009	41.1	1040	1310	1902	1.45
Average	**259.6**	**742.5**	**935.6**	**1233.7**	**1.3**

Table 4.18: Water delivery performance of Tissawewa during Yala Season in Dry zone (April To September).

Year	Rainfall (mm)	Tisawewa Tank (River Middle Reach)			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994	306.5	240	302	152	0.50
1995	280.9	280	353	431	1.22
1996	370.4	90	113	53	0.47
1997	273.3	100	126	116	0.92
1998	550.0	90	113	151	1.33
1999	124.4	361	455	368	0.81
2000	241.5	361	455	288	0.63
2001	372.0	361	455	342	0.75
2002	211.0	240	302	244	0.81
2003	256.0	280	353	475	1.35
2004	416.0	NA	NA	NA	NA
2005	159.3	361	455	286	0.63
2006	97.0	356	449	557	1.24
2007	279.0	234	295	291	0.99
2008	175.6	344	433	722	1.67
2009	41.1	NA	NA	NA	NA
Average	**259.6**	**231.1**	**291.2**	**279.9**	**1.0**

Table 4.19: Water delivery performance of Abhayawewa during Yala Season in Dry zone (April To September).

Year	Rainfall (mm)	Abhayawewa Tank (River Tail Reach)			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994	306.5	154	194	185	0.96
1995	280.9	80	101	147	1.46
1996	370.4	NA	NA	NA	NA
1997	273.3	NA	NA	NA	NA
1998	550.0	NA	NA	NA	NA
1999	124.4	100	126	89	0.70
2000	241.5	80	101	113	1.12
2001	372.0	154	194	189	0.97
2002	211.0	80	101	42	0.42
2003	256.0	108	136	143	1.05
2004	416.0	NA	NA	NA	NA
2005	159.3	90.4	114	76	0.66
2006	97.0	154	194	110	0.57
2007	279.0	39.2	49	35	0.71
2008	175.6	152	192	154	0.81
2009	41.1	154	194	136	0.70
Average	**259.6**	**84.1**	**106.0**	**88.7**	**0.8**

Table 4.20: Water delivery performance of Nuwarawewa during Maha Season in Dry zone.

Year	Rainfall (mm)	Nuwarawewa Tank (River Head Reach)			
		Cultivated Area (ha)	Volume (ha-m)		DPR
			Targeted	Delivered	
1994/95	700.1	960	1731	1633	0.94
1995/96	364.2	960	1731	731	0.42
1996/97	542.1	1000	1803	512	0.28
1997/98	782.3	960	1731	1610	0.93
1998/99	553.1	960	1731	1021	0.59
1999/00	674.2	1000	1803	1058	0.59
2000/01	601.0	240	433	646	1.49
2001/02	379.0	960	1731	547	0.32
2002/03	762.0	1000	1803	402	0.22
2003/04	371.5	1000	1803	814	0.45
2004/05	830.0	1000	1803	635	0.35
2005/06	658.7	1000	1803	839	0.47
2006/07	622.0	1040	1875	1173	0.63
2007/08	1456.9	1040	1875	494	0.26
2008/09	773.7	1040	1875	1202	0.64
Average	**671.4**	**944.0**	**1701.7**	**887.7**	**0.6**

Table 4.21: Water delivery performance of Tissawewa during Maha Season in Dry zone.

Year	Rainfall (mm)	Tissawewa Tank (River Middle Reach)			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994/95	700.1	361	651	394	0.60
1995/96	364.2	361	651	299	0.46
1996/97	542.1	361	651	272	0.42
1997/98	782.3	361	651	267	0.41
1998/99	553.1	361	651	224	0.34
1999/00	674.2	361	651	193	0.30
2000/01	601.0	361	651	165	0.25
2002/03	762.0	361	651	172	0.26
2003/04	371.5	360	649	461	0.71
2004/05	830.0	361	651	455	0.70
2005/06	658.7	361	651	259	0.40
2006/07	622.0	345	622	522	0.84
2007/08	1456.9	360	649	354	0.55
2008/09	773.7	361	651	540	0.83
Average	**692.3**	**359.7**	**648.5**	**326.9**	**0.5**

Table 4.22: Water delivery performance of Abhayawewa during Maha Season in Dry zone.

Year	Rainfall (mm)	Abhayawewa Tank (River Tail Reach)			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994/95	700.1	154	278	141	0.51
1995/96	364.2	154	278	58	0.21
1996/97	542.1	110	198	112	0.57
1997/98	782.3	130	234	67	0.28
1998/99	553.1	110	198	111	0.56
1999/00	674.2	84	151	47	0.31
2000/01	601.0	80	144	33	0.23
2002/03	762.0	154	278	68	0.24
2004/05	830.0	154	278	106	0.38
2005/06	658.7	154	278	72	0.26
2006/07	622.0	154	278	116	0.42
2007/08	1456.9	154	278	93	0.34
2008/09	773.7	154	278	136	0.49
Average	**716.9**	**134.3**	**242.1**	**89.2**	**0.4**

Table 4.23: Water delivery performance of Bathalagodawewa during Maha Season in Intermediate zone.

Year	Rainfall (mm)	Bathalagodawewa			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994/95	552.2	3053.6	5750	1845	0.32
1995/96	550.9	3053.6	5750	1796	0.31
1996/97	659.4	3053.6	5750	1980	0.34
1997/98	591.4	3053.6	5750	1671	0.29
1998/99	517.5	3053.6	5750	1687	0.29
1999/00	1204.5	3053.6	5750	1457	0.25
2000/01	602.9	3053.6	5750	1589	0.28
2001/02	591.9	3053.6	5750	1692	0.29
2002/03	577.6	3053.6	5750	1638	0.28
2003/04	620.3	3053.6	5750	1579	0.27
2004/05	527.6	3053.6	5750	1768	0.31
2005/06	484.7	3053.6	5750	1728	0.30
Average	**623.4**	**3053.6**	**5750.0**	**1702.5**	**0.30**

Table 4.24: Water Delivery Performance Of Kimbulwanaoya wewa During Maha Season in Intermediate Zone.

Year	Rainfall (mm)	Kimbulwanaoya			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994/95	552.2	672	1265	471	0.37
1995/96	550.9	658	1238	402	0.32
1996/97	659.4	658	1238	372	0.30
1997/98	591.4	658	1238	458	0.37
1998/99	517.5	658	1238	437	0.35
1999/00	1204.5	658	1238	402	0.32
2000/01	602.9	832	1567	422	0.27
2001/02	591.9	832	1567	558	0.36
2002/03	577.6	832	1567	618	0.39
2003/04	620.3	800	1506	483	0.32
2004/05	527.6	980	1845	678	0.37
2005/06	484.7	840	1582	584	0.37
Average	**623.4**	**756.5**	**1424.1**	**490.4**	**0.34**

Table 4.25: Water delivery performance of Hakwatunaoyawewa during Maha Season in Intermediate zone.

Year	Rainfall (mm)	Hakwatunaoya			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1994/95	552.2	2069.2	3896	1328	0.34
1995/96	550.9	2069.2	3896	1529	0.39
1996/97	659.4	2069.2	3896	1428	0.37
1997/98	591.4	2069.2	3896	1172	0.30
1998/99	517.5	2069.2	3896	1297	0.33
1999/00	1204.5	NA	NA	NA	NA
2000/01	602.9	2069.2	3896	1439	0.37
2001/02	591.9	2069.2	3896	1352	0.35
2002/03	577.6	NA	NA	NA	NA
2003/04	620.3	2069.2	3896	1308	0.34
2004/05	527.6	2548.4	4799	1756	0.37
2005/06	484.7	2548.4	4799	1826	0.38
Average	**623.41**	**2165.04**	**4076.60**	**1443.50**	**0.35**

Table 4.26: Water delivery performance of Bathalagodawewa during Yala Season in Intermediate zone (April To September).

Year	Rainfall (mm)	Bathalagoda			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1995	627.8	3054	5863	3478	0.59
1996	498.9	3054	5863	3652	0.62
1997	538.4	3054	5863	3436	0.59
1998	585.1	3054	5863	3541	0.60
1999	520.5	3054	5863	3689	0.63
2000	535.2	3054	5863	3395	0.58
2001	620.5	3054	5863	3256	0.56
2002	653.6	3054	5863	3324	0.57
2003	631.9	3054	5863	3536	0.60
2004	540.9	3054	5863	3879	0.66
2005	535.7	3054	5863	3700	0.63
2006	520.5	3054	5863	3688	0.63
Average	**567.42**	**3054.00**	**5863.00**	**3564.30**	**0.61**

Table 4.27: Water delivery performance of Kimbulwanaoyawewa during Yala Season in Intermediate zone (April To September).

Year	Rainfall (mm)	Kimbulwanaoya			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1995	627.8	672	1290	824	0.64
1996	498.9	664	1275	684	0.54
1997	538.4	240	461	422	0.92
1998	585.1	108	207	196	0.95
1999	520.5	658	1263	798	0.63
2000	535.2	658	1263	702	0.56
2001	620.5	658	1263	759	0.60
2002	653.6	658	1263	843	0.67
2003	631.9	827	1588	922	0.58
2004	540.9	NA	NA	NA	NA
2005	535.7	805	1545	986	0.64
2006	520.5	840	1613	1109	0.69
Average	**567.42**	**557.27**	**1069.82**	**685.73**	**0.67**

Table 4.28: Water Delivery Performance of Hakwatunaoyawewa During Yala Season in Intermediate Zone (April To September).

Year	Rainfall (mm)	Hakwatunaoya			
		Cultivated Area (ha)	Volume (ha-m)		WDP
			Targeted	Delivered	
1995	627.8	2069	3973	2418	0.61
1996	498.9	NA	NA	NA	NA
1997	538.4	NA	NA	NA	NA
1998	585.1	2069	3973	2375	0.60
1999	520.5	350	672	425	0.63
2000	535.2	1500	2880	1819	0.63
2001	620.5	2016	3871	2563	0.66
2002	653.6	2069	3973	2389	0.60
2003	631.9	2069	3973	2405	0.61
2004	540.9	NA	NA	NA	NA
2005	535.7	1000	1920	1198	0.62
2006	520.5	2548	4893	2914	0.60
Average	**567.42**	**1576.67**	**3027.56**	**1854.11**	**0.62**

4.4.3 Overall Project efficiency

The Overall Project Efficiency is defined as follows:

$$\textit{Overall Project Efficiency} = \frac{\textbf{Crop Irrigation Requirement}}{\textbf{Total Inflow into the Canal System}}$$

Total inflow of the canal system is varied according to the irrigable area and the corresponding rainfall of the particular season. Therefore overall project efficiency is calculated for a season and its average represent the desired value.

Table 4.29: Overall Project Efficiency of Nuwarawewa In Malwathuoya Basin During Yala Season (April To September).

YEAR	Nuwarawewa (Head Reach)				
	Rainfall (mm)	Area Cultivated (ha)	Net Irrigation Requirement (ha m)	Volume Delivered (ha m)	Overall project efficiency
1994	306.5	1000	1260	1748	0.72
1995	280.9	800	1008	1423	0.71
1998	550	960	1210	1691	0.72
1999	124.4	1000	1260	2098	0.60
2000	241.5	960	1210	2654	0.46
2001	372	1000	1260	1088	1.16
2002	211	220	277	214	1.29
2003	256	1000	1260	1312	0.96
2005	159.3	1000	1260	2026	0.62
2006	97	1000	1260	1463	0.86
2007	279	860	1084	888	1.22
2008	175.6	1040	1310	1231	1.06
2009	41.1	1040	1310	1902	0.69
Average	**238**	**913.8**	**1151.45**	**1518.35**	**0.85**

Table 4.30: Overall Project Efficiency of Tissawewa in Malwathuoya Basin During Yala Season (April to September).

YEAR	Tissawewa (Middle Reach)				
	Yala Season Rainfall (mm)	Area Cultivated (ha)	Net Irrigation Requirement (ha m)	Volume Delivered (ha m)	Overall Project Efficiency
1994	306.5	240	302	152	1.99
1995	280.9	280	353	431	0.82
1996	370.4	90	113	53	2.13
1997	273.3	100	126	116	1.09
1998	550	90	113	151	0.75
1999	124.4	361	455	368	1.24
2000	241.5	361	455	288	1.58
2001	372	361	455	342	1.33
2002	211	240	302	244	1.24
2003	256	280	353	475	0.74
2005	159.3	361	455	286	1.59
2006	97	356	449	557	0.81
2007	279	234	295	291	1.01
2008	175.6	344	433	722	0.60
Average	**264.1**	**264.09**	**333**	**320**	**1.21**

Table 4.31: Overall Project Efficiency of Abhayawewa in Malwathuoya Basin During Yala Season (April to September).

