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THE SPATIAL DISTRIBUTION OF IRRIGATION WATER AND YIELDS ON THE GAL OYA LEFT BANK*

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ABSTRACT

Water is not uniformly distributed in the Gal Oya left bank system. While head end areas have plenty of water, water availability drops drastically towards the tail of the system. Some tail areas are effectively rainfed. Data collected over three seasons show a high correlation between paddy yields and water availability and that most of the variation in yields can be accounted for by water alone. D channel location is the most significant determinant of water availability. In areas of scarce water, farm location along the D channel is also significant but location along the field channel appears insignificant.

INTRODUCTION

The Gal Oya Irrigation Settlement Scheme is the second biggest among the irrigation schemes of Sri Lanka and covers a geographical area of about 600 sq. miles (1550 sq. km). It is located in the eastern Dry Zone, mainly in the Ampara district with part lying in the southern portion of Batticaloa district. The scheme was designed to provide irrigation for 120,000 acres (48,600 hectares) with the left bank (LB) channel serving nearly half of this amount. The main tank has a capacity of 770,000 acre feet (950 million cubic meters) at full supply. The LB is planted mostly in paddy, while the right bank (RB) has 10,000 plus acres of sugar cane in addition to paddy.

The reservoir and main distribution system for the Gal Oya LB were completed in 1952. Settlement of colonists began at about the same time. Interviews with these original colonists, conducted in March 1980, indicate that in those early years, water deliveries were continuous throughout both seasons and ample down to the lower boundary of the LB command area.

As the colonization program continued, increasing amounts of land were brought under cultivation until, by 1965, a nominal area of about 44,500 acres (18,CC0 ha) was under irrigation in the LB command area. In addition, the development of sugar cane plantings on the RB with a priority water right placed increasing demands on reservoir storage. Large numbers of colonists date the cessation of continuous water deliveries to LB paddy to this RB development in the early sixties.

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Subsequent encroachments on drainage and right-of-way reservations and the asweddumization of land earmarked for upland crops has continued to increase the area under paddy. Currently it is estimated that paddy is being grown on as much as 65,000 acres of LB land during the *Maha* season.

THE PROBLEM

For a variety of reasons, however, management efforts have proved inadequate to the challenge. Portions of the system have reverted to rainfed status during the *Maha* season, and the LB area which can be cultivated during *Yala* is greatly restricted. Some of the head end areas[1] are provided with a continuous supply while certain areas in the tail end never receive water at all. Consequently, substantial differences, not only in water delivery and water availability, but also in farm productivity, exist between the head and tail. At the same time, drainage problems exist in upper portions of the system where overirrigation occurs, and in portions of the tail where losses from above accumulate.

OBJECTIVES AND METHODOLOGY

This paper attempts to examine the special pattern of water distribution in the Gal Oya left bank command and relate water availability to yield distribution. This analysis draws on water and yield data collected under a monitoring/record keeping study which is a component of socio-economic and agro-hydraulic research study series implemented by ARTI in collaboration with Cornell University.

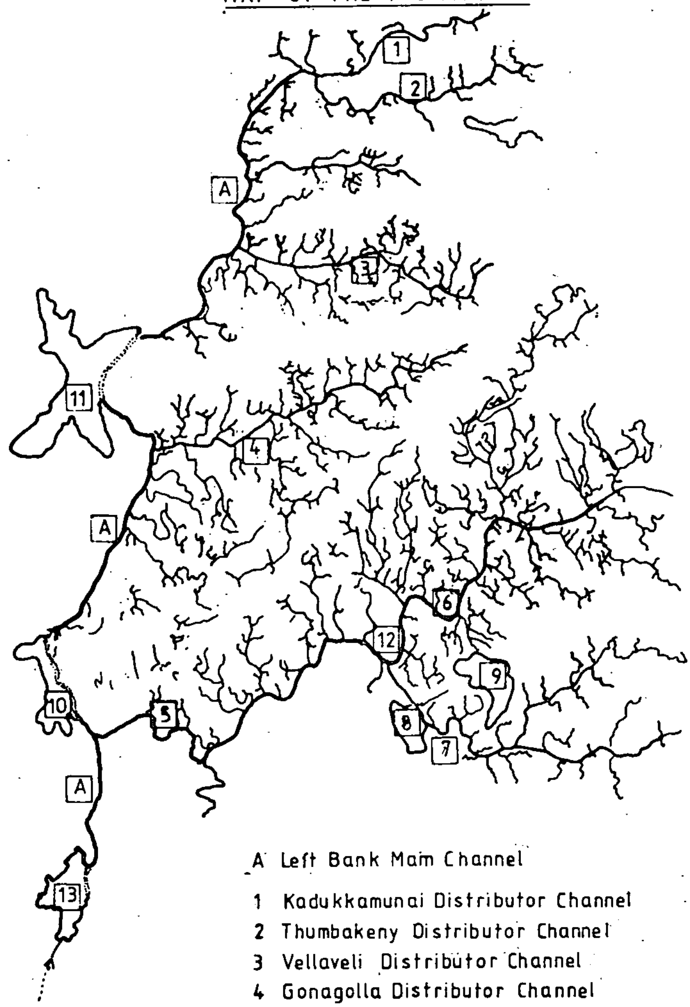
The record keeping/monitoring study was aimed at a better understanding of how water and crops are actually managed in the system. The sampling technique adopted was a two-stage random sample design with distributory channel command area as the primary sample units, field channels as the secondary units and allotments along selected field channels as the tertiary sampling units. At the second stage of sampling along a selected distributary channel unit (refer map) three field channels were selected to represent head, middle and tail portions of the distributary's command area [2].