YEAR	Abhayawewa (Tail Reach)				
	Yala Season Rainfall (mm)	Area Cultivated (ha)	Net Irrigation Requirement (ha m)	Volume Delivered (ha m)	Overall Project Efficiency
1994	306.5	154	194	185	1.05
1995	280.9	80	101	147	0.69
1999	124.4	100	126	89	1.42
2000	241.5	80	101	113	0.89
2001	372.0	154	194	189	1.03
2002	211.0	80	101	42	2.40
2003	256.0	108	136	143	0.95
2005	159.3	90.4	114	76	1.50
2006	97.0	154	194	110	1.76
2007	279.0	39.2	49	35	1.40
2008	175.6	152	192	154	1.25
2009	41.1	154	194	136	1.43
Average	**212.0**	**112**	**141.29**	**118.22**	**1.31**

Table 4.32: Overall Project Efficiency of Nuwarawewa in Malwathuoya Basin During Maha Season (October to March).

Year	Rainfall (mm)	Nuwarawewa Tank (River Head Reach)			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	700.1	960	1038	1633	0.64
1995/96	364.2	960	1038	731	1.42
1996/97	542.1	1000	1082	512	2.11
1997/98	782.3	960	1038	1610	0.65
1998/99	553.1	960	1038	1021	1.02
1999/00	674.2	1000	1082	1058	1.02
2000/01	601.0	240	260	646	0.40
2001/02	379.0	960	1038	547	1.90
2002/03	762.0	1000	1082	402	2.69
2003/04	371.5	1000	1082	814	1.33
2004/05	830.0	1000	1082	635	1.70
2005/06	658.7	1000	1082	839	1.29
2006/07	622.0	1040	1125	1173	0.96
2007/08	1456.9	1040	1125	494	2.28
2008/09	773.7	1040	1125	1202	0.94
Average	**671.4**	**944.0**	**1021.0**	**887.7**	**1.4**

Table 4.33: Overall Project Efficiency of Tissawewa in Malwathuoya Basin During Maha Season (October to March).

Year	Rainfall (mm)	Tissawewa Tank (River Middle Reach)			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	700.1	361	651	394	1.65
1995/96	364.2	361	651	299	2.18
1996/97	542.1	361	651	272	2.39
1997/98	782.3	361	651	267	2.44
1998/99	553.1	361	651	224	2.90
1999/00	674.2	361	651	193	3.37
2000/01	601.0	361	651	165	3.94
2002/03	762.0	361	651	172	3.78
2003/04	371.5	360	649	461	1.41
2004/05	830.0	361	651	455	1.43
2005/06	658.7	361	651	259	2.51
2006/07	622.0	345	622	522	1.19
2007/08	1456.9	360	649	354	1.83
2008/09	773.7	361	651	540	1.20
Average	**692.3**	**359.7**	**648.5**	**326.9**	**2.3**

Table 4.34: Overall Project Efficiency of Abhayawewa in Malwathuoya Basin During Maha Season (October to March).

Year	Rainfall (mm)	Abhayawewa Tank (River Tail Reach)			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	700.1	154	278	141	1.97
1995/96	364.2	154	278	58	4.80
1996/97	542.1	110	198	112	1.77
1997/98	782.3	130	234	67	3.52
1998/99	553.1	110	198	111	1.79
1999/00	674.2	84	151	47	3.24
2000/01	601.0	80	144	33	4.37
2002/03	762.0	154	278	68	4.11
2004/05	830.0	154	278	106	2.61
2005/06	658.7	154	278	72	3.84
2006/07	622.0	154	278	116	2.39
2007/08	1456.9	154	278	93	2.98
2008/09	773.7	154	278	136	2.05
Average	**716.9**	**134.3**	**242.1**	**89.2**	**3.0**

Table 4.35: Overall Project Efficiency of Bathalagodawewa in Deduruoya Basin During Yala Season (April to September).

Year	Rainfall (mm)	Bathalagodawewa			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			Targeted	Delivered	
1995	627.8	3054	3518	3478	1.01
1996	498.9	3054	3518	3652	0.96
1997	538.4	3054	3518	3436	1.02
1998	585.1	3054	3518	3541	0.99
1999	520.5	3054	3518	3689	0.95
2000	535.2	3054	3518	3395	1.04
2001	620.5	3054	3518	3256	1.08
2002	653.6	3054	3518	3324	1.06
2003	631.9	3054	3518	3536	0.99
2004	540.9	3054	3518	3879	0.91
2005	535.7	3054	3518	3700	0.95
2006	520.5	3054	3518	3688	0.95
Average	**567.42**	**3054.00**	**3518.00**	**3547.83**	**0.99**

Table 4.36: Overall Project Efficiency of Kimbulwanaoyawewain Kimbulwanaoya Basin During Yala Season (April to September).

Year	Rainfall (mm)	Kimbulwanaoya			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			Targeted	Delivered	
1995	627.8	672	774	824	0.94
1996	498.9	664	765	684	1.12
1997	538.4	240	276	422	0.65
1998	585.1	108	124	196	0.63
1999	520.5	658	758	798	0.95
2000	535.2	658	758	702	1.08
2001	620.5	658	758	759	1.00
2002	653.6	658	758	843	0.90
2003	631.9	827	953	922	1.03
2004	540.9	NA	NA	NA	NA
2005	535.7	805	927	986	0.94
2006	520.5	840	968	1109	0.87
Average	**567.42**	**617.09**	**710.82**	**749.55**	**0.92**

Table 4.37: Overall Project Efficiency of Hakwatunaoyawewa in Hakwatunaoya Basin During Yala Season (April to September).

Year	Rainfall (mm)	Hakwatunaoya			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			Targeted	Delivered	
1995	627.8	2069	2384	2418	0.99
1996	498.9	NA	NA	NA	NA
1997	538.4	NA	NA	NA	NA
1998	585.1	2069	2384	2375	1.00
1999	520.5	350	403	425	0.95
2000	535.2	1500	1728	1819	0.95
2001	620.5	2016	2322	2563	0.91
2002	653.6	2069	2384	2389	1.00
2003	631.9	2069	2384	2405	0.99
2004	540.9	NA	NA	NA	NA
2005	535.7	1000	1152	1198	0.96
2006	520.5	2548	2936	2914	1.01
Average	**567.42**	**1743.33**	**2008.56**	**2056.22**	**0.97**

Table 4.38: Overall Project Efficiency of Bathalagodawewa in Deduruoyaoya Basin during Maha Season (October to March).

Year	Rainfall (mm)	Bathalagoda			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	552.2	3053.6	3451	1845	1.87
1995/96	550.9	3053.6	3451	1796	1.92
1996/97	659.4	3053.6	3451	1980	1.74
1997/98	591.4	3053.6	3451	1671	2.06
1998/99	517.5	3053.6	3451	1687	2.05
1999/00	1204.5	3053.6	3451	1457	2.37
2000/01	602.9	3053.6	3451	1589	2.17
2001/02	591.9	3053.6	3451	1692	2.04
2002/03	577.6	3053.6	3451	1638	2.11
2003/04	620.3	3053.6	3451	1579	2.19
2004/05	527.6	3053.6	3451	1768	1.95
2005/06	484.7	3053.6	3451	1728	2.00
Average	**623.41**	**3053.60**	**3451.00**	**1702.50**	**2.04**

Table 4.39: Overall Project Efficiency of Kimbulwanaoyawewa in Kimbulwanaoya Basin During Maha Season (October to March).

Year	Rainfall (mm)	Kimbulwanaoya			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	552.2	672	759	471	1.61
1995/96	550.9	658	743	402	1.85
1996/97	659.4	658	743	372	2.00
1997/98	591.4	658	743	458	1.62
1998/99	517.5	658	743	437	1.70
1999/00	1204.5	658	743	402	1.85
2000/01	602.9	832	940	422	2.23
2001/02	591.9	832	940	558	1.68
2002/03	577.6	832	940	618	1.52
2003/04	620.3	800	904	483	1.87
2004/05	527.6	980	1107	678	1.63
2005/06	484.7	840	949	584	1.63
Average	**623.41**	**756.50**	**854.50**	**490.42**	**1.77**

Table 4.40: Overall Project Efficiency of Hakwatunaoyawewa in Hakwatunaoya Basin During Maha Season (October to March).

Year	Rainfall (mm)	Hakwatunaoya			
		Cultivated Area (ha)	Volume (ha-m)		Overall Project Efficiency
			NIR	Delivered	
1994/95	552.2	2069.2	2338	1328	1.76
1995/96	550.9	2069.2	2338	1529	1.53
1996/97	659.4	2069.2	2338	1428	1.64
1997/98	591.4	2069.2	2338	1172	1.99
1998/99	517.5	2069.2	2338	1297	1.80
1999/00	1204.5	NA	NA	NA	NA
2000/01	602.9	2069.2	2338	1439	1.62
2001/02	591.9	2069.2	2338	1352	1.73
2002/03	577.6	NA	NA	NA	NA
2003/04	620.3	2069.2	2338	1308	1.79
2004/05	527.6	2548.4	2880	1756	1.64
2005/06	484.7	2548.4	2880	1826	1.58
Average	**623.41**	**2165.04**	**2446.40**	**1443.50**	**1.71**

Tables 4.25 to 4.36 show the Overall project efficiency of more than 10 different seasons. It gives the different values between the systems rather than seasons. Nuwarawewa give the low efficiency compare to the Abhayawewa. Summary of overall project efficiency is given in

Table 5.5 of Dry Zone and 5.6 of intermediate zone. Overall project efficiency grater than 1 implies deficit water supply to the field.

4.4.4 Conveyance efficiency

The conveyance efficiency is defined as follows:

$$Conveyance\ Efficiency = \frac{Total\ Water\ Supplied\ by\ the\ Conveyance\ System}{Total\ Inflow\ into\ The\ Conveyance\ System}$$

In this system total water supplied by the conveyance system is discharge at FC1,FC2,FC3,FC4,FC5,FC6,FC7,FC8,FC9,FC10 and FC10A. Total inflow into the conveyance system is discharge at MC. For this calculation 2008 dry season data is used Total land preparation period is consider as a one group. Because of that period water discharge cannot compare with the irrigation requirement. It has a big different with the requirement due to uneven land preparation starting. Water issue period is 15 days for crop development stage. **Table 4.37** shows the calculation for conveyance efficiency.

4.4.5 Distribution Efficiency

The distribution efficiency is defined as follows:

$$Distribution\ Efficiency = \frac{Total\ Water\ Delivered\ to\ Field}{Total\ Inflow\ into\ Delivery\ System}$$

In this system total water supplied by the distributory system is discharge at FC1,FC2,FC3,FC4,FC5,FC6,FC7,FC8,FC9,FC10 and FC10A. Total inflow into the conveyance system is discharge at MC. For this calculation 2008 dry season data is used, and shown in **Table.4.38.**

Table 4.41: Conveyance Efficiency of Tissawewa Right Bank Canal System in Sri Lanka..

Date	Dischage (m3/sec)													Conveyance Efficiency (%)
	Main Canal	FC 1 (at 74m)	FC 2 (at 151m)	FC 3 (at 525m)	FC 4 (at 695m)	FC 5 (at 1232m)	FC 6 (at 1232m)	FC 7 (at 1468m)	FC 8 (at 1468m)	FC 9 (at 1565m)	FC 10 (at 1565m)	FC 10A (at 1560m)	Total	
1/6/08	1.221	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.452	0.384	**0.84**	0.68
2/6/08	1.218	0.000	0.115	0.000	0.000	0.392	0.000	0.000	0.000	0.411	0.000	0.000	**0.92**	0.75
3/6/08	1.216	0.000	0.000	0.000	0.918	0.000	0.000	0.000	0.104	0.000	0.000	0.000	**1.02**	0.84
4/6/08	1.265	0.401	0.000	0.000	0.000	0.000	0.000	0.676	0.000	0.000	0.000	0.000	**1.08**	0.85
5/6/08	1.266	0.000	0.000	0.718	0.000	0.000	0.343	0.000	0.000	0.000	0.000	0.000	**1.06**	0.84
11/6/08	1.297	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.469	0.401	**0.87**	0.67
12/6/08	1.231	0.000	0.116	0.000	0.000	0.402	0.000	0.000	0.000	0.473	0.000	0.000	**0.99**	0.81
13/6/08	1.183	0.000	0.000	0.000	0.926	0.000	0.000	0.000	0.112	0.000	0.000	0.000	**1.04**	0.88
14/6/08	1.151	0.425	0.000	0.000	0.000	0.000	0.000	0.671	0.000	0.000	0.000	0.000	**1.10**	0.95
15/608	1.188	0.000	0.000	0.721	0.000	0.000	0.349	0.000	0.000	0.000	0.000	0.000	**1.07**	0.90
21/6/08	1.217	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.448	0.389	**0.84**	0.69
22/6/08	1.159	0.000	0.119	0.000	0.000	0.391	0.000	0.000	0.000	0.407	0.000	0.000	**0.92**	0.79
23/6/08	1.137	0.000	0.000	0.000	0.915	0.000	0.000	0.000	0.105	0.000	0.000	0.000	**1.02**	0.90
24/6/08	1.220	0.436	0.000	0.000	0.000	0.000	0.000	0.679	0.000	0.000	0.000	0.000	**1.12**	0.91
25/6/08	1.204	0.000	0.000	0.717	0.000	0.000	0.341	0.000	0.000	0.000	0.000	0.000	**1.06**	0.88
Average	**1.212**	**0.421**	**0.117**	**0.719**	**0.920**	**0.395**	**0.344**	**0.675**	**0.107**	**0.430**	**0.456**	**0.391**	**1.00**	**0.82**

FC: Field Channel

Table 4.42: Distribution Efficiency of Tissawewa in Malwathuoya Basin during Yala Season (October to March).

Canal	Discharge (m3/sec)	Command Area (ha)	Water Delivered (Ha-m)
AT MAIN CANAL LEVEL			
MC	1.212	203.8	**157.08**
AT FIELD CANAL LEVEL			
FC1	0.42	14.40	10.91
FC2	0.12	4.50	3.03
FC3	0.72	26.00	18.64
FC4	0.92	36.40	23.85
FC5	0.40	14.00	10.24
FC6	0.34	10.00	8.92
FC7	0.68	32.00	17.50
FC8	0.11	4.80	2.77
FC9	0.43	18.40	11.15
FC10	0.46	23.00	11.82
FC10A	0.39	20.00	10.13
Total	--	**203.50**	**128.95**
Average	--	**18.50**	**11.72**
Distribution Efficiency	--	--	**0.82**

4.4.6 Field Application Efficiency

The Field Application Efficiency is defined as follows:

$$\textit{Field Application Efficiency} = \frac{\textbf{Crop Irrigation Water Requirement}}{\textbf{Water Deliverd to Field}}$$

Table 4.39. gives the field requirement of water and actual supply to the field.

Table 4.43: Field Application Efficiency of Tissawewa in Malwathuoya Basin During Yala Season (October to March).

Canal	Discharge (m3/sec)	Command Area (ha)	Water Delivered (Ha-m)	Crop Water Requirement (Ha-m)	Field Application Efficiency
AT MAIN CANAL LEVEL					
MC	1.212	203.8	157.07	108.32	**0.69**
AT FIELD CANAL LEVEL					
FC1	0.421	14.4	10.91	7.65	0.70
FC2	0.117	4.5	3.03	2.39	0.79
FC3	0.719	26.0	18.63	13.82	0.74
FC4	0.92	36.4	23.85	19.35	0.81
FC5	0.395	14.0	10.24	7.44	0.73
FC6	0.344	10.0	8.92	5.32	0.60
FC7	0.675	32.0	17.50	17.00	0.97
FC8	0.107	4.8	2.77	2.55	0.92
FC9	0.43	18.4	11.15	9.78	0.88
FC10	0.456	23.0	11.82	8.15	0.69
FC10A	0.391	20.0	10.14	6.99	0.69
Total	--	**203.50**	**128.96**	**100.44**	--
Average	**0.45**	**18.50**	**11.72**	**9.13**	**0.77**

4.4.7 Modified Inter quartile Ratio

The Modified Inter quartile Ratio is defined as follows:

$$\textbf{Modified Inter Quartile Ratio} = \frac{\textit{Average DPR of Best } 25\% \textit{ of the System}}{\textit{Average DPR of Worst } 25\% \textit{ of the System}}$$

To calculate DPR field application efficiency is taken as 0.75. Selecting best and worst areas are also somewhat difficult. In this calculation the best part selected from close to the sluice and worst part was taken from tail end. In some circumstances, particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the head and tail of the canal.

Table 4.44: Modified Inter Quartile Ratio of Tissawewa RB Canal System in Dry zone.

Date	Point B (74 m Chainage) Upper Reach			Point E (1565 m Chainage) Tail Reach		
	Actual	Target	DPR	Actual	Target	DPR
1/6/2008	0	--	--	0.45	0.55	0.82
2/6/2008	0	--	--	0	--	--
3/6/2008	0	--	--	0	--	--
4/6/2008	0.4	0.35	1.16	0	--	--
5/6/2008	0	--	--	0	--	--
11/6/2008	0	--	--	0.43	0.55	0.78
12/6/2008	0	--	--	0	--	--
13/6/2008	0	--	--	0	--	--
14/6/2008	0.43	0.35	1.23	0	--	--
15/6/2008	0	--	--	0	--	--
21/6/2008	0	--	--	0.5	0.55	0.9
22/6/2008	0	--	--	0	--	--
23/6/2008	0	--	--	0	--	--
24/6/2008	0.44	0.35	1.26	0	--	--
25/6/2008	0	--	--	0	--	--
Average	**0.08**	**0.35**	**1.22**	**0.09**	**0.55**	**0.83**
Modified Inter Quartile Ratio = 1.22 / 0.83 = 1.45						

DPR = Delivery Performance Ratio

4.4.8 Head to Tail Equity ratio

The Head to Tail Equity ratio can calculate as follows:

$$\textit{Head to Tail Equity Ratio} = \frac{\textit{Average DPR of Upper } 25\% \textit{ of the System}}{\textit{Average DPR of Tail } 25\% \textit{ of the System}}$$

Same as earlier to calculate DPR field application efficiency is taken as 0.75 which is calculated in 6.6 paragraph. Selecting upper and Tail areas are also not difficult. In this calculation the upper part selected from close to the sluice and tail part was taken according to the distance away from the sluice. Particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the head and tail of the same canal. Table 4.41 shows the DPR of upper and tail.

Table 4.45: Head to Tail Equity ratio Tissawewa RB Canal System in Dry Zone.

Date	Delivery Performance Ratio (DPR)				
	Point A (0 m Chainage)	Point B (74 m Chainage)	Point C (695 m Chainage)	Point D (1565 m Chainage)	Point E (1565 m Chainage)
1/6/2008	1.22	--	--	--	0.82
2/6/2008	1.22	--	--	--	--
3/6/2008	1.22	--	1.05	--	--
4/6/2008	1.27	1.16	--	--	--
5/6/2008	1.27	--	--	--	--
11/6/2008	1.3	--	--	--	0.78
12/6/2008	1.23	--	--	1.07	--
13/6/2008	1.18	--	1.08	--	--
14/6/2008	1.15	1.23	--	--	--
15/6/2008	1.19	--	--	--	--
21/6/2008	1.22	--	--	--	0.9
22/6/2008	1.16	--	--	0.92	--
23/6/2008	1.14	--	1.04	--	--
24/6/2008	1.22	1.26	--	--	--
25/6/2008	1.2	--	--	--	--
Average	**1.21**	**1.22**	**1.06**	**0.97**	**0.83**
Average	1.215			**0.9**	
Head to Tail Equity Ratio = 1.215/0.90 = 1.35					

4.4.9 Irrigated Area Performance

The calculation of Irrigated Area Performance is as follows.

$$\textit{Irrigation Area Performance} = \frac{\textit{Atual Area}}{\textit{Target area}}$$

Table 4.1 shows the data in scheme wise. But the real picture of district gives the Table 4.42 data. Though irrigated major scheme running properly, average district figures are not in acceptable limit for dry season. This indicator is more useful in strategic level for decision making. When planning for importing quantity of rice, this is the main factor considering to tally with consumption level.

Table 4.46: Irrigated Area Performance in Dry zone.

Irrigation Tanks	Performance Particulars	Yala Season	Maha Season
Nuwarawewa	Actual area (ha)	742	944
	Target area (ha)	500	1000
	Irrigated area performance	**1.49**	**0.94**
Tissawewa	Actual area (ha)	231	335
	Target area (ha)	180	361
	Irrigated area performance	**1.28**	**0.93**
Abhayawewa	Actual area (ha)	84	141
	Target area (ha)	77	154
	Irrigated area performance	**1.09**	**0.91**

Table 4.47: Irrigated Area Performance in Intermediate zone.

Irrigation Tanks	Performance Particulars	Yala Season	Maha Season
Bathalagoda wewa	Actual area (ha)	2708	3054
	Target area (ha)	2015	3054
	Irrigated area performance	**1.34**	**1**
Kimbulwanaoya wewa	Actual area (ha)	617	756
	Target area (ha)	533	800
	Irrigated area performance	**1.16**	**0.95**
Hakwatunaoya wewa	Actual area (ha)	1743	2448
	Target area (ha)	1700	2550
	Irrigated area performance	**1.03**	**0.96**

4.4.10 Cropping Intensity Performance

The Cropping Intensity Performance was calculated as follows

$$\text{Cropping Intensity Performance} = \frac{Actual\ Cropping\ Intensity}{Target\ Cropping\ Intensity}$$

Table 4.48: Cropping intensity Performance pattern of tank commands in Sri Lanka.

Years	Zones							
	Dry Zone				Intermediate Zone			
	Nuwarawewa	Tissawewa	Abhayawewa	Average	Batalagodawewa	Hakwatunaoya	Kimbulwanaoya	Average
93-94	1.33	1.03	1.00	**1.12**	0.95	1.02	1.2	**1.06**
94-95	1.22	1.09	1.33	**1.21**	0.95	1.02	1.2	**1.06**
95-96	0.67	0.77	1.01	**0.82**	1.08	0.43	1.2	**0.90**
96-97	0.68	0.84	NA	**0.76**	0.99	0.58	1.2	**0.92**
97-98	1.33	0.82	0.56	**0.90**	0.56	1.05	0.81	**0.81**
98-99	1.33	1.24	0.47	**1.01**	0.96	0.71	0.69	**0.79**
99-2K	1.33	1.24	0.79	**1.12**	1.08	1.06	1.2	**1.11**
00-01	0.83	1.24	0.69	**0.92**	1.2	0.52	1.2	**0.97**
01-02	0.81	0.41	0.67	**0.63**	1.2	1.02	1.2	**1.14**
02-03	0.83	1.24	1.01	**1.03**	1.2	0.51	1.2	**0.97**
03-04	0.78	0.62	0.47	**0.62**	0.84	0.01	0.75	**0.53**
04-05	1.33	1.24	0.67	**1.08**	1.2	0.88	1.2	**1.09**
05-06	1.33	1.32	1.06	**1.24**	1.2	1.2	1.2	**1.20**
0.6-07	1.24	1.07	0.83	**1.05**	1.2	0.88	1.2	**1.09**
07-08	1.33	0.91	1.33	**1.19**	1.2	1.2	1.2	**1.20**
Average	**1.09**	**1.01**	**0.85**	**0.98**	**1.05**	**0.81**	**1.11**	**0.99**

Targeted cropping intensity Dry Zone = 1.5

Targeted cropping intensity Intermediate Zone = 1.66

4.4.11 Sustainability of irrigated area

The Sustainability of Irrigation Area is calculated as

$$\textit{Sustainability of Irrigated Area} = \frac{\textit{Current Irrigable Area}}{\textit{Initial Irrigable Area}}$$

This ratio addresses primarily those aspects of the physical environment responsible for damages occurring due to the actions of irrigation management. This however does not intend to be insensitive to other aspects of the environment, but to focus on those concerns falling in the physical sustainability of the irrigation systems. The affect relate primarily to over- or under-supply of irrigation water that leads to water logging or salinity.

Table 4.49: Sustainability of Irrigated Area in Dry Zone.