Data pertaining to (a) the *adequacy* of water inputs at the individual *farm* level, and (b) the *adequacy* and *reliability* of water flows at various points in the *channel system* were also collected through this programme. On the basis of (a) above, a Water Availability Index (WAI) was computed for each farm, using a simple system of weighting to indicate the degree to which a farm's crop had water available to it during a 50-day critical period of plant growth. Because the 50-day period between 20 and 70 days before harvest is considered critical for maximizing yields representing the water sensitive reproductive phase of the rice plant the WAI was calculated for this period. With WAI calculated for each farm, average water availability indexes were calculated for those farms along a field channel and for all

1. "Headness" and "tailness" are multi-dimensional. Thus the term *head end area* does not necessarily refer to the head end areas of the main system. Irrespective of their position along the main system, the unusually long distributary and field channels have created head-tail problems. For instance a farm located at the tail end of a head end distributary channel can be worse off than a "head end farm" of a tail end distributary. The irregularity of channels and the variation in terms of lengths and in the number of bifurcations areillustrated in the map.

2. The total number of farms selected from the respective command areas of these field channels in the first round of record keeping and monitoring during the *Maha* season of 1979/80 was 536.

MAP · OF THE PROJECT AREA



A Left Bank Main Channel

1 Kadukkamunai Distributor Channel
2 Thumbakeny Distributor Channel
3 Vellaveli Distributor Channel
4 Gonagolla Distributor Channel
5 Uhana Branch Channel
6 Mandoor Distributor Channel
7 Malwatta Distributor Channel
8 Weeragoda Tank
9 Chadayanthalawa Tank
10 Nalagama Tank
11 Nawagiriaru Tank
12 Mandoor Regulator
13 Himidurawa Tank

From the Main Reservoir
(Senanayake Samudra)
(Capacity 770000 acre feet)

farms with a distributary area. It was assumed that this would indicate the adequacy of water distribution within the system and also within the subsystem. Based on these computations, comparisons were made between head and tail areas of field channels/distributary channels/subsystems etc.

The yield Figures used in this analysis have been based on a crop cutting methodology which included about 800 crop cutting *samples per crop season*. The record keeping work was undertaken by a group of about twenty trained ARTI investigators who were resident in the respective sample units for the entire duration [3] of this exercise. A detailed definition of the WAI and the description of the data gathering methodology are given in the appendix.

RESULTS AND ANALYSIS

As shown in Figures 1,2 and 3 there is a rough continuum of water availabilities extending across the system. At one end of this continuum is the land served from the LB main above Uhana branch [4] UB which is in general, amply supplied with water during both seasons. At the other extreme are command area lands in the lower portion of the system that are rainfed during *Maha*, and a much larger area which is fallow during *Yala*.

Between these two extremes lies a range of declining water availabilities. These are represented in the figures by isoquants based on the WAI of sample farms throughout the LB region. A value of 200 on this scale represents continuous standing water throughout critical rice plant growth stages. As values decline from 200, they represent increasing degrees of water stress on the plants.

It is clear from the lines of equal WAI that Uhana branch, the LB main, and the area just below Navakiri tank [5] are the most favoured portions of the system. These areas generally lie above the 180 isoquant. Along Gonagolla [6] and Mandur distributaries and in the lower portions of the Navakiri command area, on the other hand, water availability declines sharply, as indicated by the lower and more closely spaced isoquants.

One cannot expect there to be a perfect relationship between yield and WAI. A large number of factors other than the degree of water availability can affect yield levels. Examples are on-farm water management, pest and disease attacks, application of fertilizer, and other aspects of crop management. WAI does reflect certain qualities of soil (eg. soil hydraulic conductivity, depth of water table) and farmer water management practices, but it does not indicate certain other aspects such as soil fertility. In addition it does not distinguish between continuous and intermittent stress.