Description	Irrigation Tanks of Dry Zone		
	Nuwarawewa	**Tissawewa**	**Abhayawewa**
Original Planned Irrigable Area (ha)	2384	173	5371
Current Irrigable Area (ha)	2905	193	6639
Sustainability of Irrigated Area	**1.22**	**1.12**	**1.24**

Table 4.50: Sustainability of Irrigated Area in Intermediate Zone.

Description	Irrigation Tanks of Intermediate Zone		
	Bathalagoda	**Kimbulwanaoya**	**Hakwatunaoya**
Original Planned Irrigable Area (ha)	2655	658	1565
Current Irrigable Area (ha)	3054	800	2018
Sustainability of Irrigated Area	**1.15**	**1.22**	**1.29**

CHAPTER 5

CHAPTER 5

RESULTS AND DISCUSSION

This chapter presents the results obtained and discusses them in sequence of the computation of performance indices.

5.1 Evapotranspiration of Reference Crop (ETo)

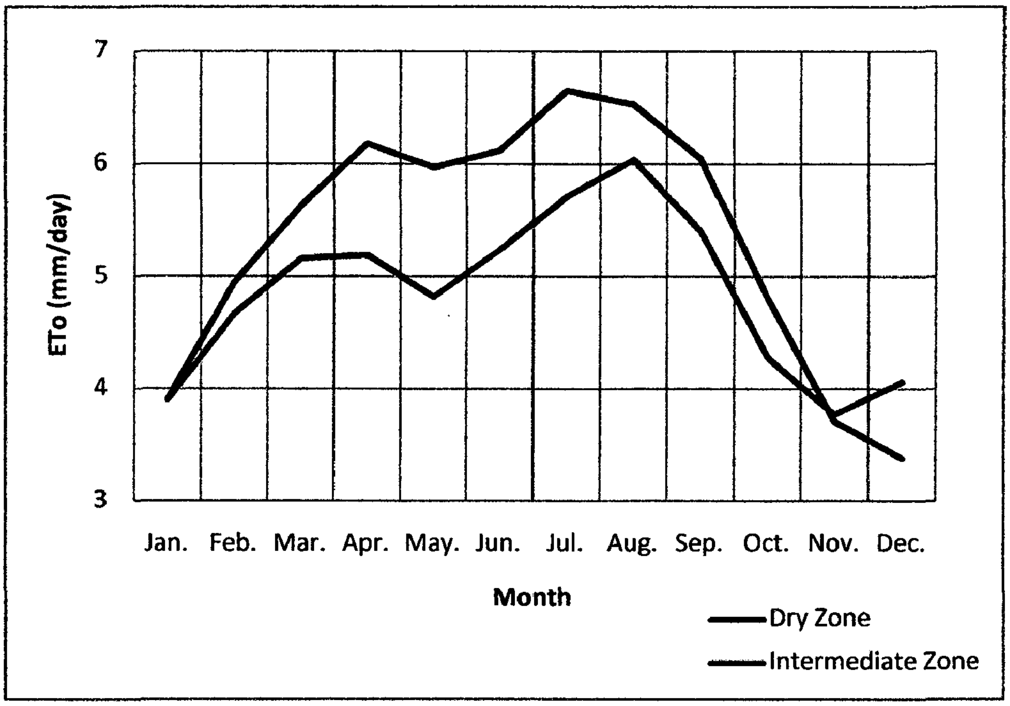
The data presented in **Table 5.1** shows the evapotranspiration computed for dry and intermediate zone in Sri Lanka by Modified Penman (5.32 & 4.85 mm/day), Radiation (4.81 & 4.71 mm/day), Penman Monteith (4.41 & 4.12 mm/day) and Blaney Criddle (3.95 & 3.90 mm/day) methods. There was a considerable difference found in the average ETo calculated by different methods. This indicated the limitation of procedures suitable to Sri Lankan condition. Government of Sri Lanka has approved the Modified Penman method of ETo calculation for the planning and

Table 5.1: Comparative Analysis of ETo Calculation for Dry and Intermediate Zones of Sri Lanka.

Months	ETo (mm/day) Calculated by Different Methods							
	Modified Penman		Radiation		Penman-Monteith		Blaney Criddle	
	Dry Zone	Intermediate Zone	Dry Zone	Intermediate Zone	Dry Zone	Intermediate Zone	Dry Zone	Intermediate Zone
Jan.	3.91	3.90	4.03	4.14	3.26	3.41	2.80	2.85
Feb.	4.95	4.67	4.92	4.75	4.01	3.98	3.80	3.84
Mar.	5.63	5.16	5.50	5.17	4.65	4.45	3.96	3.96
Apr.	6.18	5.19	5.66	4.83	5.06	4.35	4.18	4.12
May.	5.97	4.82	5.19	4.73	4.82	4.35	4.15	4.10
Jun.	6.12	5.24	5.10	4.71	4.93	4.26	4.24	4.10
Jul.	6.65	5.71	4.91	5.18	5.58	4.71	5.10	4.91
Aug.	6.53	6.04	5.19	5.49	5.19	4.82	5.00	4.85
Sep.	6.05	5.40	5.13	4.94	5.06	4.52	4.13	4.03
Oct.	4.81	4.28	4.61	3.93	4.13	3.56	3.90	3.85
Nov.	3.71	3.77	3.91	4.16	3.30	3.48	3.10	3.13
Dec.	3.38	4.06	3.53	4.45	2.93	3.60	3.02	3.07
Average	**5.32**	**4.85**	**4.81**	**4.71**	**4.41**	**4.12**	**3.95**	**3.90**

management of its Water Resources projects. The methods recording the ETo values in the descending order was Modified Penman> Radiation> Penman-Monteith> Blanney Criddle. This showed that Modified Penman method recorded the highest value whereas the Blanney Criddle method recorded the lowest value in Sri Lankan condition.

Fig 5.1:Monthly Variation of ETo in Dry and Intermediate Zones



5.2 Irrigation Requirement of Rice

There are two seasons of rice cultivation in Sri Lanka what is known as Yala (dry) season and Maha (wet) season. Crop duration of rice also vary with season. During dry season, the growing period is only 105 days whereas during wet season it increases to 135 days. The Crop Water Requirement using ETo values of Modified Penman was calculated as 1326.1 mm and 1050.2 mm in the Dry Zone during Yala (dry) and Maha (wet) season respectively whereas 1250.8 and 1093.6 mm in the Intermediate Zone during dry and wet season respectively **(Table 5.2).** A climatic characteristic difference is noticed in the dry zone and wet zone. There is virtually no rain received during dry season in Dry Zone but a substantial amount of rain is received during dry season in the Intermediate Zone. Results presented in the Table 5.2 showed that the dry season irrespective of their Zones and growing period recorded higher values of crop water requirements during dry season (1326.1, 1250.8 mm) over that of the wet season (1050.2, 1093.6 mm).

Table 5.2: Comparative Analysis of Irrigation Water Requirement of Rice in Sri Lanka

Months	Irrigation Requirement of Rice (mm/ month)			
	Dry Zone Seasons		Intermediate Zone Seasons	
	Yala (Dry) Season 105 Days Paddy	Maha (Wet) Season 135 Days Paddy	Yala (Dry) Season 105 Days Paddy	Maha (Wet) Season 135 Days Paddy
Jan.	--	262.7	--	227.8
Feb.	--	293.7	--	227.0
Mar.	--	130.5	--	129.0
Apr.	273.4	--	293.7	--
May.	329.4	--	296.7	--
Jun.	364.5	--	328.2	--
Jul.	356.5	--	321.3	--
Aug.	--	--	--	--
Sep.	--	--	--	--
Oct.	--	--	--	--
Nov.	--	164.4	--	156.0
Dec.	--	198.9	--	253.6
Total	**1323.8**	**1050.2**	**1239.9**	**1093.6**

5.3 Performance Indicators

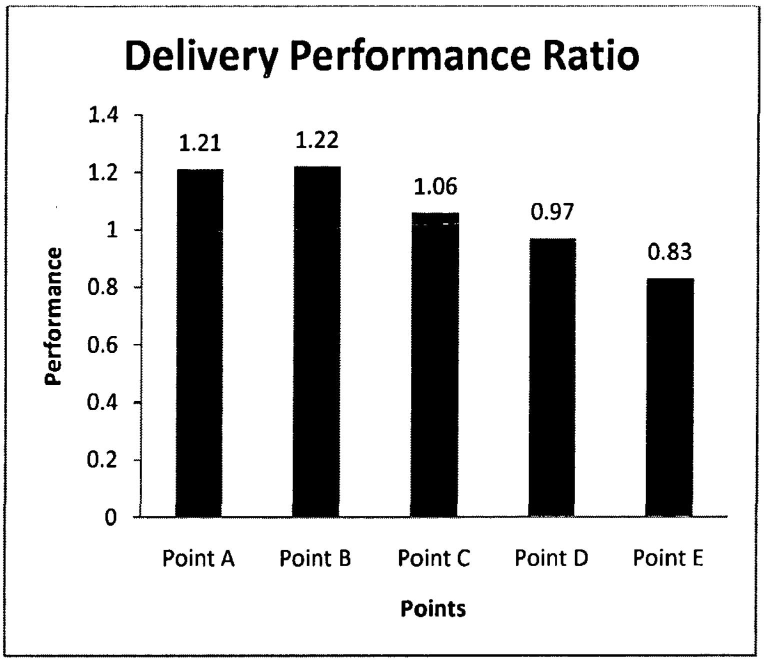
Various performance indicators are presented in **Table 5.3** and discussed in the forthcoming paragraphs:

5.3.1 Delivery Performance Ratio (DPR)

The delivery Performance Ratio was tested for Tissawewa Tank Irrigation System located in Malwathu Oya River Basin during Yala (dry) season of Dry Zone. Observations recorded in **Table 5.3** showed that the DPR decreased with the increasing distance on the distribution network. It was recorded as 1.21 at o m chainage (point A), 1.22 at 74 m chainage (point B), 1.06

at 695 m chainage (point C), 0.97 at 1565 m chainage (point D), and 0.83 at 1565 m chainage (point E).

Fig. 5.2: Delivery Performance Ratio of Tissawewa RB Canal System of Dry Zone



Delivery Performance Ratio is decreased from head reach to tail reach along the canal. Over land and base flow of water from the head reach command might be supplementing the irrigation requirement in the lower reaches of the command. Since the command of Tissawewa Right Bank Canal is small and only 250 ha therefore result is significantly visible **(Fig. 5.1 & Table 5.3).**

Table 5.3: Performance Indicators of Irrigation Tanks Located in Different Rainfall Zones in Sri Lanka

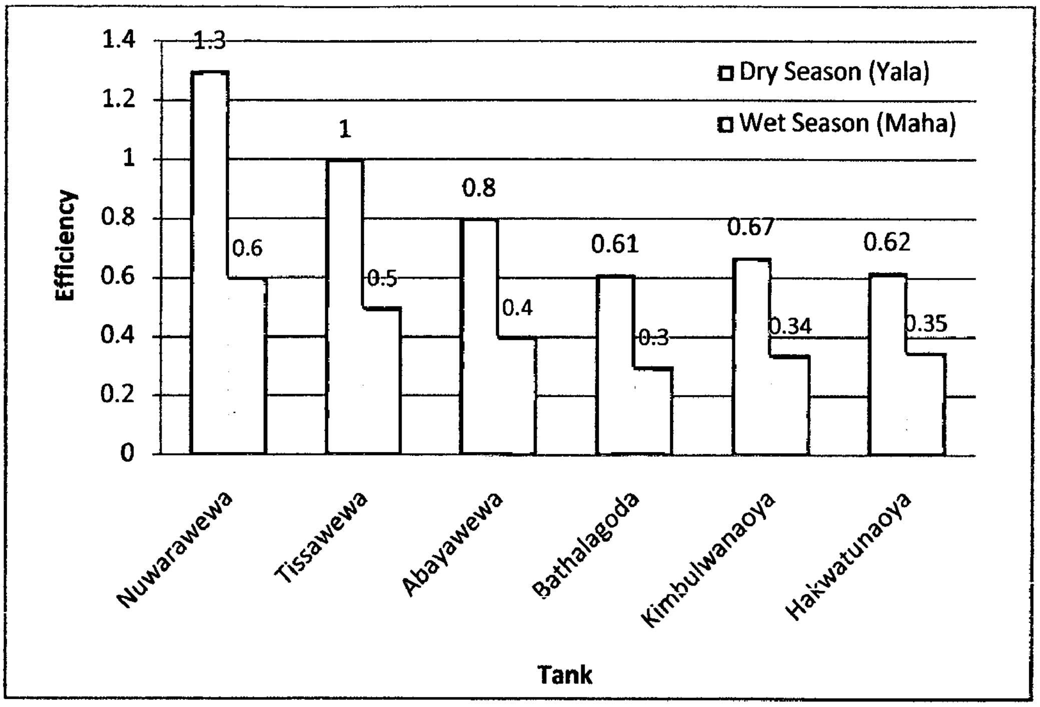
Particulars	Dry Zone						Intermediate Zone					
	Yala (Dry) Season			Maha (Wet) Season			Yala (Dry) Season			Maha (Wet) Season		
	Malwath uoya Rier			Malwath uoya Rier			Deduruo ya Rier	Kimbulw anaoya	Hakwatu naoya	Deduruo ya River	Kimbulw anaoya	Hakwatu naoya
	Nuwarawewa	Tissawewa	Adhayawewa	Nuwarawewa	Tissawewa	Adhayawewa	Bathalagoda wewa	Kimbulwanaoy awewa	Hakwatunaoya wewa	Bathalagoda wewa	Kimbulwanaoy awewa	Hakwatunaoya wewa
Delivery Performance Ratio (Actual Discharge/Targeted Discharge)												
A (0 m)	--	1.21	--	--	--	--	--	--	--	--	--	--
B (74 m)	--	1.22	--	--	--	--	--	--	--	--	--	--
C (695 m)	--	1.06	--	--	--	--	--	--	--	--	--	--
D (1565 m)	--	0.97	--	--	--	--	--	--	--	--	--	--
E (1565 m)	--	0.83	--	--	--	--	--	--	--	--	--	--
Water Delivery Performance (Actual Volume/Targeted Volume)												
Ratio	1.3	1.0	0.8	0.6	0.5	0.4	0.61	0.67	0.62	0.3	0.34	0.35
Overall Project Efficiency (Crop Irrigation Requirement/Total Inflow into the Canal System)												
Ratio	0.85	1.21	1.31	1.4	2.3	3.0	0.99	0.92	0.97	2.04	1.77	1.71
Conveyance Efficiency (Total Water Supplied by the system/Total water Inflow into the System)												
RB MC	--	0.82	--	--	--	--	--	--	--	--	--	--
Distribution Efficiency (Total Water Delivered to the Field/Total Water into the Delivery System)												
RB MC	--	0.82	--	--	--	--	--	--	--	--	--	--
Field Application Efficiency (Crop Irrigation Water Requirement/Water Delved to the field)												
RB MC	--	0.77	--	--	--	--	--	--	--	--	--	--
Modified Inter Quartile Ratio (Average DPR Best 25% of the System/ Average DPR Worst 25% of the System)												
RB MC	--	1.35	--	--	--	--	--	--	--	--	--	--
Head to Tail Equity Ratio (Average DPR of the Upper 25% of the System/ Average DPR of the Lower 25% of the System)												
RB MC	--	1.35	--	--	--	--	--	--	--	--	--	--
Irrigation Area Performance (Actual Area/Targeted Area)												
Ratio	1.49	1.28	1.09	0.94	0.93	0.91	1.34	1.16	1.03	1.00	0.95	0.96
Cropping Intensity Performance (Actual Cropping Intensity/Targeted Cropping Intensity)												
Ratio	1.09	1.01	0.85	--	--	--	1.05	1.11	0.81	--	--	--
Sustainability of Irrigated Area of Tank (Current Irrigable Area/Initial Irrigable Area)												
Ratio	1.15	1.12	1.24	--	--	--	1.15	1.22	1.29	--	--	--

5.3.2 Water Delivery Performance (WDP)

Water Delivery Performance analysis of various tanks located in dry and intermediate zone and performing in different seasons is given in Table 5.3. Results obtained show that the WDP changed with Zones (0.8 in Dry and o.5 in Intermediate), seasons of dry zone (1.0 in dry and 0.5 in wet), seasons of intermediate zones (0.63 in dry and 0.33 in wet). The three different tanks (Nurawewa, Tissawewa & Abhayawewa) located in different reaches of dry zone demonstrated their performance differently with season. The WDP reduced with the change in reaches of dry zone seasons. During dry season it was recorded as 1.3 in head, 1.0 in middle & 0.8 in tail reaches whereas in the wet season it was recorded as 0.6 in head, 0.5 in middle & 0.4 in tail reaches **(Table 5.3)**.

In the intermediate zone also the WDP varied with season and river basins. The Deduruoya, Kumbulwanaoya and Hakwatunaoya river basins recorded the WDP at o.61, 0.67 & 0.62 respectively during dry season and 0.3, 0.34 & 0.35 respectively during wet season **(Table 5.3).** The Change of WDP value with the season and the reach of the command or river basin of both the zones indicated that the canal net work system performed satisfactorily marked with the flexibility in water supply. The difference in WDP therefore might have been caused due to the change in soil type, drainage behaviour and rainfall characteristics of the command.

Fig. 5.3: Water Delivery Performance in Dry and Intermediate Zones

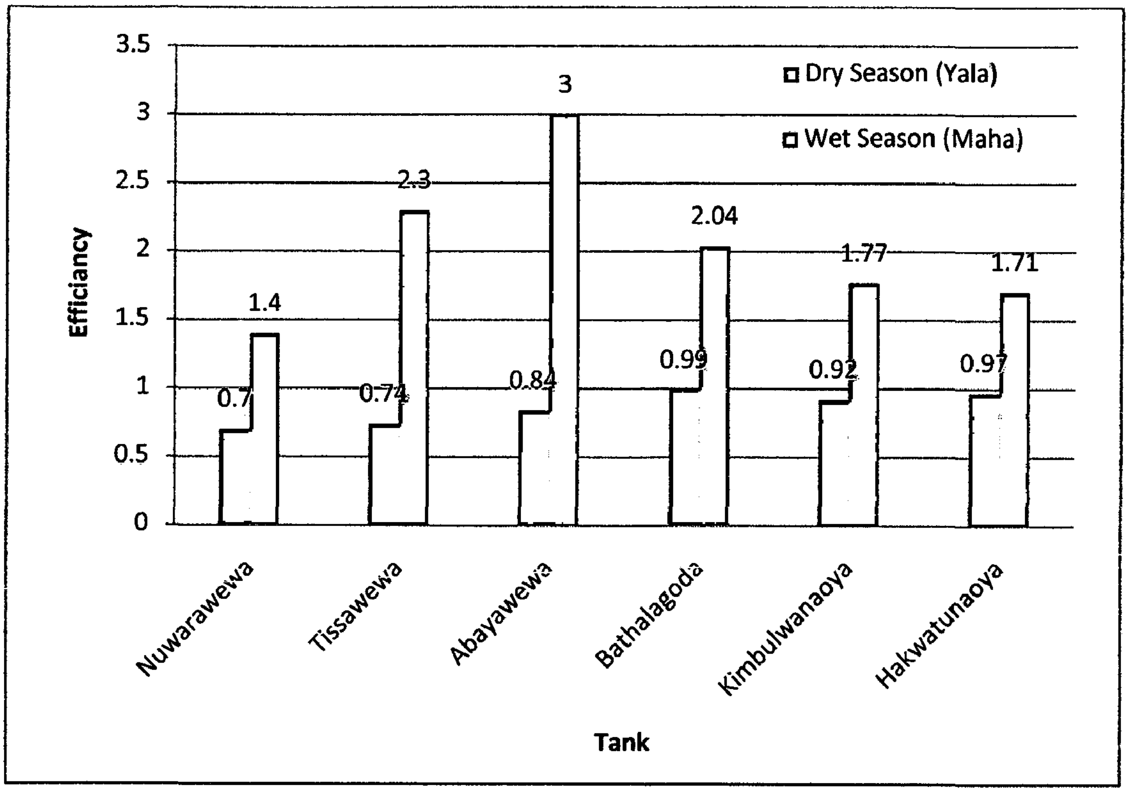


5.3.3 Overall Project Efficiency (OPE)

Water Delivery Performance analysis of various tanks located in dry and intermediate zone and performing in different seasons is given in Table 5.3. Results obtained show that the OPE changed with Zones (1.59 in Dry and 1.33 in Intermediate), seasons of dry zone (1.12 in dry and 2.23 in wet), seasons of intermediate zones (0.96 in dry and 1.84 in wet). The three different tanks (Nurawewa, Tissawewa & Abhayawewa) located in different reaches of dry zone demonstrated their performance differently with season. The OPE increased with the change in reaches of dry zone seasons. During dry season it was recorded as 0.85 in head, 1.21 in middle & 1.31 in tail reaches whereas in the wet season it was recorded as 1.4 in head, 2.3 in middle & 3.0 in tail reaches **(Table 5.3).**

In the intermediate zone the OPE varied with season and river basins. The Deduruoya, Kumbulwanaoya and Hakwatunaoya river basins recorded the OPE at o.99, 0.92 & 0.97 respectively during dry season and 2.04, 1.77 & 1.71 respectively during wet season **(Table 5.3).** The increase of OPE value with the season and the reach of the command of both the zones indicated that the canal net work system was judicious in water supply.

Fig. 5.4: Overall Project Efficiencies in Dry and Intermediate Zones



5.5 Conveyance Efficiency (CE)

Data recorded in **Table 5.3** on the conveyance efficiency of Tissawewa RB canal system. was 0.82. This is well within the permissible design limit.

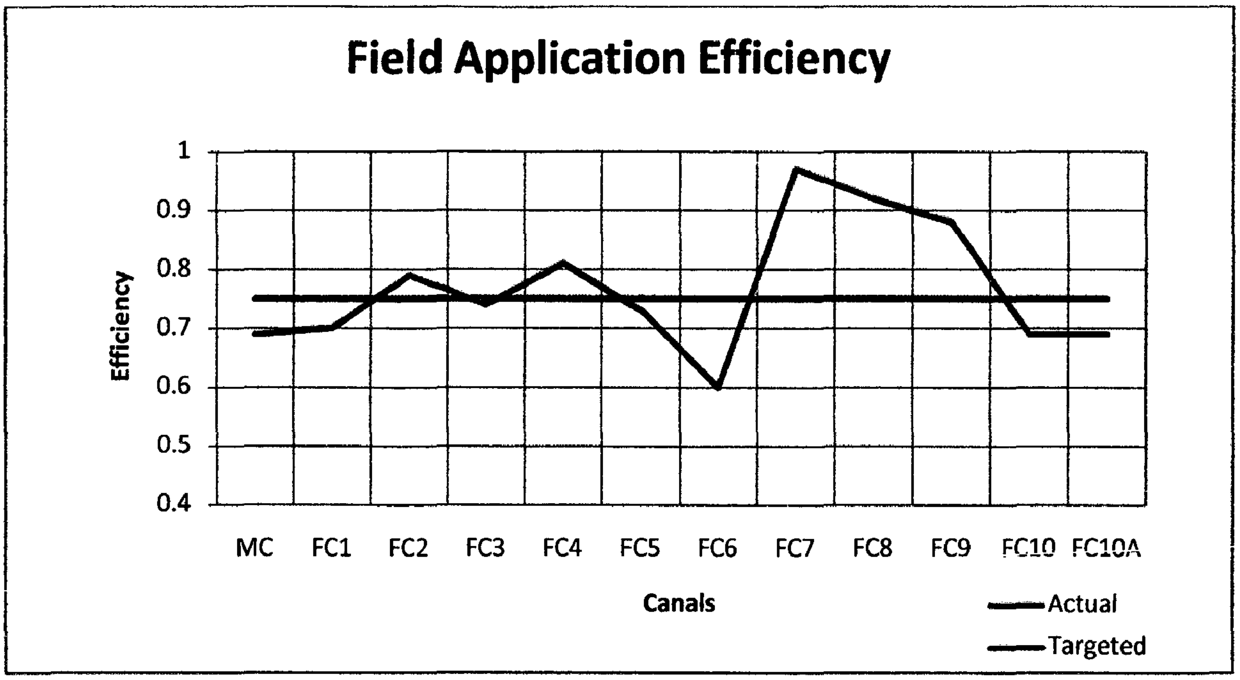
5.6 Distribution Efficiency (DE)

Data recorded in **Table 5.3** on the conveyance efficiency of Tissawewa RB canal system. was 0.82. The high efficiency values are indicative of the good performance of the irrigation system.