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3. From 1979/80 *Maha* season to date.
4. Uhana branch (UB) is the major lateral in the LB main system. The total area under UB command is about 9900 ha (24,000 acres). In this paper the upper portion of the UB command, i.e. the area above the Mandur regulator is named as the UHANA AREA (2200 ha or 5400 acres). The lower portion of UB is named as the MANDUR AREA (7700 ha or 19000 acres).
5. Navakiri is the largest sub-tank in the LB main system. Its command area is around 8500 ha (21000 acres).
6. Gonagolla is a branch channel which takes off from the LB main just above the Navakiri tank. The command area is about 3000 ha (7300 acres).

Still, given these advantages and disadvantages of WAI as an indicator, scme rather definite relationships between WAI and yield become evident in the analysis. Linear regressions of yield on WAI for each season are shown in insets[7] in Figures 1-3. Given the qualifications noted above, the r^2 values showing the strength of the relationship between the two are surprisingly high. The yield values they predict for given levels of WAI, other factors being equal, are shown in parentheses below the WAI values on the isoquants. The average yield figures based on crop-cuttings and WAI classified by head, middle and tail portions of subsystems are given in Table 1 (Cf. Appendix). When data from all three seasons are combined into a single relationship, the following ielationship results:

Yield=32.35+0.48 WAI
r2=0.46, n-72

The average maximum and minimum productivity levels that could be projected for Gal Oya left bank on the basis of this equation (i.e. in respect of the maximum and minimum levels of water availability) are 64 bushels /acre and 27 bushels/acre respectively.

In a separate analysis, multiple linear regression was done to consider the effect of water stress together with other inputs such as fertilizer application, labour, tractive power, etc. In the most satisfying model (*Yala* 1980), more than half (57%) of yield variability was accounted for by water alone. This finding is strongly suportive of the results of the simple linear regression relating yield directly to water availability.

As stated earlier, the location of farms was found to be the most important single factor which determines the WAI. The outcome of the analysis of the relationships between location and respective yield levels over four consecutive seasons could be summarised as follows:

First of all, there was no significant correlation between yield and the location of farms along the field channel. The location of field channels along the distributary also did not appear to influence the level of yields of farms along the respective field channels whether they were head, middle or tail. Given the smaller size of sample at this level the factors cited earlier would have diluted any real relationship between yield and WAI at the field channel level.

However, as expected, variation among distributaries along the main channels was seen to be significant and mean yields of farms located at the tail end distributary channels were substantially lower than for head and middle units.

Spatial differences in productivity (as a consequence of uneven distribution of water) could be observed further from Table 1 in which information of four consecutive seasons gathered through the continuous record keeping programme are presented.

The WAI is an agronomic index and not volumetric, however, and it does not indicate the degree of overirrigation taking place. Unfortunately, volumetric discharge measurements on the LB are rare. One illustrative set of readings that does exist is found in Murray-Rust and Cherry (1981). The data were obtained by means

7. The relationship between WAI and yield is most prominent in the middle area of the system because in this area, the degree of variability of WAI is greater than the head or tail areas.

Figure 1 - Lines of equal water availability (WAI) on Gal Oya L.B. and a regression of yield on WAI, Yala Season 1980

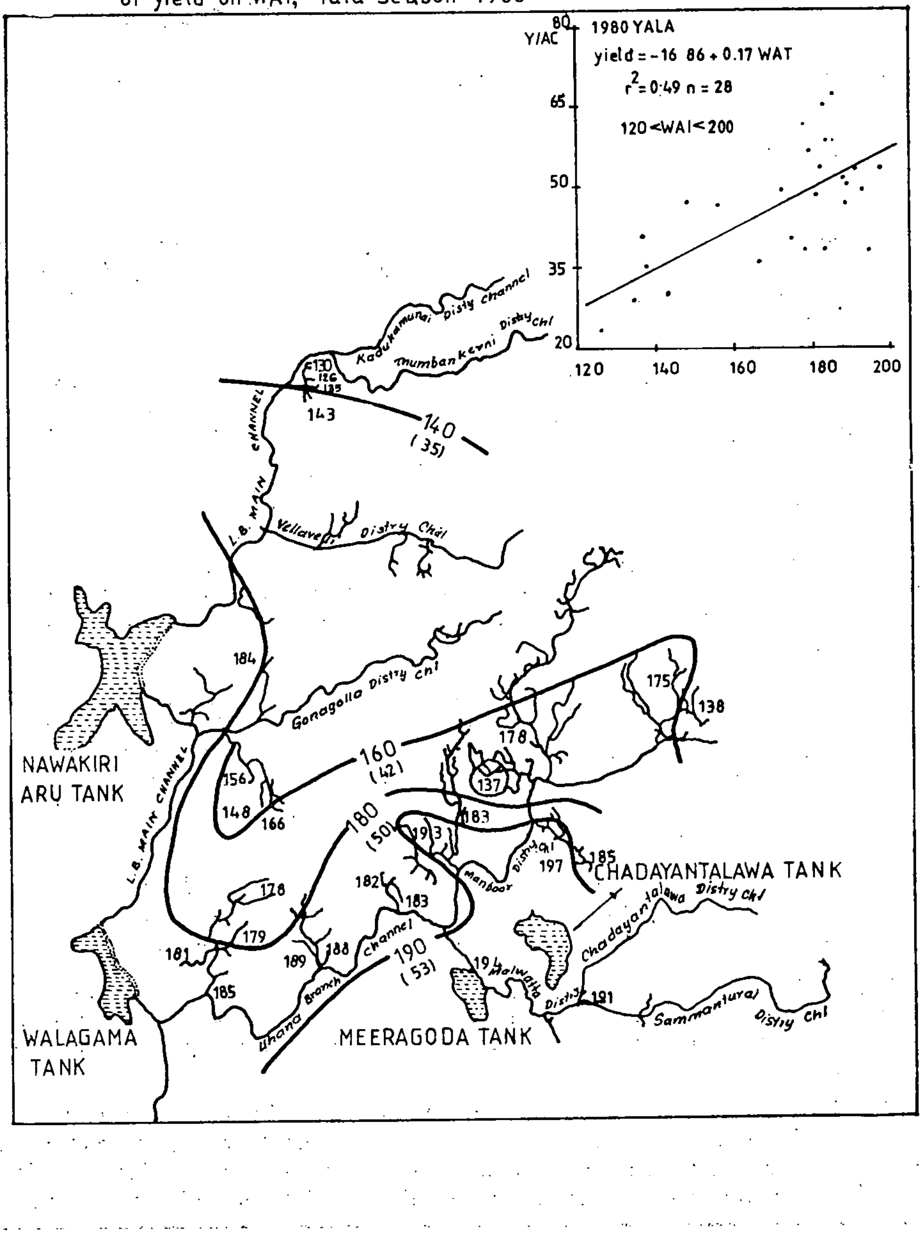


Figure 2 Line of equal water availability (WAI) on Gal Oya L.B and a regression of yield on WAI Maha Season 1980/81