5.7 Field Application Efficiency (FAE)

The overall average Field Application Efficiency for the Tissawewa RB system was computed as 0.77 **(Table 5.3, Fig5.5)** shows a reasonably satisfactory performance of the system. Field Application Efficiency largely depends on soil type and application methods.

Fig.5.5: Field Application Efficiency



5.8 Modified Interquartile Ratio (MIR)

The Inter quartile Ratio is a simple indicator giving a quick view of the overall equity of water supply in the command area for achieving a fair distribution of water. Average delivery performance ratio of the worst 25% of Tissawewa RB canal system is 0.83and the best 25% is 1.22. These values are close to 1 which shows a fair distribution of water throughout the system. The Modified Inter quartile Ratio of 1.35 i.e. 1.22/0.83 shows a variation of 35% from bad to worst reach of the system **(Table 5.3).** It is desirable for a good managed system, the ratio is close to 1.

5.8 Head to Tail Equity Ratio (HTER)

In some circumstances, particularly when looking at performance of a particular canal, it may be more useful to look at the difference between the water supply to head and to tail of the canal. **Table 5.3** shows the difference of DPR in Head to Tail of Tissawewa RB canal system. In this case average delivery performance ratio of 0.9 in tail reach is close to 1 that shows a good water delivery to the tail reach. At head reach average delivery performance ratio is 1.22 that shows a little more amount of water is delivered to the head reach. Head to Tail Equity Ratio of 1.35 **(Table 5.3)** shows a non equitable distribution of water from head to tail.

5.10 Irrigated Area Performance (IAP)

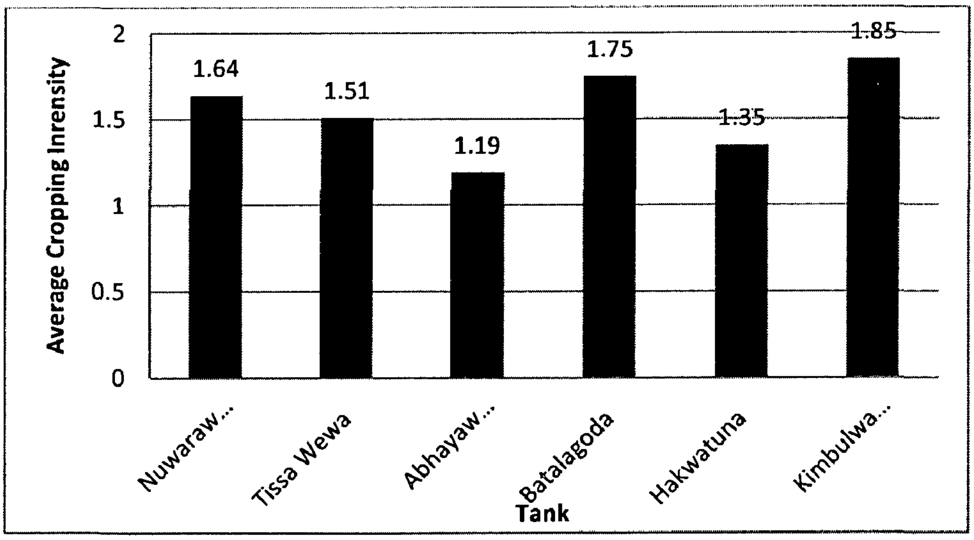
Irrigated Area Performance of various tanks located in dry and intermediate zone and performing in different seasons is given in **Table 5.3**. Results obtained show that the IAP changed with Zones (01.11 in Dry and 1.07 in Intermediate), seasons of dry zone (1.23 in dry and 0.93 in wet), seasons of intermediate zones (1.17 in dry and 0.97 in wet). The three different tanks (Nurawewa, Tissawewa & Abhayawewa) located in different reaches of dry zone demonstrated their performance differently with season. The IAP reduced with the change in reaches of dry zone seasons. During dry season it was recorded as 1.49 in head, 1.28 in middle & 1.09 in tail reaches whereas in the wet season it was recorded as 0.94 in head, 0.93 in middle & 0.91 in tail reaches **(Table 5.3).** In the intermediate zone also the IAP varied with season and river basins. The Deduruoya, Kumbulwanaoya and Hakwatunaoya river basins recorded the WDP at 1.34, 1.16 & 1.03 respectively during dry season and 1.00, 0.95 & 0.96 respectively during wet season **(Table 5.3).** The difference in IAP therefore might have been caused due to the change in soil type, drainage behaviour and rainfall characteristics of the command.The target area refers to the total irrigable area considered during the design of the system or following the latest rehabilitation. If the area ratio is averaged over one year, it quantifies the intensity of irrigation. As seen from **Tables 5.3**, all the six systems indicate irrigation area performance indicator value close to 1.0 during Maha season and > 1.0 during Yala season, implying that all the systems perform well during Maha season and Yala season

5.11 Cropping Intensity Performance (CIP)

Direct indicators for assessing the performance in terms of area irrigated include cropped area, cropping intensity and irrigation intensity. However, to more clearly understand the performance, it is useful to compare these values with expected or target. Above indicators which were discussed earlier explained the system performance in a different perspective. As seen from **Table 5.3 and Fig. 5.9** Nuwarawewa achieved cropping intensity more than 1 during every year, and the Tissawewa did not during two years. Abhayawewa did not achieve cropping intensity > 1 during four years though the water efficiency is quite high, the total output or production may be less due to less cropping intensity.

The cropping intensity performance in the dry zone during dry season has been marginally reduced in tail reaches (0.85) as compared to upper reaches (1.09) &. middle reach (1.01). In the intermediate zone during dry season the cropping intensity performance varied marginally (1.05 in Bathalagoda, 1.11 in Kimbulwanaoya and 0.81 in Hakwatunaoya)

Fig. 5.6: Average Cropping Intensity of Dry and Intermediate Zones



5.12 Sustainability of Irrigation Area (SIA)

This ratio implies primarily those aspects of the physical and environment damages occurring due to the actions of irrigation. This however does not intend to be other aspects of the environment, but to focus on those concerns falling in the realm of irrigation agency. Physical sustainability that concerns to managers may be related primarily to the over or under-supply of irrigation water that leads to water logging or salinity and affecting the irrigated area. **Table 5.3** shows the sustainability of irrigated areas during dry season in dry zone ....

CHAPTER 6

Chapter 6

SUMMERY AND CONCLUSION

The study entitled "Performance Evaluation of Tank Irrigation Projects in Different Rainfall Zones of Sri Lanka" is summarized as below:

1. The average annual ETo calculated by different methodsfor the dry and intermediate zone was 5.32 and 4.85 mm/day by Modified Penman; 4.81 and 4.71 mm/day by Radiation method; 4.41 and 4.12 mm/day by Penman Montieth method and 3.95 and 3.90 mm/day by Blaney-Criddle Method.
2. The ETo calculated by Modified Penman method was adopted for further calculations of crop water requirements as recommended by Irrigation Department of Sri Lanka.
3. The Delivary Performance Ratio from 1.2 in head reach to 0.83 in tail reach was calculated for Tissawewa tank.
4. The average Water Delivary Performance in dry zone was 0.77 and intermediate zone was 0.48.
5. The average Overall Project Efficiency in dry zone was 1.68 and intermediate zone was 1.40.
6. The average Conveyance Efficiency of Tissawewa tank was 0.82.
7. The average Distribution Efficiency of Tissawewa tank was 0.82.
8. The average Field Application Efficiency of Tissawewa tank was 0.77.
9. The average Modified Inter Quartile Ratio of Tissawewa tank was 1.35.
10. The average Head to Tail Equity Ratio of Tissawewa tank was 1.35.
11. The average Irrigation Area Performance of Dry and Intermediate zones were 1.28 , 0.93 and 1.17, 0.97 during Yala and Maha season respectively.
12. The average Cropping Intensity Performance of Dry and Intermediate zones were 0.98 and 0.99 respectively.

13. The average Sustainability of Irrigated Area of Dry and Intermediate zones were 1.19 and 1.22 respectively.

Keeping in view the above mentioned points based on the observations recorded from various tanks located in Dry and Intermediate zones in Sri Lanka the performance in general could be rated as GOOD probably due to their command area being small in size and management of irrigation water is on participatory basis in which the appropriate management decisions are prompt and timely.

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Annexure A

Weather Data

Annexure: A-1

Normal Weather data (1951-1981) of Dry Zone in Sri Lanka

Rainfall Zone: Dry Latitude: 8°21'0" N	Longitudewe: 80°23'0" E		Climatic Station : Mahailuppallama Elevation : 100 m MSL				
Month	Temperature (°C) Minimum	Temperature (°C) Maximum	Humidity (%)	Wind speed (Km/day)	Sunshine (Hours)	Radiation (mm/day)	Rainfall (mm)
January	20.9	29.6	88	49	6.1	13.6	91.7
February	21.3	31.7	85	56	7.7	14.5	42.6
March	22.9	33.8	83	49	8.4	15.3	70.2
April	24.1	34.3	83	125	8.7	15.6	175.2
May	24.8	32.9	77	135	7.9	15.3	56.2
June	24.9	32.7	73	156	8.1	15.0	24.0
July	24.5	33	70	310	7.4	15.1	26.5
August	24.4	33.2	71	181	7.8	15.4	25.0
September	24.1	33.1	72	168	7.6	15.3	55.1
October	23.3	32	84	146	6.6	14.8	241.7
November	22.5	30.3	88	65	5.4	13.9	237.5
December	21.9	29.1	89	52	4.8	13.3	187.2
Average	**23.3**	**32.1**	**80.3**	**124.3**	**7.2**	**14.8**	--
Total	--	--	--	--	--	--	**1232.9**

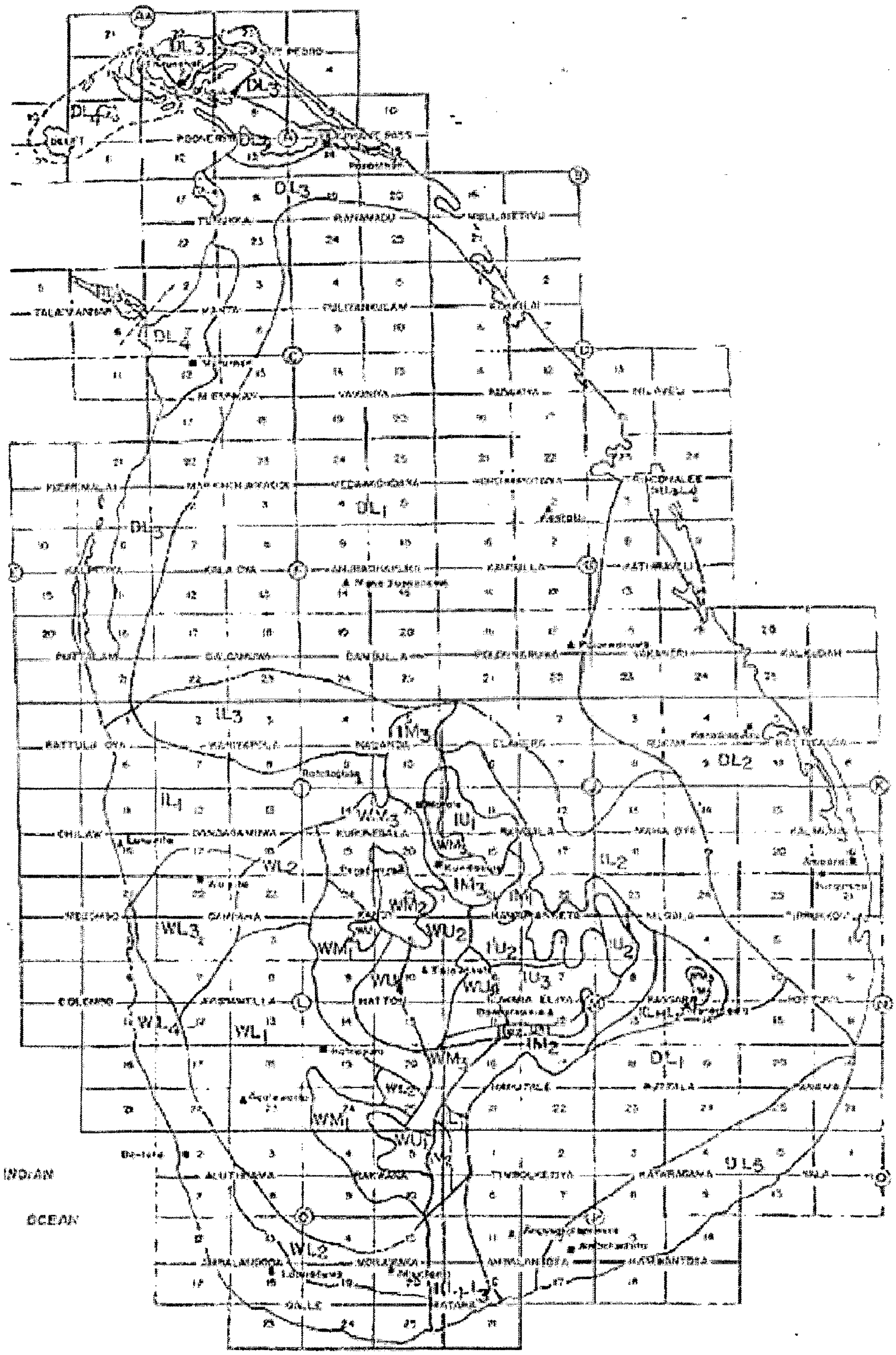
Data Source : Agriculture Department Sri Lanka

Annexure: A-2

Normal Weather data (1961-1991) of Intermediate Zone in Sri Lanka.