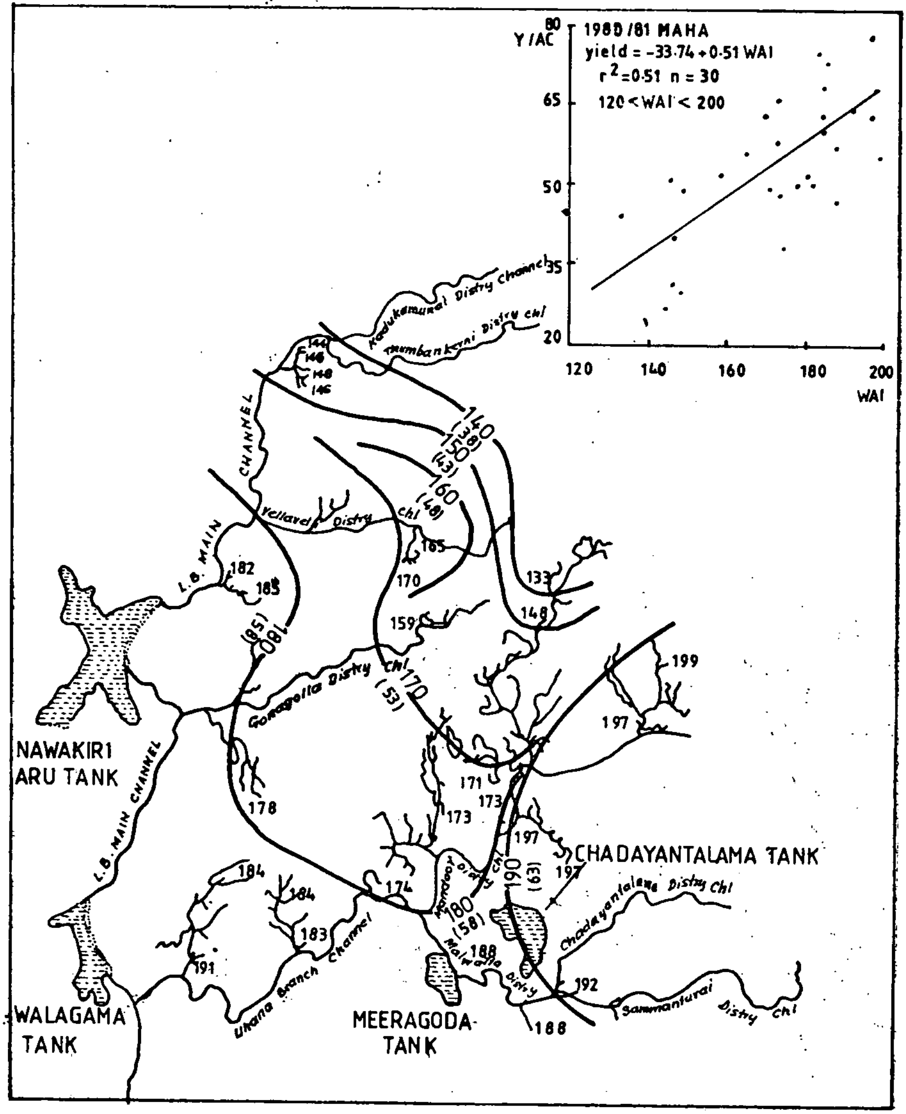


Figure 3: Lines of equal water availability (WAI) on Gal Oya L. B and a regression of yield on WAI. Yala Season 1981

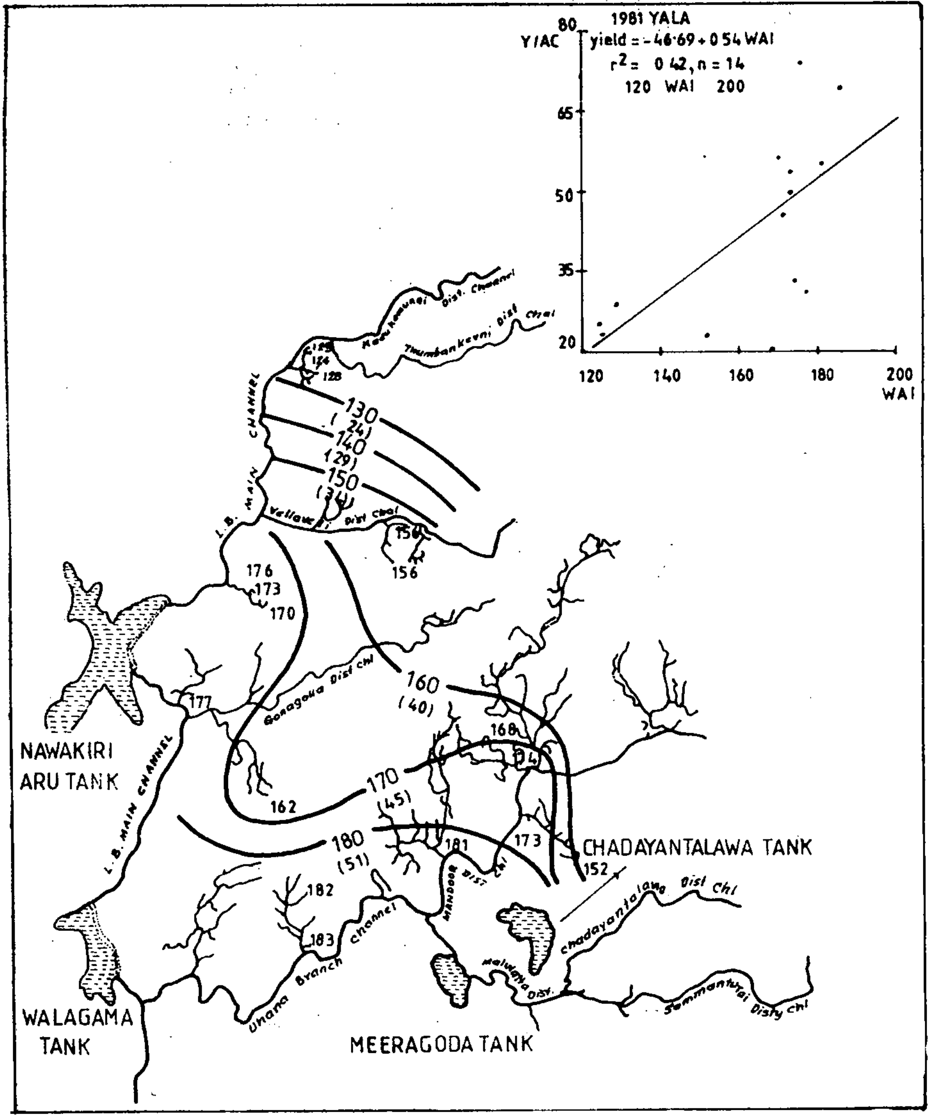


Figure-4 Measured discharges entering 16 U B. D.Channels on the same day in early Yala 1981. Adjusted for the area served

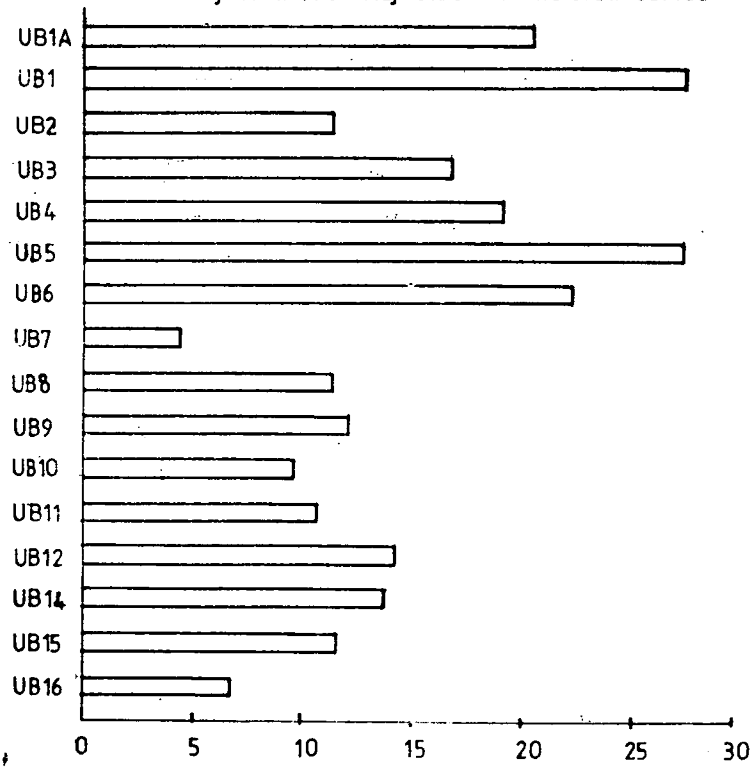
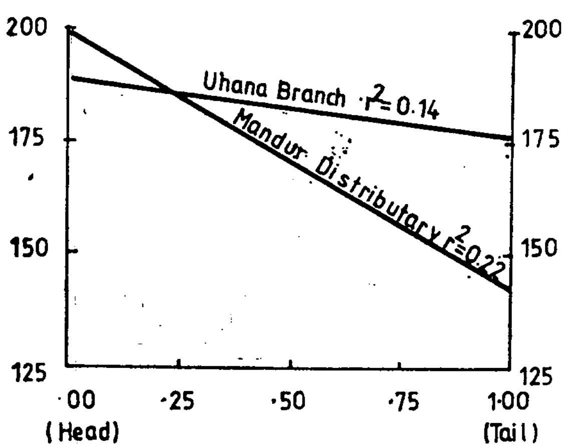
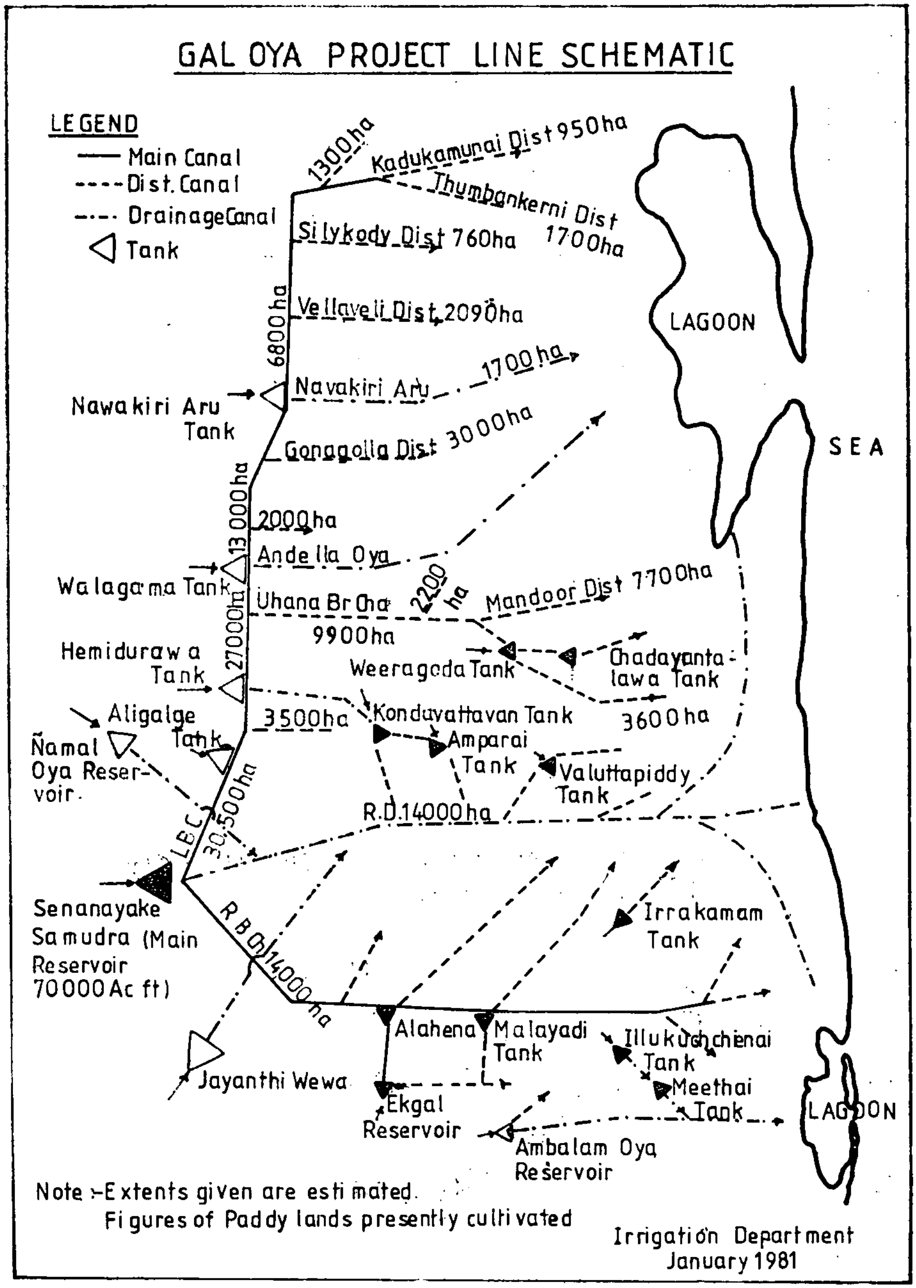