Rainfall Zone: Intermediate Latitude: 7°29'12" N	Longitude: 80°21'53" E		Climatic Station : Bathalagoda Elevation: 150 m MSL				
Month	Temperature (°C) Minimum	Temperature (°C) Maximum	Humidity (%)	Wind speed (Km/day)	Sunshine (Hours)	Radiation (mm/day)	Rainfall (mm)
January	20.7	30.8	88.1	49	6.1	13.75	74.0
February	20.9	33.1	87.7	56	7.7	14.65	65.3
March	22.4	34.3	86.9	49	8.4	15.35	139.3
April	23.6	33.5	86.2	125	8.7	15.50	308.6
May	24.4	32.2	80.6	135	7.9	15.20	170.1
June	24.2	31	81.9	156	8.1	14.85	115.4
July	23.9	30.8	82.4	310	7.4	15.00	103.2.
August	23.8	31.1	81.1	181	7.8	15.30	81.5
September	23.5	31.5	80.1	168	7.6	15.30	141.5
October	22.8	31.3	85.5	146	6.6	14.9	384.0
November	22.1	30.9	88.6	65	5.4	14.05	385.5
December	21.7	30.1	87.1	52	4.8	13.50	110.9
Average	**22.8**	**31.7**	**84.7**	**124.3**	**7.2**	**14.8**	--
Total	--	--	--	--	--	--	**1976.1**

Agro Ecological Regions of Sri Lanka



Crop Data

Crop		Initial	Development	Mid	Late
Low Land Paddy (135 Days)	Days	30	40	45	20
	Kc	1	1.15	1.2	0.9
Low Land Paddy (105 Days)	Days	20	30	30	25
	Kc	1	1.15	1.2	0.9
Up Land Paddy (135 Days)	Days	30	40	45	20
	Kc	0.9	1	1.05	0.9
Up Land Paddy (105 Days)	Days	20	30	30	25
	Kc	0.9	1	1.05	0.9

Data Source: Irrigation Department Sri Lanka

Annexure B

Water Delivery and Cultivation Data

Annexure B-1

Daily Discharge Tissawewa RB Canal System

Date	Dischage (m3/sec)											
	Main Canal	Field Canal 1	Field Canal 2	Field Canal 3	Field Canal 4	Field Canal 5	Field Canal 6	Field Canal 7	Field Canal 8	Field Canal 9	Field Canal 10	Field Canal 10A
1/6/2008	1.221	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.452	0.384
2/6/2008	1.218	0.000	0.115	0.000	0.000	0.392	0.000	0.000	0.000	0.411	0.000	0.000
3/6/2008	1.216	0.000	0.000	0.000	0.918	0.000	0.000	0.000	0.104	0.000	0.000	0.000
4/6/2008	1.265	0.401	0.000	0.000	0.000	0.000	0.000	0.676	0.000	0.000	0.000	0.000
5/6/2008	1.266	0.000	0.000	0.718	0.000	0.000	0.343	0.000	0.000	0.000	0.000	0.000
11/6/2008	1.297	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.469	0.401
12/6/2008	1.231	0.000	0.116	0.000	0.000	0.402	0.000	0.000	0.000	0.473	0.000	0.000
13/6/2008	1.183	0.000	0.000	0.000	0.926	0.000	0.000	0.000	0.112	0.000	0.000	0.000
14/6/2008	1.151	0.425	0.000	0.000	0.000	0.000	0.000	0.671	0.000	0.000	0.000	0.000
15/62008	1.188	0.000	0.000	0.721	0.000	0.000	0.349	0.000	0.000	0.000	0.000	0.000
21/6/2008	1.217	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.448	0.389
22/6/2008	1.159	0.000	0.119	0.000	0.000	0.391	0.000	0.000	0.000	0.407	0.000	0.000
23/6/2008	1.137	0.000	0.000	0.000	0.915	0.000	0.000	0.000	0.105	0.000	0.000	0.000
24/6/2008	1.220	0.436	0.000	0.000	0.000	0.000	0.000	0.679	0.000	0.000	0.000	0.000
25/6/2008	1.204	0.000	0.000	0.717	0.000	0.000	0.341	0.000	0.000	0.000	0.000	0.000

Data source Irrigation Engineer's office Anuradhapura

Annexure B-2

Cultivation data dry zone during Yala season

Year	Yala Season Rainfall (mm)	Nuwarawewa Tank		Tisawewa Tank		Abhayawewa Tank	
		Cultivated Area (ha)	Delivered	Cultivated Area (ha)	Delivered	Cultivated Area (ha)	Delivered
1994	306.5	1000	1748	240	152	154	185
1995	280.9	800	1423	280	431	80	147
1996	370.4	0	0	90	53	0	0
1997	273.3	0	0	100	116	0	0
1998	550.0	960	1691	90	151	0	0
1999	124.4	1000	2098	361	368	100	89
2000	241.5	960	2654	361	288	80	113
2001	372.0	1000	1088	361	342	154	189
2002	211.0	220	214	240	244	80	42
2003	256.0	1000	1312	280	475	108	143
2004	416.0	0	0	0	0	0	0
2005	159.3	1000	2026	361	286	90.4	76
2006	97.0	1000	1463	356	557	154	110
2007	279.0	860	888	234	291	39.2	35
2008	175.6	1040	1231	344	722	152	154
2009	41.1	1040	1902	0	0	154	136

Data source Irrigation Engineer's office Anuradhapura

Annexure B-3

Cultivation data dry zone during Mhaa season

Year	Maha Season Rainfall (mm)	Nuwarawewa Tank		Tisawewa Tank		Abhayawewa Tank	
		Cultivated Area (ha)	Water Delivered	Cultivated Area (ha)	Water Delivered	Cultivated Area (ha)	Water Delivered
1994/95	700.1	960	1633	361	394	154	141
1995/96	364.2	960	731	361	299	154	58
1996/97	542.1	1000	512	361	272	110	112
1997/98	782.3	960	1610	361	267	130	67
1998/99	553.1	960	1021	361	224	110	111
1999/00	674.2	1000	1058	361	193	84	47
2000/01	601	240	646	361	165	80	33
2001/02	379	960	547	0	0	0	0
2002/03	762	1000	402	361	172	154	68
2003/04	371.5	1000	814	360	461	0	0
2004/05	830	1000	635	361	455	154	106
2005/06	658.7	1000	839	361	259	154	72
2006/07	622	1040	1173	345	522	154	116
2007/08	1456.9	1040	494	360	354	154	93
2008/09	773.7	1040	1202	361	540	154	136

Data source Irrigation Engineer's office Anuradhapura

Annexure B-4

Cultivation data Intermediate zone during Yala season

Year	Yala Season Rainfall (mm)	Bathalagoda		Kimbulwanaoya		Hakwatunaoya	
		Cultivated Area (ha)	Water Delivered (ham)	Cultivated Area (ha)	Water Delivered (ham)	Cultivated Area (ha)	Water Delivered (ham)
1995	627.8	3054	3478	672	824	2069	2418
1996	498.9	3054	3652	664	684	Data Not Available	
1997	538.4	3054	3436	240	422	Data Not Available	
1998	585.1	3054	3541	108	196	2069	2375
1999	520.5	3054	3689	658	798	350	425
2000	535.2	3054	3395	658	702	1500	1819
2001	620.5	3054	3256	658	759	2016	2563
2002	653.6	3054	3324	658	843	2069	2389
2003	631.9	3054	3536	827	922	2069	2405
2004	540.9	3054	3879	Data Not Available		Data Not Available	
2005	535.7	3054	3700	805	986	1000	1198
2006	520.5	3054	3688	840	1109	2548	2914

Data source Irrigation Engineer's office Hiriyala

Annexure B-5

Cultivation data Intermediate zone during Maha season

Year	Maha Season Rainfall (mm)	Bathalagodawewa		Kimbulwanaoya		Hakwatunaoya	
		Cultivated Area (ha)	Water Delivered (ham)	Cultivated Area (ha)	Water Delivered (ham)	Cultivated Area (ha)	Water Delivered (ham)
1994/95	552.2	3053.6	1845	672	471	2069.2	1328
1995/96	550.9	3053.6	1796	658	402	2069.2	1529
1996/97	659.4	3053.6	1980	658	372	2069.2	1428
1997/98	591.4	3053.6	1671	658	458	2069.2	1172
1998/99	517.5	3053.6	1687	658	437	2069.2	1297
1999/00	1204.5	3053.6	1457	658	402	Data Not Available	
2000/01	602.9	3053.6	1589	832	422	2069.2	1439
2001/02	591.9	3053.6	1692	832	558	2069.2	1352
2002/03	577.6	3053.6	1638	832	618	Data Not Available	
2003/04	620.3	3053.6	1579	800	483	2069.2	1308
2004/05	527.6	3053.6	1768	980	678	2548.4	1756
2005/06	484.7	3053.6	1728	840	584	2548.4	1826

Data source Irrigation Engineer's office Hiriyala

Annexure B-6

Cropping intensity

Scheme	Cropping Intensity														
	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
Nuwarawewa	2.00	1.83	1.00	1.03	2.00	2.00	2.00	1.25	1.21	1.25	1.18	2.00	2.00	1.86	2.00
Tissa Wewa	1.55	1.63	1.16	1.26	1.23	1.86	1.86	1.86	0.62	1.86	0.93	1.86	1.99	1.60	1.37
Abhayawewa	1.50	2.00	1.52	0.00	0.84	0.71	1.19	1.04	1.00	1.52	0.70	1.00	1.59	1.25	1.99
Batalagoda	1.58	1.58	1.79	1.64	0.93	1.59	1.79	2.00	2.00	2.00	1.40	2.00	2.00	2.00	2.00
Hakwatuna	1.71	1.71	0.72	0.97	1.76	1.19	1.77	0.85	1.71	0.85	0.02	1.46	2.00	1.47	2.00
Kimbulwana	2.00	2.00	2.00	2.00	1.36	1.15	2.00	2.00	2.00	2.00	1.26	2.00	2.00	2.01	2.00

Data source Irrigation Department Head Office Colombo Sri Lanka

Annexure C

Tables and Figures for ETo Calculation

Annexure C-1

Mean Daily Percentage (P) of Annual Daytime Hours for Different Latitude

Latitude North	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5°	0.27	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.27
10°	0.26	0.27	0.27	0.28	0.28	0.29	0.29	0.28	0.28	0.27	0.26	0.26

Annexure C-2

Extra Terrestrial Radiation (Ra) in Equivalent Evaporation in mm/day

Northern Hemisphere												
Latitude North	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6°	13.9	14.8	15.4	15.4	15.1	14.7	14.9	15.2	15.3	15.0	14.2	13.7
8°	13.6	14.5	15.3	15.6	15.3	15.0	15.1	15.4	15.3	14.8	13.9	13.3
10°	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9

Annexure C-3

Mean Daily Duration of Maximum Possible Sunshine Hours (N) for Different Months and Latitudes

Latitude North	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5°	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
10°	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5

Annexure C-4

Value of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperature and Altitude