Figure-5 Graph showing the decline of WAI with position along two major L B Distributaries.




GAL OYA PROJECT LINE SCHEMATIC
LEGEND
Main Canal
Dist. Canal
Drainage Canal
Tank
1300ha
Kadukamunai Dist 950ha
Thumbankerni Dist 1700ha
Silykody Dist 760ha
Vellaveli Dist 2090ha
6800ha
Navakiri Aru 1700 ha
Nawakiri Aru Tank
Gonagolla Dist 3000ha
13 000ha
2000ha
Andella Oya
Walagama Tank
Uhana Br Cha
9900ha
2200 ha
Mandoor Dist 7700ha
27000ha
Hemiduraw a Tank
Weeragoda Tank
Chadayantalawa Tank
3600 ha
Aligalge Tank
3500ha
Konduvattavan Tank
Amparai Tank
Valuttapiddy Tank
Namal Oya Reservoir.
30500ha
R.B. 14000ha
LEC
Senanayake Samudra (Main Reservoir 70000 Ac ft)
RBC 14000 ha
Irrakamam Tank
Alahena
Malayadi Tank
Illukuchchenai Tank
Meethai Tank
Jayanthi Wewa
Ekgal Reservoir
Ambalam Oya Reservoir
LAGOON
SEA
LAGOON
Note :- Extents given are estimated.
Figures of Paddy lands presently cultivated
Irrigation Department
January 1981

of current meter readings taken along UB above Mandur regulator[8] on a single day of issue during the early part of the 1981 *Yala* season when water was extremely scarce. All operating control structures were in an open position as is typical for UB.

These data, adjusted to represent daily supplies, are presented graphically in Figure 4. They show very clearly the wide range of delivery rates to be found along the upper portion of this largely unregulated head end branch. Actual crop/soil demand for water is probably in the range of 10 to 15 mm/day in this area, not including conveyance losses. Thus while many of the lower channels along UB fall into this range, many of the head end D channels are drawing far more water than they require. If water surface elevations in UB were higher as they would be under more normal conditions, the discrepancies would probably be more pronounced.

To better understand the pattern of distribution among D channels in the UB and Mandur areas, regression studies using data from the 1980 *Yala* season were done to relate WAI values to a variable indicating location along the D channel. This locational variable was simply the distance from the head of the D channel to a particular farm's field channel offtake, divided by the total length of that D channel[9].

A value of this variable near zero thus indicates a farm near the head of the D channel, while a value of IO indicates a farm at the very tail. Location along the field channel itself is not considered here.

The relationships between these two variables for both UB and Mandur distributary were statistically significant. As Figure 5 indicates, along UB water availability drops from a WAI value of 188 at the head of the typical D channel to about 175 at the tail. This is a reasonably uniform distribution and is facilitated by heavier soils prevailing in the UB area and the generally abundant deliveries of water.

In the Mandur area, the picture is quite different. Here the WAI typical of the head end of a D channel is close to its maximum value of 200. It drops very sharply, however, as one proceeds down the D channel, to a value of around 140 at the tail. Other factors being equal, this is equivalent to a yield of only 26.6 bushels per acre.

The sharp decline with distance indicates serious problems of mal-distribution along D channels in areas where water is not abundant. This finding reinforces the picture presented by Figures 1,2 and 3 showing generally declining levels of water availability as one proceeds away from the Uhana bifurcation, along this main lateral channel.

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8. i.e. Upper portion of the Uhana branch (UB) channel.

9. In a subsequent analysis fifteen different hypothetical functions of "locational effects" on water status were tested for their statistical significance and two of the most significant ones are given below:

I. $$\text{WAI}\ f\ \frac{\text{Upstream channel length of the distributary}}{\text{Total channel length of the distributary (including the length of all field channels as well)}}$$

II. $$\text{WAI}\ f\ \frac{\text{No. of upstream bifurcations within distributary unit}}{\text{Total number of bifurcations within distributary unit}}$$

The evidence presented indicates important water distribution problems along major LB canals and D channels. Though less analysis of field channel data has been done, early results indicate that distribution along field channel is a lesser problem. As reported in the *ARTI* 1980 *Water Management Yearbook*, data for the 1979/80 *Maha* season showed no significant relationship between location along a field channel and *WAI*. This was true both in units well supplied with water and in those with inadequate supplies. For all field channels surveyed, the average WAI at the head ends of field channels was 178, compared to a very similar average of 174 at the tails.

CONCLUSION

Although additional analysis is necessary, particularly for *Yala* season these results seem to indicate that the most important water distribution problems lie above the field channel. This conclusion indicates the need for relatively more emphasis on control at the branch and D channel levels with attendent implications for control software as well as hardware.

APPENDIX

1. Discription of the Data Gathering Methodology

Agro-economic, hydrologic, social and institutional data were ascertained mainly through a record keeping/monitoring programme supplemented by informal interviewing and participant observation. A special record book with seven different recording schedules was used for this purpose. During the cultivation season, the researchers visited each one of the study locations frequently and supervised the progress of record keeping work undertaken by the trained ARTI investigators who were resident in the respective colony units for the entire duration of this exercise.

In regard to the adequacy of water inputs at the individual farm level, five degrees of water availability were specified, and daily observations were made for each farm covered by the record keeping programme. Within each farm observations were made on two selected *liyaddas*[10] from the date of planting to the date of harvest, the *liyaddas* having been selected so that one was *near to* and the other *far from* the pipe inlet supplying the farm allotment with irrigation water.

Investigators recorded each *liyadda* each day the water status of that plot as being:

(*a*) severe shortage of water (soil cracking)
(*b*) moderate shortage (soil dry)
(*c*) saturated condition (soil wet)
(*d*) standing water
(*e*) flowing water across the paddy.

10. A *liyadda* is an individually bunded plot (paddy). The number of *liyaddas* per acre varies from about 8 to 50.

2. WAI

On the basis of the conditions observed, a water availability index was computed for each farm, using a simple system of weighting to indicate the degree to which a farm's crop had more or less water available during the period 20 and 70 days before harvest as this period is considered to be the critical, water-sensitive phase of the rice varieties grown in the project area.

Date of planting		50 days critical period	20	Date of harvest

To calculate the index, the number of days in the first category (a: severe shortage) were added to the number of days in the second category (b: moderate shortage), which were weighted double plus the number of days in the third category (c: saturation) weighted triple; and the last two categories of abundant water supply (d: standing water and e: flooding) weighted as quadruple.

This can be expressed as follows:

$$\text{WAI} = (a \times 1) + (b \times 2) + (c \times 3) + (d \times 4) + (e \times 4) \quad \text{where,}$$

No. of days of severe shortage within critical period	= a
No. of days of moderate shortage within critical period	= b
No. of days of saturation with critical period	= c
No. of days of standing water within critical period	= d
No. of days of flooding within critical period	= e

(d) and (e) were weighted the same since water supplied to the plant is essentially the same; differences in aeration etc. cannot be so readily quantified. WAI is considered to be a convenient indicator of plant water stress. However, additional analysis is currently under way to improve its performance.

Table 1—AVERAGE YIELD/ACRE AND WAI CLASSIFIED BY SUB-SYSTEM

Sub-system	*Location of units*	*Average yield bushels/acre* 79/80 *Maha*	80/81 *Maha*	80 *Yala*	81 *Yala*	*Average WAI* 79/80 *Maha*	80 *Yala*
Uhana-Mandur ...	Head	36	69	52	57	182	185
	Middle	37	59	46	47	183	180
	Tail	27	44	36	26	166	116
LB main ...	Head	41	47	47	56	187	182
	Tail	29	46	30	28	NA	135
Gonagolla channel ...	Head	39	52	51	37	178	178
	Tail	22	52	—	2 *	148	NA
Malwatta– ...	Head	44	57	47	—	NA	NA
Weeragoda ...	Tail	23	—	59	—	NA	NA
Entire left bank ...		34	57	48	38	—	—

* Only 2 had harvested.

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