Temperature (°C)	20	22	24	26	28	30	32	34	36	38	40
W at Altiyude (m)											
0	0.68	0.71	0.73	0.75	0.77	0.78	0.80	0.82	0.83	0.84	0.85
500	0.70	0.72	0.74	0.76	0.78	0.79	0.81	0.82	0.84	0.85	0.86

Annexure C-5

Saturation Vapour Pressure (ea) in mbar as Function of Mean air Temperature (T) in °C

Temperature (°C)	22	23	24	25	26	27	28	29	30	31	32
ea (mbar)	26.4	28.1	29.8	31.7	33.6	35.7	37.8	40.1	42.4	44.9	47.6

Annexure C-6

Value of Wind Function $f(u) = 0.27(1+\frac{U2}{100})$ for Wind Run at 2m height

Wind (km/day)	0	10	20	30	40	50	60	70	80	90
0	--	0.3	0.32	0.35	0.39	0.41	0.43	0.46	0.49	0.51
100	0.54	0.57	0.59	0.62	0.65	0.67	0.7	0.73	0.76	0.78
200	0.81	0.84	0.86	0.89	0.92	0.94	0.97	1	1.03	1.05
300	1.08	1.11	1.13	1.16	1.19	1.21	1.24	1.27	1.3	1.32

Annexure C-7

Values of Weighting Factor (1-W) for the Effect of Wind on ETo at Different Temperature and Altitudes

Temperature (°C)	20	22	24	26	28	30	32	34	36
(1-W) at Altitude (m)									
0	0.32	0.29	0.27	0.25	0.23	0.22	0.2	0.19	0.17
500	0.3	0.28	0.26	0.24	0.22	0.21	0.19	0.18	0.16

Annexure C-8

Values of Weighting Factor (W) for the Effect of Radiation on ETo at Different Temperature and Altitudes

Temperature (°C)	20	22	24	26	28	30	32	34	36
(1-W) at Altitude (m)									
0	.0.69	0.71	0.73	0.75	0.77	0.78	0.80	0.82	0.83
500	0.70	0.72	0.74	0.76	0.78	0.79	0.81	0.82	0.84

Annexure C-9

Conversion Factor for Extra Terrestrial Radiation (Rs) to Net Solar Radiation (Rns) for a given Reflection α.

n/N	**0.00**	**0.50**	**0.10**	**0.15**	**0.20**	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**
(1-α)(0.25+0.50n/N)	0.19	0.21	0.22	0.24	0.26	0.28	0.3	0.32	0.34	0.36	0.37
n/N	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**	**0.80**	**0.85**	**0.90**	**0.95**	**1.00**	
(1-α)(0.25+0.50n/N)	0.39	0.41	0.43	0.45	0.47	0.49	0.51	0.52	0.54	0.56	

Annexure C-10

Effect of Temperature f(T) on Long wave Radiation (Rnl).

Temperature (°C)	20	22	24	26	28	30	32	34	36
$f(T) = \sigma Tk^4$	14.6	15	15.4	15.9	16.3	16.7	17.2	17.7	18.1

Effect of Vapour Pressure f(ed) on Long wave Radiation (Rnl).

ed (mbar)	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**
f(ed) = 0.34-0.044√ed	0.23	0.22	0.2	0.19	0.18	0.16	0.15	0.14	0.13
ed (mbar)	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**
f(ed) = 0.34-0.044√ed	0.12	0.12	0.11	0.1	0.09	0.08	0.08	0.07	0.06

Annexure C-12

Effect of the Ratio Actual and Maximum Bright Sunshine Hours f(n/N) on Long Wave Radiation (Rnl).

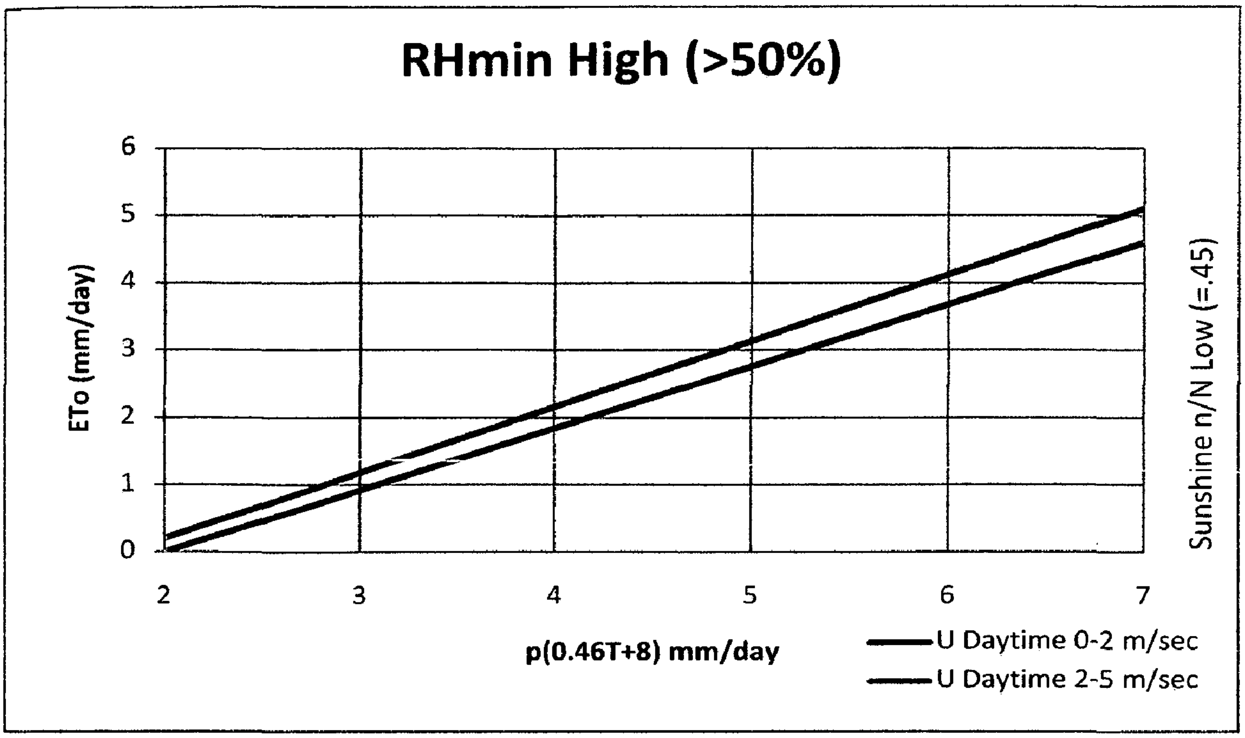
n/N	**0.00**	**0.50**	**0.10**	**0.15**	**0.20**	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**
f(n/N) = 0.1+0.9n/N	0.10	0.15	0.19	0.24	0.28	0.33	0.37	0.42	0.46	0.51	0.55
n/N	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**	**0.80**	**0.85**	**0.90**	**0.95**	**1.00**	
f(n/N) = 0.1+0.9n/N	0.60	0.64	0.69	0.73	0.78	0.82	0.87	0.91	0.96	1.00	

Annexure C-13

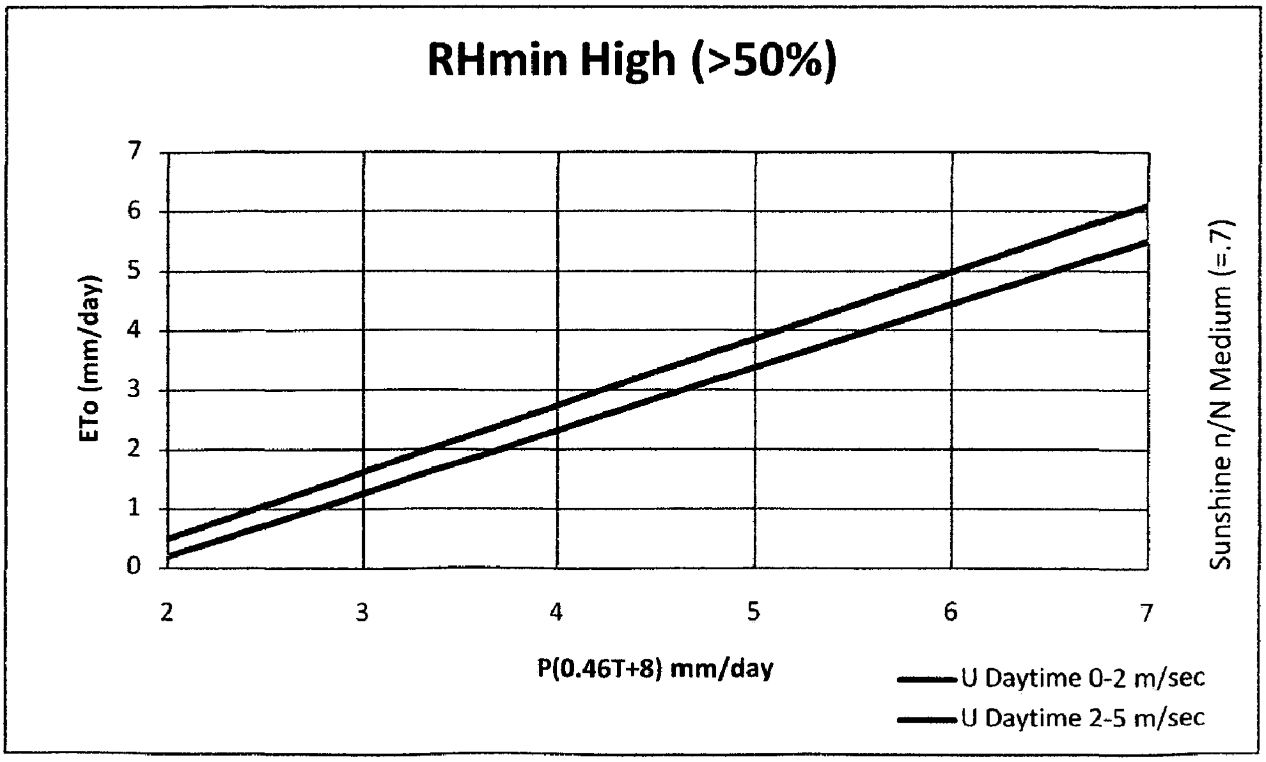
Adjustment Factor (C) in Presented Penman Equation.

	Rhmax = 30%				**Rhmax = 60%**				**Rhmax = 90%**			
Rs (mm/day)	**3**	**6**	**9**	**12**	**3**	**6**	**9**	**12**	**3**	**6**	**9**	**12**
Uday (m/sec)	**Uday/Unight = 4.0**											
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.79	0.84	0.92	0.97	0.92	1.00	1.11	1.19	0.99	1.10	1.27	1.32
6	0.68	0.77	0.87	0.93	0.85	0.96	1.11	1.19	0.94	1.10	1.26	1.33
9	0.55	0.65	0.78	0.90	0.76	0.88	1.02	1.14	0.88	1.01	1.16	1.27
Uday/Unight = 3.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.76	0.81	0.88	0.94	0.87	0.96	1.06	1.12	0.94	1.04	1.18	1.28
6	0.61	0.68	0.81	0.88	0.77	0.88	1.02	1.10	0.86	1.01	1.15	1.22
9	0.46	0.56	0.72	0.82	0.67	0.79	0.88	1.05	0.78	0.92	1.06	1.18
Uday/Unight = 2.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.69	0.76	0.85	0.92	0.83	0.91	0.99	1.05	0.89	0.98	1.10	1.14
6	0.53	0.61	0.74	0.84	0.70	0.80	0.94	1.02	0.79	0.92	1.05	1.12
9	0.37	0.48	0.65	0.76	0.59	0.70	0.84	0.95	0.71	0.81	0.96	1.06
Uday/Unight = 1.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.64	0.71	0.82	0.89	0.78	0.86	0.94	0.99	0.85	0.92	1.01	1.05
6	0.43	0.53	0.68	0.79	0.62	0.70	0.84	0.93	0.72	0.82	0.95	1.00
9	0.27	0.41	0.59	0.70	0.50	0.60	0.75	0.87	0.62	0.72	0.87	0.96

Prediction of ETo from Blaney Criddle C factor for different conditions of Minimum relative Humidity, Sunshine duration and day time wind.



Prediction of ETo from Blaney Criddle C factor for different conditions of Minimum relative Humidity, Sunshine duration and day time wind.



Prediction of ETo from Radiation Method C factor for different condi
Mean relative Humidity, Sunshine duration and day time wind.